

TECHNICAL MEMORANDUM

TO: Molly Adolfson, Adolfson/ESA
c.c. Derek Sandison, Washington Department of Ecology

DATE: August 20, 2007

FR: David Banton, L.Hg., and Mark Wirganowicz, L.Hg.

OUR REF: 063-1166.800

**RE: INFORMATION REVIEW REGARDING THE POTENTIAL FOR IMPACTS TO
THE MOSES LAKE SUPERFUND SITE FROM PROPOSED WATER
CONVEYANCE IN CRAB CREEK**

INTRODUCTION

Available documents were reviewed to evaluate the potential for impact to the Moses Lake Wellfield Superfund Site (Site) resulting from the proposed use of Crab Creek as part of the water conveyance system for the Columbia River off-channel water storage project. Because increased flows in Crab Creek may occur as a result of the conveyance, there is concern that the sources and nature and extent of contamination at the Moses Lake Superfund Site may be adversely affected. Golder Associates Inc. (Golder) was requested to review existing technical information and reports pertaining to the Site in order to evaluate whether use of Crab Creek for water conveyance could have the potential to hydraulically influence the pre-existing contamination.

Documents reviewed as part of this evaluation are listed at the end of this memorandum. The appraisal evaluation for the off-channel storage project was completed in May 2007 (WSDOE & USBR, 2007^{a,b,c}), which evaluated four proposed sites. The results of the evaluation showed that the Crab Creek site had the highest ranking for technical viability and cost-effectiveness, and as a result is the recommended site for further feasibility studies.

SITE CONDITIONS

The following list provides a general summary of information regarding the Moses Lake Superfund Site:

- The Moses Lake Superfund Site is located approximately 36 miles northeast of the proposed Crab Creek reservoir site.
- Soil and groundwater contamination is associated with the Larson Air Force base and related facilities and its use as an airfield and air-command base for military, private, and municipal flight operations since the early 1940s.

- The primary contaminant of concern at the Moses Lake Superfund Site is trichloroethylene (TCE), a dense-non-aqueous-phase-liquid (DNAPL). Other contaminants found at the site include petroleum hydrocarbons, organic compounds, metals, low-level radionuclide medical wastes.
- Subsurface formations documented at the Moses Lake Superfund Site (shallowest to deepest) include:
 - Pleistocene unconsolidated sediments (Missoula flood deposits, aka Hanford Formation) of very high permeability. Generally up to 140 feet thick.
 - Ringold Formation – generally low-permeability sediments, some caliche present in areas at base of formation. Variability in grain size and thickness (pinches out in areas) limit effectiveness as an aquitard. Up to 90 feet thick, directly overlying basalt where present.
 - Wanapum Basalt (“a-Basalt”). Consists of the Priest Rapids Member, where present and/or the flow top of the Roza Member (Upper Roza-1). Generally consists of fractured, brecciated, and vesiculated, high-permeability basalt interflow zone.
 - Wanapum Basalt (“b-Basalt”). Dense, relatively unfractured basalt flow interior of the Lower Roza-1 Member. Low-permeability – believed to act as an aquitard.
 - Wanapum Basalt (“c-Basalt”). Multiple porous and dense basalts below the “b-Basalt”, composed of the Roza-2 and Roza-3 flows.
 - Wanapum Basalt (“d-Basalt”). Dense lower portion that acts as an aquitard.
- Because the b-Basalt is believed to act as an aquitard, subsurface investigations at the Superfund Site were limited in depth to the a-Basalt.
- Stratigraphy and geologic structure indicate that sedimentary formations thicken to the west-southwest and dip to the southwest. The basalt formations also dip to the southwest, ultimately below Moses Lake. Because the potentiometric surface is well below the bottom of the lake, there is believed to be no hydraulic connection between Moses Lake and basalt formations.
- Detailed field investigations at the Superfund Site completed between 1999 and 2003. Included potential source area reconnaissance and mapping, subsurface geophysical surveys, trenching, drilling and monitoring well installation, and soil and groundwater sampling.
- Groundwater flow directions vary at the Site (depending on what area of site), but the predominant flow directions are to the south and southwest, toward Moses Lake (see Appendix A; Figures 3-11 and 3-14; Montgomery Watson, 2003). Seasonal fluctuations in hydraulic gradient and flow direction occur in response to weather patterns, irrigation return-flow, groundwater pumping, and infiltration from the Larson wastewater treatment plant (WWTP) lagoons.
- The Larson WWTP lagoons directly recharge the unconsolidated Pleistocene sediments. It is estimated that recharge occurs at a rate of approximately 350,000 to 400,000 gallons per day (390 to 450 acre-feet per year). Potentiometric maps of the unconsolidated

sediments clearly indicate mounding in the groundwater system as a result of recharge from the WWTP lagoons (see Appendix A; Figure 3-11; Montgomery Watson, 2003).

- Generally a downward component of hydraulic gradient, which increases in magnitude in the southern portion of the Site due to its relative proximity to areas of groundwater pumping from deeper portions of the basalt (lower Wanapum and Grande Ronde).
- Groundwater sampling program showed generally low TCE concentrations in dissolved phase (ranging up to 61.3 ppb) across the Site. The highest concentrations of TCE were found in basalt wells (a-Basalt) in the central portion of the site. The source areas for TCE in the subsurface have not been identified; this suggests vertical migration to deeper portions of the basalt sequence.
- Two underground vaults were identified with TCE concentrations up to 260,000 ppb. Monitoring wells immediately down-gradient of these sources did not have detectable levels of TCE. Subsequent soil vapor samples found TCE levels up to 120,000 ppbv, with the highest concentrations at 20 feet bgs.

HYDROLOGIC CHARACTERISTICS OF CRAB CREEK

Crab Creek is located to the east of the Moses Lake Superfund Site, and is generally hydraulically upgradient from the site. It flows in a southerly direction toward the Parker Horn (a northeast-southwest trending arm of Moses Lake). Flow in Crab Creek is perennial, and, in the vicinity of the Superfund Site, flow is dictated by the Columbia Basin Irrigation Project (CBIP). Water for the irrigation project is diverted from the Columbia River below the Grand Coulee Dam and is applied to approximately 70,000 acres for agricultural irrigation. USGS stream gauging data indicate that, prior to the CBIP, Crab Creek east of the site was an intermittent stream that went dry each summer (Montgomery Watson, 2003). Irrigation occurs on the highlands north and east of the site, and has caused spring/seep/wetland areas to develop at the base of the escarpment east of Crab Creek.

Drilling investigations conducted by Montgomery Watson in 1999 showed that Crab Creek, in the vicinity of the Moses Lake Superfund Site, flows over basalt. Early conceptual models of the eastern portion of the site considered the possibility that the upper permeable basalt (a-Basalt/Priest Rapids Member/Roza-1) and the Pleistocene unconsolidated sediments are in hydraulic connection with Crab Creek. To further evaluate this conceptual model, three monitoring wells (99-BW04, 99-BW-06, and 99-BW-08) were drilled and constructed near Crab Creek to the northeast, east, and southeast of the Site, respectively. Boring logs and rock core logs from these monitoring wells (see Appendix B) showed the following subsurface conditions:

- **99-BW04** – Dark gray, subrounded basalt gravel from 0 to 8 feet below ground surface (ft bgs) and grayish-black to greenish-black basalt from 8 to 27 ft bgs. Rock coring was performed from 12 to 27 ft bgs, and indicated fresh (unweathered) rock with a Weathering Index of 1 and very strong rock conditions with a Strength Index of 5. Specific information regarding fracture density (fractures per foot) was not recorded on the logs; however, good to excellent Rock Quality Designations (RQD values ranging from about 80 to 100%) were recorded for the entire coring interval, which indicate minimal rock fracturing. Vesicular rock was noted at a depth of approximately 12.5 ft bgs, and a calcite vein was noted at approximately 19 ft bgs.
- **99-BW06** – Dark gray gravel with some silt from 0 to 7 ft bgs, and dark gray to black basalt from 7 to 22 ft bgs. Vesicular rock was noted at 15.5 ft bgs, and slightly vesicular rock at 17 and 20 ft bgs. Fracture coating was noted at 14.5 ft bgs. Rock coring from

15.5 to 22 ft bgs fresh, very strong rock conditions. Fracture density was reported as 2 fractures per foot from 15.5 to 17 ft bgs, and from 17 to 22 ft bgs as <1 fracture per foot. RQD values ranged from approximately 83 to 100%, indicating good to excellent rock quality with minimal fracturing.

- **99-BW08** – Alluvium from 0 to 7 ft bgs, and gray to oxidized basalt from 7 to 25.5 ft bgs. Fine-grained, gray basalt with minor vesicles filled with yellow iron-oxides were noted at 10.5 ft bgs. Red oxidized and highly vesiculated basalt was noted at 15.5 ft bgs with yellow friable clay filling vesicles and fractures. Massive fine-grained gray basalt was noted at 20.5 ft bgs with minor clay infilling of large vesicles. Coring from 10.5 to 25.5 ft bgs indicated highly fractured rock conditions with densities of >10 fractures per foot. RQD values ranged from 0 to approximately 68%. Weathering Indices ranged between 2 and 4, indicating slightly to highly weathered rock. Strength Indices ranged between 2 and 3, indicating weak to medium strong rock conditions.

The findings from the drilling and coring programs at these sites were interpreted as indicating that the dense, low-permeability b-Basalt (Lower Roza-1) is present at locations 99-BW04 and 99-BW06 and that the relatively high-permeability a-Basalt (Priest Rapids/Upper Roza-1 Members) is present at the southeastern 99-BW08 location.

Because the Pleistocene sediments and the permeable basalt (a-Basalt/Priest Rapids Member/Upper Roza-1 Member) are absent at monitoring wells 99-BW04 and 99-BW-06, Montgomery Watson concluded that Crab Creek is not directly hydraulically connected with these formations to the east and northeast of the site. However, alluvial deposits and the a-Basalt were encountered at monitoring well 99-BW08, indicating that Crab Creek could be hydraulically connected with these formations in the southeastern portion of the study area. These interpretations of the lithologic conditions recorded during drilling and coring appear to be consistent with the hydrostratigraphic model of the Moses Lake Superfund Site, based on our review of the various reports documenting the Remedial Investigation/Feasibility Studies completed by Montgomery Watson and the lithologic information recorded at the monitoring wells described above. They are also consistent with the geologic structure documented at the site that shows that the sedimentary and basalt formations project up to the northeast (dip to the southwest), thus the Pleistocene sediments and the a-Basalt would not be expected to be present in the northerly portions of the study area along Crab Creek.

Due to the absence of Pleistocene sediments and the upper permeable basalt along Crab Creek to the east and northeast of the Site, potentiometric maps for the alluvial and uppermost basalt prepared by Montgomery Watson (Appendix A) do not illustrate the relationship between groundwater at the site and Crab Creek. Because Crab Creek in the vicinity of the Moses Lake Superfund Site appears to be predominantly flowing over the b-Basalt (Lower Roza-1), the creek may be hydraulically connected with this unit in a limited degree and areal extent due to its low permeability. Potentiometric maps illustrating the hydraulic relationship between Crab Creek and the b-Basalt were not prepared because monitoring wells were not completed in this portion of the basalt sequence.

CONCLUSIONS

The Pleistocene sediments and the permeable portion of the basalt formation (a-Basalt/Priest Rapids/Upper Roza-1 Members) appear to be absent along Crab Creek to the east and northeast of the Moses Lake Superfund Site. As a result, Crab Creek in these areas is not likely in direct hydraulic connection with these formations that are found at the Superfund Site. In these areas, Crab Creek flows over and may be in hydraulic connection with the b-Basalt; although, the degree of connection is likely limited due to low permeability of this portion of the basalt sequence. As a result, increased

flows in Crab Creek that may result from the proposed water conveyance will likely produce limited hydraulic influence at the Moses Lake Superfund Site.

Because permeable, fractured and vesiculated basalt was encountered at monitoring well 99-BW08, Crab Creek may be hydraulically connected with the a-Basalt in the southeastern portion of the study area. However, if this hydraulic connection exists in the southeastern portion of the study area as indicated, increased flows in Crab Creek resulting from the proposed water storage project are not likely to influence subsurface contamination in the southern area of the Moses Lake Superfund Site because this portion of Crab Creek is some distance downgradient of the area of contamination.

TCE concentrations reported for two of the nearest alluvial monitoring wells in the southern study area (99-AW02 and 00-AW10), which are located approximately 1½ and 2 miles from Crab Creek, were non-detect (see Figure 4-11; Montgomery Watson, 2003). Similarly, TCE has not been detected in basalt monitoring wells at these same locations (99-BW09 and 00-BW10) (see Appendix A; Figure 4-12; Montgomery Watson, 2003). The nearest apparent groundwater contamination in project monitoring wells with TCE concentrations above the drinking water standard of 5 ppb is present approximately 2½ to 3 miles west-northwest of Crab Creek. TCE concentrations reported from three monitoring wells in this area (99-BW10, 99-BW18, and 02-BW01) showed relatively low levels ranging from 16 to 37 ppb (see Appendix A; Figure 4-12; Montgomery Watson, 2003). The nearest apparent groundwater contamination in water supply wells in the southern study area is present approximately 2½ to 3½ miles west-northwest of Crab Creek. TCE concentrations reported from six water supply wells in this area (WP-13W, WP-15E, WP-15W, WP-18S, WP-18N, and WP-77) showed relatively low levels ranging from 0.32 to 28 ppb (see Appendix A; Figure 4-15; Montgomery Watson, 2003). The reported concentrations in these areas indicate dissolved TCE plumes of relatively low concentrations, although some wells reported concentrations above the drinking water standard. Increased flow in Crab Creek as a result of the storage project is thus unlikely to produce significant hydraulic influence, if any, in the areas of reported contamination due to their separation from Crab Creek by 2½ to 3½ miles.

This assessment has been completed based on the documents listed below. Should additional information become available regarding the Site, this information should be reviewed to confirm the conclusions presented above.

DOCUMENTS REVIEWED

Montgomery Watson, 1999. Management Plan. Volume 1 – Work Plan. Remedial Investigation/Feasibility Study. Moses Lake Wellfield Superfund Site. September 1999.

Montgomery Watson, 1999. Site Background Summary Report. Moses Lake Wellfield Superfund Site, Grant County, Washington. September 1999.

Montgomery Watson, 2001. Final Site Characterization Summary Report. Remedial Investigation/Feasibility Study. Moses Lake Wellfield Superfund Site. July 2001.

Montgomery Watson, 2001. Final 2000 Site Characterization Technical Memorandum. Remedial Investigation/Feasibility Study. Moses Lake Wellfield Superfund Site. June 2001.

Montgomery Watson, 2001. Results from Steady-State Groundwater Model and Contaminant Transport Simulations – Technical Memorandum. Moses Lake Wellfield Superfund Site. July 2001.

- Montgomery Watson, 2003. Final Remedial Investigation and Baseline Risk Assessment Report. Remedial Investigation/Feasibility Study – Volumes 1 and 2 of 6. Moses Lake Wellfield Superfund Site. July 2003.
- Washington State Department of Ecology, 2007. Final Programmatic Environmental Impact Statement for the Columbia River Water Management Program – Volume I. Ecology Publication No. 07-11-009. February 15, 2007.
- Washington State Department of Ecology and U.S. Bureau of Reclamation (WSDOE & USBR), 2007^a. Appraisal Evaluation of Columbia River Mainstem Off-Channel Storage Options – Executive Summary. Prepared under Contract No. 03CA10150B. May 2007.
- Washington State Department of Ecology and U.S. Bureau of Reclamation (WSDOE & USBR), 2007^b. Appraisal Evaluation of Columbia River Mainstem Off-Channel Storage Options – Volume I of II. Prepared under Contract No. 03CA10150B. May 2007.
- Washington State Department of Ecology and U.S. Bureau of Reclamation (WSDOE & USBR), 2007^c. Appraisal Evaluation of Columbia River Mainstem Off-Channel Storage Options – Volume II of II: Plates. Prepared under Contract No. 03CA10150B. May 2007.

APPENDIX A

FIGURES FROM MONTGOMERY WATSON, 2003

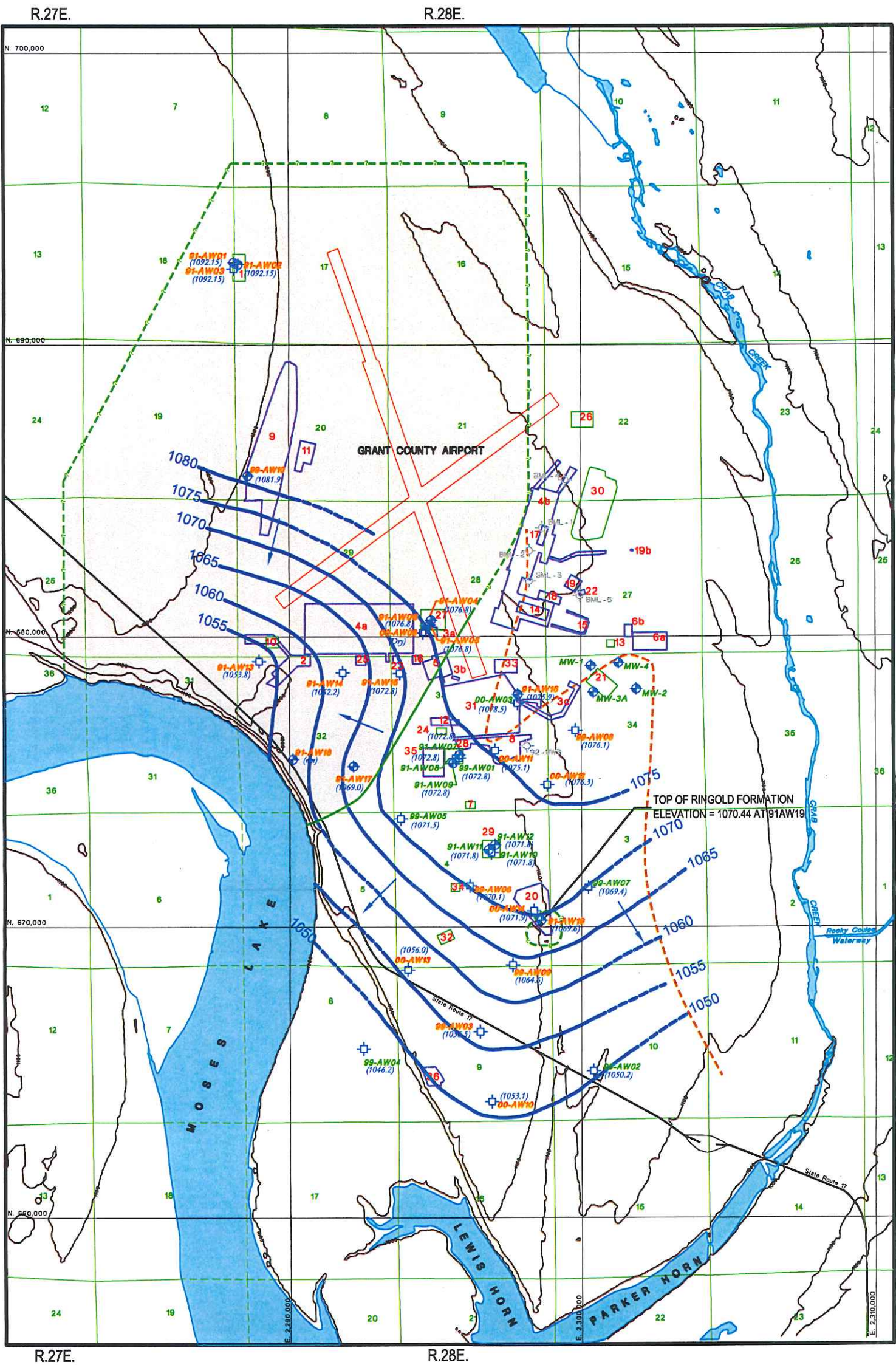
FIGURE - 3-11 ALLUVIUM POTENTIOMETRIC SURFACE MAP OCT 2002

FIGURE - 3-14 PRIEST RAPIDS & ROZA SURFACE MAP OCT 2002

**FIGURE – 4-11 TCE CONCENTRATION IN ALLUVIAL GROUNDWATER
OCT 2002**

**FIGURE - 4-12 TCE CONCENTRATIONS ROZA & PRIEST RAPIDS
GROUNDWATER 2002**

FIGURE – 4-15 TCE CONCENTRATIONS DOMESTIC WELLS



LEGEND

- MAJOR ROADS
- ABANDONED MONITORING WELL
- LOCATION OF PAIRED WELLS
- LOCATION OF SINGLE WELL
- WELL SCREENED IN HANFORD FORMATION
- WELL SCREENED IN RINGOLD FORMATION OR RINGOLD AND HANFORD FORMATION
- GROUNDWATER ELEVATION IN ALLUVIUM WELLS (feet above sea level)
- GROUNDWATER CONTOURS (feet above sea level) (dashed where inferred)
- GROUNDWATER FLOW DIRECTION
- HANFORD FORMATION UNSATURATED (dashed where inferred)
- APPROXIMATE BOUNDARY OF RINGOLD FORMATION PINCH-OUT (dashed where inferred)
- 2002 POTENTIAL SOURCE AREA
- 2002 NO FURTHER CHARACTERIZATION SOURCE AREA

- NOTES:
1. WATER LEVELS MEASURED ON OCTOBER 30 AND 31, 2002.
 2. ALLUVIUM REFERS TO THE RINGOLD FORMATION AND HANFORD FORMATION.
 3. WATER LEVELS IN CLUSTERED WELLS WERE AVERAGED, EXCEPT 91AW16/00AW03 AND 91AW19/00AW14, WHICH HAD DISTINCTLY DIFFERENT WATER LEVELS.
 4. NM = NOT MEASURED.

1	Issued for Final RI Report	2/03	T.Leeason	N.Gonzalez	T.Leeason
0	Issued for Draft RI Report	11/01	T.Leeason	J.Gates	T.Leeason
REV. No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND SIGNED BY

U.S. ARMY CORPS OF ENGINEERS

PROJECT: **Moses Lake Wellfield Superfund Site**

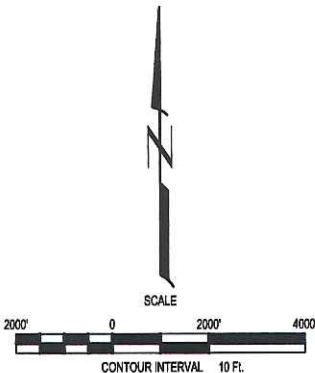
DRAWING TITLE: **ALLUVIUM POTENTIOMETRIC SURFACE MAP - OCTOBER 2002**

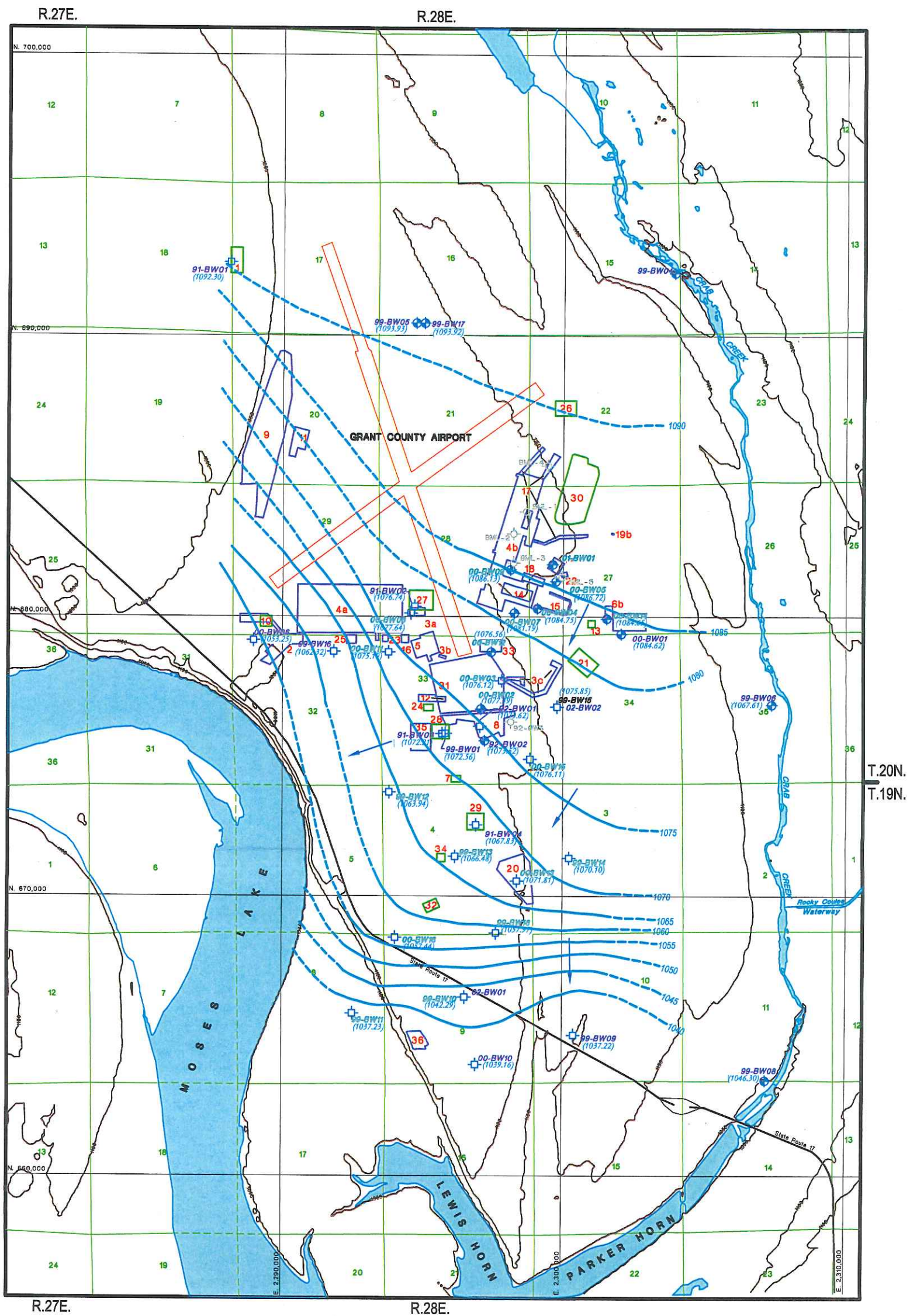
MWH

Sheet 1 of 1 Sheets

SCALE: As Shown

FIGURE No. 3-11





LEGEND

- MAJOR ROADS**
- ABANDONED MONITORING WELL
- LOCATION OF PAIRED WELLS
- LOCATION OF SINGLE WELL
- WELL SCREENED IN PRIEST RAPIDS FM
- WELL SCREENED IN ROZA FM
- WELL SCREENED IN PRIEST RAPIDS/ROZA FM
- GROUNDWATER ELEVATION (feet above sea level)
- POTENTIOMETRIC SURFACE CONTOURS (feet above sea level) (dashed where inferred)
- GROUNDWATER FLOW DIRECTION
- 2002 POTENTIAL SOURCE AREA
- 2002 NO FURTHER CHARACTERIZATION SOURCE AREA
- 2002 POTENTIAL SOURCE AREAS**
- 1 LIQUID WASTE DISPOSAL SITE
 - 2 BIG BEND COMMUNITY COLLEGE HANGAR
 - 3 AIRCRAFT WASH RACK (3a) & DISCHARGE AREAS (3b & 3c)
 - 4a TARMAC AREA A
 - 4b TARMAC AREA B
 - 5 JAL HANGAR AREA & TARMAC
 - 6a BASE CLOSURE LANDFILL
 - 6b DUMPSTER WASH AREA
 - 7 ROCK LANDFILL
 - 8 RANDOLPH ROAD BASE DUMP
 - 9 GRAVEL PIT
 - 10 FIRE TRAINING AREA BURN PIT A
 - 11 FIRE TRAINING AREA BURN PIT B
 - 12 MOTOR POOL DRAIN
 - 13 ROCK DRAIN AREA
 - 14 8-PLACE HANGAR
 - 15 8-PLACE HANGAR DITCH
 - 16 ENGINE REBUILDING FACILITY (Bldg. 2203)
 - 17 3-PLACE HANGAR (Bldg. 5801)
 - 18 PAINT HANGAR (Bldg. 5825)
 - 19 LIQUID OXYGEN GENERATING PLANT (Bldg. 5102)
 - 19b ALTERNATE LOX DISPOSAL SITE
 - 20 SOUTH BASE DUMP
 - 21 LARSON MUNICIPAL WASTE TREATMENT PLANT
 - 22 PAINT HANGAR LEACH PIT
 - 23 ENGINE BUILDUP FACILITY (Bldg. 2113)
 - 24 BUILDING 2802
 - 25 BUILDING 408
 - 26 CONVENTIONAL AMMUNITION STORAGE BUNKERS
 - 27 TETRAETHYL LEAD DISPOSAL SITE
 - 28 TETRAETHYL LEAD DISPOSAL SITE
 - 29 LOW-LEVEL RADIOACTIVE MEDICAL WASTE DISPOSAL SITE
 - 30 BUNKER DISPOSAL AREA
 - 31 19th AVENUE BASE DUMP
 - 32 SOUTH BURN PIT
 - 33 DUMP AT THE END OF RUNWAY 32
 - 34 PATTON PARK LANDFILL
 - 35 STAINED SOIL AREA
 - 36 SKYLINE AUTO WRECKING YARD

SCALE
2000' 0 2000' 4000'
CONTOUR INTERVAL 10 FL

0	Issued for Final RI Report	02/03	T.Lee	M.Gonzalez	T.Lee
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U.S. ARMY CORPS OF ENGINEERS

PROJECT: **Moses Lake Wellfield Superfund Site**

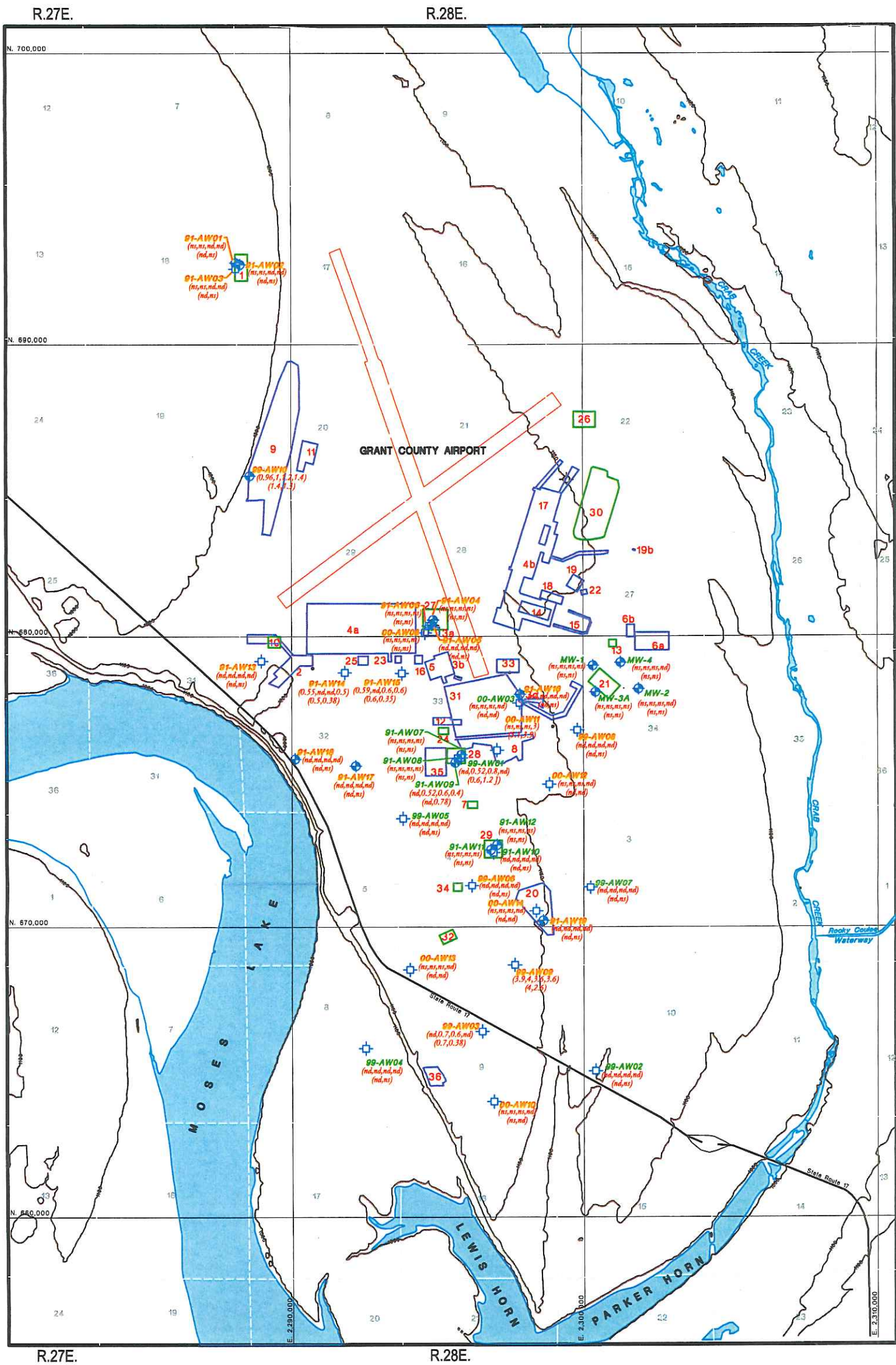
DRAWING TITLE: **PRIEST RAPIDS AND ROZA POTENTIOMETRIC SURFACE MAP - OCTOBER 2002**

Sheet 1 of 1 Sheets

SCALE: As Shown

FIGURE No. 3-14

MWH



LEGEND

- MAJOR ROADS
- LOCATION OF PAIRED WELLS
- LOCATION OF SINGLE WELLS
- WELL SCREENED IN HANFORD FORMATION
- WELL SCREENED IN RINGOLD FORMATION OR RINGOLD AND HANFORD FORMATION
- (NOV '99, MAR '00, JUNE '00, SEPT '00) TCE CONCENTRATIONS
- (JAN '01, OCT '02) TCE CONCENTRATIONS
- NOT SAMPLED
- NOT DETECTED
- 2002 POTENTIAL SOURCE AREA
- 2002 NO FURTHER CHARACTERIZATION SOURCE AREA

NOTES:
1. ALL CONCENTRATIONS ARE IN $\mu\text{g/L}$.
2. ALLUVIUM REFERS TO HANFORD AND RINGOLD FORMATIONS.
3. J - ESTIMATED CONCENTRATION.
4. 91-AW15 IS CONSIDERED PART OF THE OCTOBER 2002 SAMPLING EVENT, BUT WAS SAMPLED IN JANUARY 2003.

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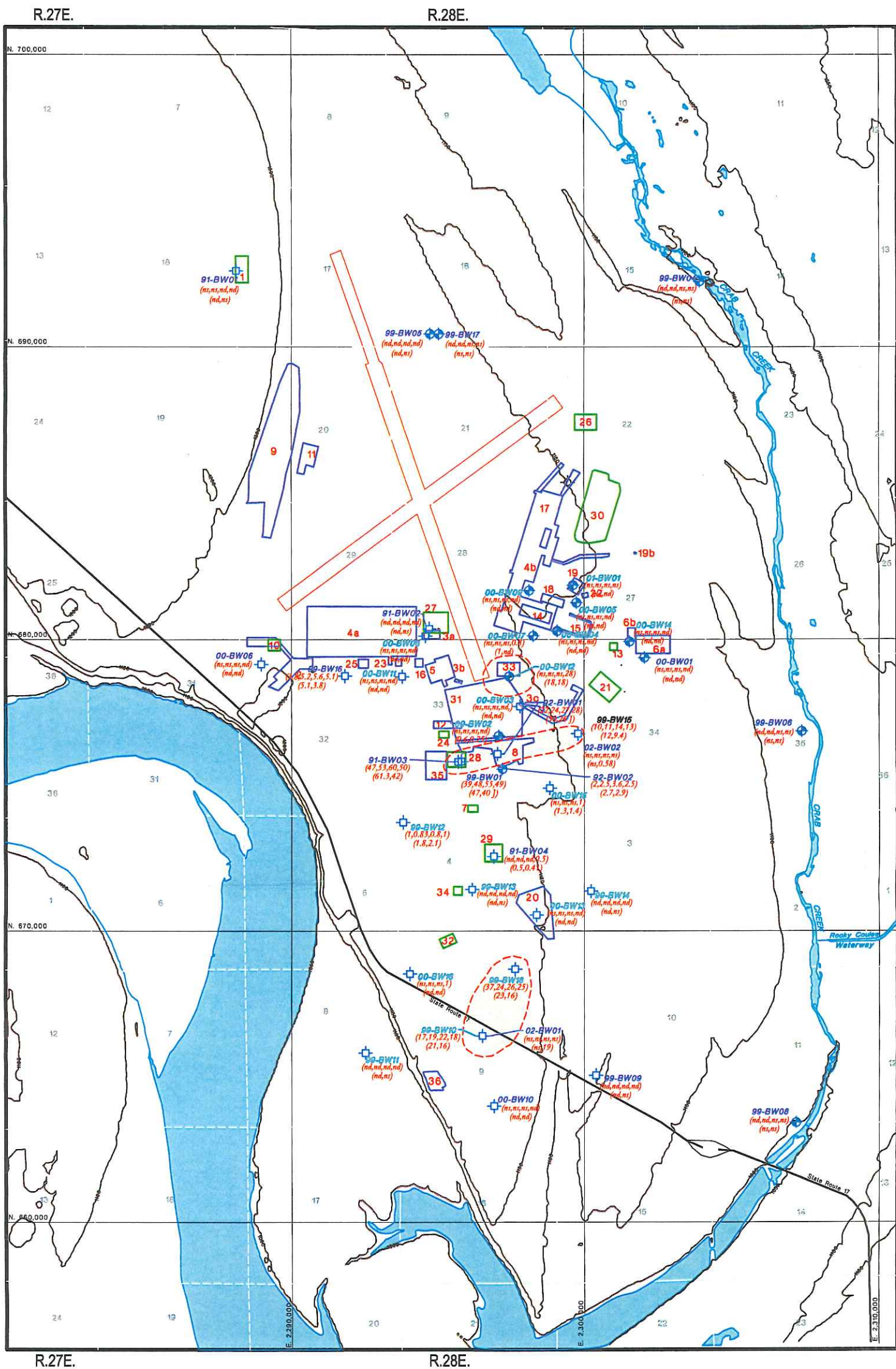
US ARMY CORPS OF ENGINEERS

PROJECT: **Moses Lake Wellfield Superfund Site**

DRAWING TITLE: **TCE CONCENTRATIONS IN ALLUVIAL GROUNDWATER - 2002**

MWH

Sheet 1 Of 1 Sheets
SCALE: As Shown
FIGURE No. 4-11



LEGEND

- MAJOR ROADS
- LOCATION OF PAIRED WELLS
- LOCATION OF SINGLE WELLS
- 99-BW04 WELL SCREENED IN ROZA FM
- 99-BW16 WELL SCREENED IN PRIEST RAPIDS/ROZA FM
- 00-BW16 WELL SCREENED IN PRIEST RAPIDS FM
- (ns,ns,ns,1) ('NOV '99, MAR '00, JUNE '00, SEPT '00) TCE CONCENTRATIONS
- (<0.5, <0.5) (JAN '01, OCT '02) TCE CONCENTRATIONS
- ns NOT SAMPLED
- nd NOT DETECTED
- 12 2002 POTENTIAL SOURCE AREA
- 32 2002 NO FURTHER CHARACTERIZATION SOURCE AREA
- AREAS OF PRIEST RAPIDS AND UPPER ROZA 1 WITH KNOWN TCE ABOVE 5 ug/L

NOTES:

1. ALL CONCENTRATIONS ARE IN $\mu\text{g/L}$.
2. J - ESTIMATED CONCENTRATION.
3. 01-BW01 IS CONSIDERED PART OF THE JANUARY 2001 SAMPLING EVENT, BUT WAS SAMPLED IN MAY 2001.
4. 00-BW14, 02-BW01 AND 02-BW02 ARE CONSIDERED PART OF THE OCTOBER 2002 SAMPLING EVENT, BUT WERE SAMPLED IN JANUARY 2003.

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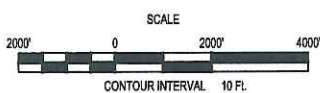
US ARMY CORPS OF ENGINEERS

PROJECT: **Moses Lake Wellfield Superfund Site**

DRAWING TITLE: **TCE CONCENTRATIONS - ROZA AND PRIEST RAPIDS GROUNDWATER - 2002**

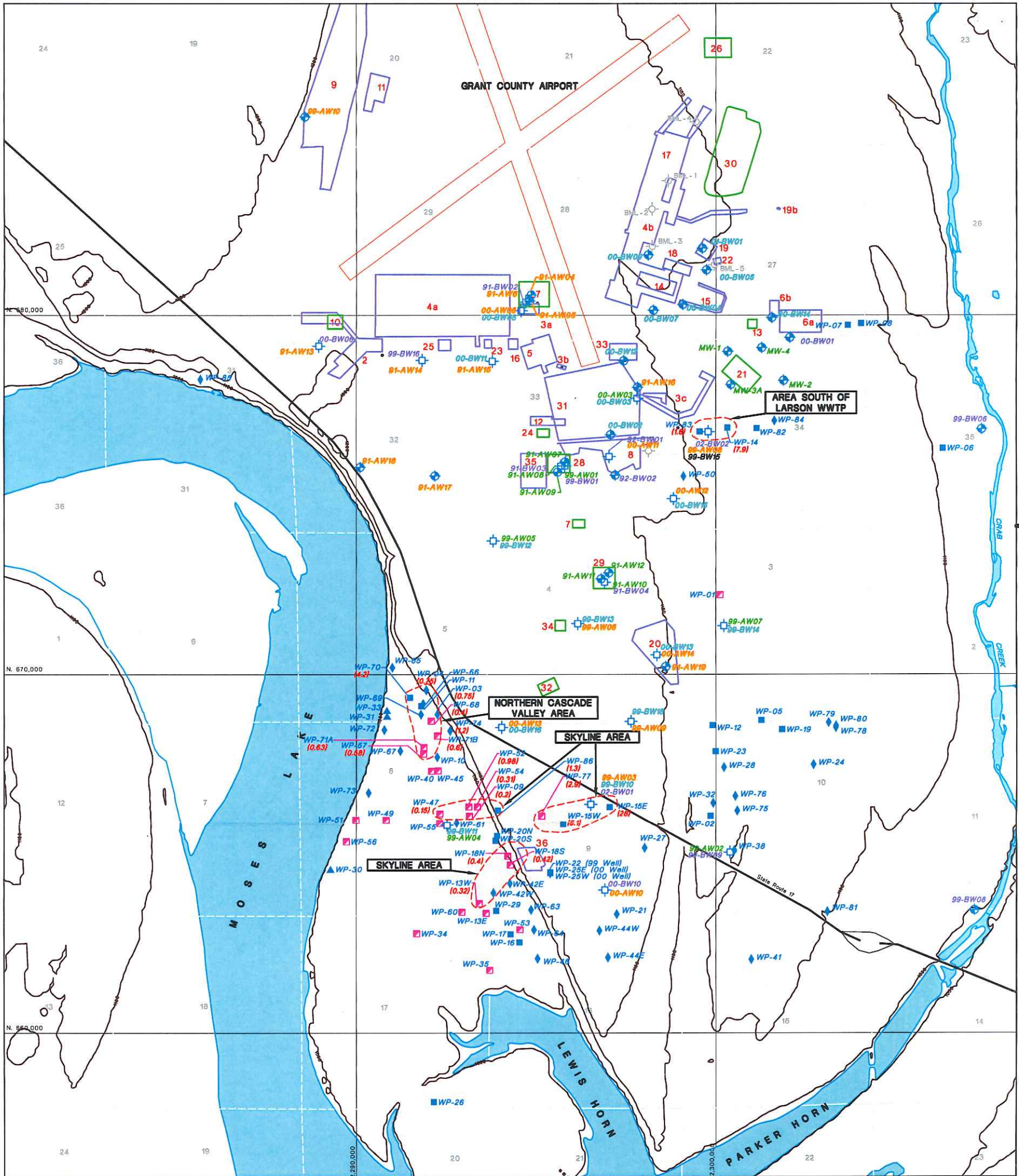
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Sheet 1 Of 1 Sheets
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FIGURE No. 4-12



R.27E.

R.28E.



T.20N.
T.19N.

R.27E.

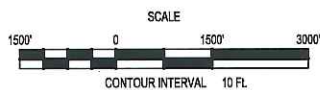
R.28E.

LEGEND

- MAJOR ROADS
- ABANDONED MONITORING WELL
- LOCATION OF PAIRED WELLS
- LOCATION OF SINGLE WELL
- WELL SCREENED IN HANFORD FORMATION
- WELL SCREENED IN RINGOLD FORMATION OR RINGOLD AND HANFORD FORMATION
- WELL SCREENED IN PRIEST RAPIDS FM
- WELL SCREENED IN ROZA FM
- WELL SCREENED IN PRIEST RAPIDS/ROZA FM
- 1999 SAMPLED DOMESTIC WELLS (TCE DETECTIONS ONLY SHOWN)
- 2000 SAMPLED DOMESTIC WELLS (TCE DETECTIONS ONLY SHOWN)
- 2001 SAMPLED DOMESTIC WELLS (TCE DETECTIONS ONLY SHOWN)
- 2002 SAMPLED DOMESTIC WELLS (TCE DETECTIONS ONLY SHOWN)
- 2002 POTENTIAL SOURCE AREA
- 2002 NO FURTHER CHARACTERIZATION SOURCE AREA
- AREAS OF KNOWN IMPACTED GROUNDWATER

NOTES:

- ALL CONCENTRATIONS ARE IN $\mu\text{g/L}$.
- J - ESTIMATED CONCENTRATION.
- WP-30, WP-31, AND WP-33 ARE CONSIDERED PART OF THE 2000 SAMPLING EVENT, BUT WERE SAMPLED IN JANUARY 2001.
- WP-01, WP-13E, WP-13W, WP-18S, WP-18N, AND WP-35 ARE CONSIDERED PART OF THE NOVEMBER SAMPLING EVENT, BUT WERE SAMPLED IN JANUARY 2003.



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REV. No.	REVISIONS	DATE	DESIGN BY	DRAWN BY	REVIEWED AND SIGNED BY
US ARMY CORPS OF ENGINEERS					
PROJECT: Moses Lake Wellfield Superfund Site					
DRAWING TITLE: TCE CONCENTRATIONS - DOMESTIC WELLS					
MWH					
Sheet 1 of 1 Sheets					
SCALE: As Shown					
FIGURE No. 4-15					

APPENDIX B

**BORING AND ROCK CORE LOGS FROM MONITORING WELLS
99-BW04, 99-BW06, AND 99BW-08**

BOREHOLE NUMBER:

99BW04

SHEET 2 OF 2

BORING LOCATION: *Moose Lake Wetland*DRILLING CO.: *Environmental Well Exploration*DRILLER: *Dan Christen*SURFACE ELEVATION: *1098.87*DATE/TIME STARTED: *8/17/99 12:00 PM*

EQUIPMENT:

DATE/TIME FINISHED: *8/17/99 12:00 PM*WATER DEPTH: *3.6'*DATE/TIME OF DEPTH: *8/18/99*LOGGED BY: *Dan Christen*

SOIL PROFILE		SAMPLES				STANDARD PENETRATION TEST "N" BLOWS PER FOOT					WELL CONSTRUCTION	
ELEV. DEPTH	SOIL DESCRIPTION	USCS CLASS	NO.	TYPE	BLOW COUNT/6"	DEPTH (UNITS)	WATER CONTENT, PERCENT & RANGE					
							20	40	60	80		Wp
Feet	(Continued)					Feet						
						25						
27.0	Total depth - 27.0' b.g.s.					30						
						35						
						40						

WELL CONSTRUCTION DETAILS

CASED INTERVAL: 0-14.5'
 CASING MATERIAL: Sch 40 PVC
 CASING DIAMETER: 4.0"
 FILTER INTERVAL/TYPE: 4.0'-14.5'

BENTONITE INTERVAL: 0-4.0'
 GROUT INTERVAL/TYPE: 0-4.0'
 SCREENED INTERVAL: 4.5'-14.5'
 SURFACE CASING WITH LOCK: YES ☒ NO ☐

Project No.:

1227010.131803

Design By:

T. Leeson

Scale:

44:1

File:

MLAKE.GPJ

Drawn By:

K. Conrath

Date:

12/10/99

Draft Soil Boring Log



MONTGOMERY WATSON

U.S. Army Corps of Engineers

SOIL WELL MAKEUP MAY BE CO. GDT 218006

Continued Next Page

P - Polished
K - Slickened
SM - Smooth
A - Rough
VR - Very Rough

Moses Lake Wellfield
U.S. Army Corps of Engineers
ROCK CORE LOG

PROJECT: Moses Lake Wellfield				DATE: 8/17/99		BOREHOLE NUMBER: 99BW04	
BOREHOLE LOCATION COORDINATES:							
ELEVATION: 1098.00'		REFERENCE POINT:		DATUM:		DRILL RIG:	
INCLINATION: 90°		AZIMUTH:		FLUSH:		FEED:	
TOTAL DEPTH: 27.0 ft.		BIT TYPE:		PAGE 2 OF 2			

CORE DIA. (DEPTH)	CASING DIA. (DEPTH)	WATER NOTES	ELEV. DEPTH	ROCK TYPE DESCRIPTION	DEPTH (Scale: feet)	CORE RECOVERY DATA		DISCONTINUITY DATA TYPE & SURFACE DESCRIPTION	STRENGTH DATA			ADDITIONAL TESTING
						T.C.R. (Length - %)	R.Q.D. (Length - %)		WEATHERING INDEX	STRENGTH INDEX	POINT LOAD INDEX	
2.5'					25	25	50	75	Fracture surfaces covered by pale green mineral, possibly opal, also calcite.	W1	R5	
			27.0	Total depth - 27.0' b.g.s.								

ABBREVIATIONS

T.C.R. - Total Core Recovery	J - Joint	PL - Planar	P - Polished
R.Q.D. - Rock Quality Description	F - Fault	C - Curved	K - Shockmilled
E.O.H. - End Of Hole	S - Shear	U - Underlying	SM - Smooth
	B - Bedding	ST - Stopped	R - Rough
	FO - Foliation	I - Irregular	VR - Very Rough

Project No.: 1227010.131803

File: MLAKE.GPJ

Design By: T. Lawson

Drawn By: K. Cunniff

Scale: 44:1

Date: 12/10/99

Moses Lake Wellfield

U.S. Army Corps of Engineers

ROCK CORE LOG

MONTGOMERY WATSON

ROCK MLAKE.GPJ MW SS CO-60T 2800

BOREHOLE NUMBER: 99BW06															
BORING LOCATION: Moses Lake Wetland						SURFACE ELEVATION: 1070.64'									
DRILLING CO.: Environmental West Exploration						DRILLER: Dan Christen									
EQUIPMENT:						DATE/TIME STARTED: 8/10/99 12:00 am									
WATER DEPTH: 5.0'						DATE/TIME FINISHED: 8/10/99 12:00 am									
DATE/TIME OF DEPTH: 8/10/99						LOGGED BY: Barry Boyd									
ELEV. DEPTH		SOIL PROFILE SOIL DESCRIPTION		SAMPLES USQS CLASS NO. TYPE BLOW COUNT			DEPTH (UNITS)			STANDARD PENETRATION TEST N BLOWS PER FOOT				WELL CONSTRUCTION	
										WATER CONTENT, PERCENT & RANGE					
										20 40 60 80 Wp Wh Wl 20 40 60 80				Top PVC elev: 2.0'	
5.0	GRAVEL, with some silt, dark gray (N3)	GM	CT				5								
7.0	BASALT, dark gray (N3)														
12.0	BASALT, black (N1)						10								
15.5	Vesicular						15								
17.0	Slightly vesicular						20								
Continued Next Page															
WELL CONSTRUCTION DETAILS															
CASED INTERVAL: 15.0'					BENTONITE INTERVAL: 0-4.5'										
CASING MATERIAL: Sch 40 PVC					GROUT INTERVAL/TYPE: 0-4.5'										
CASING DIAMETER: 4.0"					SCREENED INTERVAL: 5.0-15.0'										
FILTER INTERVAL/TYPE: 4.5-15.0'					SURFACE CASING WITH LOCK: YES ☒ NO ☐										
Project No.: 1227910.131803		Design By: T. Leeson		Scale: 44:1		Draft Soil Boring Log U.S. Army Corps of Engineers									
File: Mlake.GPJ		Drawn By: K. Corvath		Date: 12/10/99											
MONTGOMERY WATSON															

SOIL WELL Mlake.GPJ ANY SS CO GDB 2/8/00

99BW06

SHEET 2 OF 2

BOREHOLE NUMBER:

BORING LOCATION: Moss Lake Wetland

DRILLING CO.: Environmental West Exploration

DRILLER: Dan Chasson

SURFACE ELEVATION: 1070.56'

DATE/TIME STARTED: 8/18/99 12:00 am

EQUIPMENT:

DATE/TIME FINISHED: 8/18/99 12:00 am

WATER DEPTH: 3.9'

DATE/TIME OF DEPTH: 8/18/99

LOGGED BY:

Basil Boyd

ELEV. DEPTH	SOIL PROFILE SOIL DESCRIPTION	SAMPLES				DEPTH (UNITS)	STANDARD PENETRATION TEST N BLOWS PER FOOT				WELL CONSTRUCTION
		USCS CLASS	NO.	TYPE	BLOW COUNT/5'		20	40	60	80	
							WATER CONTENT, PERCENT & RANGE				
							Wp	Wh	WL	BO	
							20	40	60	80	
Feet	(Continued)					Feet					
22.0	Boring terminated @ 22.0'										
						25					
						30					
						35					
						40					

WELL CONSTRUCTION DETAILS

CASED INTERVAL: 15.0'
 CASING MATERIAL: Sch 40 PVC
 CASING DIAMETER: 4.0"
 FILTER INTERVAL/TYPE: 4.5-15.0'

BENTONITE INTERVAL: 0-4.5'
 GROUT INTERVAL/TYPE: 0-4.5'
 SCREENED INTERVAL: 5.0-15.0'
 SURFACE CASING WITH LOCK: YES ☒ NO ☐

Project No.: 1227010.131803	Design By: T. Leeson	Scale: 44:1
File: MLAKE.GPJ	Drawn By: K. Conrath	Date: 12/10/99

Draft Soil Boring Log

MONTGOMERY WATSON

U.S. Army Corps of Engineers

SOIL WELL ALAKE.GPJ MW SS CO.GDT 28820

PROJECT: Moses Lake Wellfield				DATE: 8/18/99		BOREHOLE NUMBER: 99BW06	
BOREHOLE LOCATION COORDINATES:							
ELEVATION: 1070.58'		REFERENCE POINT:		DATUM:		DRILL RIG:	
INCLINATION: 90°		AZIMUTH:		FLUSH:		FEED:	
TOTAL DEPTH: 22.0 ft.		BIT TYPE:		PAGE 1 OF 2			

CORE DIA. DEPTH	CASING DIA. DEPTH	WATER NOTES	ELEV. DEPTH	ROCK TYPE DESCRIPTION	DEPTH (Same Unit)	CORE RECOVERY DATA			DISCONTINUITY DATA	STRENGTH DATA			ADDITIONAL TESTING
						T.C.R. (Length - %)	R.Q.D. (Length - %)	FRACTURES (Per Foot)		TYPE & SURFACE DESCRIPTION	WEATHERING INDEX	STRENGTH INDEX	
			5.0	GRAVEL, with some silt, dark gray (N3)	5								
			7.0	BASALT, dark gray (N3)									
			12.0	BASALT, black (N1)									
			15.5	Vesicular									
			17.0	Slightly vesicular									
Continued Next Page													

ABBREVIATIONS

T.C.R. - Total Core Recovery	J - Joint	PL - Planar	P - Pitted
R.Q.D. - Rock Quality Description	F - Fault	C - Curved	K - Solderweld
E.O.H. - End Of Hole	S - Shear	U - Undulating	SM - Smooth
	B - Bedding	ST - Stepped	R - Rough
	FO - Foliation	I - Irregular	VR - Very Rough

Project No.: 1227010.131803	Design By: T. Lueson	Scale: 44:1
File: MLAKE.GPJ	Drawn By: K. Conrain	Date: 12/10/99

MONTGOMERY WATSON

Moses Lake Wellfield

U.S. Army Corps of Engineers

ROCK CORE LOG

ROCK MLAKE.GPJ MW SS CO.GDT 28000

PROJECT: Moses Lake Wellfield				DATE: 8/18/99		BOREHOLE NUMBER: 99BW06	
BOREHOLE LOCATION COORDINATES:							
ELEVATION: 1070.58'		REFERENCE POINT:		DATUM:		LOGGED BY: Basil Boyd	
INCLINATION: 90°		AZIMUTH:		FLUSH:		DRILL RIG:	
TOTAL DEPTH: 22.0 R.		BIT TYPE:		PAGE 2 OF 2		FEED:	

CORE DIA. DEPTH	CASING DIA. DEPTH	WATER NOTES	ELEV. DEPTH	ROCK TYPE	DEPTH (SCALING LOG)	CORE RECOVERY DATA				FRACTURES (Per Foot)	DISCONTINUITY DATA	STRENGTH DATA			ADDITIONAL TESTING
				DESCRIPTION		T.C.R. (Length - %)	R.Q.D. (Length - %)	TYPE & SURFACE DESCRIPTION	WEATHERING INDEX		STRENGTH INDEX	POINT LOAD INDEX			
			22.0	Boring terminated @ 22.0'								Slightly vesicular (continued)			

ABBREVIATIONS

T.C.R. - Total Core Recovery	J - Joint	PL - Planar	P - Polished
R.Q.D. - Rock Quality Description	F - Fault	C - Curved	K - Slickensided
E.O.H. - End Of Hole	S - Shear	U - Undulating	SM - Smooth
	B - Bedding	ST - Stepped	R - Rough
	PQ - Foliation	I - Irregular	VR - Very Rough

Project No.: 1227010.131803

Design By: T. Looson

Scale: 44:1

File: Mlake.GPJ

Drawn By: K. Conrath

Date: 12/10/99

Moses Lake Wellfield

U.S. Army Corps of Engineers

ROCK CORE LOG

MONTGOMERY WATSON

99BW08

SHEET 1 OF 2

BOREHOLE NUMBER:

BORING LOCATION: *Albany Lake Wetland*DRILLING CO.: *Environmental Wet Exploration*DRILLER: *Don Ciesion*SURFACE ELEVATION: *1049.14'*DATE/TIME STARTED: *10/12/99 12:00 PM*

EQUIPMENT:

DATE/TIME FINISHED: *10/12/99 12:00 PM*WATER DEPTH: *5.4'*DATE/TIME OF DEPTH: *10/12/99*LOGGED BY: *Andy Sehn*

SOIL PROFILE		SAMPLES				STANDARD PENETRATION TEST "N" BLOWS PER FOOT	WATER CONTENT, PERCENT & RANGE				WELL CONSTRUCTION	
ELEV.	SOIL DESCRIPTION	USCS CLASS	NO.	TYPE	BLOW COUNT/6"		DEPTH (UNITS)	WATER CONTENT, PERCENT & RANGE				
DEPTH								20	40	60		80
Feet						Feet						Top PVC elev: 2.5'
0.0	Alluvium, refused split spoon											
7.0	Basalt											
10.5	Fine-grained, gray porphyritic basalt; minor vesicles filled w/ yellow, locally iron-oxide rich material, 1-3% plagioclase phenocrysts (up to 1.5cm).											
15.6	Oxidized, burnt red, highly vesiculated, (non-brecciated) basalt; chaotic vugs and fractures filled with yellow friable clay											
	Continued Next Page											

WELL CONSTRUCTION DETAILS

CASED INTERVAL: 0-20.0'
 CASING MATERIAL: Sch 40 PVC
 CASING DIAMETER: 4.0"
 FILTER INTERVAL/TYPE: 7.0'-22.0'

BENTONITE INTERVAL: 0-7.0'
 GROUT INTERVAL/TYPE:
 SCREENED INTERVAL: 10.0-20.0'
 SURFACE CASING WITH LOCK: YES ☒ NO ☐

Project No.: 1227010.131803
 Design By: T. L. Linton
 Scale: 14:1
 File: M. J. K. G. P. J.
 Drawn By: K. Corneil
 Date: 12/10/99



MONTGOMERY WATSON

Draft Soil Boring Log

U.S. Army Corps of Engineers

SOIL WELL MAKE GPJ NW SS CO. GGT 28300

99BW08										SHEET 2 OF 2	
BOREHOLE NUMBER:											
BORING LOCATION: <i>Mass Lake Wetland</i>										SURFACE ELEVATION: <i>1242.14'</i>	
DRILLING CO.: <i>Environmental West Exploration</i>										DRILLER: <i>Dan Gleason</i>	
EQUIPMENT:										DATE/TIME STARTED: <i>12/12/99 12:00 am</i>	
WATER DEPTH: <i>5.4'</i>										DATE/TIME FINISHED: <i>12/12/99 12:00 am</i>	
DATE/TIME OF DEPTH: <i>12/13/99</i>										LOGGED BY: <i>Andy Smith</i>	
ELEV. DEPTH	SOIL PROFILE	SAMPLES				DEPTH (UNITS)	STANDARD PENETRATION TEST N BLOWS PER FOOT				WELL CONSTRUCTION
		USCS CLASS	NO.	TYPE	BLOW COUNT/6"		WATER CONTENT, PERCENT & RANGE Wp Wn WL				
Feet	(Continued)					Feet					
20.5	Massive, fine-grained, gray porphyritic basalt; 1-4% pbq phenocrysts and plagioclase glomerocrysts, up to 2cm across; plagioclase is locally resistant. Ab-twinning apparent on larger phenocrysts, large (>2cm) vesicles with minor late clay zeolite(?) fillings.					25					
25.5	Total Depth = 25.5'					30					
						35					
						40					

WELL CONSTRUCTION DETAILS			
CASED INTERVAL:	0-20.0'	BENTONITE INTERVAL:	0-7.0'
CASING MATERIAL:	Sch 40 PVC	GROUT INTERVAL/TYPE:	
CASING DIAMETER:	4.0"	SCREENED INTERVAL:	10.0-20.0'
FILTER INTERVAL/TYPE:	7.0'-22.0'	SURFACE CASING WITH LOCK:	YES ☒ NO ☐

Project No.: <i>1227010.131803</i>	Design By: <i>T. Loewson</i>	Scale: <i>44:1</i>	Draft Soil Boring Log
File: <i>MLAKE.GPJ</i>	Drawn By: <i>K. Carroth</i>	Date: <i>12/10/99</i>	
 MONTGOMERY WATSON			U.S. Army Corps of Engineers

SOIL WELL MLAKE.GPJ MW SS CO GDT 28009

PROJECT: Moses Lake Wellfield				DATE: 10/12/99 BOREHOLE NUMBER: 99BW08									
BOREHOLE LOCATION COORDINATES: _____ LOGGED BY: Andy Sabin													
ELEVATION: 1049.14'		REFERENCE POINT: _____		DATUM: _____		DRILL RIG: _____							
INCLINATION: 90°		AZIMUTH: _____		FLUSH: _____		FEED: _____							
TOTAL DEPTH: 25.6 ft.		BIT TYPE: _____		PAGE 1 OF 2									
CORE DIA. DEPTH	CASING DIA. DEPTH	WATER NOTES	ELEV. DEPTH	ROCK TYPE DESCRIPTION	DEPTH (Feet)	CORE RECOVERY DATA			DISCONTINUITY DATA TYPE & SURFACE DESCRIPTION	STRENGTH DATA			ADDITIONAL TESTING
						T.C.R. (Length - %)	R.Q.D. (Length - %)	FRACTURES (Pic. Desc)		WEATHERING INDEX	STRENGTH INDEX	POINT LOAD INDEX	
			0.0	Alluvium, refused split spoon									
			7.0	Basalt									
			10.5	Fine-grained, gray porphyritic basalt; minor vesicles filled w/yellow, locally iron-oxide rich material. 1-3% plagioclase phenocrysts (up to 1.5cm).						Yellow clay & iron-oxide staining plus minor white chalcadonic fracture filling minerals	W2	R3	
			15.5	Oxidized, burnt red, highly vesiculated, (non-brecciated) basalt; chaotic vugs and fractures filled with yellow friable clay						Yellow, friable clay filling pervasive throughout chaotic voids, fractures & vesicles	W3	R3	
											W4	R2	

Continued Next Page

T.C.R. - Total Core Recovery

R.Q.D. - Rock Quality Description

E.O.H. - End Of Hole

ABBREVIATIONS

J - Joint
F - Fault
S - Shear
B - Bedding
FO - Foliation

PL - Planar
C - Curved
U - Undulating
ST - Stepped
I - Irregular

P - Polished
K - Slickensided
SM - Smooth
R - Rough
VR - Very Rough

Project No.:

1227010.121803

Design By:

T. Loeson

Scale:

44:1

File:

MLAKE.GPJ

Drawn By:

K. Connors

Date:

12/10/99



MONTGOMERY WATSON

Moses Lake Wellfield

U.S. Army Corps of Engineers
ROCK CORE LOG

ROCK MLAKE.GPJ 10W 55 CO.501 25600

PROJECT: Moses Lake Wellfield				DATE: 10/12/99 BOREHOLE NUMBER: 99BW08			
BOREHOLE LOCATION COORDINATES:							
ELEVATION: 1049.18'		REFERENCE POINT:		DATUM:		LOGGED BY: Andy Sabin	
INCLINATION: 90°		AZIMUTH:		FLUSH:		DRILL REG:	
TOTAL DEPTH: 25.5 ft.		BIT TYPE:		PAGE 2 OF 2			

CORE DIA. DEPTH	CASING DIA. DEPTH	WATER NOTES	ELEV. DEPTH	ROCK TYPE DESCRIPTION	DEPTH (Scale feet)	CORE RECOVERY DATA			DISCONTINUITY DATA	STRENGTH DATA			ADDITIONAL TESTING
						T.C.R. (Length - %)	R.Q.D. (Length - %)	FRACTURES (per foot)		HEALTHY INDEX	STRENGTH INDEX	POST LOAD INDEX	
2.5"	4"		20.3	Massive, fine-grained, gray porphyritic basalt; 1-4% pbg phenocrysts and plagioclase glomerocrysts, up to 2cm across; plagioclase is locally resistant. Ab-twinning apparent on larger phenocrysts, large (>2cm) vesicles with minor late clay zeolite(?) fillings. Total Depth = 25.5'	25	25	50	75	>10		W2	R3	
			25			50	75	>10					
			25.5										

ABBREVIATIONS

T.C.R. - Total Core Recovery	J - Joint	PL - Planar	P - Polished
R.Q.D. - Rock Quality Description	F - Fault	C - Curved	K - Slickensided
E.O.H. - End Of Hole	S - Shear	U - Undulating	SM - Smooth
	B - Bedding	ST - Stopped	R - Rough
	FO - Foliation	I - Irregular	VR - Very Rough

Project No.: **1227010.131803**

File: **MLAKE.GPJ**

Design By: **T. Lawson**

Drawn By: **K. Cottrah**

Scale: **44:1**

Date: **12/10/99**

Moses Lake Wellfield

U.S. Army Corps of Engineers

ROCK CORE LOG

MONTGOMERY WATSON

ROCK MLAKE.GPJ MW SS CO.GDT 28006