DEPARTMENT OF
ECOLOGY
State of Washington

Quality Assurance Project Plan

Audubon Lake's Connection to Upper Crab Creek (Lincoln County): Source Assessment

April 2009
Publication No. 09-03-112

Publication Information

This plan is available on the Department of Ecology's website at www.ecy.wa.gov/biblio/0903112.html.

Data for this project will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search User Study ID, jjoy0006.

Ecology's Project Tracker Code for this study is 08-062.

Waterbody Numbers: WA-43-9015, WA-43-4000

Author and Contact Information

Joe Joy
P.O. Box 47600
Environmental Assessment Program
Washington State Department of Ecology
Olympia, WA 98504-7710

For more information contact: Carol Norsen, Communications Consultant
Phone: 360-407-7486

Washington State Department of Ecology - www.ecy.wa.gov/

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Yakima 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

Quality Assurance Project Plan

Audubon Lake's Connection to Upper Crab Creek (Lincoln County): Source Assessment

April 2009

Approved by:

Signature:	Date: April 2009
Donovan Gray, Client, Water Quality Program, ERO	
Signature:	Date: April 2009
David Knight, Client's Unit Supervisor, Water Quality Program, ERO	
Signature:	Date: April 2009
Jim Bellatty, Client's Section Manager, Water Quality Program, ERO	
Signature:	Date: April 2009
Joe Joy, Author / Project Manager / EIM Data Engineer, EOS, EAP	
Signature:	Date: April 2009
Donovan Gray, Principal Investigator, Water Quality Program, ERO	
Signature:	Date: April 2009
Gary Arnold, Author's Section Manager, EOS, EAP	
Signature:	Date: April 2009
Stuart Magoon, Director, Manchester Environmental Laboratory, EAP	
Signature:	Date: April 2009
Bill Kammin, Ecology Quality Assurance Officer	

Signatures are not available on the Internet version.

ERO – Eastern Regional Office (Spokane).
EOS – Eastern Operations Section (Yakima and Spokane).
EAP – Environmental Assessment Program.
EIM – Environmental Information Management system.

Table of Contents

List of Figures and Tables

Page

Figures

Tables

Abstract

Each study conducted by the Washington State Department of Ecology (Ecology) must have an approved Quality Assurance Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completion of the study, a final report describing the study results will be posted to the Internet.

Ecology is planning to conduct a Total Maximum Daily Load (TMDL; water cleanup plan) study for the upper Crab Creek watershed in the near future. Audubon Lake[1] lies at the headwaters of the Crab Creek watershed, but there is no documented direct outflow from the lake to the uppermost channels of Crab Creek.

Ecology scheduled this survey to determine if water from snowmelt causes the lake to overflow into surface channels that connect to upper Crab Creek. Photo-documentation and water quality samples will be used to determine if the connection exists and if nutrient loading to the creek is significant.

If a surface water connection between Audubon Lake and Crab Creek exists, the lake and Reardan Wastewater Treatment Plant will be included in the Quality Assurance Project Plan for the *Upper Crab Creek TMDL Study*.

[1] Audubon Lake is in Lincoln County in eastern Washington.

Background

A Total Maximum Daily Load (TMDL) study is planned for the upper Crab Creek watershed in the near future. Audubon Lake lies at the headwaters of the Crab Creek watershed, but there is no documented direct outflow from the lake to the uppermost channels of Crab Creek (Figure 1). A series of pothole ponds, wetlands, and dry or ephemeral channels are present that imply a connection. Local residents have told past investigators that they have seen water from Audubon Lake cross Highway 2 into Crab Creek channels during snowmelt and flood events.

The western section of Audubon Lake receives effluent from the Reardan[2] Wastewater Treatment Plant (WWTP) throughout the year. The daily effluent volume permitted into the lake averages 0.08 million gallons per day (mgd) with a maximum average daily volume of 0.23 mgd (Ecology, 2009). The effluent enriches the lake water so that the lake has become a recognized habitat for wildlife and migratory birds. The Washington State Department of Fish and Wildlife has recently purchased land on the lake to develop as a wildlife viewing area.

The transport of highly enriched lake water into the headwaters of Crab Creek could significantly alter the focus of the future TMDL study. Crab Creek has multiple 303(d) listings on the 2008 Washington State Water Quality Assessment for pH, dissolved oxygen, and fecal coliform bacteria. An evaluation will be required for (1) nutrient, oxygen demand, and bacteria loads from the lake and (2) a wasteload allocation for Reardan WWTP. A full lake study would be necessary to allocate loads to wildlife, nonpoint sources, WWTP effluent, and stormwater runoff.

If no surface connection from Audubon Lake to Crab Creek can be shown, the lake can be managed at a different time. This could be to modify beneficial use designations for the lake or to modify WWTP effluent limits.

[2] The town of Reardan, Washington, is located 22 miles west of Spokane, Washington.

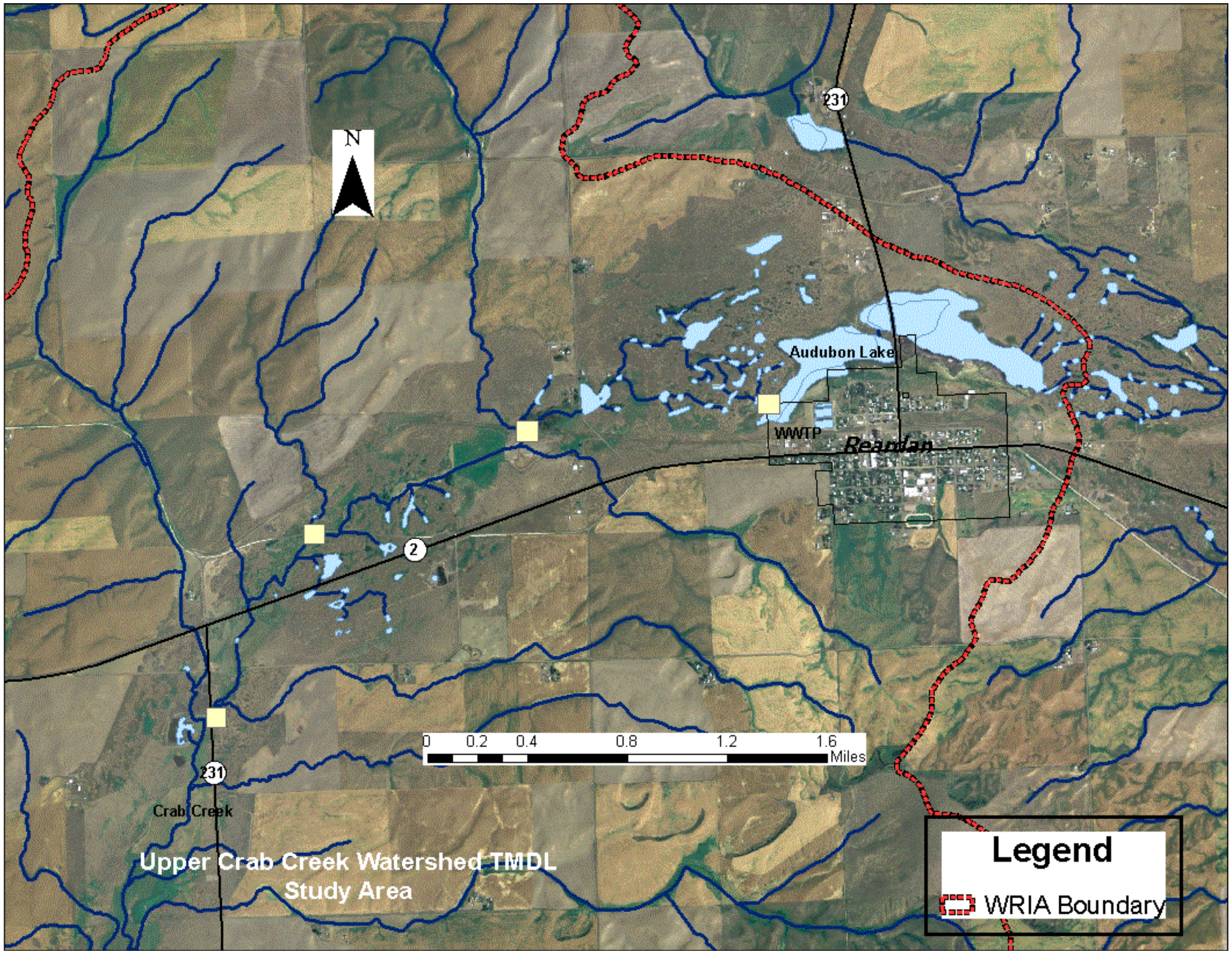

Figure 1. A map of Audubon Lake and the town of Reardan in relation to the upper reaches of Crab Creek where a future TMDL study is planned. Square symbols designate possible water quality monitoring sites.

Project Description

The single-visit survey will document whether water from Audubon Lake flows to Crab Creek during a period of spring snowmelt and runoff. Ecology field staff will follow any water flowing from the west end of Audubon Lake for approximately 4 miles through the potholes, wetlands, and intermittent channels that lead to Crab Creek south of Highway 2 (Figure 1). Field staff will conduct the survey during April while the lake connection through the wetlands is likeliest.

Photo-documentation will be supported with a few water quality samples along the water route as evidence for or against a surface connection. Principle component analysis or another multivariate statistical analysis of ionic characteristics will be used to evaluate the differences in ionic water characteristics of the sites. Piper or Stiff diagrams may be constructed to visually compare differences (Helsel and Hirsch, 1995). Nutrient concentrations will be evaluated to determine if significant nutrient loading comes from the lake to Crab Creek.

The purpose of the survey is to determine if Audubon Lake should be included in the future *Upper Crab Creek TMDL Study*. The weight-of-evidence approach will determine the following:

- If the lake is included in the TMDL, load and wasteload allocations will be needed for (1) nonpoint sources on and below the lake, and (2) the Reardan WWTP.
- If the lake does not have a direct surface connection to Crab Creek, the lake can be evaluated in a separate project with very specific goals and objectives.

Including Audubon Lake in the TMDL will require more resources than were in the preliminary project estimates. Resources and project scope will require adjustments. A groundwater study may also be required if monitoring during the TMDL project suspects unusual enrichment in surface water sites in the area south of Highway 2 (Figure 1).

Organization, Schedule, and Budget

The following people are involved in this project (Table 1). All are employees of the Washington State Department of Ecology. The schedule and budget for this project follow in Tables 2 and 3.

Table 1. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Joe Joy Eastern Operations Section EAP- HQ Phone: (360) 407-6486	Project Manager	Writes the QAPP, conducts QA review of data, analyzes and interprets data, and enters data into EIM.
Donovan Gray Water Quality Program ERO Phone: (509) 329-3458	Principal Investigator and EAP Client	Collects samples following QAPP guidelines, and ensures that samples are transported to the laboratory. Clarifies scopes of the project, provides internal review of the QAPP, and approves the final QAPP.
Jon Jones Water Quality Program ERO Phone: (509) 329-3481	Field Assistant	Helps collect samples, ensures credible data collection, and records field information.
Dan Sherratt Eastern Operations Section EAP-ERO Phone: (509) 329-3420	Field Assistant	Helps collect samples, ensures credible data collection, and records field information.
Gary Arnold Eastern Operations Section EAP-CRO/ERO Phone: (509) 454-4244	Section Manager for the Project Manager	Reviews the project scope and tracks progress. Approves the budget. Provides internal review of the draft QAPP and approves the final QAPP.
Stuart Magoon Manchester Environmental Laboratory Phone: (360) 871-8801	Director	Approves the final QAPP.
William R. Kammin Phone: (360) 407-6964	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP.

QAPP – Quality Assurance Project Plan.
EIM – Environmental Information Management system.
EAP – Environmental Assessment Program.
HQ – Headquarters, Olympia.
ERO – Eastern Regional Office, Spokane.
CRO – Central Regional Office, Yakima.

Table 2. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	
Field work completed	April 24, 2009
Laboratory analyses completed	May 29, 2009
Environmental Information System (EIM) system	
EIM data engineer	Joe Joy
EIM user study ID	jjoy0006
EIM study name	Upper Crab Creek TMDL
Data due in EIM	June 2009
Final report*	
Author lead	Joe Joy

* Data will be used in development of the *Upper Crab Creek TMDL Study*. No independent report is planned.

Total costs for laboratory analyses are expected to be approximately $2,550 for the single survey if water samples are collected (Table 3). Up to seven samples may be collected: four water-route sites, one field replicate, one blank sample, and one snow or unaffected tributary sample.

Table 3. Laboratory analytical costs for the *Audubon Lake Connection to Crab Creek* survey.

Analysis	Cost/unit	Cost for 7 samples
Alkalinity	$17	$119
Hardness*	$22	$154
Total Organic Carbon	$33	$231
Total Dissolved Solids - TDS	$11	$77
Ammonia - NH3	$13	$91
Orthophosphate	$15	$105
Total Phosphorus - TP colorimetric	$18	$126
Nitrate/Nitrite - NO2/NO3	$13	$91
Total Persulfate Nitrogen - TPN	$17	$119
Chloride	$13	$91
Fluoride	$13	$91
Sulfate	$13	$91
Total: Na, Ca, K, Si, Mn, Fe, Mg, Al, Sr, Ba	$155	$1,085

Costs include 50% discount for Manchester Laboratory.

* Hardness will be calculated from calcium and magnesium ions determined by ICP and calculated as: mg/L $CaCO_3$ = 2.497 calcium + 4.118 magnesium.

Quality Objectives

The decision objective of this survey is whether or not water from Audubon Lake is reaching upper Crab Creek. The methods of investigation will be field observation, photo-documentation, and tracking unique ionic water quality characteristics of the lake water with occasional water samples. Principle component analysis or another multivariate statistical analysis will be used to evaluate the differences in ionic characteristics of the sites (Helsel and Hirsch, 1995).

The working hypothesis is that the lake should have a distinct chemical water quality signature, different from surrounding snowmelt water, because of significant additions from the Reardan WWTP effluent. The distinct ionic signature should be measurable downstream, confirming field observations and photographic documentation. Nutrient loading from the lake to the uppermost channels of Crab Creek is of primary concern. Nutrient loads to Crab Creek should not be similar to those in Audubon Lake unless there is continuity.

Both field observation and water analyses can be used for the decision objective in the following ways:

- If the field crew finds flowing water uninterrupted from the lake to Crab Creek, then the connection is documented as 'yes'. If surface water continuity is broken, then the connection is documented as 'no'.
- If the field crew cannot remain in contact with the flowing channel, or standing water is encountered where connections are uncertain, then a comparative water sample analysis set of anions and cations will be used to determine if Audubon Lake water is present downstream.
    - If statistical analysis shows the ionic characteristics of the lake stay intact through the study reach, the connection will be documented as 'yes'.
    - If statistical analysis shows downstream ionic characteristics more reflect snowmelt, the connection will be documented as 'no'.
    - A mixed set of statistical results will require additional research and survey work.
- If nutrient concentrations are similar at all sites between Audubon Lake and Crab Creek, then a connection will be assumed.

Accurate documentation of the water route will be necessary to defend the decision. Photographs and field notes will need to be well-ordered and detailed. Water sampling sites will require accurate location data, either by map or by a calibrated Global Positioning System (GPS) instrument.

Typical measurement quality objectives (MQOs) are required to determine the chemical characteristics of the water samples. The objectives are met by standard techniques used by Manchester Environmental Laboratory (MEL). The measurement and analytical requirements are summarized in Table 4 (MEL, 2008).

Table 4. Summary of measurement quality objectives (MQOs) for field and laboratory parameters.

Parameter	Analytical Method	Accuracy (% deviation from true value)	Precision Relative Standard Deviation	Bias (% deviation from true value)	Required Reporting Limits (concentration units)
Field					
Velocity*	Marsh McBirney Flow-Mate® Flowmeter	0.1 ft/s	0.1 ft/s	N/A	0.01 ft/s
pH*	Hydrolab Minisonde®	0.05 s.u	0.05 s.u	0.10 s.u	1 - 14 s.u.
Temperature*	Hydrolab Minisonde®	0.1 °C	0.025 °C	0.05 °C	1 - 40 °C
Dissolved Oxygen	Hydrolab Minisonde®	15	5%	5	0.1 - 15 mg/L
Specific Conductivity	Hydrolab Minisonde®	25	10%	5	1 µmhos/cm
Laboratory					
Total Organic Carbon	SM 5310B	30	10%	10	1 mg/L
Alkalinity	SM 2320	20	10%	N/A	5 mg/L
Total Dissolved Solids	SM 2540C				1 mg/L
Chloride	EPA 300.0	15	5%	5	0.1 mg/L
Fluoride	EPA 300.0	15	5%	5	0.1 mg/L
Sulfate	EPA 300.0	15	5%	5	0.5 mg/L
Na, Ca, K, Si, Mn, Fe, Mg, Al, Sr, Ba	EPA 200.7	5	5	5	0.1 – 50 ug/L
Total Persulfate Nitrogen	SM 4500B	30	10%	10	0.025 mg/L
Ammonia Nitrogen	SM 4500-NH_3^- H	25	10%	5	0.01 mg/L
Nitrate & Nitrite Nitrogen	SM 4500-NO_3^- I	25	10%	5	0.01 mg/L
Orthophosphate	SM 4500-P G	25	10%	5	0.003 mg/L
Total Phosphorus	SM 4500-P F	25	10%	5	0.005 mg/L

* As units of measure, not percentages.

Sampling Process Design (Experimental Design)

The field crew will start at the western end of Audubon Lake and proceed west onto property where prior approval for entry has been gained. The field crew will follow along the shore of flowing or contiguous waterbodies as far as possible. Photo-documentation and descriptive notes and map points (or GPS way-points) will document observations. Water column samples will be taken at appropriate locations to test surface water continuity. If visible water movement is present, streamflow measurements will be taken.

Approximate site locations are as follows (Figure 1):

- Audubon Lake at western outlet.
- Snowmelt and/or water from a tributary unaffected by the lake (for background water).
- Zwainz Road.
- Old Sunset Highway.
- Alexander Road or Highway 231.

The crew will attempt to investigate the entire study area from Audubon Lake to the upper reaches of Crab Creek south of Highway 2 (Alexander Road or Highway 231 crossing).
The field survey is planned for one day between April 6 and 24, 2009.

Results from the analyses of the ionic characteristics for each sample will be compared using principle component analysis or another multivariate statistical analysis (Helsel and Hirsch, 1995). Piper or Stiff diagrams may be constructed using RockWare® or USGS GW_Chart software to visually compare differences. For example, waters with different chemical characteristics should plot at different locations on a principle component scatterplot. The lake sample should be in a different position on the Piper diagram than the Crab Creek sample.

Nutrient concentrations and any available flow measurements will be used to calculate loads at each site for comparison. Nutrient loads should decrease between the lake and the other sites. Nutrient concentrations should be significantly decreased or attenuated in the wetlands.

Sampling Procedures

Field personnel will collect samples using Environmental Assessment Program (EAP) standard procedures to ensure credible data. These include:

- EAP013 – Determining Global Position System Coordinates (Janisch, 2006).
- EAP015 – Grab sampling – Fresh water (Joy, 2006).
- EAP033 – Hydrolab® DataSonde® and MiniSonde® Multiprobes (Swanson, 2007).
- EAP034 – Collection, Processing, and Analysis of Stream Samples (Ward, 2007).

Samples will be collected following EAP safety and chemical hygiene protocols. Samples will be collected in pre-cleaned bottles supplied by MEL (2008) (Table 5). Orthophosphate samples will be filtered in the field with syringes and filters supplied by MEL. Sample collection details will be documented in the field notebook.

Once collected, samples will be clearly labeled using laboratory identification numbers supplied by the MEL. Samples will be stored in the cool and dark until transferred to an ice chest for shipping via Horizon Air to MEL.

Table 5. Containers, preservation requirements, and holding times for samples collected.

Parameter	Sample Matrix	Container	Preservative	Holding Time
Total Organic Carbon	Surface water	60 mL clear poly	1:1 HCl to pH<2; Cool to 4 °C	28 days
Total Dissolved Solids	Surface water	1000 mL poly	Cool to 4 °C	7 days
Alkalinity	Surface water	500 mL poly – no headspace	Cool to 4 °C; Fill bottle completely; Don't agitate sample	14 days
Chloride, Sulfate, and Fluoride	Surface water	500 mL poly	Cool to 4 °C	28 days
Total Persulfate Nitrogen	Surface water	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4 °C	28 days
Ammonia	Surface water	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4 °C	28 days
Nitrate/Nitrite	Surface water	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4 °C	28 days
Orthophosphate	Surface water	125 mL amber poly with Whatman Puradisc™ 25PP 0.45 µm pore size filters	Filter in field with 0.45 µm pore size filter; Cool to 4 °C	48 hours
Total Phosphorus	Surface water	60 mL clear poly	1:1 HCl to pH<2; Cool to 4 °C	28 days
Na, Ca, K, Si, Mn, Fe, Mg, Al, Sr, Ba	Surface water	500 mL HDPE w/Teflon lid	HNO3 to pH<2 and kept at 0 to 6°C	6 months

Measurement Procedures

Field personnel will collect samples using EAP standard operating procedures to ensure credible data. These include meter use and any flow measurements taken:

- EAP033 – Hydrolab® DataSonde® and MiniSonde® Multiprobes (Swanson, 2007).
- EAP024 – Estimating Streamflow (Sullivan, 2007).

Field instruments will be pre-calibrated, and measurements will be documented in the field notebook. Field instruments will be post-checked for calibration. Deviations from standard solution values will be documented in the field notebook.

Field and Laboratory Quality Control Procedures

All meters and equipment will be calibrated prior to deployment as described in the EAP standard operating procedures. Post-checking of meters will be performed on return from the field. Deviation from standard solution values will be documented in the field notebook. Any secondary sampling device will be thoroughly cleaned with dilute acid and rinsed with distilled water prior to field deployment. The secondary sampling device will be rinsed with site water several times prior to collecting samples for laboratory analysis.

One set of replicate water column samples will be collected from a randomly selected site, and one set of field transfer blanks will be collected in the study area (Table 6). Both sets will be analyzed using the same methods as the site samples. Standard MEL quality assurance practices will be followed for check standards, method blanks, lab replicates, and matrix spikes.

Table 6. Field and laboratory blank and replicate schedule for samples collected during the *Audubon Lake Connection to Crab Creek* survey.

Parameter	Field Transfer Blanks	Field Replicates	Lab Check Standard	Lab Method Blanks	Lab Replicates	Matrix Spikes
Field						
Velocity*	N/A	1	N/A	N/A	N/A	N/A
pH*	N/A	1	N/A	N/A	N/A	N/A
Temperature*	N/A	1	N/A	N/A	N/A	N/A
Dissolved Oxygen	N/A	1	N/A	N/A	N/A	N/A
Specific Conductivity	N/A	1	N/A	N/A	N/A	N/A
Laboratory						
Total Organic Carbon	1	1	1/run	1/run	1/batch	1/20 samples
Total Dissolved Solids	1	1	1/run	1/run	1/batch	N/A
Alkalinity	1	1	1/run	1/run	1/batch	N/A
Chloride, Fluoride, and Sulfate	1	1	1/run	1/run	1/batch	N/A
Total Persulfate Nitrogen	1	1	1/run	1/run	1/batch	1/20 samples
Ammonia Nitrogen	1	1	1/run	1/run	1/batch	1/20 samples
Nitrate & Nitrite Nitrogen	1	1	1/run	1/run	1/batch	1/20 samples
Orthophosphate	1	1	1/run	1/run	1/batch	1/20 samples
Total Phosphorus	1	1	1/run	1/run	1/batch	1/20 samples
Total: Na, Ca, K, Si, Mn, Fe, Mg, Al, Sr, Ba	1	1	1/10 samples	1/run	1/batch	1/20 samples

Data Management Procedures

Before leaving each site, field staff will review field book entries for accuracy and completeness. Field measurement data will be delivered to the project manager who will enter it from the field book into EXCEL® spreadsheets (Microsoft, 2007) as soon as practical after the survey This database will be used for preliminary analysis and to create a table to upload data into Ecology's Environmental Information Management (EIM) System. The database will be held in a computer space with a daily automatic back-up routine to a remote/separate computer.

Sample result data received from MEL by Ecology's Laboratory Information Management System (LIMS) will be exported prior to entry into EIM and added to a cumulative spreadsheet for laboratory results. A cover letter with quality assurance information will accompany the LIMS export. The data spreadsheet will be used to informally review and analyze data during the course of the project.

All continuous data will be stored in a project database that includes station location information and data quality assurance information. This database will facilitate summarization and graphical analysis of the water data and also create a data table to upload the data to Ecology's statewide EIM geospatial database.

An EIM user study ID (JJOY0006) has been created for this study, and all monitoring data will be available via the internet once the project data has been validated. The URL address for this geospatial database is: http://apps.ecy.wa.gov/eimreporting. All data will be uploaded to EIM by the EIM engineer after all data have been reviewed for quality assurance and finalized.

All final spreadsheet files, paper field notes, and final GIS products created as part of the data analysis and statistical analyses will be kept with the project data files.

Audits and Reports

The project manager will be responsible for storing the technical study information and using it in the *Upper Crab Creek TMDL Quality Assurance Project Plan*. Ecology's Eastern Regional Office (ERO) Water Quality Program TMDL coordinator for this project and the ERO permit manager for the Reardan WWTP will be informed of the findings. MEL will supply quality assurance statements with paper copies of the laboratory data as it is entered into LIMS.

Data Verification

Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in the MEL Users Manual (MEL, 2008). Lab results will be checked for missing and improbable data. Variability in lab duplicates will be quantified using the procedures outlined in the MEL Quality Assurance Manual (MEL, 2006). Any estimated results will be qualified and their use restricted as appropriate. A standard case narrative of laboratory quality assurance/quality control results will be sent to the project manager for each set of samples.

Field notebooks will be checked for missing or improbable measurements before leaving each site. The EXCEL® Workbook file containing field data will be labeled DRAFT until data verification is complete. Data entry will be checked against the field notebook data for errors and omissions. Missing or unusual data will be brought to the attention of the project manager for consultation. Valid data will be moved to a separate file labeled FINAL.

Data received from LIMS will be checked for omissions against the Request for Analysis forms by the field lead. Data can be in EXCEL® spreadsheets (Microsoft, 2007) or downloaded tables from EIM. These tables and spreadsheets will be located in a file labeled DRAFT until data verification is completed. Field replicate sample results will be compared to quality objectives in Table 4. Data requiring additional qualifiers will be reviewed by the project manager.

After data verification and data entry tasks are completed, all field, laboratory, and flow data will be entered into a file labeled FINAL and then into the EIM system. EIM data will be independently reviewed by another EAP field assistant for errors at an initial 10% frequency. If significant entry errors are discovered, a more intensive review will be undertaken.

Data Quality (Usability) Assessment

The project manager will verify which measurement and data quality objectives have been met for the sample set. For example, if the objectives have not been met, such as if the %RSD for phosphorus replicates exceeds the MQO or a Hydrolab shows signs of malfunctioning, then the field lead and project manager will decide whether to delete non-credible data or how to qualify the data. All data considered credible will be available in EIM and for use in the analyses with appropriate qualifiers and comments taken into account. Data may be eliminated from statistical or graphical analysis after careful consideration of all quality control processes.

The summary of the data and quality assurance results will be included in the *Upper Crab Creek Quality Assurance Project Plan*. At a minimum, the summary will include: site descriptions, data quality assurance calculations, and comparison to Quality Assurance Project Plan MQOs.

Once quality steps have been completed, data are fit for analysis. Data analysis will include evaluation of data distribution characteristics and, if necessary, appropriate distribution of transformed data. Estimation of multivariate statistical parameters and graphical presentation of the data (histograms, Stiff and Piper diagrams) will be made using appropriate software, including EXCEL® (Microsoft, 2007).

References

Ecology, 2009. National Pollutant Discharge Elimination System Waste Discharge Permit No. Wa-004530-6. Town of Reardan. Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/programs/wq/permits/permit_pdfs/reardan/reardan%20final.pdf

Helsel, D.R. and R.M. Hirsch, 1995. Statistical Methods in Water Resources. Elsevier Science Publishers, New York, NY.

Janisch, J., 2006. Standard Operating Procedure for Determining Global Position System Coordinates ,Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP013. www.ecy.wa.gov/programs/eap/quality.html

Joy, J., 2006. Standard Operating Procedure for Grab sampling – Fresh water, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP015. www.ecy.wa.gov/programs/eap/quality.html

MEL, 2006. Manchester Environmental Laboratory Quality Assurance Manual. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

MEL, 2008. Manchester Environmental Laboratory Lab Users Manual, Ninth Edition. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

Microsoft, 2007. Microsoft Office XP Professional, Version 10.0. Microsoft Corporation.

Sullivan, L., 2007. Standard Operating Procedure for Estimating Streamflow, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP024. www.ecy.wa.gov/programs/eap/quality.html

Swanson, T., 2007. Standard Operating Procedure for Hydrolab® DataSonde® and MiniSonde® Multiprobes, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP033. www.ecy.wa.gov/programs/eap/quality.html

Ward, W.J., 2007. Collection, Processing, and Analysis of Stream Samples, Version 1.3. Washington State Department of Ecology, Olympia, WA. SOP Number EAP034. www.ecy.wa.gov/programs/eap/quality.html

Appendix. Glossary, Acronyms, and Abbreviations

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards, and are not expected to improve within the next two years.

Anion, Cation, and Ion: Charged chemical particles are ions. Positively charged particles are cations, and negatively charged particles are anions. In water, an electrically neutral solution, anions and cations will be balanced.

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Load allocation: The portion of a receiving waters' loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities. This includes, but is not limited to, atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or is likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Principle component analysis: A mathematical technique for transforming a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components. The new variables account for as much of the data variability as possible, so comparisons can be made.

Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocations constitute one type of water quality-based effluent limitation.

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

Ecology	Washington State Department of Ecology
EAP	Environmental Assessment Program
EIM	Environmental Information Management database
GIS	Geographic Information System software
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
NPDES	National Pollutant Discharge Elimination System
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	Total Maximum Daily Load (water cleanup plan)
USGS	U.S. Geological Survey
WRIA	Water Resources Inventory Area
WWTP	Wastewater treatment plant

Chemicals

Al	Aluminum
Ba	Barium
Ca	Cadmium
Fe	Iron
K	Potassium
Mg	Magnesium
Mn	Manganese
Na	Sodium
Si	Silicon
Sr	Strontium

Units of Measurement

°C	degrees centigrade
ft	feet
mgd	million gallons per day
mg/Kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mL	milliliters
s.u.	standard units