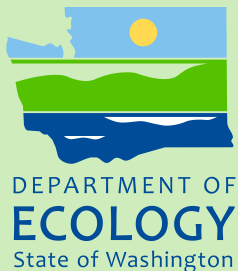




## **Audubon Lake's Connection to Upper Crab Creek (Lincoln County)**

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### **Source Assessment**



March 2010

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Cover photo: Audubon Lake near Reardan, Washington (by Donovan Gray, 2009).

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# **Audubon Lake's Connection to Upper Crab Creek (Lincoln County)**

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## **Source Assessment**

*by*  
*Joe Joy*

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Environmental Assessment Program  
Washington State Department of Ecology  
Olympia, Washington 98504-7710

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

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# Table of Contents

|  | <u>Page</u> |
|--|-------------|
| List of Figures and Tables.....                        | 4           |
| Abstract .....   | 5           |
| Acknowledgements.....                                  | 6           |
| Introduction.....                                      | 7           |
| Methods.....   | 9           |
| Results.....   | 11          |
| Quality Assurance .....                                | 11          |
| Field Observations .....                               | 12          |
| Laboratory Results .....                               | 12          |
| Discussion .....                                       | 14          |
| Conclusions and Recommendations .....                  | 17          |
| References .....                                       | 18          |
| Appendices.....  | 19          |
| Appendix A. Glossary, Acronyms, and Abbreviations..... | 21          |
| Appendix B. Field Photos .....                         | 23          |
| Appendix C. Normalized Data.....                       | 24          |

# List of Figures and Tables

Page

## Figures

|  |    |
|--|----|
| Figure 1. Audubon Lake at Reardan, Washington, and the surrounding area and watershed boundaries.....  | 7  |
| Figure 2. The location of five sample sites established to test for a surface water connection between Audubon Lake and upper Crab Creek.....  | 9  |
| Figure 3. A radar diagram showing similarities and differences in trace element concentrations at five sites between Audubon Lake and upper Crab Creek (Highway 231), April 2009. ....               | 15 |
| Figure 4. Cluster analysis of normalized trace element results and normalized nutrient results collected at four primary sites between Audubon Lake and upper Crab Creek (Hwy 231), April 2009. .... | 16 |

## Tables

|   |    |
|---|----|
| Table 1. Analytes, methods, containers, and holding times for water samples, April 21, 2009. .... | 10 |
| Table 2. Field replicate, field blank, and laboratory blank results.....                          | 11 |
| Table 3. Field measurements, April 21, 2009.....  | 12 |
| Table 4. General chemistry and trace element results, April 2009.....                             | 13 |

# Abstract

This report documents the findings of a one-day survey conducted in April 2009 to discover if surface water from Audubon Lake reaches the upper reaches of Crab Creek in Lincoln County, Washington. The transport of Audubon Lake water to upper Crab Creek would significantly increase the complexity of future nutrient and oxygen demand Total Maximum Daily Load studies in Crab Creek.

A field crew took pictures and collected five water samples from key locations between Audubon Lake and branches of upper Crab Creek after melting of a near-record snowfall. The crew did not observe water flowing from the lake to channels connected to Crab Creek. Field measurements and water sample laboratory results suggested Audubon Lake water had distinctly different chemical characteristics from upper Crab Creek. Only flowing water collected at the two sites farthest from the lake contained trace element similarities.

All lines of evidence suggest that Audubon Lake does not directly contribute surface water to upper Crab Creek.

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# Introduction

A Total Maximum Daily Load (TMDL) study is planned for the upper Crab Creek watershed in the 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 investigators that they have seen water from Audubon Lake cross Highway 2 into Crab Creek channels during snowmelt and flood events.

This report documents the findings of a one-day survey conducted in April 2009 by the Washington State Department of Ecology (Ecology) to discern if surface water from Audubon Lake was reaching the upper reaches of Crab Creek in Lincoln County.

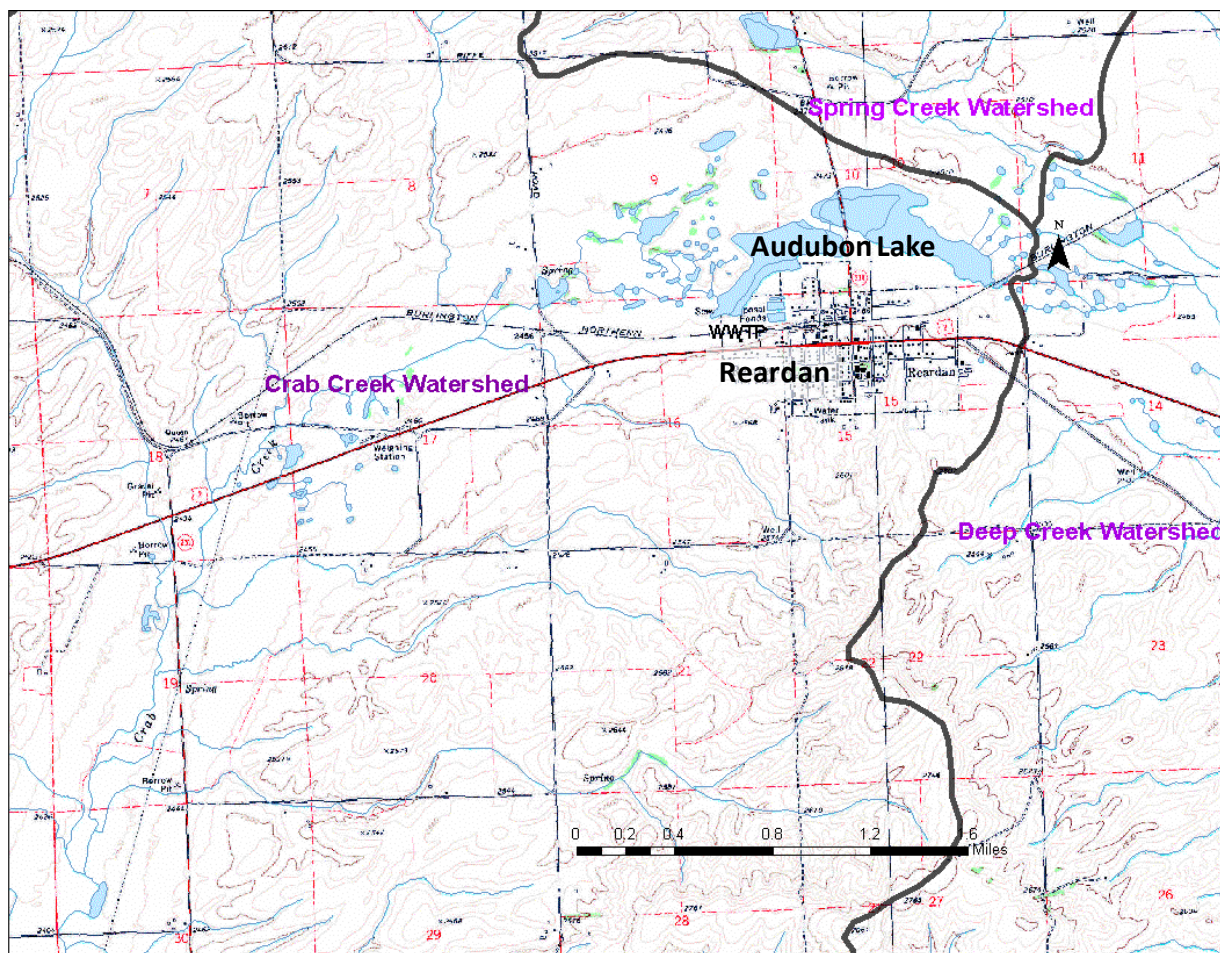


Figure 1. Audubon Lake at Reardan, Washington, and the surrounding area and watershed boundaries.

The western section of Audubon Lake receives effluent from the Reardan<sup>1</sup> 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 Department of Fish and Wildlife 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 influence 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. If nutrient loads from Audubon Lake are present, they could have a significant effect on Crab Creek dissolved oxygen and pH values. The relative contribution of the lake loads compared to other sources, their frequency of delivery to the creek, and the transformations or losses through the intervening wetland and ponds would need to be evaluated. Collecting data to answer these issues would be complex.

If no surface connection from Audubon Lake to Crab Creek can be shown, the lake can be assessed at a different time. A more intensive biological study may be necessary to modify beneficial use designations for best management of the lake. If the lake is required to meet default lake standards, a study would be necessary to assess nutrient, oxygen demand, and bacteria loads. Results of the study would allocate contaminant loads to wildlife, nonpoint sources, WWTP effluent, and stormwater runoff.

---

<sup>1</sup> The town of Reardan, Washington, is located 22 miles west of Spokane, Washington.



## Methods

A single field crew started at the western end of Audubon Lake and proceeded west on April 21, 2009, shortly after spring snowmelt. The four-member crew followed methods and procedures detailed in the Quality Assurance Project Plan (Joy, 2009). Photos (Appendix B) and descriptive notes and map points documented observations. Field measurements and water column samples were taken at five locations within three hours to analyze characteristics that would indicate surface water continuity. Site locations were as follows (Figure 2):

- Audubon Lake at western shoreline.
- Isolated pond near Audubon Lake.
- Water crossing Riffe Road.
- Water crossing old Sunset Highway.
- Upper Crab Creek at Highway 231.

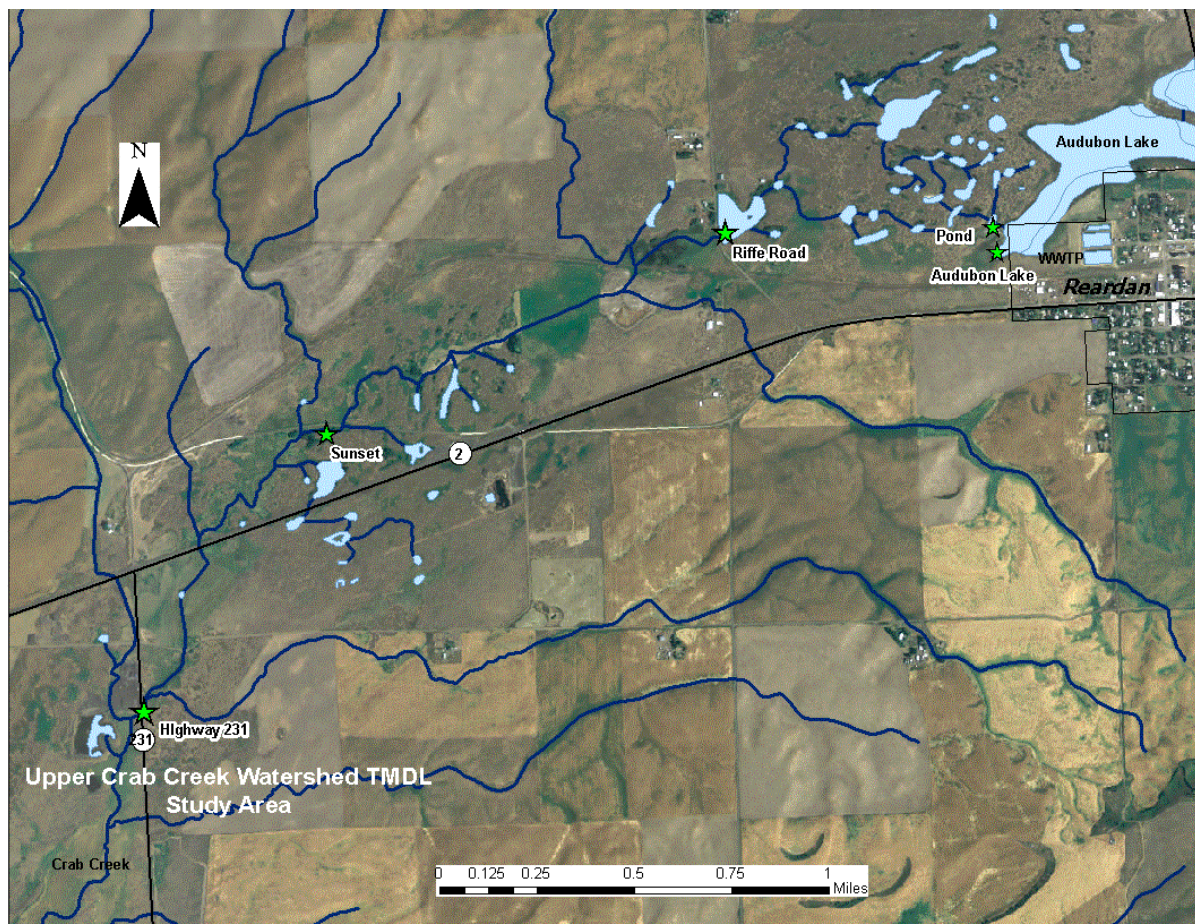


Figure 2. The location of five sample sites established to test for a surface water connection between Audubon Lake and upper Crab Creek.

The crew was unable to walk through the wetlands from Audubon Lake to the upper reaches of Crab Creek north of Highway 2 (Riffe Road and Sunset Highway) because of landowner absences and difficult terrain.

On April 21, 2009, all samples were collected in pre-cleaned bottles supplied by Manchester Environmental Laboratories (MEL, 2008) (Table 1). Orthophosphate samples were filtered in the field with syringes and filters supplied by MEL. Sample collection details were documented in a field notebook. Samples were stored in the cool and dark until transferred to an ice chest for shipping via air freight to MEL. Samples were processed and analyzed within required holding times for elements and compounds listed in Table 1. An analysis of iodine was also requested, but no standards were available to make quantitative measurements; only relative readings were reported (Momohara, 2009b).

Table 1. Analytes, methods, containers, and holding times for water samples, April 21, 2009.

| Parameter  | Analytical Method                      | Container                  | Holding Time |
|--|--|----------------------------|--------------|
| Total Organic Carbon   | SM 5310B                               | 60 mL clear poly           | 28 days      |
| Alkalinity   | SM 2320                                | 500 mL poly – no headspace | 14 days      |
| Total Dissolved Solids   | SM 2540C                               | 1000 mL poly               | 7 days       |
| Chloride, Fluoride, Sulfate  | EPA 300.0                              | 500 mL poly                | 28 days      |
| Sodium, Calcium, Potassium, Silicon, Manganese, Iron, Magnesium, Aluminum, Strontium, Barium, Iodine | EPA 200.7                              | 500 mL HDPE w/Teflon lid   | 6 months     |
| Total Persulfate Nitrogen  | SM 4500B                               | 125 mL clear poly          | 28 days      |
| Ammonia Nitrogen   | SM 4500-NH <sub>3</sub> <sup>-</sup> H | 125 mL clear poly          | 28 days      |
| Nitrate & Nitrite Nitrogen   | SM 4500-NO <sub>3</sub> <sup>-</sup> I | 125 mL clear poly          | 28 days      |
| Filtered Orthophosphate  | SM 4500-P G                            | 125 mL amber poly          | 48 hours     |
| Total Phosphorus   | SM 4500-P F                            | 60 mL clear poly           | 28 days      |

One set of duplicate samples was collected at the Sunset Highway site to check total analytical variability. A set of field blanks was run in Ecology's Eastern Regional Office lab on return from the field. MEL ran standard blank and check samples under their usual procedures (MEL, 2006).

Comparative data analyses were conducted using visual and statistical tools. Microsoft EXCEL<sup>®</sup> graphical tools and SYSTAT<sup>®</sup> software cluster analysis routines were used to test similarities between chemical fingerprints of the five sites (Microsoft, 2007; SYSTAT, 2009). After Quality Assurance (QA) checks, data were entered into the Ecology Environmental Information Management (EIM) System and are available at website [www.ecy.wa.gov/eim/index.htm](http://www.ecy.wa.gov/eim/index.htm). Search User Study ID, jjoy0006.

# Results

## Quality Assurance

The field crew and laboratory staff followed the QA Project Plan successfully. Table 2 shows that field replicate and blank results, and laboratory blank data were within QA targets (Joy, 2009). All general chemistry results were reported without qualification (Momohara, 2009a). A positive detection of total phosphorus in the field blank was two orders of magnitude lower than in samples collected during the survey and did not require data qualification (Table 2). Matrix spike recoveries of calcium and sodium were outside acceptable limits because the spiking level was insufficient for the elevated concentrations in the source sample (Momohara, 2009b). However, calcium and sodium results did not require qualification.

Table 2. Field replicate, field blank, and laboratory blank results.

*The average and standard deviation (Std. Dev.) of the field replicate samples is shown with the calculated relative percent difference (RPD).*

| Parameter                   | Units  | Field Replicate Sample |           |      | Field Blank | Lab Blank |
|-----------------------------|--------|------------------------|-----------|------|-------------|-----------|
|                             |        | Average                | Std. Dev. | RPD  |             |           |
| Sodium                      | mg/L   | 34.2                   | 0         | 0%   | <0.025      | <0.025    |
| Calcium                     | mg/L   | 47.2                   | 0.6       | 1.9% | <0.025      | <0.025    |
| Aluminum                    | mg/L   | 0.086                  | 0.001     | 1.2% | <0.025      | <0.025    |
| Barium                      | µg/L   | 0.079                  | 0.002     | 3.9% | <0.1        | <0.1      |
| Iron                        | mg/L   | 0.263                  | 0.004     | 1.9% | <0.025      | <0.025    |
| Potassium                   | mg/L   | 5.23                   | 0.04      | 1.0% | <0.25       | <0.25     |
| Magnesium                   | mg/L   | 18.1                   | 0         | 0%   | <0.025      | <0.025    |
| Manganese                   | mg/L   | 0.185                  | 0.004     | 3.2% | 0.005       | 0.005     |
| Strontium                   | mg/L   | 0.310                  | 0.008     | 3.6% | <0.1        | <0.1      |
| Silicon                     | mg/L   | 5.27                   | 0.13      | 3.4% | <0.1        | <0.1      |
| Total Dissolved Solids      | mg/L   | 309                    | 4         | 1.6% | <10         | <10       |
| Alkalinity                  | mg/L   | 208                    | 1         | 1.0% | <5          | <5        |
| Chloride                    | mg/L   | 24.1                   | 0         | 0%   | <0.1        | <0.1      |
| Fluoride                    | mg/L   | 0.32                   | 0.01      | 6.3% | <0.1        | <0.1      |
| Nitrate & Nitrite-N         | mg/L   | 0.017                  | 0.001     | 6.1% | <0.01       | <0.01     |
| Ammonia-N                   | mg/L   | > 0.01                 | 0         | 0%   | <0.01       | <0.01     |
| Total Persulfate Nitrogen   | mg/L   | 0.82                   | 0.05      | 8.0% | <0.025      | <0.025    |
| Total Phosphorus            | mg/L   | 0.25                   | 0.01      | 5.6% | 0.0066      | <0.005    |
| Soluble Reactive Phosphorus | mg/L   | 0.202                  | 0.009     | 6.5% | <0.003      | <0.003    |
| Sulfate                     | mg/L   | 22.3                   | 0.2       | 1.3% | <0.3        | <0.3      |
| Total Organic Carbon        | mg/L   | 11.7                   | 0.8       | 9.4% | <1          | <1        |
| Iodine                      | units* | 23000                  | 6000      | 35%  |             |           |

\* Iodine results were only provided as qualitative readings because standards were not available to quantify concentrations.



Field meter pre-calibration and post-calibration results were acceptable. QA measurements were within acceptable target levels. No qualification of field data was necessary.

## Field Observations

The 2008–2009 winter snow pack had been near record high levels (WRCC, 2009). Snow was not present on the ground on April 21; however, three inches were on the ground a month earlier at the nearby Davenport (Station No. 452007) weather station. Audubon Lake appeared to be at maximum stage, but no outlet channel leading west was observed by the field crew.

Channels depicted on Figure 2 leading from the pot-hole lakes to Riffe Road did not contain flowing water (Appendix B photos). The area had saturated soil or open water, but no discernable water movement was observed. Flowing water was observed only at the Sunset Highway and Highway 231 sites. Flow measurements were taken at the two sites using a Marsh-McBirney velocity meter using standard procedures (Sullivan, 2007). Flows were fairly low: 1.2 cfs at the Old Sunset Highway crossing, and 3.0 cfs at Highway 231 (Figure 2; Table 3).

Temperature, conductivity, pH, and dissolved oxygen (DO) were measured using a Hydrolab<sup>®</sup> multiprobe (Table 3). Standard operating procedures were followed (Swanson, 2007). Audubon Lake and Riffe Road temperatures and conductivities were similar, but pH and DO values were not. Sunset Highway and Highway 231 had similar conductivities compared to the Audubon Lake and Riffe Road sites. Temperature, conductivity, pH, and DO at Sunset Highway suggest water from a very different source than the lake or Riffe Road.

Table 3. Field measurements, April 21, 2009.

| Location*      | Identification Number | Time  | Temp °C | Conductivity | pH   | Dissolved Oxygen | Flow |
|----------------|-----------------------|-------|---------|--------------|------|------------------|------|
|                |                       |       |         | µmhos/cm     | su   | mg/L             | cfs  |
| Audubon Lake   | 43ALO-1.82            | 09:34 | 13.46   | 908.9        | 9.45 | 10.86            |      |
| Riffe Road     | 43UNK-00.2            | 10:30 | 12.37   | 927.7        | 7.62 | 2.79             |      |
| Sunset Highway | 43CRA-144.4           | 11:04 | 8.74    | 465.1        | 6.81 | 6.30             | 1.16 |
| Highway 231    | 43CRA-143.4           | 12:03 | 14.65   | 535.6        | 7.82 | 11.97            | 3.04 |

Field measurements were not taken at the Pond site, 43ALO-1.80.

## Laboratory Results

General chemistry and trace element laboratory results are shown in Table 4. A general chemistry sample was not collected from the pond near Audubon Lake. The Pond sample was collected to see if recent flooding from the lake was a source of its water.

The laboratory results show some of the same relational similarities to the field measurements. Generally, trace element concentrations at the Audubon Lake and Riffe Road sites are relatively similar, and the Sunset Highway and Highway 231 are similar. The Pond trace element concentrations show some similarities to the lake and Riffe Road results, but are very different

from all sites in other ways. For example, the sodium, potassium, magnesium, strontium, and iodine values are much higher in the Pond sample than any of the other samples (Table 4).

Table 4. General chemistry and trace element results, April 2009.

| Parameter              | Site   | Audubon Lake   | Riffe Road     | Sunset Highway  | Highway 231     | Pond           |
|------------------------|--------|----------------|----------------|-----------------|-----------------|----------------|
|                        | No.    | 43ALO<br>-1.82 | 43UNK<br>-00.2 | 43CRA<br>-144.4 | 43CRA<br>-143.4 | 43ALO<br>-1.80 |
|                        | Time   | 9:34           | 10:30          | 11:04           | 12:03           | 09:50          |
| Sodium                 | mg/L   | 117            | 87.2           | 34.2            | 35.1            | 621            |
| Calcium                | mg/L   | 42.2           | 57.2           | 47.6            | 51.1            | 78             |
| Aluminum               | mg/L   | 0.076          | 0.051          | 0.085           | 0.156           | <0.025         |
| Barium                 | µg/L   | 0.0532         | 0.111          | 0.0774          | 0.074           | 0.155          |
| Iron                   | mg/L   | 0.049          | 0.093          | 0.265           | 0.249           | 0.032          |
| Potassium              | mg/L   | 18.3           | 14             | 5.25            | 4.25            | 38.3           |
| Magnesium              | mg/L   | 32.2           | 36.9           | 18.1            | 19              | 94             |
| Manganese              | mg/L   | 0.028          | 0.228          | 0.182           | 0.043           | 0.177          |
| Strontium              | mg/L   | 0.42           | 0.467          | 0.304           | 0.331           | 0.933          |
| Silicon                | mg/L   | 4.63           | 21.7           | 5.36            | 8.63            | 30             |
| Iodine                 | units* | 57,000         | 67,000         | 27,000          | 23,000          | 255,000        |
| Total Dissolved Solids | mg/L   | 589            | 609            | 306             | 305             |                |
| Alkalinity             | mg/L   | 341            | 403            | 209             | 220             |                |
| Chloride               | mg/L   | 80.3           | 48.3           | 24.1            | 27              |                |
| Fluoride               | mg/L   | 0.38           | 0.45           | 0.33            | 0.29            |                |
| Ammonia-N              | mg/L   | 0.012          | <0.01          | <0.01           | 0.04            |                |
| Nitrate & Nitrite - N  | mg/L   | 0.018          | 0.01           | 0.016           | 0.576           |                |
| Total Persulfate - N   | mg/L   | 1.79           | 1.28           | 0.853           | 1.44            |                |
| Total Phosphorus - P   | mg/L   | 1.38           | 0.147          | 0.255           | 0.152           |                |
| Soluble Reactive P     | mg/L   | 1.08           | 0.087          | 0.195           | 0.116           |                |
| Organic Phosphorus     | mg/L   | 0.30           | 0.06           | 0.06            | 0.036           |                |
| Sulfate                | mg/L   | 42.8           | 50.9           | 22.1            | 20.3            |                |
| Total Organic Carbon   | mg/L   | 55             | 22.7           | 11.1            | 11.6            |                |

\* Iodine results are qualitative only.

N – Nitrogen.

P – Phosphorus.

## Discussion

Based on the conductivity readings in Table 3, upper Crab Creek on Highway 231 could be approximately 15% Riffe Road water and 85% Sunset Highway source water. Calcium, barium, iron, magnesium, strontium, silica, and alkalinity results also fell roughly within the ratio reflected by the conductivity readings. Sunset Highway water appears to have a groundwater component based on its lower temperature, lower conductivity, and lower dissolved oxygen concentration (Table 3). If Riffe Road has any Audubon Lake source water, it does not appear to be a direct connection.

Visual and statistical treatments of the chemical data were conducted to assess similar and dissimilar characteristics between sites. Data were first normalized to eliminate arbitrary effects from units of measure and broad variable ranges in the analyses (Appendix C, Table C-1). A common normalization was used (Romesburg, 1984):

$$\frac{Xi - \mu}{\sigma}$$

where,

$Xi$  is the concentration of an analyte for sample  $i$ .

$\mu$  is the mean concentration of the analyte in all samples collected.

$\sigma$  is the standard deviation of the analyte in all samples.

A radar diagram based on normalized trace element results suggests the following (Figure 3):

- The Pond sample has a very different trace element *signal* from any of the other samples at the other sites.
- Sunset Highway and Highway 231 samples are the most similar (i.e., have the most number of elements with similar concentrations).
- The Audubon Lake sample appears to have as much similarity to Highway 231 as it does to Riffe Road.
- The Riffe Road sample has many unique characteristics compared to Sunset Highway, Highway 231, and Audubon Lake.



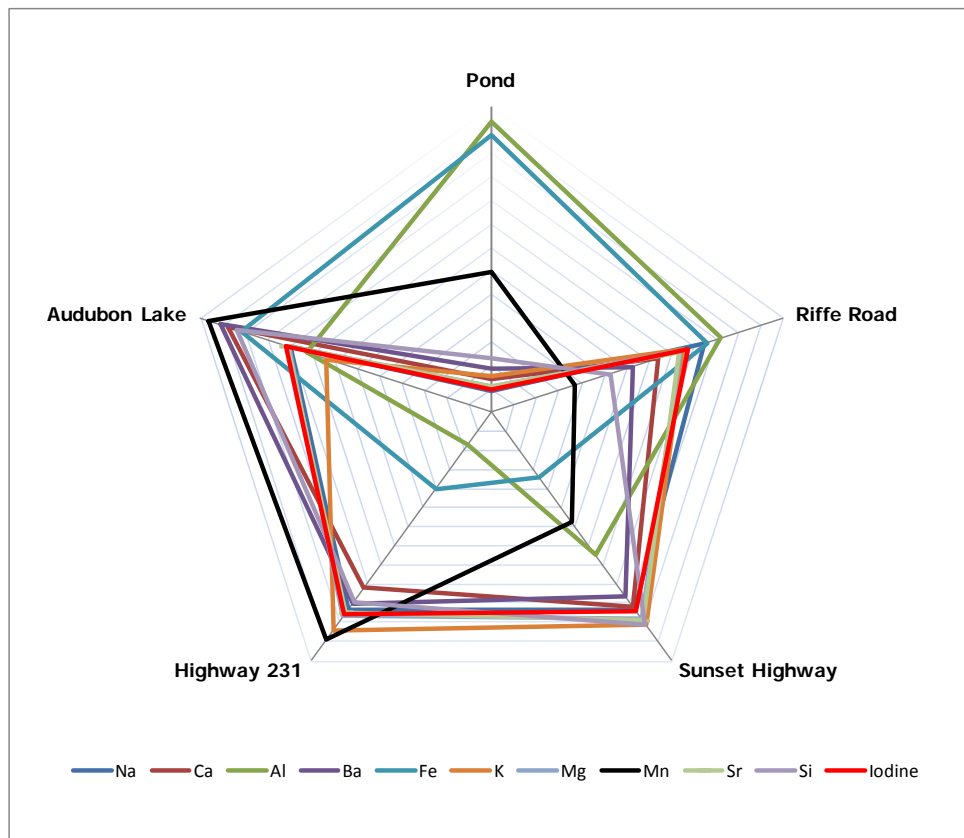


Figure 3. A radar diagram showing similarities and differences in trace element concentrations at five sites between Audubon Lake and upper Crab Creek (Highway 231), April 2009.

The Pond sample was curious. One theory put forward is that the pond concentrates some elements as seasonal inundation and evaporation occurs. (Sherwood, 2009). The Pond sample was so different as to even mask differences between normalized data at the other sites. Normalization without the Pond sample results were then conducted (Appendix C, Table C-2).

Cluster analyses of trace element results and nutrient results from the four primary sites suggest the only significant similarity (distance < 0.6) lies with trace element concentrations at Sunset Highway and Highway 231 (Figure 4a). Nutrient characteristics are quite distinct at all four sites (Figure 4b). This would be expected because of nutrient transformation processes common through wetlands and saturated soils.

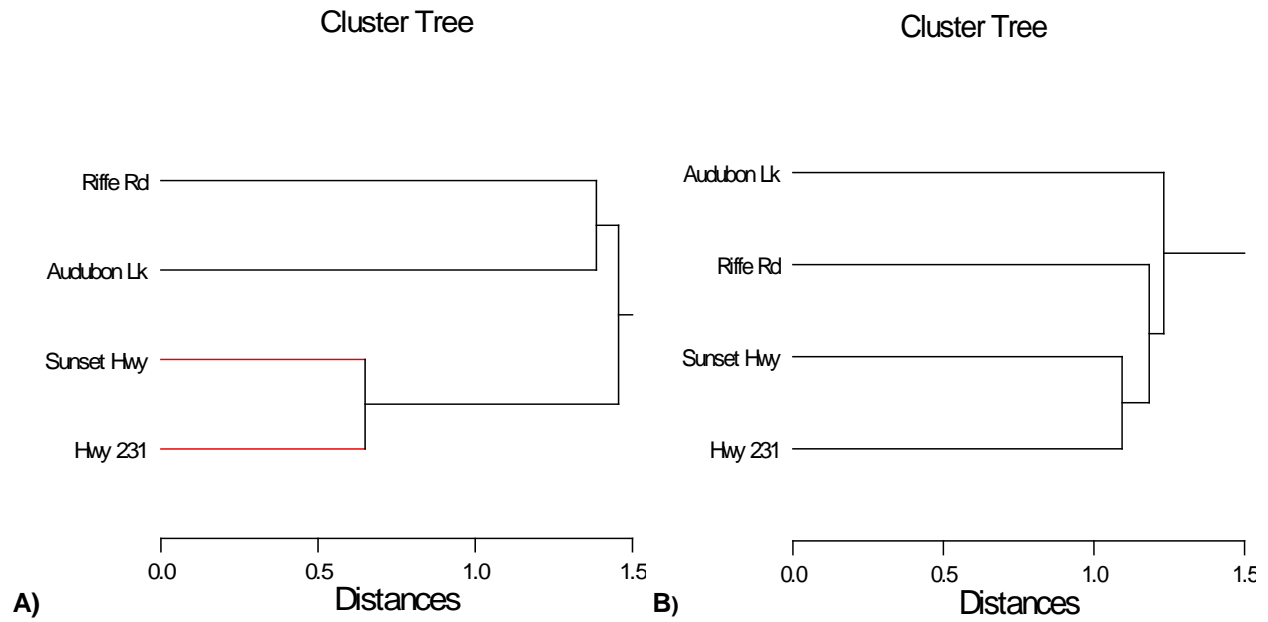


Figure 4. Cluster analysis of (A) normalized trace element results, and (B) normalized nutrient results collected at four primary sites between Audubon Lake and upper Crab Creek (Hwy 231), April 2009.

# Conclusions and Recommendations

## Conclusions

The reconnaissance survey conducted in April 2009 did not offer conclusive proof that surface water from Audubon Lake never makes it to branches of upper Crab Creek at Highway 231. However, the survey took place during a year of near-record snowfall with a high potential for a runoff event from the lake to occur. None of the physical and chemical data collected in April 2009 support a conclusion that the event occurred.

Therefore, the data suggest that if there is a surface connection between the lake and branches of Crab Creek, it is a rare event. So, it is not necessary to include the Reardan Wastewater Treatment Plant and nonpoint sources to Audubon Lake as an essential component of an upper Crab Creek TMDL evaluation.

## Recommendations

Based on the findings of this survey:

- Evaluation of Audubon Lake should not be considered an essential task to evaluate water quality in upper Crab Creek.
- A hydrogeologic evaluation may be necessary to eliminate questions about sub-surface transport of water from Audubon Lake to upper Crab Creek.
- Audubon Lake water quality should be evaluated to document and protect beneficial uses.
- Nonpoint sources of pollution west of Audubon Lake should be included in the upper Crab Creek TMDL study.

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# Appendices

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## Appendix A. Glossary, Acronyms, and Abbreviations

### Glossary

**Conductivity:** A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

**Dissolved oxygen (DO):** A measure of the amount of oxygen dissolved in water.

**Nonpoint source:** Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but 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.

**Nutrient:** A class of chemicals beneficial to biological growth and health.

**Parameter:** Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

**pH:** A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

**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.

**Stormwater:** The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

**Total Maximum Daily Load (TMDL):** Water cleanup plan. 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.

**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.

**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.

## Acronyms and Abbreviations

Following are acronyms and abbreviations used frequently in this report.

|         |   |
|---------|---|
| DO      | Dissolved oxygen                              |
| Ecology | Washington State Department of Ecology        |
| EIM     | Environmental Information Management database |
| EPA     | U.S. Environmental Protection Agency          |
| MEL     | Manchester Environmental Laboratory           |
| NPDES   | (See Glossary above)                          |
| QA      | Quality Assurance                             |
| RPD     | Relative percent difference                   |
| SOP     | Standard operating procedures                 |
| TMDL    | (See Glossary above)                          |
| WWTP    | Wastewater treatment plant                    |

### *Units of Measurement*

|          |  |
|----------|--|
| °C       | degrees centigrade                       |
| cfs      | cubic feet per second                    |
| ft       | feet                                     |
| m        | meter                                    |
| mg       | milligrams                               |
| mgd      | million gallons per day                  |
| mg/L     | milligrams per liter (parts per million) |
| mL       | milliliters                              |
| s.u.     | standard units                           |
| µg/g     | micrograms per gram (parts per million)  |
| µg/L     | micrograms per liter (parts per billion) |
| µm       | micrometer                               |
| umhos/cm | micromhos per centimeter                 |



## Appendix B. Field Photos



Figure B-1. Audubon Lake – western shore.



Figure B-2. Pot-hole ponds near Audubon Lake.



Figure B-3. Sampling at Audubon Lake site.



Figure B-4. Sampling at Riffe Road site.



Figure B-5. Sampling at Old Sunset Hwy site.



Figure B-6. Sampling at Highway 231 site.

## Appendix C. Normalized Data

Table C-1. Laboratory results normalized to the mean and standard deviation of all five site samples.

| Parameter                        | Sample Statistics |                    | Normalized Data to All Samples |       |            |                |             |
|----------------------------------|-------------------|--------------------|--------------------------------|-------|------------|----------------|-------------|
|                                  | Mean              | Standard Deviation | Audubon Lake                   | Pond  | Riffe Road | Sunset Highway | Highway 231 |
| Sodium                           | 179               | 250                | 0.25                           | -1.77 | 0.37       | 0.58           | 0.58        |
| Calcium                          | 55                | 14                 | 0.94                           | -1.64 | -0.14      | 0.55           | 0.30        |
| Aluminum                         | 0.08              | 0.05               | 0.05                           | 1.09  | 0.56       | -0.13          | -1.57       |
| Barium                           | 0.09              | 0.04               | 1.03                           | -1.53 | -0.42      | 0.42           | 0.50        |
| Iron                             | 0.14              | 0.11               | 0.80                           | 0.95  | 0.40       | -1.14          | -1.00       |
| Potassium                        | 16                | 14                 | -0.17                          | -1.62 | 0.15       | 0.78           | 0.85        |
| Magnesium                        | 40                | 31                 | 0.25                           | -1.73 | 0.10       | 0.70           | 0.67        |
| Manganese                        | 0.13              | 0.09               | 1.15                           | -0.50 | -1.07      | -0.56          | 0.98        |
| Strontium                        | 0.49              | 0.26               | 0.28                           | -1.73 | 0.09       | 0.73           | 0.63        |
| Silicon                          | 14                | 11                 | 0.84                           | -1.42 | -0.68      | 0.77           | 0.48        |
| Iodine                           | 85800             | 96453              | 0.30                           | -1.75 | 0.19       | 0.61           | 0.65        |
| TDS                              | 452               | 170                | -0.81                          |       | -0.92      | 0.86           | 0.87        |
| Alkalinity                       | 293               | 94                 | -0.51                          |       | -1.16      | 0.89           | 0.78        |
| Chloride                         | 45                | 26                 | -1.36                          |       | -0.13      | 0.80           | 0.69        |
| Fluoride                         | 0.36              | 0.07               | -0.25                          |       | -1.27      | 0.47           | 1.05        |
| NH <sub>3</sub> -N               | 0.02              | 0.02               | 0.21                           |       | 0.63       | 0.63           | -1.47       |
| NO <sub>2</sub> +NO <sub>3</sub> | 0.16              | 0.28               | 0.49                           |       | 0.52       | 0.50           | -1.50       |
| TPN                              | 1.3               | 0.4                | -1.16                          |       | 0.16       | 1.25           | -0.26       |
| Total P                          | 0.48              | 0.60               | -1.49                          |       | 0.56       | 0.38           | 0.55        |
| Soluble Reactive Phosphorus      | 0.37              | 0.48               | -1.49                          |       | 0.59       | 0.37           | 0.53        |
| Organic Phosphorus               | 0.11              | 0.12               | -1.49                          |       | 0.43       | 0.43           | 0.63        |
| Sulfate                          | 34                | 15                 | -0.58                          |       | -1.11      | 0.78           | 0.90        |
| Total Organic Carbon             | 25                | 21                 | -1.45                          |       | 0.12       | 0.68           | 0.65        |

Table C-2. Laboratory results normalized to the mean and standard deviation of the four primary site samples.

| Parameter | Sample Statistics |                    | Normalized Data to Four Primary Site Samples |            |                |             |
|-----------|-------------------|--------------------|--|------------|----------------|-------------|
|           | Mean              | Standard Deviation | Audubon Lake                                 | Riffe Road | Sunset Highway | Highway 231 |
| Sodium    | 68                | 41                 | -1.19  | -0.46      | 0.84           | 0.82        |
| Calcium   | 50                | 6                  | 1.16   | -1.22      | 0.31           | -0.25       |
| Aluminum  | 0.09              | 0.05               | 0.36   | 0.91       | 0.16           | -1.42       |
| Barium    | 0.08              | 0.02               | 1.07   | -1.34      | 0.06           | 0.20        |
| Iron      | 0.2               | 0.1                | 1.05   | 0.65       | -0.93          | -0.78       |
| Potassium | 10                | 7                  | -1.15  | -0.52      | 0.76           | 0.91        |
| Magnesium | 27                | 9                  | -0.60  | -1.10      | 0.89           | 0.80        |
| Manganese | 0.12              | 0.10               | 0.92   | -1.08      | -0.62          | 0.77        |
| Strontium | 0.38              | 0.08               | -0.52  | -1.14      | 1.01           | 0.65        |
| Silicon   | 10                | 8                  | 0.69   | -1.46      | 0.59           | 0.18        |
| Iodine    | 43500             | 21810              | -0.62  | -1.08      | 0.76           | 0.94        |