OU 2 AREA 8 HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

Naval Base Kitsap Keyport
Keyport, Washington
Final
Revision: 0

Prepared for:

Department of the Navy
Naval Facilities Engineering Command, Northwest
1101 Tautog Circle,
Silverdale, Washington 98315-1101

March 18, 2018

OU 2 AREA 8 HUMAN HEALTH AND ECOLOGICAL RISK ASSESSMENT

Naval Base Kitsap Keyport
Keyport, Washington

FINAL
VERSION: 0

Prepared for:

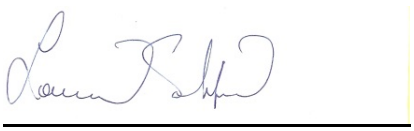
Department of the Navy
Naval Facilities Engineering Command, Northwest
1101 Tautog Circle,
Silverdale, Washington 98315-1101

Prepared by:

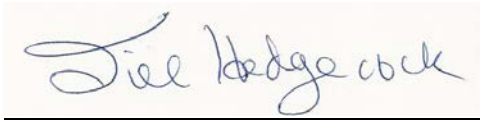
Resolution Consultants
A Joint Venture of AECOM & EnSafe
1500 Wells Fargo Building
440 Monticello Avenue
Norfolk, Virginia 23510

Contract Number: N62470-11-D-8013

May 18, 2018



Laura Scheffler, MSPH
Human Health Risk Assessor



Jill Hedgecock, MS
Ecological Risk Assessor

CONTENTS

APPENDICES

FIGURES

TABLES

TABLES (Continued)

TABLES (Continued)

This page was intentionally left blank.

ACRONYMS AND ABBREVIATIONS

90/90 UTL	90 percent upper confidence limit on the 90th percentile upper tolerance limit
ATSDR	Agency for Toxic Substances and Disease Registry
AVS	acid-volatile sulfide
BMD	benchmark dose
BTAG	Biological Technical Assistance Group
BTV	background threshold value
BW	body weight
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm	centimeter
COC	chemical of concern
COPC	chemical of potential concern
CSF	cancer slope factor
CSL	cleanup screening level
CSM	conceptual site model
CTE	central tendency exposure
CTL	critical tissue level
Ecology	Washington State Department of Ecology
EcoSSL	ecological soil screening level
EPC	exposure-point concentration
ERA	ecological risk assessment
ERL	effects range–low
ERM	effect range–median
FS	feasibility study
g/day	grams per day
g/kg-day	grams per kilogram day
HHFG	Human Health Focus Group
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
IEUBK	Integrated Exposure Uptake Biokinetic
IRIS	Integrated Risk Information System
kg	kilogram
LDW	Lower Duwamish Waterway

LOAEL	lowest observed adverse effect level
LTM	long-term monitoring
LWG	Lower Willamette Group
µg/dL	micrograms per deciliter
µg/L	micrograms per liter
µmol/g	micromole per gram
mg	milligram
mg/kg	milligrams per kilogram
mg/kg-BW/day	milligrams per kilogram body weight per day
mg/L	milligrams per liter
MLLW	mean lower low water
MTCA	Model Toxics Control Act
NBK	Naval Base Kitsap
NOAEL	no observed adverse effect level
ODEQ	Oregon Department of Environmental Quality
OU	operable unit
QAPP	quality assurance project plan
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RI	remedial investigation
RME	reasonable maximum exposure
ROD	Record of Decision
SCO	sediment cleanup objective
SCR	seafood consumption rate
SCUM II	Sediment Cleanup User Manual II
SEM	simultaneously extracted metals
SMS	Sediment Management Standards
SUF	site use factor
TOC	total organic carbon
TRV	toxicity reference value
UCL	upper confidence limit
UCL95	95 percent upper confidence limit
USEPA	U.S. Environmental Protection Agency
UTL	upper tolerance limit
WAC	Washington Administrative Code
WMW	Wilcoxon Mann Whitney

1.0 INTRODUCTION

Navy contractors perform routine long-term monitoring (LTM) of groundwater and seeps on an annual basis adjacent to Area 8 located within Operable Unit (OU) 2 at Naval Base Kitsap (NBK) Keyport, Keyport, Washington. Clam tissue and sediment sampling in the intertidal zone of Liberty Bay on the beach adjacent to Area 8 has been conducted as required by the 1994 Record of Decision (ROD) in order to support human health and ecological risk assessments. Human health and ecological risks associated with exposure to potentially contaminated media at the beach adjacent to Area 8 (i.e., clam tissue, sediment, seep water, and marine water) are estimated in this HHRA/ERA. The HHRA/ERA was developed in collaboration with site stakeholders and in accordance with the approved HHRA/ERA work plan (U.S. Navy 2016a). For ease of discussion, the beach adjacent to Area 8 shall be referred to as the "Area 8 beach" throughout the remainder of this report.

The HHRA/ERA fulfills the recommendations of the third and fourth 5-year reviews utilizing the data from the 2015 and 2016 sampling events (U.S. Navy 2016a). The specific objectives of this project are to:

- Characterize human health and ecological site risks relative to background
- Confirm the extent of contamination and update the conceptual site model
- Assess the need to implement contingent groundwater control actions based on the results of the risk assessments

The project-specific quality assurance project plan (QAPP) (U.S Navy 2015c) and the modification to the QAPP (U.S. Navy 2016b) provide details of the sampling activities at the Area 8 beach and the reference area used to establish reference area concentrations (Penrose Point State Park). In 2015, clam tissue, sediment, marine surface water, and seep samples were collected from the Area 8 beach, and clam tissue and marine surface water were collected from Penrose Point State Park. In 2016, additional clam tissue and sediment samples were collected from the Area 8 beach to further delineate the extent of contamination. The 2015 and 2016 data were analyzed for arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc.

The HHRA/ERA is organized as follows:

- Section 1.0 – Describes the site and its history, summarizes pre-record of decision (ROD) investigations at the site, summarizes the baseline risk assessments, summarizes the requirements of the ROD, and discusses the activities performed at Area 8 since the ROD was executed
- Section 2.0 – Describes the target species for clam tissue data, data to be quantitatively evaluated, the chemical analysis of chemicals of concern (COCs), and data quality review
- Section 3.0 – Discusses the HHRA, including the existing human health conceptual site model (CSM), exposure assessment, toxicity assessment, risk characterization, and uncertainties associated with the HHRA
- Section 4.0 – Discusses the ERA, including the existing ecological CSM, problem formulation, exposure analysis, effects assessment, risk characterization, and uncertainties associated with the ERA
- Section 5.0 – Discusses the methodology for determining extent of contamination, based on the risk conclusions, if warranted
- Section 6.0 – Discusses the conclusions and recommendations of the HHRA/ERA report
- Section 7.0 – Provides the references cited throughout the HHRA/ERA

1.1 Site Description and Background

NBK Keyport occupies 340 acres (including tidelands) on a small peninsula in the central portion of Puget Sound adjacent to the town of Keyport in Kitsap County, Washington. NBK Keyport is bordered by Liberty Bay on the east and north and Port Orchard Bay on the southeast (Figure 1). Area 8 is an upland site that occupies about 1 acre in the eastern portion of NBK Keyport and encompasses the location of the former plating shop (Building 72 on Figure 2) and the adjacent intertidal area. Building 72 was demolished in 1999 and replaced by an asphalt-paved parking area. Area 8 is located in a heavily industrialized part of the facility and is predominantly flat and almost entirely paved or covered by buildings.

The historical sources of chemicals released from the former plating shop in Area 8 included spillage of chrome plating solution onto the ground, discharge of plating wastes into a utility trench, and leakage of plating solutions through cracks in the building floor, from waste

disposal pipes and from sumps in the plating shop. Metals in the solvents used in the plating shop were released during plating shop operations.

1.1.1 Summary of Pre-ROD Site Investigations

Area 8 was investigated and characterized together with other areas of NBK Keyport during the initial assessment study in 1984 (U.S. Navy 1984) and the remedial investigation (RI) and feasibility study (FS) in 1993 (U.S. Navy 1993a and 1993b). Media sampled at Area 8 during the RI included subsurface soil and groundwater, as well as seeps and groundwater from piezometer well points in the intertidal zone at the adjacent Area 8 beach.

For subsurface soil at Area 8, arsenic, cadmium, and chromium were identified as the COCs. The source of these metals at Area 8 is believed to be the metal plating activities associated with Building 72, except for the low detected concentrations of arsenic that were found to be representative of reference area concentrations. Therefore, arsenic was eliminated as a COC in soil at Area 8 during development of the ROD (U.S. Navy, USEPA, and Ecology 1994).

For groundwater at Area 8, concentrations of 10 metals (antimony, arsenic, cadmium, hexavalent chromium [chromium VI], copper, lead, manganese, nickel, thallium, and zinc) exceeded the federal maximum contaminant levels or the state Model Toxics Control Act (MTCA) Method B cleanup levels for the protection of drinking water. Groundwater at Area 8 is not used as a drinking water source. A plume of metals was found to extend from the western portion of Building 72 toward Liberty Bay to the east and southeast (U.S. Navy, USEPA, and Ecology 1994). The concentrations of metals generally decreased eastward toward the bay. Within the plume, the distribution of cadmium and chromium were well defined and could be traced to former operations at Building 72 (e.g., the chromium plume could be traced to the former chrome room in Building 72).

Because the groundwater at Area 8 discharges into Liberty Bay, there is a potential for chemical migration from the groundwater to the marine environment. During the RI, some contaminants detected in beach seep samples from the Area 8 beach exceeded the water quality criteria for surface water; however, no exceedances were identified in surface water samples collected from Liberty Bay during the RI (U.S. Navy 2010).

1.1.2 Summary of 1993 Baseline Risk Assessments

The Area 8 baseline HHRA and ERA conducted in 1993 did not find unacceptable health risks under an industrial exposure scenario for either humans or ecological receptors (there is no

terrestrial habitat for ecological receptors at Area 8) (U.S. Navy 1993c and 1993d). Although the land use will remain industrial for the foreseeable future, the baseline HHRA found that COCs in soils and groundwater at Area 8 posed an unacceptable risk to hypothetical future residents. Specifically, the baseline HHRA reported cancer risk of 4×10^{-9} and a hazard index (HI) of 0.04 under a current land use scenario but a cancer risk of 1×10^{-3} and a HI of 30 for a future residential scenario. Future residential exposure pathways that contributed to risk that were not evaluated for the industrial scenario included:

- Ingestion of groundwater as drinking water from the shallow aquifer (5×10^{-4} and HI = 30). Arsenic, 1,1-DCE, and TCE contributed to risk. Cadmium, chromium, and TCE contributed to the HI.
- Inhalation of volatiles during household use of water (5×10^{-4}). 1,1-DCE and TCE contributed to risk.
- Ingestion of homegrown produce (2×10^{-5} and HI = 4). Arsenic in soil contributed to risk. Cadmium in soil resulted in the HQ of 4.

The results of the baseline ERA indicated that shallow groundwater from Area 8 discharging to Liberty Bay did not pose significant risk to marine organisms.

1.1.3 Summary of ROD

The ROD for OU 2, which includes Area 8, was signed September 28, 1994 (U.S. Navy, USEPA, and Ecology 1994). The ROD required the following:

1. Soil removal
2. The development of institutional controls to prevent the use of groundwater for drinking and to restrict the land use at Area 8 to industrial uses
3. Additional bioassay testing in Area 9 (the subtidal areas of Liberty Bay) to confirm the evaluation of risks in the ROD, which indicated that no remedial action appeared to be necessary to ensure adequate protection of human health and the environment
4. LTM of sediment and clam tissues from the intertidal areas of Liberty Bay because of the potential for residual groundwater contamination to enter Liberty Bay

The ROD anticipated that after the soil removal component of the remedy, "residual contamination may continue to be discharged into Liberty Bay for many years." The criteria in

the ROD for whether contingent groundwater control measures or further investigations must be implemented are whether the "discharges accumulate over the long-term" and a post-ROD risk assessment of human health and the environment "shows unacceptable risks or exceedances of state sediment cleanup screening levels" (U.S. Navy, USEPA, and Ecology 1994: 142 and 143). Therefore, although no remediation goal for sediment or tissue at the Area 8 beach was established in the ROD, a post-ROD evaluation of human health and ecological risks was required by the ROD based on concerns that COC concentrations in groundwater discharging to Liberty Bay might increase in the future and call into question the findings of the 1993 baseline HHRA/ERA. As specified in the ROD, the post-ROD risk assessments were to be performed using the same exposure assumptions as those in the baseline risk assessments. However, it is presumed by the 5-year review process that if there are any substantial changes to exposure assumptions found while assessing whether or not the remedy remains protective, these changes would be incorporated into future risk assessments, as was done in the subject risk assessment.

1.2 Post-ROD Activities

After execution of the ROD for OU 2, the remedy for Area 8 was implemented. The remedy included soil removal, implementation of institutional controls, additional bioassay testing in Area 9 (the subtidal areas of Liberty Bay), LTM of sediment and clam tissue, and performing human health and ecological risk assessments. The remedy for OU 2 Area 8 has been implemented as intended by the ROD.

Removal and off-site disposal of vadose-zone soil from COC hotspots were completed before the first 5-year review. The purpose of the removal actions was to contain and remove plating solutions and wastes that were released from the 1980s through the early 1990s. Institutional controls have been implemented and maintained to prevent human exposures to COCs in soil and groundwater. Although the 1994 ROD indicated that no remedial action appeared to be necessary to protect human health and the environment at Area 9 (the subtidal areas of Liberty Bay), additional bioassay testing was stipulated in the ROD because one of three bioassay results indicated the sediment may pose some ecological risk. The post-ROD confirmatory bioassay testing performed in 1996 on Area 9 sediments showed no toxicity to benthic organisms and thus confirmed the no-action decision in the ROD (U.S. Navy 1996).

LTM monitoring for seeps and groundwater have been ongoing since 1995. Tissue and sediment sampling to support the HHRA/ERAs have occurred approximately every four to five years since 1996. The results have been evaluated regularly to assess the effectiveness of the

remedy and the adequacy of the monitoring program. A comparison of sediment data to the state SMS benthic standards (Chapter 173-204 of the Washington Administrative Code [WAC]) and risk evaluations of sediment and clam tissue data were conducted as a means to evaluate whether groundwater discharges from the site could adversely affect the Liberty Bay ecological environment or future human receptors and assess the potential need for groundwater control actions.

To satisfy the risk assessment requirement in the ROD, post-ROD risk evaluations have been conducted. Risk assessments were not conducted during the first 5-year review period because only one round of sediment and tissue sampling from 1996 was available (U.S. Navy 2000). During the second 5-year review period, a human health risk evaluation using the 2004 data and the 1993 Baseline HHRA exposure parameters (i.e., FCR of 132 g/day [USEPA 1991a]) was completed that identified marginal potential risks due to cadmium concentrations in sediment and clam tissue (U.S. Navy 2005). Specifically, the cumulative HI was 2 (or 1.5 if not rounded up), slightly above the U.S. Environmental Protection Agency (USEPA) and Washington State Department of Ecology (Ecology) target health goal of 1. Cadmium contributed the majority (60 percent) to the total hazards from ingestion of clam tissue, with a hazard quotient (HQ) of 0.9. Chromium and methylmercury both had HQs of 0.3, and each contributed 20 percent to the total hazard. No COCs with carcinogenic endpoints were identified. Thus, cancer risks were not calculated.

Monitoring data collected in 2008 for the third 5-year review showed cadmium concentrations slowly increasing in intertidal sediment at the adjacent beach. Because of this and the slightly elevated hazards identified in the risk assessment completed in 2005, both human health and ecological evaluations were conducted on sediment and clam tissue data collected in 2008 using the exposure factors from the baseline risk assessments. However, based on new information (such as the USEPA Region 10 recommendation for using the Suquamish Tribe ingestion study [Suquamish Tribe 2000] in the risk assessment), the Navy, the Suquamish Tribe, the USEPA, and Ecology jointly decided not to include the results of the HHRA in the third 5-year review. In addition, the USEPA, Ecology, and the Suquamish Tribe did not agree with the findings of the ecological risk evaluation, which did not identify significant risks to the marine environment based in part on bioassays (U.S. Navy 2009a). Specifically, the USEPA, Ecology, and the Suquamish Tribe identified concerns about whether the sampling in the intertidal zone had been deep enough to address the worst-case scenario (finer grain size), given the dynamic nature of the beach environment and the limited number of bioassay sampling locations used to develop conclusions about ecological impacts. In its responses during the regulatory agency interview conducted as part of the third 5-year review (U.S. Navy 2010), Ecology stated that “the

excavation and off-site disposal of vadose-zone soil is not effective in preventing the migration of contaminants to Liberty Bay." The remedy was not intended to prevent such migration, as recognized in the ROD, unless the risk evaluations warranted groundwater control actions. Therefore, the collection of additional intertidal sediment and clam tissue data for analysis of metals and an additional ERA and HHRA were agreed to by the USEPA, Ecology, and the Suquamish Tribe and formalized as a recommendation in the third 5-year review (U.S. Navy 2010).

A project to collect additional sediment and tissue data from the Area 8 Beach was initiated during the fourth 5-year review period, and the U.S. Navy, the USEPA, Ecology, and the Suquamish Tribe met in work groups to identify data gaps and develop the scope of the project-specific sampling plan and risk assessment approaches. As an outcome of these agreements, the QAPP was finalized, and sampling was conducted in June 2015 and June 2016 (U.S. Navy 2015c, 2016a, and 2016b). Tissue, sediment, seeps/outfalls, and marine surface water were analyzed for the COCs agreed upon by the project team (which consists of the project managers from the U.S. Navy, the USEPA, Ecology, and the Suquamish Tribe): arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc.

The HHRA/ERA do not utilize the exposure factors from the baseline risk assessments, as stipulated by the ROD, because the following new information and activities completed at the Area 8 beach affect how the current risk assessments evaluate tissue and sediment results and quantify risk:

- 2000: The Suquamish Tribe published adult and child ingestion rates in a fish consumption survey (Suquamish Tribe 2000).
- 2007: The USEPA published *Final Risk Assessment Guidance for Superfund;* Volume I*, Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (USEPA 2007a).
- 2007: The USEPA published *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia* (the "Framework") (USEPA 2007b).
- 2007: Ecology revised the MTCA Cleanup Regulation, Chapter 173-340 WAC (Ecology 2007), which refined the risk assessment methodology.

- 2013: Ecology published the revised SMS rule in February 2013, effective September 2013, and a technical support document for fish consumption rates (Ecology 2013a).
- 2013: The Agency for Toxic Substances and Disease Registry (ATSDR) published its public health assessment in September 2001 using the 1996 data. In response to a request from representatives of the Suquamish Tribe and Ecology, ATSDR provided a health consultation on the data collected between 1996 and 2008, incorporating the accepted Suquamish shellfish ingestion rate (ATSDR 2013).
- 2015: Ecology published the Sediment Cleanup User's Manual II (SCUM II) guidance in March 2015, which includes natural sediment background values for metals in Puget Sound and tribal exposure factors (Ecology 2015).

2.0 DATA EVALUATION

This section reviews the available data and selects the appropriate data set for evaluating human health and ecological risks. According to USEPA guidance (USEPA 1989, 1997, and 1998a), the first step of risk assessment involves an initial screening of the sampling data to select the applicable data set for human or ecological receptors and, within that data set, to select chemicals that could be a human or environmental health concern, which are referred to as chemicals of potential concern (COPCs). This first step has been completed in previous risk assessments for the Area 8 beach, and the current agreed-upon data set and COCs have been selected in collaboration with the USEPA, Ecology, and the Suquamish Tribe as documented in the project-specific QAPP (U.S. Navy 2015c). Therefore, this HHRA/ERA does not include a screening to eliminate chemicals as COCs. This section includes a comparison of available data to the screening levels (see Appendix B for calculation of screening levels), an assessment of data usability and quality, and a comparison of available data to background concentrations. In addition, a summary of the available simultaneously extracted metals/acid-volatile sulfide (SEM/AVS) data, historical bioassay data and historical biological survey data that were utilized in the ERA are provided in this section.

2.1 Data Usability and Quality

Optimizing data usability reduces the uncertainty associated with environmental data used in a risk assessment. Issues related to data usability and quality are discussed according to USEPA guidelines (USEPA 1992a), which provide practical guidance on how to obtain an appropriate level of quality for all environmental analytical data. Four data usability questions are evaluated in the risk assessments (USEPA 1992a):

5. **What contamination is present and at what levels?** COCs were previously identified for the site. Thus, comparisons between risk-based screening level and benchmarks were not used to identify COCs or eliminate chemicals, but rather to characterize the significance of contamination at the site relative to these benchmarks. The COCs at Area 8 are metals. The analytical results for concentrations of metals at the Area 8 beach are summarized and compared to the human health risk-based screening levels (see calculations in Appendix B) and ecological benchmarks on Tables 1 through 4. The maximum detected chemical concentrations in the sediment and tissue data were compared to the human health screening levels and the ecological benchmarks, and maximum detected chemical concentrations in the seep and marine water data were compared to the ecological benchmarks. The human health values are the Suquamish

subsistence risk-based screening levels calculated using the exposure factors in Section 3, and are presented in Appendix B. The ecological benchmarks are the Oregon Department of Environmental Quality (ODEQ) critical tissue levels (CTLs), the Ecology SMS sediment cleanup objectives (SCOs), and the Ecology marine surface water criteria.

As shown on Table 1, all 41 of the clam tissue samples collected from the Area 8 beach contained cadmium and arsenic above the Suquamish subsistence risk-based screening levels and ecological CTL. Only one clam tissue sample from the Area 8 beach contained methylmercury above the Suquamish subsistence risk-based screening level. As shown on Table 2, nearly all of the sediment samples collected from the Area 8 beach contained arsenic at concentrations exceeding the Suquamish subsistence risk-based screening levels No other COCs detected in sediment were present at concentrations exceeding human health based screening levels. Also shown on Table 2, a handful of Area 8 beach sediment samples (less than 10 percent) contained cadmium, copper, nickel, silver, and mercury at concentrations exceeding their respective Ecology SMS SCOs. Only one seep sample collected from the Area 8 beach (Seep C) contained cadmium at concentrations exceeding the Ecology surface water criteria protective of aquatic life (Table 3), and no marine water samples contained concentrations of any COCs above the surface water criteria (Table 4).

2. **Are site concentrations different from background?** Concentrations of chemicals that occur on-site in the absence of site activities are defined as background concentrations. Because metals occur naturally in the environment, comparison of site data to background concentrations allows determination of the degree of contamination associated with site activities. The concentrations of metals at the Area 8 beach are compared to the reference area concentrations (tissue) and to Washington State natural background concentrations (sediment) in Section 2.4.

3. **Are all exposure pathways and areas identified and examined?** For humans, recreational and subsistence exposures to COCs in sediment by incidental ingestion and dermal contact (adults and children) and to COCs in clam tissue by ingestion (adults and children) are quantitatively evaluated, as discussed further in Section 3.0. As discussed in Section 4.0, for ecological receptors, the following pathways were quantitatively evaluated: exposure (by incidental ingestion and/or dermal uptake) to COCs in seeps and surface water for aquatic plants, aquatic and benthic invertebrates, and fish; exposure to COCs in sediment for benthic invertebrates, fish, and wildlife; and prey

ingestion by wildlife. The CSMs for human health and ecological receptors are described in detail in Sections 3.1.1 and 4.1.2, respectively.

4. **Are all exposure areas fully characterized?** Exposure area is typically defined as the area of impacted material where human and ecological exposures are likely to occur. LTM sampling has documented elevated concentrations of ROD COCs in seeps, sediments, and clam tissue in the intertidal portion of the Area 8 beach, immediately downgradient of the historical plating shop. Historically, LTM seep monitoring has been performed at seep locations A and B (Figure 3). Historical COC concentrations in seep water from Seep B and in sediment in the vicinity of Seep B (stations along Transect 1), indicated that the southerly extent of elevated COC concentrations in the intertidal zone was delineated by Seep B and Transect 1. However, based on stakeholder comments and concerns during the development of the marine data report (U.S. Navy 2016c) about adequate characterization of the southerly extent of contamination, an additional transect (Transect 14) was developed south of Transect 1. Clam tissue and sediment samples were collected along this transect during the 2016 sampling event. COC concentrations measured in tissue and sediment samples along Transect 14 confirm that the southern extent of contamination is characterized.

   During the 2014 site walk conducted by the stakeholder team as part of scoping the QAPP, Seep "A" was located and an additional five seeps were observed and located north of Seep "A". However, during the finalization of this HHRA/ERA report, a discrepancy between the location of Seep "A" in this report and other project documents including the 1994 ROD was noted. The Seep A location identified in historical and recent LTM reports (U.S. Navy 2001, 2015b, and 2018) was found to be further north than the Seep "A" location that was identified in the field during the 2014 site walk. The Seep A location was also incorrectly identified in the following project documents: Final 2008 Sediment and Tissue Long-Term Monitoring Report (U.S. Navy 2009b), Final Ecological Risk Evaluation of the Intertidal Zone (U.S. Navy 2009a), Third and Fourth Five-Year Reviews (U.S. Navy 2010 and 2015a), and Final Marine Investigation Report (2016c). The historical Seep A location was mislabeled Seep C during the 2015 field sampling investigation. Therefore, for consistency with the seep names used in the LTM reports, Seep A is located east of Well MW8-11 and Seep C is located east of MW8-14 through MW8-16. In addition, because the sediment sampling locations are in different places between the LTM and the risk assessment sampling program, the nomenclature for three risk assessment tissue and sediment sampling stations was modified to sampling stations SS03-C, SS06-C and SS09-C in order to distinguish them from

historical sampling stations 3, 6, and 9 and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Seep A remains along Transect 3. Finally, sampling station SS03-C was co-located with Seep C.

For this assessment, the exposure area extends north to Seep G to ensure that potential impacts to the north of Seep A are fully characterized. In response to stakeholder concerns, additional sediment data were collected in 2012 to evaluate the extent of metals impacts in sediment further into the intertidal and subtidal areas offshore of Area 8 (U.S. Navy 2013). These data were reviewed with stakeholders during workgroup sessions prior to development of the QAPP (see meeting minutes in Appendix A of U.S. Navy [2015]). Based on the sampling of subtidal sediments conducted in 2012 that indicated that samples collected from the subtidal areas offshore of Area 8 were minimally impacted, it was agreed among stakeholders and regulators during the stakeholder meeting on April 24, 2014 (see Appendix A of U.S. Navy [2015]), that COC impacts are limited to the intertidal zone. Thus, the exposure area for potential human and ecological receptors is limited to the intertidal areas of the Area 8 beach. The sampling conducted during the 2015 and 2016 sampling events from the south at Transect 14 to the north near Seep G delineates the extent of potential contamination and sufficiently characterizes the exposure area. Figure 2 identifies the exposure area evaluated in the risk assessments.

The shellfish survey conducted (U.S. Navy 2014) confirmed an abundance of Pacific littleneck and butter clams along the entire stretch of beach adjacent to Area 8. This finding indicates that human health and ecological exposures are possible everywhere within the currently selected exposure area, as defined by the observed seeps and historical COC concentration data.

To ensure adequate characterization of the exposure area, the number of samples and the exposure area included in the QAPP were defined in collaboration with the project team. An adequate number of samples were collected to perform meaningful statistics (greater than 22 samples). The method used to determine the number of samples required to support the statistical evaluation is included in Appendix C.

All data were collected in accordance with USEPA guidelines. The sampling events detailed in the QAPP (U.S. Navy 2015c) and QAPP modification (U.S. Navy 2016b) were designed for the specific purpose of providing data for the HHRA and ERA. In addition, all data quality objectives including those related to sample collection, data quantification, practical quantitation

limits, and data verification have been met in accordance with the QAPP, which was approved by the USEPA, Suquamish Tribe, and Ecology. All COCs were detected in nearly every sample collected during the 2015 and 2016 sampling events, with the exception of silver in reference area clam tissue. However, the reporting limits for silver in tissue are below the screening criteria. Thus, no reporting limit issues were identified that would introduce significant uncertainty in the risk evaluation and the data are of sufficient quality for its intended purpose.

When there were multiple analyses of a sample (i.e., field or laboratory duplicates), to be conservative, the highest detected concentration or the lowest reporting limit value is used as the single, most valid analytical result for the sample and was used to perform summary statistics.

2.2 Summary of Available Data

As discussed previously, seep, sediment, and tissue monitoring have been ongoing since 1995, with the results evaluated regularly to assess the effectiveness of the remedy and the adequacy of the monitoring program. As summarized in the fourth 5-Year review (U.S. Navy 2015a), the cadmium trends (the primary COC at this site) in groundwater over the last 10 years and overall trends since monitoring began are stable and decreasing. While the overall trends for cadmium in Seeps C and B appear stable and decreasing, fluctuating concentrations of cadmium in Seep C have been observed since removal of the plating shop in 1999 (U.S. Navy 2015a and 2015b), with the most recent concentration in 2015 of 45.7 µg/L again spiking above the ROD surface water RG of 8 µg/L (U.S. Navy 2015c) and approaching maximum concentrations last measured in 2004 and 2005 (U.S. Navy 2015a and 2015b). Sediment and tissue collected from sampling locations in the vicinity of Seeps C and B also show stable and slightly decreasing cadmium concentrations over the last 10 years, with the average 2015 results the lowest measured since monitoring began.

As recommended in the 3rd and 4th 5-year reviews and agreed to by the project team, the risk assessments quantitatively evaluate only the data collected during the 2015 and 2016 sampling events to assess current risks (U.S. Navy 2015c, 2016a, and 2016b). Data from historical sampling was not used to ensure this risk assessment is based on current site conditions. As described in the Area 8 marine investigation data report (marine data report) (U.S. Navy 2016c), during the 2015 and 2016 sampling events, tissue, sediment, seeps/outfalls, and marine surface water samples were collected from selected locations at the Area 8 beach. Figure 3 presents the 2015-2016 Area 8 beach sampling locations. Figures 4, 5, and 6 are simpler figures depicting only the clam sampling stations, the sediment, and the seep/surface

water and outfall sampling stations, respectively. Tissue and marine water samples were collected from the reference area, Penrose Point State Park (Figure 7). A sufficient number of samples were collected to perform meaningful statistical analysis of site versus reference area data, as detailed in Appendix C of the QAPP (U.S. Navy 2015c).

Samples were analyzed for the COCs agreed upon by the project team: arsenic (total and inorganic), cadmium, chromium (total), copper, lead, mercury (total and methylmercury), nickel, silver, and zinc. Sampling results are presented in detail in the marine data report (U.S. Navy 2016c), and Appendix A of this document contains the complete set of data evaluated in the risk assessment. The data results for the on-site and reference area sampling stations are summarized in the sections below and in Tables 1 through 4.

2.2.1 Clam Tissue Data

As detailed in the HHRA/ERA workplan (U.S. Navy 2016a), the HHRA and ERA target species selected for tissue sampling and analysis was the native Pacific littleneck clam (*Protothaca staminea*), although the backup species, Manila clam (*Tapes philippinarum*), also known as introduced Japanese littleneck, was collected if the littleneck clam was not available. The Pacific littleneck clam was noted in abundance along the Area 8 beach (U.S. Navy 2014). An abundance of butter clams (*Saxidomus gigantean*) was also noted, though butter clams secrete a toxin that make them less likely to be consumed by higher trophic-level ecological organisms than other clam species (Kraeuter and Castagna 2001). In addition, no differentiation of the shellfish consumption rates between Pacific littleneck and butter clams has been made (Suquamish Tribe 2000); therefore, Pacific littleneck clams were chosen as the indicator species for both the ERA and the HHRA and are also considered representative of the benthic invertebrate community in general (U.S. Navy 2015c: Appendix A).

Single-species composite samples of non-depurated clams were preferentially collected. Littleneck and Manila clams were composited only when an adequate number of specific organisms could not be collected at each sampling location. From a seafood ingestion perspective, there is no difference between littleneck and Manila clams. It is assumed that they are consumed in the same quantities, since manila and littleneck clams are similar organisms in appearance and are often difficult to distinguish between in the environment (http://wdfw.wa.gov/fishing/shellfish/clams). Contaminant uptake is expected to be comparable in native littleneck and the introduced Manila clam due to similarities in their life history. Both littleneck and Manila clam species are suspension feeders, primarily consuming phytoplankton, but they will also feed on zooplankton and detritus (Government of Canada

2013; U.S. Fish and Wildlife Service 1987). Because Pacific littleneck clams and Manila clams are similar species and no differentiation of the consumption rates of these two species has been made (Suquamish Tribe 2000).

A total of 41 clam tissue samples were collected from the Area 8 beach (Figure 4), and a total of 22 clam tissue samples were collected from the reference area, Penrose Point (Figure7). The available clam tissue data are presented in Appendix A. Table 1 summarizes the available clam tissue data from the Area 8 beach and Penrose Point and includes a preliminary screening comparison to risk-based criteria to identify COPCs for the human health and ecological risk assessment. Twenty-eight of the 41 clam tissue samples collected from the Area 8 beach were single-species composites consisting of littleneck clams; 1 clam tissue sample from the Area 8 beach was a single-species composite consisting of manila clam; and the remaining 12 clam tissue samples collected from the Area 8 beach were composites of littleneck and Manila clams. All clam tissue samples collected from Penrose Point were single-species composites consisting of littleneck clams. Table A3 in Appendix A summarizes the composite information for the clam samples collected from the Area 8 beach and presents the cadmium results (the primary COC at Area 8) for each sample. Table A3 in Appendix A presents the clam tissue data with respect to transect and suspected contamination sources. As shown on Table A3 in Appendix A, the concentrations of cadmium reported in single-species littleneck composites and mixed-species composites consisting of both littleneck and manila clams are not substantially different when proximity and suspected contamination sources are taken into consideration. Thus, composite samples consisting of littleneck and Manila clams are not expected to increase the uncertainty associated with the data or the risk assessment.

2.2.2 Sediment Data

Sediment samples were collected from 66 Area 8 beach sampling stations in June 2015 and June 2016. Sediment samples were collected from a depth of 0 to 10 centimeters (cm) at all 66 stations. At 10 of the 66 stations (one location per transect), sediment samples were also collected from 10 to 24 cm. No sediment was collected from Penrose Point State Park. Based on project team concurrence, Ecology's BOLD survey data (USACE 2009 and Ecology 2015), which are considered natural background sediment levels for Puget Sound, were used to evaluate background concentrations of COCs in sediment. Seventy background sediment samples are available from the BOLD survey data. The available sediment data from the Area 8 beach are presented in Appendix A. Appendix A also contains the BOLD survey data for the COCs in sediment. The sediment data from the Area 8 beach are summarized on Table 2. Figure 5 shows the sediment sampling stations at the Area 8 beach.

As discussed in the project-specific QAPP (U.S. Navy 2015c), Pacific littleneck and butter clams are typically present in the top 10 cm of substrate. However, butter clams can burrow as deep as 8 to 14 inches (20 to 34 cm). Therefore, sediment samples were collected at up to 24 cm from a subset of the sediment sampling stations, or as deep as technically feasible if hard or impenetrable substrate was encountered, to determine the vertical extent of sediments impacted by site-related contamination and assist in characterizing exposures to all potential human and ecological receptors. The concentrations of COCs from the 0 to 10 cm depth interval are compared to the 10 to 24 cm depth interval in Table 5. As shown on Table 5, there is little difference in concentration between the 0 to 10 cm depth interval and the 10 to 24 cm depth interval. With the exception of two sampling locations (Stations 08 and 40), the magnitude of difference in concentrations of all COCs between the two depth intervals is less than a factor of 2. At Station 08 (Transect 2) the concentration of mercury measured in the 0 to 10 cm depth interval is over 40 times higher than the concentration of mercury measured in the deeper interval. At Station 40 (Transect 10), the concentration of mercury is approximately 11 times higher in the 10 to 24 cm sampling interval than the concentration detected in the 0 to 10 cm sampling interval. Although there are some instances where the deeper depth interval (10-24 cm) had a higher COC concentration, it was agreed by the project team (as documented in the in meeting notes and the risk assessment work plan) that the HHRA risk characterization would focus on the surface depth interval (0-10 cm) and only this data was used to calculate risks. An uncertainty analysis of excluding the deeper sediment depth (10 – 24 cm) and the estimation of risks including the deeper sediment data is presented in the uncertainty section.

2.2.3 Seep and Outfall Data

Seep samples are representative of shallow groundwater discharge to the environment. Water samples were collected from the seven seeps (Seeps A through G) and one outfall (OF 03-701) at the Area 8 beach. COC concentrations measured from outfalls may be reviewed to evaluate whether the outfalls might be providing an additional source of contamination to Liberty Bay. No samples were collected from OF 03-703 because the outfall was dry during both sampling events. The available seep/outfall data from the Area 8 beach are presented in Appendix A and summarized on Table 3. Figure 6 shows the seep and outfall sampling stations at the Area 8 beach.

2.2.4 Marine Water Data

Marine surface water samples were collected from nine Area 8 beach sampling stations and eight reference area sampling stations and analyzed for dissolved metals. The results for metals are listed in Table 4 for the Area 8 beach and for the reference area. Figure 6 shows

the marine water sampling stations at the Area 8 beach, and Figure 7 shows the reference area marine water sampling stations. Note that the marine surface water samples were collected at the seep and outfall locations. Thus, the sample location identifiers presented on Table 4 are associated with the respective seeps and outfalls.

2.2.5 Simultaneously Extracted Metals Analysis/ Acid-Volatile Sulfide

SEM/AVS data are used in the ERA as a measure of the bioavailability of metals in the groundwater (seeps) to evaluate whether seeps, rather than sediment, are the primary medium affecting the observed concentrations of metals in clam tissue. SEM and AVS concentrations have been primarily used to assess bioavailability in terms of how they can predict toxicity. However, because the approach evaluates bioavailability (i.e., potential for exposure) it can also be used to assess chemical uptake into tissues. Therefore, the SEM data, in combination with measured clam tissue concentrations, provide important information to assess the SEM/AVS test data.

In 2015 and 2016, SEM/AVS tests were run on a total of 32 sediment samples, 17 and 15 samples respectively. SEM/AVS guidelines indicate that sampling under anaerobic conditions is optimal to avoid loss of sulfides during sample collection. However, the Area 8 beach sediments are intertidal and are naturally aerated two times per day by the tides. Therefore, the impact of sulfide loss during sampling relative to the natural conditions is expected to be minor. On the armored beach, the sediment is basically cemented between the cobbles; consequently, the collection of sediment samples required some degree of sediment disturbance. However, care was taken to prevent disturbing the sample during collection to minimize exposure to oxygen and to prevent the loss of sulfides during collection and storage. The 2015 and 2016 SEM/AVS data were considered usable for the ERA and are further evaluated in Section 4.3.4.3.

2.2.6 Bioassay Tests

Though human and ecological health risk estimates are based on the 2015 and 2016 sampling data, historical bioassay test results are considered to supplement the ecological risk evaluation and conclusions. Bioassay tests were run by Northwestern Aquatic Sciences in 2008 with sediment collected at Station SS03-C, the seep and sediment sampling location co-located with the maximum 2008 cadmium sediment concentration (13.8 mg/kg dry weight). These tests remain in compliance with the 2013 Final SMS rule. Both of the acute bioassays as well as the chronic test met the SMS test acceptability criteria. These data are further evaluated in Section 4.3.4.4. The 2008 bioassay tests performed at location SS03-C/Seep C are expected to provide

a reasonable prediction of toxicity for other sediments with concentrations exceeding the cadmium sediment benchmark, given that concentrations of cadmium across the site have been reduced since the 2008 sampling. However, additional bioassays across the site to assess current conditions on a broader spatial scale are recommended based on project team concerns.

2.2.7 Biological Surveys

There have been two shellfish surveys performed at the Keyport site that focused on characterizing the species and abundance of the Phylum Mollusca. While not quantified, casual observations were made during a site visit on June 13, 2014, and during subsequent sampling activities. Other species of marine life observed during these events included barnacles, moon snail, sea pen, copepods, sculpin, sea stars, sea anemones, and pile worms.

A *Sustainable Shellfish Harvest Report* was prepared in 2007 (U.S. Navy 2007), which evaluated 1.2 acres of the Area 8 beach and defined the clam band as 0.78 acres. The survey encompassed five transect lines where the numbers, sizes, and species of clams were documented. In 2014, an *Intertidal Shellfish Survey Report* was prepared (U.S. Navy 2014). The purpose of the report was to document the infaunal shellfish species, burial depths, and general abundance within the intertidal portion of the Area 8 beach. The most abundant clam species were the native Pacific littleneck and butter clams. Manila clams, an introduced littleneck clam, were the next most abundant clam in the survey area. These data are further evaluated in Section 4.3.4.5.

2.3 Analysis of Chemicals of Concern

All samples were analyzed for the project-specific COCs: arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc. Arsenic, mercury, and chromium required additional analyses to ensure that the sampling provided the most appropriate data set to evaluate site risks, as described further in the following subsections.

2.3.1 Arsenic

Analysis of tissue samples collected during the 2015 and 2016 sampling events included arsenic speciation and total arsenic. Arsenic in the environment can occur in inorganic or organic forms (Borak and Hosgood 2007, ATSDR 2007, and Ecology 2002). Only a small proportion of arsenic in seafood occurs in inorganic form, the most toxic form to mammals, including humans (Borak and Hosgood 2007 and ATSDR 2007). Use of the speciated arsenic data in the human health and ecological risk calculations provides site-specific information about arsenic composition in

the seafood samples and eliminates the uncertainty associated with the assumptions of the proportion of inorganic versus organic arsenic in seafood.

Table 6 summarizes the percent of inorganic arsenic measured in each of the clam tissue samples. As shown on Table 6, the percentage of inorganic arsenic to total arsenic measured in Penrose Point clam samples ranges from 1 to 3 percent, with an average of 2 percent. The percentage of inorganic arsenic to total arsenic in Area 8 beach clam samples is slightly lower, ranging from 0.5 to 2 percent, with an average of 1 percent.

2.3.2 Mercury

In addition to total mercury, samples were analyzed for the presence of methylmercury in the tissue samples collected during the 2015 and 2016 sampling events. Both total mercury and methylmercury results were evaluated in the HHRA and ERA. In seafood, the majority of mercury is organic mercury (methylmercury), for which developmental toxicity is the most sensitive endpoint for humans. Methylmercury is of particular concern because it can bioaccumulate, and even biomagnify, in freshwater and marine organisms. Methylmercury results were used to evaluate human health risks due to ingestion of seafood. Total mercury results were used to evaluate human health risks due to incidental ingestion and dermal contact with sediment. In the ERA, as methylmercury is more representative of exposure for wildlife receptors because it accumulates in their prey and total (or inorganic) mercury is more representative of exposure for lower trophic level receptors, like benthic invertebrates and macroalgae in certain environments (Paranjape and Hall 2017), that are in direct contact with sediment and surface water.

The conversion of inorganic to methylmercury is caused primarily by sulfate-reducing bacteria (Fimmen et al. 2009 and Compeau and Bartha 1986) and iron-reducing bacteria (Fleming et al. 2006). As noted above, in pelagic environments such as Arctic marine ecosystems, methylation is reported to occur in macroalgae (Paranjape and Hall 2017).

There are numerous abiotic factors affecting mercury methylation. In water and sediments the amount of methylation is affected by the amount of dissolved oxygen present, the amount of sulfur present, the pH of the water or sediment, and grain size, particularly the presence of particles of clay or organic material (MADEP 1996). Methylation is reported to occur primarily in the upper layers of sediment where there is significant microbial activity (Paranjape and Hall 2017). However, methylation can also occur in anoxic surface waters. The presence of sulfur may be important because it can be inferred that sulfate-dependent bacteria may be present that are involved in the methylation process and because sulfur serves as an electron receptor

and a ligand for mercury. Low pH is typically associated with an increase in methylation (MADEP 1996). However, recent studies have observed methylation to occur only in tropical lakes with a neutral pH and in prairie wetlands with pH above 8 (Paranjape and Hall 2017). A recent study has found that dissolved organic carbon (DOC) both mobilizes inorganic mercury and alters cell walls to facilitate uptake (Paranjape and Hall 2017). However, as noted by Tsui and Finlay (2011), the efficiency of methylmercury incorporation into the stream food webs decreased significantly with increasing DOC concentration, suggesting that methylmercury bioavailability to the base of food webs was attenuated at higher levels of DOC. Because inorganic mercury has been reported to bind to organic matter, a decrease in mercury bioavailability and, therefore, methylation has been reported when organic material is present (Paranjape and Hall 2017). Other variables to consider are iron and temperature. It has been reported that high concentrations of ferrous iron can suppress mercury methylation by complexing mercury and making it unavailable for methylation (Paranjape and Hall 2017). Previous research has suggested that warmer water temperatures may promote bacterial methylation (Paranjape and Hall 2017). Lastly, while low salinity has been touted as resulting in higher methylation rates, recent studies have shown salinity to both stimulate, and to have no correlation with, methylation potential (Paranjape and Hall 2017).Table 6 summarizes the percent of methylmercury measured in each of the clam tissue samples. As shown on Table 6, the percentage of methylmercury to total mercury measured in Penrose Point clam samples ranges from approximately 40 percent to 100 percent, with an average of 64 percent. The percentage of methylmercury to total mercury in Area 8 beach clams samples is lower, ranging from as low as 10 percent to approximately 90 percent, with an average of 54 percent.

2.3.3 Chromium

Chromium in the environment is typically present in either the trivalent form (chromium III) or the hexavalent form (chromium VI) (ATSDR 2012). Chromium compounds are stable and occur naturally in the trivalent form. Chromium VI rarely occurs naturally but is usually produced from anthropogenic sources (ATSDR 2012). Chromium VI is the most toxic form of chromium for humans (ATSDR 2012). Interestingly for mammals, USEPA's Ecological Soil Screening Level (EcoSSL) for chromium III is less than (more conservative than) the EcoSSL for chromium VI (USEPA 2008).

Historical activities at the plating shop likely released chromium VI to soil and groundwater at Area 8, and chromium was identified as a COC in soil and groundwater (U.S. Navy, USEPA, and Ecology 1994). Evaluation of the 2015 and 2016 sediment data indicates that concentrations of total chromium are consistent with Washington State background concentrations of chromium

in sediment (see further discussion in Section 2.4). In addition, the chromium concentrations measured in the 2015 seep samples were less than the ecological surface water benchmark value of 50 micrograms per liter (µg/L) at all seeps and less than the ROD-specified chromium background value for groundwater of 4 µg/L at all seeps except Seep C.

The speciation of chromium (chromium III or chromium VI) in sediments and clam tissues can be an important factor in understanding human health and ecological risks at the site. Analytical speciation methods for soil can be applied to sediment. During the development of the QAPP (U.S. Navy 2015c), the project team agreed that any 2016 sediment samples with total chromium concentrations above Ecology's background value would also be analyzed for speciated chromium. However, because no 2016 sediment samples exceeded the background level, the soil speciation methods were not applied to sediment samples and only total chromium results were reported (U.S. Navy 2016a). In addition, because there is no standard analytical approach for the speciation of chromium in tissue, the project team agreed that the 2016 clam tissue samples would only be analyzed for total chromium. All chromium is expected to be in the trivalent state in living systems as described below, and hence there is no rationale for conducting speciation in addition to total chromium analysis.

Although a historical source of chromium VI exists at Area 8, chromium VI in the environment readily reduces to chromium III, the less toxic form, in the presence of oxygen in oxidizing environments (ATSDR 2012). As chromium in groundwater migrates away from the source, conversion to chromium III occurs. In addition, chromium VI is unstable in living organisms and is ultimately reduced to chromium III in vivo by a variety of reducing agents (ATSDR 2012). As described by Outridge and Scheuhammer (1993), under normal chromium exposures, chromium in animal tissues is almost always present as chromium III, because chromium VI is rapidly and quantitatively reduced to chromium III in vivo. Outridge and Scheuhammer (1993) indicate that the reducing capacity of organismal cells is limited at higher chromium exposure levels. Though Outridge and Scheuhammer (1993) do not provide a quantitative estimate of the chromium level that would limit the reducing capacity of organismal cells, the source of chromium VI to Liberty Bay is not expected to be high enough to overwhelm the reducing capacity of marine organisms. Based on literature describing the reduction of chromium VI to chromium III in sediments and animal tissue, total chromium results in sediments and clam tissues are evaluated as chromium III in the risk assessment. The potential underestimation of risks associated with this assumption is discussed in the uncertainty section.

2.4 Reference and Background Evaluation

This section evaluates site COC concentrations relative to reference area or background concentrations. As previously discussed, no COCs will be eliminated from further risk characterization based on the results of the reference area and background comparisons, as agreed to by the project team. All COCs were carried through the full risk characterization evaluation. The reference area and background data are used to calculate incremental site risk over reference area and background risk. The calculation of incremental risk is discussed further in Section 3.0.

Penrose Point was selected as the reference area to evaluate COC concentrations in clam tissue and marine surface water. Penrose Point was selected by the project team based on the remoteness of the site, lack of nearby point sources, and good agreement with site sediment characteristics and biological habitat (U.S. Navy 2015c: Appendix A). To characterize site sediment concentrations relative to background, the Ecology BOLD natural background values, as presented in SCUM II (Table 10-1 of Ecology 2015) were used. This method was agreed to by the technical project team during stakeholder meetings (see Appendix A of U.S. Navy 2015c). The COC concentrations measured in the 41 Area 8 beach clam samples were compared to the COC concentrations measured in the 22 clam tissue samples collected from Penrose Point to evaluate whether Area 8 beach clam tissue concentrations are different from reference area clam tissue concentrations for each COC; likewise, the COC concentrations measured in the 66 shallow sediment samples collected from the Area 8 beach were compared to the 70 BOLD survey data samples to evaluate whether Area 8 beach sediment concentrations are different from the natural background concentrations in sediments of Puget Sound. As described above and detailed in Appendix C, sufficient sample data set sizes were planned for this sampling event to allow meaningful statistical comparison.

A comparison of individual analytical results to background threshold values (BTVs) is used to determine whether or not that result indicated contamination is derived from background distribution. A BTV is a statistically calculated concentration that represents the background levels of a contaminant or a concentration level that is categorized as not exceeding background levels. USEPA and Ecology both utilize some type of BTV to evaluate whether an individual analytical result exceeds background. Ecology specifies that the BTV of the 90/90 UTL (Ecology 2013a) be used to determine whether or not site contaminant concentrations exceed background. USEPA evaluates a broader range of options in selecting a BTV, as noted in the ProUCL guidance (USEPA 2015), and uses group comparison tests to determine whether or not site contaminant concentrations exceed background. The reference area and

background evaluation includes both a statistical population-population (site versus reference area/background) comparison and a single-point comparison of site concentrations to BTVs.

As described in the following subsections, to assess whether the Area 8 beach tissue and sediment concentrations are statistically different from reference area concentrations (clam) and natural background concentrations (sediment), a population-population (site versus reference area/background) comparison was performed. In order to support the re-evaluation of the CSM (Section 5.0), a single-point comparison was performed to determine the extent of site sediment and site tissue contamination relative to natural background concentrations (sediment) and reference area concentrations (clam) and to evaluate whether a pattern of contamination could be established with regard to suspected point sources. Although the marine surface water data indicates that site surface water is impacted by COC concentrations, no exceedances of benchmarks were noted. Therefore, no statistical comparison was performed between site and reference area marine surface water data.

2.4.1 Single-Point Comparison of Site versus Reference Area/Background Data

A single-point comparison was initially performed on the site and reference area/background data for tissue and sediment, to assess whether the Area 8 beach concentrations are statistically different from reference area and natural background concentrations. The single-point background sediment and reference area concentration comparison is consistent with Ecology's SMS (Ecology 2013a) and can be used to identify hotspots. It can also provide information on which seep(s) are potentially adversely affecting Liberty Bay. The results of the single-point background and reference area evaluation are discussed in the subsections below for sediment and tissue.

2.4.1.1 Sediment

Ecology's background sediment 90/90 upper tolerance limit (UTL)[1] value based on the 2008 BOLD survey data available from USACE (2009) was used as the BTV for single-point comparison to the site sediment data, as agreed to by the technical project team during stakeholder meetings (see Appendix A of U.S. Navy 2015c). Table 7 compares the individual sediment sampling results to the sediment BTV. The following observations were made based on the single-point comparison:

[1] 90 percent upper confidence limit on the 90th percentile UTL

- Arsenic and nickel were not detected above the BTV in any sediment sample collected from the Area 8 beach.
- Few exceedances of the BTVs occurred for chromium (3 percent), copper (6 percent), and zinc (5 percent), while several sporadic exceedances were noted for lead (9 percent) and mercury (14 percent). These exceedances were predominantly located along Transect 8 (near Seep C) and Transects 9 and 13 (near the outfalls) (Figure 5).
- For cadmium and silver, nearly 50 percent of the sediment samples were detected above their respective BTVs. For cadmium, exceedances were predominantly located along the southern Transects 2 and 8 (near Seep C), Transect 3 (near Seep A), Transect 10 (near Seep D), and Transect 9 (near Outfall 03-703). . For silver, the exceedances of the BTV noted in sediment were more widespread, with exceedances occurring on nearly every transect (except Transect 14). These results do not demonstrate a pattern with respect to specific potential point sources of silver to sediment in Liberty Bay.

2.4.1.2 Clam Tissue

Clam tissue samples collected from the reference area, Penrose Point State Park, were used to calculate a statistically valid BTV for single-point comparison. For arsenic and mercury, the BTV calculation and comparison was performed using the inorganic arsenic data and methylmercury data, as these are the most relevant forms of these metals with respect to human and upper trophic level ecological exposure in tissues, as discussed in Section 2.2. The approach used for derivation of the BTVs for tissue was discussed with the project team during the development of the HHRA/ERA workplan (see Appendix D of U.S. Navy 2016a). The approach described in the ProUCL Version 5.1.002 Technical Guide (USEPA 2015) was followed and summarized below:

1. Summary statistics were calculated on each data set, including the detection frequency, range of detected concentrations, and standard deviation.
2. Potential outliers were identified in each data set using ProUCL.
3. The distribution of each data set (both with and without outliers) was estimated using the goodness-of-fit tests and Q-Q Plots in ProUCL.
4. BTVs were calculated using ProUCL on the data sets (both with and without outliers) based on the assumed distributions.

Table 8 presents the relevant statistics describing each data set (e.g., minimum, maximum, average, and standard deviation) and summarizes the results of the ProUCL outputs for each COC. Appendix D contains the ProUCL output files. Several potential BTVs are presented on Table 8 to demonstrate the range of upper limits that can be used to estimate the BTVs. The ProUCL Technical Guidance (USEPA 2015) defines outliers as "measurements (usually larger or smaller than the majority of the data values in a sample) that are not representative of the population from which they were drawn." For data sets with no outliers identified, the lower of the maximum detected concentration or the UTL with a 95 percent confidence interval and 95 percent coverage (95/95 UTL) was selected as the BTV for tissue, as recommended in USEPA (2015). According to the ProUCL Technical Guidance (USEPA 2015), outliers can distort several nonparametric statistics (including UTLs) computed using higher order statistics; as shown on Table 8, inclusion of the outlier resulted in BTVs that were comparatively higher than the BTV calculated without the outlier. The outliers were identified by ProUCL and removed from the Penrose Point Tissue BTV calculation as provided on the output from USEPA's ProUCL program, based on the Dixon Test for 5% significance level (see Appendix D outputs). Including outliers in the calculation of the BTV, results in a higher BTV value, which is less conservative than performing a single point comparison of site sample results to the BTV. Thus, for those COCs with identified outliers (chromium, lead, methylmercury, and nickel), the 95/95 UTL calculated on the dataset excluding outliers was selected as the BTV. A BTV was only required to be calculated for the Penrose Point clam tissue because sediment values have been established based on the Bold data set in Table 10-1 of SCUMII (90/90 UTL) for natural background.

Table 9 compares the individual clam tissue results from the site to the tissue BTVs. The following observations were made based on the single-point comparison:

- Inorganic arsenic and zinc were not detected above the BTV in any tissue samples collected from the Area 8 beach, indicating that the concentrations of these COCs in clam tissue are consistent with reference area tissue concentrations.
- Copper was detected above the BTV in only four Area 8 beach clam samples (10 percent), sporadically across the exposure area.
- Cadmium was detected above the BTV in only seven Area 8 beach clam samples (17 percent). The exceedances were noted primarily along Transects 2 and 8 (near Seep C), Transect 3 (near Seep A), and Transect 9 (near Outfall 03-703).

- Nickel was detected above the BTV in nearly 40 percent of Area 8 beach clam samples. The exceedances were noted primarily along Transects 2 and 8 (near Seep C) and Transect 3 (near Seep A).
- For methylmercury, 90 percent of the sediment samples were detected above the BTV nearly site-wide.
- For lead and silver, 100 percent and 95 percent of the sediment samples were detected above their respective BTVs.

2.4.2 Population-To-Population Comparison of Site versus Reference Area/Background Data

A population-to-population (site versus reference area/background) comparison was also performed to provide information on-site concentrations relative to natural background (sediment) and reference areas (tissue) concentrations. More confidence is typically placed in this more rigorous statistical comparison. USEPA's ProUCL Version 5.1.002 was used to complete the population-to-population comparison. A two-sample hypothesis testing approach (e.g., Student's t-test or Wilcoxon Mann Whitney [WMW]) was used to compare the central tendency of the site versus reference area or background data sets. The use of hypothesis testing approaches tends to control the error rates more tightly and efficiently than the individual point-by-point site comparisons described above. As noted in the ProUCL Version 5.1.002 Technical Guide (USEPA 2015), outliers often have minimal influence on hypotheses testing statistics. Thus, no outliers were removed from the Area 8 beach data sets prior to performing the statistical analysis.

The statistical procedure was performed using the appropriate parametric or non-parametric statistical test based on the distribution of the data. The USEPA ProUCL Version 5.1.002 was used to run goodness of fit (GOF) statistical tests and Q-Q Plots to determine the distribution of each data set. The results of the GOF tests and Q-Q Plots are presented in Appendix D.1. Statistical tests that assume data sets follow a known statistical distribution (mostly normal) are called parametric statistical tests. For COCs with data sets for both the site and the reference areas that follow a normal distribution, the Student's t-test was used to compare the central tendencies of the data populations. Statistical tests that do not assume a specific statistical form for the data distribution(s) are called distribution-free or nonparametric statistical tests. The WMW statistical test was used to compare the central tendencies of data sets that do not follow a normal distribution. The Student's t-test and WMW statistical test were used to test the null hypothesis that site concentrations are less than background or reference area concentrations at a 95 percent confidence level (alpha = 0.05). Table 10 summarizes the

results of the population-to-population statistical comparison. Appendix D contains the ProUCL outputs associated with the evaluation. As shown on Table 10, concentrations of cadmium and silver in sediment are statistically higher than the natural background concentrations. Also shown on Table 10, concentrations of lead, nickel, silver and methylmercury in clam tissue are statistically higher than those measured in the reference clam tissue samples.

2.5 Summary of Data Quality

All data were considered usable and no reporting limit issues were identified (Section 4.4.1). The 2015 and 2016 were collected in accordance with USEPA guidelines and the QAPP (U.S. Navy 2015c) and QAPP modification (U.S. Navy 2016b) which were approved by USEPA, Suquamish Tribe, and Ecology.

Metals contamination is present in clam tissue, sediment and seep media. No marine water samples contained of any COCs at concentrations above the surface water criteria (Table 4). Cadmium and arsenic clam tissue concentrations are present above the Suquamish subsistence risk-based screening levels and ecological CTLs. Only one clam tissue sample from the Area 8 beach contained methylmercury above the Suquamish subsistence risk-based screening level. Arsenic concentrations in sediment are present at concentrations exceeding the Suquamish subsistence risk-based screening levels, while cadmium, copper, nickel, silver, and mercury are present at concentrations exceeding their respective Ecology SMS SCOs. Only one seep sample collected from the Area 8 beach (Seep C) contained cadmium at concentrations exceeding the Ecology surface water criteria protective of aquatic life. Several metals in tissue and sediment are present in excess of reference area or background concentrations. An in-depth discussion of metals concentrations relative to background is included in Section 2.4. Detailed CSMs are depicted on Figure 8 (HHRA) and Figure 9 (ERA) and include all relevant exposure pathways. No bioassays were performed as part of this investigation and further bioassay data are needed to assess the hazards to sediment benthos. However, the chemical data and spatial extent of the exposure area have been fully delineated to assess human health and ecological risks.

This page was intentionally left blank.

3.0 HUMAN HEALTH RISK ASSESSMENT

According to USEPA guidance (USEPA 1989), HHRAs are composed of four basic steps. The first step is the data evaluation, which involves identifying the applicable data set, screening the data, and selecting the COPCs. This first step was performed in Section 2.0. As discussed in Section 2.0, no screening to select COPCs was conducted in this assessment, as the analyte list is already focused on the COCs agreed to by the project team. The second step is the exposure assessment, which consists of evaluating chemical sources, pathways, receptors, exposure factors (i.e., exposure duration and frequency), and routes of exposure to quantitatively assess the amount of exposure to the COCs. The USEPA Framework document (USEPA 2007b) and the Suquamish fish consumption survey (Suquamish Tribe 2000) were used as the primary documents for Suquamish Tribe exposure parameters. The third step consists of a toxicity assessment, which qualitatively summarizes the cancer risks and noncancer hazards associated with the COCs and identifies toxicity values that estimate the dose-response relationship. The toxicity assessment provides information on the ability of chemicals to cause adverse effects. The toxicity metrics usually employed are the cancer slope factor for carcinogens or the reference dose (RfD) for non-carcinogens. The final step is the risk characterization that integrates the quantitative and qualitative results of the data evaluation, exposure assessment, and toxicity assessment. The risk characterization section estimates the cancer risks and non-cancer hazards associated with exposures to chemicals present at the site. Risks associated with exposures to background or reference area levels of contaminants are also presented. Incremental site-related risks are derived by subtracting the risks associated with exposures to background or reference area levels of contaminants from the Area 8 beach risks. Finally, an uncertainty section discusses how various aspects of the risk assessment process may lead to over- or underestimates of risk, quantifying uncertainties where possible.

The HHRA was performed in accordance with current USEPA guidelines for HHRAs (USEPA 1989, 1991a, 1991b, 2000, 2007a, 2007b, 2014, and 2016a) and Ecology's MTCA regulation and SCUM II guidance (Ecology 2007 and 2015). The HHRA was performed in consultation with the USEPA, Ecology, and the Suquamish Tribe. It follows available science where regulatory guidance is not available to address site-specific conditions. Where information is incomplete, health protective (i.e., conservative) assumptions were made so that the potential risk to human health was not underestimated.

3.1 Existing Conceptual Site Model

A CSM describes the sources of contaminants at a site, their potential release and transport through environmental media (i.e., soil and water), and the points and means by which human populations might be exposed to the chemicals. The risk assessment completed as part of the RI (U.S. Navy 1993a) included a detailed exposure assessment and CSM that addressed all potential chemicals and sources. The results of the baseline HHRA are summarized in Section 1.1.2.

At Area 8, the former plating shop discharged metals to soil by means of spills and leaks. Metals infiltrated through the soil into groundwater, and groundwater is transporting the metals to Liberty Bay through seeps in the intertidal zone. The source of the chemicals is summarized in Section 1.1.

The land use at Area 8 is industrial. Area 8 is paved, and the shoreline is protected from erosion by a riprap seawall. At high tide, the water level rises above the toe of the seawall. At low-low tide, a 150- to 200-foot-wide self-armored, naturally cobbled beach is exposed.

Currently, the beach adjacent to Area 8 is part of the NBK Keyport facility, and access by the general public is not allowed and will continue to be restricted as long as a naval facility occupies the area. Currently, clam harvesting throughout Liberty Bay is prohibited by the Washington State Department of Health (WDOH 2016) due to elevated levels of marine biotoxins. Residential populations are present along Liberty Bay, and the Area 8 beach is within the traditional, usual, and accustomed fishing areas for the Suquamish Tribe. If harvesting of clams from the Area 8 beach were ever allowed in the future, recreational and subsistence populations could potentially be exposed to contaminants in marine surface water, sediment, and marine tissue.

The receptors are the same as those that were selected for evaluation in the baseline HHRA and were confirmed by the project team for quantitative evaluation in this HHRA (U.S. Navy 1993c), as specified in the ROD for OU 2 (U.S. Navy, USEPA, and Ecology 1994):

- Future recreational site visitors
- Future subsistence shellfish harvesters

Note that while the 1993 baseline HHRA did not evaluate exposures of children, this HHRA includes both child and adult exposures. The potentially complete exposure pathways selected for quantitative evaluation include the following:

- Recreational site visitors and nearby residents (adults and children): It is assumed that local visitors and nearby residents could routinely access the area to dig clams for personal consumption. As such, it is assumed that recreational receptors could be exposed to COCs in sediment by incidental ingestion and dermal contact. For clams, occasional ingestion is the only potentially complete pathway.
- Subsistence populations (adults and children): It is assumed that Suquamish tribal members would routinely access the area to harvest shellfish. Tribal members could be exposed to COCs in sediment by incidental ingestion and dermal contact. Clams are assumed to represent all shellfish, and ingestion of shellfish is considered the most significant complete exposure pathway.

Impacts on marine surface water are minimal, based on the historical and current surface water data and relatively low COC flux in seep water compared to the volume of Liberty Bay. Marine surface water sampling was performed during the 2015 investigation, and analysis of the data in Section 2.0 indicates that the concentrations were well below Ecology's MTCA Method B surface water cleanup levels. In addition, exposure by dermal contact with contaminated surface water is expected to be insignificant relative to the exposures by dermal contact with sediment and ingestion of marine tissue and was, therefore, not included in the quantification of human health risks as agreed to by the project team during development of the QAPP (U.S. Navy 2015c). These agreements are documented in the minutes and responses to comments associated with the QAPP and are documented in Appendices A and B of the Final QAPP (U.S. Navy 2015c). The inhalation pathway is not considered a complete pathway for this evaluation since this risk assessment only considers exposures related to the marine environment. The human receptors and exposure pathways identified for Area 8 are shown on Figure 8.

3.2 Exposure Assessment

This section of the HHRA report describes the evaluation of sources, routes of exposure, receptors, and exposure parameters, such as exposure duration and frequency, to estimate potential human risk associated with site COCs. The goal of the exposure assessment is to quantify the potential dose of chemical per body weight per day for each COC for each receptor population and potentially complete exposure pathway.

The purpose of the HHRA is to assess only the site-related human health risks associated with post-ROD concentrations in clam tissue and sediment from the Area 8 beach. Therefore, it consists of a focused assessment of potential health risks due to ingestion of clams and

incidental ingestion and dermal contact with sediment by subsistence and recreational populations, as detailed in the existing CSM.

3.2.1 Exposure Area

An exposure area is typically defined as the area of contaminated material where exposures are likely to occur. Sampling associated with LTM has documented elevated concentrations of ROD-identified COCs in seeps, sediments, and clam tissue in the intertidal portion of the Area 8 beach, immediately downgradient of the former plating shop. Historical LTM of seeps has been performed at Seeps A and B and along Transects 1, 2, and 3 (Figure 2).

In response to stakeholder concerns that the extent of contamination had not been completely delineated offshore of Area 8, additional sediment data were collected in 2012, and sediment and clam tissue data were collected in 2015 and 2016. The 2012 sediment sampling event evaluated the extent of impacts due to metals in further intertidal and subtidal areas (U.S. Navy 2013), and the results indicated that samples were minimally affected. Based on these 2012 results, it was agreed by the project team that the 2015 sampling effort would focus on the intertidal zone sediment (0 to 10 cm) and clam tissue. These agreements are documented in the minutes and responses to comments associated with the QAPP and are documented in Appendices A and B of the Final QAPP (U.S. Navy 2015c). Additional sampling was conducted in 2015 north of Seeps A and B, including existing Seep C and four new seeps (Seeps D, E, F and G) and five new transects (Transects 9 through 13) (Figure 2). The results of the 2015 sampling indicated elevated concentrations of the COCs identified in the ROD; therefore, additional sediment and tissue sampling in locations south of Seep B, along Transect 14, and in uphill locations at each transect (closer to the shoreline above +1 foot mean lower low water [MLLW]) was performed in June 2016 to delineate the exposure area. Because 2015 and 2016 sediment results were below ecological screening levels (SMS benthic standards) along Transect 14 to the south of Seep B and Transect 13 to the north, results demonstrate that contamination has been appropriately bounded (see Section 4.3.4.1)

A recently conducted biological survey confirmed an abundance of Pacific littleneck and butter clams along the entire stretch of beach adjacent to Area 8 (U.S. Navy 2014). Based on the clam tissue sampling in 2015, the exposure area for the HHRA is limited to the area where clams are physically located in the clam band from the seawall at approximately +3 feet MLLW to -2.5 feet MLLW. The biological survey indicated that clams are not present in abundant numbers at deeper locations in the subtidal zone, and insufficient quantities of clams are present in the subtidal zone to collect an adequate sample size (U.S. Navy 2015c). Thus, no

clam data are available from deeper locations in the subtidal zone to demonstrate a gradient of decreasing sample concentrations away from the shore. The exposure area for potential human health exposures is limited to the intertidal areas adjacent to Area 8 and the area within the clam band from the south at Transect 14 and to the north at Transect 13 (Figure 2).

3.2.2 Selection of Exposure Factors

The information required to quantify exposures includes the daily intake of or contact rates with environmental media (e.g., the yearly amount of clams ingested), chemical specific determinants of exposure (i.e., dermal absorption factors from soil), the duration of exposure, and other population characteristics affecting exposure (e.g., body weight). The exposure factors that are used in combination with the COC concentrations in tissue and sediment to estimate chemical dose for the subsistence scenarios are provided in Tables 11 and 12, respectively. The exposure factors for the recreational scenarios are provided in Tables 13 and 14, respectively. The sources of the exposure factors are indicated in these tables and include the defaults from USEPA's Framework document (USEPA 2007b), other USEPA sources (USEPA 1989 and 1991a), Ecology guidance (Ecology 2015), and the Suquamish Tribe (Suquamish Tribe 2000). The selection of exposure factors was performed in collaboration with the project team.

A fish consumption study conducted by the Suquamish Tribe for its members presented seafood consumption rates (SCRs) for all the species that tribal members reported that they consumed, which included over 45 different species in seven broad seafood groups (Suquamish Tribe 2000, Table T-3). In consultation with the Suquamish Tribe and stakeholders, it was decided that the 95th percentile consumptions rates for adults and children from this study for shellfish Groups E and G would be used in the HHRA. For adults, USEPA modified the 95th percentile shellfish consumption rate from the rate in the Suquamish Tribe's report (615.4 grams per day [g/day]) to include only species harvested from Puget Sound. Therefore, the USEPA-modified value, 498.4 g/day (65 percent of total consumed seafood) from the USEPA Framework document (USEPA 2007b, Appendix B, Table B-2), was used in the HHRA as the appropriate adult SCR for a Puget Sound location. For children, the 95th percentile shellfish ingestion rate of 83.9 g/day was calculated using the all-shellfish tribal consumption rate of 4.994 grams per kilogram day (g/kg-day) and the tribe-specific body weight of 16.8 kilograms (kg) (Suquamish Tribe 2000, Table C-6). The uncertainties associated with the Suquamish Tribe SCR for children are included in the discussion of uncertainty in the HHRA.

USEPA Region 10 developed guidance to promote internal Region 10 consistency in assessing tribal seafood consumption risks at Comprehensive Environmental Response, Compensation,

and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) sites within Puget Sound or the Strait of Georgia Region 10 (USEPA 2007b). This guidance is a starting point for USEPA Region 10 in developing risk assessments. Final risk assessment decisions are informed by tribal consultation with USEPA should a tribe request consultation. The guidance recognizes that sustainability should be considered in the risk assessment process and addresses sustainability using a policy approach. The policy involves consideration of the amount of current or potential high-quality shellfish habitat present at, or in the vicinity of, the site. For sites with limited current or potential high quality shellfish habitat (e.g., habitat affected by urbanization), USEPA advocates use of data from a study of Tulalip Tribes fish consumption (Toy et al. 1996) to develop SCRs for risk assessment. Seafood harvest areas used by the Tulalip Tribes are affected by development. For sites with extensive areas of current or potential high-quality shellfish habitat, USEPA advocates use of data from a study of Suquamish Tribe fish consumption (Suquamish Tribe 2000) to develop SCRs for risk assessment. The Suquamish Tribe harvests seafood from areas with high-quality shellfish habitat. The Area 8 beach, though a small area, was found by the USEPA to be within a larger area of high-quality shellfish habitat. When evaluating cleanup of smaller operable units within a larger waterbody, a consumption rate appropriate for the larger water body should be used. If lower consumption rates derived on the basis of what a smaller area could sustain where used, less stringent cleanup levels and lower risk estimates would result. This could potentially result in degradation of the larger waterbody or failure to remediate the larger water body to an appropriately improved quality. It should also be noted that USEPA's guidance is a "living document" in that new tribal seafood consumption studies may be incorporated into the guidance. USEPA's guidance includes the concept of "resource switching." Resource switching is the assumption that if particular fish or shellfish species preferred for consumption are not present in the vicinity of a site, individuals harvesting seafood for consumption from the site will consume existing species at the same rate they would consume preferred species, assuming the presence of a broader range of species suitable for consumption. Thus, at Keyport, it is assumed that all shellfish consumption consists of either littleneck or Manila clams.

3.2.3 Exposure Point Concentrations

A quantification of exposures requires an estimate of the chemical concentration to which an individual may be exposed. According to the USEPA (USEPA 1992b and 2002a), the exposure point concentration (EPC) should be an estimate of the average concentration to which an individual would be exposed over a significant part of a lifetime. Because of the uncertainties associated with the true average, the 95 percent upper confidence limit of the arithmetic mean (UCL95) is generally used as the appropriate estimate of the average site concentration (USEPA

1992b and 2002a). The UCL95 is used as the EPC representing the reasonable maximum exposure (RME) estimate of the concentration to which a receptor is exposed. As a rule of thumb, a minimum of 10 samples is required to compute reliable UCL95 concentrations (USEPA 2015). At least 10 samples are available for each data set.

The formula used to calculate a UCL95 depends on the distribution of the data (i.e., the "shape" of the curve) (USEPA 2002a). A goodness of fit test was performed for each COC data set per medium to determine the best distribution assumption for the data set. The UCL95 was calculated using the USEPA's ProUCL software, Version 5.1.002 (USEPA 2015 and 2016b). All data inputs and ProUCL UCL95 outputs are included in Appendix E. Table 15 presents a summary of the EPCs (i.e., UCL95s) and the basis of each for sediment and tissue.

3.3 Toxicity Assessment

The purpose of the toxicity assessment is to weigh the available and relevant evidence regarding the potential for chemicals to cause adverse health effects in exposed individuals and to provide a quantitative estimate of the relationship between the magnitude of exposure and the likelihood of adverse effects (USEPA 1989). The toxicity assessment is divided into two steps: the hazard identification and the dose response assessment. For the hazard identification, there are two broad categories of potential effects: carcinogenic and noncarcinogenic effects. General information on the two types of toxic effects (cancer and noncancer by means of the oral and dermal exposure pathways) is provided in Sections 3.2.1 through 3.2.3.

A fundamental principle of toxicology is that the dose determines the severity and/or likelihood of experiencing an effect. Accordingly, the toxicity criteria describe the quantitative relationship between the dose of a chemical and the type and incidence of the toxic effect. This relationship is referred to as the dose response.

For the COCs quantitatively evaluated in the HHRA, the toxicity criteria are presented on Table 16. The toxicity criteria used in the HHRA were obtained from the USEPA's Regional Screening Level Table (USEPA 2016a).

The following hierarchy is used to by USEPA (2016a) to select toxicity criteria (USEPA 2003):

- Tier 1 – USEPA's Integrated Risk Information System (IRIS) database
- Tier 2 – USEPA's interim toxicity criteria, Provisional Peer Reviewed Toxicity Values, published by the National Center for Environmental Assessment

- Tier 3 – Additional USEPA and non-USEPA sources of toxicity information (e.g., ATSDR, the California Environmental Protection Agency Office of Environmental Health Hazard Assessment, etc.).

3.3.1 Oral Carcinogenic Effects

The cancer slope factor (CSF), expressed as the inverse of milligrams per kilogram per day, or $(mg/kg]\text{-}day)^{-1}$, represents excess cancer risk from a continuous lifetime exposure to a chemical as a function of dose. Historically, the dose-response model was based on high- to low-dose extrapolation and assumed that there was no lower threshold for the initiation of cancer-causing effects. Specifically, cancer effects observed at high doses in laboratory animals or from occupational or epidemiological studies were extrapolated, using mathematical models, to low doses common to environmental exposures. These models were essentially linear at low doses, such that no dose was without some risk of cancer. USEPA's approach to cancer risk assessment is evolving as new scientific information becomes available on the mechanisms of carcinogenesis and the increase in understanding of specific modes of action at the cellular level that result in a carcinogenic response (USEPA 2005a). Therefore, although the historical approach is still used for many chemicals (including those that have not been updated, as well as those for which it is an appropriate model), USEPA is shifting from the default selection of linear models (where no dose is without some risk of cancer) for chemicals where there is evidence that the default (e.g., threshold or non-linear extrapolation) is not appropriate.

3.3.2 Oral Noncarcinogenic Effects

A chronic RfD is defined as an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without appreciable risk of noncancer effects during a lifetime of exposure (USEPA 1989). Chronic RfDs are specifically developed to be protective for long-term exposure to a chemical and are generally used to evaluate the potential noncancer effects associated with exposure periods of approximately 7 years to a lifetime.

RfD values are often derived from experimental data on the no observed adverse effect level (NOAEL) or the lowest observed adverse effect level (LOAEL) in animals or humans. The NOAEL is the highest tested chemical dose given to animals or humans that has not been associated with any adverse health effect. The LOAEL is the lowest chemical dose at which health effects have been reported. RfDs are calculated by dividing the NOAEL or LOAEL by a total uncertainty factor, which represents a combination of individual factors for various sources of uncertainty associated with the database for a particular chemical, or by extrapolating animal

data to humans. IRIS also assigns a level of confidence to the RfD. The level of confidence is rated as either high, medium, or low based on confidence in the study and in the database.

The NOAEL/LOAEL approach described above has been used for many years in dose-response assessment, but has recognized limitations (USEPA 2012). Thus, the benchmark dose (BMD) approach was developed as an alternative to the NOAEL/LOAEL approach. The key advantage of the BMD approach is that it utilizes information from the complete dose response curve rather than extrapolating from a single dose (i.e. the NOAEL or the LOAEL). The BMD approach involves dose-response modeling to obtain dose levels corresponding to specific response levels near the low end of the observable range of the data, and incorporates and conveys more information than the NOAEL or LOAEL process traditionally used for noncancer health effects (USEPA 2012). This approach is similar to that for determining the point of departure for cancer endpoints. USEPA continues to move towards harmonization of approaches for cancer and noncancer risk assessment. Mode of action and evaluation of linear versus non-linear effects at low doses for noncarcinogenic endpoints are more often being considered in risk assessments.

3.3.3 Dermal Toxicity Criteria for Carcinogenic and Noncarcinogenic Effects

As discussed in Section 3.1, the dermal pathway is only complete for exposures to sediment. According to USEPA (2004), dermal absorption to soil (in this case sediment) is only quantified if USEPA (2004) provides a dermal absorption factor in Exhibit 3-4 of the website. Of the COCs that are included in the HHRA, only cadmium and arsenic have dermal absorption factors. Thus, dermal exposures to sediment were only quantified for arsenic and cadmium. Most oral RfDs and CSFs are expressed as an administered dose (i.e., the amount of substance taken into the body by swallowing). In contrast, exposure estimates for the dermal route of exposure are expressed as an absorbed dose (i.e., the amount of chemical that is actually absorbed through the skin). Because dermal toxicity criteria are not readily available, oral toxicity values are used in conjunction with an absorption factor to adjust for the difference between the administered and the absorbed dose. The magnitude of the dermal absorption factor is inversely proportional. For example, under the assumption that a chemical has an oral (administered) RfD of 10 mg/kg-day, if 100 percent of the administered dose is absorbed, the absorbed dose will be equal to 10 mg/kg-day. If only 50 percent of the administered dose is absorbed, the absorbed dose is 50 percent less, or 5 mg/kg-day. The USEPA recommends absorption factors for a limited number of metals (USEPA 2007a, Exhibit 4-1). For chemicals that do not appear in the table, the recommendation is to assume 100 percent absorption (USEPA 2007a). In other words, the dermal toxicity criteria would not differ from the oral toxicity criteria.

Of the COCs that were evaluated for dermal exposures (arsenic and cadmium), the USEPA recommends adjusting the oral criterion for only cadmium (by 2.5 percent) for dermal exposure. The dermal toxicity criterion for cadmium was calculated using the following equations (USEPA 2007a, Equations 4.2 and 4.3):

$$\text{Dermal CSF} = \text{Oral CSF} \div 0.025$$
$$\text{Dermal RfD} = \text{Oral RfD} \times 0.025$$

3.4 Risk Estimation and Characterization

Risk estimation is the step in which the noncancer hazards and cancer risks are calculated based on the exposure and toxicity information. In risk estimation, the toxicity values (RfDs and CSFs) are applied, in conjunction with exposure (i.e., dose estimates) derived from chemical concentrations and assumptions about the amount and frequency of exposure, to estimate cancer risks and noncancer health hazards.

Risk characterization is the summarizing step of a risk assessment and includes a discussion of the risk estimates in the context of the regulatory risk thresholds. This step also incorporates discussion of elements of the risk assessment that are uncertain and discusses the overall level of confidence in the HHRA. The risk estimation methodologies for chemicals other than lead are summarized in Sections 3.3.1 and 3.3.2; and the risk characterization results for chemicals other than lead are presented in Section 3.3.3. The risk estimation methodologies and risk characterization results for lead are presented in Section 3.3.4.

3.4.1 Methodology for Assessing Noncancer Hazards for Chemicals Other Than Lead

The potential for adverse health effects other than cancer (noncancer effects) is characterized by dividing estimated chemical intakes (i.e., doses) by chemical-specific RfDs. The result is the HQ, derived as follows:

$$\text{HQ} = \frac{\text{Chemical Intake (mg/kg-day)}}{\text{RfD (mg/kg-day)}}$$

The USEPA risk assessment guidelines (1989) consider the additive effects of simultaneous exposure to several chemicals by recommending that all HQs initially be summed across exposure pathways and chemicals to estimate the total noncancer HI. This summation conservatively assumes that the toxic effects of all chemicals is additive or, in other words, all chemicals cause the same toxic effect and act by the same mechanism. In addition, application of the summation approach to a number of compounds that are not expected to induce the

same type of effects or that do not act by the same mechanism could overestimate the potential for effects (USEPA 1989). This summation approach is a screening approach, such that if the overall HI exceeds one, that the overall HI will be segregated into HIs based on the toxic endpoints of the individual chemicals.

The exposure assumptions (Section 3.1.3), intake equations, and available toxicity criteria for the COCs in sediment and tissue samples were used in combination to estimate noncancer hazards for the subsistence and recreational populations for both the site and the reference area (background). Incremental hazards are calculated by subtracting the background sediment or reference area hazard from the site hazard. For the Area 8 beach, the target health goal is an incremental HI of less than or equal to 1. If the incremental HI exceeds the target health goal of 1, HIs will be calculated for individual target organs and/or critical effects associated with the COCs, as consistent with USEPA guidance (USEPA 1989).

The hazard results are summarized in Section 3.3.3. Risk calculation worksheets for the subsistence and recreational scenarios are provided in Appendix F.

3.4.2 Methodology for Assessing Cancer Risks for Chemicals Other Than Lead

The potential for cancer effects is evaluated by estimating the probability of developing cancer over a lifetime, based on exposure assumptions and chemical-specific toxicity criteria. The increased likelihood of cancer due to exposure to a particular chemical is defined as the excess cancer risk (i.e., in excess of a background cancer risk of one chance in three [0.3, or 3×10^{-1}] for every American female and one chance in two [0.5, or 5×10^{-1}] for every American male of eventually developing cancer [American Cancer Society 2015]). Excess lifetime cancer risk is estimated by multiplying the estimated chemical intake by the CSF, as follows:

$$\text{Cancer Risk} = \text{Chemical Intake (mg/kg-day)} \times \text{CSF (mg/kg-day)}^{-1}$$

The potential risks resulting from exposure to multiple carcinogens are assumed to be additive. Ecology's MTCA regulation (2007) states site-related cancer risks should not exceed 1×10^{-6} on a chemical-specific basis and that cumulative site-related cancer risk should not exceed 1×10^{-5}. The USEPA's target acceptable risk range is 1×10^{-6} to 1×10^{-4} depending on site-specific considerations. For the Area 8 beach, the target cumulative excess incremental cancer risk above reference area is 1×10^{-5} and the target individual COC excess incremental cancer risk above reference area is 1×10^{-6}.

The exposure assumptions (Section 3.1.3), intake equations, and available toxicity criteria for COCs in sediment and tissue samples are used in combination to estimate cancer risks for the subsistence and recreational populations for both the Area 8 beach and the reference area (background). Incremental risks are calculated by subtracting the background sediment or reference area risk from the Area 8 beach risk.

3.4.3 Risk Characterization Results for COCs Other Than Lead

Risks and hazards were calculated for Suquamish subsistence exposures and for recreation receptors. The risk characterization results for each population are discussed below. The risk results are summarized in Section 3.3.3 and presented on Tables 17 and 18. Risk calculation worksheets for the subsistence and recreational scenarios are provided in Appendix F. Tables 17 and 18 present the risk and hazard estimates to two significant figures to provide greater detail in the calculation results. However, due to the unavoidable multiple layers of uncertainty inherent in risk assessment (natural variability, sampling error, measurement error, and estimation error, estimation of toxicity values, etc.) presentation of more than one significant figure does not imply a higher level of accuracy and confidence in the total hazard/risk estimations. Thus, risk management decisions are made on one significant figure, consistent with USEPA (1989) risk assessment guidance.

3.4.3.1 Suquamish Subsistence Receptor

As discussed above, risks and hazards were calculated for exposure to COCs in clam tissue and sediment at the Area 8 beach, as well as for exposure to COCs from natural background (sediment) and reference areas (clam). Table 17 summarizes the risk characterization results for the Suquamish subsistence receptor.

As shown on Table 17, at the Area 8 beach the noncancer HI from subsistence ingestion of clam tissue is 4 and 5 (rounded from 4.3 and 5.4, respectively) for child and combined child/adult receptors, respectively. The noncancer HI is driven predominantly by cadmium, the only COC resulting in an individual HQ above 1. The cancer risk from subsistence ingestion of clam tissue is 3×10^{-4} (rounded from 2.6×10^{-4}), driven entirely by arsenic, the only COC associated with carcinogenic effects. Exposures to sediment at the Area 8 beach resulted in noncancer HIs less than the target health goal of 1 for both the child and combined child/adult receptors, and a cancer risk of 6×10^{-6} (rounded from 6.3×10^{-6}), slightly above USEPA's *de minimis* cancer risk level of 1×10^{-6}. Combined cumulative noncancer hazard estimates are 4 and 5 (rounded from 4.5 and 5.4, respectively) for child and combined child/adult receptors, respectively, and cancer risk estimates are 3×10^{-4} (rounded from 2.7×10^{-4}) for Suquamish

subsistence exposures to clam tissues and sediment at the Area 8 beach. Exposures to sediment have minimal influence on the combined cumulative noncancer hazard estimates.

For the reference areas, the noncancer HI from subsistence ingestion of clam tissue is 4 and 5 (rounded from 3.8 and 4.7, respectively) for child and combined child/adult receptors, respectively. As in clam tissue at the Area 8 beach, the noncancer HI from subsistence ingestion of reference area clam tissue is driven predominantly by cadmium, the only COC resulting in an individual HQ above 1. The cancer risk from subsistence ingestion of clam tissue is 3×10^{-4} (rounded from 3.4×10^{-4}), driven entirely by arsenic. Exposures to reference area sediment resulted in noncancer HIs less than the target health goal of 1 for both the child and combined child/adult receptors, and a cancer risk of 2×10^{-5} (rounded from 1.8×10^{-5}). Combined cumulative noncancer hazard estimates are 4 and 5 (rounded from 4.0 and 4.7, respectively) for child and combined child/adult receptors, respectively, and cancer risk estimates are 4×10^{-4} (rounded from 3.6×10^{-4}) for Suquamish subsistence exposures to clam tissues and sediment in reference areas.

The Area 8 beach and Penrose Point reference area (or background) risk characterization results were used to calculate incremental site risk over reference area/background to determine risks associated with site-related activities in the absence of the influence of background sources. The noncancer HIs and cancer risk estimates for the reference area clams are the same as those for the Area 8 beach when rounded to one significant figure. These results indicate that exposure to COCs in clams collected from the Area 8 beach is not substantially different than the exposure from the reference areas, and the incremental site noncancer HIs are 0.6 and 0.7 (rounded from 0.59 and 0.73, respectively) for child and combined child/adult receptors, respectively. There is no unacceptable incremental cancer risk over the reference areas because the concentrations of arsenic in reference area clams resulted in higher cancer risk estimates than those calculated for the Area 8 beach.

As shown on Table 17, Noncancer HIs and cancer risks calculated based on the natural background sediment concentrations actually resulted in slightly higher hazard and risk estimates than those estimated for the Area 8 beach sediment. Thus, there is no unacceptable incremental noncancer hazard or cancer risk from sediment. The contribution of sediment exposures to the cumulative hazard and risk estimates based on combined exposure to clam tissue and sediment is insignificant.

These results indicate that while the total or overall hazard and risk estimates calculated for the Area 8 beach exceed target health goals (due primarily to cadmium and arsenic in clam

tissues), estimated incremental risks are below target health goals. There are no unacceptable site-related risks for Suquamish subsistence receptors.

3.4.3.2 Recreational Receptor

Risks and hazards were also calculated for a recreational receptor that may visit the Area 8 beach and harvest clams for consumption. As discussed in Section 3.1, recreational exposures are assumed to be lower than those assumed for subsistence populations. Thus, the risk characterization results for the recreational receptor are lower than those presented for the Suquamish subsistence receptor in Section 3.4.3.1 above. Table 18 summarizes the risk characterization results for the recreational receptor.

As shown on Table 18, at the Area 8 beach the noncancer HI from ingestion of clam tissue is 0.2 and 0.1 (rounded from 0.23 and 0.14, respectively) for child and combined child/adult receptors, respectively, below the noncancer target health goal of 1. The cancer risk is 2×10^{-6} (rounded from 2.5×10^{-6}), slightly above the USEPA's *de minimis* cancer risk level. Recreational exposures to sediment at the Area 8 beach resulted in noncancer HIs well below the target health goal of 1 for both the child and combined child/adult receptors (0.05 [rounded from 0.054]and 0.02 [rounded from 0.017], respectively), and a cancer risk of 4×10^{-6} (rounded from 3.6×10^{-6}), slightly above USEPA's *de minimis* cancer risk level of 1×10^{-6}.

As shown on Table 18, for exposures to clams from the reference area, the noncancer HIs are the same as those for the Area 8 beach when rounded to one significant figure and the reference area cancer risks are actually higher (3×10^{-6} [rounded from 3.2×10^{-6}) than those calculated for the site. These results indicate that exposure to COCs in clams collected from the Area 8 beach is not substantially different, and even slightly lower, than the exposure from the reference areas clams. Noncancer HIs (0.09 [rounded from 0.087] and 0.03 [rounded from 0.028] for child and combined child/adult receptors, respectively) and cancer risks (4×10^{-6} [rounded from 3.9×10^{-6}]) calculated based on the natural background sediment concentrations actually resulted in slightly higher hazard and risk estimates than those estimated for the Area 8 beach.

The incremental site noncancer HIs of 0.03 and 0.02 for child and combined child/adult recreational ingestion of clam tissue, respectively, are well below the target health goal. There is no unacceptable incremental cancer risk over the reference area because the concentrations of arsenic in reference area clams resulted in higher cancer risk estimates than those calculated for the Area 8 beach. In addition, because noncancer HIs and cancer risks calculated based on the natural background sediment concentrations actually resulted in slightly higher hazard and

risk estimates in the reference area, there is no unacceptable incremental noncancer hazard or cancer risk from Area 8 beach sediment.

Because the noncancer hazard estimates calculated for the Area 8 beach are below target health goals, there is no unacceptable health risk for recreational receptors at the site, even without considering the contribution from background sources. Though the cancer risk estimates calculated for the Area 8 beach slightly exceed target health goals, non-site related sources from natural background or other ubiquitous sources contribute significantly to the concentrations of COCs measured at the site. Because the incremental noncancer hazard and cancer risk estimates are below target health goals, there are no unacceptable site-related risks for recreational receptors.

3.4.4 Risk Characterization Methodology and Results for Lead

The Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children, Version 1.1, Build 11, was used to estimate children's risk due to lead in clam tissue at the Area 8 beach. Because the IEUBK model also accounts for background exposures to lead, no evaluation of incremental risk over that in the reference area was conducted. The model inputs are provided in Table 19. The typical lead background default exposures from dust, soil, etc. were included in the model runs and are assumed to account for exposures to lead in sediments at the Area 8 beach, because the evaluation of the 2015 and 2016 sediment data indicates that lead concentrations in sediment are consistent with background sediment concentrations (see Section 2.4.2). The current target goal for lead is that no more than 5 percent of a similarly exposed population would experience blood lead levels greater than 10 micrograms per deciliter (µg/dL) (USEPA 1998b).

Although the 95th percentile SCR value and the 95UCL concentration are used for calculating risks for chemicals other than lead, the inputs into the IEUBK model are the average SCR value and the average site lead concentration of 0.0723 mg/kg (Table 15) as recommended in USEPA guidance (USEPA 2007c). The IEUBK model was run for the Suquamish subsistence scenario using the consumption rate of all shellfish by children of 0.801 g/kg bodyweight/day (Suquamish Tribe 2000, Table C-6). Coupled with a body weight of 16.8 kg (Table 11), the average SCR is 13.45 g/day. The IEUBK model (USEPA 2007) default average meat consumption is 87.16 g/day; therefore, the percentage of meat consumption consisting of clams was calculated to be 15.43 percent (i.e., 13.45 g/day divided by 87.16 g/day). Under these assumptions, the IEUBK model predicts that only 0.3 percent of a population will experience blood lead levels greater than 10 µg/dL (from subsistence consumption of shellfish), which is

well below the current target goal of no more than 5 percent. The IEUBK Model results are provided in Appendix G. Because the exposure assumptions for recreational receptors are lower (i.e., lower consumption rates and shorter exposure durations) than those assumed for Suquamish subsistence populations, exposure for children in the recreational scenario is also less than the target goal. The results of the IEUBK indicate that lead is not present in Area 8 beach shellfish at concentrations associated with a health concern.

3.5 Uncertainties in Human Health Risk Assessment

The purpose of the uncertainty discussion is to describe, in a qualitative way, where there are major uncertainties in the HHRA process that could affect the conclusions of the risk assessment. Estimating and evaluating potential health risk from exposure to environmental chemicals is a complex process with inherent uncertainties. Uncertainty reflects limitations in knowledge, and simplifying assumptions must be made in order to quantify health risks.

USEPA assesses risks assuming "reasonable maximum exposure or RME" values for variables used in exposure assessment. RME specifies use of a combination of central and upper bound values for specific exposure variables that is designed to produce an overall estimate that is the highest level of exposure that could reasonably be expected to occur at the site.

Uncertainty in the HHRA produces the potential for two kinds of errors. The first is an overestimation of the true risk, potentially resulting in remedial actions where none are warranted. The second is an underestimation of the true risk, potentially leading to a failure to implement remedial actions, resulting in ongoing exposure to environmental contaminants that remain at unacceptable levels.

Thus, risk estimates based on RME are likely to produce the first outcome noted above, estimated risks will exceed the actual risks present. This approach is preferred in that errors made will result in protection of public health. This discussion is organized according to uncertainties relating to the data analysis, exposure assumptions, toxicity, and characterization of health risks. The uncertainty assessment identifies factors associated with uncertainties in the risk assessment process and the bias in uncertainty associated with the factor (i.e., whether it leads to an under- or overestimate of the true risk). Where possible, the uncertainty is quantified.

3.5.1 Data Analysis

The data used in this HHRA were collected for the sole purpose of supporting this evaluation. Thus, the sampling program was designed to meet the data quality objectives for this risk

assessment. As discussed in Section 2.0, all COCs were detected in at least one sample, reducing the potential for uncertainties associated with elevated reporting limits. No specific reporting limit issues were identified with the available data set.

It was agreed by the project team (as documented in the in meeting notes and the risk assessment work plan) that the HHRA risk characterization would focus on the surface depth interval (0-10 cm) and only this data was used to calculate risks. However, while Pacific littleneck and butter clams are typically present in the top 10 cm of substrate, butter clams can burrow as deep as 8 to 14 inches (20 to 34 cm). Therefore, sediment samples were collected at up to 24 cm from a subset of the sediment sampling stations, or as deep as technically feasible if hard or impenetrable substrate was encountered, to determine the vertical extent of sediments impacted by site-related contamination and assist in characterizing exposures to all potential human and ecological receptors. One location on each transect and associated with the observed seeps was sampled for co-located surface sediment (0-10 cm) and subsurface sediment (10-24 cm) samples. The 10 to 24 cm depth interval data were intended to demonstrate that concentrations of COCs in the 0 to 10 cm depth interval are either higher than or no different than the concentrations of COCs in the 10 to 24 cm depth interval. Thus, it was assumed that the use of the 0 to 10 cm depth interval data would conservatively and adequately represent exposures to sediments. As shown on Table 5, there is little difference in concentration between the 0 to 10 cm depth interval and the 10 to 24 cm depth interval. With the exception of two sampling locations (Stations 08 and 40), the concentrations of COCs in the 0 to 10 cm depth interval are either higher or essentially equal to the concentrations of COCs measured in the 10 to 24 cm depth interval. At Station 08 (Transect 2) the concentration of mercury measured in the 0 to 10 cm depth interval is over 40 times higher than the concentration of mercury measured in the deeper interval. At Station 40 (Transect 10), the concentration of mercury is approximately 11 times higher in the 10 to 24 cm sampling interval than the concentration detected in the 0 to 10 cm sampling interval. If risks and hazards from exposure to sediment were calculated using the 10 to 24 cm depth interval data, risks and hazards would not change substantially, and would more than likely be even lower than those reported using the 0 to 10 cm depth interval data, based on the data presented on Table 5. Because sediment incremental risks and hazards are significantly below target health goals, the conclusions of the risk assessment would not change.

As discussed in Section 2.2, the speciation of chromium (chromium III or chromium VI) in sediments and clam tissues can be an important factor in understanding human health and ecological risks at the site. During development of the QAPP (U.S. Navy 2016b), the project team agreed that any 2016 sediment samples with total chromium concentrations above

Ecology's background value would also be analyzed for speciated chromium. However, because no 2016 sediment samples exceeded the background level, only total chromium results were reported (U.S. Navy 2016c). In addition, because there is no standard analytical approach for the speciation of chromium in tissue, the project team agreed that the 2016 clam tissue samples would be analyzed for total chromium.

Although a historical source of chromium VI exists at Area 8, because chromium VI in the environment readily reduces to chromium III, the less toxic form, total chromium results in sediments and clam tissues were evaluated as chromium III in the risk assessment, as agreed to during the development of the HHRA/ERA workplan (U.S. Navy 2016a). Though, based on the available literature, it is unlikely that a significant proportion of the total chromium measured in clam tissue and sediment is in the hexavalent form, if a proportion (small or otherwise) of the total chromium concentrations is actually chromium VI, rather than chromium III, then risks and hazards could be underestimated. If it were assumed that all chromium measured in Area 8 beach clam and sediment samples was chromium VI, then cumulative Area 8 beach cancer risks would increase from 3×10^{-4} (where arsenic was the only COC with carcinogenic endpoints) to 2×10^{-3} (where chromium VI drives cancer risks). However, under the same assumption that all chromium measured in reference area and background samples is present in the hexavalent form, reference area cancer risks would also increase such that the incremental cancer risk is still below target health goals.

It is possible that site tissue and sediment samples could have a higher percentage of chromium VI to chromium III than reference area and background tissue and sediment. Under this scenario, site risks could potentially exceed reference area risks and result in higher incremental site risks over background. However, given the large body of literature data that supports the transformation of chromium VI to chromium III in healthy marine environments, the conclusions of the risk assessment are unlikely to change.

3.5.2 Exposure Assumptions

The uncertainties related to the exposure assumptions originate the use of exposure factors that could lead to either over- or underestimation of exposure. The most significant uncertainties associated with the exposure factors are discussed below:

- **Subsistence population shellfish ingestion rates:** At the time of the Suquamish survey, the reported rates represented the highest seafood consumption rates in Washington State. However, a majority of the Suquamish survey respondents reported that their consumption patterns have changed over

time, with almost twice as many respondents reporting eating less seafood than twenty years ago. Thus, the Suquamish Tribe regards the reported values to be subject to a suppression effect. It is likely that tribal members would consume higher amounts of all seafood if pollution levels decreased and/or accessibility/availability of resources increased.

In addition, human-consumed shellfish species other than clams are likely to be of much less concern. Other shellfish species potentially consumed in significant amounts, such as crabs, oysters, mussels, and scallops, are likely present in different environments than Liberty Bay (e.g., rocks rather than sand [mussels]), or are present in deeper water (e.g., crabs). Consequently, because clams appear to be the predominant human-consumed species in the area affected by the site, clam-specific ingestion rates could be more applicable to the site. Therefore, the SCR used in this HHRA is a conservative estimate of potential high-end consuming shellfish populations and more than likely overestimates exposures to shellfish for tribal communities other than the Suquamish and could potentially even overestimate exposures for the Suquamish since clams are the most likely shellfish species of concern in Liberty Bay. Thus, though use of lower ingestion rates could reduce the risk results, the conclusions of the risk assessment would not change since the incremental site risk over background and reference area presented in the risk characterization section meets the target health goals.

- **Child shellfish consumption rates**: Child shellfish consumption exposures were included in the HHRA, as recommended in the USEPA (2007b) Framework. In consultation with the Suquamish Tribe and stakeholders, the child SCR used in the HHRA was the 95th percentile shellfish ingestion rate of 83.9 g/day. This shellfish ingestion rate was calculated using the all-shellfish tribal consumption rate of 4.994 g/kg-day and the tribe-specific child body weight of 16.8 kg (Suquamish Tribe 2000, Table C-6). However, this SCR has not been adjusted downward as was done for the adult SCR to include only species commonly found in Puget Sound. Thus, use of the 83.9 g/day likely overestimates the child exposures for consumption of shellfish harvested from Liberty Bay. The 95th percentile Puget Sound specific SCR for adults of 498.4 g/day (or 6.31 g/kg/day, assuming the Suquamish body weight of 79 kg) recommended in the USEPA (2007) Framework is 81 percent of the 95th percentile total adult SCR of 615 g/day (or 7.79 g/kg/day, assuming the Suquamish body weight of 79 kg). If this

same percentage were applied to the child SCR, then the Puget Sound SCR would reduce from 83.9 g/day to 68 g/day. Thus, though use of lower SCR could reduce the risk results, the conclusions of the risk assessment would not change since the incremental site risk over background and reference area presented in the risk characterization section meets the target health goals.

- **Exposure duration for recreational receptors**: In consultation with the Suquamish Tribe and stakeholders, it was decided that the current USEPA (2014) residential default exposure duration of 26 years (20 years for adults and 6 years for children) would be used in evaluating exposure for the recreational clam-digging scenario. During workgroup meetings during development of the QAPP and the HHRA/ERA workplan, there were several discussions surrounding the selection of the recreational exposure duration. The workgroups agreed that it is possible for local Keyport-area residents to regularly visit Liberty Bay even if they have moved away from a nearby residence. For example, it is possible for local Keyport-area residents to drive greater distances to harvest clams from a beach that contains such a prolific population of healthy organisms. This suggests that the USEPA (2014) residential default exposure duration could potentially underestimate exposures for recreational receptors. (Note that the exposure duration only affects the results of the COCs associated with carcinogenic endpoints, since the averaging time and exposure duration cancel each other out in the risk characterization of noncarcinogenic COCs.)

To investigate an appropriate exposure duration parameter to be used in the HHRA, USEPA stakeholders facilitated a study that reviewed the residence duration for counties in Washington (USEPA 2016c). The resulting technical memorandum, Keyport Area Exposure Report Approach for Determination of Residence Duration for a County in Washington (USEPA 2016c) was submitted by USEPA as part of the comments on the draft workplan. The technical memorandum concluded that an upper bound estimate of exposure duration for the Keyport area in Washington is 27 years, only slightly higher than the USEPA (2014) residential default. Use of 27 years as the exposure duration would only slightly increase the arsenic cancer risk results for the recreational receptor, but the conclusion of the risk assessment would not change because recreational exposures would still meet target health goals.

3.5.3 Toxicity Assessment

Toxicity values have been developed by the USEPA from the available toxicological data. These values frequently involve high-to-low-dose extrapolations and are often derived from animal rather than human data. In addition, there may be few studies available for a particular chemical. As the unknowns increase, the uncertainty of the value increases. Uncertainty is addressed by reducing the critical study NOAEL or LOAEL, using uncertainty factors, when developing the RfD. The greater the uncertainty, the greater the uncertainty factors which result in lower RfDs. If the RfD is considerably lower than the safe dose (NOAEL) found in the critical study, the result is a tendency to overestimate the toxicity of the chemical.

For the chemicals evaluated in this assessment, all but chromium III, total mercury, and nickel have RfDs based on human data and therefore relatively low uncertainty factors (see Table 16). Therefore, there is a high degree of confidence in the toxicity values used in the hazard estimates for this assessment, being that most, including arsenic and cadmium, were derived from human studies. Chromium III, total mercury, and nickel, are not known to be significantly toxic to humans, relative to the other COCs. For chromium, the hexavalent state (Chromium VI) is the more toxic form to humans and chromium VI is not expected to be present in significant concentrations in the marine environment (see discussion in Section 2.2.3 and 3.4.1). For mercury, methylmercury in tissue is the more toxic forms to humans and was evaluated in this HHRA. The toxicity criteria for methylmercury is based on human toxicity studies and has a higher degree of confidence compared to total mercury. Though nickel concentrations measured in site tissue were found to be significantly higher than reference area tissue (Table 10), nickel in site sediment was found to be consistent natural background concentrations. In addition, the incremental risks associated with chromium III, mercury, and nickel either well below target health goals (Table 17 and 18) or there is no incremental risk for these COCs because background/reference area risks exceed those calculated for the site. Thus, any uncertainty in the toxicity criteria for these COCs is unlikely to change the conclusions of the HHRA.

The RfD for methylmercury was derived using the BMD approach. In the BMD approach, the lower confidence limit on the dose response curve is used to estimate the dose associated with a low percentage of adverse effects (e.g., the 5^{th} or 10^{th} percentile) compared to using the NOAEL or LOAEL as the point of departure. The use of the lower confidence limit to derive the point of departure when deriving the RfD is a health protective approach. The RfDs for the other COCs were calculating using the NOAELs and LOAELs as the point of departure.

For arsenic there is some uncertainty associated with the cancer SF used in the risk calculations. The IRIS program has been re-evaluating the SF for inorganic arsenic for some time (USEPA 2010). The Final Draft of the USEPA's Toxicological Review of Inorganic Arsenic in Support of Summary Information on the IRIS (USEPA 2010) recommends an oral SF of approximately 26 $(mg/kg\text{-}day)^{-1}$. However, the IRIS profile has not yet been updated to incorporate the Draft Final Toxicological Review. Even if the arsenic cancer SF were to increase, the conclusions of the risk assessment would not be affected because site-related inorganic arsenic concentrations are less than those measured in reference areas. Thus, there is no unacceptable incremental cancer risks associated with arsenic at the Area 8 beach.

3.5.4 Risk Characterization

The uncertainties related to the risk characterization were addressed conservatively in this HHRA to overestimate, rather than underestimate, potential exposures. The potential uncertainties associated with risk characterization are described below:

- **Use of the RME scenario to estimate exposures:** USEPA (1989) guidance recommends characterization of central tendency exposure (CTE) to help bound the potential exposures and thus risks associated with exposure to a site. In this assessment, only the RME scenario was presented, as the RME scenario is what is used as the basis for remedial decisions at the site and to determine whether additional controls are necessary to reduce risks and hazards to acceptable levels (i.e., either below target health goals or consistent with background or reference area exposures). According to USEPA (1991a), the CTE scenario typically uses average concentrations and exposure assumptions, rather than the upper bound estimates (e.g., UCL95 concentrations and 95th percentile SCRs). Use of the CTE scenario would result in subsistence risk characterization results significantly lower than those presented in the risk characterization section. Because the risk results calculated under the RME scenario meet the target health goals for incremental site risk over background or reference areas, CTE risk results would also meet the target health goals. Thus, the conclusions of the HHRA would not change.

- **Harvest sustainability of the Area 8 beach:** The risk assessment assumes that all of the shellfish consumed by high-end consumers would be harvested from the Area 8 beach. . The recent biological survey confirmed an abundance of Pacific littleneck and butter clams along the entire stretch of beach adjacent to

Area 8 (U.S. Navy 2014). Though subsistence users could potentially harvest some of their shellfish diet from other beaches, it does appear that the healthy and abundant shellfish habitat at the Area 8 beach could sustain subsistence harvesting needs. If shellfish are harvested from areas other than the Area 8 beach, then risks and hazards for subsistence populations would be even lower, but the conclusions of the HHRA would not change.

- **Smaller operable units within larger waterbodies:** When evaluating cleanup of smaller operable units within a larger waterbody, a consumption rate appropriate for the larger water body should be used. If lower consumption rates derived on the basis of what a smaller area could sustain were used, less stringent cleanup levels and lower risk estimates would result. This could potentially result in degradation of the larger waterbody or failure to remediate the larger water body to an appropriately improved quality.

This page was intentionally left blank.

4.0 ECOLOGICAL RISK ASSESSMENT

Like the HHRA, the area of concern in the ERA is the intertidal land adjacent to Area 8, which is associated with an embayment located in Liberty Bay within Puget Sound (Figure 1). The shoreline abutting the Area 8 beach consists of a riprap seawall and a moderately sloped beach. The beach substrate largely consists of cobbles and gravel, with some large rocks and concrete debris (U.S. Navy 2014). At high tide, the water level rises above the toe of the seawall. At low-low tide, a 150- to 200-foot-wide self-armored cobbly beach is exposed. The beach habitat supports benthic invertebrates, fish during high tide, and semi-aquatic avian and mammalian predators.

The objective of the ERA is to evaluate the biological resources and ecological risks associated with exposure to COCs. The ERA was conducted according to federal guidance (USEPA 1997, 1998a, and 2005b) and state regulations, such as the ecologically based surface water sections of MTCA (Chapter 173-340 WAC), as revised in November 2007 (Ecology 2007); the SMS (Chapter 173-204 WAC), as revised in February 2013 (Ecology 2013b); and the associated SCUM II guidance (Ecology 2015). The ERA follows the USEPA structure (USEPA 1998a), consisting of the following elements: problem formulation, analysis, and risk characterization.

4.1 Problem Formulation

Problem formulation establishes the goals and endpoints to assist in focusing the risk assessment and typically forms the basis for the CSM. The ecological CSM is a tool for describing and evaluating animals and plants that might come in contact with site contaminants. The components of the problem formation step are the following:

1. COC selection
2. Development of an ecological CSM that includes ecological receptors and exposure pathways
3. Definition of the assessment endpoints and measures of effect

4.1.1 Chemicals of Concern for Ecological Receptors

The applicable data sets, data screening process, and list of COCs are presented in Section 2.0. As discussed in Section 2.0, no screening to select COPCs was conducted in this assessment, as the analyte list is already focused on the COCs agreed to by the project team. The chemicals of ecological concern are the same as those for the HHRA:

- Arsenic/inorganic arsenic
- Cadmium
- Chromium
- Copper
- Lead
- Mercury/methylmercury
- Nickel
- Silver
- Zinc

No chemical was eliminated from evaluation based on a comparison to risk-based concentrations during the problem formulation phase.

4.1.2 Existing Conceptual Site Model

A CSM describes the sources of contaminants at a site, their potential release and transport through environmental media (e.g., sediment and water), and the points and means by which ecological receptor populations might be exposed to the contaminants. The final outcome of the CSM development process is a schematic representation of the links between sources, release and transport mechanisms, potentially affected media, exposure routes, and potentially exposed ecological receptors.

A CSM is an iterative tool and was updated as part of this ERA. As noted in Section 5.0 of the workplan (U.S. Navy 2016a), the objective of re-evaluating the CSM is to identify sources that contribute to unacceptable site-related risks. Elements of the CSM that were considered during the risk characterization step of the ERA included 1) single-point concentrations in Area 8 beach sediment, marine water, and tissue were compared to ecological risk-based screening levels to characterize and identify potential hotspots of contamination and 2) COC concentrations measured in outfalls were reviewed to evaluate whether the outfalls might be providing an additional source of contamination to Liberty Bay.

4.1.2.1 Chemical Sources and Environmental Fate

At Area 8, the former plating shop discharged metals to soil by means of spills and leaks. Metals infiltrated the soil to groundwater, and groundwater is transporting the metals to Liberty Bay through seeps in the intertidal zone. The seeps, surface water, and sediments in the intertidal zone represent the media of concern for ecological receptors. The source of the contaminants is summarized in Section 1.1.

4.1.2.2 Ecological Receptors of Concern and Exposure Pathways

Ecological receptors of concern identified as indicator species include those that receive the most exposure to site contaminants (e.g., resident species) or may be more sensitive to the toxic effects of COCs (e.g., threatened or endangered species). For the Area 8 beach, the primary categories of receptors are sediment benthos, such as shellfish; aquatic life, such as aquatic plants, aquatic invertebrates, and fish during high tide; and semi-aquatic avian and mammalian predators.

Sediment Benthos. Benthic invertebrate communities are an important component of an ecosystem because they serve as a major food source for fish and wildlife and are active in detrital processing and cycling (U.S. Navy 2009a). Benthic invertebrates are characterized as either infaunal (living within the sediment) or epibenthic (living on top of the sediment). Clams, which are a species of bivalve, are a part of the infaunal community. Other types of sediment benthos observed during the biological survey include sculpin (carnivorous – mostly small crustaceans and worms), amphipods (carnivorous – mostly small crustaceans, and/or detritus feeders), barnacles, copepods, sea pens (plankton/detritus filter feeders), moon snails (bivalve predators), sea anenomes (fish and shrimp predators), and pile worms (detritus deposit feeders). The amphipod, (*Eohaustorius estuaries*) has also been used as a bioassay test species which is typically a carnivorous (consuming mostly small crustaceans) and/or detritus feeder. Benthic invertebrates, including clams, are primarily exposed to contaminants in sediment by ingestion of sediment or pore water, by dermal contact with sediment, and by feeding on contaminated prey (Windward 2003). Because bivalves obtain their food by feeding either from the water column (filter feeders) or from the sediment surface (surface deposit feeders), these species occupy a feeding guild that is likely to be reasonably representative of exposure to other species. Therefore, the Pacific littleneck clam, which is considered representative of the benthic invertebrate community in general and was selected for the HHRA, was also chosen as the indicator species for the ERA. Direct exposure to COCs in seeps, pore water, and sediment by dermal contact as well as ingestion are the exposure pathways of concern for the Pacific littleneck clam.

Aquatic Organisms. Aquatic plants and aquatic invertebrates could be exposed to COCs in seeps and surface water at the point of contact by uptake or dermal contact, and aquatic invertebrates could also be exposed by ingestion. Fish could be exposed to COCs through their gills and by ingestion. Most studies of fish indicate that exposure to dietary cadmium at environmentally realistic concentrations results in bioaccumulation but no appreciable adverse effects (U.S. Geological Survey 2006). In addition, fish would be present only when incoming

tides provide sufficient overlying water (i.e., approximately two times per day). With recognition of the uncertainty associated with the potential for exposure of fish, this receptor group was selected as a receptor of concern. Although fish exposure by prey ingestion is a complete exposure pathway, standard risk assessment practice is to evaluate risks with the use of surface water quality criteria because of the lack of published criteria that take bioaccumulation into account. Because risks for aquatic plants, aquatic invertebrates and fish were assessed by comparing surface water concentrations to water quality criteria, selection of a specific indicator species for this receptor group was deemed unnecessary.

Birds. Crows and gulls were observed on or near the Area 8 beach during the June 13, 2014, site walk. Northwestern crows (*Corvus caurinus*), western gulls (*Larus occidentalis*), and glaucous-winged gulls (*Larus glaucescens*) are reported to drop clams, break the shells, and eat the flesh (Maron 1982 and Barash, Donovan, and Myrick 1975). Because selecting an indicator species with a smaller body weight is a conservative approach, the body weights of these three species were compared, and the northwestern crow was found to be the smallest. Therefore, the northwestern crow was selected as the indicator species for birds. Because the COCs at the Area 8 beach can bioaccumulate in prey tissue, the primary exposure pathway for birds is food ingestion. The relative contribution of brackish water ingestion to the exposure dose for the crow is expected to be minimal, because birds can fly to a freshwater source. Dermal contact is considered insignificant, because the presence of feathers minimizes direct contact with sediments and surface water. Although incidental ingestion of sediment while foraging or preening is also insignificant relative to prey ingestion, this exposure pathway was quantitatively evaluated when estimating the daily dose.

Although a bald eagle (*Haliaeetus leucocephalus*) was observed flying over the site during the site visit on June 13, 2014, literature on bald eagle diets rarely mention benthic invertebrates and then only as insignificant prey items (Grubb 1982). In western Washington, less than 2 percent of the food of nesting bald eagles is reported to be crustaceans (Retfalvi 1970). According to USEPA's Wildlife Exposure Factors Handbook (1993), bald eagles are primarily carrion feeders that eat dead or dying fish, when available, but are known to catch live fish swimming near the surface or fish in shallow waters. No species of benthic invertebrates are listed as a food source for bald eagles in the handbook. The large foraging range of the eagle further limits potential site-related exposure for this species. Therefore, the bald eagle was not selected as an indicator species.

Mammals. North American river otters (*Lutra canadensis*) have been spotted in Liberty Bay during sampling events near the Area 8 beach. These animals can be found along food-rich

coastal areas, such as estuaries (Tesky 1993). The typical diet of the North American river otter consists primarily of fish, but they are known predators of clams and the most likely mammal to be present on the Area 8 beach. Therefore, this species was selected as the indicator species for mammals.

Because there are COCs that can bioaccumulate in prey tissue, the primary exposure pathway for mammals is ingestion. Because the seep and surface water at the Area 8 beach is brackish, it is unlikely to be consumed other than by incidental ingestion when feeding. Dermal contact is considered insignificant, because the presence of fur minimizes direct contact with sediments and surface water. Although incidental ingestion of sediment while foraging is also insignificant relative to prey ingestion, this exposure pathway was quantitatively evaluated when estimating the daily dose.

Summary. The following receptors were assessed in the ERA:

- Aquatic plants
- Aquatic invertebrates and vertebrates (fish)
- Sediment benthos (littleneck clams)
- Aquatic-dependent birds (northwestern crow)
- Aquatic-dependent mammals (river otter)

The ecological receptors and exposure pathways selected for evaluation in the ERA are shown in Figure 9.

4.1.3 Assessment Endpoints and Measures of Effect

The ecological assessment endpoints are defined by the USEPA as an "explicit expression of an environmental value to be protected" (USEPA 1997). Various definitions of valuable ecological resources include those without which ecosystem function would be significantly impaired; those that provide critical resources, such as habitat; and those perceived by humans as valuable, such as endangered species. Useful assessment endpoints define both the valuable ecological entities at the site and a characteristic of the entity to protect, such as reproductive success or production per unit area. The USEPA defines a measurement endpoint or measure of effect as a "measurable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint and is a measure of biological effects (i.e., mortality, reproduction, growth)." In many cases, ecological benchmarks are used as measures of effect. However, measures of effect may also serve to assist in assessing bioavailability (e.g., SEM/AVS), the bioaccumulation potential of COPCs in specific media (e.g., seep data) and

measures of population health (e.g., benthic abundance surveys). In this ERA, each measure correlates directly with one of the defined assessment endpoints (Table 20). Measures of exposure are expressed as medium-specific chemical concentrations or modeled doses and measures of effects are expressed as medium-specific benchmarks or toxicity reference values (TRVs).

4.2 Analysis

The analysis phase of the ERA consists of the technical evaluation of chemical and ecological data to evaluate the potential for ecological exposure to COCs and the likelihood that such exposures could result in adverse effects. The analysis phase of the ERA consists of the exposure assessment and ecological effects assessment.

4.2.1 Exposure Assessment

Exposure assessment involves defining the exposure areas, the methods for developing EPCs, and the dose calculations and exposure parameters to be used for the wildlife species.

4.2.1.1 Exposure Areas

Exposure area is defined as the area of contaminated material where ecological exposures are likely to occur. The recent biological survey confirmed an abundance of Pacific littleneck and butter clams along the entire stretch of beach adjacent to Area 8 (U.S. Navy 2014). Based on the tissue sampling conducted in 2015, the exposure area for the ERA is limited to the physical location of clams in the clam band from the seawall at approximately +3 feet MLLW to -2.5 feet MLLW. The exposure area for potential ecological exposures is limited to the intertidal areas of the Area 8 beach and the area within the clam band from the south at Transect 14 to the north at Transect 13 (Figure 2).

4.2.1.2 Exposure Point Concentrations

The media of concern are sediment, seep water, surface water, and clam tissue. The EPCs for each medium may vary by receptor. For benthic invertebrates and aquatic receptors (aquatic plants, invertebrates, and vertebrates), ecological risks were based on a direct comparison of the maximum detected concentration to a sediment or surface water/seep benchmark. However, the UCL95 was also considered in certain cases to provide an additional evaluation of the significance of the exceedances of a given COC at the population level.

Clam Tissue and Sediment EPCs for Wildlife. Because wildlife are mobile, the UCL95 is generally used as the appropriate estimate of the average site concentration for an exposure scenario for birds and mammals. This statistical approach was used for sediment and tissue data when developing EPCs for birds and mammals. The use and applicability of a statistical method (e.g., student's *t*-test, adjusted gamma-UCL, Chebyshev UCL, and bootstrap methods) depend upon data size, data skewness, and data distribution (USEPA 2015). ProUCL computes statistics using several parametric and nonparametric methods covering a wide range of data variability and sample size (USEPA 2015). The UCL95 was calculated using the latest version of USEPA's ProUCL (i.e., Version 5.1.002) software (USEPA 2016b). All data inputs and ProUCL outputs are included in Appendix D of the workplan (U.S. Navy 2016c).

Inorganic arsenic is reported to be the most toxic form of arsenic in mammals. Like mammals, arsenic in the livers of seabirds and a single jungle crow was found in organic forms (e.g., arsenobetaine, trimethylated arsenicals, etc.) (Kunito et al. 2008). Because arsenic transformation to the less toxic organic forms occurs and because biomagnification is not reported to occur, EPCs for both total arsenic and inorganic forms of arsenic in tissue were considered in the risk characterization of arsenic for the bird and mammal receptors. Because the TRV for mercury is based on methylmercury, the methylmercury concentration in tissue was considered in the risk characterization of mercury for the bird and mammal receptors.

Sediment EPCs for Benthic Organisms. Sediment data are available for two exposure depths: 0 to 10 cm and 10 to 24 cm. The majority of data are for the 0 to 10 cm depth interval. Discussions were held during work group meetings (Appendix D of U.S. Navy 2016c) on March 1, 2016, and April 18, 2016, to reach consensus on the appropriate approach for deriving EPCs based on depth. Two lines of evidence were used: chemical stratification and biological considerations.

Chemical Stratification. The concentrations of metals in the 0 to 10 cm depth interval were compared to the concentrations in the 10 to 24 cm depth interval (Table 5). As noted in Section 2.1.2, the 0 to 10 cm sampling depth interval is representative of the 10 to 24 cm depth interval or is a conservative estimation of concentrations at deeper depths. Thus, the 0 to 10 cm depth interval data is are used to characterize ecological risks.

Biological Considerations. The 2014 biological survey of intertidal shellfish included a literature review of the depths at which the clams would reside (U.S. Navy 2014). Macoma clams (*Macoma* species), rough piddocks (*Zirfaea pisbryii*), and horse clams (*Tresus genus*) burrow the deepest, with depths as great as 18 inches (45 cm), 20 inches (50 cm), and 12 to

36 inches (30 to 90 cm), respectively (U.S. Navy 2014). Only two Macoma clams were noted at the Area 8 beach (one in each of Transects 8 and 5). Sixteen rough piddocks were found only in a claystone/shale outcrop in Transect 1, which is an area of generally low metal contamination. Likewise, only two horse clams were found (one each in Transects 2 and 4). Butter clams can burrow as deep as 30 cm, but because otters are reported to feed on shallowly burrowed clams (Kraeuter and Castagna 2001), butter clams are not likely their preferred prey. Since littlenecks are found in shallower sediment where greater COC concentrations are found, they are a considered a conservative indicator species. Butter clams are also known to carry saxitoxin, a paralytic shellfish poison, and otters and gulls are known to detect clams infected with high levels and avoid them, making it more likely that they would preferentially select littlenecks.

In summary, given that the 0 to 10 cm sampling depth interval is representative of the 10 to 24 cm depth interval, the limited contamination in Transect 1 where the rough piddocks were found, and the limited number of Macoma clams and horse clams residing at deeper depths, the data from the 0 to 10 cm interval was used to estimate the sediment EPCs to characterize risks for wildlife receptors. However, the data from the 10 to 24 cm interval were compared to the sediment benchmarks and reference concentrations and a discussion of the findings is included in Section 4.3.

Surface Water and Seep EPCs for Fish and Aquatic Life. Marine surface water data are available from eight stations at the Area 8 beach that are generally co-located where seep data was collected, as well as one outfall station (see Section 2.1.4). Applicable seep data are discussed in Section 2.1.3. Surface water samples are a better measure of exposure of aquatic receptors in the intertidal zone than seep water data. For the ERA, surface water and seep EPCs were established for each sampling location and a point-by-point comparison was performed against the established surface water benchmarks. Comparisons to the Area 8 beach surface water concentrations were also performed against marine surface water data collected at Penrose Point, as described in Section 2.4. As noted in the workplan, during the March 1, 2016, exposure work group meeting (Appendix D of U.S. Navy 2016a), the members reached consensus that a quantitative evaluation of the surface water ingestion pathway would not be performed because the water was deemed too saline and surface water EPCs were not developed for wildlife.

4.2.1.3 Dose Equations and Exposure Parameters for Wildlife

The adverse effects for the bird and mammal indicator species are based on a daily dose (i.e., an amount of chemical exposure in (mg) per kilogram of body weight (BW) per day, measured in mg/kg-BW/day). This daily intake is calculated on the basis of species-specific exposure factors. Key exposure factors include the selection of appropriate allometric equation variables to estimate ingestion rates, site use factors (SUFs), and dietary composition. Although the workplan (U.S. Navy 2016a) included provisions to calculate both a conservative Tier 1 scenario and a more realistic Tier 2 scenario for the bird and mammal receptors, only a Tier 1 scenario was performed because no risks were identified under that conservative exposure scenario. The primary differences between the planned Tier 2 and Tier 1 exposure calculations was the use of receptor-specific SUFs in Tier 2 (default factor of 1 would have been reduced to 0.5 and 0.25 for the bird and mammal, respectively) and use of more realistic dietary compositions in Tier 2 assuming clams would only comprise 50% of the bird and mammal diets.

Because TRVs for wildlife are based on a daily dose, the assessment of exposure for upper-trophic-level receptors involved estimating the daily intake using the EPC and other exposure parameters. The following generic equation was used to estimate the dose for the bird and mammal indicator species:

$$\text{Dose} = \frac{[(IR_S \times EPCs) + \Sigma(IR_{food\ i} \times EPC_{food\ i} \times Df_i)] \times SUF}{BW}$$

Where:

IR_s	=	ingestion rate of sediment (kg/day dry weight) (Beyer, Connor, and Gerould 1994)
EPCs	=	area wide UCL95 or maximum chemical concentration in sediment (mg/kg dry weight)
$IR_{food\ i}$	=	ingestion rate of food item i (kg/day dry weight)
$EPC_{food\ i}$	=	measured littleneck tissue concentration
Df_i	=	proportion of diet for food item i (unitless)
SUF	=	site use factor (unitless)
BW	=	body weight (kg)

The dose equations and exposure factors used in the ERA for the bird and mammal indicator species are provided in Tables 21 and 22, respectively.

Food Ingestion Rates. Allometric equations from Nagy (2001) for all birds or for Charadriiformes (birds foraging on shorelines such as gulls and shorebirds) are potentially relevant for the northwestern crow. Because the foraging behavior and diet of this species is similar to that of Charadriiformes, the empirical coefficients (i.e., slope [*b*] and intercept [*a*] inputs to the allometric equation) from this category were used. There is not a large variation in the coefficients between the two categories (*a* value of 0.522 for Charadriiformes versus 0.638 for all birds; *b* value of 0.769 for Charadriiformes versus 0.685 for all birds), which minimizes the uncertainty associated with this decision. Empirical coefficients from Nagy (2001) for all mammals, Carnivora (a classification that encompasses 280 placental mammal species, including the river otter), or carnivores (exclusive meat eaters) are potentially relevant for the river otter. The coefficients for all mammals were considered less applicable than the other two alternatives (carnivores and Carnivora) because these alternatives are more species-specific and potentially relevant to the otter. Either of the remaining two choices is justifiable. However, because the use of coefficients for a "carnivore" resulted in a higher estimated ingestion rate and, therefore, was more conservative, the factors for carnivore were selected. The range of ingestion rates from any of the three alternative choices (0.21 to 0.24 kg dry weight per day) is narrow, minimizing the uncertainties associated with this selection process for this exposure factor.

Site Use Factor. The SUF was assumed to be 1.0 (forage 100 percent of the time at the site). This is a conservative assumption because the foraging range of the crow and the otter is much larger than the acreage represented by the Area 8 beach.

Dietary Composition. The Pacific littleneck clam was assumed to constitute 100 percent of the diets of the crow and otter. Because both of these species are opportunistic feeders, clams are unlikely to be their entire food resource. The diet of the northwestern crow is described as omnivorous and includes fish, shellfish, carrion, garbage, various insects, berries, nuts, seeds, and birds' eggs (especially in seabird colonies) (Audubon, undated). The diet of the river otter includes fish, crayfish, amphibians, mollusks, other crustaceans, fruit, a few mammals, and birds (Zeiner et al. 1990).

4.2.2 Ecological Effects

In the ERA, ecological effects on benthic invertebrates and aquatic life were assessed on the basis of chemical thresholds (i.e., media-specific toxicity benchmarks and TRVs), data from bioavailability studies (i.e., SEM/AVS analyses), and results of site-specific biological field surveys. If the chemical thresholds are exceeded, other measures, such as toxicity tests, can

be used to validate the predicted hazards associated with exposures to surface water or sediment.

Toxicity benchmarks (expressed as chemical concentrations [mg/kg or µg/L]) for sediment, surface water, seep water, and tissue data were compared directly to the site concentration data to calculate an HQ. In addition, for the wildlife receptors that are evaluated by estimating daily dose (expressed as mg/kg-BW/day), TRVs were used to calculate the HQs.

4.2.2.1 Toxicity Benchmarks for Surface Water and Seeps

In the QAPP, benchmarks for marine surface water and seep water (WAC-173-201A-240, Table 240[3]) are presented as data quality objectives. These values were selected as the benchmarks for this ERA and are based on thresholds for the protection of aquatic life from adverse effects resulting from exposure to metals in seeps or surface water. As noted in the risk assessment workplan (U.S. Navy 2016a), the USEPA national recommended water quality criterion for cadmium based on chronic exposure (i.e., criterion continuous concentration) was reduced to 7.9 µg/L in 2016, after the QAPP was finalized. Because the MTCA surface water cleanup levels must be at least as stringent as all other federal applicable or relevant and appropriate requirements, the 2016 cadmium value was used in the ERA to evaluate the potential ecological effects on aquatic marine life. The toxicity benchmarks for marine surface water and seeps are summarized in Table 23.

4.2.2.2 Toxicity Benchmarks for Sediment

Marine sediment quality standards which are described in detail in the SMS (WAC 173-204-320) are applicable to sediments in Puget Sound. Per the SMS, two types of chemical limits can be used specifically to assess the toxicity of Puget Sound sediments to benthic invertebrates: SCOs, which correspond to a sediment quality that should result in no adverse effects (WAC 173-204-320), and cleanup screening levels (CSLs), which correspond to a level above which significant adverse effects may occur (Ecology 2013b). The SCOs in Table III in the SMS Rule (Ecology 2013b) were used to assess the potential for sediment impacts on benthic organisms and the need for future sediment bioassays for all COCs, except nickel. An SCO has not been established for nickel; therefore, the effects range–low (ERL) and effects range–median (ERM) values for nickel in sediment established by the National Oceanic and Atmospheric Administration were used for screening purposes. The ERL is defined by Long et al. (1995) as the concentration of a chemical in marine sediment below which adverse effects are rarely observed among sensitive species. ERM is defined as the concentration of a chemical in sediment above which effects are frequently or always observed among most species. The

range between the ERL and the ERM values is assumed to represent the range in which effects are occasionally observed (MacDonald 1994). However, it is important to note that background concentrations of nickel are often greater than the ERL, and even at the less conservative ERM benchmark for nickel, a low accuracy of predicted adverse effects has been reported (Long et al. 1995). Therefore, uncertainty was considered in evaluating the significance of nickel concentrations greater than these benchmarks. The toxicity benchmarks for sediment are summarized in Table 23.

4.2.2.3 Critical Tissue Levels

Because the potential exists for organisms to bioaccumulate contaminants to harmful tissue levels, critical tissue levels protective of benthic organisms and fish that prey on these organisms published by the ODEQ were used to supplement the comparisons of surface water and sediment benchmarks to COC concentrations when assessing potential impacts on benthic organisms (ODEQ 2007). The CTLs were calculated either by multiplying chronic water quality criteria and water-to-fish bioconcentration factors, or through a species sensitivity distribution method (ODEQ 2007). The CTLs represent concentrations in tissue at or below which approximately 95 percent of aquatic organisms with this tissue residue concentration would be highly unlikely (less than 5 percent chance) to experience adverse health effects. For this reason, they are considered conservative screening levels that should be used in recognition of their inherent uncertainties. In the case of cadmium, a species sensitivity distribution model was used that combined both freshwater and saltwater data. However, cadmium is much more toxic to freshwater organisms as evidenced by the much lower freshwater USEPA national recommended water quality criterion continuous concentration of 0.72 µg/L as compared to 7.9 µg/L for saltwater. So, using freshwater data to calculate the CTL artificially decreases the saltwater CTL. CTL values, expressed as wet weight tissue concentrations, were published for chemicals that ODEQ identified as bioaccumulative in aquatic environments (arsenic, cadmium, lead, and mercury) and are summarized in Table 24.

4.2.2.4 Simultaneously Extracted Metals Analysis/Acid-Volatile Sulfide

Understanding the bioavailability of metals in the aqueous and sediment phases, including the use of SEM/AVS data, is important for this ERA because if unacceptable ecological risks found in tissue or sediment correlated to seep or groundwater discharge, groundwater controls may be warranted. SEM/AVS data were used in the ERA as a measure of the bioavailability of metals in the groundwater (seeps) to evaluate whether seeps are the primary medium affecting the observed concentrations of metals in clam tissue rather than sediment.

Use of SEM/AVS data as a line of evidence for assessing the bioavailability of metals in sediment is well established. The Interstate Technology and Regulatory Council's Contaminated Sediment Team describes the use of SEM/AVS as an advanced approach for assessing bioavailability of metals to sediment benthos (ITRC 2011, Table 4-2). The USEPA has also indicated that SEM/AVS can be used to assess bioavailability (USEPA 2001). Although formal guidance for the use of this method has not been developed by Ecology or USEPA Region 10, it has been found to be helpful for interpreting screening-level results as well as strengthening the findings of a quantitative ERA.

The science supporting SEM/AVS indicates that divalent metals (i.e., cadmium, copper, lead, nickel, and zinc) are tightly bound to sediments when sufficient AVS is present, effectively reducing the bioavailability of sediment-bound divalent metals (DiToro et al. 1990 and 1992, Carlson et al. 1991, and Allen et al. 1993). Stated more simply, hydrogen sulfide (H_2S) reacts with certain divalent metal ions (Cd^{+2}, Cu^{+2}, Ni^{+2}, Pb^{+2}, and Zn^{+2}), forming insoluble and non-biologically available metal sulfides. As a result, exposure (i.e., bioavailability) and toxicity to benthic organisms is minimized. This effect has been studied, and its utility for risk assessment has been investigated (Ankley et al. 1991; USEPA 1991c; Di Toro et al. 1990 and 1992; and Ankley et al. 1996a and 1996b).

This sulfide binding process is additive for SEM; therefore, the following equation demonstrates the critical components for a complete SEM analysis:

$$SEM = \Sigma[Metal^{+2}] = [Cd^{+2}] + [Cu^{+2}] + [Ni^{+2}] + [Pb^{+2}] + [Zn^{+2}]$$

The SEM and AVS concentrations are expressed on a molar basis (e.g., micromoles per gram dry weight). If the ratio of SEM to AVS does not exceed 1.0, there is sufficient AVS to bind the SEM, the metals are not bioavailable, and no toxicity would be expected. It is important to note, however, that factors other than SEM also control the bioavailability of metals in sediments (such as, organic carbon and iron oxide); hence, an SEM to AVS ratio greater than 1.0 does not necessarily mean that toxicity will occur. This approach to evaluating the bioavailability of metals has been studied in both freshwater and marine systems using numerous benthic organisms, including amphipods, mussels, grass shrimp, hard shell clams, worms, snails, and oligochaetes (DiToro et al. 1990 and 1992, Carlson et al. 1991, Ankley et al. 1991, Allen et al. 1993, Casas and Crecelius 1994, Pesch et al. 1995, and Ankley et al. 1996a and 1996b). All of these studies indicated that there were no toxic effects when sufficient AVS was available.

SEM and AVS concentrations have been primarily used to assess bioavailability in terms of how they can predict toxicity. However, because the approach evaluates bioavailability (i.e., potential for exposure) it can also be used to assess chemical uptake into tissues. A study of the factors affecting the bioaccumulation of cadmium, nickel, and zinc indicated that SEM/AVS measures may be interpreted differently from factors affecting benthic toxicity. Variables noted in a mesocosm study of two clam species (*Macoma balthica* and *Potamocorbula amurensis*) and three marine polychaetes (*Neanthes arenaceodentata*, *Heteromastus filiformis*, and *Spiophanes missionensis*) included experimental design, dietary uptake, and biological attributes of the species, including mode and depth of feeding (Lee et al. 2000). Bioaccumulation of all three metals (cadmium, nickel, and zinc) by the bivalves was significantly related to the metals concentrations extracted from sediment as SEM but not to SEM/AVS ratios or to concentrations in pore water. Therefore, the SEM data, in combination with measured clam tissue concentrations, provide important information to assess the SEM/AVS test data. The SEM/AVS data, in conjunction with the 2008 bioassay results, were also used as a tool to determine the need for future bioassays. Uncertainties associated with the data interpretation are documented in Section 4.4.

4.2.2.5 Toxicity Reference Values

For the wildlife receptors that are evaluated in terms of a daily dose, dose-based TRVs were used to quantitatively assess the potential for the COCs to adversely affect the birds and mammals. Both a NOAEL-based TRV and a LOAEL-based TRV were used to bound the potential risks for upper trophic-level species. Both NOAEL- and LOAEL-based TRVs are based on chronic or long-term exposure scenarios and often represent exposure during a sensitive life stage (e.g., embryonic development). The desired toxicity endpoints of NOAELs and LOAELs used in ERAs are typically related to reproduction, growth, or development. A NOAEL-based TRV is a conservative value consistent with a lack of chronic effects. A LOAEL-based TRV is associated with some adverse effect, where the endpoint of toxicity was ecologically relevant.

The bird and mammal TRVs used to derive the ecological soil screening levels (EcoSSLs) (USEPA 2005-2008) were preferentially selected as the NOAEL-based TRVs because the studies used as the basis for derivation of the TRVs were intensively reviewed and accepted by the USEPA. EcoSSL TRVs reflect the most sensitive endpoints under high bioavailability scenarios and were intentionally designed to derive generic, conservative screening values.

Four primary TRV sources were considered in selecting LOAEL-based TRVs, and in the few cases in which an EcoSSL was unavailable, for selection as the NOAEL-based TRV:

- The Lower Duwamish Waterway (LDW) RI tended to use the lowest available NOAEL or LOAEL as the TRV (Windward 2007).
- The ODEQ bird and mammal individual and population TRVs (ODEQ 2007) were used for NOAEL- and LOAEL-based TRVs, respectively. If no established value was presented, the ODEQ approach for estimating a LOAEL-based TRV (i.e., application of a safety factor of 5 to the EcoSSL NOAEL) was used.
- NOAEL- and LOAEL-based TRVs established by the Lower Willamette Group (LWG) for the Portland Harbor Superfund Site (LWG 2011) often used the EcoSSL toxicity values or values for species comparable to the Area 8 beach indicator species. The LWG is composed of multiple responsible parties, including the City of Portland, the Port of Portland, and a variety of private industries, such as petroleum and railroad companies, that signed agreements with the USEPA to conduct the RI/FS.
- In general, the TRVs established by the USEPA Region 9 Biological Technical Assistance Group (BTAG) (USEPA 2002b and 2009) were derived using the lowest credible, ecologically relevant NOAELs from the literature. These NOAELs are designated by the BTAG as the "low" TRVs, while "high" TRVs represent a LOAEL or midrange level of effects.
- The TRVs used in the East Waterway baseline ecological risk assessment (Windward 2012), which primarily considered the LDW TRVs (Windward 2007), were also considered in some situations (i.e., NOAEL-based nickel TRV for birds).

A summary table presenting a wide variety of NOAEL- and LOAEL-based TRVs was discussed during several exposure work group meetings, and the recommended values were accepted in concept. A complete table and in-depth discussion of each possible TRV can be found in the workplan (U.S. Navy 2016a). In general, the main criteria used as the rationale for the selection of the TRVs included the following:

- Lowest applicable TRV; studies with bounded NOAEL and LOAEL preferred
- TRVs based on a comparable species indicative of the indicator species or its diet
- TRVs based on a peer-reviewed data set
- TRVs representing a range of species sensitivity (a species sensitivity distribution)

For LOAEL-based TRVs, the magnitude of the TRV relative to the range of available NOAEL-based TRVs was also considered. The recommended NOAEL- and LOAEL-TRVs from the workplan (U.S. Navy 2016a) were used in the ERA calculations for the crow and otter and are presented in Table 25.

4.3 Risk Characterization

Risk characterization is the process of integrating the previously described elements of the ERA into quantitative or semiquantitative estimates of risk. Risk characterization consists of risk estimation and uncertainty assessment.

A final step in the risk characterization process is a comparison of the metals data for each medium against the background concentrations. Ecology's SCUM II guidance recommends using the 90/90 UTLs for comparison to background concentrations (Ecology 2015). Methods for comparing analytical data for ecological receptors to background concentrations are comparable to those for human receptors, and the USEPA *Guidance for Developing Ecological Soil Screening Levels* (USEPA 2005b) cross-references the standard USEPA *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (USEPA 2002c). Therefore, the procedures for comparing the metals data to background concentrations described in Sections 2.3 and 2.4 apply to the ERA.

4.3.1 Hazard Quotients

HQ is calculated by the following equations:

$$HQ = \frac{Dose}{TRV} \quad \text{or} \quad HQ = \frac{EPC}{Benchmark}$$

Where:

HQ = hazard quotient (unitless)

Dose = estimated contaminant intake by bird or mammal as determined in the exposure estimate (mg/kg-BW/day)

TRV = avian or mammalian toxicity reference value (mg/kg-BW/day)

EPC = exposure point concentration (mg/kg or mg/liter [L])

Benchmark = medium-specific toxicity criteria (e.g., sediment SCOs [mg/kg] or surface water quality criteria [mg/L])

For the wildlife receptors, two types of TRVs (Section 4.2.2.4) were incorporated into the hazard analysis (one based on a NOAEL and the other based on an observed adverse effect in a test species [LOAEL]) to generate upper- and lower-bound HQs. For sediment, HQs were calculated based on both the SCO and the CSL. The CSL is the maximum allowable sediment concentration. For surface water and tissue, one set of benchmarks was used to calculate HQs for community-level receptors (i.e., aquatic biota).

4.3.2 HQ Interpretation

For HQs based on a NOAEL that are less than 1, adverse effects are unlikely because of the inherent conservatism (protectiveness) built into the exposure and effects assessments. HQs based on an LOAEL (upper-bound risk estimates) that are greater than 1 indicate that exposure exceeds a known effect concentration for a test organism. In this case, implementation of groundwater controls or further assessment may be warranted for these receptors and exposure pathways. When the NOAEL-based TRV HQ is greater than 1.0 and the LOAEL-based TRV HQ is less than 1.0, the associated complete exposure pathways were considered in greater detail to evaluate whether a risk or hazard is present based on the exposure assumptions or whether further assessment is needed. Further assessment could involve performance of bioassay tests, collection of additional samples for chemical analysis, or supplemental benthic community surveys.

4.3.3 Aquatic Organisms

Marine surface water COC concentrations have minimal potential to impact aquatic life; the HQs were lower than 1 for all COCs (Table 26), suggesting that groundwater discharging from seeps and outfalls does not pose an unacceptable hazard to fish and other free-swimming organisms in the water column.

Table 27 presents a point-by-point comparison of the seep/outfall data. Table 28 presents HQs based on the maximum detected Area 8 beach seep/outfall concentration for each COC and summarizes the locations of the seep/outfall benchmark exceedances. Of the nine COCs analyzed for in seep and outfall samples, three were detected at concentrations greater than the surface water benchmark: cadmium, copper, and silver. The maximum cadmium seep concentration at Seep C exceeded the surface water benchmark resulting in a HQ of 5.8. HQs for copper and silver were 1.7 and 3.1, respectively. Only the maximum concentrations of copper and silver exceeded their respective benchmarks, and both were detected at the same outfall location (Outfall 03-701). Given that the silver and copper concentrations in Seeps A through G do not exceed the surface water benchmarks, copper and silver in discharge from

Outfall 03-701 is unlikely to be site-related (i.e., it is located over 250 feet to the north of Area 8). Thus, copper and silver discharge from Outfall 03-701 will not be addressed by groundwater controls, the selected remedy for the Area 8 beach.. In addition, the resulting HQ for copper of 1.7 based on the single exceedance at Outfall 03-701 only slightly exceeded the target health goal and the silver surface water benchmark is uncertain, as it was estimated from an acute value by applying a safety factor of 10. Due to the lack of a federal or state chronic criterion for silver, a review of the literature was performed and an alternative surface water benchmark was located. The British Columbia ambient water quality criterion for chronic exposure to silver in marine and coastal waters is 1.5 µg/L (Ministry of the Environment 1996). The maximum silver water concentration at the Area 8 beach of 0.58 µg/L does not exceed this alternative criterion. Thus, given the relatively low HQ for copper and the uncertainties of the silver surface water benchmark coupled with the lack of an exceedance of the alternative benchmark, only cadmium in groundwater discharging at Seep C was considered to pose a potential hazard to aquatic organisms as a result of Area 8 groundwater impacts. To further assess the significance of this finding, the Seep C cadmium concentration was compared to the marine surface water concentration. Although the seep concentration was 45.7 µg/L, the marine surface water value was 1.57 µg/L, or a 96 percent drop in concentration. Thus, it is likely that while the cadmium in seep water has the potential to affect infaunal invertebrates like clams, the localized cadmium exceedance is not expected to pose an unacceptable hazard to free-swimming aquatic life, and groundwater controls are not considered necessary to protect this receptor group.

4.3.4 Benthic Organisms

Various interrelationships of the chemical data for sediment, seep, and benthos tissue (clams), the SEM/AVS and existing bioassay data, and benthic survey results were considered using a line of evidence approach to address potential environmental hazards relating to benthic organisms. The specific steps are described below:

1. Area 8 beach sediment data were compared to sediment benchmarks, and a population-to-population statistical analysis was conducted to compare BOLD background sediment data to Area 8 beach sediment data.
2. Co-located seep data were evaluated at locations where sediment impacts were noted based on Step 1.
3. Clam tissue data were compared to CTLs, and a statistical analysis was conducted to compare the Penrose Point reference area clam data to Area 8 beach clam data.

4. Locations where the SEM/AVS ratio exceeded 1, or where divalent metals exceeded sediment benchmarks, were identified and evaluated relative to seep water data.
5. Existing bioassay data were evaluated relative to sediment benchmark exceedances.
6. The 2014 *Intertidal Shellfish Survey Report* (U.S. Navy 2014) and clam tissue data were evaluated relative to areas of sediment benchmark exceedances.

4.3.4.1 Sediment Data

Table 29 presents a point-by-point comparison of sediment COC concentrations relative to sediment benchmarks. Cadmium exceedance locations are presented in Figure 10, which also shows the single location with a seep concentration greater than the cadmium surface water benchmark (Seep C). Table 30 presents HQs based on the maximum detected Area 8 beach sediment concentration for each COC, summarizes the locations exceeding sediment benchmarks, indicates which Area 8 beach sediment COC concentrations are statistically different than background, and includes supplemental HQ calculations based on the UCL95s for sediment COCs. The maximum concentrations of cadmium, copper, mercury, nickel, and silver exceed sediment benchmarks. To further assess the environmental significance of these sediment benchmark exceedances, a population-to-population comparison to background sediment data was performed. Only cadmium and silver showed a statistically significant difference when compared to the background data set. Direct toxicity based HQs for the benthic community are low for copper (HQ=1.1) and relatively low for mercury (HQ=5.9), especially considering the basis of these HQs, i.e., maximum concentrations in sediment and Ecology SMS SCOs, which correspond to sediment quality that should result in no adverse effects (WAC 173-204-320).

Because there are no known endangered or threatened benthic species at the Area 8 beach and a community-level assessment is appropriate, the UCL95s for sediment COCs were also compared to sediment benchmarks in Table 30. None of the HQs based on UCL95s for sediment COCs exceeded a HQ of 1. The primary concern for copper is direct toxicity. Only one sediment sample had a concentration above the SCO for copper and six samples exceeded the SCO for mercury (Table 30). The limited extent of copper impacts coupled with the lack of a statistical increase of site data above background based on a population-to-population comparison to background sediment data, suggests copper poses a low threat to benthic organisms. The primary concern for mercury is bioaccumulation. Although six samples exceeded the SCO for mercury (Table 30), mercury did not pose a hazard to birds or mammals (see Sections 4.3.4 and 4.3.5). These findings coupled with the findings of the population-to-

population comparison to background sediment indicate that copper and mercury concentrations in Area 8 beach sediments do not pose a hazard greater than background.

Because cadmium and silver showed a statistically significant difference when compared to the background data set, the potential for these two sediment COCs to adversely affect benthic organisms were considered further.

Cadmium. To assess whether sediments could act as a bioaccumulation source in tissue as opposed to seep water, seep data were also evaluated. Cadmium exceedances of sediment benchmarks occurred at five locations, four of which are located along Transect 8 near Seep C (SS50, SS51, SS03-C, and SS06-C) and one at the discharge point of Seep A (HQ of 1.1) (Figure 5). Cadmium in Seep C was 45.7 µg/L and exceeded the water benchmark of 7.9. Location SS03-C is situated immediately adjacent to Seep C; this finding in combination of the SEM/AVS results (see Section 4.3.4.3 below; Table 31) suggests that seep water is most likely the source of cadmium in sediment. Cadmium concentrations in groundwater exceeding remediation goals have consistently been noted at MW8-11 and MW8-14.

As discussed in Section 4.3.4.2, cadmium tissue concentrations were considered statistically similar to Penrose Point reference tissue concentrations. In addition, cadmium accumulation in clam tissue does not appear to pose a hazard to clam predators (see Section 4.3.5 and 4.3.6). Potential impacts to the benthic community will be further investigated as part of the planned additional bioassay testing program to complete the ERA.

Silver. Two locations, SS70 (7.75 mg/kg) and SS72 (17 mg/kg) on Transect 9 and between Transects 9 and 10 uphill of Outfall 03-703 exceed the sediment benchmark of 6.1 mg/kg for silver. The HQ for silver in sediment based on the UCL95 was 0.35. A sufficient number of clams were available at location SS70 to collect sufficient tissue for chemical analysis for this ERA, indicating silver in sediment does not appear to be adversely impacting the clam community at this location. In addition, silver accumulation in clam tissue does not appear to pose a hazard to clam predators (see Section 4.3.5 and 4.3.6). Potential impacts to the benthic community will be further investigated as part of the planned additional bioassay testing program to complete the ERA.

4.3.4.2 Clam Tissue Data

Table 32 presents a point-by-point comparison of clam tissue data against CTLs. Total arsenic and cadmium tissue concentrations exceeded CTLs at all locations. The UCL95s for arsenic and

cadmium in clam tissue collected at the Penrose Point reference area also exceed CTLs, as shown in Table 33.

Table 33 presents HQs of 2.2 and 6.7 for arsenic and cadmium, respectively, based on the maximum COC concentrations in clam tissue and CTLs. Because there are no known endangered or threatened benthic species at the Area 8 beach and a community-level assessment is appropriate, the UCL95s for Area 8 beach clam tissue were also compared to CTLs in Table 33 and these HQs were also greater than 1 at 1.5 and 3.6, respectively. However, arsenic and cadmium tissue concentrations were considered statistically similar to Penrose Point reference tissue concentrations (Table 10), suggesting that CTLs are a poor measure of the potential for arsenic and cadmium accumulation in clam tissue to cause direct toxicity in clams at the Area 8 beach because the CTLs represent levels that are statistically lower than concentrations in unimpacted reference areas, such as Penrose Point. In addition, the conservative assumptions used in the derivation of the cadmium CTL are described in detail in Section 4.4.3.

4.3.4.3 SEM/AVS Data

The SEM/AVS data are presented in Table 31 as a line of evidence for assessing the bioavailability of divalent metal COCs in sediment. As noted above in Section 4.3.4.1, the only divalent COC for sediment and seep water with concentrations greater than sediment benchmarks and background is cadmium. Silver is not a divalent metal, and bioavailability is not measured through SEM/AVS tests. An SEM/AVS ratio greater than 1 does not indicate a hazard is present; rather, this test is a tool to assess bioavailability. For Keyport, the SEM/AVS test was run to assist in the assessment of whether groundwater seeps are contributing to observed tissue levels of COCs at a given location as opposed to a sediment source. Locations with an SEM/AVS ratio greater than 1 indicate that sediment may pose a source of metals to benthos, whereas locations with a ratio less than 1 indicate that groundwater seeps may pose a source of metals to benthos and may be a concern if elevated clam tissue COC concentrations are noted.

For AVS nondetects, the reporting limit was assumed to be the representative concentration for the purposes of the SEM/AVS ratio calculations; this uncertainty is discussed in Section 4.4. Of the eight locations that were found to have concentrations of divalent metals in excess of the AVS concentrations (SS57, SS59, SS62, SS64, SS65, SS67, SS70, SS73), four locations did not contain detectable AVS (SS57, SS62, SS64, and SS73). However, divalent metals concentrations detected in sediment from these four locations with nondetectable AVS were

below the sediment benchmarks (Tables 29 and 30). Of the remaining four locations with detectable AVS, but for which the divalent metals concentrations were higher than AVS concentrations (i.e., potential for metals bioavailability), total metals concentrations detected in sediment were also below the sediment benchmarks at SS59 and SS67. Seep water data collected near SS67 (Seep A) also contain cadmium concentrations below the surface water screening benchmark (Table 27). At the two remaining locations (SS65 and SS70), there were no exceedances of the cadmium sediment benchmark. Thus, the SEM/AVS data coupled with the sediment data for these eight locations with SEM/AVS ratios greater than 1 suggest that none of the sediment concentrations at these locations is serving as a significant source of cadmium in clam tissue.

Table 34 summarizes the SEM/AVS results for the three samples (SS62, SS64, and SS65) located near Seep C with a cadmium concentration in excess of the surface water benchmark. None of these locations had sediment benchmark exceedances for any divalent COCs, including cadmium. The primary divalent COC contributors of the five divalent metals detected at these three locations are bolded. Mercury SEM concentrations are also presented for discussion purposes, even though this COC was not shown to be a primary contributor to SEM/AVS ratios greater than 1 for these three samples. The low level mercury concentrations would suggest that the presence of any portion of mercury in the divalent form would not significantly affect the interpretation of the SEM/AVS data. The lack of mercury in clam tissue greater than the CTL also suggests mercury interference in the SEM/AVS tests is not a significant concern. The lack of sediment benchmark exceedances for cadmium at these three locations, coupled with the elevated cadmium concentrations in nearby seep water and the available SEM/AVS data, suggest that sediment-bound cadmium is not a significant contributor to cadmium levels in tissue. Furthermore, these findings suggest that Seep C water may be contributing to the cadmium levels in tissue.

The SEM/AVS testing locations were selected prior to the availability of sediment data, and there are no 2015/2016 SEM/AVS data for four of the five sediment samples where cadmium sediment benchmark exceedances were noted (Tables 29 and 30), but SEM/AVS data were available for one additional sample (SS03-C) from 2008. For the one 2015/2016 SEM/AVS sediment sample with a cadmium benchmark exceedance, there was sufficient AVS present at one location (SS06-C) to suggest that cadmium in sediment is not bioavailable. In addition, as noted in the *Ecological Risk Evaluation of Intertidal Zone*, the SEM/AVS test run at SS03-C in July 2008 also reported an SEM/AVS ratio of less than 1 (0.8) (U.S. Navy 2009a). The cadmium concentrations in sediment at SS06-C and SS03-C represent the minimum and maximum detections above the sediment benchmark, respectively.

Although the maximum cadmium SEM concentration (0.049 micromole per gram [µmol/g]) at location SS06-C (Table 31) corresponded to cadmium concentrations in sediment greater than the benchmark (5.85 mg/kg) (Table 29), sufficient AVS was present to minimize bioavailability. No tissue data were collected from SS06-C. The next highest cadmium SEM concentration was generally comparable to SS06-C and found at location SS34 (0.04421 µmol/g) near Seep A. Next to Seep C and ignoring the outfall, Seep A had the next highest cadmium concentration in seep water. Despite the similarity to the SEM cadmium concentration at SS06-C, the SEM concentration at SS34 did not correspond to an elevated cadmium concentration in sediment (3.82 mg/kg), and this location had sufficient AVS to minimize bioavailability. Clam tissue was collected from SS34, and the cadmium concentration of 0.295 mg/kg wet weight fell below the reference area UCL95 of 0.471 mg/kg wet weight. In summary, the two seep locations with the highest cadmium SEM concentrations (Seep C and Seep A) differ in that sediment concentrations were above the benchmark at Seep C but below the benchmark at Seep A. It is important to note, however, that these sediment concentrations are still very similar. Both seep locations were demonstrated to have sufficient AVS in sediment to minimize bioavailability, and the tissue data available from Seep A also demonstrated no significant difference from reference area concentrations. These lines of evidence imply that the bioavailability potential of cadmium in sediment is limited due to site-specific conditions (e.g., AVS), which is also supported by the tissue sample from SS34.

The hypothesis that cadmium in seep water is the most likely contributor to cadmium in tissue is also supported by the data from location SS64, which is less than 30 feet from Seep C. At SS64, despite that fact that the SEM/AVS ratio is greater than 1 (Table 31), the sediment concentration was less than the sediment benchmark, suggesting that sediment is not a significant contributor to the tissue concentration. SS64 is the closest location to Seep C for which tissue data are available and has the highest cadmium seep level and the highest cadmium tissue concentration. The SS64 tissue concentration of 1 mg/kg wet weight was higher than the reference area UCL95 of 0.471 mg/kg wet weight. The combination of low sediment cadmium levels, high seep cadmium concentrations, and high cadmium tissue concentrations suggest that seeps are the primary contributor to clam tissue concentrations.

In summary, based on these findings, in conjunction with the seep and tissue data, seep water rather than sediment appears to be the primary contributor to tissue accumulation of cadmium.

4.3.4.4 Historical Bioassay Data

As noted in the SMS Rule (Ecology 2013b), exceedances of marine sediment quality standards should be confirmed using biological testing that consists of two acute studies and one chronic study. Bioassay tests and test species run by Northwestern Aquatic Sciences in 2008 remain in compliance with the 2013 Final SMS rule. In addition, the 2008 tests were run with sediment collected at Station SS03-C, the seep sediment location co-located with the maximum 2008 cadmium sediment concentration (13.8 mg/kg dry weight). Location SS03-C is also the location of the maximum 2015 concentration of cadmium where the concentration is slightly lower (11.4 mg/kg dry weight) than in 2008 (13.8 mg/kg dry weight). Both of the acute bioassays as well as the chronic test met the SMS test acceptability criteria. As noted in Table 35, the responses of the 10-day amphipod test using *Eohaustorius estuarius* were comparable to the Penrose Point reference survival rates. Likewise, the bivalve larval study indicated the number of normal larvae present in SS03-C test sediment were higher than the number of normal larvae in the reference sediment. No significant toxicity was measured by the Microtox mean light output relative to the control.

To evaluate whether the sediment characteristics at SS03-C are comparable to the other four locations where cadmium concentrations in sediment exceeded the sediment benchmark, the available total organic carbon (TOC) and grain size data are summarized in Table 36. In general, the higher the TOC, the more likely the metals will be sorbed to the TOC (Paller and Knox 2013 and Baran and Tamawski 2015) and the less likely a toxic response will be observed. TOC in the 2008 SS03-C sediment sample was 0.29 percent and was comparable to TOC values at the other four locations where TOC ranged from 0.24 percent to 0.40 percent.

The range of grain size data for SS03-C was compared to three locations with grain size data where cadmium concentrations in sediment exceeded the sediment benchmark. Amphipods are particularly sensitive to grain size and should be exposed to sediments with grain size compatible with the organism's natural living conditions. The test species used in the 2008 bioassay study, *Eohaustorius estuarius,* is a common amphipod species in Pacific Coast estuaries (Kendall and McMillan 1999). Because it is an infaunal burrower, it is in almost constant contact with sediment particulates and interstitial water. As shown in Table 36, both SS03-C and three locations where cadmium concentrations in sediment exceeded the sediment benchmark met the recommended clay fraction of <20 percent for *Eohaustorius.* Because the fine fraction consists of particles with a relatively large surface area to volume ratio (Power and Chapman 1992), and metals are known to sorb and concentrate in or on finer grained sediments (WDNR 2003), the relatively low percentage of clay (<2 to <3 percent) in Keyport

sediments with cadmium exceedances suggests that the SS03-C grain size would not affect the applicability of the amphipod bioassay results relative to other sediment locations. Regardless of the slight differences in grain size distribution between SS03-C and other locations, this data point would be representative of amphipod responses where cadmium concentrations in sediment exceeded the sediment benchmark. While there are no grain size data for Seep A, this is not considered a significant data gap because the test organisms are exposed to interstitial water as well as sediment, the cadmium concentration at Seep A is substantially lower (2.41 µg/L) than Seep C (45.7 µg/L) (Table 27), and the cadmium concentration in sediment at Seep A is about half the sediment concentration at SS03-C (Table 29).

In summary, the 2008 bioassay tests performed at location SS03-C/Seep C likely provide a reasonable prediction of toxicity for other sediments with concentrations exceeding the cadmium sediment benchmark. Nonetheless, to strengthen the conclusions based on the 2015/2016 SEM/AVS data, which are available for one of the five sediment samples with an exceedance of the sediment benchmark for cadmium, and based on the bioassay results of the planned 2008 sediment and seep sampling, additional bioassays will be recommended in accordance with WAC 173-204- 562(3)(d) requirements.

4.3.4.5 Historical Biological Survey Data

As noted in a Puget Sound study, benthic invertebrate surveys produce a complex list of species at a given site and it can be difficult to determine what constitutes abnormal deviations from an expected biological assemblage (Southern California Coastal Water Research Project [SCCWRP] 2013). Benthic species composition and abundances vary naturally from habitat to habitat (SCCWRP 2013), and that the Area 8 beach is an armored beach which further complicates the interpretation of benthic surveys. According to the SMS, benthic infaunal abundance surveys should evaluate the abundance of the major taxa of Class Crustacea (e.g., amphipods, crabs, lobsters, crayfish, shrimp, and barnacles), Class Polychaeta (e.g., annelid worms), and Phylum Mollusca (e.g., clams and mussels). There have been two shellfish surveys performed at the Keyport site that focused on characterizing the species and abundance of the Phylum Mollusca. While not quantified, casual observations were made during a site visit on June 13, 2014, and subsequent sampling activities. During these events, other species of marine life observed include barnacles, moon snail, sea pen, copepods, sculpin, sea stars, sea anemones, and pile worms.

A *Sustainable Shellfish Harvest Report* was prepared in 2007 (U.S. Navy 2007), which evaluated 1.2 acres of the Area 8 beach and defined the clam band as 0.78 acres. The survey

encompassed five transect lines where the numbers, sizes, and species of clams were documented.

In 2014, an *Intertidal Shellfish Survey Report* was prepared (U.S. Navy 2014). The purpose of the report was to document the infaunal shellfish species, burial depths, and general abundance within the intertidal portion of the Area 8 beach. The most abundant clam species were the native Pacific littleneck and butter clam, with 100 and 97 clams detected, respectively (Table 37). Manila clams, an introduced littleneck clam, were the next most abundant clam in the survey area with 21 clams detected. The five transects in this survey do not correlate with the transect number used in the site investigations, with the exception of Transect 1. Transects 2, 3, 4, and 5 in the 2014 shellfish survey study are equivalent to Transect 8 (Seep C), Transect 9 (Outfall 03-703), Transect 12 (Seep F) and Transect 13 (Seep G), respectively, in the site investigation. If cadmium in Seep C is adversely impacting clam populations, then it would be expected that the number of clams at Transect 2 would be less than those found at other transects. However, as noted on Table 37, the abundance of littlenecks is comparable between Transects 2 through 5, and a larger number of Manila and butter clams were noted in Transect 2 (Seep C) than at any other transects. The lower number of littlenecks at Transect 1 is likely not chemical-related, but is more likely to be related to the difference in preferential habitat, as noted by the high number of rough piddock, which prefer heavy mud, clay, and soft rock substrates as opposed to littlenecks and butter clams, which prefer coarse and/or sandy muds.

The shellfish studies described above, in conjunction with the other lines of evidence suggest that the clam populations along the beach are not significantly impacted by metals in Area 8 groundwater discharging as seeps. The other supporting facts include: 1) that clam tissue collection was possible at the 2015 and 2016 sampling locations planned for clam tissue collection (within the clam band from the seawall at approximately +3 feet MLLW to -2.5 feet MLLW), including areas where the maximum seep and sediment cadmium concentrations have been found, and 2) cadmium concentrations in Area 8 beach clam tissue are statistically comparable to the reference clam cadmium concentrations. Given the difficulties associated with finding a suitable reference location and other challenges, alternatives to performing a biological survey in accordance with WAC 173-204- 562(3)(d) requirements to confirm there are no adverse impacts to the benthic community and complete the ERA will continue to be discussed with the project team during the planning stages of the additional bioassay test program.

4.3.4.6 Summary of Risks to Benthic Organisms

Two COCs were identified as posing a potential hazard to sediment benthos: cadmium and silver.

Cadmium. Cadmium concentrations in sediment and seeps from the area along Transect 8 between the shoreline location SS51 to sediment sample SS03-C/Seep C exceed sediment and surface water benchmarks. Based on a line of evidence approach, the abiotic medium most likely influencing cadmium uptake into clam tissue is seep water. However, cadmium concentrations in clam tissue across the Area 8 beach were statistically comparable to cadmium concentrations at the Penrose Point reference area. In addition to the SEM/AVS data that indicated sufficient AVS present at one location (SS06-C) to suggest that cadmium in sediment is not bioavailable, the 2008 acute and chronic bioassay tests conducted on sediment with the highest cadmium concentration (SS03-C) demonstrated no toxicity to the benthic test species. Furthermore, clam tissue collection was possible at all sampling locations during the 2015 and 2016 site investigations, including areas where the maximum seep and sediment cadmium concentrations have been found. Therefore, while localized effects of cadmium discharging at Seep C may be possible for some sediment benthos species, the lines of evidence suggest that cadmium is not causing substantive site-wide effects on clam populations along the Area 8 beach.

Silver. Silver concentrations in sediment at two locations exceeded the sediment benchmark. The HQ for silver in sediment based on the UCL95 was 0.35, indicating silver in sediment does not appear to be adversely impacting the clam community at the Area 8 beach. In addition, silver accumulation in clam tissue does not appear to pose a hazard to clam predators (see Section 4.3.5 and 4.3.6). The need to address potential impacts to the benthic community from silver exposure to complete the ERA will be further discussed with the project team during the planning stages of the additional bioassay test program.

4.3.5 Northwestern Crow

Table 38 presents the dose calculations and HQs for the northwestern crow. All the NOAEL-based HQs were less than 1, even under the conservative assumption that the crow feeds exclusively at the Area 8 beach. Therefore, no further evaluation was necessary to protect semi-aquatic birds.

4.3.6 River Otter

Table 39 presents the dose calculations and HQs for the river otter. All the NOAEL-based HQs were less than 1 even under the conservative assumption that the otter feeds exclusively at the Area 8 beach. Therefore, no further evaluation was necessary to protect semi-aquatic mammals.

4.4 Uncertainties in Ecological Risk Assessment

Uncertainties are inherent in all aspects of a risk assessment. The nature and magnitude of the uncertainties depend on the amount and quality of the available data, the extent of knowledge about site conditions, and the assumptions used in the risk assessment. A qualitative evaluation of the major uncertainties associated with the ERA is described in this section and includes four areas: problem formulation, assumptions related to exposure, assumptions related to effects, and risk characterization.

4.4.1 Problem Formulation

Key uncertainties during the problem formulation step include:

- None of the sediment data were reported as non-detects, and J-flagged data were treated as detected concentrations, reducing the uncertainty potentially associated with elevated method detection limits (Table 29). Only silver was reported as nondetect in clam tissue from the reference area. While there is no CTL to assess whether the detection limit is sufficiently low, because silver was detected in all Area 8 beach tissue (Table 32), this is not considered a significant uncertainty.
- As shown in Table 27, the detection limits for the nondetect seep water samples did not exceed surface water benchmarks. Nondetects noted in three reference area marine water samples for one or more COCs (i.e., cadmium, lead, silver, zinc) were also less than surface water benchmarks (Table 40). Therefore, no uncertainties were identified with the nondetect water data.
- For AVS nondetects, the detection limit was assumed to be the representative concentration for the purposes of the calculation of the SEM/AVS ratios, which has the potential to underestimate exposure because AVS may actually be present at concentrations less than the detection/reporting limit (i.e., less AVS to bind to SEM). However, because all the AVS nondetect samples had SEM/AVS ratios greater than 1, this uncertainty is unlikely to affect the ERA SEM/AVS

findings because the SEM/AVS ratios for these nondetect samples are well above 1.0 ranging from 22.6 to 85.9. This implies that any reduction in acid volatile sulfides would not likely be sufficient to result in a ratio less than 1.0.

- Mercury SEM values were nondetect in all but four samples. Because mercury is not included in the SEMs summations and because the four samples with detectable mercury all had SEM/AVS ratios greater than 1, the exclusion of mercury from the SEM calculations is unlikely to affect the ERA SEM/AVS findings.
- Cadmium and lead SEM concentrations were nondetect at location SS57. The SS57 SEM/AVS ratio was greater than 1, and even if the concentrations of these two metals were assumed to be zero, the SEM/AVS ratio for this location would remain greater than 1. Thus, the potential for overestimation of exposure by conservatively assuming cadmium and zinc SEM concentrations were equivalent to the detection limits is unlikely to affect the ERA SEM/AVS findings.
- Not all ecological receptors are quantitatively evaluated in an ERA. Representative clam and wildlife indicator species were selected in the workplan (U.S. Navy 2016a). Littleneck clams were identified as the target species, although an abundance of butter clams was also noted. Butter clams are able to sequester a paralytic shellfish toxin (Kraeuter and Castagna 2001), and birds, such as gulls, and otters are able to detect the presence of the toxin and avoid these clams. This protective mechanism makes butter clams less likely to be consumed by higher trophic-level ecological organisms than other clam species, thereby reducing the uncertainty of selecting the littleneck clams as a representative species.

4.4.2 Exposure Assumptions

Key uncertainties that relate to the exposure assessment include the following:

- Selected exposure factors could lead to either over- or underestimation of exposure, but tended to lead to an overestimation of exposure because selection of these factors erred on the conservative side (e.g., using lowest body weights, assumption of 100 percent site use).
- In accordance with the HHRA/ERA workplan (U.S. Navy 2016a), the 0 to 10 cm data was considered the primary depth interval, but the 10 to 24 cm interval data would be addressed in the uncertainty section. The data from the 10 to 24

cm interval were compared to the sediment benchmarks in Table 29. Only mercury at location SS40 at this depth interval was found to exceed a sediment benchmark. Mercury at the 0 to 10 cm interval did not exceed the sediment benchmark and mercury in tissue at this location (Table 32) and did not exceed the tissue CTL. Thus, given that no exceedances of sediment benchmarks for the two COCs identified at the 0 to 10 cm depth interval (i.e., cadmium and silver) were noted for the 10 to 24 cm interval, the focus of the ERA on cadmium concentrations at the 0 to 10 cm sediment depth is unlikely to underestimate exposure for the benthic community.

4.4.3 Effects Assumptions

Key uncertainties that relate to the effects assessment include the following:

- The maximum concentration of silver detected from Outfall 03-701 effluent was greater than the surface water benchmark. Toxicity of silver occurs mainly in the aqueous phase and depends on the concentration of active, free Ag+ ions (Ratte 1999). It is not known if the silver in Outfall 03-701 effluent consists of free ions. In addition, the initial silver surface water benchmark is based on an acute value divided by a safety factor of 10. Given that the maximum silver concentration at the Area 8 beach of 0.58 µg/L does not exceed the British Columbia ambient water quality criterion for chronic exposure to silver in marine and coastal waters of 1.5 µg/L (Ministry of the Environment 1996), and given the uncertainty regarding the form of silver present (i.e., free divalent ions), it is possible that risks from silver are over- or underestimated.
- The State of Washington has not identified a sediment benchmark for nickel in the SMS (Ecology 2013b). The confidence in risk-based sediment benchmarks for nickel is typically low (Long et al. 1995 and Long and MacDonald 1998), particularly for the ERL. The range between the ERL and the ERM values is assumed to represent the range in which effects are occasionally observed (MacDonald 1994). However, it is important to note that background concentrations of nickel are often greater than the ERL, and even at the less conservative ERM benchmark for nickel, a low accuracy of predicted adverse effects has been reported (Long et al. 1995). No concentrations of nickel in sediment exceeded the ERM (HQ of 0.8) (Table 30).
- The maximum detected Area 8 beach seep concentrations for each COC were compared to surface water benchmarks. This method has the potential to

overestimate COC hazards since seep water exposure is more significant for benthic organisms, and surface water data are considered a better measure of exposure levels for aquatic organisms.

- The CTLs are considered highly uncertain, especially if the values are lower than naturally occurring tissue concentrations, as is the case for cadmium. Thus, it is likely the predicted risks resulting from the comparison of site clam tissue to the CTLs are overestimated. The presence of clams in areas of CTL tissue exceedances further suggests that the cadmium CTL overestimates the hazards from cadmium exposure at the Area 8 beach. In addition to being lower than the reference location cadmium tissue levels, the cadmium CTL of 0.15 mg/kg wet weight is biased low because a species sensitivity distribution model was used that combined both freshwater and saltwater data. Cadmium is much more toxic to freshwater organisms as evidenced by the much lower freshwater USEPA national recommended water quality criterion continuous concentration of 0.72 µg/L, as compared to 7.9 µg/L for saltwater. Using the an alternative approach of multiplying the water criterion by the BCF which is also endorsed by ODEQ, if the current marine water quality criterion of 0.0079 mg/L and the same cadmium BCF of 64 are used, the CTL would be 0.51 mg/kg wet weight. The cadmium tissue UCL95 for the Area 8 beach is 0.53 mg/kg wet weight, which would result in an HQ of 1.0, indicating that site concentrations are essentially equivalent to the threshold. Unlike the cadmium CTL based on combined freshwater and saltwater data, the refined saltwater CTL of 0.51 mg/kg wet weight is greater than the cadmium UCL95 for the Penrose Point reference area of 0.47 mg/kg wet weight.
- Hexavalent chromium TRVs were not identified in the HHRA/ERA workplan (U.S. Navy 2016a) for birds. Unlike human health, the hexavalent chromium TRV is less stringent than total or trivalent chromium TRVs for mammals. Although hexavalent chromium HQs were not calculated in this ERA for mammals, because the total chromium HQs were less than 1, by default, hexavalent chromium is unlikely to pose a hazard to wildlife including semi-aquatic birds.
- As noted in the workplan (U.S. Navy 2016a), a number of wildlife TRVs were considered. Selection of alternative TRVs could overestimate or underestimate the predicted HQs for these receptors.

4.4.4 Risk Characterization

Key uncertainties that relate to the risk characterization include the following:

- Both total arsenic and inorganic arsenic concentrations in tissue were considered in the crow and otter HQ calculations. Although inorganic arsenic may be a better measure of the hazards from arsenic exposure, the lack of HQs greater than 1 based on total arsenic minimizes this uncertainty.
- The methylation of mercury and form of arsenic can significantly affect the prediction of ERA hazards. Collection of methylmercury in tissue and inorganic arsenic data served to reduce this uncertainty and minimize the over-estimation of hazards.
- Cumulative exposure to metals is not commonly evaluated given the various modes of action associated with individual metals and uncertainty with assuming additive toxicity. However, exposure to multiple COCs is considered in this ERA based on the summation of SEM. Mercury SEMs were not included in the summation of AVS for SEM/AVS ratio calculations because mercury was nondetect in all but four samples. Given the low or nondetect concentrations of mercury, this uncertainty is unlikely to affect the interpretation of the SEM/AVS results.
- Copper in sediment exceeded the sediment benchmark at the Area 8 beach, but was deemed comparable to background (Table 30). Only the maximum copper concentration slightly exceeded the sediment benchmark (HQ of 1.1). Additionally, the statistical analysis for copper in clam tissue demonstrated tissue concentrations below reference area tissue concentrations (Table 33). Therefore, the elimination of copper as a COC in sediment based on background is unlikely to under-predict risks to benthic organisms.
- Although mercury concentrations at seven locations were reported to exceed the sediment screening benchmark, mercury sediment concentrations at the Area 8 beach were found to be consistent with natural background based on comparison to Ecology's 90/90 UTL of 0.2 mg/kg (Table 30) and the population-population statistical comparison of the Area 8 beach data set versus the Bold natural background data set (Table 10). In addition, as noted in Table 33, mercury concentrations in clam tissue were well below the CTL. Therefore, the

elimination of mercury as a COC in sediment based on background is unlikely to under-predict risks to benthic organisms.

- There are no 2015/2016 SEM/AVS data for four of the five sediment samples where cadmium sediment benchmark exceedances were noted. However, the uncertainty regarding the bioavailability of sediment-bound cadmium is reduced by the availability of SEM/AVS data for the sample with the highest cadmium concentration in 2008 for which sufficient AVS was present to reduce bioavailability. The other sediment sample with an exceedance of the cadmium benchmark and co-located SEM/AVS data also contained sufficient AVS to reduce the sediment-bound cadmium bioavailability. Furthermore, elevated littleneck clam tissue concentrations of cadmium are found near Seep C where the highest cadmium seep concentration is present, suggesting the seep is the source of cadmium in tissue. In addition, littleneck clams are suspension feeders that acquire food by passing the water over a specialized filtering structure to feed on phytoplankton and to a lesser degree on zooplankton and detritus (Government of Canada 2013 and U.S. Fish and Wildlife Service 1987). This mode of feeding is more likely to result in accumulation of water-borne contaminants as compared to detritus/deposit feeders. Thus, the lack of SEM/AVS data from three locations is not considered a significant uncertainty.
- Only three bioassay tests based on one sediment sample collected in 2008 are available. However, the uncertainty associated with this limited data set is reduced because 1) the 2008 sediment cadmium concentration was greater than any of the measured 2015/2016 cadmium concentrations in sediment and 2) the species tested and the bioassay methods remain in compliance with the 2013 SMS Rule (Ecology 2013b). The planned additional bioassay testing program will further reduce the uncertainties associated with the limited bioassay dataset.

This page was intentionally left blank.

5.0 RE-EVALUATION OF CONCEPTUAL SITE MODEL

The existing CSM for Area 8 focuses on historical sources of groundwater contamination related to past plating shop operations. Remedial actions for the site addressed sources by removing the former plating shop and contaminated soils. However, as documented in the 1994 ROD, a plume of metals was found to extend from the western portion of the site (Building 72) toward Liberty Bay to the east and southeast. Although the baseline risk assessments did not demonstrate the need to address the marine environment, the ROD anticipated that residual contamination would continue to be discharged to Liberty Bay for many years. Therefore, provisions for LTM and re-evaluation of human health and ecological risks were established to determine if continued discharges would accumulate over time and necessitate further investigations or groundwater control measures.

Characterization of the extent of contamination in the marine environment has occurred intermittently, beginning in 1996. The potential presence of sediment contamination (0 to 10 cm) in the subtidal area was assessed during the 2012 site investigation (U.S. Navy 2013), with the conclusion that the extent of contamination was limited to the intertidal zone. The vertical extent of sediment impacts in the intertidal zone and impacts on marine surface water and seep water were considered to be adequately defined after the June 2015 sampling event (U.S. Navy 2015c). However, supplemental data was collected in the intertidal area offshore of Area 8 in 2016 to fully characterize the concentrations of contaminants in surface sediments (0 to 10 cm) and clam tissue (U.S. Navy 2016b) near the seawall. The additional 2015/2016 data confirm that a localized area near SS03-C/Seep C contains elevated cadmium concentrations.

These data sets were used to assess risks to human health and the environment. As discussed in the workplan, if the results of the HHRA/ERA indicate unacceptable site-related risk, the existing CSM was to be refined in order to support the need for additional groundwater controls or to guide additional remediation efforts.

While the HHRA concluded that there are no significant site-related health risks, bioassay data are needed to complete the ERA. As noted in the SMS Rule (Ecology 2013b), exceedances of marine sediment quality standards should be confirmed using biological testing that consists of two acute studies and one chronic study. Bioassay tests and test species run by Northwestern Aquatic Sciences in 2008 remain in compliance with the 2013 Final SMS rule and the cadmium concentration tested was greater than the current maximum cadmium concentration at the Area 8 beach. Because the sediment characteristics at SS03-C are comparable to the other four

locations where cadmium concentrations in sediment exceeded the sediment benchmark, the 2008 bioassay tests performed at location SS03-C/Seep C are expected to provide a reasonable prediction of toxicity for other sediments with concentrations exceeding the cadmium sediment benchmark. Nonetheless, additional bioassays data collection to assess current conditions is recommended.

6.0 CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the HHRA and ERA results and provides recommendations on the basis of the HHRA/ERA results and risk characterization, as well as the uncertainties inherent in the HHRA/ERA process. Furthermore, all comments and recommendations provided by stakeholders and regulators on the draft and draft final reports were addressed, and the comments and responses to those comments are provided in Appendix H. Specifically, this section determines if additional investigation is necessary and if groundwater controls are needed to protect human health and the environment.

6.1 Human Health

The ROD specified that post-ROD sediment and clam tissue samples from Liberty Bay were to be evaluated, using risk assessment procedures, to assess whether human health risks above background or reference areas are present. This HHRA evaluated the potential human health risks associated with subsistence-level and recreational-level exposures to COCs in clam tissue and sediment. As agreed to by the project team, the subsistence scenario was evaluated using the Suquamish Tribe's seafood consumption rates. The exposure assumptions for the recreational receptor scenario were decided upon in consultation with the project team. In addition, site data were compared to background and reference area data. The background and reference area evaluation was completed without influence from chemical toxicity or exposure and is used only as a guide to evaluate whether site concentrations are significantly different from background and reference areas.

The following subsections summarize the results of the background and reference area evaluation and the risk characterization results for the Suquamish subsistence and recreational receptors. In addition, the conclusions and recommendations based on the human health risk characterization results are presented.

6.1.1 Background and Reference Area Evaluation

Because metals occur naturally in the environment, comparison of site data to background concentrations allows determination of the degree of contamination associated with site activities. Natural background is defined in the SMS rule (WAC 173-204-505(11)) as the concentration of a hazardous substance consistently present in the environment that has not been influenced by localized human activities. Penrose Point was selected by the project team based on the remoteness of the site, lack of nearby point sources, and good agreement with

site sediment characteristics and biological habitat (U.S. Navy 2015c). In addition, the Ecology BOLD natural background values were used to characterize site sediment concentrations relative to background. To assess whether the Area 8 beach concentrations are statistically different from reference area concentrations, both a single-point comparison and population-population (site versus background) comparison were performed on the site and reference area data for tissue and sediment.

The single-point comparison concluded the following:

- Arsenic was not detected above the BTV in any clam or sediment sample collected from the Area 8 beach, indicating that the concentrations of arsenic are consistent with natural background and reference area concentrations.

- Cadmium exceedances in sediment were predominantly located along the southern Transects 2 and 8 (near Seep C), Transect 3 (near Seep A), Transect 10 (near Seep D), and Transect 9 (near Outfall 03-703). These results indicate that Seeps A, C, and D and Outfall 03-703 might be contributing to cadmium concentrations in sediment. However, cadmium in tissue was detected only slightly above the BTV in only seven Area 8 beach clam samples. The exceedances were noted primarily along Transects 2 and 8 (near Seep C), Transect 3 (near Seep A), and Transect 9 (near Outfall 03-703). These results indicate that Seeps A and C and Outfall 03-703 are potentially influencing cadmium concentrations in clam tissues; however, the concentrations of cadmium in clam tissue also are generally consistent with Penrose Point reference area concentrations, as the magnitude of exceedance over the BTV is low.

- Several sporadic exceedances of the BTVs for chromium, copper, lead, nickel, zinc, and mercury in sediment and tissue were noted. These results indicate that the seeps might be contributing to chromium, copper, lead, nickel, zinc, and mercury concentrations in sediment, and the outfalls might also be an additional source of these metals to the Liberty Bay.

- For silver, nearly 50 percent of the sediment samples exceeded the BTV, and nearly all of the clam tissue samples exceeded the tissue BTV. However, the exceedances of the BTV noted in sediment and clams were widespread, with exceedances occurring on nearly every transect (except Transect 14). These results indicate that the seeps might be contributing to silver concentrations in

sediment and clam tissue above reference area concentrations, but do not demonstrate a pattern with respect to specific potential point sources to Liberty Bay.

The population-population (site versus background) comparison concluded that concentrations of cadmium and silver in sediment are statistically higher than the natural background concentrations, and that concentrations of lead, nickel, silver, and methylmercury in Area 8 beach clam tissue are statistically higher than those measured in the reference clam tissue samples.

6.1.2 Suquamish Subsistence Receptors

For Suquamish subsistence receptors at the Area 8 beach, the noncancer HI from ingestion of clam tissue is 4 and 5 for child and combined child/adult receptors, respectively, and the cancer risk is 3×10^{-4}. At reference areas, the noncancer HIs and cancer risks are the same as those for the Area 8 beach when rounded to one significant figure. This result indicates that exposure to COCs in clams collected from the Area 8 beach is not substantially different than the exposure from reference areas, and the incremental site noncancer HIs are 0.6 and 0.7 for child and combined child/adult receptors, respectively. In addition, there is no unacceptable incremental cancer risk over reference areas because the concentrations of arsenic in reference area clams resulted in higher cancer risk estimates than those calculated for the Area 8 beach. For exposure to sediment at the Area 8 beach, noncancer HIs are less than the target health goal of 1 for both the child and combined child/adult receptors, and the cancer risk is 6×10^{-6}, slightly above USEPA's *de minimis* cancer risk level of 1×10^{-6}. Noncancer HIs and cancer risks calculated based on the natural background sediment concentrations actually resulted in slightly higher hazard and risk estimates for the subsistence receptor. The contribution of sediment exposures to the cumulative hazard and risk estimates based on combined exposure to clam tissue and sediment is insignificant.

These results indicate that while the hazard and risk estimates calculated for the Area 8 beach slightly exceed target health goals, non-site related sources from natural background or other ubiquitous sources contribute significantly to the concentrations of COCs measured at the site. Because the incremental noncancer hazard and cancer risk estimates are below target health goals, there is no unacceptable site-related risks for Suquamish subsistence receptors.

6.1.3 Recreational Receptors

For the recreational receptor, cancer risks and noncancer hazards are substantially lower than those for the subsistence receptor. At the Area 8 beach, the noncancer HI from ingestion of clam tissue by recreational receptors is 0.2 and 0.1 for child and combined child/adult receptors, respectively, below the noncancer target health goal of 1. The cancer risk is 2×10^{-6}, slightly above the USEPA's *de minimis* cancer risk level. At reference areas, the noncancer HIs and cancer risks are the same as those for the Area 8 beach when rounded to one significant figure. This result indicates that exposure to COCs in clams collected from the Area 8 beach is not substantially different than the exposure from reference areas, and the incremental site noncancer HIs are 0.03 and 0.02 for child and combined child/adult receptors, respectively, well below the target health goal. There is no unacceptable incremental cancer risk over reference areas because the concentrations of arsenic in reference area clams resulted in higher cancer risk estimates than those calculated for the Area 8 beach. As discussed for the subsistence receptor, the contribution of sediment exposures to the cumulative hazard and risk estimates based on combined exposure to clam tissue and sediment is insignificant

Because the noncancer hazard estimates calculated for the Area 8 beach are below target health goals, there is no unacceptable health risk for recreational receptors at the site, even without considering the contribution from background sources. Though the cancer risk estimates calculated for the Area 8 beach slightly exceed the *de minimus* target cancer risk level, non-site related sources from natural background or other ubiquitous sources contribute significantly to the concentrations of COCs measured at the site. Because the incremental noncancer hazard and cancer risk estimates are well below target health goals, there is no unacceptable site-related risk for recreational receptors.

6.1.4 Conclusions

Despite the results of the background and reference area evaluation that indicates several COCs are present in the Area 8 beach sediment and clam tissue samples at concentrations exceeding background and reference area concentrations, the incremental site risk over background for Suquamish subsistence and recreational receptors meets target health goals. As such, no additional investigation is recommended and groundwater controls are not considered necessary to protect human health.

6.2 Ecological Risk Assessment

The ERA evaluated the potential environmental hazards to ecological receptors potentially exposed to residual metal COCs associated with the former plating shop that have discharged

via groundwater to the Area 8 beach. The media evaluated included seeps, surface water, sediments, and clam tissue. The ecological receptors of concern included aquatic organisms (living in the water column), benthic community (living in sediment), and semi-aquatic birds and mammals. Table 41 presents the findings of the ERA.

6.3 Aquatic Organisms

Both surface water and seep data were used to assess whether COCs could adversely affect aquatic organisms present on the Area 8 beach.

Marine Surface Water. The HQs based on the available surface water data were all lower than 1 for all COCs, suggesting that groundwater discharging from seeps and outfalls does not pose an unacceptable hazard to fish and other free-swimming organisms.

Seeps. Although aquatic organisms do not typically reside in seeps, a comparison to surface water benchmarks was made to help with source identification. The maximum cadmium seep concentration at Seep C exceeded the surface water benchmark, resulting in a HQ of 5.8. HQs for copper and silver were 1.7 and 3.1, respectively. The maximum concentrations of copper and silver exceeded their respective benchmarks only at an outfall location (Outfall 03-701). Given that the silver and copper concentrations in Seeps A through G do not exceed the surface water benchmarks, copper and silver in discharge from Outfall 03-701 is unlikely to be site-related (i.e., it is located over 250 feet to the north of Area 8). Thus, copper and silver discharge from Outfall 03-701 will not be addressed by groundwater controls, the selected remedy for the Area 8 beach. In addition, the resulting HQ for copper of 1.7 based on the single exceedance at Outfall 03-701 only slightly exceeded the target health goal and the high degree of uncertainty associated with the silver benchmark. Thus, given the relatively low HQ for copper and the uncertainties of the silver surface water benchmark coupled with the lack of an exceedance of the alternative benchmark, only cadmium in groundwater discharging at Seep C was considered to pose a potential hazard to aquatic organisms as a result of Area 8 groundwater impacts. However, because the cadmium concentration in marine surface water represents a 96 percent drop in concentration relative to the Seep C concentration, the cadmium concentration in Seep C is more likely to adversely affect infaunal benthic invertebrates like clams than free-swimming aquatic organisms. Thus, the localized cadmium exceedance in seeps is not expected to pose an unacceptable hazard to free-swimming aquatic life, and groundwater controls are not considered necessary to protect this receptor group.

6.3.1 Benthic Organisms

A line of evidence approach was used to assess the potential for Area 8 COCs to affect the benthic community. In addition to sediment, seep, and clam tissue data comparisons to benchmarks, the results of the SEM/AVS tests, the 2008 bioassay tests, and the 2014 shellfish survey report were all used to assess whether COCs could be adversely affecting benthic organisms present on the Area 8 beach and whether additional sediment bioassays are warranted to evaluate the need for groundwater controls.

Media-Specific Benchmark Comparisons. Cadmium concentrations exceeded sediment and surface water benchmarks. Silver concentrations exceeded sediment benchmarks near Outfall 03-703, but not the British Columbia water quality criterion in surface water benchmark at Outfall 03-701. Because elevated silver in sediment does not appear to be co-located with known seep source areas containing key site-related COCs (cadmium) at location at Outfall 03-701, silver is not likely attributed to Area 8 groundwater and groundwater controls will not address these exceedances. Maximum cadmium concentrations in seep, sediment, and tissue are located along Transect 8, particularly near Seep C. Cadmium concentrations at one additional location (Seep A) also exceeded the sediment benchmark. The cadmium CTL screening criterion for tissue is lower than background concentrations at the Penrose Point reference location. In addition, site-wide cadmium levels in tissue were not statistically different than the Penrose Point reference location.

SEM/AVS Bioavailability Data. The SEM/AVS testing locations were selected concurrent with collection of sediment data; there are no 2015/2016 SEM/AVS data for four of the five sediment samples where cadmium sediment benchmark exceedances were noted, but SEM/AVS data were available for one additional sample (SS03-C) from 2008. For the one 2015/2016 SEM/AVS sediment sample with a cadmium benchmark exceedance (SS06-C), there was sufficient AVS present to suggest that cadmium in sediment is not bioavailable. In addition, as noted in the Ecological risk evaluation in the intertidal zone, the SEM/AVS test conducted at SS03-C in July 2008, which is associated with the maximum detected concentration of cadmium, also reported an SEM/AVS ratio of less than 1 (0.8) (U.S. Navy 2009a), indicating that cadmium in sediment is not bioavailable.

The hypothesis that cadmium in seep water is the most likely contributor to cadmium in tissue is also supported by the data from location SS64, which is less than 30 feet from Seep C. Despite that fact that SEM/AVS ratios are greater than 1 at SS64, the sediment concentration was less than the sediment benchmark. SS64 is the closest location to Seep C for which tissue

data are available and has the highest cadmium seep level and the highest cadmium tissue concentration. The combination of low sediment cadmium levels, high seep cadmium concentrations, and high cadmium tissue concentrations suggest that seeps, not sediment, are the primary medium contributing to cadmium in tissue concentrations. Nonetheless, because there are no 2015/2016 SEM/AVS data for four of the five sediment samples where cadmium sediment benchmark exceedances were noted, additional data, such as bioassay tests, are needed to support this hypothesis.

Bioassays. The concentration of cadmium in the sediment sample used in the 2008 bioassay tests (SS03-C/Seep C) was greater than any of the currently measured cadmium concentrations. TOC and grain size measurements at SS03-C/Seep C are comparable to the remaining locations with cadmium in exceedance of the sediment benchmark. Therefore, the 2008 bioassay tests performed at location SS03-C/Seep C are expected to provide a reasonable prediction of toxicity for other sediments with concentrations exceeding the cadmium sediment benchmark. None of the bioassay tests performed on the highest cadmium concentration in sediment and seep water showed significant toxicity.

Shellfish Abundance Metrics. As noted in a Puget Sound study, benthic invertebrate surveys produce a complex list of species at a given site and it can be difficult to determine what constitutes abnormal deviations from an expected biological assemblage (SCCWRP 2013). Benthic species composition and abundances vary naturally from habitat to habitat (SCCWRP 2013), and that the Area 8 beach is an armored beach further complicates the interpretation of benthic surveys. According to the SMS, benthic infaunal abundance surveys should evaluate the abundance of the major taxa of Class Crustacea (e.g., amphipods, crabs, lobsters, crayfish, shrimp, and barnacles), Class Polychaeta (e.g., annelid worms), and Phylum Mollusca (e.g., clams and mussels). The two shellfish abundance studies provide supporting evidence of the lack of direct impacts to populations. In addition, cadmium concentrations in Area 8 beach clam tissue are statistically comparable to the reference clam cadmium concentrations. Thus, the lines of evidence suggest that clam populations along the Area 8 beach are not significantly impacted by metals in Area 8 groundwater discharging as seeps.

In summary, the lines of evidence suggest that while there are localized elevated concentrations of cadmium in seeps and sediment based on seep and sediment benchmark comparisons, cadmium tissue concentrations are not elevated relative to background tissue levels. The presence of sufficient AVS, the findings of historical bioassay tests at the highest cadmium seep and sediment concentrations, and the two intertidal shellfish survey reports (U.S. Navy 2009a and 2014) support the hypothesis that metals in Area 8 groundwater discharging as

seeps from the former plating facility do not pose unacceptable hazards to the benthic community on the Area 8 beach. To strengthen the lines of evidence, additional bioassays will be recommended in accordance with WAC 173-204- 562(3)(d) requirements.

6.3.2 Semi-Aquatic Birds

The Northwestern crow was used to represent this receptor group, feeding on benthic invertebrates along the shoreline. Under the conservative assumption that this species consumed 100 percent of its diet as clams from the Area 8 beach, HQs were lower than 1 for all COCs, suggesting that groundwater discharging from seeps and outfalls and accumulating in prey do not pose unacceptable hazards to birds foraging on the Area 8 beach. Groundwater controls are not considered necessary to protect this receptor group.

6.3.3 Semi-Aquatic Mammals

The river otter was used to represent this receptor group, foraging on benthic invertebrates along the shoreline. Under the conservative assumption that this species consumed 100 percent of its diet as clams from the Area 8 beach, HQs were lower than 1 for all COCs, suggesting that groundwater discharging from seeps and outfalls and accumulating in prey do not pose unacceptable hazards to semi-aquatic mammals foraging on the Area 8 beach. Groundwater controls are not considered necessary to protect this receptor group.

6.3.4 Recommendations Based on the ERA

Based on the findings of no significant hazards to free-swimming aquatic life or semi-aquatic birds and mammals, groundwater controls are not considered necessary to protect these receptor groups. Likewise, the lines of evidence suggest that the hazards to benthic organisms are low despite localized elevated concentrations of cadmium in seeps and sediment. This conclusion is based on:

- Surface water and sediment benchmark comparisons that indicate localized impacts
- Cadmium clam tissue concentrations that are not elevated relative to reference area tissue levels
- The presence of sufficient AVS where the data are available to indicate sediment impacts are minimal

- The findings of the 2008 bioassay tests at the highest cadmium seep and sediment concentrations to indicate cadmium is not toxic based on the SMS Rule

- Two intertidal shellfish survey reports and casual observations that support that metals in Area 8 groundwater discharging as seeps from the former plating facility do not appear to be significantly impacting the sediment benthos on the Area 8 beach.

This page was intentionally left blank.

7.0 REFERENCES

Allen, H.E., G. Fu, and B. Deng. 1993. "Analysis of Acid-Volatile Sulfide (AVS) and Simultaneously Extracted Metals (SEM) for the Estimation of Potential Toxicity in Aquatic Sediments." *Environ Toxicol Chem* 12:1441–1453.

American Cancer Society. 2015. "Cancer Statistics, 2015." *CA-Cancer J Clin* 65:5-29.

Ankley, G.T, G.L. Phipps, E.N. Leonard, D.A. Benoit, V.R. Mattson, P.A. Kosian, A.M. Cotter, J.R. Dierkes, D.J. Hansen, and J.D. Mahony. 1991. "Acid-Volatile Sulfide as a Factor Mediating Cadmium and Nickel Bioavailability in Contaminated Sediments." *Environ Toxicol Chem* 10:1299–1307.

Ankley, G.T., D.M. Di Toro, D.J. Hansen, and W.J. Berry. 1996a. "Technical Basis and Proposal for Deriving Sediment Quality Criteria for Metals." *Environ Toxicol Chem* 15:2056–2066.

Ankley, G.T., D.M. Di Toro, D.J. Hansen, and W.J. Berry. 1996b. "Assessing the Ecological Risk of Metals in Sediments." *Environ Toxicol Chem* 15:2053–2055.

ATSDR (Agency for Toxic Substances and Disease Registry). 2013. *Health Consultation, Operable Unit 2 Area 8 Shellfish Evaluation, Naval Base Kitsap,* Keyport (Formerly Known as Naval Undersea Warfare Center, Keyport), Keyport, Kitsap County, Washington. U.S. Department of Health and Human Services, ATSDR, Division of Community Health Investigations, Atlanta, Georgia. February 25, 2013.

———. 2012. *Toxicological Profile for Chromium*. U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry. September 2012.

———. 2007. *Toxicological Profile for Arsenic*. U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry. August 2007.

Audubon. undated. Northwestern Crow. *Guide to North American Birds*. Available at http://www.audubon.org/field-guide/bird/northwestern-crow

Baran, A., and M. Tamawski. 2015. "Assessment of heavy metals mobility and toxicity in contaminated sediments by sequential extraction and a battery of bioassays." *Ecotoxicology*. 24(6): 1279–1293. Available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4515251/

Barash, D.P., P. Donovan, and R. Myrick. 1975. "Clam Dropping Behavior of the Glaucous-Winged Gull (Larus glaucescens)." *Wilson Bull* 87(1):60–64.

Beyer, W.N., E.E. Connor, and S. Gerould. 1994. "Estimates of Soil Ingestion by Wildlife." *J Wildl Manage* 58:375–382.

British Columbia Environment Protection Department. 1996. Ambient Water Quality Criteria for Silver, Section 2(e) of the Environment Management Act, 1981, February 19, http://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/approved-wqgs/silver-or.pdf

Borak, J., and H.D. Hosgood. 2007. "Seafood Arsenic: Implications for Human Risk Assessment." *Regul Toxicol and Pharm* 47(2): 204–212.

Carlson, A.R., G.L. Phipps, V.R. Mattson, P.A. Kosian, and A.M. Cotter. 1991. "The Role of Acid-Volatile Sulfide in Determining Cadmium Bioavailability and Toxicity in Freshwater Sediments." *Environ Toxicol Chem* 10:1309–1319.

Casas, A.M., and E.A. Crecelius. 1994. "Relationship between Acid Volatile Sulfide and the Toxicity of Zinc, Lead and Copper in Marine Sediments." *Environ Toxicol Chem* 13:529–536.

Compeau, G.C., and R. Bartha. 1985. "Sulfate-reducing bacteria-principal methylators of mercury in anoxic estuarine sediment." *Applied and Environmental Microbiology* 50:498-502.

Di Toro, D.M., J.D. Mahony, D.J. Hansen, K.J. Scott, A.R. Carlson, and G.T. Ankley. 1992. "Acid Volatile Sulfide Predicts the Acute Toxicity of Cadmium and Nickel in Sediments." *Environ Sci Technol* 26:96–101.

Di Toro, D.M., J.D. Mahony, D.J. Hansen, K.J. Scott, M.B. Hicks, S.M. Mayr, and M.S. Redmond. 1990. "Toxicity of Cadmium in Sediments: The Role of Acid Volatile Sulfide." *Environ Toxicol Chem* 9:1487–1502.

Ecology (Washington State Department of Ecology). 2015. *Sediment Cleanup User's Manual II, Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC*. Publication No. 12-09-057. Toxics Cleanup Program, Olympia, Washington. March 2015.

_____. 2013a. *Final Fish Consumption Rates Technical Support Document: A Review of Data and Information about Fish Consumption in Washington*. Version 2.0. Publication No. 12-09-058. January 2013.

———. 2013b. Sediment Management Standards. Washington Administrative Code, Chapter 173-204. Final Rule. February 22, 2013.

———. 2007. *Model Toxics Control Act Cleanup Regulation, Chapter 173-340-900 WAC.* Publication 94-06. Toxics Cleanup Program, Olympia, Washington. November 2007.

———. 2002. *Inorganic Arsenic Levels in Puget Sound Fish and Shellfish from 303(d) Listed Waterbodies and Other Areas*. Publication No. 02-03-057. Olympia, Washington. December 2002.

Fleming E.J., E.E. Mack, P.G.Green, and D.C. Nelson. 2006. "Mercury methylation from unexpected sources: Molybdate-inhibited freshwater sediments and an iron-reducing bacterium." *Applied and Environmental Microbiology*. 72:457–464. doi: 10.1128/AEM.72.1.457-464.2006.

Fimmen, R.L., R. Darlington, P.L. Lehocky, V. Lai, B. Sass, S. Chattopadhyay, and P. Randall." 2009. Bacterial Mercury Methylation at the Sediment-Water Interface of Mercury Contaminated Sediments." Presented at Battelle 10th International In Situ and On-Site Bioremediation Conference, Baltimore, MD, May 05 - 08.

Government of Canada. 2013. "Clam Biology." Fisheries and Oceans Canada. May 14. Available at http://www.pac.dfo-mpo.gc.ca/fm-gp/commercial/shellfish-mollusques/clam-palourde/bio-eng.html.

Grubb, T.G. 1982. "Evidence of Bald Eagles Feeding on Freshwater Mussels." *Wilson Bull* 94(1):85–87.

ITRC (Interstate Technology and Regulatory Council). 2011. "Incorporating Bioavailability Considerations into the Evaluation of Contaminated Sediment Sites." Chapter 4,

Bioavailability to Benthic Invertebrates. ITRC Contaminated Sediment Team. February 2011. Available at http://www.itrcweb.org/contseds-bioavailability/consed_4.htm.

Kendall, D.R., and R. McMillan. 1999. *Clarification on the Use of the Amphipod, Eohaustorius estuarius, Relative to Grain Size and Salinity*. DMMP Clarification Paper, SMS Draft Technical Information Memorandum. October 20. (Presented in Appendix B of the SCUM II document).

Kraeuter, J.N., and M. Castagna, eds. 2001. "Biology of the Hard Clam." *Developments in Aquaculture and Fisheries Science* 31:561. Gulf Professional Publishing. Elsevier Science B.V., Amsterdam, The Netherlands.

Kunito, T., R. Kubota, J. Fujihara, T. Agusa, and S. Tananbe. 2008. "Arsenic in Marine Mammals, Seabirds, and Sea Turtles." *Reviews of Environmental Contamination and Toxicology.* pp. 31-69. Springer.

Lee, B.G., J.S. Lee, S.N. Luoma, H.J. Choi, and C.H. Koh. 2000. "Influence of Acid Volatile Sulfide and Metal Concentrations on Metal Bioavailability to Marine Invertebrates in Contaminated Sediments." *Environ Sci Technol* 34(21): 4517–4523. Available at https://pubs.er.usgs.gov/publication/70022387.

Long, E.R., and D.D. MacDonald. 1998. "Recommended uses of empirically derived sediment quality guidelines for marine and estuarine ecosystems." *Human and Ecol. Risk Assessment* 4(5): 1019-1039.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. "Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments." *Environ Manage* 19(1): 81–97.

LWG (Lower Willamette Group). 2011. *Portland Harbor Remedial Investigation Report. Appendix G, Baseline Ecological Risk Assessment*. Prepared by Windward Environmental LLC. July 1, 2011.

MacDonald, D.D. 1994. *Approach to the Assessment of Sediment Quality of Florida Coastal Waters*. Vol. 1, Development and Evaluation of Sediment Quality Assessment Guidelines. Prepared for the Florida Department of Environmental Protection, Tallahassee, Florida. November 1994.

Maron, J.L. 1982. "Shell-Dropping Behavior of Western Gulls (*Larus occidentalis*)." *Auk* 99:565–569.

Massachusetts Department of Environmental Protection(MADEP). 1996. Mercury in Massachusetts: An Evaluation of Sources, Emissions, Impacts and Controls, Chapter 2, June. http://infohouse.p2ric.org/ref/11/10102/mercury/hgch2.htm.

Ministry of the Environment. 1996. Ambient Water Quality Criteria for Silver, Overview Report, Table 1: Recommended Criteria for the Protection of Marine and Freshwater Life, February 19. Available at http://www.env.gov.bc.ca/wat/wq/BCguidelines/silver/silver.html#tables.

Nagy, K.A. 2001. "Food Requirements of Wild Animals: Predictive Equations for Free-Living Mammals, Reptiles, and Birds." *Nutrition Abstracts and Reviews*, Series B 71, 21R–31R.

ODEQ (Oregon Department of Environmental Quality). 2008. *Human Health Focus Group Oregon Fish and Shellfish Consumption Rate Project*. DEQ Water Quality Division - Standards and Assessments. June 2008. Available at http://www.deq.idaho.gov/media/895937-oregon-hhfg-report.pdf)

———. 2007. *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment*. April 3, 2007.

Outridge, P.M., and A.M. Scheuhammer. 1993. "Bioaccumulation and Toxicology of Chromium: Implications for Wildlife." *Reviews of Environmental Contamination and Toxicology* (130):31–77.

Paller, M.H., and A.S. Knox. 2013. *Bioavailability of metals in contaminated sediments. Proceedings of the 16th International Conference on Heavy Metals in the Environment*, Volume 1, Article 02001. April 23. Available at http://www.e3s-conferences.org/articles/e3sconf/abs/2013/01/e3sconf_ichm13_02001/ e3sconf_ichm13_02001.html

Paranjape, A.R., and B.D. Hall. 2017. "Recent Advances in the Study of Mercury Methylation in Aquatic Systems." *FACETS* 2: 85–119. doi:10.1139/facets-2016-0027.

Pesch, C.E., D.J. Hansen, W.S. Boothman, W.J. Berry, and J.D. Mahony. 1995. "The Role of Acid-Volatile Sulfide and Interstitial Water Metal Concentrations in Determining

Bioavailability of Cadmium and Nickel from Contaminated Sediments to the Marine Polychaete *Neanthes arenaceodentata*." *Environ Toxicol Chem* 14:129–141.

Power, E.A., and P.M. Chapman. 1992. "Assessing Sediment Quality." Chapter 1 in *Sediment Toxicity Assessment*, G.A. Burton, Jr. Ed., Lewis Publishers.

Ratte, H.T. 1999. "Bioaccumulation and Toxicity of Silver Compounds: A Review." *Environ Toxicol Chem* 18:89–108. Available at http://onlinelibrary.wiley.com/doi/10.1002/etc.5620180112/full.

Retfalvi, I. 1970. "Food of Nesting Bald Eagles on San Juan Island Washington." *Condor* 72:358–361.

Southern California Coastal Water Research Project. 2013. Development of Puget Sound Benthic Indicators, Report to the Washington State Department of Ecology, Southern California Coastal Water Research Project Technical Report 755, Washington State Department of Ecology Publication No. 13—3-035, August.

Suquamish Tribe. 2000. *Fish Consumption Survey of the Suquamish Indian Tribe of the Port Madison Indian Reservation, Puget Sound Region.* August 2000.

Tesky, Julie L. 1993. *Lutra canadensis.* Fire Effects Information System (FEIS). U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available at http://www.feis-crs.org/feis.

Toy, K.A., N.L. Polissar, S. Liaw, and G.D. Mittelstaedt. 1996. A Fish Consumption Survey of the Tulalip and Squaxin Island Tribes of Puget Sound Region. Tulalip Tribes, Department of the Environment, 7615 Totem Beach Road, Marysville, Washington 98271.

Tsui, M.T.K., and J.C. Finlay. 2011. "Influence of dissolved organic carbon on methylmercury bioavailability across Minnesota stream ecosystems." *Environmental Science & Technology* 45 (14): 5981-5987.

USACE (U.S. Army Corp of Engineers). 2009. *OSV* BOLD *Summer 2008 Survey Data Report.* The Dredged Material Management Program. June 2009.

USEPA (U.S. Environmental Protection Agency). 2016a. *Regional Screening Levels Table and User's Guide*. May 2016. Available at https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016

———. 2016b. ProUCL, Version 5.1.002. June 20, 2016. Available at https://www.epa.gov/land-research/proucl-software.

_____. 2016c. *Keyport Area Exposure Report Approach for Determination of Residence Duration for a County in Washington*. Prepared by Battelle for United States Environmental Protection Agency Site Characterization and Monitoring Technical Support Center under Contract Number: EP-C-11-038 Task Order No. 32 / Technical Directive No. 4-11. September 28, 2016.

———. 2015. *ProUCL Version 5.1 User Guide.* Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. EPA/600/R-07/041. October 2015. Available at https://www.epa.gov/sites/production/files/2016-05/documents/proucl_5.1_user-guide.pdf.

———. 2014. *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors.* OSWER Directive 9200.1-120. Office of Solid Waste and Emergency Response. February 2014.

———. 2012. *Benchmark Dose Technical Guidance*. Risk Assessment Forum, Washington, DC 20460 Available at https://www.epa.gov/sites/production/files/2015-01/documents/benchmark_ dose_guidance.pdf

____. 2010. *IRIS Toxicological Review of Inorganic Arsenic (Cancer)* (2010 External Review Draft). U.S. Environmental Protection Agency, Washington, DC, EPA/635/R-10/001, 2010.

———. 2009. *Biological Technical Assistance Group (BTAG)-Recommended Toxicity Reference Values for Birds and Mammals.* Bird revision date February 24, 2009. Available at http://www.dtsc.ca.gov/AssessingRisk/ upload/Eco_Btag-mammal-bird-TRV-table.pdf.

———. 2005-2008. *2005–2008 Ecological Soil Screening Levels*. Interim Final. Office of Solid Waste and Emergency Response. Updated April 2008. Available at http://www.epa.gov/ecotox/ecossl/.

———. 2007a. *Final Risk Assessment Guidance for Superfund.* Vol. I*, Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)*. EPA/540/R/99/005. OSWER 9285.7-02EP. PB99-963312. July 2004; revised October 3, 2007.

———. 2007b. *Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia.* Region 10, Office of Environmental Cleanup, Office of Air, Waste, and Toxics, Office of Environmental Assessment, Seattle, Washington. August 2007.

———. 2007c. *User's Guide for the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) Windows*. United States Environmental Protection Agency, Office of Superfund Remediation and Technology Innovation. EPA 9285.7-42, 540-K-01-005. May 2007.

———. 2005a. *Guidelines for Carcinogen Risk Assessment.* EPA/630/P-03/001F. March 2005.

———. 2005b. *Guidance for Developing Ecological Soil Screening Levels*. OSWER Directive 9285.7-55. Office of Solid Waste and Emergency Response. November 2003; revised February 2005.

———. 2004. *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual* (Part E, Supplemental Guidance for Dermal Risk Assessment). Final. July 2004.

_____. 2003. *Human Health Toxicity Values in Superfund Risk Assessments*. OSWER Directive 9285.7-53. Office of Solid Waste and Emergency Response. December 2003;

———. 2002a. *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response Washington, D.C.OSWER Directive 9285.6-10.*

———. 2002b. *Biological Technical Assistance Group (BTAG)-Recommended Toxicity Reference Values for Birds and Mammals.* Mammal revision date November 21, 2002. Available at http://www.dtsc.ca.gov/AssessingRisk/ upload/Eco_Btag-mammal-bird-TRV-table.pdf.

———. 2002c. *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*. EPA-540-R-01-003. OSWER Directive 9285.7-41. September.

———. 2001. *Methods for Collection, Storage and Manipulation of Sediments for Chemical and Toxicological Analyses: Technical Manual.* Appendix G. EPA-823-B-01-002. Office of Water, October 2001.

———. 2000. *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories.* Vol. 1*, Fish Sampling and Analysis.* 3rd ed. Office of Water. November 2000.

———. 1998a. *Guidelines for Ecological Risk Assessment.* EPA/630/R-95/002F. Risk Assessment Forum, Washington D.C. April 1998.

———. 1998b. *Memorandum: OSWER Directive: Clarification to the 1994 Revised Interim Soil Lead (Pb) Guidance for CERCLA Sites and RCRA Corrective Action Facilities*. EPA/540/F-98/030, PB98-963244 OSWER Directive #9200.4-27P. August 1998.

———. 1997. *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments, Interim Final.* EPA 540-R-97-006. June 1997.

———. 1993. *Wildlife Exposure Factors Handbook.* December 1993.

———. 1992a. *Final Guidance for Data Usability in Risk Assessment.* Office of Solid Waste and Emergency Response, Washington, D.C.

———. 1992b. *Supplemental Guidance to RAGS: Calculating the Concentration Term.* Publication 9285.7-081. Office of Solid Waste and Emergency Response, Washington, D.C. May 1992.

———. 1991a. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors*. Interim Final. OSWER Directive 9285.6-03.

———. 1991b. *Risk Assessment Guidance for Superfund.* Vol. 1*, Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Goals).* Interim Final. Publication 9285.7-01B. Office of Emergency and Remedial Response, Washington, D.C. December 1991.

———. 1991c. *Handbook for Remediation of Contaminated Sediments*. EPA/625/6-91/028. Office of Research and Development, Washington, D.C.

———. 1989. *Risk Assessment Guidance for Superfund.* Vol. 1*, Human Health Evaluation Manual*. Part A. Interim Final. EPA 540/1-89/002. Office of Emergency and Remedial Response, Washington, D.C.

United States Fish and Wildlife Service. 1987. *Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest), Common Littleneck Clam.* Biological Report 82 (11.78), TR EL-82-4, U.S. Army Corp of Engineers, Coastal Ecology Group, Waterways Experiment Station, August.

U.S. Geological Survey. 2006. *Cadmium Risks to Freshwater Life: Derivation and Validation of Low-Effect Criteria Values Using Laboratory and Field Studies.* Scientific Investigations Report 2006-5245, Version 1.1. U.S. Department of the Interior. December 2006.

U.S. Navy. 2018. *Draft Spring 2017 Long-Term Monitoring Report Former Plating Shop/Waste Oil Spill Area, Area 8, Operable Unit 2.* Prepared by Sealaska Environmental Services, LLC, for NAVFAC NW under Contract No. N44255-14-D-9011, Task Order 0046. February 9, 2018.

———. 2016a. *OU 2 Area 8 Human Health/Ecological Risk Assessment Workplan*, *Naval Base Kitsap Keyport; Keyport, Washington*. Final, December 24, 2016.

———. 2016b. Modification Request – Rev 02 Navy CLEAN 8013 Program Contract N62470-11-D-8013, Contract Task Order (CTO) JP08, 2015 Keyport OU2M NB Kitsap at Bangor WA. Letter and attachment sent to Kimberly Gillette at Naval Facilities Engineering Command Northwest from Lisa Litwin, Contract Manager, Resolution Consultants. May 13, 2016.

———. 2016c. *Final Area 8 Marine Investigation Report, Naval Base Kitsap Keyport; Keyport, Washington.* Prepared by Resolution Consultants, A Joint Venture of AECOM & EnSafe Comprehensive Long-Term Environmental Action Navy Contract Number N62470-11-D-8013 CTO JP08. December 23, 2016.

———. 2015a. *Fourth Five-Year Review, Naval Base Kitsap Keyport; Keyport Washington*. Prepared by URS, for NAVFAC Northwest under Contract N44255-09-D-4001, Delivery Order 0081. Silverdale, Washington. December 2015.

———. 2015b. *Spring 2014 Long-Term Monitoring Report Former Plating Shop/Waste Oil Spill Area, Area 8, Operable Unit 2.* Prepared by Sealaska Environmental Services, LLC, for NAVFAC NW under Contract No. N44255-09-D-4005, Delivery Order 0084. March 2015.

———. 2015c. *Final Project-Specific Quality Assurance Project Plan Area 8 Marine Tissue/Sediment Evaluation, Naval Base Kitsap Keyport; Keyport, Washington*. Prepared by URS Group, Inc., a subsidiary of AECOM, Seattle, Washington. May 28, 2015.

———. 2014. *Intertidal Shellfish Survey Report, Former Plating Shop/Waste Oil Spill Area, Operable Unit 2, Area 8, Naval Base Kitsap Keyport; Keyport, Washington*. November 2014.

———. 2013. *Area 8 Marine Sediment Data Report*, *Naval Base Kitsap Keyport; Keyport, Washington.* Prepared by URS Group, Inc., for Naval Facilities Engineering Command (NAVFAC) Northwest under Contract N44255-09-4001, Delivery Order 0054. June 2013.

———. 2010. *Third Five-Year Review, Naval Base Kitsap Keyport; Keyport Washington.* Prepared by URS Group, Inc., for NAVFAC Northwest under Contract N44255-05-5100, Delivery Order 0064. Silverdale, Washington. December 2010.

———. 2009a. *Ecological Risk Evaluation of Intertidal Zone, Former Plating Shop/Waste Oil Spill Area, Area 8, Operable Unit 2, Naval Base Kitsap Keyport; Keyport, Washington*. Prepared by URS Group, Inc., for NAVFAC Northwest under Contract No. N44255-05-D-5100, Delivery Order 0029. Silverdale, Washington. May 2009.

———. 2009b. *Final 2008 Sediment and Tissue Long-Term Monitoring, Former Plating Shop/Waste Oil Spill Area, Area 8, Operable Unit 2, Naval Base Kitsap Keyport; Keyport, Washington*. Prepared by URS Group, Inc., for NAVFAC Northwest under Contract No. N44255-05-D-5100, Delivery Order 0029. Silverdale, Washington. May 29 2009.

———. 2007. *Sustainable Shellfish Harvest Report, Naval Base Kitsap Keyport; Keyport, Washington.* NAVFAC Northwest, October 10.

———. 2005. *Second Five-Year Review of Records of Decision, Operable Unit 1 and Operable Unit 2, Naval Undersea Warfare Center, Keyport, Washington*. Prepared by URS Group, Inc., for NAVFAC Northwest under Contract No. N44255-02-D-2008, Delivery Order 0043. May 12, 2005.

———. 2001. *Data Report: Former Plating Shop/Waste Oil Spill Area, Area 8, Operable Unit 2, Naval Undersea Warfare Center Division, Keyport, Washington.* Prepared by CH2M HILL Constructors, Inc. (TEC LTM Team) for Engineering Field Activity Northwest. June 2001.

———. 2000. *First Five-Year Review of Records of Decision, Operable Unit 1 and Operable Unit 2, Naval Undersea Warfare Center, Keyport, Washington*. Prepared by CH2M HILL Constructors, Inc. TEC LTM Team. Contract Task Order 002. June 2000.

———. 1996. *Results of Post-ROD Confirmatory Sampling at Area 9, Liberty Bay, Operable Unit 2, Naval Undersea Warfare Center Division, Keyport, Washington.* Prepared by EA Engineering, Science, and Technology for Engineering Field Activity Northwest.

———. 1994. *Final Record of Decision for Operable Unit 2, Naval Undersea Warfare Center, Keyport, Washington*. Prepared by Shannon and Wilson, Inc., for NAVFAC Northwest under Contract No. N62474-89-D-9295, Delivery Order No. 0010. September 1994.

———. 1993a. *Remedial Investigation Report, NUWC Keyport*. Prepared by URS Consultants, Inc., and Science Applications International Corporation for Engineering Field Activity, Northwest, under CLEAN Contract No. N62474-89-D-9295, CTO 10. October 1993.

———. 1993b. *Feasibility Study Report for NUWC Keyport*. Prepared by URS Consultants, Inc., and Science Applications International Corporation for the Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract, Task Order No. 010. November 1993.

———. 1993c. *Human Health Risk Assessment Report, NUWC Keyport*. Prepared by URS Consultants, Inc., and Science Applications International Corporation (SAIC) for Engineering Field Activity Northwest. October 1993.

———. 1993d. *Ecological Risk Assessment Report, NUWC Keyport*. Prepared by URS Consultants, Inc., and Science Applications International Corporation (SAIC) for Engineering Field Activity Northwest. October 1993.

———. 1984. *Initial Assessment Study of Naval Undersea Warfare Engineering Station, Keyport, Washington*. Prepared by SCS Engineers under NEESA 13-054.

U.S. Navy, USEPA (U.S. Environmental Protection Agency), and Ecology (Washington State Department of Ecology). 1994. *Record of Decision for Operable Unit 2, Naval Undersea*

Warfare Center Division, Keyport, Washington. Prepared by URS Consultants and Science Applications International Corporation for Engineering Field Activity Northwest under CLEAN Contract No. N62474-89-D-9295, CTO 10. September 28, 1994.

WDNR (Wisconsin Department of Natural Resources). 2003. Consensus-Based Sediment Quality Guidelines, Recommendations for Use & Application, Interim Guidance, WT-732, December.

WDOH (Washington State Department of Health). 2016. Shellfish Safety Information. Available at https://fortress.wa.gov/doh/eh/maps/biotoxin/biotoxin.html?Bidn=270230. Accessed May 23, 2016

Windward (Windward Environmental LLC). 2012. *East Waterway Operable Unit Remedial Investigation/Feasibility Study*. Appendix A, Final Baseline Ecological Risk Assessment. August 2012.

———. 2007. *Lower Duwamish Waterway Remedial Investigation, Phase 2 Remedial Investigation Report*. Appendix A, Final Baseline Ecological Risk Assessment. July 31, 2007.

_____. 2003. *Phase 1 Remedial Investigation Report.* Appendix A, "Lower Duwamish Waterway Group." Prepared for EPA Region 10 and Washington State Department of Ecology, Northwest Regional Office. Seattle, Washington. July 2003.

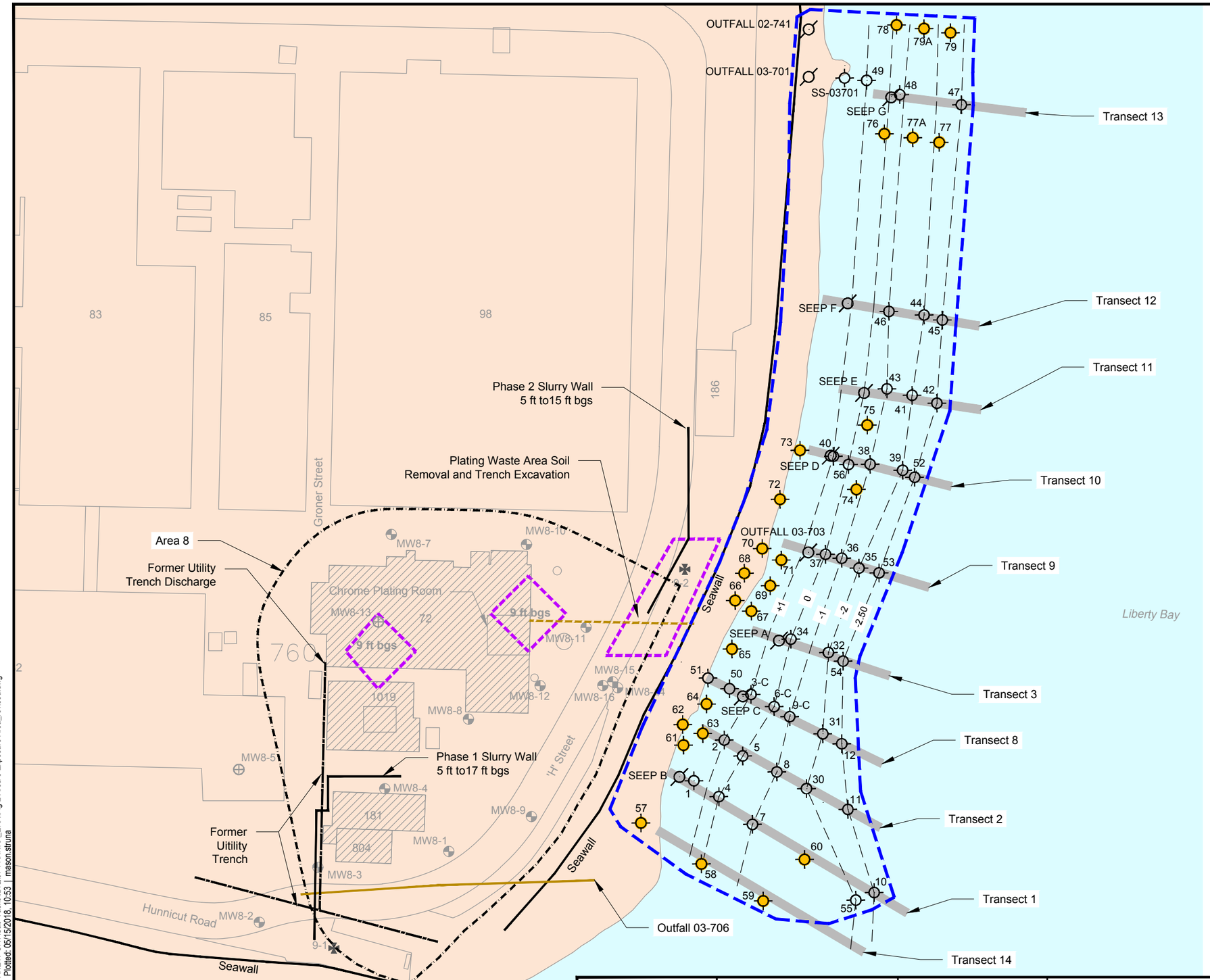
Zeiner, D.C., W.F. Laudenslayer, Jr., K.E. Mayer, and M. White. 1990. *California's Wildlife.* Vol. II, *Mammals.* CWHR System. California Department of Fish and Game. Sacramento, California.

This page was intentionally left blank.

FIGURES

J:\Seattle Support\NAVY_KeyPort\LAURA NEW PROJECT\FIG 1 Site Vicinity.dwg
Mod: 02/09/2017, 12:18 | Plotted: 02/09/2017, 12:21 | jim.gibson

U.S. NAVY	0 400 800 SCALE IN FEET	**Figure 1** **Site Vicinity**	JP11 NBK Keyport OU 2 AREA 8 HHRA/ERA



Legend

- Monitoring Well
- Abandoned Monitoring Well
- June 2015 Seep/Outfall Sampling Location
- June 2015 Sampling Location
- June 2016 Sampling Location
- Former Building
- USGS Monument
- Metals - Contaminated Soil Removal Boundaries (U.S. Navy 1999)
- Exposure Area (Area 8 Beach)
- Approximate Area 8 Boundary From OU 2 ROD
- Closed Top Drainage Trench

Notes:

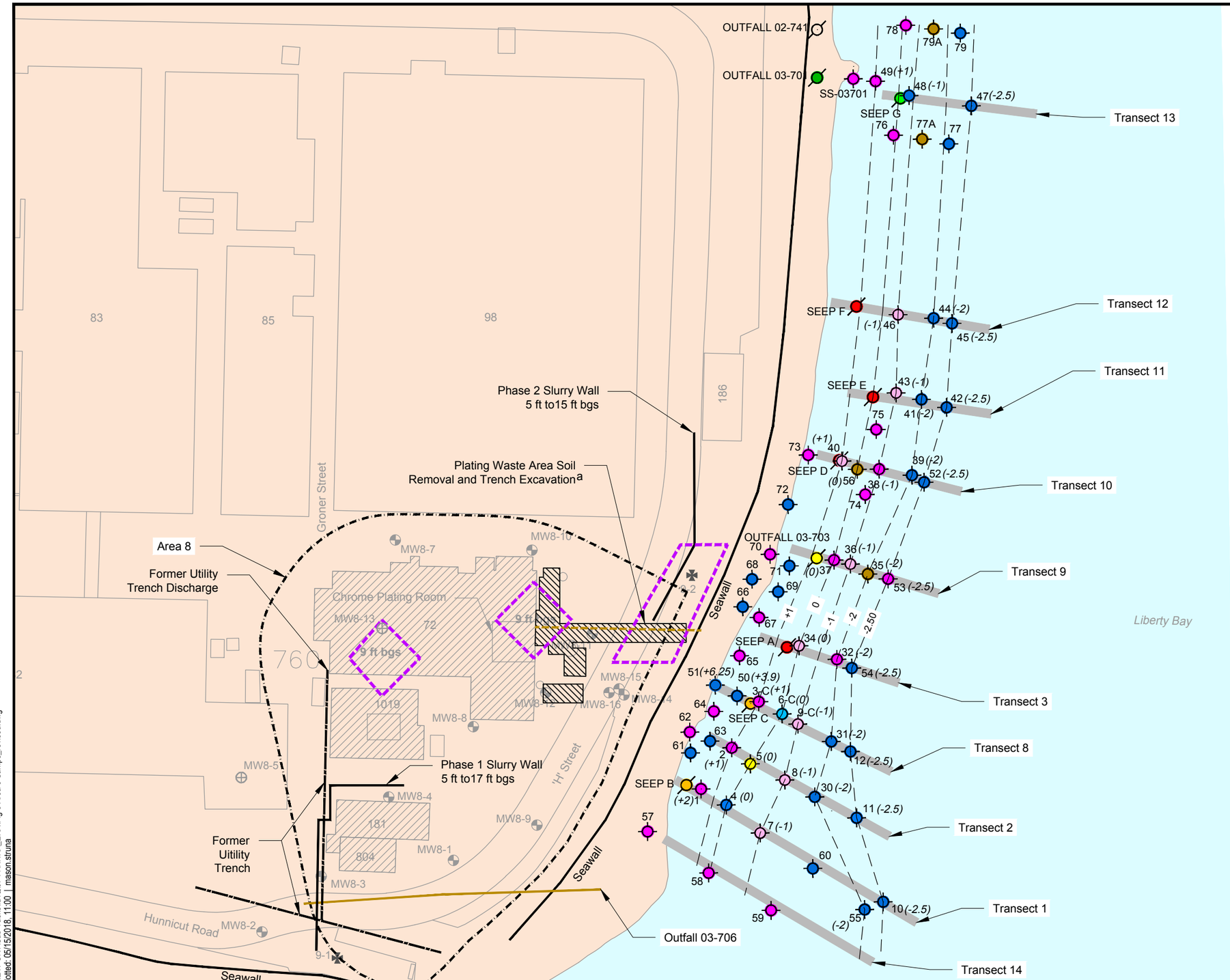
1. Existing station positions are based on horizontal and vertical measurements collected during the June 2015 and June 2016 sampling events. Beach transects were established beginning at the origins of Seeps A through G, which vary in width up to approximately 10-15 feet. Subsequent downgradient stations were sampled at 1 foot tidal intervals along the transects perpendicular to the shoreline. Variation in downgradient station position relative to transects reflect beach terrain which determines the seep pathways, and accuracy limits of field measurements.

2. Surface sediment depth is approximately 0 - 10 cm and subsurface sediment depth is approximately 10 - 24 cm.

3. During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. The nomenclature for tissue and sediment sampling stations 3, 6, and 9 was modified to sampling stations 3-C, 6-C, and 9-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sampling station 3-C is co-located with Seep C.

U.S. NAVY	JP11 NBK Keyport OU 2 AREA 8 HHRA/ERA	0 30 60 SCALE IN FEET	**Figure 2** **Area 8 Beach Site Map and Exposure Area**

J:\DCS\Projects\GIS\NAVYKEYPORT\Sub-Tasks\IDIQ\JP11\HHRA_ERA\Fig 2 Area 8 Exposure Area_revised.dwg
Mod: 05/15/2018, 10:51 | Plotted: 05/15/2018, 10:53 | mason.struna



Legend

- Monitoring Well
- Abandoned Monitoring Well
- Seep/Outfall Sampling Location
- Sampling Location
- Former Building
- USGS Monument
- Metals - Contaminated Soil Removal Boundaries (U.S. Navy 1999)
- *(0)* Approximate tidal height (Ft MLLW) based on station elevations measured during the 2015 sampling event
- Approximate Area 8 Boundary From OU 2 ROD
- Former Closed Top Drainage Trench

Media Sampled:

- Surface Sediment, Clam Tissue, Seep Water, and Marine Water
- Seep Water and Marine Water
- Surface Sediment, Clam Tissue, and Marine Water
- Sediment (Surface and Subsurface), Clam Tissue, Seep Water, and Marine Water
- Outfall Water
- Surface Sediment
- Sediment (Surface and Subsurface)
- Sediment (Surface and Subsurface) and Clam Tissue
- Surface Sediment and Clam Tissue
- Clam Tissue

Notes:

1. Figure 10-1 of the OU 2 ROD (U.S. Navy, USEPA and Ecology 1994)

2. Existing station positions are based on horizontal and vertical measurements collected during the June 2015 and June 2016 sampling events. Beach transects were established beginning at the origins of Seeps A through G, which vary in width up to approximately 10 - 15 feet. Subsequent downgradient stations were sampled at 1-foot tidal intervals along the transects perpendicular to the shoreline. Variation in downgradient station position relative to transects reflects beach terrain, which determines the seep pathways, and accuracy limits of field measurements.

3. Surface sediment depth is approximately 0 - 10 cm and subsurface sediment depth is approximately 10 - 24 cm.

4. During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. The nomenclature for tissue and sediment sampling stations 3, 6, and 9 was modified to sampling stations 3-C, 6-C, and 9-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sampling station 3-C is co-located with Seep C.

U.S. NAVY

JP11
NBK Keyport
OU 2 Area 8
HHRA/ERA

0 30 60
SCALE IN FEET

Figure 3
Area 8 Beach Sampling Locations

J:\DCS\Projects\GIS\NAVYKEYPORT\Sub-Tasks\IDIQ\JP11\HHRA_ERA\Fig 3 Area 8 Samps_revised.dwg
Mod: 05/15/2018, 10:59 | Plotted: 05/15/2018, 11:00 | mason.struna

OUTFALL 02-741
78
79A
49(+1)
SS-03701
SEEP G
76
77A
Transect 13
SEEP F
(-1) 46
Transect 12
SEEP E
43 (-1)
75
Transect 11
73
(+1)
40
SEEP D
(0) 56
38 (-1)
74
Transect 10
OUTFALL 03-703
70
36 (-1)
(0) 37
35 (-2)
53 (-2.5)
Transect 9
67
+1
0
-1
-2
-2.50
SEEP A
65
(0) 34
32 (-2)
Transect 3
3-C (+1)
64
62
9-C (-1)
Transect 8
2
(+1)
5 (0)
8 (-1)
1
(+2)
Transect 2
57
7 (-1)
58
59
Transect 1
Transect 14
Liberty Bay
Seawall
Outfall 03-706
Seawall
Seawall
Phase 2 Slurry Wall
5 ft to15 ft bgs
Plating Waste Area Soil
Removal and Trench Excavation[a]
Area 8
Former Utility
Trench Discharge
Phase 1 Slurry Wall
5 ft to17 ft bgs
Former
Uitility
Trench
Groner Street
'H' Street
Hunnicut Road
Chrome Plating Room
9 ft bgs
9 ft bgs
83
85
98
186
760
72
1019
181
804
MW8-1
MW8-2
MW8-3
MW8-4
MW8-5
MW8-7
MW8-8
MW8-9
MW8-10
MW8-11
MW8-12
MW8-13
MW8-14
MW8-15
MW8-16
9-12

Legend

- Monitoring Well
- Abandoned Monitoring Well
- Seep/Outfall Sampling Location
- Sampling Location
- Former Building
- USGS Monument
- Metals - Contaminated Soil Removal Boundaries (U.S. Navy 1999)
- (0) Approximate tidal height (Ft MLLW) based on station elevations measured during the 2015 sampling event
- Approximate Area 8 Boundary From OU 2 ROD
- Former Closed Top Drainage Trench

Media Sampled:

- Clam Tissue

Notes:
1. Figure 10-1 of the OU 2 ROD (U.S. Navy, USEPA and Ecology 1994)

2. Existing station positions are based on horizontal and vertical measurements collected during the June 2015 and June 2016 sampling events. Beach transects were established beginning at the origins of Seeps A through G, which vary in width up to approximately 10 - 15 feet. Subsequent downgradient stations were sampled at 1-foot tidal intervals along the transects perpendicular to the shoreline. Variation in downgradient station position relative to transects reflects beach terrain, which determines the seep pathways, and accuracy limits of field measurements.

3. Surface sediment depth is approximately 0 - 10 cm and subsurface sediment depth is approximately 10 - 24 cm.

4. During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. The nomenclature for tissue and sediment sampling stations 3 and 9 was modified to sampling stations 3-C and 9-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sampling station 3-C is co-located with Seep C.

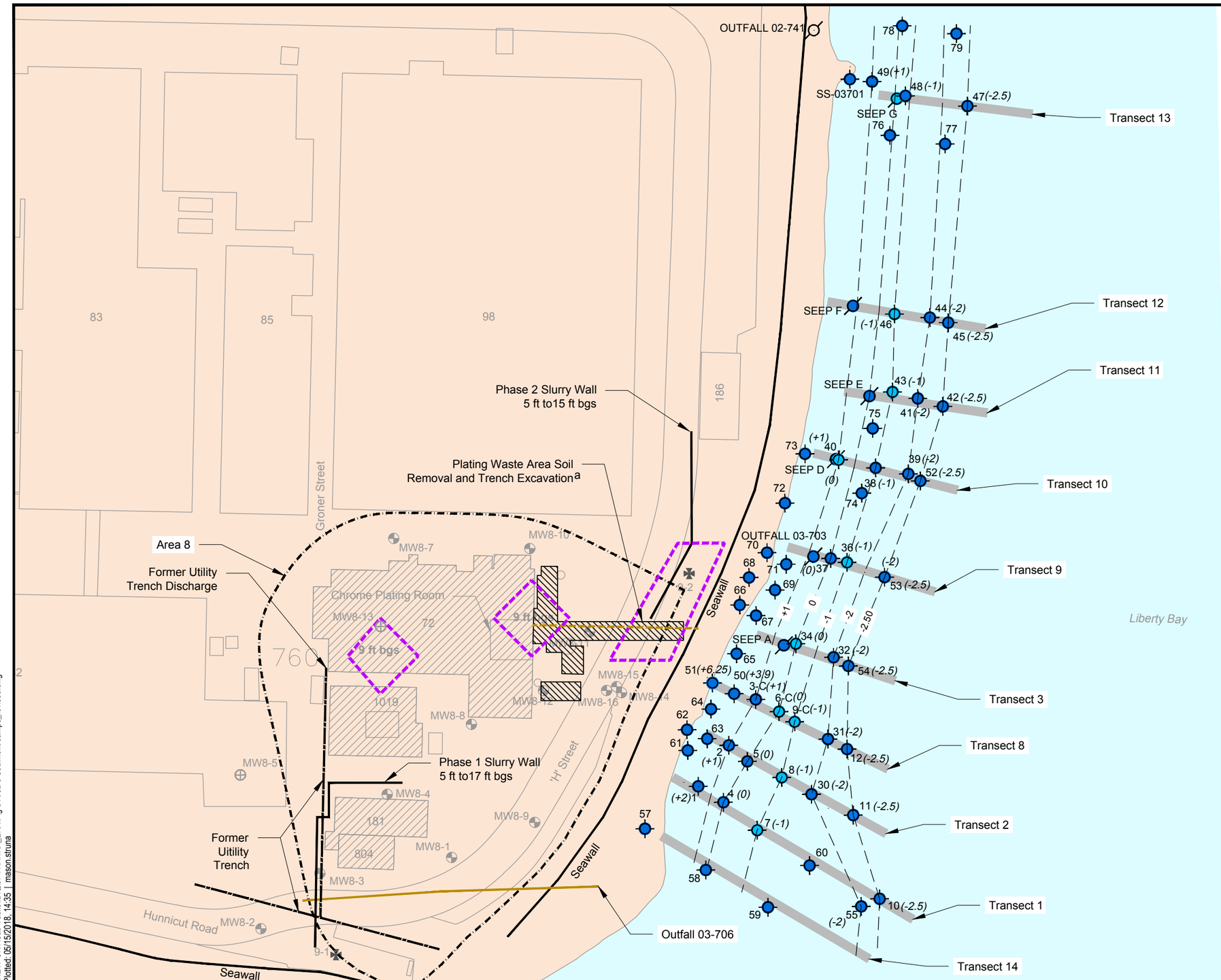
U.S. NAVY

JP11
NBK Keyport
OU 2 Area 8
HHRA/ERA

0 30 60
SCALE IN FEET

Figure 4
Area 8 Beach Clam Sampling Locations

J:\DCS\Projects\GIS\NAVY\KEYPORT\Sub-Tasks\IDIQ\JP11\HHRA_ERA\Fig 4 Area 8 Clam Sampling Locations_revised.dwg
Mod: 05/15/2018, 11:03 | Plotted: 05/15/2018, 11:03 | mason.struna



Notes:
1. Figure 10-1 of the OU 2 ROD (U.S. Navy, USEPA and Ecology 1994)

2. Existing station positions are based on horizontal and vertical measurements collected during the June 2015 and June 2016 sampling events. Beach transects were established beginning at the origins of Seeps A through G, which vary in width up to approximately 10 - 15 feet. Subsequent downgradient stations were sampled at 1-foot tidal intervals along the transects perpendicular to the shoreline. Variation in downgradient station position relative to transects reflects beach terrain, which determines the seep pathways, and accuracy limits of field measurements.

3. Surface sediment depth is approximately 0 - 10 cm and subsurface sediment depth is approximately 10 - 24 cm.

4. During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. The nomenclature for tissue and sediment sampling stations 3, 6, and 9 was modified to sampling stations 3-C, 6-C, and 9-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sampling station 3-C is co-located with Seep C.

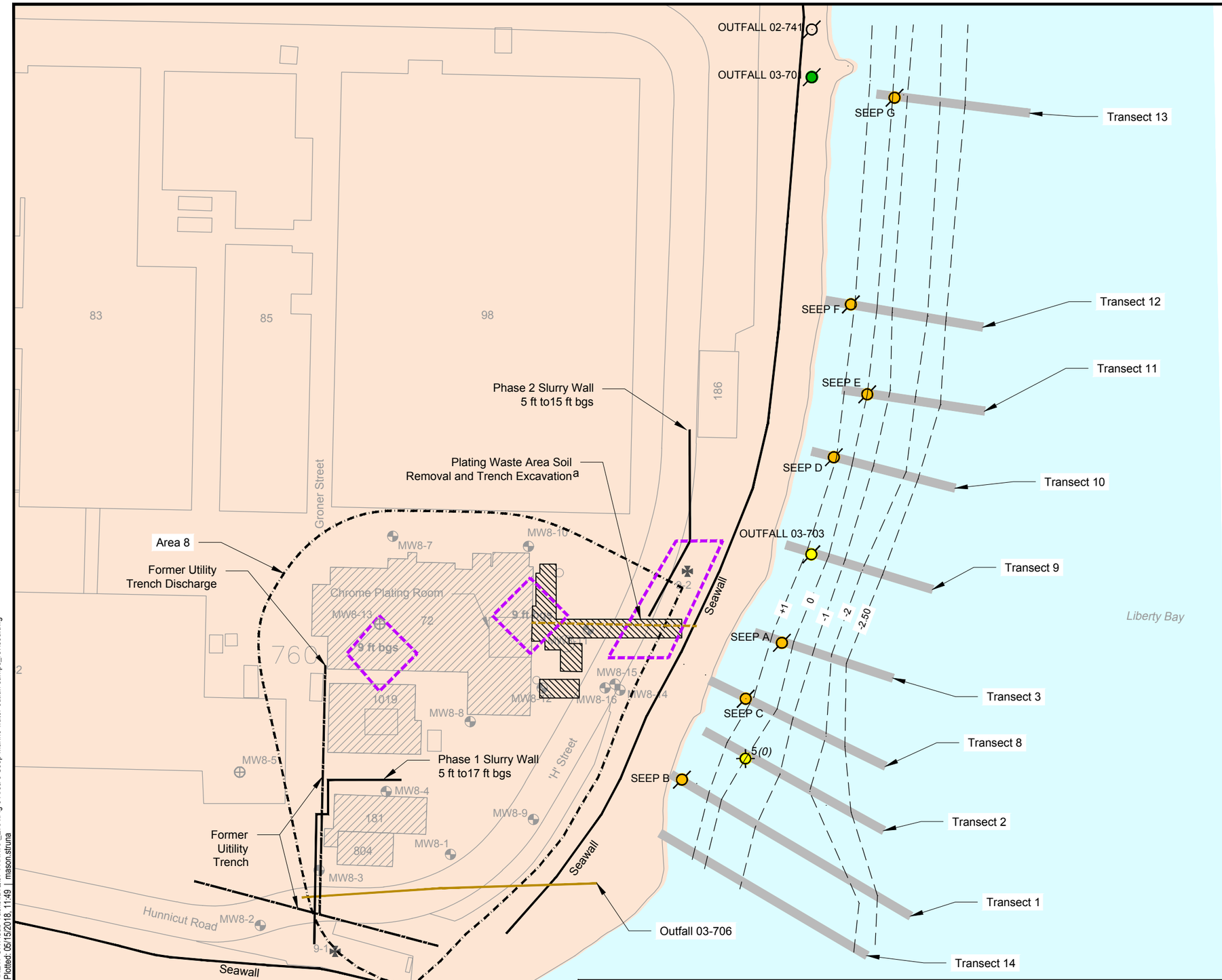
U.S. NAVY

JP11
NBK Keyport
OU 2 Area 8
HHRA/ERA

0 30 60
SCALE IN FEET

Figure 5
Area 8 Beach Sediment Sampling Locations

J:\DCS\Projects\GIS\NAVY\KEYPORT\Sub-Tasks\IDI\JP11\HHRA_ERA\Fig 5 Area 8 Sediment samps_revised.dwg
Mod: 05/15/2018, 14:15 | Plotted: 05/15/2018, 14:35 | mason.struna



Legend

- Monitoring Well
- Abandoned Monitoring Well
- Seep/Outfall Sampling Location
- Sampling Location
- Former Building
- USGS Monument
- Metals - Contaminated Soil Removal Boundaries (U.S. Navy 1999)
- *(0)* Approximate tidal height (Ft MLLW) based on station elevations measured during the 2015 sampling event
- Approximate Area 8 Boundary From OU 2 ROD
- Former Closed Top Drainage Trench

Media Sampled:

- Seep Water and Marine Water
- Marine Water
- Outfall Water

Notes:

1. Figure 10-1 of the OU 2 ROD (U.S. Navy, USEPA and Ecology 1994)

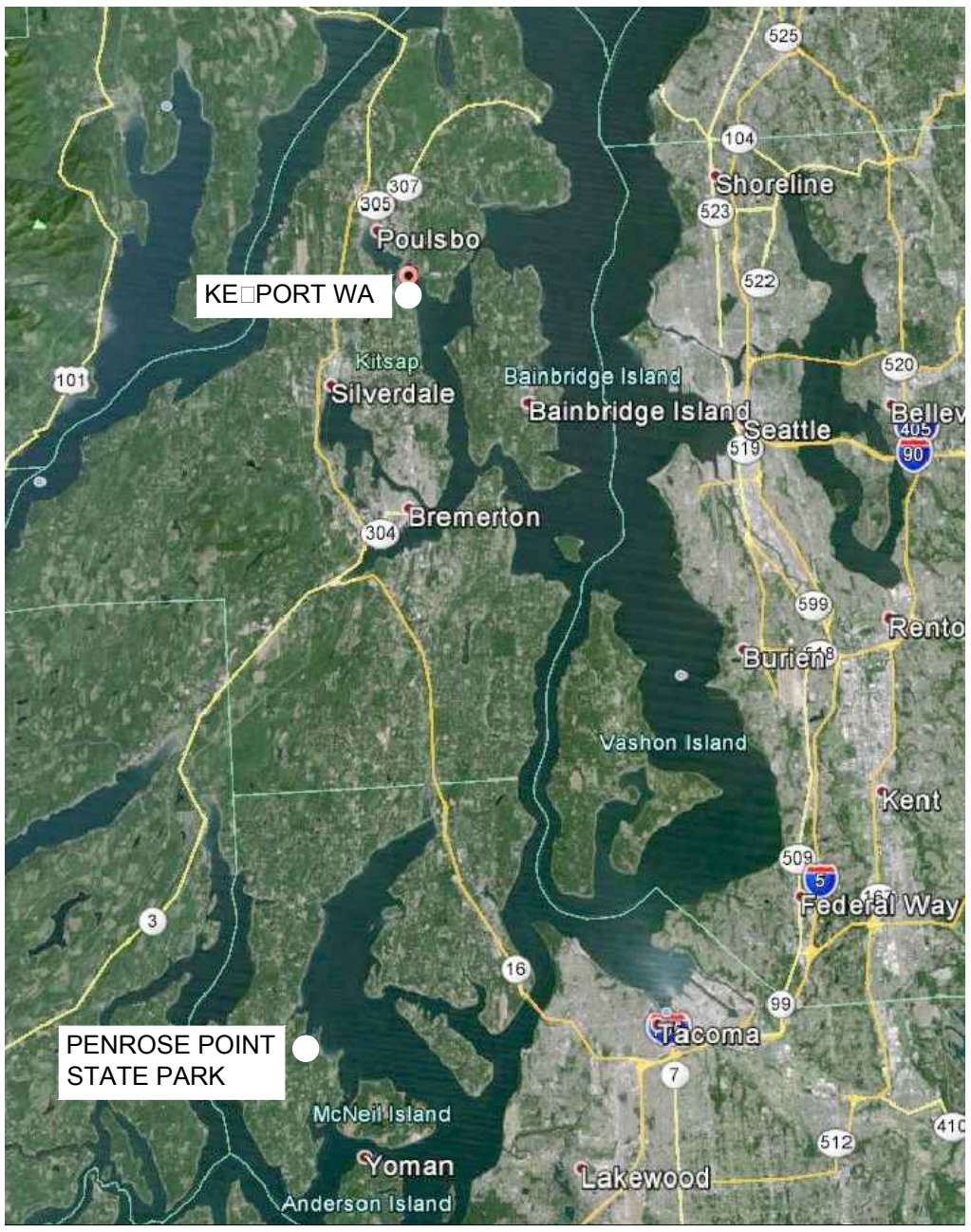
2. Existing station positions are based on horizontal and vertical measurements collected during the June 2015 and June 2016 sampling events. Beach transects were established beginning at the origins of Seeps A through G, which vary in width up to approximately 10 - 15 feet. Subsequent downgradient stations were sampled at 1-foot tidal intervals along the transects perpendicular to the shoreline. Variation in downgradient station position relative to transects reflects beach terrain, which determines the seep pathways, and accuracy limits of field measurements.

3. Surface sediment depth is approximately 0 - 10 cm and subsurface sediment depth is approximately 10 - 24 cm.

4. During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8.

U.S. NAVY	JP11 NBK Keyport OU 2 Area 8 HHRA/ERA	0 30 60 SCALE IN FEET	**Figure 6** **Area 8 Beach Seep, Marine Water, and Outfall Sampling Locations**

J:\DCS\Projects\GIS\NAVY\KEYPORT\Sub-Tasks\JD\QJP11\HHRA_ERA\Fig 6 Area 8 Seep Marine water outfall samps_revised.dwg
Mod: 05/14/2018, 13:03 | Plotted: 05/15/2018, 11:49 | mason.struna



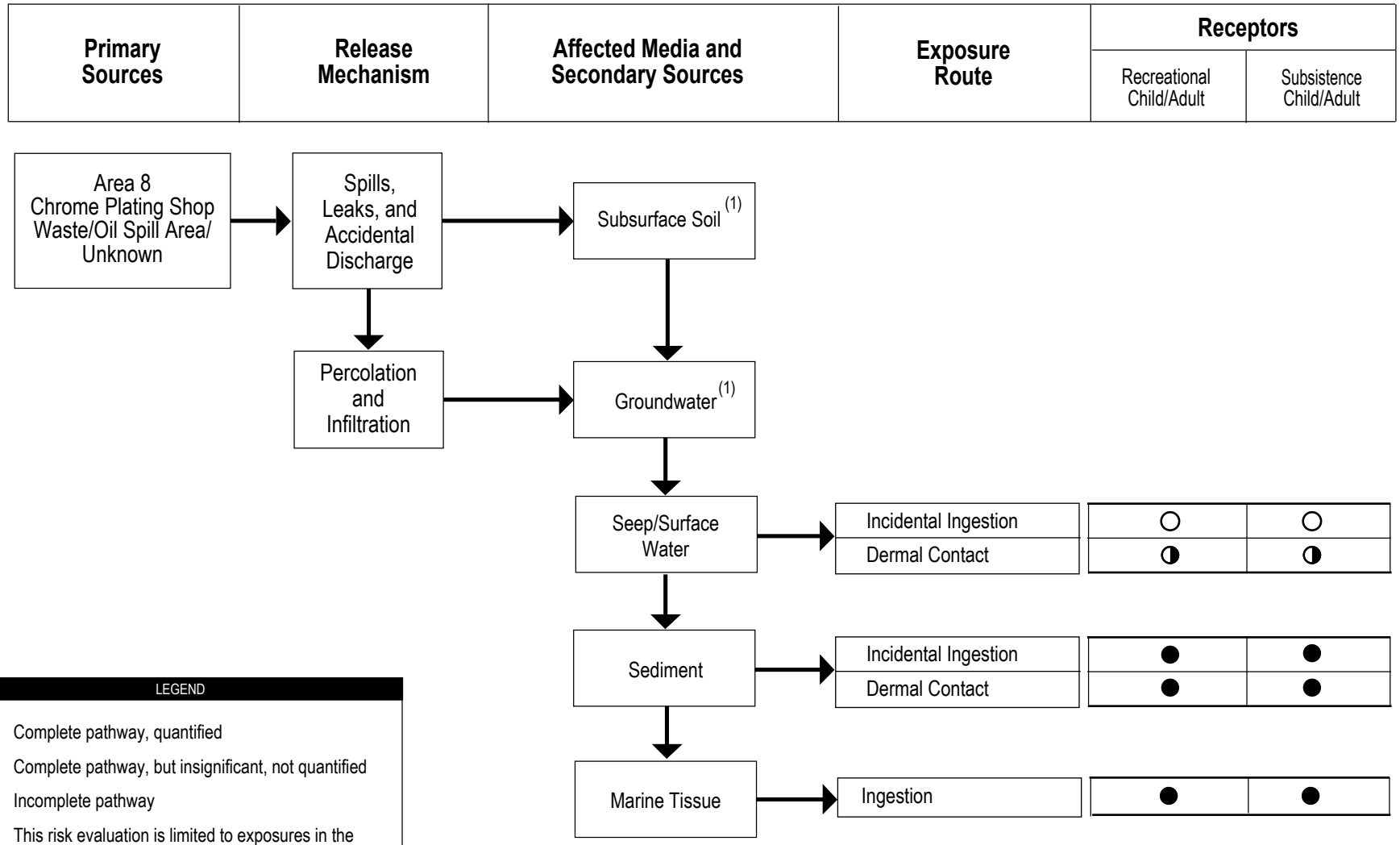
Legend

Reference Sampling Location

U.S. NAVY	0 100 200 SCALE IN FEET	**Figure 7** **Reference Area Sampling Stations**	JP11 NBK Keyport OU 2 AREA 8 HHRA/ERA

J:\Seattle Support\NAVY_KeyPort\LAURA NEW PROJECT\Fig 4 Reference Samps.dwg
Mod: 02/09/2017, 13:05 | Plotted: 02/09/2017, 13:06 | jim.gibson

J:\DCS\Resources\GRFX\Projects\60486000 NAVY JP 11 NBK Keyport\60486000_01.ai

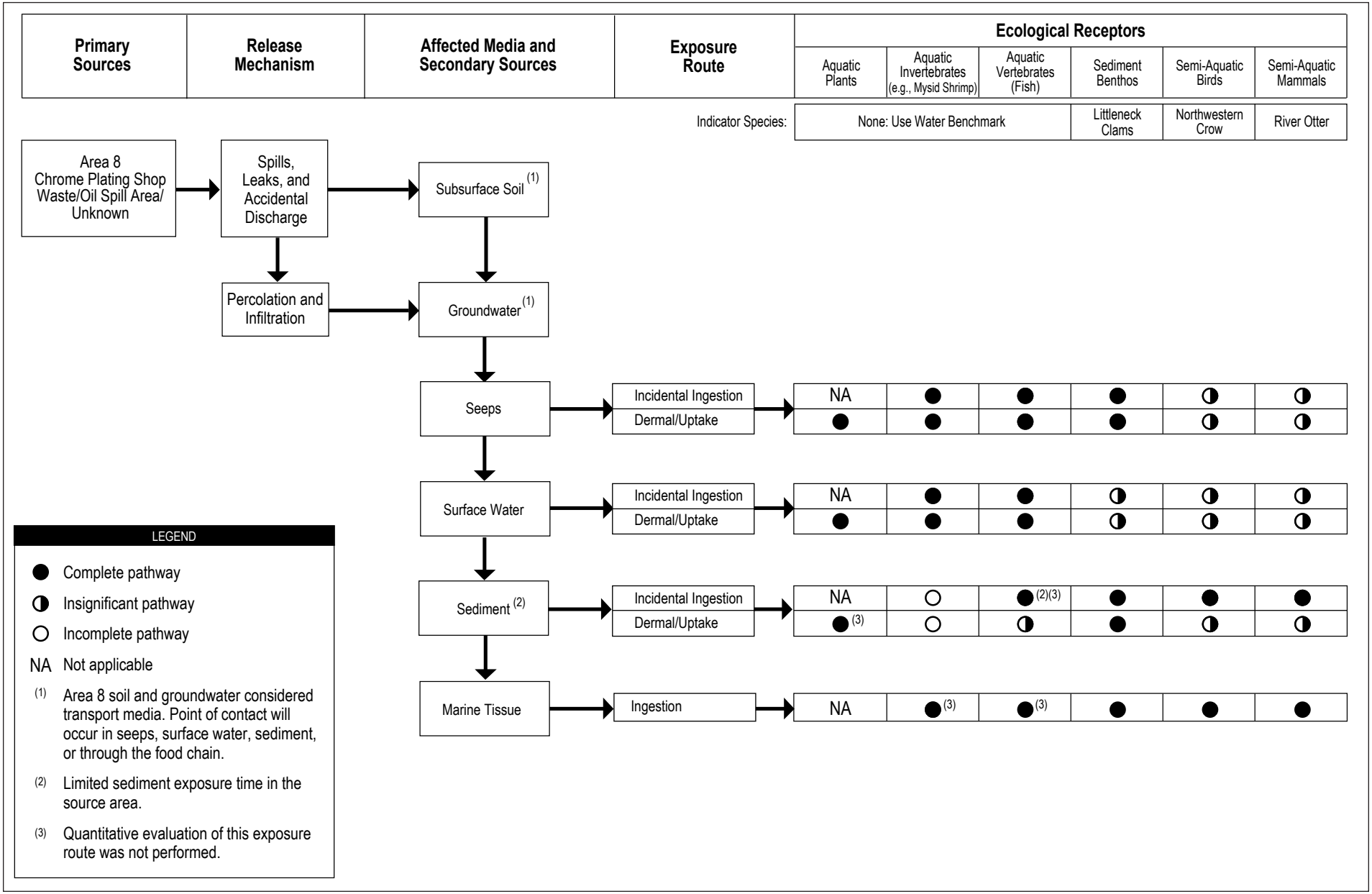


U.S. NAVY

Figure 8
Human Health Conceptual Site Model

JP11
NBK Keyport
OU 2 AREA 8
HHRA/ERA

J:\DCS\Resources\GRFX\Projects\60486000 NAVY JP 11 NBK Keyport\60486000_02.ai



U.S. NAVY

Figure 9
Ecological Conceptual Site Model

JP11
NBK Keyport
OU 2 AREA 8
HHRA/ERA

OUTFALL 02-741
OUTFALL 03-701
SS-03701
SEEP G
SEEP F
SEEP E
SEEP D
SEEP C
SEEP B
SEEP A
OUTFALL 03-703
Transect 13
Transect 12
Transect 11
Transect 10
Transect 9
Transect 3
Transect 8
Transect 2
Transect 1
Transect 14
Phase 2 Slurry Wall
5 ft to15 ft bgs
Plating Waste Area Soil
Removal and Trench Excavation
Area 8
Former Utility
Trench Discharge
Phase 1 Slurry Wall
5 ft to17 ft bgs
Former
Uitility
Trench
Outfall 03-706
Seawall
Seawall
Seawall
Groner Street
'H' Street
Hunnicut Road
Chrome Plating Room
9 ft bgs
9 ft bgs
Liberty Bay
83
85
98
186
760
72
1019
181
804
MW8-1
MW8-2
MW8-3
MW8-4
MW8-5
MW8-7
MW8-8
MW8-9
MW8-10
MW8-11
MW8-12
MW8-13
MW8-14
MW8-15
MW8-16
9-1
9-2
+1
0
-1
-2
-2.50
3-C
6-C
9-C

Legend

- Monitoring Well
- Abandoned Monitoring Well
- June 2015 Seep/Outfall Sampling Location
- June 2015 Sampling Location
- June 2016 Sampling Location
- Former Building
- USGS Monument
- Metals - Contaminated Soil Removal Boundaries (U.S. Navy 1999)
- Exposure Area (Area 8 Beach)
- Approximate Area 8 Boundary From OU 2 ROD
- Closed Top Drainage Trench

Sediment Cadmium Concentration in milligrams per kilogram (mg/kg) dry weight. Sediment benchmark for cadmium is 5.1 mg/kg.

- 5
- 10
- SEEP C — Seep cadmium concentration >7.9 micrograms per liter (ug/L)

Notes:

1. Existing station positions are based on horizontal and vertical measurements collected during the June 2015 and June 2016 sampling events. Beach transects were established beginning at the origins of Seeps A through G, which vary in width up to approximately 10-15 feet. Subsequent downgradient stations were sampled at 1 foot tidal intervals along the transects perpendicular to the shoreline. Variation in downgradient station position relative to transects reflect beach terrain which determines the seep pathways, and accuracy limits of field measurements.

2. Surface sediment depth is approximately 0 - 10 cm and subsurface sediment depth is approximately 10 - 24 cm.

3. Area 8 cadmium clam tissue concentrations were statistically similar to the reference area cadmium clam tissue concentrations.

4. During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. The nomenclature for tissue and sediment sampling stations 3, 6, and 9 was modified to sampling stations 3-C, 6-C, and 9-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sampling station 3-C is co-located with Seep C.

U.S. NAVY

JP11
NBK Keyport
OU 2 AREA 8
HHRA/ERA

0 30 60
SCALE IN FEET

Figure 10
Area 8 Beach Cadmium Sediment and Seep Concentrations Greater Than Ecological Benchmarks

J:\DCS\Projects\GIS\NAVY\KEYPORT\Sub-Tasks\IDIQ\JP11\HHRA_ERA\Fig 10 Area 8 Cadmium Sediment and Seep_revised.dwg
Mod: 05/15/2018, 11:09 | Plotted: 05/15/2018, 11:10 | mason.struna

TABLES

Table 1
Distribution of COC Concentrations in Clam Tissue at the Area 8 Beach and Penrose Point

COC	Minimum (mg/kg)	Maximum (mg/kg)	Location of Maximum	No. of Detected / No. Sampled	Range of Reporting Limits (mg/kg)	Human Health Screening Level			Ecological Screening Level		
						Suquamish Tissue Screening Levels [a] (mg/kg)	Magnitude of Exceedance	Frequency of Exceedance	ODEQ Ecological CTLs (mg/kg)	Magnitude of Exceedance	Frequency of Exceedance
Penrose Point (Reference Area)											
Arsenic	1.7	3.09	PP09	22/22	--	0.0001	30900	100%	1.6	1.9	100%
Inorganic Arsenic	0.026	0.055	PP14	22/22	--	0.0001	550	100%	NE	--	--
Cadmium	0.310	0.63	PP05	22/22	--	0.16	3.9	100%	0.15	4.2	100%
Chromium	0.216	1.72	PP14	22/22	--	242	--	--	NE	--	--
Copper	0.896	1.45	PP17	22/22	--	6.5	--	--	NE	--	--
Lead	0.0132	0.0678	PP14	22/22	--	2.29	--	--	0.4	--	--
Nickel	0.229	1.20	PP14	22/22	--	3.2	--	--	NE	--	--
Silver	--	0.0475	PP15	1/22	0.0069-0.0186	0.8	--	--	NE	--	--
Zinc	13.1	17.1	PP18	22/22	--	48.4	--	--	NE	--	--
Mercury	0.0034	0.0082	PP15	22/22	--	NE	--	--	0.18	--	--
Methyl-mercury	0.0022	0.0066	PP05	22/22	--	0.016	--	--	NE	--	--
Area 8											
Arsenic	1.65	3.5	S.STATION65	41/41	--	0.0001	35000	100%	1.6	2.2	100%
Inorganic Arsenic	0.017	0.05	SEEPG	39/41	0.014-0.015	0.0001	500	100%	NE	--	--
Cadmium	0.169	1	S.STATION64	41/41	--	0.16	6.3	100%	0.15	6.7	100%
Chromium	0.155	1.13	S.STATION03-C[b]	41/41	--	242	--	--	NE	--	--
Copper	0.759	1.73	S.STATION36	41/41	--	6.5	--	--	NE	--	--
Lead	0.0431	0.13	S.STATION70	41/41	--	2.29	--	--	0.4	--	--
Nickel	0.270	1	S.STATION65	41/41	--	3.2	--	--	NE	--	--
Silver	0.0371	0.582	S.STATION64	41/41	--	0.8	--	--	NE	--	--
Zinc	9.6	16.3	S.STATION70	41/41	--	48.4	--	--	NE	--	--
Mercury	0.0086	0.042	S.STATION70	41/41	--	NE	--	--	0.18	--	--
Methyl Mercury	0.0010	0.0180	S.STATION67	41/41	--	0.016	1.125	2%	NE	--	--

Notes:
Highlighted screening levels are exceeded by the maximum detected concentration.
COC- chemical of concern
CTLs - critical tissue level (for fish)
ERA - ecological risk assessment
HHRA - human health risk assessment
mg/kg - milligrams per kilogram
NE - not established
ODEQ - Oregon Department of Environmental Quality
[a] Suquamish Tribe screening levels were calculated using the exposure parameters and formulas provided in Appendix B.
[b] The nomenclature for S.STATION03 was modified to sampling station S.STATION03-C in order to distinguish it from historical sampling station 3 and to highlight its position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location S.STATION03-C is co-located with Seep C.

Table 2
Distribution of COC Concentrations in Sediment at the Area 8 Beach

COC	Minimum [a] (mg/kg)	Maximum [a] (mg/kg)	Transect	Location of Maximum	No. of Detected / No. Sampled	BOLD 90/90 UTL (mg/kg)	Human Health Screening Level			Ecological Screening Level		
							Suquamish Tissue Screening Levels [b] (mg/kg)	Magnitude of Exceedance	Frequency of Exceedance	Ecology SMS SCO (mg/kg)	Magnitude of Exceedance	Frequency of Exceedance
0 to 10 CM												
Arsenic	0.42	6.47	8	S.STATION03-C[c]	66/66	11	0.43	15	98%	57	--	--
Cadmium	0.152	11.4	8	S.STATION03-C[c]	66/66	0.8	80	--	--	5.1	2	8%
Total Chromium	2.32	84.8	8	S.STATION51	66/66	62	131,000	--	--	260	--	--
Copper	3.81	439	9	S.STATION71	66/66	45	3,500	--	--	390	1.1	2%
Lead	1.71	185	13	SS-03701	66/66	21	400	--	--	450	--	--
Nickel	2.37	40.8	8	S.STATION51	66/66	50	1,750	--	--	20.9	2	8%
Silver	0.048	17	9 & 10	S.STATION72	66/66	0.24	440	--	--	6.1	3	3%
Zinc	12.5	396	13	SS-03701	66/66	93	26,200	--	--	410	--	--
Mercury	0.006	2.42	8	S.STATION51	66/66	0.2	26.3	--	--	0.41	6	8%
10 to 24 CM												
Arsenic	1.44	2.87	1	S.STATION07	10/10	11	0.43	6.7	100%	57	--	--
Cadmium	0.309	4.86	8	S.STATION06-C[c]	10/10	0.8	80	--	--	5.1	--	--
Total Chromium	19.6	64.2	8	S.STATION09-C[c]	10/10	62	131,000	--	--	260	--	--
Copper	6	10.6	13	SEEPG	10/10	45	3,500	--	--	390	--	--
Lead	3.1	12.8	13	SEEPG	10/10	21	400	--	--	450	--	--
Nickel	12.4	17.4	13	SEEPG	10/10	50	1,750	--	--	20.9	--	--
Silver	0.061	1.16	10	S.STATION40	10/10	0.24	440	--	--	6.1	--	--
Zinc	23.2	43.8	13	SEEPG	10/10	93	26,200	--	--	410	--	--
Mercury	0.037	0.767	10	S.STATION40	10/10	0.2	26	--	--	0.41	1.9	10%

Notes:
Highlighted screening levels are exceeded by the maximum detected concentration.
BOLD UTL - Bold Survey 90/90 Upper Threshold Limit
cm - centimeters
COC - chemical of concern
ERA - ecological risk assessment
HHRA - human health risk assessment
mg/kg - milligrams per kilogram
SCO - sediment cleanup objective
SMS - Sediment Management Standards
[a] minimum and maximum detected concentrations
[b] Suquamish Tribe screening levels were calculated using the exposure parameters and formulas provided in Appendix B.
[c] The nomenclature for S.STATION03, S.STATION06, and S.STATION09 was modified to sampling stations S.STATION03-C, S.STATION06-C, and S.STATION09-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location S.STATION03-C is co-located with Seep C.

Table 3
Distribution of COC Concentrations in Seep/Outfall Water at the Area 8 Beach

COC	Minimum [a] (ug/L)	Maximum [a] (ug/L)	Location of Maximum	No. of Detected / No. Sampled	Range of Reporting Limits (ug/L)	Ecological SW Criteria (Chronic) Chapter 173-201A WAC (ug/L)
SEEP						
Dissolved Arsenic	0.71	2.51	SEEPF	7/7	--	36
Dissolved Cadmium	0.003	45.7	SEEPC[b]	6/7	0.003	7.9
Dissolved Chromium, Total	0.2	9.68	SEEPC[b]	7/7	--	50
Dissolved Copper	0.345	1.88	SEEPC[b]	6/7	0.132	3.1
Dissolved Lead	0.017	0.089	SEEPA[b]	6/7	0.01	8.1
Dissolved Nickel	0.53	1.81	SEEPA[b]	7/7	--	8.2
Dissolved Silver	0.003	0.057	SEEPC[b]	7/7	--	0.19
Dissolved Zinc	0.77	1.63	SEEPC[b]	6/7	0.54	81
Dissolved Mercury	0.001	0.0141	SEEPE	7/7	--	0.025
OUTFALL						
Dissolved Arsenic	--	1.6	OF 03-701	1/1	--	36
Dissolved Cadmium	--	6.91	OF 03-701	1/1	--	7.9
Dissolved Chromium, Total	--	8.25	OF 03-701	1/1	--	50
Dissolved Copper	--	5.39	OF 03-701	1/1	--	3.1
Dissolved Lead	--	0.355	OF 03-701	1/1	--	8.1
Dissolved Nickel	--	1.16	OF 03-701	1/1	--	8.2
Dissolved Silver	--	0.58	OF 03-701	1/1	--	0.19
Dissolved Zinc	--	54.9	OF 03-701	1/1	--	81
Dissolved Mercury	--	0.00534	OF 03-701	1/1	--	0.025

Notes:
Highlighted screening levels are exceeded by the maximum detected concentration.
COC - chemical of concern
ERA - ecological risk assessment
HHRA - human health risk assessment
SW - surface water
ug/L - micrograms per liter
WAC - Washington Administrative Code
[a] minimum and maximum detected concentrations
[b] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8.

Table 4
Distribution of COC Concentrations in Marine Water at the Area 8 Beach and Penrose Point

COC	Minimum [a] (ug/L)	Maximum [a] (ug/L)	Location of Maximum	No. of Detected / No. Sampled	Range of Reporting Limits (ug/L)	Ecological SW Criteria (Chronic) Chapter 173-201A WAC (ug/L)
Penrose Point (Reference Area)						
Dissolved Arsenic	0.49	1.54	PP01, PP03	8/8	--	36
Dissolved Cadmium	0.014	0.066	PP03	7/8	0.009	7.9
Dissolved Chromium, Total	0.07	0.23	PP11	8/8	--	50
Dissolved Copper	0.365	0.901	PP01	8/8	--	3.1
Dissolved Lead	0.014	0.031	PP01	6/8	0.01	8.1
Dissolved Nickel	0.51	0.93	PP15	8/8	--	8.2
Dissolved Silver	0.003	0.011	PP01	5/8	0.005	0.19
Dissolved Zinc	0.7	1.4	PP01, PP05	4/8	0.2 - 0.4	81
Dissolved Mercury	0.00021	0.00043	PP01	8/8	--	0.025
Area 8						
Dissolved Arsenic	1.23	1.58	OF03703	9/9	--	36
Dissolved Cadmium	0.041	1.57	SEEPC[b]	9/9	--	7.9
Dissolved Chromium, Total	0.19	0.86	SEEPB	9/9	--	50
Dissolved Copper	0.488	1.34	OF03703	9/9	--	3.1
Dissolved Lead	0.029	0.099	SEEPC[b]	9/9	--	8.1
Dissolved Nickel	0.45	1.01	SEEPB	9/9	--	8.2
Dissolved Silver	0.005	0.051	OF03703	9/9	--	0.19
Dissolved Zinc	0.63	3.59	SEEPB	9/9	--	81
Dissolved Mercury	0.00061	0.00372	SEEPD	9/9	--	0.025

Notes:
COC - chemical of concern
ERA - ecological risk assessment
HHRA - human health risk assessment
SW - surface water
ug/L - micrograms per liter
WAC = Washington Administrative Code
[a] minimum and maximum detected concentrations
[b] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8.

Table 5
Comparison of COC Concentrations in Shallow (0 to 10 cm) and Deep (10 to 24 cm) Sediment at the Area 8 Beach

Tran-sect	Sampling Station ID	Arsenic (mg/kg)			Cadmium (mg/kg)			Total Chromium (mg/kg)		
		Depth Interval		Magnitude of Difference in Concentration Between Depths	Depth Interval		Magnitude of Difference in Concentration Between Depths	Depth Interval		Magnitude of Difference in Concentration Between Depths
		0-10 cm	10-24 cm		0-10 cm	10-24 cm		0-10 cm	10-24 cm	
1	S.STATION07	3.33	2.87	1.2	0.41	0.309	1.3	19	19.6	1.0
2	S.STATION08	2.18	2.09	1.0	2.84	3.02	1.1	45	35	1.3
8	S.STATION06-C[a]	2.27	1.62	1.4	5.85	4.86	1.2	49.9	46.1	1.1
8	S.STATION09-C[a]	2.73	2.8	1.0	2.36	2.29	1.0	69.5	64.2	1.1
3	S.STATION34	1.74	1.54	1.1	3.82	3.77	1.0	47.7	51.1	1.1
9	S.STATION36	1.31	1.68	1.3	1.15	1.7	1.5	26	38.5	1.5
10	S.STATION40	1.41	1.44	1.0	3.82	1.16	3.3	41.1	30.2	1.4
11	S.STATION43	2.58	1.95	1.3	0.814	0.782	1.0	38.4	30	1.3
12	S.STATION46	2.53	2.5	1.0	0.677	0.88	1.3	39.1	34	1.2
13	SEEPG	2.37	2.09	1.1	0.585	0.487	1.2	26.6	31.6	1.2

Table 5 (Continued)
Comparison of COC Concentrations in Shallow (0 to 10 cm) and Deep (10 to 24 cm) Sediment at the Area 8 Beach

Tran-sect	Sampling Station ID	Cooper (mg/kg)			Lead (mg/kg)			Nickel (mg/kg)		
		Depth Interval		Magnitude of Difference in Concentration Between Depths	Depth Interval		Magnitude of Difference in Concentration Between Depths	Depth Interval		Magnitude of Difference in Concentration Between Depths
		0-10 cm	10-24 cm		0-10 cm	10-24 cm		0-10 cm	10-24 cm	
1	S.STATION07	14.8	7.41	2.0	4.43	4.18	1.1	17.5	16.3	1.1
2	S.STATION08	8.92	7.67	1.2	4.62	4.94	1.1	17.4	17.1	1.0
8	S.STATION06-C[a]	9.31	6.73	1.4	5.36	3.95	1.4	17.5	13.9	1.3
8	S.STATION09-C[a]	8.64	8.58	1.0	4.86	4.96	1.0	17.5	17.2	1.0
3	S.STATION34	8.36	7.4	1.1	4.22	4.68	1.1	14.9	13.9	1.1
9	S.STATION36	5.24	6	1.1	2.85	3.1	1.1	8.94	12.4	1.4
10	S.STATION40	9.85	9.22	1.1	5.27	4.55	1.2	14.9	14.6	1.0
11	S.STATION43	8.58	7.25	1.2	4.38	3.3	1.3	16.7	17.2	1.0
12	S.STATION46	8.05	7.64	1.1	5.11	7.82	1.5	15.7	14.5	1.1
13	SEEPG	11	10.6	1.0	8.32	12.8	1.5	15.4	17.4	1.1

Table 5 (Continued)
Comparison of COC Concentrations in Shallow (0 to 10 cm) and Deep (10 to 24 cm) Sediment at the Area 8 Beach

Tran-sect	Sampling Station ID	Silver (mg/kg)			Zinc (mg/kg)			Mercury (mg/kg)		
		Depth Interval		Magnitude of Difference in Concentration Between Depths	Depth Interval		Magnitude of Difference in Concentration Between Depths	Depth Interval		Magnitude of Difference in Concentration Between Depths
		0-10 cm	10-24 cm		0-10 cm	10-24 cm		0-10 cm	10-24 cm	
1	S.STATION07	0.059	0.061	1.0	30.6	26.3	1.2	0.038	0.037	1.0
2	S.STATION08	0.857	0.829	1.0	30.2	29.6	1.0	1.67	0.038	43.9
8	S.STATION06-C[a]	0.552	0.437	1.3	31.8	25.6	1.2	0.051	0.044	1.2
8	S.STATION09-C[a]	0.305	0.287	1.1	35.9	32.7	1.1	0.045	0.066	1.5
3	S.STATION34	0.28	0.281	1.0	27.2	26.4	1.0	0.116	0.17	1.5
9	S.STATION36	0.151	0.261	1.7	17.2	23.2	1.3	0.083	0.073	1.1
10	S.STATION40	1.41	1.16	1.2	29.8	34.1	1.1	0.068	0.767	11.3
11	S.STATION43	0.342	0.295	1.2	32.4	24.8	1.3	0.054	0.067	1.2
12	S.STATION46	0.345	0.368	1.1	29.4	34.3	1.2	0.095	0.054	1.8
13	SEEPG	0.616	0.423	1.5	40.8	43.8	1.1	0.144	0.099	1.5

Notes:
cm – centimeter
ID – identification
mg/kg – milligrams per kilogram
[a] The nomenclature for S.STATION06 and S.STATION09 was modified to sampling stations S.STATION06-C and S.STATION09-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3.

Table 6
Percentage of Inorganic Arsenic and Methylmercury Measured in Clam Tissues from Penrose Point and the Area 8 Beach

Sampling Station ID	Arsenic (mg/kg)	Inorganic Arsenic (mg/kg)	Percent Inorganic Arsenic	Mercury (ug/kg)	Methyl mercury (ug/kg)	Percent Methylmercury
Penrose Point (Reference Area)						
PP01	2.08	0.037	2%	3.35	3.4	100%
PP02	1.7	0.037	2%	6.19	3.6	58%
PP03	1.72	0.041	2%	6.51	3.2	49%
PP04	1.87	0.034	2%	5.26	3.3	63%
PP05	2.14	0.043	2%	6.1	6.6	100%
PP06	2.12	0.035	2%	5.86	3.7	63%
PP07	2.26	0.031	1%	6.56	4.1	63%
PP08	1.79	0.045	3%	5.79	3.2	55%
PP09	3.09	0.035	1%	6.28	4.3	68%
PP10	2.28	0.029	1%	5.78	4.2	73%
PP11	1.93	0.03	2%	6.59	4.4	67%
PP12	2.31	0.026	1%	5.38	4.6	86%
PP13	2.83	0.03	1%	5.18	2.2	42%
PP14	2.6	0.055	2%	8.17	4.3	53%
PP15	2.23	0.036	2%	8.22	4.6	56%
PP16	2.01	0.031	2%	6.45	3.7	57%
PP17	2.13	0.033	2%	7.71	3.7	48%
PP18	2.34	0.029	1%	6.18	3.7	60%
PP19	2.72	0.03	1%	7.55	3.3	44%
PP20	2.37	0.032	1%	6.4	3.8	59%
PP21	1.91	0.032	2%	5.19	2.9	56%
PP22	2.43	0.031	1%	5.64	4.5	80%
		Average	2%		Average	64%
Area 8						
S.STATION01	1.97	0.023	1%	10.9	5.8	53%
S.STATION07	2.01	0.032	2%	9.2	3.7	40%
S.STATION02	2.01	0.029	1%	9.73	9.1	94%
S.STATION05	2.21	0.026	1%	13.4	8	60%
S.STATION08	2.44	0.028	1%	13	6.9	53%
S.STATION62	2.96	0.017	1%	22.3	13	58%
S.STATION64	2.72	0.015 U	1%	37.5	9.1	24%
S.STATION03-C[a]	3.04	0.023	1%	14.5	9	62%
S.STATION09-C[a]	1.81	0.029	2%	9.35	5.5	59%
S.STATION65	3.5	0.018	1%	23.6	14	59%
S.STATION67	2.99	0.02	1%	25.1	18	72%
S.STATION32	1.67	0.031	2%	10.1	1 J	10%
S.STATION34	1.65	0.026	2%	12.8	6.6	52%

Table 6 (Continued)
Percentage of Inorganic Arsenic and Methylmercury Measured in Clam Tissues from Penrose Point and the Area 8 Beach

Sampling Station ID	Arsenic (mg/kg)	Inorganic Arsenic (mg/kg)	Percent Inorganic Arsenic	Mercury (ug/kg)	Methyl mercury (ug/kg)	Percent Methylmercury
SEEPA[a]	2.11	0.022	1%	11.9	7.7	65%
S.STATION70	3.09	0.017	1%	42.2	11.9	28%
OF03703	2.58	0.018	1%	20	9	45%
S.STATION35	1.84	0.027	1%	10.8	7.1	66%
S.STATION36	2.27	0.029	1%	12.4	6.8	55%
S.STATION37	2.36	0.028	1%	16.8	9.3	55%
S.STATION53	2.18	0.03	1%	10.1	5.5	54%
S.STATION74	2.33	0.034	1%	17.8	11.7	66%
S.STATION73	2.84	0.041	1%	25.2	11.4	45%
S.STATION38	2.26	0.026	1%	12.3	5.2	42%
S.STATION40	1.71	0.029	2%	11.3	6.9	61%
S.STATION56	1.87	0.026	1%	11.8	5.6	47%
SEEPD	2.91	0.023	1%	13.6	5.1	38%
S.STATION75	2.49	0.028	1%	16.4	11.9	73%
S.STATION43	1.81	0.024	1%	10.5	6.9	66%
SEEPE	2.48	0.023	1%	14.1	7.9	56%
S.STATION46	1.67	0.03	2%	11.2	6	54%
SEEPF	2.64	0.025	1%	15.4	5.6	36%
SS-03701	2.3	0.021	1%	28.9	9	31%
S.STATION49	2.86	0.022	1%	21.1	11.3	54%
SEEPG	2.4	0.05	2%	11.6	5.7	49%
S.STATION76	2.88	0.038	1%	21	13.6	65%
S.STATION77 A	1.87	0.034	2%	14.5	9.6	66%
S.STATION78	2.26	0.023	1%	19	10.4	55%
S.STATION79 A	2.03	0.039	2%	14.8	8	54%
S.STATION57	2.84 J	0.014 U	0.5%	14.8	12.3	83%
S.STATION58	1.66	0.024	1%	8.58	3.7	43%
S.STATION59	1.68	0.025	1%	9.31	6.6	71%
		Average	1%		Average	54%

Notes:
ID - identification
J - The result is an estimated concentration.
mg/kg - milligrams per kilogram
U – not detected; result is the reporting limit
ug/kg = micrograms per kilogram
[a] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is

Table 6 (Continued)
Percentage of Inorganic Arsenic and Methylmercury Measured in Clam Tissues from Penrose Point and the Area 8 Beach

located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. In addition, the nomenclature for S.STATION03 and S.STATION09 was modified to sampling stations S.STATION03-C and S.STATION09-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location S.STATION03 is co-located with Seep C.

Table 7
Point-by-Point Comparison of the Area 8 Beach Sediment Concentrations to the Sediment Background Threshold Value (90/90 UTL)

Tran-sect	Sampling Station ID	Arsenic (mg/kg)	Cadmium (mg/kg)	Total Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	Mercury (mg/kg)
	BTV	**11.00**	**0.800**	**62.0**	**45.00**	**21.00**	**50.0**	**0.240**	**93.0**	**0.200**
	Percentage of Samples Exceeding BTV	**0%**	**45%**	**3%**	**6%**	**9%**	**0%**	**47%**	**5%**	**14%**
	Minimum Site Concentration	**0.42**	**0.15**	**2.3**	**3.8**	**1.7**	**2.4**	**0.05**	**12.5**	**0.006**
	Maximum Site Concentration	**6.47**	**11.4**	**84.8**	**439**	**185**	**40.8**	**17**	**396**	**2.42**
1	S.STATION01	1.92	0.343 J	18.1 J	8.51 J	4.13	16.5	0.136	31.8 J	0.011 J
1	S.STATION04	2.03	0.395 J	22 J	7.75 J	5.59	15.6	**0.714**	28.6 J	0.032
1	S.STATION07	3.33	0.41	19 J	14.8 J	4.43	17.5	0.059	30.6	0.038
1	S.STATION60	3.22	0.325	22.3 J	8.11	5.62	16.5	0.074 J	30.5	0.048
1	S.STATION55	2.12	0.152 J	8.03 J	8.17 J	3.23	23.6	0.048	18.2 J	0.025
1	S.STATION10	3.43	0.284	11.2	7.92	4.73	9.31	0.068	21.4	0.033
1 & 2	S.STATION61	1.28	0.306	13.4	10.9	14.4 J	13.7	0.072	40.2	0.011 J
2	S.STATION62	1.57	0.484	21.1	12.5	6.18 J	19.8	0.124	44.5	0.015 J
2	S.STATION63	1.52	0.385	19.8	11.4	4.73 J	19.1	0.116	37.9	0.111
2	S.STATION02	2.56	**1.61**	29.9 J	10.6 J	3.79	12.3	**0.283**	24.7	0.05
2	S.STATION05	2.53	**3**	34.7 J	8.57 J	4.6	20.1	**1.12**	31.6	0.033
2	S.STATION08	2.18	**2.84**	45 J	8.92 J	4.62	17.4	**0.857**	30.2	**1.67**
2	S.STATION30	2.12	0.289	19.9 J	7.73 J	5.76	21.1	0.068	25.1	0.031
2	S.STATION11	3.37	0.258 J	12.5 J	6.64 J	4	12.4	0.072	21.5 J	0.034
2 & 8	S.STATION64	1.22	**2.71**	18.9	11.5	5.67 J	18.8	0.208	63.8	0.082
8	S.STATION50	1.84	**8.84 J**	38 J	19.4 J	7.2	27.9	**0.469**	53.5 J	**0.308**
8	S.STATION51	1.91	**10.2 J**	**84.8 J**	**61.6 J**	**47.8**	40.8	0.099	**113 J**	**2.42**
8	S.STATION03-C[a]	6.47	**11.4**	34.1 J	8.16	4.01 J	15.5	**0.433**	31	0.074
8	S.STATION06-C[a]	2.27	**5.85 J**	49.9 J	9.31 J	5.36	17.5	**0.552**	31.8 J	0.051
8	S.STATION09-C[a]	2.73	**2.36**	**69.5 J**	8.64 J	4.86	17.5	**0.305**	35.9	0.045
8	S.STATION31	3.27	0.468 J	37.1 J	7.14 J	4.13	12.5	0.109	23.5 J	0.028
8	S.STATION12	3.4	0.339 J	22.4 J	6.81 J	4.27	11.3	0.075	22.9 J	0.037
3 & 8	S.STATION65	1.48	**2.06**	20.3	12.1	7.66 J	16.8	0.099	39.7	**0.506**
3	S.STATION66	0.78	**0.876**	6.62	7.98	3.66 J	10.6	0.12	19.1	0.06
3	S.STATION67	3.74	**1.3**	16.8	14.2	6.41 J	11.5	0.106	46.1	0.182
3	SEEPA[a]	1.66	**6.8 J**	34.1 J	12.6 J	4.15	14.8	**0.299**	32.5 J	0.133
3	S.STATION34	2.22	**3.82**	53.4 J	14.2 J	5.04 J	21.1	**0.28**	32.9	0.132
3	S.STATION32	3.02	0.791	40.8 J	8.2 J	5.24	17.1	0.148	30.3	0.077
3	S.STATION54	4.02	0.709	36.7 J	13.3	6.53 J	19.4	0.136	38.5	0.057
3 & 9	S.STATION68	0.42 J	**1.15**	2.32	3.81	1.71 J	2.37	**0.355**	12.5	0.044
3 & 9	S.STATION69	0.73	**1.17**	5.43	4.61	2.05 J	7.07	0.076	17.1	0.055

Table 7 (Continued)
Point-by-Point Comparison of the Area 8 Beach Sediment Concentrations to the Sediment Background Threshold Value (90/90 UTL)

Tran-sect	Sampling Station ID	Arsenic (mg/kg)	Cadmium (mg/kg)	Total Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	Mercury (mg/kg)
	BTV	**11.00**	**0.800**	**62.0**	**45.00**	**21.00**	**50.0**	**0.240**	**93.0**	**0.200**
	Percentage of Samples Exceeding BTV	**0%**	**45%**	**3%**	**6%**	**9%**	**0%**	**47%**	**5%**	**14%**
	Minimum Site Concentration	**0.42**	**0.15**	**2.3**	**3.8**	**1.7**	**2.4**	**0.05**	**12.5**	**0.006**
	Maximum Site Concentration	**6.47**	**11.4**	**84.8**	**439**	**185**	**40.8**	**17**	**396**	**2.42**
9	S.STATION70	1.57	**3.18 J**	27.5 J	**77.5**	**50.2**	19.5	**7.75 J**	**148**	**0.491**
9	S.STATION71	1.49	**1.22 J**	45.3 J	**439**	19.7	23.4	**2.63 J**	46.7	0.113
9	OF03703	2.01	**3.93**	49.2 J	13.9	6.61 J	22	**1.98**	44.1	**0.627**
9	S.STATION37	1.67	**3.15**	29.1 J	8.76 J	4.42	11.8	**0.414**	26.6	0.111
9	S.STATION36	1.31	**1.15**	26 J	5.24	2.85 J	8.94	0.151	17.2	0.083
9	S.STATION53	2.31	0.44	23.6 J	5.68	4.12 J	11.4	0.1	20.9	0.027
9 & 10	S.STATION72	1.44	**1.18 J**	26.5 J	**48.8**	**67.7**	19.6	**17 J**	54.2	0.163
9 & 10	S.STATION74	1.57	**1.99 J**	36 J	10.6	5.9	16.9	**2.2 J**	35.3	0.176
10	S.STATION73	2.26	**0.9 J**	19.9 J	19.1	8.77	12.7	**1.91 J**	39.7	0.099
10	SEEPD	0.9	**1.08 J**	8.73 J	4.2 J	2.64	5.17	**0.398**	13.2 J	0.165
10	S.STATION40	1.41	**3.82**	41.1 J	9.85	5.27 J	14.9	**1.41**	29.8	0.068
10	S.STATION38	1.48	0.487	25.6 J	6.58	3.22 J	13.4	0.238	19.6	0.066
10	S.STATION39	2.49	0.524	33.2 J	6.05	7.67 J	13.7	0.113	23.8	0.034
10	S.STATION52	2.95	0.437	33.6 J	6.82	10.2 J	15.1	0.116	26.7	0.037
10 & 11	S.STATION75	2.85	**1.55 J**	34.1 J	13.4	6.83	18.2	**0.889 J**	47.7	**0.205**
11	SEEPE	1.63	0.715 J	30.9 J	9.71 J	3.99	15.4	**0.446**	27.2 J	0.107
11	S.STATION43	2.58	**0.814**	38.4 J	8.58 J	4.38	16.7	**0.342**	32.4	0.054
11	S.STATION41	3.27	0.533	34.4 J	8.5	4.98 J	16.2	0.117	30	0.045
11	S.STATION42	3.25	0.403	28.3 J	6.97	4.78 J	15.1	0.091	27.2	0.043
12	SEEPF	2.22	0.754 J	19.8 J	6.68 J	4.9	10.4	0.228	28.8 J	0.136
12	S.STATION46	2.53	0.677	39.1 J	8.05	5.11 J	15.7	**0.345**	29.4	0.095
12	S.STATION44	1.94	0.38	21.3 J	4.74	3.15 J	10.3	0.102	17.7	0.034
12	S.STATION45	3.37	0.339	30.8 J	6.48	4.45 J	16.9	0.079	28	0.034
13	SS-03701	2.47	**1.97**	30.2 J	39.8	**185 J**	24.2	**5.99**	**396**	**0.224**
13	S.STATION49	1.67	0.524	20.3 J	10.2 J	7.86	12.5	**0.999**	36.5	0.151
13	SEEPG	2.37	0.585 J	26.6 J	11 J	8.32	15.4	**0.616**	40.8 J	0.144
13	S.STATION48	3.56	0.771 J	35.8 J	23.1 J	8.83	17.4	**0.527**	45.2 J	**0.608**
13	S.STATION47	3.19	0.375	20.3 J	6.67	4.33 J	14.4	0.081	25.5	0.026
S. 13	S.STATION76	3.12	0.765 J	40.5 J	14.7	**41.8**	20.6	**0.479 J**	55.2	0.112
S. 13	S.STATION77	3.31	0.681 J	32.5 J	9.31	6.99	19	0.218 J	37.5	0.112

Table 7 (Continued)
Point-by-Point Comparison of the Area 8 Beach Sediment Concentrations to the Sediment Background Threshold Value (90/90 UTL)

Tran-sect	Sampling Station ID	Arsenic (mg/kg)	Cadmium (mg/kg)	Total Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	Mercury (mg/kg)
	BTV	**11.00**	**0.800**	**62.0**	**45.00**	**21.00**	**50.0**	**0.240**	**93.0**	**0.200**
	Percentage of Samples Exceeding BTV	**0%**	**45%**	**3%**	**6%**	**9%**	**0%**	**47%**	**5%**	**14%**
	Minimum Site Concentration	**0.42**	**0.15**	**2.3**	**3.8**	**1.7**	**2.4**	**0.05**	**12.5**	**0.006**
	Maximum Site Concentration	**6.47**	**11.4**	**84.8**	**439**	**185**	**40.8**	**17**	**396**	**2.42**
N. 13	S.STATION78	2.25	**1.14 J**	31.8 J	14.6 J	**32.5 J**	18.4	**1.33 J**	49	0.121
N. 13	S.STATION79	3.71	0.655 J	34.9 J	11	13.4	20.4	**0.356 J**	46.3	0.066
14	S.STATION57	3.16	0.33	12.9	7.04	4.61 J	10.8	0.071	42	0.006 J
14	S.STATION58	2.37	0.259	21.6	11.5	6.15 J	17.9	0.067	36.1	0.018 J
14	S.STATION59	2.44	0.233	12.9	7.93	5.1 J	12.6	0.056	25.8	0.046

Notes:
Sediment results are reported in dry weight.
BTV - background threshold value; Ecology's BOLD Survey 90/90 UTL presented on Table 10-1 of Ecology (2015)
cm - centimeter
FD - field duplicate
ID - identification
J - The result is an estimated concentration.
UTL = upper tolerance limit
[a] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. In addition, the nomenclature for S.STATION03, S.STATION06, and S.STATION09 was modified to sampling stations S.STATION03-C, S.STATION06-C, and S.STATION09-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location S.STATION03-C is co-located with Seep C.

Table 8

Calculation and Selection of Background Threshold Values for Tissue

Metal	*n*	Units	Detect. Rate	Detect Min	Detect Max	Detect Mean	Detect Std. Dev.	Outliers at 1% Significance?	Assumed Distribution Based on GOF and Q-Q Plots	Potential BTVs						Selected BTV	Statistic[e]
										95% UTL with 95% Coverage	95% UPL (t)	90% UTL with 90% Coverage[b]	90% Percentile (z) [c]	80th percentile [d]	4 x 50th percentile [d]		
Inorganic Arsenic	22	mg/kg	22/22	0.026	0.055	0.0346	0.00657	No	Lognormal	0.0511	0.0462	0.046	0.043	0.037	0.13	0.0511	95% UTL with 95% Coverage
Cadmium	22	mg/kg	22/22	0.31	0.629	0.445	0.0718	No	Normal	0.613	0.571	0.569	0.537	0.489	1.752	0.613	95% UTL with 95% Coverage
Chromium (Including Outliers)	22	mg/kg	22/22	0.216	1.72	0.4	0.305	Yes (1.72 mg/kg)	Non-Parametric	0.962	0.748	0.741	0.611	0.424	1.372	0.529	95% UTL with 95% Coverage
Chromium (Excluding Outliers)	21	mg/kg	21/21	0.216	0.496	0.338	0.0807	No	Normal	0.529	0.48	0.479	0.441	0.395	1.316		
Copper	22	mg/kg	22/22	0.896	1.45	1.159	0.162	No	Normal	1.54	1.444	1.441	1.367	1.314	4.48	1.45	Maximum Detection
Lead (Including Outliers)	22	mg/kg	22/22	0.0132	0.0678	0.022	0.011	Yes (0.0678 mg/kg)	Non-Parametric	0.0678	0.0621	0.0295	0.0249	0.0233	0.0816	0.0298	95% UTL with 95% Coverage
Lead (Excluding Outliers)	21	mg/kg	21/21	0.0132	0.0295	0.0198	0.00422	No	Normal	0.0298	0.0272	0.0272	0.0252	0.0229	0.0792		
Methylmercury (Including Outliers)	22	mg/kg	22/22	0.0022	0.0066	0.00388	0.00086	Yes (0.0066 mg/kg)	Normal	0.00589	0.00535	0.005366	0.004975	0.00438	0.0148	0.00521	95% UTL with 95% Coverage
Methylmercury (Excluding Outliers)	21	mg/kg	21/21	0.0022	0.0046	0.00375	0.00062	No	Normal	0.005214	0.00484	0.00483	0.00454	0.0043	0.0148		
Nickel (Including Outliers)	22	mg/kg	22/22	0.229	1.2	0.399	0.191	Yes (1.2 mg/kg)	Non-Parametric	1.2	1.093	0.486	0.445	0.436	1.472	0.521	95% UTL with 95% Coverage
Nickel (Excluding Outliers)	21	mg/kg	21/21	0.229	0.486	0.361	0.0676	No	Normal	0.521	0.481	0.479	0.448	0.414	1.448		
Silver	22	mg/kg	1/22	0.0475 (RL= 0.0069)	0.0475 (RL = 0.0186)	NA	NA	NA	NA	--	--	--	--	--	--	0.0475	Maximum Detection
Zinc	22	mg/kg	22/22	13.1	17.1	15	1.181	No	Normal	17.77	17.08	17.05	16.51	16.08	59	17.1	Maximum Detection

Notes:
EPA's ProUCL Version 5.1 was used to derive 95UCLs, GOF, and BTVs. Appendix C contains the ProUCL Outputs for the BTV calcuations
95UCL - 95 percent upper confidence limit
BTV - Background threshold value
COC = chemicals of concern
EPA - United States Environmental Protection Agency

Table 8 (Continued)
Calculation and Selection of Background Threshold Values for Tissue

GOF - goodness-of-fit distribution
mg/kg = milligrams per kilogram
n = sample size
NA = Not applicable
RL = reporting limit
UTL = upper tolerance limit
WAC = Washington Administrative Code

[a] ProUCL identified outliers in the data set; therefore, the statistics are shown for the data including and excluding outliers as recommended by the EPA ProUCL technical guidance.

[b] The 90/90 UTL was used by Ecology to calculate sediment background on the 2008 BOLD data. The same methodology was used here for tissue.

[c] The 90th percentile (z) from ProUCL was included as another possible statistic.

[d] Based on methods for defining background concentrations (WAC 173-340-709), for normally distributed data, the lower of the true upper 80th percentile or four times the true 50th percentile is selected.

[e] For COCs with no outliers, the selected BTV was based on the 95% UTL with 95% coverage if the value was less than the maximum result; otherwise, the selected BTV was based on the maximum detection. For COCs with outliers, the selected BTV is based on the 95% UTL with 95% coverage calculated on the data set excluding outliers.

Table 9
Point-by-Point Comparison of Area 8 Beach Tissue Concentrations to the Tissue Background Threshold Values

Tran-sect	Sampling Station ID	Inorganic Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Methylmercury (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
	BTV	**0.0501**	**0.613**	**0.529**	**1.45**	**0.0298**	**0.00521**	**0.521**	**0.0475**	**17.1**
	Percentage of Samples Exceeding BTV	**0%**	**17%**	**37%**	**10%**	**100%**	**90%**	**39%**	**95%**	**0%**
	Minimum Site Concentration	**0.017**	**0.169**	**0.155**	**0.759**	**0.0431**	**0.001**	**0.27**	**0.0371**	**9.6**
	Maximum Site Concentration	**0.05**	**1**	**1.13**	**1.73**	**0.13**	**0.018**	**1**	**0.582**	**16.3**
1	S.STATION01	0.023	0.335	0.289	1.03	**0.0587**	**0.0058**	0.329	**0.0711**	13.6
1	S.STATION07	0.032	0.222	**0.794**	**1.52**	**0.0853** J	0.0037	**0.543**	**0.106** J	11.7
2	S.STATION02	0.029	0.351	**0.617**	1.36	**0.0793** J	**0.0091**	0.465	**0.118** J	11.9
2	S.STATION05	0.026	**0.757**	**0.953**	1.15	**0.092** J	**0.008**	**0.694**	**0.211** J	14
2	S.STATION08	0.028	0.344	**0.922**	1.35	**0.0823** J	**0.0069**	**0.683**	**0.0751** J	13.6
2	S.STATION62	0.017	0.501	0.261	0.994	**0.0502**	**0.013**	**0.844**	**0.375** J	15.1
2 & 8	S.STATION64	0.015 U	**1**	**0.61**	1.24	**0.0431**	**0.0091**	**0.735**	**0.582** J	14.7
8	S.STATION03-C[a]	0.023	**0.891**	**1.13**	1.1	**0.0641**	**0.009**	**0.614**	**0.164**	13
8	S.STATION09-C[a]	0.029	0.209	**0.779**	1.2	**0.0796** J	**0.0055**	**0.538**	**0.0678** J	13.2
3 & 8	S.STATION65	0.018	**0.613**	0.434	1.29	**0.0597**	**0.014**	**1**	**0.437** J	13.8
3	S.STATION67	0.02	**0.664**	0.183	1.08	**0.0498**	**0.018**	**0.649**	**0.364** J	13.3
3	S.STATION32	0.031	0.191	**0.917**	1.36	**0.0873** J	0.001 J	**0.567**	0.0466 J	12.6
3	S.STATION34	0.026	0.295	**0.718**	1.1	**0.0828** J	**0.0066**	**0.524**	**0.066** J	12.4
3	SEEPA[a]	0.022	0.579	0.388	0.978	**0.0617**	**0.0077**	0.291	**0.0748**	10.8
9	S.STATION70	0.017	**0.973**	0.237	1.5	**0.13**	**0.0119**	**0.53**	**0.453** J	16.3
9	OF03703	0.018	**0.867**	0.38	1.12	**0.047**	**0.009**	0.329	**0.463**	14.4
9	S.STATION35	0.027	0.21	**0.66**	1.33	**0.0799** J	**0.0071**	0.448	**0.0599** J	12.9
9	S.STATION36	0.029	0.219	**0.681**	**1.73**	**0.0858** J	**0.0068**	0.482	**0.0604** J	14.4
9	S.STATION37	0.028	0.419	0.44	1.2	**0.0862** J	**0.0093**	0.405	**0.117** J	13.9
9	S.STATION53	0.03	0.209	**0.596**	**1.48**	**0.0913**	**0.0055**	0.435	**0.0959**	12.7
9 & 10	S.STATION74	0.034	0.279	0.227	0.964	**0.0794**	**0.0117**	0.45	**0.137** J	14
10	S.STATION73	0.041	0.41	0.155	1.08	**0.0689**	**0.0114**	**0.736**	**0.508** J	15.8
10	S.STATION38	0.026	0.245	0.444	1.38	**0.0789**	0.0052	0.402	**0.0735**	14.8
10	S.STATION40	0.029	0.204	**1.03**	1.32	**0.0787**	**0.0069**	**0.584**	**0.0538**	12.7
10	S.STATION56	0.026	0.22	0.363	1.11	**0.0651** J	**0.0056**	0.341	**0.0615** J	12.9
10	SEEPD	0.023	0.336	**0.57**	1.38	**0.0727**	0.0051	0.405	**0.129**	12.9
10 & 11	S.STATION75	0.028	0.237	0.242	1.1	**0.0687**	**0.0119**	0.321	**0.0756** J	13
11	S.STATION43	0.024	0.205	0.396	1.24	**0.0687** J	**0.0069**	0.372	**0.0598** J	14.6
11	SEEPE	0.023	0.264	**0.677**	1.29	**0.06**	**0.0079**	0.364	**0.0907**	14.5
12	S.STATION46	0.03	0.169	0.375	1.4	**0.0724** J	**0.006**	0.362	**0.0474** J	15
12	SEEPF	0.025	0.256	0.471	**1.52**	**0.0651**	**0.0056**	0.42	**0.181**	13.8
13	SS-03701	0.021	0.469	0.367	1.12	**0.0672**	**0.009**	0.299	**0.366**	12.4
13	S.STATION49	0.022	0.304	0.347	1.09	**0.0749**	**0.0113**	0.315	**0.35**	12.2
13	SEEPG	0.05	0.214	0.493	1.37	**0.0846**	**0.0057**	0.385	**0.129**	13.8
S. 13	S.STATION76	0.038	0.24	0.208	1.21	**0.0742**	**0.0136**	0.315	**0.095** J	15.8
S. 13	S.STATION77A	0.034	0.197	0.205	1.05	**0.0706**	**0.0096**	0.288	**0.0955** J	11.6
N. 13	S.STATION78	0.023	0.259	0.248	1.11	**0.0831**	**0.0104**	**0.628**	**0.292** J	15.1

Table 9 (Continued)
Point-by-Point Comparison of Area 8 Beach Tissue Concentrations to the Tissue Background Threshold Values

Tran-sect	Sampling Station ID	Inorganic Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Methylmercury (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
	BTV	**0.0501**	**0.613**	**0.529**	**1.45**	**0.0298**	**0.00521**	**0.521**	**0.0475**	**17.1**
	Percentage of Samples Exceeding BTV	**0%**	**17%**	**37%**	**10%**	**100%**	**90%**	**39%**	**95%**	**0%**
	Minimum Site Concentration	**0.017**	**0.169**	**0.155**	**0.759**	**0.0431**	**0.001**	**0.27**	**0.0371**	**9.6**
	Maximum Site Concentration	**0.05**	**1**	**1.13**	**1.73**	**0.13**	**0.018**	**1**	**0.582**	**16.3**
N. 13	S.STATION79A	0.039	0.201	0.182	1.21	**0.0851**	**0.008**	0.33	**0.138** J	14.4
14	S.STATION57	0.014 U	0.398	0.163	0.759	**0.0431**	**0.0123**	**0.531** J	**0.153** J	10.3
14	S.STATION58	0.024	0.203	0.158	1.03	**0.0474**	**0.0037**	0.27	**0.139** J	9.6
14	S.STATION59	0.025	0.202	0.307	0.998	**0.0582**	**0.0066**	0.277	0.0371 J	10.9

Notes:
Tissue results are reported in wet weight.

BTV = background threshold value; See Table 8 and Appendix C for details.
ID = identification
J = The result is an estimated concentration.
mg/kg = milligrams per kilogram
[a] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. The nomenclature for S.STATION03 and S.STATION09 was also modified to sampling stations S.STATION03-C and S.STATION09-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location S.STATION03-C is co-located with Seep C.

Table 10
Summary of Population-to-Population Comparison of Site Data versus Reference Area and Background Data

Tissue								Sediment							
COC	**Area 8 Mean (n = 41)**	**Keyport Area 8 Distribution***	**PPSP Mean (n = 22)**	**PPSP Distribution[a]**	**Statistical Test H0 = Area 8 (Sample 1) <= PPSP (Sample 2) Conclusion with Alpha = 0.05**	**p-Value**	**Is Site > Background ?**	**COC**	**Area 8 Mean (n = 66)**	**Keyport Area 8 Distribution**	**BOLD Mean (n = 70)**	**BOLD Survey Distribution**	**Statistical Test H0 = Area 8 (Sample 1) <= PPSP (Sample 2) Conclusion with Alpha = 0.05**	**p-Value**	**Is Site > Background ?**
Arsenic (inorganic)	0.0271	Normal	0.0346	Lognormal	WMW	1	NO	Arsenic (total)	2.371	Not discernable	6.614	Not discernable	WMW	1	NO
Cadmium	0.375	not discernable	0.445	Normal	WMW	0.999	NO	**Cadmium**	**1.665**	**Gamma**	**0.414**	**Gamma**	WMW	**8.69E-14**	**YES**
Chromium	0.478	Gamma	0.4	Not discernable	WMW	0.107	NO	Chromium	28.65	Not discernable	32.5	Lognormal	WMW	0.656	NO
Copper [b]	1.216	Normal	1.159	Normal	t-Test	0.121	NO	Copper	19.06	Not discernable	21.75	Gamma	WMW	1	NO
Lead	**0.0723**	**Gamma**	**0.022**	**Not discernable**	WMW	**1.70E-10**	**YES**	Lead	11.64	Not discernable	9.75	Gamma	WMW	0.998	NO
Nickel	**0.476**	**Gamma**	**0.399**	**Not discernable**	WMW	**0.0156**	**YES**	Nickel	16.13	Not discernable	28.88	Lognormal	WMW	1	NO
Silver	**0.176**	**not discernable**	**0.0475 (only detected value)**	**--**	WMW	**2.44E-11**	**YES**	**Silver**	**0.872**	**Not discernable**	**0.14**	**Gamma**	WMW	**3.87E-06**	**YES**
Zinc	13.38	Gamma	15	Normal	WMW	1	NO	Zinc	41.08	Lognormal	55.31	Normal	WMW	1	NO
Methyl mercury	**0.0079**	**Normal**	**0.00388**	**Normal**	WMW	**6.29E-09**	**YES**	Mercury	0.168	Not discernable	0.124	Not discernable	WMW	0.253	NO

Notes:
Tissue concentrations are reported in mg/kg wet weight.
Sediment concentrations are reported in mg/kg dry weight.
Bolded chemicals indicate Area 8 concentrations are significantly different from background or reference area concentrations.
BOLD Survey (USACE 2009)
COC = chemicals of concern
mg/kg = milligrams per kilogram
n = sample size
PPSP = Penrose Point State Park
WMW - Wilcoxon Mann Whitney
[a] Distribution based on the Q-Q plots and goodness of fit (GOF) tests from ProUCL.
[b] Copper was normally distributed at both Area 8 and Penrose Point State Park; therefore, the T-test rather than Wilcoxon-Mann-Whitney Test was used.

Table 11
Subsistence Shellfish Ingestion Exposure Assumptions and Intake Equations

Equations:

$$\text{Chemical intake (mg/kg-day)} = CTi \times SIF$$

$$SIF_{ing\text{-}child} = \frac{SCR_c \times CF \times EF \times ED_c \times FC}{BW_c \times AT}$$

$$SIF_{ing\text{-}child/adult} = \frac{[(SCR_c \times ED_c \times 1/BW_c) + (SCR_a \times ED_a \times 1/BW_a)] \times CF \times EF \times FC}{AT}$$

Where: SIF_{ing} = summary intake factor for ingestion of tissue $(day)^{-1}$

Parameter	Definition	Value	Unit	Source
CTi	Chemical concentration in clam tissue	Chemical specific	mg/kg	Data collected in summer 2015
SCR_a	Seafood consumption rate – adult	498.4	g/day	Total 95th percentile shellfish ingestion rate (Table B-2 of USEPA 2007b)
SCR_c	Seafood consumption rate – child	83.9	g/day	95th percentile total shellfish ingestion rate (Table C-6 of Suquamish Tribe 2000)
CF	Conversion factor	1×10^{-3}	kg/g	Not applicable
EF	Exposure frequency	365	Days/year	Default value (USEPA 2014)
ED_a	Exposure duration – adult	64	Years	Default lifetime value (USEPA 2014)
ED_c	Exposure duration – child	6	Years	Default value (USEPA 1989, 1991a, 2014)
FC	Fraction consumed	1	Unitless	Default value; assumes 100% consumption from the Area 8 beach
BW_a	Body weight – adult	79	kg	Default value (USEPA 2007b; Suquamish Tribe 2000)
BW_c	Body weight – child	16.8	kg	Default value (Suquamish Tribe 2000)
AT_{nc}	Averaging time for noncarcinogenic effects	ED x 365 days/year	Days	Default value (USEPA 1989, 1991a)
AT_{ca}	Averaging time for carcinogenic effects	25,550	Days	Default value (USEPA 1989, 1991a)

Table 11 (Continued)
Subsistence Shellfish Ingestion Exposure Assumptions and Intake Equations

Notes:
SIFs are calculated separately for the combined child/adults scenario and for children. The SIF for the combined child/adult is based on an age-adjusted exposure that takes into account the differences in daily shellfish ingestion rates, body weights, and exposure duration for children and adults.
g - gram
kg - kilogram
mg - milligram

Table 12
Subsistence Sediment Exposure Assumptions and Intake Equations

Equations:

$$\text{Chemical intake (mg/kg-day)} = CSd \times SIF$$

$$SIF_{ing\text{-}child} = \frac{IR_c \times CF \times EF \times ED_c}{BW_c \times AT}$$

$$SIF_{ing\text{-}child/adult} = \frac{[(IR_c \times ED_c \times 1/BW_c) + (IR_a \times ED_a \times 1/BW_a)] \times CF \times EF}{AT}$$

$$SIF_{derm\text{-}child} = \frac{SA_c \times AF_c \times EF \times EV \times ED_c \times CF \times ABS_d}{BW_c \times AT}$$

$$SIF_{derm\text{-}child/adult} = \frac{[(SA_c \times AF_c \times ED_c \times 1/BW_c) + (SA_a \times AF_a \times ED_a \times 1/BW_a)] \times CF \times EV \times EF \times ABS_d}{AT}$$

Where: SIF_{ing} = summary intake factor for ingestion of sediment, $(day)^{-1}$
SIF_{derm} = summary intake factor for dermal contact with sediment, $(day)^{-1}$

Parameter	Definition	Value	Unit	Source
CSd	Chemical concentration in sediment	Chemical specific	mg/kg	Data collected in summer 2015
IR_a	Ingestion rate – adult	100	mg/day	Default residential soil ingestion rate (USEPA 2014)
IR_c	Ingestion rate – child	200	mg/day	Default residential soil ingestion rate (USEPA 2014)
CF	Conversion factor	1×10^{-6}	kg/mg	Not applicable
EF	Exposure frequency	350	Days/year	Site-specific value based on the number of days per year that low tide will be below +3 feet MLLW at any given time (https://tidesandcurrents.noaa.gov/noaatidepredictions/NOAATidesFacade.jsp?Stationid=9445719); EPA default residential exposure frequency value (USEPA 1989, 1991a, 2014)
ED_a	Exposure duration – adult	64	Years	Default lifetime value (USEPA 2014)
ED_c	Exposure duration – child	6	Years	Default value (USEPA 1989, 1991a, 2014)

Table 12 (Continued)
Subsistence Sediment Exposure Assumptions and Intake Equations

Parameter	Definition	Value	Unit	Source
EV	Event frequency	1	Events/day	Default value (USEPA 2014)
SA_a	Surface area – adult	6,032	cm^2	USEPA 2011a, Tables 7-2 and 7-12; weighted head, hand, and forearms average of mean values for head, hands, forearms, lower legs, and feet (male and female, 21+ years) (Forearm- and lower-leg-specific data used for males and female lower leg; ratio of male forearm to arm applied to female arm data.)
SA_c	Surface area - child	2,373	cm^2	USEPA 2011a, Tables 7-2 and 7-8; weighted average of mean values for head, hands, forearms, lower legs, and feet (male and female, birth to <6 years) (Forearm- and lower-leg-specific data used when available; ratios for nearest available age group used elsewhere [per USEPA 2011b].)
ABS_d	Dermal absorption factor	Chemical specific	Unitless	USEPA 2007a, Exhibit 3-4
AF_a	Adherence factor - adult	0.12	mg/cm^2-event	USEPA 2011b, Table 7-20 and Section 7.2.2; arithmetic mean of weighted average of body-part-specific (hands, forearms, and face) mean adherence factors for adult construction activities
AF_c	Adherence factor - child	0.2	mg/cm^2-event	Default residential value (USEPA 2014)
BW_a	Body weight – adult	79	kg	Default value (USEPA 2007b; Suquamish Tribe 2000)
BW_c	Body weight – child	16.8	kg	Default value (Suquamish Tribe 2000)
AT_{nc}	Averaging time for noncarcinogenic effects	ED x 365 days/year	Days	Default value (USEPA 1989, 1991a)
AT_{ca}	Averaging time for carcinogenic effects	25,550	Days	Default value (USEPA 1989, 1991a)

Table 12 (Continued)
Subsistence Sediment Exposure Assumptions and Intake Equations

Notes:
SIFs are calculated separately for the combined child/adult scenario and for children. The SIF for the combined child/adult is based on an age-adjusted exposure that takes into account the differences in daily shellfish ingestion rates, body weights, and exposure duration for children and adults.
cm^2 - square centimeters
g - gram
kg - kilogram
mg - milligram
MLLW - mean lower low water

Table 13
Recreational Receptor Shellfish Ingestion Exposure Assumptions and Intake Equations

Equations:

$$\text{Chemical intake (mg/kg-day)} = CTi \times SIF$$

$$SIF_{ing\text{-}child} = \frac{SCR_c \times CF \times EF \times ED_c \times FC}{BW_c \times AT}$$

$$SIF_{ing\text{-}child/adult} = \frac{[(SCR_c \times ED_c \times 1/BW_c) + (SCR_a \times ED_a \times 1/BW_a)] \times CF \times EF \times FC}{AT}$$

Where: SIF_{ing} = summary intake factor for ingestion of tissue, $(day)^{-1}$

Parameter	Definition	Value	Unit	Source
CTi	Chemical concentration in clam tissue	Chemical specific	mg/kg	Data collected in summer 2015
SCR_a	Seafood consumption rate – adult	30	g/day	Equals adult 95th percentile shellfish consumption rate (30 g/day) (see Table 12b[a])
SCR_c	Seafood consumption rate – child	12	g/day	Equals adult 95th percentile shellfish consumption rate (30 g/day) x ratio of child to adult consumption rate (0.4) (see Table 12b[a])
CF	Conversion factor	1×10^{-3}	kg/g	Not applicable
EF	Exposure frequency	120	Days/year	Kissinger 2007
ED_a	Exposure duration – adult	20	Years	Default residential exposure duration (USEPA 2014)
ED_c	Exposure duration – child	6	Years	Default value (USEPA 2014)
FC	Fraction consumed	1	Unitless	Default value; assumes 100% consumption from the Area 8 beach
BW_a	Body weight – adult	80	kg	Default value (USEPA 2014)
BW_c	Body weight – child	15	kg	Default value (USEPA 2014)
AT_{nc}	Averaging time for noncarcinogenic effects	ED x 365 days/year	Days	Default value (USEPA 1989, 1991a)
AT_{ca}	Averaging time for carcinogenic effects	25,550	Days	Default value (USEPA 1989, 1991a)

Table 13 (Continuous)
Recreational Receptor Shellfish Ingestion Exposure Assumptions and Intake Equations

Notes:
SIFs are calculated separately for combined child/adults scenario and for children. The SIF for the combined child/adult is based on an age-adjusted exposure that takes into account the differences in daily shellfish ingestion rates, body weights, and exposure duration for children and adults.
g - gram
kg - kilogram
mg - milligram
[a]http://water.epa.gov/scitech/swguidance/fishshellfish/fishadvisories/upload/Estimated-Fish-Consumption-Rates-for-the-U-S-Population-and-Selected-Subpopulations-NHANES-2003-2010.pdf.

Table 14
Recreational Receptor Sediment Exposure Assumptions and Intake Equations

Equations:

$$\text{Chemical intake (mg/kg-day)} = CSd \times SIF$$

$$SIF_{ing\text{-}child} = \frac{IR_c \times CF \times EF \times ED_c}{BW_c \times AT}$$

$$SIF_{ing\text{-}child/adult} = \frac{[(IR_c \times ED_c \times 1/BW_c) + (IR_a \times ED_a \times 1/BW_a)] \times CF \times EF}{AT}$$

$$SIF_{derm\text{-}child} = \frac{SA_c \times AF_c \times EF \times EV \times ED_c \times CF \times ABS_d}{BW_c \times AT}$$

$$SIF_{derm\text{-}child/adult} = \frac{[(SA_c \times AF_c \times ED_c \times 1/BW_c) + (SA_a \times AF_a \times ED_a \times 1/BW_a)] \times CF \times EV \times EF \times ABS_d}{AT}$$

Where: SIF_{ing} = summary intake factor for ingestion of sediment, $(day)^{-1}$

SIF_{derm} = summary intake factor for dermal contact with sediment, $(day)^{-1}$

Parameter	Definition	Value	Unit	Source
CSd	Chemical concentration in sediment	Chemical specific	mg/kg	Data collected in summer 2015
IR_a	Ingestion rate – adult	100	mg/day	Default residential soil ingestion rate (USEPA 2014)
IR_c	Ingestion rate – child	200	mg/day	Default residential soil ingestion rate (USEPA 2014)
CF	Conversion factor	1×10^{-6}	kg/mg	Not applicable
EF	Exposure frequency	120	Days/year	Kissinger 2007
ED_a	Exposure duration – adult	20	Years	Default residential exposure duration (USEPA 2014)
ED_c	Exposure duration – child	6	Years	Default value (USEPA 2014)
EV	Event frequency	1	Events/day	Default value (USEPA 2014)

Table 14 (Continued)
Recreational Receptor Sediment Exposure Assumptions and Intake Equations

Parameter	Definition	Value	Unit	Source
SA_a	Surface area – adult	6,032	cm^2	USEPA 2011a, Tables 7-2 and 7-12; weighted head, hands, and forearms average of mean values for head, hands, forearms, lower legs, and feet (male and female, 21+ years) (Forearm- and lower-leg-specific data used for males and female lower leg; ratio of male forearm to arm applied to female arm data.)
SA_c	Surface area – child	2,373	cm^2	USEPA 2011a, Tables 7-2 and 7-8; weighted average of mean values for head, hands, forearms, lower legs, and feet (male and female, birth to <6 years) (Forearm- and lower-leg-specific data used when available; ratios for nearest available age group used elsewhere [USEPA 2011b].)
ABS_d	Dermal absorption factor	Chemical specific	Unitless	Exhibit 3-4 (USEPA 2007a)
AF_a	Adherence factor – adult	0.12	mg/cm^2-event	USEPA 2011b, Table 7-20 and Section 7.2.2; arithmetic mean of weighted average of body part-specific (hands, forearms, and face) mean adherence factors for adult commercial/industrial activities
AF_c	Adherence factor – child	0.2	mg/cm^2-event	Default residential value (USEPA 2014)
BW_a	Body weight – adult	80	kg	Default value (USEPA 2014)
BW_c	Body weight – child	15	kg	Default value (USEPA 2014)
AT_{nc}	Averaging time for noncarcinogenic effects	ED x 365 days/year	Days	Default value (USEPA 1989, 1991a)
AT_{ca}	Averaging time for carcinogenic effects	25,550	Days	Default value (USEPA 1989, 1991a)

Table 14 (Continued)
Recreational Receptor Sediment Exposure Assumptions and Intake Equations

Notes:
SIFs are calculated separately for the combined child/adults scenario and for children. The SIF for the combined child/adult is based on an age-adjusted exposure that takes into account the differences in daily shellfish ingestion rates, body weights, and exposure duration for children and adults.
cm^2 - square centimeter
g - gram
kg - kilogram
mg - milligram

Table 15
Summary of Exposure Point Concentrations

COC	Reference Area (Background)[a]	EPC Basis	Notes	Area 8	EPC Basis	Notes
Sediment (mg/kg)						
Arsenic	7.42	UCL95	95% Approximate Gamma UCL	2.571	UCL95	95% Student's-t UCL
Cadmium	0.42	UCL95	95% KM Approximate Gamma UCL	2.898	UCL95	95% Chebyshev (Mean, Sd) UCL
Chromium	36.44	UCL95	95% Approximate Gamma UCL	31.58	UCL95	95% Student's-t UCL
Copper	25.35	UCL95	95% Approximate Gamma UCL	48	UCL95	95% Chebyshev (Mean, Sd) UCL
Lead	9.75 (11.1)	Mean (UCL95)	The average concentration is used to evaluate human exposures to lead; the UCL95 concentration is used to evaluate ecological exposures to lead. UCL is based on the 95% Approximate Gamma UCL	11.64 (24.94)	Mean (UCL95)	The average concentration is used to evaluate human exposures to lead; the UCL95 concentration is used to evaluate ecological exposures to lead. UCL95 calculated based on 95% Chebyshev (Mean, Sd) UCL
Mercury	0.0918	UCL95	95% KM (t) UCL	0.19	UCL95	95% H-UCL
Nickel	32.77	UCL95	95% H-UCL	17.26	UCL95	95% Student's-t UCL
Silver	0.129	UCL95	95% KM (t) UCL	2.144	UCL95	95% Chebyshev (Mean, Sd) UCL
Zinc	60.52	UCL95	95% Student's-t UCL	67.24	UCL95	95% Chebyshev (Mean, Sd) UCL
Tissue (mg/kg ww)						
Arsenic, inorganic	0.037	UCL95	95% Student's-t UCL	0.0284	UCL95	95% Student's-t UCL
Cadmium	0.471	UCL95	95% Student's-t UCL	0.533	UCL95	95% Chebyshev (Mean, Sd) UCL
Chromium	0.512	UCL95	95% Student's-t UCL	0.548	UCL95	95% Student's-t UCL
Copper	1.218	UCL95	95% Student's-t UCL	1.266	UCL95	95% Student's-t UCL
Lead	0.022 (0.026)	Mean (UCL95)	The average concentration is used to evaluate human exposures to lead; the UCL95 concentration is used to evaluate ecological exposures to lead. UCL95 is based on 95% Student's-t UCL	0.0723 (0.0766)	Mean (UCL95)	The average concentration is used to evaluate human exposures to lead; the UCL95 concentration is used to evaluate ecological exposures to lead. UCL95 is based on 95% Student's-t UCL
Methyl mercury	0.004192	UCL95	95% Student's-t UCL	0.009	UCL95	95% Student's-t UCL
Nickel	0.469	UCL95	95% Student's-t UCL	0.52	UCL95	95% Student's-t UCL
Silver	0.0475	Max detected	Insufficient data available to calculate a UCL95. Result reported is the single detection of silver in reference area tissue samples.	0.226	UCL95	95% H-UCL
Zinc	15.43	UCL95	95% Student's-t UCL	13.77	UCL95	95% Student's-t UCL

Table 15 (Continued)
Summary of Exposure Point Concentrations

Notes:
ProUCL outputs for the UCL95 calculations are presented in Appendix D.
UCL95 - 95 percent upper confidence limit of the mean
COC = chemicals of concern
EPC = exposure-point concentration
KM = Kaplan-Meier statistic
mg/kg = milligrams per kilogram
Sd = standard deviation
ww = wet weight
[a] Ecology BOLD background sediment data and reference area tissue data from Penrose Point.

Table 16
Toxicity Criteria for the Chemicals of Concern

COC	Chronic RfD (mg/kg-day)	Toxic Organ	Critical Endpoint	Critical Study	Chronic RfD UF[a]	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Criteria Source
Oral Exposures							
Arsenic (Inorganic)	3.00E-04	Cardiovascular, Dermal	Hyperpigmentation, keratosis and possible vascular complications.	chronic human	3	1.5	IRIS
Cadmium	1.0E-03	Urinary	Significant Proteinuria	chronic human	10	--	IRIS
Total Chromium (Cr III)	1.5E+00	None reported	None reported	chronic rat	100	--	IRIS
Copper	4.0E-02	NA	NA	NA	NA	--	HEAST
Mercury[b]	3.0E-04	Immune, Urinary	Autoimmune effects	subchronic rat and subcutaneaous studies	1,000	--	IRIS
Methylmercury[c]	1.0E-04	Central nervous system	Developmental neuropsychological impairment.	chronic human	10	--	IRIS
Nickel	2.0E-02	Other	Decreased body and organ weight	chronic rat	300	--	IRIS

Table 16 (Continued)
Toxicity Criteria for the Chemicals of Concern

COC	Chronic RfD (mg/kg-day)	Toxic Organ	Critical Endpoint	Critical Study	Chronic RfD UF[a]	Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Criteria Source
Oral Exposures (continued)							
Silver	5.0E-03	Dermal	Discoloration of the skin	chronic human	3	--	IRIS
Zinc	3.0E-01	Immune/Hematologic	Decreases in erythrocyte Cu, Zn-superoxide dismutase (ESOD) activity in healthy adult male and female volunteers.	chronic human	3	--	IRIS
Dermal Exposures							

COC	ABSgi[d]	Dermal RfD[e] (mg/kg-day)	Dermal Cancer Slope Factor[e] $(mg/kg\text{-}day)^{-1}$	ABSd[d]
Arsenic (Inorganic)	1	3.00E-04	1.5	0.03
Cadmium	0.025	2.5E-05	--	0.001

Table 16 (Continued)
Toxicity Criteria for the Chemicals of Concern

Notes:

COC = chemicals of concern

EPA = U.S. Environmental Protection Agency

HEAST = Health Effects Assessment Summary Table

IRIS = Integrated Risk Information System (EPA's online data base)

LOAEL = lowest-observed-adverse-effect-level

mg/kg-day = milligram per kilogram per day

NA = not available

NOAEL = no-observed-adverse-effect-level

RfD = Reference Dose

UF = Uncertainty factor

[a] EPA indicates that there are generally five areas of uncertainty where an application of a UF may be warranted:

1 variation between species (applied when extrapolating from animal to human)

2 variation within species (applied to account for differences in human response and sensitive subpopulations)

3 use of a subchronic study to evaluate chronic exposure

4 use of a LOAEL, rather than a NOAEL

5 deficiencies in the data base

[b] The RfD for methylmercury was used to evaluate mercury exposures in clam tissue, because this is the predominant form of mercury in tissue.

[c] The RfD for mercuric chloride was used for mercury.

Table 16 (Continued)
Toxicity Criteria for the Chemicals of Concern

[d] Gastrointestinal absorption factor (ABSgi) and dermal absorption factors (ABSd) were from the EPA RSL table, available online at https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016, last updated June 2016 (USEPA 2016a).
[e] The dermal RfD and dermal slope factor is derived by applying the gastrointestinal absorption factor to the oral toxicity criteria, as detailed in Section 3.2.3 and recommended in USEPA (2007a).

Table 17
Summary of Risks and Hazards for Suquamish Receptors

	Noncancer Hazards						Cancer Risks		
	Area 8		Reference Area		Incremental				
COC	Child	Child-Adult	Child	Child-Adult	Child	Child-Adult	Area 8	Reference Area	Incremental
Tissue - Ingestion									
Arsenic, inorganic	0.47	0.59	0.62	0.76	None[a]	None[a]	2.6E-04	3.4E-04	None[a]
Cadmium	2.7	3.3	2.4	2.9	0.31	0.38	--	--	--
Chromium, trivalent	0.0018	0.0023	0.0017	0.0021	0.00012	0.00015	--	--	--
Copper	0.16	0.20	0.15	0.19	0.0060	0.0074	--	--	--
Methyl mercury	0.46	0.57	0.21	0.26	0.25	0.31	--	--	--
Nickel	0.13	0.16	0.12	0.15	0.013	0.016	--	--	--
Silver	0.23	0.28	0.047	0.059	0.18	0.22	--	--	--
Zinc	0.23	0.28	0.26	0.32	None[a]	None[a]	--	--	--
TOTAL	**4.3**	**5.4**	**3.8**	**4.7**	**0.59**	**0.73**	**2.6E-04**	**3.4E-04**	**None[a]**
Sediment - Ingestion + Dermal									
Arsenic	0.068	0.014	0.20	0.040	None[a]	None[a]	6.3E-06	1.8E-05	None[a]
Cadmium	0.038	0.0076	0.0055	0.0011	0.032	0.0065	--	--	--
Chromium, trivalent	0.00025	0.000046	0.00029	0.000053	None[a]	None[a]	--	--	--
Copper	0.014	0.0026	0.0075	0.0014	0.0067	0.0012	--	--	--
Mercury	0.0075	0.0014	0.0036	0.00067	0.0039	0.00071	--	--	--
Nickel	0.010	0.0019	0.020	0.0036	None[a]	None[a]	--	--	--
Silver	0.0051	0.00093	0.00031	0.000056	0.0048	0.00088	--	--	--
Zinc	0.0027	0.00049	0.0024	0.00044	0.00027	0.000049	--	--	--
TOTAL	**0.15**	**0.029**	**0.24**	**0.048**	**None[a]**	**None[a]**	**6.3E-06**	**1.8E-05**	**None[a]**
Cumulative - Tissue + Sediment									
TOTAL	**4.5**	**5.4**	**4.0**	**4.7**	**0.50**	**0.71**	**2.7E-04**	**3.6E-04**	**None[a]**

Notes:
Though EPA (1989) guidance recommends presentation of risks and hazards to one significnat figure, two significant figures are presented to provide greater detail.
Presentation of more than one significant figure does not imply a higher level of accuracy and confidence in the total hazard/risk estimations
Cumulative risks and hazards were calculated on unrounded numbers, thus the cumulative values presented may vary slightly from summation of the rounded values.
Cumulative incremental hazards were calculated as the difference between the cumulative site and cumulative reference area hazards.
COC - Chemical of concern
[a] There are no incremental risks or hazards for these COCs because the reference area risk or hazard equals or exceeds the site risk or hazard.

Table 18
Summary of Risks and Hazards for Recreational Receptors

	Noncancer Hazards						Cancer Risks		
	Area 8		Reference Area		Incremental				
COC	Child	Child-Adult	Child	Child-Adult	Child	Child-Adult	Area 8	Reference Area	Incremental
Tissue - Ingestion									
Arsenic, inorganic	0.025	0.015	0.032	0.019	None[a]	None[a]	2.5E-06	3.2E-06	None[a]
Cadmium	0.14	0.083	0.12	0.073	0.016	0.010	--	--	--
Chromium, trivalent	0.00010	0.000057	0.000090	0.000053	0.0000063	0.0000037	--	--	--
Copper	0.0083	0.0049	0.0080	0.0047	0.00032	0.00019	--	--	--
Methyl mercury	0.024	0.014	0.011	0.0065	0.013	0.0078	--	--	--
Nickel	0.0068	0.0040	0.0062	0.0036	0.00067	0.00040	--	--	--
Silver	0.012	0.0070	0.0025	0.0015	0.0094	0.0056	--	--	--
Zinc	0.012	0.0071	0.014	0.0080	None[a]	None[a]	--	--	--
TOTAL	**0.23**	**0.14**	**0.20**	**0.12**	**0.031**	**0.018**	**2.5E-06**	**3.2E-06**	**None[a]**
Sediment - Ingestion + Dermal									
Arsenic	0.025	0.0080	0.073	0.023	None[a]	None[a]	3.6E-06	3.9E-06	None[a]
Cadmium	0.014	0.0044	0.0020	0.00064	0.012	0.0038	--	--	--
Chromium, trivalent	0.000092	0.000028	0.00011	0.000032	None[a]	None[a]	--	--	--
Copper	0.0053	0.0016	0.0028	0.00084	0.0025	0.00075	--	--	--
Mercury	0.0028	0.00084	0.0013	0.00041	0.0014	0.00043	--	--	--
Nickel	0.0038	0.0011	0.0072	0.0022	None[a]	None[a]	--	--	--
Silver	0.0019	0.00057	0.00011	0.000034	0.0018	0.00054	--	--	--
Zinc	0.0010	0.00030	0.00088	0.00027	0.00010	0.000030	--	--	--
TOTAL	**0.054**	**0.017**	**0.087**	**0.028**	**None[a]**	**None[a]**	**3.6E-06**	**3.9E-06**	**None[a]**
Cumulative - Tissue + Sediment									
TOTAL	**0.28**	**0.15**	**0.28**	**0.14**	**None[a]**	**0.0076**	**6.1E-06**	**7.1E-06**	**None[a]**

Notes:
Though EPA (1989) guidance recommends presentation of risks and hazards to one significnat figure, two significant figures are presented to provide greater detail.
Presentation of more than one significant figure does not imply a higher level of accuracy and confidence in the total hazard/risk estimations
Cumulative risks and hazards were calculated on unrounded numbers, thus the cumulative values presented may vary slightly from summation of the rounded values.
Cumulative incremental hazards were calculated as the difference between the cumulative site and cumulative reference area hazards.
COC - Chemical of concern
[a] There are no incremental risks or hazards for these COCs because the reference area risk or hazard exceeds the site risk or hazard.

Table 19
IEUBK Model Inputs

IEUBK MODEL WORKSHEET			
SITE OR PROJECT: Keyport Area 8	**Model Version :** ver 1.1 Build 11	**Date:** 2/1/2017	
Model Run Control Number:	**Site Description:** Subsistence Scenario Sediment and Tissue		
PARAMETER	**DEFAULT VALUE**	**USER SELECTED OPTION BKGRD / SITE**	**UNITS**
AIR (constant)			
Outdoor air lead concentration	0.10	Model Default (USEPA 2007)	ug/m^3
Ratio of indoor to outdoor air lead concentration	30	Model Default (USEPA 2007)	%
AIR (by year)			
Air concentration Age = 0-1 year (0-11 mo) 1-2 years (12-23 mo) 2-3 years (24-35 mo) 3-4 years (36-47 mo) 4-5 years (48-59 mo) 5-6 years (60-71 mo) 6-7 years (72-84 mo)	 0.10 0.10 0.10 0.10 0.10 0.10 0.10	 Model Default (USEPA 2007)	ug/m^3
Time outdoors Age = 0-1 year (0-11 mo) 1-2 years (12-23 mo) 2-3 years (24-35 mo) 3-7 years (36-83 mo)	 1 2 3 4	 Model Default (USEPA 2007)	h/day

Table 19 (Continued)
IEUBK Model Inputs

IEUBK MODEL WORKSHEET			
SITE OR PROJECT: Keyport Area 8	**Model Version :** ver 1.1 Build 11	**Date:** 2/1/2017	
Model Run Control Number:	**Site Description:** Subsistence Scenario Sediment and Tissue		
PARAMETER	**DEFAULT VALUE**	**USER SELECTED OPTION BKGRD / SITE**	**UNITS**
Ventilation rate Age = 0-1 year (0-11 mo) 1-2 years (12-23 mo) 2-3 years (24-35 mo) 3-4 years (36-47 mo) 4-5 years (48-59 mo) 5-6 years (60-71 mo) 6-7 years (72-84 mo)	 2 3 5 5 5 7 7	 Model Default (USEPA 2007)	m^2/day
Lung absorption	32	Model Default (USEPA 2007)	%
DATA ENTRY FOR DIET (by year)			
Dietary lead intake Age = 0-1 year (0-11 mo) 1-2 years (12-23 mo) 2-3 years (24-35 mo) 3-4 years (36-47 mo) 4-5 years (48-59 mo) 5-6 years (60-71 mo) 6-7 years (72-84 mo)	 2.26 1.96 2.13 2.04 1.95 2.05 2.22	 Model Default (USEPA 2007)	ug Pb /day
DATA ENTRY FOR ALTERNATE DIET SOURCES (by food class)			
Concentration: home-grown fruits • home-grown fruits • home-grown vegetables • fish from fishing (clam tissue Pb conc.) • game animals from hunting	 0 0 0 0	 0 0 Average lead tissue concentration from site 0	ug Pb/g

Table 19 (Continued)
IEUBK Model Inputs

IEUBK MODEL WORKSHEET			
SITE OR PROJECT: Keyport Area 8	**Model Version :** ver 1.1 Build 11	**Date:** 2/1/2017	
Model Run Control Number:	**Site Description:** Subsistence Scenario Sediment and Tissue		
PARAMETER	**DEFAULT VALUE**	**USER SELECTED OPTION BKGRD / SITE**	**UNITS**
Percent of food class: • home-grown fruits • home-grown vegetables • fish from fishing (shellfish) • game animals from hunting	 0 0 0 0	 0 0 15.43 (see discussion in Section 3.3.4) 0	%
DATA ENTRY FOR DRINKING WATER			
Lead concentration in drinking water	4	Model Default	ug/L
Ingestion rate Age = 0-1 year (0-11 mo) 1-2 years (12-23 mo) 2-3 years (24-35 mo) 3-4 years (36-47 mo) 4-5 years (48-59 mo) 5-6 years (60-71 mo) 6-7 years (72-84 mo)	 0.20 0.50 0.52 0.53 0.55 0.58 0.59	 Model Default (USEPA 2007)	liters/day
DATA ENTRY FOR ALTERNATE DRINKING WATER SOURCES			
Concentration first-draw water flushed water fountain	 4 1 10	 Model Default (USEPA 2007)	ug/L

Table 19 (Continued)
IEUBK Model Inputs

IEUBK MODEL WORKSHEET			
SITE OR PROJECT: Keyport Area 8	**Model Version :** ver 1.1 Build 11	**Date:** 2/1/2017	
Model Run Control Number:	**Site Description:** Subsistence Scenario Sediment and Tissue		
PARAMETER	**DEFAULT VALUE**	**USER SELECTED OPTION BKGRD / SITE**	**UNITS**
Percentage of total intake first-draw water flushed water (not a user entry; calculated based on entries for first-draw and fountain percentages) fountain water	 50 100 minus first draw and fountain 15	 Model Default (USEPA 2007)	%
DATA ENTRY FOR SOIL/DUST (constant)			
Concentration Soil Dust	 200 200	 Model Default (USEPA 2007)	ug/g
Soil ingestion as percent of total soil and dust ingestion	45	Model Default (USEPA 2007)	%
DATA ENTRY FOR SOIL/DUST INGESTION (by year)			
Soil/dust ingestion Age = 0-1 year (0-11 mo) 1-2 years (12-23 mo) 2-3 years (24-35 mo) 3-4 years (36-47 mo) 4-5 years (48-59 mo) 5-6 years (60-71 mo) 6-7 years (72-84 mo)	 0.085 0.135 0.135 0.135 0.100 0.090 0.085	 Model Default (USEPA 2007)	g/day

Table 19 (Continued)
IEUBK Model Inputs

IEUBK MODEL WORKSHEET			
SITE OR PROJECT: Keyport Area 8	**Model Version :** ver 1.1 Build 11	**Date:** 2/1/2017	
Model Run Control Number:	**Site Description:** Subsistence Scenario Sediment and Tissue		
PARAMETER	**DEFAULT VALUE**	**USER SELECTED OPTION BKGRD / SITE**	**UNITS**
DATA ENTRY FOR SOIL (by year)			
Soil lead concentration			ug/g
Age = 0-1 year (0-11 mo)	0	0	
1-2 years (12-23 mo)	0	0	
2-3 years (24-35 mo)	0	0	
3-4 years (36-47 mo)	0	0	
4-5 years (48-59 mo)	0	0	
5-6 years (60-71 mo)	0	0	
6-7 years (72-84 mo)	0	0	
DATA ENTRY FOR DUST (by year)			
Dust lead concentration			ug/g
Age = 0-1 year (0-11 mo)	0	0	
1-2 years (12-23 mo)	0	0	
2-3 years (24-35 mo)	0	0	
3-4 years (36-47 mo)	0	0	
4-5 years (48-59 mo)	0	0	
5-6 years (60-71 mo)	0	0	
6-7 years (72-84 mo)	0	0	
DATA ENTRY FOR SOIL/DUST MULTIPLE SOURCE ANALYSIS (constant)			
Ratio of dust lead concentration to soil lead concentration	0.70		unitless
Ratio of dust lead concentration to outdoor airlead concentration	100	Model Default (USEPA 2007)	ug Pb/g dust per ug Pb/m^3_{air}

Table 19 (Continued)
IEUBK Model Inputs

IEUBK MODEL WORKSHEET			
SITE OR PROJECT: Keyport Area 8	**Model Version :** ver 1.1 Build 11	**Date:** 2/1/2017	
Model Run Control Number:	**Site Description:** Subsistence Scenario Sediment and Tissue		
PARAMETER	**DEFAULT VALUE**	**USER SELECTED OPTION BKGRD / SITE**	**UNITS**
DATA ENTRY FOR SOIL/DUST MULTIPLE SOURCE ANALYSIS WITH ALTERNATIVE HOUSEHOLD DUST LEAD SOURCES (constant)			
Concentration household dust (calculated)secondary occupational dustschool dust daycare center dustsecond home interior lead-based paint	 150 1,200 200 200 200 1,200	 Model Default (USEPA 2007)	ug/g
Percentage household dust (calculated)secondary occupational dustschool dust daycare center dustsecond home interior lead-based paint	 100 minus all other 0 0 0 0 0	 Model Default (USEPA 2007)	%
BIOAVAILABILITY DATA ENTRY FOR ALL GUT ABSORPTION PATHWAYS			
Total lead absorption (at low intake) diet drinking watersoil dust alternate source	 50 50 30 30 0	 Model Default (USEPA 2007)	%

Table 19 (Continued)
IEUBK Model Inputs

IEUBK MODEL WORKSHEET			
SITE OR PROJECT: Keyport Area 8	**Model Version :** ver 1.1 Build 11	**Date:** 2/1/2017	
Model Run Control Number:	**Site Description:** Subsistence Scenario Sediment and Tissue		
PARAMETER	**DEFAULT VALUE**	**USER SELECTED OPTION BKGRD / SITE**	**UNITS**
Fraction of lead absorbed passively at high intakediet drinking watersoil dust alternate source	 0.2 0.2 0.2 0.2 0.2	 Model Default (USEPA 2007)	unitless
DATA ENTRY FOR ALTERNATE SOURCES (by year)			
Total lead intake Age = 0-1 year (0-11 mo) 1-2 years (12-23 mo) 2-3 years (24-35 mo) 3-4 years (36-47 mo) 4-5 years (48-59 mo) 5-6 years (60-71 mo) 6-7 years (72-84 mo)	 0 0 0 0 0 0 0	Model Default (USEPA 2007)	ug/day
DATA ENTRY MENU FOR MATERNAL-TO-NEWBORN LEAD EXPOSURE			
Mother's blood lead level at time of birth	1.0	Model Default (USEPA 2007)	ug/dL
DATA ENTRY MENU FOR PLOTTING AND RISK ESTIMATION			
Geometric standard deviation for blood lead,GSD	1.8	EPA Default (USEPA 2009)	unitless
Blood lead level of concern, or cutoff	10	Default	ug/dL

Table 19 (Continued)
IEUBK Model Inputs

IEUBK MODEL WORKSHEET			
SITE OR PROJECT: Keyport Area 8	**Model Version :** ver 1.1 Build 11	**Date:** 2/1/2017	
Model Run Control Number:	**Site Description:** Subsistence Scenario Sediment and Tissue		
PARAMETER	**DEFAULT VALUE**	**USER SELECTED OPTION BKGRD / SITE**	**UNITS**
COMPUTATION OPTIONS			
Iteration time step for numerical integration	4	Not Applicable	h

Notes:
Red font indicates site-specific input value
dL - deciliter
EPA - U.S. Environmental Protection Agency
g - gram
GSD - geometric standard deviation
h - hours
L - liter
m^2 - square meters
m^3 - cubic meters
ug – microgram

Table 20
Assessment and Measurement Endpoints

Assessment Endpoint	Medium	Measures of Effect
Survival, reproduction, and health of benthic organisms	Sediment	• Comparison of measured concentrations in sediment to conservative sediment risk-based screening benchmarks • Comparison of the sum of simultaneously extracted divalent metals to concentrations of acid volatile sulfides to assess bioavailable fraction of divalent metals • Evaluation of existing bioassay data
	Seep Water	• Used as a line of evidence to assess seep data in conjunction with AVS/SEM as a potential source for metals accumulation in shellfish tissue.
	Clam Tissue	• Comparison of measured concentrations of metals in littleneck clam tissue to critical tissue levels and statistical comparison to Penrose Point Reference Area Concentrations.
	Biota	• Evaluation of shellfish abundance reported in the 2007 sustainable harvest and 2014 shellfish abundance studies.
Survival, reproduction, and health of aquatic plants, invertebrates, and fish	Marine Surface Water	• Comparison of measured concentrations in ~~seep or~~ surface water to conservative risk-based water quality benchmarks
	Seep Water	• Comparison of measured concentrations in seep water to conservative risk-based water quality benchmarks
Survival, reproduction, and health of semiaquatic birds and mammals	Sediment and Clam Tissue	• Calculation of hazard quotients based on average daily doses for indicator bird and mammal species and comparison to chemical- and receptor-specific TRVs

Notes:
TRV - toxicity reference value
AVS/SEM = acid-volatile sulfide/simultaneous extracted metals

Table 21
Exposure Assumptions and Dose Equations for the Northwestern Crow

Equation:

$$D = \frac{SUF \times (C_{F1} \times P_{F1} \times IR_{F1}) + (C_S \times IR_S)}{BW}$$

Where:

D = chemical dose (mg/kg-BW/day)
SUF = site use factor
C_{F1} = measured concentrations in clam tissue
$IR_F = 0.522 \times BW\ (\text{in grams})^{0.769} \times 0.001$[a]
$IR_S = 0.1 \times IR_F$

Parameter	Definition	Value	Unit	Source
C_{F1}	Chemical concentration in food item 1 (invertebrates)	UCL95 of measured concentration in littleneck clams	mg/kg dry	Analytical data.
C_s	UCL95 chemical concentration in sediment	Chemical specific	mg/kg dry	Analytical data.
SUF	Site use factor	1	Unitless	Assumed present 100% of the time.
P_{F1}	Proportion of food item 1 (clams)	1	Unitless	Diet assumed 100% clams.
IRs	Ingestion rate - sediment	0.00462	kg dry/day	Based on 10% of total food ingestion rate. Incidental ingestion rate for the woodcock in Beyer, Connor, and Gerould (1994) was presumed comparable to the crow.
IR_F	Ingestion rate - all food	0.0462	kg dry/day	Nagy 2001 for gulls and other shorebirds.
BW	Body weight	0.34	kg	Lower range of weights for the northwestern crow reported by Vancouver Avian Research Centre (http://birdvancouver.com/b_northwestern_crow.html).

Table 21 (Continued)
Exposure Assumptions and Dose Equations for the Northwestern Crow

Notes:
kg - kilogram
kg dry/day - kilogram per day in dry weight
mg/kg - milligram per kilogram
UCL - upper confidence limit at the 95th percentile
[a]Allometric relationships based on grams of body weight for gulls and other shorebirds.
Sources: Beyer, Connor, and Gerould 1994; USEPA 1993; and Nagy 2001.

Table 22
Exposure Assumptions and Dose Equations for the River Otter

Equation:

$$D = \frac{SUF \times (C_{F1} \times P_{F1} \times IR_{F1}) + (C_S \times IR_S)}{BW}$$

Where:

D = chemical dose (mg/kg-BW-day)
SUF = site use factor
C_{F1} = measured chemical concentration in clams
$IR_F = 0.153 \times BW \text{ (in grams)}^{0.834} \times 0.001$[a]
$IR_S = 0.02 \times IR_F$

Parameter	Definition	Value	Units	Source
C_{F1}	Chemical concentration in food item 1 (invertebrates)	UCL95 of measured concentration in littleneck clams	mg/kg dry	Analytical data.
C_s	UCL95 chemical concentration in sediment	Chemical specific	mg/kg dry	Analytical data.
SUF	Site use factor	1	Unitless	Assumed present 100% of the time.
P_{F1}	Proportion of food item 1 (clams)	1	Unitless	Diet assumed 100% clams.
IR_s	Ingestion rate - sediment	0.02241	kg dry/day	Based on 9.4% of total food ingestion rate for the raccoon (Beyer, Connor, and Gerould 1994).
IR_F	Ingestion rate - all food	0.24	kg dry/day	Nagy 2001 for carnivores.
BW	Body weight	6.73	kg	Lower range of reported weights for adult female (USEPA 1993).

Notes:
kg - kilogram
kg dry/day - kilogram per day in dry weight
mg/kg - milligram per kilogram
UCL - upper confidence limit at the 95th percentile
[a]Allometric relationships based on grams of body weight for carnivores.
Sources: Beyer, Connor, and Gerould 1994; Nagy 2001; USEPA 1993.

Table 23
Summary of Surface Water and Sediment Benchmarks

Chemical	Surface Water Benchmark [a] (µg/L)	Sediment Benchmarks [b] (mg/kg dry weight)
Arsenic	36	57
Cadmium	7.9	5.1
Chromium	50[c]	260
Copper	3.1	390
Lead	8.1	450
Mercury	0.025	0.41
Nickel [d]	8.2	20.9/51.6
Silver	0.19/1.5[e]	6.1
Zinc	81	410

Notes:
µg/L = micrograms per liter
mg/kg = milligrams per kilogram
USEPA = United State Environmental Protection Agency

[a] Surface water benchmarks are from WAC-173-201A-240, except cadmium which is based on the current recommended USEPA continuous ambient water quality criterion (AWQC) to reflect the most current value and silver which is based on the maximum AWQC divided by 10 because a continuous AWQC for long term exposure has not been established (https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table).

[b] All sediment benchmarks are Washington State SCOs (WAC 173-204-320), except nickel for which no SCO has been established.

[c] The surface water quality criteria for chromium applies to Chromium VI.

[d] National Oceanic and Atmospheric Administration effects range low/effects range median

[e] Second value is based on British Columbia Environment Protection Department. 1996. Ambient Water Quality Criteria for Silver, Section 2(e) of the Environment Management Act, 1981, February 19.

Table 24
Tissue Screening Criteria Levels for Protection of Clams

CAS ID	Chemical	CTL[a] (mg/kg wet weight)
7440-38-2	Arsenic	1.6
18540-29-9	Cadmium	0.15
7440-47-3	Chromium	NE
7440-50-8	Copper	NE
7439-92-1	Lead	0.4
7439-97-6	Mercury	0.18
22967-92-6	Methylmercury	0.18
7440-02-0	Nickel	NE
7440-22-4	Silver	NE
7440-66-6	Zinc	NE

Notes:
ID - Identification
CAS - Chemical Abstract Service
CTL - critical tissue level
mg/kg - milligram per kilogram
NE - not established
[a]CTLs are from Oregon Department of Environmental Quality (ODEQ) Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment. April 3, 2007.

Table 25
Wildlife Toxicity Reference Values

Birds				
Chemical	**NOAEL-Based TRV**	**Source**	**LOAEL-Based TRV**	**Source**
Arsenic	2.24	EcoSSL	11.2	ODEQ
Cadmium	1.47	EcoSSL	6.34	LWG
Chromium III	2.66	EcoSSL	15.6	LWG
Chromium VI	NA	NA[a]	NA	NA[a]
Copper	4.05	EcoSSL	29	LWG
Lead	1.63	EcoSSL	3.26	LWG
Methylmercury	0.018	LDW	0.091	LWG
Nickel	6.71	EcoSSL	56.3	BTAG
Silver	2.02	EcoSSL	10.1	ODEQ
Zinc	66.1	EcoSSL	171	LWG
Mammals				
Chemical	**NOAEL-Based TRV**	**Source**	**LOAEL-Based TRV**	**Source**
Arsenic	1.04	EcoSSL	5.2	ODEQ
Cadmium	0.77	EcoSSL	3.85	ODEQ
Chromium III	2.4	EcoSSL	12	ODEQ
Chromium VI	9.24	EcoSSL	46.2	ODEQ
Copper	5.6	EcoSSL	9.34	LWG
Lead	4.7	EcoSSL	23.5	ODEQ
Methylmercury	0.02	LWG	0.07	LWG
Nickel	1.7	EcoSSL	20	LDW
Silver	6.02	EcoSSL	30.1	ODEQ
Zinc	75.4	EcoSSL	320	LDW

Notes:
All units are in milligrams per kilogram body weight per day (mg/kg-BW/day).
BTAG = Biological Technical Assistance Group (EPA Region 9)
EcoSSL = ecological soil screening level
EPA = U.S. Environmental Protection Agency
LDW = Lower Duwamish Waterway baseline ecological risk assessment (Windward 2007)
LOAEL = lowest observed adverse effect level
LWG = Lower Willamette Group (LWG 2011)
NA = not available
NOAEL = no observed adverse effect level
ODEQ = Oregon Department of Environmental Quality
TRV = toxicity reference value
[a] Assess as total chromium

Table 26
Hazard Quotients Based on Maximum Area 8 Beach Marine Water Concentrations and Surface Water Benchmarks for Protection of Aquatic Organisms

Chemical	Maximum Concentration in Marine Water (ug/L)	Surface Water Benchmark [a] (ug/L)	Hazard Quotient
Arsenic	1.58	36	0.04
Cadmium	1.57	7.9	0.2
Chromium	0.86	50	0.02
Copper	1.34	3.1	0.4
Lead	0.099	8.1	0.01
Mercury	0.00372	0.025	0.1
Nickel	1.01	8.2	0.1
Silver	0.051	0.19/1.5 [b]	0.3/0.03 [b]
Zinc	3.59	81	0.04

Notes:
µg/L - micrograms per liter

[a] Surface water benchmarks are from WAC-173-201A-240, except cadmium which is based on the current recommended USEPA continuous ambient water quality criterion (AWQC) and silver which is based on the maximum AWQC divided by 10 (https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table).

[b] Second value is based on British Columbia Environment Protection Department. 1996. Ambient Water Quality Criteria for Silver, Section 2(e) of the Environment Management Act, 1981, February 19.

Table 27
Exceedances of Surface Water Benchmarks for Area 8 Beach Seeps and Outfalls

Sampling Station ID	Sample Date	Sample No.	Sample Type	Dissolved Arsenic (µg/L)	Dissolved Cadmium (µg/L)	Dissolved Chromium, Total (µg/L)	Dissolved Copper (µg/L)	Dissolved Lead (µg/L)	Dissolved Nickel (µg/L)	Dissolved Silver (µg/L)	Dissolved Zinc (µg/L)	Dissolved Mercury (µg/L)
Surface Water Benchmark [a]				**36**	**7.9**	**50**	**3.1**	**8.1**	**8.2**	**0.19/1.5[b]**	**81**	**0.025**
Maximum				2.51	**45.7**	9.68	**5.39**	0.355	1.81	**0.58**	54.9	0.0141
OF03701	2015-06-16	OF03701-OF15	N/FD[c]	1.6 J	6.91	8.25	**5.39**	0.355	1.16	0.58 [d] J	54.9	0.00534
SEEPC[e]	2015-06-15	SEEPA-SW15	N	1.26	**45.7**	9.68	1.88	0.047	1.65	0.057	1.63	0.00849
SEEPB	2015-06-15	SEEPB-SW15	N	1.44	0.321	2.61	1.13	0.026	0.93	0.021	1.24	0.0010
SEEPA[e]	2015-06-15	SEEPC-SW15	N	1.55	2.41	1.21	0.687	0.089	1.81	0.016 J	1.43	0.00866
SEEPD	2015-06-15	SEEPD-SW15	N	0.71	0.003 U	0.42	0.132 U	0.01 U	0.53	0.003 J	1.38	0.00589
SEEPE	2015-06-15	SEEPE-SW15	N	1.76	0.015 J	0.2 J	0.345	0.027	0.53	0.003 J	0.54 U	0.0141
SEEPF	2015-06-16	SEEPF-SW15	N/FD[c]	2.51	0.038 J	0.34 J	0.492	0.028 J	0.78	0.013 J	1.49 J	0.00256
SEEPG	2015-06-17	SEEPG-SW15	N	2.28	0.044	0.25	0.438	0.017 J	0.96	0.008 J	1.24	0.00129

Notes:

Bold indicates exceedance of the surface water benchmark.

FD = field duplicate

ID = Identification

J = The result is an estimated concentration.

µg/L = microgram per liter

N = normal environmental sample

No. = number

U = The compound was analyzed for, but was not detected ("nondetect") at or above the method reporting limit/method detection limit.

[a] Surface water benchmarks are from WAC-173-201A-240, except cadmium which is based on the current recommended USEPA continuous ambient water quality criterion (AWQC) and silver which is based on the criterion maximum concentration AWQC divided by 10 (https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table).

[b] Second value is based on British Columbia Environment Protection Department. 1996. Ambient Water Quality Criteria for Silver, Section 2(e) of the Environment Management Act, 1981, February 19.

[c] When there are duplicates, the maximum of the primary and duplicate results is presented.

[d] Value exceeds the maximum USEPA AWQC divided by 10, but not the chronic British Columbia AWQC.

[e] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8.

Table 28

Hazard Quotients Based on Maximum Area 8 Beach Seep Water Concentrations and Surface Water Benchmarks for Protection of Aquatic Organisms

Chemical	Maximum Concentration in Seep Water (µg/L)	Surface Water Benchmark [a] (µg/L)	Hazard Quotient	Locations Exceeding Water Benchmarks
Arsenic	2.51	36	0.07	--
Cadmium	45.7	7.9	**5.8**	Seep C[c]
Chromium	9.68	50	0.2	--
Copper	5.39	3.1	**1.7**	Outfall-03-701
Lead	0.355	8.1	0.04	--
Mercury	0.0141	0.025	0.6	--
Nickel	1.81	8.2	0.2	--
Silver	0.580	0.19/1.5 [b]	**3.1**/0.4 [b]	Outfall-03-701
Zinc	54.9	81	0.7	--

Notes:

Bold indicates a hazard quotient greater than 1.0.

[a] Surface water benchmarks are from WAC-173-201A-240, except cadmium which is based on the current recommended USEPA continuous ambient water quality criterion (AWQC) and silver which is based on the maximum AWQC divided by 10 (https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table).

[b] Second value is based on British Columbia Environment Protection Department. 1996. Ambient Water Quality Criteria for Silver, Section 2(e) of the Environment Management Act, 1981, February 19.

[c] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8.

Table 29
Exceedances of Sediment Benchmarks for the Area 8 Beach

Tran-sect	Sampling Station ID	Sample Date	Sample No.	Sample Depth (cm)	Sample Type	Arsenic (mg/kg)	Cadmium (mg/kg)	Total Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	Mercury (mg/kg)
					Sediment Benchmark [a]	**57**	**5.1**	**260**	**390**	**450**	**20.9**	**6.1**	**410**	**0.41**
					Maximum [b]	6.47	**11.4**	84.8	**439**	185	**40.8**	**17**	396	**2.42**
1	S.STATION01	2015-06-15	SS01-SD15	0-10	N	1.92	0.343 J	18.1 J	8.51 J	4.13	16.5	0.136	31.8 J	0.011 J
1	S.STATION04	2015-06-15	SS04-SD15	0-10	N	2.03	0.395 J	22 J	7.75 J	5.59	15.6	0.714	28.6 J	0.032
1	S.STATION07	2015-06-17	SS07-SD15	0-10	N	3.33	0.41	19 J	14.8 J	4.43	17.5	0.059	30.6	0.038
1	S.STATION07	2015-06-17	SS07-SD15B	10-24	N	2.87	0.309	19.6 J	7.41 J	4.18	16.3	0.061	26.3	0.037
1	S.STATION60	2016-06-21	SS60-SD16	0-10	N/FD[c]	3.22	0.325	22.3 J	8.11	5.62 J	16.5	0.074 J	30.5	0.048
1	S.STATION55	2015-06-16	SS55-SD15	0-10	N	2.12	0.152 J	8.03 J	8.17 J	3.23	**23.6**	0.048	18.2 J	0.025
1	S.STATION10	2015-06-17	SS10-SD15	0-10	N	3.43	0.284	11.2	7.92	4.73	9.31	0.068	21.4	0.033
1 & 2	S.STATION61	2016-06-21	SS61-SD16	0-10	N	1.28	0.306	13.4	10.9	14.4 J	13.7	0.072	40.2	0.011 J
2	S.STATION62	2016-06-21	SS62-SD16	0-10	N	1.57	0.484	21.1	12.5	6.18 J	19.8	0.124	44.5	0.015 J
2	S.STATION63	2016-06-21	SS63-SD16	0-10	N	1.52	0.385	19.8	11.4	4.73 J	19.1	0.116	37.9	0.111
2	S.STATION02	2015-06-17	SS02-SD15	0-10	N	2.56	1.61	29.9 J	10.6 J	3.79	12.3	0.283	24.7	0.05
2	S.STATION05	2015-06-17	SS05-SD15	0-10	N	2.53	3	34.7 J	8.57 J	4.6	20.1	1.12	31.6	0.033
2	S.STATION08	2015-06-17	SS08-SD15	0-10	N	2.18	2.84	45 J	8.92 J	4.62	17.4	0.857	30.2	**1.67**
2	S.STATION08	2015-06-17	SS08-SD15B	10-24	N	2.09	3.02	35 J	7.67 J	4.94	17.1	0.829	29.6	0.038
2	S.STATION30	2015-06-17	SS30-SD15	0-10	N	2.12	0.289	19.9 J	7.73 J	5.76	**21.1**	0.068	25.1	0.031
2	S.STATION11	2015-06-16	SS11-SD15	0-10	N	3.37	0.258 J	12.5 J	6.64 J	4	12.4	0.072	21.5 J	0.034
2 & 8	S.STATION64	2016-06-21	SS64-SD16	0-10	N	1.22	2.71	18.9	11.5	5.67 J	18.8	0.208	63.8	0.082
8	S.STATION50	2015-06-15	SS50-SD15	0-10	N	1.84	**8.84 J**	38 J	19.4 J	7.2	**27.9**	0.469	53.5 J	0.308
8	S.STATION51	2015-06-15	SS51-SD15	0-10	N	1.91	**10.2 J**	84.8 J	61.6 J	47.8	**40.8**	0.099	113 J	**2.42**
8	S.STATION03-C[d]	2015-06-16	SS03-SD15	0-10	N	6.47	**11.4**	34.1 J	8.16	4.01 J	15.5	0.433	31	0.074
8	S.STATION06-C[d]	2015-06-16	SS06-SD15	0-10	N	2.27	**5.85 J**	49.9 J	9.31 J	5.36	17.5	0.552	31.8 J	0.051
8	S.STATION06-C[d]	2015-06-16	SS06-SD15B	10-24	N	1.62	4.86 J	46.1 J	6.73 J	3.95	13.9	0.437	25.6 J	0.044
8	S.STATION09-C[d]	2015-06-17	SS09-SD15	0-10	N	2.73	2.36	69.5 J	8.64 J	4.86	17.5	0.305	35.9	0.045
8	S.STATION09-C[d]	2015-06-17	SS09-SD15B	10-24	N	2.8	2.29	64.2 J	8.58 J	4.96	17.2	0.287	32.7	0.066
8	S.STATION31	2015-06-16	SS31-SD15	0-10	N	3.27	0.468 J	37.1 J	7.14 J	4.13	12.5	0.109	23.5 J	0.028
8	S.STATION12	2015-06-16	SS12-SD15	0-10	N	3.4	0.339 J	22.4 J	6.81 J	4.27	11.3	0.075	22.9 J	0.037
3 & 8	S.STATION65	2016-06-21	SS65-SD16	0-10	N	1.48	2.06	20.3	12.1	7.66 J	16.8	0.099	39.7	**0.506**
3	S.STATION66	2016-06-21	SS66-SD16	0-10	N	0.78	0.876	6.62	7.98	3.66 J	10.6	0.12	19.1	0.06
3	S.STATION67	2016-06-21	SS67-SD16	0-10	N	3.74	1.3	16.8	14.2	6.41 J	11.5	0.106	46.1	0.182
3	SEEPA[d]	2015-06-15	SEEPC-SD15	0-10	N	1.66	**6.8 J**	34.1 J	12.6 J	4.15	14.8	0.299	32.5 J	0.133
3	S.STATION34	2015-06-17	SS34-SD15	0-10	N/FD[c]	2.22	3.82	53.4 J	14.2 J	5.04 J	**21.1**	0.274	32.9	0.132
3	S.STATION34	2015-06-17	SS34-SD15B	10-24	N/FD[c]	1.54	3.77	51.1	7.4 J	4.68	13.9	0.281	26.4	0.17 J
3	S.STATION32	2015-06-17	SS32-SD15	0-10	N	3.02	0.791	40.8 J	8.2 J	5.24	17.1	0.148	30.3	0.077
3	S.STATION54	2015-06-16	SS54-SD15	0-10	N	4.02	0.709	36.7 J	13.3	6.53 J	19.4	0.136	38.5	0.057
3 & 9	S.STATION68	2016-06-21	SS68-SD16	0-10	N	0.42 J	1.15	2.32	3.81	1.71 J	2.37	0.355	12.5	0.044
3 & 9	S.STATION69	2016-06-21	SS69-SD16	0-10	N	0.73	1.17	5.43	4.61	2.05 J	7.07	0.076	17.1	0.055
9	S.STATION70	2016-06-21	SS70-SD16	0-10	N	1.57	3.18 J	27.5 J	77.5	50.2	19.5	**7.75 J**	148	**0.491**
9	S.STATION71	2016-06-21	SS71-SD16	0-10	N	1.49	1.22 J	45.3 J	**439**	19.7	**23.4**	2.63 J	46.7	0.113
9	OF03703	2015-06-16	OF03703-SD15	0-10	N/FD[c]	2.01	3.93	49.2 J	13.9	6.61 J	**22**	1.98	44.1	**0.627**

Table 29 (Continued)
Exceedances of Sediment Benchmarks for the Area 8 Beach

Tran-sect	Sampling Station ID	Sample Date	Sample No.	Sample Depth (cm)	Sample Type	Arsenic (mg/kg)	Cadmium (mg/kg)	Total Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	Mercury (mg/kg)
9	S.STATION37	2015-06-17	SS37-SD15	0-10	N	1.67	3.15	29.1 J	8.76 J	4.42	11.8	0.414	26.6	0.111
9	S.STATION36	2015-06-16	SS36-SD15	0-10	N	1.31	1.15	26 J	5.24	2.85 J	8.94	0.151	17.2	0.083
9	S.STATION36	2015-06-16	SS36-SD15B	10-24	N	1.68	1.7	38.5 J	6	3.1 J	12.4	0.261	23.2	0.073
9	S.STATION53	2015-06-16	SS53-SD15	0-10	N	2.31	0.44	23.6 J	5.68	4.12 J	11.4	0.1	20.9	0.027
9 & 10	S.STATION72	2016-06-21	SS72-SD16	0-10	N	1.44	1.18 J	26.5 J	48.8	67.7	19.6	**17 J**	54.2	0.163
9 & 10	S.STATION74	2016-06-21	SS74-SD16	0-10	N	1.57	1.99 J	36 J	10.6	5.9	16.9	2.2 J	35.3	0.176
10	S.STATION73	2016-06-21	SS73-SD16	0-10	N	2.26	0.9 J	19.9 J	19.1	8.77	12.7	1.91 J	39.7	0.099
10	SEEPD	2015-06-15	SEEPD-SD15	0-10	N	0.9	1.08 J	8.73 J	4.2 J	2.64	5.17	0.398	13.2 J	0.165
10	S.STATION40	2015-06-16	SS40-SD15	0-10	N	1.41	3.82	41.1 J	9.85	5.27 J	14.9	1.41	29.8	0.068
10	S.STATION40	2015-06-16	SS40-SD15B	10-24	N	1.44	1.16	30.2 J	9.22	4.55 J	14.6	1.16	34.1	**0.767**
10	S.STATION38	2015-06-16	SS38-SD15	0-10	N	1.48	0.487	25.6 J	6.58	3.22 J	13.4	0.238	19.6	0.066
10	S.STATION39	2015-06-16	SS39-SD15	0-10	N	2.49	0.524	33.2 J	6.05	7.67 J	13.7	0.113	23.8	0.034
10	S.STATION52	2015-06-16	SS52-SD15	0-10	N	2.95	0.437	33.6 J	6.82	10.2 J	15.1	0.116	26.7	0.037
10 & 11	S.STATION75	2016-06-21	SS75-SD16	0-10	N	2.85	1.55 J	34.1 J	13.4	6.83	18.2	0.889 J	47.7	0.205
11	SEEPE	2015-06-15	SEEPE-SD15	0-10	N	1.63	0.715 J	30.9 J	9.71 J	3.99	15.4	0.446	27.2 J	0.107
11	S.STATION43	2015-06-17	SS43-SD15	0-10	N	2.58	0.814	38.4 J	8.58 J	4.38	16.7	0.342	32.4	0.054
11	S.STATION43	2015-06-17	SS43-SD15B	10-24	N	1.95	0.782	30 J	7.25 J	3.3	17.2	0.295	24.8	0.067
11	S.STATION41	2015-06-16	SS41-SD15	0-10	N	3.27	0.533	34.4 J	8.5	4.98 J	16.2	0.117	30	0.045
11	S.STATION42	2015-06-16	SS42-SD15	0-10	N	3.25	0.403	28.3 J	6.97	4.78 J	15.1	0.091	27.2	0.043
12	SEEPF	2015-06-15	SEEPF-SD15	0-10	N	2.22	0.754 J	19.8 J	6.68 J	4.9	10.4	0.228	28.8 J	0.136
12	S.STATION46	2015-06-16	SS46-SD15	0-10	N	2.53	0.677	39.1 J	8.05	5.11 J	15.7	0.345	29.4	0.095
12	S.STATION46	2015-06-16	SS46-SD15B	10-24	N	2.5	0.88	34 J	7.64	7.82 J	14.5	0.368	34.3	0.054
12	S.STATION44	2015-06-16	SS44-SD15	0-10	N	1.94	0.38	21.3 J	4.74	3.15 J	10.3	0.102	17.7	0.034
12	S.STATION45	2015-06-16	SS45-SD15	0-10	N	3.37	0.339	30.8 J	6.48	4.45 J	16.9	0.079	28	0.034
13	SS-03701	2015-06-16	OF03701-SD15	0-10	N	2.47	1.97	30.2 J	39.8	185 J	**24.2**	5.99	396	0.224
13	S.STATION49	2015-06-16	SS49-SD15	0-10	N	1.67	0.524	20.3 J	10.2 J	7.86	12.5	0.999	36.5	0.151
13	SEEPG	2015-06-15	SEEPG-SD15	0-10	N	2.37	0.585 J	26.6 J	11 J	8.32	15.4	0.616	40.8 J	0.144
13	SEEPG	2015-06-15	SEEPG-SD15B	10-24	N	2.09	0.487 J	31.6 J	10.6 J	12.8	17.4	0.423	43.8 J	0.099
13	S.STATION48	2015-06-15	SS48-SD15	0-10	N	3.56	0.771 J	35.8 J	23.1 J	8.83	17.4	0.527	45.2 J	**0.608**
13	S.STATION47	2015-06-16	SS47-SD15	0-10	N	3.19	0.375	20.3 J	6.67	4.33 J	14.4	0.081	25.5	0.026
S. 13	S.STATION76	2016-06-21	SS76-SD16	0-10	N	3.12	0.765 J	40.5 J	14.7	41.8	20.6	0.479 J	55.2	0.112
S. 13	S.STATION77	2016-06-21	SS77-SD16	0-10	N	3.31	0.681 J	32.5 J	9.31	6.99	19	0.218 J	37.5	0.112
N. 13	S.STATION78	2016-06-21	SS78-SD16	0-10	N/FD[c]	2.25	1.14 J	31.8 J	14.6 J	32.5 J	18.4	1.33 J	49	0.121
N. 13	S.STATION79	2016-06-21	SS79-SD16	0-10	N	3.71	0.655 J	34.9 J	11	13.4	20.4	0.356 J	46.3	0.066
14	S.STATION57	2016-06-21	SS57-SD16	0-10	N	3.16	0.33	12.9	7.04	4.61 J	10.8	0.071	42	0.006 J
14	S.STATION58	2016-06-21	SS58-SD16	0-10	N	2.37	0.259	21.6	11.5	6.15 J	17.9	0.067	36.1	0.018 J
14	S.STATION59	2016-06-21	SS59-SD16	0-10	N	2.44	0.233	12.9	7.93	5.1 J	12.6	0.056	25.8	0.046

Notes:
Sediment results are reported in dry weight.
Bold indicates exceedance of the sediment benchmark.
cm = centimeter
FD = field duplicate

Table 29 (Continued)
Exceedances of Sediment Benchmarks for the Area 8 Beach

ID = identification
J = The result is an estimated concentration.
mg/kg = milligram per kilogram
N = normal environmental sample
No. = number
[a] All sediment benchmarks are Washington State SCOs (WAC 173-204-320), except nickel, which is a National Oceanic and Atmospheric Administration Effects Range Low.
[b] Only detected concentrations are included.
[c] When there are duplicates, the maximum of the primary and duplicate results is presented.
[d] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. In addition, the nomenclature for S.STATION03, S.STATION06, and S.STATION09 was modified to sampling stations S.STATION03-C, S.STATION06-C, and S.STATION09-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location S.STATION03-C is co-located with Seep C.

Table 30
Hazard Quotients Based on Maximum Area 8 Beach Sediment Concentrations and Sediment Benchmarks for Protection of Benthic Organisms

Chemical	Maximum Concentration in Area 8 Sediment (0-10 cm) (mg/kg dw)	Ecological Sediment Benchmark [a]	Max Hazard Quotient	Locations Exceeding SCO or ERL[b]	Are Concentrations Statistically Different than Reference?[c]	UCL95 EPC in Sediment (0-10 cm) (mg/kg dw)	UCL95 Hazard Quotient	90/90 UTL	Are Concentrations Greater than the 90/90 UTL?
Arsenic	6.47	57	0.1	--	No	2.571	0.05	11	No
Cadmium	11.4	5.1	**2.2**	SS50; SS51; SS03-C[d]; SS06-C[d]; SEEPA[d]	**Yes**	2.898	0.57	0.8	**Yes**
Chromium	84.8	260	0.3	--	No	31.58	0.1	62	No
Copper	439	390	**1.1**	SS71	No	48	0.1	45	**Yes**
Lead	185	450	0.4	--	No	24.94	0.06	21	**Yes**
Mercury	2.42	0.41	**5.9**	SS08; SS51; SS65; SS70; SS48; OF03703	No	0.19	0.5	0.2	No
Nickel	40.8	20.9/51.6	**2.0**/0.8	SS30; SS34; SS50; SS51; SS55; SS71; OF03701; OF03703	No	17.26	0.8[e]	50	No
Silver	17	6.1	**2.8**	SS70; SS72	**Yes**	2.144	0.35	0.24	**Yes**
Zinc	396	410	1.0	--	No	67.24	0.2	93	No

Notes:
All units in milligram per kilogram dry weight (mg/kg dw).
Bold indicates a hazard quotient greater than 1.0.
cm = centimeter
EPC = exposure point concentration
ERL = Effects Range Low
SCO = Sediment Cleanup Objective
SS = Sampling Station
UCL = uppper confidence level

[a] All sediment benchmarks are Washington State SCOs (WAC 173-204-320), except nickel, which is a National Oceanic and Atmospheric Administration Effects Range Low/Effects Range Median.

[b] An exceedance of mercury was also noted at the SS40 location, but only at the 10 to 24 centimeter depth.

[c] Statistical comparison of Area 8 data to background performed using the Wilcoxon-Mann-Whitney test at alpha 0.05.

[d] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. The nomenclature for locations SS03 and SS06 was modified to SS03-C and SS06-C in order to distinguish them from historical sampling locations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location SS03-C is co-located with Seep C.

[e] Based on ERL.

Table 31
AVS Concentrations, SEM Sums and SEM/AVS Ratios for Area 8 Beach Sediment

Sampling Station ID	Sample Date	Sample No.	Sample Type	Acid Volatile Sulfides (µmol/g)	Cadmium (µmol/g)	Copper (µmol/g)	Lead (µmol/g)	Nickel (µmol/g)	Zinc (µmol/g)	Mercury (µmol/g)	Sum of SEM Concentrations per Station	SEM/AVS Ratio	Does SEM/AVS ratio exceed 1.0?
S.STATION06-C[a]	2015-06-16	SS06-SD15B	N	3.9	0.04937 J	0.0261	0.038	0.0325 J	0.211	5.8E-05 U	3.6E-01	0.092	No
S.STATION07	2015-06-17	SS07-SD15	N	3.65	0.00315 J	0.0271	0.0175 J	0.0278	0.207	6.3E-05 U	2.8E-01	0.077	No
S.STATION08	2015-06-17	SS08-SD15	N	4.77	0.02675	0.0318	0.0181 J	0.0365	0.229	6.1E-05 U	3.4E-01	0.072	No
S.STATION08	2015-06-17	SS08-SD15B	N	7.5	0.02361	0.0184 J	0.0154 J	0.0338	0.204	5.3E-05 U	3.0E-01	0.039	No
S.STATION09-C[a]	2015-06-17	SS09-SD15	N	7.9	0.0165	0.0148 J	0.0153 J	0.0338	0.239	5.1E-05 U	3.2E-01	0.040	No
S.STATION09-C[a]	2015-06-17	SS09-SD15B	N	8.9	0.01694	0.027	0.0188 J	0.0384	0.246	6.0E-05 U	3.5E-01	0.039	No
S.STATION34	2015-06-17	SS34-SD15	N	4.88	0.04421	0.0417	0.0245 J	0.0402	0.24	6.2E-05 U	3.9E-01	0.080	No
S.STATION35	2015-06-17	SS34-SD15B	N	0.85	0.03604 J	0.0379	0.0175	0.0398 J	0.199	6.1E-05 U	3.3E-01	0.389	No
S.STATION36	2015-06-17	DUP3-SD15	FD	3.95	0.03639	0.035	0.018 J	0.0318	0.184	5.5E-05 U	3.1E-01	0.077	No
S.STATION37	2015-06-17	DUP4-SD15B	FD	0.55	0.03042 J	0.0375	0.0181	0.0314 J	0.172	6.1E-05 U	2.9E-01	0.526	No
S.STATION38	2015-06-16	SS36-SD15	N	7.7	0.01683 J	0.0309	0.0148	0.0442 J	0.221	5.8E-05 U	3.3E-01	0.043	No
S.STATION39	2015-06-16	SS36-SD15B	N	5.98	0.01822 J	0.0272	0.0153	0.0411 J	0.226	5.9E-05 U	3.3E-01	0.055	No
S.STATION40	2015-06-16	SS40-SD15B	N	9.1	0.01199 J	0.0381	0.029	0.0605 J	0.388	6.2E-05 U	5.3E-01	0.058	No
S.STATION41	2015-06-16	SS40-SD15	N	9.3	0.01588 J	0.051	0.0235	0.0738 J	0.41	6.1E-05 U	5.7E-01	0.062	No
S.STATION42	2015-06-17	SS43-SD15	N	2.21	0.00801 J	0.0345	0.0178	0.0401 J	0.211	6.3E-05 U	3.1E-01	0.141	No
S.STATION43	2015-06-16	SS46-SD15	N	2.13	0.0073 J	0.036	0.021	0.0361 J	0.239	6.1E-05 U	3.4E-01	0.159	No
S.STATION44	2015-06-15	SS48-SD15	N	7.06	0.00625	0.043	0.0269	0.0415	0.376	6.5E-05 U	4.9E-01	0.070	No
S.STATION45	2016-06-21	SS57-SD16	N	0.017 U	0.00552 U	0.0427 J	0.0276 U	0.0249 J	0.284	6.6E-05 U	3.8E-01	**22.6**	**Yes**
S.STATION46	2016-06-21	SS58-SD16	N	2.33	0.00169 J	0.0394 J	0.0209 J	0.0359	0.233	5.4E-05 U	3.3E-01	0.142	No
S.STATION47	2016-06-21	SS59-SD16	N	0.09	0.00213 J	0.0437 J	0.0205 J	0.0229	0.22	5.4E-05 U	3.1E-01	**3.4**	**Yes**
S.STATION48	2016-06-21	SS62-SD16	N	0.013 U	0.00305 J	0.0794	0.0227	0.0297	0.297	5.2E-05 U	4.3E-01	**33.2**	**Yes**
S.STATION49	2016-06-21	SS64-SD16	N	0.013 U	0.01754	0.0874	0.0285	0.137	0.846	2.6E-05 J	1.1E+00	**85.9**	**Yes**
S.STATION50	2016-06-21	SS65-SD16	N	0.045	0.01271	0.51	0.0542	0.0556	0.37	1.6E-03	1.0E+00	**22.3**	**Yes**
S.STATION51	2016-06-21	SS67-SD16	N	0.041	0.00906	0.106	0.0316	0.055	0.509	6.1E-05 U	7.1E-01	**17.3**	**Yes**
S.STATION52	2016-06-21	SS70-SD16	N	0.016 J	0.02552 J	0.975	0.221	0.0783	1.71	3.0E-05 J	3.0E+00	**188**	**Yes**
S.STATION53	2016-06-21	SS73-SD16	N	0.012 U	0.00768 J	0.1	0.0459	0.0485	0.33	5.1E-05 J	5.3E-01	**44.3**	**Yes**
S.STATION54	2016-06-21	SS74-SD16	N	2.77	0.01725 J	0.0492	0.0328	0.0466	0.34	5.5E-05 U	4.9E-01	0.175	No
S.STATION55	2016-06-21	SS75-SD16	N	2.54	0.01619 J	0.0701	0.0312	0.0709	0.38	5.5E-05 U	5.7E-01	0.224	No
S.STATION56	2016-06-21	SS76-SD16	N	9.7	0.00724 J	0.0685	0.0488	0.072	0.614	5.6E-05 U	8.1E-01	0.084	No
S.STATION57	2016-06-21	SS77-SD16	N	1.27	0.00547 J	0.0449	0.0273	0.0373	0.27	6.1E-05 U	3.8E-01	0.303	No
S.STATION58	2016-06-21	SS78-SD16	N	1.22	0.00438 J	0.0906	0.0548	0.0683	0.515	5.3E-05 U	7.3E-01	0.601	No
S.STATION59	2016-06-21	SS79-SD16	N	2.38	0.00651 J	0.0481	0.0345	0.0451	0.391	6.0E-05 U	5.3E-01	0.221	No
S.STATION60	2016-06-21	SS-FD2	FD	1.12	0.00567 J	0.0888	0.0742	0.057	0.581	5.4E-05 U	8.1E-01	0.720	No

Notes:
Bold indicates a ratio greater than 1.0.
AVS = acid volatile sulfides
FD = field duplicate

Table 31 (Continued)
AVS Concentrations, SEM Sums and SEM/AVS Ratios for Area 8 Beach Sediment

ID = identification
J = The result is an estimated concentration.
µmol/g = micromole per gram
N = normal environmental sample
No. = number
SEM = simultaneously extracted metals
U = The compound was analyzed for, but was not detected ("nondetect") at or above the method reporting limit/method detection limit.
[a]The nomenclature for S.STATION06 and S.STATION09 was modified to sampling stations S.STATION06-C and S.STATION09-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3.

Table 32
Exceedances of Critical Tissue Levels for Area 8 Beach Clam Tissue

Tran-sect	Sampling Station ID	Sample Date	Sample No.	Arsenic (mg/kg)	Inorganic Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	Mercury (ug/kg)	Methyl Mercury (ug/kg)
			Maximum [a]	**3.5**	0.05	**1.0**	1.13	1.73	0.13	1.00	0.58	16.30	42.20	18.00
			Tissue CTL [b]	**1.6**	**1.6**	**0.15**	--	--	**0.4**	--	--	--	**180**	**180**
1	S.STATION01	2015-06-15	SS01-CL15	**1.97**	0.023	**0.335**	0.289	1.03	0.0587	0.329	0.0711	13.6	10.9	5.8
1	S.STATION07	2015-06-17	SS07-CL15	**2.01**	0.032	**0.222**	0.794	1.52	0.0853 J	0.543	0.106 J	11.7	9.2	3.7
2	S.STATION02	2015-06-07	SS02-CL15	**2.01**	0.029	**0.351**	0.617	1.36	0.0793 J	0.465	0.118 J	11.9	9.73	9.1
2	S.STATION05	2015-06-17	SS05-CL15	**2.21**	0.026	**0.757**	0.953	1.15	0.092 J	0.694	0.211 J	14	13.4	8
2	S.STATION08	2015-06-17	SS08-CL15	**2.44**	0.028	**0.344**	0.922	1.35	0.0823 J	0.683	0.0751 J	13.6	13	6.9
2	S.STATION62	2016-06-21	SS62-CL16	**2.96**	0.017	**0.501**	0.261	0.994	0.0502	0.844	0.375 J	15.1	22.3	13
2 & 8	S.STATION64	2016-06-21	SS64-CL16	**2.72**	0.015 U	**1**	0.61	1.24	0.0431	0.735	0.582 J	14.7	37.5	9.1
8	S.STATION03-C[c]	2015-06-16	SS03-CL15	**3.04**	0.023	**0.891**	1.13	1.1	0.0641	0.614	0.164	13	14.5	9
8	S.STATION09-C[c]	2015-06-17	SS09-CL15	**1.81**	0.029	**0.209**	0.779	1.2	0.0796 J	0.538	0.0678 J	13.2	9.35	5.5
3 & 8	S.STATION65	2016-06-21	SS65-CL16	**3.5**	0.018	**0.613**	0.434	1.29	0.0597	1	0.437 J	13.8	23.6	14
3	S.STATION67	2016-06-21	SS67-CL16	**2.99**	0.02	**0.664**	0.183	1.08	0.0498	0.649	0.364 J	13.3	25.1	18
3	S.STATION32	2015-06-17	SS32-CL15	**1.67**	0.031	**0.191**	0.917	1.36	0.0873 J	0.567	0.0466 J	12.6	10.1	1 J
3	S.STATION34	2015-06-17	SS34-CL15	**1.65**	0.026	**0.295**	0.718	1.1	0.0828 J	0.524	0.066 J	12.4	12.8	6.6
3	SEEPA[c]	2015-06-15	SEEPC-CL15	**2.11**	0.022	**0.579**	0.388	0.978	0.0617	0.291	0.0748	10.8	11.9	7.7
9	S.STATION70	2016-06-21	SS70-CL16	**3.09**	0.017	**0.973**	0.237	1.5	0.13	0.53	0.453 J	16.3	42.2	11.9
9	OF03703	2015-06-16	OF03703-CL15	**2.58**	0.018	**0.867**	0.38	1.12	0.047	0.329	0.463	14.4	20	9
9	S.STATION35	2015-06-17	SS35-CL15	**1.84**	0.027	**0.21**	0.66	1.33	0.0799 J	0.448	0.0599 J	12.9	10.8	7.1
9	S.STATION36	2015-06-16	SS36-CL15	**2.27**	0.029	**0.219**	0.681	1.73	0.0858 J	0.482	0.0604 J	14.4	12.4	6.8
9	S.STATION37	2015-06-17	SS37-CL15	**2.36**	0.028	**0.419**	0.44	1.2	0.0862 J	0.405	0.117 J	13.9	16.8	9.3
9	S.STATION53	2015-06-16	SS53-CL15	**2.18**	0.03	**0.209**	0.596	1.48	0.0913	0.435	0.0959	12.7	10.1	5.5
9 & 10	S.STATION74	2016-06-21	SS74-CL16	**2.33**	0.034	**0.279**	0.227	0.964	0.0794	0.45	0.137 J	14	17.8	11.7
10	S.STATION73	2016-06-21	SS73-CL16	**2.84**	0.041	**0.41**	0.155	1.08	0.0689	0.736	0.508 J	15.8	25.2	11.4
10	S.STATION38	2015-06-16	SS38-CL15	**2.26**	0.026	**0.245**	0.444	1.38	0.0789	0.402	0.0735	14.8	12.3	5.2
10	S.STATION40	2015-06-16	SS40-CL15	**1.71**	0.029	**0.204**	1.03	1.32	0.0787	0.584	0.0538	12.7	11.3	6.9
10	S.STATION56	2015-06-17	SS56-CL15	**1.87**	0.026	**0.22**	0.363	1.11	0.0651 J	0.341	0.0615 J	12.9	11.8	5.6
10	SEEPD	2015-06-15	SEEPD-CL15	**2.91**	0.023	**0.336**	0.57	1.38	0.0727	0.405	0.129	12.9	13.6	5.1
10 & 11	S.STATION75	2016-06-21	SS75-CL16	**2.49**	0.028	**0.237**	0.242	1.1	0.0687	0.321	0.0756 J	13	16.4	11.9
11	S.STATION43	2015-06-17	SS43-CL15	**1.81**	0.024	**0.205**	0.396	1.24	0.0687 J	0.372	0.0598 J	14.6	10.5	6.9
11	SEEPE	2015-06-15	SEEPE-CL15	**2.48**	0.023	**0.264**	0.677	1.29	0.06	0.364	0.0907	14.5	14.1	7.9
12	S.STATION46	2015-06-17	SS46-CL15	**1.67**	0.03	**0.169**	0.375	1.4	0.0724 J	0.362	0.0474 J	15	11.2	6
12	SEEPF	2015-06-15	SEEPF-CL15	**2.64**	0.025	**0.256**	0.471	1.52	0.0651	0.42	0.181	13.8	15.4	5.6
13	SS-03701	2015-06-16	OF03701-CL15	**2.3**	0.021	**0.469**	0.367	1.12	0.0672	0.299	0.366	12.4	28.9	9
13	S.STATION49	2015-06-16	SS49-CL15	**2.86**	0.022	**0.304**	0.347	1.09	0.0749	0.315	0.35	12.2	21.1	11.3
13	SEEPG	2015-06-15	SEEPG-CL15	**2.4**	0.05	**0.214**	0.493	1.37	0.0846	0.385	0.129	13.8	11.6	5.7
S. 13	S.STATION76	2016-06-21	SS76-CL16	**2.88**	0.038	**0.24**	0.208	1.21	0.0742	0.315	0.095 J	15.8	21	13.6
S. 13	S.STATION77A	2016-06-21	SS77A-CL16	**1.87**	0.034	**0.197**	0.205	1.05	0.0706	0.288	0.0955 J	11.6	14.5	9.6
N. 13	S.STATION78	2016-06-21	SS78-CL16	**2.26**	0.023	**0.259**	0.248	1.11	0.0831	0.628	0.292 J	15.1	19	10.4
N. 13	S.STATION79A	2016-06-21	SS79A-CL16	**2.03**	0.039	**0.201**	0.182	1.21	0.0851	0.33	0.138 J	14.4	14.8	8

Table 32 (Continued)
Exceedances of Critical Tissue Levels for Area 8 Beach Clam Tissue

Tran-sect	Sampling Station ID	Sample Date	Sample No.	Arsenic (mg/kg)	Inorganic Arsenic (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	Mercury (ug/kg)	Methyl Mercury (ug/kg)
			Maximum [a]	**3.5**	0.05	**1**	1.13	1.73	0.13	1.00	0.58	16.30	42.20	18.00
			Tissue CTL [b]	**1.6**	**1.6**	**0.15**	--	--	**0.4**	--	--	--	**180**	**180**
14	S.STATION57	2016-06-21	SS57-CL16	**2.84 J**	0.014 U	**0.398**	0.163	0.759	0.0431	0.531 J	0.153 J	10.3	14.8	12.3
14	S.STATION58	2016-06-21	SS58-CL16	**1.66**	0.024	**0.203**	0.158	1.03	0.0474	0.27	0.139 J	9.6	8.58	3.7
14	S.STATION59	2016-06-21	SS59-CL16	**1.68**	0.025	**0.202**	0.307	0.998	0.0582	0.277	0.0371 J	10.9	9.31	6.6

Notes:

Tissue results are reported in wet weight.

Bold indicates exceedance of the CTL.

CTL = critical tissue level

ID = identification

J = The result is an estimated concentration.

mg/kg = milligram per kilogram; mg/kg is equivalent to micrograms per gram (µg/g)

µg/kg = micrograms per kilogram ; µg/kg is equivalent to nanograms per gram (ng/g)

No. = number

U = The compound was analyzed for, but was not detected ("nondetect") at or above the method reporting limit/method detection limit.

[a] Only detected concentrations are included.

[b] CTLs are from Oregon Department of Environmental Quality (ODEQ). *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment*. April 3, 2007.

[c] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. The nomenclature for S.STATION03 and S.STATION09 was also modified to sampling stations S.STATION03-C and S.STATION09-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location S.STATION03-C is co-located with Seep C.

Table 33
Hazard Quotients Based on Area 8 Beach Clam Tissue Concentrations and Screening Criteria for Protection of Clams

Chemical	Maximum Detected Concentration	UCL95 EPC in Clam Tissue (mg/kg)	CTL [a]	Hazard Quotient - Maximum	Are Concentrations Statistically Different than Reference?[b]	Reference Area UCL95 (mg/kg)	Hazard Quotient - UCL95
Arsenic (Total)	3.5	2.45	1.6	**2.2**	No	2.35	**1.5**
Arsenic (inorganic)	0.05	0.0284	1.6	0.031	No	0.037	0.018
Cadmium	1	0.533	0.15	**6.7**	No	0.471	**3.6**
Chromium	1.13	0.548	NE	--	No	0.512	--
Copper	1.73	1.266	NE	--	No	1.218	--
Lead	0.13	0.0766	0.4	0.33	**Yes**	0.026	0.192
Methylmercury	0.018	0.00918	0.18	0.10	**Yes**	0.004192	0.051
Nickel	1	0.52	NE	--	**Yes**	0.469	--
Silver	0.582	0.226	NE	--	**Yes**	0.0475 [c]	--
Zinc	16.3	13.77	NE	--	No	15.43	--

Notes:
All units in milligram per kilogram (mg/kg) wet weight.
Bold indicates a hazard quotient greater than 1.0
CTL = critical tissue level
EPC = exposure point concentration
NE = not established
UCL95 = upper confidence level at 95th percentile
[a] CTLs are from Oregon Department of Environmental Quality (ODEQ). *Guidance for Assessing Bioaccumulative Chemicals of Concern in Sediment*. April 3, 2007.
[b] Statistical comparison of Area 8 data to background performed using the Wilcoxon-Mann-Whitney test at alpha 0.05.
[c] UCL not calculated due to large number of nondetections; value is the single detected value.

Table 34
Evaluation of SEM/AVS Results for Area 8 Beach Sediment that Exceeded a Ratio of 1

Sample No.	Acid Volatile Sulfides (µmol/g)	Cadmium (µmol/g)	Copper (µmol/g)	Lead (µmol/g)	Nickel (µmol/g)	Zinc (µmol/g)	Mercury [a] (µmol/g)	Sum of SEM Concentrations per Station	SEM/AVS Ratio	Nearest Seep(s)[b]	Seep Water Exceedances?	Exceedances of Sediment Benchmark?
SS62-SD16	0.013 U	0.00305 J	**0.0794**	**0.0227**	**0.0297**	**0.297**	0.000052 U	0.432	33.2	Seep B/C	Cd (Seep C)	--
SS64-SD16	0.013 U	**0.0175**	**0.0874**	**0.0285**	**0.137**	**0.846**	0.000026 J	1.12	85.9	Seep C	Cd	--
SS65-SD16	0.045	0.01271	**0.51**	**0.0542**	**0.0556**	**0.37**	0.001613	1.00	22.3	Seep A/C	Cd (Seep C)	--

Notes:

Bold indicates individual detected SEM concentration exceeds the AVS concentration or AVS detection limit.

AVS = acid volatile sulfides

Cd = cadmium

J = The result is an estimated concentration.

No. = number

SEM = simultaneously extracted metals

µmol/g = micromole per gram

U = The compound was analyzed for, but was not detected ("nondetect") at or above the method reporting limit/method detection limit.

[a] Data provided to evaluate significance as a contributor to enhanced bioavailability. Mercury exceedances of the CTL were not noted (Table 32).

[b] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8.

Table 35
Summary of Bioassay Findings

Sample Type	***Euhaustorius*** **Percent Mortality**	***Mytilus*** **Number of Normal Larvae**	**Microtox Light Output (5 min/15min)**
Control	1.0±2.2 (Sediment)	247±13 (Seawater)	73.2/57 (Laboratory)
Reference	19.0±7.4	207±20	139.2/133
Site Sample SS03-C (Seep)	4.0±4.2	220±7	123.2/112 [a]

Notes:
[a]A significant decrease in Microtox luminescence was observed relative to the reference sample (Microtox, $p<0.05$), but no significant decrease was observed relative to the control.

Table 36

Cadmium Concentrations, Total Organic Carbon, Total Solids, and Grain Size Analysis Results for Area 8 Beach Sediment With Cadmium Sediment Benchmark Exceedances

Sampling Station ID	Sample Date	Sample No.	Cadmium Concentration (mg/kg dry weight)	Total Organic Carbon (%)	Total Solids (%)	Gravel >2 mm (%)	Sand, Very Coarse 1-2 mm (%)	Sand, Coarse 0.5-1 mm (%)	Sand, Medium 0.25-0.5 mm (%)	Sand, Fine 0.125-0.25 mm (%)	Sand, Very Fine 0.0625-0.125 mm (%)	Silt 0.0039-0.0625 mm (%)	Clay < 0.0039 mm (%)
S.STATION03-C[a]	2008-07-28	Seep A	13.8 J	0.29	NA	42.5	14	15.7	19.1	5.53	1.23	3.22	1.75
S.STATION06-C[a]	2015-06-16	SS06-SD15	5.85 J	NA	81.3	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION06-C[a]	2015-06-16	SS06-SD15B	4.86 J	0.333	81.9	12.69	7.36	13.99	38.7	9.73	1.4	3.65	2.16
S.STATION50	2015-06-15	SS50-SD15	8.84 J	0.245	84.7	30.7	25.8	24.02	9.92	2.37	0.61	4.06	2.95
S.STATION51	2015-06-15	SS51-SD15	10.2 J	0.239	91.4	37.5	19.59	16.18	9.79	3.06	0.92	3.1	2.25
SEEPA[a]	2015-06-15	SEEPC-SD15	6.8 J	0.402	73.9	NA	NA	NA	NA	NA	NA	NA	NA

Notes:
Total organic carbon and grain size analytical method for 2015 data was American Society for Testing and Materials D422. modified for the Puget Sound Estuary Program.
ID = identification
J = The result is an estimated concentration
mg/kg = milligrams per kilogram
N = normal environmental sample
NA = not analyzed
No. = number
mm = millimeter
[a] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. The nomenclature for S.STATION03 and S.STATION06 was also modified to sampling stations S.STATION03-C and S.STATION06-C in order to distinguish them from historical sampling stations and to highlight their position on the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location S.STATION03-C is co-located with Seep C.

Table 37
Clam Abundance by Transect from the 2014 Shellfish Survey Report

Transect	Cockle	Softshell Clam	Manila	Native Littleneck	Butter	*Macoma* spp.	Rough Piddock	Horse Clam	Unknown
1	0	1	4	9	7	0	16	0	0
2	0	0	12	22	42	0	0	1	1
3	0	0	3	21	21	1	0	0	0
4	0	0	0	23	6	0	0	1	0
5	1	0	2	25	21	1	0	0	0
Total	**1**	**1**	**21**	**100**	**97**	**2**	**16**	**2**	**1**

Source:

U.S. Navy. 2014. *Intertidal Shellfish Survey Report, Former Plating Shop/Waste Oil Spill Area, Operable Unit 2, Area 8, Naval Base Kitsap, Keyport, Washington*. November 2014.

Table 38
Calculation of Doses and Hazard Quotients for the Northwestern Crow

Chemical	UCL95 EPC in Sediment (0-10 cm) (mg/kg dw)	Invertebrate Tissue Concentration (mg/kg dw)	Ingestion Rate Sediment (kg-dry/day)	Ingestion Rate Food (kg-dry/day)	PF Invertebrate (%)	SUF	BW (kg)	Dose (mg/kg-bw/day)	NOAEL-based TRV [a] (mg/kg-bw/day)	NOAEL-based HQ	LOAEL-based TRV [a] (mg/kg-bw/day)	LOAEL-based HQ
Arsenic (Total)	2.571	15.43	0.00462	0.0462	1.0	1	0.34	2.13	2.24	0.952	11.2	0.1903
Arsenic (Inorganic Tissue)	2.571	0.174	0.00462	0.0462	1.0	1	0.34	0.06	2.24	0.026	11.2	0.0052
Cadmium	2.898	3.425	0.00462	0.0462	1.0	1	0.34	0.50	1.47	0.343	6.34	0.080
Chromium III	31.58	3.286	0.00462	0.0462	1.0	1	0.34	0.88	2.66	0.329	15.6	0.056
Copper	48	7.634	0.00462	0.0462	1.0	1	0.34	1.69	4.05	0.417	29	0.058
Lead	24.94	0.461	0.00462	0.0462	1.0	1	0.34	0.40	1.63	0.246	3.26	0.123
Mercury (methyl)	0.19	0.0581	0.00462	0.0462	1.0	1	0.34	0.0105	0.018	0.582	0.091	0.12
Nickel	17.26	3.19	0.00462	0.0462	1.0	1	0.34	0.67	6.71	0.100	56.3	0.0119
Silver	2.144	1.793	0.00462	0.0462	1.0	1	0.34	0.27	2.02	0.135	10.1	0.0270
Zinc	67.24	84.42	0.00462	0.0462	1.0	1	0.34	12.38	66.1	0.187	171	0.0724

Notes
% = percent
BW = body weight
cm = centimeter
Dose = average daily dose in milligrams per kilogram per day
EPC = exposure point concentration = lower of the maximum or upper confidence limit (UCL). If UCL cannot be calculated, maximum is shown.
HQ = hazard quotient
kg = kilogram
LOAEL - lowest observed adverse effect level
mg/kg dw= milligrams per kilogram dry weight
NOAEL = no observed adverse effect level
PF = proportion of food item
TRV = toxicity reference value
SUF = Site Use Factor
UCL - upper confidence level at the 95th percentile
[a] Sources listed on Table 25.

Table 39
Calculation of Doses and Hazard Quotients for the River Otter

Chemical	UCL95 EPC in Sediment (0-10 cm) (mg/kg dw)	Invertebrate Tissue Concentration (mg/kg dw)	Ingestion Rate Sediment (kg-dry/day)	Ingestion Rate Food (kg-dry/day)	PF Invertebrate (%)	SUF	BW (kg)	Dose (mg/kg-bw/day)	NOAEL-based TRV [a] (mg/kg-bw/day)	NOAEL-based HQ	LOAEL-based TRV [a] (mg/kg-bw/day)	LOAEL-based HQ
Arsenic (Total)	2.571	15.43	0.02241	0.24	1.0	1	6.73	0.56	1.04	0.537	5.2	0.1075
Arsenic (Inorganic Tissue)	2.571	0.174	0.02241	0.24	1.0	1	6.73	0.01	1.04	0.014	5.2	0.0028
Cadmium	2.898	3.425	0.02241	0.24	1.0	1	6.73	0.13	0.77	0.171	3.85	0.034
Chromium III	31.58	3.286	0.02241	0.24	1.0	1	6.73	0.22	2.4	0.093	12	0.019
Copper	48	7.634	0.02241	0.24	1.0	1	6.73	0.43	5.6	0.077	9.34	0.046
Lead	24.94	0.461	0.02241	0.24	1.0	1	6.73	0.10	4.7	0.021	23.5	0.004
Mercury (methylmercury in tissue)	0.19	0.0581	0.02241	0.24	1.0	1	6.73	0.00	0.02	0.135	0.07	0.039
Nickel	17.26	3.19	0.02241	0.24	1.0	1	6.73	0.17	1.7	0.101	20	0.0086
Silver	2.144	1.793	0.02241	0.24	1.0	1	6.73	0.07	6.02	0.012	30.1	0.0024
Zinc	67.24	84.42	0.02241	0.24	1.0	1	6.73	3.23	75.4	0.043	320	0.0101

Notes
% = percent
BW = body weight
cm = centimeters
Dose = average daily dose in milligrams per kilogram per day
EPC = exposure point concentration = lower of the maximum or upper confidence limit (UCL). If UCL cannot be calculated, maximum is shown.
HQ = hazard quotient
kg = kilogram
LOAEL = lowest observed adverse effect level
mg/kg dw= milligrams per kilogram dry weight
NOAEL = no observed adverse effect level
PF = proportion of food item
TRV = toxicity reference value
SUF = Site Use Factor
UCL = upper confidence level at the 95th percentile
[a] Sources listed on Table 25.

Table 40
Evaluation of Nondetected Metals Analysis Results for Reference Area Marine Water

Sampling Station ID	Sample Date	Sample No.	Dissolved Arsenic (µg/L)	Dissolved Cadmium (µg/L)	Dissolved Chromium, Total (µg/L)	Dissolved Copper (µg/L)	Dissolved Lead (µg/L)	Dissolved Nickel (µg/L)	Dissolved Silver (µg/L)	Dissolved Zinc (µg/L)	Dissolved Mercury (µg/L)
Surface Water Benchmark [a]			36	7.9	50	3.1	8.1	8.2	0.19/1.5[b]	81	0.025
PP09	2015-06-03	PP9-MW15	0.65	0.014 J	0.1 J	0.386	0.01 U	0.93	0.005 U	0.3 U	0.00036 J
PP13	2015-06-03	PP13-MW15	0.91	0.026	0.12 J	0.63	0.014 J	0.84	0.005 U	0.4 U	0.00035 J
PP15	2015-06-03	PP15-MW15	0.49 J	0.009 U	0.07 J	0.365	0.01 U	0.93	0.005 U	0.2 U	0.00037 J

Notes:

ID = identification

J = The result is an estimated concentration.

N = normal environmental sample

No. = number

µg/L = microgram per liter

U = The compound was analyzed for, but was not detected ("nondetect") at or above the method reporting limit/method detection limit.

[a] Surface water benchmarks are from WAC-173-201A-240, except cadmium which is based on the current recommended USEPA continuous ambient water quality criterion (AWQC) and silver which is based on the maximum AWQC divided by 10 (https://www.epa.gov/wqc/national-recommended-water-quality-criteria-aquatic-life-criteria-table).

[b] Second value is based on British Columbia Environment Protection Department. 1996. Ambient Water Quality Criteria for Silver, Section 2(e) of the Environment Management Act, 1981, February 19

Table 41
Summary of ERA

Ecological Receptor	Exposure Medium	Measures of Effect	Assessment Findings
Benthic Invertebrates	Sediment	Comparison of measured concentrations in sediment to conservative sediment risk-based screening benchmarks.	**Cadmium.** Cadmium exceedances of sediment benchmarks occurred at five locations, four of which are located along Transect 8 near Seep C[a] (SS50, SS51, SS03-C[a], and SS06-C[a]) and one at the discharge point of Seep A[a]. Based on statistical comparison and in conjunction with bioassay results below; **NSR.** **Silver.** Silver concentrations in sediment exceeded the sediment benchmark at two locations. Both locations are near Outfall 03-703 (Figure 3), where seep concentrations also exceed the surface water benchmark. The sediment 95UCL does not exceed sediment benchmark; significant number of clams at Outfall 03-703, indicating the silver does not appear to be adversely affecting clam populations. **NSR.**
		Comparison of the sum of simultaneously extracted divalent metals to concentrations of acid volatile sulfides to assess bioavailable fraction of divalent metals.	AVS/SEM ratios less than one (i.e., divalent metals are not bioavailable); sufficient AVS available or other lines of evidence exist indicating cadmium in sediment is not likely a contributing source to tissue cadmium levels. **NSR.**
		Evaluation of existing bioassay tests	No significant toxicity noted in sediment with highest cadmium concentration. **NSR.**
	Seep Water	Used as a line of evidence to assess seep data in conjunction with AVS/SEM as a potential source for metals accumulation in shellfish tissue.	Seep water is most likely the source of cadmium in clam tissue. However, based on shellfish abundance studies and risk findings for mammals and birds (hazard quotients less than one based on cadmium clam tissue concentrations), bioaccumulation is not significant. **NSR**.
	Clam Tissue	Comparison of measured concentrations of metals in littleneck clam tissue to critical tissue levels (CTLs) and statistical comparison to Penrose Point Reference Area Concentrations.	Arsenic and cadmium CTL exceedances at all site locations. Arsenic and cadmium tissue concentrations were considered statistically similar to Penrose Point reference tissue concentrations. **NSR.**
	Biota	Evaluation of 2007 sustainable harvest and 2014 shellfish abundance studies.	Clam populations along the beach are not significantly impacted by metals in Area 8 groundwater discharging as seeps. **NSR.**

Table 41 (Continued)
Summary of ERA

Ecological Receptor	Exposure Medium	Measures of Effect	Assessment Findings
Aquatic Plants, Invertebrates and Fish	Marine Surface Water Seep Water	Comparison of measured concentrations in seep or surface water to conservative risk-based water quality benchmarks.	Seep water exceedances for cadmium, but no exceedances for the more relevant exposure medium: marine surface water. **NSR.**
Semiaquatic Birds and Mammals	Sediment and Clam Tissue	Calculation of hazard quotients based on average daily doses for indicator bird and mammal species and comparison to chemical- and receptor-specific TRVs	Hazard quotients less than one. **NSR.**

Notes:
[a] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. The nomenclature for SS03 and SS06 was modified to sampling stations SS03-C and SS06-C in order to distinguish them from historical sampling stations and to highlight their downgradient position from the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location SS03-C is co-located with Seep C.
NSR = no significant risk
AVS/SEM = acid-volatile sulfide/simultaneous extracted metals

APPENDICES

APPENDIX A
Data Used in Risk Assessments

Table A1
Metals and Total Solids Analysis Results for Reference Area Tissue

Sampling Station ID	Sample Date	Sample No.	Arsenic (mg/kg)	Inorganic Arsenic (µg/g)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	Mercury (ng/g)	Methyl Mercury (ng/g)	Total Solids (%)
		Mean [a]	**2.22**	**0.035**	**0.445**	**0.400**	**1.16**	**0.0220**	**0.399**	**--**	**15.0**	**6.20**	**3.9**	**14.6**
		Median [a]	**2.19**	**0.033**	**0.438**	**0.343**	**1.12**	**0.0204**	**0.368**	**--**	**14.8**	**6.19**	**3.7**	**14.6**
		Minimum [a]	**1.7**	**0.026**	**0.310**	**0.216**	**0.896**	**0.0132**	**0.229**	**--**	**13.1**	**3.35**	**2.2**	**13.3**
		Maximum [a]	**3.09**	**0.055**	**0.63**	**1.72**	**1.45**	**0.0678**	**1.20**	**0.0475**	**17.1**	**8.22**	**6.6**	**16.2**
		No. of Detected / No. Sampled	**22/22**	**22/22**	**22/22**	**22/22**	**22/22**	**22/22**	**22/22**	**1/22**	**22/22**	**22/22**	**22/22**	**22/22**
		Range of Reporting Limits	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**0.0069-0.0186**	**--**	**--**	**--**	**--**
PP01	2015-06-02	PP1-CL15	2.08	0.037	0.512	0.387	1.04	0.025	0.441	0.0156 U	16.2	3.35	3.4	13.3
PP02	2015-06-02	PP2-CL15	1.7	0.037	0.484	0.251	1.23	0.0164	0.348	0.0126 U	17	6.19	3.6	13.7
PP03	2015-06-02	PP3-CL15	1.72	0.041	0.438	0.432	1.12	0.0219	0.486	0.0143 U	15.6	6.51	3.2	13.7
PP04	2015-06-02	PP4-CL15	1.87	0.034	0.365	0.461	1.29	0.021	0.414	0.0186 U	14.9	5.26	3.3	14.4
PP05	2015-06-02	PP5-CL15	2.14	0.043	0.629	0.381	1.42	0.0211	0.445	0.0118 U	16.6	6.1	6.6	13.9
PP06	2015-06-02	PP6-CL15	2.12	0.035	0.372	0.31	1.35	0.0244	0.412	0.0101 U	17	5.86	3.7	14.6
PP07	2015-06-02	PP7-CL15	2.26	0.031	0.404	0.329	0.986	0.0295	0.318	0.0086 U	14.1	6.56	4.1	14.6
PP08	2015-06-02	PP8-CL15	1.79	0.045	0.31	0.496	1.34	0.0229	0.404	0.0115 U	14	5.79	3.2	15.2
PP09	2015-06-02	PP9-CL15	3.09	0.035	0.506	0.307	0.994	0.0149	0.385	0.0076 U	13.8	6.28	4.3	13.9
PP10	2015-06-03	PP10-CL15	2.28	0.029	0.444	0.285	1.19	0.0194	0.335	0.0073 U	14.7	5.78	4.2	14.1
PP11	2015-06-03	PP11-CL15	1.93	0.03	0.418	0.383	1.12	0.0184	0.443	0.0089 U	15.5	6.59	4.4	15.2
PP12	2015-06-03	PP12-CL15	2.31	0.026	0.462	0.258	1.04	0.0142	0.287	0.009 U	13.1	5.38	4.6	14.7
PP13	2015-06-03	PP13-CL15	2.83	0.03	0.49	0.395	0.896	0.0152	0.387	0.0096 U	13.5	5.18	2.2	13.5
PP14	2015-06-03	PP14-CL15	2.6	0.055	0.411	1.72	1.32	0.0678	1.2	0.0093 U	14.7	8.17	4.3	16.2
PP15	2015-06-03	PP15-CL15	2.23	0.036	0.415	0.283	1.07	0.0228	0.311	0.0475	14.5	8.22	4.6	16.1
PP16	2015-06-03	PP16-CL15	2.01	0.031	0.481	0.357	1.27	0.0164	0.362	0.0129 U	14.5	6.45	3.7	15.3
PP17	2015-06-03	PP17-CL15	2.13	0.033	0.461	0.369	1.45	0.0222	0.373	0.0117 U	14.7	7.71	3.7	15.5
PP18	2015-06-03	PP18-CL15	2.34	0.029	0.396	0.235	0.96	0.0151	0.229	0.0113 U	17.1	6.18	3.7	16.1
PP19	2015-06-03	PP19-CL15	2.72	0.03	0.565	0.216	0.996	0.0132	0.253	0.0094 U	13.5	7.55	3.3	13.8
PP20	2015-06-03	PP20-CL15	2.37	0.032	0.437	0.224	1.01	0.0198	0.325	0.0069 U	14.9	6.4	3.8	13.9
PP21	2015-06-03	PP21-CL15	1.91	0.032	0.349	0.431	1.12	0.0234	0.339	0.0123 U	14.8	5.19	2.9	14.9
PP22	2015-06-03	PP22-CL15	2.43	0.031	0.434	0.298	1.28	0.0186	0.287	0.0098 U	15.3	5.64	4.5	14.9

Notes:

Tissue results are reported in wet weight.

[a] Only detected concentrations are included

ID - identification

µg/g - microgram per gram

mg/kg - milligram per kilogram

ng/g - nanogram per gram

No. - number

U - The compound was analyzed for, but was not detected ("nondetect") at or above the method reporting limit/method detection limit

Table A2
Metals and Total Solids Analysis Results for Area 8 Tissue

Tran-sect	Sampling Station ID	Sample Date	Sample No.	Arsenic (mg/kg)	Inorganic Arsenic (µg/g)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	Mercury (ng/g)	Methyl Mercury (ng/g)	Total Solids (%)
			Mean [a]	**2.32**	**0.027**	**0.375**	**0.478**	**1.22**	**0.0723**	**0.476**	**0.176**	**13.4**	**16.1**	**8.3**	**16.4**
			Median [a]	**2.27**	**0.026**	**0.264**	**0.396**	**1.20**	**0.0727**	**0.435**	**0.117**	**13.6**	**13.6**	**7.9**	**16.5**
			Minimum [a]	**1.65**	**0.017**	**0.169**	**0.155**	**0.759**	**0.0431**	**0.270**	**0.0371**	**9.6**	**8.6**	**1**	**11.8**
			Maximum [a]	**3.5**	**0.05**	**1**	**1.13**	**1.73**	**0.13**	**1**	**0.582**	**16.3**	**42.2**	**18**	**19**
			No. of Detected / No. Sampled	**41/41**	**39/41**	**41/41**	**41/41**	**41/41**	**41/41**	**41/41**	**41/41**	**41/41**	**41/41**	**41/41**	**41/41**
			Range of Reporting Limits	**--**	**0.014-0.015**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**
1	S.STATION01	2015-06-15	SS01-CL15	1.97	0.023	0.335	0.289	1.03	0.0587	0.329	0.0711	13.6	10.9	5.8	14.2
1	S.STATION07	2015-06-17	SS07-CL15	2.01	0.032	0.222	0.794	1.52	0.0853 J	0.543	0.106 J	11.7	9.2	3.7	18.6
2	S.STATION02	2015-06-07	SS02-CL15	2.01	0.029	0.351	0.617	1.36	0.0793 J	0.465	0.118 J	11.9	9.73	9.1	15.6
2	S.STATION05	2015-06-17	SS05-CL15	2.21	0.026	0.757	0.953	1.15	0.092 J	0.694	0.211 J	14	13.4	8	17.8
2	S.STATION08	2015-06-17	SS08-CL15	2.44	0.028	0.344	0.922	1.35	0.0823 J	0.683	0.0751 J	13.6	13	6.9	18.9
2	S.STATION62	2016-06-21	SS62-CL16	2.96	0.017	0.501	0.261	0.994	0.0502	0.844	0.375 J	15.1	22.3	13	14.6
2 & 8	S.STATION64	2016-06-21	SS64-CL16	2.72	0.015 U	1	0.61	1.24	0.0431	0.735	0.582 J	14.7	37.5	9.1	14.6
8	S.STATION03-C[b]	2015-06-16	SS03-CL15	3.04	0.023	0.891	1.13	1.1	0.0641	0.614	0.164	13	14.5	9	16.4
8	S.STATION09-C[b]	2015-06-17	SS09-CL15	1.81	0.029	0.209	0.779	1.2	0.0796 J	0.538	0.0678 J	13.2	9.35	5.5	17.3
3 & 8	S.STATION65	2016-06-21	SS65-CL16	3.5	0.018	0.613	0.434	1.29	0.0597	1	0.437 J	13.8	23.6	14	16.3
3	S.STATION67	2016-06-21	SS67-CL16	2.99	0.02	0.664	0.183	1.08	0.0498	0.649	0.364 J	13.3	25.1	18	15.4
3	S.STATION32	2015-06-17	SS32-CL15	1.67	0.031	0.191	0.917	1.36	0.0873 J	0.567	0.0466 J	12.6	10.1	1 J	17.8
3	S.STATION34	2015-06-17	SS34-CL15	1.65	0.026	0.295	0.718	1.1	0.0828 J	0.524	0.066 J	12.4	12.8	6.6	16.5
3	SEEPA[b]	2015-06-15	SEEPC-CL15	2.11	0.022	0.579	0.388	0.978	0.0617	0.291	0.0748	10.8	11.9	7.7	13.6
9	S.STATION70	2016-06-21	SS70-CL16	3.09	0.017	0.973	0.237	1.5	0.13	0.53	0.453 J	16.3	42.2	11.9	15.8
9	OF03703	2015-06-16	OF03703-CL15	2.58	0.018	0.867	0.38	1.12	0.047	0.329	0.463	14.4	20	9	14.9
9	S.STATION35	2015-06-17	SS35-CL15	1.84	0.027	0.21	0.66	1.33	0.0799 J	0.448	0.0599 J	12.9	10.8	7.1	18.9
9	S.STATION36	2015-06-16	SS36-CL15	2.27	0.029	0.219	0.681	1.73	0.0858 J	0.482	0.0604 J	14.4	12.4	6.8	18.8
9	S.STATION37	2015-06-17	SS37-CL15	2.36	0.028	0.419	0.44	1.2	0.0862 J	0.405	0.117 J	13.9	16.8	9.3	17.9
9	S.STATION53	2015-06-16	SS53-CL15	2.18	0.03	0.209	0.596	1.48	0.0913	0.435	0.0959	12.7	10.1	5.5	18.1
9 & 10	S.STATION74	2016-06-21	SS74-CL16	2.33	0.034	0.279	0.227	0.964	0.0794	0.45	0.137 J	14	17.8	11.7	15.1
10	S.STATION73	2016-06-21	SS73-CL16	2.84	0.041	0.41	0.155	1.08	0.0689	0.736	0.508 J	15.8	25.2	11.4	17.2
10	S.STATION38	2015-06-16	SS38-CL15	2.26	0.026	0.245	0.444	1.38	0.0789	0.402	0.0735	14.8	12.3	5.2	19
10	S.STATION40	2015-06-16	SS40-CL15	1.71	0.029	0.204	1.03	1.32	0.0787	0.584	0.0538	12.7	11.3	6.9	18.7
10	S.STATION56	2015-06-17	SS56-CL15	1.87	0.026	0.22	0.363	1.11	0.0651 J	0.341	0.0615 J	12.9	11.8	5.6	17.5
10	SEEPD	2015-06-15	SEEPD-CL15	2.91	0.023	0.336	0.57	1.38	0.0727	0.405	0.129	12.9	13.6	5.1	16.1
10 & 11	S.STATION75	2016-06-21	SS75-CL16	2.49	0.028	0.237	0.242	1.1	0.0687	0.321	0.0756 J	13	16.4	11.9	14.9
11	S.STATION43	2015-06-17	SS43-CL15	1.81	0.024	0.205	0.396	1.24	0.0687 J	0.372	0.0598 J	14.6	10.5	6.9	17.7
11	SEEPE	2015-06-15	SEEPE-CL15	2.48	0.023	0.264	0.677	1.29	0.06	0.364	0.0907	14.5	14.1	7.9	17
12	S.STATION46	2015-06-17	SS46-CL15	1.67	0.03	0.169	0.375	1.4	0.0724 J	0.362	0.0474 J	15	11.2	6	19
12	SEEPF	2015-06-15	SEEPF-CL15	2.64	0.025	0.256	0.471	1.52	0.0651	0.42	0.181	13.8	15.4	5.6	17.8
13	SS-03701	2015-06-16	OF03701-CL15	2.3	0.021	0.469	0.367	1.12	0.0672	0.299	0.366	12.4	28.9	9	14.6
13	S.STATION49	2015-06-16	SS49-CL15	2.86	0.022	0.304	0.347	1.09	0.0749	0.315	0.35	12.2	21.1	11.3	15.4
13	SEEPG	2015-06-15	SEEPG-CL15	2.4	0.05	0.214	0.493	1.37	0.0846	0.385	0.129	13.8	11.6	5.7	15.7
S. 13	S.STATION76	2016-06-21	SS76-CL16	2.88	0.038	0.24	0.208	1.21	0.0742	0.315	0.095 J	15.8	21	13.6	16.9
S. 13	S.STATION77A	2016-06-21	SS77A-CL16	1.87	0.034	0.197	0.205	1.05	0.0706	0.288	0.0955 J	11.6	14.5	9.6	14.7
N. 13	S.STATION78	2016-06-21	SS78-CL16	2.26	0.023	0.259	0.248	1.11	0.0831	0.628	0.292 J	15.1	19	10.4	18.9
N. 13	S.STATION79A	2016-06-21	SS79A-CL16	2.03	0.039	0.201	0.182	1.21	0.0851	0.33	0.138 J	14.4	14.8	8	18.6
14	S.STATION57	2016-06-21	SS57-CL16	2.84 J	0.014 U	0.398	0.163	0.759	0.0431	0.531 J	0.153 J	10.3	14.8	12.3	12
14	S.STATION58	2016-06-21	SS58-CL16	1.66	0.024	0.203	0.158	1.03	0.0474	0.27	0.139 J	9.6	8.58	3.7	11.8
14	S.STATION59	2016-06-21	SS59-CL16	1.68	0.025	0.202	0.307	0.998	0.0582	0.277	0.0371 J	10.9	9.31	6.6	13.4

Table A2 (Continued)
Metals and Total Solids Analysis Results for Area 8 Tissue

Notes:

Tissue results are reported in wet weight.
[a] Only detected concentrations are included
[b] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. The nomenclature for S.STATION03 and S.STATION09 was also modified to sampling stations S.STATION03-C and S.STATION09-C in order to distinguish them from historical sampling stations and to highlight their downgradient position from the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location S.STATION03-C is co-located with Seep C.
ID - identification
J - The result is an estimated concentration.
µg/g - microgram per gram
mg/kg - milligram per kilogram
ng/g - nanogram per gram
No. - number
U - The compound was analyzed for, but was not detected ("nondetect") at or above the method reporting limit/method detection limit

Table A3
Composite Information and Cadmium Results for Area 8 Clam Tissue Samples

Location ID	Sample Date	Cadmium (mg/kg)	Number of Littleneck Clam in Composite Sample	Number of Manila Clam in Composite Sample
Transects 1 and 14				
S.STATION59	2016-06-21	0.202	20	0
S.STATION58	2016-06-21	0.203	19	1
S.STATION7	2015-06-17	0.222	10	0
S.STATION1	2015-06-15	0.335	10	0
S.STATION57	2016-06-21	0.398	11	9
Transect 10 (Seep D)				
S.STATION40	2015-06-16	0.204	10	0
S.STATION56	2015-06-17	0.22	10	0
S.STATION38	2015-06-16	0.245	20	0
S.STATION74	2016-06-21	0.279	14	6
SEEPD	2015-06-15	0.336	10	0
S.STATION73	2016-06-21	0.41	0	20
Transect 11 (Seep E)				
S.STATION43	2015-06-17	0.205	10	0
S.STATION75	2016-06-21	0.237	20	0
SEEPE	2015-06-15	0.264	10	0
Transect 12 (Seep F)				
S.STATION46	2015-06-17	0.169	10	0
SEEPF	2015-06-15	0.256	10	0
Transect 13 (Seep G and Outfall 03-701)				
S.STATION77A	2016-06-21	0.197	19	1
S.STATION79A	2016-06-21	0.201	17	3
SEEPG	2015-06-15	0.214	10	0
S.STATION76	2016-06-21	0.24	33	2
S.STATION78	2016-06-21	0.259	5	15
S.STATION49	2015-06-16	0.304	8	0
SS-03701	2015-06-16	0.469	10	0
Transects 2, 3, and 8 (Seeps A and C)				
S.STATION32	2015-06-17	0.191	11	0
S.STATION9-C[a]	2015-06-17	0.209	12	0
S.STATION34	2015-06-17	0.295	10	0
S.STATION8	2015-06-17	0.344	10	0
S.STATION2	2015-06-07	0.351	28	0
S.STATION62	2016-06-21	0.501	4	16
SEEPA[a]	2015-06-15	0.579	9	0
S.STATION65	2016-06-21	0.613	1	19
S.STATION67	2016-06-21	0.664	4	16

Table A3 (Continued)
Composite Information and Cadmium Results for Area 8 Clam Tissue Samples

Location ID	Sample Date	Cadmium (mg/kg)	Number of Littleneck Clam in Composite Sample	Number of Manila Clam in Composite Sample
S.STATION5	2015-06-17	0.757	10	0
S.STATION3-C[a]	2015-06-16	0.891	10	0
S.STATION64	2016-06-21	1	3	17
Transect 9 (Outfall 03-703)				
S.STATION53	2015-06-16	0.209	9	0
S.STATION35	2015-06-17	0.21	12	0
S.STATION36	2015-06-16	0.219	12	0
S.STATION37	2015-06-17	0.419	10	0
OF03703	2015-06-16	0.867	10	0
S.STATION70	2016-06-21	0.973	7	13

Notes:

Tissue results are reported in wet weight.

[a] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. The nomenclature for S.STATION03 and S.STATION09 was also modified to sampling stations S.STATION03-C and S.STATION09-C in order to distinguish them from historical sampling stations and to highlight their downgradient position from the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location S.STATION03-C is co-located with Seep C.

mg/kg = milligrams per kilogram

Table A4
Metals Analysis Results for Area 8 Sediment

Tran-sect	Sampling Station ID	Sample Date	Sample No.	Sample Depth (cm)	Sample Type	Arsenic (mg/kg)	Cadmium (mg/kg)	Total Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	Mercury (mg/kg)
					Mean [a]	**2.32**	**1.734**	**30.2**	**17.19**	**10.64**	**16.1**	**0.806**	**39.3**	**0.165**
					Median [a]	**2.22**	**0.787**	**30.2**	**8.58**	**5.01**	**16.1**	**0.281**	**30.8**	**0.067**
					Minimum [a]	**0.42**	**0.152**	**2.32**	**3.81**	**1.71**	**2.37**	**0.048**	**12.5**	**0.006**
					Maximum [a]	**6.47**	**11.4**	**84.8**	**439**	**185**	**40.8**	**17**	**396**	**2.42**
					No. of Detected / No. Sampled	**81/81**	**81/81**	**81/81**	**81/81**	**81/81**	**81/81**	**81/81**	**81/81**	**81/81**
1	S.STATION01	2015-06-15	SS01-SD15	0-10	N	1.92	0.343 J	18.1 J	8.51 J	4.13	16.5	0.136	31.8 J	0.011 J
1	S.STATION04	2015-06-15	SS04-SD15	0-10	N	2.03	0.395 J	22 J	7.75 J	5.59	15.6	0.714	28.6 J	0.032
1	S.STATION07	2015-06-17	SS07-SD15	0-10	N	3.33	0.41	19 J	14.8 J	4.43	17.5	0.059	30.6	0.038
1	S.STATION07	2015-06-17	SS07-SD15B	10-24	N	2.87	0.309	19.6 J	7.41 J	4.18	16.3	0.061	26.3	0.037
1	S.STATION60	2016-06-21	SS60-SD16	0-10	N	3.22	0.325	18	8.11	5.46 J	15.9	0.07	30.5	0.029
1	S.STATION60	2016-06-21	SS-FD1	0-10	FD	3.18	0.302 J	22.3 J	7.86	5.62	16.5	0.074 J	29	0.048
1	S.STATION55	2015-06-16	SS55-SD15	0-10	N	2.12	0.152 J	8.03 J	8.17 J	3.23	23.6	0.048	18.2 J	0.025
1	S.STATION10	2015-06-17	SS10-SD15	0-10	N	3.43	0.284	11.2	7.92	4.73	9.31	0.068	21.4	0.033
1 & 2	S.STATION61	2016-06-21	SS61-SD16	0-10	N	1.28	0.306	13.4	10.9	14.4 J	13.7	0.072	40.2	0.011 J
2	S.STATION62	2016-06-21	SS62-SD16	0-10	N	1.57	0.484	21.1	12.5	6.18 J	19.8	0.124	44.5	0.015 J
2	S.STATION63	2016-06-21	SS63-SD16	0-10	N	1.52	0.385	19.8	11.4	4.73 J	19.1	0.116	37.9	0.111
2	S.STATION02	2015-06-17	SS02-SD15	0-10	N	2.56	1.61	29.9 J	10.6 J	3.79	12.3	0.283	24.7	0.05
2	S.STATION05	2015-06-17	SS05-SD15	0-10	N	2.53	3	34.7 J	8.57 J	4.6	20.1	1.12	31.6	0.033
2	S.STATION08	2015-06-17	SS08-SD15	0-10	N	2.18	2.84	45 J	8.92 J	4.62	17.4	0.857	30.2	1.67
2	S.STATION08	2015-06-17	SS08-SD15B	10-24	N	2.09	3.02	35 J	7.67 J	4.94	17.1	0.829	29.6	0.038
2	S.STATION30	2015-06-17	SS30-SD15	0-10	N	2.12	0.289	19.9 J	7.73 J	5.76	21.1	0.068	25.1	0.031
2	S.STATION11	2015-06-16	SS11-SD15	0-10	N	3.37	0.258 J	12.5 J	6.64 J	4	12.4	0.072	21.5 J	0.034
2 & 3	S.STATION64	2016-06-21	SS64-SD16	0-10	N	1.22	2.71	18.9	11.5	5.67 J	18.8	0.208	63.8	0.082
3	S.STATION50	2015-06-15	SS50-SD15	0-10	N	1.84	8.84 J	38 J	19.4 J	7.2	27.9	0.469	53.5 J	0.308
3	S.STATION51	2015-06-15	SS51-SD15	0-10	N	1.91	10.2 J	84.8 J	61.6 J	47.8	40.8	0.099	113 J	2.42
3	S.STATION03-C[b]	2015-06-16	SS03-SD15	0-10	N	6.47	11.4	34.1 J	8.16	4.01 J	15.5	0.433	31	0.074
3	S.STATION06-C[b]	2015-06-16	SS06-SD15	0-10	N	2.27	5.85 J	49.9 J	9.31 J	5.36	17.5	0.552	31.8 J	0.051
3	S.STATION06-C[b]	2015-06-16	SS06-SD15B	10-24	N	1.62	4.86 J	46.1 J	6.73 J	3.95	13.9	0.437	25.6 J	0.044
3	S.STATION09-C[b]	2015-06-17	SS09-SD15	0-10	N	2.73	2.36	69.5 J	8.64 J	4.86	17.5	0.305	35.9	0.045
3	S.STATION09-C[b]	2015-06-17	SS09-SD15B	10-24	N	2.8	2.29	64.2 J	8.58 J	4.96	17.2	0.287	32.7	0.066
3	S.STATION31	2015-06-16	SS31-SD15	0-10	N	3.27	0.468 J	37.1 J	7.14 J	4.13	12.5	0.109	23.5 J	0.028
3	S.STATION12	2015-06-16	SS12-SD15	0-10	N	3.4	0.339 J	22.4 J	6.81 J	4.27	11.3	0.075	22.9 J	0.037
3 & 8	S.STATION65	2016-06-21	SS65-SD16	0-10	N	1.48	2.06	20.3	12.1	7.66 J	16.8	0.099	39.7	0.506
8	S.STATION66	2016-06-21	SS66-SD16	0-10	N	0.78	0.876	6.62	7.98	3.66 J	10.6	0.12	19.1	0.06
8	S.STATION67	2016-06-21	SS67-SD16	0-10	N	3.74	1.3	16.8	14.2	6.41 J	11.5	0.106	46.1	0.182
8	SEEPA[b]	2015-06-15	SEEPC-SD15	0-10	N	1.66	6.8 J	34.1 J	12.6 J	4.15	14.8	0.299	32.5 J	0.133
8	S.STATION34	2015-06-17	SS34-SD15	0-10	N	2.22	3.38	53.4 J	14.2 J	5.04 J	21.1	0.274	32.9	0.132
8	S.STATION34	2015-06-17	DUP3-SD15	0-10	FD	1.74	3.82	47.7 J	8.36 J	4.22	14.9	0.28	27.2	0.116
8	S.STATION34	2015-06-17	SS34-SD15B	10-24	N	1.54	3.77	51.1 J	7.4 J	4.68	13.9	0.281	26.4	0.17 J
8	S.STATION34	2015-06-17	DUP4-SD15B	10-24	FD	1.47	3.48	43.8 J	6.33 J	3.79	12.6	0.245	23.4	0.083 J
8	S.STATION32	2015-06-17	SS32-SD15	0-10	N	3.02	0.791	40.8 J	8.2 J	5.24	17.1	0.148	30.3	0.077
8	S.STATION54	2015-06-16	SS54-SD15	0-10	N	4.02	0.709	36.7 J	13.3	6.53 J	19.4	0.136	38.5	0.057
8 & 9	S.STATION68	2016-06-21	SS68-SD16	0-10	N	0.42 J	1.15	2.32	3.81	1.71 J	2.37	0.355	12.5	0.044
8 & 9	S.STATION69	2016-06-21	SS69-SD16	0-10	N	0.73	1.17	5.43	4.61	2.05 J	7.07	0.076	17.1	0.055
9	S.STATION70	2016-06-21	SS70-SD16	0-10	N	1.57	3.18 J	27.5 J	77.5	50.2	19.5	7.75 J	148	0.491
9	S.STATION71	2016-06-21	SS71-SD16	0-10	N	1.49	1.22 J	45.3 J	439	19.7	23.4	2.63 J	46.7	0.113
9	OF03703	2015-06-16	OF03703-SD15	0-10	N	2.01	3.33	49.2 J	13.9	6.61 J	22	1.47	44.1	0.627
9	OF03703	2015-06-16	DUP5-SD15	0-10	FD	1.93	3.93	46.4 J	12.2	5.77 J	19.6	1.98	37.9	0.422
9	S.STATION37	2015-06-17	SS37-SD15	0-10	N	1.67	3.15	29.1 J	8.76 J	4.42	11.8	0.414	26.6	0.111

Table A4 (Continued)
Metals Analysis Results for Area 8 Sediment

Tran-sect	Sampling Station ID	Sample Date	Sample No.	Sample Depth (cm)	Sample Type	Arsenic (mg/kg)	Cadmium (mg/kg)	Total Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	Mercury (mg/kg)
9	S.STATION36	2015-06-16	SS36-SD15	0-10	N	1.31	1.15	26 J	5.24	2.85 J	8.94	0.151	17.2	0.083
9	S.STATION36	2015-06-16	SS36-SD15B	10-24	N	1.68	1.7	38.5 J	6	3.1 J	12.4	0.261	23.2	0.073
9	S.STATION53	2015-06-16	SS53-SD15	0-10	N	2.31	0.44	23.6 J	5.68	4.12 J	11.4	0.1	20.9	0.027
9 & 10	S.STATION72	2016-06-21	SS72-SD16	0-10	N	1.44	1.18 J	26.5 J	48.8	67.7	19.6	17 J	54.2	0.163
9 & 10	S.STATION74	2016-06-21	SS74-SD16	0-10	N	1.57	1.99 J	36 J	10.6	5.9	16.9	2.2 J	35.3	0.176
10	S.STATION73	2016-06-21	SS73-SD16	0-10	N	2.26	0.9 J	19.9 J	19.1	8.77	12.7	1.91 J	39.7	0.099
10	SEEPD	2015-06-15	SEEPD-SD15	0-10	N	0.9	1.08 J	8.73 J	4.2 J	2.64	5.17	0.398	13.2 J	0.165
10	S.STATION40	2015-06-16	SS40-SD15	0-10	N	1.41	3.82	41.1 J	9.85	5.27 J	14.9	1.41	29.8	0.068
10	S.STATION40	2015-06-16	SS40-SD15B	10-24	N	1.44	1.16	30.2 J	9.22	4.55 J	14.6	1.16	34.1	0.767
10	S.STATION38	2015-06-16	SS38-SD15	0-10	N	1.48	0.487	25.6 J	6.58	3.22 J	13.4	0.238	19.6	0.066
10	S.STATION39	2015-06-16	SS39-SD15	0-10	N	2.49	0.524	33.2 J	6.05	7.67 J	13.7	0.113	23.8	0.034
10	S.STATION52	2015-06-16	SS52-SD15	0-10	N	2.95	0.437	33.6 J	6.82	10.2 J	15.1	0.116	26.7	0.037
10 & 11	S.STATION75	2016-06-21	SS75-SD16	0-10	N	2.85	1.55 J	34.1 J	13.4	6.83	18.2	0.889 J	47.7	0.205
11	SEEPE	2015-06-15	SEEPE-SD15	0-10	N	1.63	0.715 J	30.9 J	9.71 J	3.99	15.4	0.446	27.2 J	0.107
11	S.STATION43	2015-06-17	SS43-SD15	0-10	N	2.58	0.814	38.4 J	8.58 J	4.38	16.7	0.342	32.4	0.054
11	S.STATION43	2015-06-17	SS43-SD15B	10-24	N	1.95	0.782	30 J	7.25 J	3.3	17.2	0.295	24.8	0.067
11	S.STATION41	2015-06-16	SS41-SD15	0-10	N	3.27	0.533	34.4 J	8.5	4.98 J	16.2	0.117	30	0.045
11	S.STATION42	2015-06-16	SS42-SD15	0-10	N	3.25	0.403	28.3 J	6.97	4.78 J	15.1	0.091	27.2	0.043
12	SEEPF	2015-06-15	SEEPF-SD15	0-10	N	2.22	0.754 J	19.8 J	6.68 J	4.9	10.4	0.228	28.8 J	0.136
12	S.STATION46	2015-06-16	SS46-SD15	0-10	N	2.53	0.677	39.1 J	8.05	5.11 J	15.7	0.345	29.4	0.095
12	S.STATION46	2015-06-16	SS46-SD15B	10-24	N	2.5	0.88	34 J	7.64	7.82 J	14.5	0.368	34.3	0.054
12	S.STATION44	2015-06-16	SS44-SD15	0-10	N	1.94	0.38	21.3 J	4.74	3.15 J	10.3	0.102	17.7	0.034
12	S.STATION45	2015-06-16	SS45-SD15	0-10	N	3.37	0.339	30.8 J	6.48	4.45 J	16.9	0.079	28	0.034
13	SS-03701	2015-06-16	OF03701-SD15	0-10	N	2.47	1.97	30.2 J	39.8	185 J	24.2	5.99	396	0.224
13	S.STATION49	2015-06-16	SS49-SD15	0-10	N	1.67	0.524	20.3 J	10.2 J	7.86	12.5	0.999	36.5	0.151
13	SEEPG	2015-06-15	SEEPG-SD15	0-10	N	2.37	0.585 J	26.6 J	11 J	8.32	15.4	0.616	40.8 J	0.144
13	SEEPG	2015-06-15	SEEPG-SD15B	10-24	N	2.09	0.487 J	31.6 J	10.6 J	12.8	17.4	0.423	43.8 J	0.099
13	S.STATION48	2015-06-15	SS48-SD15	0-10	N	3.56	0.771 J	35.8 J	23.1 J	8.83	17.4	0.527	45.2 J	0.608
13	S.STATION47	2015-06-16	SS47-SD15	0-10	N	3.19	0.375	20.3 J	6.67	4.33 J	14.4	0.081	25.5	0.026
S. 13	S.STATION76	2016-06-21	SS76-SD16	0-10	N	3.12	0.765 J	40.5 J	14.7	41.8	20.6	0.479 J	55.2	0.112
S. 13	S.STATION77	2016-06-21	SS77-SD16	0-10	N	3.31	0.681 J	32.5 J	9.31	6.99	19	0.218 J	37.5	0.112
N. 13	S.STATION78	2016-06-21	SS78-SD16	0-10	N	2.25	1.14 J	31.8 J	14.6 J	12.5 J	18.4	1.33 J	49	0.107
N. 13	S.STATION78	2016-06-21	SS-FD2	0-10	FD	1.46	0.285 J	18.2 J	8.68 J	32.5 J	12.6	0.622 J	31.2	0.121
N. 13	S.STATION79	2016-06-21	SS79-SD16	0-10	N	3.71	0.655 J	34.9 J	11	13.4	20.4	0.356 J	46.3	0.066
14	S.STATION57	2016-06-21	SS57-SD16	0-10	N	3.16	0.33	12.9	7.04	4.61 J	10.8	0.071	42	0.006 J
14	S.STATION58	2016-06-21	SS58-SD16	0-10	N	2.37	0.259	21.6	11.5	6.15 J	17.9	0.067	36.1	0.018 J
14	S.STATION59	2016-06-21	SS59-SD16	0-10	N	2.44	0.233	12.9	7.93	5.1 J	12.6	0.056	25.8	0.046

Notes:
Sediment results are reported in dry weight.
[a] Only detected concentrations are included
[b] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. In addition, the nomenclature for S.STATION03, S.STATION06, and S.STATION09 was modified to sampling stations S.STATION03-C, S.STATION06-C, and S.STATION09-C in order to distinguish them from historical sampling stations and to highlight their downgradient position from the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location S.STATION03-C is co-located with Seep C.
cm - centimeter
FD - field duplicate
ID - identification
J - The result is an estimated concentration
mg/kg - milligram per kilogram
N - normal environmental sample
No. - number

Table A5
AVS/SEM Analysis Results for Area 8 Sediment

Sampling Station ID	Sample Date	Sample No.	Sample Type	Acid Volatile Sulfides (µmol/g)	Cadmium (µmol/g)	Copper (µmol/g)	Lead (µmol/g)	Nickel (µmol/g)	Zinc (µmol/g)	Mercury (µmol/g)
S.STATION06-C[a]	2015-06-16	SS06-SD15B	N	3.9	0.04937 J	0.0261	0.038	0.0325 J	0.211	5.8E-05 U
S.STATION07	2015-06-17	SS07-SD15	N	3.65	0.00315 J	0.0271	0.0175 J	0.0278	0.207	6.3E-05 U
S.STATION08	2015-06-17	SS08-SD15	N	4.77	0.02675	0.0318	0.0181 J	0.0365	0.229	6.1E-05 U
S.STATION08	2015-06-17	SS08-SD15B	N	7.5	0.02361	0.0184 J	0.0154 J	0.0338	0.204	5.3E-05 U
S.STATION09-C[a]	2015-06-17	SS09-SD15	N	7.9	0.0165	0.0148 J	0.0153 J	0.0338	0.239	5.1E-05 U
S.STATION09-C[a]	2015-06-17	SS09-SD15B	N	8.9	0.01694	0.027	0.0188 J	0.0384	0.246	6.0E-05 U
S.STATION34	2015-06-17	SS34-SD15	N	4.88	0.04421	0.0417	0.0245 J	0.0402	0.24	6.2E-05 U
S.STATION34	2015-06-17	SS34-SD15B	N	0.85	0.03604 J	0.0379	0.0175	0.0398 J	0.199	6.1E-05 U
S.STATION34	2015-06-17	DUP3-SD15	FD	3.95	0.03639	0.035	0.018 J	0.0318	0.184	5.5E-05 U
S.STATION34	2015-06-17	DUP4-SD15B	FD	0.55	0.03042 J	0.0375	0.0181	0.0314 J	0.172	6.1E-05 U
S.STATION36	2015-06-16	SS36-SD15	N	7.7	0.01683 J	0.0309	0.0148	0.0442 J	0.221	5.8E-05 U
S.STATION36	2015-06-16	SS36-SD15B	N	5.98	0.01822 J	0.0272	0.0153	0.0411 J	0.226	5.9E-05 U
S.STATION40	2015-06-16	SS40-SD15B	N	9.1	0.01199 J	0.0381	0.029	0.0605 J	0.388	6.2E-05 U
S.STATION40	2015-06-16	SS40-SD15	N	9.3	0.01588 J	0.051	0.0235	0.0738 J	0.41	6.1E-05 U
S.STATION43	2015-06-17	SS43-SD15	N	2.21	0.00801 J	0.0345	0.0178	0.0401 J	0.211	6.3E-05 U
S.STATION46	2015-06-16	SS46-SD15	N	2.13	0.0073 J	0.036	0.021	0.0361 J	0.239	6.1E-05 U
S.STATION48	2015-06-15	SS48-SD15	N	7.06	0.00625	0.043	0.0269	0.0415	0.376	6.5E-05 U
S.STATION57	2016-06-21	SS57-SD16	N	0.017 U	0.00552 U	0.0427 J	0.0276 U	0.0249 J	0.284	6.6E-05 U
S.STATION58	2016-06-21	SS58-SD16	N	2.33	0.00169 J	0.0394 J	0.0209 J	0.0359	0.233	5.4E-05 U
S.STATION59	2016-06-21	SS59-SD16	N	0.09	0.00213 J	0.0437 J	0.0205 J	0.0229	0.22	5.4E-05 U
S.STATION62	2016-06-21	SS62-SD16	N	0.013 U	0.00305 J	0.0794	0.0227	0.0297	0.297	5.2E-05 U
S.STATION64	2016-06-21	SS64-SD16	N	0.013 U	0.01754	0.0874	0.0285	0.137	0.846	2.6E-05 J
S.STATION65	2016-06-21	SS65-SD16	N	0.045	0.01271	0.51	0.0542	0.0556	0.37	1.6E-03
S.STATION67	2016-06-21	SS67-SD16	N	0.041	0.00906	0.106	0.0316	0.055	0.509	6.1E-05 U
S.STATION70	2016-06-21	SS70-SD16	N	0.016 J	0.02552 J	0.975	0.221	0.0783	1.71	3.0E-05 J
S.STATION73	2016-06-21	SS73-SD16	N	0.012 U	0.00768 J	0.1	0.0459	0.0485	0.33	5.1E-05 J
S.STATION74	2016-06-21	SS74-SD16	N	2.77	0.01725 J	0.0492	0.0328	0.0466	0.34	5.5E-05 U
S.STATION75	2016-06-21	SS75-SD16	N	2.54	0.01619 J	0.0701	0.0312	0.0709	0.38	5.5E-05 U
S.STATION76	2016-06-21	SS76-SD16	N	9.7	0.00724 J	0.0685	0.0488	0.072	0.614	5.6E-05 U
S.STATION77	2016-06-21	SS77-SD16	N	1.27	0.00547 J	0.0449	0.0273	0.0373	0.27	6.1E-05 U
S.STATION78	2016-06-21	SS78-SD16	N	1.22	0.00438 J	0.0906	0.0548	0.0683	0.515	5.3E-05 U
S.STATION79	2016-06-21	SS79-SD16	N	2.38	0.00651 J	0.0481	0.0345	0.0451	0.391	6.0E-05 U
S.STATION78	2016-06-21	SS-FD2	FD	1.12	0.00567 J	0.0888	0.0742	0.057	0.581	5.4E-05 U

Notes:

[a] The nomenclature for S.STATION06 and S.STATION09 was modified to sampling stations S.STATION06-C and S.STATION09-C in order to distinguish them from historical sampling stations and to highlight their downgradient position from the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3.

AVS - acid volatile sulfides
FD - field duplicate
ID - identification
J - The result is an estimated concentration.
µmol/g - micromole per gram
N - normal environmental sample
No. - number
SEM - simultaneously extracted metals
U - The compound was analyzed for, but was not detected ("nondetect") at or above the method reporting limit/method detection limit

Table A6
Total Organic Carbon, Total Solids, and Grain Size Analysis Results for Area 8 Sediment

Sampling Station ID	Sample Date	Sample No.	Sample Type	Total Organic Carbon (%)	Total Solids (%)	Gravel >2 mm (%)	Sand, Very Coarse 1-2 mm (%)	Sand, Coarse 0.5-1 mm (%)	Sand, Medium 0.25-0.5 mm (%)	Sand, Fine 0.125-0.25 mm (%)	Sand, Very Fine 0.0625-0.125 mm (%)	Silt 0.0039-0.0625 mm (%)	Clay < 0.0039 mm (%)
OF03701	2015-06-16	OF03701-SD15	N	0.723	72.3	59.39	13.12	12.44	7.71	2.52	1.16	6.39	4
OF03703	2015-06-16	OF03703-SD15	N	0.4	81.8	31.23	16.98	25.01	16.79	4.85	1.63	5.42	2.38
OF03703	2015-06-16	DUP5-SD15	FD	0.398	82.2	34.29	16.13	22.64	16.56	4.86	1.77	5.23	2.3
S.STATION01	2015-06-15	SS01-SD15	N	NA	79.8	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION02	2015-06-17	SS02-SD15	N	NA	76.5	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION03-C[a]	2015-06-16	SS03-SD15	N	0.221	78.4	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION04	2015-06-15	SS04-SD15	N	NA	73.8	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION05	2015-06-17	SS05-SD15	N	NA	80.8	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION06-C[a]	2015-06-16	SS06-SD15	N	NA	81.3	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION06-C[a]	2015-06-16	SS06-SD15B	N	0.333	81.9	12.69	7.36	13.99	38.7	9.73	1.4	3.65	2.16
S.STATION07	2015-06-17	SS07-SD15	N	NA	74.9	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION07	2015-06-17	SS07-SD15B	N	0.36	73.5	19.7	15.6	13.5	30.53	13.95	1.8	4.14	2.73
S.STATION08	2015-06-17	SS08-SD15	N	NA	77.6	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION08	2015-06-17	SS08-SD15B	N	0.362	73.2	47.98	5.7	9.67	23.3	16.01	1.22	3.31	1.88
S.STATION09-C[a]	2015-06-17	SS09-SD15	N	NA	86	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION09-C[a]	2015-06-17	SS09-SD15B	N	0.424	76.2	23.64	6.74	17.35	29.54	11.26	1.89	6.65	2.76
S.STATION10	2015-06-17	SS10-SD15	N	NA	69	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION11	2015-06-16	SS11-SD15	N	NA	77.1	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION12	2015-06-16	SS12-SD15	N	NA	72.6	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION30	2015-06-17	SS30-SD15	N	0.439	76.7	36.94	9.49	11.89	18.75	11.18	4.11	7.86	2.23
S.STATION31	2015-06-16	SS31-SD15	N	0.469	76.1	37.83	11.11	8.74	21.82	9.01	2.47	5.38	2.36
S.STATION32	2015-06-17	SS32-SD15	N	0.51	72.3	8.42	4.41	10.8	36.22	17.62	9.11	14.58	3.61
S.STATION34	2015-06-17	SS34-SD15	N	0.433	75.2	22.06	13.78	23.54	22.7	5.97	1.99	6.81	2.33
S.STATION34	2015-06-17	SS34-SD15B	N	0.273	77.6	47.24	14.94	17.3	16.26	3.67	1.06	2.48	1.49
S.STATION34	2015-06-17	DUP3-SD15	FD	0.392	80.5	32.47	12.52	20.25	18.72	4.69	1.6	5.12	2.09
S.STATION34	2015-06-17	DUP4-SD15B	FD	0.268	78.2	40.23	16.1	19.07	18.23	4.08	1.16	2.7	1.59
S.STATION36	2015-06-16	SS36-SD15	N	0.405	80.3	11.38	9.55	22.87	34.02	8.54	2.52	5.42	2.71
S.STATION36	2015-06-16	SS36-SD15B	N	0.235	78.8	18.71	14.37	24.09	31.7	6.11	1.14	2.21	1.41
S.STATION37	2015-06-17	SS37-SD15	N	0.464	72.2	22.57	18.89	28.87	21.45	4.62	1.4	4.21	2.21
S.STATION38	2015-06-16	SS38-SD15	N	0.254	77.8	24.72	11.9	21.94	30	5.6	1.37	2.46	1.77
S.STATION39	2015-06-16	SS39-SD15	N	0.451	77.4	9.9	4.9	10.55	48.14	14.71	2.63	4.09	2.04
S.STATION40	2015-06-16	SS40-SD15B	N	0.274	74.7	23.13	22.48	29.22	17.63	3.58	0.98	2.31	1.92
S.STATION40	2015-06-16	SS40-SD15	N	0.257	73.7	30.97	20.44	27.12	15.64	3.4	1.03	2.41	1.98
S.STATION41	2015-06-16	SS41-SD15	N	0.382	79.6	15.63	5.67	7.89	38.4	19.38	4.33	5.39	2.41
S.STATION42	2015-06-16	SS42-SD15	N	0.334	77.4	11.22	5.8	7.03	40.87	19.26	4.63	6.75	2.51
S.STATION43	2015-06-17	SS43-SD15B	N	0.242	81	41.92	10.69	14.33	26.39	6.01	1.16	1.13	1.01
S.STATION43	2015-06-17	SS43-SD15	N	0.36	74.7	20.99	11.38	19.9	31.69	8.32	3.17	4.79	2.21

Table A6 (Continued)
Total Organic Carbon, Total Solids, and Grain Size Analysis Results for Area 8 Sediment

Sampling Station ID	Sample Date	Sample No.	Sample Type	Total Organic Carbon (%)	Total Solids (%)	Gravel >2 mm (%)	Sand, Very Coarse 1-2 mm (%)	Sand, Coarse 0.5-1 mm (%)	Sand, Medium 0.25-0.5 mm (%)	Sand, Fine 0.125-0.25 mm (%)	Sand, Very Fine 0.0625-0.125 mm (%)	Silt 0.0039-0.0625 mm (%)	Clay < 0.0039 mm (%)
S.STATION44	2015-06-16	SS44-SD15	N	0.259	77	8.75	5.87	10.37	41.32	21.49	3.87	3.98	1.93
S.STATION45	2015-06-16	SS45-SD15	N	0.254	77.3	13.45	3.49	5.96	38.03	27.48	5.5	4.54	2.06
S.STATION46	2015-06-16	SS46-SD15	N	0.321	77.3	16.8	5.77	9.88	38.18	15.96	4.11	4.85	2.05
S.STATION46	2015-06-16	SS46-SD15B	N	0.293	77.8	39.45	7.35	8.97	29.09	11.01	2.52	3.02	1.61
S.STATION47	2015-06-16	SS47-SD15	N	0.353	76.5	18.25	6.72	7.83	30.37	19.39	6.04	7.26	2.56
S.STATION48	2015-06-15	SS48-SD15	N	0.399	72.1	4.8	4.05	13.5	45.93	14.07	4.23	6.76	3.04
S.STATION49	2015-06-16	SS49-SD15	N	0.411	76	NA	NA	NA	NA	NA	NA	NA	NA
S.STATION50	2015-06-15	SS50-SD15	N	0.245	84.7	30.7	25.8	24.02	9.92	2.37	0.61	4.06	2.95
S.STATION51	2015-06-15	SS51-SD15	N	0.239	91.4	37.5	19.59	16.18	9.79	3.06	0.92	3.1	2.25
S.STATION52	2015-06-16	SS52-SD15	N	0.269	79	11.32	4.86	10.65	48.83	14.13	3.12	4.89	2.16
S.STATION53	2015-06-16	SS53-SD15	N	0.435	76.9	49.87	5.31	6.46	22.87	9.31	2.91	6.23	2.28
S.STATION54	2015-06-16	SS54-SD15	N	0.757	63.4	10.34	3.88	5.08	23.72	15.7	8.98	27.86	6.03
S.STATION55	2015-06-16	SS55-SD15	N	NA	78.7	NA	NA	NA	NA	NA	NA	NA	NA
SEEPA[a]	2015-06-15	SEEPC-SD15	N	0.402	73.9	NA	NA	NA	NA	NA	NA	NA	NA
SEEPD	2015-06-15	SEEPD-SD15	N	0.412	74.4	NA	NA	NA	NA	NA	NA	NA	NA
SEEPE	2015-06-15	SEEPE-SD15	N	0.313	74.8	29.38	19.05	26.71	18.32	3.35	0.84	1.78	1.49
SEEPF	2015-06-15	SEEPF-SD15	N	0.411	73.2	27.24	18.51	22.48	22.41	4.28	1.07	2.38	2.11
SEEPG	2015-06-15	SEEPG-SD15	N	0.429	74	11.17	11.11	24.64	29.67	7.02	2.53	6.85	3.63
SEEPG	2015-06-15	SEEPG-SD15B	N	0.201	80.8	37.77	11.4	20.55	22.83	4.37	1.23	2.46	1.88

Notes:

Total organic carbon and grain size analytical method was American Society for Testing and Materials D422 modified for the Puget Sound Estuary Program.

[a] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8. In addition, the nomenclature for S.STATION03, S.STATION06, and S.STATION09 was modified to sampling stations S.STATION03-C, S.STATION06-C, and S.STATION09-C in order to distinguish them from historical sampling stations and to highlight their downgradient position from the newly identified Seep C Transect 8, rather than the historical Seep A Transect 3. Sample location S.STATION03-C is co-located with Seep C.

FD - field duplicate
ID - identification
N - normal environmental sample
NA - not analyzed
No. - number
mm - millimeter

Table A7
Metals Analysis Results for Area 8 Seeps and Outfalls

Sampling Station ID	Sample Date	Sample No.	Sample Type	Dissolved Arsenic (µg/L)	Dissolved Cadmium (µg/L)	Dissolved Chromium, Total (µg/L)	Dissolved Copper (µg/L)	Dissolved Lead (µg/L)	Dissolved Nickel (µg/L)	Dissolved Silver (µg/L)	Dissolved Zinc (µg/L)	Dissolved Mercury (µg/L)
OF03701	2015-06-16	OF03701-OF15	N	0.84 J	6.91	8.25	5.39	0.355	1.13	0.266 J	54.9	0.00427
OF03701	2015-06-16	DUP6-OF15	FD	1.6 J	5.7	6.77	5.06	0.344	1.16	0.58 J	40.2	0.00534
SEEPC[a]	2015-06-15	SEEPA-SW15	N	1.26	45.7	9.68	1.88	0.047	1.65	0.057	1.63	0.00849
SEEPB	2015-06-15	SEEPB-SW15	N	1.44	0.321	2.61	1.13	0.026	0.93	0.021	1.24	0.0010
SEEPA[a]	2015-06-15	SEEPC-SW15	N	1.55	2.41	1.21	0.687	0.089	1.81	0.016 J	1.43	0.00866
SEEPD	2015-06-15	SEEPD-SW15	N	0.71	0.003 U	0.42	0.132 U	0.01 U	0.53	0.003 J	1.38	0.00589
SEEPE	2015-06-15	SEEPE-SW15	N	1.76	0.015 J	0.2 J	0.345	0.027	0.53	0.003 J	0.54 U	0.0141
SEEPF	2015-06-16	SEEPF-SW15	N	2.51	0.027 J	0.34 J	0.492	0.028 J	0.78	0.011 J	1.49 J	0.00205 J
SEEPF	2015-06-16	DUP2-SW15	FD	1.96	0.038 J	0.24 J	0.44	0.023 J	0.53	0.013 J	0.77 J	0.00256
SEEPG	2015-06-17	SEEPG-SW15	N	2.28	0.044	0.25	0.438	0.017 J	0.96	0.008 J	1.24	0.00129

Notes:

[a] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8.

FD - field duplicate

ID - Identification

J - The result is an estimated concentration

µg/L - microgram per liter

N - normal environmental sample

No. - number

U - The compound was analyzed for, but was not detected ("nondetect") at or above the method reporting limit/method detection limit

Table A8
Metals Analysis Results for Reference Area Marine Water

Sampling Station ID	Sample Date	Sample No.	Sample Type	Dissolved Arsenic (µg/L)	Dissolved Cadmium (µg/L)	Dissolved Chromium, Total (µg/L)	Dissolved Copper (µg/L)	Dissolved Lead (µg/L)	Dissolved Nickel (µg/L)	Dissolved Silver (µg/L)	Dissolved Zinc (µg/L)	Dissolved Mercury (µg/L)
			Mean [a]	**1.08**	**0.047**	**0.14**	**0.604**	**0.018**	**0.77**	**0.006**	**1.0**	**0.00032**
			Median [a]	**1.17**	**0.056**	**0.16**	**0.537**	**0.016**	**0.78**	**0.005**	**0.9**	**0.00033**
			Minimum [a]	**0.49**	**0.014**	**0.07**	**0.365**	**0.014**	**0.51**	**0.003**	**0.6**	**0.00021**
			Maximum [a]	**1.54**	**0.066**	**0.23**	**0.901**	**0.031**	**0.93**	**0.011**	**1.4**	**0.00043**
			No. of Detected / No. Sampled	**9/9**	**8/9**	**9/9**	**9/9**	**7/9**	**9/9**	**6/9**	**5/9**	**9/9**
			Range of Reporting Limits	**--**	**0.009**	**--**	**--**	**0.01**	**--**	**0.005**	**0.2 - 0.4**	**--**
PP01	2015-06-03	PP1-MW15	N	1.54	0.064	0.11 J	0.901	0.031	0.75	0.011 J	1.4	0.00043 J
PP03	2015-06-03	PP3-MW15	N	1.21	0.066	0.16 J	0.537	0.021	0.71	0.006 J	0.6	0.00033 J
PP03	2015-06-03	PPDUP-MW15	FD	1.54	0.059	0.17 J	0.822	0.014 J	0.65	0.005 J	0.9	0.00029 J
PP05	2015-06-03	PP5-MW15	N	1.17	0.052	0.16 J	0.456	0.016 J	0.86	0.005 J	1.4	0.00029 J
PP07	2015-06-03	PP7-MW15	N	1.18	0.06	0.17 J	0.534	0.015 J	0.51	0.005 J	0.7	0.00028 J
PP09	2015-06-03	PP9-MW15	N	0.65	0.014 J	0.1 J	0.386	0.01 U	0.93	0.005 U	0.3 U	0.00036 J
PP11	2015-06-03	PP11-MW15	N	1.06	0.035	0.23	0.804	0.018 J	0.78	0.003 J	0.4 U	0.00021 J
PP13	2015-06-03	PP13-MW15	N	0.91	0.026	0.12 J	0.63	0.014 J	0.84	0.005 U	0.4 U	0.00035 J
PP15	2015-06-03	PP15-MW15	N	0.49 J	0.009 U	0.07 J	0.365	0.01 U	0.93	0.005 U	0.2 U	0.00037 J

Notes:

[a] Only detected concentrations are included

FD - field duplicate
ID - identification
J - The result is an estimated concentration
N - normal environmental sample
No. - number
µg/L - microgram per liter
U - The compound was analyzed for, but was not detected ("nondetect") at or above the method reporting limit/method detection limit

Table A9
Metals Analysis Results for Area 8 Marine Water

Sampling Station ID	Sample Date	Sample No.	Sample Type	Dissolved Arsenic (µg/L)	Dissolved Cadmium (µg/L)	Dissolved Chromium, Total (µg/L)	Dissolved Copper (µg/L)	Dissolved Lead (µg/L)	Dissolved Nickel (µg/L)	Dissolved Silver (µg/L)	Dissolved Zinc (µg/L)	Dissolved Mercury (µg/L)
			Mean [a]	**1.34**	**0.430**	**0.43**	**0.696**	**0.056**	**0.63**	**0.012**	**1.39**	**0.00168**
			Median [a]	**1.31**	**0.185**	**0.43**	**0.609**	**0.047**	**0.60**	**0.009**	**0.96**	**0.00141**
			Minimum [a]	**1.23**	**0.041**	**0.19**	**0.488**	**0.029**	**0.45**	**0.005**	**0.63**	**0.00061**
			Maximum [a]	**1.58**	**1.57**	**0.86**	**1.34**	**0.099**	**1.01**	**0.051**	**3.59**	**0.00372**
			No. of Detected / No. Sampled	**10/10**	**10/10**	**10/10**	**10/10**	**10/10**	**10/10**	**10/10**	**10/10**	**10/10**
OF03703	2015-06-15	OF03703-MW15	N	1.58	0.224	0.21	1.34	0.08	0.76	0.051	1.88	0.00243
S.STATION05	2015-06-16	SS5-MW15	N	1.23	0.277	0.58	0.803	0.047	0.68	0.005 J	0.86	0.00061
SEEPC[b]	2015-06-15	SEEPA-MW15	N	1.37	1.3	0.46	0.614	0.099	0.75	0.009 J	0.76 J	0.00089
SEEPC[b]	2015-06-15	DUP1-MW15	FD	1.35	1.57	0.42	0.604	0.074	0.6	0.009 J	0.63	0.00099
SEEPB	2015-06-15	SEEPB-MW15	N	1.24	0.145	0.86	0.843	0.047	1.01	0.014 J	3.59	0.00127
SEEPA[b]	2015-06-15	SEEPC-MW15	N	1.27	0.551	0.43	0.635	0.056	0.6	0.008 J	0.94	0.00248
SEEPD	2015-06-15	SEEPD-MW15	N	1.32	0.041	0.58	0.488	0.029	0.5	0.005 J	0.97	0.00372
SEEPE	2015-06-15	SEEPE-MW15	N	1.29	0.055	0.21	0.501	0.045	0.45	0.005 J	1.48	0.00161
SEEPF	2015-06-15	SEEPF-MW15	N	1.24	0.052	0.19 J	0.534	0.04	0.46	0.005 J	2.05	0.00135
SEEPG	2015-06-15	SEEPG-MW15	N	1.5	0.089	0.34	0.596	0.047	0.49	0.01 J	0.71	0.00147

Notes:

[a] Only detected concentrations are included
[b] During completion of this report, a discrepancy in the naming of Seep A was identified within project documents. For consistency with the Seep A name used in the long-term monitoring reports, Seep A is located east of Well MW8-11 on Transect 3 and Seep C is located east of MW8-14 through MW8-16 on Transect 8.

FD - field duplicate
ID - Identification
J - The result is an estimated concentration
µg/L - microgram per liter
N - normal environmental sample
No. - number

Table A10
BOLD Natural Background Sediment Concentrations for Chemicals of Concern

Study ID	Collection Date	Location ID	Arsenic (mg/kg)	Cadmium (mg/kg)	Total Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	Mercury (mg/kg)
BOLD 2008	8/1/2008	AI_1	3.6 J	0.052 U	22.1 J	6.8 J	4 J	28	0.022 U	31.7	0.04 U
BOLD 2008	8/1/2008	AI_11_C	2.2 J	0.027 U	15.3 J	4 J	1.6 J	23.2	0.0074 J	21.1	0.0054 U
BOLD 2008	8/3/2008	AI_13_C	3 J	0.11 U	13.3 J	7.5 J	4.2 J	18.1	0.035 U	26.1	0.05 U
BOLD 2008	8/1/2008	AI_20_C_GS	3.4 J	0.14 U	22.9 J	9.3 J	4.7 J	23.9	0.059 U	37.6	0.0048 U
BOLD 2008	8/1/2008	AI_5_C	3.5 J	0.1 U	19.1 J	7.8 J	4.3 J	23.3	0.04 U	32.4	0.013 U
BOLD 2008	8/4/2008	CPS_0	3.8 J	0.15 J	15.1	15.7 J	9.1	13.3	0.12 J	55.4 J	0.091 U
BOLD 2008	8/4/2008	CPS_1	8.2	0.45 J	25.2	20.4 J	13	26.9	0.12 J	53.7 J	0.15
BOLD 2008	7/31/2008	CPS_3	4.8 J	0.13 U	25.3 J	11.9 J	7 J	30.6	0.08 J	40.8	0.049 U
BOLD 2008	8/4/2008	CPS_4	11.3	0.32 J	17.4	13.6 J	17.6	28.5	0.065 J	58 J	0.11
BOLD 2008	7/31/2008	CPS_5	3.1 J	0.076 U	18.4 J	7.4 J	5.7 J	19.5	0.037 U	30.9	0.042 U
BOLD 2008	8/2/2008	HC_0	6.7	0.3 J	49 J	56.7 J	17.2 J	42	0.17 J	99.1	0.13
BOLD 2008	8/2/2008	HC_1	4.2 J	0.24 J	24.2 J	9.9 J	5.1 J	25.2	0.046 U	44.3	0.084
BOLD 2008	8/2/2008	HC_2	21	2.3 J	70.4 J	91.2 J	10.4 J	46.7	0.24 J	92.3	0.088 J
BOLD 2008	8/2/2008	HC_3	5.2	0.29 J	28.1 J	16.3 J	7.8 J	25.5	0.084 J	57.1	0.087
BOLD 2008	8/2/2008	HC_6	6.2	0.38 J	36.4 J	25.8 J	11 J	29.2	0.14 J	73	0.091
BOLD 2008	7/31/2008	NCPS_0	5.9	0.38 J	27.6 J	14.2 J	8.1 J	26.1	0.091 J	54.8	0.059
BOLD 2008	7/31/2008	NCPS_1	2.1 J	0.022 U	12.4 J	3.2 J	2.9 J	13	0.013 U	17.9	0.011 U
BOLD 2008	8/3/2008	NCPS_2	4.8 J	0.094 U	32.1 J	13 J	8.4 J	27.5	0.2 J	47.4	0.076
BOLD 2008	7/31/2008	NCPS_3	5.1	0.28 J	26.1 J	13 J	6.6 J	28.7	0.065 J	49	0.082
BOLD 2008	7/31/2008	NCPS_4	3.6 J	0.12 U	19.1 J	9.8 J	4.8 J	20.5	0.046 U	33.7	0.041 U
BOLD 2008	8/3/2008	PSPS_1	5.1	0.079 J	32.2	20.5 J	7.5	31.1	0.088 J	42.4 J	0.12
BOLD 2008	8/3/2008	PSPS_2	11	0.18 J	53.8	48.1 J	14.7	49.5	0.24 J	80.8 J	0.21
BOLD 2008	8/3/2008	PSPS_3	13.2	0.15 U	105	42.9	13.4	94.7	0.15 J	95.5 J	0.16
BOLD 2008	8/3/2008	PSPS_8	2.2 J	0.03 U	22	3.3 J	3.3 J	19.3	0.013 U	18.6 J	0.028 U
BOLD 2008	8/3/2008	PSPS_9	14	0.15 J	97.1	41.1	14.5	84 J	0.16 J	92.9	0.078
BOLD 2008	8/4/2008	R_CAR_0	8.6	0.7 J	50.1	28.8 J	12.3	50.9	0.15 J	79.2 J	0.19
BOLD 2008	8/4/2008	R_CAR_1	6.7	0.46 J	29.7	14.4 J	9.6	25.1	0.095 J	47.2 J	0.16
BOLD 2008	8/4/2008	R_CAR_4	14.6	2.8	53.4	39.6 J	16.5	43	0.32 J	93.5 J	0.26
BOLD 2008	8/4/2008	R_CAR_5	8.6	0.39 J	23.9	36.7 J	20.9	22.7	0.24 J	69 J	0.23
BOLD 2008	8/4/2008	R_CAR_6_C	1.9 J	0.049 J	12	4.6 J	2.9 J	12.9	0.019 J	18.2 J	0.038 U
BOLD 2008	8/2/2008	R_DAB_0	3.3 J	0.16 J	27.4 J	25.3 J	6.5 J	20	0.065 J	55.6	0.048 U
BOLD 2008	8/2/2008	R_DAB_1	8.6	0.41 J	49.3 J	51.3 J	12.1 J	39.8	0.2 J	84.4	0.14
BOLD 2008	8/2/2008	R_DAB_2	7	0.23 J	42.6	31.7	14.1	31.4 J	0.15 J	79.6	0.072
BOLD 2008	8/2/2008	R_DAB_5	6.3	0.3 J	37.4	24.1	11.6	28 J	0.13 J	70.5	0.084
BOLD 2008	8/2/2008	R_DAB_7_C	5.9	0.17 J	38.8 J	32 J	10.6 J	30.7	0.095 J	69.4	0.14
BOLD 2008	8/3/2008	R_HOL_0	1.6 J	0.065 J	10.8	3.6 J	1.9 J	10	0.023 J	13.9 J	0.05 U
BOLD 2008	8/3/2008	R_HOL_1	4.3 J	0.74 J	18.2	10.6 J	2.6 J	17.3	0.072 J	26.4 J	0.062 U
BOLD 2008	8/3/2008	R_HOL_3	2.8 J	0.032 J	15.2	3.3 J	2.6 J	13	0.012 J	15.5 J	0.047 U
BOLD 2008	8/3/2008	R_HOL_4	17.8	1.2 J	76.3	57 J	17.6	62.5	0.45 J	109 J	0.24

Table A10 (Continued)
BOLD Natural Background Sediment Concentrations for Chemicals of Concern

Study ID	Collection Date	Location ID	Arsenic (mg/kg)	Cadmium (mg/kg)	Total Chromium (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)	Mercury (mg/kg)
BOLD 2008	8/3/2008	R_HOL_7	6.1	0.68 J	26.2	19.7 J	4.7 J	22	0.17 J	37.3 J	0.1
BOLD 2008	8/1/2008	R_SAM_0	8.4	0.45 J	41.2	26.4	12	33.7	0.14 J	73.9 J	0.096
BOLD 2008	8/1/2008	R_SAM_1	6.6	0.25 U	26.5	15.6	7.1	24.1	0.085 U	46.9 J	0.05 U
BOLD 2008	8/1/2008	R_SAM_3	5.7	0.23 U	31	19.3	10.3	25.4	0.099 U	63.4 J	0.13
BOLD 2008	8/1/2008	R_SAM_4	6.9	0.21 U	34.8	21.7	11.4	28.5	0.1 U	68.1 J	0.1
BOLD 2008	8/1/2008	R_SAM_5	9.2	0.52 J	46.2	30.2	13.6	38.6	0.19 J	83.7 J	0.098
BOLD 2008	8/4/2008	SCPS_1	9.2	0.37 J	34.8	34.6	22.8	28.8 J	0.29 J	81.3	0.15
BOLD 2008	8/5/2008	SCPS_10_C	4 J	0.071 J	19	8.9	7.5	19.5 J	0.046 J	30.3	0.036
BOLD 2008	8/4/2008	SCPS_2	3.8 J	0.076 J	17.1	6.6	7.6	18.6 J	0.028 J	27.7	0.02 U
BOLD 2008	8/4/2008	SCPS_3	2.9 J	0.037 J	14.1	3.6 J	5.7	12.4 J	0.013 J	20.7	0.02 U
BOLD 2008	8/4/2008	SCPS_5	8.7	0.36 J	35.7	37.3	27.5	30.1 J	0.3 J	86.5	0.17
BOLD 2008	8/1/2008	SJF_10_C	3.7 J	0.073 J	16.9	7.1 J	3.6 J	18.4	0.019 J	28.4 J	0.045 U
BOLD 2008	8/2/2008	SJF_12_C_GS	11.9	0.9 J	41.3	29	13.7	29.7	0.21 J	81.6 J	0.11
BOLD 2008	8/1/2008	SJF_2	3.5 J	0.093 J	16.9	9.2 J	4.7 J	14.8	0.029 J	32.8 J	0.071 U
BOLD 2008	8/1/2008	SJF_3	3.1 J	0.13 J	18.9	10.4 J	5	20.1	0.03 J	39.3 J	0.055 U
BOLD 2008	8/1/2008	SJF_9_C	4.7 J	0.12 J	21	12.3 J	6	19.1	0.037 J	43.2 J	0.078 U
BOLD 2008	8/1/2008	SJI_0	6	0.26 J	26.2	15.6	8.4	21.2	0.081 U	57.1 J	0.051 U
BOLD 2008	8/2/2008	SJI_1	6.3	0.25 U	23.9	10.6	6.1	23.4	0.041 U	44 J	0.05 U
BOLD 2008	8/2/2008	SJI_20_C_GS	6.4	0.41 J	33.1	20.2	11.1	23.7	0.13 J	69.4 J	0.08
BOLD 2008	8/2/2008	SJI_3	6	0.18 U	23.4	11.8	6.5	18.2	0.044 U	46.8 J	0.069 U
BOLD 2008	8/2/2008	SJI_8_C	6.7	0.11 U	20	9.2	5.2	15.7	0.039 U	40.3 J	0.048 U
BOLD 2008	8/3/2008	SPSB_0	9.7	0.17 U	61.6	37.2	21.9	54.5	0.21 J	93.1 J	0.17
BOLD 2008	8/3/2008	SPSB_1	10.2	0.21 U	61.7	37.9	16.4	51.5	0.21 J	87.1 J	0.13
BOLD 2008	8/3/2008	SPSB_2	10.2	0.21 U	64.2	40.2	21.3	55.8	0.24 J	97.3 J	0.17
BOLD 2008	8/3/2008	SPSB_3	9.2	0.15 J	39.1	26.8	6.6	33.6 J	0.11 J	53.9	0.06
BOLD 2008	8/3/2008	SPSB_8_C	4.6 J	0.08 U	24.1	16.4	3.5 J	24.7	0.052 U	35.4 J	0.034 U
BOLD 2008	8/4/2008	SS_0	8.9	0.84 J	34.4	31.5	16.8	26.6 J	0.23 J	75.1	0.22
BOLD 2008	8/4/2008	SS_1	1.1 J	0.018 J	7.1	5.8	1.2 J	4 J	0.0094 J	14 J	0.02 U
BOLD 2008	8/4/2008	SS_2	3.4 J	0.14 J	10.6	13	6	8.4 J	0.055 J	25.8	0.031
BOLD 2008	8/4/2008	SS_8_C	4.1 J	0.19 J	11.6	14.7	7.6	9.7 J	0.072 J	30.3	0.042
BOLD 2008	8/4/2008	SS_9_C	9.2	0.83 J	31.8	39.4	22.2	24.7 J	0.32 J	86.2	0.13

Notes:

Source: USACE (U.S. Army Corp of Engineers). 2009. OSV BOLD Summer 2008 Survey Data Report. The Dredged Material Management Program. June 2009.

ID - Identification
J - The result is an estimated concentration
mg/kg - milligram per kilogram

APPENDIX B
Calculation of Suquamish Subsistence Screening Levels

Table B1

Risk-Based Screening Levels for Future Tribal Subsistence Population Exposures to Chemicals in Shellfish Tissue

Exposure Medium: Shellfish Tissue
Exposure Point: Area 8 Beach in Liberty Bay
Receptor Population: Tribal Subsistence
Receptor Age: Adults and Children

Noncancer Screening Level = RfDo x THQ / SIFnc
Cancer Screening Level = TCR / (CSFo x SIFc)

Parameter	Unit	RME Adult Total Shellfish	RME Child Total Shellfish
Chemical Concentration in Tissue (CTi)	mg/kg	chem-specific	chem-specific
Ingestion Rate of Shellfish Tissue (IR)[a]	g/day	498.4	83.90
Fracton of Clam from Contaminated Source (FC)	unitless	1	1
Exposure Frequency (EF)	days/year	365	365
Exposure Duration (ED)	years	64	6
Conversion Factor (CF)	kg/g	1.00E-03	1.00E-03
Body Weight (BW)	kg	79	16.8
Averaging Time (noncancer) (ATnc)	days	23,360	2,190
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc = (IR*FC*EF*ED*CF)/(BW*ATnc)	$(day)^{-1}$	6.31E-03	4.99E-03
IngFadj (Ingestion Adjusted Factor)= (IRc*EDc/BWc)+(IRa*EDa/BWa)		4.34E+02	
SIFnc (child/adult) = ((InhFadj*EF)/(ATnc))		6.20E-03	
SIFc = (IngFadj*FC*EF*CF)/ATc	$(day)^{-1}$	6.20E-03	

Chemical	RfDo (mg/kg-d)	CSFo $(mg/kg-d)^{-1}$
Antimony (metallic)	4.0E-04	--
Arsenic (total)	3.0E-04	1.5E+00
Cadmium (diet)	1.0E-03	--
Chromium (based on CrVI)	3.0E-03	5.0E-01
Chromium III	1.5E+00	--
Copper	4.0E-02	--
Lead	--	--
Mercury (methyl)	1.0E-04	--
Nickel (soluble salts)	2.0E-02	--
Selenium	5.0E-03	--
Silver	5.0E-03	--
Vanadium	5.0E-03	--
Zinc	3.0E-01	--

[a] Adult shellfish ingestion rate from the EPA framework document (USEPA 2007b, Table B-2); child ingestion rate from Suquamish Tribe fish consumption survey (Suquamish Tribe 2000, Table C-3).

Chemical	Risk-Based Screening Level					
	THQ	TCR	Noncancer - Child (mg/kg)	Noncancer - Child and Adult (mg/kg)	Cancer - Lifetime (mg/kg)	Final RBSL (mg/kg)
Arsenic (total)	1	1.0E-06	0.0601	0.0484	0.00011	0.0001
Cadmium (diet)	1	1.0E-06	0.2002	0.1614	--	0.16
Chromium III	1	1.0E-06	300.36	242.09	--	242
Copper	1	1.0E-06	8.0095	6.4556	--	6.5
Mercury (methyl)	1	1.0E-06	0.0200	0.0161	--	0.016
Nickel (soluble salts)	1	1.0E-06	4.0048	3.2278	--	3.2
Silver	1	1.0E-06	1.0012	0.8070	--	0.81
Zinc	1	1.0E-06	60.0715	48.4171	--	48.42

Notes:

CSFo = oral cancer slope factor
g = grams
kg = kilograms
mg/kg = milligrams per kilogram
mg/kg-d = milligrams per kilogram per day
RBSL = risk-based screening level
RfDo = oral reference dose
RME = reasonable maximum exposure
SIF = summary intake factor
SL = screening level
TCR = target cancer risk level
THQ = target hazard quotient

Table B2
Risk-Based Screening Levels for Future Tribal Subsistence Population Exposures to Chemicals in Sediment by Incidental Ingestion

Exposure Medium: Sediment
Exposure Point: Area 8 Beach in Liberty Bay
Receptor Population: Suquamish Tribe
Receptor Age: Children and Adults

Noncancer Screening Level = (THQ x RfDo) / (SIFnc x RBA x ABSo)
Cancer Screening Level = (TCR) / (SIFc x CSFo x RBA x ABSo)

Parameter	Units	Child	Adult
Chemical Concentration in Sediment (C-sd)	mg/kg	chem-specific	chem-specific
Ingestion Rate of Sediment (IR)	mg/day	200	100
Exposure Frequency (EF)	days/year	350	350
Exposure Duration (ED)	years	6	64
Conversion Factor (CF)	kg/mg	1.00E-06	1.00E-06
Body Weight (BW)	kg	16.8	79
Averaging Time (noncancer) (ATnc)	days	2,190	23,360
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc = (IR*EF*ED*CF)/(BW*ATnc)	$(day)^{-1}$	1.14E-05	1.21E-06
IngFadj (Ingestion Adjusted Factor)= (IRch*EDch/BWch)+(IRa*EDa/BWa)	mg-yr/day-kg	152.44	
SIFnc (child/adult) = (IngFadj*EF*CF)/(ATnc(child) +AT	$(day)^{-1}$	2.09E-06	
SIFc = (IngFadj*EF*CF)/ATc	$(day)^{-1}$	2.09E-06	

Chemical	RfDo (mg/kg-d)	CSFo $(mg/kg-d)^{-1}$	RBA unitless	ABSo unitless
Arsenic (total)	3.0E-04	1.5E+00	6.0E-01	1.0E+00
Cadmium (diet)	1.0E-03	--	1.0E+00	1.0E+00
Chromium, hexavalent	3.0E-03	5.0E-01	1.0E+00	1.0E+00
Chromium, trivalent	1.5E+00	--	1.0E+00	1.0E+00
Copper	4.0E-02	--	1.0E+00	1.0E+00
Mercury (salts)	3.0E-04	--	1.0E+00	1.0E+00
Nickel (soluble salts)	2.0E-02	--	1.0E+00	1.0E+00
Silver	5.0E-03	--	1.0E+00	1.0E+00
Zinc	3.0E-01	--	1.0E+00	1.0E+00

Chemical	Ingestion Sediment Screening Levels				
	THQ	TCR	Noncancer - Child (mg/kg)	Noncancer - Child and Adult (mg/kg)	Cancer - Lifetime (mg/kg)
Arsenic (total)	1.00	1.00E-06	44	239	0.53
Cadmium (diet)	1.00	1.00E-06	87.6	479	--
Chromium, trivalent	1.00	1.00E-06	131,400	718,310	--
Copper	1.00	1.00E-06	3,504	19,155	--
Mercury (salts)	1.00	1.00E-06	26.3	144	--
Nickel (soluble salts)	1.00	1.00E-06	1,752	9,577	--
Silver	1.00	1.00E-06	438	2,394	--
Zinc	1.00	1.00E-06	26,280	143,662	--

Notes:

ABSo = oral absorption factor
C-sd = concentration in sediment
CSFo = oral cancer slope factor
kg = kilograms
mg = milligrams
mg/kg-d = milligrams per kilogram per day
mg-yr/day-kg = milligrams per year per day per kilogram
kg/mg = kilograms per milligram
mg/kg = milligrams per kilogram
RBA = relative bioavailability factor
RfDo = oral reference dose
SIF = summary intake factor
TCR = target cancer risk level
THQ = target hazard quotient

Table B3
Risk-Based Screening Levels for Future Tribal Subsistence Population Exposures to Chemicals in Sediment by Dermal Contact

Exposure Medium: Sediment
Exposure Point: Area 8 Beach in Liberty Bay
Receptor Population: Suquamish Tribe
Receptor Age: Children and Adults

Noncancer Screening Level = (THQ x RfDd) / (SIFnc x ABSd)
Cancer Screening Level = (TCR) / (SIFc x CSFd x ABSd)

Parameter	Units	RME	
		Child	Adult
Chemical Concentration in Sediment (C-sd)	mg/kg	chem-specific	chem-specific
Exposure Frequency (EF)	days/year	350	350
Exposure Duration (ED)	years	6	64
Surface Area Available for Contact (SA)	cm^2	2,373	6,032
Adherence Factor (AF)	mg/cm^2	0.2	0.12
Fraction of day for dermal exposures (FC)	unitless	1	1
Conversion Factor (CF)	kg/mg	1.0E-06	1.0E-06
Body Weight (BW)	kg	16.8	79
Averaging Time (noncancer) (ATnc)	days	2190	23360
Averaging Time (cancer) (ATc)	days	25550	25550
SIFnc = (EF*ED*SA*AF*FC*CF)/(BW*ATnc)	$(day)^{-1}$	3.07E-05	1.03E-05
DFadj (Dermal Adjusted Factor) = (EDch*SAch*AFch /BWch) +(EDa*SAa*AFa/BWa)	mg-yr/day-kg	876.28	
SIFc = (DFadj*EF*FC*CF)/ATc	$(day)^{-1}$	1.20E-05	

Chemical	RfDd (mg/kg-d)	CSFd $(mg/kg-d)^{-1}$	ABSd
Arsenic (total)	3.0E-04	1.5E+00	3.0E-02
Cadmium (diet)	2.5E-05	--	1.0E-03
Chromium, hexavalent	7.5E-05	2.0E+01	--
Chromium, trivalent	2.0E-02	--	--
Copper	4.0E-02	--	--
Mercury (salts)	2.1E-05	--	--
Nickel (soluble salts)	8.0E-04	--	--
Silver	2.0E-04	--	--
Zinc	3.0E-01	--	--

Chemical	Dermal Sediment Screening Levels				
	THQ	TCR	Noncancer - Child (mg/kg)	Noncancer - Child and Adult (mg/kg)	Cancer - Lifetime (mg/kg)
Arsenic (total)	1.00	1.00E-06	369	1138	2.1
Cadmium (diet)	1.00	1.00E-06	923	2845	--
Chromium, trivalent	1.00	1.00E-06	--	--	--
Copper	1.00	1.00E-06	--	--	--
Mercury (salts)	1.00	1.00E-06	--	--	--
Nickel (soluble salts)	1.00	1.00E-06	--	--	--
Silver	1.00	1.00E-06	--	--	--
Zinc	1.00	1.00E-06	--	--	--

Notes:

ABSd = dermal absorption
cm^2 = square centimeters
C-sd = concentration in sediment
CSFd = dermal cancer slope factor
kg = kilograms
kg/mg = kilograms per milligram
mg/cm^2 = milligrams per square centimeter
mg/kg = milligrams per kilogram
mg/kg-d = milligrams per kilogram per day
mg-yr/day-kg = milligrams per year per day per kilogran
RfDd = dermal reference dose
SIF = summary intake factor
TCR = target cancer risk level
THQ = target hazard quotient
yr = year

Table B4
Summary of Risk-Based Sediment Screening Levels for Future Tribal Subsistence Population Exposures

Chemical	Final Sediment Screening Level (mg/kg)	Total Sediment Screening Levels[a] (mg/kg)			Ingestion Sediment Screening Levels (mg/kg)			Dermal Sediment Screening Levels (mg/kg)		
		Noncancer - Child	Noncancer - Child and Adult	Cancer - Lifetime	Noncancer - Child	Noncancer - Child and Adult	Cancer - Lifetime	Noncancer - Child	Noncancer - Child and Adult	Cancer - Lifetime
Metals										
Arsenic	0.43	38.6	186	0.413	43.8	239	0.53	369	1138	2.15
Cadmium	80.0	79.1	389	--	87.6	479	--	923	2845	--
Chromium III	131,400	131,400	718,310	--	131,400	718,310	--	--	--	--
Copper	3,504	3,504	19,155	--	3,504	19,155	--	--	--	--
Mercury	26.3	26.28	143.7	--	26.3	143.7	--	--	--	--
Nickel	1,752	1,752	9,577	--	1,752	9,577	--	--	--	--
Silver	438	438	2,394	--	438	2,394	--	--	--	--
Zinc	26,280	26,280	143,662	--	26,280	143,662	--	--	--	--

[a]Total Sediment Screening Level (SL_{tot}) takes into account combined incidental ingestion (SL_{ing}) and dermal exposure (SL_{derm}) and is calculated using the following formula:

$$SLtot = \frac{1}{\frac{1}{SL_{ing}} + \frac{1}{SL_{derm}}}$$

Note:
mg/kg = milligrams per kilogram

APPENDIX C
Sample Number Size Determination

APPENDIX C

SAMPLE SIZE DETERMINATION FOR STATISTICAL COMPARISON BETWEEN REFERENCE AND SITE AREAS

One of the data quality objectives for the current assessment is to answer the following question: Are concentrations in sediment and tissue collected in the site area significantly different from those measured in the selected reference area?

In order to answer this question, a statistical population-to-population comparison test, based on a one-way analysis of variance (ANOVA) model, is suggested, if other "factors" or "variables" are expected to be the same or similarly randomly distributed between the groups. An adequate number of samples of each type from the site area and the selected reference area is required to perform meaningful statistical comparison of the data. For an ANOVA evaluation, a standard formula can be used to determine the required number of samples based on defined statistical parameters: level of significance (α), power of detection (1-β), and differences to be detected (Δ).

If the data set could be assumed to follow a normal distribution:

$$n = \frac{2s_p^2(z_{1-\alpha} + z_{1-\beta})^2}{\Delta^2} + \frac{z_{1-\alpha}^2}{4}$$

If the data set could not be assumed to follow a normal distribution (i.e., nonparametric):

$$n = \frac{(z_{1-\alpha} + z_{1-\beta})^2}{3(\Phi\left[\frac{\Delta}{\sqrt{2}s_p}\right] - 0.5)^2} \times \frac{1}{2}$$

Where: s_p = pooled standard deviation
z = standard normal z statistics
$\Phi[\ ]$ = standard normal cumulative distribution function

Table 1 summarizes the sample size requirements for the nonparametric assumption under different permutations of statistical parameters. For this project, an α of 5 percent and a β of 10 percent (or 1-β of 90 percent) were selected. For Δ, an understanding of the concentration variance for the entire population may be required. For data sets with greater data variability, a larger sample size is often required to achieve the desired confidence level and statistical power in the comparison results.

The available historical data were evaluated, and the summary statistics were calculated to evaluate the variability of the existing data set. Table 2 summarizes these findings. As shown in Table 2, the coefficient of variation (CV) (which is the standard deviation divided by the mean) for each data set is between 0.16 to 2.00 and the average CV is 0.87. As such, a Δ of one standard deviation appears to be appropriate for the comparison of reference versus site data for most analytes. Based on the aforementioned assumptions and parameters, a sample size of at least 22 is required in each area (i.e., 22 reference samples and 22 site samples) in order to achieve the desired confidence level and statistical power.

In order to address the question of what sample size is required for tissue for Δ's that will result in risks of 10^{-6} or less and HQs that are one or less, ProUCL was used to calculate sample size requirements for each chemical using Δ's based on risk-based screening levels for tissue protective of a range of target cancer risks (10^{-6} to 10^{-4}) and a target hazard quotient of 1. These results are presented on Table 3. As shown on Table 3, the tissue sample size requirements for cadmium, chromium, and mercury using the risk-based approach are too high to achieve given the armored nature of the beach and the time constraints inherent during a tidally controlled sampling event. These high sample sizes are the result of the risk-based concentrations being significantly lower than the standard deviation of the site data. In contrast, the risk-based concentrations for copper, silver, and zinc are higher than the standard deviations, thus the sample size requirements for these chemicals using the risk-based approach are substantially lower than the sample size determination of 22 based a Δ of one standard deviation. Because using the risk-based approach will result in unreasonable large sample size requirements for most chemicals and too small for the other chemicals, the Δ is set to be one standard deviation in order to take into account the natural variability of sample data, i.e., if the data are naturally varying this much.

Table 1
Sample Size Requirements Based on Nonparametric Assumption

Significance Level (α)	Power of Detection (1-β)	Delta (Δ)				
		0.1 Std Dev	0.25 Std Dev	0.5 Std Dev	1 Std Dev	2 Std Dev
5%	95%	2,271	367	95	27	11
	90%	1,797	290	75	22	9
	80%	1,298	210	54	16	6
10%	95%	1,797	290	75	22	9
	90%	1,379	223	58	17	7
	80%	946	153	40	12	5
20%	95%	1,298	210	54	16	6
	90%	946	153	40	12	5
	80%	595	96	25	7	3

Note: Std Dev - standard deviation

Table 2
Summary Statistics of Historical Sediment and Tissue Data

Matrix	Analyte	No. of Samples	Detection Rate	Mean	Std Dev	CV	Min Detected Value (mg/kg)	Max Detected Value (mg/kg)	Min DL of NDs (mg/kg)	Max DL of NDs (mg/kg)
Sediment	Cadmium	127	83%	1.87	3.39	1.81	0.018	21.9	0.022	0.26
	Chromium	128	100%	38.2	28.5	0.75	3.9	194	-	-
	Copper	128	100%	17.6	13.0	0.74	3.2	86.3	-	-
	Lead	127	100%	8.86	6.30	0.71	1.2	37.6	-	-
	Mercury	128	73%	0.118	0.236	2.00	0.015	1.9	0.0048	0.091
	Nickel	126	100%	25.8	12.8	0.50	4	94.7	-	-
	Silver	127	86%	0.225	0.242	1.08	0.0094	1.54	0.0074	0.1
	Zinc	128	100%	48.4	21.6	0.45	11	109	-	-
Tissue	Cadmium	37	97%	1.47	1.38	0.94	0.09	5.75	0.3	0.3
	Chromium	37	100%	1.17	1.55	1.33	0.19	8.78	-	-
	Copper	37	100%	1.17	0.31	0.27	0.57	1.82	-	-
	Lead	32	94%	0.0742	0.0402	0.54	0.04	0.21	0.044	0.14
	Mercury	37	100%	0.0292	0.0354	1.21	0.01	0.18	-	-
	Nickel	37	100%	0.615	0.332	0.54	0.32	1.9	-	-
	Silver	37	100%	0.411	0.377	0.92	0.07	2.2	-	-
	Zinc	37	97%	13.4	2.2	0.16	9.6	18.5	10.9	10.9

Notes:

These data were obtained from previous reports and included results from both the site and reference areas for sediment and only from the site for tissue.

Table 2 (Continued)
Summary Statistics of Historical Sediment and Tissue Data

For data sets with nondetections, mean and standard deviation were estimated by the Kaplan-Meier method.
CV - coefficient of variation
DL - detection limit
Max - maximum
Min - minimum
NDs - nondetections

Table 3
Sample Size Requirements (N) for Tissue for a Range of Delta Values

COPC	TCR 10^{-6} RBSL (mg/kg)	N (Delta= 10^{-6} RBSL)	TCR 10^{-5} RBSL (mg/kg)	N (Delta= 10^{-5} RBSL)	TCR 10^{-4} RBSL (mg/kg)	N (Delta= 10^{-4} RBSL)	THQ 1 RBSL (mg/kg)	N (Delta= THQ 1 RBSL)	St Dev of Site Data (mg/kg)	N (Delta=St Dev)
Cadmium	--	--	--	--	--	--	0.16	1338	1.38	22
Chromium	0.00032	>10,000	0.0032	>10,000	0.032	>10,000	--	--	1.55	22
Copper	--	--	--	--	--	--	6.4	6	0.31	22
Methylmercury	--	--	--	--	--	--	0.016	91	0.035	22
Nickel	--	--	--	--	--	--	3.2	6	0.33	22
Silver	--	--	--	--	--	--	0.80	8	0.38	22
Zinc	--	--	--	--	--	--	48	6	2	22

Note: Sample size requirement for a=5% and 1-b=90%, non-parametric assumption. n=sample size from each population.

RBSL = risk-based screening level

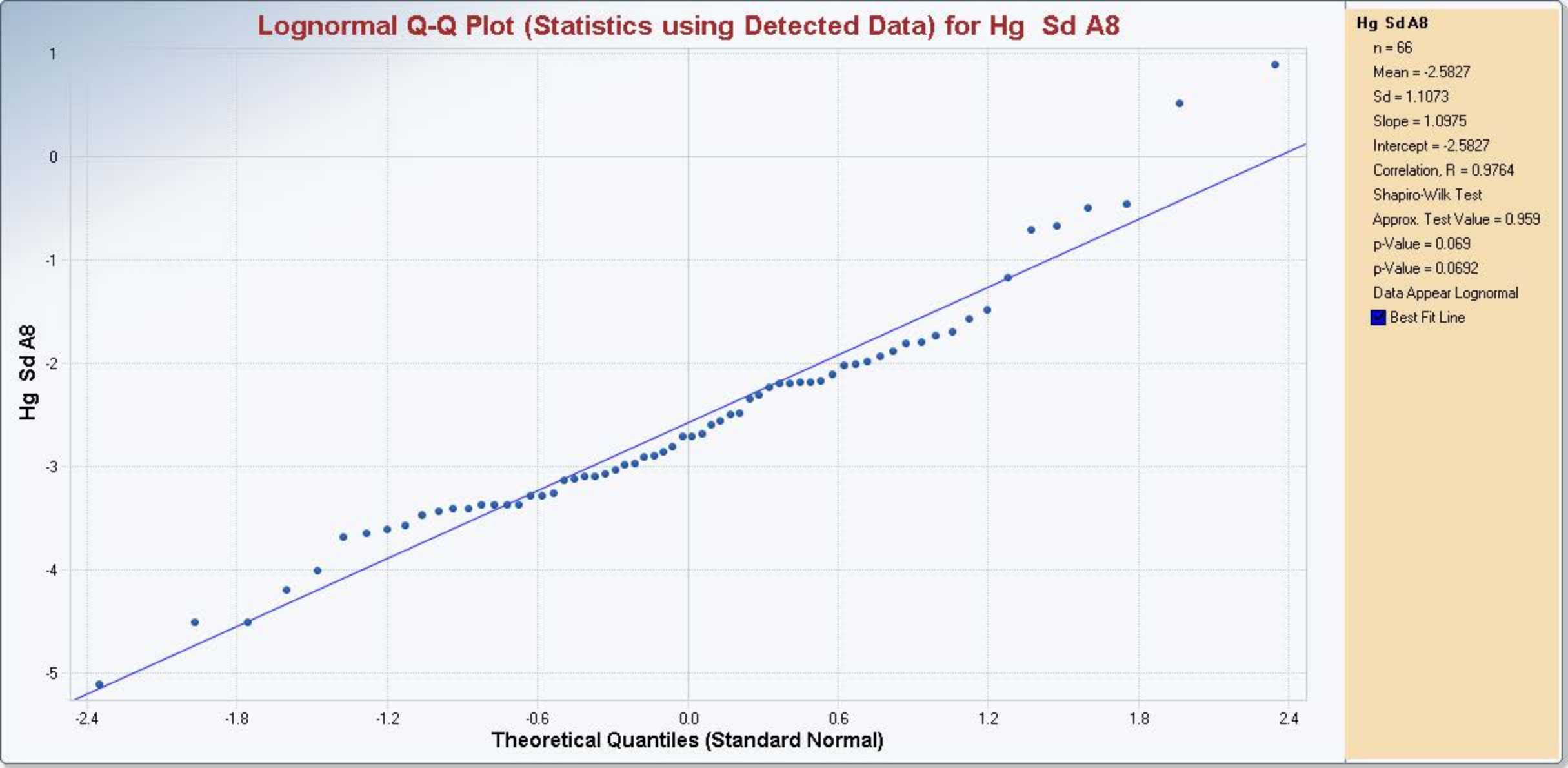
TCR = target cancer risk

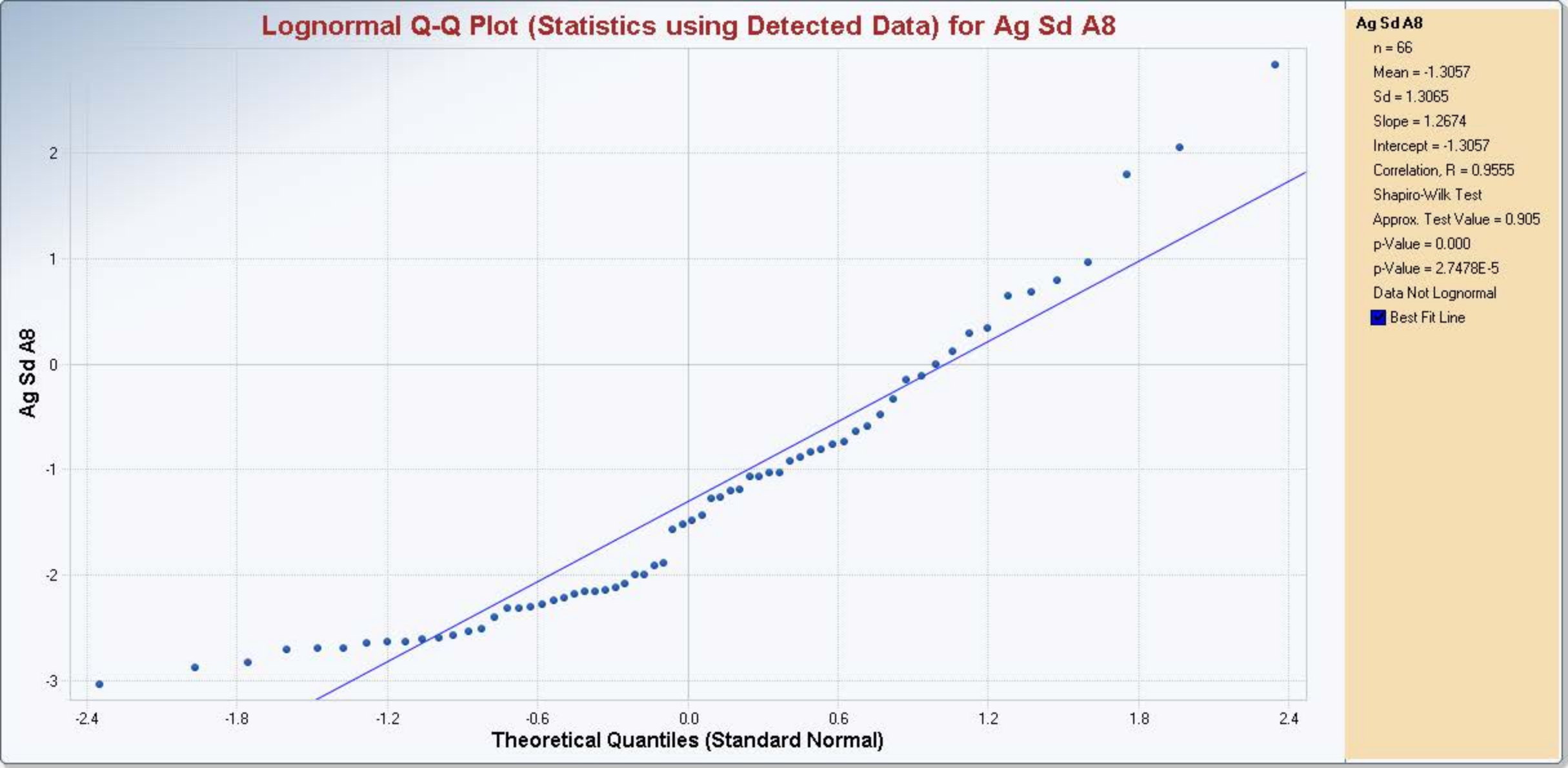
THQ = target hazard quotient

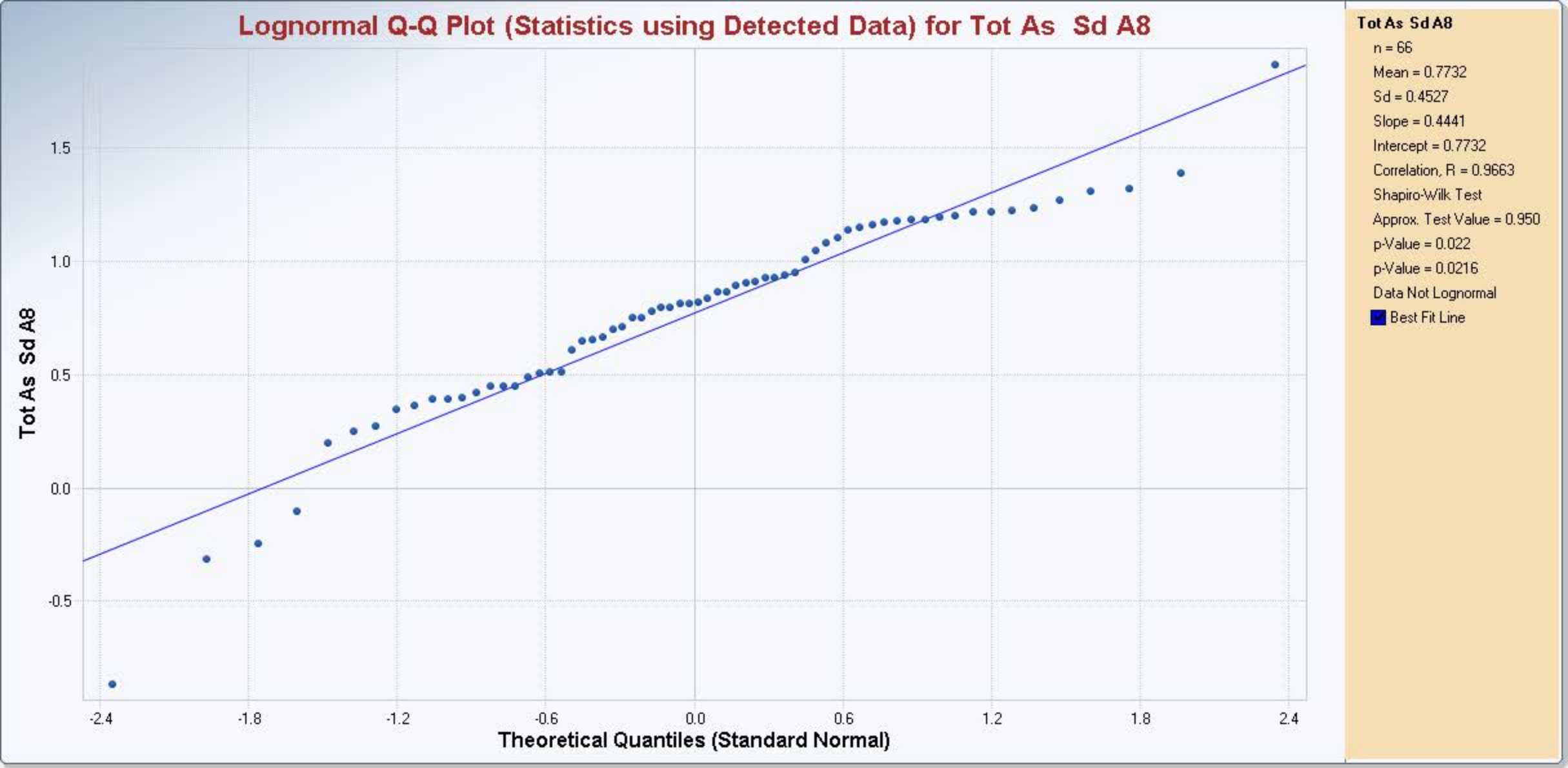
St Dev = standard deviation

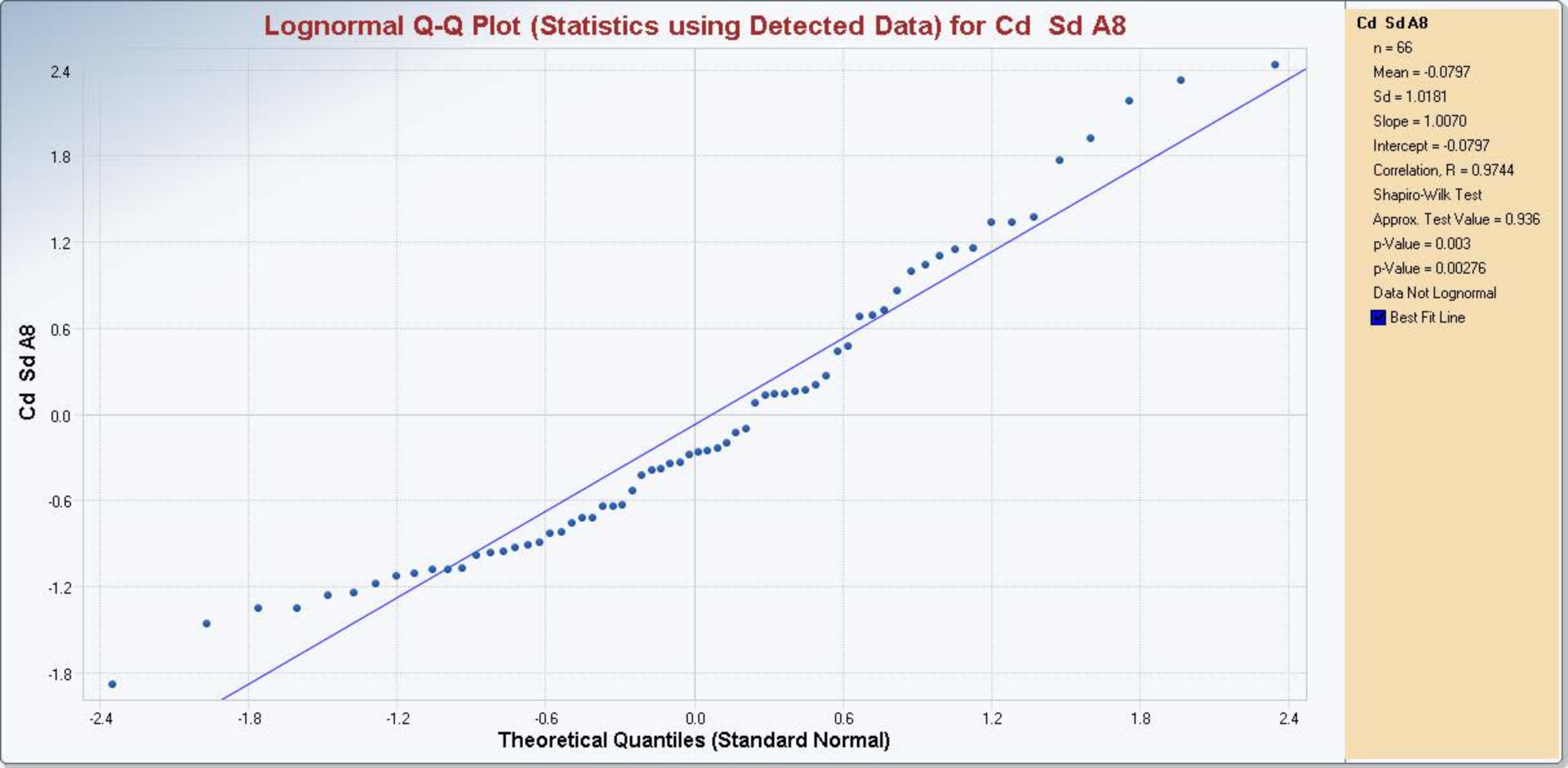
APPENDIX D
Background and Reference Area Evaluation ProUCL Outputs

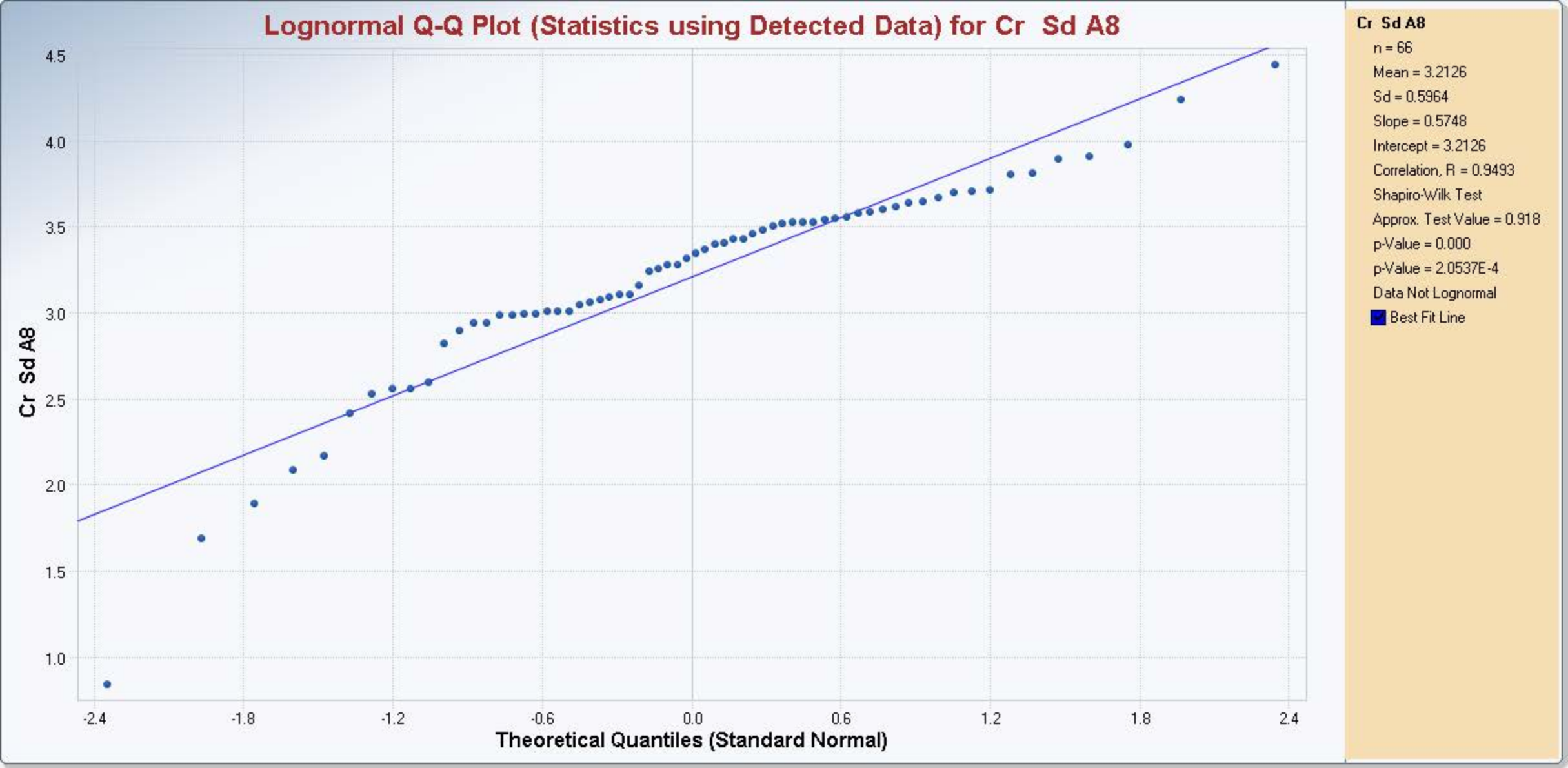
D1
Distribution Analysis

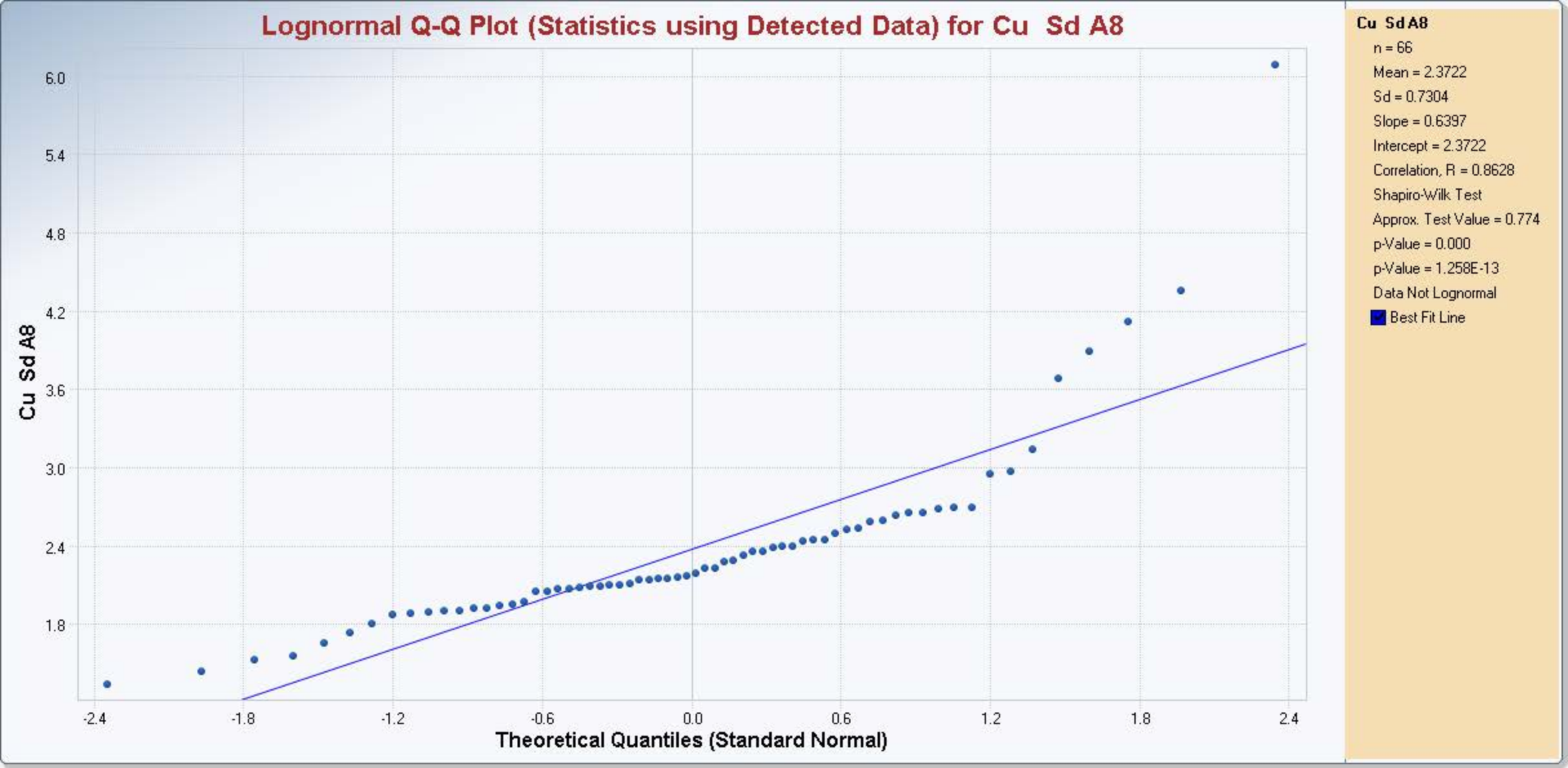

Lognormal Q-Q Plot (Statistics using Detected Data) for Hg Sd A8
Hg Sd A8
n = 66
Mean = -2.5827
Sd = 1.1073
Slope = 1.0975
Intercept = -2.5827
Correlation, R = 0.9764
Shapiro-Wilk Test
Approx. Test Value = 0.959
p-Value = 0.069
p-Value = 0.0692
Data Appear Lognormal
Best Fit Line
Hg Sd A8
1
0
-1
-2
-3
-4
-5
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

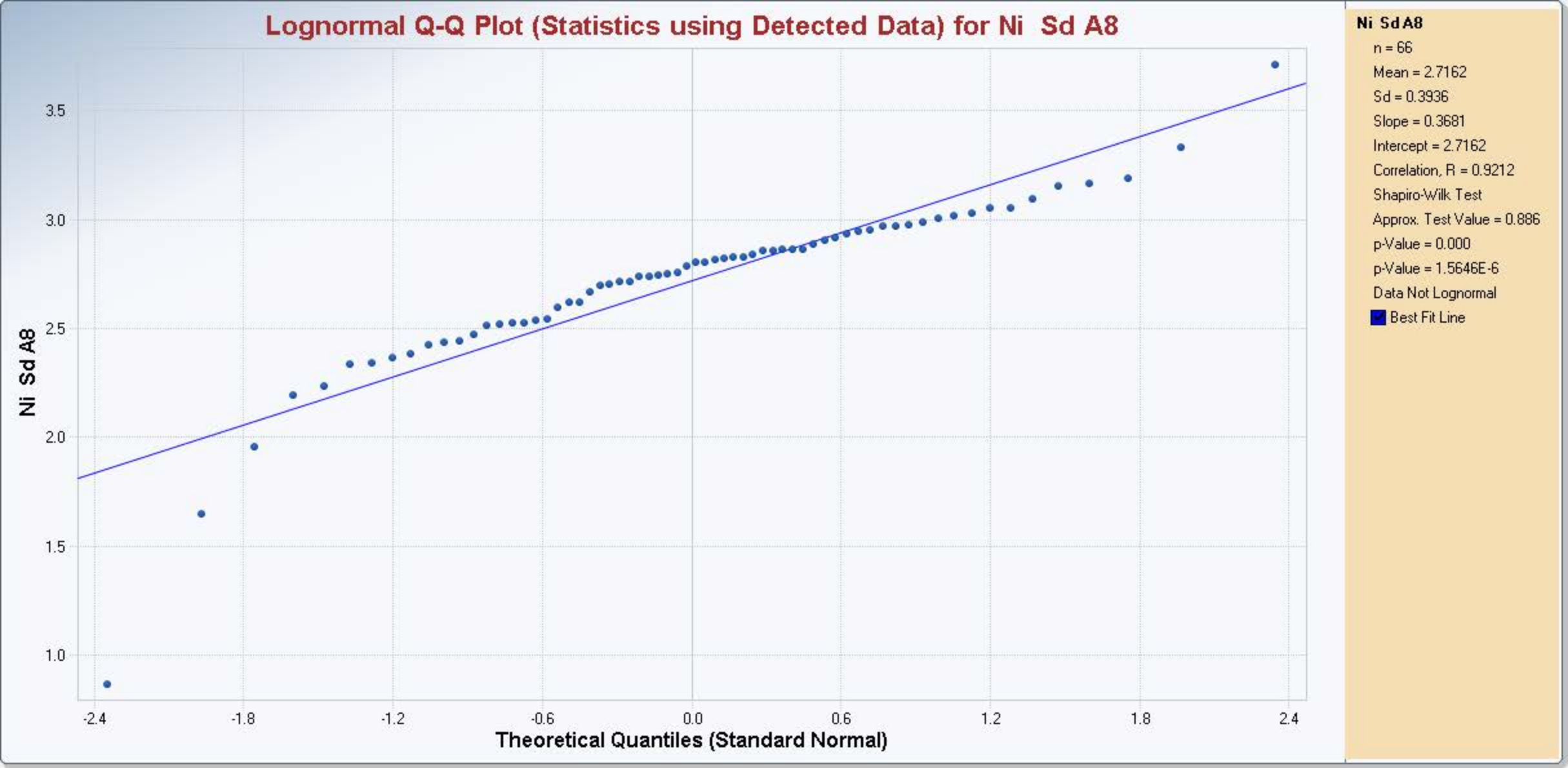

Lognormal Q-Q Plot (Statistics using Detected Data) for Ag Sd A8
Ag Sd A8
n = 66
Mean = -1.3057
Sd = 1.3065
Slope = 1.2674
Intercept = -1.3057
Correlation, R = 0.9555
Shapiro-Wilk Test
Approx. Test Value = 0.905
p-Value = 0.000
p-Value = 2.7478E-5
Data Not Lognormal
Best Fit Line
Ag Sd A8
2
1
0
-1
-2
-3
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

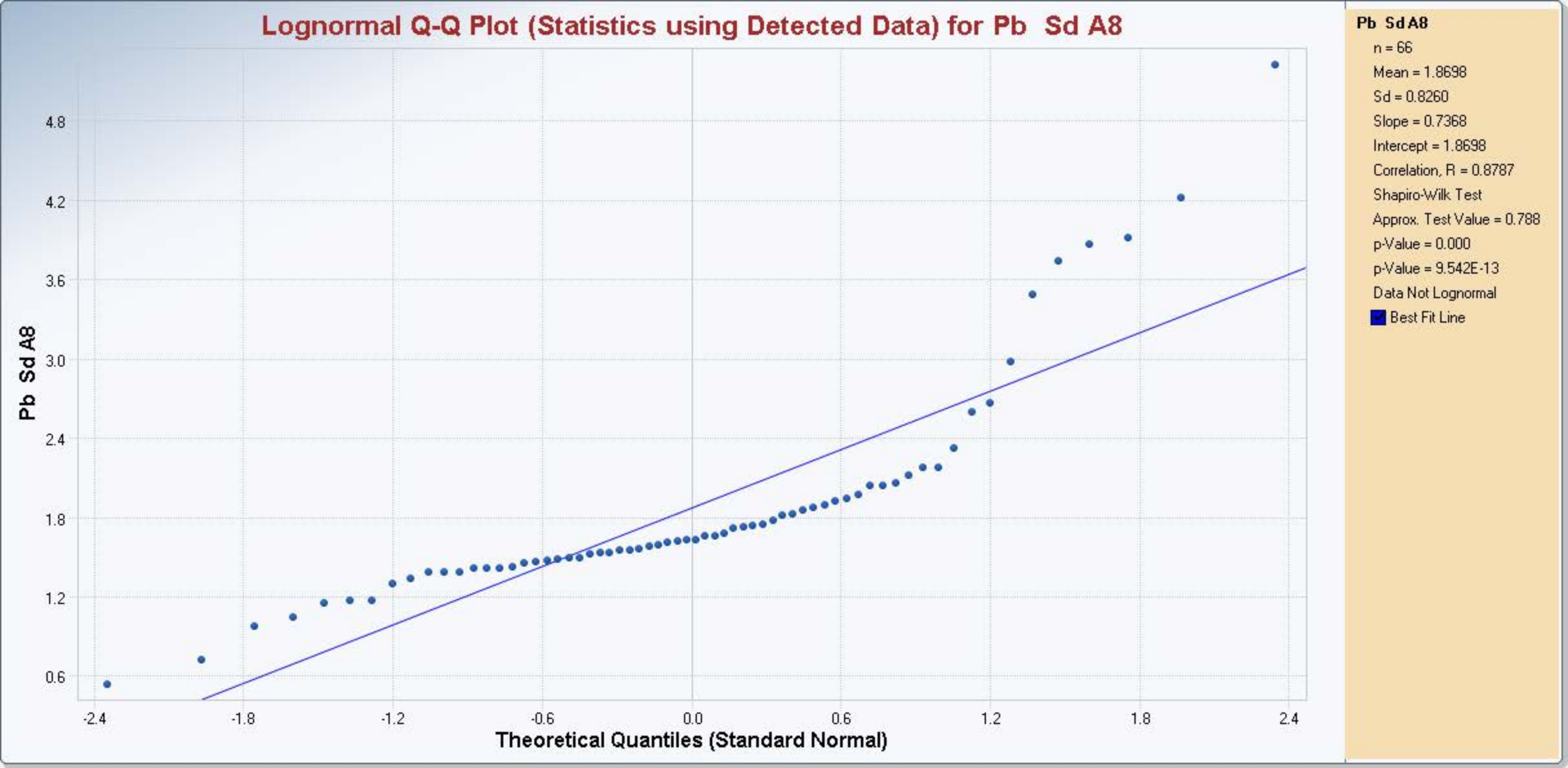

Lognormal Q-Q Plot (Statistics using Detected Data) for Tot As Sd A8
Tot As Sd A8
n = 66
Mean = 0.7732
Sd = 0.4527
Slope = 0.4441
Intercept = 0.7732
Correlation, R = 0.9663
Shapiro-Wilk Test
Approx. Test Value = 0.950
p-Value = 0.022
p-Value = 0.0216
Data Not Lognormal
Best Fit Line
Tot As Sd A8
1.5
1.0
0.5
0.0
-0.5
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

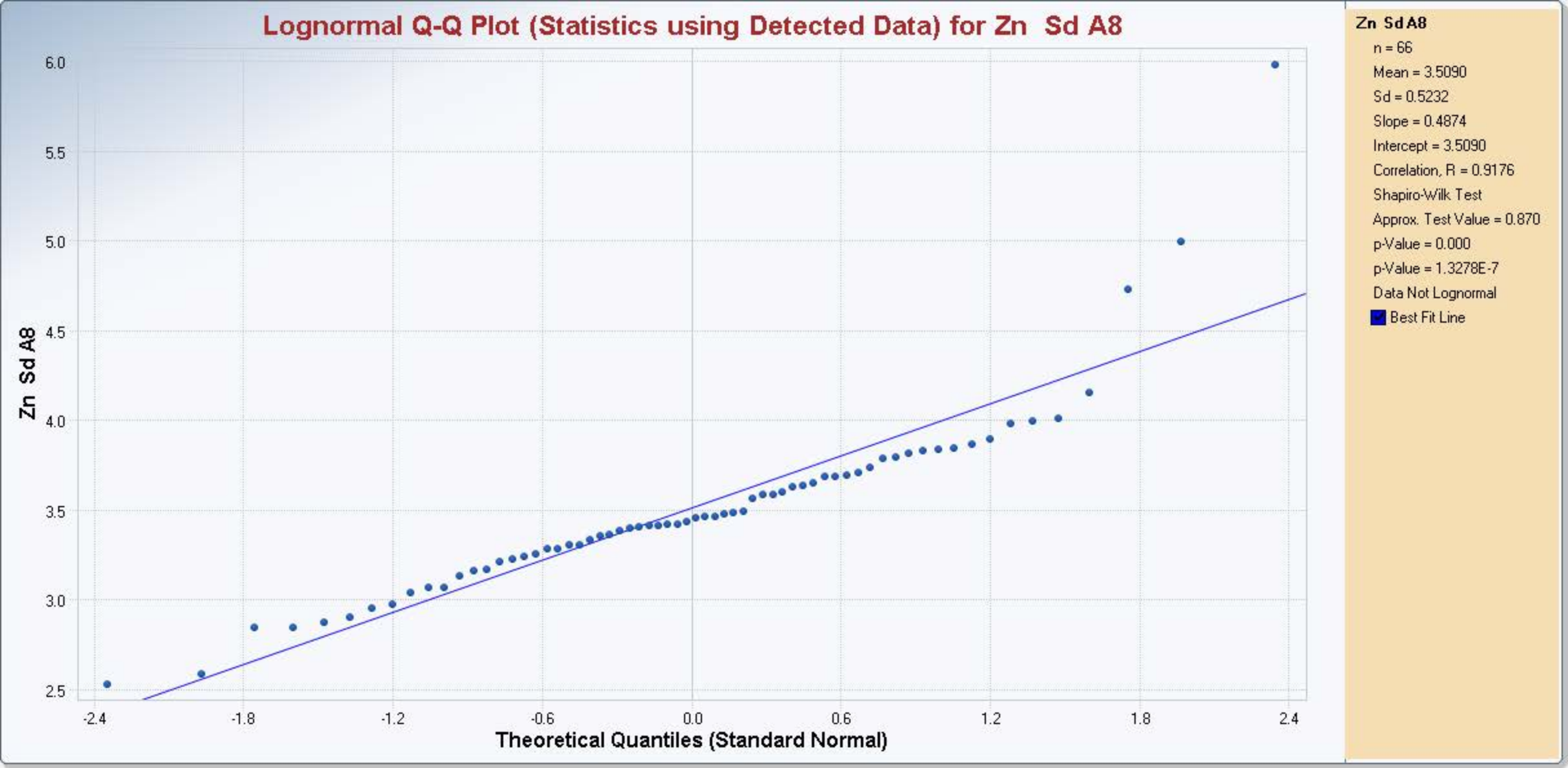

Lognormal Q-Q Plot (Statistics using Detected Data) for Cd Sd A8
Cd Sd A8
Theoretical Quantiles (Standard Normal)
2.4
1.8
1.2
0.6
0.0
-0.6
-1.2
-1.8
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Cd Sd A8
n = 66
Mean = -0.0797
Sd = 1.0181
Slope = 1.0070
Intercept = -0.0797
Correlation, R = 0.9744
Shapiro-Wilk Test
Approx. Test Value = 0.936
p-Value = 0.003
p-Value = 0.00276
Data Not Lognormal
Best Fit Line

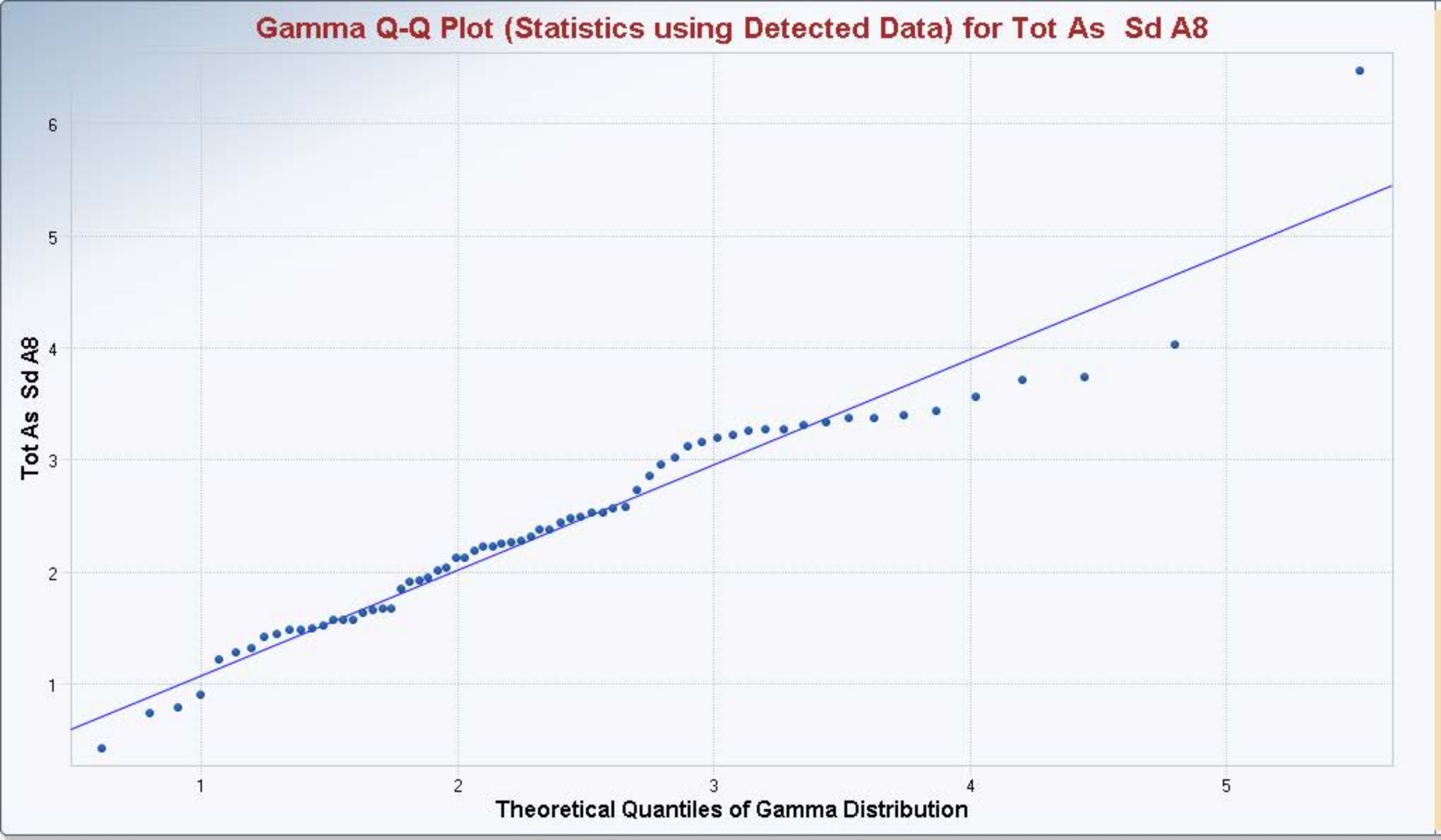

Lognormal Q-Q Plot (Statistics using Detected Data) for Cr Sd A8
Cr Sd A8
n = 66
Mean = 3.2126
Sd = 0.5964
Slope = 0.5748
Intercept = 3.2126
Correlation, R = 0.9493
Shapiro-Wilk Test
Approx. Test Value = 0.918
p-Value = 0.000
p-Value = 2.0537E-4
Data Not Lognormal
Best Fit Line
Cr Sd A8
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)


Lognormal Q-Q Plot (Statistics using Detected Data) for Cu Sd A8
Cu Sd A8
n = 66
Mean = 2.3722
Sd = 0.7304
Slope = 0.6397
Intercept = 2.3722
Correlation, R = 0.8628
Shapiro-Wilk Test
Approx. Test Value = 0.774
p-Value = 0.000
p-Value = 1.258E-13
Data Not Lognormal
Best Fit Line
Cu Sd A8
6.0
5.4
4.8
4.2
3.6
3.0
2.4
1.8
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)


Lognormal Q-Q Plot (Statistics using Detected Data) for Ni Sd A8
Ni Sd A8
n = 66
Mean = 2.7162
Sd = 0.3936
Slope = 0.3681
Intercept = 2.7162
Correlation, R = 0.9212
Shapiro-Wilk Test
Approx. Test Value = 0.886
p-Value = 0.000
p-Value = 1.5646E-6
Data Not Lognormal
Best Fit Line
Ni Sd A8
3.5
3.0
2.5
2.0
1.5
1.0
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

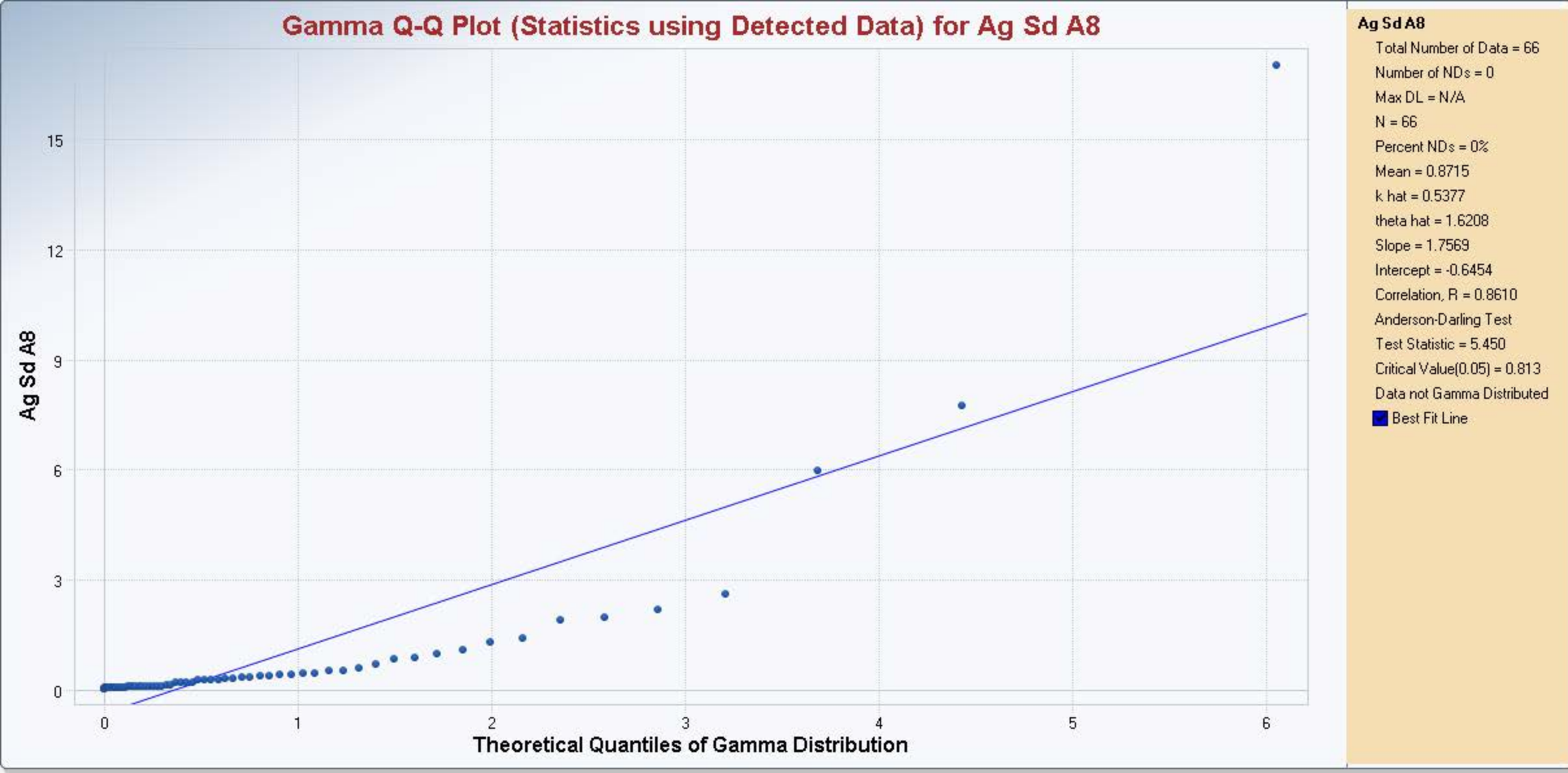

Lognormal Q-Q Plot (Statistics using Detected Data) for Pb Sd A8
Pb Sd A8
n = 66
Mean = 1.8698
Sd = 0.8260
Slope = 0.7368
Intercept = 1.8698
Correlation, R = 0.8787
Shapiro-Wilk Test
Approx. Test Value = 0.788
p-Value = 0.000
p-Value = 9.542E-13
Data Not Lognormal
Best Fit Line
Pb Sd A8
4.8
4.2
3.6
3.0
2.4
1.8
1.2
0.6
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

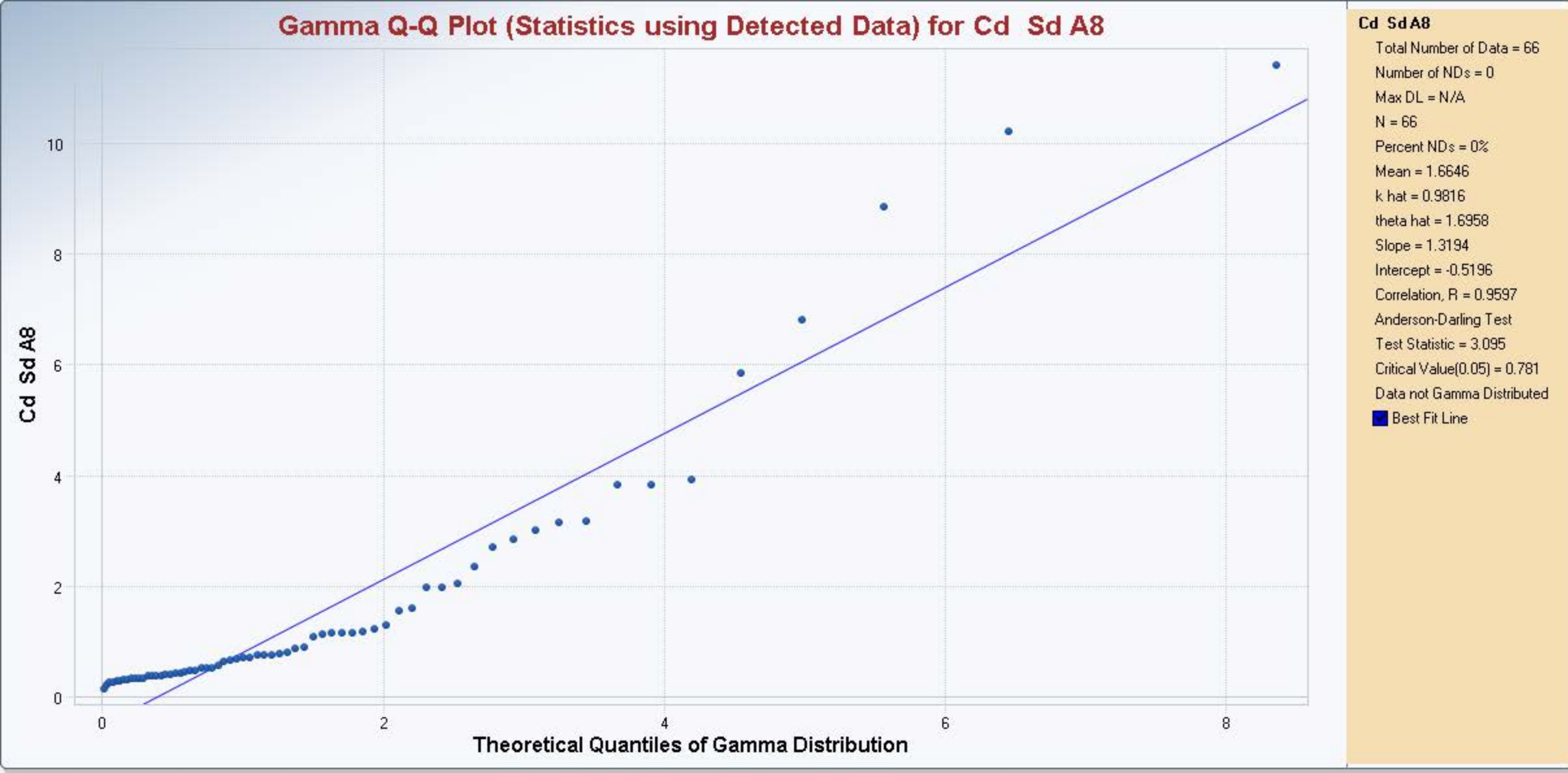

Lognormal Q-Q Plot (Statistics using Detected Data) for Zn Sd A8
Zn Sd A8
n = 66
Mean = 3.5090
Sd = 0.5232
Slope = 0.4874
Intercept = 3.5090
Correlation, R = 0.9176
Shapiro-Wilk Test
Approx. Test Value = 0.870
p-Value = 0.000
p-Value = 1.3278E-7
Data Not Lognormal
Best Fit Line
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
Zn Sd A8
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

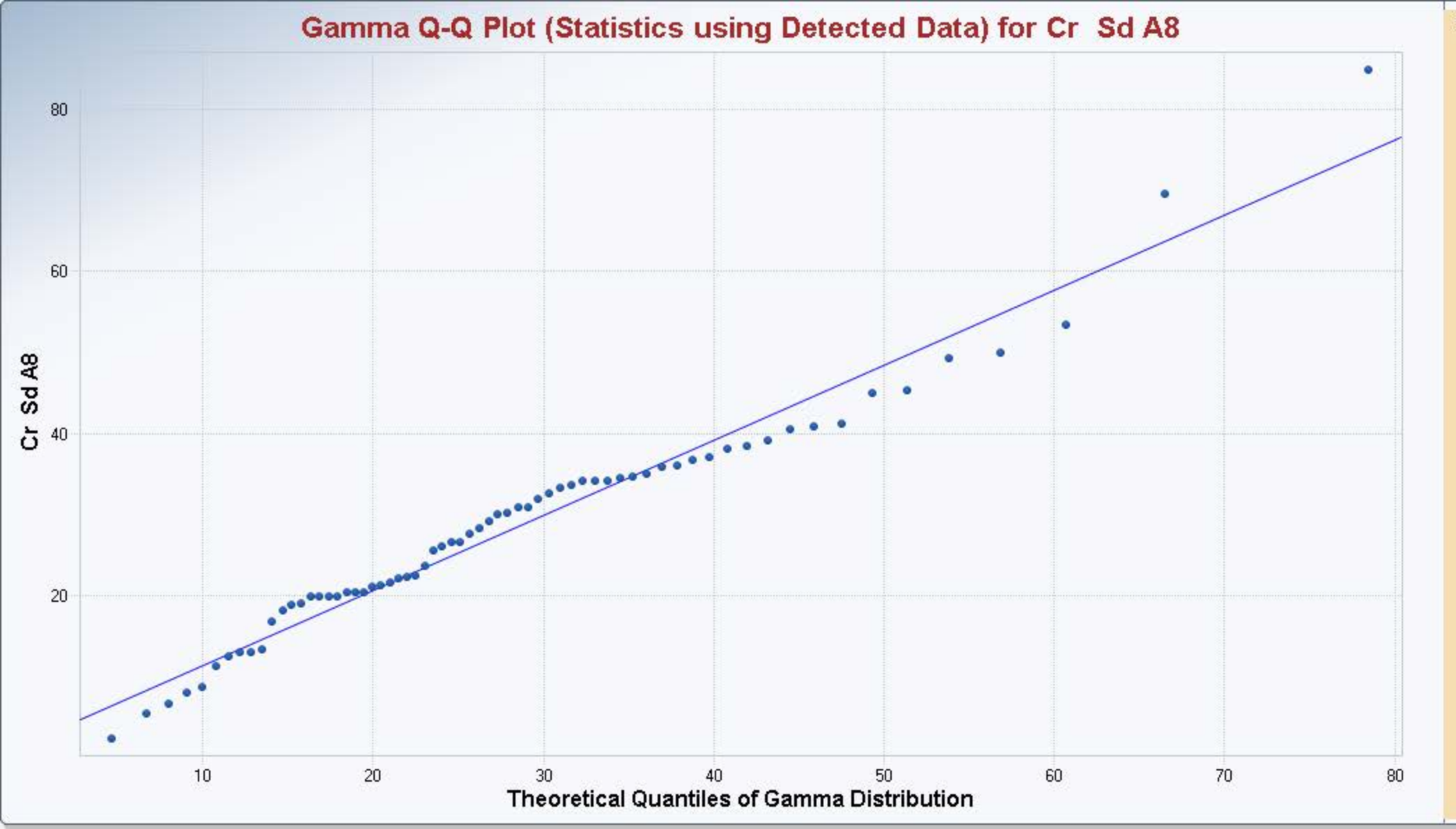


Tot As Sd A8

Total Number of Data = 66
Number of NDs = 0
Max DL = N/A
N = 66
Percent NDs = 0%
Mean = 2.3709
k hat = 5.7114
theta hat = 0.4151
Slope = 0.9420
Intercept = 0.1400
Correlation, R = 0.9737
Anderson-Darling Test
Test Statistic = 0.552
Critical Value(0.05) = 0.753
Data appear Gamma Distributed
Best Fit Line


Gamma Q-Q Plot (Statistics using Detected Data) for Ag Sd A8
Ag Sd A8
Total Number of Data = 66
Number of NDs = 0
Max DL = N/A
N = 66
Percent NDs = 0%
Mean = 0.8715
k hat = 0.5377
theta hat = 1.6208
Slope = 1.7569
Intercept = -0.6454
Correlation, R = 0.8610
Anderson-Darling Test
Test Statistic = 5.450
Critical Value(0.05) = 0.813
Data not Gamma Distributed
Best Fit Line
Ag Sd A8
0
3
6
9
12
15
0
1
2
3
4
5
6
Theoretical Quantiles of Gamma Distribution


Gamma Q-Q Plot (Statistics using Detected Data) for Cd Sd A8
Cd Sd A8
Theoretical Quantiles of Gamma Distribution
0
2
4
6
8
10
Cd Sd A8
Total Number of Data = 66
Number of NDs = 0
Max DL = N/A
N = 66
Percent NDs = 0%
Mean = 1.6646
k hat = 0.9816
theta hat = 1.6958
Slope = 1.3194
Intercept = -0.5196
Correlation, R = 0.9597
Anderson-Darling Test
Test Statistic = 3.095
Critical Value(0.05) = 0.781
Data not Gamma Distributed
Best Fit Line



Cr Sd A8

Total Number of Data = 66

Number of NDs = 0

Max DL = N/A

N = 66

Percent NDs = 0%

Mean = 28.6489

k hat = 3.6666

theta hat = 7.8134

Slope = 0.9249

Intercept = 2.1957

Correlation, R = 0.9831

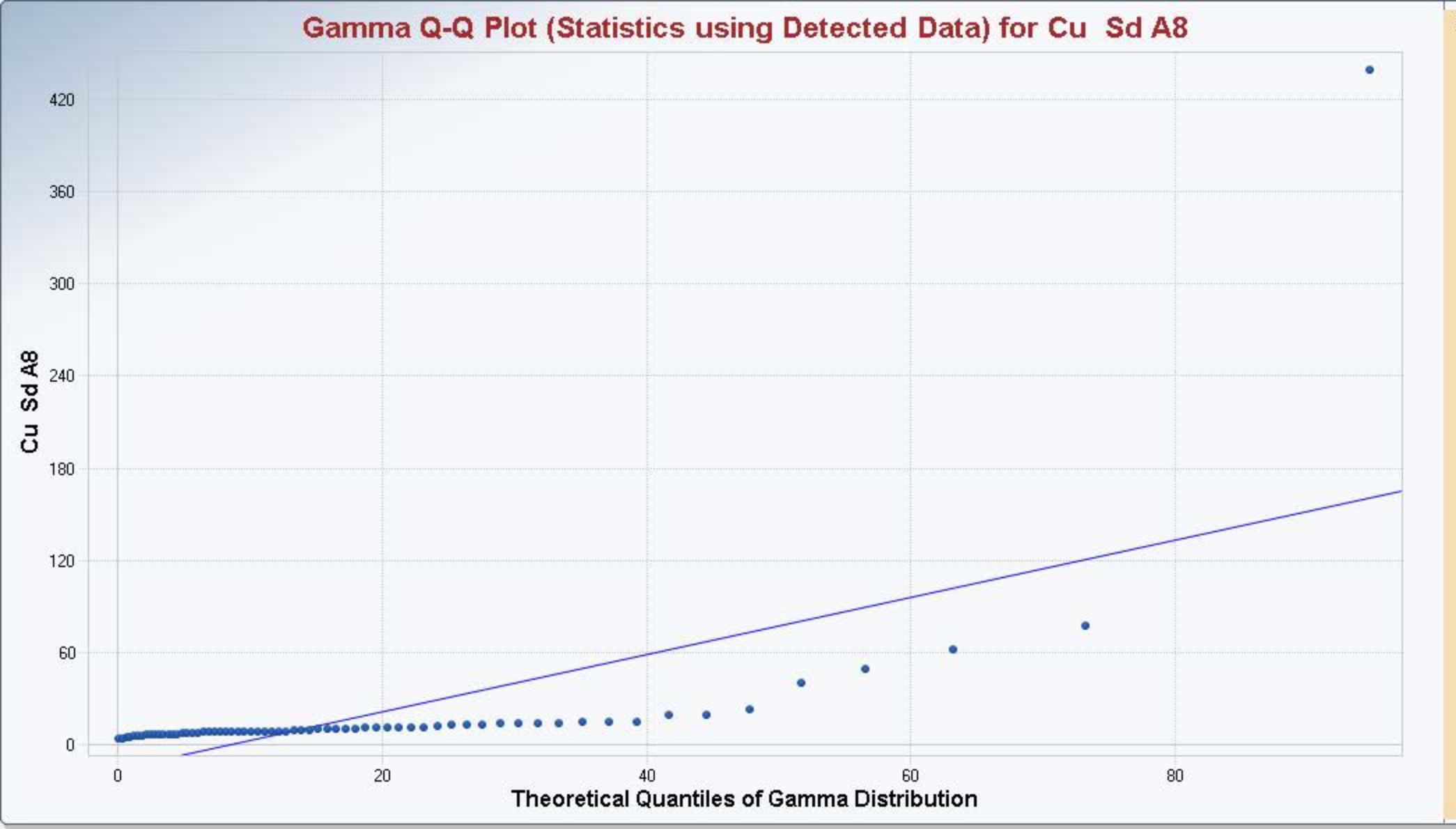
Anderson-Darling Test

Test Statistic = 0.782

Critical Value(0.05) = 0.756

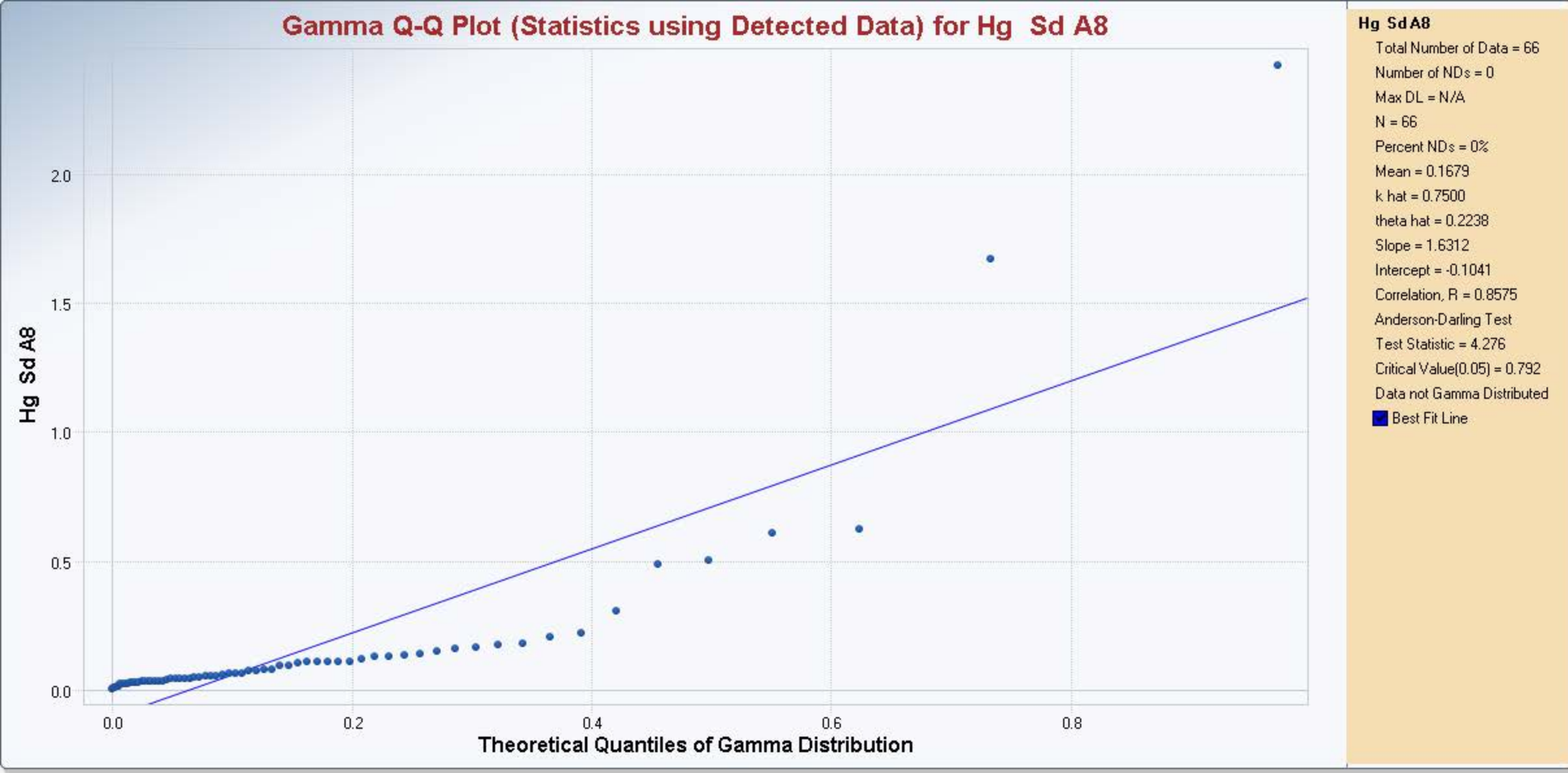
Data not Gamma Distributed

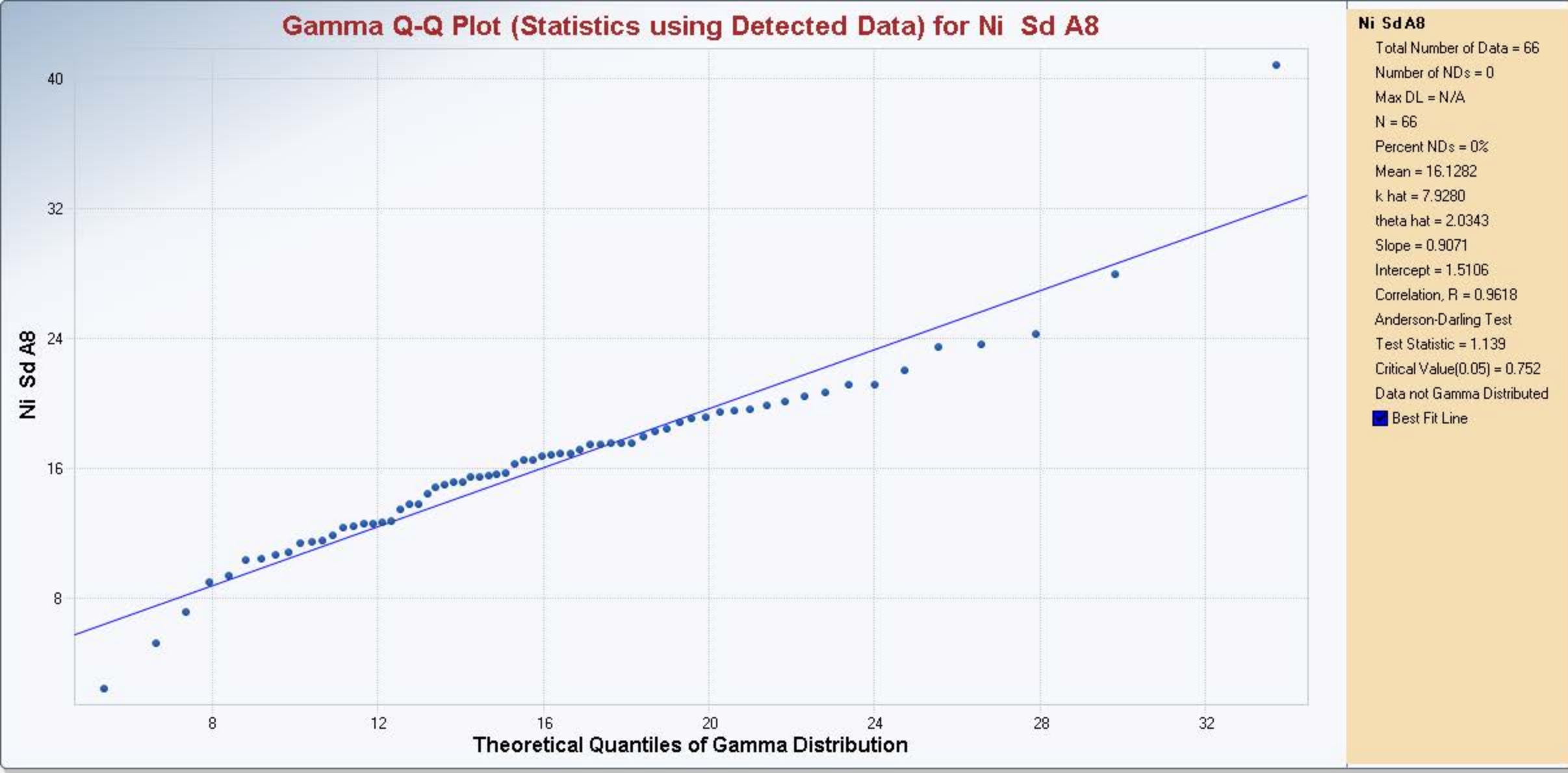
Best Fit Line

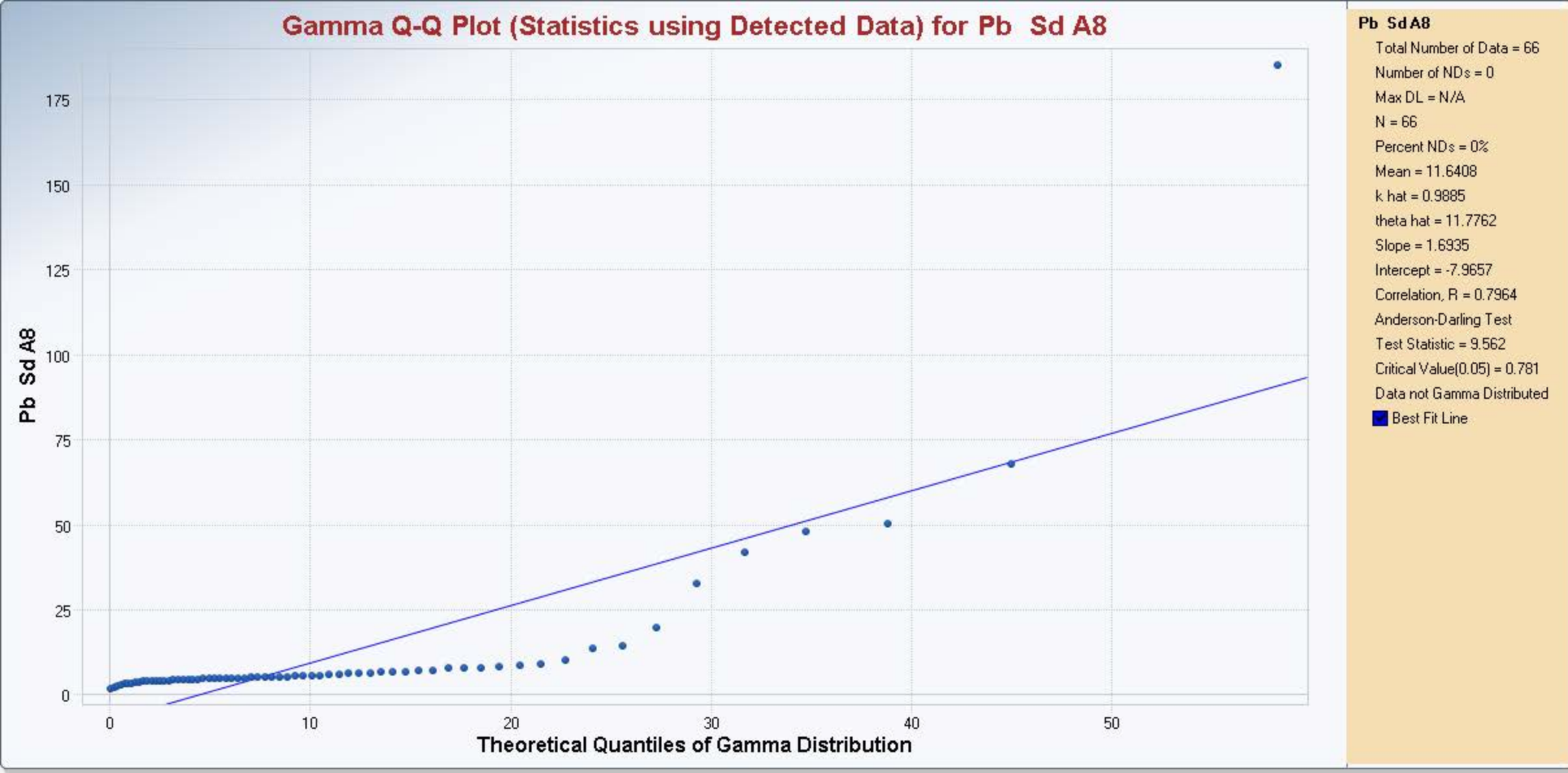


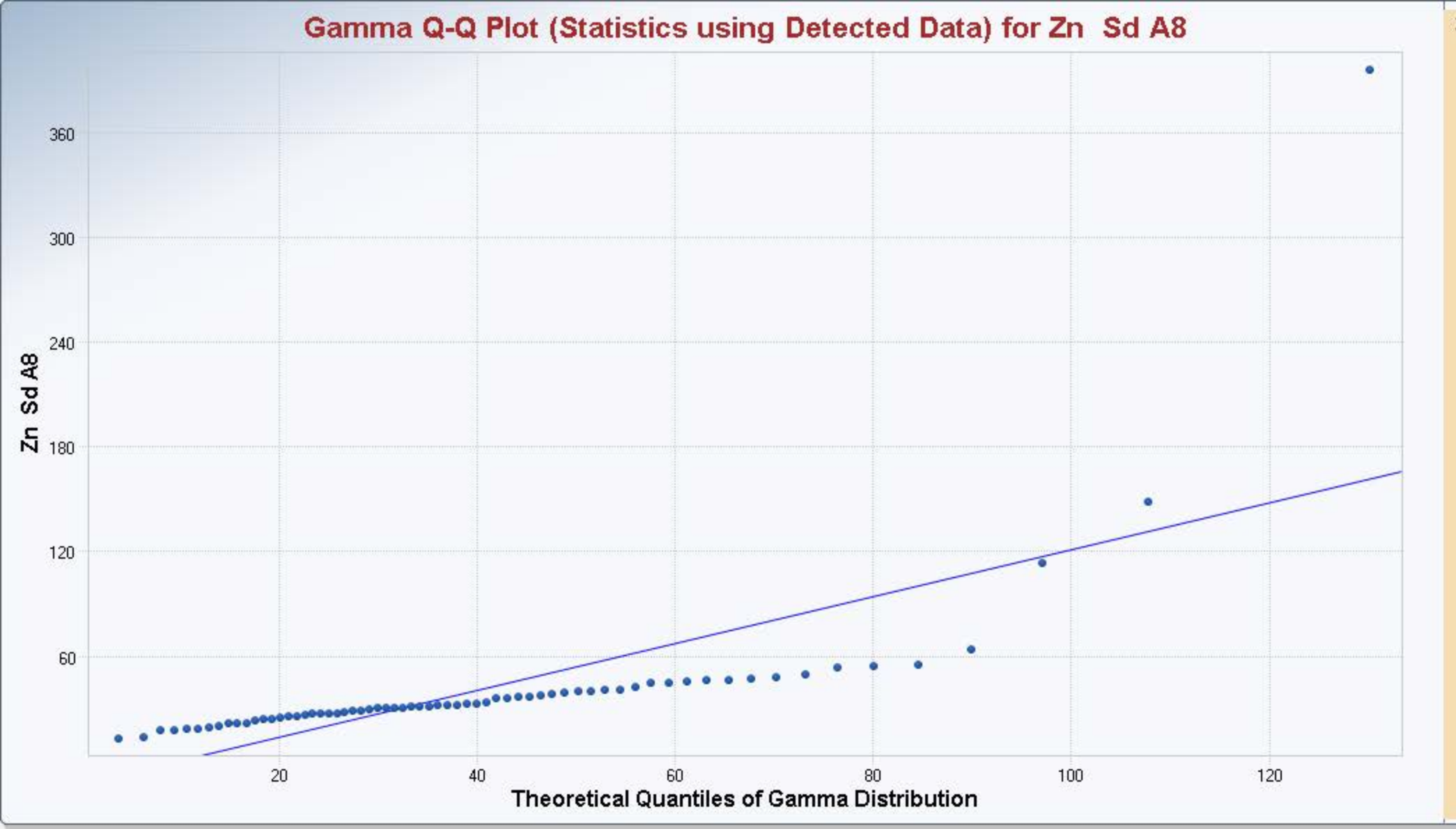
Cu Sd A8

Total Number of Data = 66
Number of NDs = 0
Max DL = N/A
N = 66
Percent NDs = 0%
Mean = 19.0624
k hat = 1.0026
theta hat = 19.0121
Slope = 1.8698
Intercept = -16.3878
Correlation, R = 0.6573
Anderson-Darling Test
Test Statistic = 10.048
Critical Value(0.05) = 0.780
Data not Gamma Distributed
Best Fit Line


Gamma Q-Q Plot (Statistics using Detected Data) for Hg Sd A8
Hg Sd A8
Total Number of Data = 66
Number of NDs = 0
Max DL = N/A
N = 66
Percent NDs = 0%
Mean = 0.1679
k hat = 0.7500
theta hat = 0.2238
Slope = 1.6312
Intercept = -0.1041
Correlation, R = 0.8575
Anderson-Darling Test
Test Statistic = 4.276
Critical Value(0.05) = 0.792
Data not Gamma Distributed
Best Fit Line
Hg Sd A8
0.0
0.5
1.0
1.5
2.0
0.0
0.2
0.4
0.6
0.8
Theoretical Quantiles of Gamma Distribution

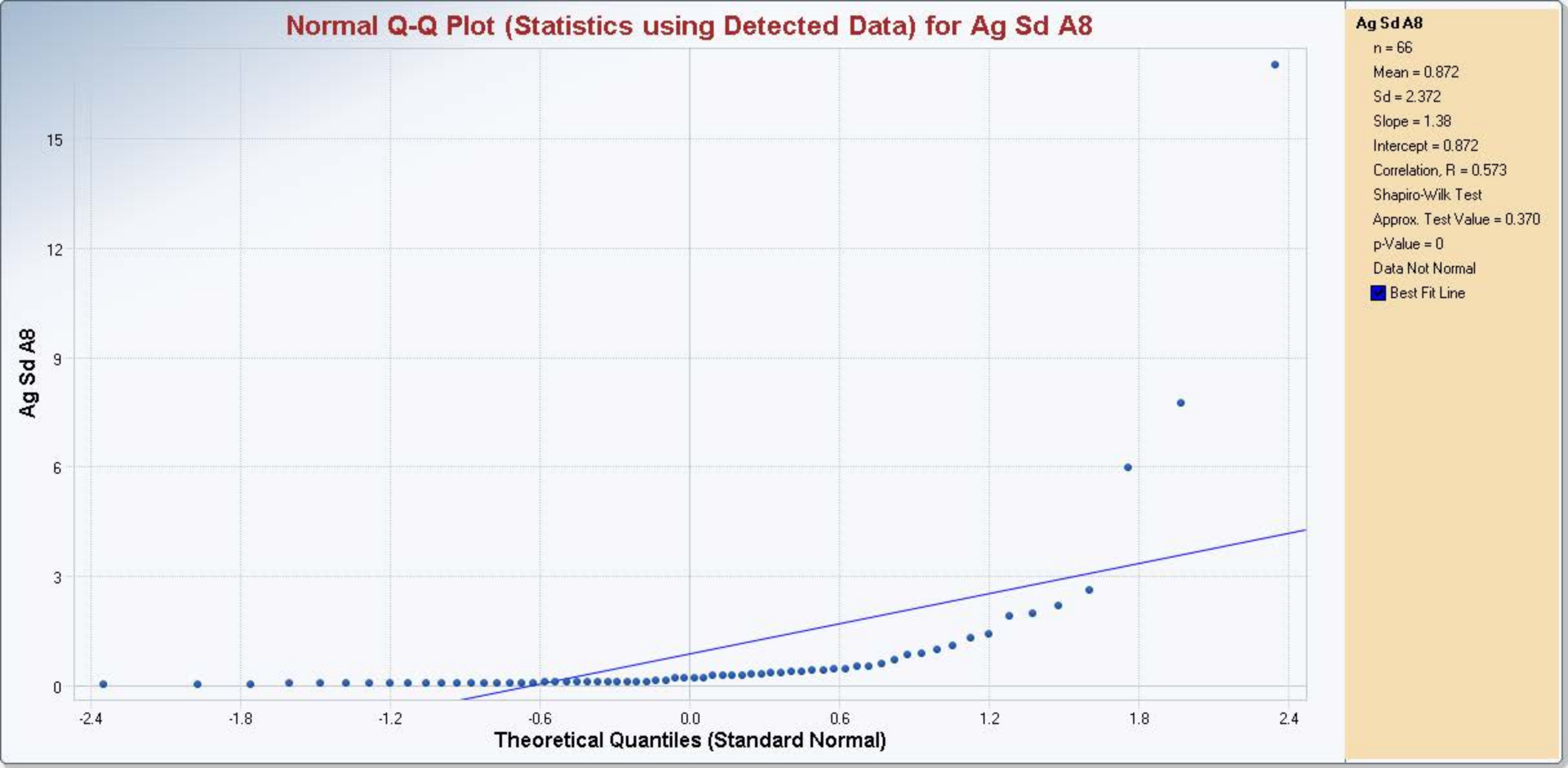

Gamma Q-Q Plot (Statistics using Detected Data) for Ni Sd A8
Ni Sd A8
Total Number of Data = 66
Number of NDs = 0
Max DL = N/A
N = 66
Percent NDs = 0%
Mean = 16.1282
k hat = 7.9280
theta hat = 2.0343
Slope = 0.9071
Intercept = 1.5106
Correlation, R = 0.9618
Anderson-Darling Test
Test Statistic = 1.139
Critical Value(0.05) = 0.752
Data not Gamma Distributed
Best Fit Line
Ni Sd A8
40
32
24
16
8
8
12
16
20
24
28
32
Theoretical Quantiles of Gamma Distribution

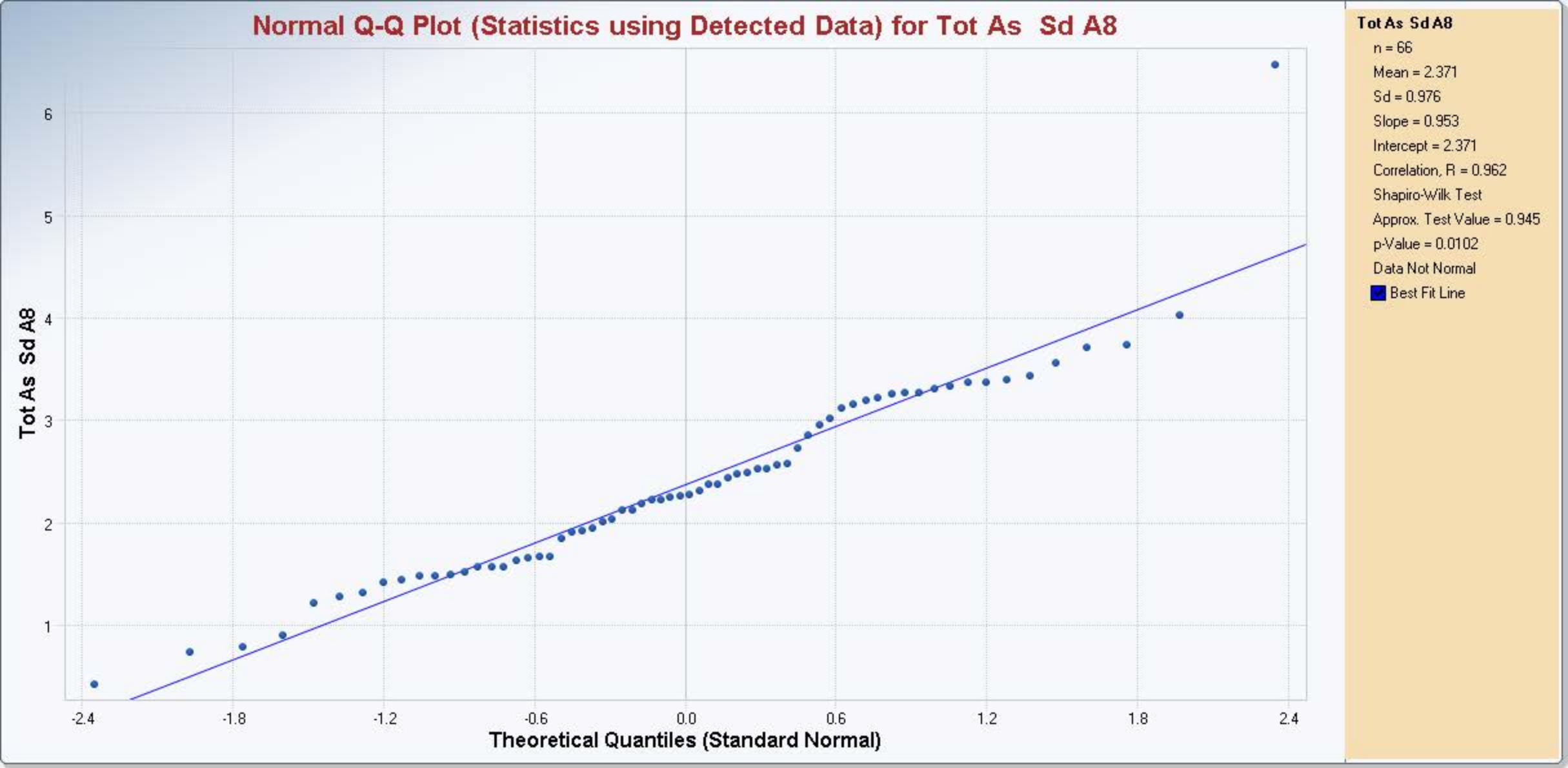

Gamma Q-Q Plot (Statistics using Detected Data) for Pb Sd A8
Pb Sd A8
Total Number of Data = 66
Number of NDs = 0
Max DL = N/A
N = 66
Percent NDs = 0%
Mean = 11.6408
k hat = 0.9885
theta hat = 11.7762
Slope = 1.6935
Intercept = -7.9657
Correlation, R = 0.7964
Anderson-Darling Test
Test Statistic = 9.562
Critical Value(0.05) = 0.781
Data not Gamma Distributed
Best Fit Line
Pb Sd A8
0
25
50
75
100
125
150
175
0
10
20
30
40
50
Theoretical Quantiles of Gamma Distribution

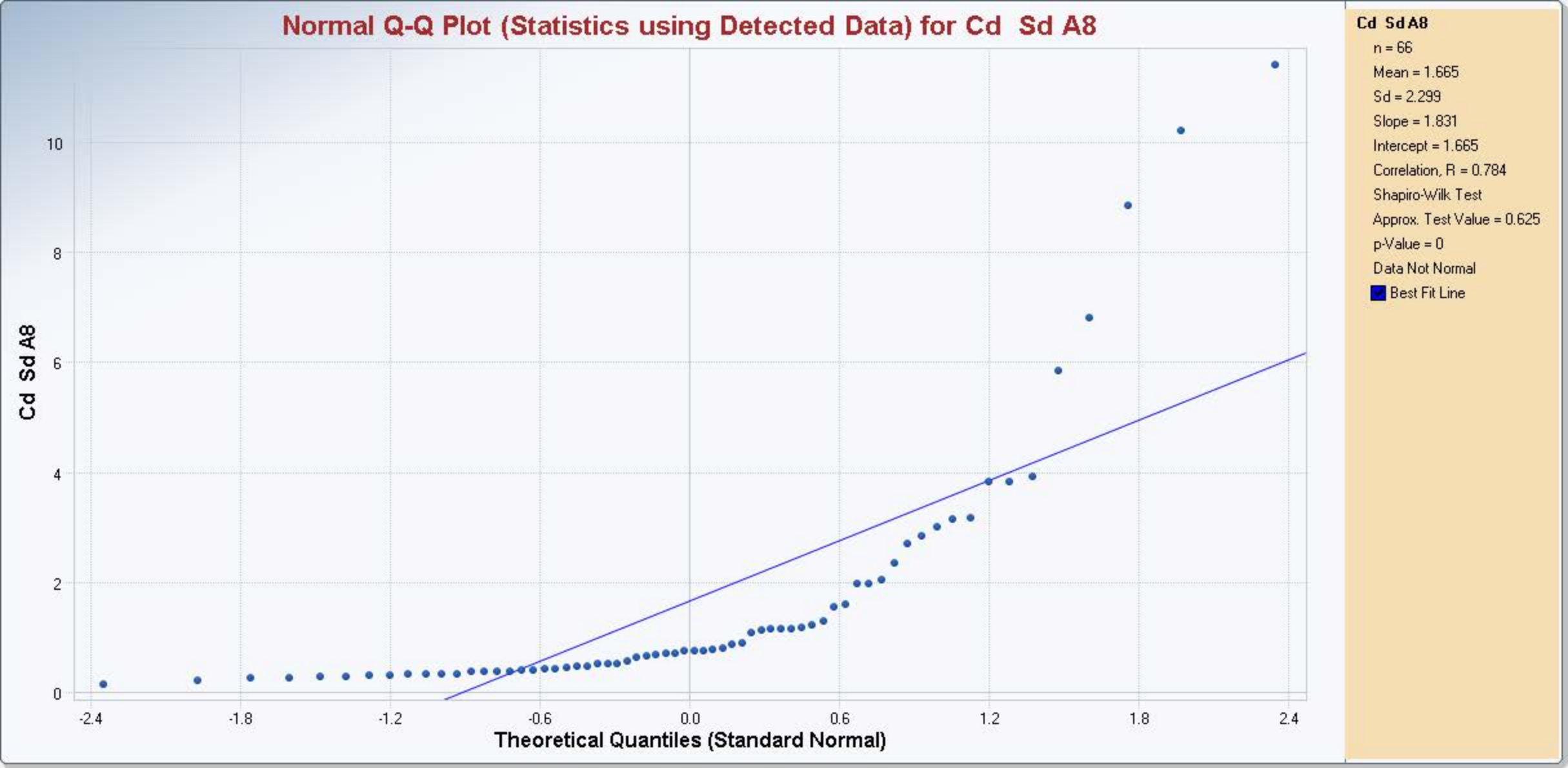


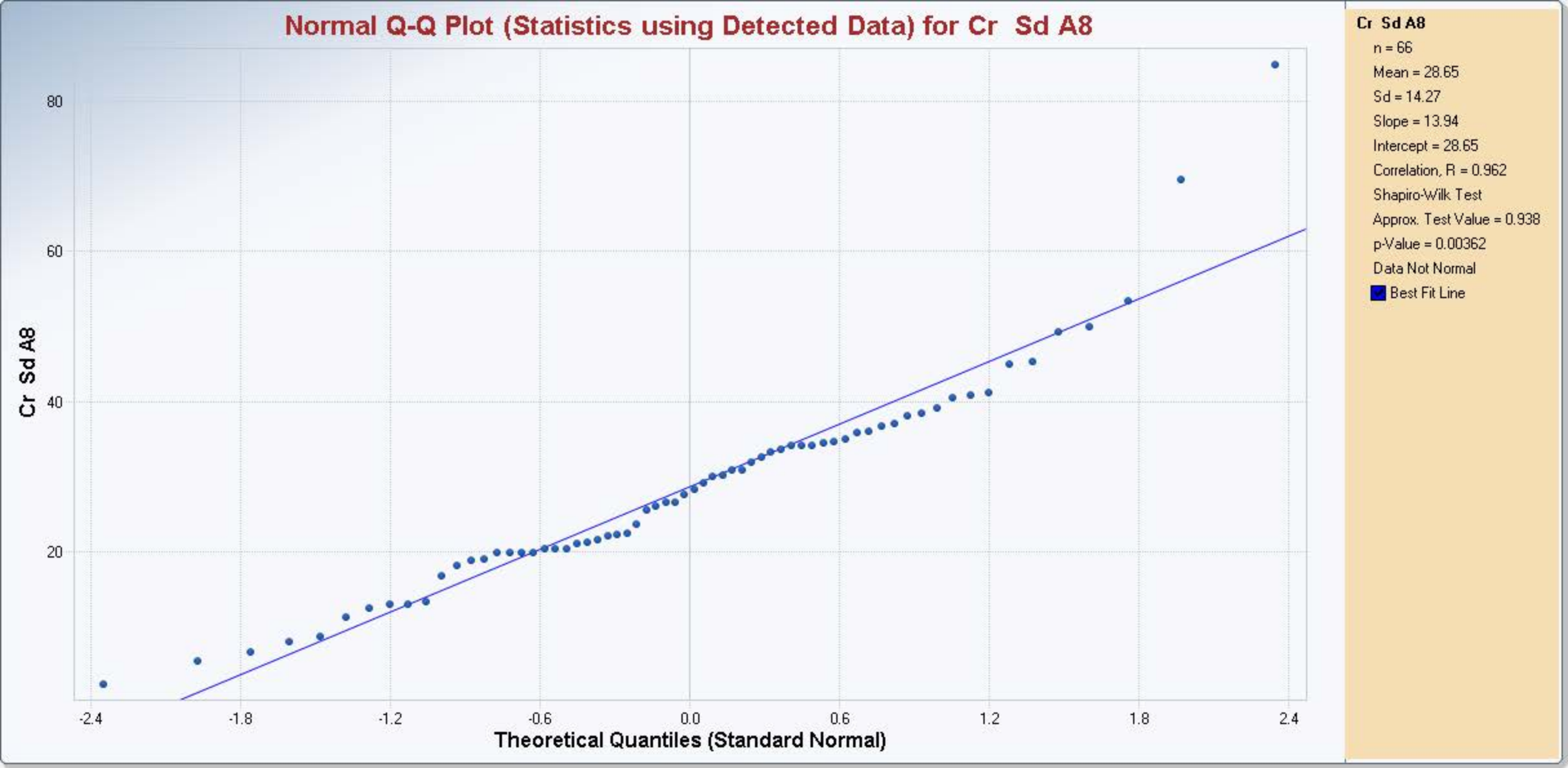
Zn Sd A8

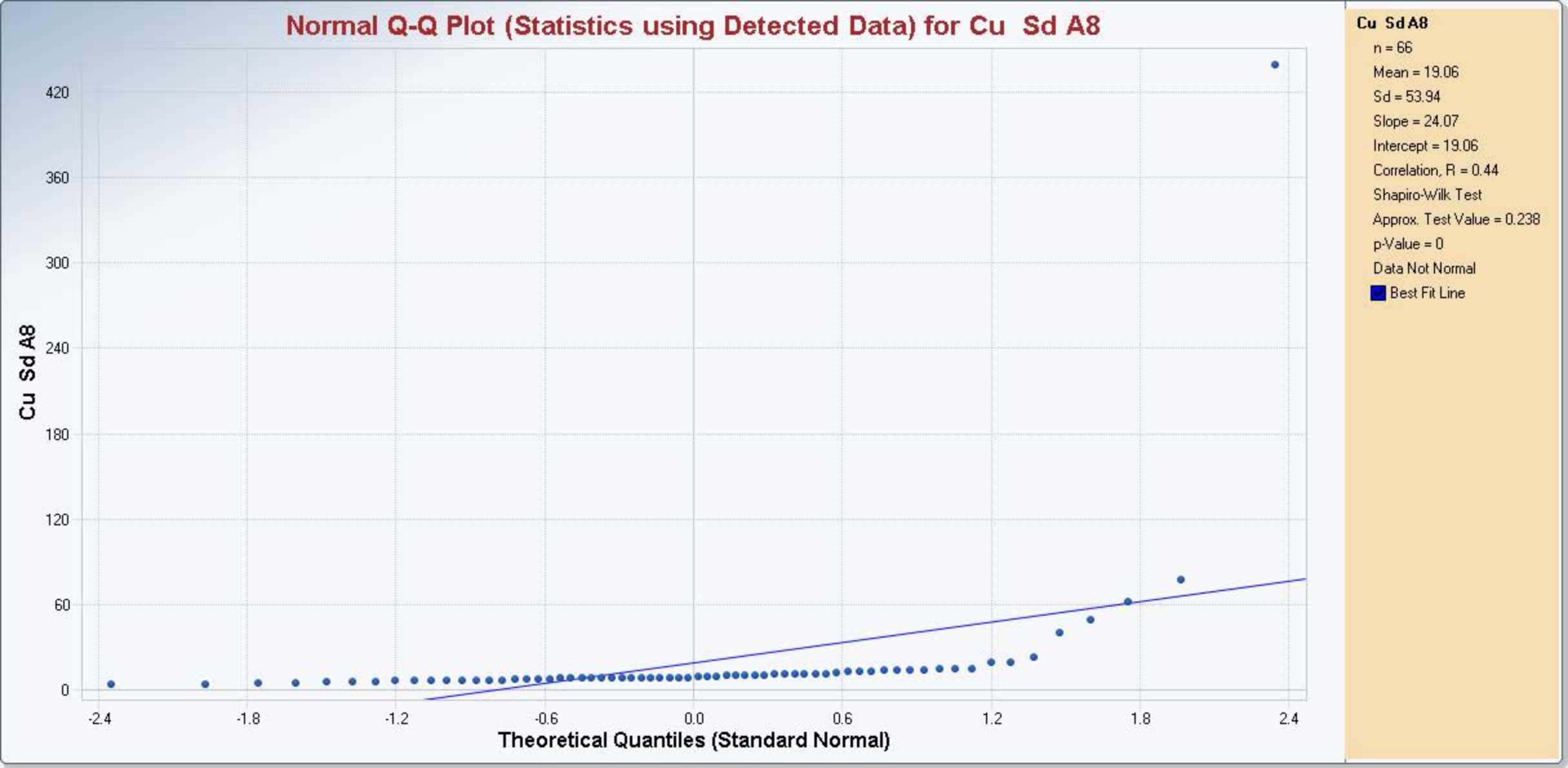
Total Number of Data = 66
Number of NDs = 0
Max DL = N/A
N = 66
Percent NDs = 0%
Mean = 41.0758
k hat = 2.5769
theta hat = 15.9400
Slope = 1.3521
Intercept = -14.3334
Correlation, R = 0.7172
Anderson-Darling Test
Test Statistic = 4.830
Critical Value(0.05) = 0.760
Data not Gamma Distributed
Best Fit Line

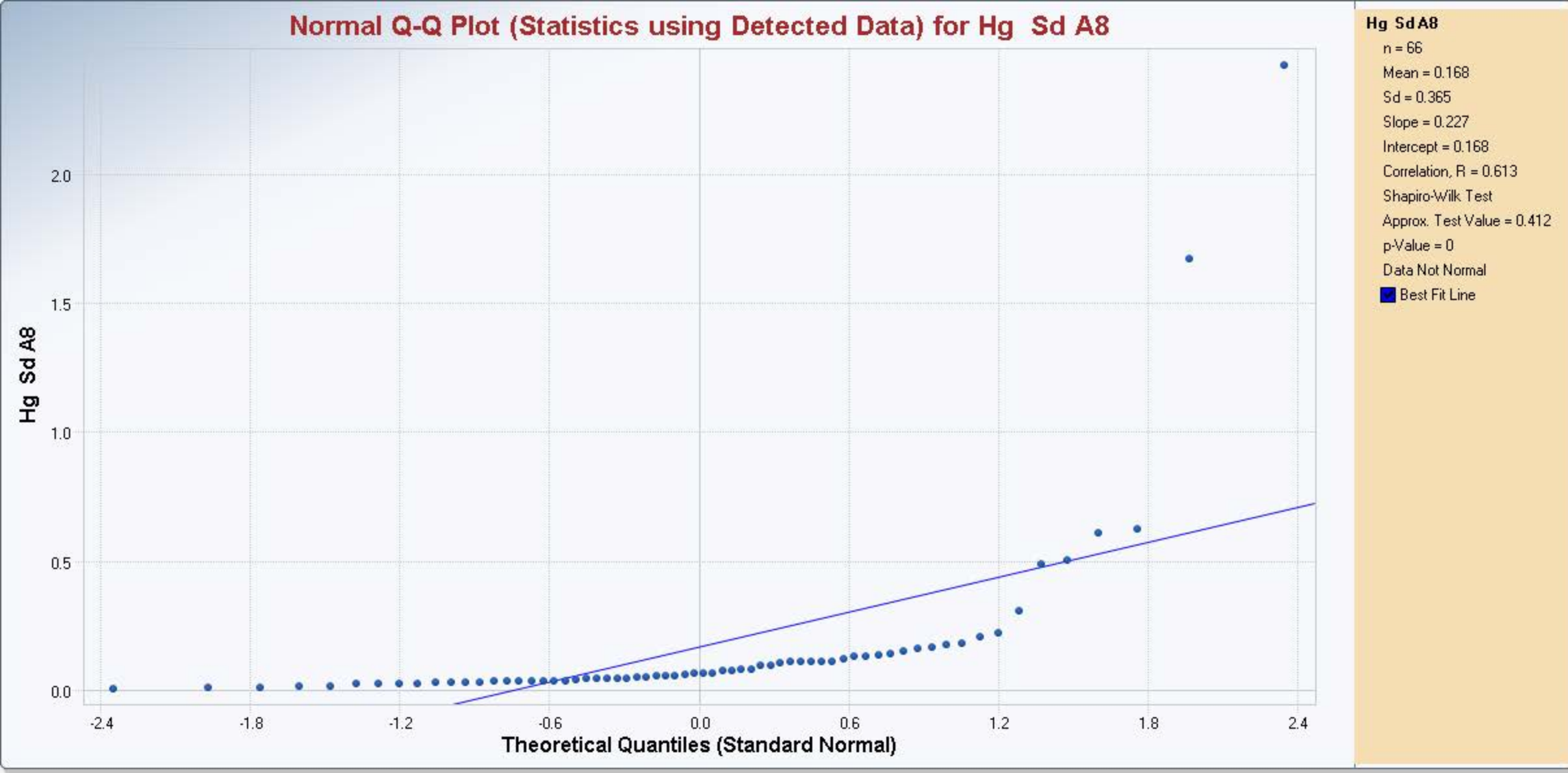

Normal Q-Q Plot (Statistics using Detected Data) for Ag Sd A8
Ag Sd A8
n = 66
Mean = 0.872
Sd = 2.372
Slope = 1.38
Intercept = 0.872
Correlation, R = 0.573
Shapiro-Wilk Test
Approx. Test Value = 0.370
p-Value = 0
Data Not Normal
Best Fit Line
Ag Sd A8
15
12
9
6
3
0
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

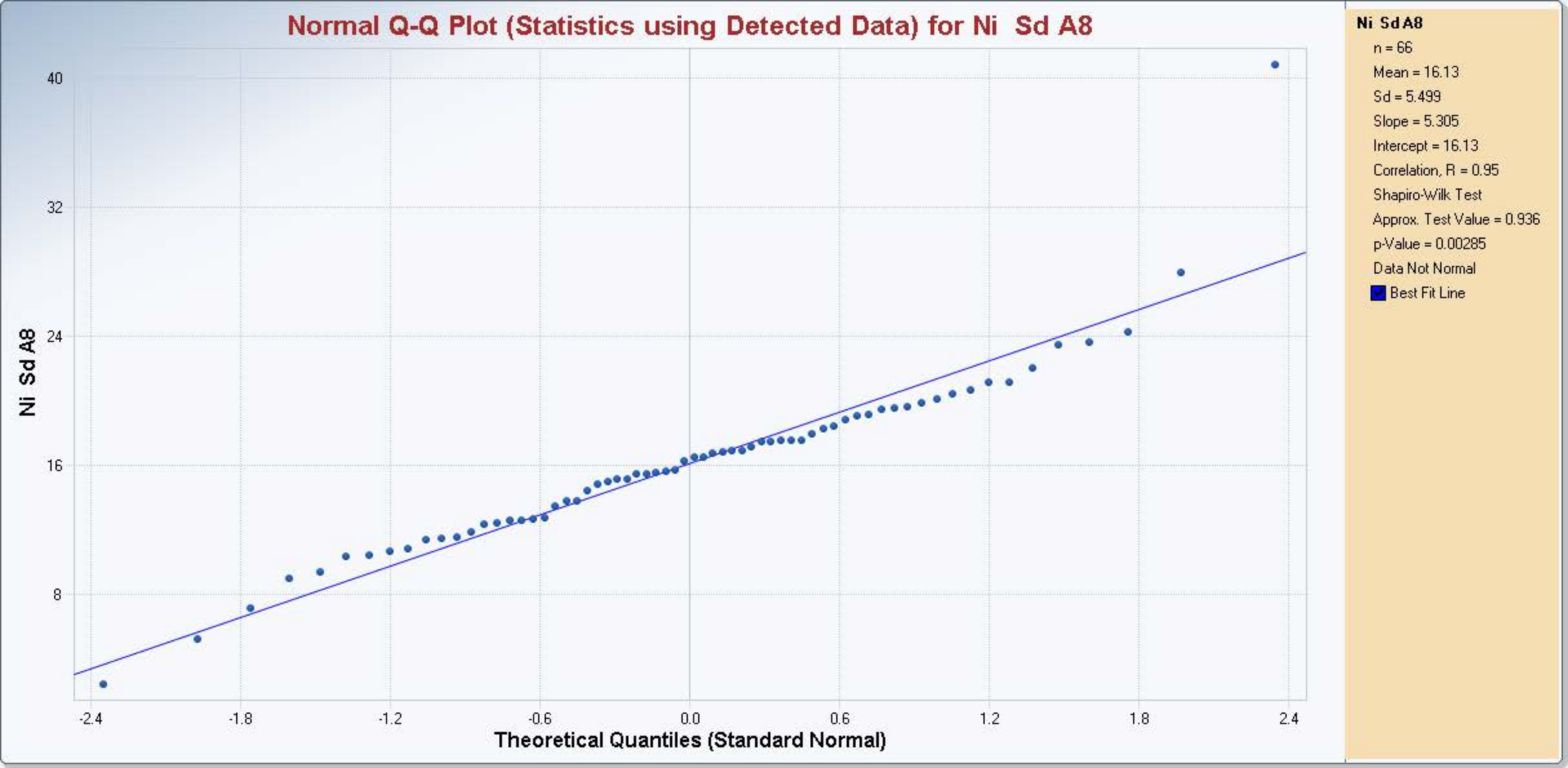

Normal Q-Q Plot (Statistics using Detected Data) for Tot As Sd A8
Tot As Sd A8
n = 66
Mean = 2.371
Sd = 0.976
Slope = 0.953
Intercept = 2.371
Correlation, R = 0.962
Shapiro-Wilk Test
Approx. Test Value = 0.945
p-Value = 0.0102
Data Not Normal
Best Fit Line
Tot As Sd A8
6
5
4
3
2
1
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

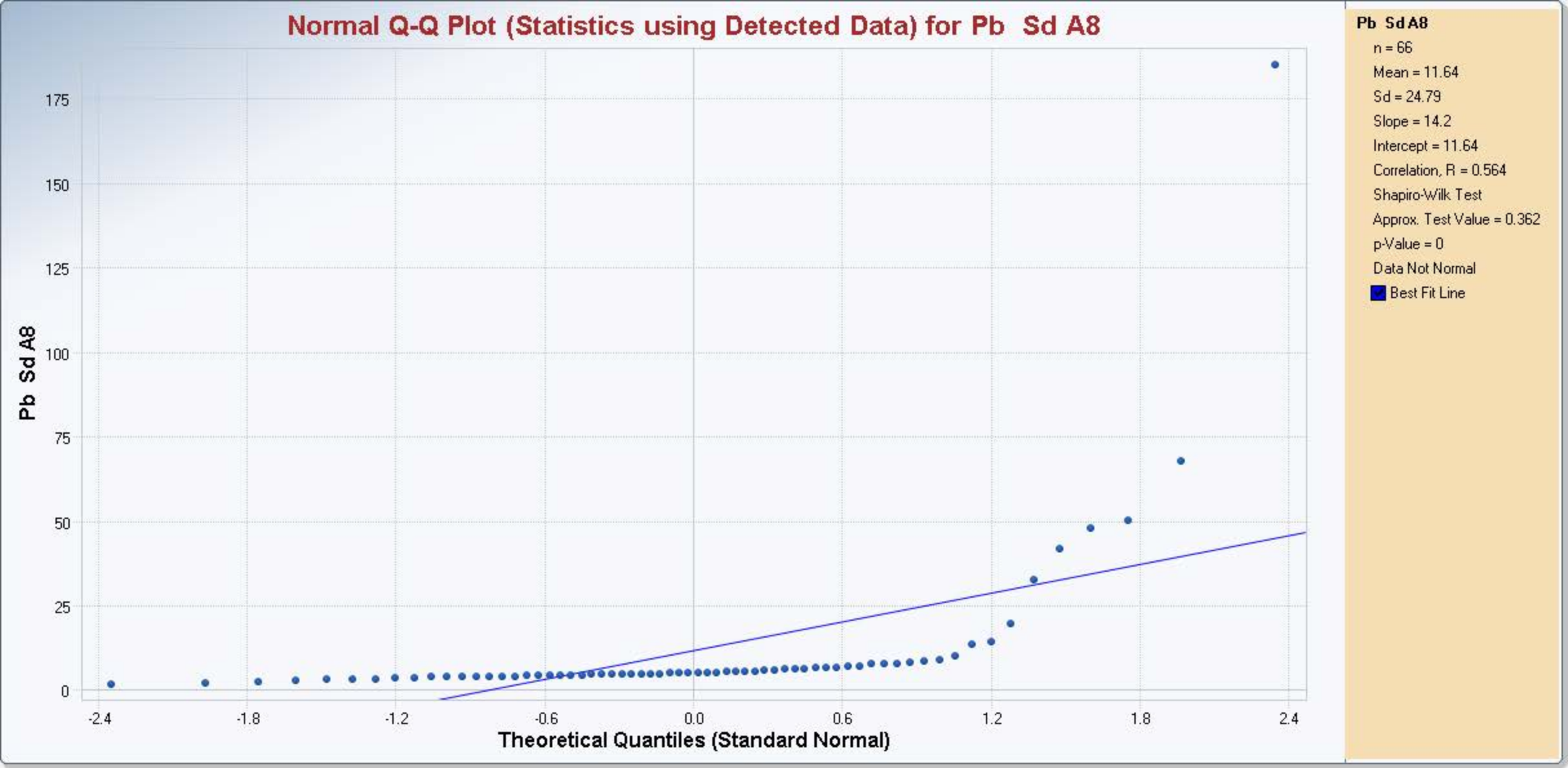

Normal Q-Q Plot (Statistics using Detected Data) for Cd Sd A8
Cd Sd A8
Theoretical Quantiles (Standard Normal)
0
2
4
6
8
10
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Cd Sd A8
n = 66
Mean = 1.665
Sd = 2.299
Slope = 1.831
Intercept = 1.665
Correlation, R = 0.784
Shapiro-Wilk Test
Approx. Test Value = 0.625
p-Value = 0
Data Not Normal
Best Fit Line

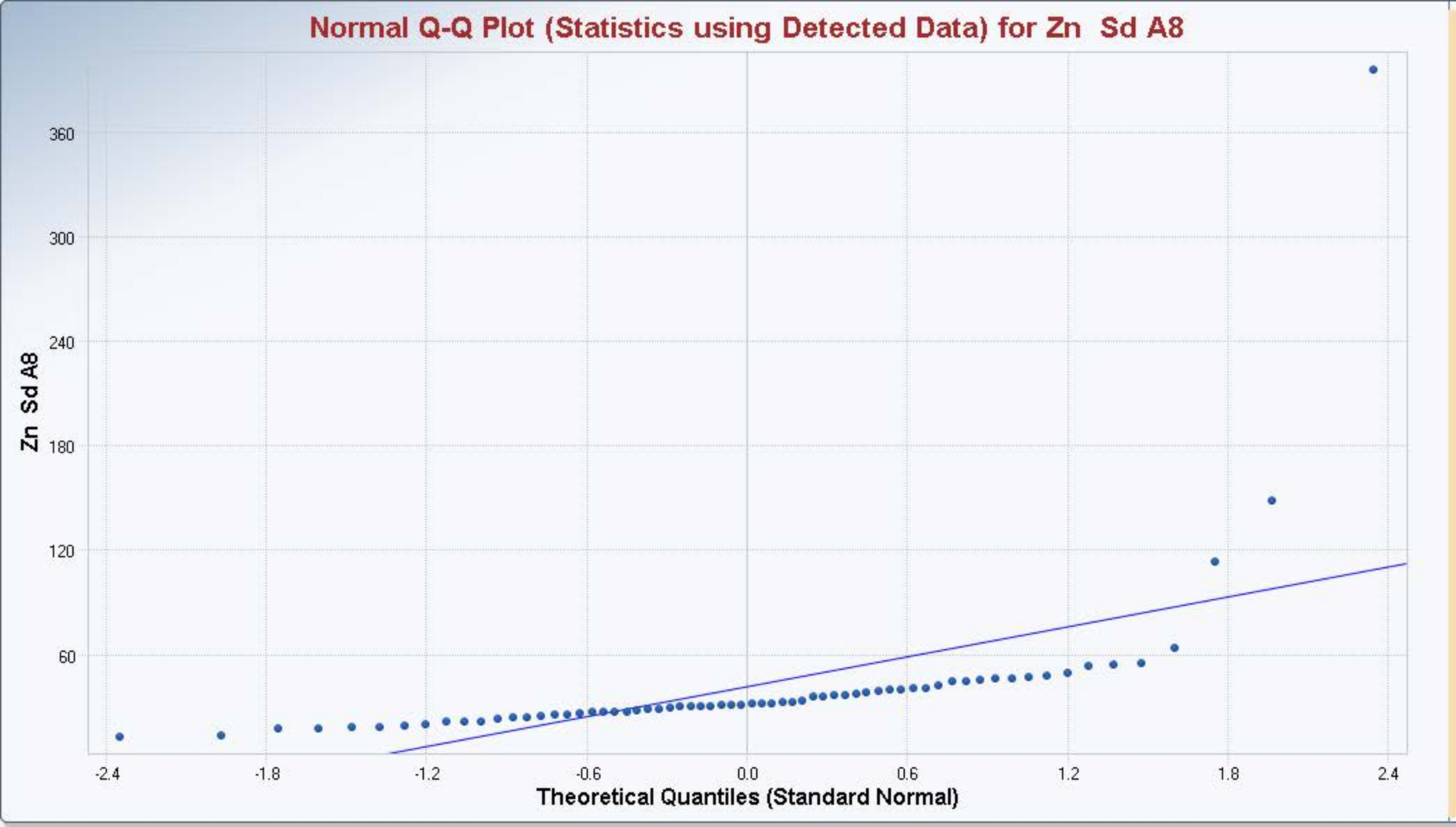

Normal Q-Q Plot (Statistics using Detected Data) for Cr Sd A8
Cr Sd A8
n = 66
Mean = 28.65
Sd = 14.27
Slope = 13.94
Intercept = 28.65
Correlation, R = 0.962
Shapiro-Wilk Test
Approx. Test Value = 0.938
p-Value = 0.00362
Data Not Normal
Best Fit Line
Cr Sd A8
80
60
40
20
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)


Normal Q-Q Plot (Statistics using Detected Data) for Cu Sd A8
Cu Sd A8
n = 66
Mean = 19.06
Sd = 53.94
Slope = 24.07
Intercept = 19.06
Correlation, R = 0.44
Shapiro-Wilk Test
Approx. Test Value = 0.238
p-Value = 0
Data Not Normal
Best Fit Line
Cu Sd A8
420
360
300
240
180
120
60
0
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)


Normal Q-Q Plot (Statistics using Detected Data) for Hg Sd A8
Hg Sd A8
n = 66
Mean = 0.168
Sd = 0.365
Slope = 0.227
Intercept = 0.168
Correlation, R = 0.613
Shapiro-Wilk Test
Approx. Test Value = 0.412
p-Value = 0
Data Not Normal
Best Fit Line
Hg Sd A8
2.0
1.5
1.0
0.5
0.0
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)


Normal Q-Q Plot (Statistics using Detected Data) for Ni Sd A8
Ni Sd A8
n = 66
Mean = 16.13
Sd = 5.499
Slope = 5.305
Intercept = 16.13
Correlation, R = 0.95
Shapiro-Wilk Test
Approx. Test Value = 0.936
p-Value = 0.00285
Data Not Normal
Best Fit Line
40
32
24
16
8
Ni Sd A8
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)


Normal Q-Q Plot (Statistics using Detected Data) for Pb Sd A8
Pb Sd A8
n = 66
Mean = 11.64
Sd = 24.79
Slope = 14.2
Intercept = 11.64
Correlation, R = 0.564
Shapiro-Wilk Test
Approx. Test Value = 0.362
p-Value = 0
Data Not Normal
Best Fit Line
175
150
125
100
75
50
25
0
Pb Sd A8
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)



Zn Sd A8

n = 66

Mean = 41.08

Sd = 48.76

Slope = 28.81

Intercept = 41.08

Correlation, R = 0.582

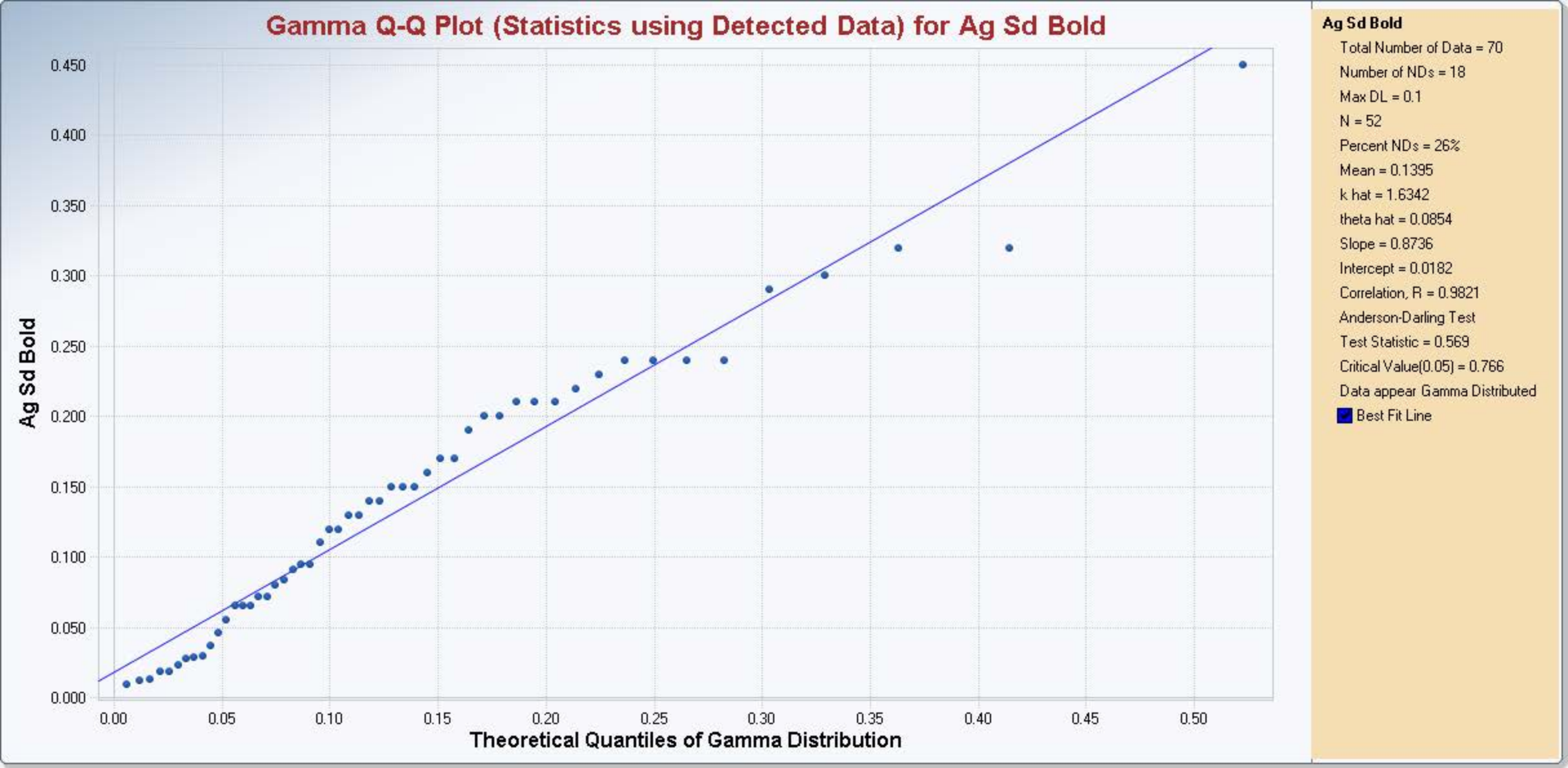
Shapiro-Wilk Test

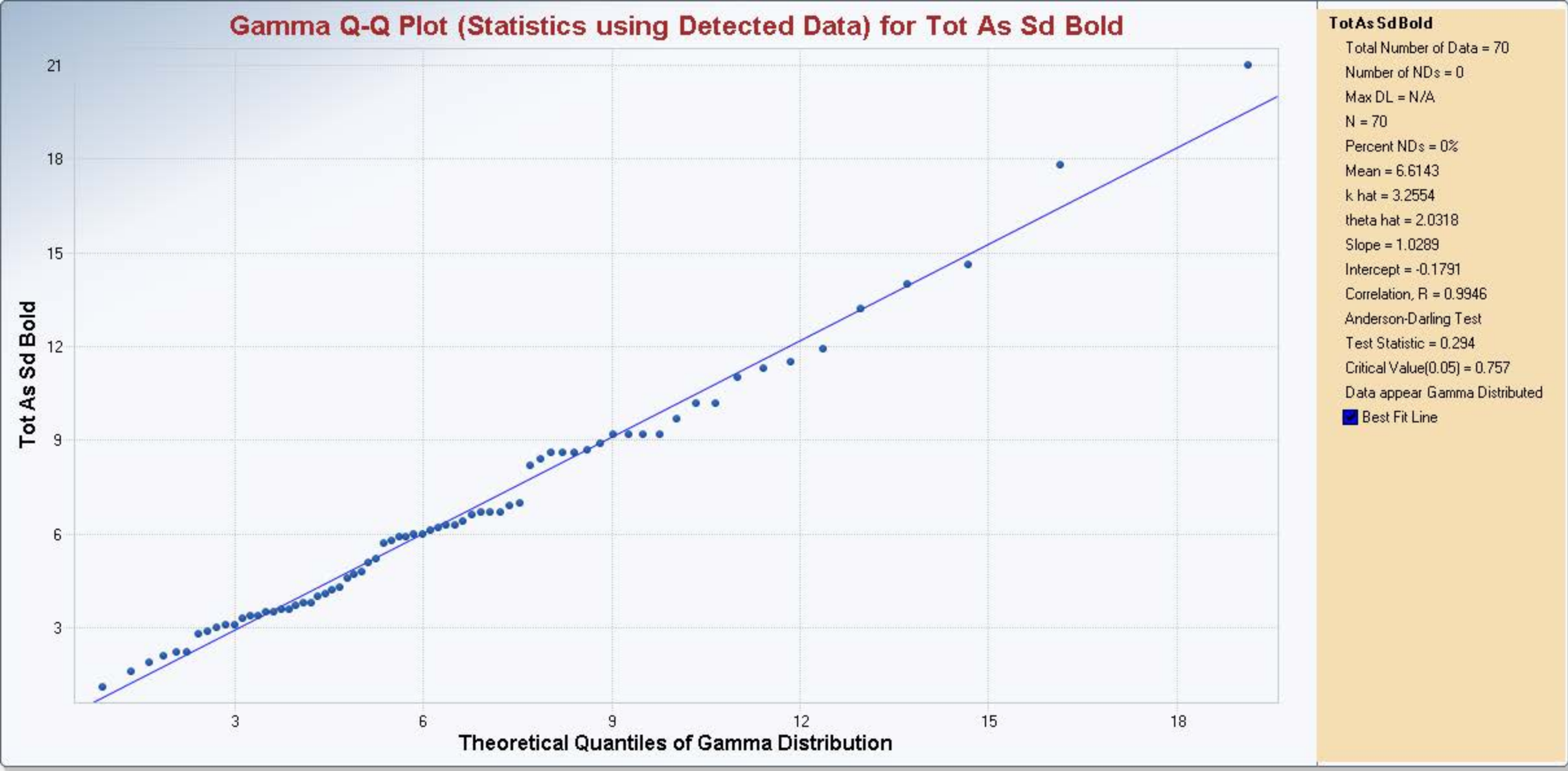
Approx. Test Value = 0.387

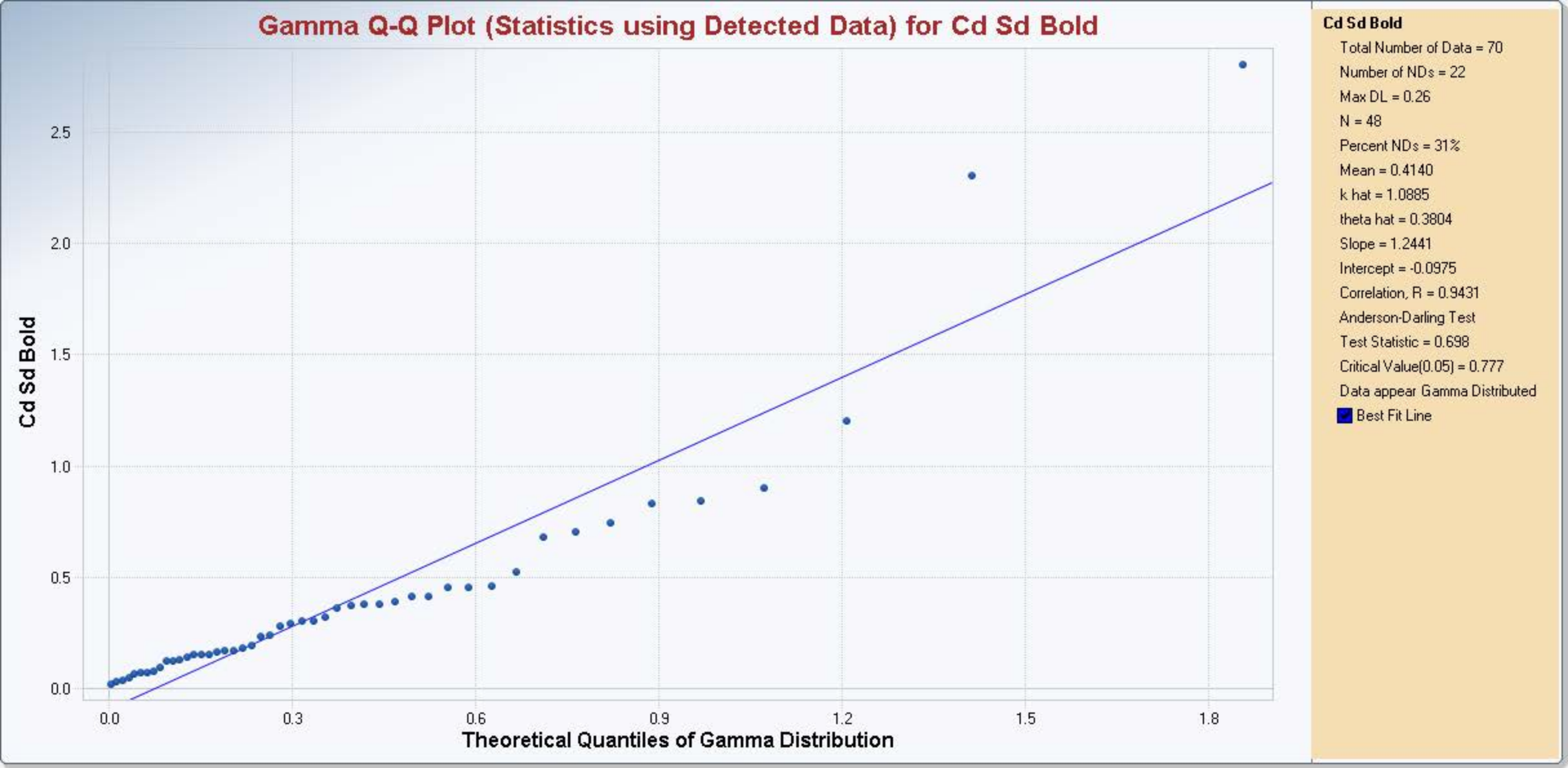
p-Value = 0

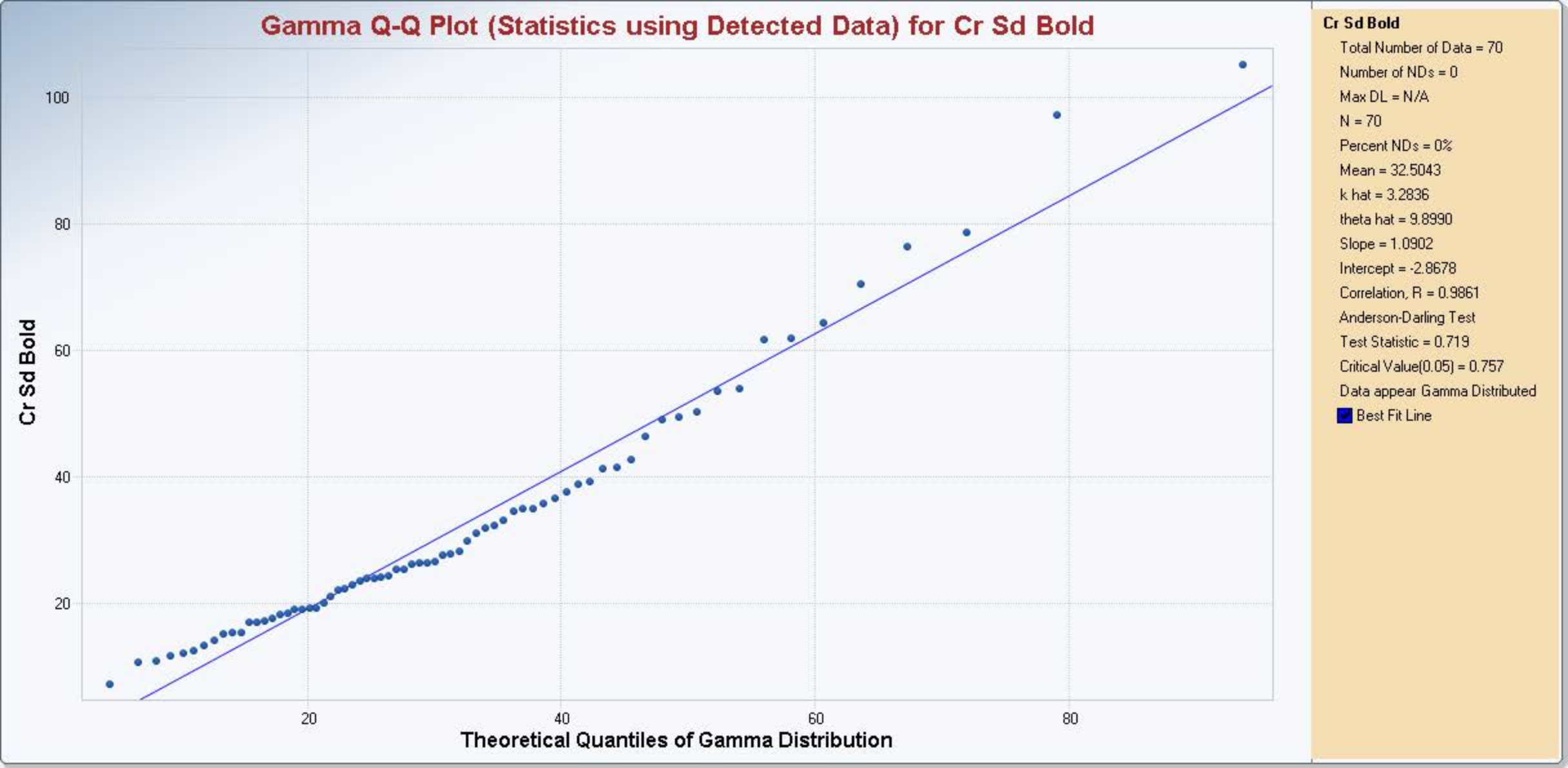
Data Not Normal

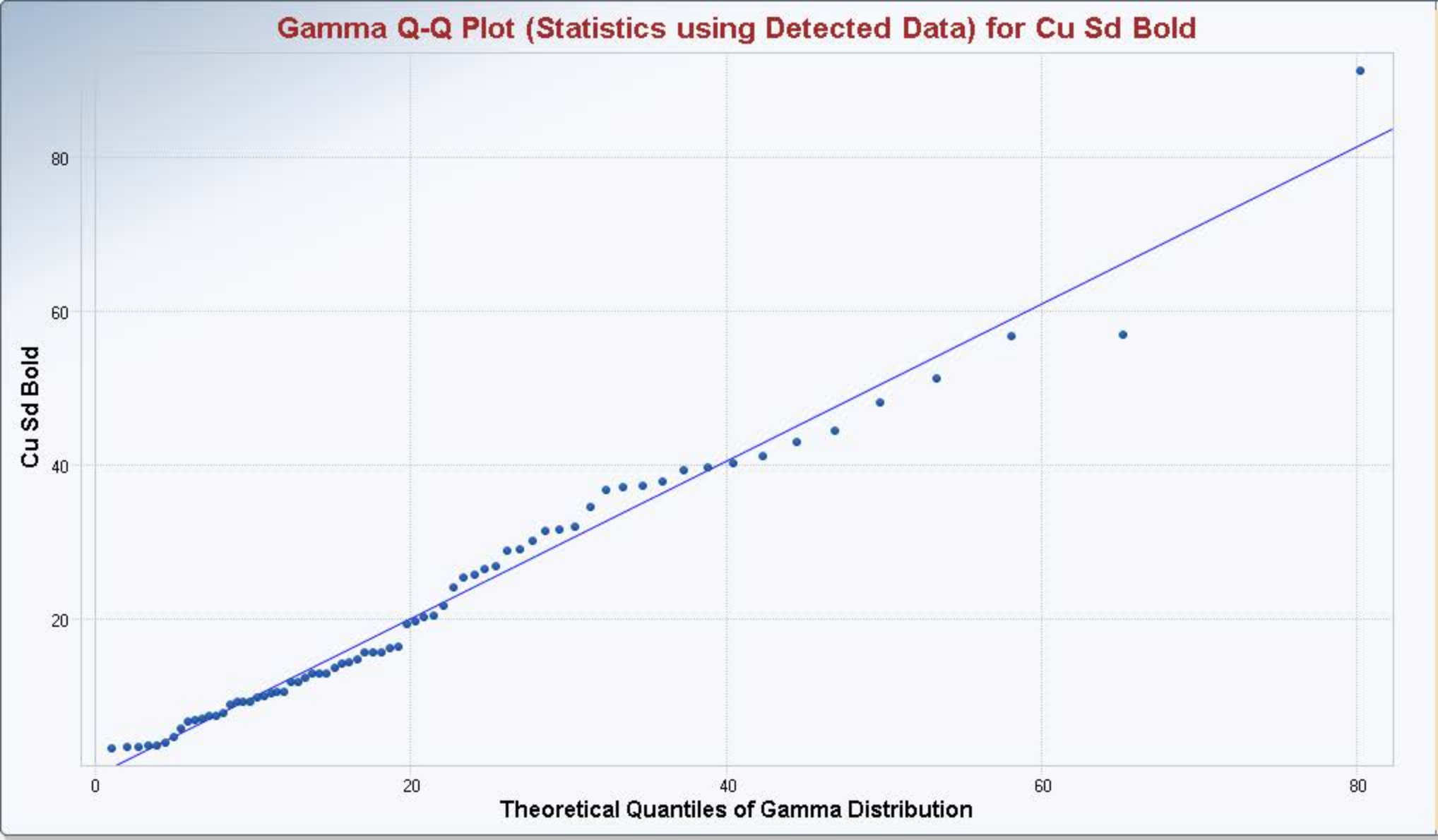
Best Fit Line


Gamma Q-Q Plot (Statistics using Detected Data) for Ag Sd Bold
Ag Sd Bold
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Theoretical Quantiles of Gamma Distribution
Ag Sd Bold
Total Number of Data = 70
Number of NDs = 18
Max DL = 0.1
N = 52
Percent NDs = 26%
Mean = 0.1395
k hat = 1.6342
theta hat = 0.0854
Slope = 0.8736
Intercept = 0.0182
Correlation, R = 0.9821
Anderson-Darling Test
Test Statistic = 0.569
Critical Value(0.05) = 0.766
Data appear Gamma Distributed
Best Fit Line


Gamma Q-Q Plot (Statistics using Detected Data) for Tot As Sd Bold
Tot As Sd Bold
Theoretical Quantiles of Gamma Distribution
21
18
15
12
9
6
3
3
6
9
12
15
18
Tot As Sd Bold
Total Number of Data = 70
Number of NDs = 0
Max DL = N/A
N = 70
Percent NDs = 0%
Mean = 6.6143
k hat = 3.2554
theta hat = 2.0318
Slope = 1.0289
Intercept = -0.1791
Correlation, R = 0.9946
Anderson-Darling Test
Test Statistic = 0.294
Critical Value(0.05) = 0.757
Data appear Gamma Distributed
Best Fit Line

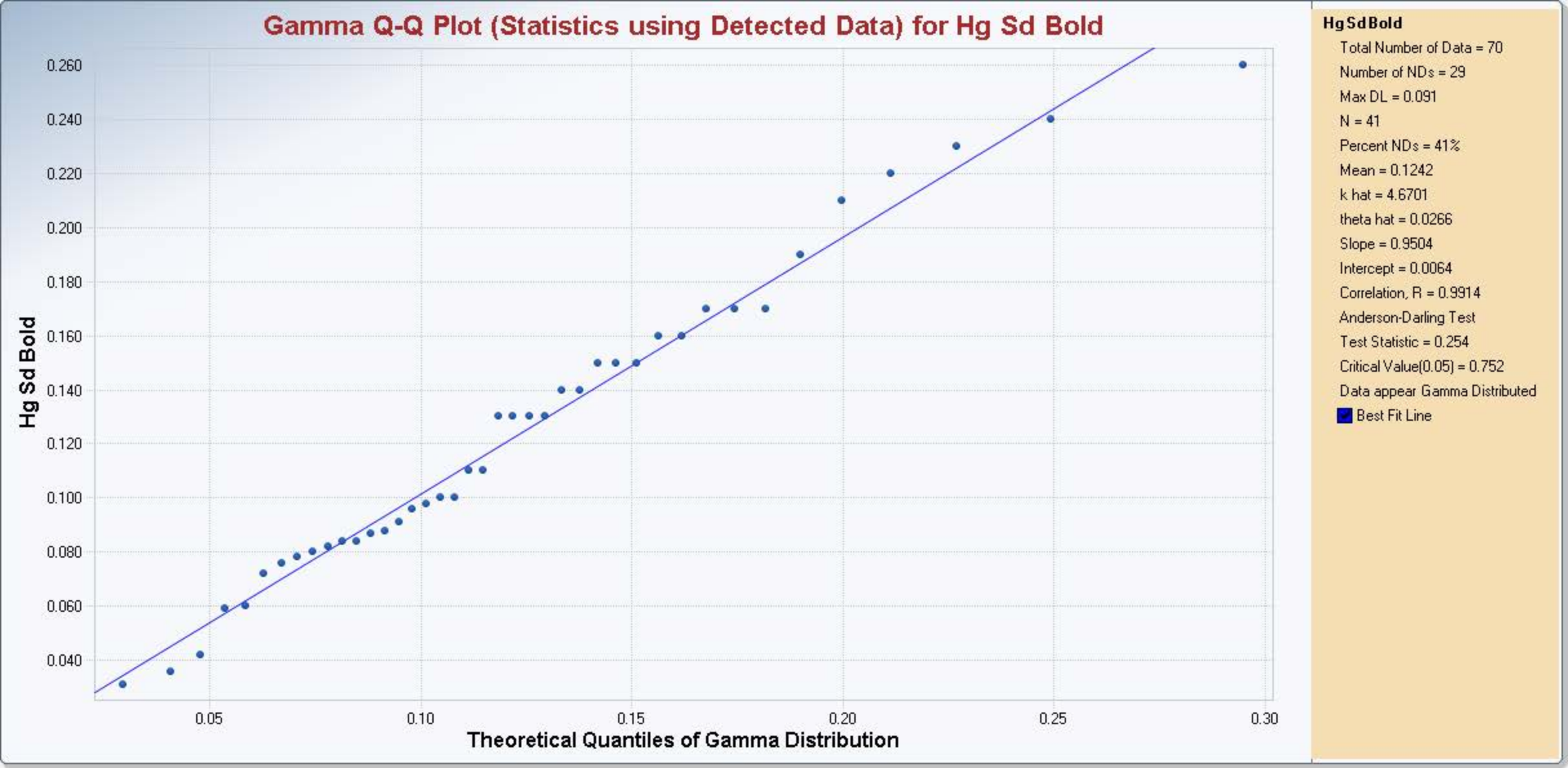

Gamma Q-Q Plot (Statistics using Detected Data) for Cd Sd Bold
Cd Sd Bold
Theoretical Quantiles of Gamma Distribution
0.0
0.5
1.0
1.5
2.0
2.5
0.0
0.3
0.6
0.9
1.2
1.5
1.8
Cd Sd Bold
Total Number of Data = 70
Number of NDs = 22
Max DL = 0.26
N = 48
Percent NDs = 31%
Mean = 0.4140
k hat = 1.0885
theta hat = 0.3804
Slope = 1.2441
Intercept = -0.0975
Correlation, R = 0.9431
Anderson-Darling Test
Test Statistic = 0.698
Critical Value(0.05) = 0.777
Data appear Gamma Distributed
Best Fit Line

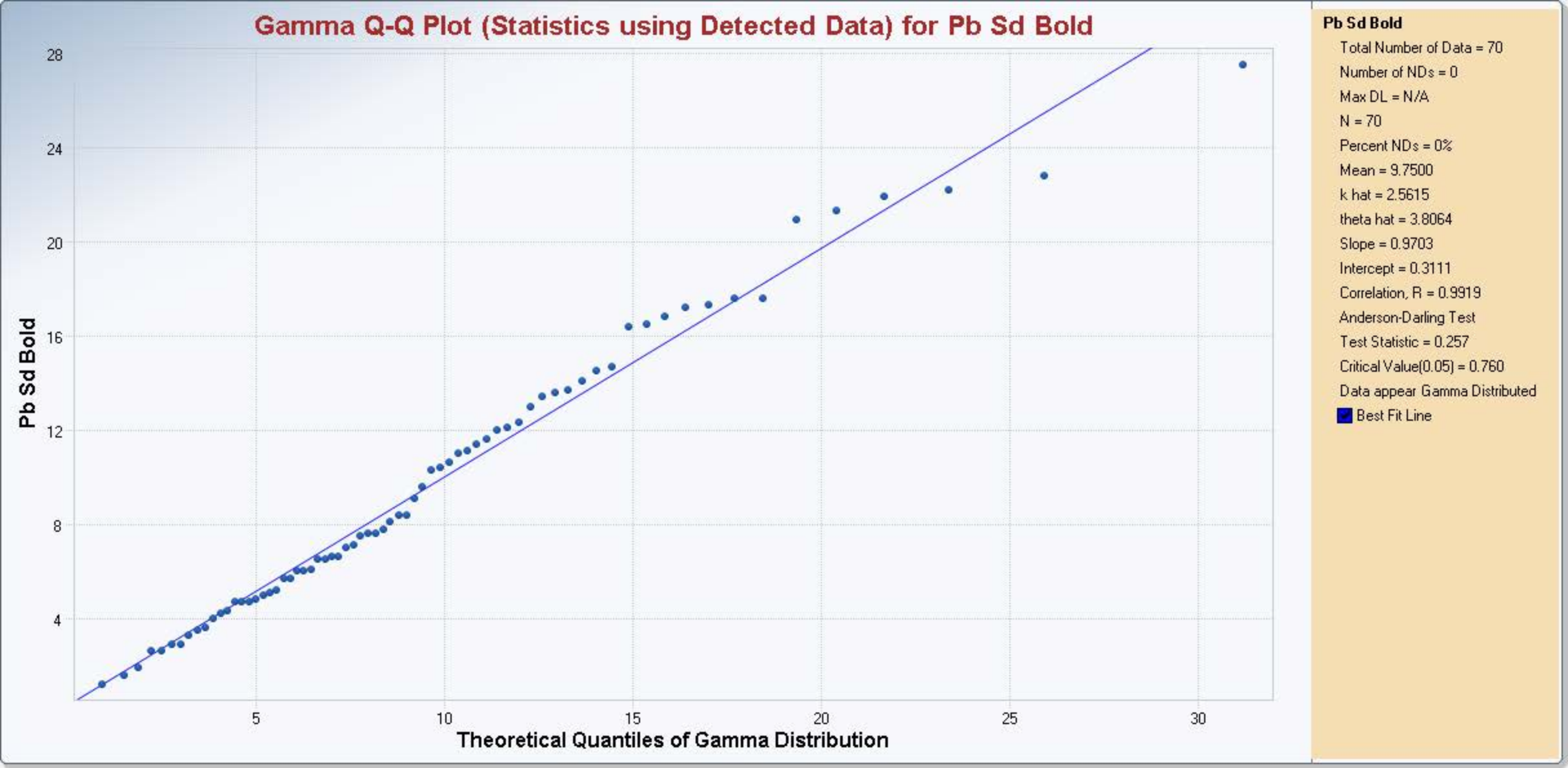

Gamma Q-Q Plot (Statistics using Detected Data) for Cr Sd Bold
Cr Sd Bold
Total Number of Data = 70
Number of NDs = 0
Max DL = N/A
N = 70
Percent NDs = 0%
Mean = 32.5043
k hat = 3.2836
theta hat = 9.8990
Slope = 1.0902
Intercept = -2.8678
Correlation, R = 0.9861
Anderson-Darling Test
Test Statistic = 0.719
Critical Value(0.05) = 0.757
Data appear Gamma Distributed
Best Fit Line
Cr Sd Bold
100
80
60
40
20
20
40
60
80
Theoretical Quantiles of Gamma Distribution

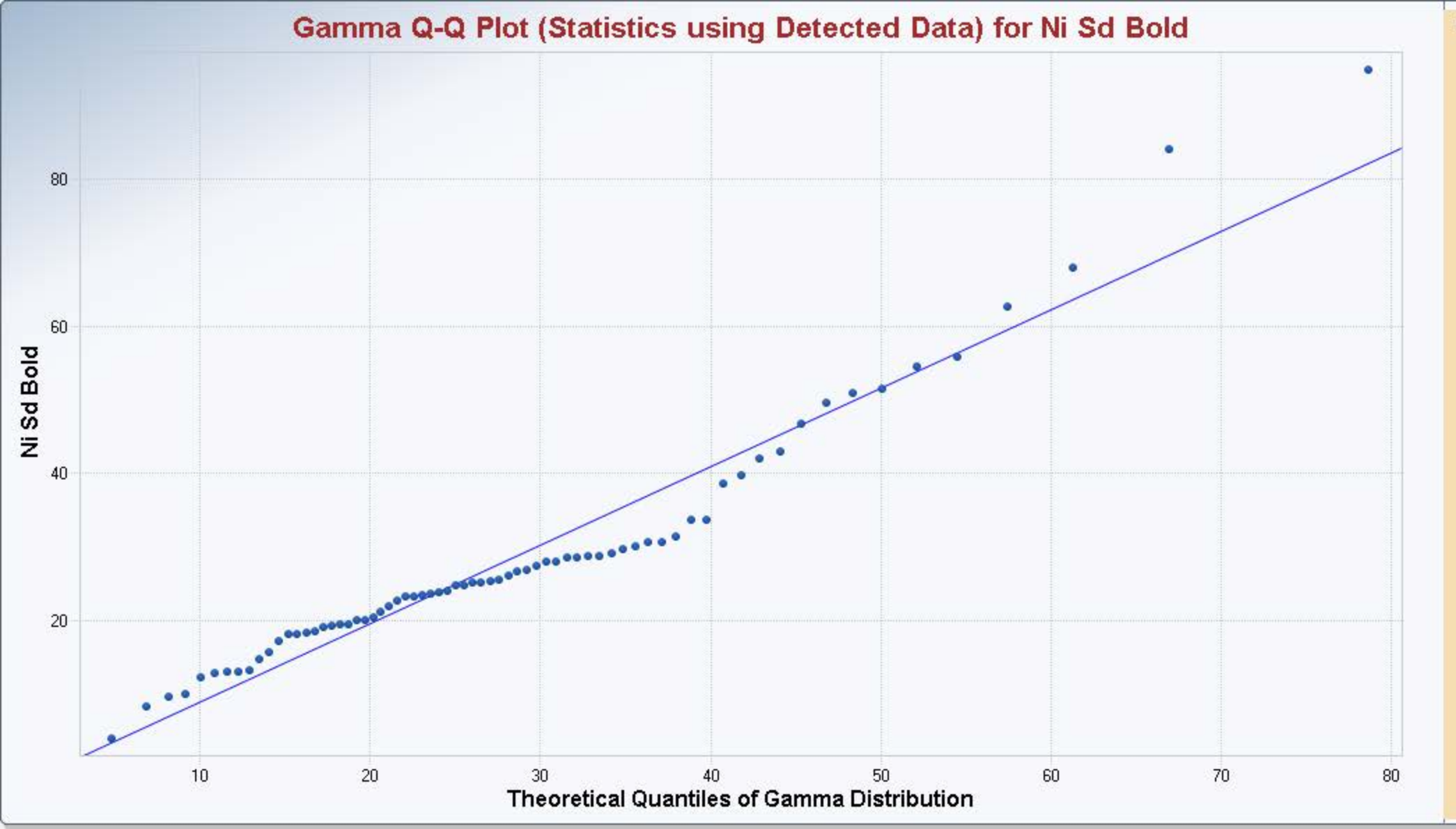


Cu Sd Bold

Total Number of Data = 70
Number of NDs = 0
Max DL = N/A
N = 70
Percent NDs = 0%
Mean = 21.7514
k hat = 1.8691
theta hat = 11.6372
Slope = 1.0235
Intercept = -0.4445
Correlation, R = 0.9904
Anderson-Darling Test
Test Statistic = 0.495
Critical Value(0.05) = 0.765
Data appear Gamma Distributed
Best Fit Line

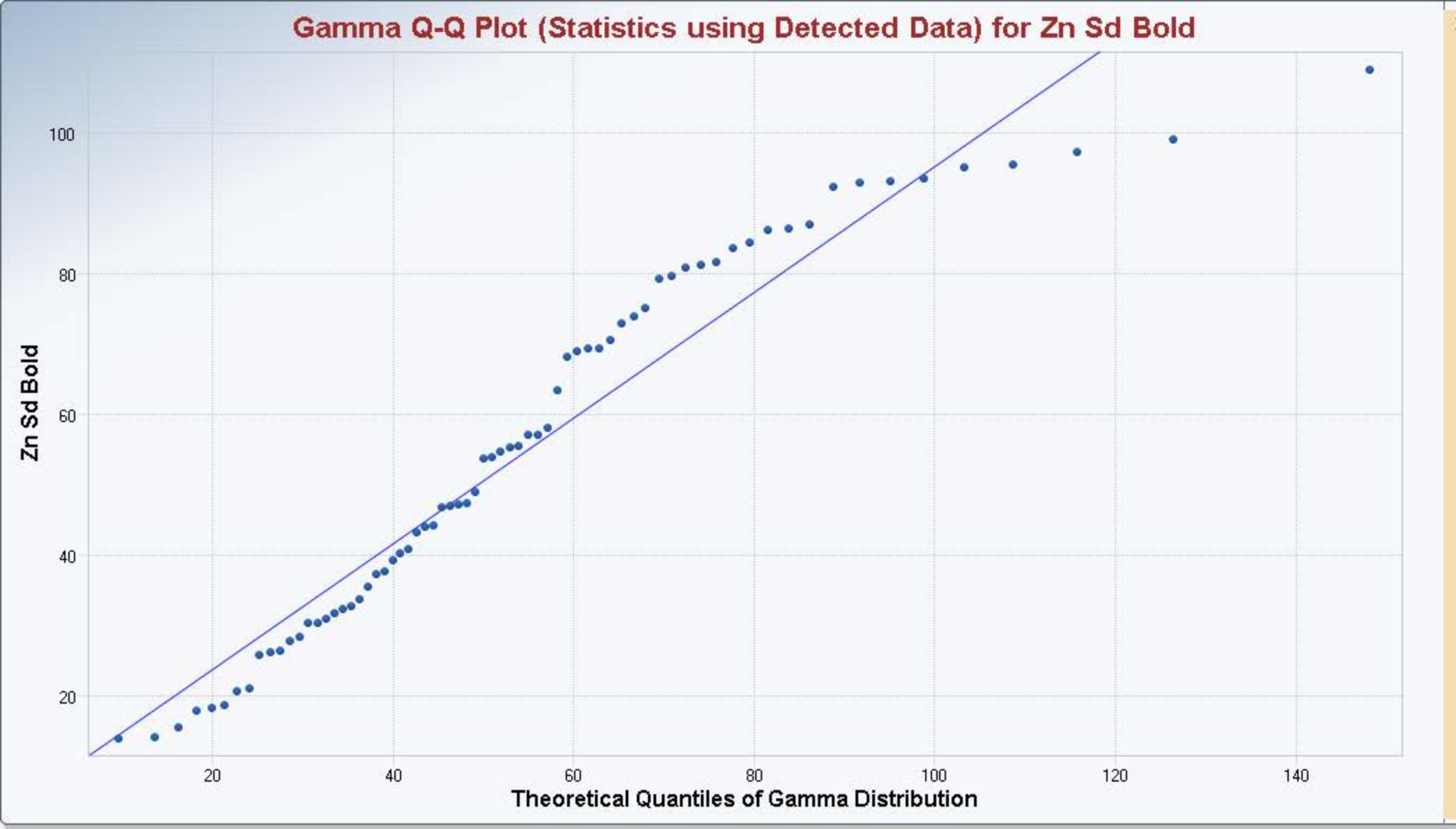

Gamma Q-Q Plot (Statistics using Detected Data) for Hg Sd Bold
Hg Sd Bold
0.260
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.05
0.10
0.15
0.20
0.25
0.30
Theoretical Quantiles of Gamma Distribution
HgSdBold
Total Number of Data = 70
Number of NDs = 29
Max DL = 0.091
N = 41
Percent NDs = 41%
Mean = 0.1242
k hat = 4.6701
theta hat = 0.0266
Slope = 0.9504
Intercept = 0.0064
Correlation, R = 0.9914
Anderson-Darling Test
Test Statistic = 0.254
Critical Value(0.05) = 0.752
Data appear Gamma Distributed
Best Fit Line


Gamma Q-Q Plot (Statistics using Detected Data) for Pb Sd Bold
Pb Sd Bold
Total Number of Data = 70
Number of NDs = 0
Max DL = N/A
N = 70
Percent NDs = 0%
Mean = 9.7500
k hat = 2.5615
theta hat = 3.8064
Slope = 0.9703
Intercept = 0.3111
Correlation, R = 0.9919
Anderson-Darling Test
Test Statistic = 0.257
Critical Value(0.05) = 0.760
Data appear Gamma Distributed
Best Fit Line
Pb Sd Bold
Theoretical Quantiles of Gamma Distribution
28
24
20
16
12
8
4
5
10
15
20
25
30



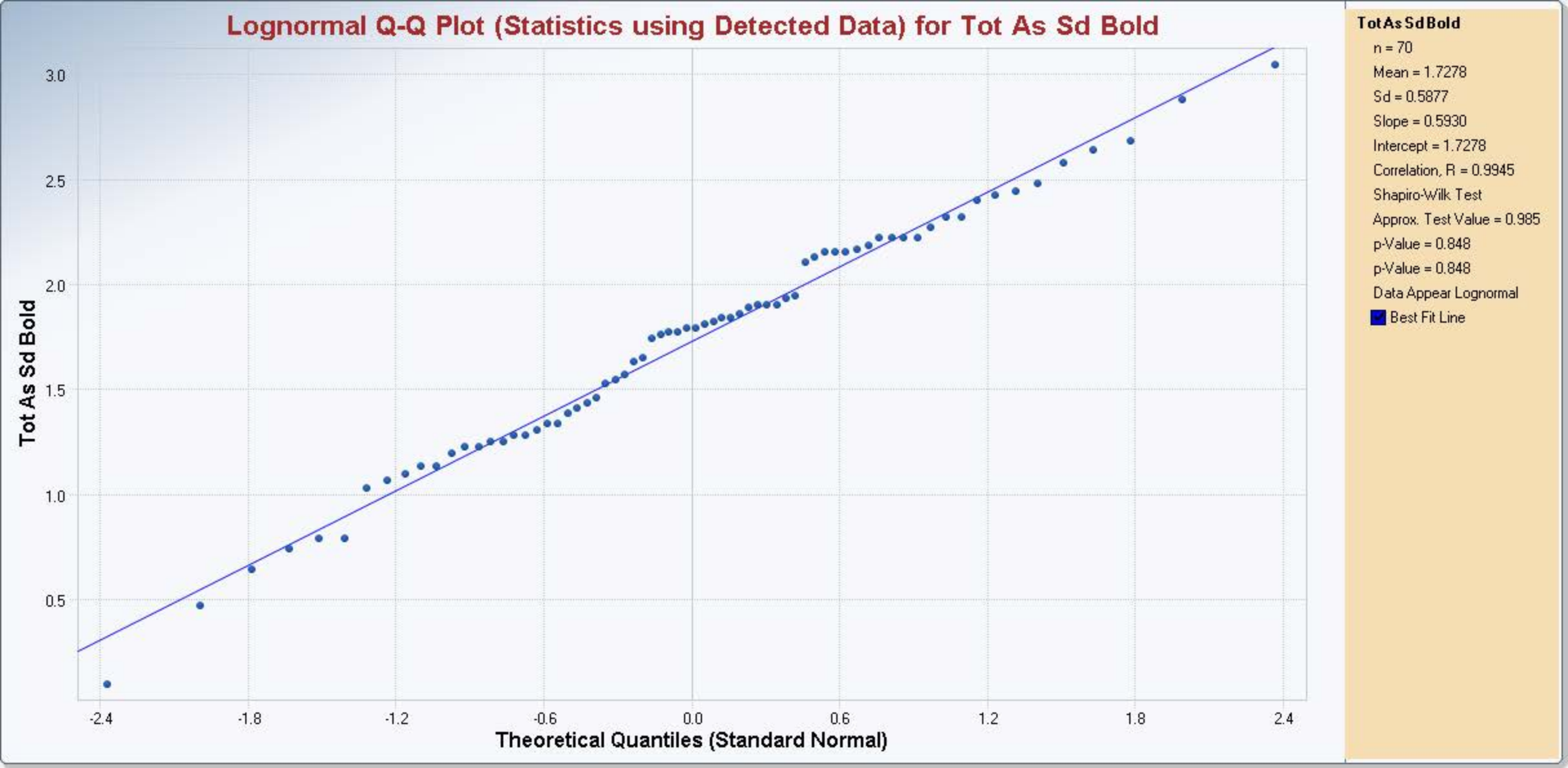
Ni Sd Bold

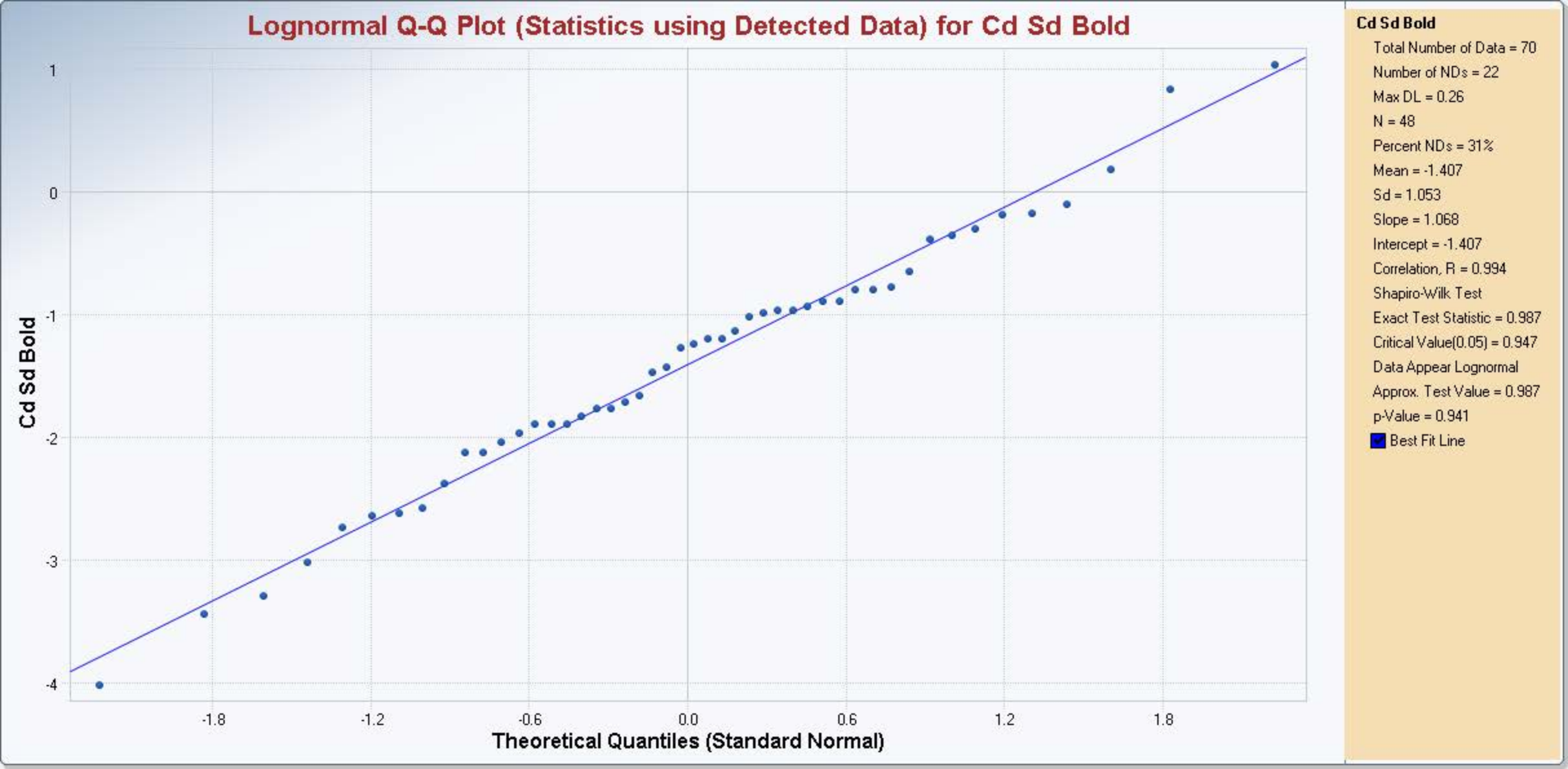
Total Number of Data = 70
Number of NDs = 0
Max DL = N/A
N = 70
Percent NDs = 0%
Mean = 28.8843
k hat = 3.7870
theta hat = 7.6272
Slope = 1.0671
Intercept = -1.8910
Correlation, R = 0.9725
Anderson-Darling Test
Test Statistic = 1.158
Critical Value(0.05) = 0.756
Data not Gamma Distributed
Best Fit Line

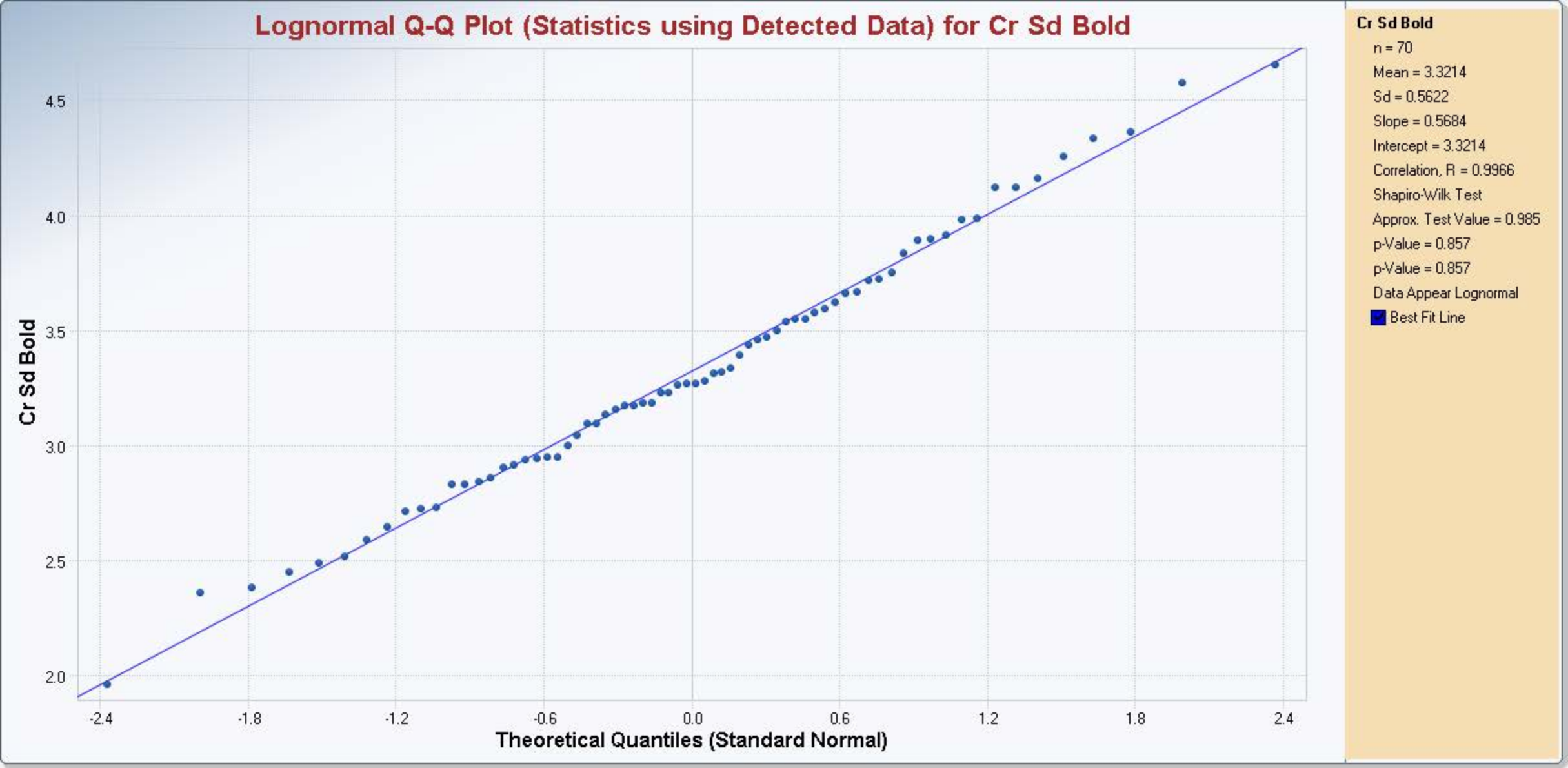


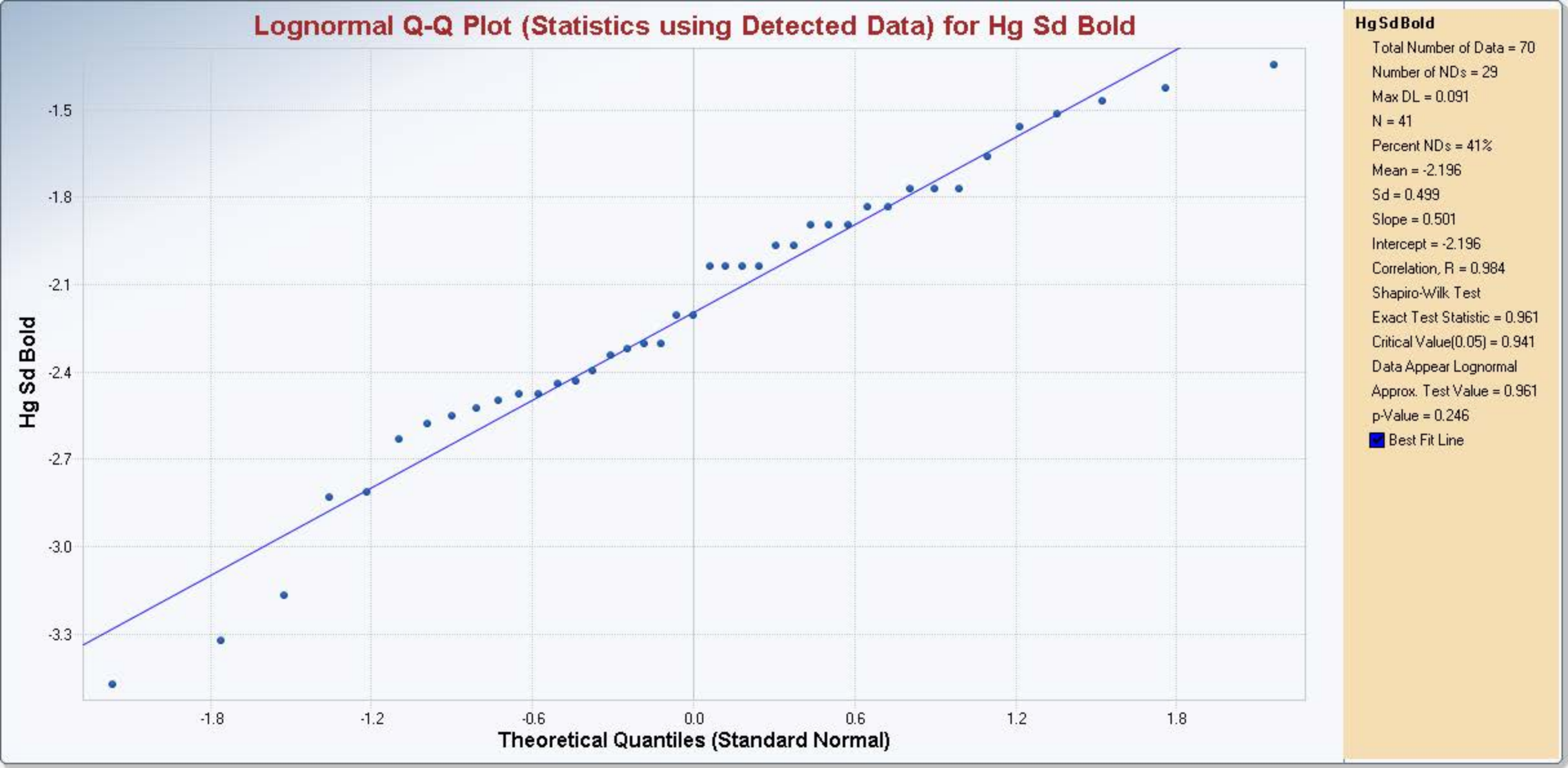
Zn Sd Bold

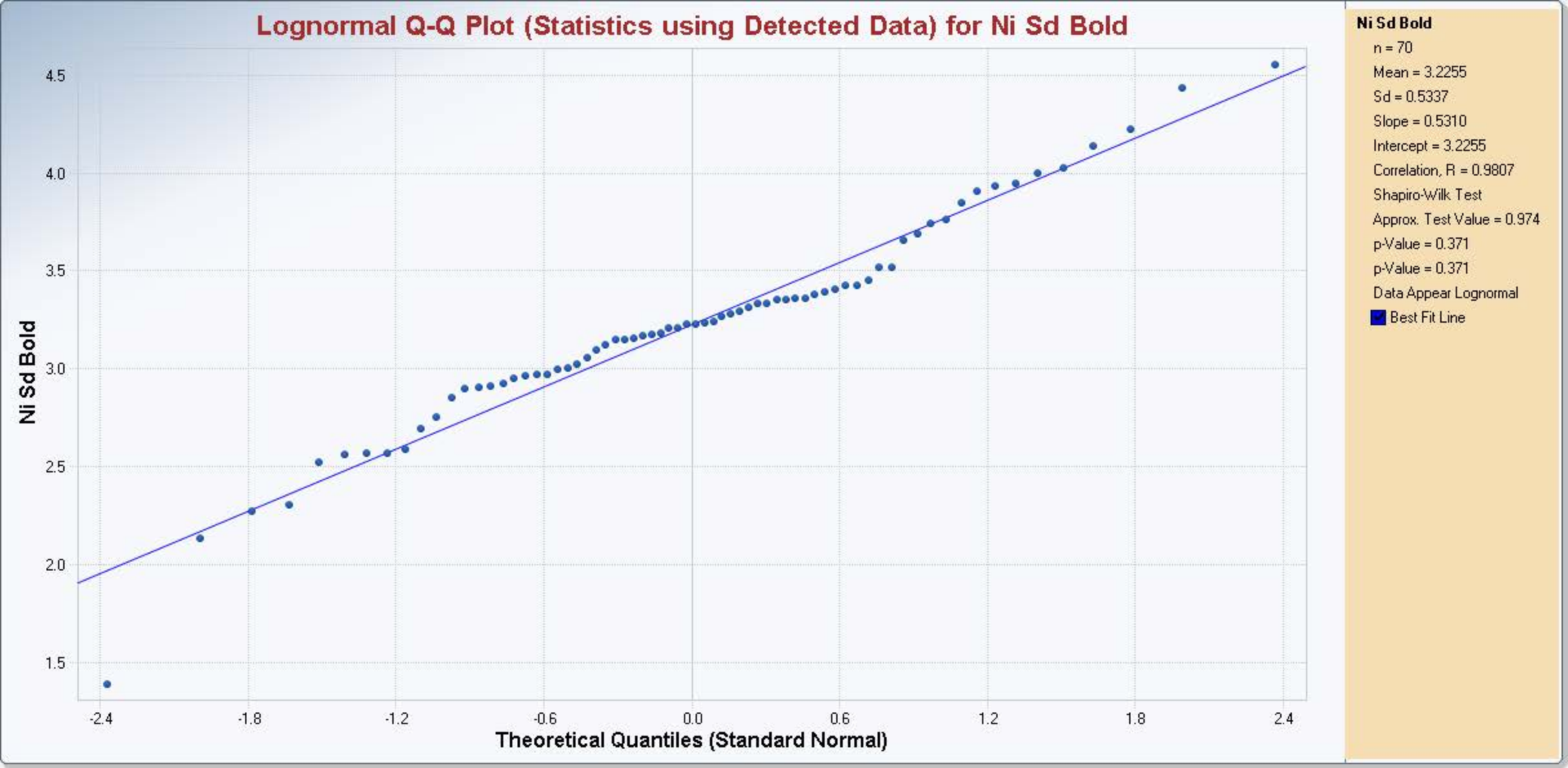
Total Number of Data = 70
Number of NDs = 0
Max DL = N/A
N = 70
Percent NDs = 0%
Mean = 55.3086
k hat = 3.9544
theta hat = 13.9864
Slope = 0.8946
Intercept = 5.9031
Correlation, R = 0.9641
Anderson-Darling Test
Test Statistic = 0.852
Critical Value(0.05) = 0.756
Data not Gamma Distributed
Best Fit Line

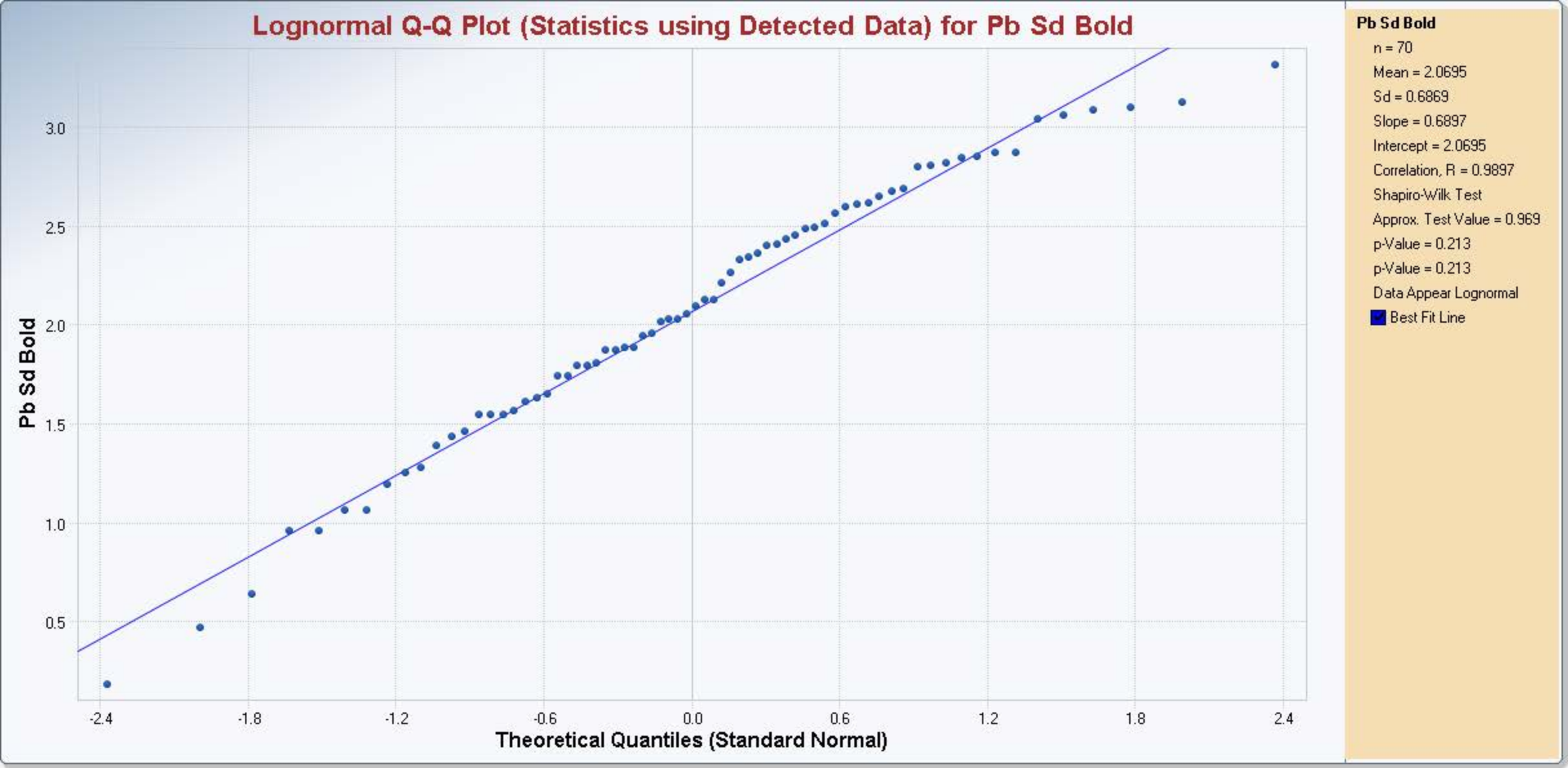

Lognormal Q-Q Plot (Statistics using Detected Data) for Tot As Sd Bold
Tot As Sd Bold
3.0
2.5
2.0
1.5
1.0
0.5
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)
Tot As Sd Bold
n = 70
Mean = 1.7278
Sd = 0.5877
Slope = 0.5930
Intercept = 1.7278
Correlation, R = 0.9945
Shapiro-Wilk Test
Approx. Test Value = 0.985
p-Value = 0.848
p-Value = 0.848
Data Appear Lognormal
Best Fit Line

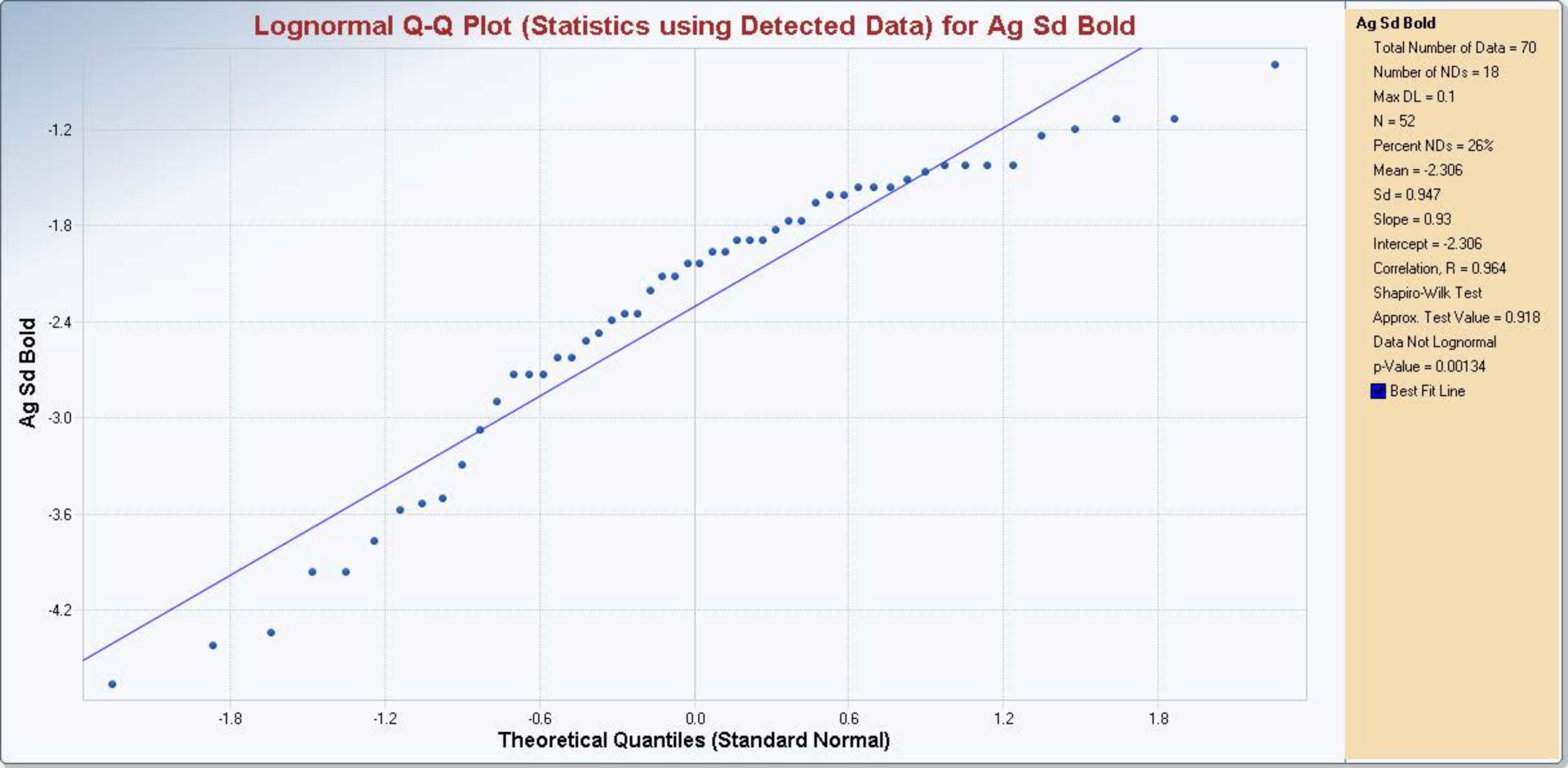

Lognormal Q-Q Plot (Statistics using Detected Data) for Cd Sd Bold
Cd Sd Bold
Total Number of Data = 70
Number of NDs = 22
Max DL = 0.26
N = 48
Percent NDs = 31%
Mean = -1.407
Sd = 1.053
Slope = 1.068
Intercept = -1.407
Correlation, R = 0.994
Shapiro-Wilk Test
Exact Test Statistic = 0.987
Critical Value(0.05) = 0.947
Data Appear Lognormal
Approx. Test Value = 0.987
p-Value = 0.941
Best Fit Line
Cd Sd Bold
1
0
-1
-2
-3
-4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)

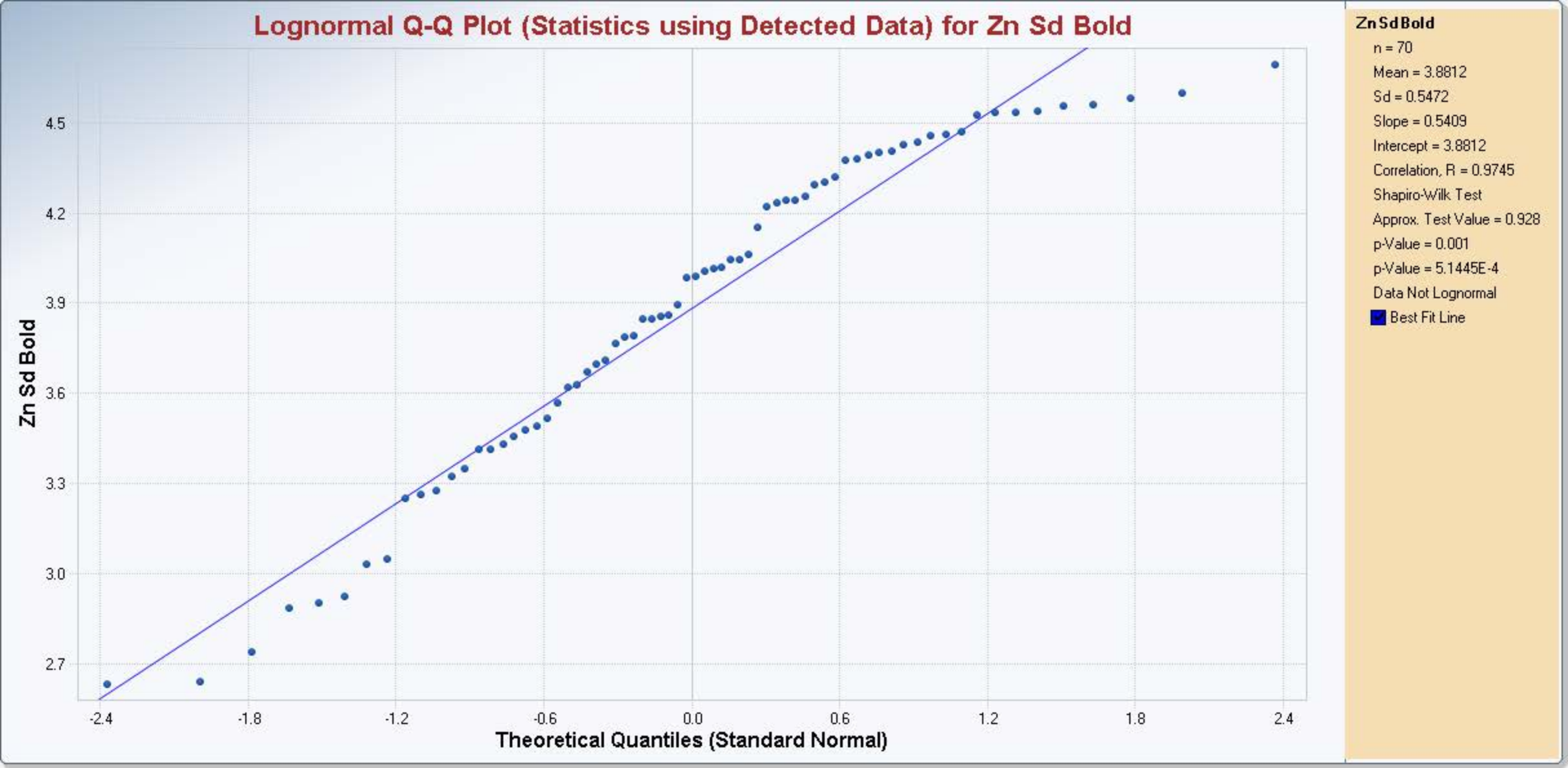

Lognormal Q-Q Plot (Statistics using Detected Data) for Cr Sd Bold
Cr Sd Bold
4.5
4.0
3.5
3.0
2.5
2.0
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)
Cr Sd Bold
n = 70
Mean = 3.3214
Sd = 0.5622
Slope = 0.5684
Intercept = 3.3214
Correlation, R = 0.9966
Shapiro-Wilk Test
Approx. Test Value = 0.985
p-Value = 0.857
p-Value = 0.857
Data Appear Lognormal
Best Fit Line

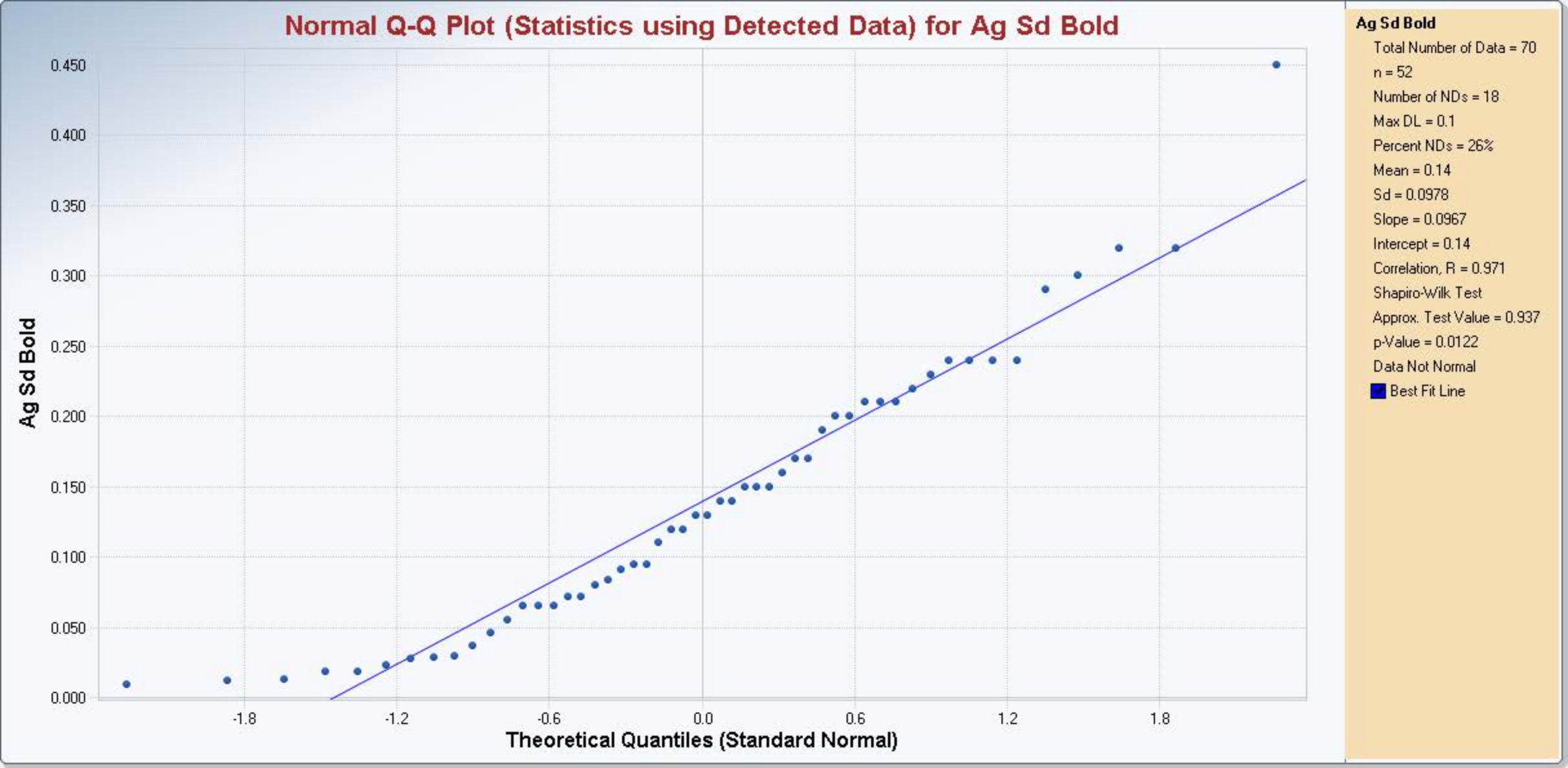

Lognormal Q-Q Plot (Statistics using Detected Data) for Hg Sd Bold
Hg Sd Bold
-1.5
-1.8
-2.1
-2.4
-2.7
-3.0
-3.3
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Hg Sd Bold
Total Number of Data = 70
Number of NDs = 29
Max DL = 0.091
N = 41
Percent NDs = 41%
Mean = -2.196
Sd = 0.499
Slope = 0.501
Intercept = -2.196
Correlation, R = 0.984
Shapiro-Wilk Test
Exact Test Statistic = 0.961
Critical Value(0.05) = 0.941
Data Appear Lognormal
Approx. Test Value = 0.961
p-Value = 0.246
Best Fit Line

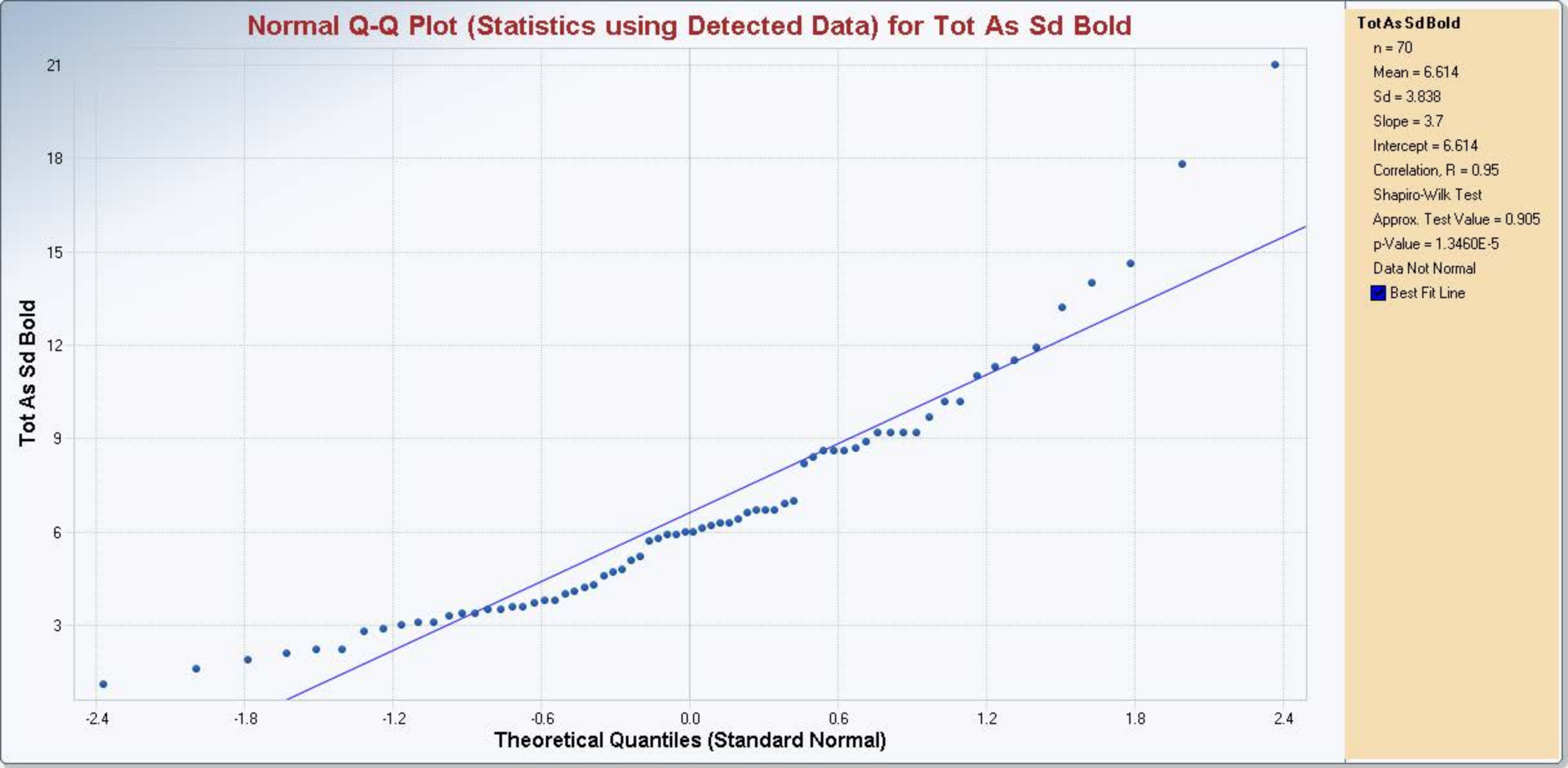

Lognormal Q-Q Plot (Statistics using Detected Data) for Ni Sd Bold
Ni Sd Bold
4.5
4.0
3.5
3.0
2.5
2.0
1.5
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)
Ni Sd Bold
n = 70
Mean = 3.2255
Sd = 0.5337
Slope = 0.5310
Intercept = 3.2255
Correlation, R = 0.9807
Shapiro-Wilk Test
Approx. Test Value = 0.974
p-Value = 0.371
p-Value = 0.371
Data Appear Lognormal
Best Fit Line

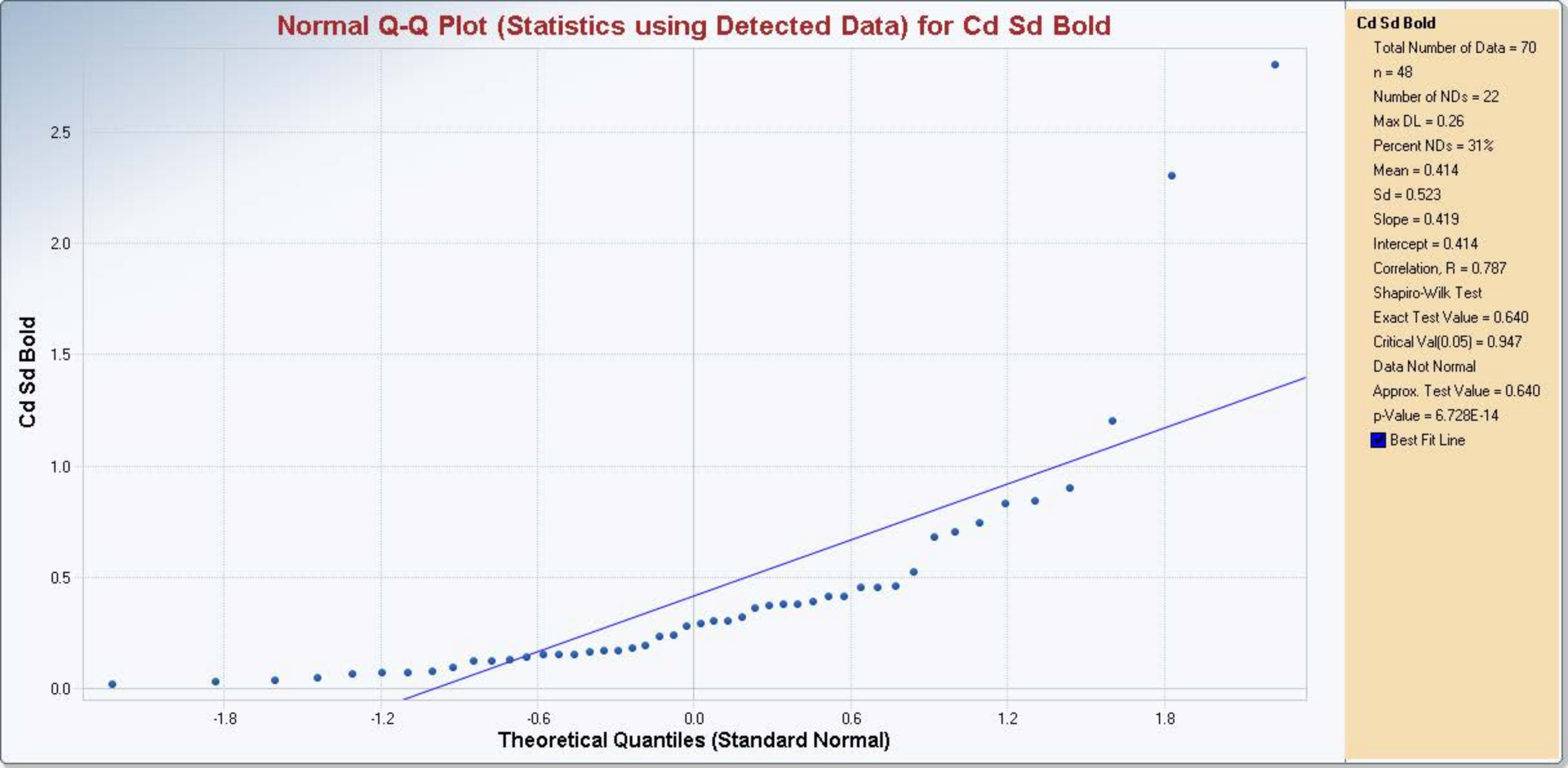

Lognormal Q-Q Plot (Statistics using Detected Data) for Pb Sd Bold
Pb Sd Bold
n = 70
Mean = 2.0695
Sd = 0.6869
Slope = 0.6897
Intercept = 2.0695
Correlation, R = 0.9897
Shapiro-Wilk Test
Approx. Test Value = 0.969
p-Value = 0.213
p-Value = 0.213
Data Appear Lognormal
Best Fit Line
Pb Sd Bold
3.0
2.5
2.0
1.5
1.0
0.5
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

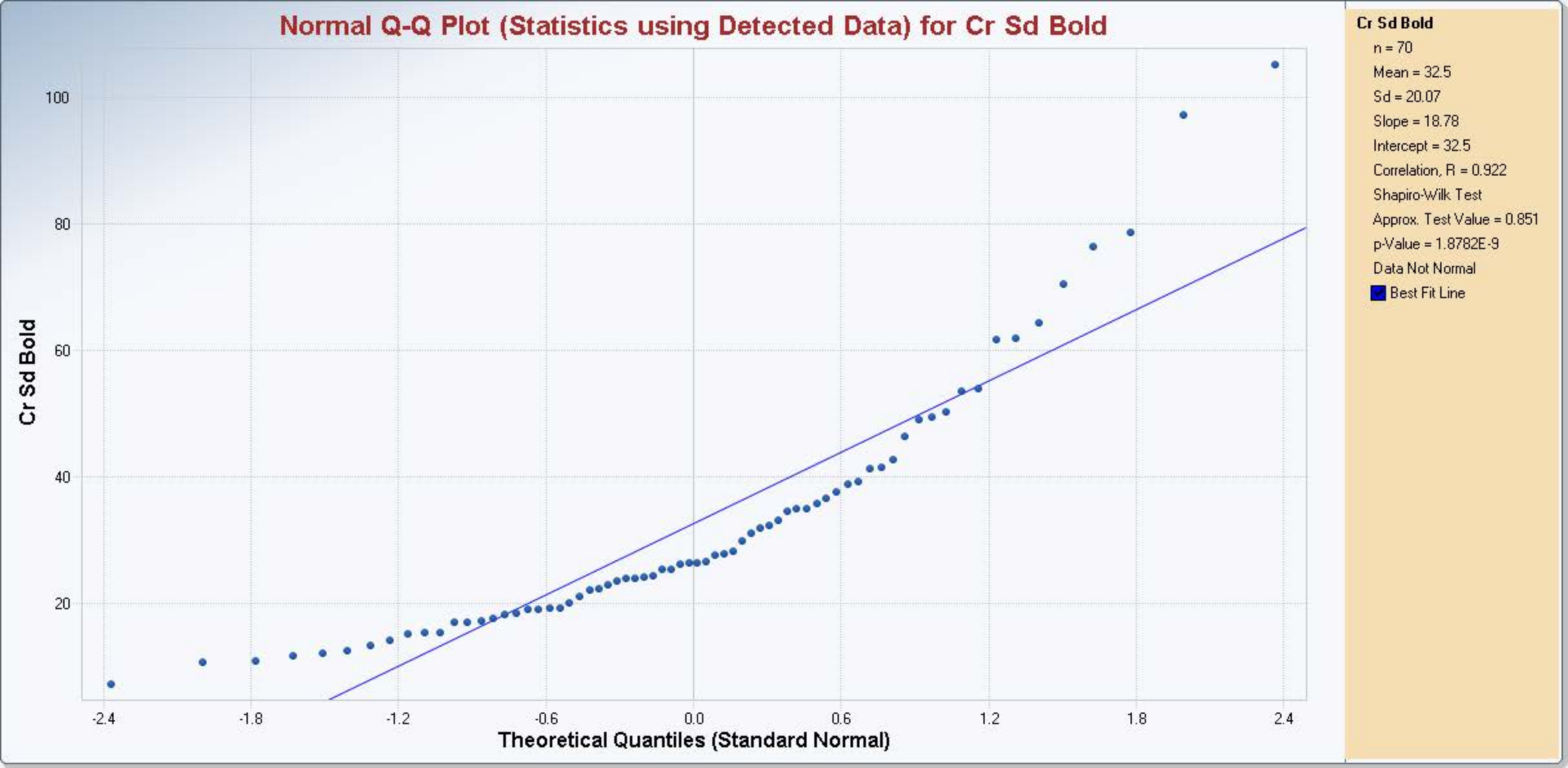

Lognormal Q-Q Plot (Statistics using Detected Data) for Ag Sd Bold
Ag Sd Bold
-1.2
-1.8
-2.4
-3.0
-3.6
-4.2
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Ag Sd Bold
Total Number of Data = 70
Number of NDs = 18
Max DL = 0.1
N = 52
Percent NDs = 26%
Mean = -2.306
Sd = 0.947
Slope = 0.93
Intercept = -2.306
Correlation, R = 0.964
Shapiro-Wilk Test
Approx. Test Value = 0.918
Data Not Lognormal
p-Value = 0.00134
Best Fit Line

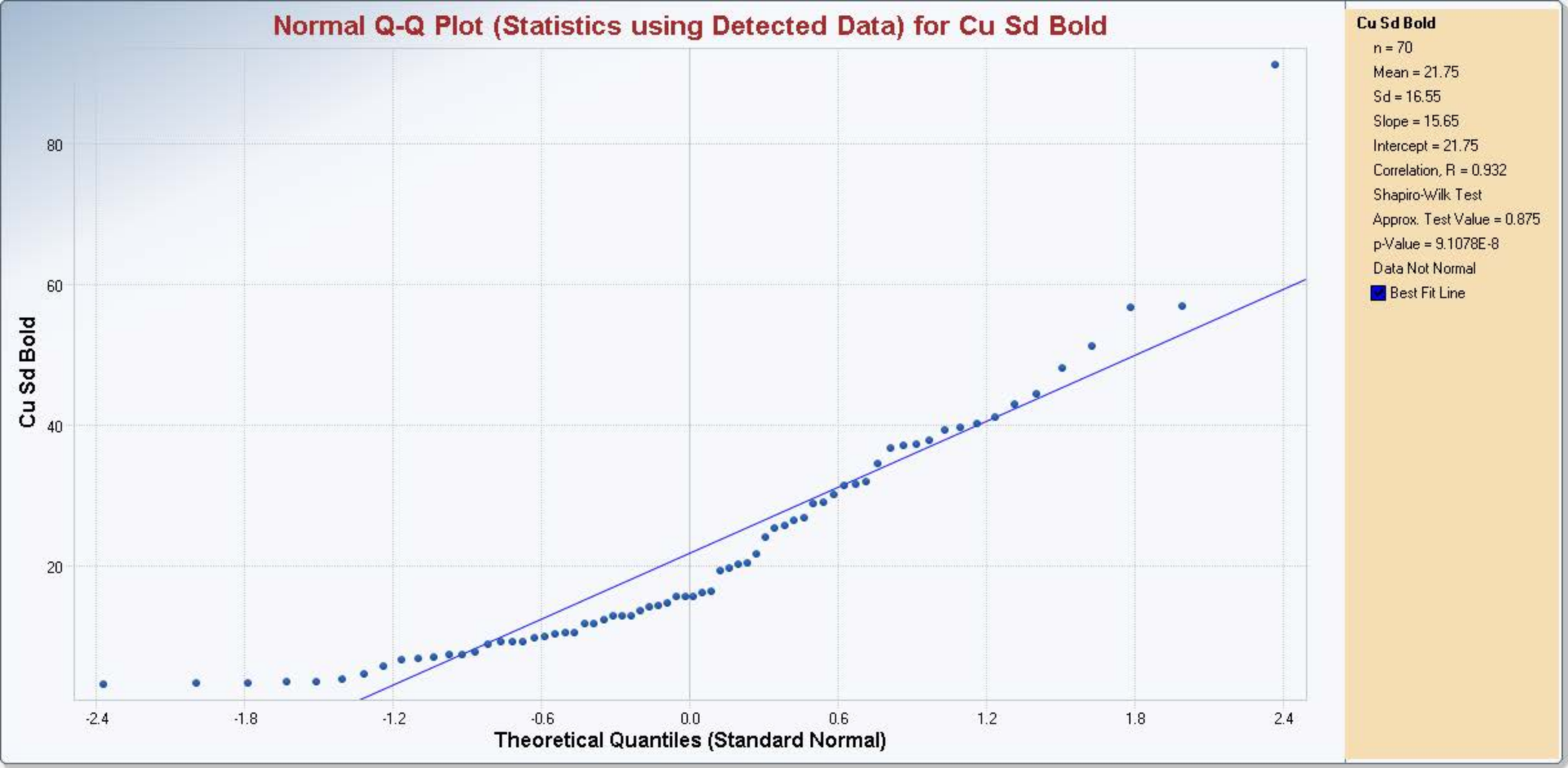

Lognormal Q-Q Plot (Statistics using Detected Data) for Zn Sd Bold
Zn Sd Bold
4.5
4.2
3.9
3.6
3.3
3.0
2.7
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)
Zn Sd Bold
n = 70
Mean = 3.8812
Sd = 0.5472
Slope = 0.5409
Intercept = 3.8812
Correlation, R = 0.9745
Shapiro-Wilk Test
Approx. Test Value = 0.928
p-Value = 0.001
p-Value = 5.1445E-4
Data Not Lognormal
Best Fit Line

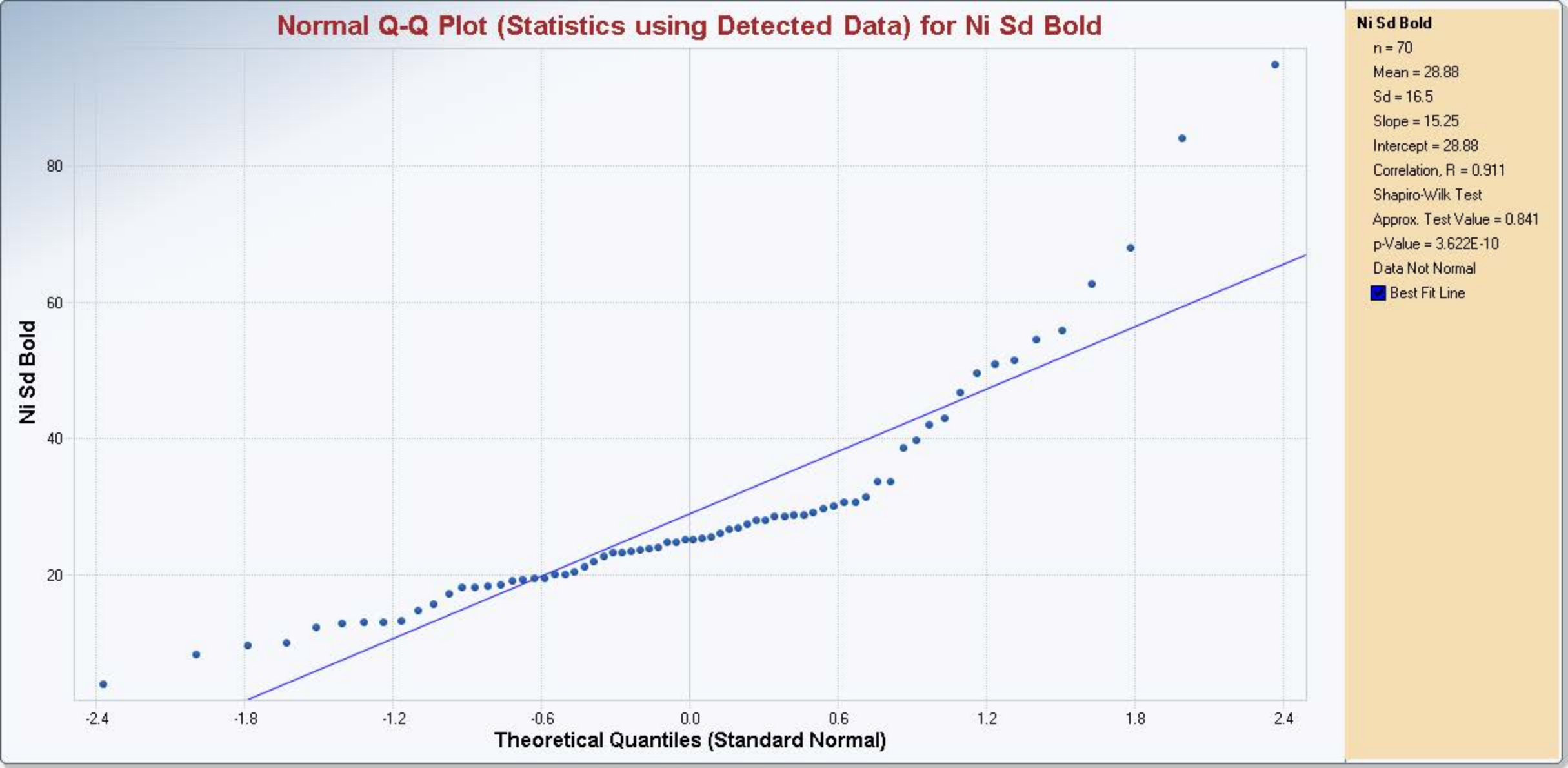

Normal Q-Q Plot (Statistics using Detected Data) for Ag Sd Bold
Ag Sd Bold
Total Number of Data = 70
n = 52
Number of NDs = 18
Max DL = 0.1
Percent NDs = 26%
Mean = 0.14
Sd = 0.0978
Slope = 0.0967
Intercept = 0.14
Correlation, R = 0.971
Shapiro-Wilk Test
Approx. Test Value = 0.937
p-Value = 0.0122
Data Not Normal
Best Fit Line
Ag Sd Bold
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)

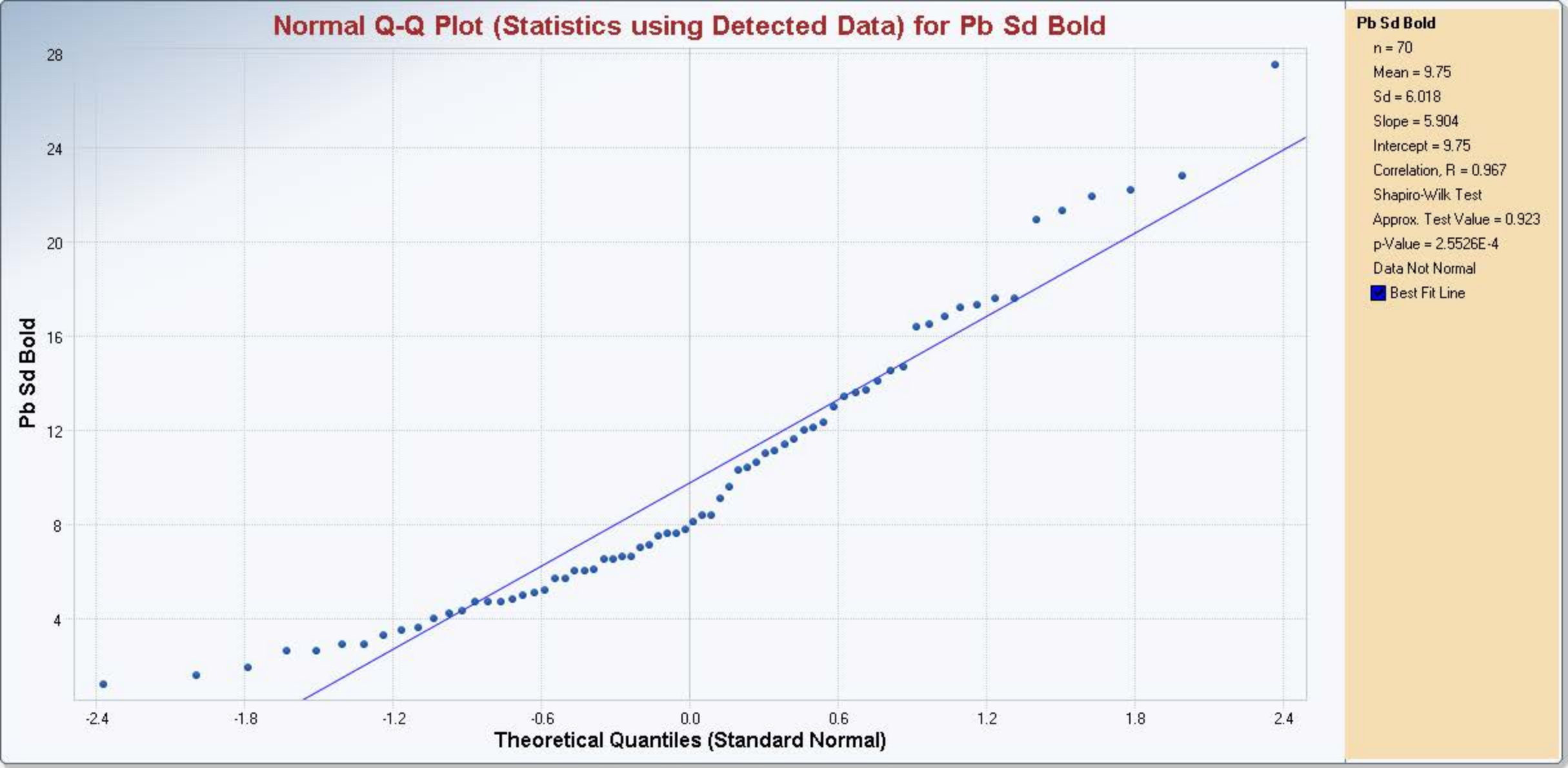

Normal Q-Q Plot (Statistics using Detected Data) for Tot As Sd Bold
Tot As Sd Bold
n = 70
Mean = 6.614
Sd = 3.838
Slope = 3.7
Intercept = 6.614
Correlation, R = 0.95
Shapiro-Wilk Test
Approx. Test Value = 0.905
p-Value = 1.3460E-5
Data Not Normal
Best Fit Line
Tot As Sd Bold
21
18
15
12
9
6
3
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

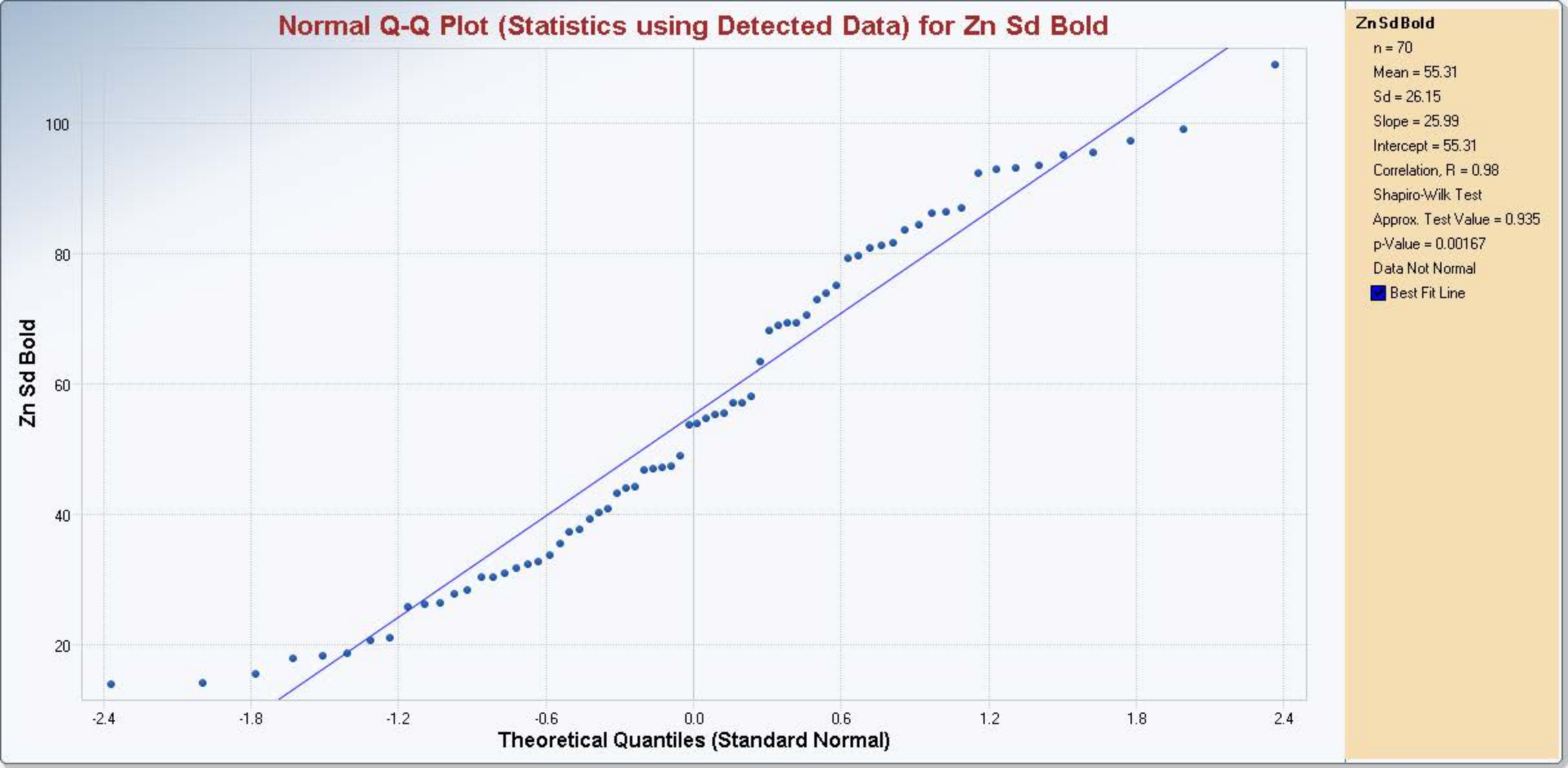

Normal Q-Q Plot (Statistics using Detected Data) for Cd Sd Bold
Cd Sd Bold
Total Number of Data = 70
n = 48
Number of NDs = 22
Max DL = 0.26
Percent NDs = 31%
Mean = 0.414
Sd = 0.523
Slope = 0.419
Intercept = 0.414
Correlation, R = 0.787
Shapiro-Wilk Test
Exact Test Value = 0.640
Critical Val(0.05) = 0.947
Data Not Normal
Approx. Test Value = 0.640
p-Value = 6.728E-14
Best Fit Line
Cd Sd Bold
2.5
2.0
1.5
1.0
0.5
0.0
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)

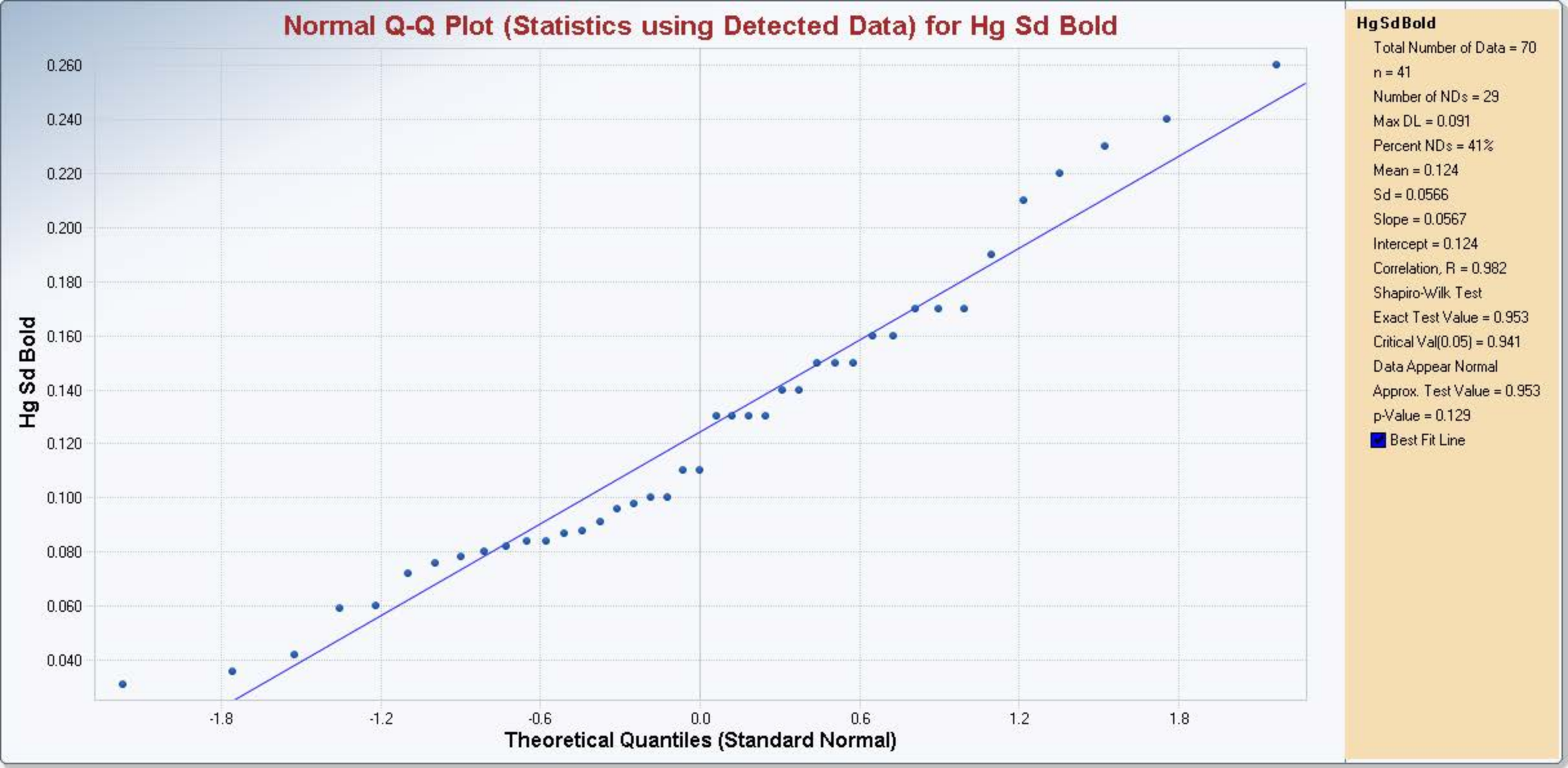

Normal Q-Q Plot (Statistics using Detected Data) for Cr Sd Bold
Cr Sd Bold
n = 70
Mean = 32.5
Sd = 20.07
Slope = 18.78
Intercept = 32.5
Correlation, R = 0.922
Shapiro-Wilk Test
Approx. Test Value = 0.851
p-Value = 1.8782E-9
Data Not Normal
Best Fit Line
Cr Sd Bold
100
80
60
40
20
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

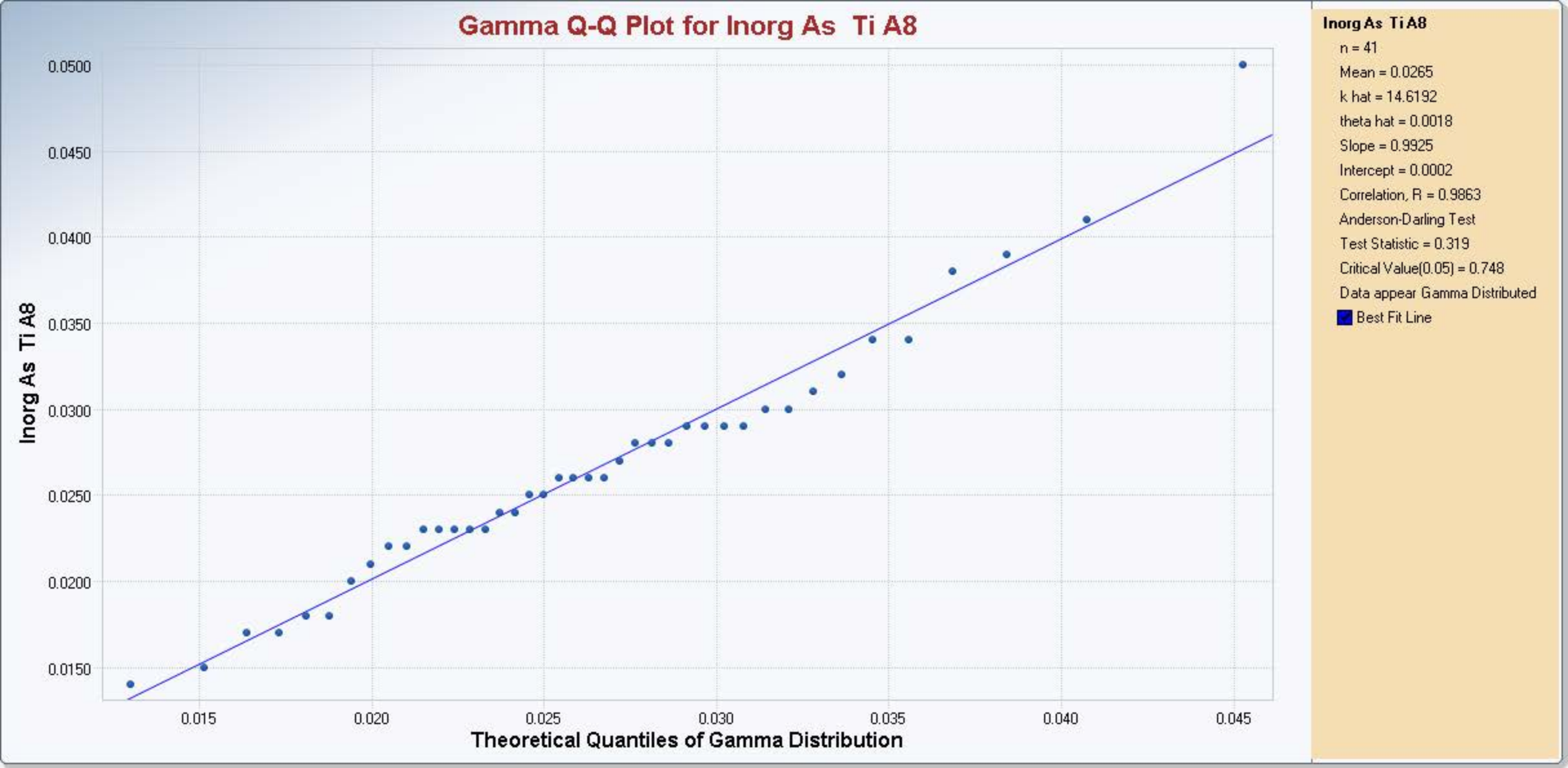

Normal Q-Q Plot (Statistics using Detected Data) for Cu Sd Bold
Cu Sd Bold
n = 70
Mean = 21.75
Sd = 16.55
Slope = 15.65
Intercept = 21.75
Correlation, R = 0.932
Shapiro-Wilk Test
Approx. Test Value = 0.875
p-Value = 9.1078E-8
Data Not Normal
Best Fit Line
Cu Sd Bold
80
60
40
20
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

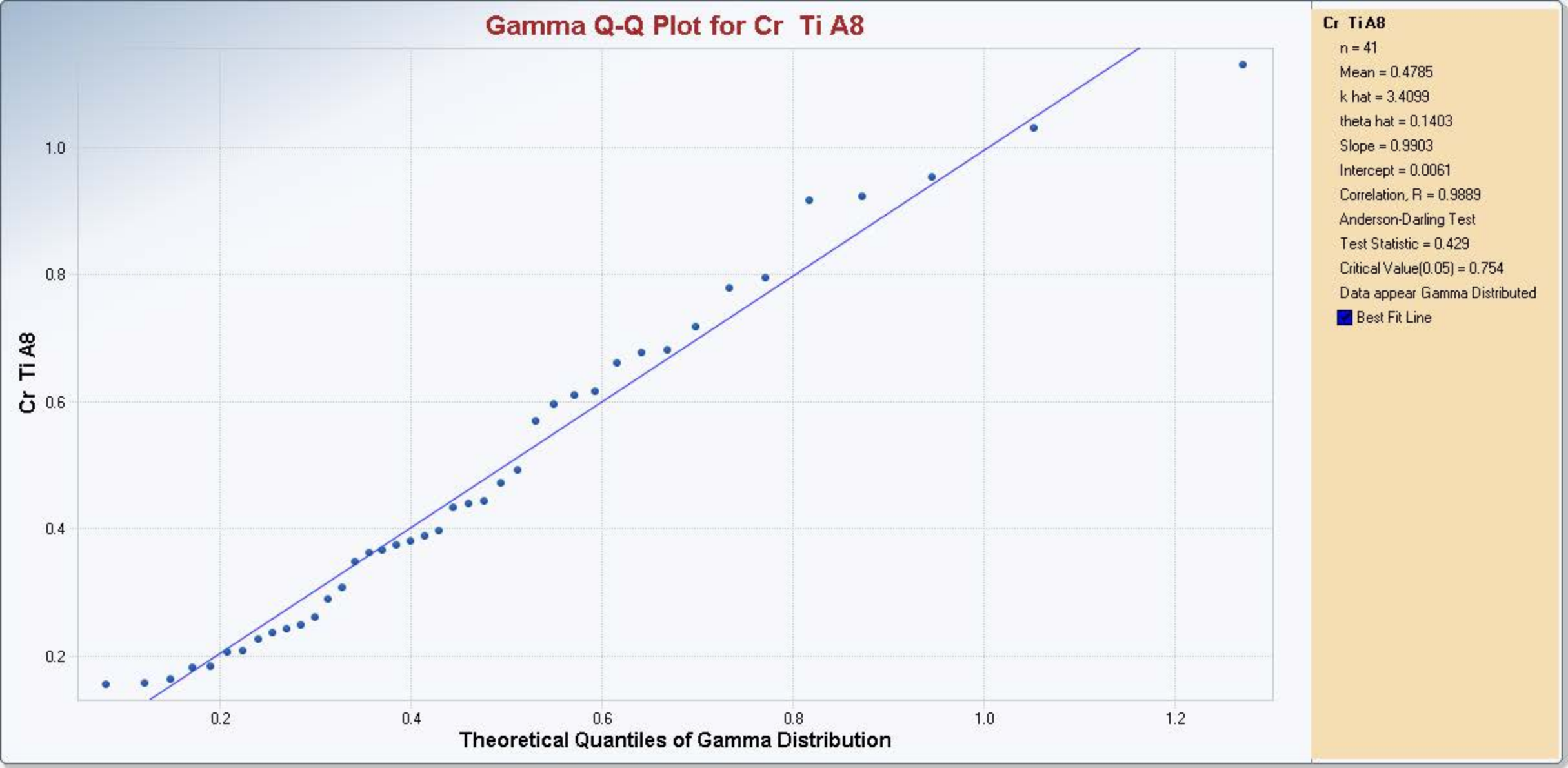

Normal Q-Q Plot (Statistics using Detected Data) for Ni Sd Bold
Ni Sd Bold
n = 70
Mean = 28.88
Sd = 16.5
Slope = 15.25
Intercept = 28.88
Correlation, R = 0.911
Shapiro-Wilk Test
Approx. Test Value = 0.841
p-Value = 3.622E-10
Data Not Normal
Best Fit Line
Ni Sd Bold
80
60
40
20
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

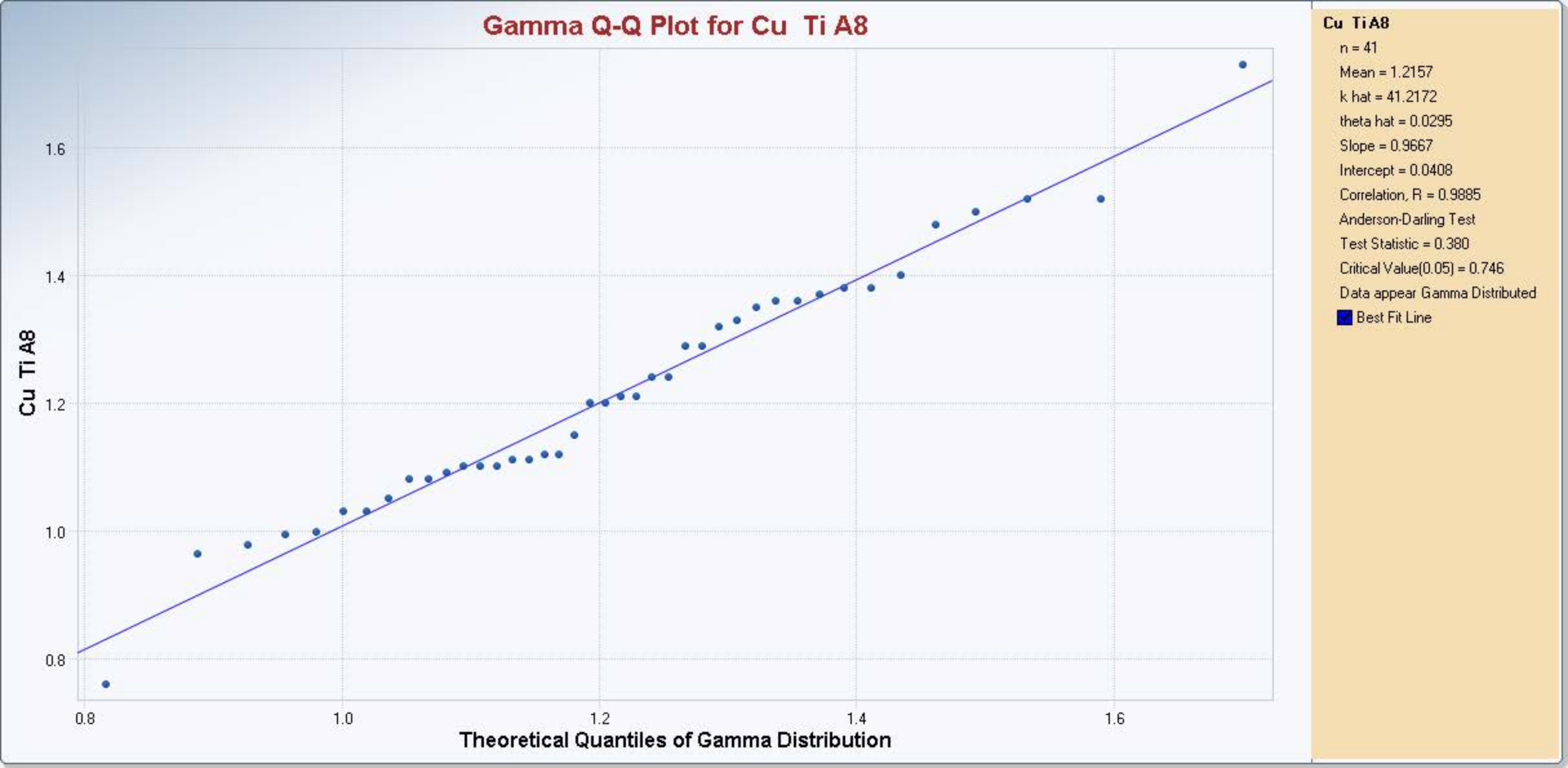

Normal Q-Q Plot (Statistics using Detected Data) for Pb Sd Bold
Pb Sd Bold
n = 70
Mean = 9.75
Sd = 6.018
Slope = 5.904
Intercept = 9.75
Correlation, R = 0.967
Shapiro-Wilk Test
Approx. Test Value = 0.923
p-Value = 2.5526E-4
Data Not Normal
Best Fit Line
Pb Sd Bold
28
24
20
16
12
8
4
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)

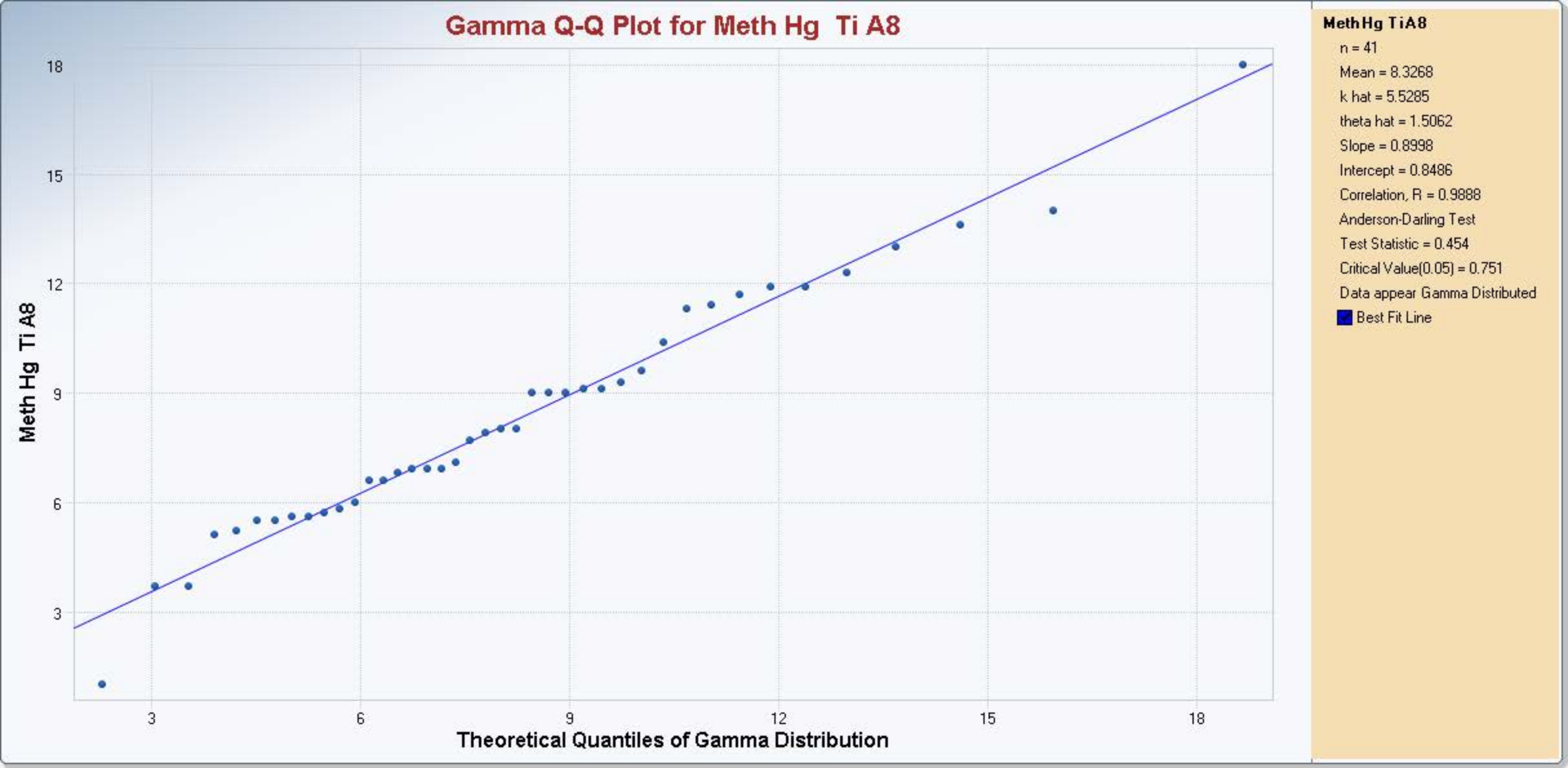

Normal Q-Q Plot (Statistics using Detected Data) for Zn Sd Bold
Zn Sd Bold
100
80
60
40
20
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)
Zn Sd Bold
n = 70
Mean = 55.31
Sd = 26.15
Slope = 25.99
Intercept = 55.31
Correlation, R = 0.98
Shapiro-Wilk Test
Approx. Test Value = 0.935
p-Value = 0.00167
Data Not Normal
Best Fit Line

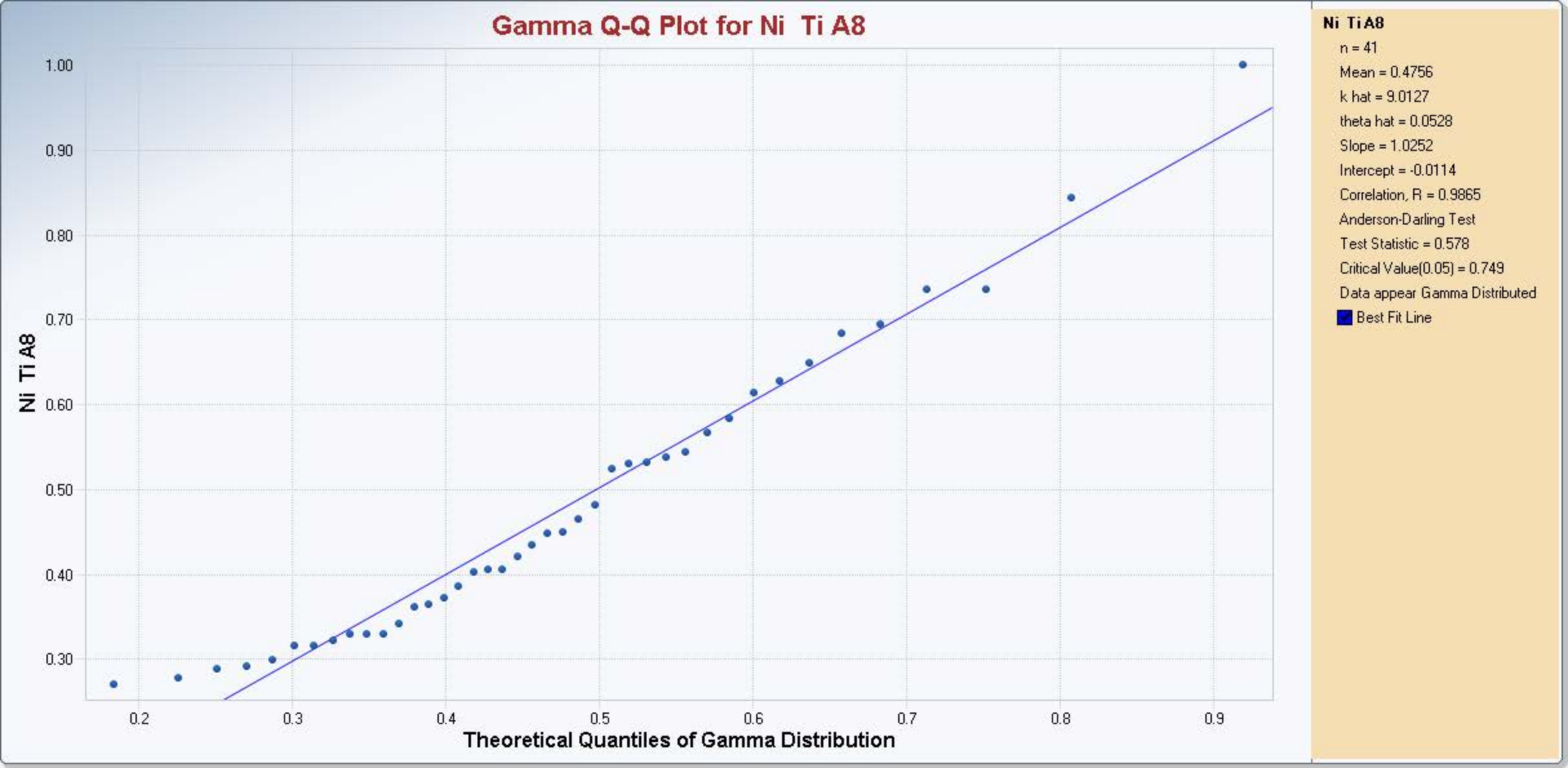

Normal Q-Q Plot (Statistics using Detected Data) for Hg Sd Bold
Hg Sd Bold
0.260
0.240
0.220
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Hg Sd Bold
Total Number of Data = 70
n = 41
Number of NDs = 29
Max DL = 0.091
Percent NDs = 41%
Mean = 0.124
Sd = 0.0566
Slope = 0.0567
Intercept = 0.124
Correlation, R = 0.982
Shapiro-Wilk Test
Exact Test Value = 0.953
Critical Val(0.05) = 0.941
Data Appear Normal
Approx. Test Value = 0.953
p-Value = 0.129
Best Fit Line

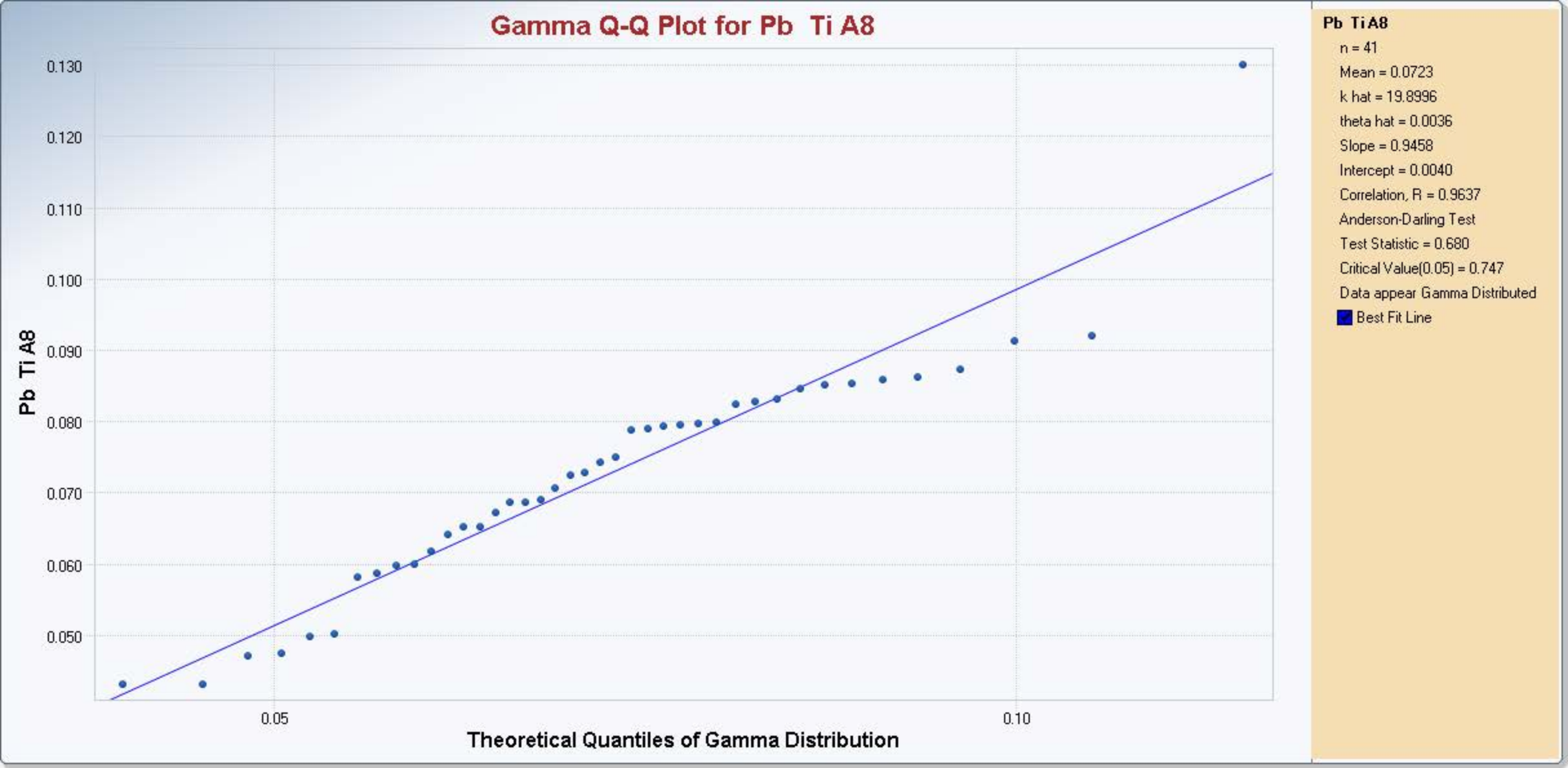

Gamma Q-Q Plot for Inorg As Ti A8
Inorg As Ti A8
n = 41
Mean = 0.0265
k hat = 14.6192
theta hat = 0.0018
Slope = 0.9925
Intercept = 0.0002
Correlation, R = 0.9863
Anderson-Darling Test
Test Statistic = 0.319
Critical Value(0.05) = 0.748
Data appear Gamma Distributed
Best Fit Line
Inorg As Ti A8
0.0500
0.0450
0.0400
0.0350
0.0300
0.0250
0.0200
0.0150
0.015
0.020
0.025
0.030
0.035
0.040
0.045
Theoretical Quantiles of Gamma Distribution

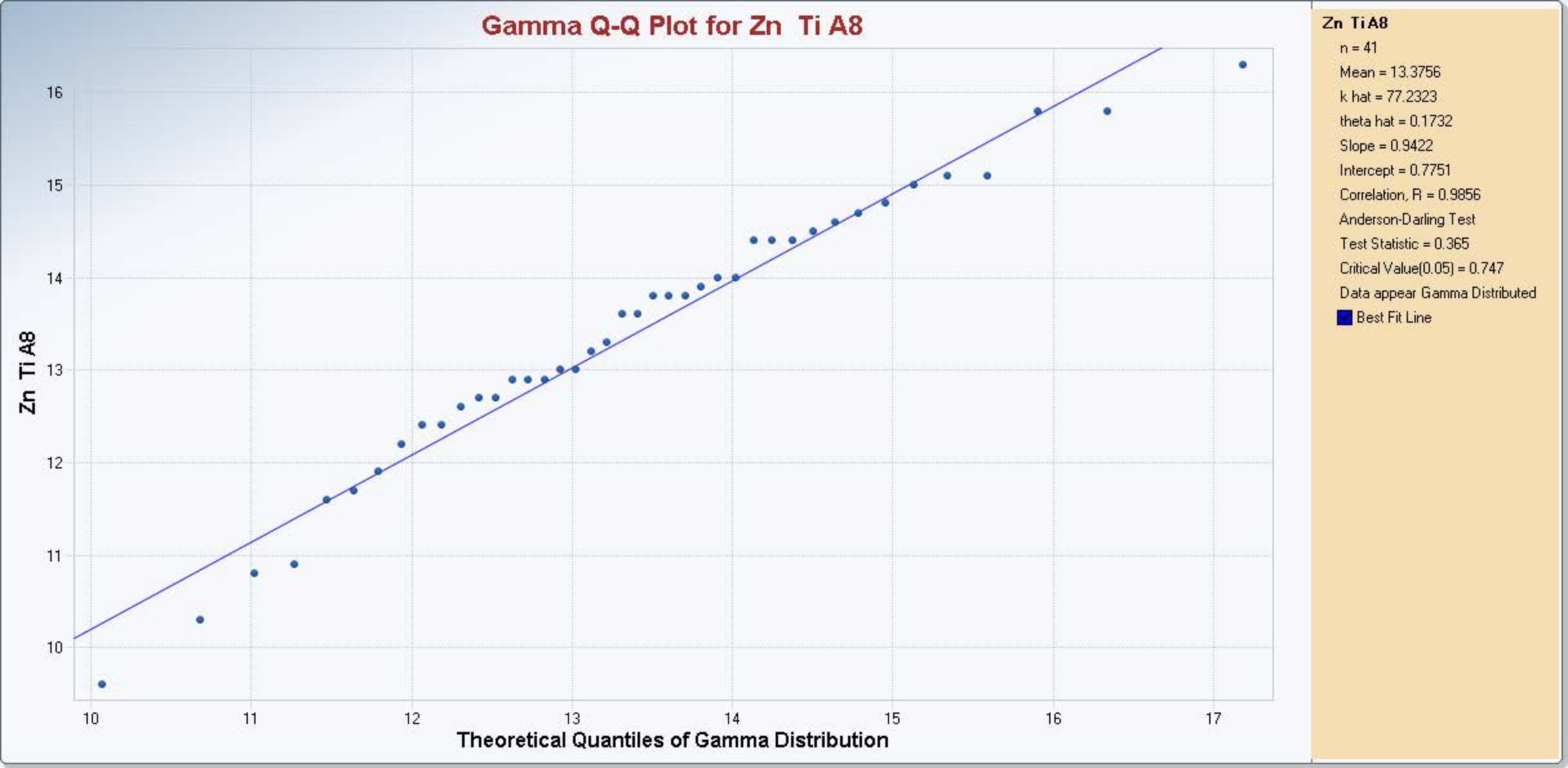

Gamma Q-Q Plot for Cr Ti A8
Cr Ti A8
1.0
0.8
0.6
0.4
0.2
0.2
0.4
0.6
0.8
1.0
1.2
Theoretical Quantiles of Gamma Distribution
Cr Ti A8
n = 41
Mean = 0.4785
k hat = 3.4099
theta hat = 0.1403
Slope = 0.9903
Intercept = 0.0061
Correlation, R = 0.9889
Anderson-Darling Test
Test Statistic = 0.429
Critical Value(0.05) = 0.754
Data appear Gamma Distributed
Best Fit Line

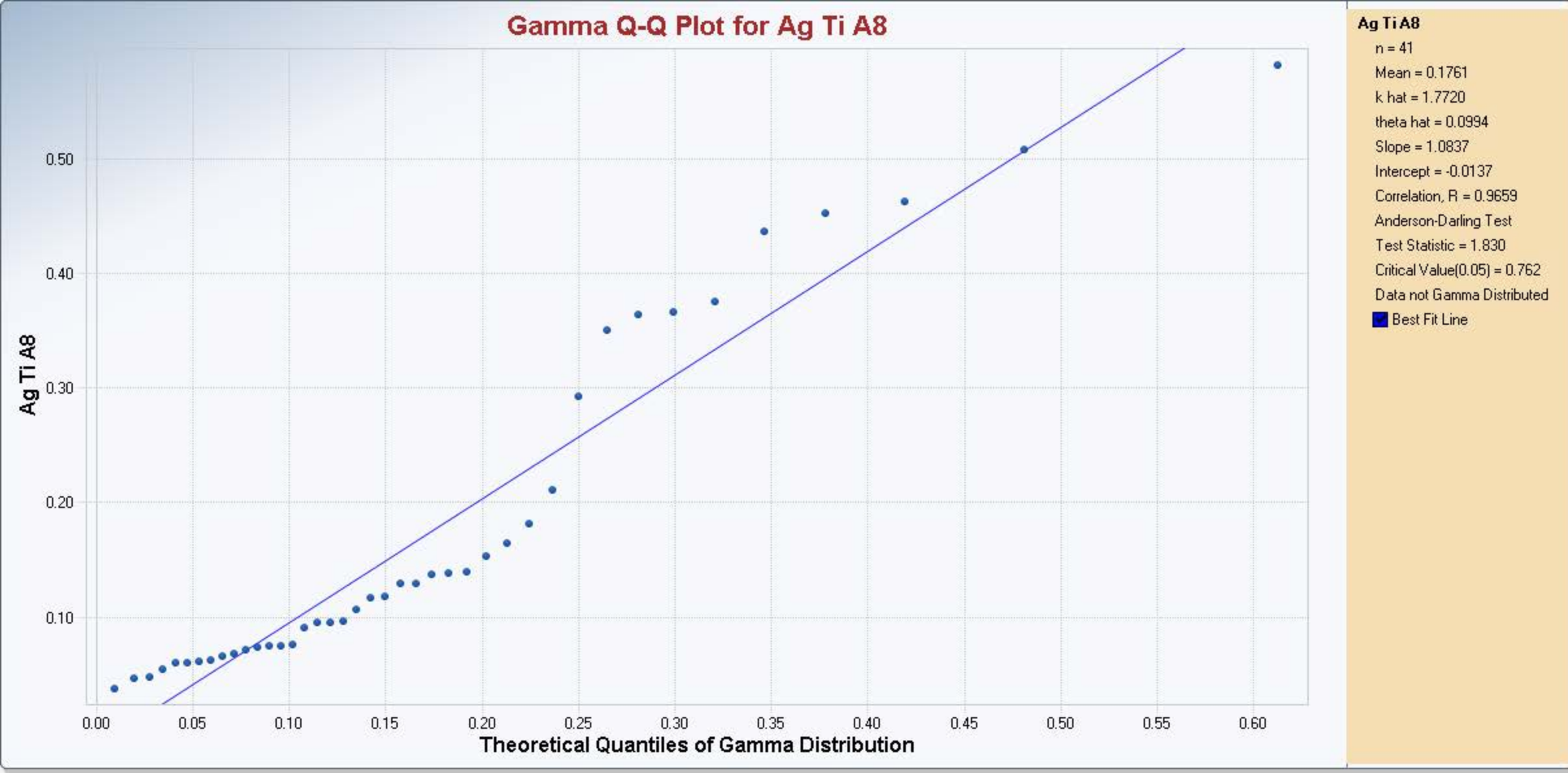

Gamma Q-Q Plot for Cu Ti A8
Cu Ti A8
n = 41
Mean = 1.2157
k hat = 41.2172
theta hat = 0.0295
Slope = 0.9667
Intercept = 0.0408
Correlation, R = 0.9885
Anderson-Darling Test
Test Statistic = 0.380
Critical Value(0.05) = 0.746
Data appear Gamma Distributed
Best Fit Line
Cu Ti A8
0.8
1.0
1.2
1.4
1.6
Theoretical Quantiles of Gamma Distribution

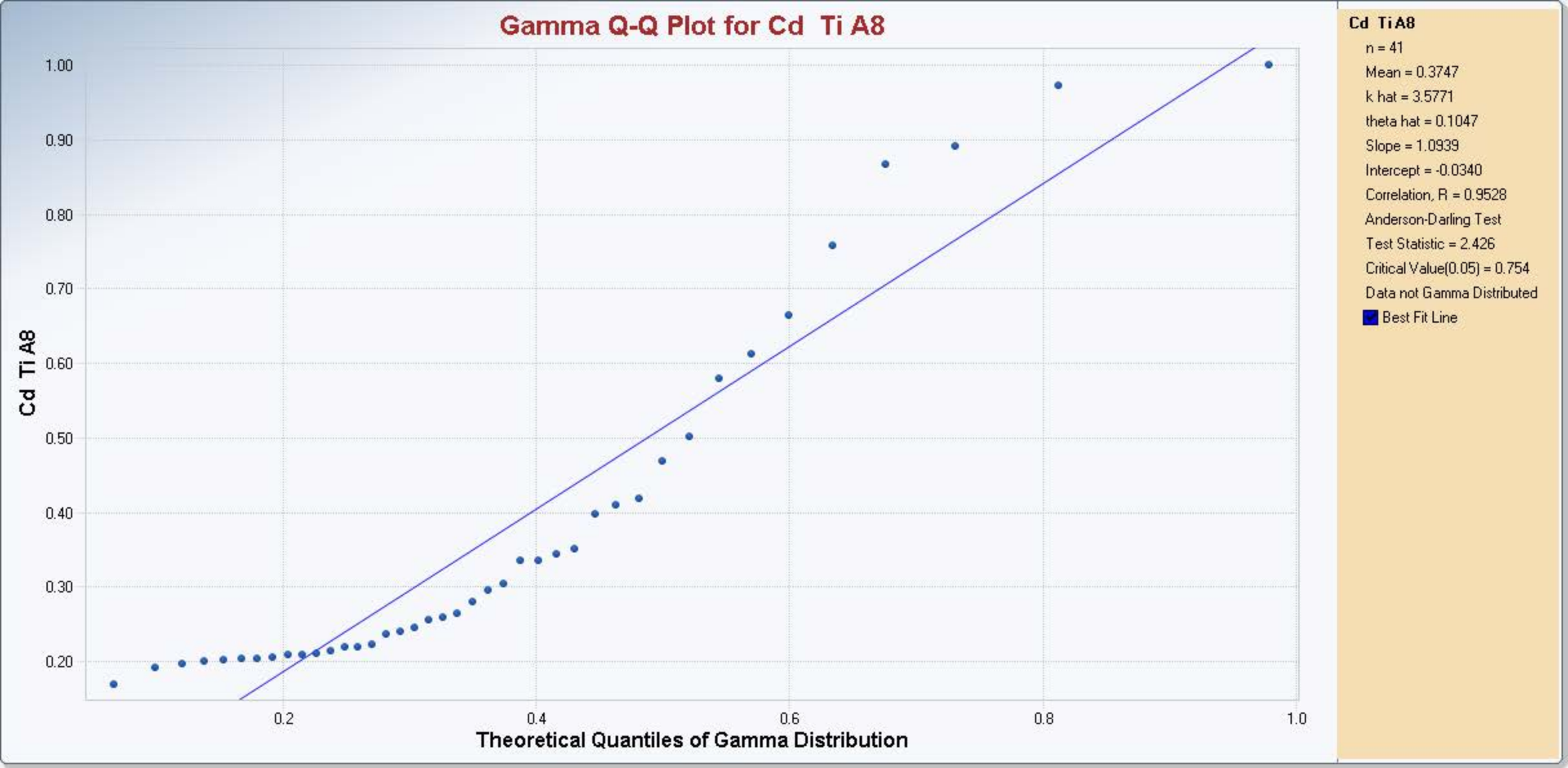

Gamma Q-Q Plot for Meth Hg Ti A8
Meth Hg Ti A8
Theoretical Quantiles of Gamma Distribution
3
6
9
12
15
18
Meth Hg Ti A8
n = 41
Mean = 8.3268
k hat = 5.5285
theta hat = 1.5062
Slope = 0.8998
Intercept = 0.8486
Correlation, R = 0.9888
Anderson-Darling Test
Test Statistic = 0.454
Critical Value(0.05) = 0.751
Data appear Gamma Distributed
Best Fit Line

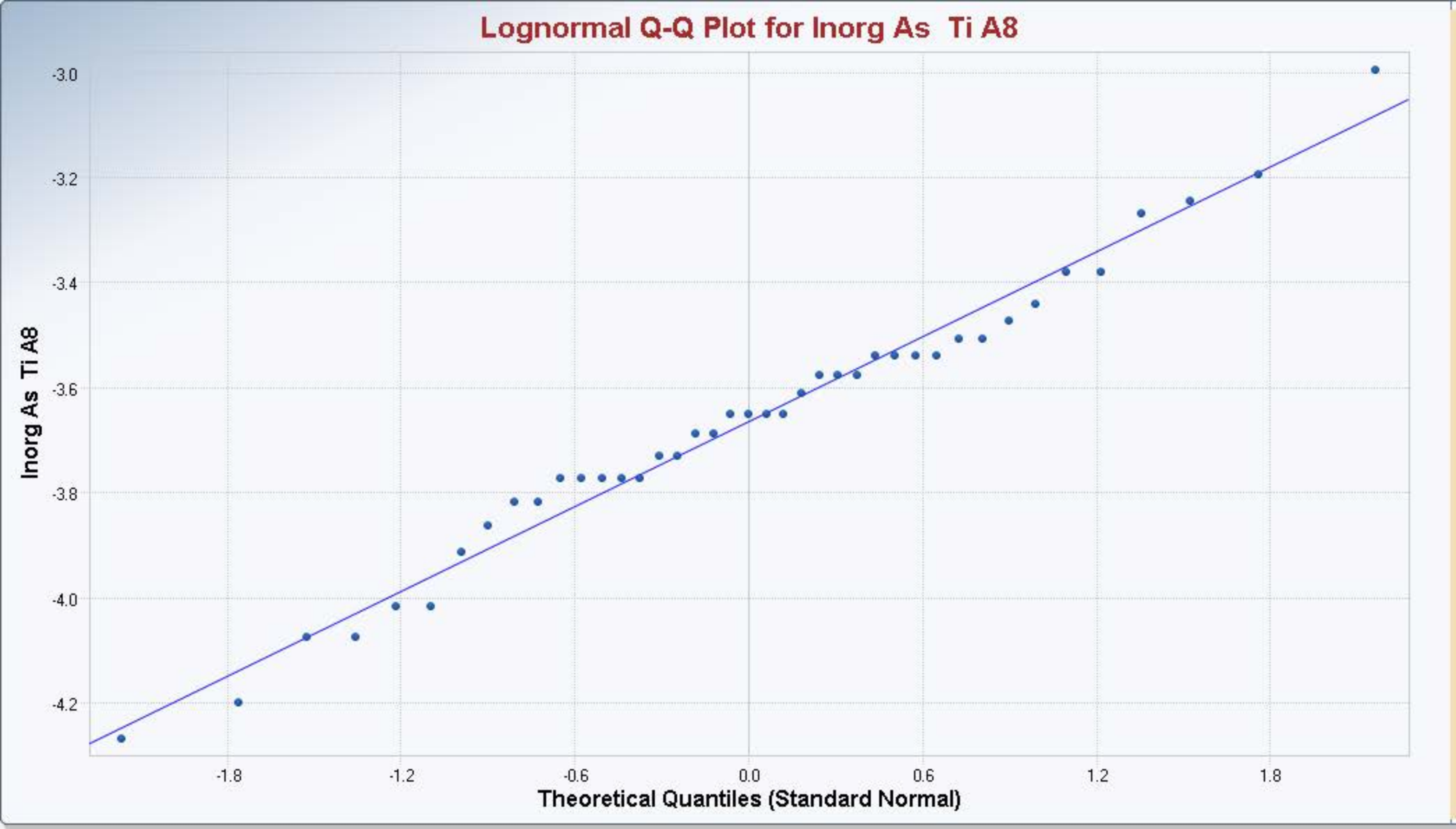

Gamma Q-Q Plot for Ni Ti A8
Ni Ti A8
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Theoretical Quantiles of Gamma Distribution
Ni Ti A8
n = 41
Mean = 0.4756
k hat = 9.0127
theta hat = 0.0528
Slope = 1.0252
Intercept = -0.0114
Correlation, R = 0.9865
Anderson-Darling Test
Test Statistic = 0.578
Critical Value(0.05) = 0.749
Data appear Gamma Distributed
Best Fit Line


Gamma Q-Q Plot for Pb Ti A8
Pb Ti A8
n = 41
Mean = 0.0723
k hat = 19.8996
theta hat = 0.0036
Slope = 0.9458
Intercept = 0.0040
Correlation, R = 0.9637
Anderson-Darling Test
Test Statistic = 0.680
Critical Value(0.05) = 0.747
Data appear Gamma Distributed
Best Fit Line
0.130
0.120
0.110
0.100
0.090
0.080
0.070
0.060
0.050
Pb Ti A8
0.05
0.10
Theoretical Quantiles of Gamma Distribution


Gamma Q-Q Plot for Zn Ti A8
Zn Ti A8
Theoretical Quantiles of Gamma Distribution
10
11
12
13
14
15
16
17
Zn Ti A8
n = 41
Mean = 13.3756
k hat = 77.2323
theta hat = 0.1732
Slope = 0.9422
Intercept = 0.7751
Correlation, R = 0.9856
Anderson-Darling Test
Test Statistic = 0.365
Critical Value(0.05) = 0.747
Data appear Gamma Distributed
Best Fit Line

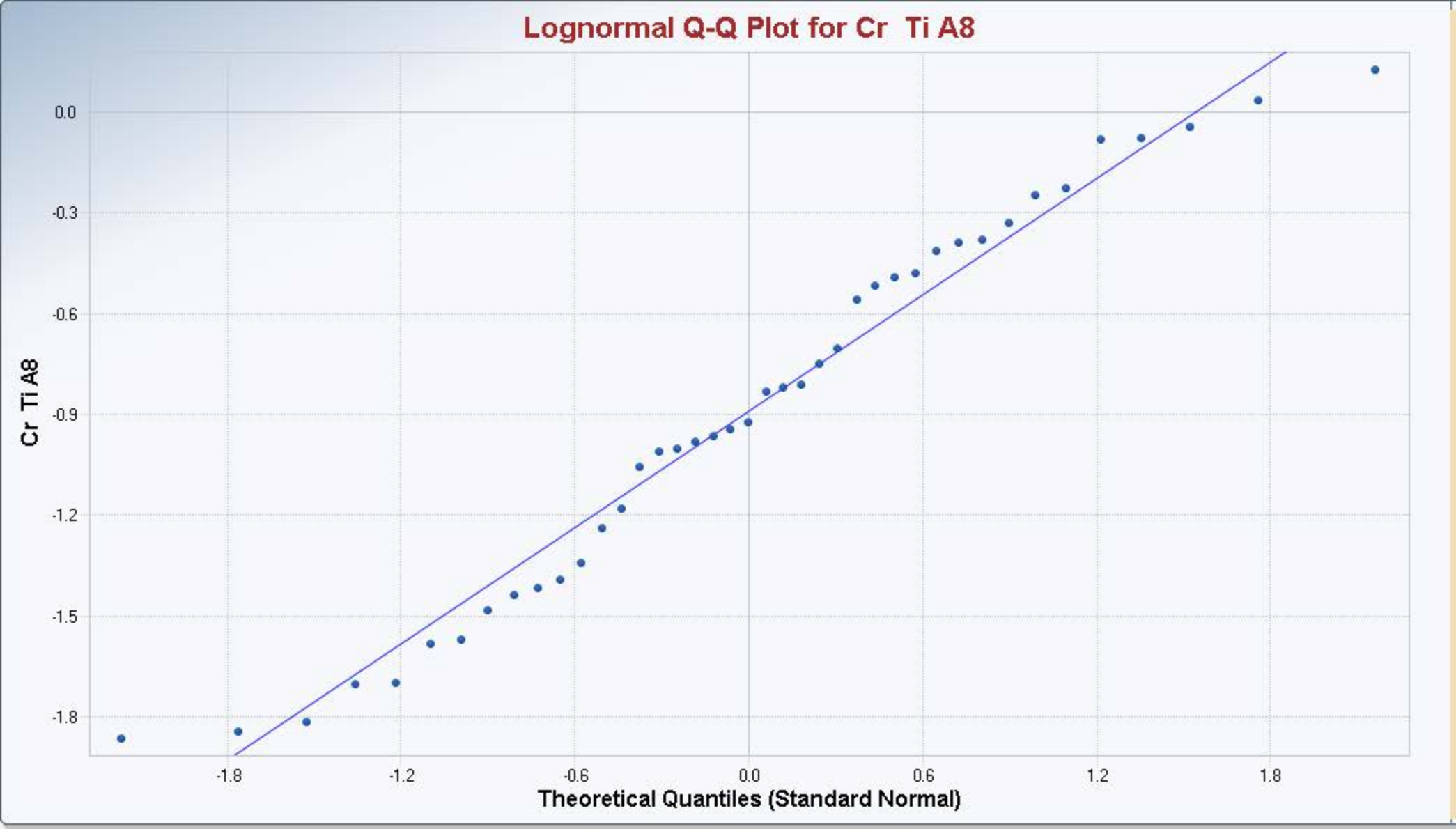

Gamma Q-Q Plot for Ag Ti A8
Ag Ti A8
0.10
0.20
0.30
0.40
0.50
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
Theoretical Quantiles of Gamma Distribution
Ag Ti A8
n = 41
Mean = 0.1761
k hat = 1.7720
theta hat = 0.0994
Slope = 1.0837
Intercept = -0.0137
Correlation, R = 0.9659
Anderson-Darling Test
Test Statistic = 1.830
Critical Value(0.05) = 0.762
Data not Gamma Distributed
Best Fit Line


Gamma Q-Q Plot for Cd Ti A8
Cd Ti A8
n = 41
Mean = 0.3747
k hat = 3.5771
theta hat = 0.1047
Slope = 1.0939
Intercept = -0.0340
Correlation, R = 0.9528
Anderson-Darling Test
Test Statistic = 2.426
Critical Value(0.05) = 0.754
Data not Gamma Distributed
Best Fit Line
Cd Ti A8
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.2
0.4
0.6
0.8
1.0
Theoretical Quantiles of Gamma Distribution



Inorg As Ti A8

n = 41
Mean = -3.665
Sd = 0.266
Slope = 0.27
Intercept = -3.665
Correlation, R = 0.991
Shapiro-Wilk Test
Exact Test Statistic = 0.983
Critical Value(0.05) = 0.941
Data Appear Lognormal
Approx. Test Value = 0.983
p-Value = 0.871
Best Fit Line



Cr Ti A8

n = 41

Mean = -0.891

Sd = 0.571

Slope = 0.577

Intercept = -0.891

Correlation, R = 0.987

Shapiro-Wilk Test

Exact Test Statistic = 0.953

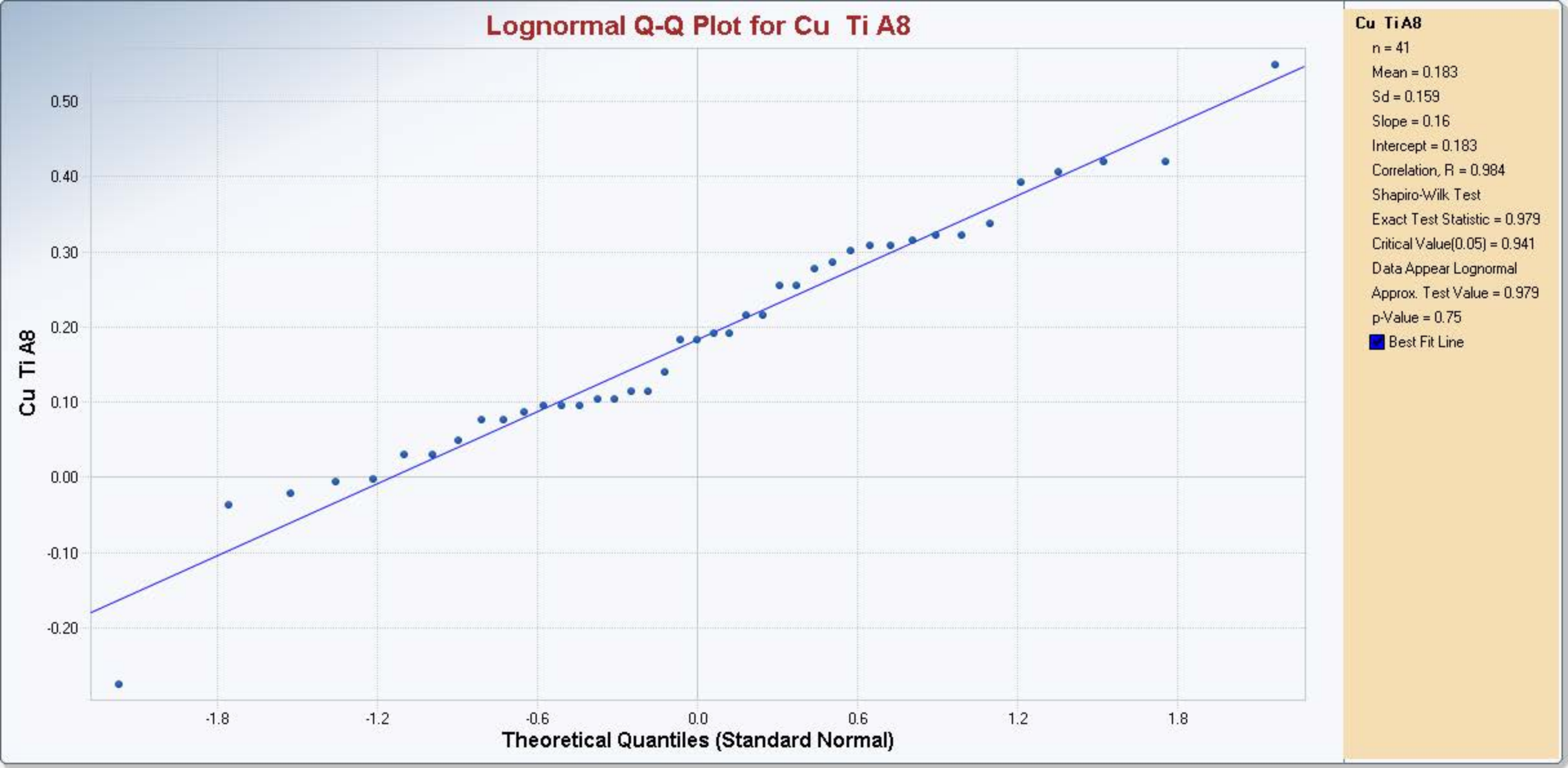
Critical Value(0.05) = 0.941

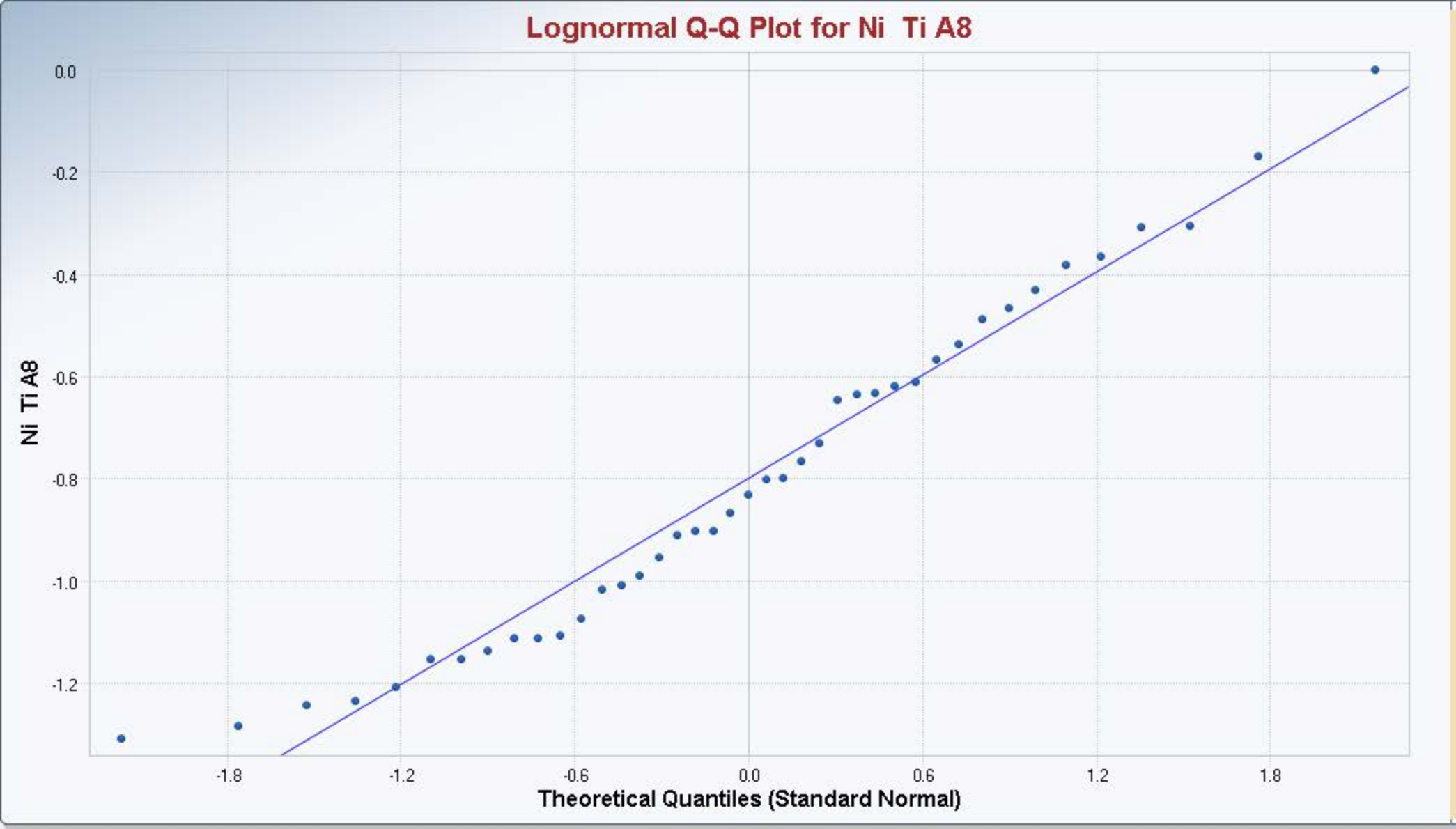
Data Appear Lognormal

Approx. Test Value = 0.953

p-Value = 0.135

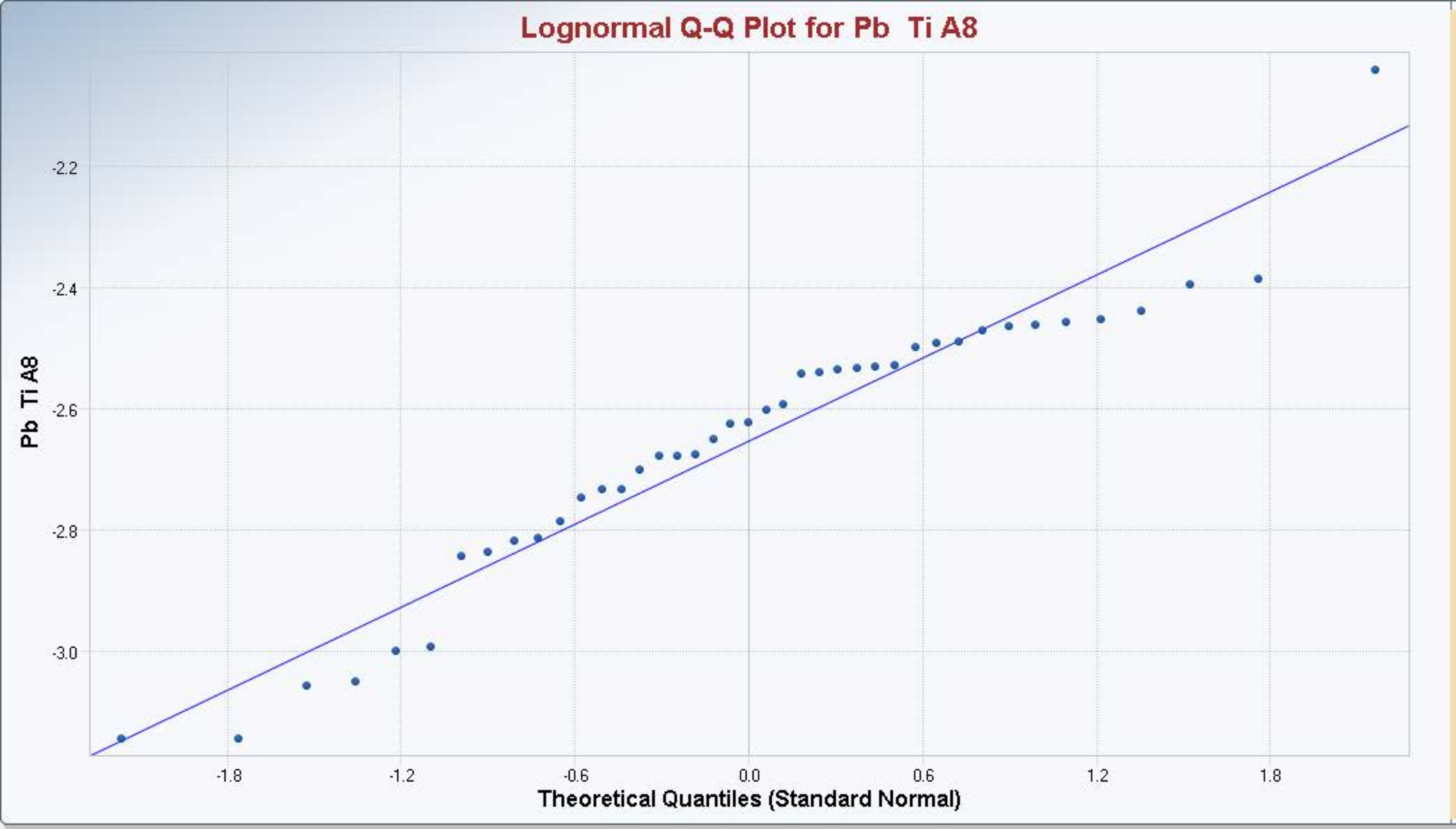
Best Fit Line


Lognormal Q-Q Plot for Cu Ti A8
Cu Ti A8
n = 41
Mean = 0.183
Sd = 0.159
Slope = 0.16
Intercept = 0.183
Correlation, R = 0.984
Shapiro-Wilk Test
Exact Test Statistic = 0.979
Critical Value(0.05) = 0.941
Data Appear Lognormal
Approx. Test Value = 0.979
p-Value = 0.75
Best Fit Line
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
Cu Ti A8
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)



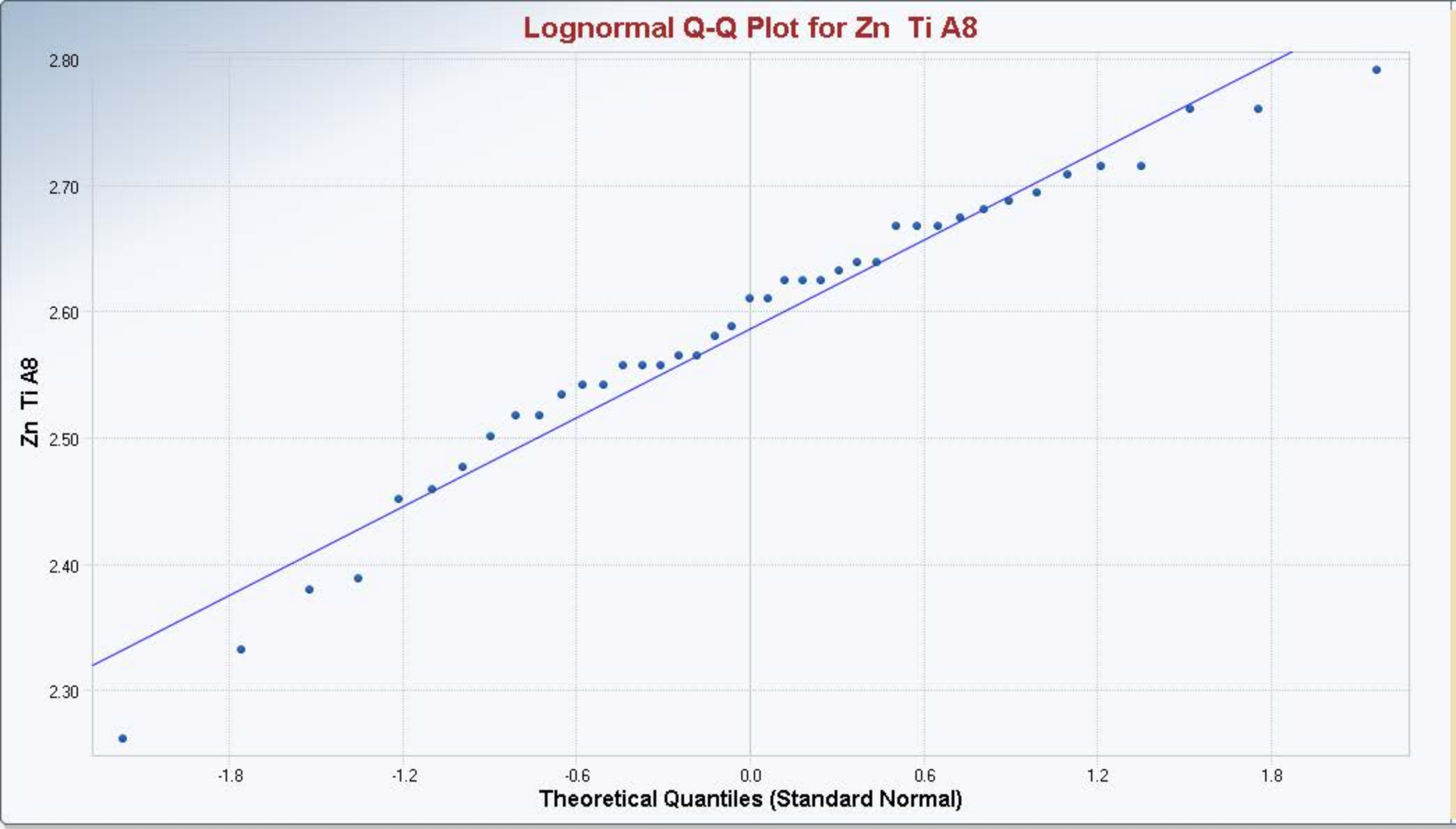
Ni Ti A8

n = 41
Mean = -0.8
Sd = 0.334
Slope = 0.337
Intercept = -0.8
Correlation, R = 0.985
Shapiro-Wilk Test
Exact Test Statistic = 0.957
Critical Value(0.05) = 0.941
Data Appear Lognormal
Approx. Test Value = 0.957
p-Value = 0.177
Best Fit Line



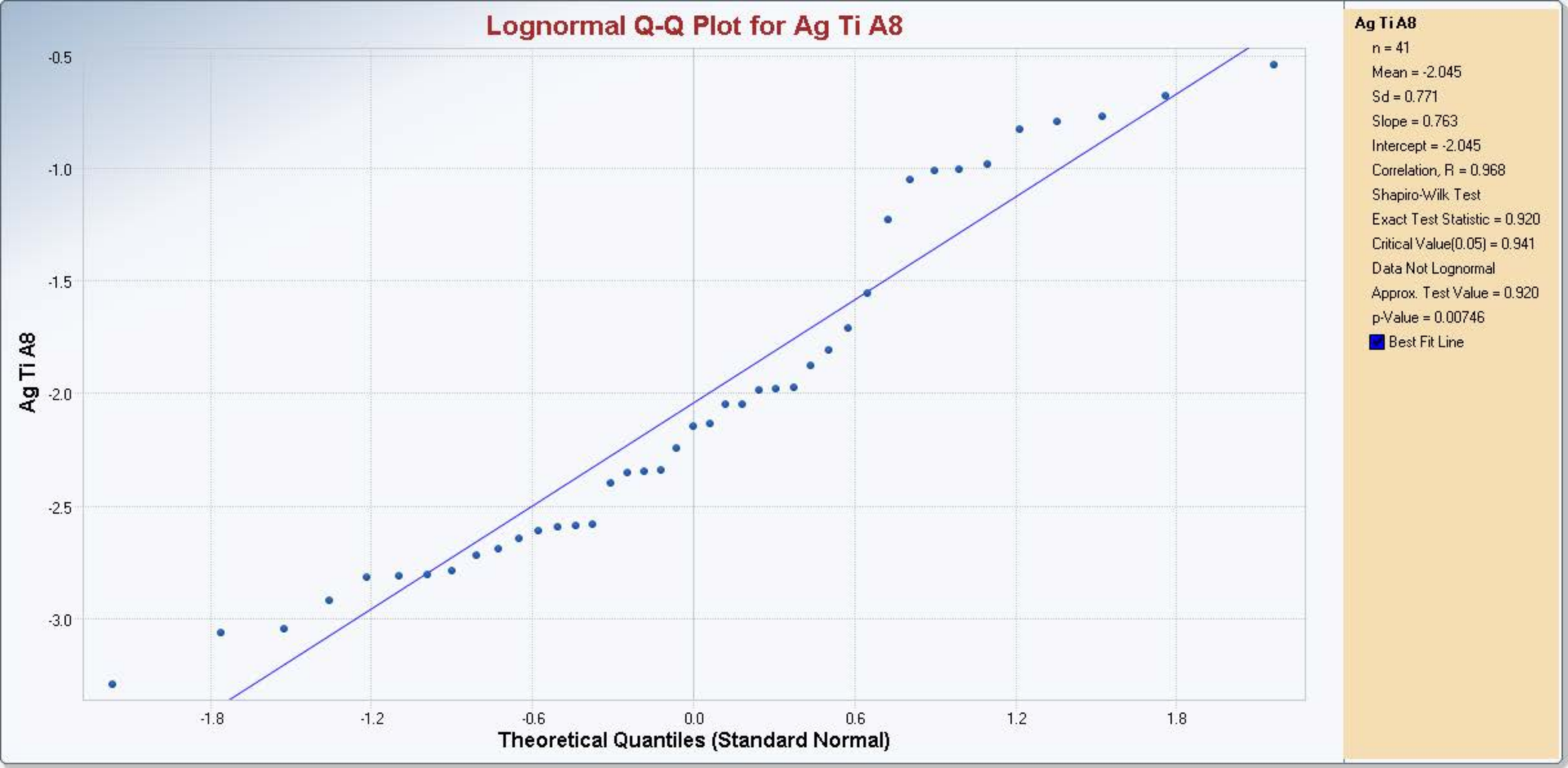
Pb Ti A8

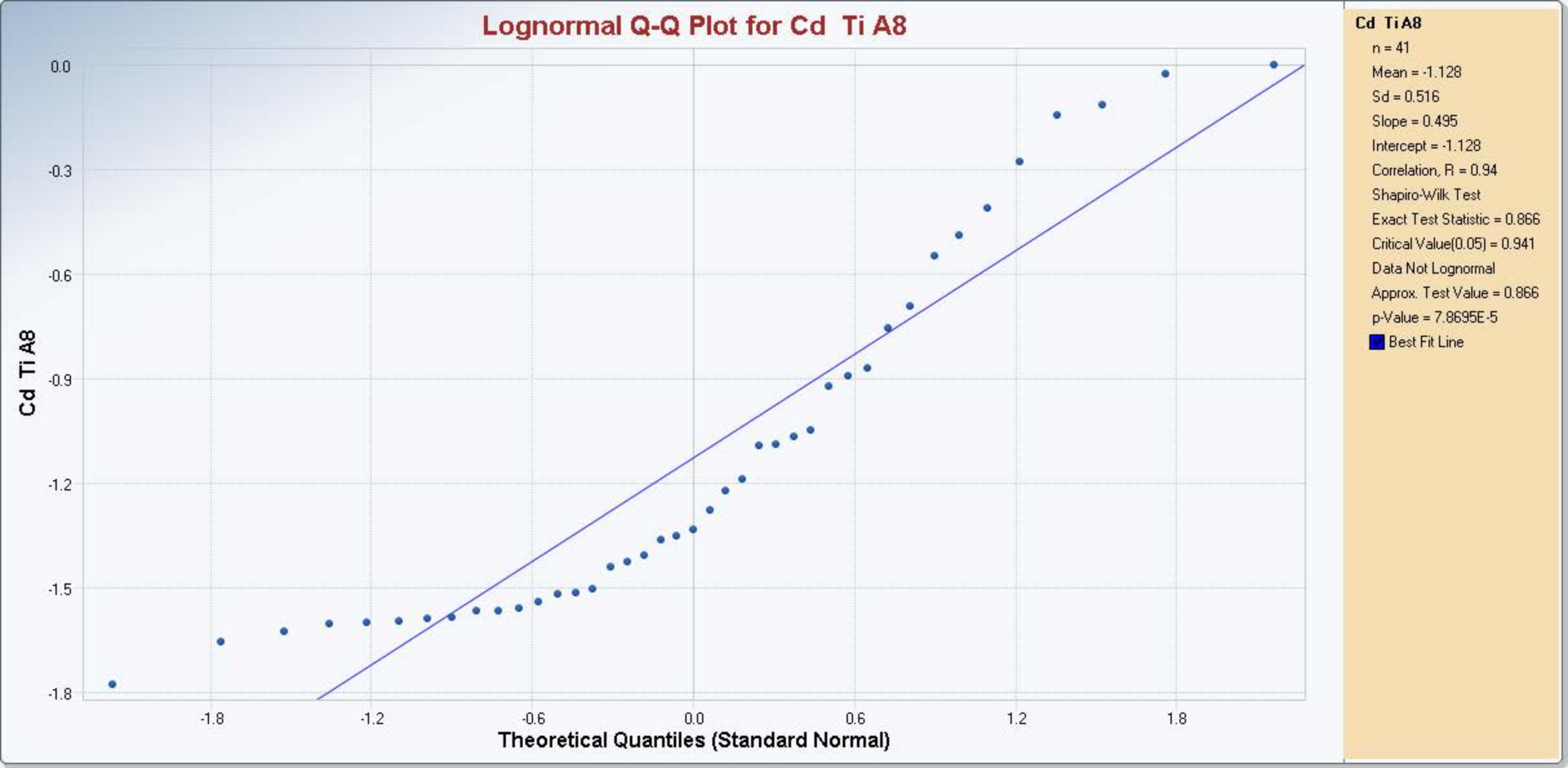
n = 41
Mean = -2.653
Sd = 0.23
Slope = 0.229
Intercept = -2.653
Correlation, R = 0.971
Shapiro-Wilk Test
Exact Test Statistic = 0.948
Critical Value(0.05) = 0.941
Data Appear Lognormal
Approx. Test Value = 0.947
p-Value = 0.082
Best Fit Line

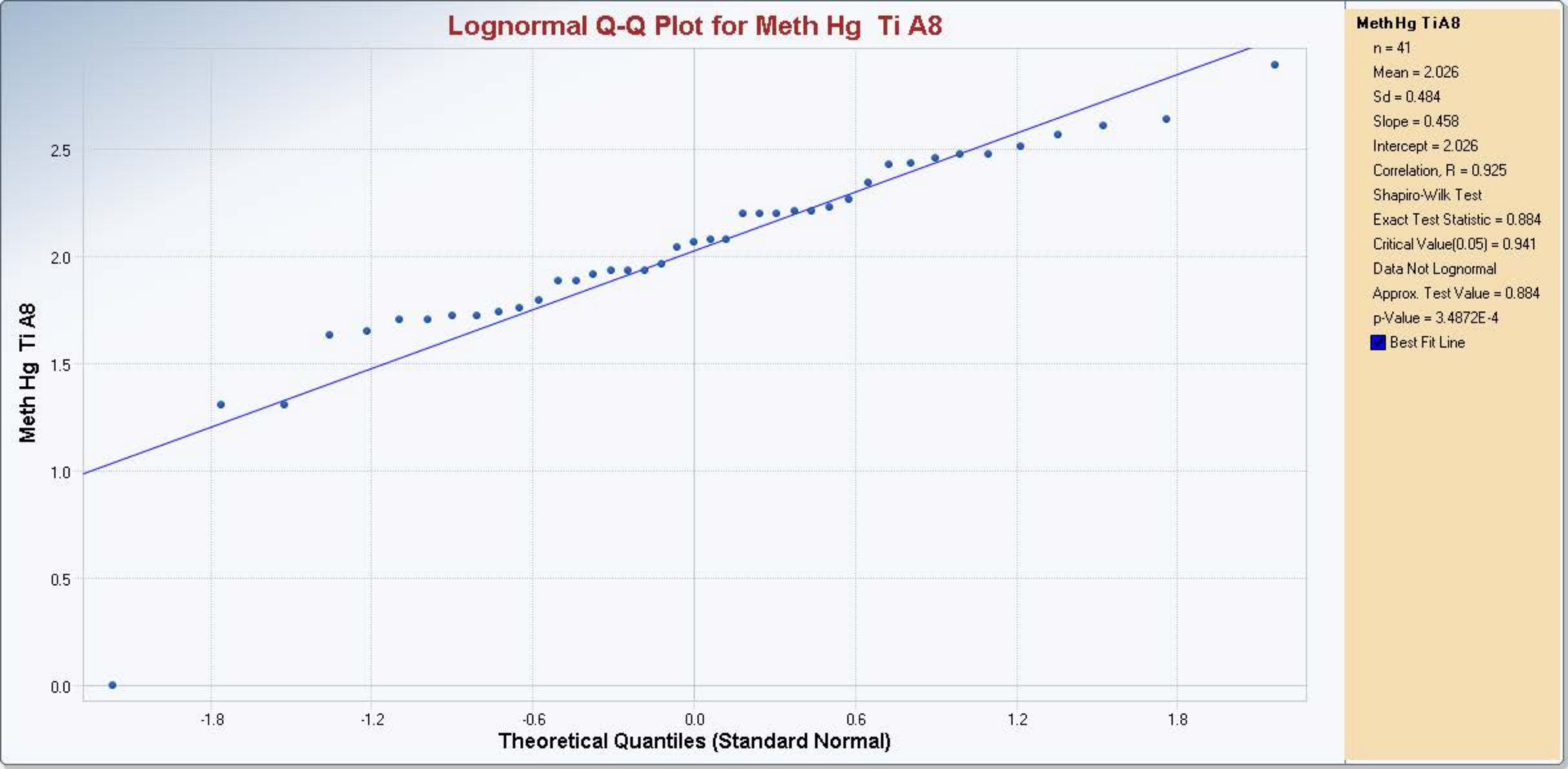


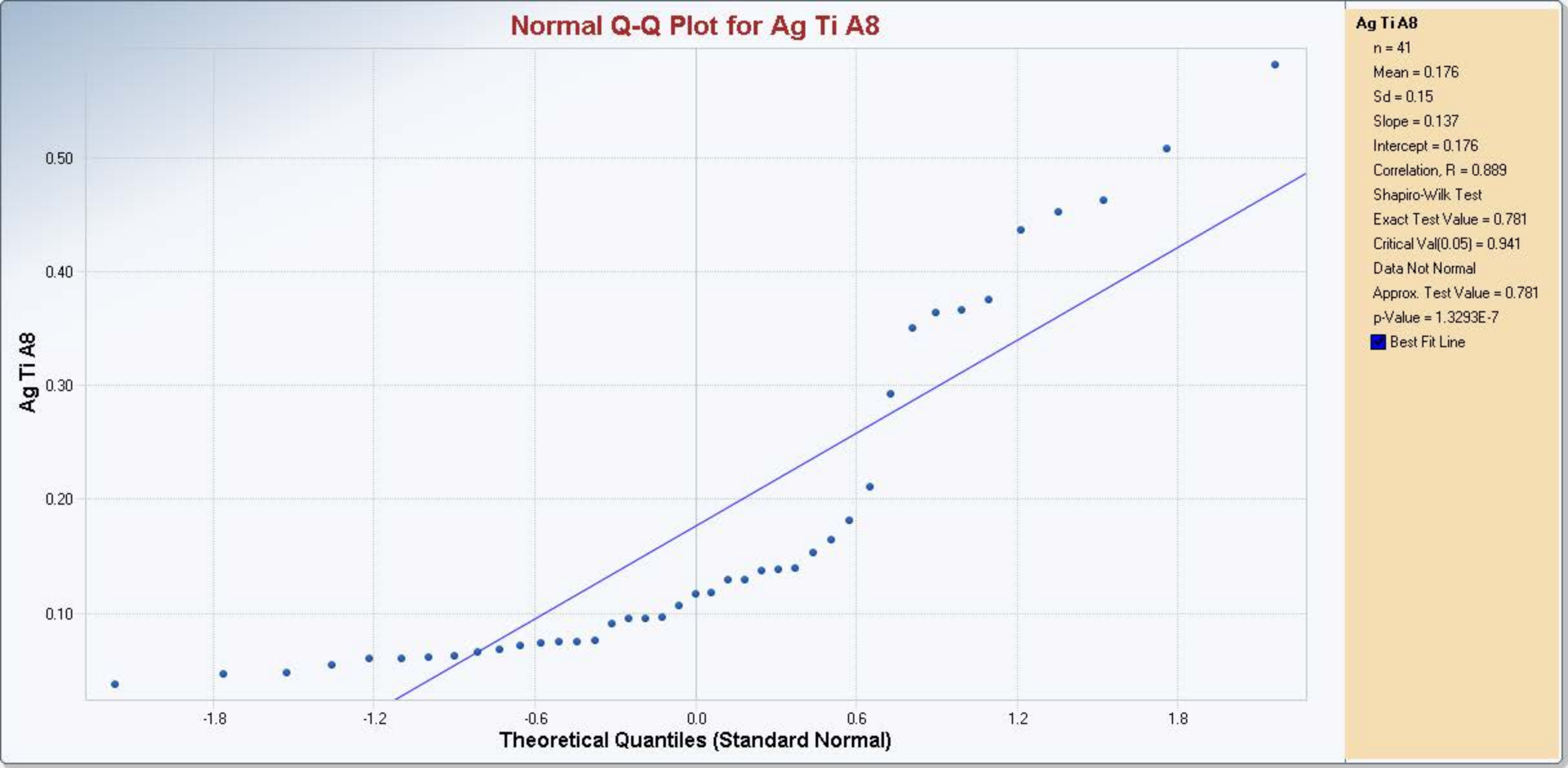
Zn Ti A8

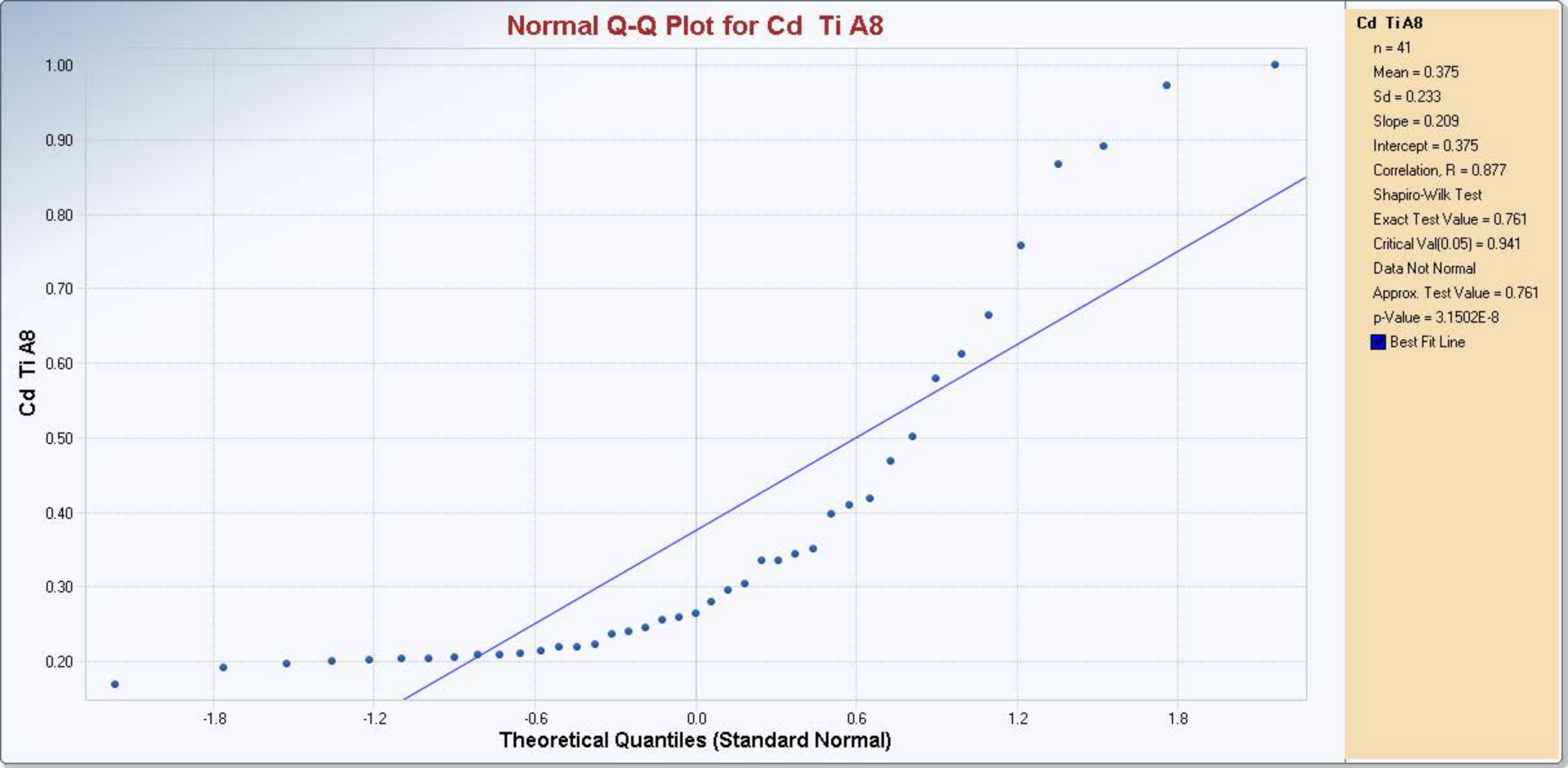
n = 41
Mean = 2.587
Sd = 0.117
Slope = 0.117
Intercept = 2.587
Correlation, R = 0.981
Shapiro-Wilk Test
Exact Test Statistic = 0.961
Critical Value(0.05) = 0.941
Data Appear Lognormal
Approx. Test Value = 0.960
p-Value = 0.234
Best Fit Line

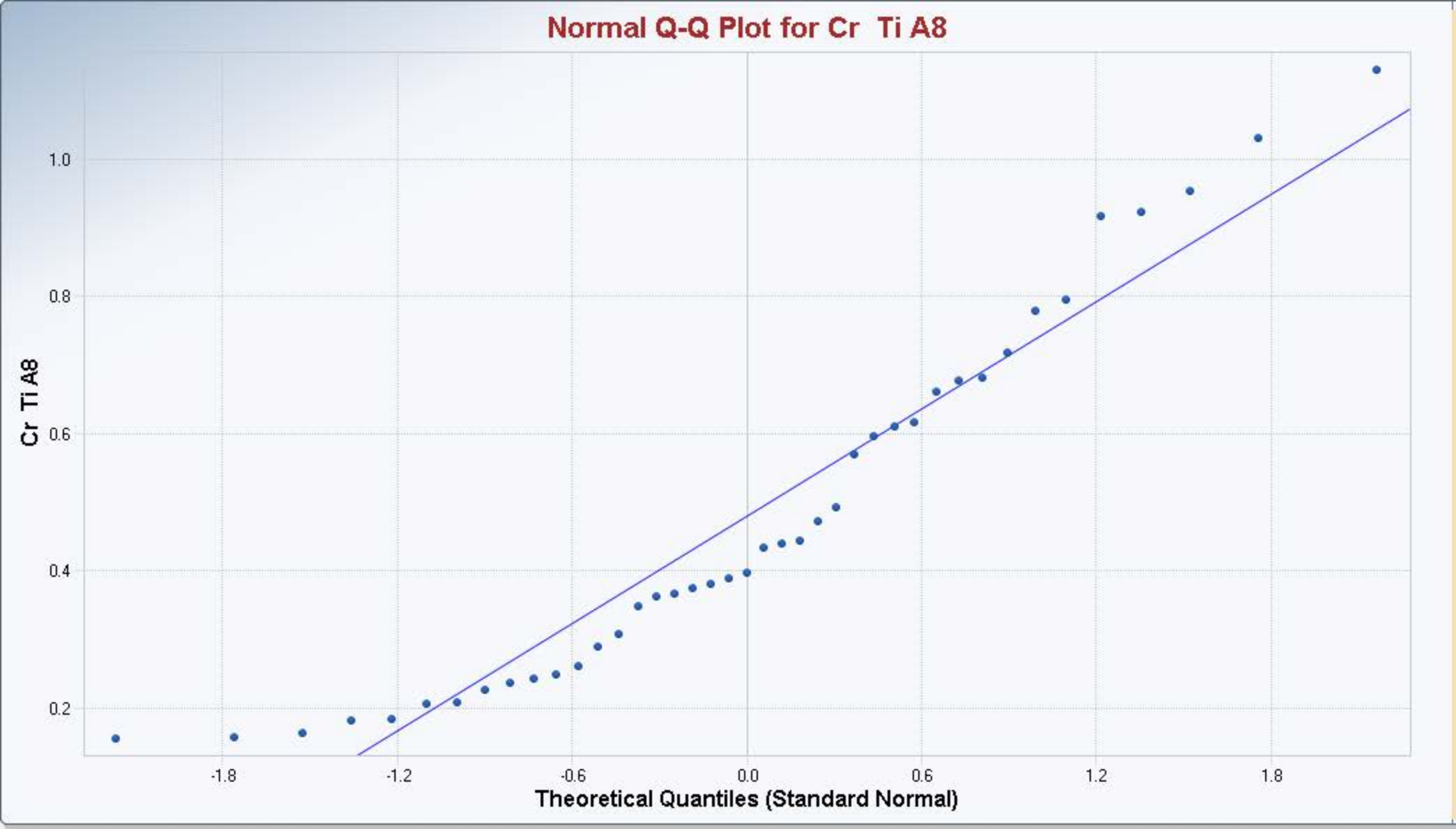

Lognormal Q-Q Plot for Ag Ti A8
Ag Ti A8
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Ag Ti A8
n = 41
Mean = -2.045
Sd = 0.771
Slope = 0.763
Intercept = -2.045
Correlation, R = 0.968
Shapiro-Wilk Test
Exact Test Statistic = 0.920
Critical Value(0.05) = 0.941
Data Not Lognormal
Approx. Test Value = 0.920
p-Value = 0.00746
Best Fit Line


Lognormal Q-Q Plot for Cd Ti A8
Cd Ti A8
0.0
-0.3
-0.6
-0.9
-1.2
-1.5
-1.8
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Cd Ti A8
n = 41
Mean = -1.128
Sd = 0.516
Slope = 0.495
Intercept = -1.128
Correlation, R = 0.94
Shapiro-Wilk Test
Exact Test Statistic = 0.866
Critical Value(0.05) = 0.941
Data Not Lognormal
Approx. Test Value = 0.866
p-Value = 7.8695E-5
Best Fit Line


Lognormal Q-Q Plot for Meth Hg Ti A8
Meth Hg Ti A8
2.5
2.0
1.5
1.0
0.5
0.0
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Meth Hg Ti A8
n = 41
Mean = 2.026
Sd = 0.484
Slope = 0.458
Intercept = 2.026
Correlation, R = 0.925
Shapiro-Wilk Test
Exact Test Statistic = 0.884
Critical Value(0.05) = 0.941
Data Not Lognormal
Approx. Test Value = 0.884
p-Value = 3.4872E-4
Best Fit Line

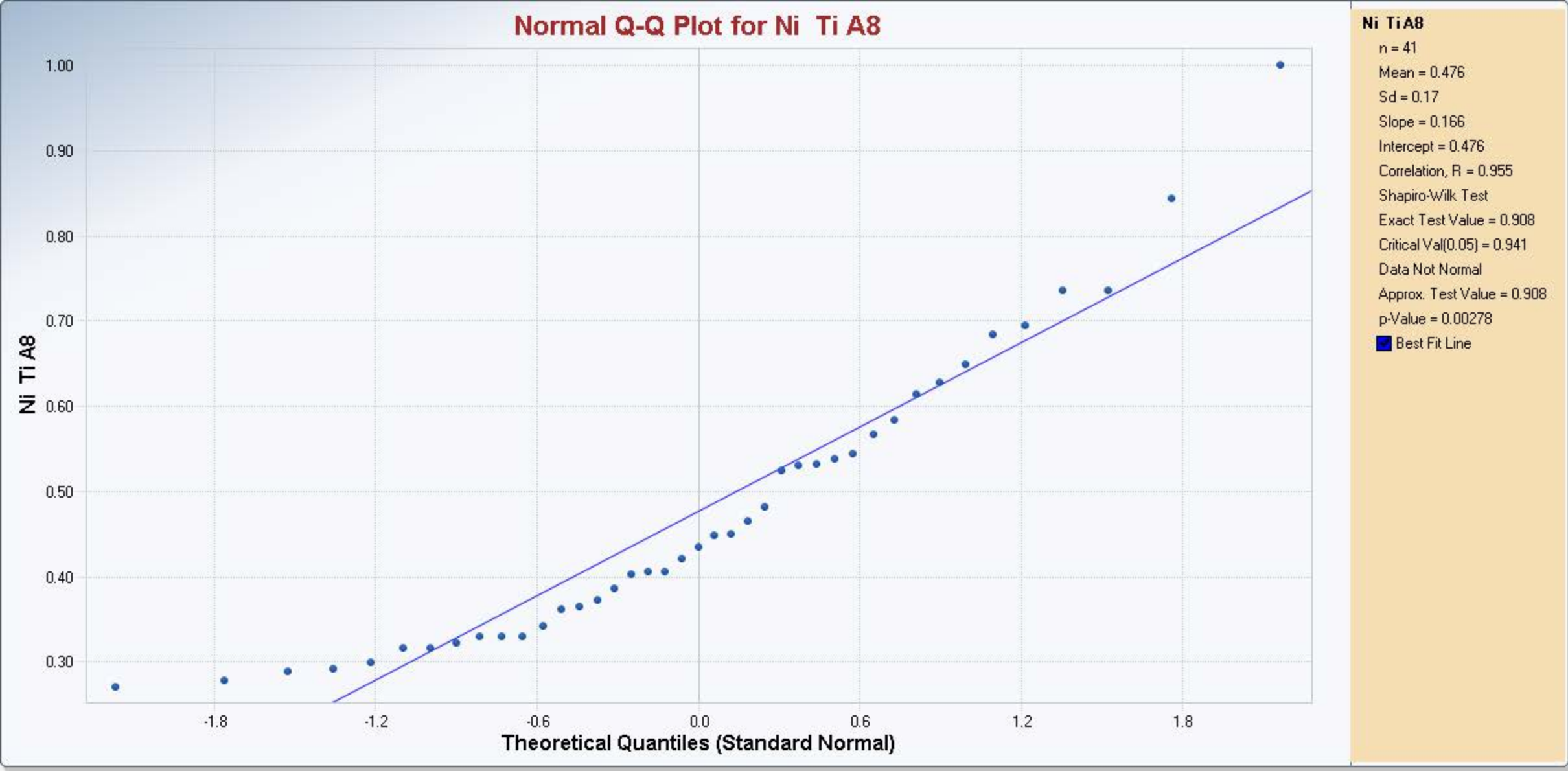

Normal Q-Q Plot for Ag Ti A8
Ag Ti A8
n = 41
Mean = 0.176
Sd = 0.15
Slope = 0.137
Intercept = 0.176
Correlation, R = 0.889
Shapiro-Wilk Test
Exact Test Value = 0.781
Critical Val(0.05) = 0.941
Data Not Normal
Approx. Test Value = 0.781
p-Value = 1.3293E-7
Best Fit Line
0.50
0.40
0.30
0.20
0.10
Ag Ti A8
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)

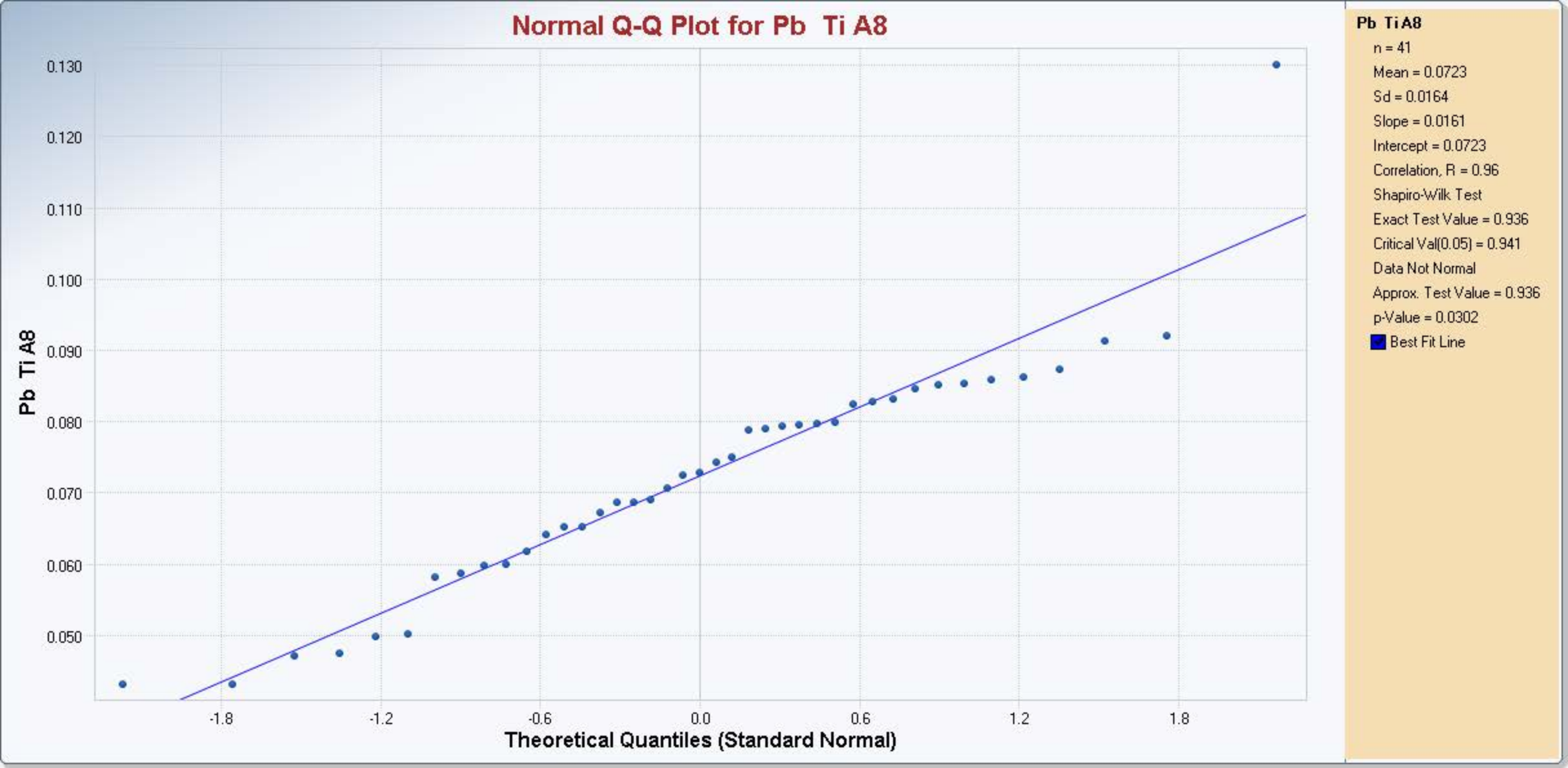

Normal Q-Q Plot for Cd Ti A8
Cd Ti A8
n = 41
Mean = 0.375
Sd = 0.233
Slope = 0.209
Intercept = 0.375
Correlation, R = 0.877
Shapiro-Wilk Test
Exact Test Value = 0.761
Critical Val(0.05) = 0.941
Data Not Normal
Approx. Test Value = 0.761
p-Value = 3.1502E-8
Best Fit Line
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
Cd Ti A8
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)

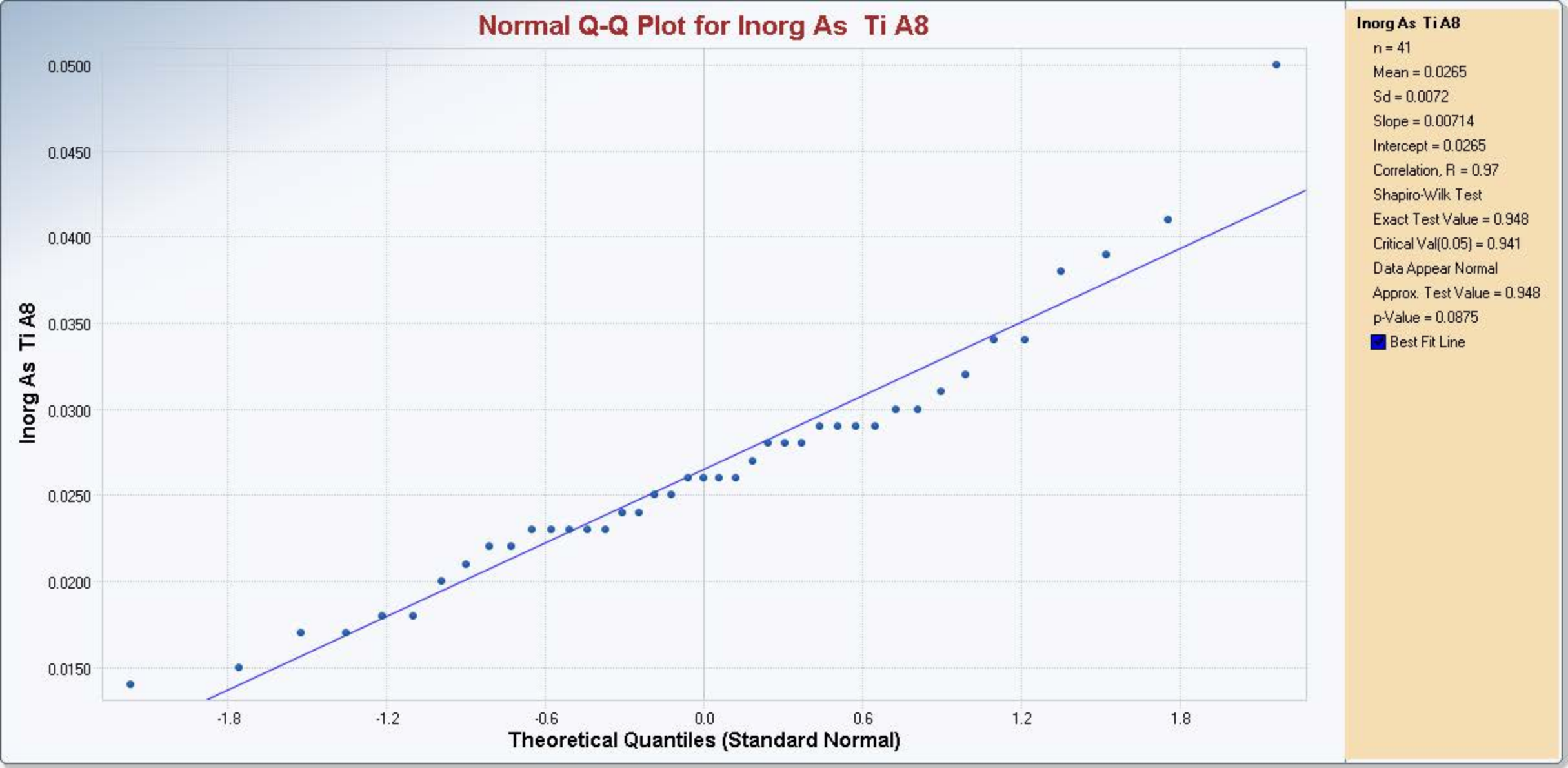


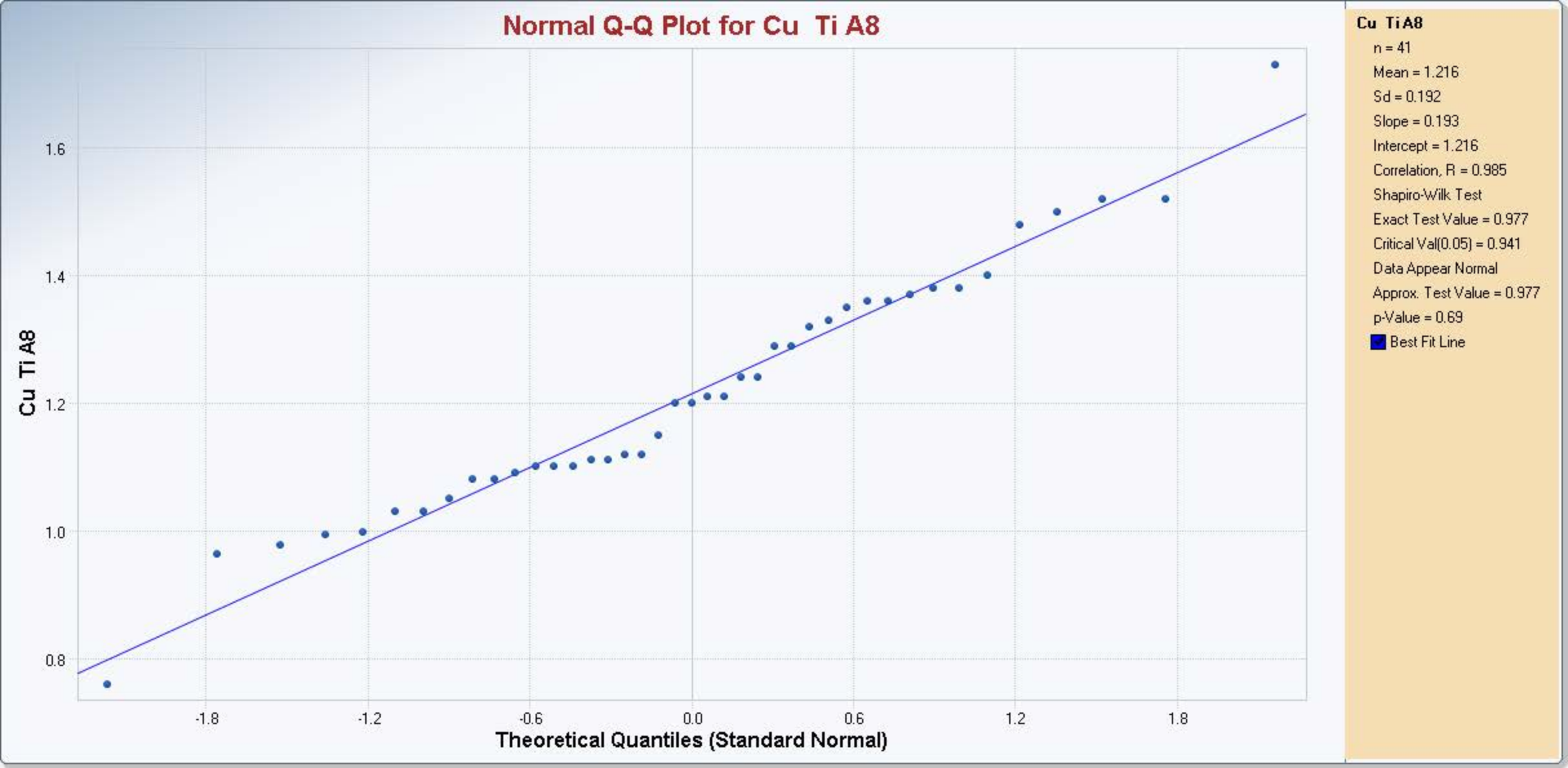
Cr Ti A8

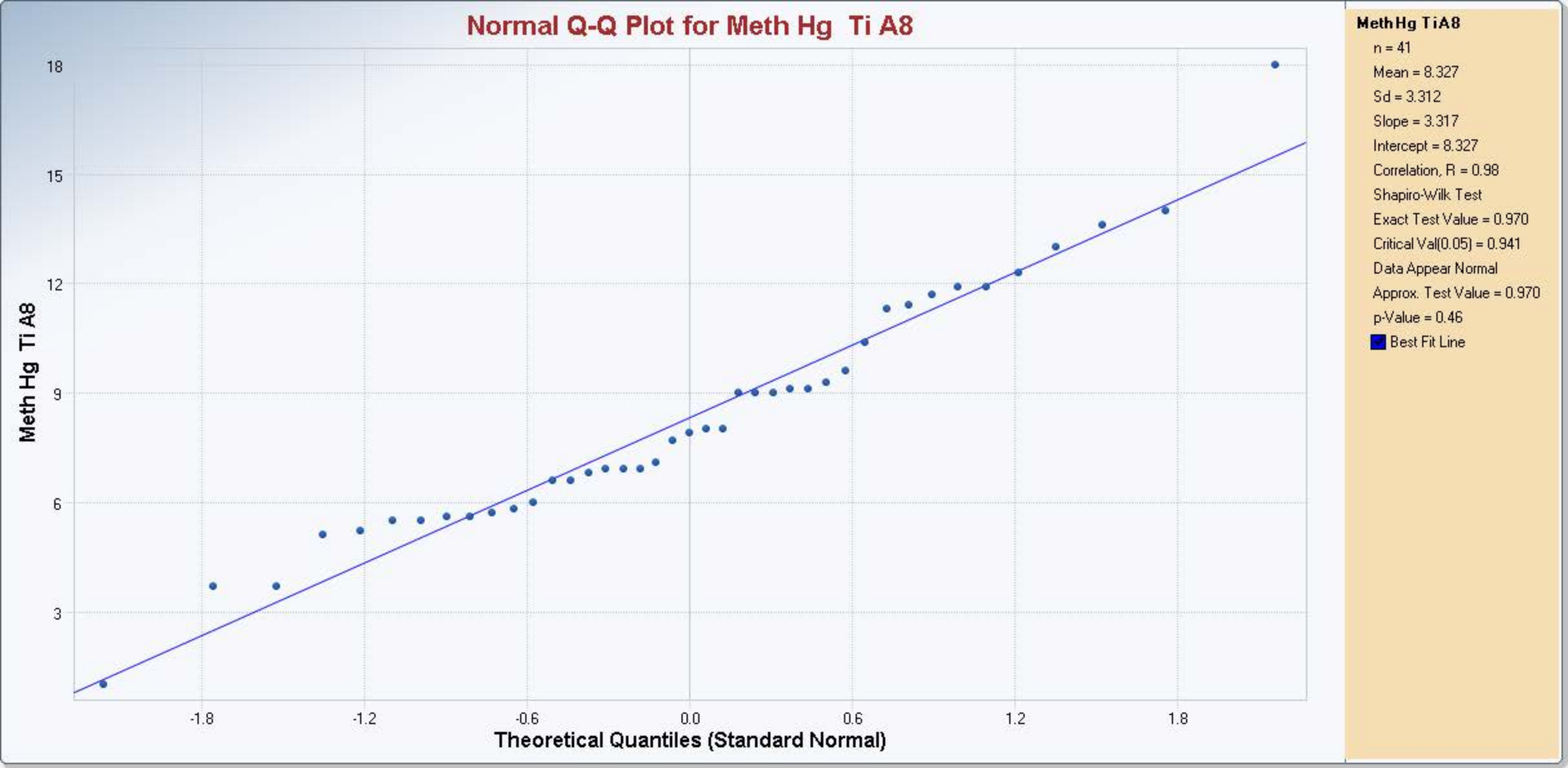
n = 41
Mean = 0.478
Sd = 0.265
Slope = 0.261
Intercept = 0.478
Correlation, R = 0.963
Shapiro-Wilk Test
Exact Test Value = 0.912
Critical Val(0.05) = 0.941
Data Not Normal
Approx. Test Value = 0.912
p-Value = 0.00388
Best Fit Line

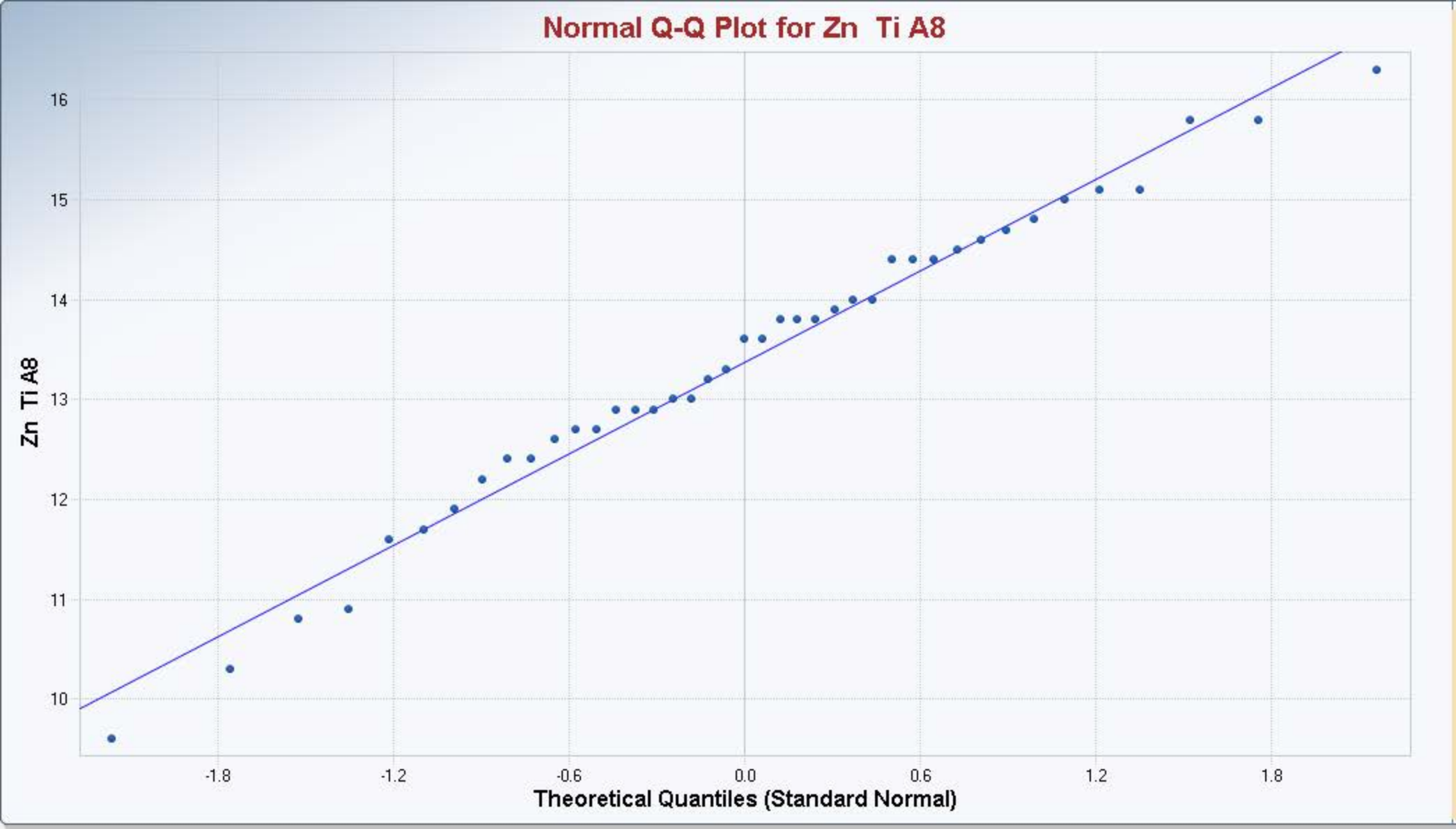

Normal Q-Q Plot for Ni Ti A8
Ni Ti A8
n = 41
Mean = 0.476
Sd = 0.17
Slope = 0.166
Intercept = 0.476
Correlation, R = 0.955
Shapiro-Wilk Test
Exact Test Value = 0.908
Critical Val(0.05) = 0.941
Data Not Normal
Approx. Test Value = 0.908
p-Value = 0.00278
Best Fit Line
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
Ni Ti A8
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)


Normal Q-Q Plot for Pb Ti A8
Pb Ti A8
0.130
0.120
0.110
0.100
0.090
0.080
0.070
0.060
0.050
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Pb Ti A8
n = 41
Mean = 0.0723
Sd = 0.0164
Slope = 0.0161
Intercept = 0.0723
Correlation, R = 0.96
Shapiro-Wilk Test
Exact Test Value = 0.936
Critical Val(0.05) = 0.941
Data Not Normal
Approx. Test Value = 0.936
p-Value = 0.0302
Best Fit Line


Normal Q-Q Plot for Inorg As Ti A8
Inorg As Ti A8
n = 41
Mean = 0.0265
Sd = 0.0072
Slope = 0.00714
Intercept = 0.0265
Correlation, R = 0.97
Shapiro-Wilk Test
Exact Test Value = 0.948
Critical Val(0.05) = 0.941
Data Appear Normal
Approx. Test Value = 0.948
p-Value = 0.0875
Best Fit Line
Inorg As Ti A8
0.0500
0.0450
0.0400
0.0350
0.0300
0.0250
0.0200
0.0150
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)


Normal Q-Q Plot for Cu Ti A8
Cu Ti A8
n = 41
Mean = 1.216
Sd = 0.192
Slope = 0.193
Intercept = 1.216
Correlation, R = 0.985
Shapiro-Wilk Test
Exact Test Value = 0.977
Critical Val(0.05) = 0.941
Data Appear Normal
Approx. Test Value = 0.977
p-Value = 0.69
Best Fit Line
Cu Ti A8
1.6
1.4
1.2
1.0
0.8
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)


Normal Q-Q Plot for Meth Hg Ti A8
Meth Hg Ti A8
n = 41
Mean = 8.327
Sd = 3.312
Slope = 3.317
Intercept = 8.327
Correlation, R = 0.98
Shapiro-Wilk Test
Exact Test Value = 0.970
Critical Val(0.05) = 0.941
Data Appear Normal
Approx. Test Value = 0.970
p-Value = 0.46
Best Fit Line
Meth Hg Ti A8
18
15
12
9
6
3
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)



Zn Ti A8

n = 41

Mean = 13.38

Sd = 1.506

Slope = 1.526

Intercept = 13.38

Correlation, R = 0.992

Shapiro-Wilk Test

Exact Test Value = 0.980

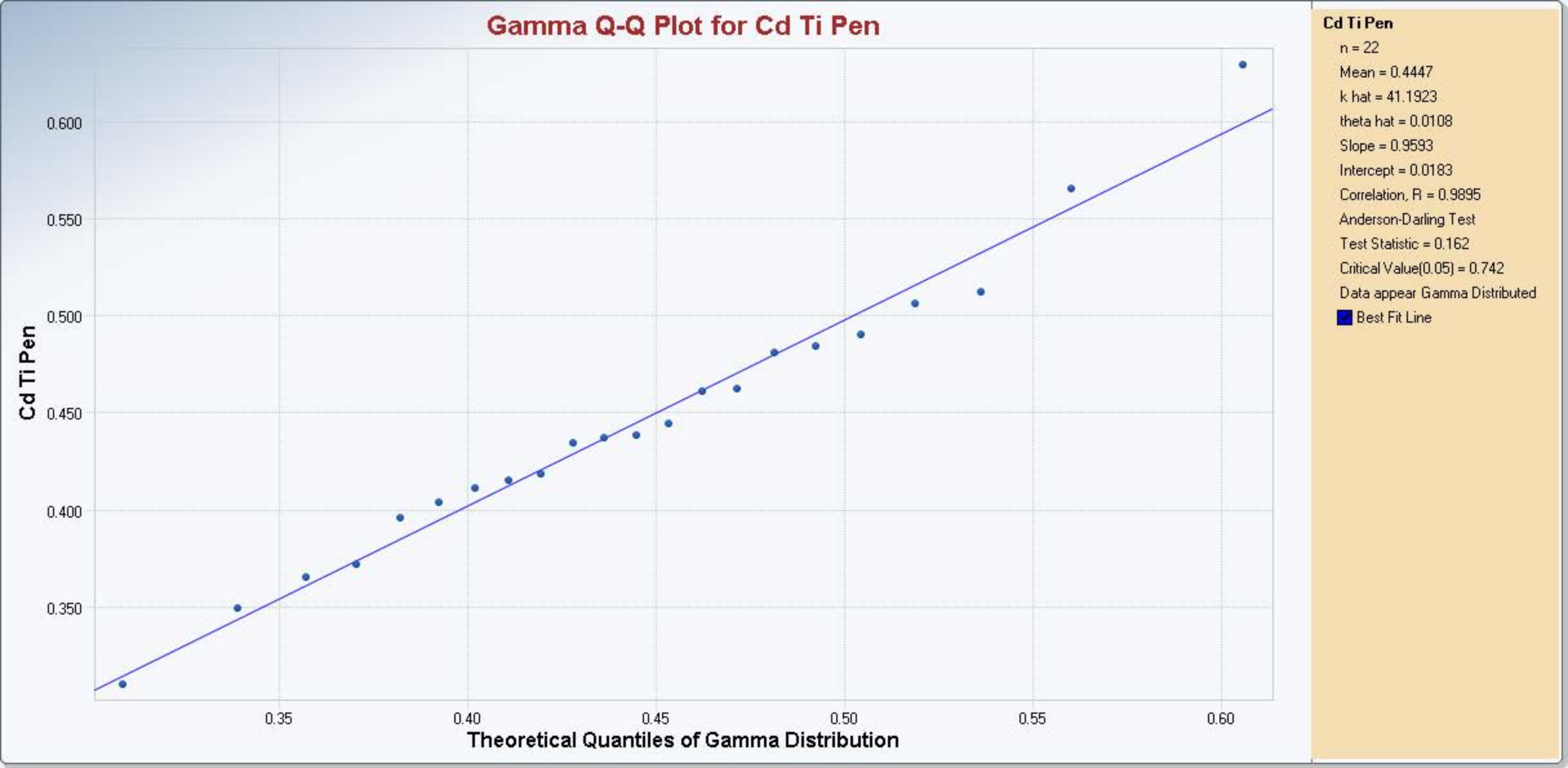
Critical Val(0.05) = 0.941

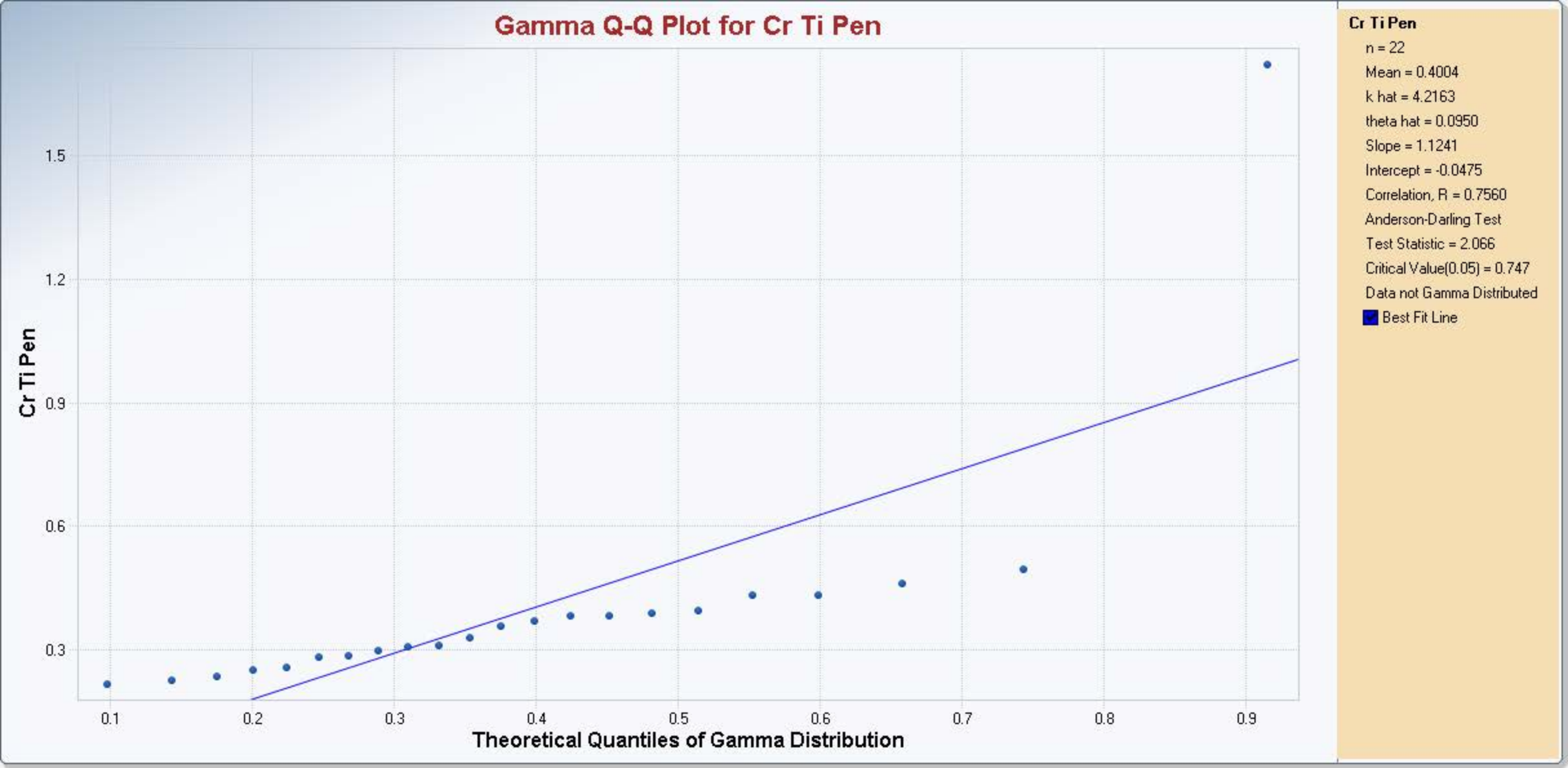
Data Appear Normal

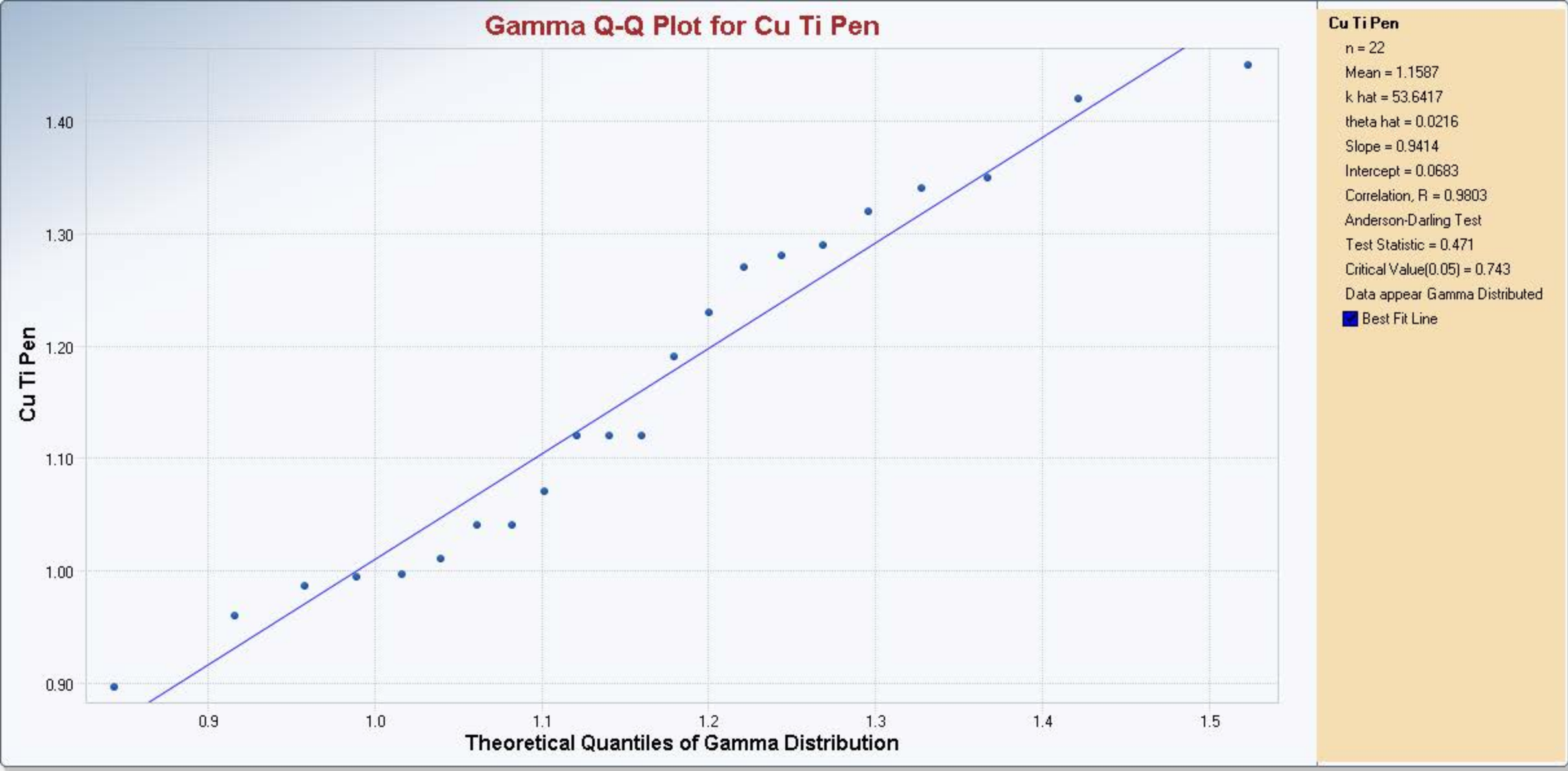
Approx. Test Value = 0.979

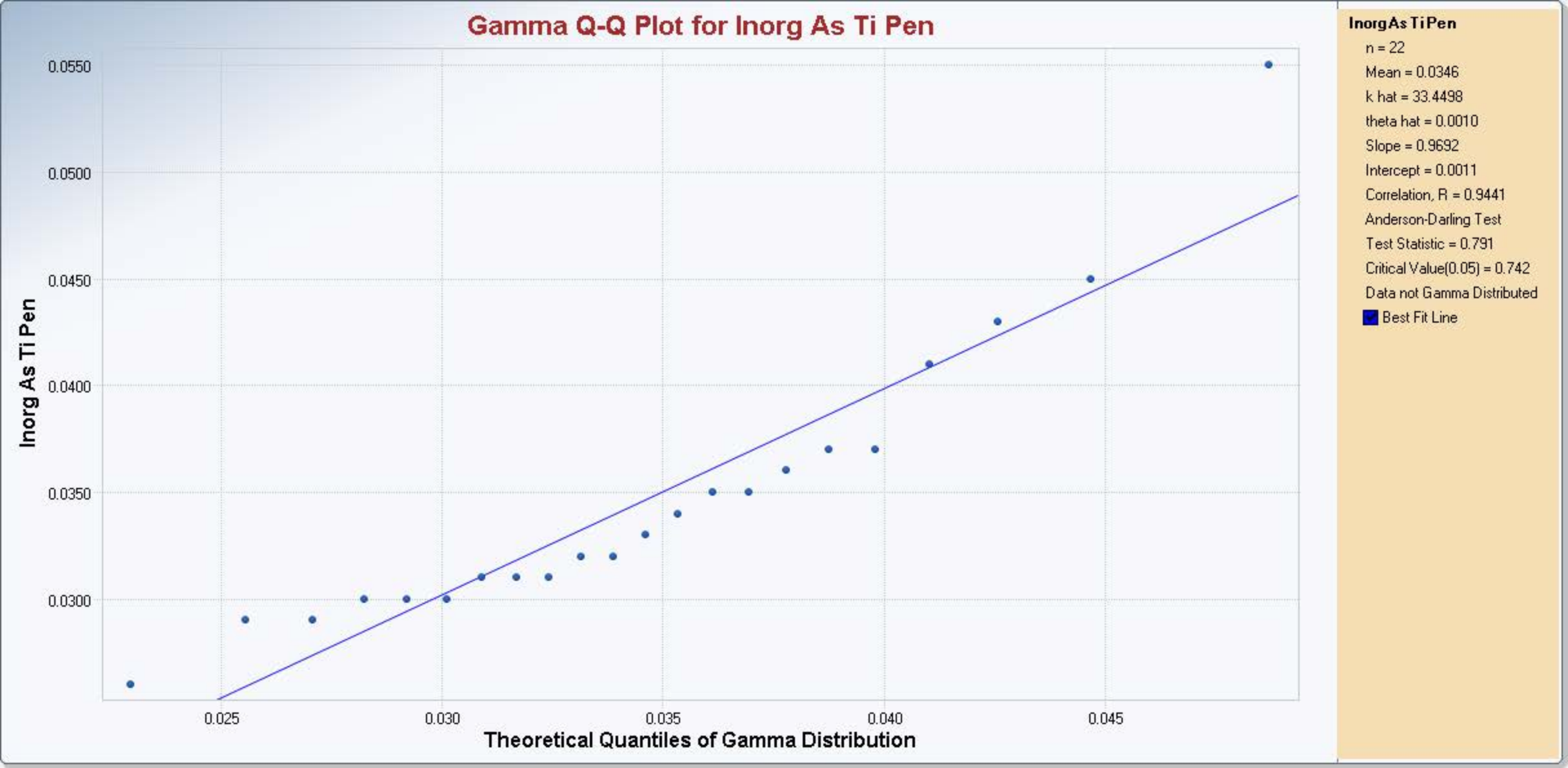
p-Value = 0.758

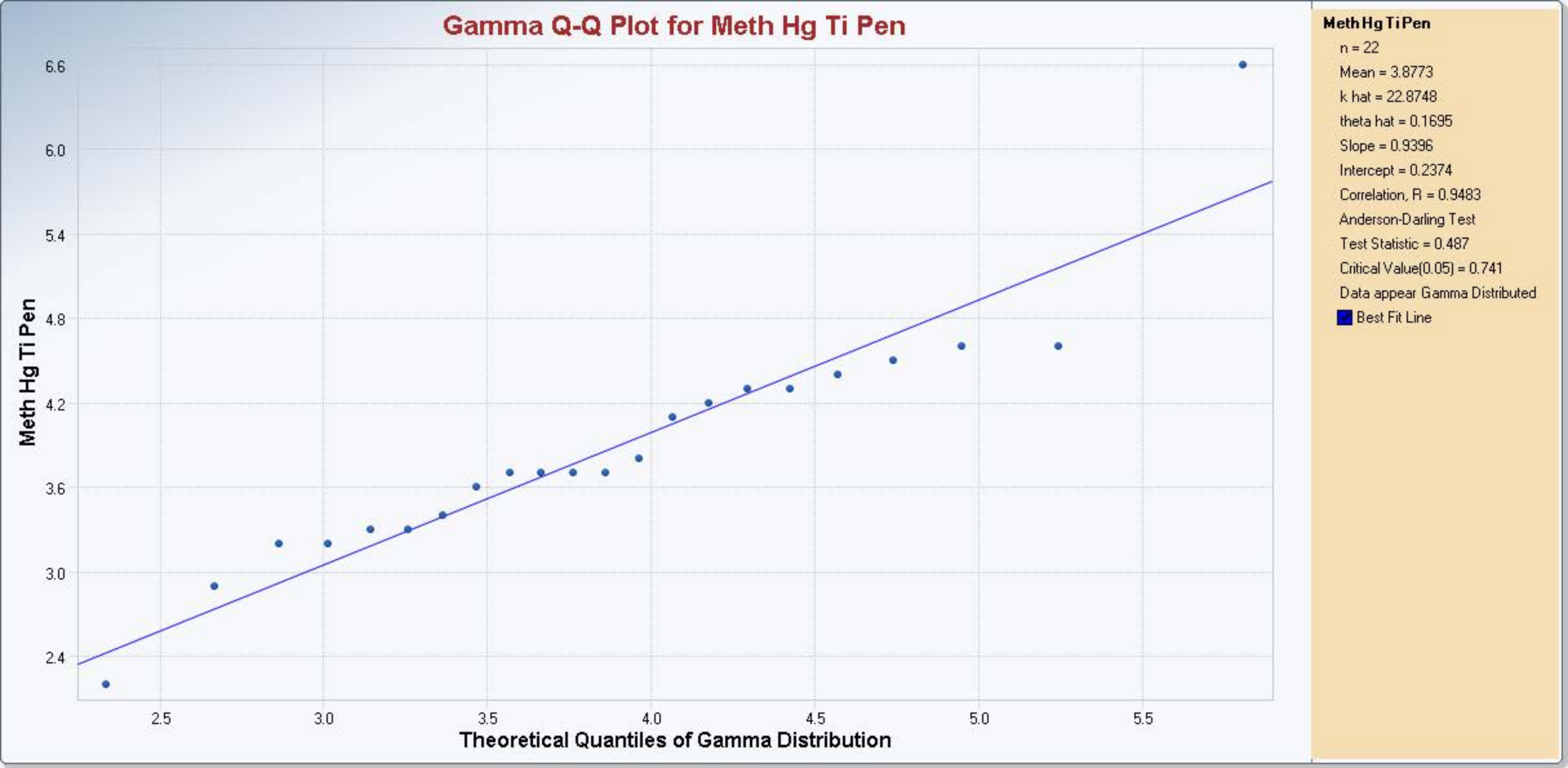
Best Fit Line

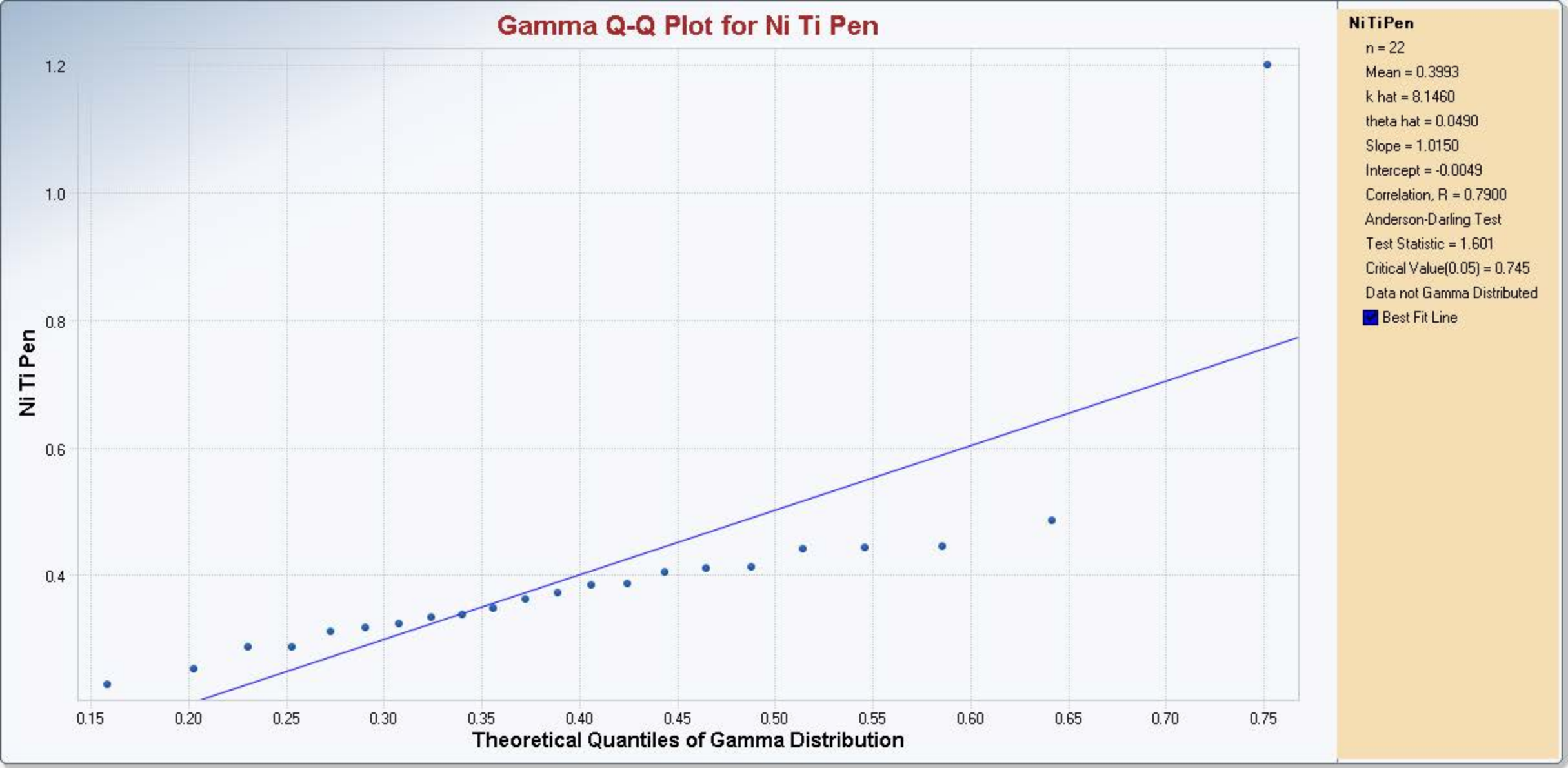

Gamma Q-Q Plot for Cd Ti Pen
Cd Ti Pen
0.600
0.550
0.500
0.450
0.400
0.350
0.35
0.40
0.45
0.50
0.55
0.60
Theoretical Quantiles of Gamma Distribution
Cd Ti Pen
n = 22
Mean = 0.4447
k hat = 41.1923
theta hat = 0.0108
Slope = 0.9593
Intercept = 0.0183
Correlation, R = 0.9895
Anderson-Darling Test
Test Statistic = 0.162
Critical Value(0.05) = 0.742
Data appear Gamma Distributed
Best Fit Line

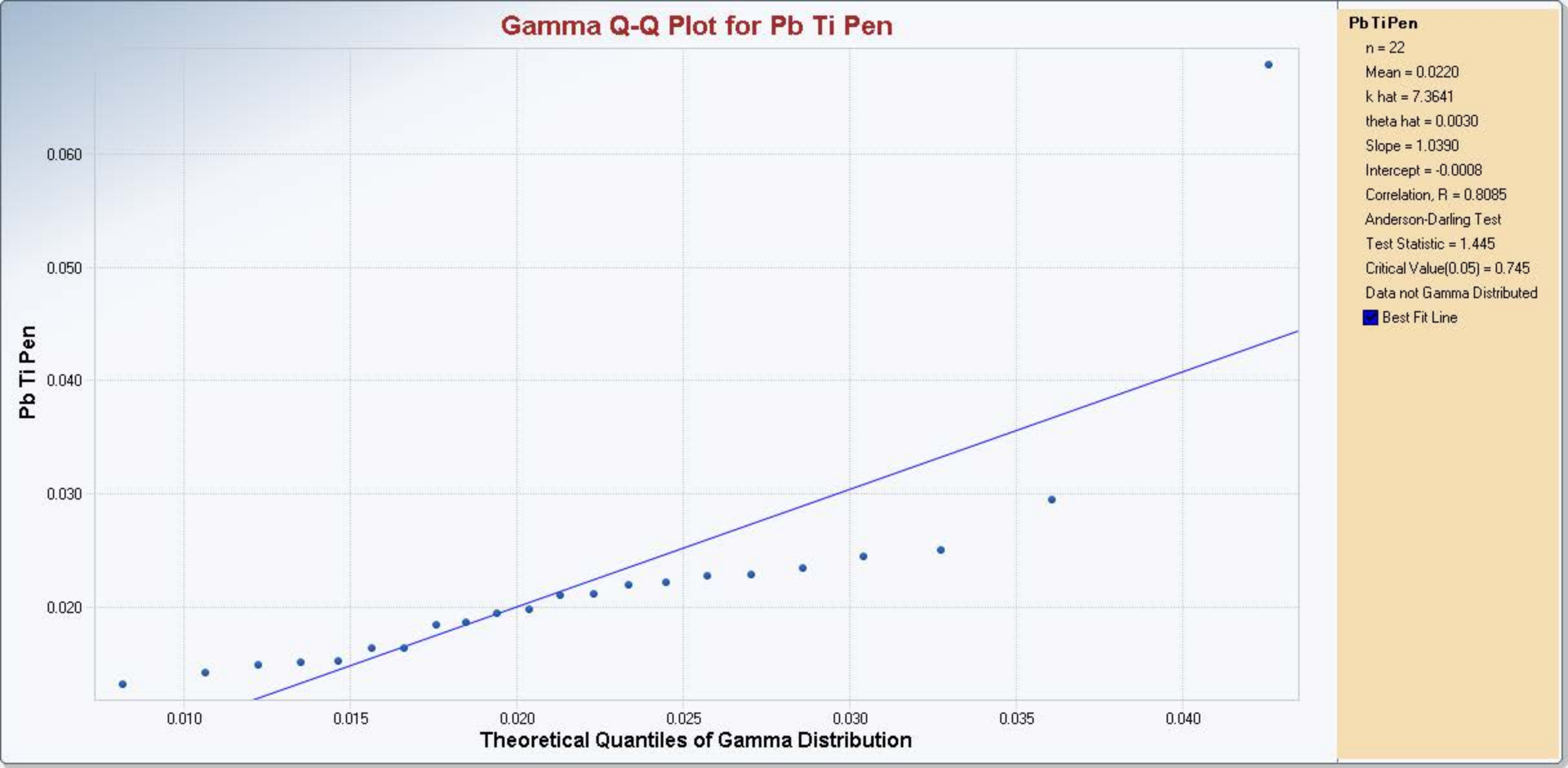

Gamma Q-Q Plot for Cr Ti Pen
Cr Ti Pen
n = 22
Mean = 0.4004
k hat = 4.2163
theta hat = 0.0950
Slope = 1.1241
Intercept = -0.0475
Correlation, R = 0.7560
Anderson-Darling Test
Test Statistic = 2.066
Critical Value(0.05) = 0.747
Data not Gamma Distributed
Best Fit Line
Cr Ti Pen
1.5
1.2
0.9
0.6
0.3
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Theoretical Quantiles of Gamma Distribution

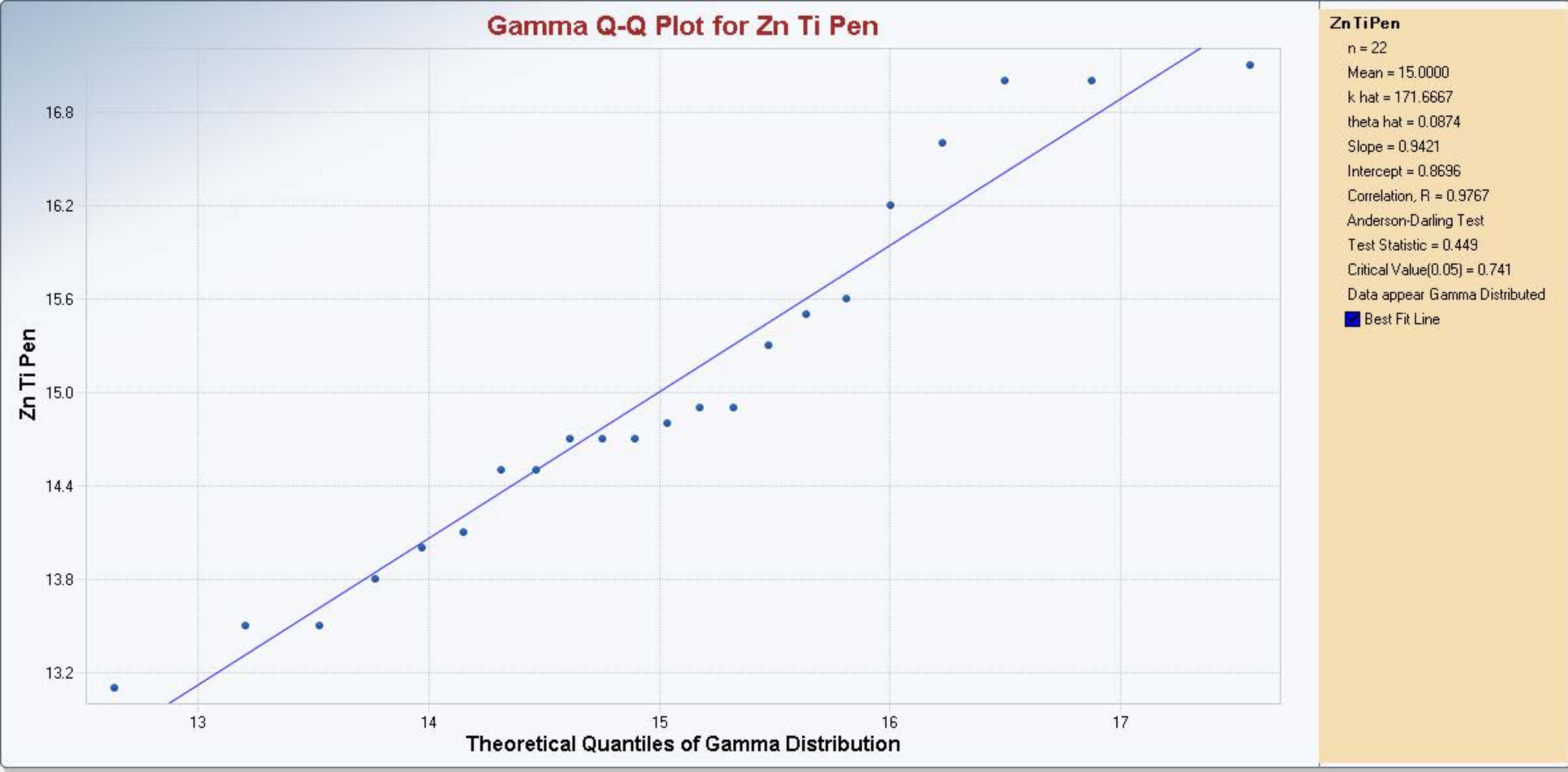

Gamma Q-Q Plot for Cu Ti Pen
Cu Ti Pen
1.40
1.30
1.20
1.10
1.00
0.90
0.9
1.0
1.1
1.2
1.3
1.4
1.5
Theoretical Quantiles of Gamma Distribution
Cu Ti Pen
n = 22
Mean = 1.1587
k hat = 53.6417
theta hat = 0.0216
Slope = 0.9414
Intercept = 0.0683
Correlation, R = 0.9803
Anderson-Darling Test
Test Statistic = 0.471
Critical Value(0.05) = 0.743
Data appear Gamma Distributed
Best Fit Line

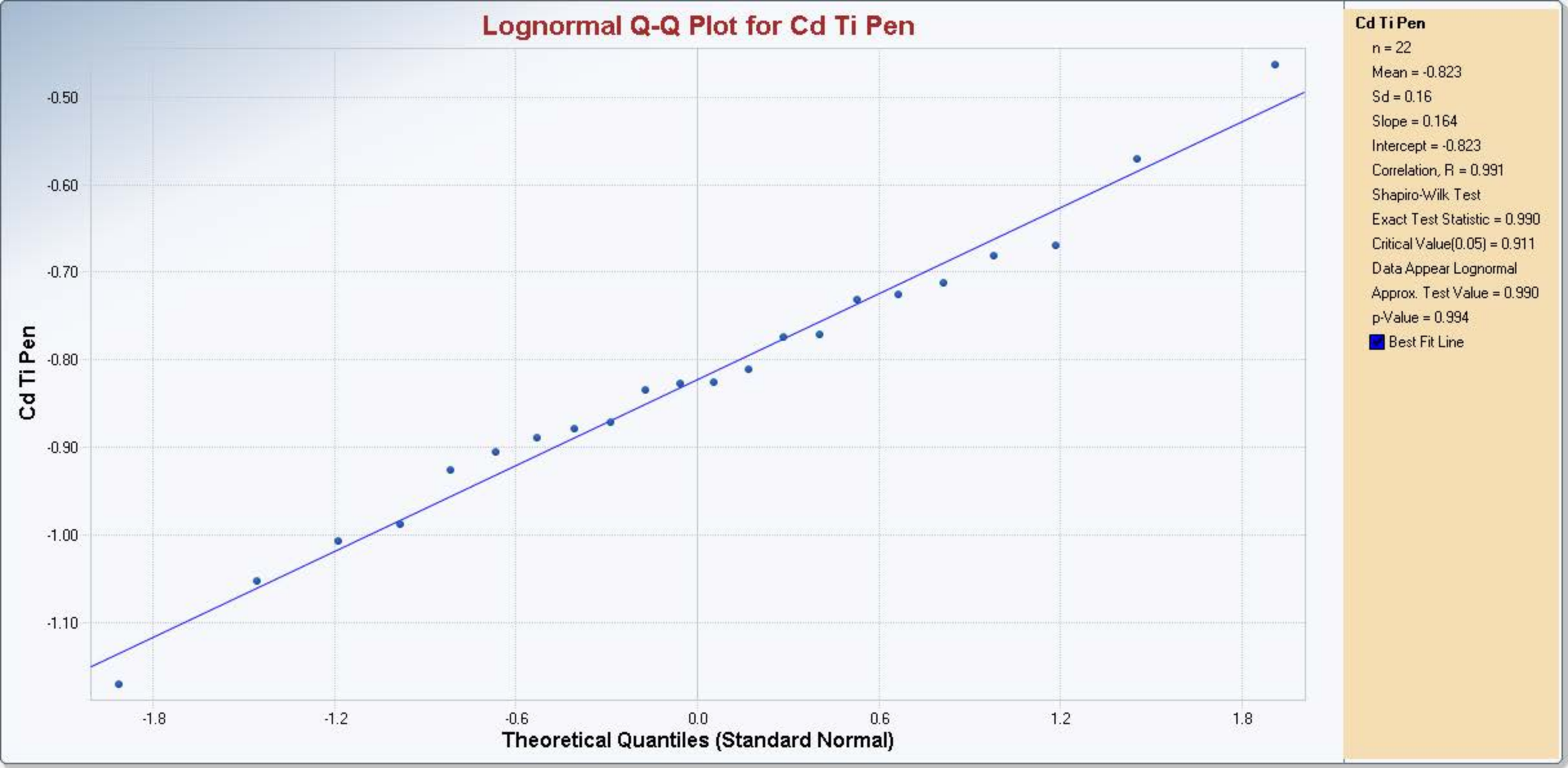

Gamma Q-Q Plot for Inorg As Ti Pen
Inorg As Ti Pen
0.0550
0.0500
0.0450
0.0400
0.0350
0.0300
0.025
0.030
0.035
0.040
0.045
Theoretical Quantiles of Gamma Distribution
InorgAsTiPen
n = 22
Mean = 0.0346
k hat = 33.4498
theta hat = 0.0010
Slope = 0.9692
Intercept = 0.0011
Correlation, R = 0.9441
Anderson-Darling Test
Test Statistic = 0.791
Critical Value(0.05) = 0.742
Data not Gamma Distributed
Best Fit Line

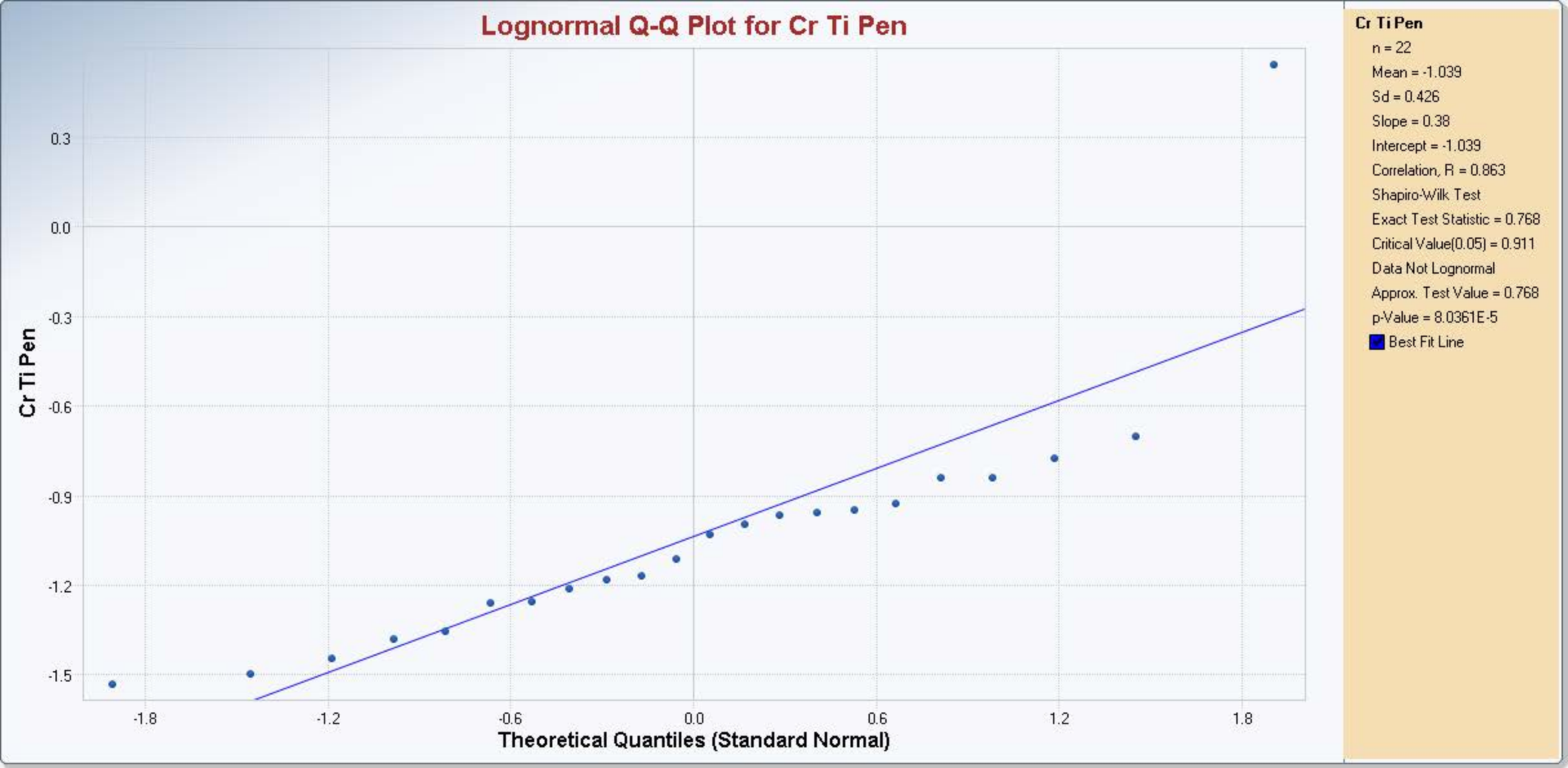

Gamma Q-Q Plot for Meth Hg Ti Pen
Meth Hg Ti Pen
6.6
6.0
5.4
4.8
4.2
3.6
3.0
2.4
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Theoretical Quantiles of Gamma Distribution
Meth Hg Ti Pen
n = 22
Mean = 3.8773
k hat = 22.8748
theta hat = 0.1695
Slope = 0.9396
Intercept = 0.2374
Correlation, R = 0.9483
Anderson-Darling Test
Test Statistic = 0.487
Critical Value(0.05) = 0.741
Data appear Gamma Distributed
Best Fit Line

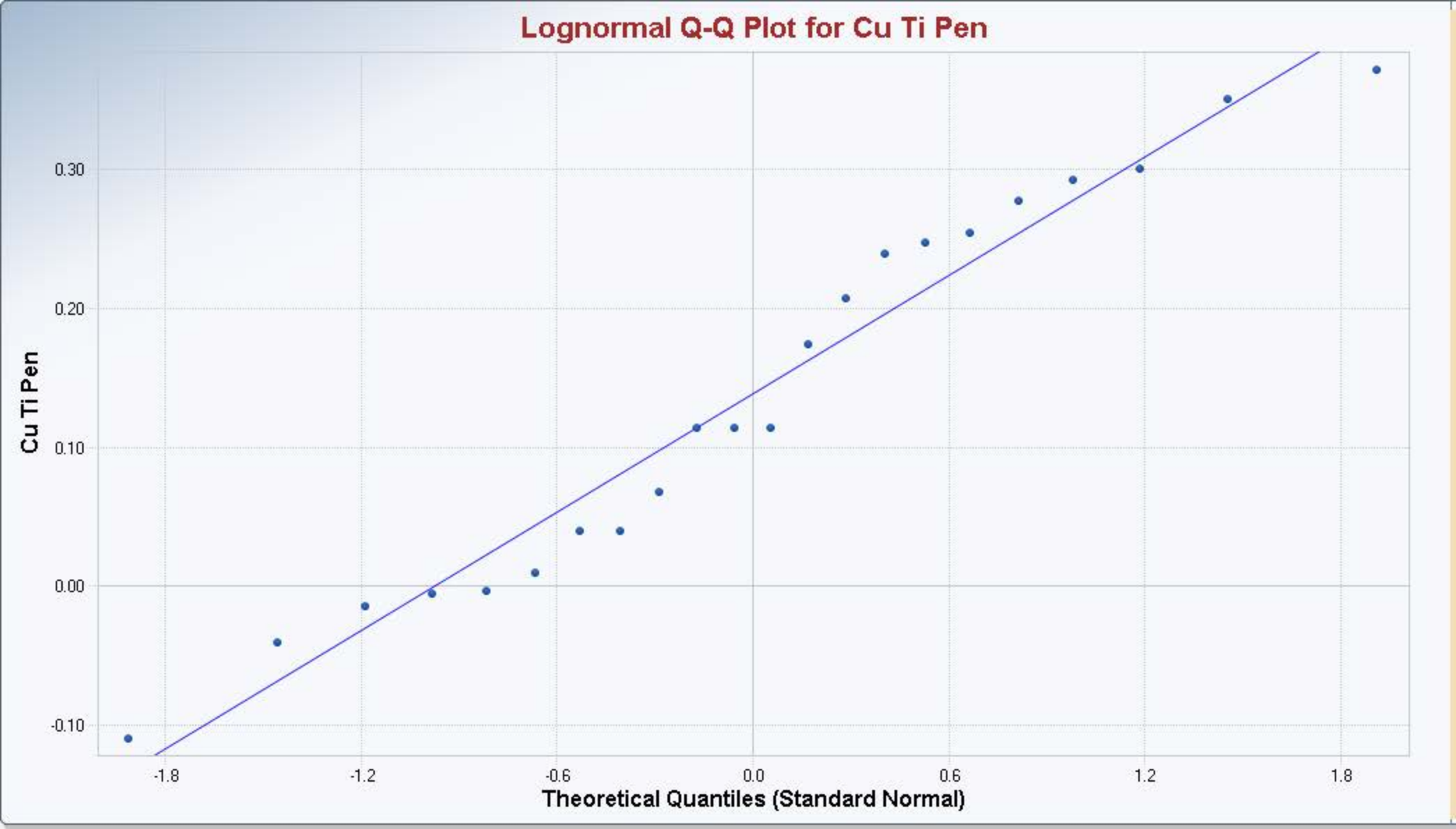

Gamma Q-Q Plot for Ni Ti Pen
Ni Ti Pen
Theoretical Quantiles of Gamma Distribution
1.2
1.0
0.8
0.6
0.4
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0.65
0.70
0.75
NiTiPen
n = 22
Mean = 0.3993
k hat = 8.1460
theta hat = 0.0490
Slope = 1.0150
Intercept = -0.0049
Correlation, R = 0.7900
Anderson-Darling Test
Test Statistic = 1.601
Critical Value(0.05) = 0.745
Data not Gamma Distributed
Best Fit Line


Gamma Q-Q Plot for Pb Ti Pen
Pb Ti Pen
0.060
0.050
0.040
0.030
0.020
0.010
0.015
0.020
0.025
0.030
0.035
0.040
Theoretical Quantiles of Gamma Distribution
Pb Ti Pen
n = 22
Mean = 0.0220
k hat = 7.3641
theta hat = 0.0030
Slope = 1.0390
Intercept = -0.0008
Correlation, R = 0.8085
Anderson-Darling Test
Test Statistic = 1.445
Critical Value(0.05) = 0.745
Data not Gamma Distributed
Best Fit Line


Gamma Q-Q Plot for Zn Ti Pen
Zn Ti Pen
16.8
16.2
15.6
15.0
14.4
13.8
13.2
13
14
15
16
17
Theoretical Quantiles of Gamma Distribution
Zn Ti Pen
n = 22
Mean = 15.0000
k hat = 171.6667
theta hat = 0.0874
Slope = 0.9421
Intercept = 0.8696
Correlation, R = 0.9767
Anderson-Darling Test
Test Statistic = 0.449
Critical Value(0.05) = 0.741
Data appear Gamma Distributed
Best Fit Line

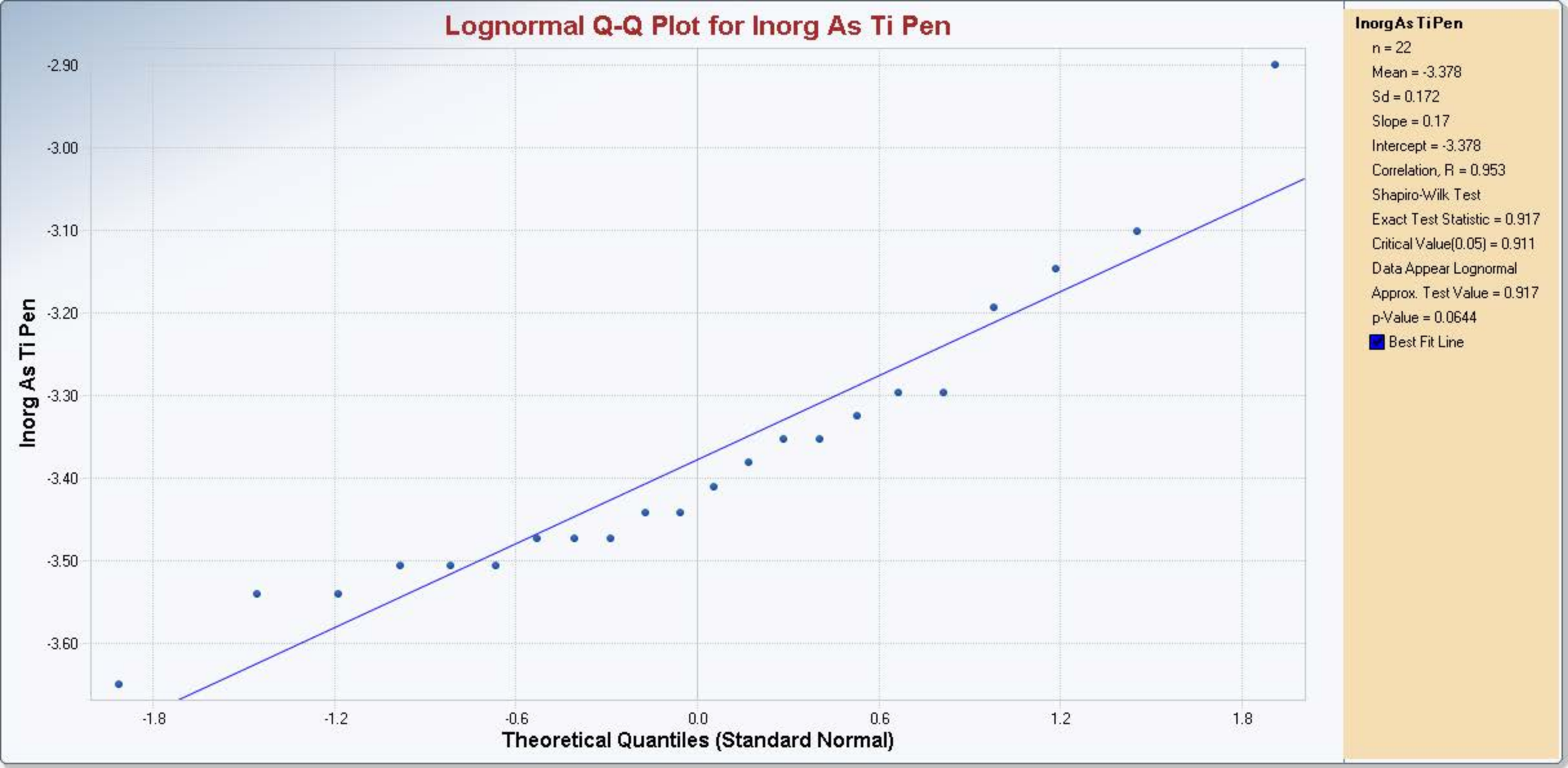

Lognormal Q-Q Plot for Cd Ti Pen
Cd Ti Pen
-0.50
-0.60
-0.70
-0.80
-0.90
-1.00
-1.10
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Cd Ti Pen
n = 22
Mean = -0.823
Sd = 0.16
Slope = 0.164
Intercept = -0.823
Correlation, R = 0.991
Shapiro-Wilk Test
Exact Test Statistic = 0.990
Critical Value(0.05) = 0.911
Data Appear Lognormal
Approx. Test Value = 0.990
p-Value = 0.994
Best Fit Line

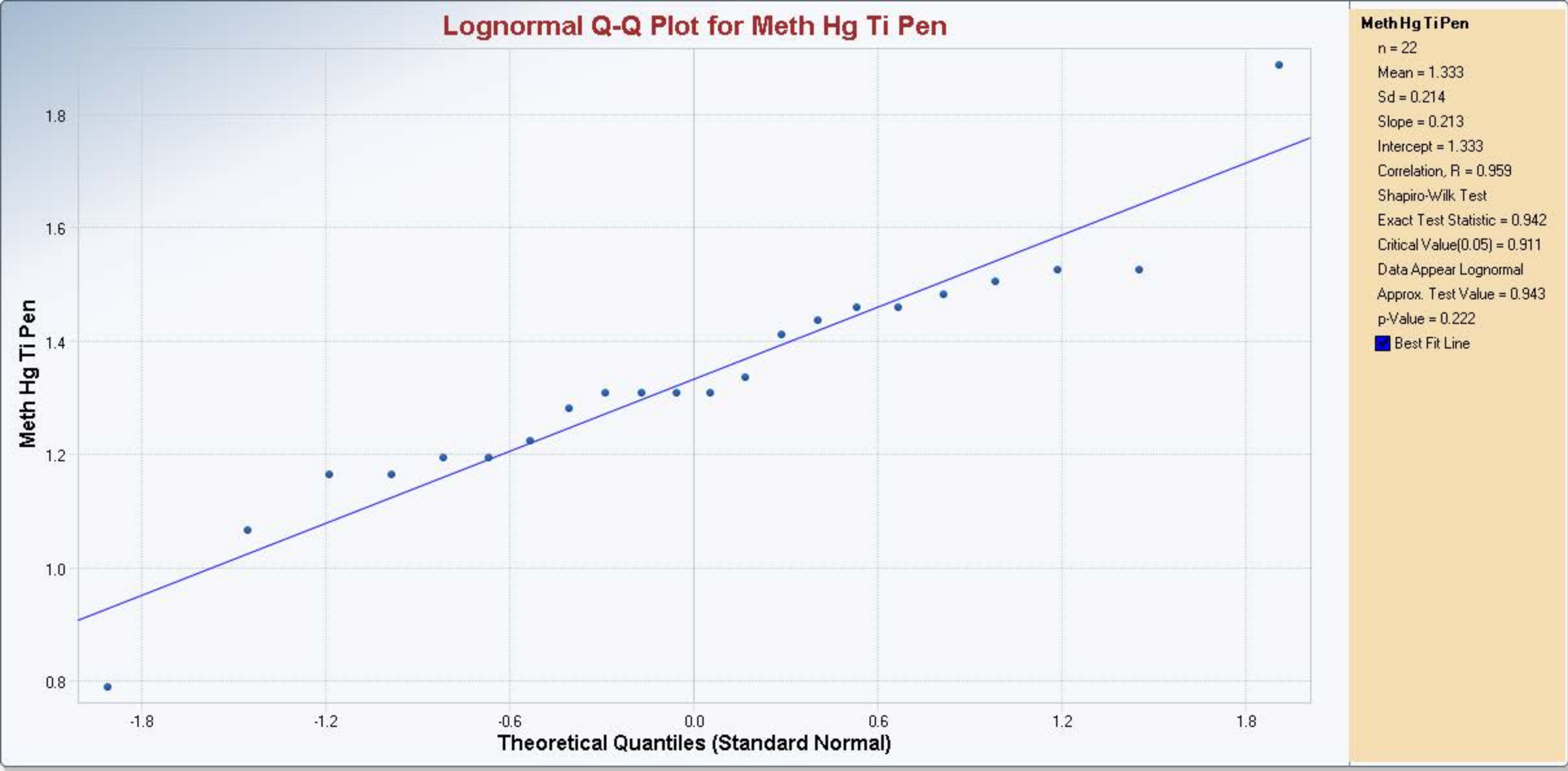

Lognormal Q-Q Plot for Cr Ti Pen
Cr Ti Pen
0.3
0.0
-0.3
-0.6
-0.9
-1.2
-1.5
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Cr Ti Pen
n = 22
Mean = -1.039
Sd = 0.426
Slope = 0.38
Intercept = -1.039
Correlation, R = 0.863
Shapiro-Wilk Test
Exact Test Statistic = 0.768
Critical Value(0.05) = 0.911
Data Not Lognormal
Approx. Test Value = 0.768
p-Value = 8.0361E-5
Best Fit Line

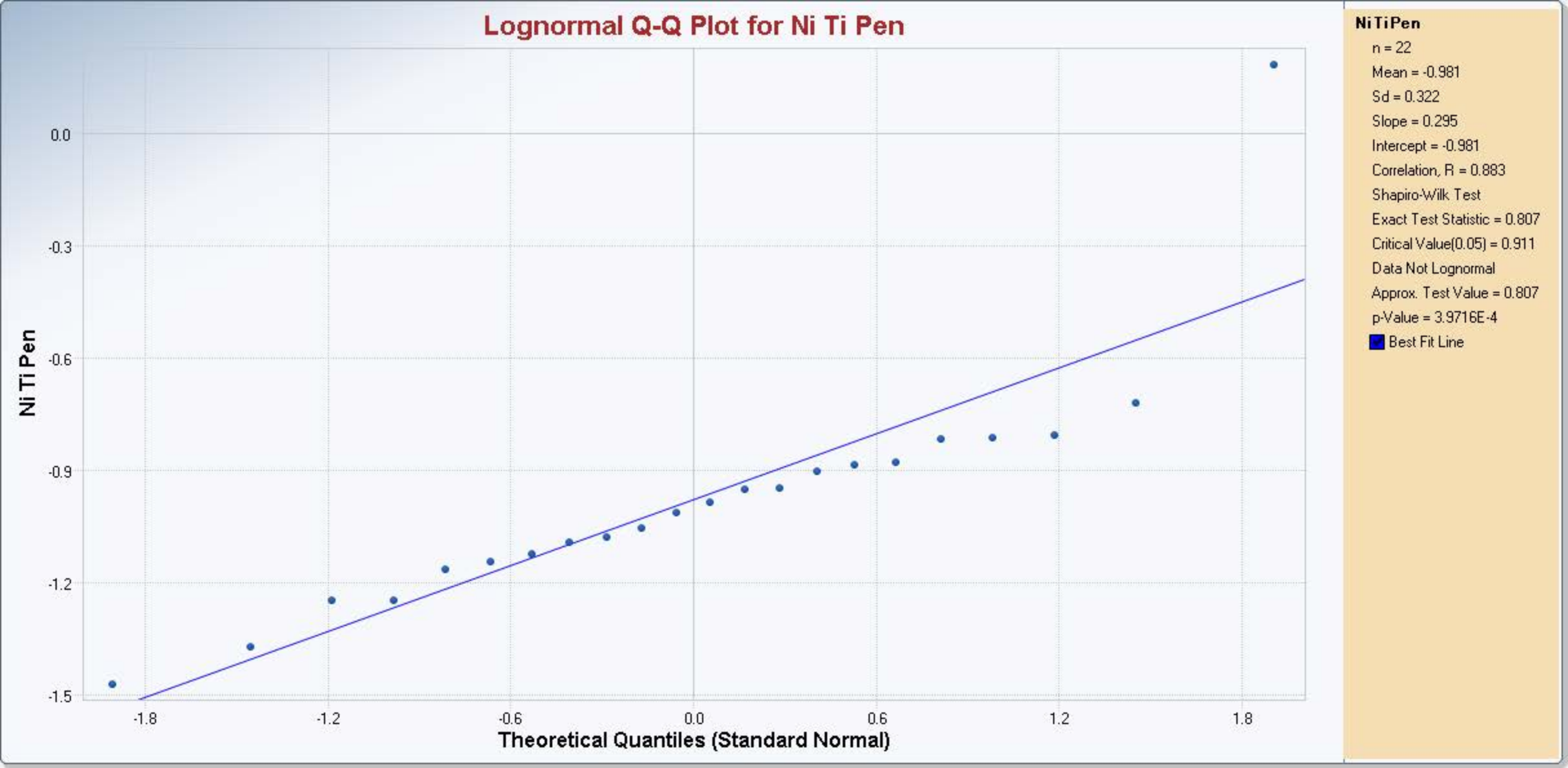


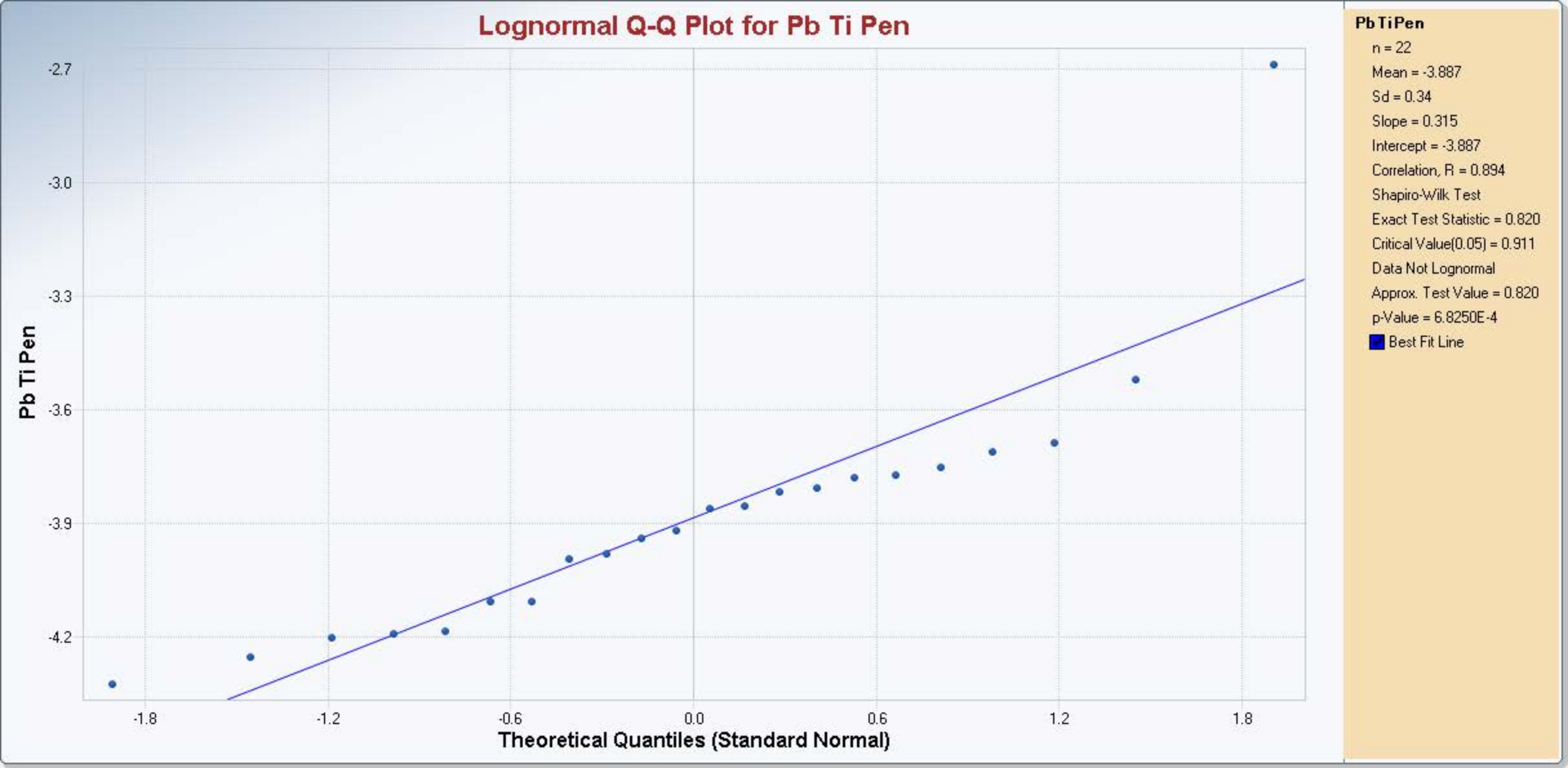
Cu Ti Pen

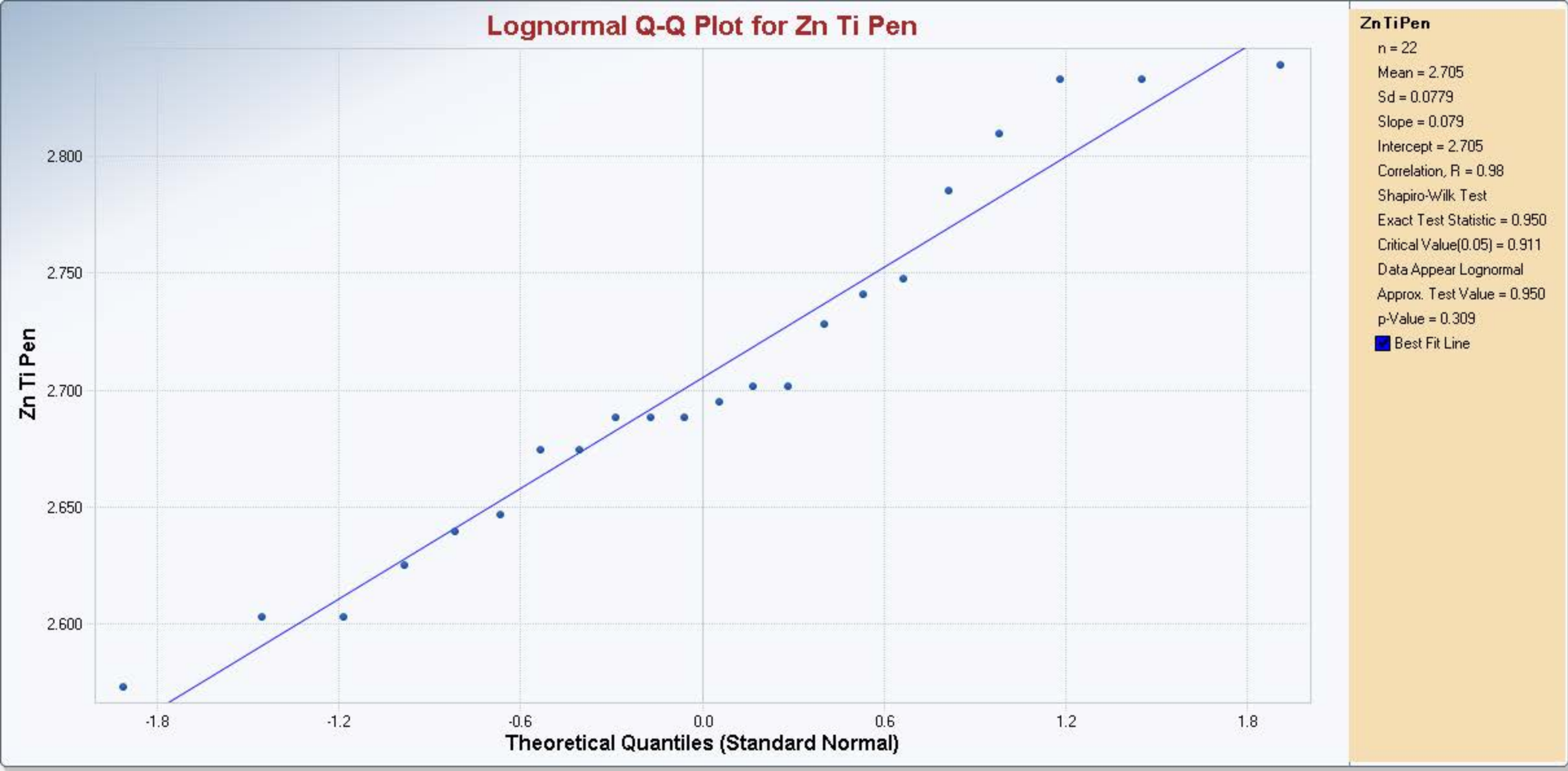
n = 22
Mean = 0.138
Sd = 0.14
Slope = 0.142
Intercept = 0.138
Correlation, R = 0.982
Shapiro-Wilk Test
Exact Test Statistic = 0.953
Critical Value(0.05) = 0.911
Data Appear Lognormal
Approx. Test Value = 0.953
p-Value = 0.366
Best Fit Line

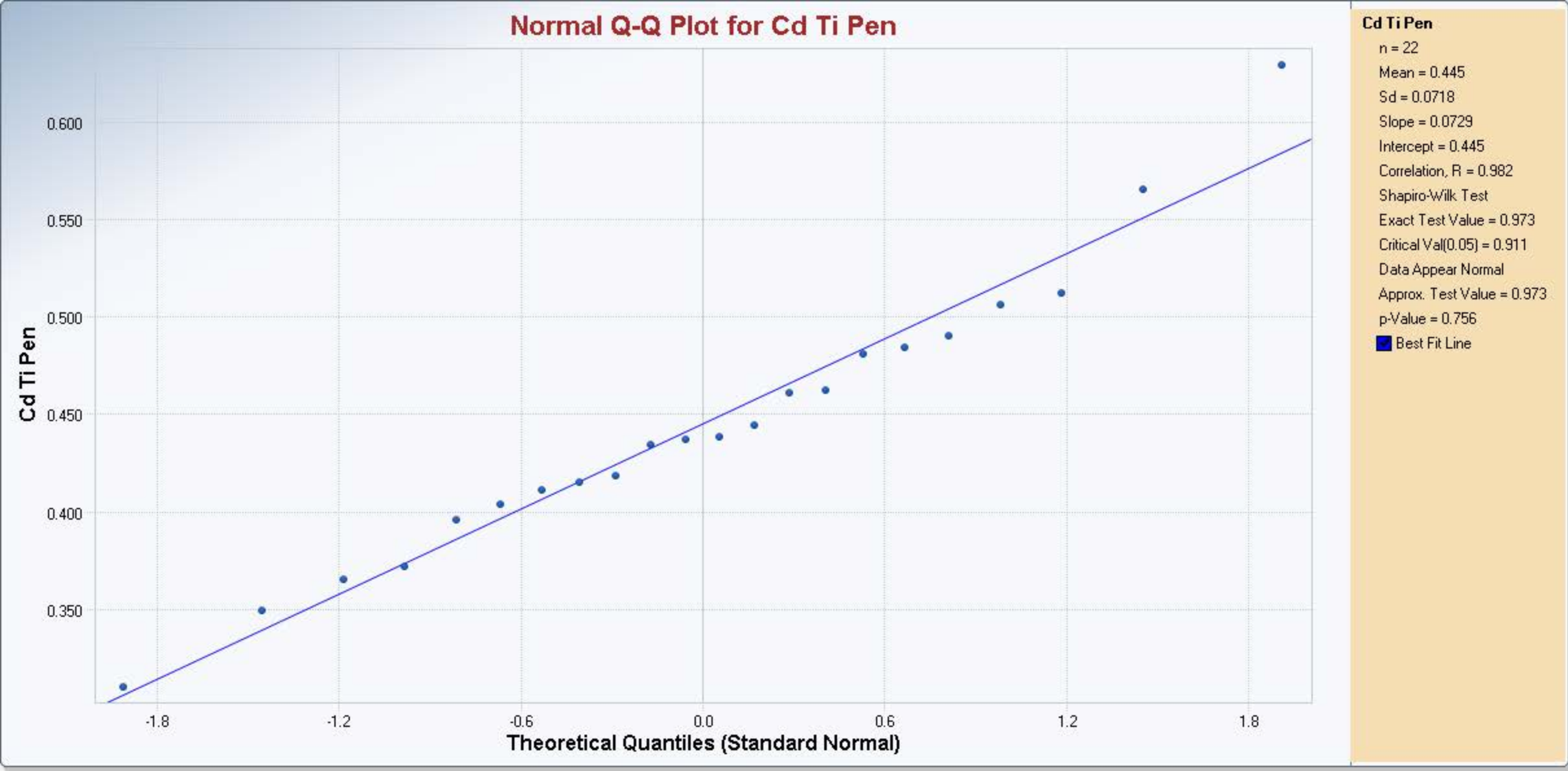

Lognormal Q-Q Plot for Inorg As Ti Pen
Inorg As Ti Pen
-2.90
-3.00
-3.10
-3.20
-3.30
-3.40
-3.50
-3.60
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
InorgAs Ti Pen
n = 22
Mean = -3.378
Sd = 0.172
Slope = 0.17
Intercept = -3.378
Correlation, R = 0.953
Shapiro-Wilk Test
Exact Test Statistic = 0.917
Critical Value(0.05) = 0.911
Data Appear Lognormal
Approx. Test Value = 0.917
p-Value = 0.0644
Best Fit Line

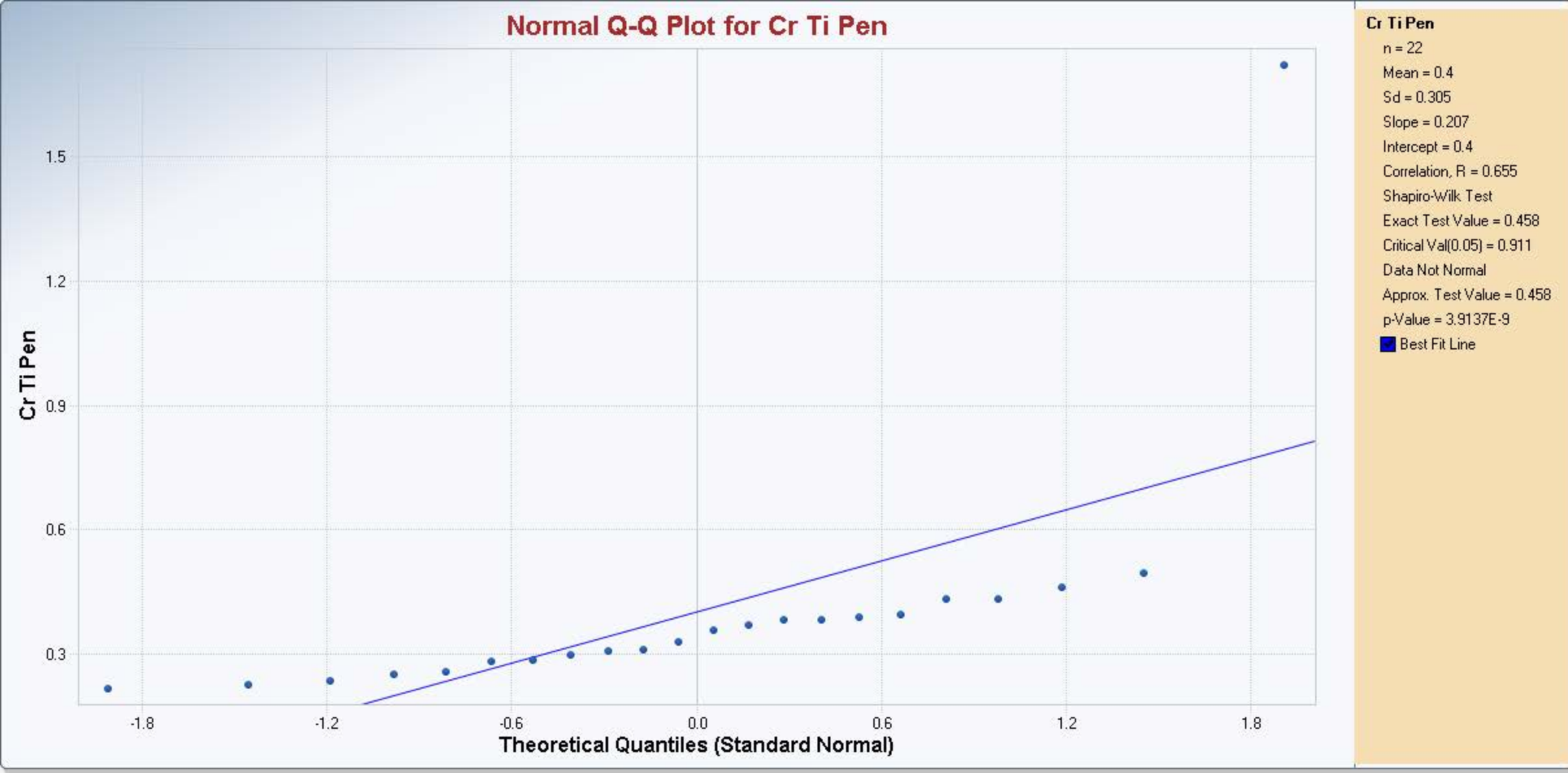

Lognormal Q-Q Plot for Meth Hg Ti Pen
Meth Hg Ti Pen
1.8
1.6
1.4
1.2
1.0
0.8
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Meth Hg Ti Pen
n = 22
Mean = 1.333
Sd = 0.214
Slope = 0.213
Intercept = 1.333
Correlation, R = 0.959
Shapiro-Wilk Test
Exact Test Statistic = 0.942
Critical Value(0.05) = 0.911
Data Appear Lognormal
Approx. Test Value = 0.943
p-Value = 0.222
Best Fit Line

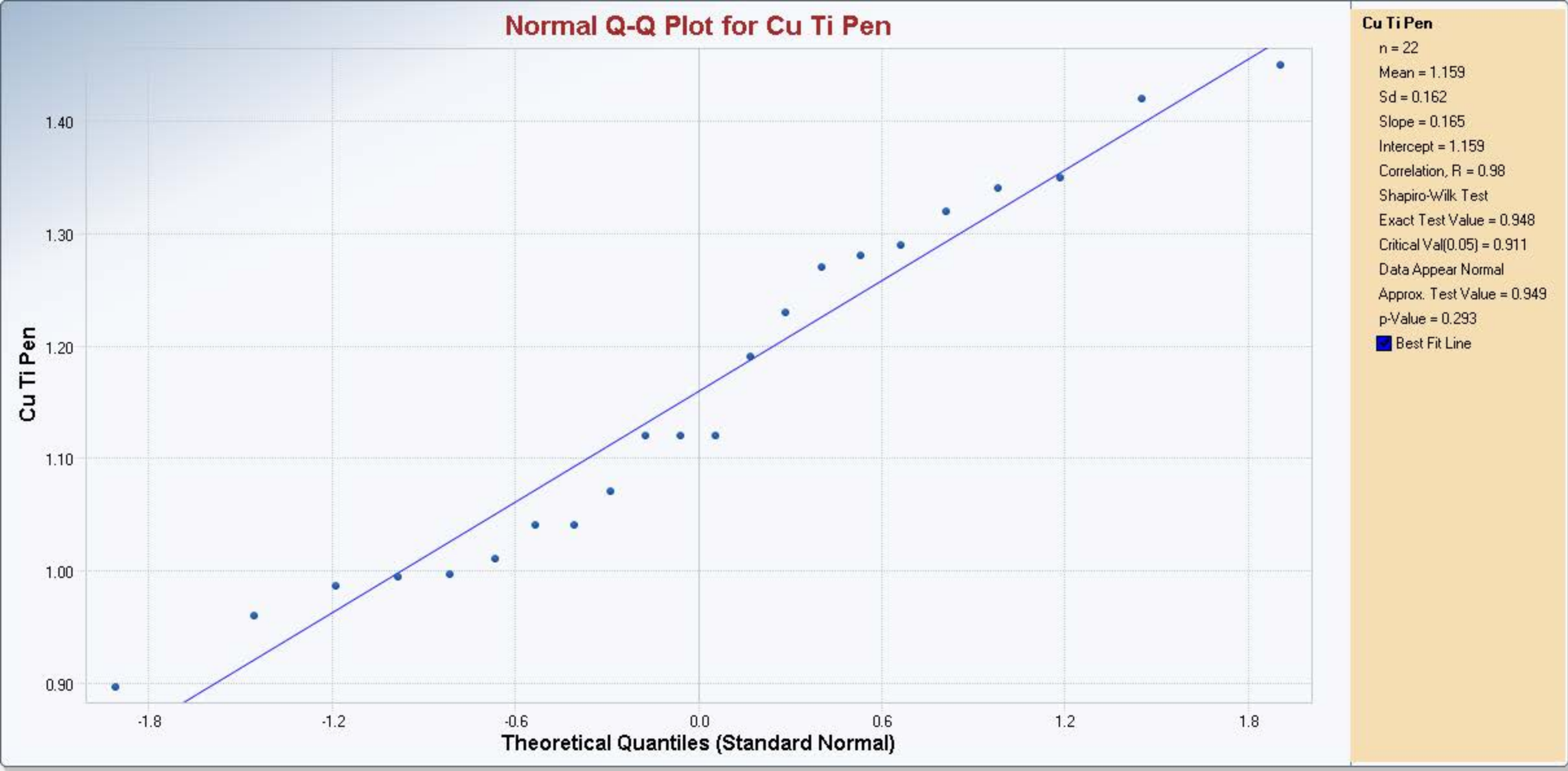

Lognormal Q-Q Plot for Ni Ti Pen
Ni Ti Pen
0.0
-0.3
-0.6
-0.9
-1.2
-1.5
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
NiTiPen
n = 22
Mean = -0.981
Sd = 0.322
Slope = 0.295
Intercept = -0.981
Correlation, R = 0.883
Shapiro-Wilk Test
Exact Test Statistic = 0.807
Critical Value(0.05) = 0.911
Data Not Lognormal
Approx. Test Value = 0.807
p-Value = 3.9716E-4
Best Fit Line

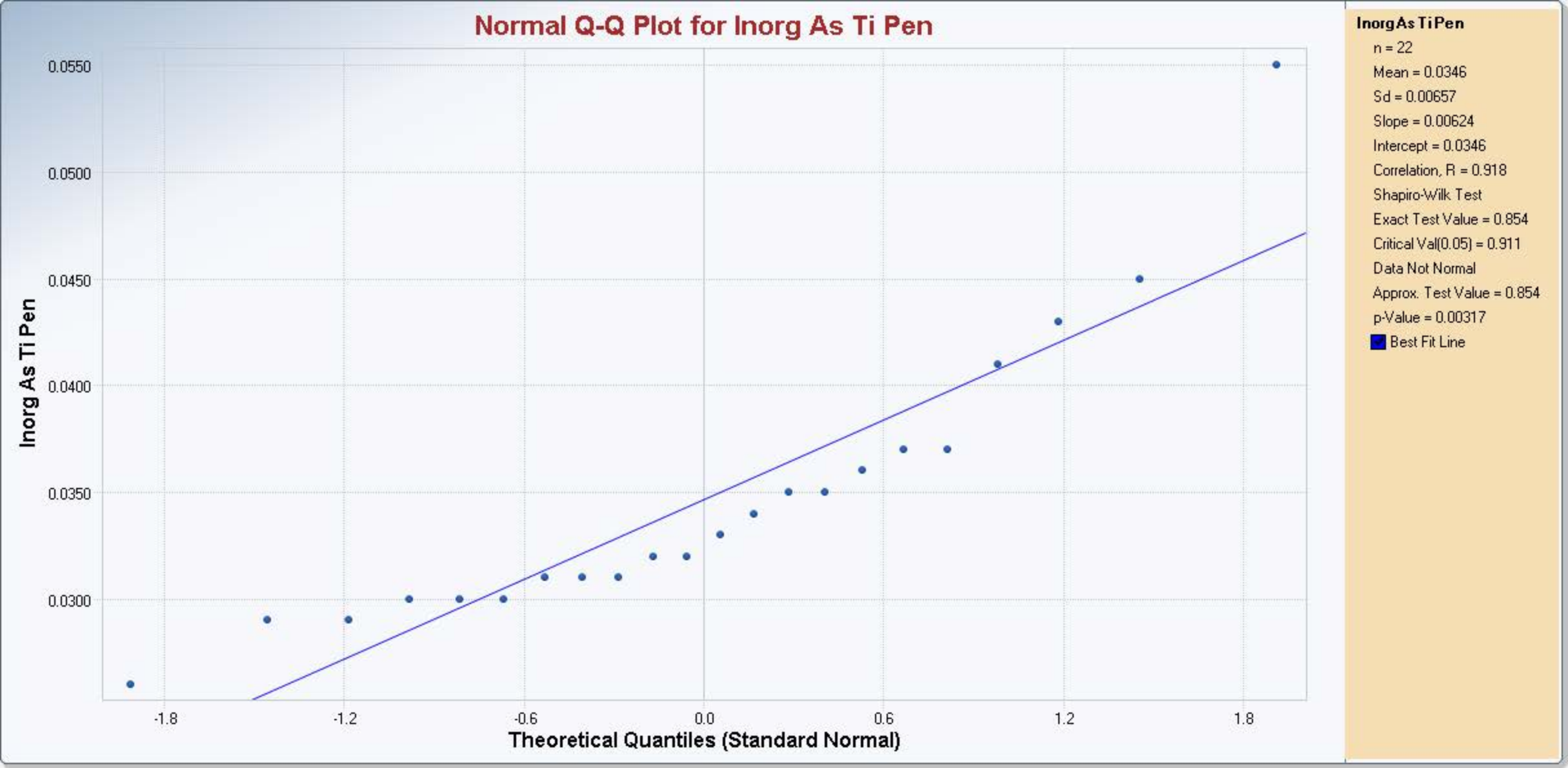

Lognormal Q-Q Plot for Pb Ti Pen
Pb Ti Pen
-2.7
-3.0
-3.3
-3.6
-3.9
-4.2
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Pb Ti Pen
n = 22
Mean = -3.887
Sd = 0.34
Slope = 0.315
Intercept = -3.887
Correlation, R = 0.894
Shapiro-Wilk Test
Exact Test Statistic = 0.820
Critical Value(0.05) = 0.911
Data Not Lognormal
Approx. Test Value = 0.820
p-Value = 6.8250E-4
Best Fit Line

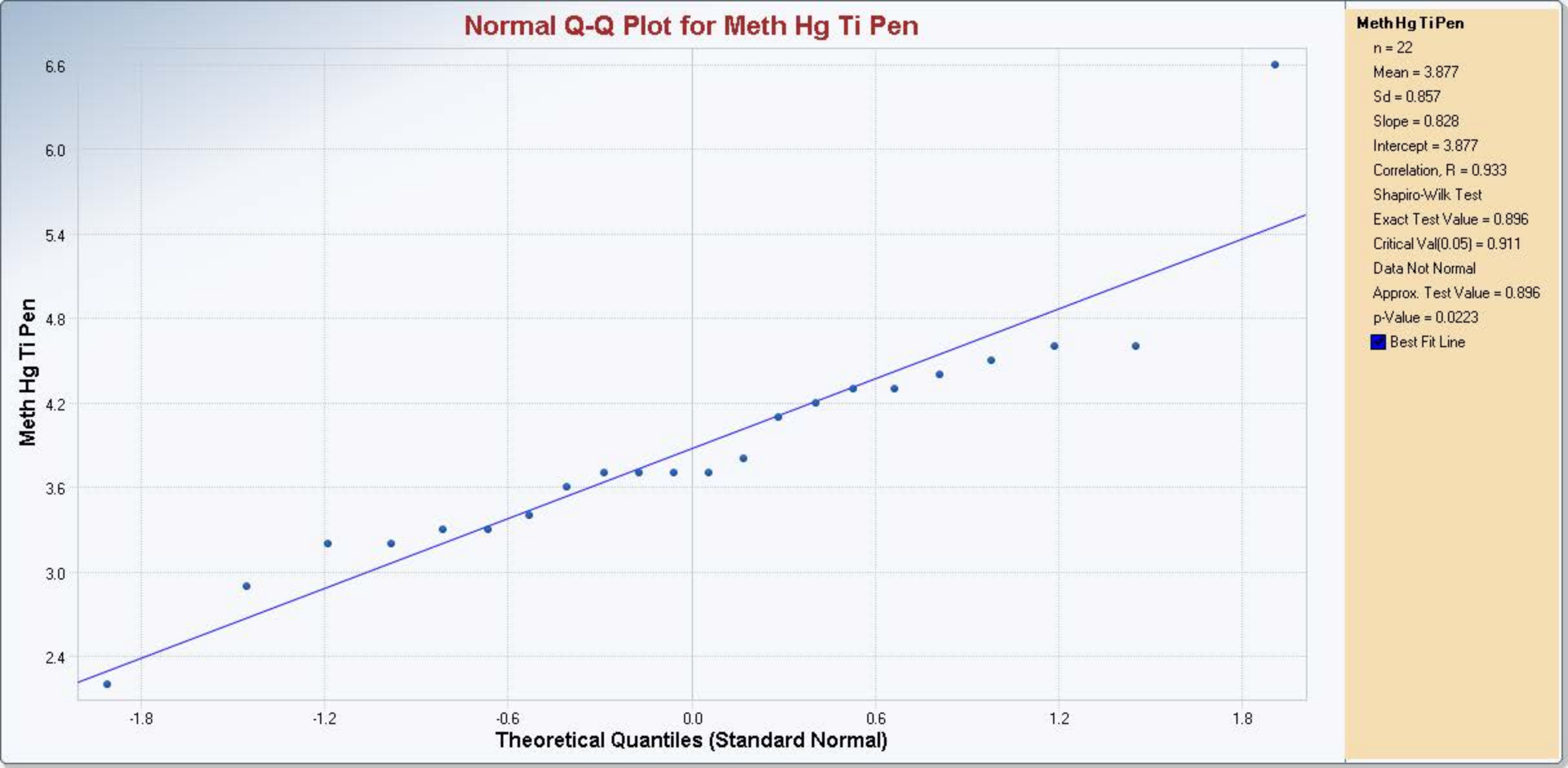

Lognormal Q-Q Plot for Zn Ti Pen
Zn Ti Pen
2.800
2.750
2.700
2.650
2.600
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
ZnTiPen
n = 22
Mean = 2.705
Sd = 0.0779
Slope = 0.079
Intercept = 2.705
Correlation, R = 0.98
Shapiro-Wilk Test
Exact Test Statistic = 0.950
Critical Value(0.05) = 0.911
Data Appear Lognormal
Approx. Test Value = 0.950
p-Value = 0.309
Best Fit Line

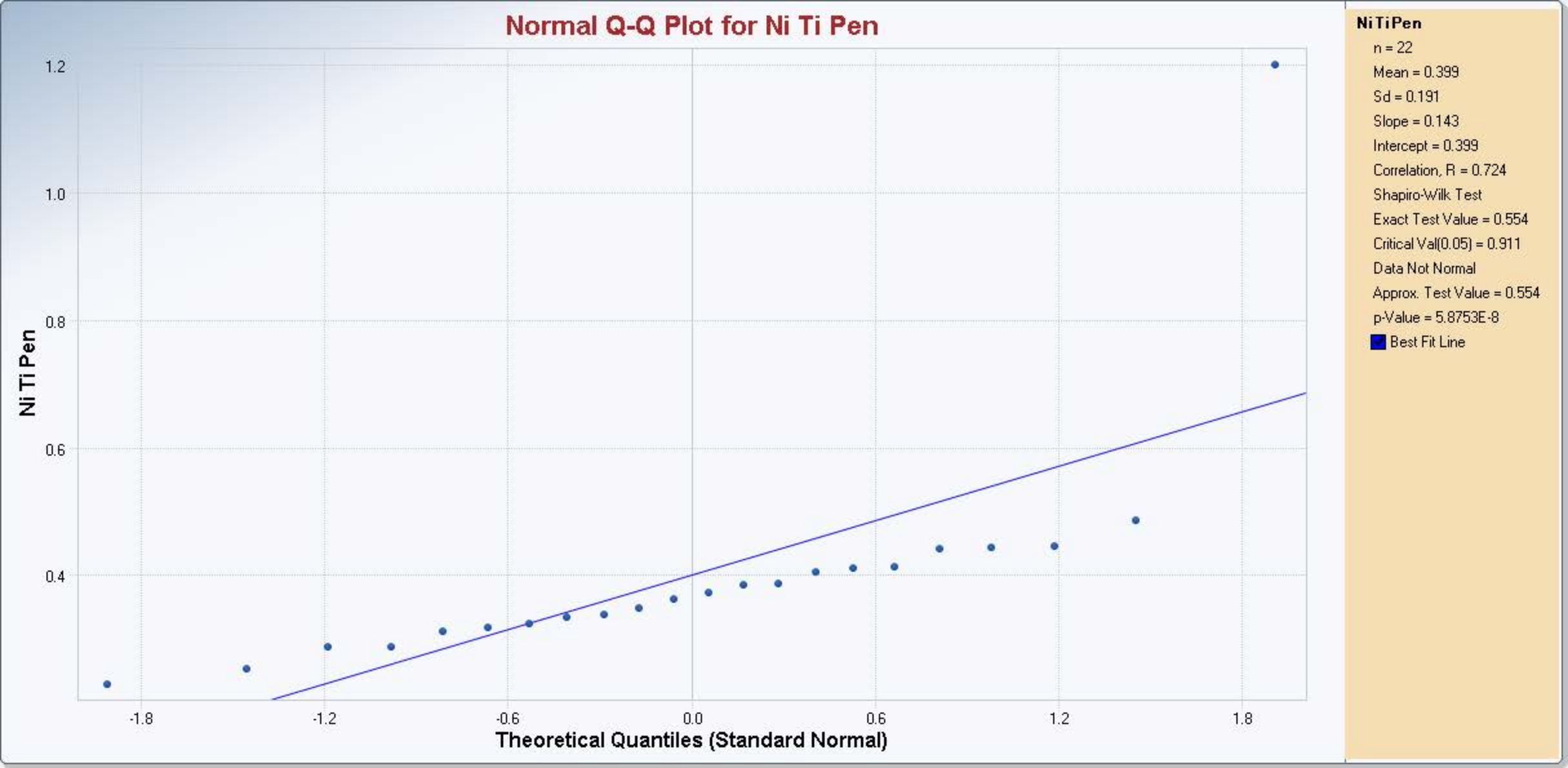

Normal Q-Q Plot for Cd Ti Pen
Cd Ti Pen
0.600
0.550
0.500
0.450
0.400
0.350
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Cd Ti Pen
n = 22
Mean = 0.445
Sd = 0.0718
Slope = 0.0729
Intercept = 0.445
Correlation, R = 0.982
Shapiro-Wilk Test
Exact Test Value = 0.973
Critical Val(0.05) = 0.911
Data Appear Normal
Approx. Test Value = 0.973
p-Value = 0.756
Best Fit Line

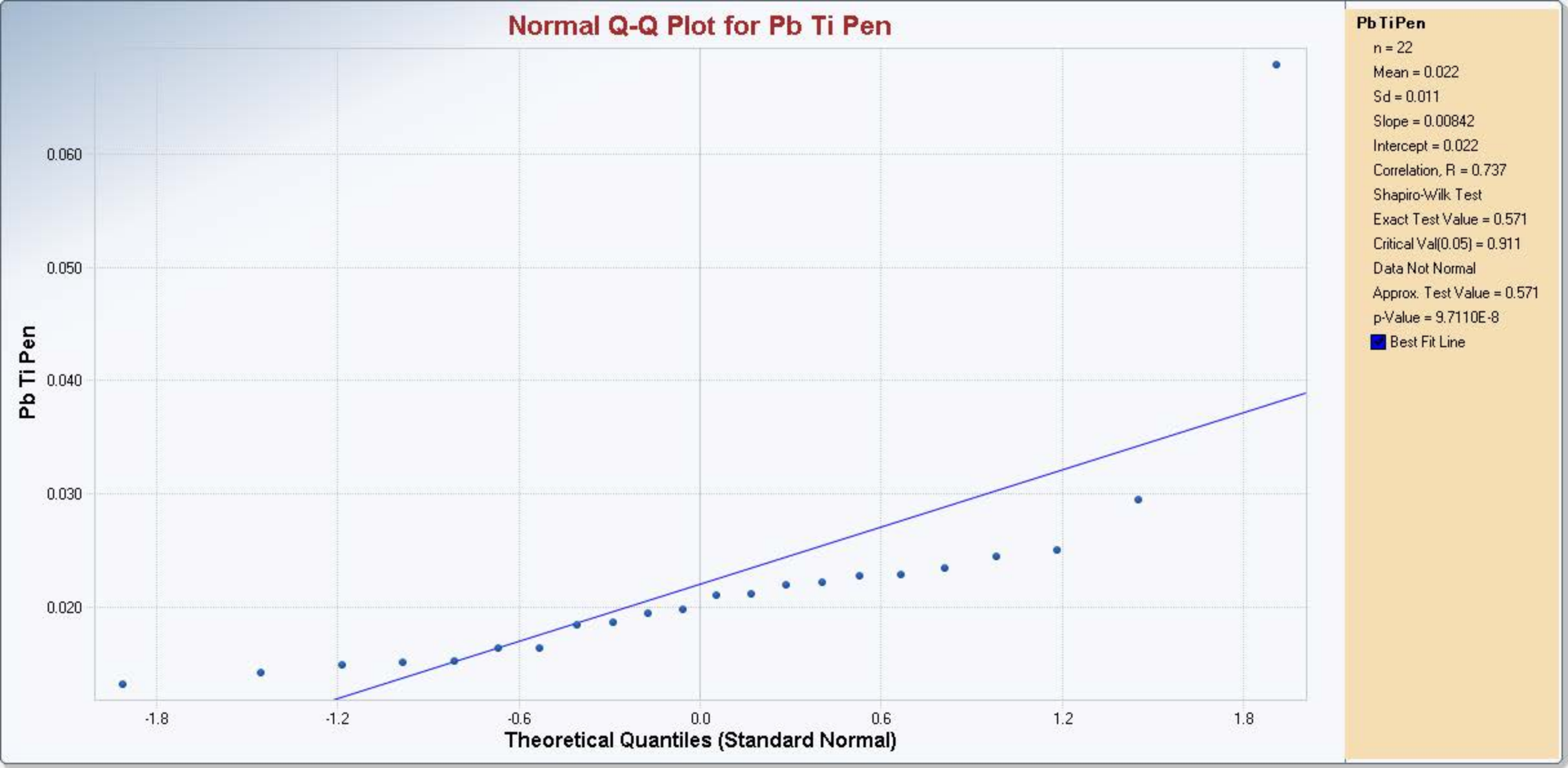

Normal Q-Q Plot for Cr Ti Pen
Cr Ti Pen
n = 22
Mean = 0.4
Sd = 0.305
Slope = 0.207
Intercept = 0.4
Correlation, R = 0.655
Shapiro-Wilk Test
Exact Test Value = 0.458
Critical Val(0.05) = 0.911
Data Not Normal
Approx. Test Value = 0.458
p-Value = 3.9137E-9
Best Fit Line
Cr Ti Pen
1.5
1.2
0.9
0.6
0.3
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)

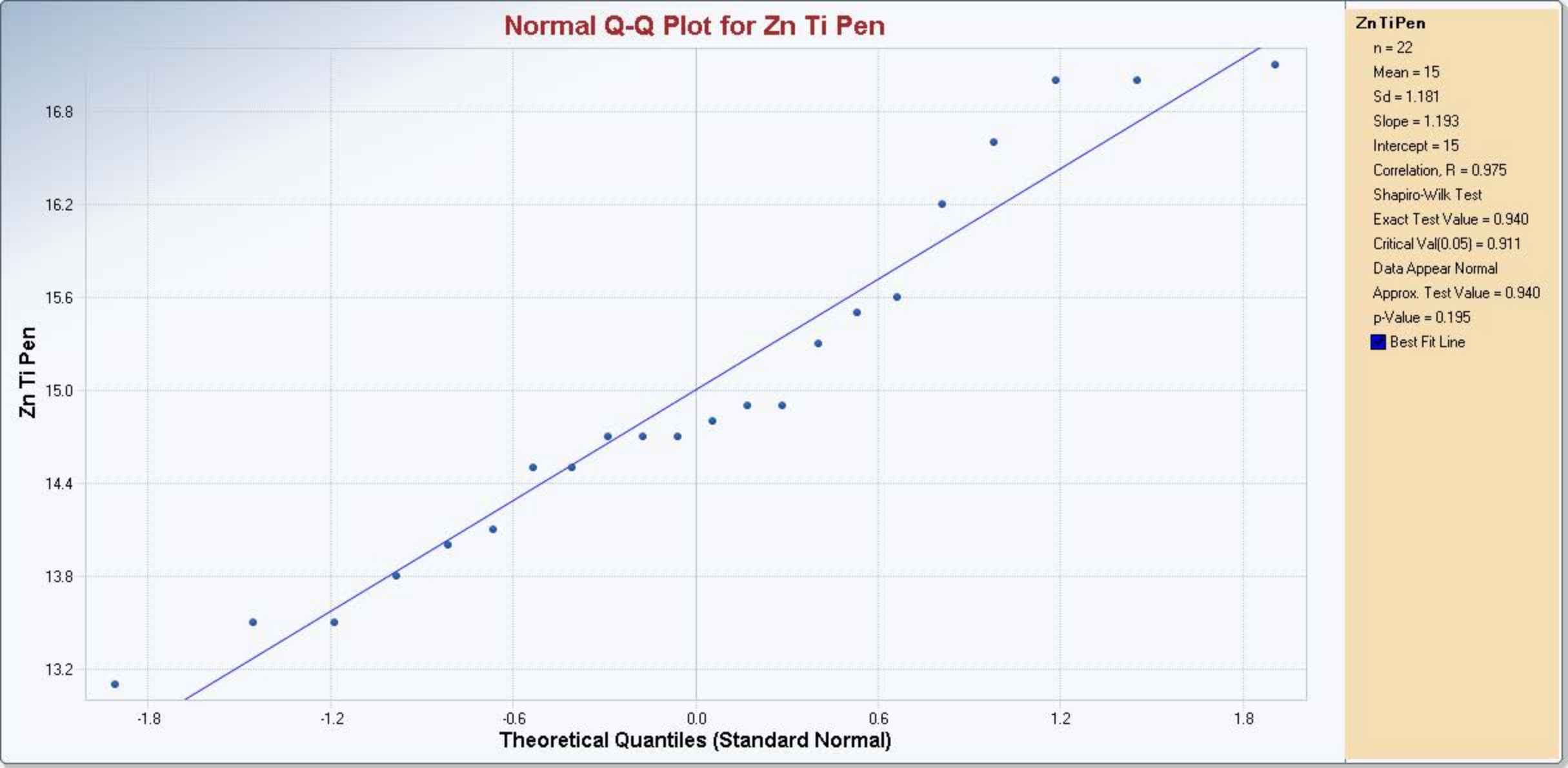

Normal Q-Q Plot for Cu Ti Pen
Cu Ti Pen
1.40
1.30
1.20
1.10
1.00
0.90
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Cu Ti Pen
n = 22
Mean = 1.159
Sd = 0.162
Slope = 0.165
Intercept = 1.159
Correlation, R = 0.98
Shapiro-Wilk Test
Exact Test Value = 0.948
Critical Val(0.05) = 0.911
Data Appear Normal
Approx. Test Value = 0.949
p-Value = 0.293
Best Fit Line

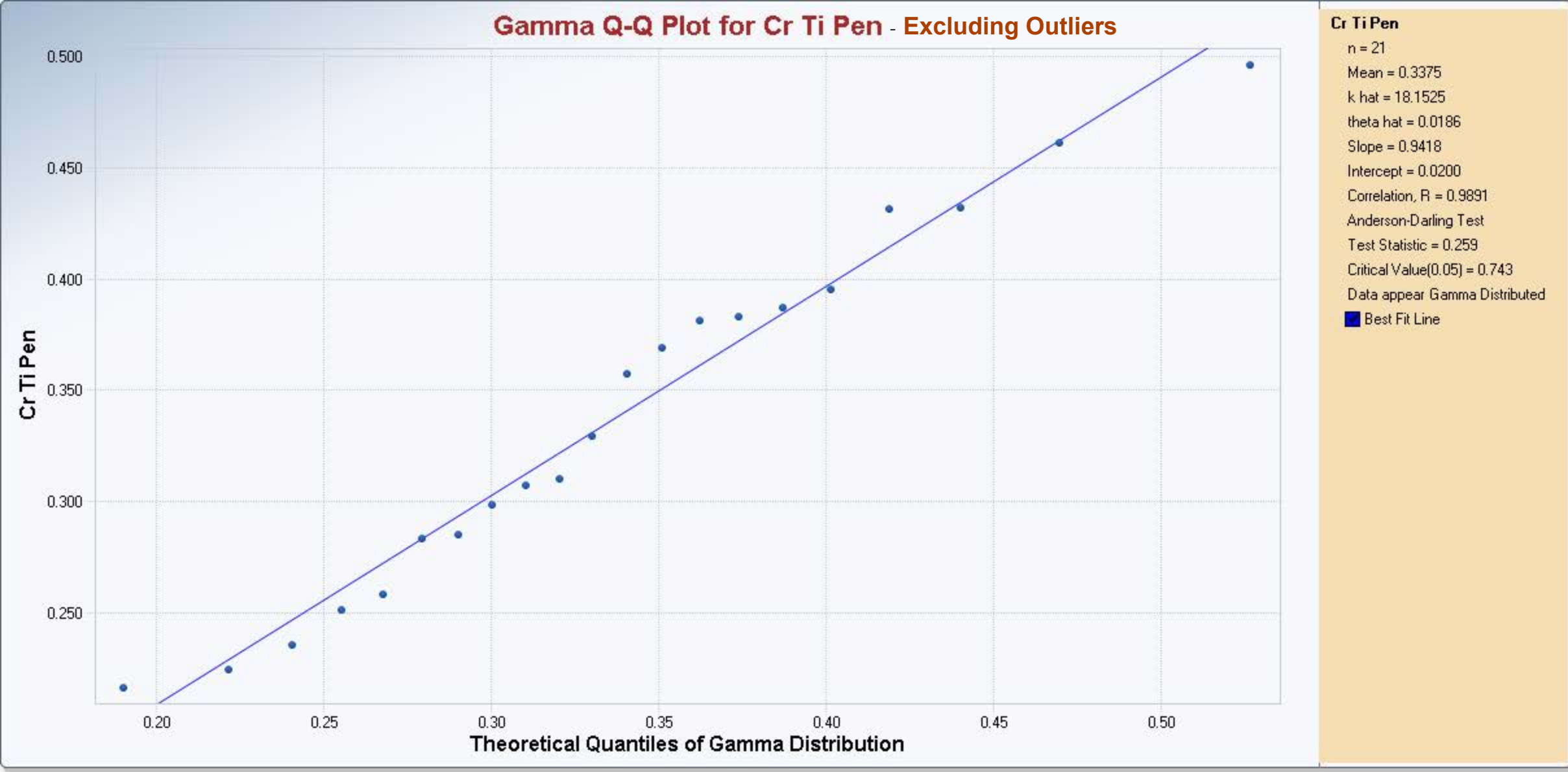

Normal Q-Q Plot for Inorg As Ti Pen
Inorg As Ti Pen
0.0550
0.0500
0.0450
0.0400
0.0350
0.0300
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
InorgAsTiPen
n = 22
Mean = 0.0346
Sd = 0.00657
Slope = 0.00624
Intercept = 0.0346
Correlation, R = 0.918
Shapiro-Wilk Test
Exact Test Value = 0.854
Critical Val(0.05) = 0.911
Data Not Normal
Approx. Test Value = 0.854
p-Value = 0.00317
Best Fit Line

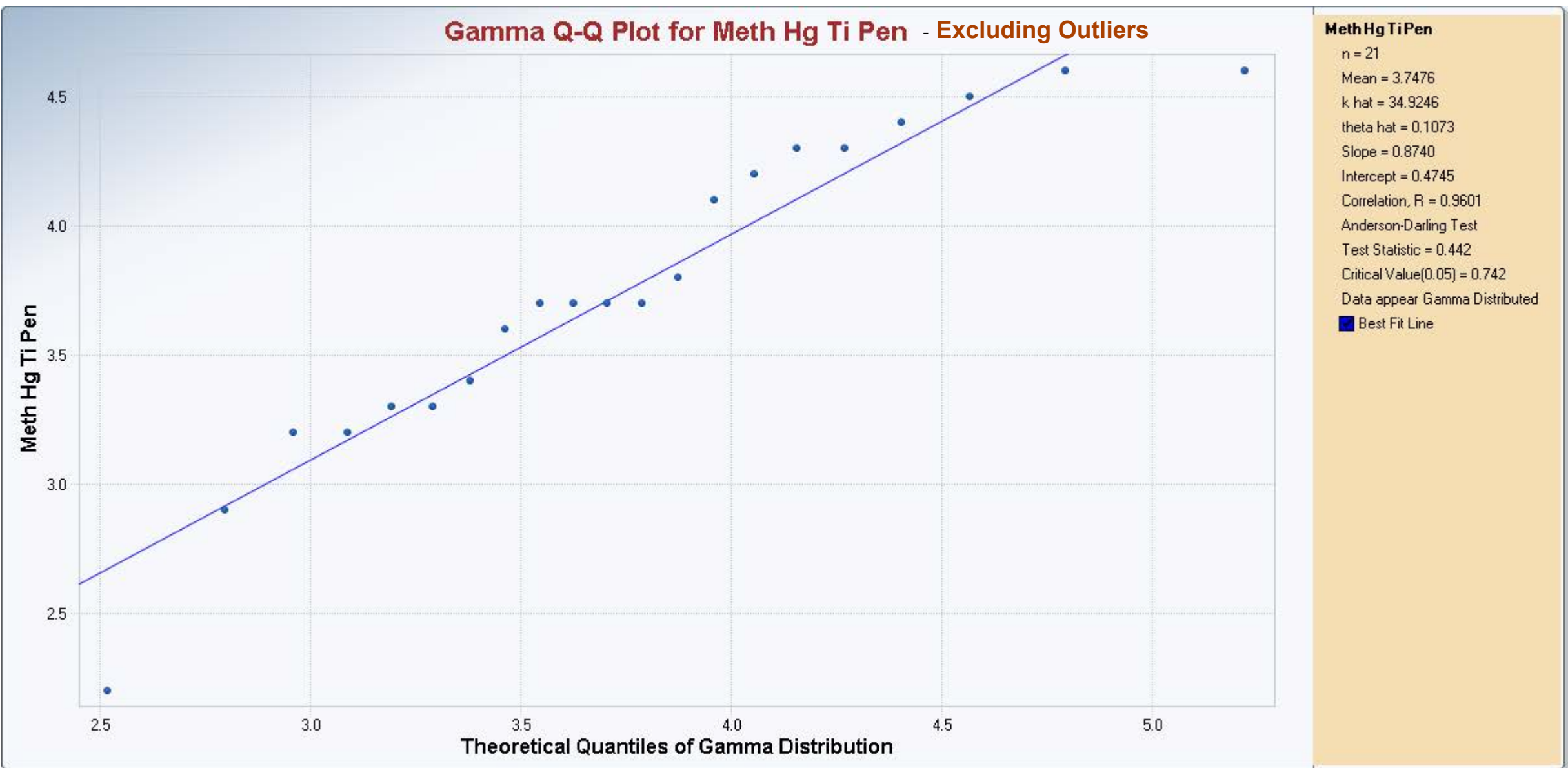

Normal Q-Q Plot for Meth Hg Ti Pen
Meth Hg Ti Pen
6.6
6.0
5.4
4.8
4.2
3.6
3.0
2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Meth Hg Ti Pen
n = 22
Mean = 3.877
Sd = 0.857
Slope = 0.828
Intercept = 3.877
Correlation, R = 0.933
Shapiro-Wilk Test
Exact Test Value = 0.896
Critical Val(0.05) = 0.911
Data Not Normal
Approx. Test Value = 0.896
p-Value = 0.0223
Best Fit Line

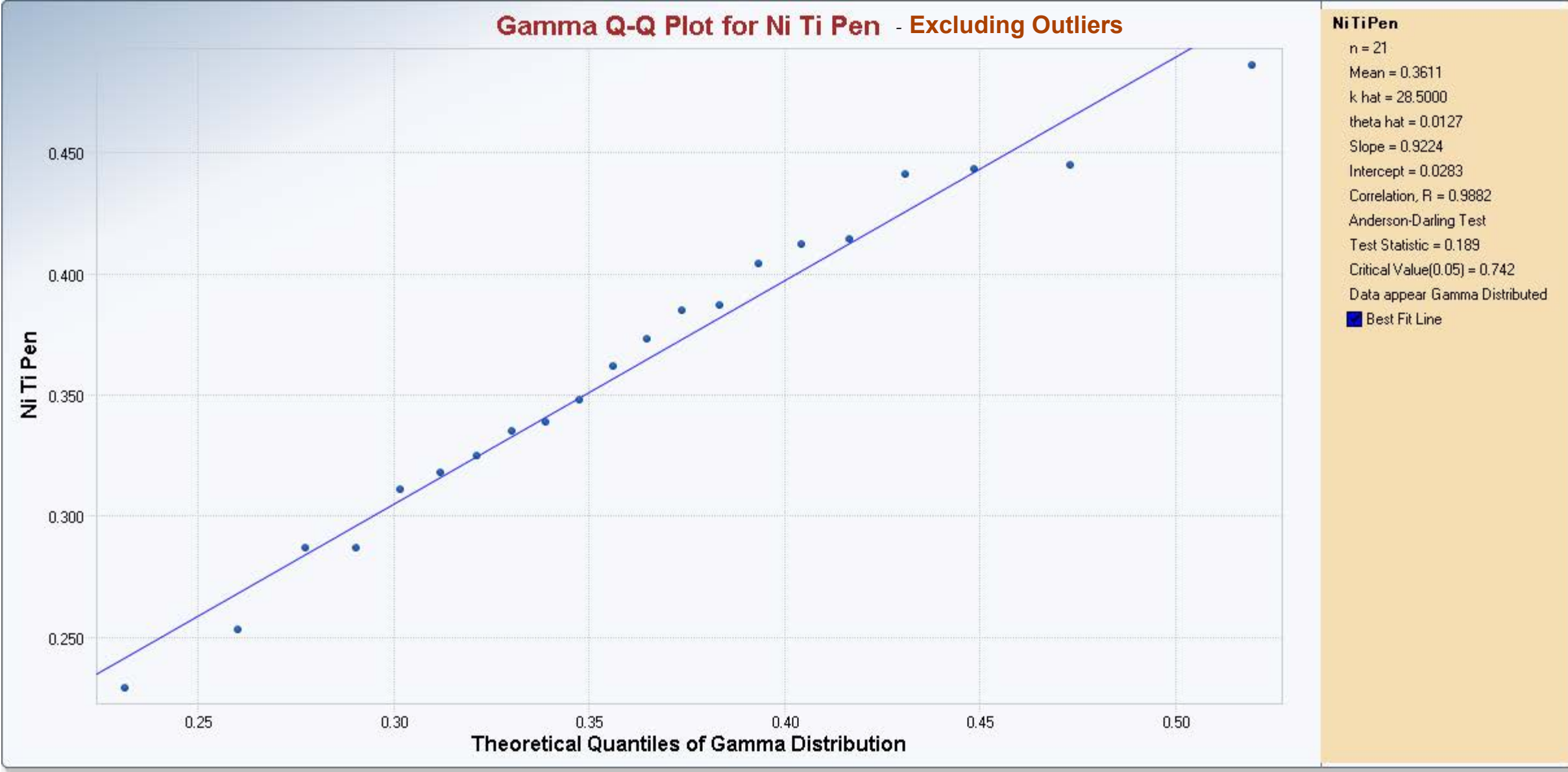

Normal Q-Q Plot for Ni Ti Pen
Ni Ti Pen
1.2
1.0
0.8
0.6
0.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
NiTiPen
n = 22
Mean = 0.399
Sd = 0.191
Slope = 0.143
Intercept = 0.399
Correlation, R = 0.724
Shapiro-Wilk Test
Exact Test Value = 0.554
Critical Val(0.05) = 0.911
Data Not Normal
Approx. Test Value = 0.554
p-Value = 5.8753E-8
Best Fit Line

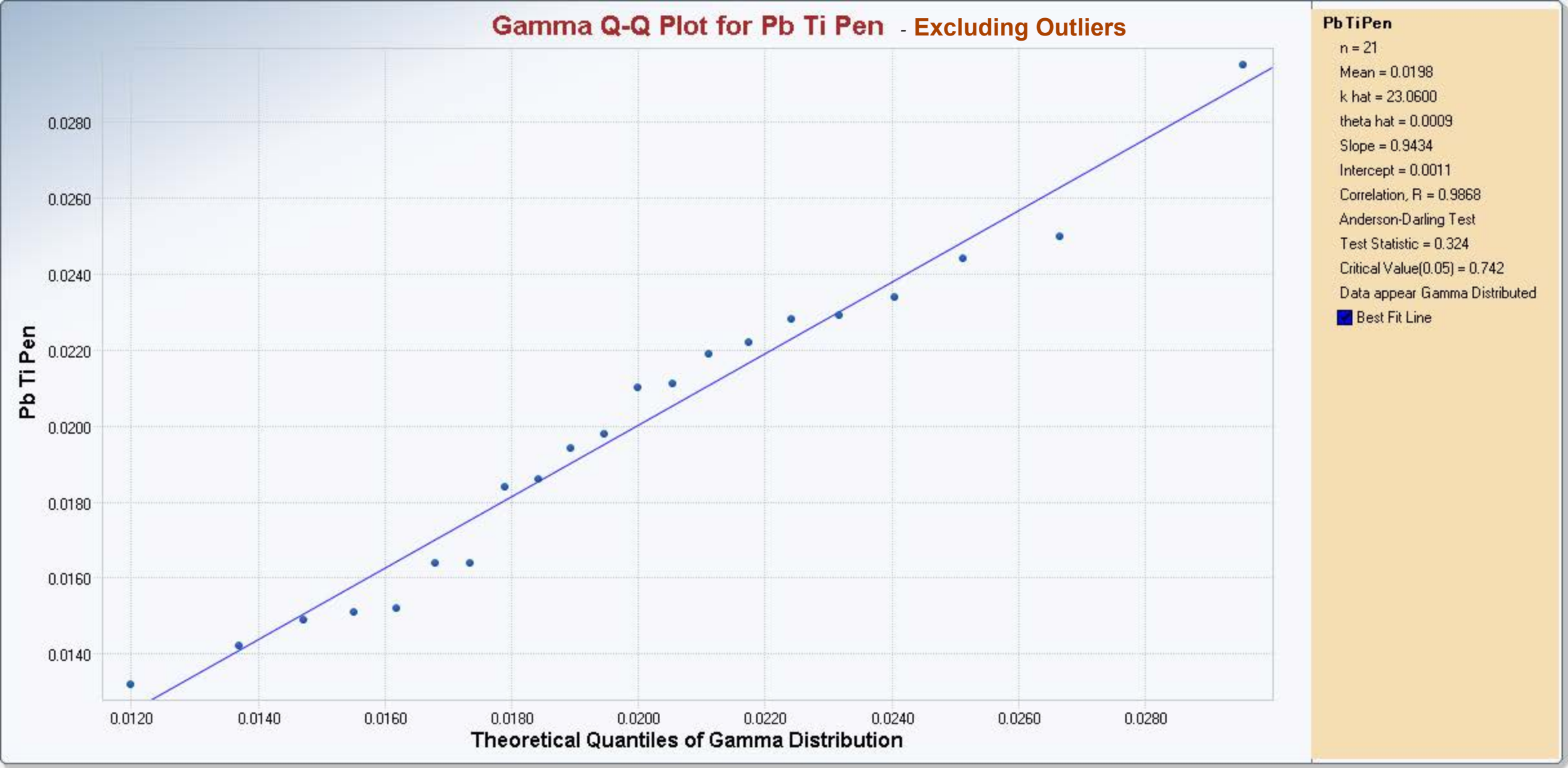

Normal Q-Q Plot for Pb Ti Pen
Pb Ti Pen
0.060
0.050
0.040
0.030
0.020
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Pb Ti Pen
n = 22
Mean = 0.022
Sd = 0.011
Slope = 0.00842
Intercept = 0.022
Correlation, R = 0.737
Shapiro-Wilk Test
Exact Test Value = 0.571
Critical Val(0.05) = 0.911
Data Not Normal
Approx. Test Value = 0.571
p-Value = 9.7110E-8
Best Fit Line

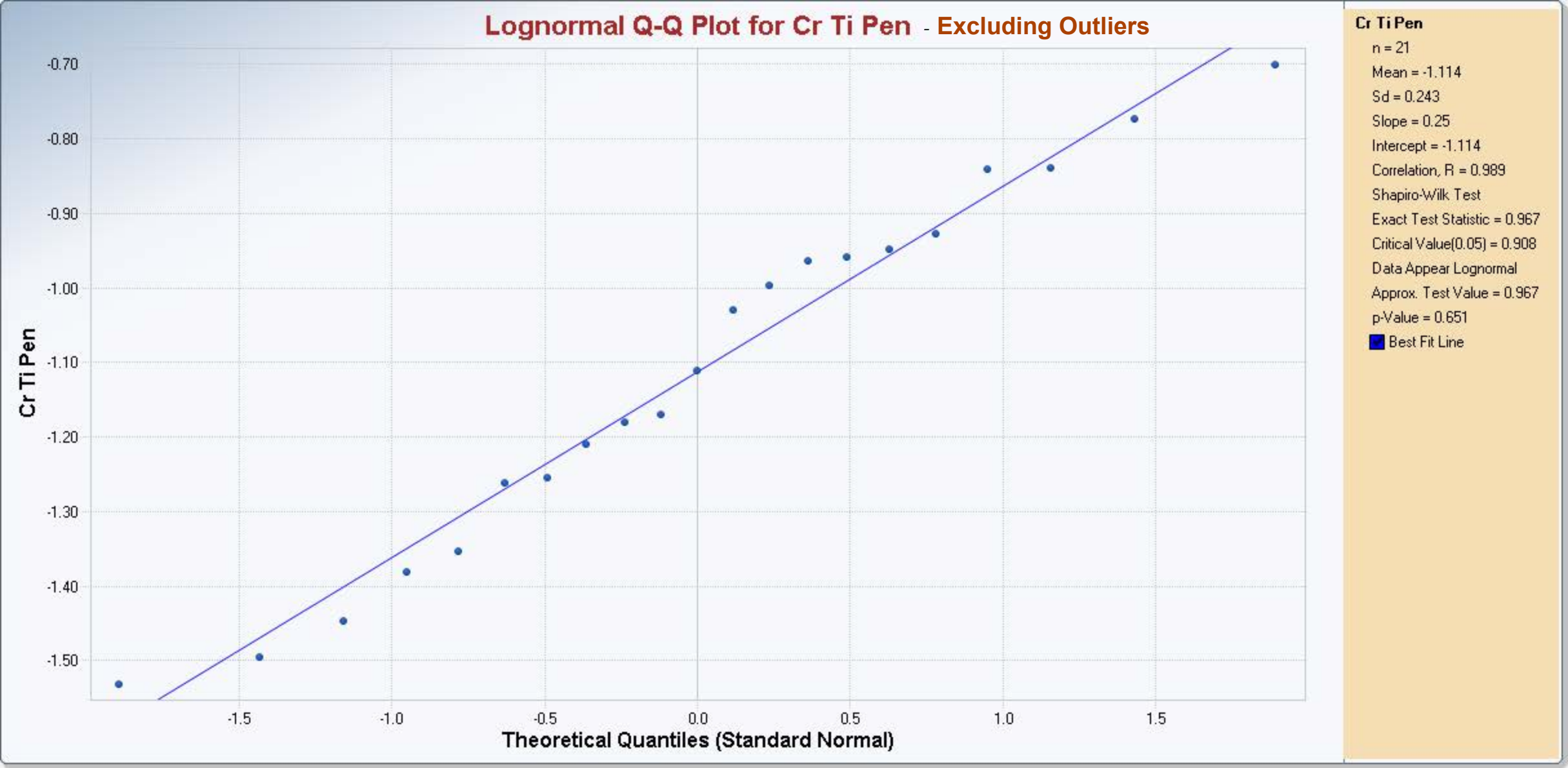

Normal Q-Q Plot for Zn Ti Pen
Zn Ti Pen
16.8
16.2
15.6
15.0
14.4
13.8
13.2
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
ZnTiPen
n = 22
Mean = 15
Sd = 1.181
Slope = 1.193
Intercept = 15
Correlation, R = 0.975
Shapiro-Wilk Test
Exact Test Value = 0.940
Critical Val(0.05) = 0.911
Data Appear Normal
Approx. Test Value = 0.940
p-Value = 0.195
Best Fit Line

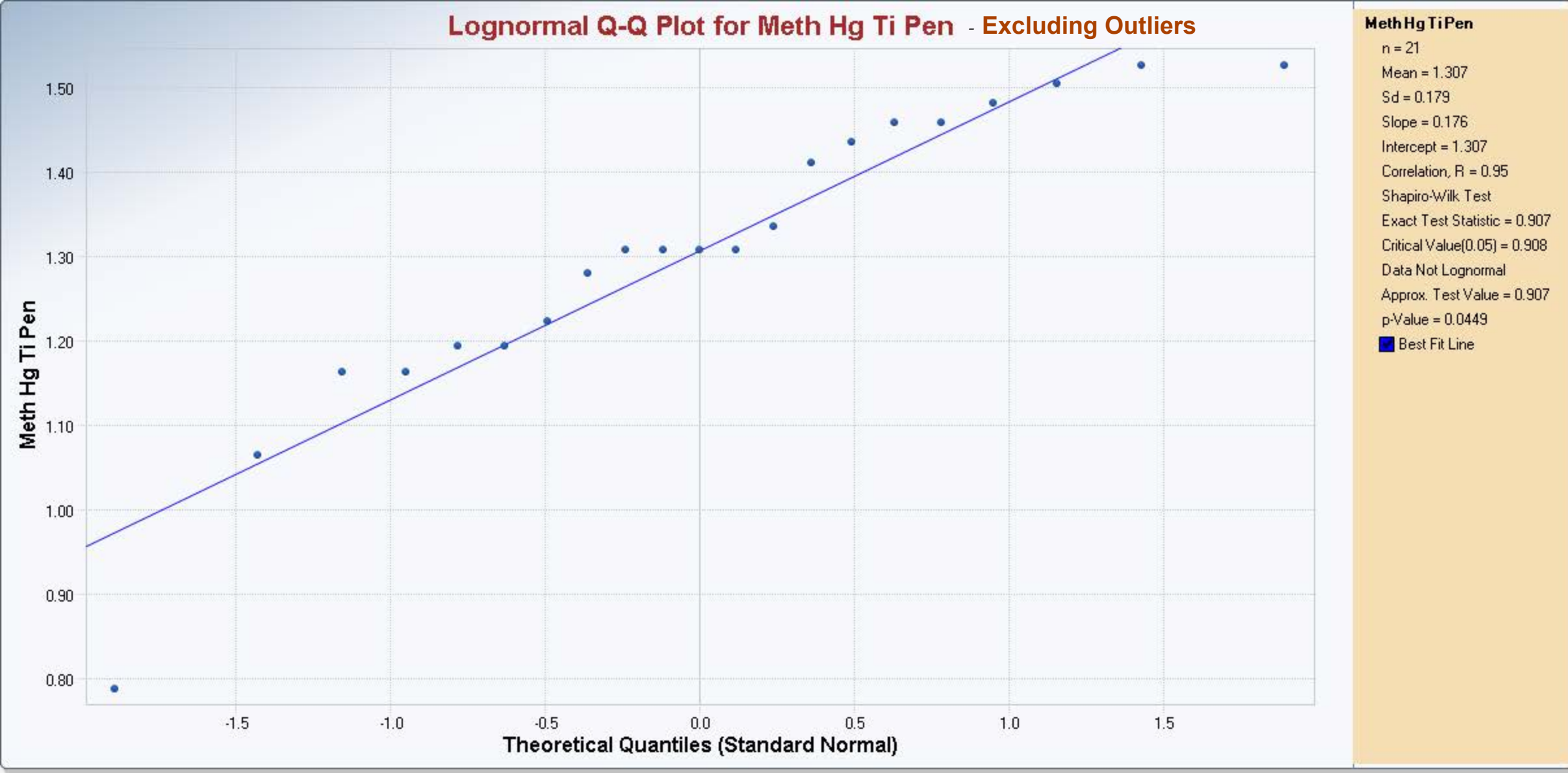

Gamma Q-Q Plot for Cr Ti Pen - Excluding Outliers
Cr Ti Pen
0.500
0.450
0.400
0.350
0.300
0.250
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Theoretical Quantiles of Gamma Distribution
Cr Ti Pen
n = 21
Mean = 0.3375
k hat = 18.1525
theta hat = 0.0186
Slope = 0.9418
Intercept = 0.0200
Correlation, R = 0.9891
Anderson-Darling Test
Test Statistic = 0.259
Critical Value(0.05) = 0.743
Data appear Gamma Distributed
Best Fit Line

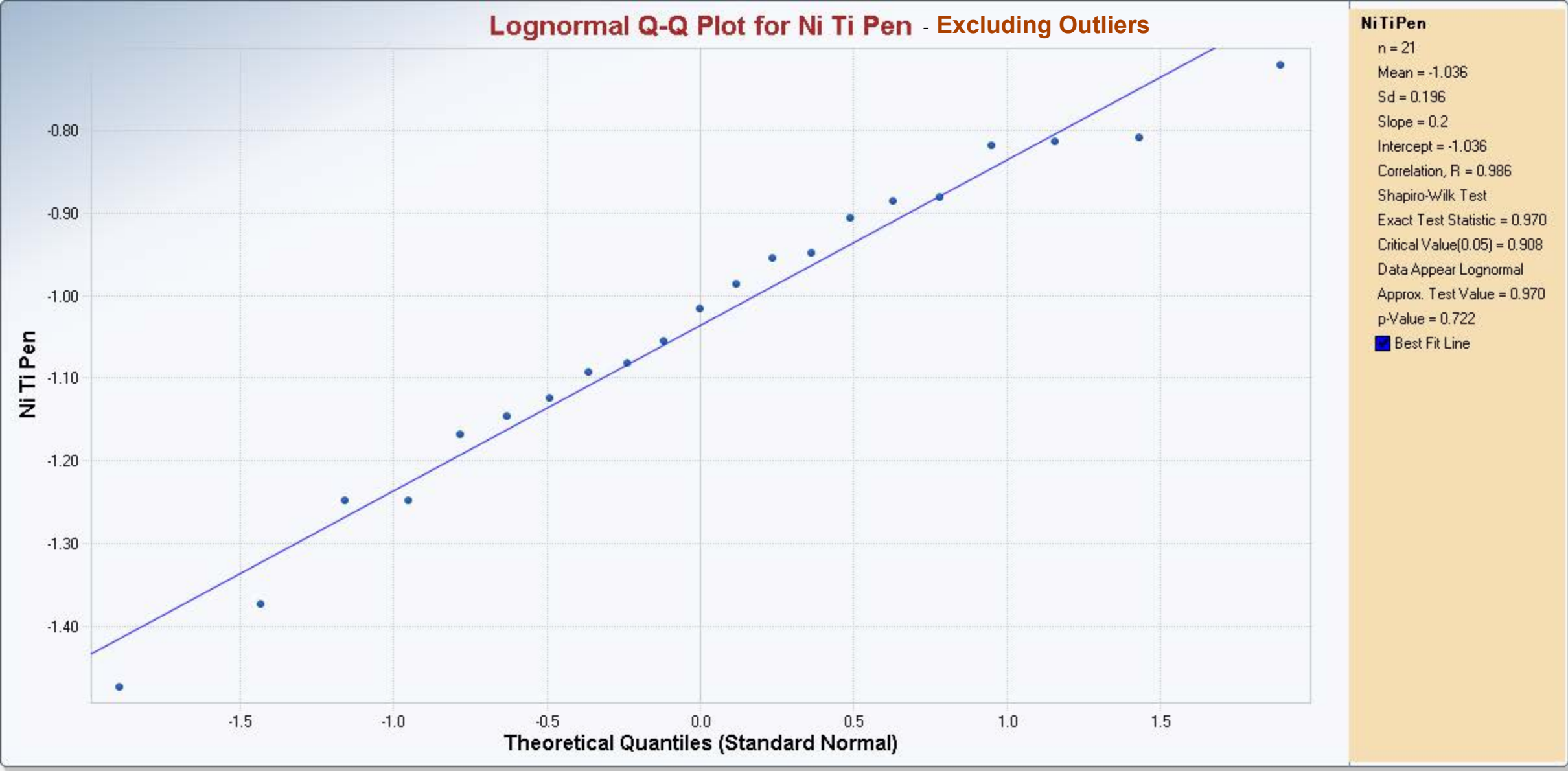

Gamma Q-Q Plot for Meth Hg Ti Pen - Excluding Outliers
Meth Hg Ti Pen
Theoretical Quantiles of Gamma Distribution
4.5
4.0
3.5
3.0
2.5
2.5
3.0
3.5
4.0
4.5
5.0
Meth Hg Ti Pen
n = 21
Mean = 3.7476
k hat = 34.9246
theta hat = 0.1073
Slope = 0.8740
Intercept = 0.4745
Correlation, R = 0.9601
Anderson-Darling Test
Test Statistic = 0.442
Critical Value(0.05) = 0.742
Data appear Gamma Distributed
Best Fit Line

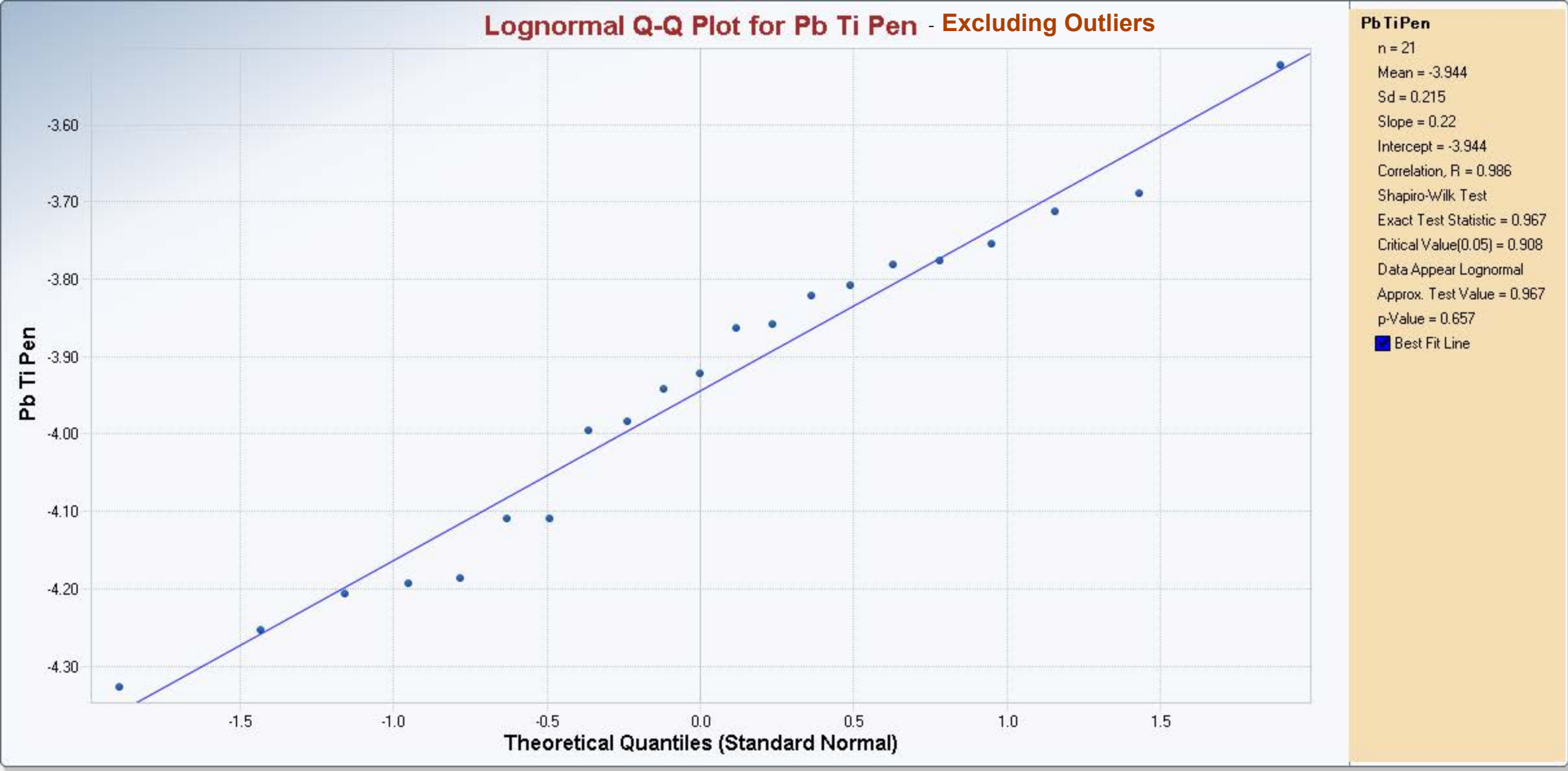

Gamma Q-Q Plot for Ni Ti Pen - Excluding Outliers
Ni Ti Pen
0.450
0.400
0.350
0.300
0.250
0.25
0.30
0.35
0.40
0.45
0.50
Theoretical Quantiles of Gamma Distribution
NiTiPen
n = 21
Mean = 0.3611
k hat = 28.5000
theta hat = 0.0127
Slope = 0.9224
Intercept = 0.0283
Correlation, R = 0.9882
Anderson-Darling Test
Test Statistic = 0.189
Critical Value(0.05) = 0.742
Data appear Gamma Distributed
Best Fit Line

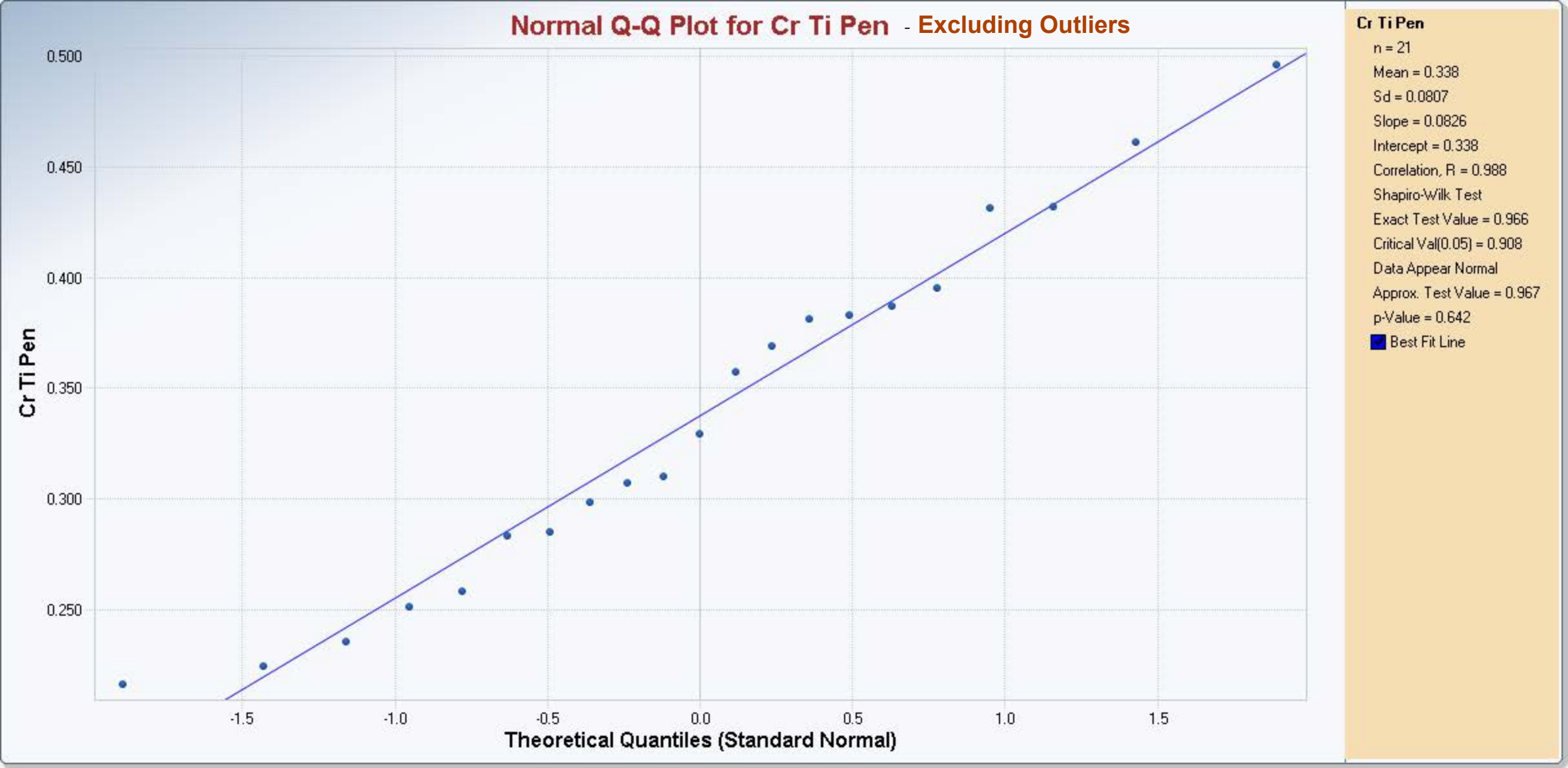

Gamma Q-Q Plot for Pb Ti Pen - Excluding Outliers
Pb Ti Pen
0.0280
0.0260
0.0240
0.0220
0.0200
0.0180
0.0160
0.0140
0.0120
0.0140
0.0160
0.0180
0.0200
0.0220
0.0240
0.0260
0.0280
Theoretical Quantiles of Gamma Distribution
Pb Ti Pen
n = 21
Mean = 0.0198
k hat = 23.0600
theta hat = 0.0009
Slope = 0.9434
Intercept = 0.0011
Correlation, R = 0.9868
Anderson-Darling Test
Test Statistic = 0.324
Critical Value(0.05) = 0.742
Data appear Gamma Distributed
Best Fit Line

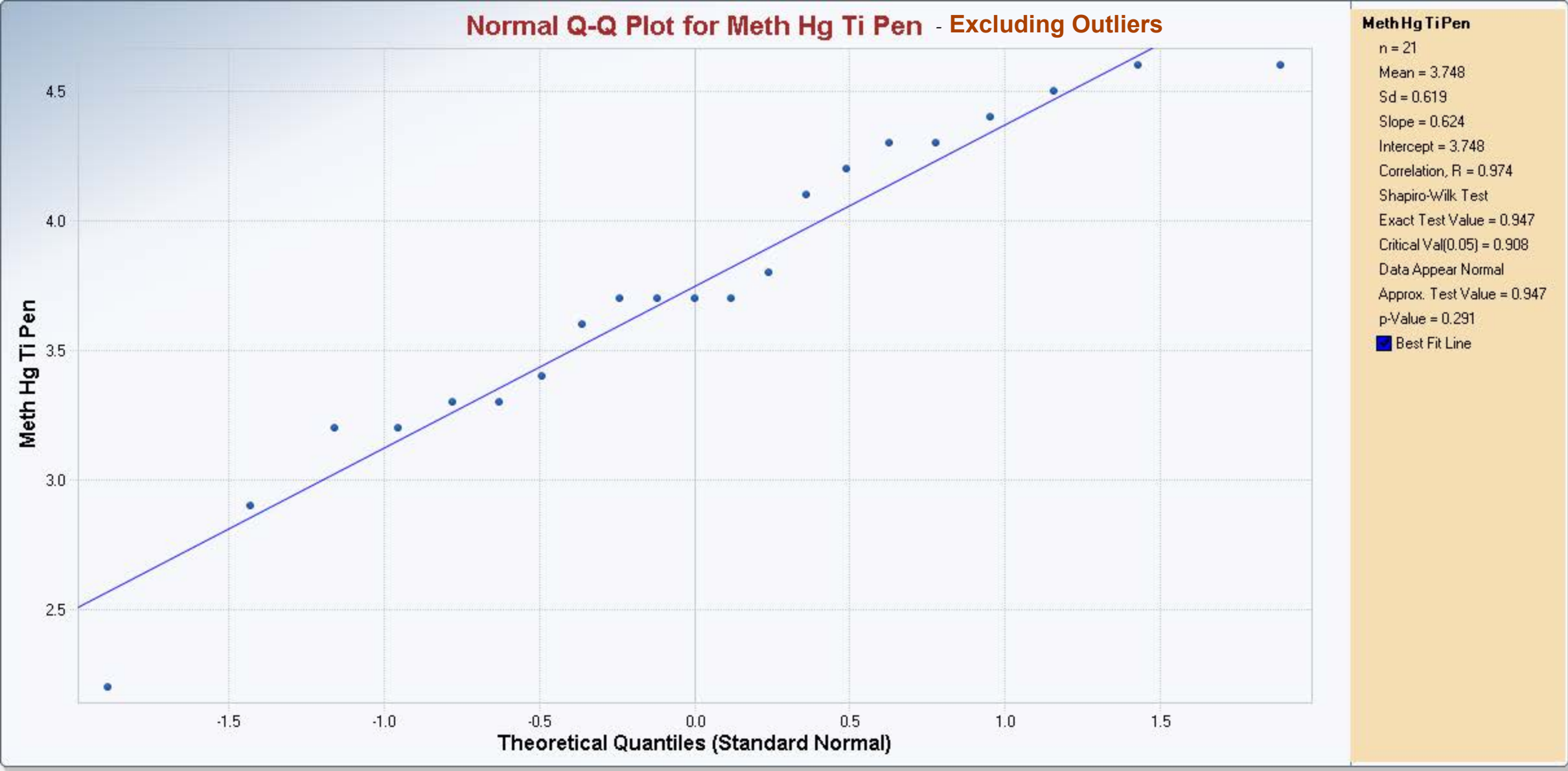

Lognormal Q-Q Plot for Cr Ti Pen - Excluding Outliers
Cr Ti Pen
-0.70
-0.80
-0.90
-1.00
-1.10
-1.20
-1.30
-1.40
-1.50
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Theoretical Quantiles (Standard Normal)
Cr Ti Pen
n = 21
Mean = -1.114
Sd = 0.243
Slope = 0.25
Intercept = -1.114
Correlation, R = 0.989
Shapiro-Wilk Test
Exact Test Statistic = 0.967
Critical Value(0.05) = 0.908
Data Appear Lognormal
Approx. Test Value = 0.967
p-Value = 0.651
Best Fit Line

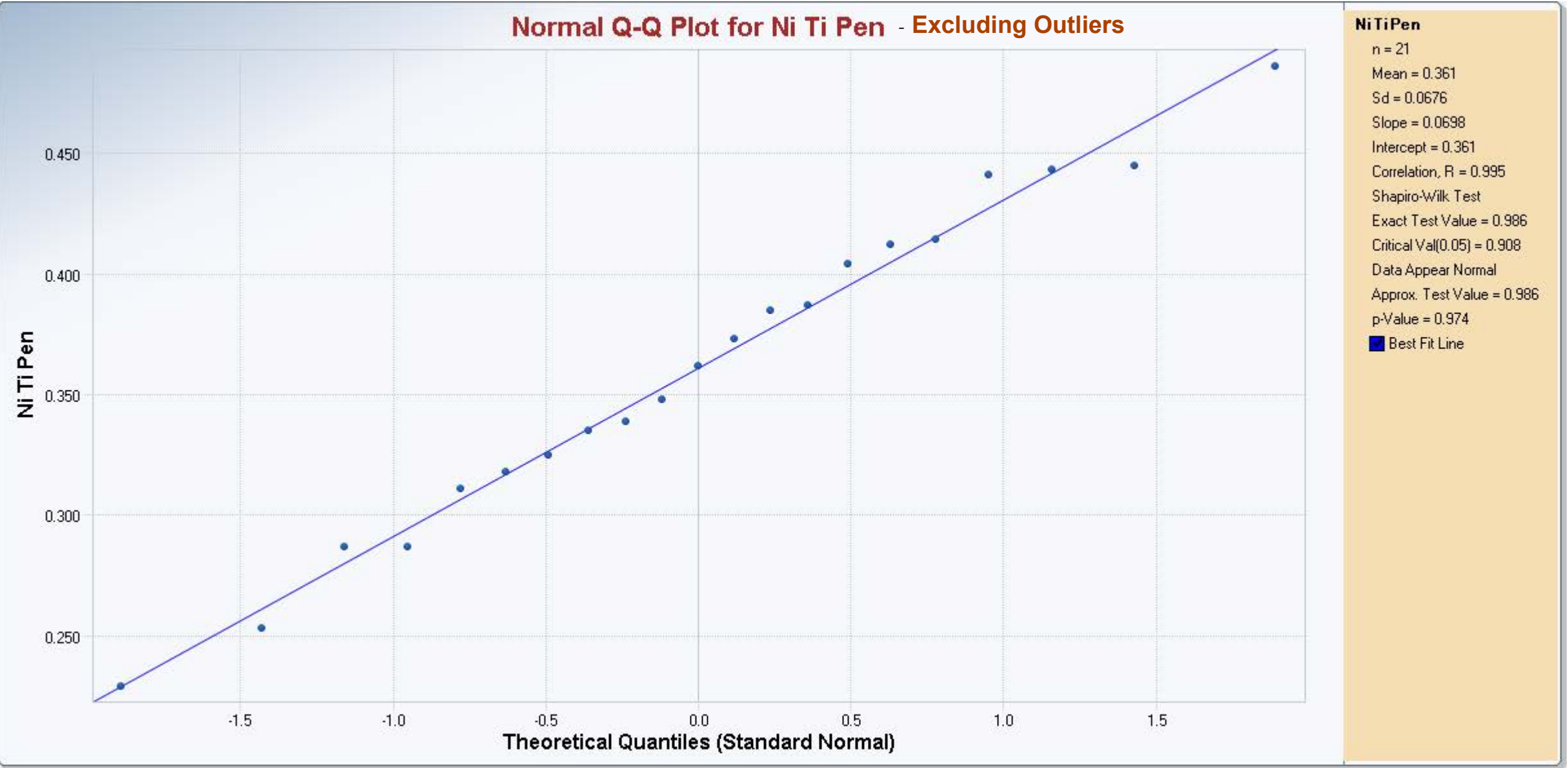

Lognormal Q-Q Plot for Meth Hg Ti Pen - Excluding Outliers
Meth Hg Ti Pen
1.50
1.40
1.30
1.20
1.10
1.00
0.90
0.80
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Theoretical Quantiles (Standard Normal)
Meth Hg Ti Pen
n = 21
Mean = 1.307
Sd = 0.179
Slope = 0.176
Intercept = 1.307
Correlation, R = 0.95
Shapiro-Wilk Test
Exact Test Statistic = 0.907
Critical Value(0.05) = 0.908
Data Not Lognormal
Approx. Test Value = 0.907
p-Value = 0.0449
Best Fit Line

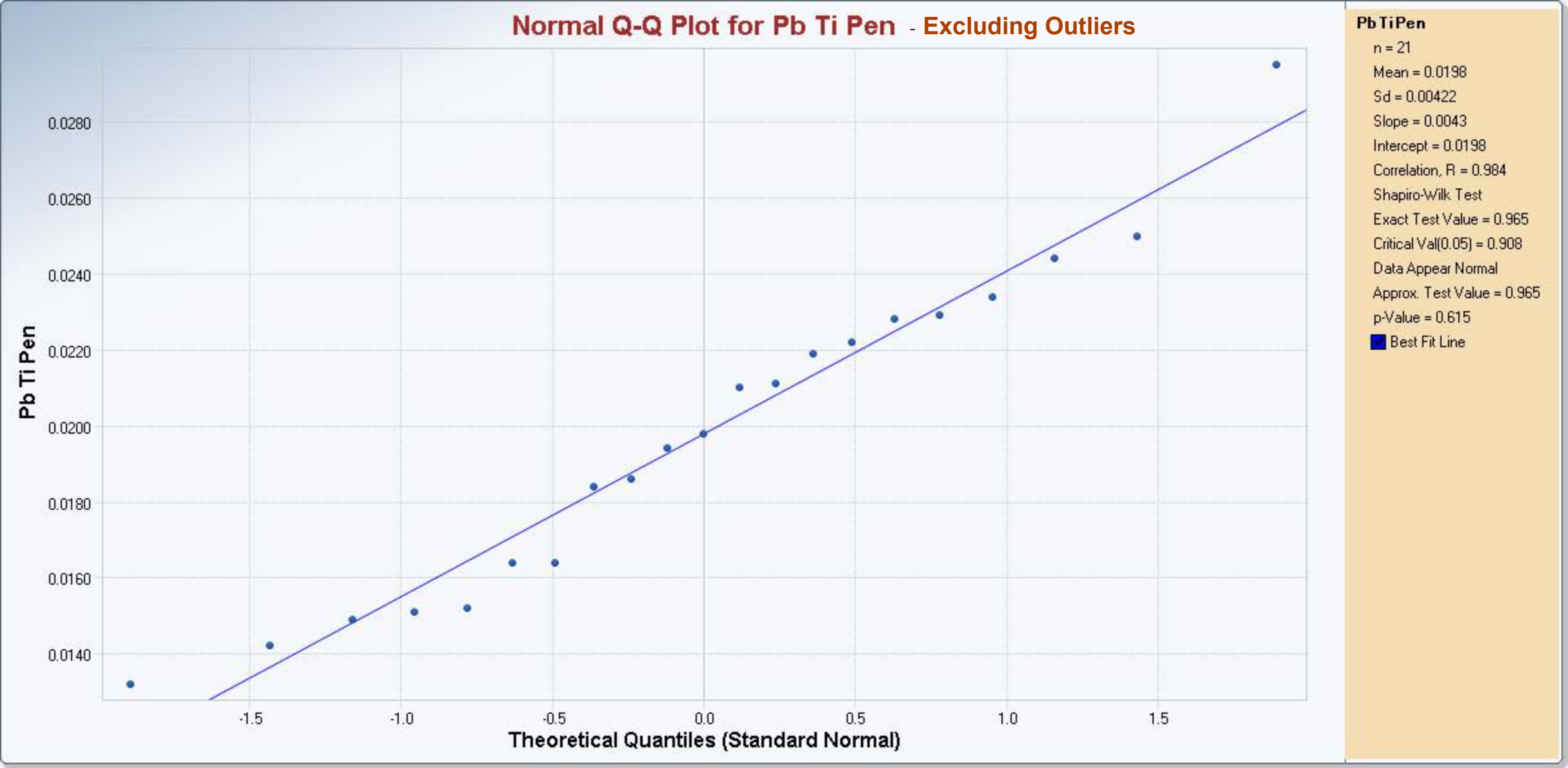

Lognormal Q-Q Plot for Ni Ti Pen - Excluding Outliers
Ni Ti Pen
-0.80
-0.90
-1.00
-1.10
-1.20
-1.30
-1.40
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Theoretical Quantiles (Standard Normal)
NiTiPen
n = 21
Mean = -1.036
Sd = 0.196
Slope = 0.2
Intercept = -1.036
Correlation, R = 0.986
Shapiro-Wilk Test
Exact Test Statistic = 0.970
Critical Value(0.05) = 0.908
Data Appear Lognormal
Approx. Test Value = 0.970
p-Value = 0.722
Best Fit Line


Lognormal Q-Q Plot for Pb Ti Pen - Excluding Outliers
Pb Ti Pen
-3.60
-3.70
-3.80
-3.90
-4.00
-4.10
-4.20
-4.30
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Theoretical Quantiles (Standard Normal)
PbTiPen
n = 21
Mean = -3.944
Sd = 0.215
Slope = 0.22
Intercept = -3.944
Correlation, R = 0.986
Shapiro-Wilk Test
Exact Test Statistic = 0.967
Critical Value(0.05) = 0.908
Data Appear Lognormal
Approx. Test Value = 0.967
p-Value = 0.657
Best Fit Line


Normal Q-Q Plot for Cr Ti Pen - Excluding Outliers
Cr Ti Pen
0.500
0.450
0.400
0.350
0.300
0.250
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Theoretical Quantiles (Standard Normal)
Cr Ti Pen
n = 21
Mean = 0.338
Sd = 0.0807
Slope = 0.0826
Intercept = 0.338
Correlation, R = 0.988
Shapiro-Wilk Test
Exact Test Value = 0.966
Critical Val(0.05) = 0.908
Data Appear Normal
Approx. Test Value = 0.967
p-Value = 0.642
Best Fit Line


Normal Q-Q Plot for Meth Hg Ti Pen - Excluding Outliers
Meth Hg Ti Pen
n = 21
Mean = 3.748
Sd = 0.619
Slope = 0.624
Intercept = 3.748
Correlation, R = 0.974
Shapiro-Wilk Test
Exact Test Value = 0.947
Critical Val(0.05) = 0.908
Data Appear Normal
Approx. Test Value = 0.947
p-Value = 0.291
Best Fit Line
Meth Hg Ti Pen
4.5
4.0
3.5
3.0
2.5
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Theoretical Quantiles (Standard Normal)


Normal Q-Q Plot for Ni Ti Pen - Excluding Outliers
Ni Ti Pen
0.450
0.400
0.350
0.300
0.250
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Theoretical Quantiles (Standard Normal)
NiTiPen
n = 21
Mean = 0.361
Sd = 0.0676
Slope = 0.0698
Intercept = 0.361
Correlation, R = 0.995
Shapiro-Wilk Test
Exact Test Value = 0.986
Critical Val(0.05) = 0.908
Data Appear Normal
Approx. Test Value = 0.986
p-Value = 0.974
Best Fit Line


Normal Q-Q Plot for Pb Ti Pen - Excluding Outliers
Pb Ti Pen
0.0280
0.0260
0.0240
0.0220
0.0200
0.0180
0.0160
0.0140
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
Theoretical Quantiles (Standard Normal)
Pb Ti Pen
n = 21
Mean = 0.0198
Sd = 0.00422
Slope = 0.0043
Intercept = 0.0198
Correlation, R = 0.984
Shapiro-Wilk Test
Exact Test Value = 0.965
Critical Val(0.05) = 0.908
Data Appear Normal
Approx. Test Value = 0.965
p-Value = 0.615
Best Fit Line

Penrose Point BTVs
Outlier Test Tissue

Outlier Tests for Selected Uncensored Variables

User Selected Options

Date/Time of Computation	ProUCL 5.11/30/2017 5:23:47 PM
From File	Penrose Tissue ProUCL BTV Inputs.xls
Full Precision	OFF

Dixon's Outlier Test for Ag Ti Pen

Number of Observations = 22
10% critical value: 0.382
5% critical value: 0.43
1% critical value: 0.514

1. Observation Value 0.0475 is a Potential Outlier (Upper T

Test Statistic: 0.799

For 10% significance level, 0.0475 is an outlier.
For 5% significance level, 0.0475 is an outlier.
For 1% significance level, 0.0475 is an outlier.

2. Observation Value 0.0069 is a Potential Outlier (Lower T

Test Statistic: 0.080

For 10% significance level, 0.0069 is not an outlier.
For 5% significance level, 0.0069 is not an outlier.
For 1% significance level, 0.0069 is not an outlier.

Penrose Point BTVs
Outlier Test Tissue

Dixon's Outlier Test for Inorg As Ti Pen

Number of Observations = 22
10% critical value: 0.382
5% critical value: 0.43
1% critical value: 0.514

1. Observation Value 0.055 is a Potential Outlier (Upper Ta

Test Statistic: 0.462

For 10% significance level, 0.055 is an outlier.
For 5% significance level, 0.055 is an outlier.
For 1% significance level, 0.055 is not an outlier.

2. Observation Value 0.026 is a Potential Outlier (Lower Tai

Test Statistic: 0.176

For 10% significance level, 0.026 is not an outlier.
For 5% significance level, 0.026 is not an outlier.
For 1% significance level, 0.026 is not an outlier.

Dixon's Outlier Test for Cd Ti Pen

Number of Observations = 22
10% critical value: 0.382
5% critical value: 0.43
1% critical value: 0.514

1. Observation Value 0.629 is a Potential Outlier (Upper Ta

Test Statistic: 0.443

For 10% significance level, 0.629 is an outlier.
For 5% significance level, 0.629 is an outlier.
For 1% significance level, 0.629 is not an outlier.

2. Observation Value 0.31 is a Potential Outlier (Lower Tail)

Test Statistic: 0.272

For 10% significance level, 0.31 is not an outlier.
For 5% significance level, 0.31 is not an outlier.
For 1% significance level, 0.31 is not an outlier.

Penrose Point BTVs
Outlier Test Tissue

Dixon's Outlier Test for Cr Ti Pen

Number of Observations = 22
10% critical value: 0.382
5% critical value: 0.43
1% critical value: 0.514

1. Observation Value 1.72 is a Potential Outlier (Upper Tail

Test Statistic: 0.848

For 10% significance level, 1.72 is an outlier.
For 5% significance level, 1.72 is an outlier.
For 1% significance level, 1.72 is an outlier.

2. Observation Value 0.216 is a Potential Outlier (Lower Tai

Test Statistic: 0.078

For 10% significance level, 0.216 is not an outlier.
For 5% significance level, 0.216 is not an outlier.
For 1% significance level, 0.216 is not an outlier.

Dixon's Outlier Test for Cu Ti Pen

Number of Observations = 22
10% critical value: 0.382
5% critical value: 0.43
1% critical value: 0.514

1. Observation Value 1.45 is a Potential Outlier (Upper Tail

Test Statistic: 0.216

For 10% significance level, 1.45 is not an outlier.
For 5% significance level, 1.45 is not an outlier.
For 1% significance level, 1.45 is not an outlier.

2. Observation Value 0.896 is a Potential Outlier (Lower Tai

Test Statistic: 0.198

For 10% significance level, 0.896 is not an outlier.
For 5% significance level, 0.896 is not an outlier.
For 1% significance level, 0.896 is not an outlier.

Penrose Point BTVs
Outlier Test Tissue

Dixon's Outlier Test for Pb Ti Pen

Number of Observations = 22
10% critical value: 0.382
5% critical value: 0.43
1% critical value: 0.514

1. Observation Value 0.0678 is a Potential Outlier (Upper T

Test Statistic: 0.809

For 10% significance level, 0.0678 is an outlier.
For 5% significance level, 0.0678 is an outlier.
For 1% significance level, 0.0678 is an outlier.

2. Observation Value 0.0132 is a Potential Outlier (Lower Ta

Test Statistic: 0.144

For 10% significance level, 0.0132 is not an outlier.
For 5% significance level, 0.0132 is not an outlier.
For 1% significance level, 0.0132 is not an outlier.

Dixon's Outlier Test for Ni Ti Pen

Number of Observations = 22
10% critical value: 0.382
5% critical value: 0.43
1% critical value: 0.514

1. Observation Value 1.2 is a Potential Outlier (Upper Tail)'

Test Statistic: 0.827

For 10% significance level, 1.2 is an outlier.
For 5% significance level, 1.2 is an outlier.
For 1% significance level, 1.2 is an outlier.

2. Observation Value 0.229 is a Potential Outlier (Lower Tai

Test Statistic: 0.269

For 10% significance level, 0.229 is not an outlier.
For 5% significance level, 0.229 is not an outlier.
For 1% significance level, 0.229 is not an outlier.

Penrose Point BTVs
Outlier Test Tissue

Dixon's Outlier Test for Zn Ti Pen

Number of Observations = 22
10% critical value: 0.382
5% critical value: 0.43
1% critical value: 0.514

1. Observation Value 17.1 is a Potential Outlier (Upper Tail

Test Statistic: 0.028

For 10% significance level, 17.1 is not an outlier.
For 5% significance level, 17.1 is not an outlier.
For 1% significance level, 17.1 is not an outlier.

2. Observation Value 13.1 is a Potential Outlier (Lower Tail)

Test Statistic: 0.103

For 10% significance level, 13.1 is not an outlier.
For 5% significance level, 13.1 is not an outlier.
For 1% significance level, 13.1 is not an outlier.

Dixon's Outlier Test for Meth Hg Ti Pen

Number of Observations = 22
10% critical value: 0.382
5% critical value: 0.43
1% critical value: 0.514

1. Observation Value 6.6 is a Potential Outlier (Upper Tail)'

Test Statistic: 0.588

For 10% significance level, 6.6 is an outlier.
For 5% significance level, 6.6 is an outlier.
For 1% significance level, 6.6 is an outlier.

2. Observation Value 2.2 is a Potential Outlier (Lower Tail)?

Test Statistic: 0.417

For 10% significance level, 2.2 is an outlier.
For 5% significance level, 2.2 is not an outlier.
For 1% significance level, 2.2 is not an outlier.

GOF
Penrose Point Tissue - All Data

Goodness-of-Fit Test Statistics for Uncensored Full Data Sets without Non-Detects

User Selected Options

Date/Time of Computation	ProUCL 5.11/30/2017 4:27:41 PM
From File	Penrose Tissue ProUCL BTV Inputs_a.xls
Full Precision	OFF
Confidence Coefficient	0.95

Inorg As Ti Pen

Raw Statistics

Number of Valid Observations	22
Number of Distinct Observations	14
Minimum	0.026
Maximum	0.055
Mean of Raw Data	0.0346
Standard Deviation of Raw Data	0.00657
Khat	33.45
Theta hat	0.00104
Kstar	28.92
Theta star	0.0012
Mean of Log Transformed Data	-3.378
Standard Deviation of Log Transformed Data	0.172

Normal GOF Test Results

Correlation Coefficient R	0.918
Shapiro Wilk Test Statistic	0.854
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	0.00317
Lilliefors Test Statistic	0.178
Lilliefors Critical (0.05) Value	0.184

Data appear Approximate Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.944
A-D Test Statistic	0.791
A-D Critical (0.05) Value	0.742
K-S Test Statistic	0.153
K-S Critical(0.05) Value	0.185

Data follow Appr. Gamma Distribution at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.953
Shapiro Wilk Test Statistic	0.917
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	0.0644
Lilliefors Test Statistic	0.145
Lilliefors Critical (0.05) Value	0.184

Data appear Lognormal at (0.05) Significance Level

Cd Ti Pen

GOF
Penrose Point Tissue - All Data

Raw Statistics

Number of Valid Observations	22
Number of Distinct Observations	22
Minimum	0.31
Maximum	0.629
Mean of Raw Data	0.445
Standard Deviation of Raw Data	0.0718
Khat	41.19
Theta hat	0.0108
Kstar	35.61
Theta star	0.0125
Mean of Log Transformed Data	-0.823
Standard Deviation of Log Transformed Data	0.16

Normal GOF Test Results

Correlation Coefficient R	0.982
Shapiro Wilk Test Statistic	0.973
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	0.756
Lilliefors Test Statistic	0.0947
Lilliefors Critical (0.05) Value	0.184

Data appear Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.99
A-D Test Statistic	0.162
A-D Critical (0.05) Value	0.742
K-S Test Statistic	0.0741
K-S Critical(0.05) Value	0.185

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.991
Shapiro Wilk Test Statistic	0.99
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	0.994
Lilliefors Test Statistic	0.0777
Lilliefors Critical (0.05) Value	0.184

Data appear Lognormal at (0.05) Significance Level

GOF
Penrose Point Tissue - All Data

Cr Ti Pen

Raw Statistics

Number of Valid Observations	22
Number of Distinct Observations	22
Minimum	0.216
Maximum	1.72
Mean of Raw Data	0.4
Standard Deviation of Raw Data	0.305
Khat	4.216
Theta hat	0.095
Kstar	3.672
Theta star	0.109
Mean of Log Transformed Data	-1.039
Standard Deviation of Log Transformed Data	0.426

Normal GOF Test Results

Correlation Coefficient R	0.655
Shapiro Wilk Test Statistic	0.458
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	3.9137E-9
Lilliefors Test Statistic	0.332
Lilliefors Critical (0.05) Value	0.184

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.756
A-D Test Statistic	2.066
A-D Critical (0.05) Value	0.747
K-S Test Statistic	0.238
K-S Critical(0.05) Value	0.186

Data not Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.863
Shapiro Wilk Test Statistic	0.768
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	8.0361E-5
Lilliefors Test Statistic	0.183
Lilliefors Critical (0.05) Value	0.184

Data appear Approximate_Lognormal at (0.05) Significance Level

GOF
Penrose Point Tissue - All Data

Cu Ti Pen

Raw Statistics

Number of Valid Observations	22
Number of Distinct Observations	19
Minimum	0.896
Maximum	1.45
Mean of Raw Data	1.159
Standard Deviation of Raw Data	0.162
Khat	53.64
Theta hat	0.0216
Kstar	46.36
Theta star	0.025
Mean of Log Transformed Data	0.138
Standard Deviation of Log Transformed Data	0.14

Normal GOF Test Results

Correlation Coefficient R	0.98
Shapiro Wilk Test Statistic	0.948
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	0.293
Lilliefors Test Statistic	0.14
Lilliefors Critical (0.05) Value	0.184

Data appear Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.98
A-D Test Statistic	0.471
A-D Critical (0.05) Value	0.743
K-S Test Statistic	0.131
K-S Critical(0.05) Value	0.185

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.982
Shapiro Wilk Test Statistic	0.953
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	0.366
Lilliefors Test Statistic	0.128
Lilliefors Critical (0.05) Value	0.184

Data appear Lognormal at (0.05) Significance Level

GOF
Penrose Point Tissue - All Data

Pb Ti Pen

Raw Statistics

Number of Valid Observations	22
Number of Distinct Observations	21
Minimum	0.0132
Maximum	0.0678
Mean of Raw Data	0.022
Standard Deviation of Raw Data	0.011
Khat	7.364
Theta hat	0.00299
Kstar	6.39
Theta star	0.00344
Mean of Log Transformed Data	-3.887
Standard Deviation of Log Transformed Data	0.34

Normal GOF Test Results

Correlation Coefficient R	0.737
Shapiro Wilk Test Statistic	0.571
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	9.7110E-8
Lilliefors Test Statistic	0.301
Lilliefors Critical (0.05) Value	0.184

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.809
A-D Test Statistic	1.445
A-D Critical (0.05) Value	0.745
K-S Test Statistic	0.225
K-S Critical(0.05) Value	0.186

Data not Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.894
Shapiro Wilk Test Statistic	0.82
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	6.8250E-4
Lilliefors Test Statistic	0.189
Lilliefors Critical (0.05) Value	0.184

Data not Lognormal at (0.05) Significance Level

Non-parametric GOF Test Results

Data do not follow a discernible distribution at (0.05) Level of Significan

GOF
Penrose Point Tissue - All Data

Ni Ti Pen

Raw Statistics

Number of Valid Observations	22
Number of Distinct Observations	21
Minimum	0.229
Maximum	1.2
Mean of Raw Data	0.399
Standard Deviation of Raw Data	0.191
Khat	8.146
Theta hat	0.049
Kstar	7.066
Theta star	0.0565
Mean of Log Transformed Data	-0.981
Standard Deviation of Log Transformed Data	0.322

Normal GOF Test Results

Correlation Coefficient R	0.724
Shapiro Wilk Test Statistic	0.554
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	5.8753E-8
Lilliefors Test Statistic	0.314
Lilliefors Critical (0.05) Value	0.184

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.79
A-D Test Statistic	1.601
A-D Critical (0.05) Value	0.745
K-S Test Statistic	0.242
K-S Critical(0.05) Value	0.186

Data not Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.883
Shapiro Wilk Test Statistic	0.807
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	3.9716E-4
Lilliefors Test Statistic	0.207
Lilliefors Critical (0.05) Value	0.184

Data not Lognormal at (0.05) Significance Level

Non-parametric GOF Test Results

Data do not follow a discernible distribution at (0.05) Level of Significan

GOF
Penrose Point Tissue - All Data

Zn Ti Pen

Raw Statistics

Number of Valid Observations	22
Number of Distinct Observations	16
Minimum	13.1
Maximum	17.1
Mean of Raw Data	15
Standard Deviation of Raw Data	1.181
Khat	171.7
Theta hat	0.0874
Kstar	148.3
Theta star	0.101
Mean of Log Transformed Data	2.705
Standard Deviation of Log Transformed Data	0.0779

Normal GOF Test Results

Correlation Coefficient R	0.975
Shapiro Wilk Test Statistic	0.94
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	0.195
Lilliefors Test Statistic	0.17
Lilliefors Critical (0.05) Value	0.184

Data appear Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.977
A-D Test Statistic	0.449
A-D Critical (0.05) Value	0.741
K-S Test Statistic	0.161
K-S Critical(0.05) Value	0.185

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.98
Shapiro Wilk Test Statistic	0.95
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	0.309
Lilliefors Test Statistic	0.156
Lilliefors Critical (0.05) Value	0.184

Data appear Lognormal at (0.05) Significance Level

GOF
Penrose Point Tissue - All Data

Meth Hg Ti Pen

Raw Statistics

Number of Valid Observations	22
Number of Distinct Observations	15
Minimum	2.2
Maximum	6.6
Mean of Raw Data	3.877
Standard Deviation of Raw Data	0.857
Khat	22.87
Theta hat	0.169
Kstar	19.79
Theta star	0.196
Mean of Log Transformed Data	1.333
Standard Deviation of Log Transformed Data	0.214

Normal GOF Test Results

Correlation Coefficient R	0.933
Shapiro Wilk Test Statistic	0.896
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	0.0223
Lilliefors Test Statistic	0.154
Lilliefors Critical (0.05) Value	0.184

Data appear Approximate Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.948
A-D Test Statistic	0.487
A-D Critical (0.05) Value	0.741
K-S Test Statistic	0.136
K-S Critical(0.05) Value	0.185

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.959
Shapiro Wilk Test Statistic	0.942
Shapiro Wilk Critical (0.05) Value	0.911
Approximate Shapiro Wilk P Value	0.222
Lilliefors Test Statistic	0.138
Lilliefors Critical (0.05) Value	0.184

Data appear Lognormal at (0.05) Significance Level

GOF
Penrose Point Tissue- Excluding Outliers

Goodness-of-Fit Test Statistics for Uncensored Full Data Sets without Non-Detects

User Selected Options

Date/Time of Computation	ProUCL 5.11/30/2017 5:05:18 PM
From File	Penrose Tissue ProUCL BTV Inputs_a.xls
Full Precision	OFF
Confidence Coefficient	0.95

Cr Ti Pen

Raw Statistics

Number of Valid Observations	21
Number of Distinct Observations	21
Minimum	0.216
Maximum	0.496
Mean of Raw Data	0.338
Standard Deviation of Raw Data	0.0807
Khat	18.15
Theta hat	0.0186
Kstar	15.59
Theta star	0.0216
Mean of Log Transformed Data	-1.114
Standard Deviation of Log Transformed Data	0.243

Normal GOF Test Results

Correlation Coefficient R	0.988
Shapiro Wilk Test Statistic	0.966
Shapiro Wilk Critical (0.05) Value	0.908
Approximate Shapiro Wilk P Value	0.642
Lilliefors Test Statistic	0.11
Lilliefors Critical (0.05) Value	0.188

Data appear Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.989
A-D Test Statistic	0.259
A-D Critical (0.05) Value	0.743
K-S Test Statistic	0.108
K-S Critical(0.05) Value	0.189

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.989
Shapiro Wilk Test Statistic	0.967
Shapiro Wilk Critical (0.05) Value	0.908
Approximate Shapiro Wilk P Value	0.651
Lilliefors Test Statistic	0.113
Lilliefors Critical (0.05) Value	0.188

Data appear Lognormal at (0.05) Significance Level

Pb Ti Pen

GOF
Penrose Point Tissue- Excluding Outliers

Raw Statistics

Number of Valid Observations	21
Number of Distinct Observations	20
Minimum	0.0132
Maximum	0.0295
Mean of Raw Data	0.0198
Standard Deviation of Raw Data	0.00422
Khat	23.06
Theta hat	8.5863E-4
Kstar	19.8
Theta star	0.001
Mean of Log Transformed Data	-3.944
Standard Deviation of Log Transformed Data	0.215

Normal GOF Test Results

Correlation Coefficient R	0.984
Shapiro Wilk Test Statistic	0.965
Shapiro Wilk Critical (0.05) Value	0.908
Approximate Shapiro Wilk P Value	0.615
Lilliefors Test Statistic	0.123
Lilliefors Critical (0.05) Value	0.188

Data appear Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.987
A-D Test Statistic	0.324
A-D Critical (0.05) Value	0.742
K-S Test Statistic	0.123
K-S Critical(0.05) Value	0.189

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.986
Shapiro Wilk Test Statistic	0.967
Shapiro Wilk Critical (0.05) Value	0.908
Approximate Shapiro Wilk P Value	0.657
Lilliefors Test Statistic	0.122
Lilliefors Critical (0.05) Value	0.188

Data appear Lognormal at (0.05) Significance Level

GOF
Penrose Point Tissue- Excluding Outliers

Ni Ti Pen

Raw Statistics

Number of Valid Observations	21
Number of Distinct Observations	20
Minimum	0.229
Maximum	0.486
Mean of Raw Data	0.361
Standard Deviation of Raw Data	0.0676
Khat	28.5
Theta hat	0.0127
Kstar	24.46
Theta star	0.0148
Mean of Log Transformed Data	-1.036
Standard Deviation of Log Transformed Data	0.196

Normal GOF Test Results

Correlation Coefficient R	0.995
Shapiro Wilk Test Statistic	0.986
Shapiro Wilk Critical (0.05) Value	0.908
Approximate Shapiro Wilk P Value	0.974
Lilliefors Test Statistic	0.0716
Lilliefors Critical (0.05) Value	0.188

Data appear Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.988
A-D Test Statistic	0.189
A-D Critical (0.05) Value	0.742
K-S Test Statistic	0.0867
K-S Critical(0.05) Value	0.189

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.986
Shapiro Wilk Test Statistic	0.97
Shapiro Wilk Critical (0.05) Value	0.908
Approximate Shapiro Wilk P Value	0.722
Lilliefors Test Statistic	0.0903
Lilliefors Critical (0.05) Value	0.188

Data appear Lognormal at (0.05) Significance Level

GOF
Penrose Point Tissue- Excluding Outliers

Meth Hg Ti Pen

Raw Statistics

Number of Valid Observations	21
Number of Distinct Observations	14
Minimum	2.2
Maximum	4.6
Mean of Raw Data	3.748
Standard Deviation of Raw Data	0.619
Khat	34.92
Theta hat	0.107
Kstar	29.97
Theta star	0.125
Mean of Log Transformed Data	1.307
Standard Deviation of Log Transformed Data	0.179

Normal GOF Test Results

Correlation Coefficient R	0.974
Shapiro Wilk Test Statistic	0.947
Shapiro Wilk Critical (0.05) Value	0.908
Approximate Shapiro Wilk P Value	0.291
Lilliefors Test Statistic	0.102
Lilliefors Critical (0.05) Value	0.188

Data appear Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.96
A-D Test Statistic	0.442
A-D Critical (0.05) Value	0.742
K-S Test Statistic	0.112
K-S Critical(0.05) Value	0.189

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.95
Shapiro Wilk Test Statistic	0.907
Shapiro Wilk Critical (0.05) Value	0.908
Approximate Shapiro Wilk P Value	0.0449
Lilliefors Test Statistic	0.123
Lilliefors Critical (0.05) Value	0.188

Data appear Approximate_Lognormal at (0.05) Significance Level

GOF
BOLD Sediment

Goodness-of-Fit Test Statistics for Data Sets with Non-Detects

User Selected Options

Date/Time of Computation	ProUCL 5.112/2/2016 1:45:21 PM
From File	WMWT Sed & Clam tissue_input_11_29_16_a.xls
Full Precision	OFF
Confidence Coefficient	0.95

Ag Sd Bold

	Num Obs	Num Miss	Num Valid	Detects	NDs	% NDs
Raw Statistics	70	0	70	52	18	25.71%

	Number	Minimum	Maximum	Mean	Median	SD
Statistics (Non-Detects Only)	18	0.0074	0.1	0.0477	0.0425	0.0278
Statistics (Non-Detects Only)	52	0.0094	0.45	0.14	0.13	0.0978
Statistics (All: NDs treated as DL value)	70	0.0074	0.45	0.116	0.088	0.0943
Statistics (All: NDs treated as DL/2 value)	70	0.0037	0.45	0.11	0.076	0.0985
Statistics (Normal ROS Imputed Data)	70	-0.137	0.45	0.0988	0.076	0.111
Statistics (Gamma ROS Imputed Data)	70	0.0094	0.45	0.11	0.076	0.0987
Statistics (Lognormal ROS Imputed Data)	70	0.00712	0.45	0.11	0.076	0.0984

	K hat	K Star	Theta hat	Log Mean	Log Stdv	Log CV
Statistics (Non-Detects Only)	1.634	1.553	0.0854	-2.306	0.947	-0.411
Statistics (NDs = DL)	1.419	1.368	0.0817	-2.547	0.98	-0.385
Statistics (NDs = DL/2)	1.106	1.068	0.0992	-2.725	1.142	-0.419
Statistics (Gamma ROS Estimates)	1.134	1.095	0.0966	-2.714	1.102	-0.406
Statistics (Lognormal ROS Estimates)	--	--	--	-2.693	1.071	-0.398

Normal GOF Test Results

	No NDs	NDs = DL	NDs = DL/2	Normal ROS
Correlation Coefficient R	0.971	0.946	0.939	0.981

	Apr. Test	P Value	Conclusion with Alpha(0.05)
Shapiro-Wilk (Detects Only)	0.937	0.0122	Data Not Normal
Shapiro-Wilk (NDs = DL)	0.891	1.2919E-6	Data Not Normal
Shapiro-Wilk (NDs = DL/2)	0.874	8.4266E-8	Data Not Normal
Shapiro-Wilk (Normal ROS Estimates)	0.963	0.112	Data Appear Normal
	Test value	Crit. (0.05)	Conclusion with Alpha(0.05)
Lilliefors (Detects Only)	0.0986	0.122	Data Appear Normal
Lilliefors (NDs = DL)	0.138	0.106	Data Not Normal
Lilliefors (NDs = DL/2)	0.149	0.106	Data Not Normal
Lilliefors (Normal ROS Estimates)	0.118	0.106	Data Not Normal

Gamma GOF Test Results

	No NDs	NDs = DL	NDs = DL/2	Gamma ROS
Correlation Coefficient R	0.982	0.99	0.981	0.981

	Test value	Crit. (0.05)	Conclusion with Alpha(0.05)
Anderson-Darling (Detects Only)	0.569	0.766	
Kolmogorov-Smirnov (Detects Only)	0.089	0.125	Detected Data Appear Gamma Distributed
Anderson-Darling (NDs = DL)	0.369	0.771	
Kolmogorov-Smirnov (NDs = DL)	0.0728	0.109	Data Appear Gamma Distributed
Anderson-Darling (NDs = DL/2)	0.885	0.778	
Kolmogorov-Smirnov (NDs = DL/2)	0.111	0.109	Data Not Gamma Distributed
Anderson-Darling (Gamma ROS Estimates)	1.2	0.777	
Kolmogorov-Smirnov (Gamma ROS Est.)	0.12	0.109	Data Not Gamma Distributed

GOF
BOLD Sediment

Lognormal GOF Test Results

	No NDs	NDs = DL	NDs = DL/2	Log ROS
Correlation Coefficient R	0.964	0.984	0.979	0.976

	Apr. Test	P Value	Conclusion with Alpha(0.05)
Shapiro-Wilk (Detects Only)	0.918	0.00134	Data Not Lognormal
Shapiro-Wilk (NDs = DL)	0.953	0.0248	Data Not Lognormal
Shapiro-Wilk (NDs = DL/2)	0.943	0.00573	Data Not Lognormal
Shapiro-Wilk (Lognormal ROS Estimates)	0.932	0.00102	Data Not Lognormal
	Test value	Crit. (0.05)	Conclusion with Alpha(0.05)
Lilliefors (Detects Only)	0.135	0.122	Data Not Lognormal
Lilliefors (NDs = DL)	0.0831	0.106	Data Appear Lognormal
Lilliefors (NDs = DL/2)	0.116	0.106	Data Not Lognormal
Lilliefors (Lognormal ROS Estimates)	0.121	0.106	Data Not Lognormal

Note: Substitution methods such as DL or DL/2 are not recommended.

GOF
BOLD Sediment

Tot As Sd Bold

Raw Statistics

Number of Valid Observations	70
Number of Distinct Observations	53
Minimum	1.1
Maximum	21
Mean of Raw Data	6.614
Standard Deviation of Raw Data	3.838
Khat	3.255
Theta hat	2.032
Kstar	3.125
Theta star	2.116
Mean of Log Transformed Data	1.728
Standard Deviation of Log Transformed Data	0.588

Normal GOF Test Results

Correlation Coefficient R	0.95
Approximate Shapiro Wilk Test Statistic	0.905
Approximate Shapiro Wilk P Value	1.3460E-5
Lilliefors Test Statistic	0.134
Lilliefors Critical (0.05) Value	0.106

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.995
A-D Test Statistic	0.294
A-D Critical (0.05) Value	0.757
K-S Test Statistic	0.065
K-S Critical(0.05) Value	0.107

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.994
Approximate Shapiro Wilk Test Statistic	0.985
Approximate Shapiro Wilk P Value	0.848
Lilliefors Test Statistic	0.08
Lilliefors Critical (0.05) Value	0.106

Data appear Lognormal at (0.05) Significance Level

GOF
BOLD Sediment

Cd Sd Bold

	Num Obs	Num Miss	Num Valid	Detects	NDs	% NDs
Raw Statistics	70	0	70	48	22	31.43%

	Number	Minimum	Maximum	Mean	Median	SD
Statistics (Non-Detects Only)	22	0.022	0.26	0.139	0.13	0.0767
Statistics (Non-Detects Only)	48	0.018	2.8	0.414	0.285	0.523
Statistics (All: NDs treated as DL value)	70	0.018	2.8	0.327	0.185	0.452
Statistics (All: NDs treated as DL/2 value)	70	0.011	2.8	0.306	0.145	0.461
Statistics (Normal ROS Imputed Data)	70	-0.57	2.8	0.21	0.146	0.539
Statistics (Gamma ROS Imputed Data)	70	0.01	2.8	0.288	0.145	0.47
Statistics (Lognormal ROS Imputed Data)	70	0.018	2.8	0.301	0.145	0.464

	K hat	K Star	Theta hat	Log Mean	Log Stdv	Log CV
Statistics (Non-Detects Only)	1.089	1.034	0.38	-1.407	1.053	-0.749
Statistics (NDs = DL)	1.071	1.034	0.306	-1.651	1.027	-0.622
Statistics (NDs = DL/2)	0.86	0.832	0.356	-1.869	1.181	-0.632
Statistics (Gamma ROS Estimates)	0.557	0.543	0.518	-2.366	1.692	-0.715
Statistics (Lognormal ROS Estimates)	--	--	--	-1.924	1.194	-0.62

Normal GOF Test Results

	No NDs	NDs = DL	NDs = DL/2	Normal ROS
Correlation Coefficient R	0.787	0.748	0.749	0.884

	Apr. Test	P Value	Conclusion with Alpha(0.05)
Shapiro-Wilk (NDs = DL)	0.586	0	Data Not Normal
Shapiro-Wilk (NDs = DL/2)	0.588	0	Data Not Normal
Shapiro-Wilk (Normal ROS Estimates)	0.804	1.159E-12	Data Not Normal
	Test value	Crit. (0.05)	Conclusion with Alpha(0.05)
Shapiro-Wilk (Detects Only)	0.64	0.947	Data Not Normal
Lilliefors (Detects Only)	0.257	0.127	Data Not Normal
Lilliefors (NDs = DL)	0.247	0.106	Data Not Normal
Lilliefors (NDs = DL/2)	0.261	0.106	Data Not Normal
Lilliefors (Normal ROS Estimates)	0.179	0.106	Data Not Normal

Gamma GOF Test Results

	No NDs	NDs = DL	NDs = DL/2	Gamma ROS
Correlation Coefficient R	0.943	0.923	0.939	0.964

	Test value	Crit. (0.05)	Conclusion with Alpha(0.05)
Anderson-Darling (Detects Only)	0.698	0.777	
Kolmogorov-Smirnov (Detects Only)	0.124	0.131	Detected Data Appear Gamma Distributed
Anderson-Darling (NDs = DL)	1.301	0.779	
Kolmogorov-Smirnov (NDs = DL)	0.106	0.109	Detected Data appear Approximate Gamma Distri
Anderson-Darling (NDs = DL/2)	1.355	0.787	
Kolmogorov-Smirnov (NDs = DL/2)	0.133	0.11	Data Not Gamma Distributed
Anderson-Darling (Gamma ROS Estimates)	1.745	0.811	
Kolmogorov-Smirnov (Gamma ROS Est.)	0.162	0.112	Data Not Gamma Distributed

GOF
BOLD Sediment

Lognormal GOF Test Results

	No NDs	NDs = DL	NDs = DL/2	Log ROS
Correlation Coefficient R	0.994	0.995	0.997	0.99

	Apr. Test	P Value	Conclusion with Alpha(0.05)
Shapiro-Wilk (NDs = DL)	0.984	0.822	Data Appear Lognormal
Shapiro-Wilk (NDs = DL/2)	0.984	0.796	Data Appear Lognormal
Shapiro-Wilk (Lognormal ROS Estimates)	0.963	0.109	Data Appear Lognormal
	Test value	Crit. (0.05)	Conclusion with Alpha(0.05)
Shapiro-Wilk (Detects Only)	0.987	0.947	Data Appear Lognormal
Lilliefors (Detects Only)	0.0714	0.127	Data Appear Lognormal
Lilliefors (NDs = DL)	0.0542	0.106	Data Appear Lognormal
Lilliefors (NDs = DL/2)	0.0529	0.106	Data Appear Lognormal
Lilliefors (Lognormal ROS Estimates)	0.107	0.106	Data Not Lognormal

Note: Substitution methods such as DL or DL/2 are not recommended.

GOF
BOLD Sediment

Cr Sd Bold

Raw Statistics

Number of Valid Observations	70
Number of Distinct Observations	65
Minimum	7.1
Maximum	105
Mean of Raw Data	32.5
Standard Deviation of Raw Data	20.07
Khat	3.284
Theta hat	9.899
Kstar	3.152
Theta star	10.31
Mean of Log Transformed Data	3.321
Standard Deviation of Log Transformed Data	0.562

Normal GOF Test Results

Correlation Coefficient R	0.922
Approximate Shapiro Wilk Test Statistic	0.851
Approximate Shapiro Wilk P Value	1.8782E-9
Lilliefors Test Statistic	0.158
Lilliefors Critical (0.05) Value	0.106

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.986
A-D Test Statistic	0.719
A-D Critical (0.05) Value	0.757
K-S Test Statistic	0.0995
K-S Critical(0.05) Value	0.107

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.997
Approximate Shapiro Wilk Test Statistic	0.985
Approximate Shapiro Wilk P Value	0.857
Lilliefors Test Statistic	0.0613
Lilliefors Critical (0.05) Value	0.106

Data appear Lognormal at (0.05) Significance Level

GOF
BOLD Sediment

Cu Sd Bold

Raw Statistics

Number of Valid Observations	70
Number of Distinct Observations	63
Minimum	3.2
Maximum	91.2
Mean of Raw Data	21.75
Standard Deviation of Raw Data	16.55
Khat	1.869
Theta hat	11.64
Kstar	1.799
Theta star	12.09
Mean of Log Transformed Data	2.789
Standard Deviation of Log Transformed Data	0.804

Normal GOF Test Results

Correlation Coefficient R	0.932
Approximate Shapiro Wilk Test Statistic	0.875
Approximate Shapiro Wilk P Value	9.1078E-8
Lilliefors Test Statistic	0.17
Lilliefors Critical (0.05) Value	0.106

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.99
A-D Test Statistic	0.495
A-D Critical (0.05) Value	0.765
K-S Test Statistic	0.0897
K-S Critical(0.05) Value	0.108

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.989
Approximate Shapiro Wilk Test Statistic	0.961
Approximate Shapiro Wilk P Value	0.085
Lilliefors Test Statistic	0.0801
Lilliefors Critical (0.05) Value	0.106

Data appear Lognormal at (0.05) Significance Level

GOF
BOLD Sediment

Pb Sd Bold

Raw Statistics

Number of Valid Observations	70
Number of Distinct Observations	59
Minimum	1.2
Maximum	27.5
Mean of Raw Data	9.75
Standard Deviation of Raw Data	6.018
Khat	2.561
Theta hat	3.806
Kstar	2.461
Theta star	3.961
Mean of Log Transformed Data	2.07
Standard Deviation of Log Transformed Data	0.687

Normal GOF Test Results

Correlation Coefficient R	0.967
Approximate Shapiro Wilk Test Statistic	0.923
Approximate Shapiro Wilk P Value	2.5526E-4
Lilliefors Test Statistic	0.132
Lilliefors Critical (0.05) Value	0.106

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.992
A-D Test Statistic	0.257
A-D Critical (0.05) Value	0.76
K-S Test Statistic	0.0588
K-S Critical(0.05) Value	0.107

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.99
Approximate Shapiro Wilk Test Statistic	0.969
Approximate Shapiro Wilk P Value	0.213
Lilliefors Test Statistic	0.0774
Lilliefors Critical (0.05) Value	0.106

Data appear Lognormal at (0.05) Significance Level

GOF
BOLD Sediment

Ni Sd Bold

Raw Statistics

Number of Valid Observations	70
Number of Distinct Observations	65
Minimum	4
Maximum	94.7
Mean of Raw Data	28.88
Standard Deviation of Raw Data	16.5
Khat	3.787
Theta hat	7.627
Kstar	3.634
Theta star	7.948
Mean of Log Transformed Data	3.225
Standard Deviation of Log Transformed Data	0.534

Normal GOF Test Results

Correlation Coefficient R	0.911
Approximate Shapiro Wilk Test Statistic	0.841
Approximate Shapiro Wilk P Value	3.622E-10
Lilliefors Test Statistic	0.213
Lilliefors Critical (0.05) Value	0.106

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.973
A-D Test Statistic	1.158
A-D Critical (0.05) Value	0.756
K-S Test Statistic	0.143
K-S Critical(0.05) Value	0.107

Data not Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.981
Approximate Shapiro Wilk Test Statistic	0.974
Approximate Shapiro Wilk P Value	0.371
Lilliefors Test Statistic	0.112
Lilliefors Critical (0.05) Value	0.106

Data appear Approximate_Lognormal at (0.05) Significance Level

GOF
BOLD Sediment

Zn Sd Bold

Raw Statistics

Number of Valid Observations	70
Number of Distinct Observations	67
Minimum	13.9
Maximum	109
Mean of Raw Data	55.31
Standard Deviation of Raw Data	26.15
Khat	3.954
Theta hat	13.99
Kstar	3.794
Theta star	14.58
Mean of Log Transformed Data	3.881
Standard Deviation of Log Transformed Data	0.547

Normal GOF Test Results

Correlation Coefficient R	0.98
Approximate Shapiro Wilk Test Statistic	0.935
Approximate Shapiro Wilk P Value	0.00167
Lilliefors Test Statistic	0.0909
Lilliefors Critical (0.05) Value	0.106

Data appear Approximate Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.964
A-D Test Statistic	0.852
A-D Critical (0.05) Value	0.756
K-S Test Statistic	0.11
K-S Critical(0.05) Value	0.107

Data not Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.974
Approximate Shapiro Wilk Test Statistic	0.928
Approximate Shapiro Wilk P Value	5.1445E-4
Lilliefors Test Statistic	0.118
Lilliefors Critical (0.05) Value	0.106

Data not Lognormal at (0.05) Significance Level

GOF
BOLD Sediment

Hg Sd Bold

	Num Obs	Num Miss	Num Valid	Detects	NDs	% NDs
Raw Statistics	70	0	70	41	29	41.43%

	Number	Minimum	Maximum	Mean	Median	SD
Statistics (Non-Detects Only)	29	0.0048	0.091	0.0425	0.047	0.0212
Statistics (Non-Detects Only)	41	0.031	0.26	0.124	0.11	0.0566
Statistics (All: NDs treated as DL value)	70	0.0048	0.26	0.0904	0.078	0.0607
Statistics (All: NDs treated as DL/2 value)	70	0.0024	0.26	0.0816	0.074	0.0672
Statistics (Normal ROS Imputed Data)	70	-0.0581	0.26	0.0695	0.074	0.0794
Statistics (Gamma ROS Imputed Data)	70	0.01	0.26	0.0816	0.074	0.067
Statistics (Lognormal ROS Imputed Data)	70	0.0241	0.26	0.0881	0.074	0.0611

	K hat	K Star	Theta hat	Log Mean	Log Stdv	Log CV
Statistics (Non-Detects Only)	4.67	4.345	0.0266	-2.196	0.499	-0.227
Statistics (NDs = DL)	2.004	1.927	0.0451	-2.674	0.83	-0.31
Statistics (NDs = DL/2)	1.24	1.196	0.0658	-2.961	1.095	-0.37
Statistics (Gamma ROS Estimates)	1.366	1.317	0.0597	-2.914	0.977	-0.335
Statistics (Lognormal ROS Estimates)	--	--	--	-2.656	0.677	-0.255

Normal GOF Test Results

	No NDs	NDs = DL	NDs = DL/2	Normal ROS
Correlation Coefficient R	0.982	0.963	0.951	0.974

	Apr. Test	P Value	Conclusion with Alpha(0.05)
Shapiro-Wilk (NDs = DL)	0.914	5.7081E-5	Data Not Normal
Shapiro-Wilk (NDs = DL/2)	0.886	5.5384E-7	Data Not Normal
Shapiro-Wilk (Normal ROS Estimates)	0.93	7.2748E-4	Data Not Normal
	Test value	Crit. (0.05)	Conclusion with Alpha(0.05)
Shapiro-Wilk (Detects Only)	0.953	0.941	Data Appear Normal
Lilliefors (Detects Only)	0.129	0.137	Data Appear Normal
Lilliefors (NDs = DL)	0.124	0.106	Data Not Normal
Lilliefors (NDs = DL/2)	0.165	0.106	Data Not Normal
Lilliefors (Normal ROS Estimates)	0.143	0.106	Data Not Normal

Gamma GOF Test Results

	No NDs	NDs = DL	NDs = DL/2	Gamma ROS
Correlation Coefficient R	0.991	0.99	0.973	0.975

	Test value	Crit. (0.05)	Conclusion with Alpha(0.05)
Anderson-Darling (Detects Only)	0.254	0.752	
Kolmogorov-Smirnov (Detects Only)	0.0877	0.138	Detected Data Appear Gamma Distributed
Anderson-Darling (NDs = DL)	0.287	0.763	
Kolmogorov-Smirnov (NDs = DL)	0.0676	0.108	Data Appear Gamma Distributed
Anderson-Darling (NDs = DL/2)	0.917	0.775	
Kolmogorov-Smirnov (NDs = DL/2)	0.106	0.109	Detected Data appear Approximate Gamma Distri
Anderson-Darling (Gamma ROS Estimates)	1.485	0.772	
Kolmogorov-Smirnov (Gamma ROS Est.)	0.134	0.109	Data Not Gamma Distributed

GOF
BOLD Sediment

Lognormal GOF Test Results

	No NDs	NDs = DL	NDs = DL/2	Log ROS
Correlation Coefficient R	0.984	0.968	0.971	0.962

	Apr. Test	P Value	Conclusion with Alpha(0.05)
Shapiro-Wilk (NDs = DL)	0.933	0.0012	Data Not Lognormal
Shapiro-Wilk (NDs = DL/2)	0.929	5.9926E-4	Data Not Lognormal
Shapiro-Wilk (Lognormal ROS Estimates)	0.901	6.5007E-6	Data Not Lognormal
	Test value	Crit. (0.05)	Conclusion with Alpha(0.05)
Shapiro-Wilk (Detects Only)	0.961	0.941	Data Appear Lognormal
Lilliefors (Detects Only)	0.111	0.137	Data Appear Lognormal
Lilliefors (NDs = DL)	0.0842	0.106	Data Appear Lognormal
Lilliefors (NDs = DL/2)	0.137	0.106	Data Not Lognormal
Lilliefors (Lognormal ROS Estimates)	0.183	0.106	Data Not Lognormal

Note: Substitution methods such as DL or DL/2 are not recommended.

GOF
Area 8 Sediment

Goodness-of-Fit Test Statistics for Data Sets with Non-Detects

User Selected Options

Date/Time of Computation	ProUCL 5.112/2/2016 1:45:21 PM
From File	WMWT Sed & Clam tissue_input_11_29_16_a.xls
Full Precision	OFF
Confidence Coefficient	0.95

Ag Sd A8

Raw Statistics

Number of Valid Observations	66
Number of Distinct Observations	61
Minimum	0.048
Maximum	17
Mean of Raw Data	0.872
Standard Deviation of Raw Data	2.372
Khat	0.538
Theta hat	1.621
Kstar	0.523
Theta star	1.665
Mean of Log Transformed Data	-1.306
Standard Deviation of Log Transformed Data	1.307

Normal GOF Test Results

Correlation Coefficient R	0.573
Approximate Shapiro Wilk Test Statistic	0.37
Approximate Shapiro Wilk P Value	0
Lilliefors Test Statistic	0.364
Lilliefors Critical (0.05) Value	0.109

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.861
A-D Test Statistic	5.45
A-D Critical (0.05) Value	0.813
K-S Test Statistic	0.213
K-S Critical(0.05) Value	0.116

Data not Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.956
Approximate Shapiro Wilk Test Statistic	0.905
Approximate Shapiro Wilk P Value	2.7478E-5
Lilliefors Test Statistic	0.142
Lilliefors Critical (0.05) Value	0.109

Data not Lognormal at (0.05) Significance Level

Non-parametric GOF Test Results

Data do not follow a discernible distribution at (0.05) Level of Significan

GOF
Area 8 Sediment

Tot As Sd A8

Raw Statistics

Number of Valid Observations	66
Number of Distinct Observations	56
Minimum	0.42
Maximum	6.47
Mean of Raw Data	2.371
Standard Deviation of Raw Data	0.976
Khat	5.711
Theta hat	0.415
Kstar	5.462
Theta star	0.434
Mean of Log Transformed Data	0.773
Standard Deviation of Log Transformed Data	0.453

Normal GOF Test Results

Correlation Coefficient R	0.962
Approximate Shapiro Wilk Test Statistic	0.945
Approximate Shapiro Wilk P Value	0.0102
Lilliefors Test Statistic	0.0818
Lilliefors Critical (0.05) Value	0.109

Data appear Approximate Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.974
A-D Test Statistic	0.552
A-D Critical (0.05) Value	0.753
K-S Test Statistic	0.0679
K-S Critical(0.05) Value	0.11

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.966
Approximate Shapiro Wilk Test Statistic	0.95
Approximate Shapiro Wilk P Value	0.0216
Lilliefors Test Statistic	0.0869
Lilliefors Critical (0.05) Value	0.109

Data appear Approximate_Lognormal at (0.05) Significance Level

GOF
Area 8 Sediment

Cd Sd A8

Raw Statistics

Number of Valid Observations	66
Number of Distinct Observations	62
Minimum	0.152
Maximum	11.4
Mean of Raw Data	1.665
Standard Deviation of Raw Data	2.299
Khat	0.982
Theta hat	1.696
Kstar	0.947
Theta star	1.758
Mean of Log Transformed Data	-0.0797
Standard Deviation of Log Transformed Data	1.018

Normal GOF Test Results

Correlation Coefficient R	0.784
Approximate Shapiro Wilk Test Statistic	0.625
Approximate Shapiro Wilk P Value	0
Lilliefors Test Statistic	0.275
Lilliefors Critical (0.05) Value	0.109

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.96
A-D Test Statistic	3.095
A-D Critical (0.05) Value	0.781
K-S Test Statistic	0.175
K-S Critical(0.05) Value	0.113

Data not Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.974
Approximate Shapiro Wilk Test Statistic	0.936
Approximate Shapiro Wilk P Value	0.00276
Lilliefors Test Statistic	0.11
Lilliefors Critical (0.05) Value	0.109

Data not Lognormal at (0.05) Significance Level

Non-parametric GOF Test Results

Data do not follow a discernible distribution at (0.05) Level of Significan

GOF
Area 8 Sediment

Cr Sd A8

Raw Statistics

Number of Valid Observations	66
Number of Distinct Observations	59
Minimum	2.32
Maximum	84.8
Mean of Raw Data	28.65
Standard Deviation of Raw Data	14.27
Khat	3.667
Theta hat	7.813
Kstar	3.51
Theta star	8.162
Mean of Log Transformed Data	3.213
Standard Deviation of Log Transformed Data	0.596

Normal GOF Test Results

Correlation Coefficient R	0.962
Approximate Shapiro Wilk Test Statistic	0.938
Approximate Shapiro Wilk P Value	0.00362
Lilliefors Test Statistic	0.0854
Lilliefors Critical (0.05) Value	0.109

Data appear Approximate Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.983
A-D Test Statistic	0.782
A-D Critical (0.05) Value	0.756
K-S Test Statistic	0.104
K-S Critical(0.05) Value	0.11

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.949
Approximate Shapiro Wilk Test Statistic	0.918
Approximate Shapiro Wilk P Value	2.0537E-4
Lilliefors Test Statistic	0.141
Lilliefors Critical (0.05) Value	0.109

Data not Lognormal at (0.05) Significance Level

GOF
Area 8 Sediment

Cu Sd A8

Raw Statistics

Number of Valid Observations	66
Number of Distinct Observations	61
Minimum	3.81
Maximum	439
Mean of Raw Data	19.06
Standard Deviation of Raw Data	53.94
Khat	1.003
Theta hat	19.01
Kstar	0.967
Theta star	19.71
Mean of Log Transformed Data	2.372
Standard Deviation of Log Transformed Data	0.73

Normal GOF Test Results

Correlation Coefficient R	0.44
Approximate Shapiro Wilk Test Statistic	0.238
Approximate Shapiro Wilk P Value	0
Lilliefors Test Statistic	0.41
Lilliefors Critical (0.05) Value	0.109

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.657
A-D Test Statistic	10.05
A-D Critical (0.05) Value	0.78
K-S Test Statistic	0.339
K-S Critical(0.05) Value	0.113

Data not Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.863
Approximate Shapiro Wilk Test Statistic	0.774
Approximate Shapiro Wilk P Value	1.258E-13
Lilliefors Test Statistic	0.208
Lilliefors Critical (0.05) Value	0.109

Data not Lognormal at (0.05) Significance Level

Non-parametric GOF Test Results

Data do not follow a discernible distribution at (0.05) Level of Significan

GOF
Area 8 Sediment

Pb Sd A8

Raw Statistics

Number of Valid Observations	66
Number of Distinct Observations	64
Minimum	1.71
Maximum	185
Mean of Raw Data	11.64
Standard Deviation of Raw Data	24.79
Khat	0.988
Theta hat	11.78
Kstar	0.954
Theta star	12.21
Mean of Log Transformed Data	1.87
Standard Deviation of Log Transformed Data	0.826

Normal GOF Test Results

Correlation Coefficient R	0.564
Approximate Shapiro Wilk Test Statistic	0.362
Approximate Shapiro Wilk P Value	0
Lilliefors Test Statistic	0.394
Lilliefors Critical (0.05) Value	0.109

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.796
A-D Test Statistic	9.562
A-D Critical (0.05) Value	0.781
K-S Test Statistic	0.315
K-S Critical(0.05) Value	0.113

Data not Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.879
Approximate Shapiro Wilk Test Statistic	0.788
Approximate Shapiro Wilk P Value	9.542E-13
Lilliefors Test Statistic	0.211
Lilliefors Critical (0.05) Value	0.109

Data not Lognormal at (0.05) Significance Level

Non-parametric GOF Test Results

Data do not follow a discernible distribution at (0.05) Level of Significan

GOF
Area 8 Sediment

Ni Sd A8

Raw Statistics

Number of Valid Observations	66
Number of Distinct Observations	56
Minimum	2.37
Maximum	40.8
Mean of Raw Data	16.13
Standard Deviation of Raw Data	5.499
Khat	7.928
Theta hat	2.034
Kstar	7.578
Theta star	2.128
Mean of Log Transformed Data	2.716
Standard Deviation of Log Transformed Data	0.394

Normal GOF Test Results

Correlation Coefficient R	0.95
Approximate Shapiro Wilk Test Statistic	0.936
Approximate Shapiro Wilk P Value	0.00285
Lilliefors Test Statistic	0.092
Lilliefors Critical (0.05) Value	0.109

Data appear Approximate Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.962
A-D Test Statistic	1.139
A-D Critical (0.05) Value	0.752
K-S Test Statistic	0.104
K-S Critical(0.05) Value	0.11

Data follow Appr. Gamma Distribution at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.921
Approximate Shapiro Wilk Test Statistic	0.886
Approximate Shapiro Wilk P Value	1.5646E-6
Lilliefors Test Statistic	0.13
Lilliefors Critical (0.05) Value	0.109

Data not Lognormal at (0.05) Significance Level

GOF
Area 8 Sediment

Zn Sd A8

Raw Statistics

Number of Valid Observations	66
Number of Distinct Observations	63
Minimum	12.5
Maximum	396
Mean of Raw Data	41.08
Standard Deviation of Raw Data	48.76
Khat	2.577
Theta hat	15.94
Kstar	2.47
Theta star	16.63
Mean of Log Transformed Data	3.509
Standard Deviation of Log Transformed Data	0.523

Normal GOF Test Results

Correlation Coefficient R	0.582
Approximate Shapiro Wilk Test Statistic	0.387
Approximate Shapiro Wilk P Value	0
Lilliefors Test Statistic	0.329
Lilliefors Critical (0.05) Value	0.109

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.717
A-D Test Statistic	4.83
A-D Critical (0.05) Value	0.76
K-S Test Statistic	0.204
K-S Critical(0.05) Value	0.111

Data not Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.918
Approximate Shapiro Wilk Test Statistic	0.87
Approximate Shapiro Wilk P Value	1.3278E-7
Lilliefors Test Statistic	0.127
Lilliefors Critical (0.05) Value	0.109

Data not Lognormal at (0.05) Significance Level

Non-parametric GOF Test Results

Data do not follow a discernible distribution at (0.05) Level of Significan

GOF
Area 8 Sediment

Hg Sd A8

Raw Statistics

Number of Valid Observations	66
Number of Distinct Observations	56
Minimum	0.006
Maximum	2.42
Mean of Raw Data	0.168
Standard Deviation of Raw Data	0.365
Khat	0.75
Theta hat	0.224
Kstar	0.726
Theta star	0.231
Mean of Log Transformed Data	-2.583
Standard Deviation of Log Transformed Data	1.107

Normal GOF Test Results

Correlation Coefficient R	0.613
Approximate Shapiro Wilk Test Statistic	0.412
Approximate Shapiro Wilk P Value	0
Lilliefors Test Statistic	0.348
Lilliefors Critical (0.05) Value	0.109

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.857
A-D Test Statistic	4.276
A-D Critical (0.05) Value	0.792
K-S Test Statistic	0.187
K-S Critical(0.05) Value	0.114

Data not Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.976
Approximate Shapiro Wilk Test Statistic	0.959
Approximate Shapiro Wilk P Value	0.0692
Lilliefors Test Statistic	0.0831
Lilliefors Critical (0.05) Value	0.109

Data appear Lognormal at (0.05) Significance Level

GOF
Area 8 Tissue

Goodness-of-Fit Test Statistics for Data Sets with Non-Detects

User Selected Options

Date/Time of Computation	ProUCL 5.112/2/2016 1:40:31 PM
From File	WMWT Sed & Clam tissue_input_11_29_16.xls
Full Precision	OFF
Confidence Coefficient	0.95

Ag Ti A8

Raw Statistics

Number of Valid Observations	41
Number of Distinct Observations	40
Minimum	0.0371
Maximum	0.582
Mean of Raw Data	0.176
Standard Deviation of Raw Data	0.15
Khat	1.772
Theta hat	0.0994
Kstar	1.659
Theta star	0.106
Mean of Log Transformed Data	-2.045
Standard Deviation of Log Transformed Data	0.771

Normal GOF Test Results

Correlation Coefficient R	0.889
Shapiro Wilk Test Statistic	0.781
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	1.3293E-7
Lilliefors Test Statistic	0.256
Lilliefors Critical (0.05) Value	0.137

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.966
A-D Test Statistic	1.83
A-D Critical (0.05) Value	0.762
K-S Test Statistic	0.177
K-S Critical(0.05) Value	0.14

Data not Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.968
Shapiro Wilk Test Statistic	0.92
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	0.00746
Lilliefors Test Statistic	0.123
Lilliefors Critical (0.05) Value	0.137

Data appear Approximate_Lognormal at (0.05) Significance Level

Inorg As Ti A8

GOF
Area 8 Tissue

	Num Obs	Num Miss	Num Valid	Detects	NDs	% NDs
Raw Statistics	41	0	41	39	2	4.88%

	Number	Minimum	Maximum	Mean	Median	SD
Statistics (Non-Detects Only)	2	0.014	0.015	0.0145	0.0145	7.0711E-4
Statistics (Non-Detects Only)	39	0.017	0.05	0.0271	0.026	0.00683
Statistics (All: NDs treated as DL value)	41	0.014	0.05	0.0265	0.026	0.0072
Statistics (All: NDs treated as DL/2 value)	41	0.007	0.05	0.0262	0.026	0.00794
Statistics (Normal ROS Imputed Data)	41	0.0112	0.05	0.0264	0.026	0.00751
Statistics (Gamma ROS Imputed Data)	41	0.0133	0.05	0.0265	0.026	0.0073
Statistics (Lognormal ROS Imputed Data)	41	0.0149	0.05	0.0265	0.026	0.00717

	K hat	K Star	Theta hat	Log Mean	Log Stdv	Log CV
Statistics (Non-Detects Only)	17.8	16.45	0.00152	-3.636	0.238	-0.0655
Statistics (NDs = DL)	14.62	13.57	0.00181	-3.665	0.266	-0.0727
Statistics (NDs = DL/2)	9.259	8.597	0.00283	-3.699	0.365	-0.0987
Statistics (Gamma ROS Estimates)	13.87	12.87	0.00191	-3.669	0.275	-0.0751
Statistics (Lognormal ROS Estimates)	--	--	--	-3.663	0.263	-0.0718

Normal GOF Test Results

	No NDs	NDs = DL	NDs = DL/2	Normal ROS
Correlation Coefficient R	0.957	0.97	0.971	0.974

	Test value	Crit. (0.05)	Conclusion with Alpha(0.05)
Shapiro-Wilk (Detects Only)	0.924	0.939	Data Not Normal
Shapiro-Wilk (NDs = DL)	0.948	0.941	Data Appear Normal
Shapiro-Wilk (NDs = DL/2)	0.958	0.941	Data Appear Normal
Shapiro-Wilk (Normal ROS Estimates)	0.959	0.941	Data Appear Normal
Lilliefors (Detects Only)	0.136	0.14	Data Appear Normal
Lilliefors (NDs = DL)	0.121	0.137	Data Appear Normal
Lilliefors (NDs = DL/2)	0.119	0.137	Data Appear Normal
Lilliefors (Normal ROS Estimates)	0.118	0.137	Data Appear Normal

Gamma GOF Test Results

	No NDs	NDs = DL	NDs = DL/2	Gamma ROS
Correlation Coefficient R	0.979	0.986	0.972	0.986

	Test value	Crit. (0.05)	Conclusion with Alpha(0.05)
Anderson-Darling (Detects Only)	0.397	0.747	
Kolmogorov-Smirnov (Detects Only)	0.102	0.141	Detected Data Appear Gamma Distributed
Anderson-Darling (NDs = DL)	0.319	0.748	
Kolmogorov-Smirnov (NDs = DL)	0.0896	0.138	Data Appear Gamma Distributed
Anderson-Darling (NDs = DL/2)	1.13	0.749	
Kolmogorov-Smirnov (NDs = DL/2)	0.149	0.138	Data Not Gamma Distributed
Anderson-Darling (Gamma ROS Estimates)	0.358	0.748	
Kolmogorov-Smirnov (Gamma ROS Est.)	0.0938	0.138	Data Appear Gamma Distributed

GOF
Area 8 Tissue

Lognormal GOF Test Results

	No NDs	NDs = DL	NDs = DL/2	Log ROS
Correlation Coefficient R	0.988	0.991	0.913	0.99

	Test value	Crit. (0.05)	Conclusion with Alpha(0.05)
Shapiro-Wilk (Detects Only)	0.974	0.939	Data Appear Lognormal
Shapiro-Wilk (NDs = DL)	0.983	0.941	Data Appear Lognormal
Shapiro-Wilk (NDs = DL/2)	0.853	0.941	Data Not Lognormal
Shapiro-Wilk (Lognormal ROS Estimates)	0.979	0.941	Data Appear Lognormal
Lilliefors (Detects Only)	0.0888	0.14	Data Appear Lognormal
Lilliefors (NDs = DL)	0.0993	0.137	Data Appear Lognormal
Lilliefors (NDs = DL/2)	0.178	0.137	Data Not Lognormal
Lilliefors (Lognormal ROS Estimates)	0.0954	0.137	Data Appear Lognormal

Note: Substitution methods such as DL or DL/2 are not recommended.

GOF
Area 8 Tissue

Cd Ti A8

Raw Statistics

Number of Valid Observations	41
Number of Distinct Observations	40
Minimum	0.169
Maximum	1
Mean of Raw Data	0.375
Standard Deviation of Raw Data	0.233
Khat	3.577
Theta hat	0.105
Kstar	3.332
Theta star	0.112
Mean of Log Transformed Data	-1.128
Standard Deviation of Log Transformed Data	0.516

Normal GOF Test Results

Correlation Coefficient R	0.877
Shapiro Wilk Test Statistic	0.761
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	3.1502E-8
Lilliefors Test Statistic	0.223
Lilliefors Critical (0.05) Value	0.137

Data not Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.953
A-D Test Statistic	2.426
A-D Critical (0.05) Value	0.754
K-S Test Statistic	0.184
K-S Critical(0.05) Value	0.139

Data not Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.94
Shapiro Wilk Test Statistic	0.866
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	7.8695E-5
Lilliefors Test Statistic	0.166
Lilliefors Critical (0.05) Value	0.137

Data not Lognormal at (0.05) Significance Level

Non-parametric GOF Test Results

Data do not follow a discernible distribution at (0.05) Level of Significan

GOF
Area 8 Tissue

Cr Ti A8

Raw Statistics

Number of Valid Observations	41
Number of Distinct Observations	41
Minimum	0.155
Maximum	1.13
Mean of Raw Data	0.478
Standard Deviation of Raw Data	0.265
Khat	3.41
Theta hat	0.14
Kstar	3.177
Theta star	0.151
Mean of Log Transformed Data	-0.891
Standard Deviation of Log Transformed Data	0.571

Normal GOF Test Results

Correlation Coefficient R	0.963
Shapiro Wilk Test Statistic	0.912
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	0.00388
Lilliefors Test Statistic	0.137
Lilliefors Critical (0.05) Value	0.137

Data appear Approximate Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.989
A-D Test Statistic	0.429
A-D Critical (0.05) Value	0.754
K-S Test Statistic	0.0887
K-S Critical(0.05) Value	0.139

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.987
Shapiro Wilk Test Statistic	0.953
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	0.135
Lilliefors Test Statistic	0.0848
Lilliefors Critical (0.05) Value	0.137

Data appear Lognormal at (0.05) Significance Level

GOF
Area 8 Tissue

Cu Ti A8

Raw Statistics

Number of Valid Observations	41
Number of Distinct Observations	28
Minimum	0.759
Maximum	1.73
Mean of Raw Data	1.216
Standard Deviation of Raw Data	0.192
Khat	41.22
Theta hat	0.0295
Kstar	38.22
Theta star	0.0318
Mean of Log Transformed Data	0.183
Standard Deviation of Log Transformed Data	0.159

Normal GOF Test Results

Correlation Coefficient R	0.985
Shapiro Wilk Test Statistic	0.977
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	0.69
Lilliefors Test Statistic	0.13
Lilliefors Critical (0.05) Value	0.137

Data appear Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.989
A-D Test Statistic	0.38
A-D Critical (0.05) Value	0.746
K-S Test Statistic	0.119
K-S Critical(0.05) Value	0.137

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.984
Shapiro Wilk Test Statistic	0.979
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	0.75
Lilliefors Test Statistic	0.109
Lilliefors Critical (0.05) Value	0.137

Data appear Lognormal at (0.05) Significance Level

GOF
Area 8 Tissue

Pb Ti A8

Raw Statistics

Number of Valid Observations	41
Number of Distinct Observations	38
Minimum	0.0431
Maximum	0.13
Mean of Raw Data	0.0723
Standard Deviation of Raw Data	0.0164
Khat	19.9
Theta hat	0.00363
Kstar	18.46
Theta star	0.00392
Mean of Log Transformed Data	-2.653
Standard Deviation of Log Transformed Data	0.23

Normal GOF Test Results

Correlation Coefficient R	0.96
Shapiro Wilk Test Statistic	0.936
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	0.0302
Lilliefors Test Statistic	0.107
Lilliefors Critical (0.05) Value	0.137

Data appear Approximate Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.964
A-D Test Statistic	0.68
A-D Critical (0.05) Value	0.747
K-S Test Statistic	0.116
K-S Critical(0.05) Value	0.138

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.971
Shapiro Wilk Test Statistic	0.948
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	0.082
Lilliefors Test Statistic	0.124
Lilliefors Critical (0.05) Value	0.137

Data appear Lognormal at (0.05) Significance Level

GOF
Area 8 Tissue

Ni Ti A8

Raw Statistics

Number of Valid Observations	41
Number of Distinct Observations	38
Minimum	0.27
Maximum	1
Mean of Raw Data	0.476
Standard Deviation of Raw Data	0.17
Khat	9.013
Theta hat	0.0528
Kstar	8.37
Theta star	0.0568
Mean of Log Transformed Data	-0.8
Standard Deviation of Log Transformed Data	0.334

Normal GOF Test Results

Correlation Coefficient R	0.955
Shapiro Wilk Test Statistic	0.908
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	0.00278
Lilliefors Test Statistic	0.125
Lilliefors Critical (0.05) Value	0.137

Data appear Approximate Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.987
A-D Test Statistic	0.578
A-D Critical (0.05) Value	0.749
K-S Test Statistic	0.103
K-S Critical(0.05) Value	0.138

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.985
Shapiro Wilk Test Statistic	0.957
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	0.177
Lilliefors Test Statistic	0.0905
Lilliefors Critical (0.05) Value	0.137

Data appear Lognormal at (0.05) Significance Level

GOF
Area 8 Tissue

Zn Ti A8

Raw Statistics

Number of Valid Observations	41
Number of Distinct Observations	28
Minimum	9.6
Maximum	16.3
Mean of Raw Data	13.38
Standard Deviation of Raw Data	1.506
Khat	77.23
Theta hat	0.173
Kstar	71.6
Theta star	0.187
Mean of Log Transformed Data	2.587
Standard Deviation of Log Transformed Data	0.117

Normal GOF Test Results

Correlation Coefficient R	0.992
Shapiro Wilk Test Statistic	0.98
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	0.758
Lilliefors Test Statistic	0.0744
Lilliefors Critical (0.05) Value	0.137

Data appear Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.986
A-D Test Statistic	0.365
A-D Critical (0.05) Value	0.747
K-S Test Statistic	0.0866
K-S Critical(0.05) Value	0.137

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.981
Shapiro Wilk Test Statistic	0.961
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	0.234
Lilliefors Test Statistic	0.0906
Lilliefors Critical (0.05) Value	0.137

Data appear Lognormal at (0.05) Significance Level

GOF
Area 8 Tissue

Meth Hg Ti A8

Raw Statistics

Number of Valid Observations	41
Number of Distinct Observations	30
Minimum	1
Maximum	18
Mean of Raw Data	8.327
Standard Deviation of Raw Data	3.312
Khat	5.528
Theta hat	1.506
Kstar	5.14
Theta star	1.62
Mean of Log Transformed Data	2.026
Standard Deviation of Log Transformed Data	0.484

Normal GOF Test Results

Correlation Coefficient R	0.98
Shapiro Wilk Test Statistic	0.97
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	0.46
Lilliefors Test Statistic	0.108
Lilliefors Critical (0.05) Value	0.137

Data appear Normal at (0.05) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.989
A-D Test Statistic	0.454
A-D Critical (0.05) Value	0.751
K-S Test Statistic	0.106
K-S Critical(0.05) Value	0.138

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.925
Shapiro Wilk Test Statistic	0.884
Shapiro Wilk Critical (0.05) Value	0.941
Approximate Shapiro Wilk P Value	3.4872E-4
Lilliefors Test Statistic	0.133
Lilliefors Critical (0.05) Value	0.137

Data appear Approximate_Lognormal at (0.05) Significance Level

COC	Normal		Gamma		Log		Distribution
	Q-Q Plot	GOF	Q-Q Plot	GOF	Q-Q Plot	GOF	
A8 Tissue							
Ag	No	No	No	No	No	Yes	Not discernable
Inorg As	Yes	Yes	Yes	Yes	Yes	Yes	Normal
Cd	No	No	No	No	No	No	Not discernable
Cr	No	Yes	Yes	Yes	Yes	Yes	Gamma
Cu	Yes	Yes	Yes	Yes	Yes	Yes	Normal
Ni	No	Yes	Yes	Yes	Yes	Yes	Gamma
Pb	No	Yes	Yes	Yes	Yes	Yes	Gamma
MeHg	Yes	Yes	Yes	Yes	No	Yes	Normal
Zn	No	Yes	Yes	Yes	Yes	Yes	Gamma
Pen Tissue							
Ag	--		--		--		--
Inorg As	No	Yes	No	Yes	Yes	Yes	Lognormal
Cd	Yes	Yes	Yes	Yes	Yes	Yes	Normal
Cr	No	No	No	No	No	Yes	Not discernable
Cu	Yes	Yes	Yes	Yes	Yes	Yes	Normal
Ni	No	No	No	No	No	No	Not discernable
Pb	No	No	No	No	No	No	Not discernable
MeHg	No	Yes	Yes	Yes	Yes	Yes	Gamma
Zn	Yes	Yes	Yes	Yes	Yes	Yes	Normal
A8 Sed							
Ag	No	No	No	No	No	No	Not discernable
As	No	Yes	Yes	Yes	No	Yes	Gamma
Cd	No	No	No	No	No	No	Not discernable
Cr	No	Yes	No	Yes	No	No	Not discernable
Cu	No	No	No	No	No	No	Not discernable
Ni	No	Yes	No	Yes	No	No	Not discernable
Pb	No	No	No	No	No	No	Not discernable
Hg	No	No	No	No	Yes	Yes	Lognormal
Zn	No	No	No	No	No	No	Not discernable
Bold Sed							
Ag	No	No	Yes	No	No	No	Not discernable
As	No	No	Yes	Yes	Yes	Yes	Gamma
Cd	No	No	Yes	No	Yes	Yes	Lognormal
Cr	No	No	Yes	Yes	Yes	Yes	Gamma
Cu	No	No	Yes	Yes	Yes	Yes	Gamma
Ni	No	No	No	No	Yes	Yes	Lognormal
Pb	No	No	Yes	Yes	Yes	Yes	Gamma
Hg	Yes	No	Yes	Yes	Yes	Yes	Normal
Zn	No	Yes	No	No	No	No	Not discernable

D2
Tissue Background Threshold Value Calculation

Penrose Point Tissue BTVs
90-90 UTL - All Data

Background Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	ProUCL 5.11/30/2017 5:20:49 PM
From File	C:\Users\laura.scheffler\Documents\Laura Work\Keyport Area 8\Risk Assessment\BTV ProUCL input_output\Pe
Full Precision	OFF
Confidence Coefficient	90%
Coverage	90%
New or Future K Observations	1
Number of Bootstrap Operations	2000

Ag Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	22
Minimum	0.0069	First Quartile	0.00908
Second Largest	0.0186	Median	0.0107
Maximum	0.0475	Third Quartile	0.0125
Mean	0.0126	SD	0.00829
Coefficient of Variation	0.659	Skewness	3.874
Mean of logged Data	-4.481	SD of logged Data	0.403

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.737	d2max (for USL)	2.429

Normal GOF Test

Shapiro Wilk Test Statistic	0.523	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.302	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with	90% Coverage	0.027	90% Percentile (z)	0.0232
	90% UPL (t)	0.0238	95% Percentile (z)	0.0262
	90% USL	0.0327	99% Percentile (z)	0.0319

Gamma GOF Test

A-D Test Statistic	1.771	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.746	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.236	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.186	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Penrose Point Tissue BTVs
90-90 UTL - All Data

Gamma Statistics

k hat (MLE)	4.95	k star (bias corrected MLE)	4.305
Theta hat (MLE)	0.00254	Theta star (bias corrected MLE)	0.00292
nu hat (MLE)	217.8	nu star (bias corrected)	189.4
MLE Mean (bias corrected)	0.0126	MLE Sd (bias corrected)	0.00606

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	0.0207	90% Percentile	0.0207
90% Hawkins Wixley (HW) Approx. Gamma UPL	0.0204	95% Percentile	0.0239
90% WH Approx. Gamma UTL with 90% Coverage	0.0239	99% Percentile	0.0307
90% HW Approx. Gamma UTL with 90% Coverage	0.0236		
90% WH USL	0.0305	90% HW USL	0.0304

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.806	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.192	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.184	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	0.0228	90% Percentile (z)	0.019
90% UPL (t)	0.0195	95% Percentile (z)	0.022
90% USL	0.0302	99% Percentile (z)	0.0289

Nonparametric Distribution Free Background Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	21	90% UTL with 90% Coverage	0.0186
Approx, f used to compute achieved CC	1.167	Approximate Actual Confidence Coefficient achieved by UTL	0.661
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	0.0186	90% BCA Bootstrap UTL with 90% Coverage	0.0186
90% UPL	0.0177	90% Percentile	0.0155
90% Chebyshev UPL	0.038	95% Percentile	0.0185
95% Chebyshev UPL	0.0495	99% Percentile	0.0414
90% USL	0.0475		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Penrose Point Tissue BTVs
90-90 UTL - All Data

Inorg As Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	14
Minimum	0.026	First Quartile	0.0303
Second Largest	0.045	Median	0.0325
Maximum	0.055	Third Quartile	0.0368
Mean	0.0346	SD	0.00657
Coefficient of Variation	0.19	Skewness	1.655
Mean of logged Data	-3.378	SD of logged Data	0.172

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.737	d2max (for USL)	2.429

Normal GOF Test

Shapiro Wilk Test Statistic	0.854	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.178	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with 90% Coverage	0.046	90% Percentile (z)	0.043
90% UPL (t)	0.0435	95% Percentile (z)	0.0454
90% USL	0.0506	99% Percentile (z)	0.0499

Gamma GOF Test

A-D Test Statistic	0.791	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.742	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.153	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	33.45	k star (bias corrected MLE)	28.92
Theta hat (MLE)	0.00104	Theta star (bias corrected MLE)	0.0012
nu hat (MLE)	1472	nu star (bias corrected)	1272
MLE Mean (bias corrected)	0.0346	MLE Sd (bias corrected)	0.00644

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	0.0432	90% Percentile	0.0431
90% Hawkins Wixley (HW) Approx. Gamma UPL	0.0432	95% Percentile	0.0459
90% WH Approx. Gamma UTL with 90% Coverage	0.046	99% Percentile	0.0514
90% HW Approx. Gamma UTL with 90% Coverage	0.046		
90% WH USL	0.0513	90% HW USL	0.0514

Penrose Point Tissue BTVs
90-90 UTL - All Data

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.917	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.145	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	0.046	90% Percentile (z)	0.0425
90% UPL (t)	0.0431	95% Percentile (z)	0.0453
90% USL	0.0518	99% Percentile (z)	0.0509

Nonparametric Distribution Free Background Statistics
Data appear Approximate Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	21	90% UTL with 90% Coverage	0.045
Approx, f used to compute achieved CC	1.167	Approximate Actual Confidence Coefficient achieved by UTL	0.661
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	0.045	90% BCA Bootstrap UTL with 90% Coverage	0.045
90% UPL	0.0444	90% Percentile	0.0428
90% Chebyshev UPL	0.0548	95% Percentile	0.0449
95% Chebyshev UPL	0.0639	99% Percentile	0.0529
90% USL	0.055		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Cd Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	22
Minimum	0.31	First Quartile	0.406
Second Largest	0.565	Median	0.438
Maximum	0.629	Third Quartile	0.483
Mean	0.445	SD	0.0718
Coefficient of Variation	0.161	Skewness	0.606
Mean of logged Data	-0.823	SD of logged Data	0.16

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.737	d2max (for USL)	2.429

Normal GOF Test

Shapiro Wilk Test Statistic	0.973	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.0947	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Penrose Point Tissue BTVs
90-90 UTL - All Data

Background Statistics Assuming Normal Distribution

90% UTL with	90% Coverage	0.569	90% Percentile (z)	0.537
	90% UPL (t)	0.542	95% Percentile (z)	0.563
	90% USL	0.619	99% Percentile (z)	0.612

Gamma GOF Test

A-D Test Statistic	0.162	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.742	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0741	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	41.19	k star (bias corrected MLE)	35.61
Theta hat (MLE)	0.0108	Theta star (bias corrected MLE)	0.0125
nu hat (MLE)	1812	nu star (bias corrected)	1567
MLE Mean (bias corrected)	0.445	MLE Sd (bias corrected)	0.0745

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL		0.544	90% Percentile	0.542
90% Hawkins Wixley (HW) Approx. Gamma UPL		0.544	95% Percentile	0.574
90% WH Approx. Gamma UTL with	90% Coverage	0.575	99% Percentile	0.636
90% HW Approx. Gamma UTL with	90% Coverage	0.576		
	90% WH USL	0.636	90% HW USL	0.638

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.99	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0777	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with	90% Coverage	0.58	90% Percentile (z)	0.539
	90% UPL (t)	0.545	95% Percentile (z)	0.571
	90% USL	0.647	99% Percentile (z)	0.637

Nonparametric Distribution Free Background Statistics

Data appear Normal at 5% Significance Level

Penrose Point Tissue BTVs
90-90 UTL - All Data

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	21	90% UTL with 90% Coverage	0.565
Approx, f used to compute achieved CC	1.167	Approximate Actual Confidence Coefficient achieved by UTL	0.661
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	0.565	90% BCA Bootstrap UTL with 90% Coverage	0.565
90% UPL	0.549	90% Percentile	0.511
90% Chebyshev UPL	0.665	95% Percentile	0.562
95% Chebyshev UPL	0.764	99% Percentile	0.616
90% USL	0.629		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Cr Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	22
Minimum	0.216	First Quartile	0.284
Second Largest	0.496	Median	0.343
Maximum	1.72	Third Quartile	0.393
Mean	0.4	SD	0.305
Coefficient of Variation	0.762	Skewness	4.189
Mean of logged Data	-1.039	SD of logged Data	0.426

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.737	d2max (for USL)	2.429

Normal GOF Test

Shapiro Wilk Test Statistic	0.458	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.332	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with 90% Coverage	0.93	90% Percentile (z)	0.791
90% UPL (t)	0.813	95% Percentile (z)	0.902
90% USL	1.141	99% Percentile (z)	1.11

Gamma GOF Test

A-D Test Statistic	2.066	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.747	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.238	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.186	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Penrose Point Tissue BTVs
90-90 UTL - All Data

Gamma Statistics

k hat (MLE)	4.216	k star (bias corrected MLE)	3.672
Theta hat (MLE)	0.095	Theta star (bias corrected MLE)	0.109
nu hat (MLE)	185.5	nu star (bias corrected)	161.6
MLE Mean (bias corrected)	0.4	MLE Sd (bias corrected)	0.209

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	0.678	90% Percentile	0.681
90% Hawkins Wixley (HW) Approx. Gamma UPL	0.665	95% Percentile	0.794
90% WH Approx. Gamma UTL with 90% Coverage	0.791	99% Percentile	1.038
90% HW Approx. Gamma UTL with 90% Coverage	0.777		
90% WH USL	1.026	90% HW USL	1.016

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.768	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.183	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level	

Data appear Approximate Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	0.741	90% Percentile (z)	0.611
90% UPL (t)	0.629	95% Percentile (z)	0.713
90% USL	0.995	99% Percentile (z)	0.953

Nonparametric Distribution Free Background Statistics

Data appear Approximate Lognormal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	21	90% UTL with 90% Coverage	0.496
Approx, f used to compute achieved CC	1.167	Approximate Actual Confidence Coefficient achieved by UTL	0.661
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	0.496	90% BCA Bootstrap UTL with 90% Coverage	0.496
90% UPL	0.486	90% Percentile	0.458
90% Chebyshev UPL	1.336	95% Percentile	0.494
95% Chebyshev UPL	1.76	99% Percentile	1.463
90% USL	1.72		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Penrose Point Tissue BTVs
90-90 UTL - All Data

Cu Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	19
Minimum	0.896	First Quartile	1.018
Second Largest	1.42	Median	1.12
Maximum	1.45	Third Quartile	1.288
Mean	1.159	SD	0.162
Coefficient of Variation	0.14	Skewness	0.221
Mean of logged Data	0.138	SD of logged Data	0.14

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.737	d2max (for USL)	2.429

Normal GOF Test

Shapiro Wilk Test Statistic	0.948	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.14	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with 90% Coverage	1.441	90% Percentile (z)	1.367
90% UPL (t)	1.378	95% Percentile (z)	1.426
90% USL	1.553	99% Percentile (z)	1.536

Gamma GOF Test

A-D Test Statistic	0.471	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.743	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.131	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	53.64	k star (bias corrected MLE)	46.36
Theta hat (MLE)	0.0216	Theta star (bias corrected MLE)	0.025
nu hat (MLE)	2360	nu star (bias corrected)	2040
MLE Mean (bias corrected)	1.159	MLE Sd (bias corrected)	0.17

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	1.384	90% Percentile	1.381
90% Hawkins Wixley (HW) Approx. Gamma UPL	1.385	95% Percentile	1.452
90% WH Approx. Gamma UTL with 90% Coverage	1.455	99% Percentile	1.591
90% HW Approx. Gamma UTL with 90% Coverage	1.457		
90% WH USL	1.589	90% HW USL	1.595

Penrose Point Tissue BTVs
90-90 UTL - All Data

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.953	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.128	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	1.464	90% Percentile (z)	1.373
90% UPL (t)	1.387	95% Percentile (z)	1.445
90% USL	1.613	99% Percentile (z)	1.59

Nonparametric Distribution Free Background Statistics
Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	21	90% UTL with 90% Coverage	1.42
Approx, f used to compute achieved CC	1.167	Approximate Actual Confidence Coefficient achieved by UTL	0.661
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	1.42	90% BCA Bootstrap UTL with 90% Coverage	1.42
90% UPL	1.399	90% Percentile	1.349
90% Chebyshev UPL	1.657	95% Percentile	1.417
95% Chebyshev UPL	1.882	99% Percentile	1.444
90% USL	1.45		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Pb Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	21
Minimum	0.0132	First Quartile	0.0164
Second Largest	0.0295	Median	0.0204
Maximum	0.0678	Third Quartile	0.0229
Mean	0.022	SD	0.011
Coefficient of Variation	0.502	Skewness	3.67
Mean of logged Data	-3.887	SD of logged Data	0.34

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.737	d2max (for USL)	2.429

Normal GOF Test

Shapiro Wilk Test Statistic	0.571	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.301	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.184	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Penrose Point Tissue BTVs
90-90 UTL - All Data

Background Statistics Assuming Normal Distribution

90% UTL with	90% Coverage	0.0411	90% Percentile (z)	0.0361
	90% UPL (t)	0.0369	95% Percentile (z)	0.0401
	90% USL	0.0488	99% Percentile (z)	0.0476

Gamma GOF Test

A-D Test Statistic	1.445	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.745	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.225	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.186	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	7.364	k star (bias corrected MLE)	6.39
Theta hat (MLE)	0.00299	Theta star (bias corrected MLE)	0.00344
nu hat (MLE)	324	nu star (bias corrected)	281.2
MLE Mean (bias corrected)	0.022	MLE Sd (bias corrected)	0.0087

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	0.0337	90% Percentile	0.0336
90% Hawkins Wixley (HW) Approx. Gamma UPL	0.0333	95% Percentile	0.038
90% WH Approx. Gamma UTL with 90% Coverage	0.038	99% Percentile	0.0471
90% HW Approx. Gamma UTL with 90% Coverage	0.0377		
90% WH USL	0.0469	90% HW USL	0.0468

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.82	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.189	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.184	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with	90% Coverage	0.037	90% Percentile (z)	0.0317
	90% UPL (t)	0.0325	95% Percentile (z)	0.0359
	90% USL	0.0468	99% Percentile (z)	0.0452

Nonparametric Distribution Free Background Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	21		90% UTL with	90% Coverage	0.0295
Approx, f used to compute achieved CC	1.167		Approximate Actual Confidence Coefficient achieved by UTL		0.661
			Approximate Sample Size needed to achieve specified CC		37
90% Percentile Bootstrap UTL with	90% Coverage	0.0295	90% BCA Bootstrap UTL with	90% Coverage	0.0295
	90% UPL	0.0282		90% Percentile	0.0249
	90% Chebyshev UPL	0.0558		95% Percentile	0.0293
	95% Chebyshev UPL	0.0711		99% Percentile	0.0598
	90% USL	0.0678			

Penrose Point Tissue BTVs
90-90 UTL - All Data

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers
and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data
represents a background data set and when many onsite observations need to be compared with the BTV.

Ni Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	21
Minimum	0.229	First Quartile	0.32
Second Largest	0.486	Median	0.368
Maximum	1.2	Third Quartile	0.414
Mean	0.399	SD	0.191
Coefficient of Variation	0.477	Skewness	3.789
Mean of logged Data	-0.981	SD of logged Data	0.322

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.737	d2max (for USL)	2.429

Normal GOF Test

Shapiro Wilk Test Statistic	0.554	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.314	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.184	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with	90% Coverage	0.73	90% Percentile (z)	0.644
	90% UPL (t)	0.657	95% Percentile (z)	0.713
	90% USL	0.862	99% Percentile (z)	0.843

Gamma GOF Test

A-D Test Statistic	1.601	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.745	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.242	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.186	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	8.146	k star (bias corrected MLE)	7.066
Theta hat (MLE)	0.049	Theta star (bias corrected MLE)	0.0565
nu hat (MLE)	358.4	nu star (bias corrected)	310.9
MLE Mean (bias corrected)	0.399	MLE Sd (bias corrected)	0.15

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	0.601	90% Percentile	0.6
90% Hawkins Wixley (HW) Approx. Gamma UPL	0.595	95% Percentile	0.674
90% WH Approx. Gamma UTL with 90% Coverage	0.675	99% Percentile	0.829
90% HW Approx. Gamma UTL with 90% Coverage	0.67		
90% WH USL	0.825	90% HW USL	0.823

Penrose Point Tissue BTVs
90-90 UTL - All Data

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.807	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.207	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.184	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with	90% Coverage	0.657	90% Percentile (z)		0.567
	90% UPL (t)	0.58	95% Percentile (z)		0.637
	90% USL	0.821	99% Percentile (z)		0.794

Nonparametric Distribution Free Background Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r		21	90% UTL with	90% Coverage	0.486
Approx, f used to compute achieved CC		1.167	Approximate Actual Confidence Coefficient achieved by UTL		0.661
			Approximate Sample Size needed to achieve specified CC		37
90% Percentile Bootstrap UTL with	90% Coverage	0.486	90% BCA Bootstrap UTL with	90% Coverage	0.486
	90% UPL	0.474		90% Percentile	0.445
	90% Chebyshev UPL	0.984		95% Percentile	0.484
	95% Chebyshev UPL	1.249		99% Percentile	1.05
	90% USL	1.2			

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Zn Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	16
Minimum	13.1	First Quartile	14.2
Second Largest	17	Median	14.75
Maximum	17.1	Third Quartile	15.58
Mean	15	SD	1.181
Coefficient of Variation	0.0787	Skewness	0.446
Mean of logged Data	2.705	SD of logged Data	0.0779

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.737	d2max (for USL)	2.429

Normal GOF Test

Shapiro Wilk Test Statistic	0.94	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.17	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level	

Data appear Normal at 5% Significance Level

Penrose Point Tissue BTVs
90-90 UTL - All Data

Background Statistics Assuming Normal Distribution

90% UTL with	90% Coverage	17.05	90% Percentile (z)	16.51
	90% UPL (t)	16.6	95% Percentile (z)	16.94
	90% USL	17.87	99% Percentile (z)	17.75

Gamma GOF Test

A-D Test Statistic	0.449	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.741	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.161	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	171.7	k star (bias corrected MLE)	148.3
Theta hat (MLE)	0.0874	Theta star (bias corrected MLE)	0.101
nu hat (MLE)	7553	nu star (bias corrected)	6525
MLE Mean (bias corrected)	15	MLE Sd (bias corrected)	1.232

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	16.61	90% Percentile	16.6
90% Hawkins Wixley (HW) Approx. Gamma UPL	16.61	95% Percentile	17.08
90% WH Approx. Gamma UTL with 90% Coverage	17.1	99% Percentile	18.01
90% HW Approx. Gamma UTL with 90% Coverage	17.1		
90% WH USL	18	90% HW USL	18.01

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.95	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.156	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with	90% Coverage	17.12	90% Percentile (z)	16.53
	90% UPL (t)	16.62	95% Percentile (z)	17
	90% USL	18.07	99% Percentile (z)	17.93

Nonparametric Distribution Free Background Statistics
Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	21		90% UTL with	90% Coverage	17
Approx, f used to compute achieved CC	1.167		Approximate Actual Confidence Coefficient achieved by UTL		0.661
			Approximate Sample Size needed to achieve specified CC		37
90% Percentile Bootstrap UTL with	90% Coverage	17	90% BCA Bootstrap UTL with	90% Coverage	17
90% UPL		17	90% Percentile		16.96
90% Chebyshev UPL		18.62	95% Percentile		17
95% Chebyshev UPL		20.26	99% Percentile		17.08
90% USL		17.1			

Penrose Point Tissue BTVs
90-90 UTL - All Data

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers
and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data
represents a background data set and when many onsite observations need to be compared with the BTV.

Meth Hg Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	15
Minimum	2.2	First Quartile	3.325
Second Largest	4.6	Median	3.7
Maximum	6.6	Third Quartile	4.3
Mean	3.877	SD	0.857
Coefficient of Variation	0.221	Skewness	1.225
Mean of logged Data	1.333	SD of logged Data	0.214

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.737	d2max (for USL)	2.429

Normal GOF Test

Shapiro Wilk Test Statistic	0.896	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.154	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with 90% Coverage	5.366	90% Percentile (z)	4.975
90% UPL (t)	5.037	95% Percentile (z)	5.287
90% USL	5.959	99% Percentile (z)	5.871

Gamma GOF Test

A-D Test Statistic	0.487	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.741	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.136	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	22.87	k star (bias corrected MLE)	19.79
Theta hat (MLE)	0.169	Theta star (bias corrected MLE)	0.196
nu hat (MLE)	1006	nu star (bias corrected)	870.6
MLE Mean (bias corrected)	3.877	MLE Sd (bias corrected)	0.872

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	5.043	90% Percentile	5.028
90% Hawkins Wixley (HW) Approx. Gamma UPL	5.047	95% Percentile	5.414
90% WH Approx. Gamma UTL with 90% Coverage	5.432	99% Percentile	6.188
90% HW Approx. Gamma UTL with 90% Coverage	5.446		
90% WH USL	6.182	90% HW USL	6.225

Penrose Point Tissue BTVs
90-90 UTL - All Data

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.942	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.138	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with	90% Coverage	5.502	90% Percentile (z)	4.991
	90% UPL (t)	5.067	95% Percentile (z)	5.394
	90% USL	6.38	99% Percentile (z)	6.242

Nonparametric Distribution Free Background Statistics
Data appear Approximate Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

	Order of Statistic, r	21	90% UTL with 90% Coverage	4.6
	Approx, f used to compute achieved CC	1.167	Approximate Actual Confidence Coefficient achieved by UTL	0.661
			Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with	90% Coverage	4.6	90% BCA Bootstrap UTL with 90% Coverage	4.6
	90% UPL	4.6	90% Percentile	4.59
	90% Chebyshev UPL	6.506	95% Percentile	4.6
	95% Chebyshev UPL	7.696	99% Percentile	6.18
	90% USL	6.6		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Penrose Point Tissue BTVs
95-95 UTL - All Data

Background Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	ProUCL 5.11/30/2017 5:16:49 PM
From File	C:\Users\laura.scheffler\Documents\Laura Work\Keyport Area 8\Risk Assessment\BTV ProUCL input_output\Pe
Full Precision	OFF
Confidence Coefficient	95%
Coverage	95%
New or Future K Observations	1
Number of Bootstrap Operations	2000

Ag Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	22
Minimum	0.0069	First Quartile	0.00908
Second Largest	0.0186	Median	0.0107
Maximum	0.0475	Third Quartile	0.0125
Mean	0.0126	SD	0.00829
Coefficient of Variation	0.659	Skewness	3.874
Mean of logged Data	-4.481	SD of logged Data	0.403

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.349	d2max (for USL)	2.603

Normal GOF Test

Shapiro Wilk Test Statistic	0.523	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.302	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.184	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

95% UTL with	95% Coverage	0.032	90% Percentile (z)	0.0232
	95% UPL (t)	0.0272	95% Percentile (z)	0.0262
	95% USL	0.0341	99% Percentile (z)	0.0319

Gamma GOF Test

A-D Test Statistic	1.771	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.746	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.236	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.186	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Penrose Point Tissue BTVs
95-95 UTL - All Data

Gamma Statistics

k hat (MLE)	4.95	k star (bias corrected MLE)	4.305
Theta hat (MLE)	0.00254	Theta star (bias corrected MLE)	0.00292
nu hat (MLE)	217.8	nu star (bias corrected)	189.4
MLE Mean (bias corrected)	0.0126	MLE Sd (bias corrected)	0.00606

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL	0.0241	90% Percentile	0.0207
95% Hawkins Wixley (HW) Approx. Gamma UPL	0.0238	95% Percentile	0.0239
95% WH Approx. Gamma UTL with 95% Coverage	0.0297	99% Percentile	0.0307
95% HW Approx. Gamma UTL with 95% Coverage	0.0295		
95% WH USL	0.0324	95% HW USL	0.0323

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.806	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.192	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.184	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with 95% Coverage	0.0292	90% Percentile (z)	0.019
95% UPL (t)	0.023	95% Percentile (z)	0.022
95% USL	0.0324	99% Percentile (z)	0.0289

Nonparametric Distribution Free Background Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	22	95% UTL with 95% Coverage	0.0475
Approx, f used to compute achieved CC	1.158	Approximate Actual Confidence Coefficient achieved by UTL	0.676
		Approximate Sample Size needed to achieve specified CC	59
95% Percentile Bootstrap UTL with 95% Coverage	0.0475	95% BCA Bootstrap UTL with 95% Coverage	0.0475
95% UPL	0.0432	90% Percentile	0.0155
90% Chebyshev UPL	0.038	95% Percentile	0.0185
95% Chebyshev UPL	0.0495	99% Percentile	0.0414
95% USL	0.0475		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Penrose Point Tissue BTVs
95-95 UTL - All Data

Inorg As Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	14
Minimum	0.026	First Quartile	0.0303
Second Largest	0.045	Median	0.0325
Maximum	0.055	Third Quartile	0.0368
Mean	0.0346	SD	0.00657
Coefficient of Variation	0.19	Skewness	1.655
Mean of logged Data	-3.378	SD of logged Data	0.172

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.349	d2max (for USL)	2.603

Normal GOF Test

Shapiro Wilk Test Statistic	0.854	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.178	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

95% UTL with 95% Coverage	0.0501	90% Percentile (z)	0.043
95% UPL (t)	0.0462	95% Percentile (z)	0.0454
95% USL	0.0517	99% Percentile (z)	0.0499

Gamma GOF Test

A-D Test Statistic	0.791	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.742	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.153	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	33.45	k star (bias corrected MLE)	28.92
Theta hat (MLE)	0.00104	Theta star (bias corrected MLE)	0.0012
nu hat (MLE)	1472	nu star (bias corrected)	1272
MLE Mean (bias corrected)	0.0346	MLE Sd (bias corrected)	0.00644

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL	0.0461	90% Percentile	0.0431
95% Hawkins Wixley (HW) Approx. Gamma UPL	0.0462	95% Percentile	0.0459
95% WH Approx. Gamma UTL with 95% Coverage	0.0507	99% Percentile	0.0514
95% HW Approx. Gamma UTL with 95% Coverage	0.0508		
95% WH USL	0.0527	95% HW USL	0.0529

Penrose Point Tissue BTVs
95-95 UTL - All Data

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.917	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.145	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with	95% Coverage	0.0511	90% Percentile (z)	0.0425
	95% UPL (t)	0.0462	95% Percentile (z)	0.0453
	95% USL	0.0534	99% Percentile (z)	0.0509

Nonparametric Distribution Free Background Statistics
Data appear Approximate Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	22		95% UTL with 95% Coverage	0.055
Approx, f used to compute achieved CC	1.158		Approximate Actual Confidence Coefficient achieved by UTL	0.676
			Approximate Sample Size needed to achieve specified CC	59
95% Percentile Bootstrap UTL with	95% Coverage	0.055	95% BCA Bootstrap UTL with 95% Coverage	0.055
	95% UPL	0.0535	90% Percentile	0.0428
	90% Chebyshev UPL	0.0548	95% Percentile	0.0449
	95% Chebyshev UPL	0.0639	99% Percentile	0.0529
	95% USL	0.055		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Cd Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	22
Minimum	0.31	First Quartile	0.406
Second Largest	0.565	Median	0.438
Maximum	0.629	Third Quartile	0.483
Mean	0.445	SD	0.0718
Coefficient of Variation	0.161	Skewness	0.606
Mean of logged Data	-0.823	SD of logged Data	0.16

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.349	d2max (for USL)	2.603

Normal GOF Test

Shapiro Wilk Test Statistic	0.973	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.0947	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Penrose Point Tissue BTVs
95-95 UTL - All Data

Background Statistics Assuming Normal Distribution

95% UTL with	95% Coverage	0.613	90% Percentile (z)	0.537
	95% UPL (t)	0.571	95% Percentile (z)	0.563
	95% USL	0.631	99% Percentile (z)	0.612

Gamma GOF Test

A-D Test Statistic	0.162	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.742	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0741	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	41.19	k star (bias corrected MLE)	35.61
Theta hat (MLE)	0.0108	Theta star (bias corrected MLE)	0.0125
nu hat (MLE)	1812	nu star (bias corrected)	1567
MLE Mean (bias corrected)	0.445	MLE Sd (bias corrected)	0.0745

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL		0.577	90% Percentile	0.542
95% Hawkins Wixley (HW) Approx. Gamma UPL		0.578	95% Percentile	0.574
95% WH Approx. Gamma UTL with	95% Coverage	0.628	99% Percentile	0.636
95% HW Approx. Gamma UTL with	95% Coverage	0.631		
	95% WH USL	0.651	95% HW USL	0.655

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.99	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0777	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with	95% Coverage	0.639	90% Percentile (z)	0.539
	95% UPL (t)	0.582	95% Percentile (z)	0.571
	95% USL	0.665	99% Percentile (z)	0.637

Penrose Point Tissue BTVs
95-95 UTL - All Data

Nonparametric Distribution Free Background Statistics
Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	22	95% UTL with 95% Coverage	0.629
Approx, f used to compute achieved CC	1.158	Approximate Actual Confidence Coefficient achieved by UTL	0.676
		Approximate Sample Size needed to achieve specified CC	59
95% Percentile Bootstrap UTL with 95% Coverage	0.629	95% BCA Bootstrap UTL with 95% Coverage	0.629
95% UPL	0.619	90% Percentile	0.511
90% Chebyshev UPL	0.665	95% Percentile	0.562
95% Chebyshev UPL	0.764	99% Percentile	0.616
95% USL	0.629		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Cr Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	22
Minimum	0.216	First Quartile	0.284
Second Largest	0.496	Median	0.343
Maximum	1.72	Third Quartile	0.393
Mean	0.4	SD	0.305
Coefficient of Variation	0.762	Skewness	4.189
Mean of logged Data	-1.039	SD of logged Data	0.426

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.349	d2max (for USL)	2.603

Normal GOF Test

Shapiro Wilk Test Statistic	0.458	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.332	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.184	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

95% UTL with 95% Coverage	1.117	90% Percentile (z)	0.791
95% UPL (t)	0.937	95% Percentile (z)	0.902
95% USL	1.194	99% Percentile (z)	1.11

Penrose Point Tissue BTVs
95-95 UTL - All Data

Gamma GOF Test

A-D Test Statistic	2.066	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.747	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.238	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.186	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.216	k star (bias corrected MLE)	3.672
Theta hat (MLE)	0.095	Theta star (bias corrected MLE)	0.109
nu hat (MLE)	185.5	nu star (bias corrected)	161.6
MLE Mean (bias corrected)	0.4	MLE Sd (bias corrected)	0.209

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL	0.798	90% Percentile	0.681
95% Hawkins Wixley (HW) Approx. Gamma UPL	0.784	95% Percentile	0.794
95% WH Approx. Gamma UTL with 95% Coverage	0.997	99% Percentile	1.038
95% HW Approx. Gamma UTL with 95% Coverage	0.986		
95% WH USL	1.092	95% HW USL	1.084

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.768	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.183	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level	

Data appear Approximate Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with 95% Coverage	0.962	90% Percentile (z)	0.611
95% UPL (t)	0.748	95% Percentile (z)	0.713
95% USL	1.072	99% Percentile (z)	0.953

Nonparametric Distribution Free Background Statistics
Data appear Approximate Lognormal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	22	95% UTL with 95% Coverage	1.72
Approx, f used to compute achieved CC	1.158	Approximate Actual Confidence Coefficient achieved by UTL	0.676
		Approximate Sample Size needed to achieve specified CC	59
95% Percentile Bootstrap UTL with 95% Coverage	1.72	95% BCA Bootstrap UTL with 95% Coverage	1.72
95% UPL	1.536	90% Percentile	0.458
90% Chebyshev UPL	1.336	95% Percentile	0.494
95% Chebyshev UPL	1.76	99% Percentile	1.463
95% USL	1.72		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Penrose Point Tissue BTVs
95-95 UTL - All Data

Cu Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	19
Minimum	0.896	First Quartile	1.018
Second Largest	1.42	Median	1.12
Maximum	1.45	Third Quartile	1.288
Mean	1.159	SD	0.162
Coefficient of Variation	0.14	Skewness	0.221
Mean of logged Data	0.138	SD of logged Data	0.14

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.349	d2max (for USL)	2.603

Normal GOF Test

Shapiro Wilk Test Statistic	0.948	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.14	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level	

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

95% UTL with	95% Coverage	1.54	90% Percentile (z)	1.367
	95% UPL (t)	1.444	95% Percentile (z)	1.426
	95% USL	1.581	99% Percentile (z)	1.536

Gamma GOF Test

A-D Test Statistic	0.471	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.743	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.131	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	53.64	k star (bias corrected MLE)	46.36
Theta hat (MLE)	0.0216	Theta star (bias corrected MLE)	0.025
nu hat (MLE)	2360	nu star (bias corrected)	2040
MLE Mean (bias corrected)	1.159	MLE Sd (bias corrected)	0.17

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL	1.459	90% Percentile	1.381
95% Hawkins Wixley (HW) Approx. Gamma UPL	1.461	95% Percentile	1.452
95% WH Approx. Gamma UTL with 95% Coverage	1.573	99% Percentile	1.591
95% HW Approx. Gamma UTL with 95% Coverage	1.578		
95% WH USL	1.624	95% HW USL	1.631

Penrose Point Tissue BTVs
95-95 UTL - All Data

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.953	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.128	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with 95% Coverage	1.595	90% Percentile (z)	1.373
95% UPL (t)	1.468	95% Percentile (z)	1.445
95% USL	1.652	99% Percentile (z)	1.59

Nonparametric Distribution Free Background Statistics
Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	22	95% UTL with 95% Coverage	1.45
Approx, f used to compute achieved CC	1.158	Approximate Actual Confidence Coefficient achieved by UTL	0.676
		Approximate Sample Size needed to achieve specified CC	59
95% Percentile Bootstrap UTL with 95% Coverage	1.45	95% BCA Bootstrap UTL with 95% Coverage	1.45
95% UPL	1.446	90% Percentile	1.349
90% Chebyshev UPL	1.657	95% Percentile	1.417
95% Chebyshev UPL	1.882	99% Percentile	1.444
95% USL	1.45		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Pb Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	21
Minimum	0.0132	First Quartile	0.0164
Second Largest	0.0295	Median	0.0204
Maximum	0.0678	Third Quartile	0.0229
Mean	0.022	SD	0.011
Coefficient of Variation	0.502	Skewness	3.67
Mean of logged Data	-3.887	SD of logged Data	0.34

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.349	d2max (for USL)	2.603

Normal GOF Test

Shapiro Wilk Test Statistic	0.571	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.301	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.184	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Penrose Point Tissue BTVs
95-95 UTL - All Data

Background Statistics Assuming Normal Distribution

95% UTL with	95% Coverage	0.0479	90% Percentile (z)		0.0361
	95% UPL (t)	0.0414	95% Percentile (z)		0.0401
	95% USL	0.0507	99% Percentile (z)		0.0476

Gamma GOF Test

A-D Test Statistic	1.445	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.745	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.225	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.186	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	7.364	k star (bias corrected MLE)	6.39
Theta hat (MLE)	0.00299	Theta star (bias corrected MLE)	0.00344
nu hat (MLE)	324	nu star (bias corrected)	281.2
MLE Mean (bias corrected)	0.022	MLE Sd (bias corrected)	0.0087

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL		0.0383	90% Percentile		0.0336
95% Hawkins Wixley (HW) Approx. Gamma UPL		0.038	95% Percentile		0.038
95% WH Approx. Gamma UTL with	95% Coverage	0.0458	99% Percentile		0.0471
95% HW Approx. Gamma UTL with	95% Coverage	0.0457			
	95% WH USL	0.0493	95% HW USL		0.0493

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.82	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.189	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with	95% Coverage	0.0456	90% Percentile (z)		0.0317
	95% UPL (t)	0.0373	95% Percentile (z)		0.0359
	95% USL	0.0497	99% Percentile (z)		0.0452

Nonparametric Distribution Free Background Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for Background Threshold Values

	Order of Statistic, r	22	95% UTL with	95% Coverage	0.0678
Approx, f used to compute achieved CC		1.158	Approximate Actual Confidence Coefficient achieved by UTL		0.676
			Approximate Sample Size needed to achieve specified CC		59
95% Percentile Bootstrap UTL with	95% Coverage	0.0678	95% BCA Bootstrap UTL with	95% Coverage	0.0678
	95% UPL	0.0621		90% Percentile	0.0249
	90% Chebyshev UPL	0.0558		95% Percentile	0.0293
	95% Chebyshev UPL	0.0711		99% Percentile	0.0598
	95% USL	0.0678			

Penrose Point Tissue BTVs
95-95 UTL - All Data

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers
and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data
represents a background data set and when many onsite observations need to be compared with the BTV.

Ni Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	21
Minimum	0.229	First Quartile	0.32
Second Largest	0.486	Median	0.368
Maximum	1.2	Third Quartile	0.414
Mean	0.399	SD	0.191
Coefficient of Variation	0.477	Skewness	3.789
Mean of logged Data	-0.981	SD of logged Data	0.322

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.349	d2max (for USL)	2.603

Normal GOF Test

Shapiro Wilk Test Statistic	0.554	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.314	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

95% UTL with 95% Coverage	0.847	90% Percentile (z)	0.644
95% UPL (t)	0.735	95% Percentile (z)	0.713
95% USL	0.895	99% Percentile (z)	0.843

Gamma GOF Test

A-D Test Statistic	1.601	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.745	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.242	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.186	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	8.146	k star (bias corrected MLE)	7.066
Theta hat (MLE)	0.049	Theta star (bias corrected MLE)	0.0565
nu hat (MLE)	358.4	nu star (bias corrected)	310.9
MLE Mean (bias corrected)	0.399	MLE Sd (bias corrected)	0.15

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL	0.68	90% Percentile	0.6
95% Hawkins Wixley (HW) Approx. Gamma UPL	0.675	95% Percentile	0.674
95% WH Approx. Gamma UTL with 95% Coverage	0.807	99% Percentile	0.829
95% HW Approx. Gamma UTL with 95% Coverage	0.804		
95% WH USL	0.866	95% HW USL	0.865

Penrose Point Tissue BTVs
95-95 UTL - All Data

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.807	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.207	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with	95% Coverage	0.8	90% Percentile (z)	0.567
	95% UPL (t)	0.661	95% Percentile (z)	0.637
	95% USL	0.868	99% Percentile (z)	0.794

Nonparametric Distribution Free Background Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Upper Limits for Background Threshold Values

	Order of Statistic, r	22	95% UTL with 95% Coverage	1.2
	Approx, f used to compute achieved CC	1.158	Approximate Actual Confidence Coefficient achieved by UTL	0.676
			Approximate Sample Size needed to achieve specified CC	59
95% Percentile Bootstrap UTL with	95% Coverage	1.2	95% BCA Bootstrap UTL with 95% Coverage	1.164
	95% UPL	1.093	90% Percentile	0.445
	90% Chebyshev UPL	0.984	95% Percentile	0.484
	95% Chebyshev UPL	1.249	99% Percentile	1.05
	95% USL	1.2		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Zn Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	16
Minimum	13.1	First Quartile	14.2
Second Largest	17	Median	14.75
Maximum	17.1	Third Quartile	15.58
Mean	15	SD	1.181
Coefficient of Variation	0.0787	Skewness	0.446
Mean of logged Data	2.705	SD of logged Data	0.0779

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.349	d2max (for USL)	2.603

Normal GOF Test

Shapiro Wilk Test Statistic	0.94	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.17	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Penrose Point Tissue BTVs
95-95 UTL - All Data

Background Statistics Assuming Normal Distribution

95% UTL with	95% Coverage	17.77	90% Percentile (z)		16.51
	95% UPL (t)	17.08	95% Percentile (z)		16.94
	95% USL	18.07	99% Percentile (z)		17.75

Gamma GOF Test

A-D Test Statistic	0.449	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.741	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.161	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	171.7	k star (bias corrected MLE)	148.3
Theta hat (MLE)	0.0874	Theta star (bias corrected MLE)	0.101
nu hat (MLE)	7553	nu star (bias corrected)	6525
MLE Mean (bias corrected)	15	MLE Sd (bias corrected)	1.232

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL		17.13	90% Percentile		16.6
95% Hawkins Wixley (HW) Approx. Gamma UPL		17.13	95% Percentile		17.08
95% WH Approx. Gamma UTL with	95% Coverage	17.89	99% Percentile		18.01
95% HW Approx. Gamma UTL with	95% Coverage	17.91			
	95% WH USL	18.23	95% HW USL		18.25

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.95	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.156	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with	95% Coverage	17.96	90% Percentile (z)		16.53
	95% UPL (t)	17.15	95% Percentile (z)		17
	95% USL	18.32	99% Percentile (z)		17.93

Nonparametric Distribution Free Background Statistics
Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r		22	95% UTL with	95% Coverage	17.1
Approx, f used to compute achieved CC		1.158	Approximate Actual Confidence Coefficient achieved by UTL		0.676
			Approximate Sample Size needed to achieve specified CC		59
95% Percentile Bootstrap UTL with	95% Coverage	17.1	95% BCA Bootstrap UTL with	95% Coverage	17.1
	95% UPL	17.09	90% Percentile		16.96
	90% Chebyshev UPL	18.62	95% Percentile		17
	95% Chebyshev UPL	20.26	99% Percentile		17.08
	95% USL	17.1			

Penrose Point Tissue BTVs
95-95 UTL - All Data

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers
and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data
represents a background data set and when many onsite observations need to be compared with the BTV.

Meth Hg Ti Pen

General Statistics

Total Number of Observations	22	Number of Distinct Observations	15
Minimum	2.2	First Quartile	3.325
Second Largest	4.6	Median	3.7
Maximum	6.6	Third Quartile	4.3
Mean	3.877	SD	0.857
Coefficient of Variation	0.221	Skewness	1.225
Mean of logged Data	1.333	SD of logged Data	0.214

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.349	d2max (for USL)	2.603

Normal GOF Test

Shapiro Wilk Test Statistic	0.896	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.154	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

95% UTL with	95% Coverage	5.89	90% Percentile (z)	4.975
	95% UPL (t)	5.385	95% Percentile (z)	5.287
	95% USL	6.108	99% Percentile (z)	5.871

Gamma GOF Test

A-D Test Statistic	0.487	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.741	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.136	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	22.87	k star (bias corrected MLE)	19.79
Theta hat (MLE)	0.169	Theta star (bias corrected MLE)	0.196
nu hat (MLE)	1006	nu star (bias corrected)	870.6
MLE Mean (bias corrected)	3.877	MLE Sd (bias corrected)	0.872

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL	5.455	90% Percentile	5.028
95% Hawkins Wixley (HW) Approx. Gamma UPL	5.47	95% Percentile	5.414
95% WH Approx. Gamma UTL with 95% Coverage	6.092	99% Percentile	6.188
95% HW Approx. Gamma UTL with 95% Coverage	6.131		
95% WH USL	6.381	95% HW USL	6.433

Penrose Point Tissue BTVs
95-95 UTL - All Data

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.942	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.138	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with	95% Coverage	6.272	90% Percentile (z)	4.991
	95% UPL (t)	5.528	95% Percentile (z)	5.394
	95% USL	6.622	99% Percentile (z)	6.242

Nonparametric Distribution Free Background Statistics
Data appear Approximate Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

	Order of Statistic, r	22	95% UTL with 95% Coverage	6.6
	Approx, f used to compute achieved CC	1.158	Approximate Actual Confidence Coefficient achieved by UTL	0.676
			Approximate Sample Size needed to achieve specified CC	59
95% Percentile Bootstrap UTL with	95% Coverage	6.6	95% BCA Bootstrap UTL with 95% Coverage	6.5
	95% UPL	6.3	90% Percentile	4.59
	90% Chebyshev UPL	6.506	95% Percentile	4.6
	95% Chebyshev UPL	7.696	99% Percentile	6.18
	95% USL	6.6		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Penrose Point Tissue BTVs
95-95 UTL - Excluding Outliers

Background Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	ProUCL 5.11/30/2017 5:18:53 PM
From File	C:\Users\laura.scheffler\Documents\Laura Work\Keyport Area 8\Risk Assessment\BTV ProUCL input_output\Pen
Full Precision	OFF
Confidence Coefficient	95%
Coverage	95%
New or Future K Observations	1
Number of Bootstrap Operations	2000

Cr Ti Pen

General Statistics

Total Number of Observations	21	Number of Distinct Observations	21
Minimum	0.216	First Quartile	0.283
Second Largest	0.461	Median	0.329
Maximum	0.496	Third Quartile	0.387
Mean	0.338	SD	0.0807
Coefficient of Variation	0.239	Skewness	0.226
Mean of logged Data	-1.114	SD of logged Data	0.243

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.371	d2max (for USL)	2.58

Normal GOF Test

Shapiro Wilk Test Statistic	0.966	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.908	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.11	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.188	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

95% UTL with	95% Coverage	0.529	90% Percentile (z)	0.441
	95% UPL (t)	0.48	95% Percentile (z)	0.47
	95% USL	0.546	99% Percentile (z)	0.525

Gamma GOF Test

A-D Test Statistic	0.259	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.743	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.108	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.189	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Penrose Point Tissue BTVs
95-95 UTL - Excluding Outliers

Gamma Statistics

k hat (MLE)	18.15	k star (bias corrected MLE)	15.59
Theta hat (MLE)	0.0186	Theta star (bias corrected MLE)	0.0216
nu hat (MLE)	762.4	nu star (bias corrected)	654.8
MLE Mean (bias corrected)	0.338	MLE Sd (bias corrected)	0.0855

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL	0.494	90% Percentile	0.451
95% Hawkins Wixley (HW) Approx. Gamma UPL	0.496	95% Percentile	0.489
95% WH Approx. Gamma UTL with 95% Coverage	0.56	99% Percentile	0.567
95% HW Approx. Gamma UTL with 95% Coverage	0.566		
95% WH USL	0.584	95% HW USL	0.591

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.967	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.908	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.113	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.188	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with 95% Coverage	0.585	90% Percentile (z)	0.448
95% UPL (t)	0.505	95% Percentile (z)	0.49
95% USL	0.615	99% Percentile (z)	0.578

Nonparametric Distribution Free Background Statistics

Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	21	95% UTL with 95% Coverage	0.496
Approx, f used to compute achieved CC	1.105	Approximate Actual Confidence Coefficient achieved by UTL	0.659
		Approximate Sample Size needed to achieve specified CC	59
95% Percentile Bootstrap UTL with 95% Coverage	0.496	95% BCA Bootstrap UTL with 95% Coverage	0.496
95% UPL	0.493	90% Percentile	0.432
90% Chebyshev UPL	0.585	95% Percentile	0.461
95% Chebyshev UPL	0.697	99% Percentile	0.489
95% USL	0.496		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Penrose Point Tissue BTVs
95-95 UTL - Excluding Outliers

Pb Ti Pen

General Statistics

Total Number of Observations	21	Number of Distinct Observations	20
Minimum	0.0132	First Quartile	0.0164
Second Largest	0.025	Median	0.0198
Maximum	0.0295	Third Quartile	0.0228
Mean	0.0198	SD	0.00422
Coefficient of Variation	0.213	Skewness	0.306
Mean of logged Data	-3.944	SD of logged Data	0.215

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.371	d2max (for USL)	2.58

Normal GOF Test

Shapiro Wilk Test Statistic	0.965	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.908	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.123	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.188	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

95% UTL with	95% Coverage	0.0298	90% Percentile (z)	0.0252
	95% UPL (t)	0.0272	95% Percentile (z)	0.0267
	95% USL	0.0307	99% Percentile (z)	0.0296

Gamma GOF Test

A-D Test Statistic	0.324	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.742	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.123	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.189	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	23.06	k star (bias corrected MLE)	19.8
Theta hat (MLE)	8.5863E-4	Theta star (bias corrected MLE)	0.001
nu hat (MLE)	968.5	nu star (bias corrected)	831.5
MLE Mean (bias corrected)	0.0198	MLE Sd (bias corrected)	0.00445

Penrose Point Tissue BTVs
95-95 UTL - Excluding Outliers

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL	0.0279	90% Percentile	0.0257
95% Hawkins Wixley (HW) Approx. Gamma UPL	0.028	95% Percentile	0.0276
95% WH Approx. Gamma UTL with 95% Coverage	0.0312	99% Percentile	0.0316
95% HW Approx. Gamma UTL with 95% Coverage	0.0315		
95% WH USL	0.0324	95% HW USL	0.0327

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.967	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.908	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.122	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.188	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with 95% Coverage	0.0323	90% Percentile (z)	0.0255
95% UPL (t)	0.0283	95% Percentile (z)	0.0276
95% USL	0.0338	99% Percentile (z)	0.032

Nonparametric Distribution Free Background Statistics

Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	21	95% UTL with 95% Coverage	0.0295
Approx, f used to compute achieved CC	1.105	Approximate Actual Confidence Coefficient achieved by UTL	0.659
		Approximate Sample Size needed to achieve specified CC	59
95% Percentile Bootstrap UTL with 95% Coverage	0.0295	95% BCA Bootstrap UTL with 95% Coverage	0.0295
95% UPL	0.0291	90% Percentile	0.0244
90% Chebyshev UPL	0.0328	95% Percentile	0.025
95% Chebyshev UPL	0.0386	99% Percentile	0.0286
95% USL	0.0295		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Penrose Point Tissue BTVs
95-95 UTL - Excluding Outliers

Ni Ti Pen

General Statistics

Total Number of Observations	21	Number of Distinct Observations	20
Minimum	0.229	First Quartile	0.318
Second Largest	0.445	Median	0.362
Maximum	0.486	Third Quartile	0.412
Mean	0.361	SD	0.0676
Coefficient of Variation	0.187	Skewness	-0.123
Mean of logged Data	-1.036	SD of logged Data	0.196

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.371	d2max (for USL)	2.58

Normal GOF Test

Shapiro Wilk Test Statistic	0.986	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.908	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.0716	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.188	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

95% UTL with	95% Coverage	0.521	90% Percentile (z)	0.448
	95% UPL (t)	0.481	95% Percentile (z)	0.472
	95% USL	0.536	99% Percentile (z)	0.518

Gamma GOF Test

A-D Test Statistic	0.189	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.742	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0867	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.189	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	28.5	k star (bias corrected MLE)	24.46
Theta hat (MLE)	0.0127	Theta star (bias corrected MLE)	0.0148
nu hat (MLE)	1197	nu star (bias corrected)	1027
MLE Mean (bias corrected)	0.361	MLE Sd (bias corrected)	0.073

Penrose Point Tissue BTVs
95-95 UTL - Excluding Outliers

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL	0.493	90% Percentile	0.457
95% Hawkins Wixley (HW) Approx. Gamma UPL	0.495	95% Percentile	0.489
95% WH Approx. Gamma UTL with 95% Coverage	0.546	99% Percentile	0.552
95% HW Approx. Gamma UTL with 95% Coverage	0.55		
95% WH USL	0.566	95% HW USL	0.571

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.97	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.908	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0903	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.188	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with 95% Coverage	0.564	90% Percentile (z)	0.456
95% UPL (t)	0.501	95% Percentile (z)	0.49
95% USL	0.588	99% Percentile (z)	0.559

Nonparametric Distribution Free Background Statistics

Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	21	95% UTL with 95% Coverage	0.486
Approx, f used to compute achieved CC	1.105	Approximate Actual Confidence Coefficient achieved by UTL	0.659
		Approximate Sample Size needed to achieve specified CC	59
95% Percentile Bootstrap UTL with 95% Coverage	0.486	95% BCA Bootstrap UTL with 95% Coverage	0.486
95% UPL	0.482	90% Percentile	0.443
90% Chebyshev UPL	0.569	95% Percentile	0.445
95% Chebyshev UPL	0.663	99% Percentile	0.478
95% USL	0.486		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Penrose Point Tissue BTVs
95-95 UTL - Excluding Outliers

Meth Hg Ti Pen

General Statistics

Total Number of Observations	21	Number of Distinct Observations	14
Minimum	2.2	First Quartile	3.3
Second Largest	4.6	Median	3.7
Maximum	4.6	Third Quartile	4.3
Mean	3.748	SD	0.619
Coefficient of Variation	0.165	Skewness	-0.573
Mean of logged Data	1.307	SD of logged Data	0.179

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.371	d2max (for USL)	2.58

Normal GOF Test

Shapiro Wilk Test Statistic	0.947	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.908	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.102	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.188	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

95% UTL with 95% Coverage	5.214	90% Percentile (z)	4.54
95% UPL (t)	4.84	95% Percentile (z)	4.765
95% USL	5.344	99% Percentile (z)	5.187

Gamma GOF Test

A-D Test Statistic	0.442	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.742	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.112	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.189	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	34.92	k star (bias corrected MLE)	29.97
Theta hat (MLE)	0.107	Theta star (bias corrected MLE)	0.125
nu hat (MLE)	1467	nu star (bias corrected)	1259
MLE Mean (bias corrected)	3.748	MLE Sd (bias corrected)	0.685

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL	4.973	90% Percentile	4.647
95% Hawkins Wixley (HW) Approx. Gamma UPL	4.994	95% Percentile	4.94
95% WH Approx. Gamma UTL with 95% Coverage	5.463	99% Percentile	5.521
95% HW Approx. Gamma UTL with 95% Coverage	5.504		
95% WH USL	5.64	95% HW USL	5.69

Penrose Point Tissue BTVs
95-95 UTL - Excluding Outliers

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.907	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.908	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.123	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.188	Data appear Lognormal at 5% Significance Level	

Data appear Approximate Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with	95% Coverage	5.648	90% Percentile (z)		4.647
	95% UPL (t)	5.068	95% Percentile (z)		4.96
	95% USL	5.864	99% Percentile (z)		5.603

Nonparametric Distribution Free Background Statistics
Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

	Order of Statistic, r	21	95% UTL with	95% Coverage	4.6
	Approx, f used to compute achieved CC	1.105	Approximate Actual Confidence Coefficient achieved by UTL		0.659
			Approximate Sample Size needed to achieve specified CC		59
95% Percentile Bootstrap UTL with	95% Coverage	4.6	95% BCA Bootstrap UTL with	95% Coverage	4.6
	95% UPL	4.6		90% Percentile	4.5
	90% Chebyshev UPL	5.647		95% Percentile	4.6
	95% Chebyshev UPL	6.507		99% Percentile	4.6
	95% USL	4.6			

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Penrose Point Tissue BTVs
90-90 UTL - Excluding Outliers

Background Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	ProUCL 5.11/30/2017 5:22:13 PM
From File	C:\Users\laura.scheffler\Documents\Laura Work\Keyport Area 8\Risk Assessment\BTV ProUCL input_output\Pen
Full Precision	OFF
Confidence Coefficient	90%
Coverage	90%
New or Future K Observations	1
Number of Bootstrap Operations	2000

Cr Ti Pen

General Statistics

Total Number of Observations	21	Number of Distinct Observations	21
Minimum	0.216	First Quartile	0.283
Second Largest	0.461	Median	0.329
Maximum	0.496	Third Quartile	0.387
Mean	0.338	SD	0.0807
Coefficient of Variation	0.239	Skewness	0.226
Mean of logged Data	-1.114	SD of logged Data	0.243

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.75	d2max (for USL)	2.408

Normal GOF Test

Shapiro Wilk Test Statistic	0.966	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.908	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.11	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.188	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with 90% Coverage	0.479	90% Percentile (z)	0.441
90% UPL (t)	0.447	95% Percentile (z)	0.47
90% USL	0.532	99% Percentile (z)	0.525

Gamma GOF Test

A-D Test Statistic	0.259	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.743	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.108	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.189	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Penrose Point Tissue BTVs
90-90 UTL - Excluding Outliers

Gamma Statistics

k hat (MLE)	18.15	k star (bias corrected MLE)	15.59
Theta hat (MLE)	0.0186	Theta star (bias corrected MLE)	0.0216
nu hat (MLE)	762.4	nu star (bias corrected)	654.8
MLE Mean (bias corrected)	0.338	MLE Sd (bias corrected)	0.0855

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	0.453	90% Percentile	0.451
90% Hawkins Wixley (HW) Approx. Gamma UPL	0.453	95% Percentile	0.489
90% WH Approx. Gamma UTL with 90% Coverage	0.493	99% Percentile	0.567
90% HW Approx. Gamma UTL with 90% Coverage	0.495		
90% WH USL	0.564	90% HW USL	0.57

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.967	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.908	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.113	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.188	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	0.503	90% Percentile (z)	0.448
90% UPL (t)	0.457	95% Percentile (z)	0.49
90% USL	0.59	99% Percentile (z)	0.578

Nonparametric Distribution Free Background Statistics

Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	20	90% UTL with 90% Coverage	0.461
Approx, f used to compute achieved CC	1.111	Approximate Actual Confidence Coefficient achieved by UTL	0.635
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	0.461	90% BCA Bootstrap UTL with 90% Coverage	0.461
90% UPL	0.455	90% Percentile	0.432
90% Chebyshev UPL	0.585	95% Percentile	0.461
95% Chebyshev UPL	0.697	99% Percentile	0.489
90% USL	0.496		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Penrose Point Tissue BTVs
90-90 UTL - Excluding Outliers

Pb Ti Pen

General Statistics

Total Number of Observations	21	Number of Distinct Observations	20
Minimum	0.0132	First Quartile	0.0164
Second Largest	0.025	Median	0.0198
Maximum	0.0295	Third Quartile	0.0228
Mean	0.0198	SD	0.00422
Coefficient of Variation	0.213	Skewness	0.306
Mean of logged Data	-3.944	SD of logged Data	0.215

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.75	d2max (for USL)	2.408

Normal GOF Test

Shapiro Wilk Test Statistic	0.965	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.908	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.123	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.188	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with 90% Coverage	0.0272	90% Percentile (z)	0.0252
90% UPL (t)	0.0255	95% Percentile (z)	0.0267
90% USL	0.03	99% Percentile (z)	0.0296

Gamma GOF Test

A-D Test Statistic	0.324	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.742	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.123	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.189	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	23.06	k star (bias corrected MLE)	19.8
Theta hat (MLE)	8.5863E-4	Theta star (bias corrected MLE)	0.001
nu hat (MLE)	968.5	nu star (bias corrected)	831.5
MLE Mean (bias corrected)	0.0198	MLE Sd (bias corrected)	0.00445

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	0.0258	90% Percentile	0.0257
90% Hawkins Wixley (HW) Approx. Gamma UPL	0.0258	95% Percentile	0.0276
90% WH Approx. Gamma UTL with 90% Coverage	0.0278	99% Percentile	0.0316
90% HW Approx. Gamma UTL with 90% Coverage	0.0279		
90% WH USL	0.0314	90% HW USL	0.0317

Penrose Point Tissue BTVs
90-90 UTL - Excluding Outliers

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.967	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.908	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.122	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.188	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with	90% Coverage	0.0282	90% Percentile (z)	0.0255
	90% UPL (t)	0.0259	95% Percentile (z)	0.0276
	90% USL	0.0325	99% Percentile (z)	0.032

Nonparametric Distribution Free Background Statistics
Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

	Order of Statistic, r	20	90% UTL with 90% Coverage	0.025
	Approx, f used to compute achieved CC	1.111	Approximate Actual Confidence Coefficient achieved by UTL	0.635
			Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with	90% Coverage	0.025	90% BCA Bootstrap UTL with 90% Coverage	0.025
	90% UPL	0.0249	90% Percentile	0.0244
	90% Chebyshev UPL	0.0328	95% Percentile	0.025
	95% Chebyshev UPL	0.0386	99% Percentile	0.0286
	90% USL	0.0295		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Ni Ti Pen

General Statistics

Total Number of Observations	21	Number of Distinct Observations	20
Minimum	0.229	First Quartile	0.318
Second Largest	0.445	Median	0.362
Maximum	0.486	Third Quartile	0.412
Mean	0.361	SD	0.0676
Coefficient of Variation	0.187	Skewness	-0.123
Mean of logged Data	-1.036	SD of logged Data	0.196

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.75	d2max (for USL)	2.408

Penrose Point Tissue BTVs
90-90 UTL - Excluding Outliers

Normal GOF Test

Shapiro Wilk Test Statistic	0.986	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.908	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.0716	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.188	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with	90% Coverage	0.479	90% Percentile (z)	0.448
	90% UPL (t)	0.453	95% Percentile (z)	0.472
	90% USL	0.524	99% Percentile (z)	0.518

Gamma GOF Test

A-D Test Statistic	0.189	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.742	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0867	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.189	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	28.5	k star (bias corrected MLE)	24.46
Theta hat (MLE)	0.0127	Theta star (bias corrected MLE)	0.0148
nu hat (MLE)	1197	nu star (bias corrected)	1027
MLE Mean (bias corrected)	0.361	MLE Sd (bias corrected)	0.073

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL		0.459	90% Percentile	0.457
90% Hawkins Wixley (HW) Approx. Gamma UPL		0.46	95% Percentile	0.489
90% WH Approx. Gamma UTL with	90% Coverage	0.491	99% Percentile	0.552
90% HW Approx. Gamma UTL with	90% Coverage	0.493		
	90% WH USL	0.55	90% HW USL	0.554

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.97	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.908	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0903	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.188	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with	90% Coverage	0.5	90% Percentile (z)	0.456
	90% UPL (t)	0.463	95% Percentile (z)	0.49
	90% USL	0.568	99% Percentile (z)	0.559

Nonparametric Distribution Free Background Statistics

Data appear Normal at 5% Significance Level

Penrose Point Tissue BTVs
90-90 UTL - Excluding Outliers

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	20	90% UTL with 90% Coverage	0.445
Approx, f used to compute achieved CC	1.111	Approximate Actual Confidence Coefficient achieved by UTL	0.635
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	0.445	90% BCA Bootstrap UTL with 90% Coverage	0.445
90% UPL	0.445	90% Percentile	0.443
90% Chebyshev UPL	0.569	95% Percentile	0.445
95% Chebyshev UPL	0.663	99% Percentile	0.478
90% USL	0.486		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

Meth Hg Ti Pen

General Statistics

Total Number of Observations	21	Number of Distinct Observations	14
Minimum	2.2	First Quartile	3.3
Second Largest	4.6	Median	3.7
Maximum	4.6	Third Quartile	4.3
Mean	3.748	SD	0.619
Coefficient of Variation	0.165	Skewness	-0.573
Mean of logged Data	1.307	SD of logged Data	0.179

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	1.75	d2max (for USL)	2.408

Normal GOF Test

Shapiro Wilk Test Statistic	0.947	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.908	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.102	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.188	Data appear Normal at 5% Significance Level	

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

90% UTL with 90% Coverage	4.83	90% Percentile (z)	4.54
90% UPL (t)	4.587	95% Percentile (z)	4.765
90% USL	5.237	99% Percentile (z)	5.187

Penrose Point Tissue BTVs
90-90 UTL - Excluding Outliers

Gamma GOF Test

A-D Test Statistic	0.442	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.742	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.112	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.189	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	34.92	k star (bias corrected MLE)	29.97
Theta hat (MLE)	0.107	Theta star (bias corrected MLE)	0.125
nu hat (MLE)	1467	nu star (bias corrected)	1259
MLE Mean (bias corrected)	3.748	MLE Sd (bias corrected)	0.685

Background Statistics Assuming Gamma Distribution

90% Wilson Hilferty (WH) Approx. Gamma UPL	4.659	90% Percentile	4.647
90% Hawkins Wixley (HW) Approx. Gamma UPL	4.671	95% Percentile	4.94
90% WH Approx. Gamma UTL with 90% Coverage	4.961	99% Percentile	5.521
90% HW Approx. Gamma UTL with 90% Coverage	4.982		
90% WH USL	5.494	90% HW USL	5.537

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.907	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.908	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.123	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.188	Data appear Lognormal at 5% Significance Level

Data appear Approximate Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

90% UTL with 90% Coverage	5.054	90% Percentile (z)	4.647
90% UPL (t)	4.71	95% Percentile (z)	4.96
90% USL	5.686	99% Percentile (z)	5.603

Nonparametric Distribution Free Background Statistics
Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	20	90% UTL with 90% Coverage	4.6
Approx, f used to compute achieved CC	1.111	Approximate Actual Confidence Coefficient achieved by UTL	0.635
		Approximate Sample Size needed to achieve specified CC	37
90% Percentile Bootstrap UTL with 90% Coverage	4.6	90% BCA Bootstrap UTL with 90% Coverage	4.6
90% UPL	4.58	90% Percentile	4.5
90% Chebyshev UPL	5.647	95% Percentile	4.6
95% Chebyshev UPL	6.507	99% Percentile	4.6
90% USL	4.6		

Penrose Point Tissue BTVs
90-90 UTL - Excluding Outliers

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data represents a background data set and when many onsite observations need to be compared with the BTV.

D3
Population to Population Comparison

Wilcoxon Mann Whitney
Tissue - Silver

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 10:59:41 AM
From File	WMWT Sed & Clam tissue_input_11_29_16.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Ag Ti A8
Sample 2 Data: Ag Ti Pen

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	41	22
Number of Non-Detects	0	21
Number of Detect Data	41	1
Minimum Non-Detect	N/A	0.0069
Maximum Non-Detect	N/A	0.0186
Percent Non-detects	0.00%	95.45%
Minimum Detect	0.0371	0.0475
Maximum Detect	0.582	0.0475
Mean of Detects	0.176	0.0475
Median of Detects	0.117	0.0475
SD of Detects	0.15	N/A

WMW test is meant for a Single Detection Limit Case
Use of Gehan or T-W test is suggested when multiple detection limits are present
All observations <= 0.0186 (Max DL) are ranked the same

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	1760
Standardized WMW U-Stat	6.575
Mean (U)	451
SD(U) - Adj ties	69.36
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	2.438E-11

Conclusion with Alpha = 0.05
Reject H0, Conclude Sample 1 > Sample 2
P-Value < alpha (0.05)

Wilcoxon Mann Whitney
Tissue - Inorg Arsenic

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 11:19:44 AM
From File	WMWT Sed & Clam tissue_input_11_29_16.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Inorg As Ti A8

Sample 2 Data: Inorg As Ti Pen

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	41	22
Number of Non-Detects	2	0
Number of Detect Data	39	22
Minimum Non-Detect	0.014	N/A
Maximum Non-Detect	0.015	N/A
Percent Non-detects	4.88%	0.00%
Minimum Detect	0.017	0.026
Maximum Detect	0.05	0.055
Mean of Detects	0.0271	0.0346
Median of Detects	0.026	0.0325
SD of Detects	0.00683	0.00657

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	1002
Standardized WMW U-Stat	-4.483
Mean (U)	451
SD(U) - Adj ties	69.25
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	1

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)

Wilcoxon Mann Whitney
Tissue - Cadmium

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Uncensor Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 11:21:30 AM
From File	WMWT Sed & Clam tissue_input_11_29_16.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0.000
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Cd Ti A8

Sample 2 Data: Cd Ti Pen

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	41	22
Number of Distinct Observations	40	22
Minimum	0.169	0.31
Maximum	1	0.629
Mean	0.375	0.445
Median	0.264	0.438
SD	0.233	0.0718
SE of Mean	0.0364	0.0153

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	1093
Standardized WMW U-Stat	-3.165
Mean (U)	451
SD(U) - Adj ties	69.36
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	0.999

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)

Wilcoxon Mann Whitney
Tissue - Chromium

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Uncensor Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 11:24:20 AM
From File	WMWT Sed & Clam tissue_input_11_29_16.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0.000
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Cr Ti A8

Sample 2 Data: Cr Ti Pen

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	41	22
Number of Distinct Observations	41	22
Minimum	0.155	0.216
Maximum	1.13	1.72
Mean	0.478	0.4
Median	0.396	0.343
SD	0.265	0.305
SE of Mean	0.0415	0.065

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	1399
Standardized WMW U-Stat	1.24
Mean (U)	451
SD(U) - Adj ties	69.36
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	0.107

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)

Wilcoxon Mann Whitney
Tissue - Copper

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Uncensor Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 11:26:00 AM
From File	WMWT Sed & Clam tissue_input_11_29_16.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0.000
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Cu Ti A8

Sample 2 Data: Cu Ti Pen

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	41	22
Number of Distinct Observations	28	19
Minimum	0.759	0.896
Maximum	1.73	1.45
Mean	1.216	1.159
Median	1.2	1.12
SD	0.192	0.162
SE of Mean	0.0299	0.0346

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	1397
Standardized WMW U-Stat	1.212
Mean (U)	451
SD(U) - Adj ties	69.33
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	0.113

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)

T-Test
Copper in Tissue

t-Test Sample 1 vs Sample 2 Comparison for Uncensored Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	ProUCL 5.112/8/2016 1:44:49 PM
From File	WMWT Sed & Clam tissue_input_11_29_16.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference (S)	0.000
Selected Null Hypothesis	Sample 1 Mean <= Sample 2 Mean (Form 1)
Alternative Hypothesis	Sample 1 Mean > the Sample 2 Mean

Sample 1 Data: Cu Ti A8
Sample 2 Data: Cu Ti Pen

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	41	22
Number of Distinct Observations	28	19
Minimum	0.759	0.896
Maximum	1.73	1.45
Mean	1.216	1.159
Median	1.2	1.12
SD	0.192	0.162
SE of Mean	0.0299	0.0346

Sample 1 vs Sample 2 Two-Sample t-Test

H0: Mean of Sample 1 - Mean of Sample 2 <= 0

Method	DF	t-Test Value	Critical t (0.05)	P-Value
Pooled (Equal Variance)	61	1.184	1.670	0.121
Welch-Satterthwaite (Unequal Varian	49.6	1.245	1.676	0.110

Pooled SD 0.182

Conclusion with Alpha = 0.050

Student t (Pooled) Test: Do Not Reject H0, Conclude Sample 1 <= Sample 2

Welch-Satterthwaite Test: Do Not Reject H0, Conclude Sample 1 <= Sample 2

Test of Equality of Variances

Variance of Sample 1	0.0367
Variance of Sample 2	0.0264

Numerator DF	Denominator DF	F-Test Value	P-Value
40	21	1.392	0.421

Conclusion with Alpha = 0.05

Two variances appear to be equal

Wilcoxon Mann Whitney
Tissue - Methylmercury

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Uncensor Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 11:45:06 AM
From File	WMWT Sed & Clam tissue_input_11_29_16.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0.000
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Meth Hg Ti A8

Sample 2 Data: Meth Hg Ti Pen

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	41	22
Number of Distinct Observations	30	15
Minimum	1	2.2
Maximum	18	6.6
Mean	8.327	3.877
Median	7.9	3.7
SD	3.312	0.857
SE of Mean	0.517	0.183

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	1707
Standardized WMW U-Stat	5.692
Mean (U)	451
SD(U) - Adj ties	69.31
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	6.2917E-9

Conclusion with Alpha = 0.05

Reject H0, Conclude Sample 1 > Sample 2

P-Value < alpha (0.05)

Wilcoxon Mann Whitney
Tissue - Nickel

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Uncensor Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 11:28:16 AM
From File	WMWT Sed & Clam tissue_input_11_29_16.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0.000
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Ni Ti A8

Sample 2 Data: Ni Ti Pen

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	41	22
Number of Distinct Observations	38	21
Minimum	0.27	0.229
Maximum	1	1.2
Mean	0.476	0.399
Median	0.435	0.368
SD	0.17	0.191
SE of Mean	0.0265	0.0406

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	1462
Standardized WMW U-Stat	2.156
Mean (U)	451
SD(U) - Adj ties	69.35
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	0.0156

Conclusion with Alpha = 0.05

Reject H0, Conclude Sample 1 > Sample 2

P-Value < alpha (0.05)

Wilcoxon Mann Whitney
Tissue - Lead

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Uncensor Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 11:27:18 AM
From File	WMWT Sed & Clam tissue_input_11_29_16.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0.000
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Pb Ti A8

Sample 2 Data: Pb Ti Pen

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	41	22
Number of Distinct Observations	38	21
Minimum	0.0431	0.0132
Maximum	0.13	0.0678
Mean	0.0723	0.022
Median	0.0727	0.0204
SD	0.0164	0.011
SE of Mean	0.00257	0.00235

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	1748
Standardized WMW U-Stat	6.279
Mean (U)	451
SD(U) - Adj ties	69.36
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	1.701E-10

Conclusion with Alpha = 0.05

Reject H0, Conclude Sample 1 > Sample 2

P-Value < alpha (0.05)

Wilcoxon Mann Whitney
Tissue - Zinc

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Uncensor Full Data Sets without NDs

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 11:43:56 AM
From File	WMWT Sed & Clam tissue_input_11_29_16.xls
Full Precision	OFF
Confidence Coefficient	95%
Substantial Difference	0.000
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Zn Ti A8

Sample 2 Data: Zn Ti Pen

Raw Statistics

	Sample 1	Sample 2
Number of Valid Observations	41	22
Number of Distinct Observations	28	16
Minimum	9.6	13.1
Maximum	16.3	17.1
Mean	13.38	15
Median	13.6	14.75
SD	1.506	1.181
SE of Mean	0.235	0.252

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	1041
Standardized WMW U-Stat	-3.924
Mean (U)	451
SD(U) - Adj ties	69.32
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	1

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)

Wilcoxon Mann Whitney
Sediment - Silver

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 2:25:42 PM
From File	WMWT Sed & Clam tissue_input_11_29_16_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Ag Sd A8
Sample 2 Data: Ag Sd Bold

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	66	70
Number of Non-Detects	0	18
Number of Detect Data	66	52
Minimum Non-Detect	N/A	0.0074
Maximum Non-Detect	N/A	0.1
Percent Non-detects	0.00%	25.71%
Minimum Detect	0.048	0.0094
Maximum Detect	17	0.45
Mean of Detects	0.872	0.14
Median of Detects	0.223	0.13
SD of Detects	2.372	0.0978

WMW test is meant for a Single Detection Limit Case
Use of Gehan or T-W test is suggested when multiple detection limits are present
All observations <= 0.1 (Max DL) are ranked the same

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	5508
Standardized WMW U-Stat	4.473
Mean (U)	2310
SD(U) - Adj ties	229.7
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	3.8655E-6

Conclusion with Alpha = 0.05
Reject H0, Conclude Sample 1 > Sample 2
P-Value < alpha (0.05)

Wilcoxon Mann Whitney
Sediment - Arsenic

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 2:26:43 PM
From File	WMWT Sed & Clam tissue_input_11_29_16_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Tot As Sd A8
Sample 2 Data: Tot As Sd Bold

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	66	70
Number of Non-Detects	0	0
Number of Detect Data	66	70
Minimum Non-Detect	N/A	N/A
Maximum Non-Detect	N/A	N/A
Percent Non-detects	0.00%	0.00%
Minimum Detect	0.42	1.1
Maximum Detect	6.47	21
Mean of Detects	2.371	6.614
Median of Detects	2.265	6
SD of Detects	0.976	3.838

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	2649
Standardized WMW U-Stat	-8.154
Mean (U)	2310
SD(U) - Adj ties	229.7
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	1

Conclusion with Alpha = 0.05
Do Not Reject H0, Conclude Sample 1 <= Sample 2
P-Value >= alpha (0.05)

Wilcoxon Mann Whitney
Sediment - Cadmium

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 2:27:43 PM
From File	WMWT Sed & Clam tissue_input_11_29_16_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Cd Sd A8

Sample 2 Data: Cd Sd Bold

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	66	70
Number of Non-Detects	0	22
Number of Detect Data	66	48
Minimum Non-Detect	N/A	0.022
Maximum Non-Detect	N/A	0.26
Percent Non-detects	0.00%	31.43%
Minimum Detect	0.152	0.018
Maximum Detect	11.4	2.8
Mean of Detects	1.665	0.414
Median of Detects	0.76	0.285
SD of Detects	2.299	0.523

WMW test is meant for a Single Detection Limit Case

Use of Gehan or T-W test is suggested when multiple detection limits are present

All observations <= 0.26 (Max DL) are ranked the same

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	6174
Standardized WMW U-Stat	7.368
Mean (U)	2310
SD(U) - Adj ties	229.7
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	8.693E-14

Conclusion with Alpha = 0.05

Reject H0, Conclude Sample 1 > Sample 2

P-Value < alpha (0.05)

Wilcoxon Mann Whitney
Sediment - Chromium

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 2:28:56 PM
From File	WMWT Sed & Clam tissue_input_11_29_16_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Cr Sd A8

Sample 2 Data: Cr Sd Bold

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	66	70
Number of Non-Detects	0	0
Number of Detect Data	66	70
Minimum Non-Detect	N/A	N/A
Maximum Non-Detect	N/A	N/A
Percent Non-detects	0.00%	0.00%
Minimum Detect	2.32	7.1
Maximum Detect	84.8	105
Mean of Detects	28.65	32.5
Median of Detects	27.9	26.2
SD of Detects	14.27	20.07

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	4429
Standardized WMW U-Stat	-0.403
Mean (U)	2310
SD(U) - Adj ties	229.7
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	0.656

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)

Wilcoxon Mann Whitney
Sediment - Copper

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 2:29:49 PM
From File	WMWT Sed & Clam tissue_input_11_29_16_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Cu Sd A8

Sample 2 Data: Cu Sd Bold

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	66	70
Number of Non-Detects	0	0
Number of Detect Data	66	70
Minimum Non-Detect	N/A	N/A
Maximum Non-Detect	N/A	N/A
Percent Non-detects	0.00%	0.00%
Minimum Detect	3.81	3.2
Maximum Detect	439	91.2
Mean of Detects	19.06	21.75
Median of Detects	8.84	15.65
SD of Detects	53.94	16.55

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	3643
Standardized WMW U-Stat	-3.827
Mean (U)	2310
SD(U) - Adj ties	229.7
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	1

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)

Wilcoxon Mann Whitney
Sediment - Mercury

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 2:33:20 PM
From File	WMWT Sed & Clam tissue_input_11_29_16_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Hg Sd A8

Sample 2 Data: Hg Sd Bold

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	66	70
Number of Non-Detects	0	29
Number of Detect Data	66	41
Minimum Non-Detect	N/A	0.0048
Maximum Non-Detect	N/A	0.091
Percent Non-detects	0.00%	41.43%
Minimum Detect	0.006	0.031
Maximum Detect	2.42	0.26
Mean of Detects	0.168	0.124
Median of Detects	0.066	0.11
SD of Detects	0.365	0.0566

WMW test is meant for a Single Detection Limit Case

Use of Gehan or T-W test is suggested when multiple detection limits are present

All observations <= 0.091 (Max DL) are ranked the same

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	4656
Standardized WMW U-Stat	0.666
Mean (U)	2310
SD(U) - Adj ties	229.7
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	0.253

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)

Wilcoxon Mann Whitney
Sediment - Nickel

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 2:31:37 PM
From File	WMWT Sed & Clam tissue_input_11_29_16_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Ni Sd A8

Sample 2 Data: Ni Sd Bold

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	66	70
Number of Non-Detects	0	0
Number of Detect Data	66	70
Minimum Non-Detect	N/A	N/A
Maximum Non-Detect	N/A	N/A
Percent Non-detects	0.00%	0.00%
Minimum Detect	2.37	4
Maximum Detect	40.8	94.7
Mean of Detects	16.13	28.88
Median of Detects	16.35	25.15
SD of Detects	5.499	16.5

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	3044
Standardized WMW U-Stat	-6.436
Mean (U)	2310
SD(U) - Adj ties	229.7
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	1

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)

Wilcoxon Mann Whitney
Sediment - Lead

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 2:30:31 PM
From File	WMWT Sed & Clam tissue_input_11_29_16_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Pb Sd A8

Sample 2 Data: Pb Sd Bold

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	66	70
Number of Non-Detects	0	0
Number of Detect Data	66	70
Minimum Non-Detect	N/A	N/A
Maximum Non-Detect	N/A	N/A
Percent Non-detects	0.00%	0.00%
Minimum Detect	1.71	1.2
Maximum Detect	185	27.5
Mean of Detects	11.64	9.75
Median of Detects	5.105	7.95
SD of Detects	24.79	6.018

Wilcoxon-Mann-Whitney (WMW) Test

H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	3843
Standardized WMW U-Stat	-2.957
Mean (U)	2310
SD(U) - Adj ties	229.7
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	0.998

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)

Wilcoxon Mann Whitney
Sediment - Zinc

Wilcoxon-Mann-Whitney Sample 1 vs Sample 2 Comparison Test for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.111/30/2016 2:32:30 PM
From File	WMWT Sed & Clam tissue_input_11_29_16_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Selected Null Hypothesis	Sample 1 Mean/Median <= Sample 2 Mean/Median (Form 1)
Alternative Hypothesis	Sample 1 Mean/Median > Sample 2 Mean/Median

Sample 1 Data: Zn Sd A8

Sample 2 Data: Zn Sd Bold

Raw Statistics

	Sample 1	Sample 2
Number of Valid Data	66	70
Number of Non-Detects	0	0
Number of Detect Data	66	70
Minimum Non-Detect	N/A	N/A
Maximum Non-Detect	N/A	N/A
Percent Non-detects	0.00%	0.00%
Minimum Detect	12.5	13.9
Maximum Detect	396	109
Mean of Detects	41.08	55.31
Median of Detects	31.3	53.8
SD of Detects	48.76	26.15

Wilcoxon-Mann-Whitney (WMW) Test

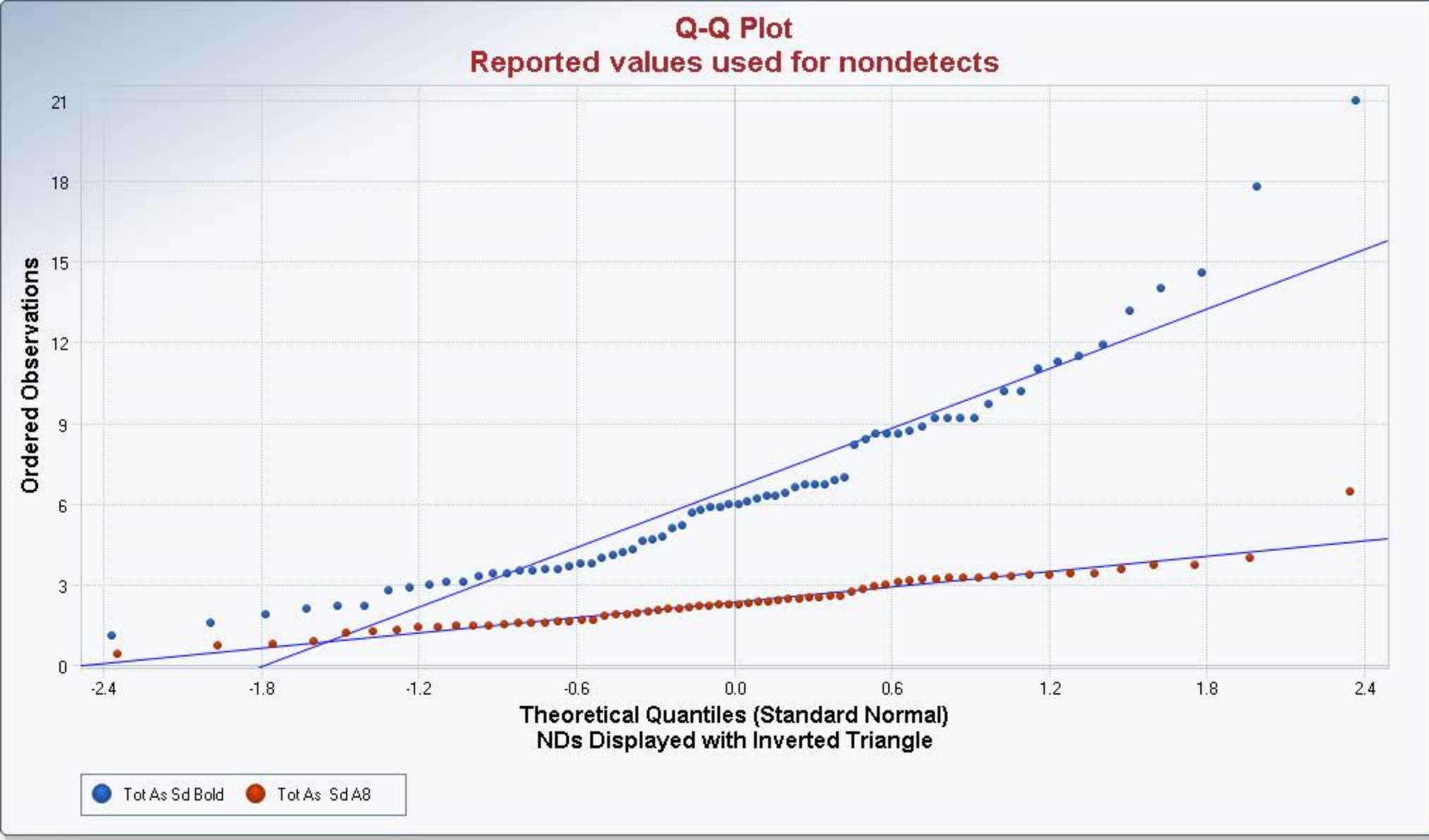
H0: Mean/Median of Sample 1 <= Mean/Median of Sample 2

Sample 1 Rank Sum W-Stat	3489
Standardized WMW U-Stat	-4.498
Mean (U)	2310
SD(U) - Adj ties	229.7
Approximate U-Stat Critical Value (0.05)	1.645
P-Value (Adjusted for Ties)	1

Conclusion with Alpha = 0.05

Do Not Reject H0, Conclude Sample 1 <= Sample 2

P-Value >= alpha (0.05)



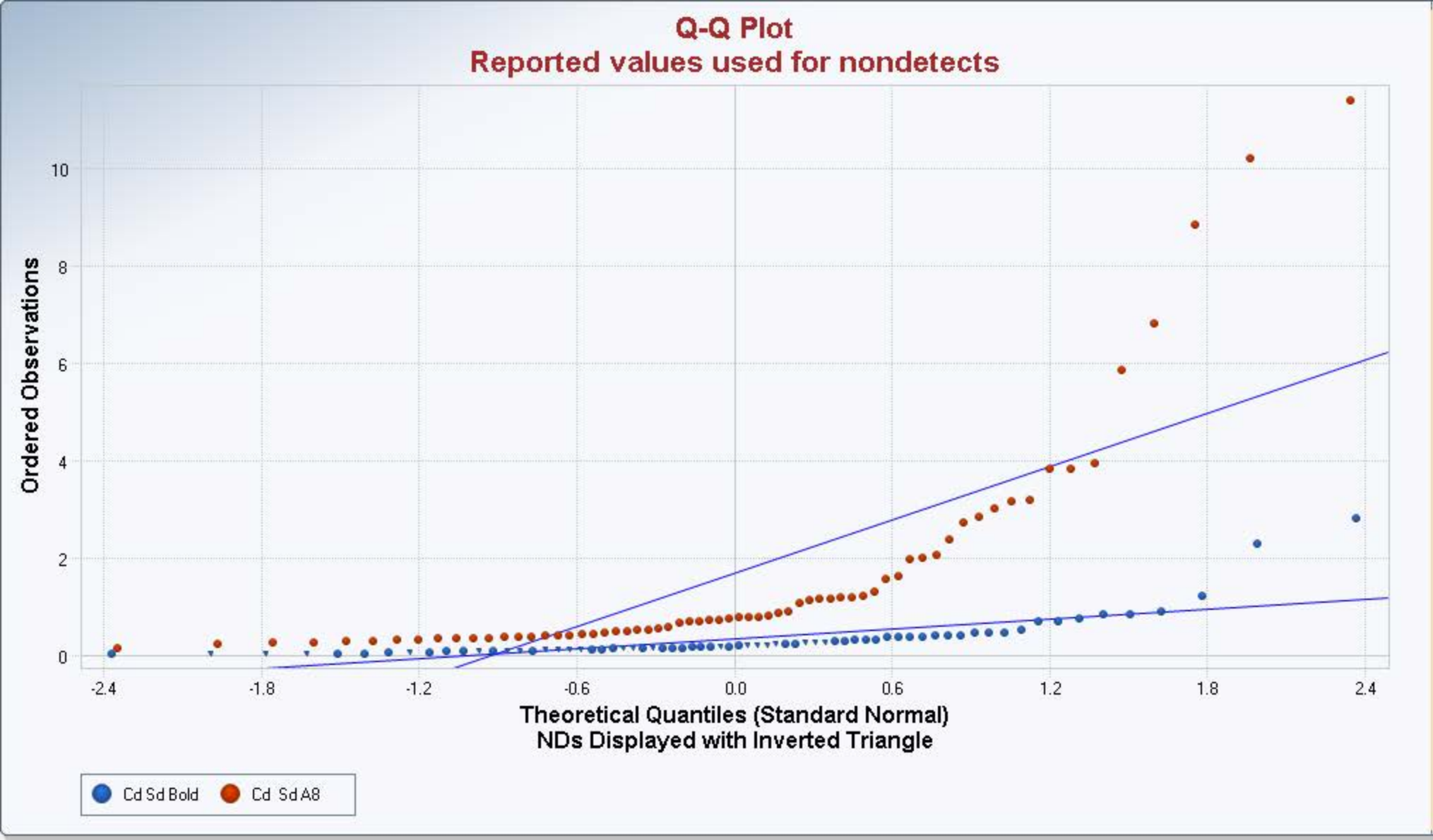
Tot As Sd Bold

Total Number of Data = 70
Number of Non-Detects = 0
Number of Detects = 70
Detected Mean = 6.614
Detected Sd = 3.838
Slope (displayed data) = 3.7
Intercept (displayed data)= 6.614
Correlation, R = 0.95

Tot As Sd A8

Total Number of Data = 66
Number of Non-Detects = 0
Number of Detects = 66
Detected Mean = 2.371
Detected Sd = 0.976
Slope (displayed data) = 0.953
Intercept (displayed data)= 2.371
Correlation, R = 0.962

Best Fit Line



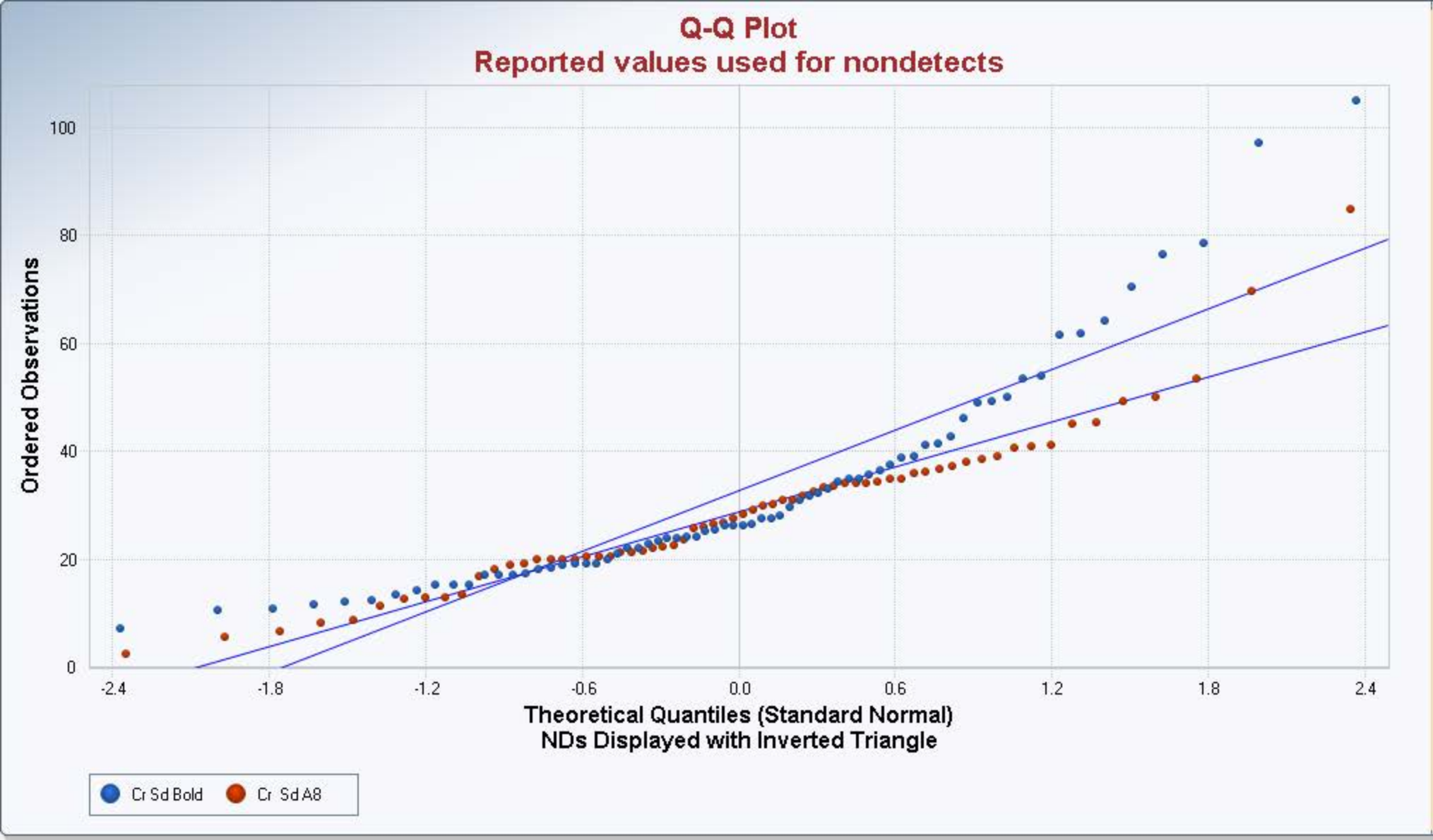
Cd Sd Bold

Total Number of Data = 70
Number of Non-Detects = 22
Number of Detects = 48
Detected Mean = 0.414
Detected Sd = 0.523
Slope (displayed data) = 0.343
Intercept (displayed data)= 0.327
Correlation, R = 0.748

Cd Sd A8

Total Number of Data = 66
Number of Non-Detects = 0
Number of Detects = 66
Detected Mean = 1.665
Detected Sd = 2.299
Slope (displayed data) = 1.831
Intercept (displayed data)= 1.665
Correlation, R = 0.784

Best Fit Line



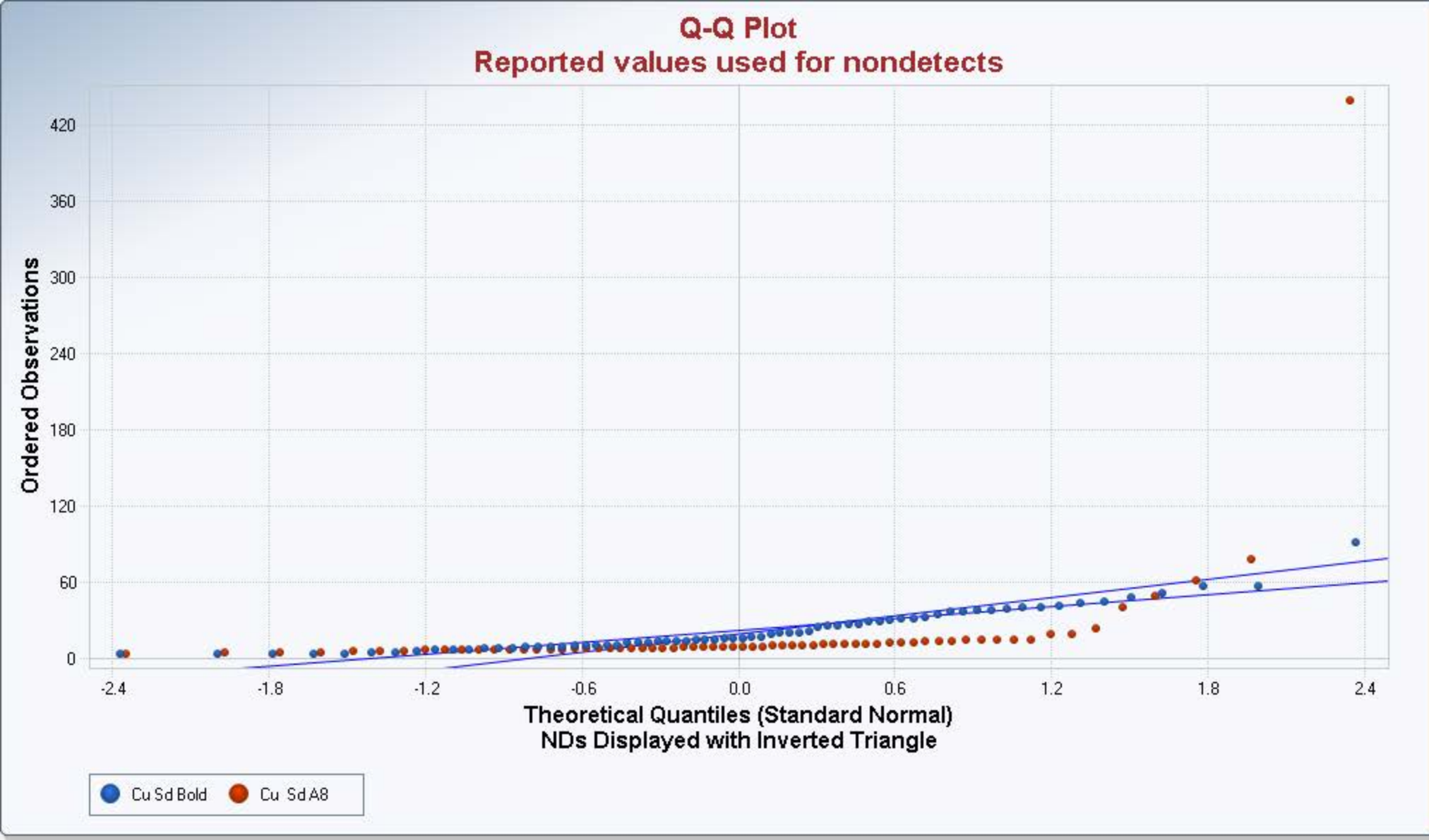
Cr Sd Bold

Total Number of Data = 70
Number of Non-Detects = 0
Number of Detects = 70
Detected Mean = 32.5
Detected Sd = 20.07
Slope (displayed data) = 18.78
Intercept (displayed data)= 32.5
Correlation, R = 0.922

Cr Sd A8

Total Number of Data = 66
Number of Non-Detects = 0
Number of Detects = 66
Detected Mean = 28.65
Detected Sd = 14.27
Slope (displayed data) = 13.94
Intercept (displayed data)= 28.65
Correlation, R = 0.962

Best Fit Line



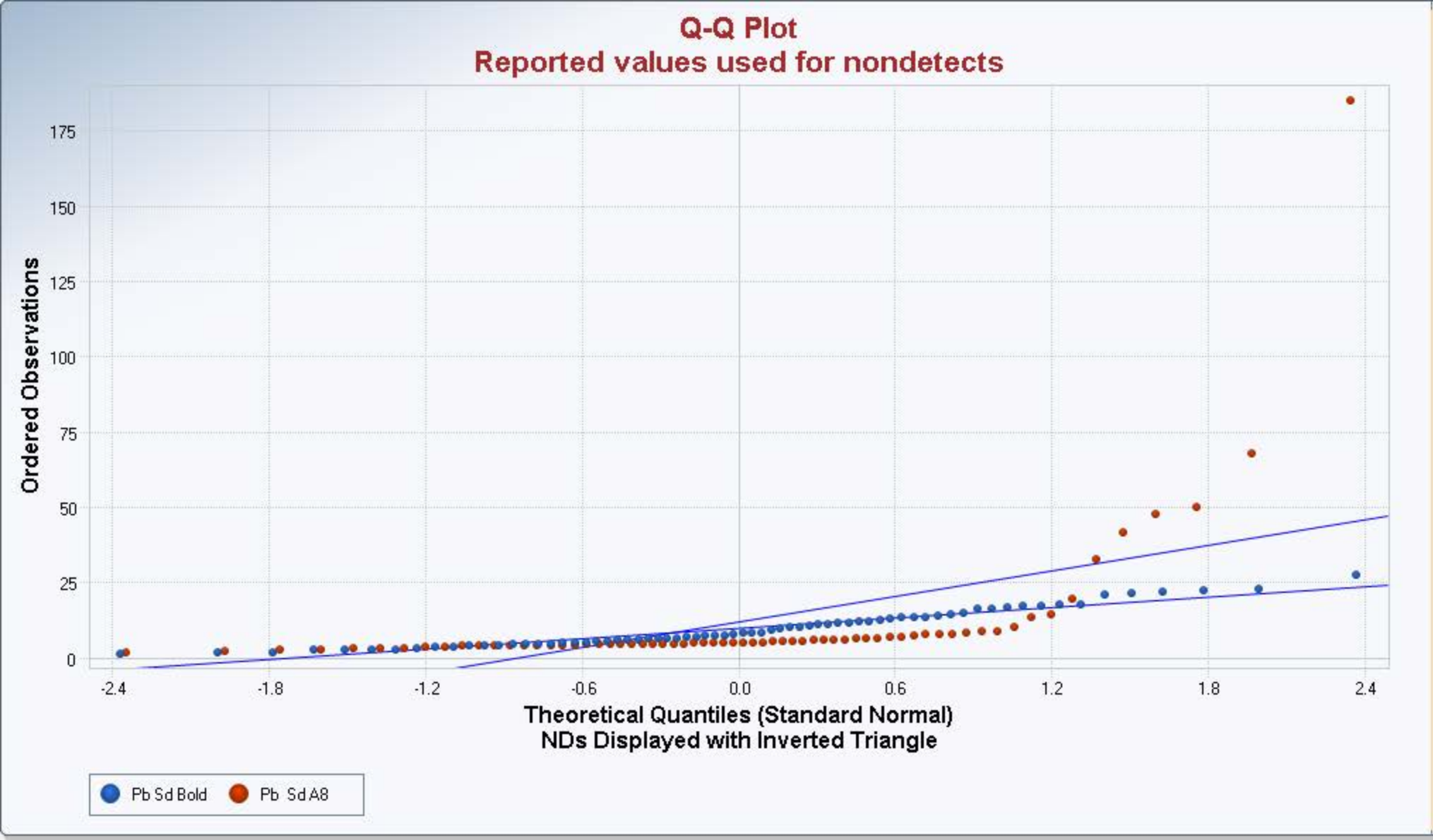
Cu Sd Bold

Total Number of Data = 70
Number of Non-Detects = 0
Number of Detects = 70
Detected Mean = 21.75
Detected Sd = 16.55
Slope (displayed data) = 15.65
Intercept (displayed data)= 21.75
Correlation, R = 0.932

Cu Sd A8

Total Number of Data = 66
Number of Non-Detects = 0
Number of Detects = 66
Detected Mean = 19.06
Detected Sd = 53.94
Slope (displayed data) = 24.07
Intercept (displayed data)= 19.06
Correlation, R = 0.44

Best Fit Line



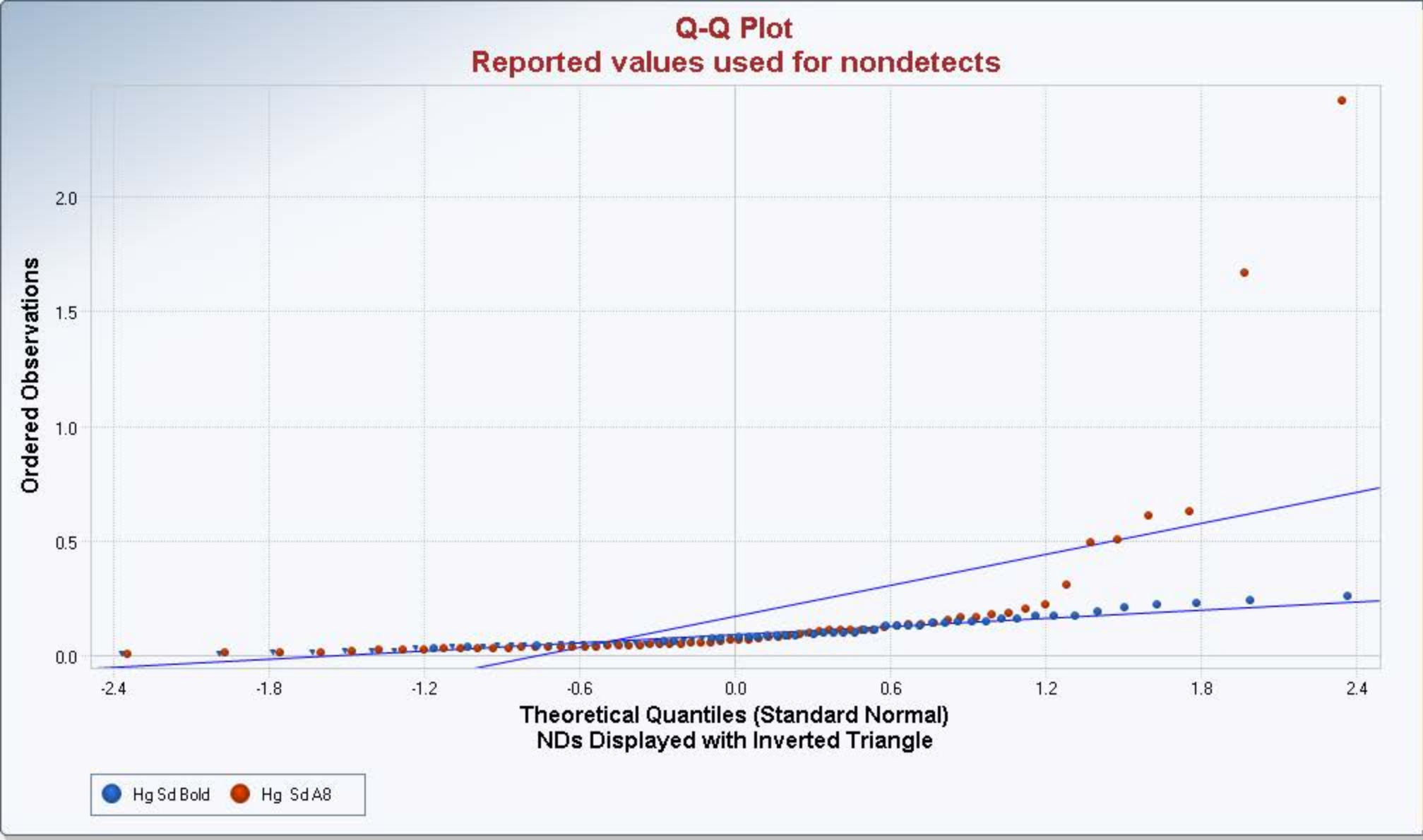
Pb Sd Bold

Total Number of Data = 70
Number of Non-Detects = 0
Number of Detects = 70
Detected Mean = 9.75
Detected Sd = 6.018
Slope (displayed data) = 5.904
Intercept (displayed data)= 9.75
Correlation, R = 0.967

Pb Sd A8

Total Number of Data = 66
Number of Non-Detects = 0
Number of Detects = 66
Detected Mean = 11.64
Detected Sd = 24.79
Slope (displayed data) = 14.2
Intercept (displayed data)= 11.64
Correlation, R = 0.564

Best Fit Line



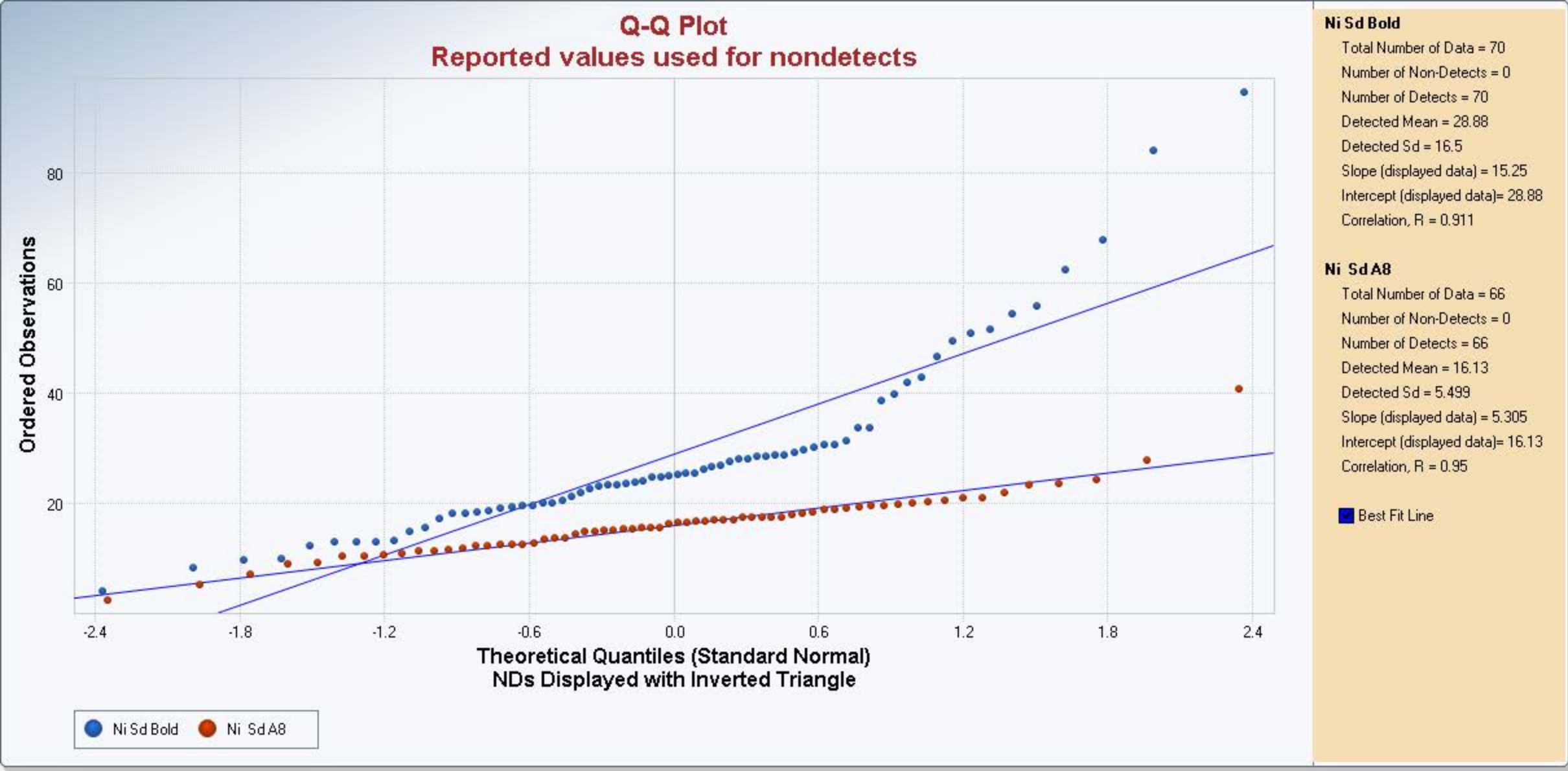
Hg Sd Bold

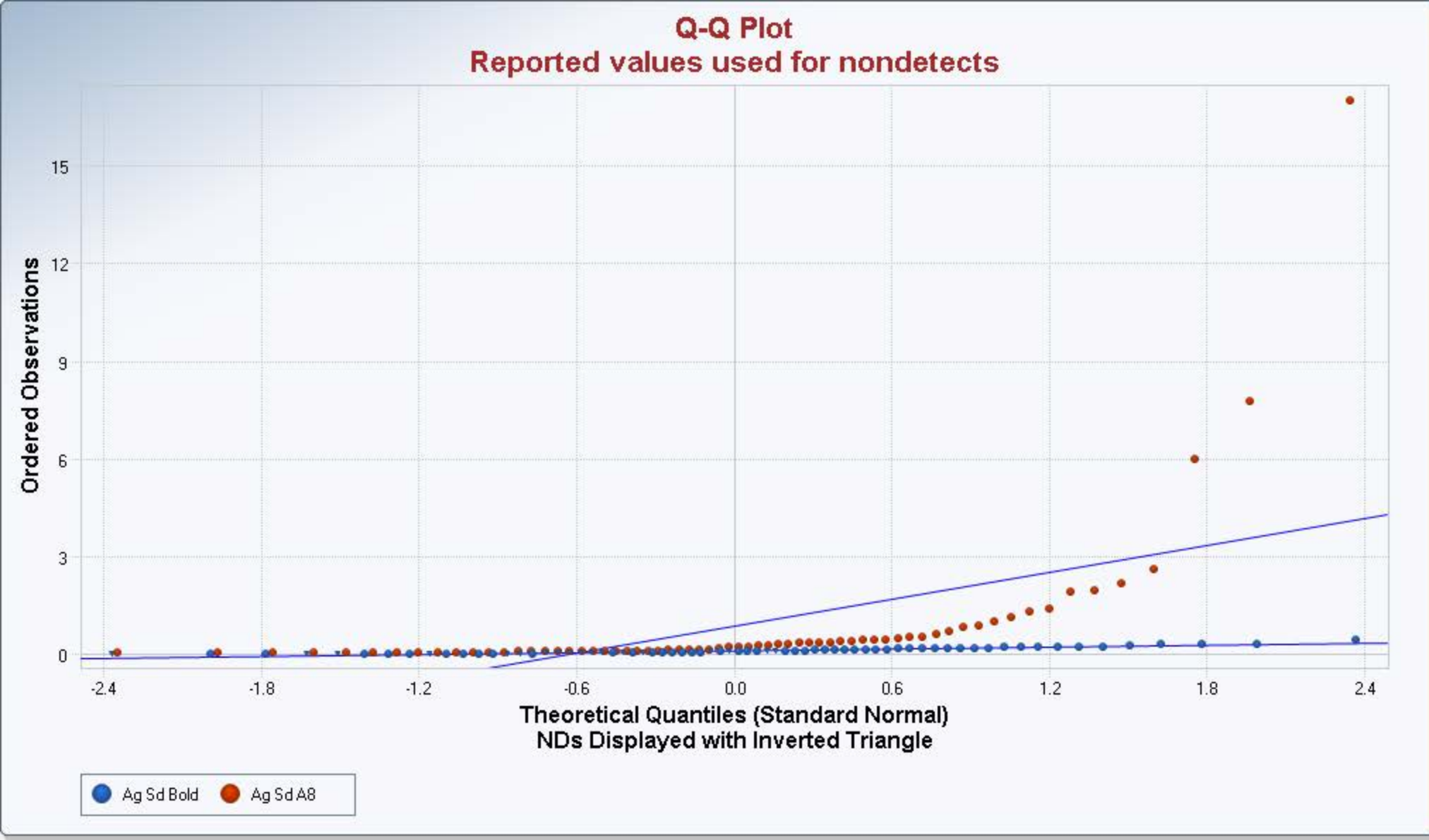
Total Number of Data = 70
Number of Non-Detects = 29
Number of Detects = 41
Detected Mean = 0.124
Detected Sd = 0.0566
Slope (displayed data) = 0.0593
Intercept (displayed data)= 0.0904
Correlation, R = 0.963

Hg Sd A8

Total Number of Data = 66
Number of Non-Detects = 0
Number of Detects = 66
Detected Mean = 0.168
Detected Sd = 0.365
Slope (displayed data) = 0.227
Intercept (displayed data)= 0.168
Correlation, R = 0.613

Best Fit Line


Q-Q Plot
Reported values used for nondetects
Ordered Observations
80
60
40
20
-2.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
2.4
Theoretical Quantiles (Standard Normal)
NDs Displayed with Inverted Triangle
Ni Sd Bold
Ni Sd A8
Ni Sd Bold
Total Number of Data = 70
Number of Non-Detects = 0
Number of Detects = 70
Detected Mean = 28.88
Detected Sd = 16.5
Slope (displayed data) = 15.25
Intercept (displayed data)= 28.88
Correlation, R = 0.911
Ni Sd A8
Total Number of Data = 66
Number of Non-Detects = 0
Number of Detects = 66
Detected Mean = 16.13
Detected Sd = 5.499
Slope (displayed data) = 5.305
Intercept (displayed data)= 16.13
Correlation, R = 0.95
Best Fit Line



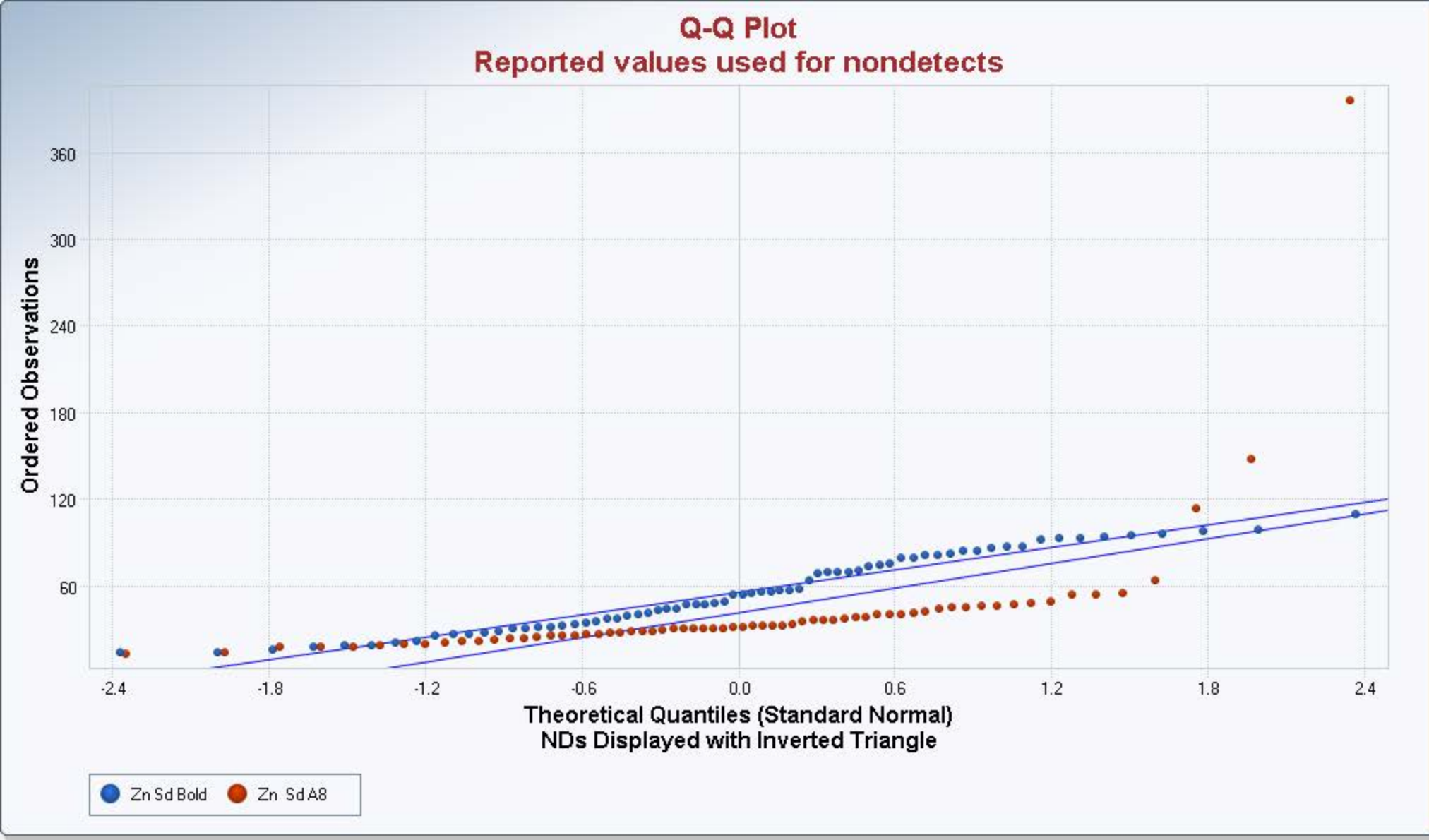
Ag Sd Bold

Total Number of Data = 70
Number of Non-Detects = 18
Number of Detects = 52
Detected Mean = 0.14
Detected Sd = 0.0978
Slope (displayed data) = 0.0905
Intercept (displayed data)= 0.116
Correlation, R = 0.946

Ag Sd A8

Total Number of Data = 66
Number of Non-Detects = 0
Number of Detects = 66
Detected Mean = 0.872
Detected Sd = 2.372
Slope (displayed data) = 1.38
Intercept (displayed data)= 0.872
Correlation, R = 0.573

Best Fit Line



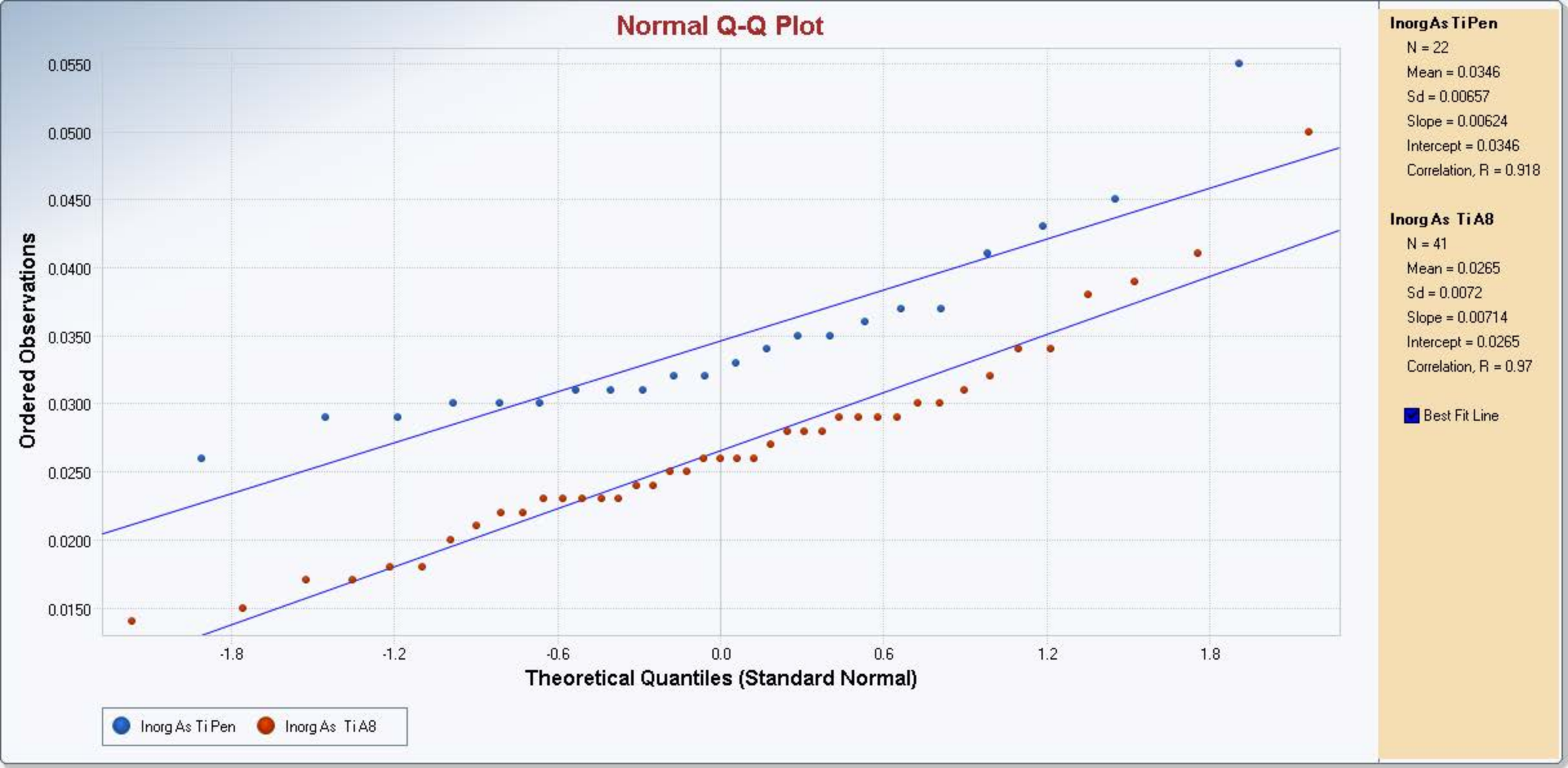
Zn Sd Bold

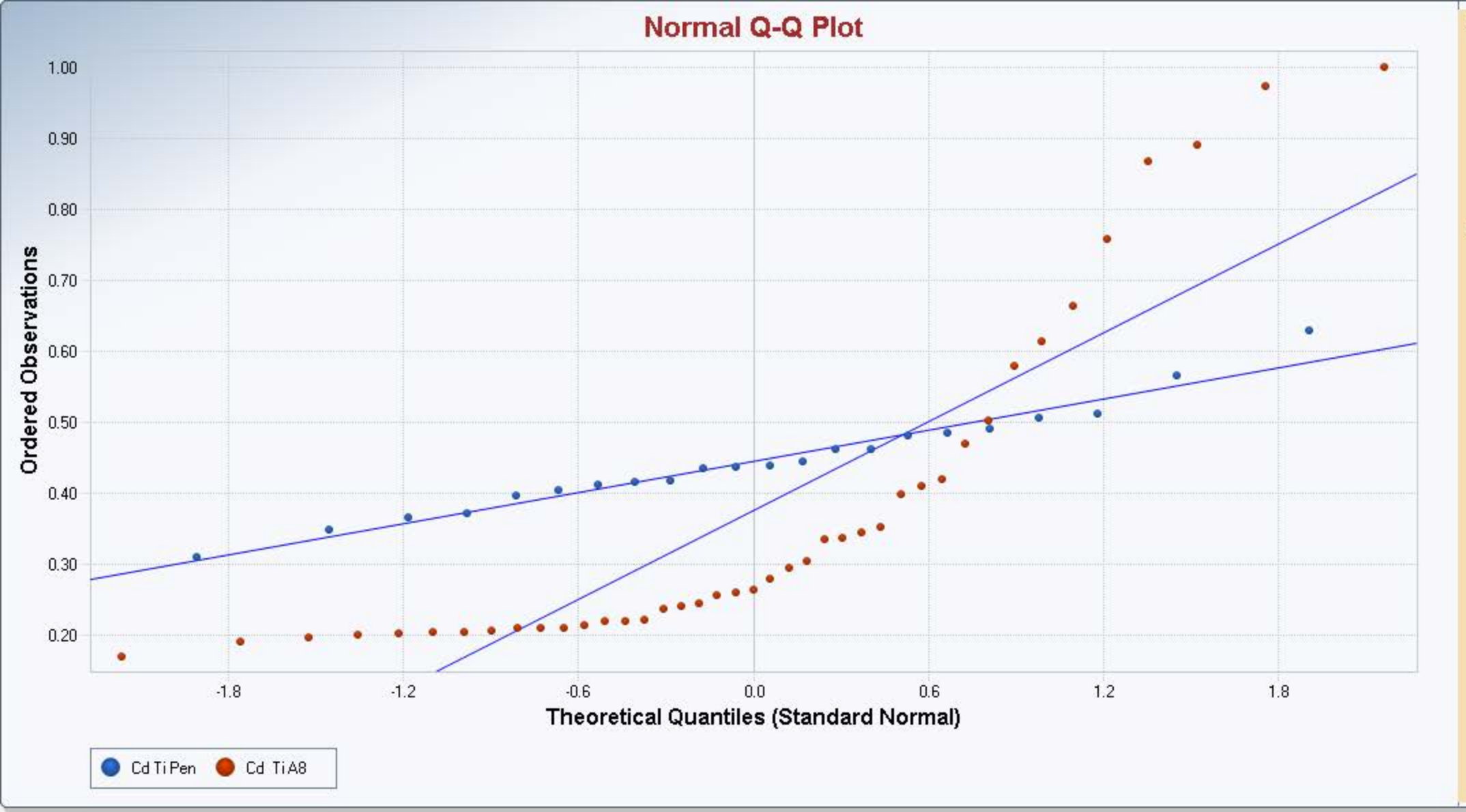
Total Number of Data = 70
Number of Non-Detects = 0
Number of Detects = 70
Detected Mean = 55.31
Detected Sd = 26.15
Slope (displayed data) = 25.99
Intercept (displayed data)= 55.31
Correlation, R = 0.98

Zn Sd A8

Total Number of Data = 66
Number of Non-Detects = 0
Number of Detects = 66
Detected Mean = 41.08
Detected Sd = 48.76
Slope (displayed data) = 28.81
Intercept (displayed data)= 41.08
Correlation, R = 0.582

Best Fit Line


Normal Q-Q Plot
Ordered Observations
0.0550
0.0500
0.0450
0.0400
0.0350
0.0300
0.0250
0.0200
0.0150
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Inorg As Ti Pen
Inorg As Ti A8
InorgAs TiPen
N = 22
Mean = 0.0346
Sd = 0.00657
Slope = 0.00624
Intercept = 0.0346
Correlation, R = 0.918
Inorg As TiA8
N = 41
Mean = 0.0265
Sd = 0.0072
Slope = 0.00714
Intercept = 0.0265
Correlation, R = 0.97
Best Fit Line



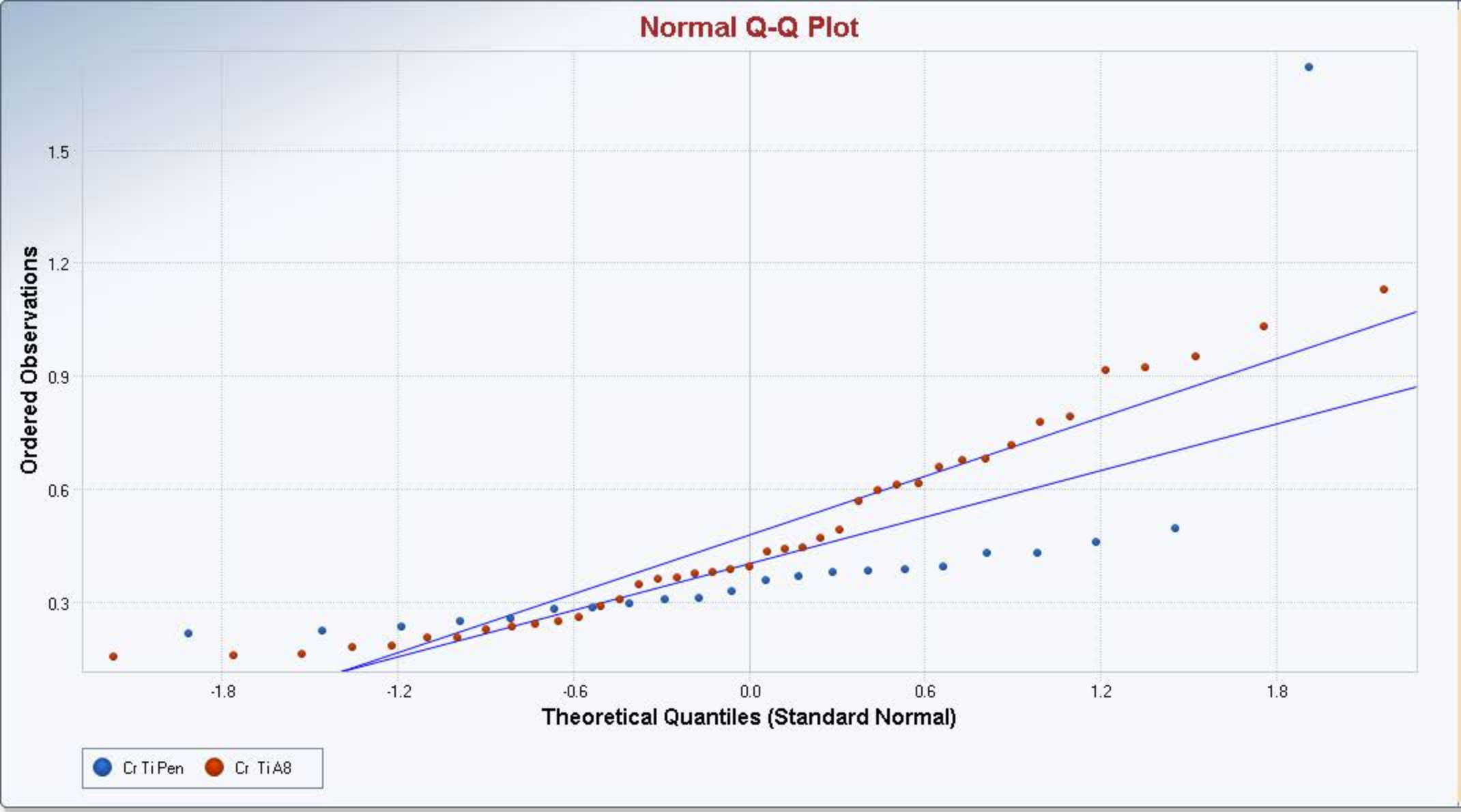
Cd Ti Pen

N = 22
Mean = 0.445
Sd = 0.0718
Slope = 0.0729
Intercept = 0.445
Correlation, R = 0.982

Cd TiA8

N = 41
Mean = 0.375
Sd = 0.233
Slope = 0.209
Intercept = 0.375
Correlation, R = 0.877

Best Fit Line



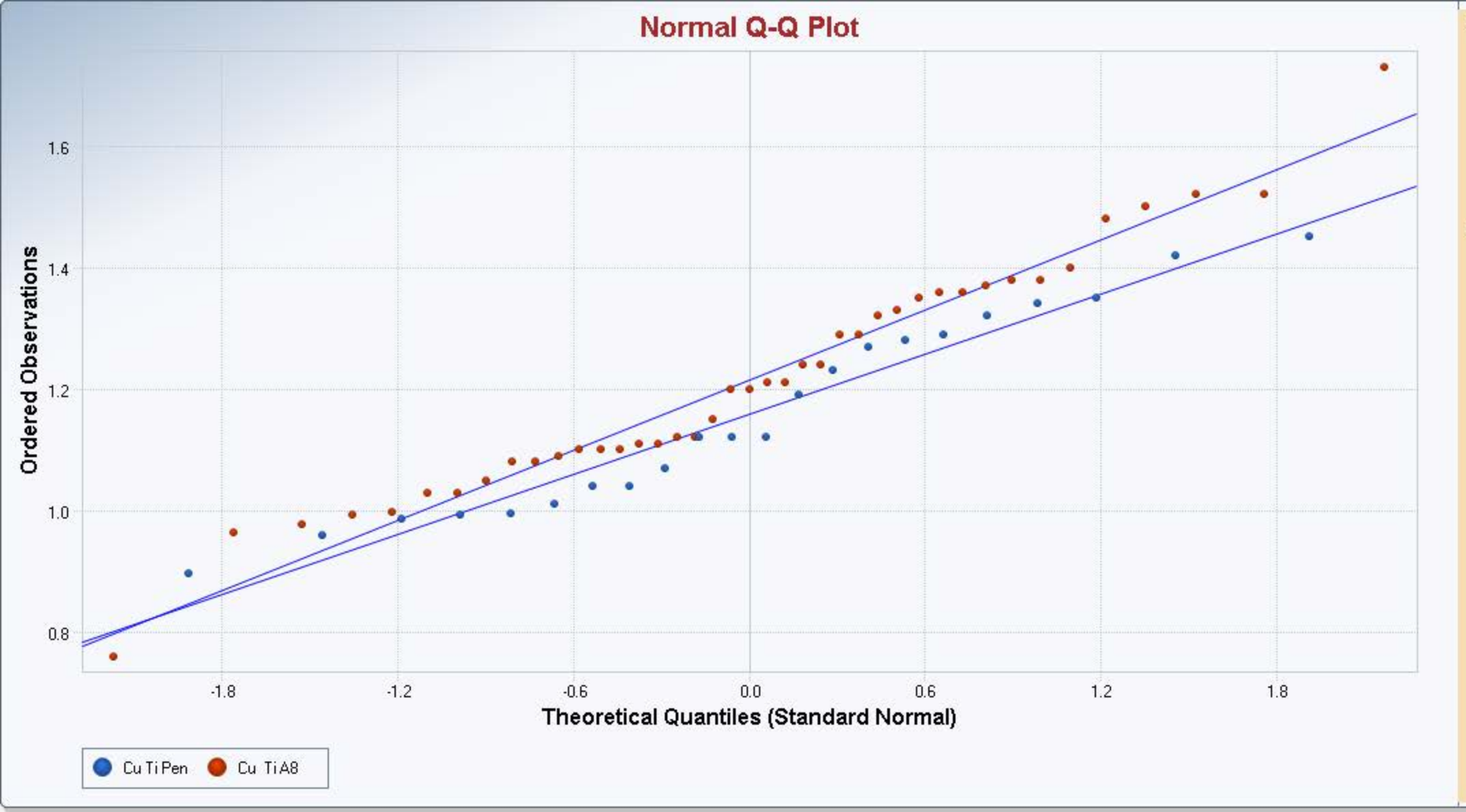
Cr Ti Pen

N = 22
Mean = 0.4
Sd = 0.305
Slope = 0.207
Intercept = 0.4
Correlation, R = 0.655

Cr Ti A8

N = 41
Mean = 0.478
Sd = 0.265
Slope = 0.261
Intercept = 0.478
Correlation, R = 0.963

Best Fit Line



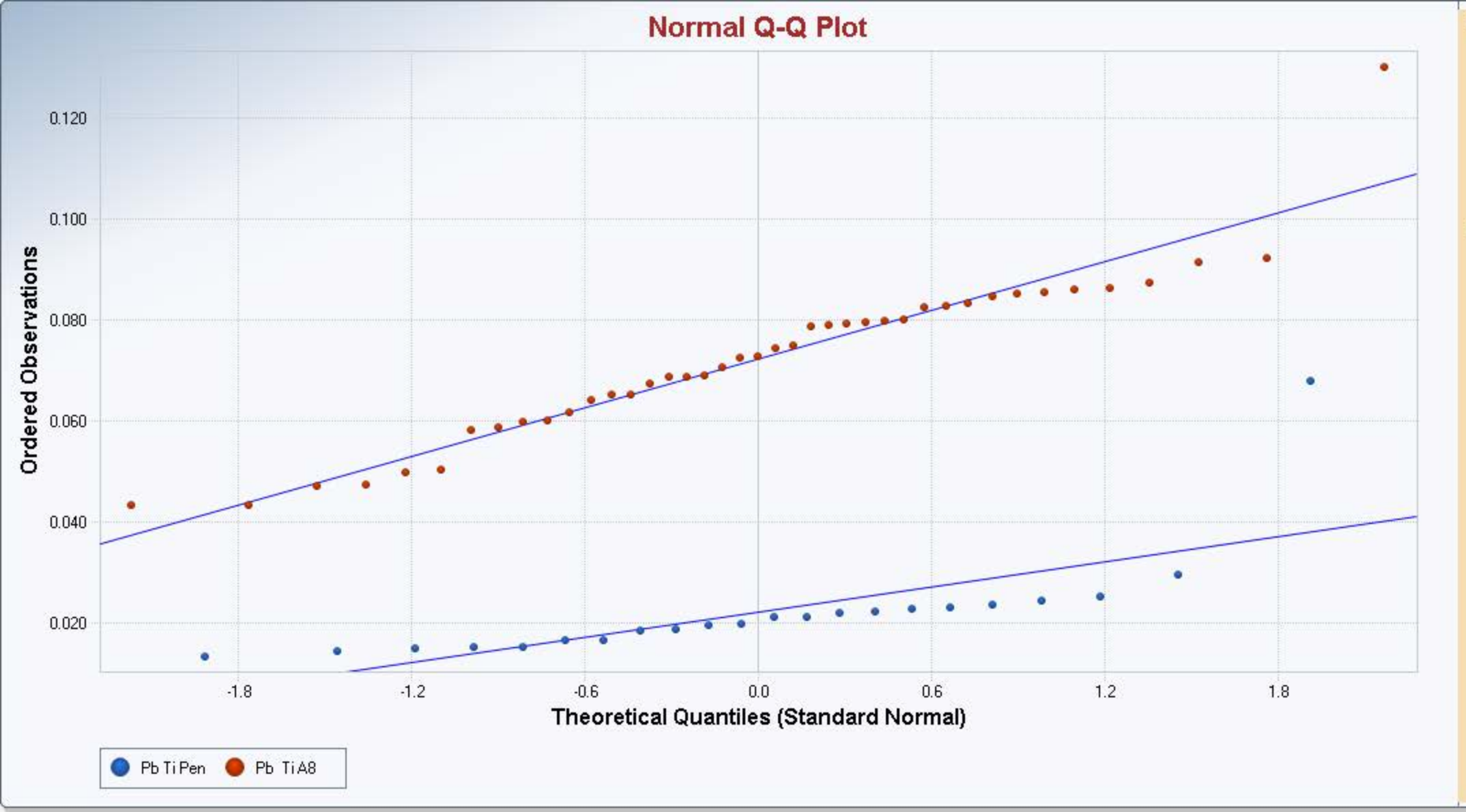
Cu Ti Pen

N = 22
Mean = 1.159
Sd = 0.162
Slope = 0.165
Intercept = 1.159
Correlation, R = 0.98

Cu TiA8

N = 41
Mean = 1.216
Sd = 0.192
Slope = 0.193
Intercept = 1.216
Correlation, R = 0.985

Best Fit Line



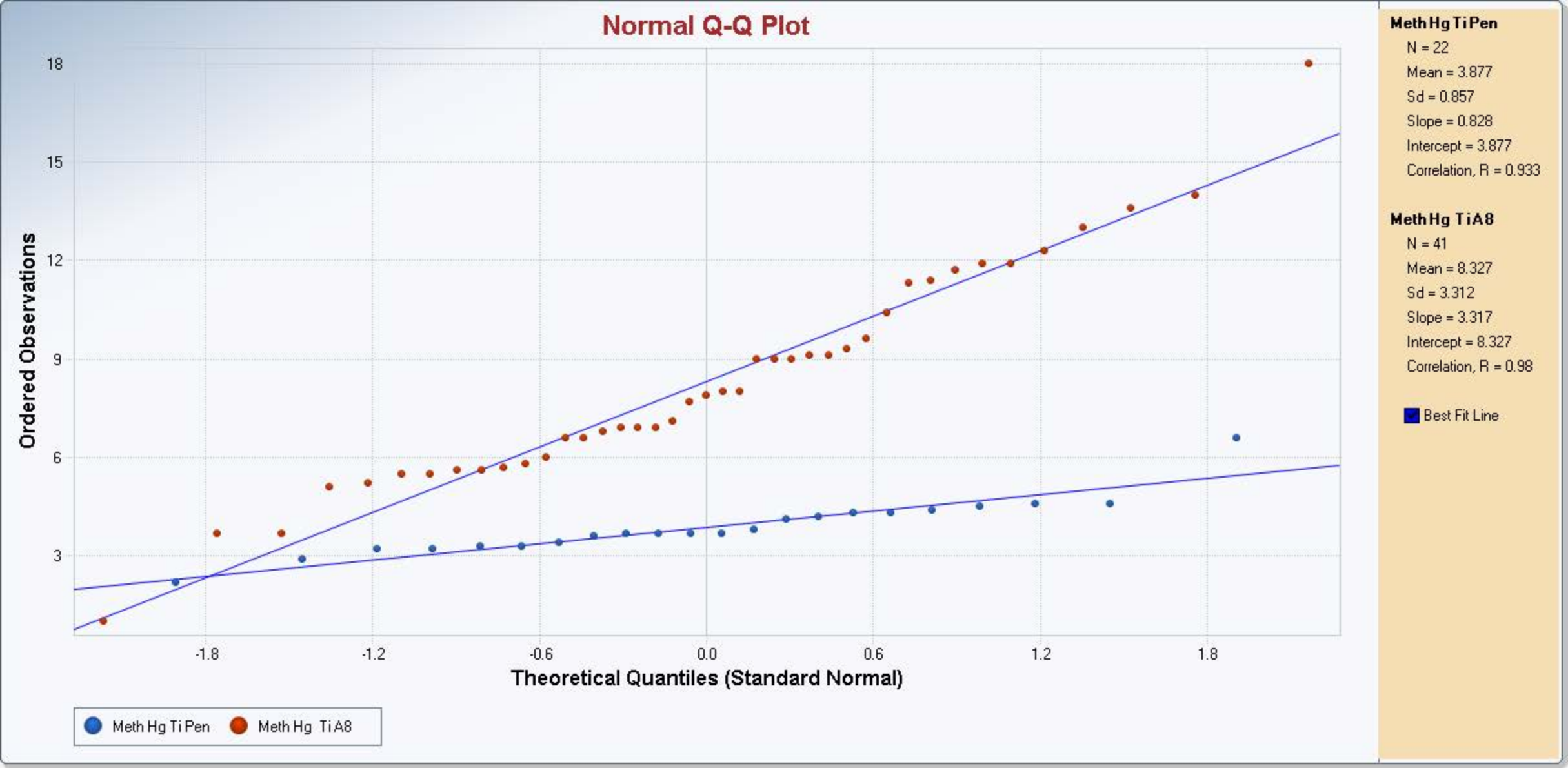
Pb Ti Pen

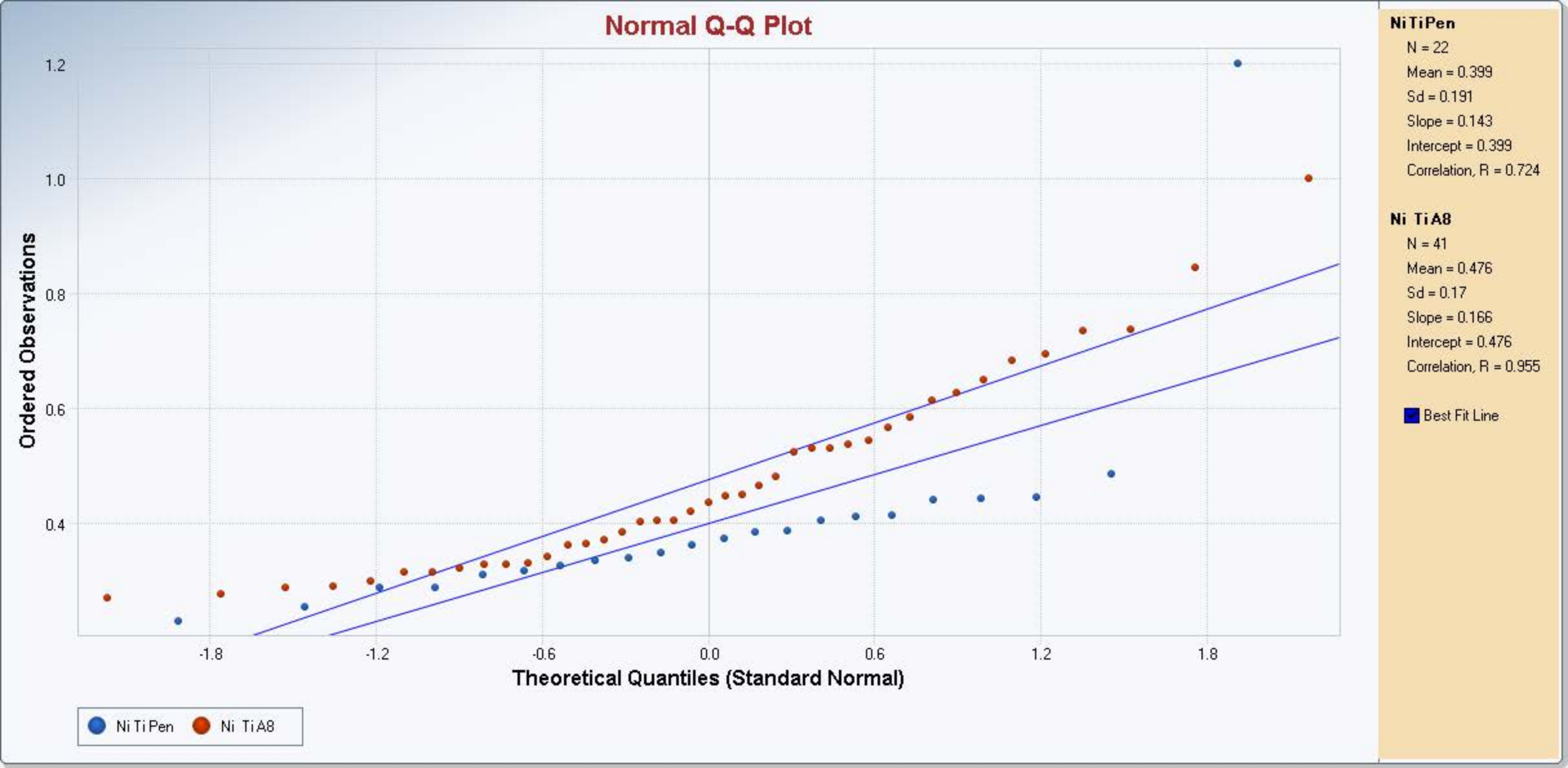
N = 22
Mean = 0.022
Sd = 0.011
Slope = 0.00842
Intercept = 0.022
Correlation, R = 0.737

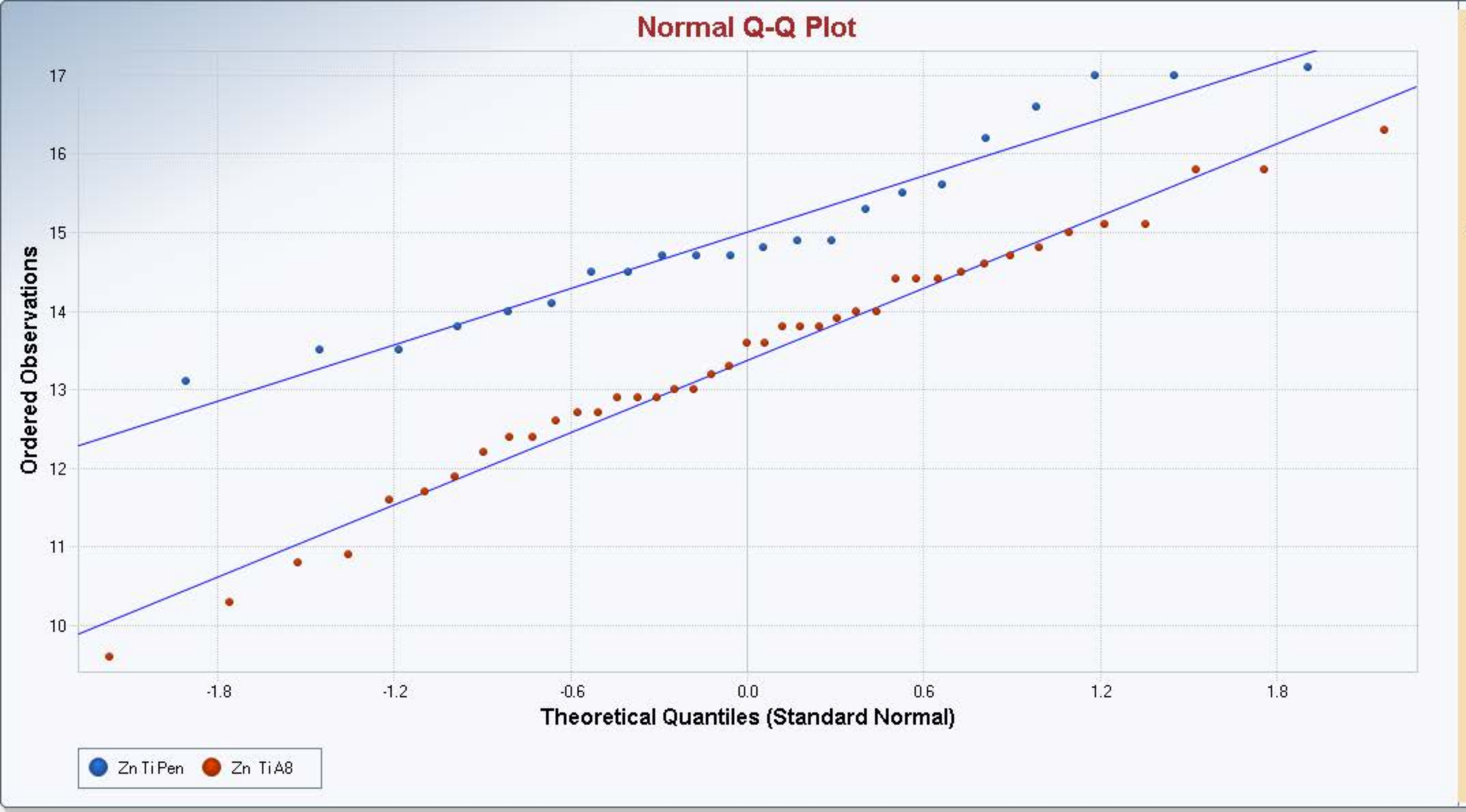
Pb TiA8

N = 41
Mean = 0.0723
Sd = 0.0164
Slope = 0.0161
Intercept = 0.0723
Correlation, R = 0.96

Best Fit Line


Normal Q-Q Plot
Ordered Observations
18
15
12
9
6
3
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Meth Hg Ti Pen
Meth Hg TiA8
Meth Hg Ti Pen
N = 22
Mean = 3.877
Sd = 0.857
Slope = 0.828
Intercept = 3.877
Correlation, R = 0.933
Meth Hg TiA8
N = 41
Mean = 8.327
Sd = 3.312
Slope = 3.317
Intercept = 8.327
Correlation, R = 0.98
Best Fit Line


Normal Q-Q Plot
Ordered Observations
1.2
1.0
0.8
0.6
0.4
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Ni Ti Pen
Ni Ti A8
NiTiPen
N = 22
Mean = 0.399
Sd = 0.191
Slope = 0.143
Intercept = 0.399
Correlation, R = 0.724
Ni Ti A8
N = 41
Mean = 0.476
Sd = 0.17
Slope = 0.166
Intercept = 0.476
Correlation, R = 0.955
Best Fit Line


Normal Q-Q Plot
Ordered Observations
17
16
15
14
13
12
11
10
-1.8
-1.2
-0.6
0.0
0.6
1.2
1.8
Theoretical Quantiles (Standard Normal)
Zn TiPen
Zn TiA8
ZnTiPen
N = 22
Mean = 15
Sd = 1.181
Slope = 1.193
Intercept = 15
Correlation, R = 0.975
Zn TiA8
N = 41
Mean = 13.38
Sd = 1.506
Slope = 1.526
Intercept = 13.38
Correlation, R = 0.992
Best Fit Line

APPENDIX E
UCL95 ProUCL Outputs

95UCL Calcuations
Sediment

UCL Statistics for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.112/8/2016 3:30:34 PM
From File	WMWT Sed & Clam tissue_input_11_29_16_a.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Ag Sd Bold (mg/kg)

General Statistics

Total Number of Observations	70	Number of Distinct Observations	47
Number of Detects	52	Number of Non-Detects	18
Number of Distinct Detects	34	Number of Distinct Non-Detects	16
Minimum Detect	0.0094	Minimum Non-Detect	0.0074
Maximum Detect	0.45	Maximum Non-Detect	0.1
Variance Detects	0.00956	Percent Non-Detects	25.71%
Mean Detects	0.14	SD Detects	0.0978
Median Detects	0.13	CV Detects	0.701
Skewness Detects	0.779	Kurtosis Detects	0.55
Mean of Logged Detects	-2.306	SD of Logged Detects	0.947

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.937	**Normal GOF Test on Detected Observations Only**
5% Shapiro Wilk P Value	0.0122	Detected Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.0986	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.122	Detected Data appear Normal at 5% Significance Level

Detected Data appear Approximate Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.109	KM Standard Error of Mean	0.012
KM SD	0.0988	95% KM (BCA) UCL	0.13
95% KM (t) UCL	0.129	95% KM (Percentile Bootstrap) UCL	0.128
95% KM (z) UCL	0.128	95% KM Bootstrap t UCL	0.13
90% KM Chebyshev UCL	0.145	95% KM Chebyshev UCL	0.161
97.5% KM Chebyshev UCL	0.184	99% KM Chebyshev UCL	0.228

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.569	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.766	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.089	**Kolmogorov-Smirnov GOF**
5% K-S Critical Value	0.125	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

95UCL Calcuations
Sediment

Gamma Statistics on Detected Data Only

k hat (MLE)	1.634	k star (bias corrected MLE)	1.553
Theta hat (MLE)	0.0854	Theta star (bias corrected MLE)	0.0898
nu hat (MLE)	170	nu star (bias corrected)	161.5
Mean (detects)	0.14		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.0094	Mean	0.11
Maximum	0.45	Median	0.076
SD	0.0987	CV	0.901
k hat (MLE)	1.134	k star (bias corrected MLE)	1.095
Theta hat (MLE)	0.0966	Theta star (bias corrected MLE)	0.1
nu hat (MLE)	158.8	nu star (bias corrected)	153.3
Adjusted Level of Significance (β)	0.0466		
Approximate Chi Square Value (153.30, α)	125.7	Adjusted Chi Square Value (153.30, β)	125.2
95% Gamma Approximate UCL (use when n>=50)	0.134	95% Gamma Adjusted UCL (use when n<50)	0.134

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	0.109	SD (KM)	0.0988
Variance (KM)	0.00977	SE of Mean (KM)	0.012
k hat (KM)	1.21	k star (KM)	1.168
nu hat (KM)	169.5	nu star (KM)	163.5
theta hat (KM)	0.0898	theta star (KM)	0.0931
80% gamma percentile (KM)	0.173	90% gamma percentile (KM)	0.241
95% gamma percentile (KM)	0.309	99% gamma percentile (KM)	0.464

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (163.52, α)	135	Adjusted Chi Square Value (163.52, β)	134.4
95% Gamma Approximate KM-UCL (use when n>=50)	0.132	95% Gamma Adjusted KM-UCL (use when n<50)	0.132

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Approximate Test Statistic	0.918	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0.00134	Detected Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.135	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.122	Detected Data Not Lognormal at 5% Significance Level	

Detected Data Not Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	0.11	Mean in Log Scale	-2.693
SD in Original Scale	0.0984	SD in Log Scale	1.071
95% t UCL (assumes normality of ROS data)	0.129	95% Percentile Bootstrap UCL	0.129
95% BCA Bootstrap UCL	0.131	95% Bootstrap t UCL	0.13
95% H-UCL (Log ROS)	0.16		

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-2.781	KM Geo Mean	0.062
KM SD (logged)	1.189	95% Critical H Value (KM-Log)	2.155
KM Standard Error of Mean (logged)	0.15	95% H-UCL (KM -Log)	0.171
KM SD (logged)	1.189	95% Critical H Value (KM-Log)	2.155
KM Standard Error of Mean (logged)	0.15		

DL/2 Statistics

DL/2 Normal		**DL/2 Log-Transformed**	
Mean in Original Scale	0.11	Mean in Log Scale	-2.725
SD in Original Scale	0.0985	SD in Log Scale	1.142
95% t UCL (Assumes normality)	0.129	95% H-Stat UCL	0.17

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics
Detected Data appear Approximate Normal Distributed at 5% Significance Level

Suggested UCL to Use

95% KM (t) UCL	0.129

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Tot As Sd Bold (mg/kg)

General Statistics

Total Number of Observations	70	Number of Distinct Observations	53
		Number of Missing Observations	0
Minimum	1.1	Mean	6.614
Maximum	21	Median	6
SD	3.838	Std. Error of Mean	0.459
Coefficient of Variation	0.58	Skewness	1.317

Normal GOF Test

Shapiro Wilk Test Statistic	0.905	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	1.3460E-5	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.134	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.106	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	7.379	95% Adjusted-CLT UCL (Chen-1995)	7.446
		95% Modified-t UCL (Johnson-1978)	7.391

Gamma GOF Test

A-D Test Statistic	0.294	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.757	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.065	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.107	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.255	k star (bias corrected MLE)	3.125
Theta hat (MLE)	2.032	Theta star (bias corrected MLE)	2.116
nu hat (MLE)	455.7	nu star (bias corrected)	437.6
MLE Mean (bias corrected)	6.614	MLE Sd (bias corrected)	3.741
		Approximate Chi Square Value (0.05)	390.1
Adjusted Level of Significance	0.0466	Adjusted Chi Square Value	389.1

95UCL Calcuations
Sediment

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	7.42	95% Adjusted Gamma UCL (use when n<50)	7.438

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.985	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	0.848	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.08	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.106	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	0.0953	Mean of logged Data	1.728
Maximum of Logged Data	3.045	SD of logged Data	0.588

Assuming Lognormal Distribution

95% H-UCL	7.669	90% Chebyshev (MVUE) UCL	8.178
95% Chebyshev (MVUE) UCL	8.861	97.5% Chebyshev (MVUE) UCL	9.808
99% Chebyshev (MVUE) UCL	11.67		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	7.369	95% Jackknife UCL	7.379
95% Standard Bootstrap UCL	7.352	95% Bootstrap-t UCL	7.503
95% Hall's Bootstrap UCL	7.539	95% Percentile Bootstrap UCL	7.37
95% BCA Bootstrap UCL	7.389		
90% Chebyshev(Mean, Sd) UCL	7.991	95% Chebyshev(Mean, Sd) UCL	8.614
97.5% Chebyshev(Mean, Sd) UCL	9.479	99% Chebyshev(Mean, Sd) UCL	11.18

Suggested UCL to Use

95% Approximate Gamma UCL	7.42

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Cd Sd Bold (mg/kg)

General Statistics

Total Number of Observations	70	Number of Distinct Observations	51
Number of Detects	48	Number of Non-Detects	22
Number of Distinct Detects	40	Number of Distinct Non-Detects	17
Minimum Detect	0.018	Minimum Non-Detect	0.022
Maximum Detect	2.8	Maximum Non-Detect	0.26
Variance Detects	0.273	Percent Non-Detects	31.43%
Mean Detects	0.414	SD Detects	0.523
Median Detects	0.285	CV Detects	1.263
Skewness Detects	3.178	Kurtosis Detects	11.61
Mean of Logged Detects	-1.407	SD of Logged Detects	1.053

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.64	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.947	Detected Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.257	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.127	Detected Data Not Normal at 5% Significance Level

Detected Data Not Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.301	KM Standard Error of Mean	0.0557
KM SD	0.46	95% KM (BCA) UCL	0.405
95% KM (t) UCL	0.394	95% KM (Percentile Bootstrap) UCL	0.397
95% KM (z) UCL	0.393	95% KM Bootstrap t UCL	0.454
90% KM Chebyshev UCL	0.469	95% KM Chebyshev UCL	0.544
97.5% KM Chebyshev UCL	0.649	99% KM Chebyshev UCL	0.856

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.698	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.777	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.124	**Kolmogorov-Smirnov GOF**
5% K-S Critical Value	0.131	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	1.089	k star (bias corrected MLE)	1.034
Theta hat (MLE)	0.38	Theta star (bias corrected MLE)	0.4
nu hat (MLE)	104.5	nu star (bias corrected)	99.3
Mean (detects)	0.414		

95UCL Calcuations
Sediment

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	0.288
Maximum	2.8	Median	0.145
SD	0.47	CV	1.632
k hat (MLE)	0.557	k star (bias corrected MLE)	0.543
Theta hat (MLE)	0.518	Theta star (bias corrected MLE)	0.531
nu hat (MLE)	77.98	nu star (bias corrected)	75.97
Adjusted Level of Significance (β)	0.0466		
Approximate Chi Square Value (75.97, α)	56.89	Adjusted Chi Square Value (75.97, β)	56.55
95% Gamma Approximate UCL (use when n>=50)	0.385	95% Gamma Adjusted UCL (use when n<50)	0.387

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	0.301	SD (KM)	0.46
Variance (KM)	0.212	SE of Mean (KM)	0.0557
k hat (KM)	0.429	k star (KM)	0.42
nu hat (KM)	60.02	nu star (KM)	58.78
theta hat (KM)	0.703	theta star (KM)	0.718
80% gamma percentile (KM)	0.489	90% gamma percentile (KM)	0.844
95% gamma percentile (KM)	1.232	99% gamma percentile (KM)	2.201

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (58.78, α)	42.16	Adjusted Chi Square Value (58.78, β)	41.86
95% Gamma Approximate KM-UCL (use when n>=50)	0.42	95% Gamma Adjusted KM-UCL (use when n<50)	0.423

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.987	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.947	Detected Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0714	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.127	Detected Data appear Lognormal at 5% Significance Level

Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	0.301	Mean in Log Scale	-1.924
SD in Original Scale	0.464	SD in Log Scale	1.194
95% t UCL (assumes normality of ROS data)	0.393	95% Percentile Bootstrap UCL	0.401
95% BCA Bootstrap UCL	0.429	95% Bootstrap t UCL	0.44
95% H-UCL (Log ROS)	0.405		

95UCL Calcuations
Sediment

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-1.973	KM Geo Mean	0.139
KM SD (logged)	1.28	95% Critical H Value (KM-Log)	2.073
KM Standard Error of Mean (logged)	0.166	95% H-UCL (KM -Log)	0.434
KM SD (logged)	1.28	95% Critical H Value (KM-Log)	2.073
KM Standard Error of Mean (logged)	0.166		

DL/2 Statistics

DL/2 Normal		**DL/2 Log-Transformed**	
Mean in Original Scale	0.306	Mean in Log Scale	-1.869
SD in Original Scale	0.461	SD in Log Scale	1.181
95% t UCL (Assumes normality)	0.398	95% H-Stat UCL	0.421

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics
Detected Data appear Gamma Distributed at 5% Significance Level

Suggested UCL to Use

95% KM Approximate Gamma UCL	0.42	95% GROS Approximate Gamma UCL	0.385

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Cr Sd Bold (mg/kg)

General Statistics

Total Number of Observations	70	Number of Distinct Observations	65
		Number of Missing Observations	0
Minimum	7.1	Mean	32.5
Maximum	105	Median	26.2
SD	20.07	Std. Error of Mean	2.399
Coefficient of Variation	0.617	Skewness	1.609

Normal GOF Test

Shapiro Wilk Test Statistic	0.851	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	1.8782E-9	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.158	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.106	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	36.5	95% Adjusted-CLT UCL (Chen-1995)	36.94
		95% Modified-t UCL (Johnson-1978)	36.58

Gamma GOF Test

A-D Test Statistic	0.719	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.757	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.0995	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.107	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.284	k star (bias corrected MLE)	3.152
Theta hat (MLE)	9.899	Theta star (bias corrected MLE)	10.31
nu hat (MLE)	459.7	nu star (bias corrected)	441.3
MLE Mean (bias corrected)	32.5	MLE Sd (bias corrected)	18.31
		Approximate Chi Square Value (0.05)	393.6
Adjusted Level of Significance	0.0466	Adjusted Chi Square Value	392.7

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	36.44	95% Adjusted Gamma UCL (use when n<50)	36.53

95UCL Calcuations
Sediment

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.985	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.857	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0613	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.106	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	1.96	Mean of logged Data	3.321
Maximum of Logged Data	4.654	SD of logged Data	0.562

Assuming Lognormal Distribution

95% H-UCL	36.93	90% Chebyshev (MVUE) UCL	39.32
95% Chebyshev (MVUE) UCL	42.47	97.5% Chebyshev (MVUE) UCL	46.84
99% Chebyshev (MVUE) UCL	55.43		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	36.45	95% Jackknife UCL	36.5
95% Standard Bootstrap UCL	36.43	95% Bootstrap-t UCL	37.08
95% Hall's Bootstrap UCL	37.2	95% Percentile Bootstrap UCL	36.26
95% BCA Bootstrap UCL	37.09		
90% Chebyshev(Mean, Sd) UCL	39.7	95% Chebyshev(Mean, Sd) UCL	42.96
97.5% Chebyshev(Mean, Sd) UCL	47.49	99% Chebyshev(Mean, Sd) UCL	56.37

Suggested UCL to Use

95% Approximate Gamma UCL	36.44

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Cu Sd Bold (mg/kg)

General Statistics

Total Number of Observations	70	Number of Distinct Observations	63
		Number of Missing Observations	0
Minimum	3.2	Mean	21.75
Maximum	91.2	Median	15.65
SD	16.55	Std. Error of Mean	1.978
Coefficient of Variation	0.761	Skewness	1.469

Normal GOF Test

Shapiro Wilk Test Statistic	0.875	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	9.1078E-8	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.17	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.106	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	25.05	95% Adjusted-CLT UCL (Chen-1995)	25.38
		95% Modified-t UCL (Johnson-1978)	25.11

Gamma GOF Test

A-D Test Statistic	0.495	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.765	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0897	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.108	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.869	k star (bias corrected MLE)	1.799
Theta hat (MLE)	11.64	Theta star (bias corrected MLE)	12.09
nu hat (MLE)	261.7	nu star (bias corrected)	251.8
MLE Mean (bias corrected)	21.75	MLE Sd (bias corrected)	16.22
		Approximate Chi Square Value (0.05)	216.1
Adjusted Level of Significance	0.0466	Adjusted Chi Square Value	215.4

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	25.35	95% Adjusted Gamma UCL (use when n<50)	25.43

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.961	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.085	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0801	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.106	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal Statistics

Minimum of Logged Data	1.163	Mean of logged Data	2.789
Maximum of Logged Data	4.513	SD of logged Data	0.804

Assuming Lognormal Distribution

95% H-UCL	27.56	90% Chebyshev (MVUE) UCL	29.61
95% Chebyshev (MVUE) UCL	32.91	97.5% Chebyshev (MVUE) UCL	37.48
99% Chebyshev (MVUE) UCL	46.46		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	25	95% Jackknife UCL	25.05
95% Standard Bootstrap UCL	24.93	95% Bootstrap-t UCL	25.49
95% Hall's Bootstrap UCL	25.51	95% Percentile Bootstrap UCL	25.18
95% BCA Bootstrap UCL	25.32		
90% Chebyshev(Mean, Sd) UCL	27.68	95% Chebyshev(Mean, Sd) UCL	30.37
97.5% Chebyshev(Mean, Sd) UCL	34.1	99% Chebyshev(Mean, Sd) UCL	41.43

Suggested UCL to Use

95% Approximate Gamma UCL	25.35

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Pb Sd Bold (mg/kg)

General Statistics

Total Number of Observations	70	Number of Distinct Observations	59
		Number of Missing Observations	0
Minimum	1.2	Mean	9.75
Maximum	27.5	Median	7.95
SD	6.018	Std. Error of Mean	0.719
Coefficient of Variation	0.617	Skewness	0.834

Normal GOF Test

Shapiro Wilk Test Statistic	0.923	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	2.5526E-4	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.132	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.106	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	10.95	95% Adjusted-CLT UCL (Chen-1995)	11.01
		95% Modified-t UCL (Johnson-1978)	10.96

Gamma GOF Test

A-D Test Statistic	0.257	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.76	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0588	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.107	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.561	k star (bias corrected MLE)	2.461
Theta hat (MLE)	3.806	Theta star (bias corrected MLE)	3.961
nu hat (MLE)	358.6	nu star (bias corrected)	344.6
MLE Mean (bias corrected)	9.75	MLE Sd (bias corrected)	6.215
		Approximate Chi Square Value (0.05)	302.6
Adjusted Level of Significance	0.0466	Adjusted Chi Square Value	301.7

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	11.1	95% Adjusted Gamma UCL (use when n<50)	11.13

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.969	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.213	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0774	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.106	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal Statistics

Minimum of Logged Data	0.182	Mean of logged Data	2.07
Maximum of Logged Data	3.314	SD of logged Data	0.687

Assuming Lognormal Distribution

95% H-UCL	11.84	90% Chebyshev (MVUE) UCL	12.69
95% Chebyshev (MVUE) UCL	13.91	97.5% Chebyshev (MVUE) UCL	15.6
99% Chebyshev (MVUE) UCL	18.94		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	10.93	95% Jackknife UCL	10.95
95% Standard Bootstrap UCL	10.95	95% Bootstrap-t UCL	11.06
95% Hall's Bootstrap UCL	11.01	95% Percentile Bootstrap UCL	10.91
95% BCA Bootstrap UCL	10.97		
90% Chebyshev(Mean, Sd) UCL	11.91	95% Chebyshev(Mean, Sd) UCL	12.89
97.5% Chebyshev(Mean, Sd) UCL	14.24	99% Chebyshev(Mean, Sd) UCL	16.91

Suggested UCL to Use

95% Approximate Gamma UCL	11.1

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Ni Sd Bold (mg/kg)

General Statistics

Total Number of Observations	70	Number of Distinct Observations	65
		Number of Missing Observations	0
Minimum	4	Mean	28.88
Maximum	94.7	Median	25.15
SD	16.5	Std. Error of Mean	1.972
Coefficient of Variation	0.571	Skewness	1.837

Normal GOF Test

Shapiro Wilk Test Statistic	0.841	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	3.622E-10	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.213	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.106	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	32.17	95% Adjusted-CLT UCL (Chen-1995)	32.59
		95% Modified-t UCL (Johnson-1978)	32.24

Gamma GOF Test

A-D Test Statistic	1.158	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.756	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.143	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.107	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.787	k star (bias corrected MLE)	3.634
Theta hat (MLE)	7.627	Theta star (bias corrected MLE)	7.948
nu hat (MLE)	530.2	nu star (bias corrected)	508.8
MLE Mean (bias corrected)	28.88	MLE Sd (bias corrected)	15.15
		Approximate Chi Square Value (0.05)	457.5
Adjusted Level of Significance	0.0466	Adjusted Chi Square Value	456.5

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	32.12	95% Adjusted Gamma UCL (use when n<50)	32.2

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.974	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.371	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.112	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.106	Data Not Lognormal at 5% Significance Level

Data appear Approximate Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal Statistics

Minimum of Logged Data	1.386	Mean of logged Data	3.225
Maximum of Logged Data	4.551	SD of logged Data	0.534

Assuming Lognormal Distribution

95% H-UCL	32.77	90% Chebyshev (MVUE) UCL	34.83
95% Chebyshev (MVUE) UCL	37.49	97.5% Chebyshev (MVUE) UCL	41.18
99% Chebyshev (MVUE) UCL	48.43		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	32.13	95% Jackknife UCL	32.17
95% Standard Bootstrap UCL	32.16	95% Bootstrap-t UCL	32.74
95% Hall's Bootstrap UCL	32.66	95% Percentile Bootstrap UCL	32.16
95% BCA Bootstrap UCL	32.84		
90% Chebyshev(Mean, Sd) UCL	34.8	95% Chebyshev(Mean, Sd) UCL	37.48
97.5% Chebyshev(Mean, Sd) UCL	41.2	99% Chebyshev(Mean, Sd) UCL	48.51

Suggested UCL to Use

95% H-UCL	32.77

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

95UCL Calcuations
Sediment

Zn Sd Bold (mg/kg)

General Statistics

Total Number of Observations	70	Number of Distinct Observations	67
		Number of Missing Observations	0
Minimum	13.9	Mean	55.31
Maximum	109	Median	53.8
SD	26.15	Std. Error of Mean	3.126
Coefficient of Variation	0.473	Skewness	0.187

Normal GOF Test

Shapiro Wilk Test Statistic	0.935	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0.00167	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.0909	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.106	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	60.52	95% Adjusted-CLT UCL (Chen-1995)	60.53
		95% Modified-t UCL (Johnson-1978)	60.53

Gamma GOF Test

A-D Test Statistic	0.852	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.756	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.11	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.107	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.954	k star (bias corrected MLE)	3.794
Theta hat (MLE)	13.99	Theta star (bias corrected MLE)	14.58
nu hat (MLE)	553.6	nu star (bias corrected)	531.2
MLE Mean (bias corrected)	55.31	MLE Sd (bias corrected)	28.39
		Approximate Chi Square Value (0.05)	478.8
Adjusted Level of Significance	0.0466	Adjusted Chi Square Value	477.7

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	61.37	95% Adjusted Gamma UCL (use when n<50)	61.5

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.928	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	5.1445E-4	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.118	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.106	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal Statistics

Minimum of Logged Data	2.632	Mean of logged Data	3.881
Maximum of Logged Data	4.691	SD of logged Data	0.547

Assuming Lognormal Distribution

95% H-UCL	63.83	90% Chebyshev (MVUE) UCL	67.89
95% Chebyshev (MVUE) UCL	73.2	97.5% Chebyshev (MVUE) UCL	80.56
99% Chebyshev (MVUE) UCL	95.03		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	60.45	95% Jackknife UCL	60.52
95% Standard Bootstrap UCL	60.43	95% Bootstrap-t UCL	60.72
95% Hall's Bootstrap UCL	60.34	95% Percentile Bootstrap UCL	60.5
95% BCA Bootstrap UCL	60.45		
90% Chebyshev(Mean, Sd) UCL	64.69	95% Chebyshev(Mean, Sd) UCL	68.93
97.5% Chebyshev(Mean, Sd) UCL	74.83	99% Chebyshev(Mean, Sd) UCL	86.41

Suggested UCL to Use

95% Student's-t UCL	60.52

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Hg Sd Bold (mg/kg)

General Statistics

Total Number of Observations	70	Number of Distinct Observations	49
Number of Detects	41	Number of Non-Detects	29
Number of Distinct Detects	29	Number of Distinct Non-Detects	23
Minimum Detect	0.031	Minimum Non-Detect	0.0048
Maximum Detect	0.26	Maximum Non-Detect	0.091
Variance Detects	0.0032	Percent Non-Detects	41.43%
Mean Detects	0.124	SD Detects	0.0566
Median Detects	0.11	CV Detects	0.455
Skewness Detects	0.583	Kurtosis Detects	-0.196
Mean of Logged Detects	-2.196	SD of Logged Detects	0.499

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.953	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.941	Detected Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.129	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.137	Detected Data appear Normal at 5% Significance Level

Detected Data appear Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.0773	KM Standard Error of Mean	0.0087
KM SD	0.0709	95% KM (BCA) UCL	0.0924
95% KM (t) UCL	0.0918	95% KM (Percentile Bootstrap) UCL	0.0925
95% KM (z) UCL	0.0916	95% KM Bootstrap t UCL	0.0922
90% KM Chebyshev UCL	0.103	95% KM Chebyshev UCL	0.115
97.5% KM Chebyshev UCL	0.132	99% KM Chebyshev UCL	0.164

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	0.254	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.752	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0877	**Kolmogorov-Smirnov GOF**
5% K-S Critical Value	0.138	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	4.67	k star (bias corrected MLE)	4.345
Theta hat (MLE)	0.0266	Theta star (bias corrected MLE)	0.0286
nu hat (MLE)	382.9	nu star (bias corrected)	356.3
Mean (detects)	0.124		

95UCL Calcuations
Sediment

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	0.0816
Maximum	0.26	Median	0.074
SD	0.067	CV	0.821
k hat (MLE)	1.366	k star (bias corrected MLE)	1.317
Theta hat (MLE)	0.0597	Theta star (bias corrected MLE)	0.062
nu hat (MLE)	191.3	nu star (bias corrected)	184.4
Adjusted Level of Significance (β)	0.0466		
Approximate Chi Square Value (184.44, α)	154	Adjusted Chi Square Value (184.44, β)	153.4
95% Gamma Approximate UCL (use when n>=50)	0.0977	95% Gamma Adjusted UCL (use when n<50)	0.0981

Estimates of Gamma Parameters using KM Estimates

Mean (KM)	0.0773	SD (KM)	0.0709
Variance (KM)	0.00503	SE of Mean (KM)	0.0087
k hat (KM)	1.189	k star (KM)	1.148
nu hat (KM)	166.5	nu star (KM)	160.7
theta hat (KM)	0.065	theta star (KM)	0.0674
80% gamma percentile (KM)	0.123	90% gamma percentile (KM)	0.172
95% gamma percentile (KM)	0.221	99% gamma percentile (KM)	0.332

Gamma Kaplan-Meier (KM) Statistics

Approximate Chi Square Value (160.68, α)	132.4	Adjusted Chi Square Value (160.68, β)	131.8
95% Gamma Approximate KM-UCL (use when n>=50)	0.0938	95% Gamma Adjusted KM-UCL (use when n<50)	0.0942

Lognormal GOF Test on Detected Observations Only

Shapiro Wilk Test Statistic	0.961	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.941	Detected Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.111	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.137	Detected Data appear Lognormal at 5% Significance Level	

Detected Data appear Lognormal at 5% Significance Level

Lognormal ROS Statistics Using Imputed Non-Detects

Mean in Original Scale	0.0881	Mean in Log Scale	-2.656
SD in Original Scale	0.0611	SD in Log Scale	0.677
95% t UCL (assumes normality of ROS data)	0.1	95% Percentile Bootstrap UCL	0.1
95% BCA Bootstrap UCL	0.102	95% Bootstrap t UCL	0.102
95% H-UCL (Log ROS)	0.104		

95UCL Calcuations
Sediment

Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution

KM Mean (logged)	-3.345	KM Geo Mean	0.0353
KM SD (logged)	1.507	95% Critical H Value (KM-Log)	2.319
KM Standard Error of Mean (logged)	0.204	95% H-UCL (KM -Log)	0.167
KM SD (logged)	1.507	95% Critical H Value (KM-Log)	2.319
KM Standard Error of Mean (logged)	0.204		

DL/2 Statistics

DL/2 Normal		**DL/2 Log-Transformed**	
Mean in Original Scale	0.0816	Mean in Log Scale	-2.961
SD in Original Scale	0.0672	SD in Log Scale	1.095
95% t UCL (Assumes normality)	0.095	95% H-Stat UCL	0.127

DL/2 is not a recommended method, provided for comparisons and historical reasons

Nonparametric Distribution Free UCL Statistics
Detected Data appear Normal Distributed at 5% Significance Level

Suggested UCL to Use

95% KM (t) UCL	0.0918

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Ag Sd A8 (mg/kg)

General Statistics

Total Number of Observations	66	Number of Distinct Observations	61
		Number of Missing Observations	0
Minimum	0.048	Mean	0.872
Maximum	17	Median	0.223
SD	2.372	Std. Error of Mean	0.292
Coefficient of Variation	2.721	Skewness	5.527

Normal GOF Test

Shapiro Wilk Test Statistic	0.37	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.364	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.109	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.359	95% Adjusted-CLT UCL (Chen-1995)	1.564
		95% Modified-t UCL (Johnson-1978)	1.392

Gamma GOF Test

A-D Test Statistic	5.45	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.813	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.213	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.116	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.538	k star (bias corrected MLE)	0.523
Theta hat (MLE)	1.621	Theta star (bias corrected MLE)	1.665
nu hat (MLE)	70.98	nu star (bias corrected)	69.09
MLE Mean (bias corrected)	0.872	MLE Sd (bias corrected)	1.205
		Approximate Chi Square Value (0.05)	50.95
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	50.61

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	1.182	95% Adjusted Gamma UCL (use when n<50)	1.19

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.905	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	2.7478E-5	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.142	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.109	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal Statistics

Minimum of Logged Data	-3.037	Mean of logged Data	-1.306
Maximum of Logged Data	2.833	SD of logged Data	1.307

Assuming Lognormal Distribution

95% H-UCL	0.907	90% Chebyshev (MVUE) UCL	1.008
95% Chebyshev (MVUE) UCL	1.183	97.5% Chebyshev (MVUE) UCL	1.426
99% Chebyshev (MVUE) UCL	1.904		

Nonparametric Distribution Free UCL Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	1.352	95% Jackknife UCL	1.359
95% Standard Bootstrap UCL	1.365	95% Bootstrap-t UCL	2.063
95% Hall's Bootstrap UCL	2.932	95% Percentile Bootstrap UCL	1.411
95% BCA Bootstrap UCL	1.675		
90% Chebyshev(Mean, Sd) UCL	1.747	95% Chebyshev(Mean, Sd) UCL	2.144
97.5% Chebyshev(Mean, Sd) UCL	2.695	99% Chebyshev(Mean, Sd) UCL	3.776

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	2.144

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Tot As Sd A8 (mg/kg)

General Statistics

Total Number of Observations	66	Number of Distinct Observations	56
		Number of Missing Observations	0
Minimum	0.42	Mean	2.371
Maximum	6.47	Median	2.265
SD	0.976	Std. Error of Mean	0.12
Coefficient of Variation	0.412	Skewness	1.022

Normal GOF Test

Shapiro Wilk Test Statistic	0.945	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0.0102	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.0818	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.109	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	2.571	95% Adjusted-CLT UCL (Chen-1995)	2.585
		95% Modified-t UCL (Johnson-1978)	2.574

Gamma GOF Test

A-D Test Statistic	0.552	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.753	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0679	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.11	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	5.711	k star (bias corrected MLE)	5.462
Theta hat (MLE)	0.415	Theta star (bias corrected MLE)	0.434
nu hat (MLE)	753.9	nu star (bias corrected)	721
MLE Mean (bias corrected)	2.371	MLE Sd (bias corrected)	1.014
		Approximate Chi Square Value (0.05)	659.7
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	658.4

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	2.591	95% Adjusted Gamma UCL (use when n<50)	2.596

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.95	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.0216	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0869	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.109	Data appear Lognormal at 5% Significance Level

Data appear Approximate Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal Statistics

Minimum of Logged Data	-0.868	Mean of logged Data	0.773
Maximum of Logged Data	1.867	SD of logged Data	0.453

Assuming Lognormal Distribution

95% H-UCL	2.661	90% Chebyshev (MVUE) UCL	2.814
95% Chebyshev (MVUE) UCL	3.004	97.5% Chebyshev (MVUE) UCL	3.267
99% Chebyshev (MVUE) UCL	3.783		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	2.568	95% Jackknife UCL	2.571
95% Standard Bootstrap UCL	2.564	95% Bootstrap-t UCL	2.591
95% Hall's Bootstrap UCL	2.607	95% Percentile Bootstrap UCL	2.561
95% BCA Bootstrap UCL	2.572		
90% Chebyshev(Mean, Sd) UCL	2.731	95% Chebyshev(Mean, Sd) UCL	2.894
97.5% Chebyshev(Mean, Sd) UCL	3.121	99% Chebyshev(Mean, Sd) UCL	3.566

Suggested UCL to Use

95% Student's-t UCL	2.571

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Cd Sd A8 (mg/kg)

General Statistics

Total Number of Observations	66	Number of Distinct Observations	62
		Number of Missing Observations	0
Minimum	0.152	Mean	1.665
Maximum	11.4	Median	0.76
SD	2.299	Std. Error of Mean	0.283
Coefficient of Variation	1.381	Skewness	2.738

Normal GOF Test

Shapiro Wilk Test Statistic	0.625	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.275	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.109	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	2.137	95% Adjusted-CLT UCL (Chen-1995)	2.232
		95% Modified-t UCL (Johnson-1978)	2.153

Gamma GOF Test

A-D Test Statistic	3.095	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.781	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.175	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.113	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.982	k star (bias corrected MLE)	0.947
Theta hat (MLE)	1.696	Theta star (bias corrected MLE)	1.758
nu hat (MLE)	129.6	nu star (bias corrected)	125
MLE Mean (bias corrected)	1.665	MLE Sd (bias corrected)	1.71
		Approximate Chi Square Value (0.05)	100.2
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	99.7

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	2.077	95% Adjusted Gamma UCL (use when n<50)	2.087

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.936	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.00276	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.11	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.109	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal Statistics

Minimum of Logged Data	-1.884	Mean of logged Data	-0.0797
Maximum of Logged Data	2.434	SD of logged Data	1.018

Assuming Lognormal Distribution

95% H-UCL	2.062	90% Chebyshev (MVUE) UCL	2.22
95% Chebyshev (MVUE) UCL	2.531	97.5% Chebyshev (MVUE) UCL	2.963
99% Chebyshev (MVUE) UCL	3.812		

Nonparametric Distribution Free UCL Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	2.13	95% Jackknife UCL	2.137
95% Standard Bootstrap UCL	2.131	95% Bootstrap-t UCL	2.335
95% Hall's Bootstrap UCL	2.285	95% Percentile Bootstrap UCL	2.142
95% BCA Bootstrap UCL	2.222		
90% Chebyshev(Mean, Sd) UCL	2.514	95% Chebyshev(Mean, Sd) UCL	2.898
97.5% Chebyshev(Mean, Sd) UCL	3.432	99% Chebyshev(Mean, Sd) UCL	4.481

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	2.898

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Cr Sd A8 (mg/kg)

General Statistics

Total Number of Observations	66	Number of Distinct Observations	59
		Number of Missing Observations	0
Minimum	2.32	Mean	28.65
Maximum	84.8	Median	27.9
SD	14.27	Std. Error of Mean	1.757
Coefficient of Variation	0.498	Skewness	1.141

Normal GOF Test

Shapiro Wilk Test Statistic	0.938	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	0.00362	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.0854	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.109	Data appear Normal at 5% Significance Level	

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	31.58	95% Adjusted-CLT UCL (Chen-1995)	31.8
		95% Modified-t UCL (Johnson-1978)	31.62

Gamma GOF Test

A-D Test Statistic	0.782	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.756	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.104	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.11	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.667	k star (bias corrected MLE)	3.51
Theta hat (MLE)	7.813	Theta star (bias corrected MLE)	8.162
nu hat (MLE)	484	nu star (bias corrected)	463.3
MLE Mean (bias corrected)	28.65	MLE Sd (bias corrected)	15.29
		Approximate Chi Square Value (0.05)	414.4
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	413.4

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	32.03	95% Adjusted Gamma UCL (use when n<50)	32.11

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.918	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk P Value	2.0537E-4	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.141	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.109	Data Not Lognormal at 5% Significance Level	

Data Not Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal Statistics

Minimum of Logged Data	0.842	Mean of logged Data	3.213
Maximum of Logged Data	4.44	SD of logged Data	0.596

Assuming Lognormal Distribution

95% H-UCL	34.24	90% Chebyshev (MVUE) UCL	36.58
95% Chebyshev (MVUE) UCL	39.75	97.5% Chebyshev (MVUE) UCL	44.15
99% Chebyshev (MVUE) UCL	52.79		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	31.54	95% Jackknife UCL	31.58
95% Standard Bootstrap UCL	31.61	95% Bootstrap-t UCL	31.88
95% Hall's Bootstrap UCL	32.28	95% Percentile Bootstrap UCL	31.59
95% BCA Bootstrap UCL	31.57		
90% Chebyshev(Mean, Sd) UCL	33.92	95% Chebyshev(Mean, Sd) UCL	36.31
97.5% Chebyshev(Mean, Sd) UCL	39.62	99% Chebyshev(Mean, Sd) UCL	46.13

Suggested UCL to Use

95% Student's-t UCL	31.58

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Cu Sd A8 (mg/kg)

General Statistics

Total Number of Observations	66	Number of Distinct Observations	61
		Number of Missing Observations	0
Minimum	3.81	Mean	19.06
Maximum	439	Median	8.84
SD	53.94	Std. Error of Mean	6.639
Coefficient of Variation	2.829	Skewness	7.513

Normal GOF Test

Shapiro Wilk Test Statistic	0.238	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.41	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.109	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	30.14	95% Adjusted-CLT UCL (Chen-1995)	36.54
		95% Modified-t UCL (Johnson-1978)	31.16

Gamma GOF Test

A-D Test Statistic	10.05	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.78	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.339	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.113	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.003	k star (bias corrected MLE)	0.967
Theta hat (MLE)	19.01	Theta star (bias corrected MLE)	19.71
nu hat (MLE)	132.3	nu star (bias corrected)	127.7
MLE Mean (bias corrected)	19.06	MLE Sd (bias corrected)	19.38
		Approximate Chi Square Value (0.05)	102.6
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	102.1

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	23.73	95% Adjusted Gamma UCL (use when n<50)	23.84

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.774	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	1.258E-13	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.208	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.109	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal Statistics

Minimum of Logged Data	1.338	Mean of logged Data	2.372
Maximum of Logged Data	6.084	SD of logged Data	0.73

Assuming Lognormal Distribution

95% H-UCL	16.84	90% Chebyshev (MVUE) UCL	18.09
95% Chebyshev (MVUE) UCL	19.97	97.5% Chebyshev (MVUE) UCL	22.59
99% Chebyshev (MVUE) UCL	27.72		

Nonparametric Distribution Free UCL Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	29.98	95% Jackknife UCL	30.14
95% Standard Bootstrap UCL	29.72	95% Bootstrap-t UCL	71.37
95% Hall's Bootstrap UCL	64.77	95% Percentile Bootstrap UCL	32.03
95% BCA Bootstrap UCL	40.62		
90% Chebyshev(Mean, Sd) UCL	38.98	95% Chebyshev(Mean, Sd) UCL	48
97.5% Chebyshev(Mean, Sd) UCL	60.52	99% Chebyshev(Mean, Sd) UCL	85.12

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	48

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Pb Sd A8 (mg/kg)

General Statistics

Total Number of Observations	66	Number of Distinct Observations	64
		Number of Missing Observations	0
Minimum	1.71	Mean	11.64
Maximum	185	Median	5.105
SD	24.79	Std. Error of Mean	3.051
Coefficient of Variation	2.13	Skewness	5.737

Normal GOF Test

Shapiro Wilk Test Statistic	0.362	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.394	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.109	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	16.73	95% Adjusted-CLT UCL (Chen-1995)	18.96
		95% Modified-t UCL (Johnson-1978)	17.09

Gamma GOF Test

A-D Test Statistic	9.562	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.781	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.315	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.113	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.988	k star (bias corrected MLE)	0.954
Theta hat (MLE)	11.78	Theta star (bias corrected MLE)	12.21
nu hat (MLE)	130.5	nu star (bias corrected)	125.9
MLE Mean (bias corrected)	11.64	MLE Sd (bias corrected)	11.92
		Approximate Chi Square Value (0.05)	101
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	100.5

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	14.51	95% Adjusted Gamma UCL (use when n<50)	14.58

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.788	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	9.542E-13	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.211	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.109	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal Statistics

Minimum of Logged Data	0.536	Mean of logged Data	1.87
Maximum of Logged Data	5.22	SD of logged Data	0.826

Assuming Lognormal Distribution

95% H-UCL	11.34	90% Chebyshev (MVUE) UCL	12.2
95% Chebyshev (MVUE) UCL	13.62	97.5% Chebyshev (MVUE) UCL	15.59
99% Chebyshev (MVUE) UCL	19.46		

Nonparametric Distribution Free UCL Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	16.66	95% Jackknife UCL	16.73
95% Standard Bootstrap UCL	16.75	95% Bootstrap-t UCL	23.31
95% Hall's Bootstrap UCL	33.71	95% Percentile Bootstrap UCL	17.1
95% BCA Bootstrap UCL	20.38		
90% Chebyshev(Mean, Sd) UCL	20.8	95% Chebyshev(Mean, Sd) UCL	24.94
97.5% Chebyshev(Mean, Sd) UCL	30.7	99% Chebyshev(Mean, Sd) UCL	42

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	24.94

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Ni Sd A8 (mg/kg)

General Statistics

Total Number of Observations	66	Number of Distinct Observations	56
		Number of Missing Observations	0
Minimum	2.37	Mean	16.13
Maximum	40.8	Median	16.35
SD	5.499	Std. Error of Mean	0.677
Coefficient of Variation	0.341	Skewness	1.157

Normal GOF Test

Shapiro Wilk Test Statistic	0.936	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0.00285	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.092	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.109	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	17.26	95% Adjusted-CLT UCL (Chen-1995)	17.34
		95% Modified-t UCL (Johnson-1978)	17.27

Gamma GOF Test

A-D Test Statistic	1.139	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.752	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.104	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.11	Detected data appear Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	7.928	k star (bias corrected MLE)	7.578
Theta hat (MLE)	2.034	Theta star (bias corrected MLE)	2.128
nu hat (MLE)	1046	nu star (bias corrected)	1000
MLE Mean (bias corrected)	16.13	MLE Sd (bias corrected)	5.859
		Approximate Chi Square Value (0.05)	927.8
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	926.3

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	17.39	95% Adjusted Gamma UCL (use when n<50)	17.42

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.886	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	1.5646E-6	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.13	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.109	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal Statistics

Minimum of Logged Data	0.863	Mean of logged Data	2.716
Maximum of Logged Data	3.709	SD of logged Data	0.394

Assuming Lognormal Distribution

95% H-UCL	17.84	90% Chebyshev (MVUE) UCL	18.77
95% Chebyshev (MVUE) UCL	19.88	97.5% Chebyshev (MVUE) UCL	21.42
99% Chebyshev (MVUE) UCL	24.45		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	17.24	95% Jackknife UCL	17.26
95% Standard Bootstrap UCL	17.22	95% Bootstrap-t UCL	17.32
95% Hall's Bootstrap UCL	17.51	95% Percentile Bootstrap UCL	17.32
95% BCA Bootstrap UCL	17.36		
90% Chebyshev(Mean, Sd) UCL	18.16	95% Chebyshev(Mean, Sd) UCL	19.08
97.5% Chebyshev(Mean, Sd) UCL	20.36	99% Chebyshev(Mean, Sd) UCL	22.86

Suggested UCL to Use

95% Student's-t UCL	17.26

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Zn Sd A8 (mg/kg)

General Statistics

Total Number of Observations	66	Number of Distinct Observations	63
		Number of Missing Observations	0
Minimum	12.5	Mean	41.08
Maximum	396	Median	31.3
SD	48.76	Std. Error of Mean	6.002
Coefficient of Variation	1.187	Skewness	6.311

Normal GOF Test

Shapiro Wilk Test Statistic	0.387	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.329	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.109	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	51.09	95% Adjusted-CLT UCL (Chen-1995)	55.93
		95% Modified-t UCL (Johnson-1978)	51.87

Gamma GOF Test

A-D Test Statistic	4.83	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.76	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.204	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.111	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2.577	k star (bias corrected MLE)	2.47
Theta hat (MLE)	15.94	Theta star (bias corrected MLE)	16.63
nu hat (MLE)	340.2	nu star (bias corrected)	326
MLE Mean (bias corrected)	41.08	MLE Sd (bias corrected)	26.14
		Approximate Chi Square Value (0.05)	285.2
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	284.3

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	46.96	95% Adjusted Gamma UCL (use when n<50)	47.1

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.87	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	1.3278E-7	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.127	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.109	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal Statistics

Minimum of Logged Data	2.526	Mean of logged Data	3.509
Maximum of Logged Data	5.981	SD of logged Data	0.523

Assuming Lognormal Distribution

95% H-UCL	43.29	90% Chebyshev (MVUE) UCL	46.04
95% Chebyshev (MVUE) UCL	49.58	97.5% Chebyshev (MVUE) UCL	54.49
99% Chebyshev (MVUE) UCL	64.13		

Nonparametric Distribution Free UCL Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	50.95	95% Jackknife UCL	51.09
95% Standard Bootstrap UCL	50.93	95% Bootstrap-t UCL	67.98
95% Hall's Bootstrap UCL	88.64	95% Percentile Bootstrap UCL	52.01
95% BCA Bootstrap UCL	57.8		
90% Chebyshev(Mean, Sd) UCL	59.08	95% Chebyshev(Mean, Sd) UCL	67.24
97.5% Chebyshev(Mean, Sd) UCL	78.56	99% Chebyshev(Mean, Sd) UCL	100.8

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	67.24

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Sediment

Hg Sd A8 (mg/kg)

General Statistics

Total Number of Observations	66	Number of Distinct Observations	56
		Number of Missing Observations	0
Minimum	0.006	Mean	0.168
Maximum	2.42	Median	0.066
SD	0.365	Std. Error of Mean	0.0449
Coefficient of Variation	2.172	Skewness	4.906

Normal GOF Test

Shapiro Wilk Test Statistic	0.412	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.348	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.109	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.243	95% Adjusted-CLT UCL (Chen-1995)	0.271
		95% Modified-t UCL (Johnson-1978)	0.247

Gamma GOF Test

A-D Test Statistic	4.276	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.792	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.187	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.114	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.75	k star (bias corrected MLE)	0.726
Theta hat (MLE)	0.224	Theta star (bias corrected MLE)	0.231
nu hat (MLE)	99	nu star (bias corrected)	95.84
MLE Mean (bias corrected)	0.168	MLE Sd (bias corrected)	0.197
		Approximate Chi Square Value (0.05)	74.26
Adjusted Level of Significance	0.0464	Adjusted Chi Square Value	73.83

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.217	95% Adjusted Gamma UCL (use when n<50)	0.218

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.959	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk P Value	0.0692	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0831	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.109	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

95UCL Calcuations
Sediment

Lognormal Statistics

Minimum of Logged Data	-5.116	Mean of logged Data	-2.583
Maximum of Logged Data	0.884	SD of logged Data	1.107

Assuming Lognormal Distribution

95% H-UCL	0.19	90% Chebyshev (MVUE) UCL	0.206
95% Chebyshev (MVUE) UCL	0.237	97.5% Chebyshev (MVUE) UCL	0.28
99% Chebyshev (MVUE) UCL	0.365		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.242	95% Jackknife UCL	0.243
95% Standard Bootstrap UCL	0.239	95% Bootstrap-t UCL	0.369
95% Hall's Bootstrap UCL	0.568	95% Percentile Bootstrap UCL	0.247
95% BCA Bootstrap UCL	0.282		
90% Chebyshev(Mean, Sd) UCL	0.303	95% Chebyshev(Mean, Sd) UCL	0.363
97.5% Chebyshev(Mean, Sd) UCL	0.448	99% Chebyshev(Mean, Sd) UCL	0.614

Suggested UCL to Use

95% H-UCL	0.19

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

95UCL Calcuations
Tissue

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.112/8/2016 3:28:04 PM
From File	WMWT Sed & Clam tissue_input_11_29_16.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Inorg As Ti Pen (mg/kg ww)

General Statistics

Total Number of Observations	22	Number of Distinct Observations	14
		Number of Missing Observations	0
Minimum	0.026	Mean	0.0346
Maximum	0.055	Median	0.0325
SD	0.00657	Std. Error of Mean	0.0014
Coefficient of Variation	0.19	Skewness	1.655

Normal GOF Test

Shapiro Wilk Test Statistic	0.854	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.178	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.037	95% Adjusted-CLT UCL (Chen-1995)	0.0375
		95% Modified-t UCL (Johnson-1978)	0.0371

Gamma GOF Test

A-D Test Statistic	0.791	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.742	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.153	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	33.45	k star (bias corrected MLE)	28.92
Theta hat (MLE)	0.00104	Theta star (bias corrected MLE)	0.0012
nu hat (MLE)	1472	nu star (bias corrected)	1272
MLE Mean (bias corrected)	0.0346	MLE Sd (bias corrected)	0.00644
		Approximate Chi Square Value (0.05)	1191
Adjusted Level of Significance	0.0386	Adjusted Chi Square Value	1185

95UCL Calcuations
Tissue

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.037	95% Adjusted Gamma UCL (use when n<50)	0.0372

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.917	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.145	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	-3.65	Mean of logged Data	-3.378
Maximum of Logged Data	-2.9	SD of logged Data	0.172

Assuming Lognormal Distribution

95% H-UCL	0.037	90% Chebyshev (MVUE) UCL	0.0384
95% Chebyshev (MVUE) UCL	0.0402	97.5% Chebyshev (MVUE) UCL	0.0426
99% Chebyshev (MVUE) UCL	0.0473		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.0369	95% Jackknife UCL	0.037
95% Standard Bootstrap UCL	0.0369	95% Bootstrap-t UCL	0.0379
95% Hall's Bootstrap UCL	0.0386	95% Percentile Bootstrap UCL	0.0369
95% BCA Bootstrap UCL	0.0375		
90% Chebyshev(Mean, Sd) UCL	0.0388	95% Chebyshev(Mean, Sd) UCL	0.0407
97.5% Chebyshev(Mean, Sd) UCL	0.0434	99% Chebyshev(Mean, Sd) UCL	0.0486

Suggested UCL to Use

95% Student's-t UCL	0.037

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Tissue

Cd Ti Pen (mg/kg ww)

General Statistics

Total Number of Observations	22	Number of Distinct Observations	22
		Number of Missing Observations	0
Minimum	0.31	Mean	0.445
Maximum	0.629	Median	0.438
SD	0.0718	Std. Error of Mean	0.0153
Coefficient of Variation	0.161	Skewness	0.606

Normal GOF Test

Shapiro Wilk Test Statistic	0.973	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.0947	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.471	95% Adjusted-CLT UCL (Chen-1995)	0.472
		95% Modified-t UCL (Johnson-1978)	0.471

Gamma GOF Test

A-D Test Statistic	0.162	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.742	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0741	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	41.19	k star (bias corrected MLE)	35.61
Theta hat (MLE)	0.0108	Theta star (bias corrected MLE)	0.0125
nu hat (MLE)	1812	nu star (bias corrected)	1567
MLE Mean (bias corrected)	0.445	MLE Sd (bias corrected)	0.0745
		Approximate Chi Square Value (0.05)	1476
Adjusted Level of Significance	0.0386	Adjusted Chi Square Value	1469

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.472	95% Adjusted Gamma UCL (use when n<50)	0.474

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.99	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0777	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	-1.171	Mean of logged Data	-0.823
Maximum of Logged Data	-0.464	SD of logged Data	0.16

Assuming Lognormal Distribution

95% H-UCL	0.473	90% Chebyshev (MVUE) UCL	0.49
95% Chebyshev (MVUE) UCL	0.511	97.5% Chebyshev (MVUE) UCL	0.54
99% Chebyshev (MVUE) UCL	0.596		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.47	95% Jackknife UCL	0.471
95% Standard Bootstrap UCL	0.469	95% Bootstrap-t UCL	0.474
95% Hall's Bootstrap UCL	0.475	95% Percentile Bootstrap UCL	0.47
95% BCA Bootstrap UCL	0.472		
90% Chebyshev(Mean, Sd) UCL	0.491	95% Chebyshev(Mean, Sd) UCL	0.511
97.5% Chebyshev(Mean, Sd) UCL	0.54	99% Chebyshev(Mean, Sd) UCL	0.597

Suggested UCL to Use

95% Student's-t UCL	0.471

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Tissue

Cr Ti Pen (mg/kg ww)

General Statistics

Total Number of Observations	22	Number of Distinct Observations	22
		Number of Missing Observations	0
Minimum	0.216	Mean	0.4
Maximum	1.72	Median	0.343
SD	0.305	Std. Error of Mean	0.065
Coefficient of Variation	0.762	Skewness	4.189

Normal GOF Test

Shapiro Wilk Test Statistic	0.458	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.332	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.512	95% Adjusted-CLT UCL (Chen-1995)	0.569
		95% Modified-t UCL (Johnson-1978)	0.522

Gamma GOF Test

A-D Test Statistic	2.066	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.747	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.238	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.186	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	4.216	k star (bias corrected MLE)	3.672
Theta hat (MLE)	0.095	Theta star (bias corrected MLE)	0.109
nu hat (MLE)	185.5	nu star (bias corrected)	161.6
MLE Mean (bias corrected)	0.4	MLE Sd (bias corrected)	0.209
		Approximate Chi Square Value (0.05)	133.2
Adjusted Level of Significance	0.0386	Adjusted Chi Square Value	131.2

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.486	95% Adjusted Gamma UCL (use when n<50)	0.493

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.768	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.183	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Approximate Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	-1.532	Mean of logged Data	-1.039
Maximum of Logged Data	0.542	SD of logged Data	0.426

Assuming Lognormal Distribution

95% H-UCL	0.464	90% Chebyshev (MVUE) UCL	0.494
95% Chebyshev (MVUE) UCL	0.543	97.5% Chebyshev (MVUE) UCL	0.611
99% Chebyshev (MVUE) UCL	0.744		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.507	95% Jackknife UCL	0.512
95% Standard Bootstrap UCL	0.505	95% Bootstrap-t UCL	0.735
95% Hall's Bootstrap UCL	0.941	95% Percentile Bootstrap UCL	0.519
95% BCA Bootstrap UCL	0.598		
90% Chebyshev(Mean, Sd) UCL	0.595	95% Chebyshev(Mean, Sd) UCL	0.684
97.5% Chebyshev(Mean, Sd) UCL	0.807	99% Chebyshev(Mean, Sd) UCL	1.048

Suggested UCL to Use

95% Student's-t UCL	0.512	or 95% Modified-t UCL	0.522
or 95% H-UCL	0.464		

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

95UCL Calcuations
Tissue

Cu Ti Pen (mg/kg ww)

General Statistics

Total Number of Observations	22	Number of Distinct Observations	19
		Number of Missing Observations	0
Minimum	0.896	Mean	1.159
Maximum	1.45	Median	1.12
SD	0.162	Std. Error of Mean	0.0346
Coefficient of Variation	0.14	Skewness	0.221

Normal GOF Test

Shapiro Wilk Test Statistic	0.948	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.14	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.218	95% Adjusted-CLT UCL (Chen-1995)	1.217
		95% Modified-t UCL (Johnson-1978)	1.219

Gamma GOF Test

A-D Test Statistic	0.471	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.743	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.131	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	53.64	k star (bias corrected MLE)	46.36
Theta hat (MLE)	0.0216	Theta star (bias corrected MLE)	0.025
nu hat (MLE)	2360	nu star (bias corrected)	2040
MLE Mean (bias corrected)	1.159	MLE Sd (bias corrected)	0.17
		Approximate Chi Square Value (0.05)	1936
Adjusted Level of Significance	0.0386	Adjusted Chi Square Value	1928

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	1.221	95% Adjusted Gamma UCL (use when n<50)	1.226

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.953	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.128	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	-0.11	Mean of logged Data	0.138
Maximum of Logged Data	0.372	SD of logged Data	0.14

Assuming Lognormal Distribution

95% H-UCL	1.223	90% Chebyshev (MVUE) UCL	1.263
95% Chebyshev (MVUE) UCL	1.31	97.5% Chebyshev (MVUE) UCL	1.375
99% Chebyshev (MVUE) UCL	1.504		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	1.216	95% Jackknife UCL	1.218
95% Standard Bootstrap UCL	1.216	95% Bootstrap-t UCL	1.221
95% Hall's Bootstrap UCL	1.214	95% Percentile Bootstrap UCL	1.215
95% BCA Bootstrap UCL	1.216		
90% Chebyshev(Mean, Sd) UCL	1.263	95% Chebyshev(Mean, Sd) UCL	1.31
97.5% Chebyshev(Mean, Sd) UCL	1.375	99% Chebyshev(Mean, Sd) UCL	1.503

Suggested UCL to Use

95% Student's-t UCL	1.218

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Tissue

Pb Ti Pen (mg/kg ww)

General Statistics

Total Number of Observations	22	Number of Distinct Observations	21
		Number of Missing Observations	0
Minimum	0.0132	Mean	0.022
Maximum	0.0678	Median	0.0204
SD	0.011	Std. Error of Mean	0.00235
Coefficient of Variation	0.502	Skewness	3.67

Normal GOF Test

Shapiro Wilk Test Statistic	0.571	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.301	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.026	95% Adjusted-CLT UCL (Chen-1995)	0.0278
		95% Modified-t UCL (Johnson-1978)	0.0263

Gamma GOF Test

A-D Test Statistic	1.445	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.745	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.225	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.186	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	7.364	k star (bias corrected MLE)	6.39
Theta hat (MLE)	0.00299	Theta star (bias corrected MLE)	0.00344
nu hat (MLE)	324	nu star (bias corrected)	281.2
MLE Mean (bias corrected)	0.022	MLE Sd (bias corrected)	0.0087
		Approximate Chi Square Value (0.05)	243.3
Adjusted Level of Significance	0.0386	Adjusted Chi Square Value	240.7

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.0254	95% Adjusted Gamma UCL (use when n<50)	0.0257

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.82	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.189	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	-4.328	Mean of logged Data	-3.887
Maximum of Logged Data	-2.691	SD of logged Data	0.34

Assuming Lognormal Distribution

95% H-UCL	0.025	90% Chebyshev (MVUE) UCL	0.0265
95% Chebyshev (MVUE) UCL	0.0286	97.5% Chebyshev (MVUE) UCL	0.0316
99% Chebyshev (MVUE) UCL	0.0376		

Nonparametric Distribution Free UCL Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.0259	95% Jackknife UCL	0.026
95% Standard Bootstrap UCL	0.0257	95% Bootstrap-t UCL	0.0311
95% Hall's Bootstrap UCL	0.0425	95% Percentile Bootstrap UCL	0.0263
95% BCA Bootstrap UCL	0.0291		
90% Chebyshev(Mean, Sd) UCL	0.029	95% Chebyshev(Mean, Sd) UCL	0.0322
97.5% Chebyshev(Mean, Sd) UCL	0.0367	99% Chebyshev(Mean, Sd) UCL	0.0454

Suggested UCL to Use

95% Student's-t UCL	0.026	or 95% Modified-t UCL	0.0263

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Tissue

Ni Ti Pen (mg/kg ww)

General Statistics

Total Number of Observations	22	Number of Distinct Observations	21
		Number of Missing Observations	0
Minimum	0.229	Mean	0.399
Maximum	1.2	Median	0.368
SD	0.191	Std. Error of Mean	0.0406
Coefficient of Variation	0.477	Skewness	3.789

Normal GOF Test

Shapiro Wilk Test Statistic	0.554	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.314	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.469	95% Adjusted-CLT UCL (Chen-1995)	0.501
		95% Modified-t UCL (Johnson-1978)	0.475

Gamma GOF Test

A-D Test Statistic	1.601	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.745	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.242	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.186	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	8.146	k star (bias corrected MLE)	7.066
Theta hat (MLE)	0.049	Theta star (bias corrected MLE)	0.0565
nu hat (MLE)	358.4	nu star (bias corrected)	310.9
MLE Mean (bias corrected)	0.399	MLE Sd (bias corrected)	0.15
		Approximate Chi Square Value (0.05)	271
Adjusted Level of Significance	0.0386	Adjusted Chi Square Value	268.3

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.458	95% Adjusted Gamma UCL (use when n<50)	0.463

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.807	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.207	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	-1.474	Mean of logged Data	-0.981
Maximum of Logged Data	0.182	SD of logged Data	0.322

Assuming Lognormal Distribution

95% H-UCL	0.45	90% Chebyshev (MVUE) UCL	0.477
95% Chebyshev (MVUE) UCL	0.514	97.5% Chebyshev (MVUE) UCL	0.566
99% Chebyshev (MVUE) UCL	0.668		

Nonparametric Distribution Free UCL Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.466	95% Jackknife UCL	0.469
95% Standard Bootstrap UCL	0.466	95% Bootstrap-t UCL	0.559
95% Hall's Bootstrap UCL	0.748	95% Percentile Bootstrap UCL	0.477
95% BCA Bootstrap UCL	0.511		
90% Chebyshev(Mean, Sd) UCL	0.521	95% Chebyshev(Mean, Sd) UCL	0.576
97.5% Chebyshev(Mean, Sd) UCL	0.653	99% Chebyshev(Mean, Sd) UCL	0.804

Suggested UCL to Use

95% Student's-t UCL	0.469	or 95% Modified-t UCL	0.475

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Tissue

Zn Ti Pen (mg/kg ww)

General Statistics

Total Number of Observations	22	Number of Distinct Observations	16
		Number of Missing Observations	0
Minimum	13.1	Mean	15
Maximum	17.1	Median	14.75
SD	1.181	Std. Error of Mean	0.252
Coefficient of Variation	0.0787	Skewness	0.446

Normal GOF Test

Shapiro Wilk Test Statistic	0.94	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.17	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	15.43	95% Adjusted-CLT UCL (Chen-1995)	15.44
		95% Modified-t UCL (Johnson-1978)	15.44

Gamma GOF Test

A-D Test Statistic	0.449	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.741	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.161	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	171.7	k star (bias corrected MLE)	148.3
Theta hat (MLE)	0.0874	Theta star (bias corrected MLE)	0.101
nu hat (MLE)	7553	nu star (bias corrected)	6525
MLE Mean (bias corrected)	15	MLE Sd (bias corrected)	1.232
		Approximate Chi Square Value (0.05)	6338
Adjusted Level of Significance	0.0386	Adjusted Chi Square Value	6324

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	15.44	95% Adjusted Gamma UCL (use when n<50)	15.48

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.95	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.156	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	2.573	Mean of logged Data	2.705
Maximum of Logged Data	2.839	SD of logged Data	0.0779

Assuming Lognormal Distribution

95% H-UCL	N/A	90% Chebyshev (MVUE) UCL	15.75
95% Chebyshev (MVUE) UCL	16.09	97.5% Chebyshev (MVUE) UCL	16.56
99% Chebyshev (MVUE) UCL	17.48		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	15.41	95% Jackknife UCL	15.43
95% Standard Bootstrap UCL	15.4	95% Bootstrap-t UCL	15.47
95% Hall's Bootstrap UCL	15.47	95% Percentile Bootstrap UCL	15.41
95% BCA Bootstrap UCL	15.42		
90% Chebyshev(Mean, Sd) UCL	15.76	95% Chebyshev(Mean, Sd) UCL	16.1
97.5% Chebyshev(Mean, Sd) UCL	16.57	99% Chebyshev(Mean, Sd) UCL	17.51

Suggested UCL to Use

95% Student's-t UCL	15.43

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Tissue

Meth Hg Ti Pen (ug/kg ww)

General Statistics

Total Number of Observations	22	Number of Distinct Observations	15
		Number of Missing Observations	0
Minimum	2.2	Mean	3.877
Maximum	6.6	Median	3.7
SD	0.857	Std. Error of Mean	0.183
Coefficient of Variation	0.221	Skewness	1.225

Normal GOF Test

Shapiro Wilk Test Statistic	0.896	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.154	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	4.192	95% Adjusted-CLT UCL (Chen-1995)	4.229
		95% Modified-t UCL (Johnson-1978)	4.2

Gamma GOF Test

A-D Test Statistic	0.487	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.741	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.136	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.185	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	22.87	k star (bias corrected MLE)	19.79
Theta hat (MLE)	0.169	Theta star (bias corrected MLE)	0.196
nu hat (MLE)	1006	nu star (bias corrected)	870.6
MLE Mean (bias corrected)	3.877	MLE Sd (bias corrected)	0.872
		Approximate Chi Square Value (0.05)	803.1
Adjusted Level of Significance	0.0386	Adjusted Chi Square Value	798.3

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	4.203	95% Adjusted Gamma UCL (use when n<50)	4.228

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.942	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.911	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.138	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.184	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	0.788	Mean of logged Data	1.333
Maximum of Logged Data	1.887	SD of logged Data	0.214

Assuming Lognormal Distribution

95% H-UCL	4.218	90% Chebyshev (MVUE) UCL	4.412
95% Chebyshev (MVUE) UCL	4.654	97.5% Chebyshev (MVUE) UCL	4.99
99% Chebyshev (MVUE) UCL	5.651		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	4.178	95% Jackknife UCL	4.192
95% Standard Bootstrap UCL	4.173	95% Bootstrap-t UCL	4.252
95% Hall's Bootstrap UCL	4.377	95% Percentile Bootstrap UCL	4.173
95% BCA Bootstrap UCL	4.232		
90% Chebyshev(Mean, Sd) UCL	4.425	95% Chebyshev(Mean, Sd) UCL	4.674
97.5% Chebyshev(Mean, Sd) UCL	5.018	99% Chebyshev(Mean, Sd) UCL	5.695

Suggested UCL to Use

95% Student's-t UCL	4.192

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Tissue

Ag Ti A8 (mg/kg ww)

General Statistics

Total Number of Observations	41	Number of Distinct Observations	40
		Number of Missing Observations	0
Minimum	0.0371	Mean	0.176
Maximum	0.582	Median	0.117
SD	0.15	Std. Error of Mean	0.0235
Coefficient of Variation	0.853	Skewness	1.302

Normal GOF Test

Shapiro Wilk Test Statistic	0.781	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.256	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.137	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.216	95% Adjusted-CLT UCL (Chen-1995)	0.22
		95% Modified-t UCL (Johnson-1978)	0.216

Gamma GOF Test

A-D Test Statistic	1.83	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.762	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.177	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.14	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.772	k star (bias corrected MLE)	1.659
Theta hat (MLE)	0.0994	Theta star (bias corrected MLE)	0.106
nu hat (MLE)	145.3	nu star (bias corrected)	136
MLE Mean (bias corrected)	0.176	MLE Sd (bias corrected)	0.137
		Approximate Chi Square Value (0.05)	110.1
Adjusted Level of Significance	0.0441	Adjusted Chi Square Value	109.2

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.218	95% Adjusted Gamma UCL (use when n<50)	0.219

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.92	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.123	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.137	Data appear Lognormal at 5% Significance Level

Data appear Approximate Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	-3.294	Mean of logged Data	-2.045
Maximum of Logged Data	-0.541	SD of logged Data	0.771

Assuming Lognormal Distribution

95% H-UCL	0.226	90% Chebyshev (MVUE) UCL	0.242
95% Chebyshev (MVUE) UCL	0.273	97.5% Chebyshev (MVUE) UCL	0.316
99% Chebyshev (MVUE) UCL	0.402		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.215	95% Jackknife UCL	0.216
95% Standard Bootstrap UCL	0.215	95% Bootstrap-t UCL	0.222
95% Hall's Bootstrap UCL	0.219	95% Percentile Bootstrap UCL	0.214
95% BCA Bootstrap UCL	0.221		
90% Chebyshev(Mean, Sd) UCL	0.246	95% Chebyshev(Mean, Sd) UCL	0.278
97.5% Chebyshev(Mean, Sd) UCL	0.323	99% Chebyshev(Mean, Sd) UCL	0.41

Suggested UCL to Use

95% H-UCL	0.226

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

95UCL Calcuations
Tissue

Inorg As Ti A8 (mg/kg ww)

General Statistics

Total Number of Observations	41	Number of Distinct Observations	22
		Number of Missing Observations	0
Minimum	0.014	Mean	0.0265
Maximum	0.05	Median	0.026
SD	0.0072	Std. Error of Mean	0.00113
Coefficient of Variation	0.272	Skewness	0.941

Normal GOF Test

Shapiro Wilk Test Statistic	0.948	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.121	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.137	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.0284	95% Adjusted-CLT UCL (Chen-1995)	0.0285
		95% Modified-t UCL (Johnson-1978)	0.0284

Gamma GOF Test

A-D Test Statistic	0.319	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.748	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0896	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.138	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	14.62	k star (bias corrected MLE)	13.57
Theta hat (MLE)	0.00181	Theta star (bias corrected MLE)	0.00195
nu hat (MLE)	1199	nu star (bias corrected)	1112
MLE Mean (bias corrected)	0.0265	MLE Sd (bias corrected)	0.0072
		Approximate Chi Square Value (0.05)	1036
Adjusted Level of Significance	0.0441	Adjusted Chi Square Value	1033

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.0285	95% Adjusted Gamma UCL (use when n<50)	0.0285

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.983	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0993	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.137	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	-4.269	Mean of logged Data	-3.665
Maximum of Logged Data	-2.996	SD of logged Data	0.266

Assuming Lognormal Distribution

95% H-UCL	0.0286	90% Chebyshev (MVUE) UCL	0.0299
95% Chebyshev (MVUE) UCL	0.0314	97.5% Chebyshev (MVUE) UCL	0.0335
99% Chebyshev (MVUE) UCL	0.0376		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.0284	95% Jackknife UCL	0.0284
95% Standard Bootstrap UCL	0.0284	95% Bootstrap-t UCL	0.0286
95% Hall's Bootstrap UCL	0.0287	95% Percentile Bootstrap UCL	0.0283
95% BCA Bootstrap UCL	0.0286		
90% Chebyshev(Mean, Sd) UCL	0.0299	95% Chebyshev(Mean, Sd) UCL	0.0314
97.5% Chebyshev(Mean, Sd) UCL	0.0335	99% Chebyshev(Mean, Sd) UCL	0.0377

Suggested UCL to Use

95% Student's-t UCL	0.0284

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Tissue

Cd Ti A8 (mg/kg ww)

General Statistics

Total Number of Observations	41	Number of Distinct Observations	40
		Number of Missing Observations	0
Minimum	0.169	Mean	0.375
Maximum	1	Median	0.264
SD	0.233	Std. Error of Mean	0.0364
Coefficient of Variation	0.621	Skewness	1.526

Normal GOF Test

Shapiro Wilk Test Statistic	0.761	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.223	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.137	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.436	95% Adjusted-CLT UCL (Chen-1995)	0.444
		95% Modified-t UCL (Johnson-1978)	0.437

Gamma GOF Test

A-D Test Statistic	2.426	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.754	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.184	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.139	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.577	k star (bias corrected MLE)	3.332
Theta hat (MLE)	0.105	Theta star (bias corrected MLE)	0.112
nu hat (MLE)	293.3	nu star (bias corrected)	273.2
MLE Mean (bias corrected)	0.375	MLE Sd (bias corrected)	0.205
		Approximate Chi Square Value (0.05)	235.9
Adjusted Level of Significance	0.0441	Adjusted Chi Square Value	234.7

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.434	95% Adjusted Gamma UCL (use when n<50)	0.436

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.866	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.166	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.137	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	-1.778	Mean of logged Data	-1.128
Maximum of Logged Data	0	SD of logged Data	0.516

Assuming Lognormal Distribution

95% H-UCL	0.432	90% Chebyshev (MVUE) UCL	0.462
95% Chebyshev (MVUE) UCL	0.504	97.5% Chebyshev (MVUE) UCL	0.563
99% Chebyshev (MVUE) UCL	0.679		

Nonparametric Distribution Free UCL Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	0.434	95% Jackknife UCL	0.436
95% Standard Bootstrap UCL	0.432	95% Bootstrap-t UCL	0.453
95% Hall's Bootstrap UCL	0.441	95% Percentile Bootstrap UCL	0.433
95% BCA Bootstrap UCL	0.437		
90% Chebyshev(Mean, Sd) UCL	0.484	95% Chebyshev(Mean, Sd) UCL	0.533
97.5% Chebyshev(Mean, Sd) UCL	0.602	99% Chebyshev(Mean, Sd) UCL	0.736

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	0.533

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Tissue

Cr Ti A8 (mg/kg ww)

General Statistics

Total Number of Observations	41	Number of Distinct Observations	41
		Number of Missing Observations	0
Minimum	0.155	Mean	0.478
Maximum	1.13	Median	0.396
SD	0.265	Std. Error of Mean	0.0415
Coefficient of Variation	0.555	Skewness	0.77

Normal GOF Test

Shapiro Wilk Test Statistic	0.912	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.941	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.137	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.137	Data appear Normal at 5% Significance Level	

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.548	95% Adjusted-CLT UCL (Chen-1995)	0.552
		95% Modified-t UCL (Johnson-1978)	0.549

Gamma GOF Test

A-D Test Statistic	0.429	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.754	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.0887	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.139	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.41	k star (bias corrected MLE)	3.177
Theta hat (MLE)	0.14	Theta star (bias corrected MLE)	0.151
nu hat (MLE)	279.6	nu star (bias corrected)	260.5
MLE Mean (bias corrected)	0.478	MLE Sd (bias corrected)	0.268
		Approximate Chi Square Value (0.05)	224.1
Adjusted Level of Significance	0.0441	Adjusted Chi Square Value	222.9

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.556	95% Adjusted Gamma UCL (use when n<50)	0.559

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.953	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.941	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.0848	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.137	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	-1.864	Mean of logged Data	-0.891
Maximum of Logged Data	0.122	SD of logged Data	0.571

Assuming Lognormal Distribution

95% H-UCL	0.576	90% Chebyshev (MVUE) UCL	0.617
95% Chebyshev (MVUE) UCL	0.679	97.5% Chebyshev (MVUE) UCL	0.765
99% Chebyshev (MVUE) UCL	0.934		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.547	95% Jackknife UCL	0.548
95% Standard Bootstrap UCL	0.548	95% Bootstrap-t UCL	0.552
95% Hall's Bootstrap UCL	0.555	95% Percentile Bootstrap UCL	0.548
95% BCA Bootstrap UCL	0.549		
90% Chebyshev(Mean, Sd) UCL	0.603	95% Chebyshev(Mean, Sd) UCL	0.659
97.5% Chebyshev(Mean, Sd) UCL	0.737	99% Chebyshev(Mean, Sd) UCL	0.891

Suggested UCL to Use

95% Student's-t UCL	0.548

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Tissue

Cu Ti A8 (mg/kg ww)

General Statistics

Total Number of Observations	41	Number of Distinct Observations	28
		Number of Missing Observations	0
Minimum	0.759	Mean	1.216
Maximum	1.73	Median	1.2
SD	0.192	Std. Error of Mean	0.0299
Coefficient of Variation	0.158	Skewness	0.319

Normal GOF Test

Shapiro Wilk Test Statistic	0.977	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.13	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.137	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	1.266	95% Adjusted-CLT UCL (Chen-1995)	1.266
		95% Modified-t UCL (Johnson-1978)	1.266

Gamma GOF Test

A-D Test Statistic	0.38	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.746	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.119	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.137	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	41.22	k star (bias corrected MLE)	38.22
Theta hat (MLE)	0.0295	Theta star (bias corrected MLE)	0.0318
nu hat (MLE)	3380	nu star (bias corrected)	3134
MLE Mean (bias corrected)	1.216	MLE Sd (bias corrected)	0.197
		Approximate Chi Square Value (0.05)	3005
Adjusted Level of Significance	0.0441	Adjusted Chi Square Value	3000

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	1.268	95% Adjusted Gamma UCL (use when n<50)	1.27

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.979	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.109	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.137	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	-0.276	Mean of logged Data	0.183
Maximum of Logged Data	0.548	SD of logged Data	0.159

Assuming Lognormal Distribution

95% H-UCL	1.27	90% Chebyshev (MVUE) UCL	1.307
95% Chebyshev (MVUE) UCL	1.348	97.5% Chebyshev (MVUE) UCL	1.405
99% Chebyshev (MVUE) UCL	1.517		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	1.265	95% Jackknife UCL	1.266
95% Standard Bootstrap UCL	1.265	95% Bootstrap-t UCL	1.265
95% Hall's Bootstrap UCL	1.268	95% Percentile Bootstrap UCL	1.263
95% BCA Bootstrap UCL	1.265		
90% Chebyshev(Mean, Sd) UCL	1.305	95% Chebyshev(Mean, Sd) UCL	1.346
97.5% Chebyshev(Mean, Sd) UCL	1.403	99% Chebyshev(Mean, Sd) UCL	1.513

Suggested UCL to Use

95% Student's-t UCL	1.266

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Tissue

Pb Ti A8 (mg/kg ww)

General Statistics

Total Number of Observations	41	Number of Distinct Observations	38
		Number of Missing Observations	0
Minimum	0.0431	Mean	0.0723
Maximum	0.13	Median	0.0727
SD	0.0164	Std. Error of Mean	0.00257
Coefficient of Variation	0.227	Skewness	0.665

Normal GOF Test

Shapiro Wilk Test Statistic	0.936	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.107	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.137	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.0766	95% Adjusted-CLT UCL (Chen-1995)	0.0768
		95% Modified-t UCL (Johnson-1978)	0.0766

Gamma GOF Test

A-D Test Statistic	0.68	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.747	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.116	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.138	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	19.9	k star (bias corrected MLE)	18.46
Theta hat (MLE)	0.00363	Theta star (bias corrected MLE)	0.00392
nu hat (MLE)	1632	nu star (bias corrected)	1514
MLE Mean (bias corrected)	0.0723	MLE Sd (bias corrected)	0.0168
		Approximate Chi Square Value (0.05)	1424
Adjusted Level of Significance	0.0441	Adjusted Chi Square Value	1421

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.0768	95% Adjusted Gamma UCL (use when n<50)	0.077

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.948	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.124	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.137	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	-3.144	Mean of logged Data	-2.653
Maximum of Logged Data	-2.04	SD of logged Data	0.23

Assuming Lognormal Distribution

95% H-UCL	0.0771	90% Chebyshev (MVUE) UCL	0.0802
95% Chebyshev (MVUE) UCL	0.0838	97.5% Chebyshev (MVUE) UCL	0.0887
99% Chebyshev (MVUE) UCL	0.0984		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.0765	95% Jackknife UCL	0.0766
95% Standard Bootstrap UCL	0.0764	95% Bootstrap-t UCL	0.0768
95% Hall's Bootstrap UCL	0.0773	95% Percentile Bootstrap UCL	0.0764
95% BCA Bootstrap UCL	0.0768		
90% Chebyshev(Mean, Sd) UCL	0.08	95% Chebyshev(Mean, Sd) UCL	0.0835
97.5% Chebyshev(Mean, Sd) UCL	0.0883	99% Chebyshev(Mean, Sd) UCL	0.0978

Suggested UCL to Use

95% Student's-t UCL	0.0766

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Tissue

Ni Ti A8 (mg/kg ww)

General Statistics

Total Number of Observations	41	Number of Distinct Observations	38
		Number of Missing Observations	0
Minimum	0.27	Mean	0.476
Maximum	1	Median	0.435
SD	0.17	Std. Error of Mean	0.0265
Coefficient of Variation	0.357	Skewness	1.066

Normal GOF Test

Shapiro Wilk Test Statistic	0.908	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.125	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.137	Data appear Normal at 5% Significance Level

Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	0.52	95% Adjusted-CLT UCL (Chen-1995)	0.524
		95% Modified-t UCL (Johnson-1978)	0.521

Gamma GOF Test

A-D Test Statistic	0.578	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.749	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.103	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.138	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	9.013	k star (bias corrected MLE)	8.37
Theta hat (MLE)	0.0528	Theta star (bias corrected MLE)	0.0568
nu hat (MLE)	739	nu star (bias corrected)	686.3
MLE Mean (bias corrected)	0.476	MLE Sd (bias corrected)	0.164
		Approximate Chi Square Value (0.05)	626.5
Adjusted Level of Significance	0.0441	Adjusted Chi Square Value	624.4

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	0.521	95% Adjusted Gamma UCL (use when n<50)	0.523

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.957	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0905	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.137	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	-1.309	Mean of logged Data	-0.8
Maximum of Logged Data	0	SD of logged Data	0.334

Assuming Lognormal Distribution

95% H-UCL	0.523	90% Chebyshev (MVUE) UCL	0.551
95% Chebyshev (MVUE) UCL	0.585	97.5% Chebyshev (MVUE) UCL	0.633
99% Chebyshev (MVUE) UCL	0.727		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	0.519	95% Jackknife UCL	0.52
95% Standard Bootstrap UCL	0.519	95% Bootstrap-t UCL	0.526
95% Hall's Bootstrap UCL	0.524	95% Percentile Bootstrap UCL	0.519
95% BCA Bootstrap UCL	0.528		
90% Chebyshev(Mean, Sd) UCL	0.555	95% Chebyshev(Mean, Sd) UCL	0.591
97.5% Chebyshev(Mean, Sd) UCL	0.641	99% Chebyshev(Mean, Sd) UCL	0.739

Suggested UCL to Use

95% Student's-t UCL	0.52

When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test
When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

95UCL Calcuations
Tissue

Zn Ti A8 (mg/kg ww)

General Statistics

Total Number of Observations	41	Number of Distinct Observations	28
		Number of Missing Observations	0
Minimum	9.6	Mean	13.38
Maximum	16.3	Median	13.6
SD	1.506	Std. Error of Mean	0.235
Coefficient of Variation	0.113	Skewness	-0.408

Normal GOF Test

Shapiro Wilk Test Statistic	0.98	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.0744	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.137	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	13.77	95% Adjusted-CLT UCL (Chen-1995)	13.75
		95% Modified-t UCL (Johnson-1978)	13.77

Gamma GOF Test

A-D Test Statistic	0.365	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.747	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0866	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.137	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	77.23	k star (bias corrected MLE)	71.6
Theta hat (MLE)	0.173	Theta star (bias corrected MLE)	0.187
nu hat (MLE)	6333	nu star (bias corrected)	5871
MLE Mean (bias corrected)	13.38	MLE Sd (bias corrected)	1.581
		Approximate Chi Square Value (0.05)	5694
Adjusted Level of Significance	0.0441	Adjusted Chi Square Value	5688

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	13.79	95% Adjusted Gamma UCL (use when n<50)	13.81

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.961	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.941	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.0906	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.137	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	2.262	Mean of logged Data	2.587
Maximum of Logged Data	2.791	SD of logged Data	0.117

Assuming Lognormal Distribution

95% H-UCL	13.81	90% Chebyshev (MVUE) UCL	14.11
95% Chebyshev (MVUE) UCL	14.45	97.5% Chebyshev (MVUE) UCL	14.91
99% Chebyshev (MVUE) UCL	15.81		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	13.76	95% Jackknife UCL	13.77
95% Standard Bootstrap UCL	13.74	95% Bootstrap-t UCL	13.76
95% Hall's Bootstrap UCL	13.76	95% Percentile Bootstrap UCL	13.75
95% BCA Bootstrap UCL	13.77		
90% Chebyshev(Mean, Sd) UCL	14.08	95% Chebyshev(Mean, Sd) UCL	14.4
97.5% Chebyshev(Mean, Sd) UCL	14.84	99% Chebyshev(Mean, Sd) UCL	15.72

Suggested UCL to Use

95% Student's-t UCL	13.77

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Note: For highly negatively-skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positvely skewed data sets.

95UCL Calcuations
Tissue

Meth Hg Ti A8 (ug/kg ww)

General Statistics

Total Number of Observations	41	Number of Distinct Observations	30
		Number of Missing Observations	0
Minimum	1	Mean	8.327
Maximum	18	Median	7.9
SD	3.312	Std. Error of Mean	0.517
Coefficient of Variation	0.398	Skewness	0.568

Normal GOF Test

Shapiro Wilk Test Statistic	0.97	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.941	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.108	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.137	Data appear Normal at 5% Significance Level	

Data appear Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	9.198	95% Adjusted-CLT UCL (Chen-1995)	9.227
		95% Modified-t UCL (Johnson-1978)	9.205

Gamma GOF Test

A-D Test Statistic	0.454	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.751	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.106	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.138	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	5.528	k star (bias corrected MLE)	5.14
Theta hat (MLE)	1.506	Theta star (bias corrected MLE)	1.62
nu hat (MLE)	453.3	nu star (bias corrected)	421.5
MLE Mean (bias corrected)	8.327	MLE Sd (bias corrected)	3.673
		Approximate Chi Square Value (0.05)	374.9
Adjusted Level of Significance	0.0441	Adjusted Chi Square Value	373.3

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	9.362	95% Adjusted Gamma UCL (use when n<50)	9.402

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.884	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.941	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.133	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.137	Data appear Lognormal at 5% Significance Level	

Data appear Approximate Lognormal at 5% Significance Level

95UCL Calcuations
Tissue

Lognormal Statistics

Minimum of Logged Data	0	Mean of logged Data	2.026
Maximum of Logged Data	2.89	SD of logged Data	0.484

Assuming Lognormal Distribution

95% H-UCL	9.855	90% Chebyshev (MVUE) UCL	10.52
95% Chebyshev (MVUE) UCL	11.43	97.5% Chebyshev (MVUE) UCL	12.7
99% Chebyshev (MVUE) UCL	15.19		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	9.178	95% Jackknife UCL	9.198
95% Standard Bootstrap UCL	9.167	95% Bootstrap-t UCL	9.246
95% Hall's Bootstrap UCL	9.263	95% Percentile Bootstrap UCL	9.183
95% BCA Bootstrap UCL	9.254		
90% Chebyshev(Mean, Sd) UCL	9.879	95% Chebyshev(Mean, Sd) UCL	10.58
97.5% Chebyshev(Mean, Sd) UCL	11.56	99% Chebyshev(Mean, Sd) UCL	13.47

Suggested UCL to Use

95% Student's-t UCL	9.198

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
Recommendations are based upon data size, data distribution, and skewness.
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

APPENDIX F
Detailed Human Health Risk Calculations

F1
Tribal Risk Calculations

Table 1: Tribal Exposures at Reference Area
Ingestion of Tissue
Future

Exposure Medium: Clam Tissue
Exposure Point: Reference Area Penrose Point State Park
Receptor Population: Suquamish Tribe
Receptor Age: Children and Adults

Noncancer Hazard = EPC x SIFnc x ABSo / RfD
Cancer Risk = EPC x SIFc x ABSo x CSF

Parameter	Units	RME	
		Child	Adult
Chemical Concentration in Tissue (C-t)	mg/kg	chem-specific	chem-specific
Ingestion Rate of Tissue (IR)	g/day	83.9	498.4
Exposure Frequency (EF)	days/year	365	365
Exposure Duration (ED)	years	6	64
Fraction of Diet from Source (FC)	unitless	1	1
Conversion Factor (CF)	kg/g	1.00E-03	1.00E-03
Body Weight (BW)	kg	16.8	79
Averaging Time (noncancer) (ATnc)	days	2,190	23,360
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc (child) = (IR*FC*EF*ED*CF)/(BW*ATnc)	$(day)^{-1}$	4.99E-03	
IngFadj (Ingestion Adjusted Factor)= (IRc*EDc/BWc)+(IRa*EDa/BWa)	mg-yr/day-kg	4.34E+02	
SIFnc (child/adult) = ((InhFadj*EF)/(ATnc-child + ATnc-adult))	$(day)^{-1}$	6.20E-03	
SIFc = (IngFadj*FC*EF*CF)/ATc		6.20E-03	

Chemical	RfD-O (mg/kg-d)	CSF-O $(mg/kg-d)^{-1}$	ABSo unitless
Arsenic, inorganic	3.0E-04	1.5E+00	1.0E+00
Cadmium	1.0E-03	--	1.0E+00
Chromium, trivalent	1.5E+00	--	1.0E+00
Copper	4.0E-02	--	1.0E+00
Methyl mercury	1.0E-04	--	1.0E+00
Nickel	2.0E-02	--	1.0E+00
Silver	5.0E-03	--	1.0E+00
Zinc	3.0E-01	--	1.0E+00

Chemical	RME - Hazard and Risk Results						
	Tissue EPC (mg/kg ww)	Noncancer Intake Child (mg/kg-d)	Noncancer Intake Child-Adult (mg/kg-d)	Cancer Intake Lifetime (mg/kg-d)	Noncancer Hazard Child	Noncancer Hazard Child-Adult	Cancer Risk Lifetime
Arsenic, inorganic	0.037	1.85E-04	2.29E-04	2.29E-04	0.62	0.76	3.4E-04
Cadmium	0.471	2.35E-03	2.92E-03	2.92E-03	2.35	2.92	--
Chromium, trivalent	0.512	2.56E-03	3.17E-03	3.17E-03	0.0017	0.0021	--
Copper	1.218	6.08E-03	7.55E-03	7.55E-03	0.15	0.19	--
Methyl mercury	0.004192	2.09E-05	2.60E-05	2.60E-05	0.21	0.26	--
Nickel	0.469	2.34E-03	2.91E-03	2.91E-03	0.12	0.15	--
Silver	0.0475	2.37E-04	2.94E-04	2.94E-04	0.047	0.059	--
Zinc	15.43	7.71E-02	9.56E-02	9.56E-02	0.26	0.32	--
Total					**3.8**	**4.7**	**3.4E-04**

Table 2: Tribal Exposures at Area 8
Ingestion of Tissue
Future

Exposure Medium: Clam Tissue
Exposure Point: Area 8 Beach in Liberty Bay
Receptor Population: Suquamish Tribe
Receptor Age: Children and Adults

Noncancer Hazard = EPC x SIFnc / RfD
Cancer Risk = EPC x SIFc x CSF

Parameter	Units	RME	
		Child	Adult
Chemical Concentration in Tissue (C-t)	mg/kg	chem-specific	chem-specific
Ingestion Rate of Tissue (IR)	g/day	83.9	498.4
Exposure Frequency (EF)	days/year	365	365
Exposure Duration (ED)	years	6	64
Fraction of Diet from Source (FC)	unitless	1	1
Conversion Factor (CF)	kg/g	1.00E-03	1.00E-03
Body Weight (BW)	kg	16.8	79
Averaging Time (noncancer) (ATnc)	days	2,190	23,360
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc (child) = (IR*FC*EF*ED*CF)/(BW*ATnc)	$(day)^{-1}$	4.99E-03	
IngFadj (Ingestion Adjusted Factor)= (IRc*EDc/BWc)+(IRa*EDa/BWa)	mg-yr/day-kg	4.34E+02	
SIFnc (child/adult) = ((InhFadj*EF)/(ATnc-child + ATnc-adult))	$(day)^{-1}$	6.20E-03	
SIFc = (IngFadj*FC*EF*CF)/ATc		6.20E-03	

Chemical	RfD-O (mg/kg-d)	CSF-O $(mg/kg-d)^{-1}$	ABSo unitless
Arsenic, inorganic	3.0E-04	1.5E+00	1.0E+00
Cadmium (diet)	1.0E-03	--	1.0E+00
Chromium, trivalent	1.5E+00	--	1.0E+00
Copper	4.0E-02	--	1.0E+00
Mercury (methyl)	1.0E-04	--	1.0E+00
Nickel (soluble salts)	2.0E-02	--	1.0E+00
Silver	5.0E-03	--	1.0E+00
Zinc	3.0E-01	--	1.0E+00

Chemical	RME - Hazard and Risk Results						
	Tissue EPC EPC (mg/kg ww)	Noncancer Intake Child (mg/kg-d)	Noncancer Intake Child-Adult (mg/kg-d)	Cancer Intake Lifetime (mg/kg-d)	Noncancer Hazard Child	Noncancer Hazard Child-Adult	Cancer Risk Lifetime
Arsenic, inorganic	0.0284	1.42E-04	1.76E-04	1.76E-04	0.47	0.59	2.6E-04
Cadmium	0.533	2.66E-03	3.30E-03	3.30E-03	2.66	3.30	--
Chromium, trivalent	0.548	2.74E-03	3.40E-03	3.40E-03	0.0018	0.0023	--
Copper	1.266	6.32E-03	7.84E-03	7.84E-03	0.16	0.20	--
Methyl mercury	0.009	4.59E-05	5.70E-05	5.70E-05	0.46	0.57	--
Nickel	0.52	2.60E-03	3.22E-03	3.22E-03	0.13	0.16	--
Silver	0.226	1.13E-03	1.40E-03	1.40E-03	0.23	0.28	--
Zinc	13.77	6.88E-02	8.53E-02	8.53E-02	0.23	0.28	--
Total					**4.34**	**5.4**	**2.6E-04**

Table 3: Tribal Exposures at Natural Background
Incidental Ingestion of Sediment
Future

Exposure Medium: Sediment
Exposure Point: Puget Sound Natural Background (*Bold* Data set)
Receptor Population: Suquamish Tribe
Receptor Age: Children and Adults

Noncancer Hazard = EPC x SIFnc x ABSo x RBA / RfD
Cancer Risk = EPC x SIFc x ABSo x RBA x CSF

Parameter	Units	Child	Adult
Chemical Concentration in Sediment (C-sd)	mg/kg	chem-specific	chem-specific
Ingestion Rate of Sediment (IR)	mg/day	200	100
Exposure Frequency (EF)	days/year	365	365
Exposure Duration (ED)	years	6	64
Conversion Factor (CF)	kg/mg	1.00E-06	1.00E-06
Body Weight (BW)	kg	16.8	79
Averaging Time (noncancer) (ATnc)	days	2,190	23,360
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc (child) = (IR*EF*ED*CF)/(BW*ATnc)	$(day)^{-1}$	1.19E-05	
IngFadj (Ingestion Adjusted Factor)= (IRch*EDch/BWch)+(IRa*EDa/BWa)	mg-yr/day-kg	152.44	
SIFnc (child/adult) = (IngFadj*EF*CF)/(ATnc(child) +ATnc(adult))	$(day)^{-1}$	2.18E-06	
SIFc = (IngFadj*EF*CF)/ATc	$(day)^{-1}$	2.18E-06	

Chemical	RfD-O (mg/kg-d)	CSF-O $(mg/kg-d)^{-1}$	RBA unitless	ABSo unitless
Arsenic	3.0E-04	1.5E+00	6.0E-01	1.0E+00
Cadmium	1.0E-03	--	1.0E+00	1.0E+00
Chromium, trivalent	1.5E+00	--	1.0E+00	1.0E+00
Copper	4.0E-02	--	1.0E+00	1.0E+00
Mercury	3.0E-04	--	1.0E+00	1.0E+00
Nickel	2.0E-02	--	1.0E+00	1.0E+00
Silver	5.0E-03	--	1.0E+00	1.0E+00
Zinc	3.0E-01	--	1.0E+00	1.0E+00

Chemical	RME - Hazard and Risk Results						
	Sediment EPC (mg/kg)	Noncancer Intake Child (mg/kg-d)	Noncancer Intake Child-Adult (mg/kg-d)	Cancer Intake Lifetime (mg/kg-d)	Noncancer Hazard Child	Noncancer Hazard Child-Adult	Cancer Risk Lifetime
Arsenic	7.42	8.83E-05	1.62E-05	1.62E-05	0.18	0.032	1.5E-05
Cadmium	0.42	5.00E-06	9.15E-07	9.15E-07	0.0050	0.00091	--
Chromium, trivalent	36.44	4.34E-04	7.94E-05	7.94E-05	0.00029	0.000053	--
Copper	25.35	3.02E-04	5.52E-05	5.52E-05	0.0075	0.00138	--
Mercury	0.0918	1.09E-06	2.00E-07	2.00E-07	0.0036	0.00067	--
Nickel	32.77	3.90E-04	7.14E-05	7.14E-05	0.020	0.0036	--
Silver	0.129	1.54E-06	2.81E-07	2.81E-07	0.00031	0.000056	--
Zinc	60.52	7.20E-04	1.32E-04	1.32E-04	0.0024	0.00044	--
Total					**0.22**	**0.039**	**1.5E-05**

Table 4: Tribal Exposures at Natural Background
Dermal Contact with Sediment
Future

Exposure Medium: Sediment
Exposure Point: Puget Sound Natural Background (*Bold* Data set)
Receptor Population: Suquamish Tribe
Receptor Age: Children and Adults

Noncancer Hazard = EPC x SIFnc x ABSd / RfD
Cancer Risk = EPC x SIFc x ABSd x CSF

Parameter	Units	RME	
		child	adult
Chemical Concentration in Sediment (C-sd)	mg/kg	chem-specific	chem-specific
Exposure Frequency (EF)	days/year	365	365
Exposure Duration (ED)	years	6	64
Surface Area Available for Contact (SA)	cm^2	2,373	6,032
Adherence Factor (AF)	mg/cm^2	0.2	0.12
Fraction of day for dermal exposures (FC)	unitless	1	1
Conversion Factor (CF)	kg/mg	1.0E-06	1.0E-06
Body Weight (BW)	kg	16.8	79
Averaging Time (noncancer) (ATnc)	days	2190	23360
Averaging Time (cancer) (ATc)	days	25550	25550
SIFnc-child = (EF*ED*SA*AF*FC*CF)/(BW*ATnc)	$(day)^{-1}$	2.83E-05	
DFadj (Dermal Adjusted Factor) =	mg-yr/day-kg	755.90	
(EDch*SAch*AFch /BWch) +(EDa*SAa*AFa/BWa)			
SIFnc (child/adult) = (DFadj*EF*FC*CF)/(ATnc-child + ATnc-adult)		1.08E-05	
SIFc = (DFadj*EF*FC*CF)/ATc	$(day)^{-1}$	1.08E-05	

Chemical	RfD-D (mg/kg-d)	CSF-D $(mg/kg-d)^{-1}$	AbsD
Arsenic	3.0E-04	1.5E+00	3.0E-02
Cadmium	2.5E-05	--	1.0E-03
Chromium, trivalent	2.0E-02	--	--
Copper	4.0E-02	--	--
Mercury	2.1E-05	--	--
Nickel	8.0E-04	--	--
Silver	2.0E-04	--	--
Zinc	3.0E-01	--	--

Chemical	RME - Hazard and Risk Results						
	Sediment EPC (mg/kg)	Noncancer Intake Child (mg/kg-d)	Noncancer Intake Child-Adult (mg/kg-d)	Cancer Intake Lifetime (mg/kg-d)	Noncancer Hazard Child	Noncancer Hazard Child-Adult	Cancer Risk Lifetime
Arsenic	7.42	2.10E-04	8.01E-05	8.01E-05	0.021	0.0080	3.6E-06
Cadmium	0.42	1.19E-05	4.54E-06	4.54E-06	0.00047	0.00018	--
Chromium, trivalent	36.44	1.03E-03	3.94E-04	3.94E-04	--	--	--
Copper	25.35	7.16E-04	2.74E-04	2.74E-04	--	--	--
Mercury	0.0918	2.59E-06	9.91E-07	9.91E-07	--	--	--
Nickel	32.77	9.26E-04	3.54E-04	3.54E-04	--	--	--
Silver	0.129	3.64E-06	1.39E-06	1.39E-06	--	--	--
Zinc	60.52	1.71E-03	6.54E-04	6.54E-04	--	--	--
Total					**0.021**	**0.0082**	**3.6E-06**

Table 5: Tribal Exposures at Natural Background
Sediment Summary (Ingestion + Dermal Exposures)
Future

Exposure Medium: Sediment
Exposure Point: Puget Sound Natural Background (*Bold* Data set)
Receptor Population: Suquamish Tribe
Receptor Age: Children and Adults

	Ingestion			Dermal			Cumulative		
	Noncancer Hazards		Cancer Risk	Noncancer Hazards		Cancer Risk	Noncancer Hazards		Cancer Risk
	Child	Child-Adult	Lifetime	Child	Child-Adult	Lifetime	Child	Child-Adult	Lifetime
Arsenic	0.18	0.032	1.5E-05	0.021	0.0080	3.6E-06	0.20	0.040	1.8E-05
Cadmium	0.0050	0.00091	--	0.00047	0.00018	--	0.0055	0.0011	--
Chromium, trivalent	0.00029	0.000053	--	--	--	--	0.00029	0.000053	--
Copper	0.0075	0.0014	--	--	--	--	0.0075	0.0014	--
Mercury	0.0036	0.00067	--	--	--	--	0.0036	0.00067	--
Nickel	0.020	0.0036	--	--	--	--	0.020	0.0036	--
Silver	0.00031	0.000056	--	--	--	--	0.00031	0.000056	--
Zinc	0.0024	0.00044	--	--	--	--	0.0024	0.00044	--
TOTAL	**0.22**	**0.039**	**1.5E-05**	**0.021**	**0.0082**	**3.6E-06**	**0.24**	**0.048**	**1.8E-05**

Table6: Tribal Exposures at Area 8
Incidental Ingestion of Sediment
Future

Exposure Medium: Sediment
Exposure Point: Area 8 Beach in Liberty Bay
Receptor Population: Suquamish Tribe
Receptor Age: Children and Adults

Noncancer Hazard = EPC x SIFnc x ABSo x RBA / RfD
Cancer Risk = EPC x SIFc x ABSo x RBA x CSF

Parameter	Units	Child	Adult
Chemical Concentration in Sediment (C-sd)	mg/kg	chem-specific	chem-specific
Ingestion Rate of Sediment (IR)	mg/day	200	100
Exposure Frequency (EF)	days/year	365	365
Exposure Duration (ED)	years	6	64
Conversion Factor (CF)	kg/mg	1.00E-06	1.00E-06
Body Weight (BW)	kg	16.8	79
Averaging Time (noncancer) (ATnc)	days	2,190	23,360
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc (child) = (IR*EF*ED*CF)/(BW*ATnc)	$(day)^{-1}$	1.19E-05	
IngFadj (Ingestion Adjusted Factor)= (IRch*EDch/BWch)+(IRa*EDa/BWa)	mg-yr/day-kg	152.44	
SIFnc (child/adult) = (IngFadj*EF*CF)/(ATnc(child) +	$(day)^{-1}$	2.18E-06	
SIFc = (IngFadj*EF*CF)/ATc	$(day)^{-1}$	2.18E-06	

Chemical	RfD-O (mg/kg-d)	CSF-O $(mg/kg-d)^{-1}$	RBA unitless	ABSo unitless
Arsenic	3.0E-04	1.5E+00	6.0E-01	1.0E+00
Cadmium	1.0E-03	--	1.0E+00	1.0E+00
Chromium, trivalent	1.5E+00	--	1.0E+00	1.0E+00
Copper	4.0E-02	--	1.0E+00	1.0E+00
Mercury	3.0E-04	--	1.0E+00	1.0E+00
Nickel	2.0E-02	--	1.0E+00	1.0E+00
Silver	5.0E-03	--	1.0E+00	1.0E+00
Zinc	3.0E-01	--	1.0E+00	1.0E+00

Chemical	RME - Hazard and Risk Results						
	Sediment EPC (mg/kg)	Noncancer Intake Child (mg/kg-d)	Noncancer Intake Child-Adult (mg/kg-d)	Cancer Intake Lifetime (mg/kg-d)	Noncancer Hazard Child	Noncancer Hazard Child-Adult	Cancer Risk Lifetime
Arsenic	2.571	3.06E-05	5.60E-06	5.60E-06	0.061	0.0112	5.0E-06
Cadmium	2.898	3.45E-05	6.31E-06	6.31E-06	0.035	0.0063	--
Chromium, trivalent	31.58	3.76E-04	6.88E-05	6.88E-05	0.00025	0.000046	--
Copper	48	5.71E-04	1.05E-04	1.05E-04	0.014	0.0026	--
Mercury	0.19	2.26E-06	4.14E-07	4.14E-07	0.0075	0.00138	--
Nickel	17.26	2.05E-04	3.76E-05	3.76E-05	0.010	0.0019	--
Silver	2.144	2.55E-05	4.67E-06	4.67E-06	0.0051	0.00093	--
Zinc	67.24	8.00E-04	1.46E-04	1.46E-04	0.0027	0.00049	--
Total					**0.14**	**0.025**	**5.0E-06**

Table 7: Tribal Exposures at Area 8
Dermal Contact with Sediment
Future

Exposure Medium: Sediment
Exposure Point: Area 8 Beach in Liberty Bay
Receptor Population: Suquamish Tribe
Receptor Age: Children and Adults

Noncancer Hazard = EPC x SIFnc x ABSd / RfD
Cancer Risk = EPC x SIFc x ABSd x CSF

Parameter	Units	RME	
		child	adult
Chemical Concentration in Sediment (C-sd)	mg/kg	chem-specific	chem-specific
Exposure Frequency (EF)	days/year	365	365
Exposure Duration (ED)	years	6	64
Surface Area Available for Contact (SA)	cm^2	2,373	6,032
Adherence Factor (AF)	mg/cm^2	0.2	0.12
Fraction of day for dermal exposures (FC)	unitless	1	1
Conversion Factor (CF)	kg/mg	1.0E-06	1.0E-06
Body Weight (BW)	kg	16.8	79
Averaging Time (noncancer) (ATnc)	days	2190	23360
Averaging Time (cancer) (ATc)	days	25550	25550
SIFnc-child = (EF*ED*SA*AF*FC*CF)/(BW*ATnc)	$(day)^{-1}$	2.83E-05	
DFadj (Dermal Adjusted Factor) = (EDch*SAch*AFch /BWch) +(EDa*SAa*AFa/BWa)	mg-yr/day-kg	755.90	
SIFnc (child/adult) = (DFadj*EF*FC*CF)/(ATnc-child + ATnc-adult)		1.08E-05	
SIFc = (DFadj*EF*FC*CF)/ATc	$(day)^{-1}$	1.08E-05	

Chemical	RfD-D (mg/kg-d)	CSF-D $(mg/kg-d)^{-1}$	AbsD
Arsenic	3.0E-04	1.5E+00	3.0E-02
Cadmium	2.5E-05	--	1.0E-03
Chromium, trivalent	2.0E-02	--	--
Copper	4.0E-02	--	--
Mercury	2.1E-05	--	--
Nickel	8.0E-04	--	--
Silver	2.0E-04	--	--
Zinc	3.0E-01	--	--

Chemical	RME - Hazard and Risk Results						
	Sediment EPC (mg/kg)	Noncancer Intake Child (mg/kg-d)	Noncancer Intake Child-Adult (mg/kg-d)	Cancer Intake Lifetime (mg/kg-d)	Noncancer Hazard Child	Noncancer Hazard Child-Adult	Cancer Risk Lifetime
Arsenic	2.571	7.26E-05	2.78E-05	2.78E-05	0.00726	0.00278	1.2E-06
Cadmium	2.898	8.19E-05	3.13E-05	3.13E-05	0.00327	0.00125	--
Chromium, trivalent	31.58	8.92E-04	3.41E-04	3.41E-04	--	--	--
Copper	48	1.36E-03	5.18E-04	5.18E-04	--	--	--
Mercury	0.19	5.37E-06	2.05E-06	2.05E-06	--	--	--
Nickel	17.26	4.88E-04	1.86E-04	1.86E-04	--	--	--
Silver	2.144	6.06E-05	2.32E-05	2.32E-05	--	--	--
Zinc	67.24	1.90E-03	7.26E-04	7.26E-04	--	--	--
Total					**0.011**	**0.0040**	**1.2E-06**

Table 8: Tribal Exposures at Area 8
Sediment Summary (Ingestion + Dermal Exposures)
Future

Exposure Medium: Sediment
Exposure Point: Area 8 Beach in Liberty Bay
Receptor Population: Suquamish Tribe
Receptor Age: Children and Adults

	Ingestion			Dermal			Cumulative		
	Noncancer Hazards		Cancer Risk	Noncancer Hazards		Cancer Risk	Noncancer Hazards		Cancer Risk
	Child	Child-Adult	Lifetime	Child	Child-Adult	Lifetime	Child	Child-Adult	Lifetime
Arsenic	0.061	0.011	5.0E-06	0.0073	0.0028	1.2E-06	0.068	0.014	6.3E-06
Cadmium	0.035	0.0063	--	0.0033	0.0013	--	0.038	0.0076	--
Chromium, triva	0.00025	0.000046	--	--	--	--	0.00025	0.000046	--
Copper	0.014	0.0026	--	--	--	--	0.014	0.0026	--
Mercury	0.0075	0.0014	--	--	--	--	0.0075	0.0014	--
Nickel	0.010	0.0019	--	--	--	--	0.010	0.0019	--
Silver	0.0051	0.00093	--	--	--	--	0.0051	0.00093	--
Zinc	0.0027	0.00049	--	--	--	--	0.0027	0.00049	--
TOTAL	**0.14**	**0.025**	**5.0E-06**	**0.011**	**0.0040**	**1.2E-06**	**0.15**	**0.029**	**6.3E-06**

Table 9: Keyport Area 8 - Subsistence Incremental Risk Over Background

Chemical	Noncancer Hazards						Cancer Risks		
	Area 8		Reference Area		Incremental				
	Child	Child-Adult	Child	Child-Adult	Child	Child-Adult	Area 8	Reference Area	Incremental
Tissue - Ingestion									
Arsenic, inorganic	0.47	0.59	0.62	0.76	None	None	2.6E-04	3.4E-04	None
Cadmium	2.7	3.3	2.4	2.9	0.31	0.38	--	--	--
Chromium, trivalent	0.0018	0.0023	0.0017	0.0021	0.00012	0.00015	--	--	--
Copper	0.16	0.20	0.15	0.19	0.0060	0.0074	--	--	--
Methyl mercury	0.46	0.57	0.21	0.26	0.25	0.31	--	--	--
Nickel	0.13	0.16	0.12	0.15	0.013	0.016	--	--	--
Silver	0.23	0.28	0.047	0.059	0.18	0.22	--	--	--
Zinc	0.23	0.28	0.26	0.32	None	None	--	--	--
TOTAL	**4.3**	**5.4**	**3.8**	**4.7**	**0.59**	**0.73**	**2.6E-04**	**3.4E-04**	**None**
Sediment - Ingestion + Dermal									
Arsenic	0.068	0.014	0.20	0.040	None	None	6.3E-06	1.8E-05	None
Cadmium	0.038	0.0076	0.0055	0.0011	0.032	0.0065	--	--	--
Chromium, trivalent	0.00025	0.000046	0.00029	0.000053	None	None	--	--	--
Copper	0.014	0.0026	0.0075	0.0014	0.0067	0.0012	--	--	--
Mercury	0.0075	0.0014	0.0036	0.00067	0.0039	0.00071	--	--	--
Nickel	0.010	0.0019	0.020	0.0036	None	None	--	--	--
Silver	0.0051	0.00093	0.00031	0.000056	0.0048	0.00088	--	--	--
Zinc	0.0027	0.00049	0.0024	0.00044	0.00027	0.000049	--	--	--
TOTAL	**0.15**	**0.029**	**0.24**	**0.048**	**None**	**None**	**6.3E-06**	**1.8E-05**	**None**
Cumulative - Tissue + Sediment									
TOTAL	**4.5**	**5.4**	**4.0**	**4.7**	**0.50**	**0.71**	**2.7E-04**	**3.6E-04**	**None**

F2
Recreational Risk Calculations

Table 1: Recreational Exposures at Reference Area
Ingestion of Tissue
Future

Exposure Medium: Clam Tissue
Exposure Point: Reference Area Penrose Point State Park
Receptor Population: Recreational Populations
Receptor Age: Children and Adults

Noncancer Hazard = EPC x SIFnc x ABSo / RfD
Cancer Risk = EPC x SIFc x ABSo x CSF

Parameter	Units	RME	
		Child	Adult
Chemical Concentration in Tissue (C-t)	mg/kg	chem-specific	chem-specific
Ingestion Rate of Tissue (IR)	g/day	12	30
Exposure Frequency (EF)	days/year	120	120
Exposure Duration (ED)	years	6	20
Fraction of Diet from Source (FC)	unitless	1	1
Conversion Factor (CF)	kg/g	1.00E-03	1.00E-03
Body Weight (BW)	kg	15	80
Averaging Time (noncancer) (ATnc)	days	2,190	7,300
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc (child) = (IR*FC*EF*ED*CF)/(BW*ATnc)	$(day)^{-1}$	2.63E-04	
IngFadj (Ingestion Adjusted Factor)= (IRc*EDc/BWc)+(IRa*EDa/BWa)	mg-yr/day-kg	1.23E+01	
SIFnc (child/adult) = ((InhFadj*EF)/(ATnc-child + ATnc-adult))	$(day)^{-1}$	1.56E-04	
SIFc = (IngFadj*FC*EF*CF)/ATc		5.78E-05	

Chemical	RfD-O (mg/kg-d)	CSF-O $(mg/kg-d)^{-1}$	ABSo unitless
Arsenic, inorganic	3.0E-04	1.5E+00	1.0E+00
Cadmium	1.0E-03	--	1.0E+00
Chromium, trivalent	1.5E+00	--	1.0E+00
Copper	4.0E-02	--	1.0E+00
Methyl mercury	1.0E-04	--	1.0E+00
Nickel	2.0E-02	--	1.0E+00
Silver	5.0E-03	--	1.0E+00
Zinc	3.0E-01	--	1.0E+00

Chemical	RME - Hazard and Risk Results						
	Tissue EPC (mg/kg ww)	Noncancer Intake Child (mg/kg-d)	Noncancer Intake Child-Adult (mg/kg-d)	Cancer Intake Lifetime (mg/kg-d)	Noncancer Hazard Child	Noncancer Hazard Child-Adult	Cancer Risk Lifetime
Arsenic, inorganic	0.037	9.73E-06	5.75E-06	2.14E-06	0.032	0.019	3.2E-06
Cadmium	0.471	1.24E-04	7.33E-05	2.72E-05	0.12	0.073	--
Chromium, trivalent	0.512	1.35E-04	7.96E-05	2.96E-05	0.000090	0.000053	--
Copper	1.218	3.20E-04	1.89E-04	7.04E-05	0.0080	0.0047	--
Methyl mercury	0.004192	1.10E-06	6.52E-07	2.42E-07	0.011	0.0065	--
Nickel	0.469	1.23E-04	7.29E-05	2.71E-05	0.0062	0.0036	--
Silver	0.0475	1.25E-05	7.39E-06	2.74E-06	0.0025	0.0015	--
Zinc	15.43	4.06E-03	2.40E-03	8.91E-04	0.014	0.0080	--
Total					**0.20**	**0.12**	**3.2E-06**

Table 2: Recreational Exposures at Area 8
Ingestion of Tissue
Future

Exposure Medium: Clam Tissue
Exposure Point: Area 8 Beach in Liberty Bay
Receptor Population: Recreational Populations
Receptor Age: Children and Adults

Noncancer Hazard = EPC x SIFnc / RfD
Cancer Risk = EPC x SIFc x CSF

Parameter	Units	RME	
		Child	Adult
Chemical Concentration in Tissue (C-t)	mg/kg	chem-specific	chem-specific
Ingestion Rate of Tissue (IR)	g/day	12	30
Exposure Frequency (EF)	days/year	120	120
Exposure Duration (ED)	years	6	20
Fraction of Diet from Source (FC)	unitless	1	1
Conversion Factor (CF)	kg/g	1.00E-03	1.00E-03
Body Weight (BW)	kg	15	80
Averaging Time (noncancer) (ATnc)	days	2,190	7,300
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc (child) = (IR*FC*EF*ED*CF)/(BW*ATnc)	$(day)^{-1}$	2.63E-04	
IngFadj (Ingestion Adjusted Factor)= (IRc*EDc/BWc)+(IRa*EDa/BWa)	mg-yr/day-kg	1.23E+01	
SIFnc (child/adult) = ((InhFadj*EF)/(ATnc-child + ATnc-adult))	$(day)^{-1}$	1.56E-04	
SIFc = (IngFadj*FC*EF*CF)/ATc		5.78E-05	

Chemical	RfD-O (mg/kg-d)	CSF-O $(mg/kg-d)^{-1}$	ABSo unitless
Arsenic, inorganic	3.0E-04	1.5E+00	1.0E+00
Cadmium (diet)	1.0E-03	--	1.0E+00
Chromium, trivalent	1.5E+00	--	1.0E+00
Copper	4.0E-02	--	1.0E+00
Mercury (methyl)	1.0E-04	--	1.0E+00
Nickel (soluble salts)	2.0E-02	--	1.0E+00
Silver	5.0E-03	--	1.0E+00
Zinc	3.0E-01	--	1.0E+00

Chemical	RME - Hazard and Risk Results						
	Tissue EPC EPC (mg/kg ww)	Noncancer Intake Child (mg/kg-d)	Noncancer Intake Child-Adult (mg/kg-d)	Cancer Intake Lifetime (mg/kg-d)	Noncancer Hazard Child	Noncancer Hazard Child-Adult	Cancer Risk Lifetime
Arsenic, inorganic	0.0284	7.47E-06	4.42E-06	1.64E-06	0.025	0.015	2.5E-06
Cadmium	0.533	1.40E-04	8.29E-05	3.08E-05	0.14	0.083	--
Chromium, trivalent	0.548	1.44E-04	8.52E-05	3.17E-05	0.00010	0.000057	--
Copper	1.266	3.33E-04	1.97E-04	7.31E-05	0.0083	0.0049	--
Methyl mercury	0.009	2.42E-06	1.43E-06	5.31E-07	0.024	0.014	--
Nickel	0.52	1.37E-04	8.09E-05	3.00E-05	0.0068	0.0040	--
Silver	0.226	5.94E-05	3.52E-05	1.31E-05	0.012	0.0070	--
Zinc	13.77	3.62E-03	2.14E-03	7.95E-04	0.012	0.0071	--
Total					**0.23**	**0.14**	**2.5E-06**

Table 3: Recreational Exposures at Natural Background
Incidental Ingestion of Sediment
Future

Exposure Medium: Sediment
Exposure Point: Puget Sound Natural Background (*Bold* Data set)
Receptor Population: Recreational Populations
Receptor Age: Children and Adults

Noncancer Hazard = EPC x SIFnc x ABSo x RBA / RfD
Cancer Risk = EPC x SIFc x ABSo x RBA x CSF

Parameter	Units	Child	Adult
Chemical Concentration in Sediment (C-sd)	mg/kg	chem-specific	chem-specific
Ingestion Rate of Sediment (IR)	mg/day	200	100
Exposure Frequency (EF)	days/year	120	120
Exposure Duration (ED)	years	6	20
Conversion Factor (CF)	kg/mg	1.00E-06	1.00E-06
Body Weight (BW)	kg	15	80
Averaging Time (noncancer) (ATnc)	days	2,190	7,300
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc (child) = (IR*EF*ED*CF)/(BW*ATnc)	$(day)^{-1}$	4.38E-06	
IngFadj (Ingestion Adjusted Factor)= (IRch*EDch/BWch)+(IRa*EDa/BWa)	mg-yr/day-kg	105.00	
SIFnc (child/adult) = (IngFadj*EF*CF)/(ATnc(child) +ATnc(adult))	$(day)^{-1}$	1.33E-06	
SIFc = (IngFadj*EF*CF)/ATc	$(day)^{-1}$	4.93E-07	

Chemical	RfD-O (mg/kg-d)	CSF-O $(mg/kg-d)^{-1}$	RBA unitless	ABSo unitless
Arsenic	3.0E-04	1.5E+00	6.0E-01	1.0E+00
Cadmium	1.0E-03	--	1.0E+00	1.0E+00
Chromium, trivalent	1.5E+00	--	1.0E+00	1.0E+00
Copper	4.0E-02	--	1.0E+00	1.0E+00
Mercury	3.0E-04	--	1.0E+00	1.0E+00
Nickel	2.0E-02	--	1.0E+00	1.0E+00
Silver	5.0E-03	--	1.0E+00	1.0E+00
Zinc	3.0E-01	--	1.0E+00	1.0E+00

Chemical	RME - Hazard and Risk Results						
	Sediment EPC (mg/kg)	Noncancer Intake Child (mg/kg-d)	Noncancer Intake Child-Adult (mg/kg-d)	Cancer Intake Lifetime (mg/kg-d)	Noncancer Hazard Child	Noncancer Hazard Child-Adult	Cancer Risk Lifetime
Arsenic	7.42	3.25E-05	9.85E-06	3.66E-06	0.065	0.020	3.3E-06
Cadmium	0.42	1.84E-06	5.58E-07	2.07E-07	0.0018	0.00056	--
Chromium, trivalent	36.44	1.60E-04	4.84E-05	1.80E-05	0.00011	0.000032	--
Copper	25.35	1.11E-04	3.37E-05	1.25E-05	0.0028	0.00084	--
Mercury	0.0918	4.02E-07	1.22E-07	4.53E-08	0.0013	0.00041	--
Nickel	32.77	1.44E-04	4.35E-05	1.62E-05	0.0072	0.0022	--
Silver	0.129	5.65E-07	1.71E-07	6.36E-08	0.00011	0.000034	--
Zinc	60.52	2.65E-04	8.04E-05	2.98E-05	0.00088	0.00027	--
Total					**0.079**	**0.024**	**3.3E-06**

Table 4: Recreational Exposures at Natural Background
Dermal Contact with Sediment
Future

Exposure Medium: Sediment
Exposure Point: Puget Sound Natural Background (*Bold* Data set)
Receptor Population: Recreational Populations
Receptor Age: Children and Adults

Noncancer Hazard = EPC x SIFnc x ABSd / RfD
Cancer Risk = EPC x SIFc x ABSd x CSF

Parameter	Units	RME	
		child	adult
Chemical Concentration in Sediment (C-sd)	mg/kg	chem-specific	chem-specific
Exposure Frequency (EF)	days/year	120	120
Exposure Duration (ED)	years	6	20
Surface Area Available for Contact (SA)	cm^2	2,373	6,032
Adherence Factor (AF)	mg/cm^2	0.2	0.12
Fraction of day for dermal exposures (FC)	unitless	1	1
Conversion Factor (CF)	kg/mg	1.0E-06	1.0E-06
Body Weight (BW)	kg	15	80
Averaging Time (noncancer) (ATnc)	days	2190	7300
Averaging Time (cancer) (ATc)	days	25550	25550
SIFnc-child = (EF*ED*SA*AF*FC*CF)/(BW*ATnc)	$(day)^{-1}$	1.04E-05	
DFadj (Dermal Adjusted Factor) =	mg-yr/day-kg	370.80	
(EDch*SAch*AFch /BWch) +(EDa*SAa*AFa/BWa)			
SIFnc (child/adult) = (DFadj*EF*FC*CF)/(ATnc-child + ATnc-adult)		4.69E-06	
SIFc = (DFadj*EF*FC*CF)/ATc	$(day)^{-1}$	1.74E-06	

Chemical	RfD-D (mg/kg-d)	CSF-D $(mg/kg-d)^{-1}$	AbsD
Arsenic	3.0E-04	1.5E+00	3.0E-02
Cadmium	2.5E-05	--	1.0E-03
Chromium, trivalent	2.0E-02	--	--
Copper	4.0E-02	--	--
Mercury	2.1E-05	--	--
Nickel	8.0E-04	--	--
Silver	2.0E-04	--	--
Zinc	3.0E-01	--	--

Chemical	RME - Hazard and Risk Results						
	Sediment EPC (mg/kg)	Noncancer Intake Child (mg/kg-d)	Noncancer Intake Child-Adult (mg/kg-d)	Cancer Intake Lifetime (mg/kg-d)	Noncancer Hazard Child	Noncancer Hazard Child-Adult	Cancer Risk Lifetime
Arsenic	7.42	7.72E-05	3.48E-05	1.29E-05	0.0077	0.0035	5.8E-07
Cadmium	0.42	4.37E-06	1.97E-06	7.31E-07	0.00017	0.00008	--
Chromium, trivalent	36.44	3.79E-04	1.71E-04	6.35E-05	--	--	--
Copper	25.35	2.64E-04	1.19E-04	4.41E-05	--	--	--
Mercury	0.0918	9.55E-07	4.30E-07	1.60E-07	--	--	--
Nickel	32.77	3.41E-04	1.54E-04	5.71E-05	--	--	--
Silver	0.129	1.34E-06	6.05E-07	2.25E-07	--	--	--
Zinc	60.52	6.30E-04	2.84E-04	1.05E-04	--	--	--
Total					**0.0079**	**0.0036**	**5.8E-07**

Table 5: Recreational Exposures at Natural Background
Sediment Summary (Ingestion + Dermal Exposures)
Future

Exposure Medium: Sediment
Exposure Point: Puget Sound Natural Background (*Bold* Data set)
Receptor Population: Recreational Populations
Receptor Age: Children and Adults

	Ingestion			Dermal			Cumulative		
	Noncancer Hazards		Cancer Risk	Noncancer Hazards		Cancer Risk	Noncancer Hazards		Cancer Risk
	Child	Child-Adult	Lifetime	Child	Child-Adult	Lifetime	Child	Child-Adult	Lifetime
Arsenic	0.065	0.020	3.3E-06	0.0077	0.0035	5.8E-07	0.073	0.023	3.9E-06
Cadmium	0.0018	0.00056	--	0.00017	0.000079	--	0.0020	0.00064	--
Chromium, trivalent	0.00011	0.000032	--	--	--	--	0.00011	0.000032	--
Copper	0.0028	0.00084	--	--	--	--	0.0028	0.00084	--
Mercury	0.0013	0.00041	--	--	--	--	0.0013	0.00041	--
Nickel	0.0072	0.0022	--	--	--	--	0.0072	0.0022	--
Silver	0.00011	0.000034	--	--	--	--	0.00011	0.000034	--
Zinc	0.00088	0.00027	--	--	--	--	0.00088	0.00027	--
TOTAL	**0.079**	**0.024**	**3.3E-06**	**0.0079**	**0.0036**	**5.8E-07**	**0.087**	**0.028**	**3.9E-06**

Table 6: Recreational Exposures at Area 8
Incidental Ingestion of Sediment
Future

Exposure Medium: Sediment
Exposure Point: Area 8 Beach in Liberty Bay
Receptor Population: Recreational Populations
Receptor Age: Children and Adults

Noncancer Hazard = EPC x SIFnc x ABSo x RBA / RfD
Cancer Risk = EPC x SIFc x ABSo x RBA x CSF

Parameter	Units	Child	Adult
Chemical Concentration in Sediment (C-sd)	mg/kg	chem-specific	chem-specific
Ingestion Rate of Sediment (IR)	mg/day	200	100
Exposure Frequency (EF)	days/year	120	120
Exposure Duration (ED)	years	6	20
Conversion Factor (CF)	kg/mg	1.00E-06	1.00E-06
Body Weight (BW)	kg	15	80
Averaging Time (noncancer) (ATnc)	days	2,190	7,300
Averaging Time (cancer) (ATc)	days	25,550	25,550
SIFnc (child) = (IR*EF*ED*CF)/(BW*ATnc)	$(day)^{-1}$	4.38E-06	
IngFadj (Ingestion Adjusted Factor)= (IRch*EDch/BWch)+(IRa*EDa/BWa)	mg-yr/day-kg	105.00	
SIFnc (child/adult) = (IngFadj*EF*CF)/(ATnc(child) +	$(day)^{-1}$	1.33E-06	
SIFc = (IngFadj*EF*CF)/ATc	$(day)^{-1}$	4.93E-07	

Chemical	RfD-O (mg/kg-d)	CSF-O $(mg/kg-d)^{-1}$	RBA unitless	ABSo unitless
Arsenic	3.0E-04	1.5E+00	6.0E-01	1.0E+00
Cadmium	1.0E-03	--	1.0E+00	1.0E+00
Chromium, trivalent	1.5E+00	--	1.0E+00	1.0E+00
Copper	4.0E-02	--	1.0E+00	1.0E+00
Mercury	3.0E-04	--	1.0E+00	1.0E+00
Nickel	2.0E-02	--	1.0E+00	1.0E+00
Silver	5.0E-03	--	1.0E+00	1.0E+00
Zinc	3.0E-01	--	1.0E+00	1.0E+00

Chemical	RME - Hazard and Risk Results						
	Sediment EPC (mg/kg)	Noncancer Intake Child (mg/kg-d)	Noncancer Intake Child-Adult (mg/kg-d)	Cancer Intake Lifetime (mg/kg-d)	Noncancer Hazard Child	Noncancer Hazard Child-Adult	Cancer Risk Lifetime
Arsenic	2.571	1.13E-05	3.41E-06	3.41E-06	0.023	0.0068	3.1E-06
Cadmium	2.898	1.27E-05	3.85E-06	3.85E-06	0.013	0.0038	--
Chromium, trivalent	31.58	1.38E-04	4.19E-05	4.19E-05	0.000092	0.000028	--
Copper	48	2.10E-04	6.37E-05	6.37E-05	0.0053	0.0016	--
Mercury	0.19	8.33E-07	2.52E-07	2.52E-07	0.0028	0.00084	--
Nickel	17.26	7.57E-05	2.29E-05	2.29E-05	0.0038	0.0011	--
Silver	2.144	9.40E-06	2.85E-06	2.85E-06	0.0019	0.00057	--
Zinc	67.24	2.95E-04	8.93E-05	8.93E-05	0.0010	0.00030	--
Total					**0.050**	**0.015**	**3.1E-06**

Table 7: Recreational Exposures at Area 8
Dermal Contact with Sediment
Future

Exposure Medium: Sediment
Exposure Point: Area 8 Beach in Liberty Bay
Receptor Population: Recreational Populations
Receptor Age: Children and Adults

Noncancer Hazard = EPC x SIFnc x ABSd / RfD
Cancer Risk = EPC x SIFc x ABSd x CSF

Parameter	Units	RME	
		child	adult
Chemical Concentration in Sediment (C-sd)	mg/kg	chem-specific	chem-specific
Exposure Frequency (EF)	days/year	120	120
Exposure Duration (ED)	years	6	20
Surface Area Available for Contact (SA)	cm^2	2,373	6,032
Adherence Factor (AF)	mg/cm^2	0.2	0.12
Fraction of day for dermal exposures (FC)	unitless	1	1
Conversion Factor (CF)	kg/mg	1.0E-06	1.0E-06
Body Weight (BW)	kg	15	80
Averaging Time (noncancer) (ATnc)	days	2190	7300
Averaging Time (cancer) (ATc)	days	25550	25550
SIFnc-child = (EF*ED*SA*AF*FC*CF)/(BW*ATnc)	$(day)^{-1}$	1.04E-05	
DFadj (Dermal Adjusted Factor) = (EDch*SAch*AFch /BWch) +(EDa*SAa*AFa/BWa)	mg-yr/day-kg	370.80	
SIFnc (child/adult) = (DFadj*EF*FC*CF)/(ATnc-child + ATnc-adult)		4.69E-06	
SIFc = (DFadj*EF*FC*CF)/ATc	$(day)^{-1}$	1.74E-06	

Chemical	RfD-D (mg/kg-d)	CSF-D $(mg/kg-d)^{-1}$	AbsD
Arsenic	3.0E-04	1.5E+00	3.0E-02
Cadmium	2.5E-05	--	1.0E-03
Chromium, trivalent	2.0E-02	--	--
Copper	4.0E-02	--	--
Mercury	2.1E-05	--	--
Nickel	8.0E-04	--	--
Silver	2.0E-04	--	--
Zinc	3.0E-01	--	--

Chemical	RME - Hazard and Risk Results						
	Sediment EPC (mg/kg)	Noncancer Intake Child (mg/kg-d)	Noncancer Intake Child-Adult (mg/kg-d)	Cancer Intake Lifetime (mg/kg-d)	Noncancer Hazard Child	Noncancer Hazard Child-Adult	Cancer Risk Lifetime
Arsenic	2.571	2.67E-05	1.21E-05	1.21E-05	0.0027	0.0012	5.4E-07
Cadmium	2.898	3.01E-05	1.36E-05	1.36E-05	0.0012	0.00054	--
Chromium, trivalent	31.58	3.29E-04	1.48E-04	1.48E-04	--	--	--
Copper	48	4.99E-04	2.25E-04	2.25E-04	--	--	--
Mercury	0.19	1.98E-06	8.91E-07	8.91E-07	--	--	--
Nickel	17.26	1.80E-04	8.09E-05	8.09E-05	--	--	--
Silver	2.144	2.23E-05	1.01E-05	1.01E-05	--	--	--
Zinc	67.24	6.99E-04	3.15E-04	3.15E-04	--	--	--
Total					**0.0039**	**0.0017**	**5.4E-07**

Table 8: Recreational Exposures at Area 8
Sediment Summary (Ingestion + Dermal Exposures)
Future

Exposure Medium: Sediment
Exposure Point: Area 8 Beach in Liberty Bay
Receptor Population: Recreational Populations
Receptor Age: Children and Adults

	Ingestion			Dermal			Cumulative		
	Noncancer Hazards		Cancer Risk	Noncancer Hazards		Cancer Risk	Noncancer Hazards		Cancer Risk
	Child	Child-Adult	Lifetime	Child	Child-Adult	Lifetime	Child	Child-Adult	Lifetime
Arsenic	0.023	0.0068	3.1E-06	0.0027	0.0012	5.4E-07	0.025	0.0080	3.6E-06
Cadmium	0.013	0.0038	--	0.0012	0.00054	--	0.014	0.0044	--
Chromium, triva	0.000092	0.000028	--	--	--	--	0.000092	0.000028	--
Copper	0.0053	0.0016	--	--	--	--	0.0053	0.0016	--
Mercury	0.0028	0.00084	--	--	--	--	0.0028	0.00084	--
Nickel	0.0038	0.0011	--	--	--	--	0.0038	0.0011	--
Silver	0.0019	0.00057	--	--	--	--	0.0019	0.00057	--
Zinc	0.0010	0.00030	--	--	--	--	0.0010	0.00030	--
TOTAL	**0.050**	**0.015**	**3.1E-06**	**0.0039**	**0.0017**	**5.4E-07**	**0.054**	**0.017**	**3.6E-06**

Table 9: Keyport Area 8 - Recreational Populations Incremental Risk Over Background

Tissue - Ingestion

Chemical	Noncancer Hazards						Cancer Risks		
	Area 8		Reference Area		Incremental				
	Child	Child-Adult	Child	Child-Adult	Child	Child-Adult	Area 8	Reference Area	Incremental
Arsenic, inorganic	0.025	0.015	0.032	0.019	None	None	2.5E-06	3.2E-06	None
Cadmium	0.14	0.083	0.12	0.073	0.016	0.010	--	--	--
Chromium, trivalent	0.00010	0.000057	0.000090	0.000053	0.0000063	0.0000037	--	--	--
Copper	0.0083	0.0049	0.0080	0.0047	0.00032	0.00019	--	--	--
Methyl mercury	0.024	0.014	0.011	0.0065	0.013	0.0078	--	--	--
Nickel	0.0068	0.0040	0.0062	0.0036	0.00067	0.00040	--	--	--
Silver	0.012	0.0070	0.0025	0.0015	0.0094	0.0056	--	--	--
Zinc	0.012	0.0071	0.014	0.0080	None	None	--	--	--
TOTAL	**0.23**	**0.14**	**0.20**	**0.12**	**0.031**	**0.018**	**2.5E-06**	**3.2E-06**	**None**

Sediment - Ingestion + Dermal

Chemical	Noncancer Hazards						Cancer Risks		
	Area 8		Reference Area		Incremental				
	Child	Child-Adult	Child	Child-Adult	Child	Child-Adult	Area 8	Reference Area	Incremental
Arsenic	0.025	0.0080	0.073	0.023	None	None	3.6E-06	3.9E-06	None
Cadmium	0.014	0.0044	0.0020	0.00064	0.012	0.0038	--	--	--
Chromium, trivalent	0.000092	0.000028	0.00011	0.000032	None	None	--	--	--
Copper	0.0053	0.0016	0.0028	0.00084	0.0025	0.0008	--	--	--
Mercury	0.0028	0.00084	0.0013	0.00041	0.0014	0.00043	--	--	--
Nickel	0.0038	0.0011	0.0072	0.0022	None	None	--	--	--
Silver	0.0019	0.00057	0.00011	0.000034	0.0018	0.00054	--	--	--
Zinc	0.0010	0.00030	0.00088	0.00027	0.00010	0.000030	--	--	--
TOTAL	**0.054**	**0.017**	**0.087**	**0.028**	**None**	**None**	**3.6E-06**	**3.9E-06**	**None**

APPENDIX G
IEUBK Model Outputs

LEAD MODEL FOR WINDOWS Version 1.1

==========

Model Version: 1.1 Build11
User Name: Laura Scheffler
Date: 2/1/2017
Site Name: Keyport Area 8
Operable Unit:
Run Mode: Research

==========

****** Air ******

Indoor Air Pb Concentration: 30.000 percent of outdoor.
Other Air Parameters:

Age	Time Outdoors (hours)	Ventilation Rate (m^3/day)	Lung Absorption (%)	Outdoor Air Pb Conc (µg Pb/m^3)
.5-1	1.000	2.000	32.000	0.100
1-2	2.000	3.000	32.000	0.100
2-3	3.000	5.000	32.000	0.100
3-4	4.000	5.000	32.000	0.100
4-5	4.000	5.000	32.000	0.100
5-6	4.000	7.000	32.000	0.100
6-7	4.000	7.000	32.000	0.100

****** Diet ******

Age	Diet Intake(µg/day)
.5-1	2.371
1-2	2.272
2-3	2.531
3-4	2.467
4-5	2.405
5-6	2.540
6-7	2.788

Alternative Dietary Values
Home grown fruits concentration: 0.000 µg/g
Home grown vegetables concentration: 0.000 µg/g
Fish from fishing concentration: 0.072 µg/g
Game animals from hunting concentration: 0.000 µg/g
Home grown fruits factor: 0.000 % of all fruits
Home grown vegetables factor: 0.000 % of all vegetables
Fish from fishing factor: 15.360 %of all meat
Game animals from hunting factor: 0.000 % of all meat

****** Drinking Water ******

Water Consumption:

Age	Water (L/day)
.5-1	0.200
1-2	0.500
2-3	0.520
3-4	0.530
4-5	0.550
5-6	0.580
6-7	0.590

Drinking Water Concentration: 4.000 µg Pb/L

****** Soil & Dust ******

Multiple Source Analysis Used
Average multiple source concentration: 150.000 µg/g

Mass fraction of outdoor soil to indoor dust conversion factor: 0.700
Outdoor airborne lead to indoor household dust lead concentration: 100.000
Use alternate indoor dust Pb sources? No

Age	Soil (µg Pb/g)	House Dust (µg Pb/g)
.5-1	200.000	150.000
1-2	200.000	150.000
2-3	200.000	150.000
3-4	200.000	150.000
4-5	200.000	150.000
5-6	200.000	150.000
6-7	200.000	150.000

****** Alternate Intake ******

Age	Alternate (µg Pb/day)
.5-1	0.000
1-2	0.000
2-3	0.000
3-4	0.000
4-5	0.000
5-6	0.000
6-7	0.000

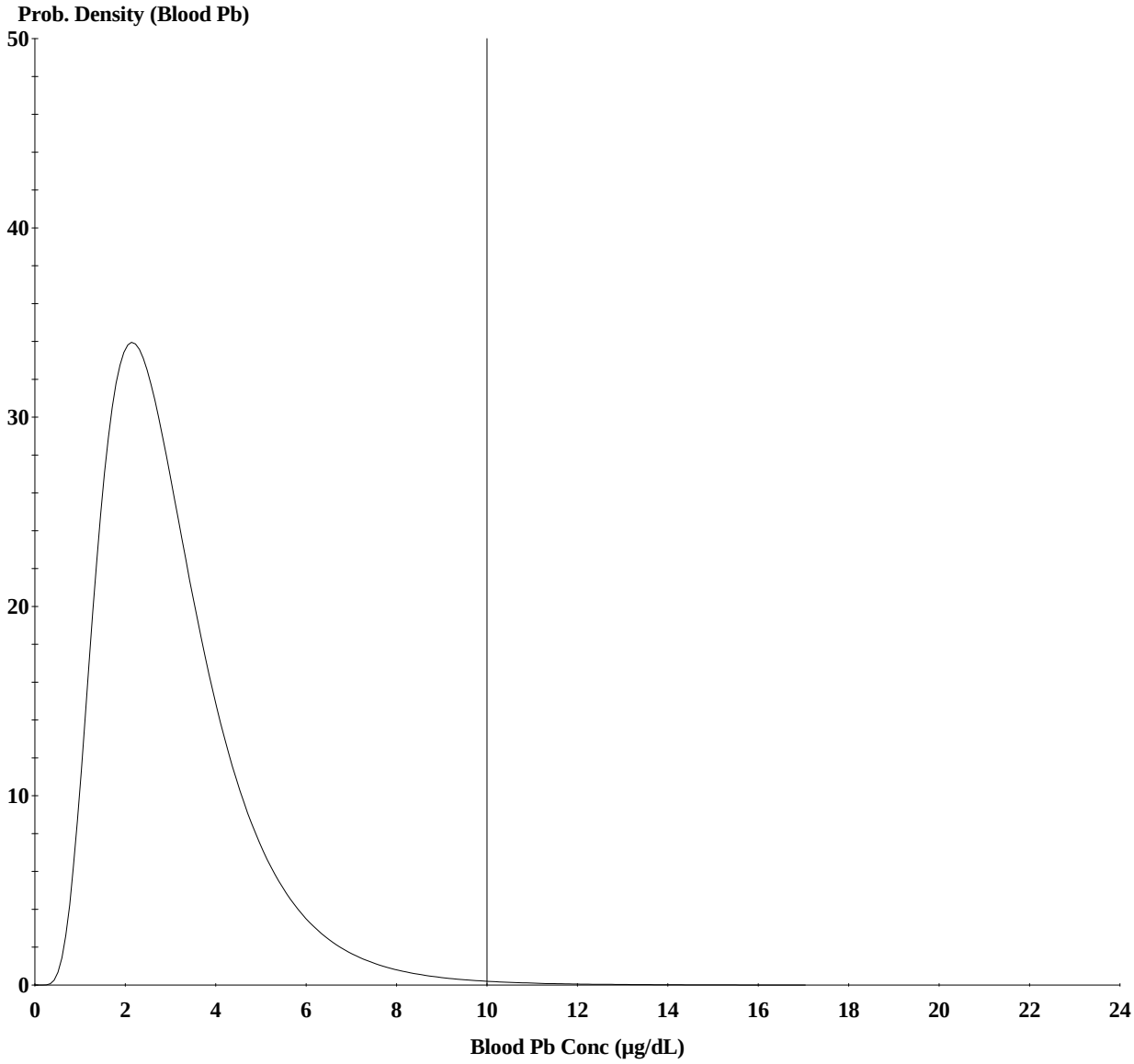
****** Maternal Contribution: Infant Model ******

Maternal Blood Concentration: 1.000 µg Pb/dL

****
CALCULATED BLOOD LEAD AND LEAD UPTAKES:
****

Year	Air (µg/day)	Diet (µg/day)	Alternate (µg/day)	Water (µg/day)
.5-1	0.021	1.112	0.000	0.375
1-2	0.034	1.054	0.000	0.928
2-3	0.062	1.186	0.000	0.975
3-4	0.067	1.167	0.000	1.002
4-5	0.067	1.156	0.000	1.058
5-6	0.093	1.228	0.000	1.122
6-7	0.093	1.353	0.000	1.145

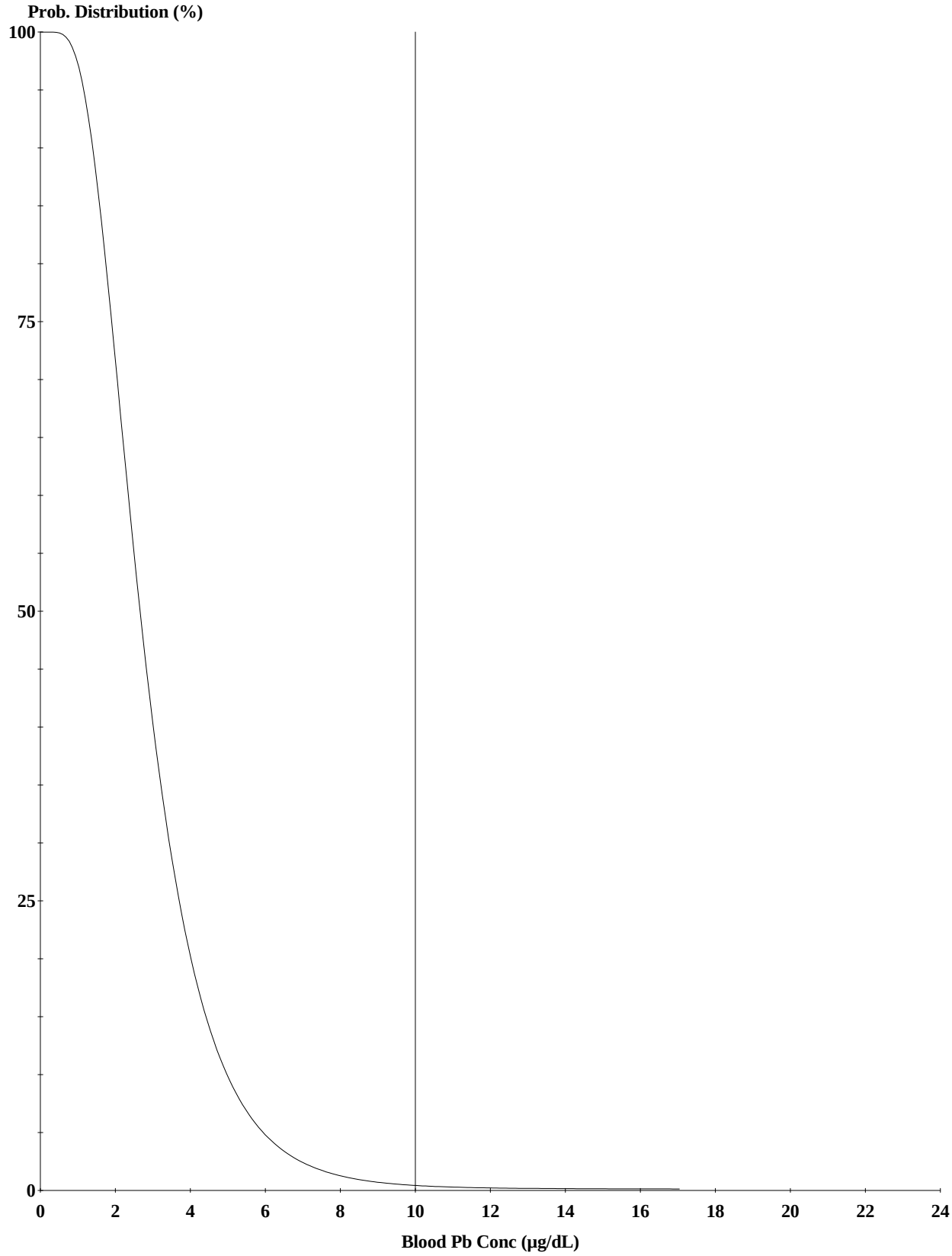
Year	Soil+Dust (µg/day)	Total (µg/day)	Blood (µg/dL)
.5-1	4.126	5.635	3.1
1-2	6.485	8.502	3.5
2-3	6.547	8.770	3.3
3-4	6.607	8.843	3.1
4-5	4.975	7.256	2.6
5-6	4.505	6.949	2.2
6-7	4.268	6.859	2.0



Cutoff = 10.000 µg/dl
Geo Mean = 2.788
GSD = 1.600
% Above = 0.329
% Below = 99.671

Age Range = 0 to 84 months

Run Mode = Research



Cutoff = 10.000 µg/dl
Geo Mean = 2.788
GSD = 1.600
% Above = 0.329

Age Range = 0 to 84 months

Run Mode = Research

APPENDIX H

Agency Comments on the Draft and Draft Final Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report and Responses to Comments

Response to Dept. of Ecology Comments (by John Evered, Cleanup PM) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
1	General Comment	Use of AVS/SEM to determine bioavailability - The ecological risk assessment relies heavily on the assumption that metals, particularly cadmium, are not bioavailable in the sediment due to there being enough AVS available to bind the SEM, suggesting that seeps are the primary medium contributing to elevated cadmium concentrations in shellfish tissue. Ecology concurs that although the AVS/SEM method can be useful in predicting bioavailability of cationic metals in anoxic sediments, there are limitations which must be taken in to account when interpreting the results. The AVS/SEM model assumes that reducing conditions will remain constant, i.e., that reducing conditions at the time of sampling will remain stable in the future and throughout the site. The model does not account for both spatial and temporal variability of sulfate that would be typical of a dynamic (page 6 of the introduction) intertidal beach that is naturally aerated two times a day (section 4.2.2.4). The model also does not take in to account the potential for dissociation during oxidation of the metal sulfide complexes, thus increasing bioavailability, which may occur during resuspension or aeration events typical of a dynamic intertidal environment. Another major uncertainty of the AVS/SEM model is that it assumes no exposure from dietary metal uptake from sediments despite the fact that even under reducing conditions direct uptake can occur in some species following sediment ingestion (Luoma and Je1me 1977, Lee et al 2000). Lee et al (2000) described dietary uptake as the best explanation for the	To strengthen the conclusions based on the 2015/2016 AVS/SEM data, which are available for one of the five sediment samples with an exceedance of the sediment benchmark for cadmium, and based on the bioassay results for the 2008 sediment sample, additional bioassays will be recommended in accordance with WAC 173-204- 562(3)(d) requirements. Specifics regarding the potential bioassays and/or bioaccumulation tests will be discussed with the project team. See Suquamish Tribe RTC#18.) The following text was added to the end of Section 4.3.4: Nonetheless, to strengthen the conclusions based on the 2015/2016 SEM/AVS data, which are available for one of the five sediment samples with an exceedance of the sediment benchmark for cadmium, and based on the bioassay results from the planned 2008 sediment and seep sampling, additional bioassays will be recommended in accordance with WAC 173-204- 562(3)(d) requirements.

Comment	Section	Comment/Recommendation	Response
		poor correlation that was observed between measured Cd, Zn, and Ni bioaccumulation by five different benthic species (including 2 species of clams) and the AVS/SEM model assumptions. Furthermore, the assumption that cadmium is not bioavailable in the sediments is predicated on one AVS/SEM sample where cadmium sediment benchmarks exceedances were recorded and one bioassay from 2008. As stated in the report there are no 2015/2016 AVS/SEM data available for 4 other sediment samples with cadmium sediment exceedances. Ecology believes that one AVS/SEM sample and one bioassay result that is almost 10 years old is not sufficient to make a determination on the cmTent bioavailability of contaminants based upon the concerns described above. It is known that natural factors such as ammonia concentrations (Kolm et al 1997), sulfides (Wang et al 1999), grain size (Lawrence et al 1997), TOC, salinity and dissolved oxygen can all influence the outcome of bioassays. To assume that all of these variables remained constant over 10 years, meaning the assumptions of the 2008 bioassays are still valid today, does not take in to account the inherent spatial and temporal variability of intertidal ecosystems. To extrapolate older data whilst ignoring the potential for significant change of a number of variables does not provide an accurate representation of the current bioavailability of contaminants at the site. Ecology is not disagreeing that the source of contamination in tissue is the seep water, but without further investigation it is hard to make that determination.	

Response to Dept. of Ecology Comments (by John Evered, Cleanup PM) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
		Ecology requests that additional bioassays be performed per the requirements of WAC 173-204- 562(3)(d) (two acute and one chronic test), and the document be amended accordingly. The locations for additional bioassays should be determined with input from the project team to confirm the hypothesis that seep water is the primary medium contributing to elevated cadmium tissue concentrations.	
2	General Comment	Reference area sediment concentrations - Has an evaluation of the sediment contaminant concentrations been performed at the Penrose Point reference area? As HQ values for the reference area were similar or higher than site values, an understanding of Penrose baseline sediment concentrations will confirm that an appropriate reference site was selected for comparison.	Penrose Point was selected by the project team based on the remoteness of the site, lack of nearby point sources, and good agreement with site sediment characteristics and biological habitat (U.S. Navy 2015c). As specified in the approved QAPP (U.S. Navy 2015c) and HHERA Work Plan (U.S. Navy 2016a), reference area tissue (littleneck clam) and marine surface water were collected from Penrose Point State Park, and background sampling for sediment was not conducted because the Ecology *Bold* natural background sediment levels for Puget Sound were selected as the background sediment COC concentrations for the HHERA.
3	Section 1.2 Post ROD activities, page 5, 1st full paragraph, 3rd sentence.	Please revise the following sentence "A comparison of sediment data to the state SMS... .. . ." to read that the data was compared to the state SMS benthic standards.	The sentence will be revised as follows: "A comparison of sediment data to the state SMS **benthic standards** (Chapter 173-204 of the Washington Administrative Code [WAC]) ..."
4	Section 2.1.1	Please add a citation to the text following the statement that	The sentence will be revised as follows:

Response to Dept. of Ecology Comments (by John Evered, Cleanup PM) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
	Clam Tissue data, page 10, 2nd paragraph, 3rd sentence.	Manila and littleneck clams are similar organisms, often confused for each other in the environment, and are consumed in the same quantities.	"It is assumed that they are consumed in the same quantities, since manila and littleneck clams are similar organisms in appearance and are often confused for each other in the environment (http://wdfw.wa.gov/fishing/shellfish/clams)."
5	Section 2.2.2 Mercury, page 13, 1st paragraph, last sentence.	The text states that both total mercury and methylmercury are evaluated in the ERA. Please revise to reflect that total and methyl mercury were also addressed in the HHRA.	The text (now Section 2.3.2) will be revised as follows: "**In addition to total mercury, methylmercury was analyzed for in** the tissue samples collected during the 2015 and 2016 sampling events. **Both total mercury and methylmercury results were evaluated in the HHRA and ERA.** … Methylmercury **results were** used to evaluate human health risks due to ingestion of seafood. **Total mercury results were used to evaluate human health risks due to incidental ingestion and dermal contact with sediment.** ~~Both total mercury and methylmercury are evaluated~~ In the ERA, ~~as~~ methylmercury…"
6	Section 2.2.3 Chromium, page 14, 1st paragraph, last sentence.	Text states that EPAs ecological soil screening level for chromium III is less than the EcoSSL for chromium IV. Should this state that the EcoSSL for Cr III is less than the EcoSSL for Cr VI (not IV)?	The typo will be corrected: "…for chromium III is less than (more conservative than) the EcoSSL for chromium **VI** (EPA 2008)."

Response to Dept. of Ecology Comments (by John Evered, Cleanup PM) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
7	Section 2.4.3 Clam Tissue, page 21.	Please expand on the methods that were used to identify potential outliers in the clam tissue, especially as it is stated that inclusion of these outliers resulted in higher BTVs than the BTV calculated without the outliers. Additionally was this approach used to identify outliers in the area 8 tissue and sediment datasets.	Additional text will be added to Section 2.4.3 based on the response below (see also Suquamish Tribe RTC#8 and EPA LK RTC#14). Outliers were not removed from the Area 8 data sets (see Section 2.4.4). The outliers were identified by ProUCL and removed for the Penrose Point Tissue BTV calculation as provided on the output by EPA's ProUCL based on the Dixon Test for 5% significance level (see Appendix C outputs). Including outliers in the calculation of the BTV results in a higher value which is less conservative when performing a single point comparison of site sample results to the BTV. A BTV was only calculated for the Penrose Point clam tissue because sediment values have been established based on the Bold data set in Table 10-1 of SCUMII (90/90 UTL) for natural background. As discussed on page 22, outliers were not identified or excluded from the Area 8 tissue and sediment data set because "As noted in the ProUCL Version 5.1.002 Technical Guide (USEPA 2015), outliers often have minimal influence on

Comment	Section	Comment/Recommendation	Response
			hypotheses testing statistics. Thus, no outliers were removed from the Area 8 data sets prior to performing the statistical analysis."
8	Section 3.1.2 Exposure Area, page 28.	There is no description here or in any of the figures that provide an outline of the areas that had sediment contaminant concentrations above screening levels (SMS benthic standards). If concentrations along transect 14 below screening levels it should be stated so as to demonstrate that contamination has been appropriately bounded.	There were only four stations that exceeded SMS benthic standards as listed on Table 29. The following text will be added at the end of the second paragraph: "Because 2015 and 2016 sediment results were below ecological screening levels (SMS benthic standards) along transect 14 to the south of Seep B and transect 13 to the north, results demonstrate that contamination has been appropriately bounded (see Table 29)."
9	Section 4.3.4.5 Historical Biological Survey Data, page 71, last paragraph, 2nd sentence.	The final paragraph in this section states,".....that clam tissue collection was possible at all sampling locations during the 2015 and 2016 site investigations... ", however on page 28 in the Exposure Area section the report states, "insufficient quantities of clams are present in the subtidal zone to collect an adequate sample size". Please reconcile or revise these sentences for continuity.	The 2015 and 2016 clam sample locations were established within the clam band from the seawall at approximately +3 feet MLLW to -2.5 feet MLLW. Page 28 is referring to the subtidal zone deeper than -2.5 feet MLLW which is beyond the clam band. The sentence will be revised as follows: "The other supporting facts include: 1) that clam tissue collection was possible at

Response to Dept. of Ecology Comments (by John Evered, Cleanup PM) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
			the ~~all~~ 2015 and 2016 sampling locations planned for clam tissue collection (within the clam band from the seawall at approximately +3 feet MLLW to -2.5 feet MLLW), including areas where the maximum seep and sediment cadmium concentrations have been found..."
10	Section 4.4.1 Problem Formulation, page 73, 3rd bullet, 2nd sentence.	Third bullet states, "However, because all the AVS nondetect samples had AVS/SEM ratios greater than 1, this uncertainty is unlikely to effect the ERA AVS/SEM findings." Does the word 'findings' relate to the fact that the SEM/AVS ratios shown on table 31 are large enough that any reduction in acid volatile sulfides would not likely be sufficient to result in a ratio less than 1? This sentence could currently be read to mean that 'findings' relates to the hypothesis that is presented that sediment does is not a source of bioavailable metals.	The statement in the third bullet will be revised as follows: "....this uncertainty is unlikely to affect the ERA AVS/SEM findings *because the SEM/AVS ratios for these nondetect samples are well above 1.0 ranging from 22.6 to 85.9. This implies that any reduction in acid volatile sulfides would not likely be sufficient to result in a ratio less than 1.0.*"
11	Table 31 AVS Concentrations, SEM Sums and AVS/SEM Ratios for Area 8 Sediment.	The ratios that are displayed in the table are titled SEM\AVS ratio, which is intuitive as the ratio is derived by dividing the sum of SEM concentration per station by the acid volatile sulfides concentration. The rest of the document (including the title of the table) expresses this ratio as AVS/SEM. More recent literature seems to display the difference as ∑SEM-AVS rather, please consider revising the text to reflect this difference.	The calculation of the ratio is the sum of SEM concentrations divided by the AVS concentrations, so the reviewer is correct in that it is often referenced as the SEM/AVS ratio. However, AVS/SEM has historically been used and is still commonly used, but may be considered an outdated term. The text and tables will be changed to SEM/AVS as requested.
12	Section 4.4.4 Risk	Final bullet states, "mercury sediment concentrations were found to be comparable to mercury in background (table 30)".	Table 30 will be revised to include the 90/90 UTL Bold natural background values

Comment	Section	Comment/Recommendation	Response
	Characterization, page 76, last bullet, 1st sentence.	Per section 2.4.2, the 90/90 UTL BOLD natural background dataset was used as the background threshold value, however this is not displayed in table 30, as is implied in this sentence. Suggest replacing the work 'background' with either natural background or BTV, and adding a column in table that shows 90/90 UTL concentrations from the BOLD study for comparison. For information page 10-16 of Ecology's SCUM II manual shows calculated natural background values.	as listed on Table 10-1 of SCUM II. The 1st sentence will be revised as follows: "...mercury sediment concentrations **at Area 8** were found to be **consistent with natural background based on comparison to Ecology's 90/90 UTL of 0.2 mg/kg (Table 30) and the population-population statistical comparison of the Area 8 data set versus the Bold natural background data set (Table 10)."**
13	Section 6.1.1 Background and Reference Area Evaluation, page 81, 1st sentence.	The first sentence of this section is confusing as background concentrations of chemicals are defined as concentrations that occur on site in the absence of site activities. Later in the paragraph it is stated that the Ecology BOLD natural background values were used to characterize site sediment concentrations relative to background. Please consider revising or removing the first sentence to reflect Ecology's definition of background.	The first sentence will be deleted. The rest of the introductory paragraph will be revised to read: "Because metals occur naturally in the environment, comparison of site data to background concentrations allows determination of the degree of contamination associated with site activities. **Natural background is defined in the SMS rule (WAC 173-204-505(11)) as the concentration of a hazardous substance consistently present in the environment that has not been influenced by localized human activities.** Penrose Point was selected by the project team as the reference location based on the remoteness of the site, lack of nearby

Comment	Section	Comment/Recommendation	Response
			point sources, and good agreement with site sediment characteristics and biological habitat (U.S. Navy 2015c). **In addition,** the Ecology BOLD natural background values were used to characterize site sediment concentrations relative to background."
14	Section 6.1.1 Background and Reference Area Evaluation, page 82, 2nd bullet, last sentence.	In the second bullet, please replace "regional reference area concentrations" with "Penrose Point reference area concentrations so as to avoid any confusion with Ecology's regional background definition. See WAC 173-204-505(16) of the SMS for further definitions of regional background.	The sentence will be revised as follows: "...however, the concentrations of cadmium in clam tissue also are generally consistent with **Penrose Point** reference area concentrations, as the magnitude of exceedance over the BTV is low".
15	Section 6.2.2 Benthic Organisms, page 87, under **Shellfish Abundance Metrics**, 1st paragraph, last sentence.	Per the SMS benthic abundance should be evaluated per SMS' biological criteria, see table IV in WAC 173-204-562. Without a quantitative evaluation of shellfish population abundance, in addition to an assessment of taxonomic richness of benthic macroinvertebrates at both the site and a reference area it not appropriate to state that clam populations along the Area 8 beach are not significantly impacted. Please consider revising or removing this statement.	Please also see Response to Suqamish Tribe Comment 20. ~~Although the shellfish abundance surveys did not follow strict SMS guidance and were focused on clams, these reports were used as one benchmark in the weight of evidence assessment of benthic community health.~~ The first sentence will be removed and replaced by the following text: "The two shellfish abundance studies provide supporting evidence of the lack of direct impacts to populations."

Comment	Section	Comment / Recommendation	Response
			In addition, The word “conclusion” will be replaced with “hypothesis” in the second to last sentence. The last sentence in this paragraph will be deleted. ~~Thus, the lines of evidence suggest that clam populations along the Area 8 beach are not significantly impacted by metals in Area 8 groundwater discharging as seeps.~~

References:

Kohn, N.P., Word, J.Q., Niyogi, D.K., Ross, L.T., Dillon, T., and Moore, D.W., 1994, "Acute Toxicity of Ammonia to Four Specie of Marine Amphipod," Mar. Environ. Res. 38(1): 1-5.

Lawrence, C., Duh, D., Myers, J., and Pallop, T., 1997, "The Effects of grain Size and TOC on Marine Amphipods in Whole Sediment Bioassays," SETAC, 18th Annual Meeting, IT Corporation, 2200 Cottontail Ln, Somerset, NJ, 08873.

Lee, B.-G., J.-S. Lee, S. N. Luoma, H. J. Choi, and C.-H. Koh. 2000. "Influence of Acid Volatile Sulfide and Metal Concentrations on Metal Bioavailability to Marine Invertebrates in Contaminated Sediments," *Environmental Science and Technology* **34:** 4517-23.

Luoma, S. N., and E. A. Jenne. 1977. "The Availability of Sediment Bound Cobalt, Silver, and Zinc to a Deposit-Feeding Clam," in *Biological Implications of Metals in the Environment,* R. E. Wildung and H. Drucker, eds. CONF-750929.Springfield, Va.: National Teclmical Information Service.

Wang, F. and Chapman, P.M., 1999, "Biological Implications of Sulfide in Sediment-A Review Focusing on Sediment Toxicity," Environmental Toxicology and Chemistry 18(11): 2526-2532.

Response to Dept. of Ecology Comments (by Mahbub Alam, PhD, PE) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
1	Section 2.1, Page 9, 2nd paragraph .	"The risk assessments quantitatively evaluate only the data collected during the 2015 and 2016 sampling events to assess current risks. Data from historical sampling was not used to ensure this risk assessment is based on current site conditions." Was this based on project team consensus or recommendation?	It was a recommendation in the 3rd and 4th 5-year reviews and it was a project team consensus to only include the data collected during 2015 and 2016 sampling events as documented in the QAPP, QAPP addendum, and risk assessment work plan. These documents will be referenced at the end of the first sentence.
2	Section 2.4,Page 19, Last sentence of Section 2.4 (before Section 2.4.1)	"Because the marine surface water data indicates that site surface water is minimally impacted by COC concentrations and no exceedances of benchmarks were noted, no statistical comparison was performed between site and reference area marine surface water data." While it is true marine water near Area 8 meets surface water quality standards, it seems concentrations are elevated compared to reference area concentration. Some seep samples exceed the surface water quality ARARs. It would be nice to perform a statistical comparison to verify whether a statistically significant difference in surface water concentration between reference area and Area 8 exists or not.	As discussed in the risk assessment work plan, the marine water data was to be compared to ecological benchmarks and further analysis would be performed only if the benchmarks were exceeded. As indicated in the ROD, the main focus of the HHRA and ERA is on sediment and tissue at the site. While no statistical comparisons of the surface water data were performed, the site and reference area surface water data are presented together on Table 4. The last sentence of Section 2.4 will be modified as follows: Although the marine surface water data indicates that site surface water is impacted by COC concentrations, no exceedances of benchmarks were noted. Therefore, no statistical comparison was performed between site and reference area marine surface water data.

Response to Dept. of Ecology Comments (by Mahbub Alam, PhD, PE) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
3	Tables 7 and 9	The maximum and minimum values in these multipage Tables are misleading as these seem to not include all data reflecting only the displayed one page data. On the other hand, the % samples exceeding BTV are based on all data. The minimum and maximum should be based on all data.	Tables 7 and 9 will be corrected to reflect the minimum/maximum across the entire data set.
4	Table 17	Ecology believes the hazard and risk results should be reported to at least two significant figures to discern the incremental change in Hazard and risk. Table 17 show one significant figure while the calculations in Appendix E spreadsheets show two significant figures. It is important to note that calculations should be consistent with the measured values. It is also necessary not to include "exact" numbers such as coefficient, design parameters in the considerations for significant figures calculation.	Table 17 summarizes the results to one significant figure as prescribed by EPA guidance (USEPA 1989; USEPA 2001). Appendix E reports at least two significant figures in order to provide more detail,. The significant figures will be reviewed in Table 17 and Appendix E to ensure consistency. Given the unavoidable multiple layers of uncertainty inherent in risk assessment (natural variability, sampling error, measurement error, and estimation error, estimation of toxicity values, etc.) showing the total hazard/risk to more than 1 significant figure gives an inappropriate level of accuracy and confidence in the risk estimations. During comment resolution, the Navy agreed to add 2 significant figures to the risk estimates presented on Tables 17 and 18. A note of caution regarding the perceived precision of risk estimates at 2 significant

Comment	Section	Comment/Recommendation	Response
			figures versus 1 significant figure will be added to the discussion in Section 3.3.3 and as a footnote to Tables 17 and 18, as shown in the redline Draft Final document for review.
5	Section 3.3.3.1, Page 36, 2nd paragraph, 3rd sentence.	"This result indicates that exposure to COCs in clams collected from Area 8 is not substantially different than the exposure from the reference areas, and the incremental site noncancer HIs are 0.6 and 0.7 for child and combined child/adult receptors, respectively." Ecology would also like to look at the % incremental hazard & risk from reference station. The following Table is created from the original Table by adding additional columns for % incremental. Since cumulative hazard index in both Area 8 and reference station exceed one (HI>1), it needs to be discussed whether percent incremental hazard is allowable for individual chemicals like Mercury, Silver and Cadmium. Note for sediment ingestion plus dermal hazard, the total hazard is predominantly influenced by Arsenic where reference area exposure point concentration is higher that Area 8. As a result total hazard calculation is skewed. Also, if incremental noncancer hazards for child-adult are summed up, cumulative total for Child-Adult for tissue ingestion is 0.94 (Table says 0.7) and tissue plus sediment ingestion is 0.95 which is very close to target health goal of 1. The project team needs to decide whether incremental hazards would be calculated by adding the individual increments of each chemical of interest or by the difference of total hazards by all chemicals	The calculation of incremental site hazard and risk were carried out as agreed upon by the project team and documented in the risk assessment work plan. A separate discussion of risk estimates for tribal and recreational harvesters will be provided, including COCs contributing as "risk drivers" to cumulative risk levels. (See Suquamish Tribe RTC#12.) However, the % increase in incremental hazard and risk from reference station will not be included, as suggested. If the incremental risk meets target health goals, then the % increase in incremental risk is not relevant. Additionally, inclusion of this calculation in the report suggests that it is a factor being considered for the site management, which is not the case due to the lack on national guidance for such interpretation relative to site management. A footnote will be added to Tables 17 and 18 that cumulative risks and hazards were calculated on the unrounded numbers, thus the cumulative values presented may vary

Comment	Section	Comment/Recommendation	Response
		of interests (subtracting the site and the reference). If we account for total hazards, then the chemicals having higher concentrations in the reference area downplays the total hazards for the chemicals that are significantly higher than the reference area.	slightly from summation of the rounded values. The cumulative incremental hazards were calculated as the difference between the cumulative site and cumulative reference area hazards – not summation of the individual chemical incremental risks. This approach considers the contribution of each COC evaluated in the cumulative calculations, which is appropriate for determining overall incremental risks. Since USEPA recommends a noncancer target hazard index of equal to or greater than 1 as a starting point for remediation goals in the CERCLA program, which is what 0.95 may be rounded to (depending on the 3rd significant figure), taking action on an HI of 0.95 will not impact the overall site management and would potentially detract from other parts of the site that should be addressed. During comment resolution, Ecology requested input from the EPA risk assessor on the response to this comment, since the EPA risk assessor was not able to attend the comment resolution meeting. On Friday September 29, Laura Scheffler (AECOM risk assessor) consulted by phone with Lon Kissinger (EPA risk assessor), on the subject of this comment. Lon agreed with the Navy's

Comment	Section	Comment/Recommendation	Response
			response to this comment in that the cumulative incremental risks and hazards were correctly calculated as the difference between cumulative Area 8 and cumulative reference area risks and hazards. In addition, Lon agreed that a discussion of percent incremental increase over reference areas is irrelevant when target health goals are met, as is the case at this site. Thus, no changes were made to the document in response to this comment.

Table 9: Keyport Area 8 - Subsistence Incremental Risk Over Background

	Noncancer Hazards								Cancer Risks		
	Area 8		Reference Area		Incremental						
Chemical	Child	Child-Adult	Child	Child-Adult	Child	% increase	Child-Adult	% increase	Area 8	Reference Area	Incremental
Tissue - Ingestion											
Arsenic, inorganic	0.5	0.6	0.6	0.8	None		None		3E-04	3E-04	None
Cadmium	3	3	2	3	0.3	13%	0.4	13%	--	--	--
Chromium, trivalent	0.002	0.002	0.002	0.002	0.0001	7%	0.0001	7%	--	--	--
Copper	0.2	0.2	0.2	0.2	0.006	4%	0.007	4%	--	--	--
Methyl mercury	0.5	0.6	0.2	0.3	0.3	119%	0.3	119%	--	--	--
Nickel	0.1	0.2	0.1	0.1	0.01	11%	0.02	11%	--	--	--
Silver	0.2	0.3	0.0	0.1	0.2	376%	0.2	376%	--	--	--
Zinc	0.2	0.3	0.3	0.3	None		None		--	--	--
TOTAL	**4**	**5**	**4**	**5**	**0.6**	**16%**	**0.7**	**16%**	**3E-04**	**3E-04**	**None**
Sediment - Ingestion + Dermal											
Arsenic	0.07	0.01	0.2	0.04	None		None		6E-06	2E-05	None
Cadmium	0.04	0.008	0.005	0.001	0.03	590%	0.006	590%	--	--	--
Chromium, trivalent	0.0003	0.00005	0.0003	0.00005	None		None		--	--	--
Copper	0.01	0.003	0.008	0.001	0.007	89%	0.001	89%	--	--	--
Mercury	0.008	0.001	0.004	0.0007	0.004	107%	0.0007	107%	--	--	--
Nickel	0.01	0.002	0.02	0.004	None		None		--	--	--
Silver	0.005	0.0009	0.0003	0.00006	0.005	1562%	0.0009	1562%	--	--	--
Zinc	0.003	0.0005	0.002	0.0004	0.0003	11%	0.00005	11%	--	--	--
TOTAL	**0.1**	**0.03**	**0.2**	**0.05**	**None**		**None**		**6E-06**	**2E-05**	**None**
Cumulative - Tissue + Sediment											
TOTAL	**4**	**5**	**4**	**5**	**0.5**	**12%**	**0.7**	**15%**	**3E-04**	**4E-04**	**None**

Response to Dept. of Ecology Comments (by Mahbub Alam, PhD, PE) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
6	Table 23	This Table and several other places in the report noted the surface water quality standard of chromium III as 50 ug/L citing WAC 173-201A-240. However, no such criterion exists for chromium III in WAC 173-201A-240. The criterion of 50 ug/L applies to chromium VI. It should be corrected in the report.	"Chromium III" will be revised to "chromium" in this table and elsewhere in the report regarding surface water quality. On Table 23, a note will be added that the surface water quality standard of 50 ug/L applies to chromium VI.

Response to EPA Comments (by Joe Goulet) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
1	2.1 Summary of Available Data, Page 9, 2nd paragraph.	A. This section describes that historical data will not be used in this assessment, but the 2008 bioassay data is later used to justify not further bioassays relating to Cadmium. Please clarify this. Is the 2008 bioassay data considered recent? B. Did the 2008 bioassays only include the SS03-C/Seep C location? If other bioassays were conducted, they should be included, as well.	A. The most recent data was used for this assessment and the 2008 bioassay data are the most recent bioassay data available. The 2008 sediment bioassay tests were conducted on sediment collected at the location with the maximum 2008 cadmium sediment concentration (very similar to, but slightly higher than, the maximum in 2015, which was detected at this same location). In addition, the bioassay tests and test species run by Northwestern Aquatic Sciences in 2008 remain in compliance with the 2013 Final SMS Rule. Therefore, although not very recent, the 2008 bioassay test results were considered still scientifically valid and likely representative of worst-case conditions in terms of exposure concentrations of cadmium in sediment. To strengthen the conclusions in the HHERA based on the 2008 bioassay data, additional bioassay testing will be recommended in accordance with WAC 173-204- 562(3)(d) requirements. Specifics regarding the bioassays will be discussed with the project team. B. Yes, the 2008 bioassays only included the SS03-C/Seep C location. Note: Since the completion of the Draft Final HHRA, a discrepancy between the Seep A and

Response to EPA Comments (by Joe Goulet) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
			transect nomenclature in long-term monitoring (LTM) reports and other post-2008 historic reports has been noted that affects the responses in the sections addressed in this comment. For completeness, these nomenclature changes have been noted in this response. Further explanation is provided in the clarification text that has been added to Section 2.1, Item 4, second paragraph. Because the risk assessments did not utilize LTM data, these changes did not affect the risk assessment beyond nomenclature changes.
2	4.1.2.2 Ecological Receptors of Concern and Exposure Pathways, Page 49, 2nd paragraph, 2nd to last sentence.	This section describes littleneck clams as the representative receptor for benthic invertebrates. The benthic community in general should also be included as receptors in this discussion. Clams alone do not represent these receptors, and the benthic community was assessed using comparison to screening values and bioassays as discussed in Table 41.	Additional description of the benthic community will be added to Section 4.1.2.2 that will include a discussion of the different feeding guilds present, test species that have been used in bioassays representing the site (e.g., amphipod, *Eohaustorius estuarius*), and organisms observed during historical biological surveys (e.g., barnacles, moon snail, sea pen, copepods, sculpin, sea stars, sea anemones, and pile worms).
3	4.3.4.4 Historical Bioassay Data, Page 70, last sentence of the section.	"In summary, the 2008 bioassay tests performed at location SS03-C/Seep C are expected to provide a reasonable prediction of toxicity for other sediments with concentrations exceeding the cadmium sediment benchmark." Assuming this is the only location that bioassays were conducted, these bioassays may not reflect current conditions and do not represent the site	To strengthen the conclusions in the HHERA based on the 2015/2016 AVS/SEM data and the bioassay results for the 2008 sediment sample, additional bioassay testing will be recommended in accordance with WAC 173-204- 562(3)(d)

Comment	Section	Comment/Recommendation	Response
		spatially. Granted, the document points out that elevated toxicity is not seen at this one location (SS03-C/Seep C) that had elevated cadmium in 2008. Additional bioassays may be needed to reduce this uncertainty.	requirements. Specifics regarding the bioassays will be discussed with the project team.

Response to EPA Comments (by Lon Kissinger) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment / Recommendation	Response
			On August 16, 2017, Lon Kissinger provided a response to his review of the Navy's responses to these comments. Lon's responses and his additional comments, as well as the Navy's responses are appended to this table.
1	Section 1.1.2, Page 3.	Identify additional exposure pathways and changes in specific exposure parameters that contributed to the enhanced risk in the residential vs. industrial.	The additional exposure pathways and changes in specific exposure parameters that contributed to the enhanced risk in the residential vs. industrial will be identified in the text, as follows: Future residential exposure pathways that contributed to risk that were not evaluated for the industrial scenario included: • Ingestion of groundwater as drinking water from the shallow aquifer (5×10^{-4} and HI = 30). Arsenic, 1,1-DCE, and TCE contributed to risk. Cadmium, chromium, and TCE contributed to the HI. • Inhalation of volatiles during household use of water (5×10^{-4}). 1,1-DCE and TCE contributed to risk. • Ingestion of homegrown produce (2×10^{-5} and HI = 4). Arsenic in soil contributed to risk. Cadmium in soil resulted in the HQ of 4.

Response to EPA Comments (by Lon Kissinger) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
2	Section 1.1.3, Page 4.	"As specified in the ROD, the post ROD risk assessments were to be performed using the same exposure parameters as those in the baseline risk assessments." This statement should be qualified or should reference the subsequent discussion on page 6. This appears to be somewhat at odds with the nature of five year reviews, which re-evaluate any substantial changes in the basis for assessing site risks and whether or not a remedy continues to be protective.	The text will be revised as follows: "As specified in the ROD, the post ROD risk assessments were to be performed using the same exposure **assumptions** as those in the baseline risk assessments. However, it is presumed as part of the 5-year process that if there were any substantial changes to exposure assumptions found while assessing whether or not the remedy remains protective, these changes would be incorporated into the risk assessments, as was done in these current risk assessments."
3	Section 1.2, Page 4.	Provide additional detail to support how additional bioassay testing in 1996 supported the conclusion that no additional remedial action was needed to protect human health and the environment. In particular, it is unclear how bioassay testing would support any conclusions about the levels of human health risk experienced.	The two sentences will be revised as follows: "Although the 1994 ROD indicated that no remedial action appeared to be necessary to protect human health and the environment at Area 9 (the subtidal areas of Liberty Bay), additional bioassay testing was stipulated in the ROD because one of three bioassay results indicated the sediment may pose some ecological risk. The post-ROD confirmatory bioassay testing performed in 1996 on Area 9 sediments showed no toxicity to benthic organisms and thus confirmed the no-action decision in the ROD (U.S. Navy 1996)." (See Suquamish Tribe RTC #2.)
4	Section 1.2, Page 5, 2nd full ¶ on	The HI is marginally above 1. Was there any consideration of breaking the HI down into endpoint specific HIs? Such an analysis might have resulted in a finding of insignificant human	The 2005 HHRA did not breakdown the cumulative HIs into endpoint specific HIs. The intention of Section 1.2 is to

Comment	Section	Comment/Recommendation	Response
	page.	health risk. What FCRs were used to determine human health risks? If the Suquamish data were not used in the 2005 risk analysis, this should be noted. The much higher Suquamish FCRs likely would have resulted in significantly higher HIs.	summarize the results of the previous risk assessments, and further details on the endpoint specific HIs for the 2005 HHRA does not provide additional information that would impact the methods or results and conclusions of the current HHRA. The 2005 HHRA used the same FCR that was used in the 1993 baseline HHRA of 132 g/day for subsistence receptors (USEPA 1991). The next paragraph on Page 5 indicates that the 2005 HHRA was not finalized due to lack of stakeholder agreement on the exposure parameters, in particular the FCR. Section 1.2, Page 5 will be revised as follows: "During the second 5-year review period, a human health risk evaluation using the 2004 data **and the 1993 Baseline HHRA exposure parameters (i.e., FCR of 132 g/day [U.S. EPA 1991a])** was completed that identified marginal potential risks due to cadmium concentrations in sediment and clam tissue (U.S. Navy 2005)."
5	Section 2.1, Page 9, Figure 3.	Figure 3 is difficult to interpret. It would be helpful to have additional figures that allowed visualization of sampling locations of specific sample types (e.g. clam tissue, surface sediment, sub-surface sediment, etc.).	Figure 3 is a complicated figure, but it adequately shows where co-located samples exist. Thus Figure 3 will not be removed from the document. However, two additional figures will be included – one showing just the locations of clam samples and one showing just the locations of

Comment	Section	Comment / Recommendation	Response
			sediment and surface water samples.
6	Section 2.1.2, Page 11, Table 1.	Please provide footnotes referring to text describing how screening levels were calculated or the actual formulas themselves.	The Suquamish Tribe screening levels were included in Appendix B of the risk assessment work plan. They will also be appended to the risk assessment as Appendix B. Footnote a will be added to Table 1 as follows: [a]Suquamish Tribe screening levels were calculated using the exposure parameters and formulas provided in Appendix B."
7	Section 2.1.2, Page 11.	What was the rationale for selecting stations for the comparison of 0 to 10 and 20 to 24 cm depth concentrations? The data presented seem to be quite limited. What about evaluation of data closer in to the shoreline or throughout the area of higher sediment cadmium concentrations identified in Figure 7? The limited stations for which 0 to 10 and 10 to 24 cm depth concentrations were compared does not seem to support conclusions for the entire site.	During the development of the QAPP and as documented in the risk assessment work plan, it was agreed by the project team that the 2015 sampling effort would focus on the intertidal zone sediment depth of 0 to 10 cm. Hence, there are limited deep sediment data. The last three sentences of the first paragraph on page 12 will be revised as follows: "Although there are some instances where the deeper depth interval (10-24 cm) had a higher COC concentration, it was agreed by the project team (as documented in the in meeting notes and the risk assessment work plan) that the HHRA risk characterization would focus on the surface depth interval (0-10 cm) and only this data was used to calculate risks. An uncertainty analysis of

Comment	Section	Comment/Recommendation	Response
			excluding the deeper sediment depth (10 – 24 cm) and the estimation of risks including the deeper sediment data is in the uncertainty section." The discussion in the uncertainty section will also include the limited sediment samples for which 0 to 10 and 10 to 24 depth chemical concentrations were compared and the adequacy of characterizing contaminant concentrations for these two depths. The changed language is included in the redlined Draft Final report
8	Section 2.2, Pages 12 & 13.	It is difficult to determine which site tissue stations were sampled for arsenic and mercury from the existing figure. Again, it would be helpful to have clam tissue stations on a separate map. The rationale as to why the tissue samples selected for analysis are representative of the site should be presented.	All 2015 and 2016 tissue samples were analyzed for arsenic and mercury. A figure showing only clam tissue stations will be provided, as indicated in RTC #5. The rationale as to why tissue samples are representative of the site is presented on Page 16, Bullet 4, Section 3.1.2 and Section 4.2.1.
9	Page 14, 2nd full ¶	Might add a sentence to the end of this paragraph noting that all chromium is expected to be in the +3 valence state in living systems as described below, and hence there is no rationale for conducting speciation in addition to total chromium analysis.	A sentence will be added to the end of the 2nd full paragraph as follows: "All chromium is expected to be in the trivalent state in living systems as described below, and hence there is no rationale for conducting speciation in addition to total chromium analysis."
10	Section 2.3, Page 15, item	The screening level approach seems to be something that would be used to develop a COC list, so it is not clear why it would be	The Navy agrees that the COC list has already been determined. The presentation

Response to EPA Comments (by Lon Kissinger) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
	1.	used, as COCs have been determined. The question of what contamination is present and at what levels would be better presented by noting minimum, maximum, average, standard deviation, and 95% UCL values. Whether or not chemical concentrations are of concern on the basis of human health risks is the subject of the human health risk assessment.	of screening levels in Section 2.3 was not used to screen out chemicals from further evaluation, but rather to provide context for the magnitude of concentrations. The work plan also indicated that the maximum concentrations would be compared to HH- and Eco-based screening levels, as was done on Tables 1 through 4. See Lon's additional comments from August 16, 2017 and the Navy's responses, in the appended memo.
11	Section 2.3, Page 16, item 4.	Please discuss the limited sediment samples for which 0 to 10 and 10 to 24 depth chemical concentrations were compared, the adequacy of charactering contaminant concentrations for these two depths, and the use of these data for the risk analysis.	See response to comment 7.
12	Section 2.4, Page 18.	EPA does not utilize Ecology's 90/90 UTL to site average comparison to determine whether or not site contaminant concentrations exceed background, but rather utilizes a group comparison test. Further discussion will be needed on this issue.	Section 2.4 presents both a point by point comparison of site data to reference area data using the BTVs for sediment and tissue (consistent with Ecology's background evaluation methodology) and a population to population statistical comparison of site data to reference area data (consistent with EPA's background evaluation methodology). It was agreed by the project team that both approaches would be presented in the risk assessment. If there is a specific comment on the methodology presented, the Navy is open to discussion. See Lon's additional comments from August 16, 2017 and the Navy's responses, in the appended memo.

Response to EPA Comments (by Lon Kissinger) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
13	Section 2.4.2, Page 19.	Page 19, 2.4.2: Please provide a more specific reference for the comparison of the 90/90 UTL to individual results. ProUCL describes use of background distribution statistics for comparison to individual site results to assess site boundaries. However, the 90/90 UTL is not specifically identified as the appropriate statistic to use. The document should describe or reference previous discussion as to why the 90/90 UTL is the appropriate statistic to use for this purpose.	See response to comment 12. It was agreed to by the project team that for sediment the 90/90 UTLs as calculated by Ecology and presented in the SMS would be used as the BTV for sediment. See Lon's additional comments from August 16, 2017 and the Navy's responses, in the appended memo.
14	Section 2.4.3, Page 20.	Please provide more background on identification of outliers. In particular, there should be a discussion as to whether or not the data meet the assumptions/requirements of the outlier test use.	Additional text regarding identification of outliers will be provided including whether or not the data meet the assumptions/ requirements of the outlier test use will be added to Section 2.4.3 based on the response below. (See also Ecology's JE RTC#7 and Suquamish Tribe RTC 8#). In the case of derivation of the BTV, "outlier" is defined in the ProUCL Version 5.1.002 Technical Guide as "Measurements (usually larger or smaller than the majority of the data values in a sample) that are not representative of the population from which they were drawn." The outliers were identified by ProUCL, so met the assumptions/requirements of outlier test use, and where removed for the Penrose Point Tissue BTV calculation based on the Dixon Test for 5% significance level as indicated on the EPA ProUCL output (see Appendix C outputs). Including outliers in

Comment	Section	Comment / Recommendation	Response
			the calculation of the BTV results in a higher value which is less conservative when performing a single point comparison of site sample results to BTV.
15	Section 2.4.3, Page 21.	Generally, whether or not site results exceed background should be done using group comparison tests. As noted in the comment on Page 19, Section 2.4.2, individual site and background BTV results are used to determine the extent of site sediment contamination, but it is unclear as to the application of this approach for tissue results.	The last paragraph of Section 2.4 on Page 19 will be modified as follows: "The reference area and background evaluation includes both a statistical population-population (site versus reference area/background) comparison and a single-point comparison of site concentrations to background threshold values (BTVs). As described in the following subsections, to assess whether the Area 8 beach tissue and sediment concentrations are statistically different from reference area concentrations (clam) and natural background concentrations (sediment), a population-population (site versus reference area/background) comparison was performed. In order to support the re-evaluation of the CSM (Section 5.0), a single-point comparison was performed to determine the extent of site sediment and site tissue contamination relative to natural background concentrations (sediment) and reference area concentrations (clam) and to evaluate whether a pattern of contamination could be established with regard to suspected

Comment	Section	Comment/Recommendation	Response
			point sources….."
16	Section 2.4.3, Page 21.	Note that Table 8 also documents relevant statistics describing each data set (e.g. minimum, maximum, average, and standard deviation).	Page 21 will be revised as follows: "Table 8 **presents the relevant statistics describing each data set (e.g. minimum, maximum, average, and standard deviation)** and summarizes the results of the ProUCL outputs for each COC."
17	Section 2.4.3, Page 22.	Mercury: As noted above whether or not clam tissue site mercury results exceed background should be done using a group comparison analysis.	The group comparison analysis for mercury was completed in Section 2.4.4.
18	Section 2.4.4, Page 22.	The group comparison results should be used as the basis for determining whether or not site contaminant concentrations exceed background rather than point by point comparisons. The test used to determine whether or not any distribution is normal should be described, including the assumptions of the test and how the site and background distributions meet the test assumptions. The null hypothesis should be described here in addition to **Table 10,** as well as the values for α and β that were used.	See response to Comment 15. The following sentence will be added after the first sentence of the last paragraph on Page 22: "The EPA ProUCL Version 5.1.002 was used to run goodness of fit (GOF) statistical tests and Q-Q Plots to determine the distribution of each data set. The results of the GOF tests and Q-Q Plots are presented in Appendix C.1" Table 10 contains the null hypothesis and the alpha values used. Beta does not appear to be a variable that can be modified in the ProUCL program for the WMW or Student's t-test. The following sentence will be added after the 5th

Comment	Section	Comment/Recommendation	Response
			sentence of the last paragraph on Page 22: "The Student's t-test and WMW statistical test were used to test the null hypothesis that site concentrations are less than background or reference area concentrations at a 95 percent confidence level (alpha = 0.05)." See Lon's additional comments from August 16, 2017 and the Navy's responses, in the appended memo.
19	Section 3.0, bottom of Page 25.	Preference is to use the term "health protective" rather than "conservative." The meaning of the term "conservative" is not as clear as the term "health protective."	The sentence will be revised as follows: "Where information is incomplete, health protective (conservative) assumptions were made so that the potential risk to human health was not underestimated."
20	Section 3.1, Page 26	Rather than exposure point factors, prefer the use of exposure parameters, which are those factors used to determine the dose of a contaminant a receptor receives via contact with all relevant exposure media containing that contaminant.	The term exposure point factors will be revised to exposure parameters throughout the document.
21	Section 3.1.3, Page 29.	In addition there may be chemical specific determinants of exposure (e.g. dermal absorption factors from soil).	The first sentence of the paragraph will be revised as follows: "The information required to quantify exposures includes the rates of daily intake of, or contact with environmental media (e.g., the yearly amount of clams ingested), **chemical specific determinants of exposure (e.g. dermal**

Comment	Section	Comment/Recommendation	Response
			absorption factors from soil), the duration of exposure, and other population characteristics affecting exposure (e.g., body weight)."
22	Section 3.1.3, Page 29.	(Editorial). This guidance is a starting point for USEPA Region 10 in developing risk assessments. Final risk assessment decisions are informed by tribal consultation with EPA should a tribe request consultation.	The last sentence on page 29 will be revised to two sentences as recommended in the comment as follows: "This guidance is a starting point for USEPA Region 10 in developing risk assessments. Final risk assessment decisions are informed by tribal consultation with EPA should a tribe request consultation."
23	Section 3.1.3, Page 30.	It is also important to note that when evaluating cleanup of smaller operable units within a larger waterbody, that a consumption rate appropriate for the larger water body be used. If lower consumption rates derived on the basis of what a smaller area could sustain where used, higher cleanup levels and lower risks would result. This could potentially result in degradation of the larger waterbody or failure to remediate the larger water body to an appropriately improved quality.	This comment language will be added as text to Section 3.1.3.
24	Section 3.1.4, Page 30, 2nd paragraph, 2nd sentence.	**A goodness of fit** ~~statistical~~...	The sentence will be revised as follows: "A **goodness of fit** test was performed for each COC data set per medium to determine the best distribution assumption for the data set."
25	Section 3.1.4, Page 30.	Discuss also the number of results required to compute a defensible UCL and how the results obtained meet these requirements.	The following sentence will be added to the end of the first paragraph of Section 3.1.4: "As a rule of thumb, a minimum of 10 samples is required to compute reliable

Comment	Section	Comment/Recommendation	Response
			UCL95 concentrations (USEPA 2015). At least 10 samples are available for each data set."
26	Section 3.2.1, Page 32, final sentence.	For chemicals where the default is not appropriate (**e.g. threshold or non-linear extrapolation**).	The sentence will be revised as follows: "Therefore, although the historical approach … for chemicals where there is evidence that the default (**e.g. threshold or non-linear extrapolation)** is not appropriate.
27	Section 3.2.2, Page 32, final ¶ on page:	Add after second sentence from the beginning of the paragraph: The key advantage of the BMD approach is that it utilizes information from the complete dose response curve rather than extrapolating from a single dose (i.e. the NOAEL or the LOAEL).	As recommended, the sentence will be added after second sentence from the beginning of the paragraph.
28	Page 33, first ¶ on page.	The meaning of the final sentence of this paragraph is unclear.	The sentence will be revised as follows: "USEPA continues to move towards harmonization of approaches for cancer and noncancer risk assessment. Mode of action and evaluation of linear versus non-linear effects at low doses for noncarcinogenic endpoints are more often being considered in risk assessments."
29	Section 3.3.1, Page 34.	Should also note that the overall HI is a screening approach and that if the overall HI exceeds one, that the overall HI should be segregated into HIs based on the toxic endpoints of the chemicals that are present. Another limitation with the hazard index approach is that the assumption of dose additivity is most properly applied to compounds that induce the same effect by the same mechanism of action. Consequently, application of the hazard index equation to a number of compounds that are not expected to induce the	The following sentence will be added after the last sentence of the second paragraph in Section 3.3.1: "In addition, application of the summation approach to a number of compounds that are not expected to induce the same type of effects or that do not act by the same mechanism could overestimate the potential for effects (USEPA 1989). This summation approach is a screening

Comment	Section	Comment/Recommendation	Response
		same type of effects or that do not act by the same mechanism could overestimate the potential for effects, although such an approach is appropriate at a screening level. This possibility is generally not of concern if only one or two substances are responsible for driving the HI above unity. If the HI is greater than unity as a consequence of summing several hazard quotients of similar value, it would be appropriate to segregate the compounds by effect and by mechanism of action and to derive separate hazard indices for each group. From U.S. EPA 1989. Risk Assessment Guidance for Superfund, Part I, Volume A.	approach, such that if the overall HI exceeds one, that the overall HI will be segregated into HIs based on the toxic endpoints of the individual chemicals."
30	Section 3.3.4, Page 38.	In discussing the percentage of meat consumption that consists of shellfish, please include the children's shellfish consumption rate and a reference to the section of the HHRA where that shellfish consumption rate is derived.	The average children's shellfish consumption rate of 13.45 g/day and how it was derived is included within this section. The 95th percentile children's shellfish consumption rate of 83.9 g/day was derived in Section 3.1.3, but is not applicable to this lead discussion. The sentence in the second paragraph will be revised as follows: "The average meat consumption ~~used in the~~ IEUBK model **(USEPA 2007) default** is 87.16 g/day; therefore, the percentage of meat consumption consisting of clams was calculated to be 15.43 percent **(13.45 g/day divided by 87.16 g/day)**."
31	Section 3.4, Page 39, 1st two full paragraphs.	Suggested text to use in place of the first two full paragraphs on the page: EPA assesses risks assuming "reasonable maximum exposure or RME" values for variables used in exposure assessment. RME specifies use of a combination of central and	As recommended the first two full paragraphs on page 39 will be replaced with the suggested language in the comment.

Comment	Section	Comment/Recommendation	Response
		upper bound values for specific exposure variables that is designed to produce an overall estimate that is the highest level of exposure that could reasonably be expected to occur at the site. Uncertainty in the HHRA produces the potential for two kinds of errors. The first is an overestimation of the true risk, potentially resulting in remedial actions where none are warranted. The second is an underestimation of the true risk, potentially leading to a failure to implement remedial actions, resulting in ongoing exposure to environmental contaminants that remain at unacceptable levels. Thus, risk estimates based on RME are likely to produce the first outcome noted above, estimated risks will exceed the actual risks present. This approach is preferred in that errors made will result in protection of public health.	
32	Section 3.4.2, Pages 40-41.	Rather than citing the ODEQ focus group publication of the Oregon Fish and Shellfish Consumption Rate project, the preferred source for documenting fish and shellfish consumption rates should be Appendix C from Ecology's Technical Support Document describing fish consumption rates in relation to environmental regulation, https://fortress.wa.gov/ecy/publications/parts/1209058part3.pdf. In addition, U.S. general population fish consumption rates have been re-evaluated by U.S.EPA. The appropriate reference to be used for U.S. FCRs is: U.S. EPA. 2014. Estimated Fish Consumption Rates for the U.S. Population and Selected Subpopulations (NHANES 2003-2010), Final Report, April 2014, EPA-820-R-14-002. https://www.epa.gov/sites/production/files/2015-	In response to Squamish Tribe Comments #13 and #14, this language was deleted from the risk assessment. No additional references were included.

Response to EPA Comments (by Lon Kissinger) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment / Recommendation	Response
		01/documents/fish-consumption-rates-2014.pdf.	
33	Section 3.4.2, Page 42.	There should be additional discussion of the nature of fish consumption distributions noting that they tend to be right skewed, with the resultant property that the average exceeds the median fish consumption rate. http://air.idaho.gov/media/1024862-58_0102_1201_ruffle.pdf	In response to Squamish Tribe Comments #13 and #14, this language was deleted from the risk assessment. No additional references were included.
34	Section 3.4.3, Page 44.	There should also be discussion of the treatment of conservatism in the benchmark dose approach, SEE: https://www.epa.gov/risk/benchmark-dose-technical-guidance. Basically the lower confidence limit on the dose response curve is used to estimate the dose associated with a low percentage of adverse effects (e.g. the 5th or 10th percentile). The use of the lower confidence limit imparts health protectiveness in derivation of the point of departure.	An additional discussion will be added regarding the treatment of conservatism in the benchmark dose approach based on the supplied reference. This changed language is included in the redlined Draft Final report.
35	Section 3.4.3, Page 44.	There should be some discussion of uncertainty in the slope factor for inorganic arsenic. The IRIS program has been re-evaluating the SF for inorganic arsenic for some time, and it may be potentially increasing from 1.5 to approximately 26. However, even this increase in the slope factor may not alter the conclusions of the risk assessment given that site-related inorganic arsenic concentrations are less than reference area values.	An additional discussion will be added regarding the uncertainty in the slope factor for inorganic arsenic. This changed language is included in the redlined Draft Final report.
36	Section 3.4.4, Page 45.	See comment on Page 30, 3.1.3.	A new bullet using text from comment 23 will be added to Section 3.4.4.

Review of Navy Responses to EPA Comments from Lon Kissinger on the Keyport HHRA, Lon Kissinger, 8/16/17

Comment 7, 2.1.2., page 11: Please provide the draft text of the uncertainty analysis regarding characterizing concentration differences for 0 to 10 and 10 to 24 cm for review.

Response: The Navy will provide a redline Draft Final for review of text changes.

Comment 10, 2.3, page 15 item 1: The key point for data usability is whether analytical results are detections, or, if non-detects, whether those non-detect values are below risk based levels of concern. This item should focus on this aspect of data usability, and this bullet should be modified to address this point. The text as, written, does provide insight into the severity of existing contamination from a human and ecological health risk perspective. However, it is the job of the HH/ERA to provide more detailed analysis. This section then, seems somewhat superfluous. It seems that the material in this section would potentially be of use in supporting evaluation of ARAR compliance. However, that is not a function of the HH/ERA. However, rather than removing much of this section, this section can be retained if there introductory text is added that more clearly identifies the section's purpose: "COCs were previously identified for the site. Thus, comparisons between risk-based screening level and benchmarks were not used to identify COCs or eliminate chemicals, but rather to characterize the significance of contamination at the site relative to these benchmarks."

Response: The Navy will include the suggested language in Section 2.3.

Comment 12, 2.4, page 18: Though statistical approaches were agreed upon, there are differences between EPA and Ecology methods. It would be helpful to have an introductory paragraph clearly delineating statistical approaches that are specific to Ecology and those that are specific to EPA. There should then be a brief discussion of the structure of the document noting where point by point and group comparison results are presented.

Response: The Navy will include a discussion of the differences between the Ecology and EPA statistical approaches. The discussion will be provided in a redline Draft Final for review of text changes.

Comment 13, 2.4.2, page 19: As noted previously, it would be helpful to provide more context. EPA and Ecology both utilize some type of BTV to evaluate whether an individual analytical result exceeds background. Ecology specifies that the BTV is the 90/90 UTL. EPA evaluates a broader range of options in selecting a BTV as noted in ProUCL guidance. For the Keyport project specifically, EPA agreed to Ecology's use of the 90/90 UTL as the BTV.

Response: The Navy will include a discussion of the differences between the Ecology and EPA statistical approaches. The discussion will be provided in a redline Draft Final for review of text changes.

Comment 18, 2.4.4, page 22: It would be helpful to identify the function of different statistical procedures and which agency (ies) relies on them. A comparison of an individual analytical

result to a BTV is to determine whether or not that result indicates contamination or comes from a background distribution. Ecology utilizes the 90/90 UTL as a BTV. EPA chooses from a broader range of options. Ecology's comparison of the site average to the 90/90 UTL is to determine whether or not site contaminant concentrations exceed background. EPA's group comparison tests are used to determine whether or not site contaminant concentrations exceed background.

Response: The Navy will include a discussion of the differences between the Ecology and EPA statistical approaches. The discussion will be provided in a redline Draft Final for review of text changes.

Response to Suquamish Tribe (Denice Taylor) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
			Based on discussions during the November 20, 2017 and December 7, 2017 meetings, it was agreed the following text clarifications regarding the cadmium critical tissue level should be added to the HHERA. These text changes include: In addition, further clarification regarding the uncertainties associated with the cadmium critical tissue level (CTL) were added to Section 4.2.2.3 and the fourth bullet of Section 4.4.3. The text changes to Section 4.2.2.3 include: The following additional bolded text was added to the first sentence: **Because the potential exists for organisms to bioaccumulate contaminants to harmful tissue levels,** critical tissue levels protective…. The following additional text was added as the second to last sentence. **In the case of cadmium, a species sensitivity distribution model was used that combined both freshwater and**

Comment	Section	Comment/Recommendation	Response
			saltwater data. However, cadmium is much more toxic to freshwater organisms as evidenced by the much lower freshwater EPA national recommended water quality criterion continuous concentration of 0.72 ug/L as compared to 7.9 ug/L for saltwater. So, using freshwater data to calculate the CTL artificially decreases the saltwater CTL. CTL values…,. The end of the fourth bullet of Section 4.4.3 now reads: **In addition to being lower than the reference location cadmium tissue levels, the cadmium CTL of 0.15 mg/kg wet weight is biased low because a species sensitivity distribution model was used that combined both freshwater and saltwater data. Cadmium is much more toxic to freshwater organisms as evidenced by the much lower freshwater EPA national recommended water quality criterion continuous concentration of 0.72 ug/L, as compared to 7.9 ug/L for saltwater. Using the an alternative approach of multiplying the water**

Comment	Section	Comment/Recommendation	Response
			criterion by the BCF which is also endorsed by ODEQ, if the current marine water quality criterion of 0.0079 mg/L and the same cadmium BCF of 64 are used, the CTL would be 0.51 mg/kg wet weight. The cadmium tissue UCL95 for the Area 8 beach is 0.53 mg/kg wet weight, which would result in an HQ of 1.0, indicating that site concentrations are essentially equivalent to the threshold. Unlike the cadmium CTL based on combined freshwater and saltwater data, the refined saltwater CTL of 0.51 mg/kg wet weight is greater than the cadmium UCL95 for the Penrose Point reference area of 0.47 mg/kg wet weight.
1	Section 1.0, page 1.	Include the objectives for the project.	The objectives of the project will be added to Section 1.0, as follows: • Characterize human health and ecological site risks relative to background • Confirm the extent of contamination and update the conceptual site model • Assess the need to implement contingent groundwater control actions based on the results of the

Response to Suquamish Tribe (Denice Taylor) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
			risk assessments
2	Section 1.2, page 4, 2nd paragraph, 4th sentence.	Clarify that the 1996 Area 9 bioassay testing indicated that there was no risk to benthic organisms. Bioassays do not indicate risks to human health or higher trophic level ecological receptors.	The two sentences will be revised as follows: "Although the 1994 ROD indicated that no remedial action appeared to be necessary to protect human health and the environment at Area 9 (the subtidal areas of Liberty Bay), additional bioassay testing was stipulated in the ROD because one of three bioassay results indicated the sediment may pose some ecological risk. The post-ROD confirmatory bioassay testing performed in 1996 on Area 9 sediments showed no toxicity to benthic organisms and thus confirmed the no-action decision in the ROD (U.S. Navy 1996)." (See EPA LK RTC #3.)
3	Section 2.0, pages 4-7.	A. This section needs to be reviewed and revised to clarify the focus and objective of the data evaluation. Suggest bringing Section 2.3 Data Usability and Quality forward as Section 2.1 to give better context for the rest of the data discussions. If Section 2.3 is brought forward, suggest following with the summary of available data, the analysis of COCs, and comparison to reference and background data, as well as relevant criteria. B. Also suggest that this section include initial discussions of all data sets (AVS/SEM, 2008 bioassay and biological survey results) in this section rather than in the ecological risk assessment.	Section 2.0 will be revised as recommended in this comment. The changed language is included in the redlined Draft Final report

Response to Suquamish Tribe (Denice Taylor) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
		C. The section ends without pulling together any conclusions or summary related to the 4 questions that were posed for data usability and quality. Suggest adding a final subsection.	
4	Section 2.1.1, pages 10-11.	How many clam samples were mixed species and where were they collected? It could be interesting to compare single species composites and mixed species composites to see if there are noticeable differences in concentrations. If they are similar, considering location, it would add support to the assumption that compositing multiple species does not introduce additional uncertainty in the risk assessments.	The following will be added to Section 2.1.1: " Twenty-eight of the 41 clam tissue samples collected from Area 8 were single-species composites consisting of littleneck clams; 1 clam tissue sample from Area 8 was a single-species composite consisting of manila clam; and the remaining 12 clam tissue samples collected from Area 8 were composites of littleneck and Manila clams. All clam tissue samples collected from Penrose Point were single-species composites consisting of littleneck clams. Table 2 summarizes the composite information for the clam samples collected from Area 8 and presents the cadmium results (the primary COC at Area 8) for each sample. Table 2 presents the clam tissue data with respect to transect and suspected contamination sources. As shown on Table 2, the concentrations of cadmium reported in single-species littleneck composites and mixed-species composites consisting of both littleneck and manila clams are not substantially different when proximity and suspected contamination sources are taken into consideration. Thus, composite

Response to Suquamish Tribe (Denice Taylor) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
			samples consisting of littleneck and Manila clams are not expected to increase the uncertainty associated with the data or the risk assessment."
5	Section 2.1.2, page 11, 1st paragraph, 2nd to last sentence.	States that Appendix A contains the BOLD survey data for the COCs in sediment, but there is no table with that data in Appendix A.	The BOLD survey sediment data table will be included in Appendix A.
6	Section 2.1.3, page 12.	Indicate that seep samples are representative of shallow groundwater discharge to the marine environment.	The following sentence will be added after the 1st sentence in Section 2.1.3: "Seep samples are representative of shallow groundwater discharge to the environment."
7	Section 2.1.3, page 12.	Are outfall samples also considered to be representative of groundwater discharges at the site? It is confusing later in the ecological risk assessment when outfall sample results are excluded because "outfall discharges are regulated under a different regulatory program". Are all of the outfalls at the site permitted discharges? Do the COCs detected in outfall samples have permit limits?	The following sentence will be added after the 2nd sentence in Section 2.1.3, "COC concentrations measured from outfalls may be reviewed to evaluate whether the outfalls might be providing an additional source of contamination to Liberty Bay." All of the outfalls at NBK Keyport fall under an installation-wide general permit. Carlotta will send out most current permit to Project Team Members.
8	Section 2.4.3, page 20, under 1st paragraph (No.2, 3, and 4).	Provide additional discussion regarding the identification and removal of "outliers" from the clam tissue data sets. The term outlier is typically used to refer to analytical results that are not useable because of sample collection/handling errors or analytical concerns.	Additional text will be added to Section 2.4.3 based on the response below (see also Ecology's JE RTC#7 and EPA LK RTC#14). In the case of derivation of the BTV, "outlier" is defined in the ProUCL Version

Response to Suquamish Tribe (Denice Taylor) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
			5.1.002 Technical Guide as "Measurements (usually larger or smaller than the majority of the data values in a sample) that are not representative of the population from which they were drawn." The outliers were identified by ProUCL and removed for only the Penrose Point Tissue BTV calculation as provided on the output by EPA's ProUCL based on the Dixon Test for 5% significance level (see Appendix C outputs). Including outliers in the calculation of the BTV results in a higher value which is less conservative when performing a single point comparison of site sample results to BTV.
9	Section 2.4.3, Page 21, 1st bullet.	Correct the phrase natural background concentration to read reference area tissue concentrations.	The first bullet will be updated to "Inorganic arsenic and zinc were not detected above the BTV in any tissue samples collected from Area 8, indicating that the concentrations of these COCs in clam tissue are consistent with **reference area tissue** concentrations."
10	Section 2.4.3, pages 21-22, bullets listed under 2nd paragraph.	Also, why are exceedance factors introduced in the discussion of clam tissue? Was there agreement by the project team on what would define a significant level of exceedance? If not, those statements should be deleted.	Discussion of exceedance factors will be removed from this section.
11	Section 3.0,	Suggest moving the discussion of the existing CSM forward as	Section 3.0 will be revised as recommended

Response to Suquamish Tribe (Denice Taylor) on
Draft Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (May 11, 2017)
Responses Developed August 3, 2017

Comment	Section	Comment/Recommendation	Response
	section begins on page 25.	Section 3.1 and grouping all the exposure assessment discussions together as Section 3.2 (the toxicity assessment would become Section 3.3)	in this comment.
12	Section 3.0 (3.3.3), pages 35-39.	It would be helpful to have the risk estimates for tribal and recreational harvesters presented separately from the incremental risk discussion and to include detail about what COCs are contributing to cumulative risk levels.	A discussion of risk estimates for tribal and recreational harvesters separate from incremental risks will be provided, including COCs contributing as "risk drivers" to cumulative risk levels. (See Ecology MA RTC#5.) The changed language will be presented at the comment resolution meeting.
13	Section 3.4.2, pgs. 40-44.	There is really no "contention" that there are differences in seafood consumption rates and patterns among Puget Sound tribes. However, because Liberty Bay is within the exclusive U&A of the Suquamish Tribe, the discussion of other tribal consumption rates is out of place and should be deleted. No other tribe has treaty rights to harvest in this area and no other tribal consumption rates need be considered.	The first two paragraphs and the first sentence of the third paragraph of this bulleted uncertainty discussion will be deleted, if the project team agrees.
14	Section 3.4.2, page 42.	The Suquamish tribal consumption survey is a peer-reviewed technical report and is the appropriate basis for establishing the RME for tribal harvest at the site. All of the reported consumption rates are considered to be representative of tribal consumption at the time of the survey (2000), although they may be suppressed. Statements questioning the inclusion of "the few high-consuming individuals" need to be removed.	Statements questioning the inclusion of "the few high-consuming individuals" will be removed from the document. The first paragraph on page 42 will be deleted.
15	Section 4.3.3, pages 63-64, (pages 72 and 85).	The report states that although only the maximum concentration of silver at outfall 03- 701 exceeded surface water benchmarks, silver was not evaluated further because outfall discharges are regulated under a different regulatory	The text will be revised on pages 72 and 85 to indicate that the silver exceedance in water is related to Outfall 03-701, not 03-703.

Comment	Section	Comment/Recommendation	Response
		program and silver concentrations in seeps did not exceed benchmarks. On page 72, and also on page 85, please review the locations of the silver exceedances relative to the outfalls. The summaries on pages 72 and 85 say that the surface water exceedance was near outfall 03-703 rather than 03-701. Aside from surface water exceedances, sediment exceedances near outfall 03-703 do seem to be site-related as the upland area adjacent to outfall 03-703 was subject to remedial action.	<u>To address the location of silver sediment exceedances, the following changes will be made to Section 4.3.4.1, subheading Silver:</u> Two locations, SS70 (7.75 mg/kg) and SS72 (17 mg/kg) on Transect 9 and between Transects 9 and 10 uphill of Outfall 03-703 exceed the sediment benchmark of 6.1 mg/kg for silver. The HQ for silver in sediment based on the UCL95 was 0.35. A sufficient number of clams were available at location SS70 to collect sufficient tissue for chemical analysis for this ERA, indicating silver in sediment does not appear to be adversely impacting the clam community at this location. In addition, silver accumulation in clam tissue does not appear to pose a hazard to clam predators (see Section 4.3.5 and 4.3.6). The need to address potential impacts to the benthic community from silver exposure to complete the ERA will be further investigated as part of the planned additional bioassay testing program. The second sentence of the “Media-Specific Benchmark Comparisons” section on page 85 will be revised as follows: Cadmium concentrations exceeded sediment

Comment	Section	Comment/Recommendation	Response
			and surface water benchmarks. Silver concentrations exceeded sediment benchmarks near Outfall 03-703 and surface water benchmarks at Outfall 03-701. Because elevated silver in sediment does not appear to be co-located with known seep source areas containing key site-related COCs (cadmium), at location at Outfall 03-701, silver is not likely attributed to Area 8 groundwater and groundwater controls will not address these exceedances. Maximum cadmium concentrations in seep, sediment, and tissue are located along Transect 8, particularly near Seep C. Cadmium concentrations at one additional location (Seep A) also exceeded the sediment benchmark. The cadmium CTL screening criterion for tissue is lower than background concentrations at the Penrose Point reference location. In addition, site-wide cadmium levels in tissue were not statistically different than the Penrose Point reference location. Note: Since the completion of the Draft Final HHRA, a discrepancy between the Seep A and transect nomenclature used in long-term monitoring (LTM) reports and other post-2008 historic reports has been noted that affects the responses in the sections

Comment	Section	Comment/Recommendation	Response
			addressed by this comment. For completeness, these nomenclature changes have been noted in this response. Further explanation is provided in the clarification text that has been added to Section 2.1, Item 4, second paragraph. Because the risk assessments did not utilize LTM data, these changes did not affect the risk assessment beyond nomenclature changes. Tables 23, 26, 27, 28 and 40 have been revised to include the alternative British Columbia AWQC for silver and a footnote added as follows: Second value is based on British Columbia Environment Protection Department. 1996. Ambient Water Quality Criteria for Silver, Section 2(e) of the Environment Management Act, 1981, February 19. For Table 27, a footnote d will also be added as follows: [d] Value exceeds the criterion maximum concentration USEPA AWQC divided by 10, but not the chronic British Columbia AWQC. The following will be added to the reference section:

Comment	Section	Comment/Recommendation	Response
			British Columbia Environment Protection Department. 1996. Ambient Water Quality Criteria for Silver, Section 2(e) of the Environment Management Act, 1981, February 19, http://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/approved-wqgs/silver-or.pdf
16	Section 4.3.3, pages 63-64, 2nd paragraph, 3rd sentence on page 64.	Considering that silver concentrations in sediment also indicate that silver is present at the site at concentrations greater than natural background, delete statements that silver is not related to Area 8 activities.	The sentence will be revised as follows: Thus, given the relatively low HQ for copper and the uncertainties of the silver surface water benchmark coupled with the lack of an exceedance of the alternative benchmark, only cadmium in groundwater discharging at Seep C was considered to pose a potential hazard to aquatic organisms as a result of Area 8 groundwater impacts.
17	Section 4.3.4.1, pages 65-66.	A. The project team agreed that COCs would not be eliminated from the risk assessments based on comparison with background or reference area concentrations. Copper and mercury, however, are eliminated from further consideration in the ecological risk assessment based on the population to population comparison to background sediment data. B. Additionally, while the HQ of 0.57 for cadmium indicates that cadmium in sediments does not appear to be having an adverse impact on clams, there is not enough quantitative evidence to support the statement regarding potential impacts	A. Copper and mercury were not eliminated as COCs strictly on the basis of the population to population sediment background comparison but on several lines of evidence: • Direct toxicity based HQs for the benthic community are low for copper (HQ=1.1) and relatively low for mercury (HQ=5.9), especially considering the basis of these HQs, i.e., maximum concentrations in sediment and Ecology SMS SCOs, which

Comment	Section	Comment/Recommendation	Response
		at the community level. Similarly, the fact that there were clams present near outfall 03-701, does not indicate that silver concentrations in sediment are not impacting clams at the community level. The biological surveys that were performed prior to sampling do not support an assessment of aquatic community structure or health.	correspond to sediment quality that should result in no adverse effects (WAC 173-204-320). • Direct toxicity based HQs using the UCL95s and SCOs are below 1.0. • Only one sediment sample had a concentration above the SCO for copper and six samples exceeded the SCO for mercury (listed in Table 30). • Only 6% of all sediment samples exceeded the BTV for copper and 14% exceeded the BTV for mercury. • Dietary based HQs representing bioaccumulation exposure were below 1.0 for copper and mercury for the crow and otter. • Dietary based HQs assume exposure via ingestion of COCs in clam tissue and incidental ingestion of COCs in sediment. In summary, direct toxicity to the benthic community, which is a primary concern for copper, has been demonstrated to be of minimal concern for both metals. Dietary toxicity to wildlife, which is of primary concern for mercury, has also been demonstrated to be of minimal concern for both metals.

Comment	Section	Comment/Recommendation	Response
			Additional text will be added to Section 4.3.4.1 as indicated below to describe the findings of the direct toxicity sediment screening shown in Table 30. This information will supplement the text already presented that describes the findings of the population to population comparison to background sediment data. The findings of the risk assessment for the crow and otter will also be referenced to support the idea that mercury and copper in sediment do not pose an ecological hazard. The following text will be added to the end of the first paragraph: Direct toxicity based HQs for the benthic community are low for copper (HQ=1.1) and relatively low for mercury (HQ=5.9), especially considering the basis of these HQs, i.e., maximum concentrations in sediment and Ecology SMS SCOs, which correspond to sediment quality that should result in no adverse effects (WAC 173-204-320). The following text will be added to the end of the second paragraph: The primary concern for copper is direct

Comment	Section	Comment/Recommendation	Response
			toxicity. Only one sediment sample had a concentration above the SCO for copper and six samples exceeded the SCO for mercury (Table 30). The limited extent of copper impacts coupled with the lack of a statistical increase of site data above background based on a population-to-population comparison to background sediment data, suggests copper poses a low threat to benthic organisms. The primary concern for mercury is bioaccumulation. Although six samples exceeded the SCO for mercury (Table 30), mercury did not pose a hazard to birds or mammals (see Sections 4.3.4 and 4.3.5). These findings coupled with the findings of the population-to-population comparison to background sediment indicate that copper and mercury concentrations in Area 8 beach sediments do not pose a hazard greater than background. Nonetheless, Bbecause cadmium and silver… B. The two shellfish abundance studies are one line of evidence (using clam as an indicator species) used to assess environmental health. These findings, in conjunction with the fact that clam tissue collection was possible at all sampling

Comment	Section	Comment/Recommendation	Response
			locations during the 2015 and 2016 site investigations (including areas where the maximum seep and sediment cadmium concentrations have been found), suggest that COCs at Area 8 are not adversely affecting the benthic community. Nonetheless, the following text will be deleted: Cadmium in sediment does not appear to be adversely impacting clams at the community level at Area 8 for the following reasons: HQ for cadmium in sediment is 0.57, based on the UCL95 when compared to the ecological sediment benchmark and abundance of clams along the beach. Additionally As discussed in Section 4.3.4.2, cadmium tissue concentrations were considered statistically similar to Penrose Point reference tissue concentrations. The following text will be added to the end of the cadmium subsection: The need to address potential impacts to the benthic community from cadmium exposure to complete the ERA will be further investigated as part of the planned additional bioassay testing program.
18	Section	Conclusions related to AVS/SEM and the bioavailability of	The Navy agrees that additional data

Comment	Section	Comment/Recommendation	Response
	4.3.4.3, pages 66-69.	cadmium in sediments are based on very limited data. Additional testing would be necessary to validate a finding that seeps may be the primary contributor to tissue accumulation of cadmium in clams.	collection with correlated AVS/SEM samples should be performed to assess current conditions. (See Ecology JE RTC #1.)
19	Section 4.3.4.4, pages 69-70.	The Tribe has commented numerous times regarding the limitations associated with the bioassay testing conducted in 2008. In summary, bioassays do not establish a cause of toxicity and the results from a single test location cannot be extrapolated across the site. The Tribe does not agree that the 2008 bioassay data should be considered a reasonable predictor of other onsite sediments where cadmium concentrations exceed sediment benchmarks.	The text will be revised as follows: In summary, the 2008 bioassay tests performed at location SS03-C/Seep C are expected to likely provide a reasonable prediction of toxicity for other sediments with concentrations exceeding the cadmium sediment benchmark. Nonetheless, to strengthen the conclusions based on the 2015/2016 SEM/AVS data, which are available for one of the five sediment samples with an exceedance of the sediment benchmark for cadmium, and based on the bioassay results of the planned 2008 sediment and seep sampling, additional bioassays will be recommended in accordance with WAC 173-204- 562(3)(d) requirements. The Navy agrees that additional bioassays should be performed with input from the project team. (See Ecology JE RTC #1.)
20	Section 4.3.4.5, pages 70-71.	The survey conducted prior to sampling cannot be considered a quantitative evaluation of benthic abundance, community structure or health. The presence of clams does not indicate that there is no impact to clams from contaminated groundwater discharging to the marine environment.	Additional bioassays will be recommended to confirm the findings for the benthic community under current conditions. The following text will be added to the

Comment	Section	Comment/Recommendation	Response
			beginning of this section: As noted in a Puget Sound study, benthic invertebrate surveys produce a complex list of species at a given site and it can be difficult to determine what constitutes abnormal deviations from an expected biological assemblage (Southern California Coastal Water Research Project [SCCWRP] 2013). Benthic species composition and abundances vary naturally from habitat to habitat (SCCWRP 2013), and that the Area 8 beach is an armored beach which further complicates the interpretation of benthic surveys. The following will be added to the reference section: Southern California Coastal Water Research Project. 2013. Development of Puget Sound Benthic Indicators, Report to the Washington State Department of Ecology, Southern California Coastal Water Research Project Technical Report 755, Washington State Department of Ecology Publication No. 13—3-035, August. The following text will be added to the end

Comment	Section	Comment/Recommendation	Response
			of this section. Given the difficulties associated with finding a suitable reference location and other challenges, alternatives to performing a biological survey in accordance with WAC 173-204- 562(3)(d) requirements to confirm there are no adverse impacts to the benthic community and complete the ERA will be discussed with the project team during the planning stages further investigated as part of the additional bioassay test program. In addition, the following change will be made to Section 6.2.2, Shellfish Abundance Matrix subsection: As noted in a Puget Sound study, benthic invertebrate surveys produce a complex list of species at a given site and it can be difficult to determine what constitutes abnormal deviations from an expected biological assemblage (Southern California Coastal Water Research Project [SCCWRP] 2013). Benthic species composition and abundances vary naturally from habitat to habitat (SCCWRP 2013), and the Area 8 beach is an armored beach which further complicates the interpretation of benthic surveys. According to the SMS, benthic infaunal abundance surveys should evaluate

Comment	Section	Comment/Recommendation	Response
			the abundance of the major taxa of Class Crustacea (e.g., amphipods, crabs, lobsters, crayfish, shrimp, and barnacles), Class Polychaeta (e.g., annelid worms), and Phylum Mollusca (e.g., clams and mussels).
21	Section 5.0, pages 79-80.	This section could include a more detailed discussion of whether the results of the current site characterization and risk assessments confirm the findings of previous sampling and risk assessments and support the existing CSM.	A more detailed discussion will be included that indicates that the current site characterization and risk assessments confirm the findings of previous sampling and risk assessment and support the existing CSM. The following text will be added to the end of the second paragraph of Section 5. The additional 2015/2016 data confirm that a localized area near SS03-C/Seep C contains elevated cadmium concentrations. The first sentence of the third paragraph will be revised to read: While the HHRA concluded that there are no significant site-related health risks, bioassay data are needed to complete the ERA.
22	Section 5.0, pages 79-80, last paragraph of section.	As commented above, the Tribe does not agree with statements that the 2008 bioassay testing at a single location should be accepted as a reasonable prediction of toxicity for other sediments with concentrations exceeding the cadmium sediment benchmark.	The text will be revised as follows: Nonetheless, performance of additional bioassays data collection to assess current conditions is recommended.

Comment	Section	Comment/Recommendation	Response
			Thus, the remedial action appears to have reduced source input to Liberty Bay such that human and ecological exposures to COCs at the site are consistent with exposures to COCs associated with natural background or other ubiquitous sources. No additional controls are recommended based on the conclusions of this assessment.
23	Sections 6.2.2 and 6.2.5, pages 85-86, page 88.	The Tribe does not agree that the limited AVS/SEM data, the 2008 bioassay data or the biological survey observations provide sufficient evidence to conclude that there are no adverse impacts to the benthic community. This section should be revised to identify data gaps and determine if additional testing is necessary to confirm this as a finding.	This section will be revised to include the following sentence at the end of the SEM/AVS Bioavailability Data subsection text to identify data gaps, and additional bioassaytesting to confirm there are no adverse impacts to the benthic community will be recommended. Nonetheless, because there are no 2015/2016 SEM/AVS data for four of the five sediment samples where cadmium sediment benchmark exceedances were noted, additional data, such as bioassay tests, are needed to support this hypothesis. The Navy agrees that additional data collection should be performed with input from the project team. (See Ecology JE RTC #1.)

Response to EPA Comments (Lon Kissinger) on
Draft Final Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (January 9, 2018)
Responses Developed April 18, 2018

Comment	Section	Comment/Recommendation	Response
1	Section 3.2.2 Page 39 and Section 3.4.4 Page 59	If lower consumption rates derived on the basis of what a smaller area could sustain where used, ~~higher~~ **less stringent** cleanup levels and lower risk **estimates** would result.	The sentence will revised in both sections as requested.
2	Section 3.5.2, Page 53-54	It is unclear to me why information describing the basis for the risk assessment's FCRs base on Suquamish adult subsistence consumption rates was struck. For any risk assessment, it is exceedingly important that the basis for exposure parameters be provided.	Email response from Lon Kissinger dated April 10, 2018: Denice and I have talked. We both agree that if the text discussing uncertainty in the Suquamish FCRs is retained, that additional wordsmithing would be required. The site has been deemed a no action site, and the project time line has been unduly long. For these reasons, I agree with Denice that the sections she has identified for removal should be taken out of the Keyport HHRA. Therefore, no changes are required to the HHRA text based on this email communication.

Response to Suquamish Tribe (Denice Taylor) on
Draft Final Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (January 9, 2018)
Responses Developed March 22, 2018

Comment	Section	Comment/Recommendation	Response
1	Section 2.2.7 Biological Survey and Section 4.3.4.5	These sections cite a 2007 Navy report titled A Sustainable Shellfish Harvest Report. This survey was not performed as an evaluation related to the Keyport Area 8 risk evaluation. While it is acceptable to describe the survey objectives and observations concerning conditions at the time of the survey, the Tribe requests that conclusions regarding the level of sustainable harvest be removed. The Keyport Area 8 project team agreed to exposure parameters and the level of harvest that are different from the report conclusions.	The following sentence will be deleted in section 2.2.7 and Section 4.3.4.5: **"The report concluded that sustainable harvesting of clams could occur such that 1 to 20 people could obtain 100 percent of their annual clam intake."**
2	Section 2.3.2~~3~~ Mercury	Consider adding some discussion about factors that may affect methylation.	Factors that affect methylation will be added to Section 2.3.2 as follows: **"The conversion of inorganic to methylmercury is caused primarily by sulfate-reducing bacteria (Fimmen et al. 2009; Compeau and Bartha 1986) and iron-reducing bacteria (Fleming et al. 2006). In pelagic environments such as Arctic marine ecosystems, methylation is reported to occur in macroalgae (Paranjape and Hall 2017).** **There are numerous abiotic factors affecting mercury methylation. In water and sediments the amount of methylation is affected by the amount of dissolved oxygen present, the amount of sulfur present, the pH of the water or sediment and grain size, particularly the presence of particles of**

Comment	Section	Comment / Recommendation	Response
			clay or organic material (MADEP, 1996). Methylation is reported to occur primarily in the upper layers of sediment where there is significant microbial activity (Paranjape and Hall, 2017). However, methylation can also occur in anoxic surface waters. The presence of sulfur may be important because it can be inferred that sulfate-dependent bacteria may be present that are involved in the methylation process and because sulfur serves as an electron receptor and a ligand for mercury. Low pH is typically associated with an increase in methylation (MADEP, 1996). However, recent studies have observed methylation to occur only in tropical lakes with a neutral pH and in prairie wetlands with pH above 8 (Paranjape and Hall, 2017). A recent study has found that dissolved organic carbon (DOC) both mobilizes inorganic mercury and alters cell walls to facilitate uptake (Paranjape and Hall 2017). However, as noted by Tsui and Finlay (2011), the efficiency of methylmercury incorporation into the stream food webs decreased significantly with increasing DOC concentration, suggesting that

Comment	Section	Comment/Recommendation	Response
			methylmercury bioavailability to the base of food webs was attenuated at higher levels of DOC. Because inorganic mercury has been reported to bind to organic matter, a decrease in mercury bioavailability and, therefore, methylation has been reported when organic material is present (Paranjape and Hall 2017). Other variables to consider are iron and temperature. It has been reported that high concentrations of ferrous iron can suppress mercury methylation by complexing mercury and making it unavailable for methylation (Paranjape and Hall, 2017). Previous research has suggested that warmer water temperatures may promote bacterial methylation (Paranjape and Hall, 2017). Lastly, while low salinity has been touted as resulting in higher methylation rates, recent studies have shown salinity to both stimulate, and to have no correlation with, methylation potential (Paranjape and Hall, 2017).” The following references will be added to the reference section: **Compeau, G. C. and R.**

Comment	Section	Comment/Recommendation	Response
			Bartha. 1985. Sulfate-reducing bacteria-principal methylators of mercury in anoxic estuarine sediment. *Appl. Environ. Microbiol.* 50:498-502. **Fleming E.J., Mack E.E., Green P.G., and D.C. Nelson. 2006. Mercury methylation from unexpected sources: Molybdate-inhibited freshwater sediments and an iron-reducing bacterium. Applied and Environmental *Microbiology*. 72:457–464. doi: 10.1128/AEM.72.1.457-464.2006.** **Fimmen, R. L., R. Darlington, P. L. Lehocky, V. Lai, B. Sass, S. Chattopadhyay, AND P. Randall. 2009. Bacterial Mercury Methylation at the Sediment-Water Interface of Mercury Contaminated Sediments. Presented at Battelle 10th International In Situ and On-Site Bioremediation Conference, Baltimore, MD, May 05 - 08.** **Massachusetts Department of Environmental Protection, 1996.**

Response to Suquamish Tribe (Denice Taylor) on
Draft Final Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (January 9, 2018)
Responses Developed March 22, 2018

Comment	Section	Comment/Recommendation	Response
			Mercury in Massachusetts: An Evaluation of Sources, Emissions, Impacts and Controls, Chapter 2, June. http://infohouse.p2ric.org/ref/11/10102/mercury/hgch2.htm. **Paranjape, A.R. and B.D. Hall. 2017. Recent Advances in the Study of Mercury Methylation in Aquatic Systems. FACETS 2: 85–119. doi:10.1139/facets-2016-0027.** **Tsui, M.T.K. and J.C. Finlay. 2011. Influence of dissolved organic carbon on methylmercury bioavailability across Minnesota stream ecosystems. *Environmental Science & Technology* 45 (14): 5981-5987.**
3	Section 2.4	Reference and Background Evaluation: Define and explain BTV, if this is the first use. (I think this just got left out when this section was reorganized.)	The 1st sentence of the 3rd paragraph in section 2.4 will be updated to: "A comparison of individual analytical results to **background threshold values (**BTVs**)** is used to determine whether or not that result indicated contamination is derived from background distribution. **A BTV is a statistically calculated concentration that represents the background levels**

Comment	Section	Comment/Recommendation	Response
			of a contaminant or a concentration level that is categorized as not exceeding background levels."
4	Section 2.4.1.2 Clam Tissue	The discussions regarding the comparison to BTVs should be revised to reflect only the results of the comparisons, without biasing the observation with words like "slightly" or phrases such as "more than likely". The cadmium discussion comes across as discounting the observed exceedances. The locations where the exceedances were observed are proximate to a known discharge. In addition, the conclusion that "seeps might be contributing to lead and silver concentrations in clam tissue above reference area concentrations, but do not demonstrate a pattern with respect to specific potential point sources to Liberty Bay" is not clearly supported and should be removed from this section.	Since the completion of the Draft Final HHRA, a discrepancy between the Seep A and transect nomenclature used in long-term monitoring (LTM) reports and other post-2008 historic reports has been noted that affects the responses in the sections addressed by this comment. For completeness, these nomenclature changes have been noted in this response. Further explanation is provided in the clarification text that has been added to Section 2.1, Item 4, second paragraph. Because the risk assessments did not utilize LTM data, these changes did not affect the risk assessment beyond nomenclature changes. Sections 2.4.1.1 and 2.4.1.2 will be revised as follows: Section 2.4.1.1, Bullets on Pages 27 - 28: • "Arsenic and nickel were not detected above the BTV in any sediment sample collected from the Area 8 beach~~,~~ ~~**indicating that the concentrations of these chemicals are consistent with natural background**~~

Comment	Section	Comment/Recommendation	Response
			~~**concentrations**~~. • Few exceedances of the BTVs occurred for chromium (3 percent), copper (6 percent), and zinc (5 percent), while several sporadic exceedances were noted for lead (9 percent) and mercury (14 percent). These exceedances were predominantly located along Transect 8 (near Seep C) and Transects 9 and 13 (near the outfalls) (Figure 5). ~~**These results indicate that Seep A might be contributing to chromium, copper, lead, zinc, and mercury concentrations in sediment, and the outfalls might also be an additional source of these metals to Liberty Bay.**~~ • For cadmium and silver, nearly 50 percent of the sediment samples were detected above their respective BTVs. For cadmium, exceedances were predominantly located along the southern Transects 2 and ~~3~~**8** (near Seep **C**~~A~~), Transect **3** ~~8~~ (near Seep **A** ~~C~~), Transect 10 (near Seep D), and Transect 9 (near Outfall 03-703). ~~**These results indicate that Seeps A, C, and D and Outfall 03-703 might be contributing to cadmium**~~

Comment	Section	Comment/Recommendation	Response
			~~**concentrations in sediment.**~~ For silver, the exceedances of the BTV noted in sediment were more widespread, with exceedances occurring on nearly every transect (except Transect 14). These results do not demonstrate a pattern with respect to specific potential point sources of silver to sediment in Liberty Bay." Secton 2.4.1.2, Bullets on Pages 29-30: • "Copper was detected ~~**slightly**~~ above the BTV in only four Area 8 beach clam samples (10 percent), sporadically across the exposure area. ~~**These results indicate that the concentrations of copper in clam tissue are more than likely consistent with reference area tissue concentrations.**~~ • Cadmium was detected ~~**slightly**~~ above the BTV in only seven Area 8 beach clam samples (17 percent). The exceedances were noted primarily along Transects 2 and **8** (near Seep **C**), Transect ~~8~~ 3 (near Seep **A** ~~C~~), and Transect 9 (near Outfall 03-703). ~~**These results indicate that Seeps A and C**~~

Comment	Section	Comment/Recommendation	Response
			~~**and Outfall 03-703 could potentially be influencing cadmium concentrations in clam tissues; however, the concentrations of cadmium in clam tissue could also be consistent with reference area concentrations, as the magnitude of exceedance over the BTV is low.**~~ • Nickel was detected above the BTV in nearly 40 percent of Area 8 beach clam samples. The exceedances were noted primarily along Transects 2 and ~~3~~ 8 (near Seep **C** ~~A~~) and Transect **3** ~~8~~ (near Seep **A** ~~C~~). ~~**These results indicate that Seeps A and C could potentially be influencing nickel concentrations in clam tissues.**~~ • For methylmercury, 90 percent of the sediment samples were detected ~~**slightly**~~ above the BTV~~**; indicating only slightly elevated concentrations over reference area concentrations, though**~~ nearly site-wide. • For lead and silver, 100 percent and 95 percent of the sediment samples were detected above their respective BTVs. ~~**These results indicate that the seeps might be contributing to lead**~~

Response to Suquamish Tribe (Denice Taylor) on
Draft Final Keyport OU 2 Area 8 Human Health and Ecological Risk Assessment Report
Naval Base Kitsap Keyport (January 9, 2018)
Responses Developed March 22, 2018

Comment	Section	Comment/Recommendation	Response
			~~**and silver concentrations in clam tissue above reference area concentrations, but do not demonstrate a pattern with respect to specific potential point sources to Liberty Bay.**~~"
5	Section 2.5 Summary of Data Quality	In the second paragraph, please revise to read "Several metals in tissue and sediment are present in excess of background concentrations.	The sentence will be revised as follows: "Several metals in tissue and sediment are present in excess of ~~**background**~~ **reference area or background concentrations**."
6	Section 3.4.3.1 Suquamish Subsistence Receptor and Section 6.1.2	As currently written, the emphasis in the last paragraph is falling on how sources contribute to site concentrations. This section is summarizing risks. Please revise the last paragraph to read "These results indicate that while the total or overall hazard and risk estimates calculated for the Area 8 beach exceed target health goals (due primarily to cadmium and arsenic in clam tissues), estimated incremental risks are below target health goals. There are no unacceptable site-related risks for Suquamish subsistence receptors.	The paragraph will be revised as requested.
7	Section 3.5.4 Risk Characterization	In the discussion of harvest sustainability, please delete the second sentence. The rest of the paragraph correctly identifies the assumptions used in the risk assessment and the impact on risk estimates if clams are harvested from other areas.	The second sentence will be deleted as requested.
8	Section 4.3.4.1 Sediment Data	As commented a number of times, additional bioassays will not be able to be used to establish causality for any observed toxicity to specific COCs, including cadmium and silver.	The text will be revised as follows: ~~**"The need to address**~~ ~~p~~ Potential impacts to the benthic community ~~**from cadmium**~~

Comment	Section	Comment/Recommendation	Response
			~~**exposure to complete the ERA**~~ will be further investigated as part of the planned additional bioassay testing program **to complete the ERA**." and ~~**"The need to address**~~ Potential impacts to the benthic community ~~**from silver exposure to complete the ERA**~~ will be further investigated as part of the planned additional bioassay testing program **to complete the ERA**."
9	Sections 4.3.4.2, 4.3.4.5 and 4.3.4.6	In the discussion in Section 4.3.4.2, it is noted that clam tissue samples from the site exceeded CTLs, as well as effect levels (HQs), for arsenic and cadmium in point-by-point and a community-level comparisons. The discussion further states that based on a lack of statistical difference between the site and the reference area, CTLs are a poor measure of the potential for arsenic and cadmium accumulation in clam tissue to cause direct toxicity in clams. In subsequent sections, only the statistical comparison is cited to support a conclusion that there is no difference between the site and reference areas. Please revise the discussions to clarify why the CTL comparisons are not being considered.	The following text in Section 4.3.4.2 will be revised as follows: "However, arsenic and cadmium tissue concentrations were considered statistically similar to Penrose Point reference tissue concentrations (Table 10), suggesting that CTLs are a poor measure of the potential for arsenic and cadmium accumulation in clam tissue to cause direct toxicity in clams at the Area 8 beach **because the CTLs represent levels that are statistically lower than concentrations in unimpacted reference areas, such as Penrose Point**. **In addition, the**

Comment	Section	Comment/Recommendation	Response
			conservative assumptions used in the derivation of the cadmium CTL are described in detail in Section 4.4.3." For cadmium, a detailed discussion of the uncertainties regarding the CTL values is presented in the uncertainty section (Section 4.4.3) and this section will be cross-referenced. No changes are proposed for Sections 4.3.4.5 and 4.3.4.6.
10	Section 4.4.4 Risk Characterization	The last paragraph seems to contradict earlier recommendations for additional bioassays.	The last sentence in the last bullet will be deleted: **"Therefore, lack of additional bioassay data is not expected to influence the findings of the ERA."** And replaced with: "**The planned additional bioassay testing program will further reduce the uncertainties associated with the limited bioassay dataset.**"
11	Section 6.2.1 Aquatic Organisms	The seep discussion gets confusing at the end. The last sentence states that cadmium exceedances in seeps are expected to pose an unacceptable hazard to free-swimming aquatic life. However, the preceding section on marine surface	This was a typo. The sentence will be revised to read: "Thus, the localized cadmium exceedance in

Comment	Section	Comment/Recommendation	Response
		water states that there are no unacceptable hazards to fish and other free-swimming organisms. If seeps present an unacceptable risk, and are a known discharge for contaminated groundwater from the site, groundwater controls should be recommended.	seeps is **not** expected to pose an unacceptable hazard to free-swimming aquatic life, and groundwater controls are not considered necessary to protect this receptor group."
12	Section 6.2.2 Bioassays	None of the 2008 bioasssay tests indicated that cadmium in Area 8 beach sediments poses a hazard to the benthic community because that is not what the bioassays were designed to evaluate. The 2008 bioassays indicated that there was no toxicity to benthic organisms at the site of the test location.	The last sentence of the Bioassays section will be updated to the following: "None of the bioassay tests **performed on the highest cadmium concentration in sediment and seep water showed significant toxicity** ~~**indicated that cadmium in Area 8 beach sediments poses a hazard to the benthic community**~~**.**"