Quality Assurance Project Plan

Twin Lakes Hydrologic Study



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- Big and Little Twin Lakes Winthrop, Washington. (Google Earth)

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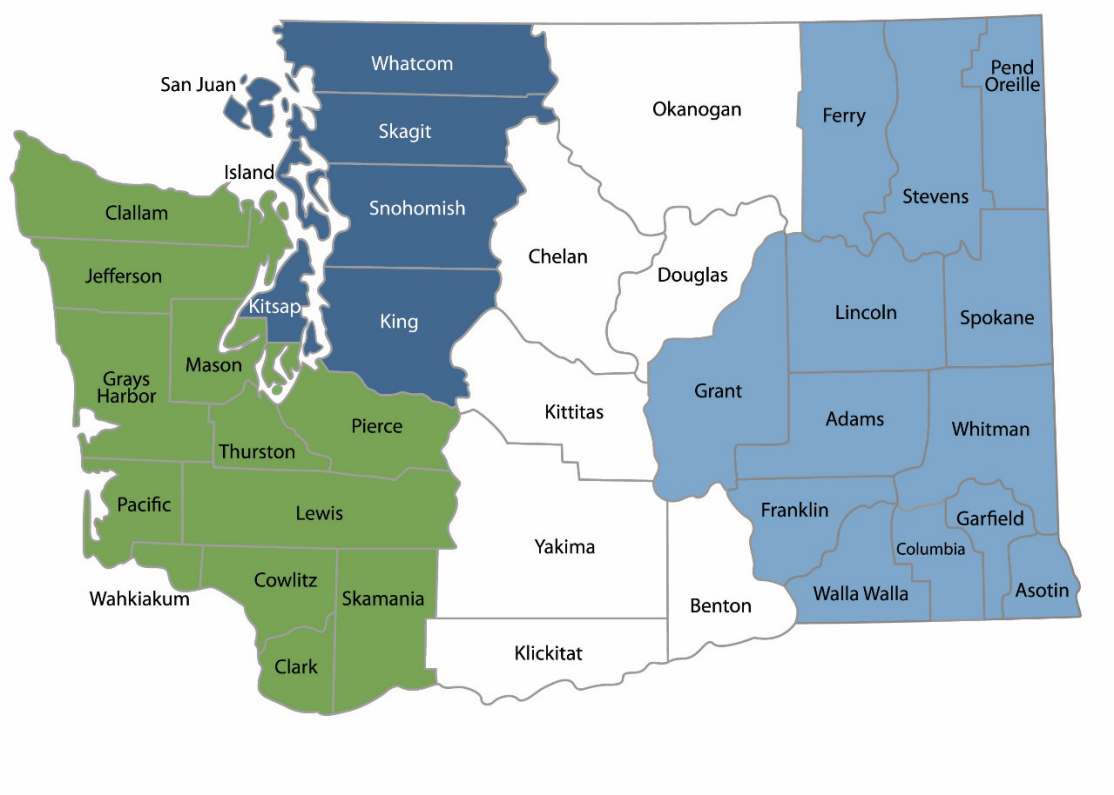

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Quality Assurance Project Plan

Twin Lakes Hydrologic Study

OCR Master Contract No: C2400181

Work Assignment No: ACI005 by Jessica Hartman and Dawn Chapel

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2.0 Abstract

This Study aims to improve the understanding of groundwater–surface water interactions in the Twin Lakes Study area and the key factors contributing to lake level fluctuations. The Study focuses on Big Twin Lake, the largest of a series of groundwater-fed kettle lakes within a shallow glaciofluvial aquifer in the upper Methow Valley (Big Twin, Little Twin, Dibble, and Barnsley Lakes). The kettle lakes function as a delayed-release storage system in direct hydraulic connection with the surrounding aquifer, attenuating and lagging groundwater-level fluctuations through the temporary storage and gradual release of groundwater.

Seasonal and multi-year lake level fluctuations reflect variability in groundwater recharge from precipitation, snowmelt, and irrigation return flows, as well as groundwater withdrawals and irrigation infrastructure changes that influence aquifer storage and groundwater levels.

Better quantification of these processes in the Twin Lakes Study Area is important for improving understanding of groundwater-surface water interactions and the factors controlling lake-level fluctuations. Data collection under this Quality Assurance Project Plan (QAPP) will be accomplished through installation and calibration of hydrologic monitoring equipment to measure lake levels, groundwater levels, and streamflow along Thompson Creek for one full year. The newly collected data will be integrated with historical datasets (2006–2017) to refine the hydrologic conceptual model of Twin Lakes and evaluate the relative influence of climatic and anthropogenic factors on lake-level fluctuations.

The data will be used to develop a simplified steady-state water balance for Big Twin Lake under both gaining and losing conditions, including periods when rising groundwater levels result in groundwater discharge to the lake and periods when declining groundwater levels cause the lake to gradually release stored water to the surrounding aquifer. The study will improve our understanding of lake-aquifer storage dynamics and periodic recharge events that can temporarily reverse hydraulic gradients between the lake and surrounding groundwater system. Results will be used to refine previous interpretations of groundwater-surface water interactions and provide additional context for review of prior evaluations of the lake system as a potential water storage and retiming project. Together with previous investigations, this work will provide an improved scientific basis for future water resource planning in the Twin Lakes area.

3.0 Background

3.1 Introduction and problem statement

An updated conceptual hydrologic model of groundwater-surface water interactions for the Twin Lakes area in the Methow Valley is necessary to support future water resources planning in the Study area.. The Twin Lake Study area consists of the Big Twin, Little Twin, Dibble and Barnsley lakes near Winthrop, Washington, a kettle lake system in hydraulic connection with the local alluvial-glaciofluvial aquifer and the Methow River. Groundwater in the aquifer is also utilized for domestic and irrigation supplies.

Previous lake-level observations in the Study Area documented an approximately 11-foot decline between 1998 and 2002 and attributed at least a portion of the decline to the mandated piping of the nearby Wolf Creek Reclamation District irrigation canal in 2001. Subsequent monitoring of lake levels, groundwater levels, and streamflow along Thompson Creek between 2006 and 2017 documented a partial recovery in lake levels and demonstrated sensitivity to natural climatic variability, including precipitation and snowmelt-driven recharge (Aspect, 2009 and on-going collaborative monitoring between Aspect and Twin Lakes Aquifer Coalition).

A final phase of data collection and monitoring is needed to supplement existing datasets, improve understanding of groundwater-surface water interactions, and refine the hydrologic conceptual model of the Twin Lakes system. This study will re-establish selected historical monitoring stations, install additional monitoring locations as needed, conduct at least one year of hydrologic monitoring, and compile and evaluate all available project data. Field observations will be used to evaluate factors influencing lake-level fluctuations and to develop simplified water balances for Big Twin Lake under both gaining and losing groundwater conditions.

Results will be used to refine the conceptual understanding of lake-aquifer interactions, evaluate the relative influence of climatic and anthropogenic factors on lake levels, and provide updated technical information for review of previous studies, including prior evaluations of water-storage and retiming concepts. Together with previous investigations, this work will provide an improved scientific basis for future water-resource planning and management in the Twin Lakes area.

This QAPP was prepared in accordance with the Washington State Department of Ecology's Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (Lombard and Kirchmer, 2004).

3.2 Study area and surroundings

The Study area is located within the Methow River basin near the confluence of the Methow and Chewuch Rivers. The basin consists of numerous U-shaped valleys resulting from extensive glacial erosion during the Pleistocene glacial epoch (Barksdale, 1975). During glaciation, drainages within many areas of the basin were diverted, causing sediment-laden meltwater

streams to deposit large amounts of silt, sand, and gravel around ice remnants. As the ice remnants melted, kettle lakes formed within the resulting depressions of glaciofluvial sediments, known as “kettle lakes”.

The physiographic features of the Twin Lakes Study area include the recent channel of the Methow River, a glaciofluvial terrace occupied by kettle lakes (Barnsley, Big Twin, Little Twin, and Dibble Lakes), and an upland area separating the Twin Lakes area from the Methow River cored by shallow bedrock. The bedrock beneath the glaciofluvial sediments, and as exposed at higher elevations in adjacent ridges of the study area, consist of the Jurassic aged Twisp Formation of the Newby Group, which is characterized by thin bedded black shale, black argillites, with volcanic lithic sandstone interbeds.

The climate of the Study area is generally classified as semi-arid characterized by warm summers and mild winters. The average annual precipitation is 15.19 inches, and the average annual snow fall is 59.4 inches (Winthrop 1 WSW, WA station 1991 to 2020).

The topography of the Twin Lakes area generally undulates with elevations ranging between 1,800 to 2,000 feet. The peak elevation of adjacent ridges ranges from 3,511 feet to the west (Patterson Mountain), 3,346 feet to the north (Lewis Butte), and 2,610 feet to the east (Studhorse Mountain).

The lower slopes of the Methow basin between Mazama and Twisp are largely non-forested, but in some regions may be covered by sparse ponderosa pine, steppe mosaic with bitterbrush, and beardless blue bunch wheat grass (Barksdale, 1975). Land use in the Study area is mainly rural domestic and agricultural. The most common crop is alfalfa. The town of Winthrop (a popular recreational destination with a population of approximately 600) is located approximately 1.5 miles northeast of Big and Little Twin Lakes.

Figure 1 (next page) features a map of the Study area.

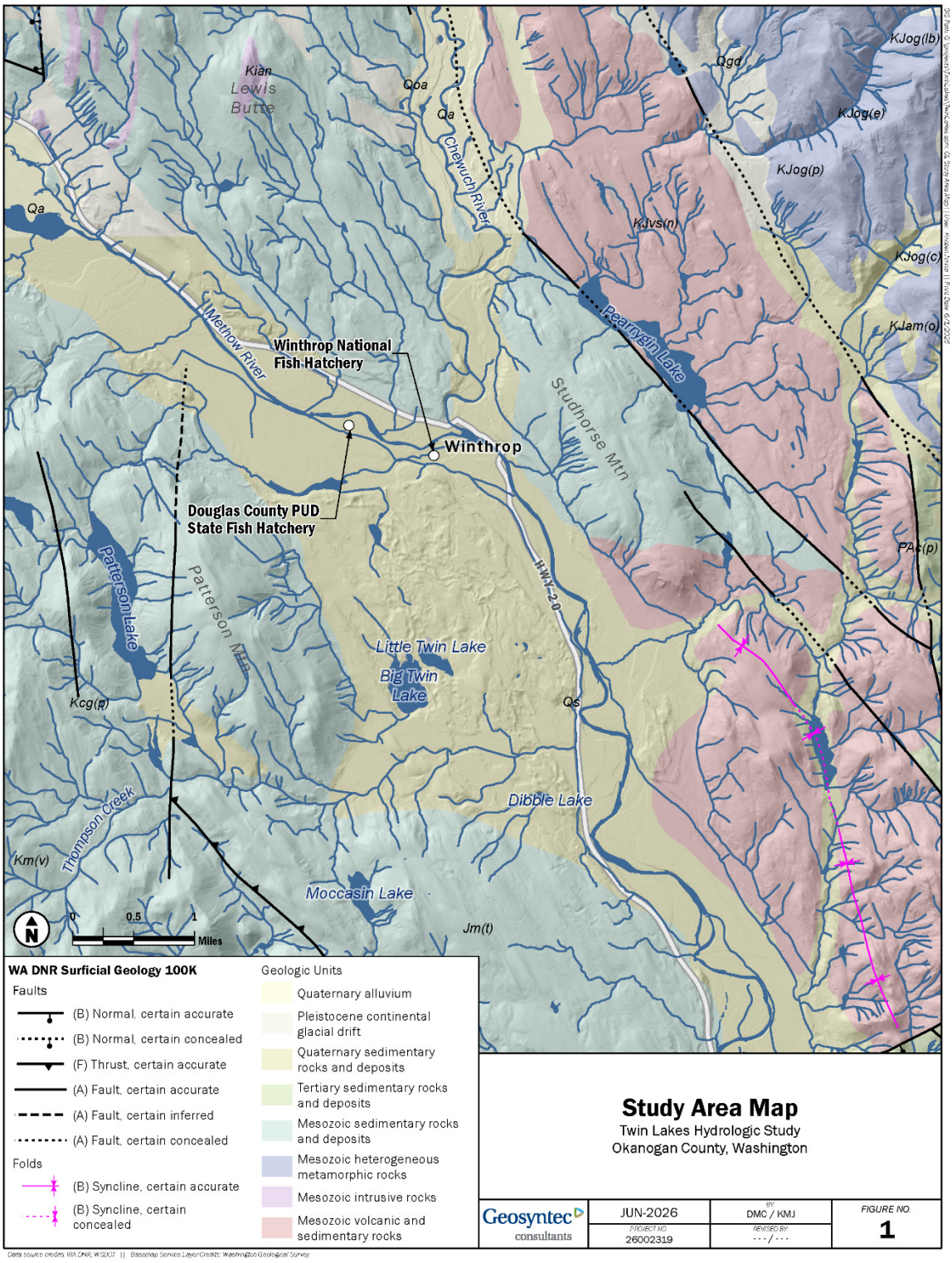

Figure 1. Map of Study area.

3.2.1 History of study area

The Study area was historically inhabited by the indigenous Methow. Homesteaders were first drawn to the area in the late 19th century pursuing agricultural, mining, and timber land uses. The Town of Winthrop was incorporated in 1924.

Following completion of the North Cascades Highway in 1972, recreational use and residential development increased throughout the basin, including construction of seasonal cabins and year-round residences in the Twin Lakes area served primarily by permit-exempt domestic wells. The family-owned Big Twin Lake Campground remains a popular camping and fishing destination along the western shoreline of Big Twin Lake. Most wells within the Study Area obtain water from the shallow unconsolidated alluvial and glaciofluvial aquifer underlying the Twin Lakes area.

Agricultural irrigation, together with operations at the Winthrop National Fish Hatchery and Douglas County Public Utility District Hatchery, represents the primary water use within the Study Area. Total consumptive water use was previously estimated at approximately 525 acre-feet per year (AFY), with agricultural uses accounting for about 79 percent of total consumption and domestic uses accounting for the remaining 21 percent (Aspect, 2009).

Water resources in the Methow Basin are influenced by a combination of seasonal runoff patterns, groundwater availability, irrigation practices, and regulatory requirements intended to protect instream flows. As a result, understanding groundwater-surface water interactions is important for evaluating water-resource conditions and informing future management decisions. Previous investigations of the Twin Lakes area have identified complex hydraulic connections among the kettle lakes, the surrounding aquifer, Thompson Creek, irrigation infrastructure, and seasonal recharge sources. These investigations also recognized the need for additional data to improve understanding of lake-aquifer interactions and the factors controlling long-term lake-level fluctuations.

This study builds upon previous investigations by collecting additional hydrologic data to refine the conceptual model of groundwater-surface water interactions within the Twin Lakes system and improve understanding of the climatic and anthropogenic factors influencing lake levels.

3.2.2 Summary of previous studies and existing data

Previous studies of the Twin Lakes area were initiated in response to a 2003 legislative directive to understand declining lake levels in Twin Lakes and to investigate options to offset impacts. A new storage project supported by local stakeholders emerged and a hydrogeologic evaluation was conducted in support of the Twin lake Aquifer Coalition (TLAC) water right application No. G4-34915 (Aspect, 2009). Application No. G4-34915 sought to withdraw 2,000 gallons-per-minute (subject to minimum instream flows) and a quantity of 800 AFY from wells located along the Methow River to support new in-stream and out-of-stream uses via water storage in Barnsley and Twin Lakes and the associated Twin Lakes aquifer.

Initial field investigations were conducted between 2006-2008 in support of the 2009 Hydrogeologic study (Aspect, 2009). Monitoring of lake levels, groundwater levels, and streamflow continued periodically through 2017 with support from Ecology, Aspect Consulting,

and Twin Lakes Aquifer Coalition volunteers to supplement available datasets and further refine the hydrologic conceptual model of the Twin Lakes system.

Key findings from previous studies related to the hydrologic conceptual model include the following:

- The Twin Lakes aquifer is composed of an upper and lower aquifer consisting of high permeability sediments separated by an aquitard consisting of low permeability sediments.
- A bedrock high occurs between the Twin Lakes area and the Methow River to the east. This subsurface bedrock high forms an eastern barrier to the Twin Lakes aquifer.
- The Twin Lakes aquifer water table forms a divide near Big Twin Lake with horizontal flow both northward and southeastward towards the Methow River.
- A water balance was estimated for the Twin Lakes aquifer system in the 2009 study. Recharge components were dominated by subsurface inflow (51%), precipitation (20%), and irrigation return flows (12%). The remaining inputs included runoff, mountain front recharge, and Thompson Creek discharge. Discharge components were dominated by subsurface outflows (41%), evapotranspiration (36%), and irrigation groundwater withdrawals (17%). Domestic withdrawals accounted for less than 5% of the outflows.
- Review of historical monitoring data suggests that lake levels are influenced by both climatic conditions and irrigation operations. Lake levels increase during periods of elevated recharge when groundwater levels rise above lake levels, resulting in groundwater inflow to the lakes. Conversely, lake levels decline during lower recharge periods as groundwater levels drop below lake levels and the lakes gradually release stored water to the surrounding aquifer.

A summary of the existing data sources from these prior studies are provided in the following sections.

Groundwater Levels

Hand measured groundwater levels were collected from 50 surveyed domestic supply wells in the Study area (August 2006, December 2007, and May 2008). During collection, field staff noted whether the well was pumping or off. Key surveyed wells were also pooled with 278 other well logs to delineate hydrostratigraphic units and to construct a series of cross-sections. These data were used in construction of a numerical groundwater model of the system in 2009 (Aspect, 2009).

Continuous groundwater level monitoring (15-minute intervals) from two domestic wells located north (15B10) and south (23F02) of Twin Lakes was conducted between 2010 and 2017. A data gap in the record for 23F02 occurs between September 2014 and September 2015, and a data gap for 15B10 occurs from September 2014 to November 2015. Data was collected using PT2X Smart Sensor pressure transducer and data loggers. Hand measurements were collected

during periodic downloads, and water levels were converted to elevations based on surveyed top of casing (TOC).

Lake Levels

Staff gages were installed at Big and Little Twin Lakes on August 28, 2006, and later in Barnsley Lake on December 18, 2007, to monitor lake levels. The 10-foot staff gages were attached to steel pipes driven into the lakebed in approximately 4 feet of water (near the shoreline). The top elevations of the steel pipes (or a nearby benchmark) were surveyed by Erlandsen and Associates in order to convert readings to elevations and have an accuracy of +/- 0.1 foot.

Continuous lake level monitoring (15-minute intervals) from Big Twin Lake was conducted between June 2010 and November 2013 using a PT2X Smart Sensor pressure transducer and data logger. The logger and direct read cable were secured within a flexible pipe, then extended about 30 feet from the shoreline at a depth of about 4.4 feet. The pipe was secured into the lakebed using metal rebar. Lake levels were converted to elevations using the relative height of the surveyed staff gage.

Thompson Creek Stream Discharge

Surface water seepage losses and irrigation return flows in the Thompson Creek drainage area south of Big Twin Lake are a source of recharge to the Twin Lakes Study area.

Synoptic measurements of discharge were collected in December 2007 and May 2008 at nine locations along Thompson Creek to evaluate gaining and losing reaches (Stations 1U, 1D, 2UD, 2UU, 2D, 3, 4U, 4DU, 4D, and 4DD). Measurements were collected with a Swoffer current meter along established transects.

Staff gages and pressure transducers were later installed in June 2010 at stations 1U and 4U for continuous measurements of discharge. Rating curves were developed using a range of discharge measurements collected between June 2010 and June 2011.

Surveys

Erlandsen and Associates surveyed the locations and measuring point elevations of 44 domestic wells and lake level staff gages (or nearby reference mark) using a differential GPS when possible (limited number of trees present) or with a combination of differential GPS and traditional survey techniques. Elevations were within +/- 0.1 foot. Erlandson and Associates also surveyed surface elevations along shoreline control points around Barnsley and Big Twin Lake to support estimates of maximum storage capacities.

Survey coordinates and elevations for previous project investigations were referenced to the Washington State Plane Coordinate System, South Zone, North American Datum of 1983 (WAC SPS83), and the National Geodetic Vertical Datum of 1929. Any new surveys collected during this Study will reference the same coordinate system and datum.

3.2.3 Parameters of interest and potential sources

This Study does not include evaluation of environmental pollutants or contaminants. The Study focuses on hydrologic parameters needed to characterize surface water-groundwater interactions, update the hydrologic conceptual model, and updated the water balance for the Twin Lakes system under gaining and losing conditions.

Parameters of interest include the following:

- Lake water levels (stage): Used to evaluate hydrologic responses and changes in lake storage over time.
- Thompson Creek discharge: Used to evaluate seepage losses that contribute recharge to the Twin Lakes area.
- Groundwater levels and hydraulic gradients: Measured to assess connectivity between the lakes and surrounding aquifer system and to infer groundwater exchange with lakes.
- Groundwater inflow and outflow estimates: Interpreted from observed hydraulic conditions and conceptual understanding of the Study area.
- Precipitation: Considered as a direct input to the lake surface and recharge to aquifer.
- Lake geometry (surface area and, if available, bathymetry): Used to relate water level to storage volume.

Data will be obtained primarily from site-specific field measurements and project-specific datasets collected during the Study to supplement previous investigations and datasets. These parameters will be used collectively to develop a conceptual and quantitative understanding of the lake water balance and the relative role of groundwater and surface water processes.

3.2.4 Regulatory criteria or standards

Not applicable. Water quality samples will not be collected under this study.

3.3 Water quality impairment studies

Not applicable.

3.4 Effectiveness monitoring studies

Not applicable.

4.0 Project Description

The project seeks to re-establish the hydrologic monitoring network within the Twin Lakes area to collect groundwater and surface water data needed to refine the hydrologic conceptual model, evaluate the factors controlling lake-level fluctuations, and develop simplified water balances for Big Twin Lake under both gaining and losing groundwater conditions. Previous investigations and feasibility evaluations will also be summarized within the context of newly collected data to provide updated technical information for future water-resource planning and management.

4.1 Project goals

Project goals for the proposed Study under this QAPP include but are not limited to the following:

- Advance the existing hydrologic conceptual model for Twin Lakes through collection of site-specific data.
- Identify key factors that influence lake levels annually and seasonally, including climatic and anthropogenic influences.
- Develop a water balance for Twin Lakes under high and low lake level conditions.
- Provide an updated conceptual hydrologic model for Twin Lakes to support future water resources planning of the area.

4.2 Project objectives

Project objectives through specific field activities and data analysis include but are not limited to the following:

- Re-establish monitoring stations in the Twin Lakes area and conduct at least 1 year of monitoring of lake levels, groundwater levels in up to three monitoring wells, and stream discharge on Thompson Creek.
- Measure stream flows at streamflow gauges in Thompson Creek during at least four data download periods from six transducers (3 wells, 1 lake level and 2 streamflow gauges) and update rating curves.
- Conduct at least one synoptic seepage survey along accessible reaches of Thompson Creek to verify previously identified gaining and losing reaches under current hydrologic conditions and provide supplemental information for updating the hydrologic conceptual model. The survey will be conducted during baseflow conditions, which typically occur during late summer, fall, or winter when streamflow on Thompson Creek is generally only a couple cubic feet per second, to maximum ability to identify groundwater gains and losses and compare seepage pattern to those observed during the previous investigation.

The new data will be integrated with previously collected project data and available climatologic data (e.g., precipitation, snowfall, temperature, and evapotranspiration estimates) to refine the hydrologic conceptual model of the Twin Lakes system and support development of simplified water balances for Big Twin Lake under gaining and losing hydrologic conditions. The kettle lake system functions as a dynamic component of the local groundwater system, exchanging water with the surrounding aquifer in response to variations in recharge and groundwater levels. Evaluation of groundwater levels, lake levels, Thompson Creek discharge, and climatic conditions will improve understanding of the hydrologic processes controlling seasonal and interannual lake-level fluctuations, groundwater-surface water interactions, and the transient availability of lake storage under varying hydrologic conditions. Results will provide updated technical information to support interpretation of previous studies and future water-resource planning in the Twin Lakes area.

4.3 Information needed and sources

Additional continuous data collection of lake levels, groundwater levels, and stream discharge is needed to support updating the hydrologic conceptual model of the Twin Lakes system under high and low lake-level conditions. The new data will be evaluated together with intermittent and continuous monitoring data collected between 2006 and 2017, including groundwater elevations, lake levels, and Thompson Creek discharge measurements. Project data will include both synoptic manual measurements and continuous monitoring using pressure transducers and rating curves established for study monitoring locations. Many of the proposed monitoring locations are at sites established during previous investigations where monitoring equipment has been removed, is no longer operational, or monitoring has been discontinued. The current study will re-establish monitoring at selected historical locations to facilitate comparison with previous datasets and evaluate hydrologic conditions under current climate and watershed conditions. One additional groundwater monitoring location is proposed near the Big Twin Campground to improve coverage of groundwater conditions adjacent to Big Twin Lake.

In addition to site-specific monitoring data, the study will utilize publicly available datasets to provide climatic, land use, and hydrologic context for interpretation of study results. These datasets may include precipitation and temperature records from the NOAA Winthrop 1 WSW station, historical and current aerial imagery, Washington State Department of Agriculture crop maps, and other publicly available climatological and land-use datasets. These information sources will be used to support interpretation of groundwater-level, lake-level, and streamflow trends, evaluate potential influences of land-use and irrigation practices, provide context regarding historical hydrologic conditions, and support refinement of the hydrologic conceptual model and water balance analysis.

4.4 Tasks required

The objectives related to data collection under this Study will be accomplished through the investigative tasks listed below.

Monitoring and maintenance tasks will occur throughout the 1-year monitoring period. Field staff will conduct four scheduled site visits, in addition to instrument deployment and recovery,

to download automated data, inspect monitoring equipment, and collect manual groundwater-level, lake-level, stream-stage, and stream-discharge measurements. These measurements will be used to support development of rating curves, verification of automated data, and assessment of data quality.

Task 1 – Groundwater Level Monitoring

- Groundwater level monitoring will be conducted to evaluate seasonal hydraulic gradients between groundwater and lake levels in support of the conceptual site model.
- Groundwater levels will be monitored in three domestic wells, contingent upon access and homeowner authorization.
- Each well will be instrumented with a LevelScout 2 pressure transducer with a direct-read cable.
- One location will also be equipped with a BaroScout 2 to record barometric pressure for data correction.
- Field staff will conduct four site visits (in addition to initial instrumentation and retrieval) to download automated data and to collect manual measurements of groundwater levels, lake levels, and stream discharge.

Task 2 – Lake Level Monitoring

- Lake level monitoring will be conducted at Big and Little Twin lakes to evaluate seasonal gradients between groundwater and lake levels in support of the conceptual site model.
- Both lakes will be equipped with a surveyed staff gage for manual measurements of water levels and conversion of lake stage to elevation.
- A monitoring station will be established at Big Twin Lake to collect continuous lake level measurements with a LevelScout 2 pressure transducer with direct-read cable.

Task 3 – Stream Discharge Measurement and Monitoring

- Streamflow in Thompson Creek will be measured at previously established locations upgradient (1U) and downgradient of the Moccasin Ranch (4U).
- Irrigation on the Moccasin Ranch is supplied by water diverted from Thompson Creek.
- Irrigation operations are understood to influence lake levels and will be evaluated as part of the Study.
- At least one synoptic seepage survey of discharge along accessible reaches of Thompson Creek during low-flow conditions to evaluate the location and magnitude of gaining and losing reaches and compare results with previous investigations.

Task 4 – Survey (Contingent Task)

- If previously established benchmarks by Erlandsen and Associates are not available to convert water levels to elevations for this Study, then new benchmarks will be surveyed using a survey grade GPS (see Section 6.2).

Task 5 – Data Analysis and Reporting

- Data collected during this study and previous investigations will be compiled and analyzed to support development of an updated water balance and conceptual understanding of the Twin Lakes system.
- Rating curves for stream monitoring locations will be updated or redeveloped, as needed, using discharge measurements collected during this study and, where appropriate, supplemented with historical measurements from previous investigation.
- Hydrographs of groundwater levels, lake levels, and stream discharge will be developed and updated, incorporating available historical data (2006–2017) where applicable.
- A water balance for the lake system will be conducted, considering precipitation, evaporation, groundwater inflow and outflow, and estimated influences from Thompson Creek and irrigation at the Moccasin Ranch and adjacent fields.
- Leakage from the Wolf Creek Ditch is not expected to be a contributing component, as the ditch has been piped.

4.5 Systematic planning process

This QAPP has been prepared to satisfy the systematic planning needs of this project.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1 shows the responsibilities of those who will be involved in this project.

Table 1. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Ingrid Ekstrom, Hydrogeologist **Department of Ecology, Office of Columbia River** **Phone: 509-823-3495**	**Project Manager, OCR**	**Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.**
Dawn Chapel, Senior Hydrogeologist Geosyntec Consultants, Inc **Phone: 206-948-2263**	**Project Manager and Principal Investigator**	**Co-author of QAPP. Oversees field work. Conducts QA review of data, analyzes and interprets data. Writes the draft report and final report.**
Tyson Carlson, Principal Hydrogeologist Geosyntec Consultants, Inc **Phone: 509-895-5923**	**Project Director and Senior Review**	**Oversees approach development, data analysis, and QA/QC. Reviews final report.**
Stephen Bartlett, Geologist Geosyntec Consultants, Inc Phone: 509-834-7040	**Senior Staff Geologist**	**Installs monitoring stations. Performs data entry and field observations.**
Jessica Hartman, Geologist Geosyntec Consultants, Inc Phone: 509-864-1299	**Senior Staff Geologist**	**Co-author of QAPP and technical support.**
McKenna Murray Department of Ecology **Phone: 509-823-0996**	**Quality Assurance Coordinator, OCR**	**Reviews the draft QAPP and recommends the final QAPP for approval.**

QA/QC: Quality Assurance/Quality Control
QAPP: Quality Assurance Project Plan
NEP: National Estuary Program
WQX: Water Quality Exchange

5.2 Special training and certifications

A hydrogeologist licensed in the State of Washington will perform all analyses and interpretation of field data and provide oversight of hydrogeologic data collection. All field staff involved in this project have either the relevant experience in the required standard operating procedures (SOPs) or will be trained by more senior field staff or the project manager who has the required experience. The experienced staff will then lead the field data collection and oversee/mentor less-experienced staff.

5.3 Organization chart

See Table 1 above.

5.4 Proposed project schedule

Table 2 lists key tasks and the anticipated schedule proposed under this project.

Table 2. Tentative project schedule

Task	Target Completion Date	Lead staff	Notes
Project QAPP (this document)	September 2026	Jessica Hartman and Dawn Chapel	--
EIM Study ID	June 2026	Dawn Chapel	Establish EIM Study ID
Field Work Preparation (June-September 2026)	September 2026	Dawn Chapel and Stephen Bartlett	Access Agreements, Permits, Equipment
Re-Establish Monitoring Network (September-October 2026)	October 2026	Stephen Bartlett	Requires approval of QAPP
Data Download and Stream Flow Measurements (4 Events) (October 2026-October 2027)	October 2027	Stephen Bartlett	Requires approval of QAPP
Data Analysis (November 2027-February 2028)	February 2028	Stephen Bartlett	Hydrographs, water balance, updated conceptual site model
Draft Project Report (February 2028-May2028)	May 2028	Dawn Chapel and Tyson Carlson	For Ecology Review
Final Project Report	August 2028	Dawn Chapel and Tyson Carlson	--
EIM Data Load	August 2028	Hanna Winter	Upload data to EIM

EIM: Environmental Information Management
QAPP: Quality Assurance Project Plan

5.5 Budget and funding

The project budget is being funded by an Ecology OCR work assignment under a Master Contract (No. C2400181) with an Aspect Consulting (a Geosyntec Company) work assignment (No. ACI005).

6.0 Quality Objectives

6.1 Data quality objectives [2]

The main Data Quality Objective (DQO) for this field investigation is to collect representative groundwater levels, lake levels, and stream discharge rates at specific sites in the Study area. The analysis will use standard methods to measure and collect water levels and discharge measurements that meet the measurement quality objectives (MQOs) described below.

6.2 Measurement quality objectives

MQOs are statements of the precision, bias, and detection or measurement limits necessary to meet the study objectives. Precision and bias together characterize data accuracy, while additional data quality indicators include representativeness, completeness, and comparability.

The field investigation will include measurements of groundwater and lake elevations and stream discharge in Thompson Creek.

The MQOs presented in Table 3 were selected based on the study objectives of characterizing groundwater-surface water interactions, evaluating lake-level fluctuations, and developing simplified water balances. The primary purpose of streamflow measurements is to characterize relative flow conditions in Thompson Creek, evaluate gaining and losing reaches, and provide supporting information for the hydrologic conceptual model. Streamflow data are not intended to serve as the primary basis for quantifying the lake water balance; therefore, an MQO of ±10 to 15 percent is considered sufficient for study objectives.

Field equipment and monitoring methods were selected to meet or exceed the MQOs. Equipment specifications and expected measurement performance are summarized in Table 4.

[2] DQO can also refer to ***Decision*** Quality Objectives. The need to identify Decision Quality Objectives during the planning phase of a project is less common. For projects that do lead to important decisions, DQOs are often expressed as tolerable limits on the probability or chance (risk) of the collected data leading to an erroneous decision. And for projects that intend to estimate present or future conditions, DQOs are often expressed in terms of acceptable uncertainty (e.g., width of an uncertainty band or interval) associated with a point estimate at a desired level of statistical confidence.

Table 3. Measurement Quality Objectives

Parameter	MQO	Basis for MQO
Groundwater Level Elevation	+/- 0.10 ft	Define hydraulic gradients and groundwater-surface water interactions.
Lake Level Elevation	+/- 0.10 ft	Evaluate seasonal and interannual lake-level fluctuations and water balance.
Relative Water-Level Trends (continuous monitoring)	+/- 0.05 ft	Characterize temporal responses and hydraulic relationships
Stream discharge Measurements	+/- 10%-15%	Characterize relative flow conditions, develop rating curves, and evaluate gaining/losing reaches.
Surveyed Measuring Point Elevations	+/- 0.10 ft	Compare groundwater and lake levels across monitoring locations
Data Completeness	>/= 80% continuous data; >/= 95% discrete measurements	Capture seasonal conditions

Table 4. Field Equipment and Performance Specifications

Parameter	Equipment Method	Bias (median)	Precision Field Duplicates (median)	Equipment Information			Expected Range
				Accuracy	Resolution	Range	
Water Level Monitoring							
Depth to Water	Waterline Envirotech 500-ft Water	--	--	+/-0.05 ft	+/-0.01 ft	0.5 to 500 ft	50 to 200 ft
Pressure	LevelScout2X v2.8	--	--	+/-0.05% FS (+/-0.035ft-H_2O; +/- 0.04 ft H_2O combined with Baro)	0.0034% FS (0.002 ft-H_2O)	Max 70 ft-H_2O (abs.)	5 to 25 ft-H_2O
Barometric Pressure	BaroScout2x v2.8	--	--	0.05% FS (0.017 ft-H_2O)	0.0034% FS (0.001 ft-H_2O)	Max 35 ft-H_2O	30 to 32 ft-H_2O
Staff Gage	USGS Style C Staff Gage	--	--	0.01 to 0.05 ft	0.01 ft	0 to 10 ft	0 to 9 ft
Wellhead and Staff Gage Positions (GPS)	Arrow Gold+ GNSS Receiver	--	--	0.03 ft	0.01 ft	Not range-limited, Dependent on line of site to satellite	--
Stream Discharge Monitoring							
Stream Discharge	Sontek Flow Tracker 2	Minimal with proper deployment	2 to 5% discharge	+/- 1% measured velocity	0.0003 ft/sec	0.003 to 13 ft/sec	0.1 to 3 ft/sec

ft: feet
ft/sec: feet per second
MQO: measurement quality objectives
USGS: United States Geological Survey

6.2.1 Targets for precision, bias, and sensitivity

Field equipment and monitoring methods were selected to meet or exceed the MQOs presented in Table 3. Evaluation of precision, bias, and sensitivity will focus on the ability of the collected data to support interpretation of groundwater-surface water interactions, lake-level fluctuations, hydraulic gradients, and streamflow conditions within the Study area. The criteria described below establish the basis for evaluating whether collected measurements are of sufficient quality to meet study objectives.

6.2.1.1 Precision

Precision is defined as the level of agreement among independent, repeated measurements collected under similar conditions. For this study, precision will be evaluated for water level and stream discharge measurements using replicate field measurements rather than traditional water-quality duplicates.

- For groundwater and lake levels, precision will be assessed by collecting periodic replicate manual measurements (e.g., using electric tapes or staff gages) during the same site visit. Agreement within +/- 0.02 feet will be considered acceptable, along with consistency with pressure transducer records within manufacturer specifications.
- For stream discharge, precision will be evaluated through repeat discharge measurements collected at the same location under stable flow conditions using the same methods and equipment. Repeat measurements should generally agree within 5 to 8 %, consistent with standard hydrologic practice. Because seepage surveys are intended primarily to identify gaining and losing reaches and support the conceptual model, seepage survey results will be interpreted in consideration of the expected precision of the measurement relative to the magnitude of the apparent gain or loss.

These approaches ensure that variability in water levels and streamflow reflect actual hydrologic conditions rather than measurement error.

6.2.1.2 Bias

Bias is defined as the systematic difference between a measured value and the true value. For this study, potential sources of bias in water level and stream discharge measurements include improper instrument calibration, sensor drift, datum or reference point errors, and deviations from standard measurement protocols.

Bias will be minimized through strict adherence to established field procedures and routine equipment maintenance and calibration. Water level measurements will be referenced to surveyed datums, and automatic pressure transducers will be periodically checked against manual measurements. Differences greater than ±0.02 feet will trigger evaluation and correction of instrument drift or referencing errors.

For stream discharge measurements, bias will be minimized by following standard measurement techniques (e.g., appropriate velocity meter selection, correct subsectioning, and

stable control conditions) and maintaining properly calibrated equipment. Rating curves will be updated using measured discharge data to reduce systematic deviations between observed and predicted flows.

Overall, periodic comparison of automated and manual measurements, along with consistent application of standardized methods, will be used to identify, quantify, and correct bias, ensuring that data accurately represent site conditions.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of the field method and instrument used to detect a change in the parameter being measured. Sensitivity is reflected by the range, accuracy, and resolution of the selected instrumentation. Equipment specifications summarized in Table 4 demonstrate that instrument performance meets or exceeds the MQOs presented in Table 3.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Factors that influence comparability between studies can include the availability and extent of previous data, training of field staff, field data-collection similarities (location, duration, time of year, weather conditions, etc.), SOPs, and instrumentation sensitivity. Field staff will adhere to common field protocols, and all field measurements will follow SOPs to improve comparability. Where feasible, monitoring will be conducted at previously established monitoring locations using methods consistent with previous investigation (2006-2017) to facilitate comparison with historical groundwater levels, lake levels, stream discharge measurements, and stage-discharge relationships.

A complete list and discussion of SOPs is included below in the Field Procedures section (Section 8).

6.2.2.2 Representativeness

Representativeness refers to the degree to which collected data accurately characterizes the hydrologic system under study. In this project, representativeness is addressed primarily through study design, including the selection and distribution of monitoring locations and the duration of data collection.

Monitoring stations are being re-established at key locations within the Twin Lakes Study area to capture critical components of the lake–groundwater–stream system, including lake levels, groundwater levels in the shallow glaciofluvial aquifer, and discharge along Thompson Creek. These locations were selected based on prior investigations and their importance for quantifying recharge, storage, and discharge processes.

Continuous monitoring over at least 1 year will capture seasonal patterns and variability associated with precipitation, snowmelt, and irrigation practices. When combined with

historical data (2006–2017), the dataset will represent both current and longer-term hydrologic conditions, including interannual variability and anthropogenic influences.

Together, the spatial distribution of monitoring points and the temporal coverage of measurements are designed to ensure that the data are representative of system behavior and sufficient to support refinement of the hydrologic conceptual model and evaluation of storage and flow-retiming processes in the Twin Lakes–Methow River system.

6.2.2.3 Completeness

Completeness will be calculated as follows:

$$Completeness\ (\%) = \left({}^{V}/_{P}\right) x\ 100$$

Where:

V= number of valid measurements
P= number of planned measurements

Valid and invalid data (i.e., data qualified with the R flag [rejected]) will be identified during data verification (Section 13).

The goal for the field investigation Study is to correctly collect and analyze 100% of the measurements for each project. However, problems occasionally arise during data collection, such as site access or equipment malfunction that cannot be controlled; thus, a completeness of 95% is acceptable for discrete measurements.

For continuous deployed measurements, additional variables can negatively impact completeness, including vandalism/theft/tampering, equipment failure, unacceptable fouling or drift, and unpredictable hydrologic events (large storms or steep drops in water level between visits). For these reasons, a completeness of 80% is acceptable for continuous measurements.

6.3 Acceptance criteria for quality of existing data

Existing data for the Study area is summarized in Section 3.2.2 and includes groundwater levels, surface water levels, and stream discharge measurements collected both manually and with automated data loggers at project established monitoring stations. These data were collected and analyzed by licensed professionals in support of an Ecology funded Cost Reimbursement Project for the Twin Lakes water right application No. G4-34915 and the associated hydrogeologic report (Aspect, 2009). A separate QAPP was not prepared for the earlier investigation; however, field methods and data collection procedures were documented in Appendix B of the report (Aspect, 2009).

The current study will re-establish key monitoring stations and conduct similar monitoring of groundwater levels, surface water levels, and stream discharge over a 1-year period using similar methodologies for consistency. Automated data collection will be compared with manual measurements collected during instrument deployment, four data download events over the 1-year investigative period, and equipment recovery as part of the project quality

control activities. Historical data will also be reviewed for completeness, consistency, and potential anomalies prior to use, and any identified limitations will be documented.

Aside from local climatological data (NOAA Winthrop 1 WSW), no other outside unpublished data is anticipated to be used as part of the analysis completed within the scope of this QAPP. However, if additional data is identified relevant to this Study, it will be considered acceptable if collected according to another Ecology approved QAPP, data was produced using the same analytical procedure and QA criteria as defined in this QAPP, or peer reviewed documents.

6.4 Model quality objectives

This study does not include development of a numerical groundwater-flow model or predictive hydrologic model. The primary analytical objective is to use newly collected and historical monitoring data to refine the hydrologic conceptual model of groundwater-surface water interactions in the Twin Lakes system and improve understanding of the factors influencing lake-level fluctuations. A simplified spreadsheet-based water balance will also be developed to evaluate lake storage changes and net groundwater exchange under representative gaining and losing hydrologic conditions, as described in Section 7.3. Because the analysis is based on simplified accounting of water-balance components rather than simulation of groundwater flow or predictive system behavior, formal model calibration and validation procedures are not applicable. Assumptions, input data, and calculation methods will be documented and evaluated for consistency and reasonableness.

7.0 Study Design

7.1 Study boundaries

The Study area is defined by the Twin Lakes aquifer and its boundaries with either bedrock or the Methow River (Figure 1). The preliminary location of monitoring stations to be re-established as part of the scope in this QAPP are shown below in Figure 2. The proposed monitoring locations were selected to build upon previous investigations and maximize continuity with existing datasets. Most locations represent previously established monitoring stations where stream gages, lake gages, or pressure transducers were operated during earlier phases of the study. Re-establishing these stations allows direct comparison with historical groundwater, lake-level, and streamflow records while taking advantage of existing station development, surveyed reference points, and prior rating-curve information. The lake monitoring network focuses on Big and Little Twin Lakes because these lakes are central to the study objectives and have the most extensive historical monitoring records. Continuous lake-level monitoring was previously conducted at Big Twin Lake, while staff gage measurements were historically collected at both Big and Little Twin Lakes. One additional groundwater monitoring location is proposed near Big Twin Lake (15N) to improve characterization of groundwater conditions adjacent to the lake and supplement the existing monitoring network.

Final locations may be adjusted depending on access agreements.

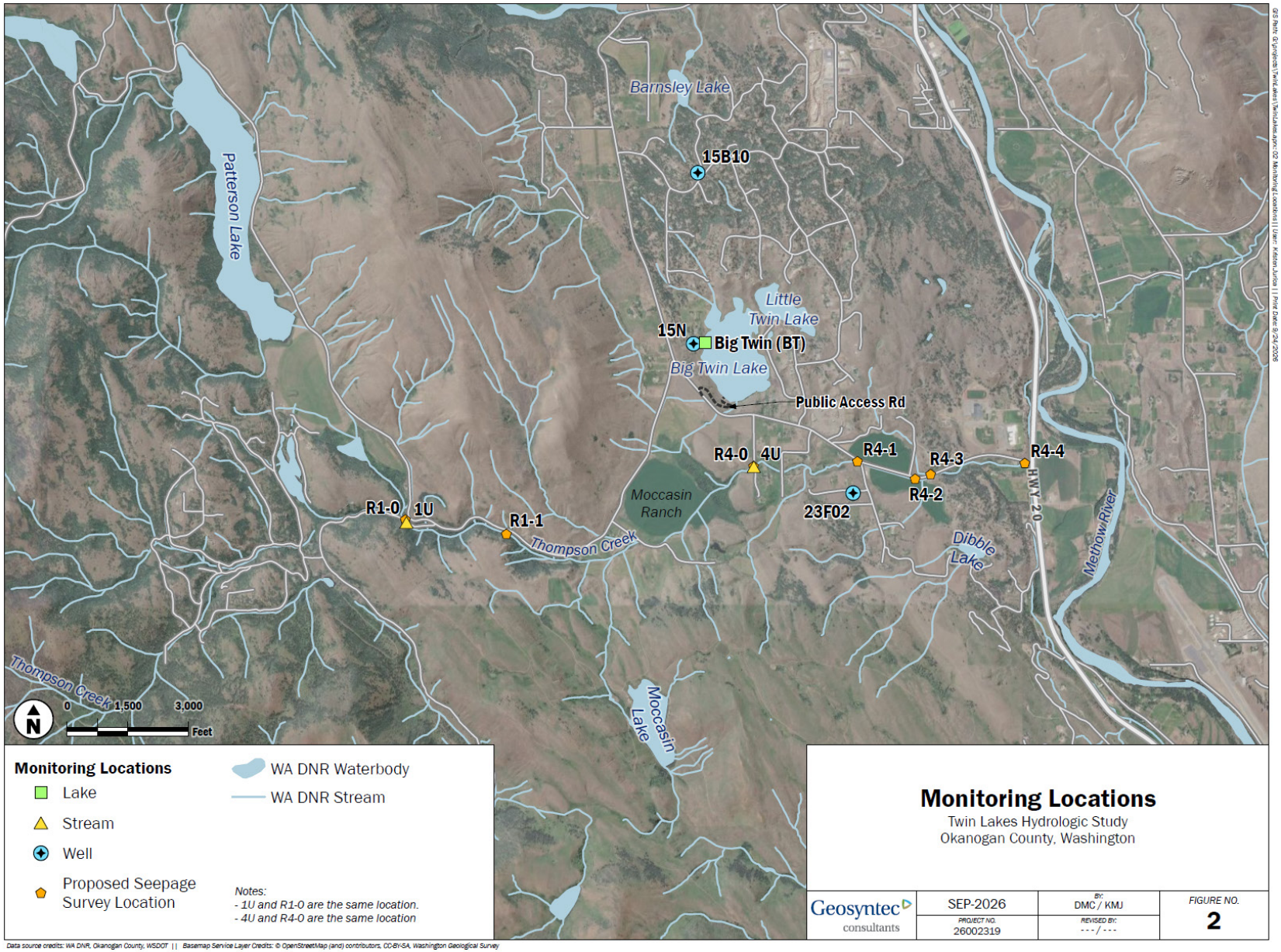

Figure 2. Map of proposed monitoring locations

7.2 Field data collection

Specific field data collected under this Study are listed in Table 3 and include: Groundwater level monitoring in local domestic wells; Lake level monitoring in Big Twin Lake; and Stream discharge measurements in Thompson Creek (an important recharge area for Big Twin Lake). Preliminary monitoring locations are shown in Figure 2.

7.2.1 Sampling locations and frequency

Sampling for this study will follow a subjective (targeted) sampling strategy, in which monitoring locations will be selected based on their relevance to evaluating groundwater–surface water interactions and water balance components. This approach is appropriate because the study is focused on understanding hydrologic relationships at specific features (e.g., Big Twin Lakes, nearby wells, and Thompson Creek), rather than statistical characterization of a larger population.

Target sampling and monitoring locations include the following:

- Groundwater level monitoring locations: Three domestic wells located in proximity to the lake system, selected based on availability, access, and suitability for representing groundwater conditions influencing the lakes (15B10, 23F02, and N15 in Figure 2). Alternate locations may include other accessible domestic wells within the Study area if access to these wells is unavailable.
- Lake level monitoring location: A fixed monitoring station at Big Twin Lake (BT in Figure 2). This location will serve as the primary reference point for lake stage and storage changes. The station location may be moved and constructed on the southwest end of the lake where the lake is deeper which may provide more favorable conditions for station set up (access via Public Fishing Road in Figure 2).
- Surface water monitoring locations: Thompson Creek discharges will be monitored at locations upgradient (1U in Figure 2) and downgradient (4U in Figure 2) of the Moccasin Ranch to evaluate seepage losses and potential recharge influences on the Twin Lakes area. Alternate measurement locations may be selected in the field based on access, flow conditions, and channel geometry suitable for discharge measurements and development of stage-discharge rating curves. The upstream station will remain downstream of Patterson Lake inflows and upstream of the Moccasin Ranch diversion, while the downstream station will remain downstream of Moccasin Ranch operations.
- Synoptic seepage survey locations along Thompson Creek will target one reach above Moccasin Ranch (stations R1-0 and R1-1 in Figure 2) and on reach below Moccasin Ranch (stations R4-0 through R4-4 in Figure 2). Final stations will depend on accessibility. Access agreements to collect streamflow measurements along Thompson Creek on Moccasin Ranch private property has not been granted for the study.
- Sampling frequency will be designed to capture seasonal variability while maintaining consistency across datasets:

- Continuous monitoring: Groundwater levels, lake levels, and stream stages will be recorded at 15-minute intervals using pressure transducers throughout the monitoring period to capture temporal trends.
- Manual verification measurements: Manual groundwater-level, lake-level, and stream-stage measurements will be collected during instrument deployment, four scheduled site visits, and instrument recovery in accordance with applicable Ecology SOPs and used to verify and supplement continuous monitoring data..
- Stream discharge measurements: Streamflows in Thompson Creek will be measured during instrument deployment at stations 1U and 4U, four scheduled data download events distributed over the monitoring period, and instrument recovery to support development and refinement of stage-discharge rating curves. Download events will be scheduled, to the extent practical, to capture a range of low-, moderate-, and high-flow conditions. A synoptic seepage survey will also be conducted at several locations along Thompson Creek (depending on accessibility) during low-flow conditions to evaluate gaining and losing reaches and compare results with previous investigations.

7.2.2 Field parameters and laboratory analytes to be measured

The following environmental parameters will measured as part of this Study:

- Lake water levels (stage): Continuous lake-level measurements will be collected using a pressure transducer installed at Big Twin Lake. Manual lake-level measurements will be collected during instrument deployment, four scheduled data download events, and instrument recovery using staff gages to verify automated measurements and evaluate temporal changes in lake levels and storage.
- Groundwater levels: Continuous groundwater-level measurements will be collected using pressure transducers installed in monitoring wells. Manual groundwater-level measurements will be collected during instrument deployment, four scheduled data download events, and instrument recovery to verify automated measurements and evaluate seasonal hydraulic gradients.
- Barometric pressure readings: Continuous measurements from a barometric pressure transducer installed at a secure location within the Study area, selected to provide reliable operation throughout the monitoring period. Data will be used to correct water-level measurements for atmospheric pressure fluctuations (Spane, 2002).
- Thompson Creek discharge: Continuous stream-stage measurements will be collected at established monitoring stations using pressure transducers. Manual staff gage readings and discharge measurements will be collected during instrument deployment, four scheduled data download events, and instrument recovery to develop and refine stage-discharge rating curves. Measurement events will be scheduled, to the extent practical, to capture a range of low-, moderate-, and high-flow conditions.

- Thompson Creek Seepage Survey: A single synoptic seepage survey will be conducted during low-flow conditions to evaluate gaining and losing reaches along accessible portions of Thompson Creek and compare results with previous investigations. Discharge measurements will be collected at discrete locations both above and below Moccasin Ranch targeting similar reaches to previous investigations (Stations R1-0 and R1-1 above and Stations R4-0 through R4-4 in Figure 2).
- Qualitative Observations: Qualitative information relevant to groundwater recharge and lake-level fluctuations will be compiled from field observations, historical and current aerial imagery, Washington State Department of Agriculture crop maps, and other publicly available information sources. Historical imagery may also be reviewed to document past high- and low-lake conditions and changes in land and water use within the Study area. These observations will be used to support interpretation of groundwater-level, lake-level, and streamflow trends and refinement of the hydrologic conceptual model.

No water quality samples or chemical analyses are included as part of this Study.

7.3 Modeling and analysis design

A combined data collection, conceptual model update, and water balance analysis will be conducted to evaluate groundwater-surface water interactions and factors influencing lake-level fluctuations within the Twin Lakes system. This Study builds on existing historical datasets and incorporates one year of additional monitoring to refine the hydrologic conceptual model and improve understanding of hydrologic conditions controlling groundwater levels, lake levels, and streamflow within the Study area.

The lake system is conceptualized as a groundwater-dominated kettle lake with no significant surface water inflows or outflows. Lake level fluctuations are primarily controlled by a groundwater exchange driven by temporal variations in recharge and water table elevation. Review of project monitoring data collected since the 2009 hydrogeologic investigation (Aspect, 2009) shows that lake levels respond to changes in groundwater levels with a temporal lag and that the lake may exhibit a relatively stable lower-bound elevation (“base level”), potentially reflecting subsurface geologic controls. These interpretations will be further evaluated using historical and newly collected data as part of this Study.

The analysis will integrate historical and newly collected data to achieve the following:

- Refine the conceptual understanding of the lake–groundwater system
- Quantify changes in lake storage under contrasting hydrologic conditions
- Estimate groundwater exchange using a simplified water balance approach
- Evaluate feasibility of using Twin Lakes for seasonal storage and retiming

7.3.1 Analytical framework

The analytical approach for this Study consists of a simple, deterministic, lumped water balance model developed to represent the primary hydrologic processes controlling lake levels. The analysis will be applied at the seasonal or annual scale with the governing equation:

$$\Delta S = P + GWin - GWout - ET$$

$$\Delta S = P + GWin - GWout - ET$$

Where:

ΔS = change in lake storage
P = precipitation on the lake surface
ET = evaporation from the lake surface
$GWin$ = groundwater inflow
$GWout$ = groundwater outflow

Because individual groundwater fluxes cannot be directly measured, net groundwater exchange (GWnet) will be estimated as a residual:

$$GWnet = \Delta S + ET - P$$

The analysis will be conducted for two representative end-member conditions:

- High water (wet/recharge) condition: Rising groundwater levels and increasing lake stage
- Low water (dry) condition: Declining groundwater levels and decreasing lake stage

These conditions will be defined using representative study datasets. The framework is intended to provide order-of-magnitude estimates of groundwater exchange and storage change, rather than detailed process-based simulation. The model is conceptual and empirical in nature, relying on observed data and basic mass balance relationships rather than mechanistic or distributed simulation.

7.3.2 Model setup and data needs

The water balance analysis will be conducted using standard computational tools (e.g., spreadsheets and graphical analysis). No specialized modeling software or numerical modeling packages are required, as the model is intended to support screening-level interpretation and the development of the conceptual understanding of groundwater–surface water interactions.

Data needs and uses for the water balance include the following:

- Lake levels (continuous and manual measurements): used to calculate change in storage (ΔS) using an estimate of the lake surface area or elevation – volume relationship.
- Groundwater levels from nearby wells (continuous and manual measurements): used to evaluate gradients, confirm directionality of groundwater exchange with the lake, and interpret lag relationships with lake response. Data will rely on data collected from the Study monitoring wells; however, historical groundwater level data and potentiometric maps developed during the previous 2009 investigation (Aspect, 2009) may also be used

to supplement interpretation of groundwater flow directions and hydraulic gradients within the broader Study area.

- Climatic data (NOAA Winthrop 1 WSW station and other publicly available climatological datasets): used to quantify precipitation and estimate lake evaporation for the water balance analysis. Temperature and precipitation data from the NOAA Winthrop 1 WSW station will provide local climatic context, while additional publicly available climatological datasets may be utilized, as appropriate, to estimate open-water evaporation. Evaporation will be assumed negligible during periods of complete ice cover.
- Lake surface area or elevation–volume relationship (estimated from previous surveys and publicly available LiDAR and Bathymetric datasets): to support calculated change in storage (ΔS)

In addition to the water balance analysis, historical and newly collected project data will be synthesized to update the hydrologic conceptual model of the Twin Lakes system. The conceptual model evaluation will consider groundwater-level trends, lake-level responses, streamflow conditions, climatological data, geologic information, historical investigations, aerial imagery, land-use information, and other qualitative observations relevant to groundwater recharge and lake-level fluctuations. The objective of this evaluation is to improve understanding of the hydrologic processes and physical controls influencing groundwater-surface water interactions and lake-level fluctuations within the Study area and to provide an updated summary of the conceptual understanding developed from all available information.

7.4 Assumptions of study design

This Study assumes that necessary access to planned monitoring locations, including domestic groundwater wells and measurement sites along the lakes and Thompson Creek, will be obtained and maintained throughout the monitoring period. It is also assumed that installed monitoring equipment will function properly and provide reliable data when maintained and operated according to standard procedures, consistent with typical QAPP assumptions regarding data quality and instrumentation performance.

The Study further assumes that historical and newly collected data will be sufficient to characterize seasonal trends in groundwater-surface water interactions at a conceptual level. Conditions observed during the monitoring period will be evaluated within the context of historical project data collected between 2006 and 2017, including synoptic groundwater-level measurements, lake-level measurements, streamflow measurements, and continuous monitoring records from pressure transducers, together with available climatological data. Comparison of the monitoring period to these historical datasets will be used to assess whether observed conditions represent relatively wet, dry, or average hydrologic conditions within the Twin Lakes system. Limitations associated with access, data gaps, site-specific variability, or the occurrence of unusually wet or dry conditions during the study period will be documented and considered in the interpretation of results.

7.5 Possible challenges and contingencies

Potential challenges include limited access to planned monitoring locations, variable site conditions affecting measurement quality (e.g., low flows or well availability), and data gaps resulting from equipment malfunction or maintenance needs. If access to primary monitoring locations is not available, alternate wells or measurement locations will be identified to maintain spatial coverage. Data gaps or anomalous measurements will be addressed through supplemental measurements, data screening, and documentation of uncertainties to ensure results remain defensible for the intended level of analysis.

7.5.1 Logistical problems

Logistical challenges may include obtaining and maintaining access agreements with property owners for monitoring and obtaining necessary permits. In addition, winter weather conditions may limit the ability to conduct fieldwork; therefore, installation of monitoring equipment and initial site setup will need to be completed prior to the onset of winter conditions.

Prior to re-establishing groundwater monitoring stations, written access agreements will be obtained from willing property owners. These agreements will grant permission for personnel to enter the property, instrument the well with pressure transducer, and authorize periodic site visits to download data, collect manual measurements, and inspect equipment. Agreements will define any site-specific conditions or restrictions identified by the property owner. If access cannot be obtained for specific locations, alternate monitoring wells will be identified, where feasible, to meet project objectives.

Installation of monitoring equipment in surface water bodies (lake and stream gages) will likely require submittal of a Joint Aquatic Resources Permit Application (JARPA) and issuance of a Hydraulic Project Approval (HPA), which may affect project scheduling due to agency review timelines or seasonal work windows. The proposed work consists primarily of re-establishing previously permitted monitoring stations, and documentation of prior approvals is available to support efficient review. Standard application materials and prior permit conditions will be used as templates, and pre-application coordination with regulatory agencies will be conducted to confirm requirements and streamline the permitting process, minimizing the potential for project delays.

7.5.2 Practical constraints

Practical constraints that can interfere with a project include scheduling problems with personnel, equipment failure, or availability of adequate resources. Funding opportunities are typically the greatest limitation to field data collection.

7.5.3 Schedule limitations

The project schedule is driven by the objective to complete one full year of monitoring to capture seasonal variability in lake and groundwater conditions. The preferred schedule assumes monitoring stations are installed and operational by fall 2026, allowing data collection through fall 2027, followed by data analysis and reporting in late 2027 through mid- to late-2028.

This schedule may be affected by several factors, including the timing of QAPP approval, execution of property access agreements, and acquisition of required permits (e.g., HPA/JARPA). Delays in any of these elements, or in completing field installation prior to winter conditions, could shift the start of monitoring.

If installation is delayed beyond fall 2026, monitoring would shift to begin in spring/early summer of 2027 and continue through spring/early summer 2028, with data analysis and reporting conducted in late 2028/early 2029. This would result in an approximate 6-month delay to the overall project schedule (Section 5.4).

To reduce the likelihood of delays, QAPP review, property owner coordination, and permit applications will be initiated as early as practicable, and installation will be prioritized to occur within seasonal access windows.

8.0 Field Procedures

The field investigation entails three major components: infiltration testing, collection of discharge measurements, and water level monitoring. The procedures to collect measurements are described below.

8.1 Invasive species evaluation

Field activities associated with this project have the potential to transport aquatic invasive species or noxious weeds between sites via equipment, footwear, and other gear. In accordance with Washington State requirements and Ecology guidance (e.g., SOP EAP070 Version 2.4), measures will be implemented to prevent the introduction and spread of invasive species during all field operations.

All equipment that contacts water or wet environments (e.g., waders, boots, sampling devices, water level monitoring equipment, and any watercraft or flotation devices) will be inspected, cleaned, and, where appropriate, disinfected or dried prior to use at a new location. Visible plant material, sediment, and debris will be removed from equipment before leaving each site.

Field personnel will follow a general “clean, drain, and dry” procedure:

- Clean: Remove all mud, vegetation, and debris from equipment and gear
- Drain: Eliminate standing water from equipment before transport
- Dry: Allow sufficient drying time between site visits when feasible

When working between multiple sites, efforts will be made to sequence field activities from least to most potentially impacted areas, where practicable, to further reduce risk.

These procedures will be incorporated into field protocols and are consistent with applicable permit conditions (e.g., HPA) related to invasive species prevention. All field staff will be trained in these practices prior to conducting work.

8.2 Measurement and sampling procedures

Field measurements and data collection for this project will follow established Ecology SOPs, supplemented by manufacturer guidance where appropriate. The selected SOPs reflect the types of measurements being conducted and are sufficient to ensure consistency, data quality, and repeatability.

The following SOPS will be used as follows:

- SOP EAP052 (Version 1.4) – Manual Measurement of Depth to Groundwater: Used for periodic manual verification of groundwater levels in monitoring wells (Ecology, 2023b).
- SOP EAP074 (Version 1.2) – Use of Submersible Pressure Transducers during Groundwater Studies: Used for installation, operation, and maintenance of pressure transducers for continuous groundwater and lake level monitoring (Ecology, 2019b).

- SOP EAP058 – Operation of a SonTek FlowTracker: Used in conjunction with the SonTek FlowTracker2 manufacturer's user manual and QA/QC guidance for collection of point velocity measurements in streams.
- SOP EAP056 – Measuring and Calculating Stream Discharge: Provides procedures for applying velocity–area methods to calculate discharge based on field measurements (Ecology, 2007).
- SOP EAP042 – Measuring Gage Height of Streams: Used for installation and measurement of stream stage (gage height) at monitoring locations (Ecology, 2023a).

These SOPs collectively address all primary field measurement activities for the project, including groundwater level monitoring, surface water stage measurement, and stream discharge measurement. SOPs are taken from Ecology's quality assurance web page (Ecology 2019a). No additional project-specific SOPs are anticipated at this time. If modifications to these procedures are required during project implementation, they will be documented and included in the final project record.

Prior to all field measurements, as required, private property owners will be contacted to confirm entry to private property according to signed access agreements.

8.2.1 Groundwater level monitoring

Groundwater levels will be measured at available groundwater wells with both manual electronic water level indicator and with automated pressure transducers installed in each well. Long term monitoring data will be collected with a pressure transducer installed below the anticipated minimum water level of the well. A barometric pressure logger will collect paired atmospheric observations in the Study area, which will be used to correct pressure transducer data into gaged submergence pressure (feet of water above the sensor). Both the submerged and atmospheric pressure transducers will be programmed to record at 15-minute intervals. Transducers will be downloaded during four scheduled monitoring events distributed over the monitoring period to capture a range of hydrologic conditions. Download events will be coordinated with landowner access requirements for each monitoring station. All equipment shall be decontaminated as described in Section 8.4.

Manual measurements will be collected during instrument deployment, four scheduled data download events, and instrument recovery to verify automated transducer measurements and evaluate potential drift or measurement offsets in the continuous monitoring record. Water levels will be collected manually using an electrical water level meter with a resolution of 0.01-feet and accuracy of 0.05-feet (Section 6.2, Table 3). Water levels will be measured from the established MP at each well to ensure data comparability. Note that MP's have been established and professionally surveyed with an accuracy of +/- 0.1-feet at the previously established groundwater stations (15B10 and 23F02 in Figure 2). If different or new groundwater stations are used for this Study and a MP does not exist, then we will establish one based on the following procedure:

1. MPs are normally established on the north side of the top rim of the actual well casing; this position is commonly referred to as TOC. Locate the MP at a convenient place from

which to measure the water level. If the TOC is level, collect the measurement from the north edge.
2. Clearly mark the MP. The MP must be as permanent as possible and be clearly visible and easily located. The MP may be marked using a permanent black marker, bright colored paint stick, or with a notch filed into the TOC.
3. Describe the position of the MP clearly in the field-data sheets.
4. Survey the MP using survey grade GPS (see Section 6.2, Table 3).

All subsequent water level measurements should be referenced to the established MP. The MP value will be used to convert water level measurements into elevations.

After a permanent MP is established for each well, collect measurements of water levels using the following process.

Manual groundwater level measurements are as follows:

1. Remove wellhead cap in a manner that prevents contamination. Note condition of wellhead or any sounds of “popping” that would indicate pressure buildup.
2. Record data and time of measurement.
3. Measure depth to water (DTW) from MP to nearest 0.01 feet using an electric water level indicator.
4. Record readings at approximately 10-second intervals.
5. If consecutive measurements collected over 1-minute vary by no more than 0.02 feet and show no consistent upward to downward trend, the water level shall be considered stable (static).
6. If the measurement shows a consistent rise or decline, continue monitoring for up to 5 minutes and document the rate and direction of change (rising and declining).
7. Record and classify the final measurement as either static (stable within +/- 0.02 feet over 1 minute), pumping (water level actively declining), or recovery (water level actively rising).

Care shall be taken to avoid disturbing the well or influencing water levels during measurements. All measurements shall be recorded immediately and legibly on standardized field forms. Any deviation from these procedures shall be documented and justified in field notes.

Automated groundwater level measurements

At the time of deployment, pressure transducers shall be installed in domestic wells using direct-read cables, with sensors positioned at a fixed depth at least 15 feet below the observed static water level to ensure continuous submergence under anticipated seasonal fluctuations. Field staff shall record the deployment depth relative to the MP, to the date and time of installation, and to the initial transducer reading. A concurrent manual water level measurement shall be collected to ±0.01 feet to establish an initial reference and offset.

The transducer cable shall be secured at the wellhead to maintain a fixed vertical position. Attachment methods may include a stainless steel eye hook, use of existing well cap hardware, or other minimally invasive anchoring approaches appropriate for private domestic wells. Care

shall be taken when working with pitless adapter-style wellheads to avoid interference with existing pump wiring, drop pipe, or electrical connections. The well cap shall be handled in a manner that preserves sanitary integrity, and the cable shall be routed to avoid abrasion, kinking, or pinch points. Installation shall not interfere with normal operation of the well or compromise the well seal, consistent with standard practices for using domestic wells for monitoring purposes.

During each download event, instruments will not be reprogrammed in order to minimize the risk of data loss over the 1-year monitoring period. Field staff will perform the following steps:

1. Connect laptop to the direct-read cable and download stored data.
2. Record date and time of download.
3. Collect manual water level measurement from the MP to ±0.01 feet and record the concurrent transducer reading.
4. Document whether the well is in static, pumping, or recovery conditions and, if feasible, collect measurements under non-pumping conditions.
5. Inspect and confirm that the cable is securely anchored and that the transducer depth has not changed.
6. Document any observed issues, including drift, fouling, or disturbance to the installation.

Manual and transducer measurements collected during deployment and subsequent visits will be compared to evaluate drift and confirm or update any measurement offset. Continuous data will be corrected, converted to depth to water, and subsequently to water level elevation using surveyed MP elevations and barometric pressure data.

8.2.2 Lake level monitoring

Lake levels will be measured using both manual and automated methods to provide continuous and quality-controlled water surface elevation data. The collection of surface water levels will generally follow methodology presented in Ecology's SOP EAP042.

Manual lake level measurements will be obtained from a re-established staff gage installed at the Big Twin Lake monitoring location. The staff gage will be securely attached to a metal post driven into the lakebed just offshore in a stable location. Staff gage readings will be recorded to the nearest +/- 0.01 feet. The gage datum will be referenced to the established benchmark at a 5-foot concrete tile near the station shoreline (Figure 2), allowing conversion of staff gage readings to water surface elevations consistent with project datum. The staff gage will serve as the primary reference for verifying and correcting automated measurements.

Continuous lake level measurements will be collected using submersible, non-vented pressure transducers. Atmospheric pressure will be measured using the Study area barometric pressure transducer, and lake level data will be corrected during processing to account for atmospheric effects. Automated measurements will be recorded at 15-minute intervals.

The pressure transducer will be deployed within a flexible HDPE conduit system extending from the shoreline to the monitoring location. The conduit will be trenched at the shoreline and will extend at least 30 feet into the lake to a minimum water depth of approximately 5 feet. The

conduit will be weighted and secured to the lakebed using rebar or equivalent ballast to maintain position and prevent movement due to wave action, ice, or seasonal changes in lake level. At the submerged end of the conduit, the pressure transducer will be housed within a vertical stilling well constructed of perforated pipe fitted with a cap and anchored using concrete blocks and stabilizing supports designed to maintain a vertical orientation.

The transducer cable and protective conduit will extend to the shoreline through a shallow trench and will terminate in a temporary, surface-accessible vault equipped with a lid to allow data retrieval without disturbing the installation.

Field measurement and download procedure

During initial deployment and each subsequent site visit, field staff will perform the following steps:

1. Record staff gage reading to the nearest ±0.01 feet on field forms.
2. Connect to the direct-read cable within the shoreline vault to a laptop and download stored transducer data.
3. Record the date and time of the download in the field notes.
4. Observe and document current lake conditions, including evidence of wave action, ice cover, or other factors that may influence measurements.
5. Verify that the conduit, stilling well, and cable remain in stable configuration and have not shifted from the original installation.
6. Document any observed issues, including sediment accumulation, fouling, damage, or disturbance to the installation.

Staff gage readings collected during each visit will be paired with transducer data to establish and confirm the relationship between pressure measurements and lake level. These paired measurements will be used to evaluate drift and convert continuous pressure transducer data to lake water surface elevations referenced to the surveyed benchmark.

8.2.3 Stream discharge monitoring

Stream gaging stations will be re-established at previously monitored locations along Thompson Creek (Stations 1U and 4U in Figure 2) to maintain continuity with historical data collection efforts. Stations will be installed using the same or equivalent local reference points and relative benchmarks previously established at each site (e.g., top of a nearby culvert or other stable, fixed feature), which will serve as the site-specific gage datum for all stage measurements. These reference points will be documented and verified during each site visit to ensure they remain stable and unchanged.

Each station will consist of a staff gage and a co-located pressure transducer installed to provide both manual and continuous stage data. The staff gage will be securely attached to a metal stake driven into the streambed in a stable location with uniform flow conditions and minimal backwater influence. The pressure transducer will be secured to the same support or an adjacent fixed structure and installed below the minimum expected water level. The transducer will be housed within a perforated PVC stilling well with a protective cap and

anchored using rebar, concrete blocks, or equivalent stabilization to maintain vertical alignment and protect the instrument from debris, ice, and channel movement.

Manual stage readings will be collected from the staff gage to the nearest +/- 0.01 feet during each site visit and concurrent with discharge measurements. These readings will be used to verify and adjust pressure transducer data and to maintain consistency between manual and automated records.

Discharge measurements will be collected during instrument deployment, four scheduled data download events distributed over the monitoring period, and instrument recovery using a SonTek FlowTracker 2 acoustic Doppler velocimeter in general accordance with Ecology SOPs EAP056 and EAP058. Measurement events will be scheduled, to the extent practical, to capture a range of low-, moderate-, and high-flow conditions to support development and refinement of stage-discharge rating curves. Measurements will be conducted using the velocity–area method at representative cross sections exhibiting stable, uniform flow conditions, and results will be used to develop and refine stage–discharge relationships (rating curves) for each site. Where historical rating curves exist, those relationships will be evaluated for consistency with current site conditions and may be used to supplement or extend updated rating curves where appropriate.

Discharge measurement event

During each discharge measurement event, field staff will perform the following steps:

1. Select a measurement cross section that is straight, free of obstructions, and exhibits relatively uniform flow with minimal turbulence and backwater effects.
2. Establish a measuring tape or tagline perpendicular to flow across the channel to define the cross section and provide a reference for horizontal position.
3. Divide the cross section into a series of vertical measurement locations (“verticals”), where each vertical represents a subsection of the stream and is spaced so that no individual subsection contributes more than approximately 5 to 10% of the total discharge.
4. Measure the horizontal position of each vertical along the tape (distance from an initial bank reference point) and measure the water depth at that vertical, which defines the cross-sectional area associated with that subsection.
5. Collect velocity measurements at each vertical using the SonTek FlowTracker 2, where a “vertical” refers to a single measurement location defined by its horizontal position and depth.
6. Measure the velocity at 0.6 of the total water depth below the surface when total water depth is less than approximately 2.5 feet, as this single-point measurement is considered representative of the mean velocity for shallow conditions.
7. Measure velocity at both 0.2 and 0.8 of the total depth when water depth exceeds approximately 2.5 feet, and the average of these two measurements shall be used to represent the mean velocity for that vertical.

8. Ensure the FlowTracker 2 is properly configured and allow the instrument to record velocity and compute discharge for each subsection based on measured depth, velocity, and subsection width.
9. Proceed sequentially across the channel from one bank to the other, ensuring the entire wetted width is measured and repeating any measurements that exhibit poor signal quality or unstable velocity readings.
10. Record the total discharge as calculated by the instrument along with the concurrent stage measurement, measurement conditions, and any factors that may affect data quality, including bed irregularities, vegetation, debris, or unsteady flow conditions.

All field measurements shall be recorded on standardized field forms, including staff gage readings, discharge measurement file names, instrument settings, and observations of channel and flow conditions. Repeated measurements collected across a range of stages will be used to develop and maintain accurate stage–discharge relationships for each monitoring location.

A similar velocity–area method will be applied during synoptic seepage surveys conducted along accessible reaches of Thompson Creek during low-flow conditions. Discharge measurements will be collected at multiple locations both above and below Moccasin Ranch similar to previous investigation (Stations R1-0 and R1-1 and R4-0 through R4-4 in Figure 2). Access to the creek on the private Moccasin Ranch property was not granted for this study. Discharge will be measured using the SonTek FlowTracker 2 to evaluate gaining the losing reaches and compare with previous investigations. Final measurement locations will be selected based on site accessibility, suitability of discharge measurements, and consistency with locations evaluated during previous seepage surveys where practical.

8.3 Containers, preservation methods, holding times

Not applicable.

8.4 Equipment decontamination

Field equipment will be cleaned between monitoring locations to prevent cross-contamination and the spread of invasive species (SOP EAP070 Version 2.4). All equipment contacting water or wells will be inspected and cleared of visible debris prior to use.

The electric water level meter will be kept thoroughly clean and disinfected. Before use in a well, the bottom 3 feet of the water level indicator will be decontaminated using the following four-point cleaning procedure:

1. Scrub probe and cable with low phosphate detergent
2. Spray rinse with potable or distilled water
3. Spray rinse with 6% sodium hypochlorite (e.g., Chlorox)
4. Spray rinse with distilled water

Pressure transducers and cable shall be cleaned and disinfected following steps 1 through 4 above, except that Step 3 shall consist of soaking the transducer body and cable in a 50-part per million available chlorine solution for 12 hours to provide extended disinfection for equipment

that will remain in the well. An acceptable mix is 1 part bleach to 1,000 parts water. Following disinfection, the transducer and cable shall be rinsed with distilled water and stored in clean protective bags prior to deployment.

All decontamination will be conducted in accordance with applicable SOPs, manufacturer guidance, and permit conditions.

8.5 Sample ID

Not applicable.

8.6 Chain of custody

Not applicable.

8.7 Field log requirements

During the collection of any field samples, accompanying field documentation must be made that clearly states the following:

- Name and location of project
- Field personnel
- Sequence of events
- Any changes or deviations from the QAPP or SOPs
- Environmental conditions
- Field measurement results
- Unusual circumstances that might affect interpretation of results

For this Study, data collected in the field will be contained in a field log (a binder backed by electronic scans of documents) that will consist of field notes (freehand notes) and Geosyntec field data sheets (Appendix A).

Field notes will be bound in waterproof notebooks with prenumbered pages (Rite in the Rain®). Permanent, waterproof ink should be used for all entries. Corrections will be made with single-line strikethroughs, initials, and date of correction. Use of white-out or correction fluid is not permitted.

8.8 Other activities

Not applicable.

9.0 Laboratory Procedures

9.1 Lab procedures table

Not applicable.

9.2 Sample preparation method(s)

Not applicable.

9.3 Special method requirements

Not applicable.

9.4 Laboratories accredited for methods

Not applicable.

10.0 Quality Control Procedures

Implementing QC procedures provides the information needed to assess the quality of the data that is collected. These procedures also help identify problems or issues associated with data collection or data analysis while the project is underway.

10.1 Table of field and laboratory quality control

This project does not include collection of laboratory-analyzed environmental samples; therefore, traditional laboratory quality control samples (e.g., blanks, duplicates, spikes) are not applicable. Instead, quality control for field measurements will focus on verification of measurement accuracy, instrument performance, and data consistency.

Quality control measures will include the following:

- Manual verification of groundwater and surface water levels collected using pressure transducers, consistent with SOP EAP052
- Periodic comparison of manual measurements to automated data logger readings to confirm instrument accuracy
- Repeat streamflow measurements, as appropriate, to evaluate measurement consistency
- Use of manufacturer-recommended QA/QC indicators for the SonTek FlowTracker2 (e.g., signal quality, measurement stability)
- Routine inspection and maintenance of monitoring equipment, including checks for drift, fouling, or damage

These procedures provide a practical means of ensuring data quality and are consistent with the types of measurements collected for this study.

10.2 Corrective action processes

Because this project does not involve laboratory analysis, corrective actions are focused on field measurements, instrumentation, and data quality review.

If data quality issues are identified during field activities or data evaluation, appropriate corrective actions will be implemented. Potential issues may include instrument malfunction, measurement drift, data gaps, anomalous values, or inconsistencies between manual and automated measurements. Data quality concerns may be identified when measurements do not meet the MQOs and acceptance criteria described in Sections 6.2 and 13.1, including failure to meet precision targets, evidence of instrument drift or bias, unexpected data gaps, or measurements that are inconsistent with field observations and other lines of hydrologic evidence.

Corrective actions may include the following:

- Verification measurements, such as manual water level readings to confirm automated data logger performance
- Inspection, maintenance, cleaning, repair, replacement, or adjustment of field instrumentation when equipment malfunction, excessive drift, or other data quality issues are identified
- Repeat measurements, where feasible, to confirm discharge or stage measurements that do not meet MQOs, appear inconsistent with field observations, or otherwise warrant verification during field activities
- Adjustment or flagging of suspect data during data review and processing
- Documentation of issues and actions taken in field notes or project records

If significant data gaps or equipment failures occur, efforts will be made to restore monitoring as soon as practicable and assess impacts on data usability. These actions are intended to ensure that data collected are of known and acceptable quality for the purposes of this study.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

Field staff will record all measurements and observations using water-resistant field notebooks, electronic data forms, and standard field data sheets (Appendix A). Prior to leaving each site, field staff will review entries for completeness and identify any missing or potentially erroneous measurements.

Field-collected data will be entered into project spreadsheets or databases as soon as practicable following field activities. Data collected electronically (e.g., data logger downloads) will be transferred to the project network upon return to the office, where routine server backups are in place. Raw data files will be retained in their original format and stored separately from processed data files to maintain data integrity and traceability.

Data entry will be checked against field records by the field geologist or hydrogeologist to identify and correct errors or omissions. Any missing or anomalous data will be documented and communicated to the project manager for evaluation

Data will be uploaded to Ecology's Environmental Information Management (EIM) database as described in Section 11.4.

11.2 Laboratory data package requirements

Not applicable.

11.3 Electronic transfer requirements

Not applicable.

11.4 Data upload procedures

Following completion of the QC procedures described in Section 10, all quality assured data will be formatted and uploaded to Ecology's EIM database using Study ID: C2400181-ACI005.

11.5 Model information management

This project does not involve development of a formal numerical model. Analytical efforts will consist of a spreadsheet-based water balance and graphical evaluation (e.g., hydrographs) to support interpretation of lake storage dynamics and groundwater–lake interactions.

The water balance analysis will use a relatively limited set of input data, consisting primarily of site-specific monitoring data (e.g., lake levels, groundwater levels, streamflow measurements, and local climatic data), and will produce summary output datasets and graphical representations (e.g., hydrographs and water balance component estimates).

All analysis files, including spreadsheets used for calculations, data summaries, and graphical outputs, will be maintained on the project network and organized within structured directories

using consistent file naming conventions. Input datasets will be preserved in their original format and clearly linked to corresponding analysis files to ensure traceability between datasets, calculations, and results.

Version control will be maintained through incremental file naming (e.g., date- or version-based) and documentation of major updates to assumptions, input data, or calculation methods. Post-processed outputs (e.g., summarized water balance components and figures) will be clearly associated with the corresponding analysis version to ensure transparency and reproducibility.

All calculations, assumptions, and data processing steps will be documented within the analysis files or supporting materials, and final analysis files will be retained as part of the project record.

12.0 Audits and Reports

12.1 Audits

Field technicians will be required to review this QAPP prior to each field event and to maintain a copy of the QAPP and its appendices in the field. Field technicians may be audited at any time by the appropriate project manager or the Geosyntec data manager (Table 1) to check that field work is being completed according to this QAPP, work plan, and published SOPs.

12.2 Responsible personnel

Personnel responsible for the audits are as follows:

- Field audit: Geosyntec Project Manager
- Field consistency review: experienced (at least 3 years) staff (senior hydrogeologist or project manager)
- Data analysis: Geosyntec hydrogeologists (project, senior, and principal, as required for specific analysis)

Personnel assigned to these roles are listed in Table 1.

12.3 Frequency and distribution of reports

Results of the field data collection, data quality assessment, and any data analysis will be documented in a published report. The final report will be distributed to all other stakeholders involved or interested in the Study.

Field data will be entered into EIM when data collection is complete and Quality Control assessment has been finished.

12.4 Responsibility for reports

The Geosyntec Project Manager is responsible for verifying data completeness and usability before the data are used in the technical report and entered into the EIM database. The Geosyntec Project Manager is also responsible for writing the final technical report or memo, unless an alternate author is agreed upon and documented prior to the start of the report.

The Geosyntec Project Manager is responsible for assigning a peer reviewer with the appropriate expertise to review technical report. A draft report will be prepared and submitted to Ecology, then a final report will be prepared that addresses Ecology's comments. The peer reviewer is responsible for working with the author to resolve or clarify any issues with the report.

13.0 Data Verification

Data verification is the process of evaluating the completeness, correctness, and conformance of a specific data set against the method, procedural, or contractual requirements.

13.1 Field data verification, requirements, and responsibilities

Field notebooks, data sheets, and electronic information storage will be checked for missing or improbable measurements, and initial data will be verified before leaving each site. This process involves checking the data sheet (written or electronic) for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be flagged on the data sheet and repeated if possible. The field hydrogeologist or field technician is responsible for in-field data verification.

Upon returning from the field, data are either manually entered (data recorded on paper) or downloaded from instruments and then uploaded into the appropriate database or project folder (see Section 11). Manually entered data will be verified/checked by a staff member who did not enter the data. Downloaded electronic data files will also be checked for completeness and appropriate metadata (such as file name and time code).

Following data entry verification, raw field measurement data will undergo a quality analysis (consistent with MQOs listed in Section 6) verification process to evaluate the performance of the sensors.

Duplicate measurements will be used to determine if the collected field data meets the precision standards stated in Section 6.2.1.1. Based on the calculated precision, field measurements will either be qualified, rejected, or accepted as appropriate.

Field measurement data may be adjusted for bias or drift (increasing bias over time) based on review of data as described below.

Review Discrete Field QC Checks

The field check of instrumentation will consist of a manual measurement for water levels. The post-check data from the field QC instrument check (water level) will be reviewed, and the result will be qualified, rejected, or accepted as appropriate.

Review/Adjust Time Series (Continuous) Data

1. Plot raw time series with field checks.
2. Reject data based on deployment/retrieval times, site visit disruption, blatant fouling events, and sensor/equipment failure.
3. Review sensor offsets for post-deployment. Flag any potential chronic drift or bias issues specific to the instrument.
4. If applicable, review fouling check and make drift adjustment, if necessary. In some situations, an event fouling adjustment may be warranted.

5. Review residuals from both field checks and post-checks, together referred to as QC checks. Adjust data, as appropriate, using a weight-of-evidence approach. Give the most weight to post-checks, then accept, reject, or qualify the field checks. Potential data adjustments include the following:
    a. **Bias** – Data are adjusted by the average difference between the QC checks and deployed instrument. The majority of QC checks must show bias to use this method.
    b. **Regression** – Data are adjusted using regression, typically linear, between QC checks and deployed instrument. This accounts for both a slope and bias adjustment. The regression must have at least five data points and an R^2 value of >0.95 to use for adjustment. Do not extrapolate regressions beyond the range of the QC checks.
    c. **Calibration/Sensor Drift** – Data are adjusted using linear regression with time from calibration or deployment to post-check or retrieval. The majority of QC checks, particularly post-checks, must confirm pattern of drift.
6. If the evidence is weak, or inconclusive, do not adjust the data.

It will be noted in the final report if any data is adjusted. Data adjustment must be performed or reviewed by the Geosyntec Project Manager or personnel with the appropriate training and experience in processing raw sensor data.

13.2 Laboratory data verification

Not applicable.

13.3 Validation requirements, if necessary

Not applicable.

13.4 Model quality assessment

Model quality assessment for this study will be conducted qualitatively by evaluating whether water balance results are consistent with observed groundwater levels, lake levels, and streamflow conditions, and the hydrologic conceptual model of the Twin Lake system. Model inputs, assumptions, and calculations will be reviewed for consistency and reasonableness, and results will be evaluated to determine whether they reasonably reflect observed hydrologic relationships. Sensitivity of model results to key inputs will be considered at a high level to assess uncertainty. Model limitations will be documented, and results will be interpreted as screening-level estimates intended to support conceptual understanding rather than precise prediction.

13.4.1 Calibration and validation

The water balance analysis described in Section 7.3 is not a calibrated numerical groundwater-flow model and will not be used for predictive simulation of future conditions. Therefore,

formal calibration and validation procedures are not applicable. Instead, the reasonableness of the analysis will be evaluated through comparison of water balance results to observed groundwater levels, lake levels, streamflow trends, and the hydrologic conceptual model. Assumptions, input parameters, and calculation methods will be documented and reviewed to ensure consistency with available project data and the overall understanding of the Twin Lakes system.

Precision

Precision for the water balance model is not defined in a strict quantitative sense due to the simplified nature of the analysis and inherent uncertainty in estimating some water balance components (e.g., groundwater fluxes). Instead, precision will be evaluated qualitatively based on the consistency and resolution of input data and the model's ability to reproduce observed trends. Results will be reported with appropriate acknowledgment of uncertainty and level of confidence.

Bias

Bias in the water balance model is not quantitatively defined due to the simplified approach and reliance on estimated components. Potential bias will be evaluated qualitatively by comparing model outputs to observed data to identify systematic over- or under-estimation of water balance components. Any identified sources of bias will be documented and discussed in the interpretation of results.

Representativeness

Model inputs are considered representative of site conditions to the extent that they are derived from site-specific data collected during the current Study period and supplemented with available historical data. Spatial and temporal representativeness may be limited by the number of monitoring locations and the duration of data collection. These limitations will be acknowledged, and model results will be interpreted within the context of available data coverage.

Qualitative assessment

A qualitative assessment will be conducted to evaluate whether the collected data and resulting analyses are sufficient to support project objectives and the conceptual understanding of the system. This assessment will consider data completeness, consistency with observed conditions, and alignment with the conceptual model. Limitations and uncertainties in the dataset and analysis will be documented and considered in the interpretation of results.

13.4.2 Analysis of sensitivity and uncertainty

Sensitivity and uncertainty will be evaluated qualitatively by assessing how changes in key model inputs (e.g., groundwater flux estimates or other water balance components) influence

model results. Emphasis will be placed on identifying which inputs have the greatest influence on outcomes and where data limitations introduce uncertainty. Results will be interpreted with appropriate acknowledgment of these uncertainties and their implications for understanding system behavior.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

The Geosyntec Project Manager will assess all data (qualified and unqualified), results or verification, compliance with MQOs, and the overall quality of the data set to provide a final determination regarding usability in the context of the project-specific goals and objectives. The final report will document whether the final, acceptable-quality data set meets the needs of the project (allows desired conclusion/decisions to be made with the desired level of certainty).

14.2 Treatment of non-detects

Not applicable.

14.3 Data analysis and presentation methods

Data found to be of acceptable quality for project objectives will be analyzed before being summarized. Any relevant and interesting data analysis will be presented in the final report using a combination of tables and time series plots.

The report will contain a summary table of water level trends over time, figures of continuous data (water level hydrographs, etc.), discussion of results pertaining to each sample location, and a map of the Study area.

14.4 Sampling design evaluation

The Geosyntec Project Manager will decide whether:(1) the data package meets the MQOs, and criteria for completeness, representativeness, and comparability, and whether (2) meaningful conclusions (with enough statistical power) can be drawn from summary statistics. If so, the sampling design will be considered effective. If the sampling design is found ineffective, the approach will be modified in accordance with Ecology, and/or the Study will be halted for redesign.

14.5 Documentation of assessment

In the final report, the Geosyntec Project Manager will include a summary and detailed description of the data quality assessment and model quality evaluation findings. This summary is usually included in the Data Quality section. The final report will also provide results of the data analysis, uncertainty analysis, and margin of safety.

15.0 References

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16.0 Appendices

Appendix A. Study Field Forms

Twin Lakes Hydrologic Study
Discharge Measurements

Site Information

Station Name: _____

Field Personnel: _____

Date/Start Time _____

Instrument (Model S/N): _____

Firmware Version: _____

Stage/Gage Height (ft): _____

Edge Method: Zero-Velocity; 0.2-ft Depth; Measured Edge; Extrpolated; No-Flow Dry (circle one)

Mean-Velocity Method : Single point 0.6-depth; Two point 0.2/0.8 depth; both (circle one)

Comments/Site Conditions: _____

Cross Sectional Measurement Table

Time	Vertical Distance from LB (ft)	Depth (ft)	Vel@0.2	Vel@0.6	Vel@0.8	Mean Vel (ft/s)	Width (ft)	Area (ft^2)	Q (cfs)

Twin Lakes Hydrologic Study
Surface Water Monitoring

Site	Initials	Date	Time	Download Filename	Staff Gauge	- Transducer	= Offset	Previous Offsets
1U								
Comments/Site Conditions:								
4U								
Comments/Site Conditions:								
BIG TWIN LAKE								
Comments/Site Conditions:								
Comments/Site Conditions:								

Make all measurements to not less than 0.01'

Offset = Staff Gauge - Transducer

Twin Lakes Hydrologic Study
Discharge Measurements

Site Information

Station Name:
Field Personnel:
Date/Start Time
Instrument (Model S/N):
Firmware Version:
Stage/Gage Height (ft):
Edge Method: Zero-Velocity; 0.2-ft Depth; Measured Edge; Extrpolated; No-Flow Dry (circle one)
Mean-Velocity Method : Single point 0.6-depth; Two point 0.2/0.8 depth; both (circle one)
Comments/Site Conditions:

Cross Sectional Measurement Table

Time	Vertical Distance from LB (ft)	Depth (ft)	Vel@0.2	Vel@0.6	Vel@0.8	Mean Vel (ft/s	Width (ft)	Area (ft^2)	Q (cfs)

Twin Lake Hydrologic Study
Well Monitoring Form

Site	Initials	Date	Time	Download Filename	SWL	+ Transducer	= DTT	Previous DTTs
15B10								
Comments:								
23F02								
Comments:								
Comments:								

SWL = static water level to top of casing (TOC)
Transducer = Simulaneous transducer reading
DTT = depth to transducer = SWL + Transducer
Make all measurements to not less than 0.01'

Appendix B. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Anthropogenic: Human-caused.

Freshet: A great overflow or rise in a stream due to heavy rains or melted snow.

Reach: A specific portion or segment of a stream.

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

Streamflow: Discharge of water in a surface stream (river or creek).

Synoptic survey: Data collected simultaneously or over a short period of time.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Acronyms and Abbreviations

a.k.a.	Also known as
DQO	Data Quality Objective
DTW	depth to water
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
e.g.	For example
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
HPA	Hydraulic Project Approval
i.e.	In other words
JARPA	Joint Aquatic Resources Permit Application
MEL	Manchester Environmental Laboratory
MP	Measuring point
MQO	Measurement quality objective
QA	Quality assurance
QC	Quality control

SOP	Standard operating procedures
TLAC	Twin Lake Aquifer Coalition
TOC	Top of casing
WAC	Washington Administrative Code
WQX	Water Quality Exchange
WRIA	Water Resource Inventory Area

Units of Measurement

AFY	Acre-feet per year
cfs	cubic feet per second
ft	feet

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data (Kammin, 2010). For Ecology, it is defined according to WAC 173-50-040: "Formal recognition by [Ecology] that an environmental laboratory is capable of producing accurate and defensible analytical data."

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms *precision* and *bias* be used to convey the information associated with the term *accuracy* (USEPA, 2014).

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella (Kammin, 2010).

Bias: Discrepancy between the expected value of an estimator and the population parameter being estimated (Gilbert, 1987; USEPA, 2014).

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process (USGS, 1998).

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured (Ecology, 2004).

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all

check standards but should be referred to by their actual designator, e.g., CRM, LCS (Kammin, 2010; Ecology, 2004).

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator (USEPA, 2014; USEPA, 2020).

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator (USEPA, 2014; USEPA 2020).

Continuing Calibration Verification Standard (CCV): A quality control (QC) sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run (Kammin, 2010).

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system (Kammin, 2010; Ecology 2004).

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean (Kammin, 2010).

Data integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading (Kammin, 2010).

Data quality indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity (USEPA, 2006).

Data quality objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA, 2006).

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010).

Data validation: The process of determining that the data satisfy the requirements as defined by the data user (USEPA, 2020). There are various levels of data validation (USEPA, 2009).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology, 2004).

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero (Ecology, 2004).

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner.

Duplicate samples are used to assess variability of all method activities including sampling and analysis (USEPA, 2014).

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport (Ecology, 2004).

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples (Kammin, 2010).

Laboratory Control Sample (LCS)/LCS duplicate: A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. Monitors a lab's performance for bias and precision (USEPA, 2014).

Matrix spike/Matrix spike duplicate: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias and precision errors due to interference or matrix effects (Ecology, 2004).

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness (USEPA, 2006).

Measurement result: A value obtained by performing the procedure described in a method (Ecology, 2004).

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed (USEPA, 2001).

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples (Ecology, 2004; Kammin, 2010).

Method Detection Limit (MDL): The minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results (USEPA, 2016). MDL is a measure of the capability of an analytical method of distinguished samples that do not contain a specific analyte from a sample that contains a low concentration of the analyte (USEPA, 2020).

Minimum level: Either the sample concentration equivalent to the lowest calibration point in a method or a multiple of the method detection limit (MDL), whichever is higher. For the purposes of NPDES compliance monitoring, EPA considers the following terms to be synonymous: "quantitation limit," "reporting limit," and "minimum level" (40 CFR 136).

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all parameters (Kammin, 2010; Ecology, 2004).

Population: The hypothetical set of all possible observations of the type being investigated (Ecology, 2004).

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator (USGS, 1998).

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data (Kammin, 2010).

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives (Kammin, 2010; Ecology, 2004).

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data (Ecology, 2004).

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$RPD = \left[\frac{Abs(a-b)}{(a+b)/2}\right] x\ 100\%$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Relative Standard Deviation (RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$RSD = (100\% * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled (USGS, 1998).

Reporting level: Unless specified otherwise by a regulatory authority or in a discharge permit, results for analytes that meet the identification criteria (i.e., rules for determining qualitative presence/absence of an analyte) are reported down to the concentration of the minimum level established by the laboratory through calibration of the instrument. EPA considers the terms "reporting limit," "quantitation limit," and "minimum level" to be synonymous (40 CFR 136).

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator (USGS, 1998).

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population (USGS, 1998).

Sample (statistical): A finite part or subset of a statistical population (USEPA, 1992).

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit (Ecology, 2004).

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method (USEPA, 2014).

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency (USEPA, 2014).

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010).

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity (Kammin, 2010).

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin, 2010).

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning (USEPA, 2006).

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