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GIS as a tool to help determine the effects of aquatic systems polluted with nutrients

CEE 6440 – GIS in Water Resources

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Term Project

Introduction

Oxygen is important because it controls aquatic chemistry and sets the redox phase of water systems. An aquatic system is said to be polluted with nutrients when there is a noticeable increase in oxygen concentration due to photosynthesis during the day and a drop in oxygen concentrations at night due to respiration. Photosynthesis from plants growing in and around waterways contribute to a significant amount of oxygen concentrations in aquatic system. Aquatic animals, plants, and bacteria consume a huge amount of oxygen and the consumption is noticeable at night in polluted systems that are primarily depended on photosynthesis. Other ways to add oxygen to water systems are by diffusion, chemical oxidation, and consumption. (McLean (a), 2015).

Phosphorus is an important nutrient that stimulates aquatic plant growth in surface waters. Of all the nutrients required for aquatic plant growth, phosphorus typically limits plant growth. An increase or addition of phosphorus to an aquatic system leads to an explosion of plant growth, a process called eutrophication. When the aquatic plants grow and die, they serve as organic matter (food source) for aerobic microorganisms. As microorganisms feed on the organic matter they consume dissolved oxygen needed for aquatic animal's survival. A reduction in the concentration of dissolved oxygen increases the death rate of aquatic life (e.g., fish kills) leading to the eventual contamination of waterways. This is the primary reason why the States and Federal agencies are trying to control the amount of phosphorus discharged into waterways (McFarland, 2015).

The purpose of this project is to use GIS as a tool to help facilitate analyses and integrate information from the Utah Water Research Laboratory, College of Engineering, Utah State University and other data obtained using CUAHSI HydroDesktop GIS based tools to visually show the effects of excess nutrition on an aquatic system. The obtained data and plotted time series of observations will be illustrated on maps, charts, and graphs Samples and data from the Logan River and Little Bear River will be compared to determine if the river system is clean or polluted. A clean water system is ideal for the health of fish (Tarboton, 2015).

Materials and Methods

Samples were collected from the Logan River and Little Bear River were analyzed and compared with data obtained from CUAHSI HydroDesktop GIS based tools. The samples were analyzed to determine the concentrations of dissolved oxygen in the system. Using procedures from the lab handout, three methods were used to determine dissolved oxygen concentrations namely: Iodometric (with azide modification), field kit, and membrane probes (McLean (b), 2015). CUAHSI HydroDesktop was used to access 24-hr continuous monitoring data of dissolved oxygen from the Logan River and Little Bear River. Data from the Utah Water Research Laboratory, College of Engineering, Utah State University was also used to obtain a time series of observation from water quality monitoring site in the both Rivers. The 24-hr continuous monitoring is necessary because oxygen diffuses slowly in and out of water systems. Some of these increase in DO levels occur just twice a day while others happen slowly all through the day. 24-hr continuous monitoring is essential in maintaining accurate data (McLean, 2015).

Results and Discussions

The illustrations of obtained data and plotted time series of observations on maps gave visual insights of the problem. The land cover around the area shows some reasonable sources of phosphorus. The data obtained will be used to determine if DO levels are affected by temperature (Tarboton, 2015).

The Logan River was the cleanest compared to the Little Bear River because it is less impacted by human activity. Little Bear River is impacted by animal grazing, input from livestock waste, feedlots, slaughter house, wastewater treatment plant, and agricultural inputs (McLean (a), 2015). CUAHSI HydroDesktop was used to obtain water quality monitoring data of dissolved oxygen from the Logan River and Little Bear River. Data from the Utah Water Research Laboratory, College of Engineering, Utah State University was also used to obtain a time series of observation from water quality monitoring sites in both Rivers. Laboratory data was not adequate for this project. The data obtained from the 24hr monitoring stations show a time series of observation that is ideal for this project.

Figure 1. Logan River watershed/land cover

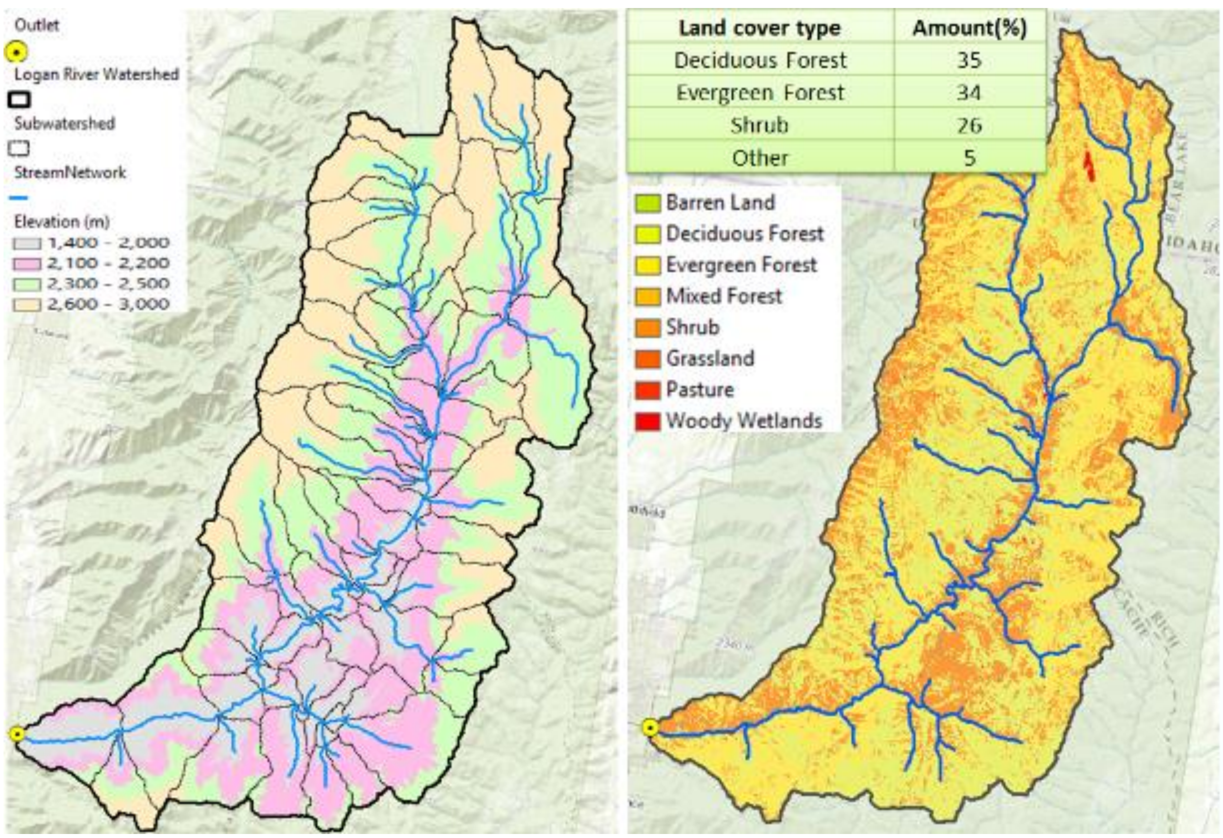
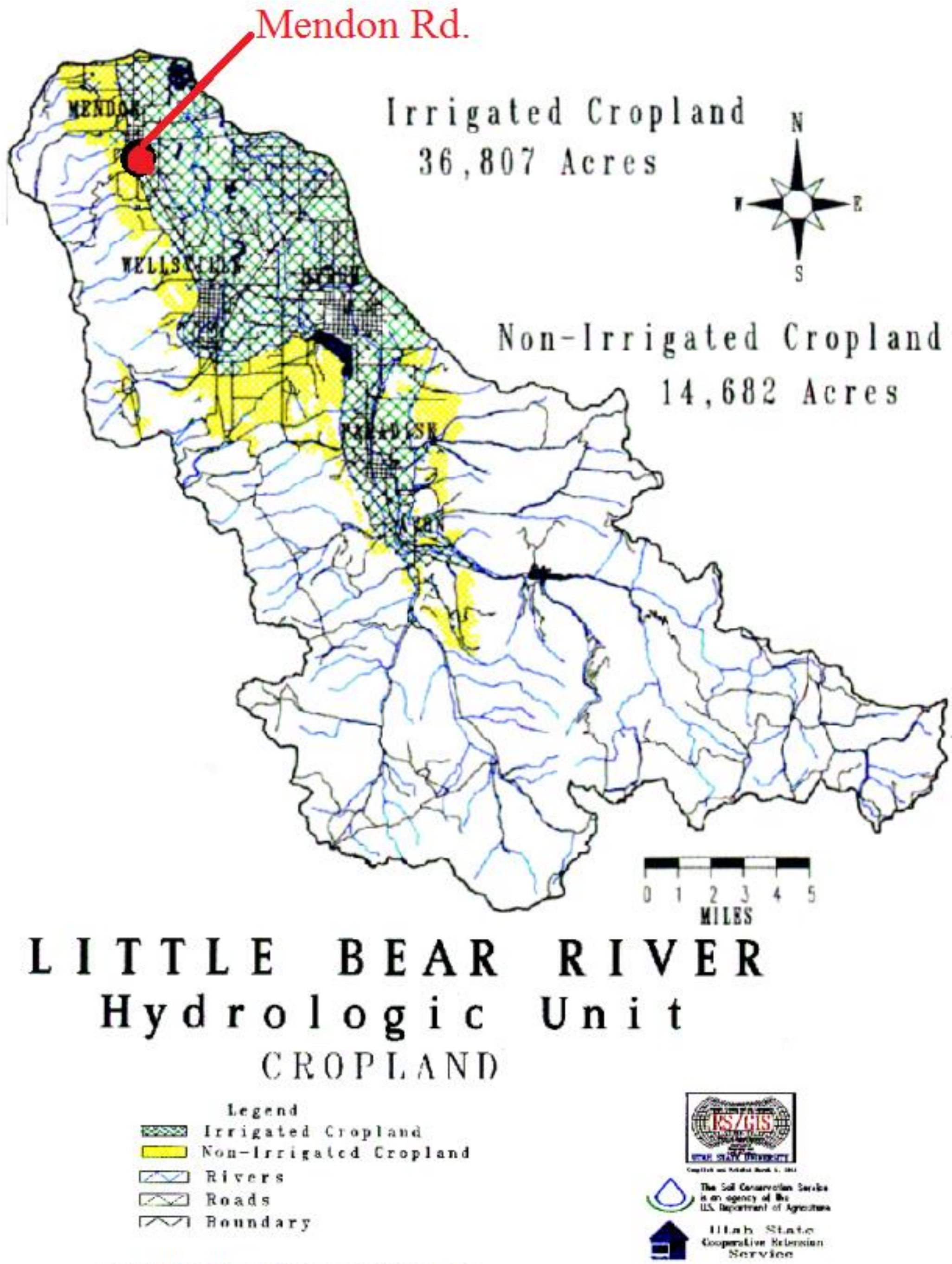


Figure 1. Shows that the land cover around the Logan River is surrounded by forests and shrubs. The Logan River is also a fast flowing river and it undergoes a lot of mixing. This is why the Logan River is clean compared to Little Bear River.

Figure 2. Shows the Little Bear River watershed surrounded by a lot of agriculture and human activity. The land around this watershed is impacted by agriculture, feedlot, animal grazing,

excess nutrient concentration from fertilizers and animal waste, nutrient loading, several industries and Hyrum Wastewater Treatment Plant located in the area. This is why the area is impacted with high levels phosphorus and low levels of DO at night (Utah DEQ).

Figure 2. Little Bear River Watershed/Cropland



Little Bear River Watershed / Cropland

http://www.deq.utah.gov/ProgramsServices/programs/water/watersheds/docs/2006/09Sep/Little_Bear_River_TMDL.pdf

Figure 3. Monitoring stations in the Logan River and Little Bear River

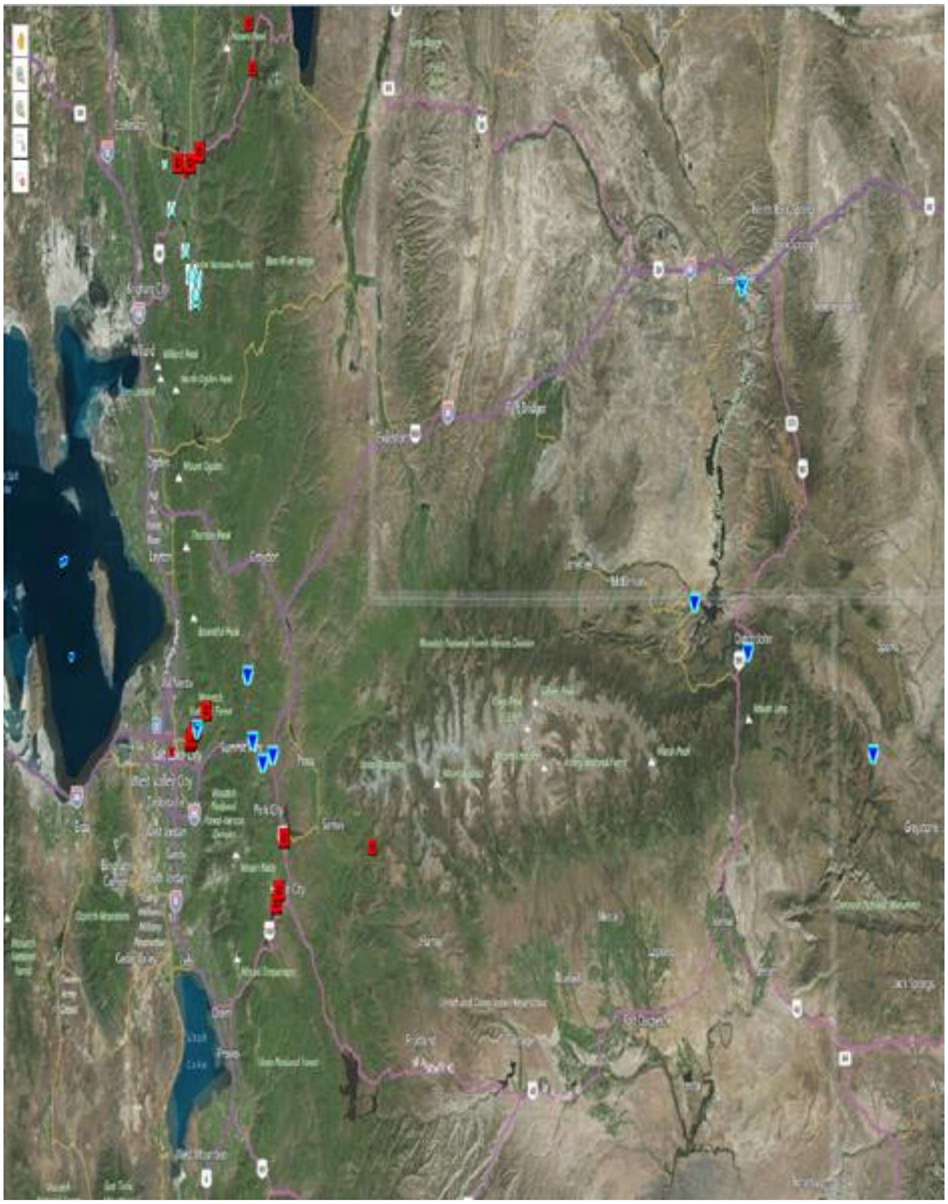


Figure 3. Shows some phosphorus and dissolved oxygen monitoring stations in the Logan River and Little Bear River. The blueish dots are dissolved oxygen monitoring stations while the red dots are phosphorus monitoring stations.

Figure 4. Graph of DO levels in the Logan River

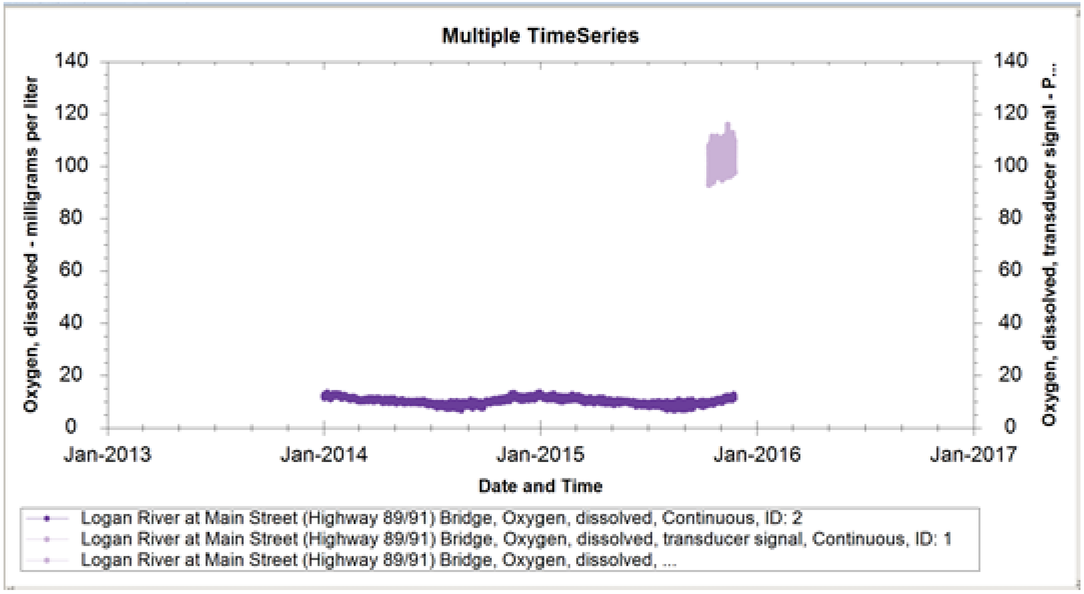


Figure 4. Shows uniform levels of DO in the Logan River. This a clean system because there is uniform amount of DO in the morning and at night it is not affected by photosynthesis or net respiration. There is a slight increase in DO levels in January, 2015 and this could be as a result of temperature change in the winter (Tarboton, 2015).

Figure 5. Graph of DO levels in the Little Bear River

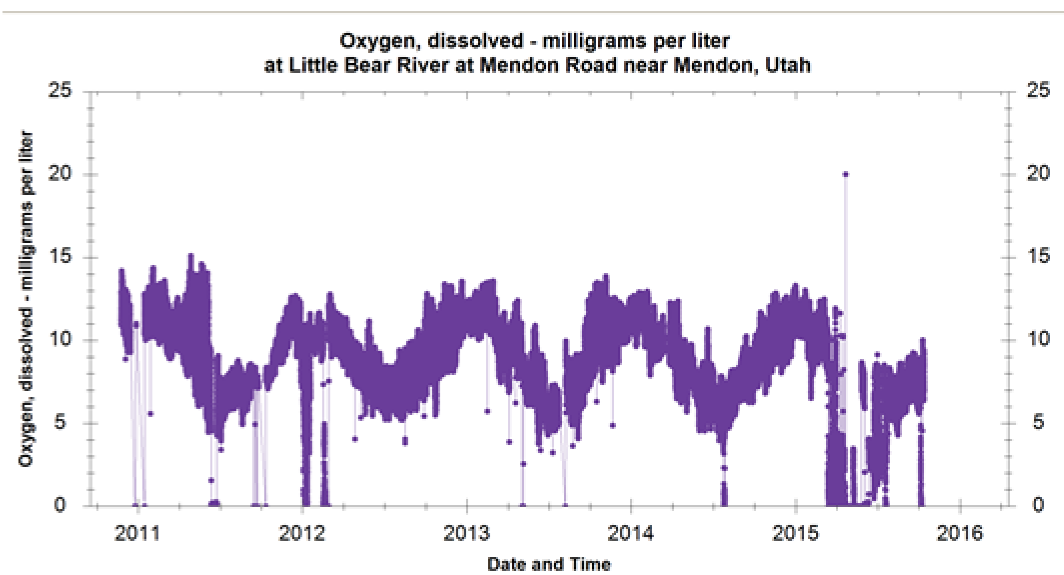


Figure 5. Is a polluted system because there is a noticeable increase and decrease in DO levels. The increase in oxygen concentration is due to photosynthesis during the day and the drop in oxygen concentrations at night is due to net respiration. Oxygen is produced through photosynthesis while aquatic animals, plants, and bacteria consume a huge amount of the produced oxygen at night via net respiration. Eutrophication causes a lot of plant growth and

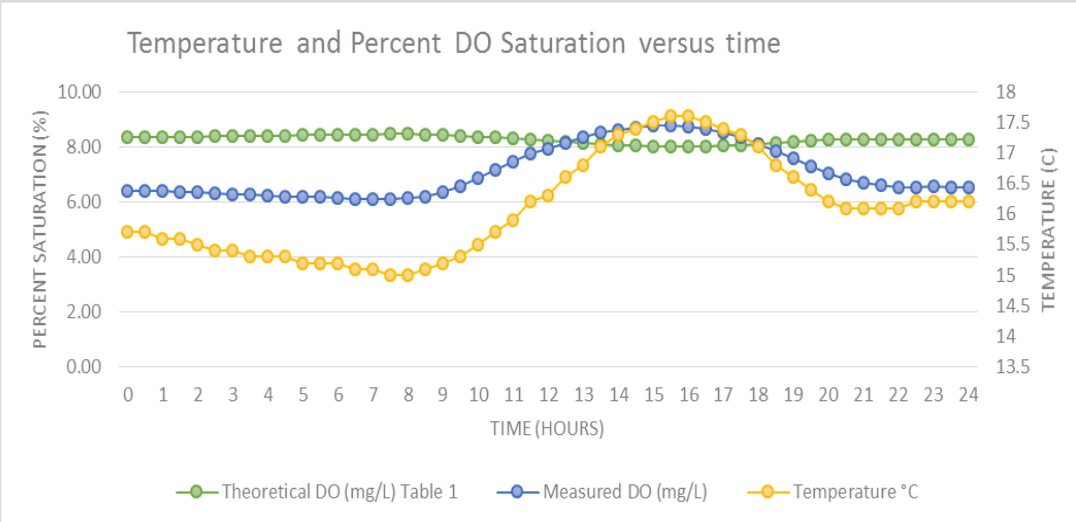
when the plants die they serve as a food source for aerobic microorganisms. As microorganisms feed on the organic matter they consume dissolved oxygen needed for aquatic animal's survival and this is why we see drops in the DO levels at night.

Table 1. Temperature and Percent DO Saturation of Little Bear River versus time

Temperature °C	Measured DO (mg/L)	Theoretical DO (mg/L) Table 1	Percent Saturation	Date and Time	Time Interval (hours)
15.7	6.39	8.34	76.68	2015-10-07, 12:00:00 AM	0
15.7	6.39	8.34	76.68	12:30:00 AM	0.5
15.6	6.38	8.35	76.32	1:00:00 AM	1
15.6	6.35	8.35	76.06	1:30:00 AM	1.5
15.5	6.34	8.37	75.70	2:00:00 AM	2
15.4	6.31	8.39	75.24	2:30:00 AM	2.5
15.4	6.29	8.39	74.95	3:00:00 AM	3
15.3	6.28	8.41	74.71	3:30:00 AM	3.5
15.3	6.24	8.41	74.25	4:00:00 AM	4
15.3	6.20	8.41	73.78	4:30:00 AM	4.5
15.2	6.19	8.42	73.48	5:00:00 AM	5
15.2	6.17	8.42	73.19	5:30:00 AM	5.5
15.2	6.12	8.42	72.69	6:00:00 AM	6
15.1	6.10	8.44	72.25	6:30:00 AM	6.5
15.1	6.08	8.44	72.01	7:00:00 AM	7
15	6.10	8.46	72.07	7:30:00 AM	7.5
15	6.13	8.46	72.45	8:00:00 AM	8
15.1	6.20	8.44	73.45	8:30:00 AM	8.5
15.2	6.34	8.42	75.21	9:00:00 AM	9
15.3	6.57	8.41	78.18	9:30:00 AM	9.5
15.5	6.88	8.37	82.23	10:00:00 AM	10
15.7	7.17	8.34	86.06	10:30:00 AM	10.5
15.9	7.47	8.30	89.98	11:00:00 AM	11
16.2	7.74	8.25	93.83	11:30:00 AM	11.5
16.3	7.94	8.23	96.50	12:00:00 PM	12
16.6	8.13	8.18	99.45	12:30:00 PM	12.5
16.8	8.35	8.14	102.54	1:00:00 PM	13
17.1	8.51	8.09	105.18	1:30:00 PM	13.5
17.3	8.60	8.06	106.78	2:00:00 PM	14
17.4	8.69	8.04	108.14	2:30:00 PM	14.5
17.5	8.76	8.02	109.18	3:00:00 PM	15
17.6	8.79	8.01	109.78	3:30:00 PM	15.5
17.6	8.72	8.01	108.91	4:00:00 PM	16
17.5	8.65	8.02	107.81	4:30:00 PM	16.5
17.4	8.52	8.04	105.94	5:00:00 PM	17
17.3	8.35	8.06	103.68	5:30:00 PM	17.5
17.1	8.12	8.09	100.34	6:00:00 PM	18
16.8	7.86	8.14	96.48	6:30:00 PM	18.5
16.6	7.59	8.18	92.85	7:00:00 PM	19
16.4	7.29	8.21	88.81	7:30:00 PM	19.5
16.2	7.01	8.25	85.04	8:00:00 PM	20
16.1	6.83	8.26	82.60	8:30:00 PM	20.5
16.1	6.70	8.26	81.01	9:00:00 PM	21
16.1	6.61	8.26	79.92	9:30:00 PM	21.5
16.1	6.54	8.26	79.11	10:00:00 PM	22
16.2	6.52	8.25	79.04	10:30:00 PM	22.5
16.2	6.55	8.25	79.44	11:00:00 PM	23
16.2	6.53	8.25	79.16	11:30:00 PM	23.5
16.2	6.51	8.25	78.88	2015-10-08, 12:00:00 AM	24

Table 1. Shows a series of data on temperature, DO concentrations, and time from October 10, 2015. The data was obtained from the USU water lab monitoring station located at the Little Bear River Mendon road. The drop in DO levels occur at night when there is a drop in temperature and little or no production of DO. These drops are due to net respiration that occur at night. An increase in temperature during the day facilitates photosynthesis that results in production of DO.

Figure 6. Graphical illustration of the Temperature and Percent DO Saturation versus time



To effectively describe the data from HydroDesktop, a single day's data (Table 1 and Figure 6) was obtained from the Utah Water Research Laboratory, College of Engineering, Utah State University and plotted in excel. There is a noticeable increase in the saturation of oxygen as temperature increases (Figure 6). There is also an up and down flow in the oxygen concentration during the day and a drop in oxygen levels at night. This up and down flow in DO levels is as a result of excess nutrient pollution in the river system. The theoretical values obtained from the water laboratory show an ideal system where oxygen levels are not impacted by photosynthesis of change in temperature. The spreadsheet with calculations can be attached or posted on hydroshare upon request. An ideal water system produces oxygen not primarily by photosynthesis but also diffusion, chemical oxidation, and consumption (McLean, 2015).

Summary and Conclusion

An aquatic system is said to be polluted with nutrients when there is a noticeable spike in oxygen concentration via net photosynthesis during the day and a drop in oxygen levels via net respiration at night. An ideal system should be driven by physical processes and not dependent on photosynthesis. The land cover around the rivers was helpful in determining sources of phosphorus. GIS based tools helped facilitate analyses and integrate information by showing a visual representation of the area. Logan River is clean compared to the Little Bear River. Little Bear River is impacted by animal grazing, input from livestock waste, feedlots, slaughter house, wastewater treatment plant, and agricultural inputs. In comparison to historic data, the phosphate problem have been controlled by the implementation of various management practices namely: improving river banks to minimize erosion, State and Federal limits on nutrient discharge from wastewater treatment facilities, reduction of cattle grazing in and out of the river, removal of feedlot on river, reduction in intensive grazing, approved manure management, added Incentives, and education (McLean, 2015).

Reference

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Horsburgh, J. Lecture Set CUAHSI Hydrologic Information System. GIS in Water Resources CEE6440.

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"Logan River, Utah." Map. Google Maps. Google, 29 November 2015. Web. 29 November 2015.

Appendix

Spreadsheet with calculations can be attached or posted on hydroshare upon request.