

**Overview of the Water Quality of Selected Irrigation
Diversions and Return Flows to Mission Creek, Post Creek,
and Spring Creek**

Bios35503 Practicum in Field Biology 2

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Abstract

Water quality studies give insight into the characteristics and the health of natural streams. Monitoring a system for the physical and chemical properties of the water is just one way of collecting water quality data but provides insight into potential sources of degradation. The scope of this project was to monitor the water quality of three creeks in the Lake County territory of Montana over the course of a single summer. The three creeks in Lake County that were chosen for study include, Mission Creek, Post Creek and Spring Creek (Spring Creek is a tributary to South Crow Creek). Water is diverted from each of these creeks into ditches that supply water for irrigation uses and also serve to return agricultural drainage. Aspects that were monitored included flow and temperature, standard mineral analysis, including dissolved oxygen (DO), water temperature, electrical conductivity (EC), salinity, percent H⁺ ions (pH), and total suspended solids (TSS). Samples were collected to test for concentrations of selected nutrients, including ammonia, nitrate, phosphorus, and phosphate. Results indicated that the three irrigation return ditches contained significantly higher amounts of TSS, phosphorus, and phosphate than feeder or stream locations.

Introduction

Water survey studies have always been an important part of watershed management. There are many reasons for knowing what types of nutrients and chemicals are flowing in the water; reasons such as knowing what is available for agricultural use and for knowing what types of chemicals are in the daily drinking water. Farmers who are looking to keep their crops and animals healthy need to know the nutrients and chemicals found within the water (Department of Water Resources, 1992). For those who have underground wells, it may be worth knowing what the quality of their ground water is like if they are using it for human consumption. Because of these needs, the U.S. Environmental Protection Agency (EPA) has established a set of water quality standards that streams, irrigation canals, lakes and reservoirs must meet depending on their intended usage. As the California Department of Water Resources (DWR) states, the quality of the water determines the eventual usage of the water (1992). By the same token, for specific uses, different aspects of water quality can be tested to see if the water is usable for that designation. The EPA water quality standards allow scientists to know if the water they are testing meets such standards. Similarly, the California State Water Resources Control Board sets water quality standards for various parameters (salinity, EC, selenium, boron, DO, etc) that are based on the acceptable limits for those parameters (Kapahi 2006).

Environmental ecologists also need to know the physical and chemical conditions of a stream so that they can understand what may be structuring the plant and animal communities (Hem 2005). For example, an ecologist should note whether the water in the

location he is working in is high in nitrogen or phosphorus because these two chemicals alone can dramatically affect the communities of plants that are using the water from the streams for sustenance.

Physical properties of stream systems such as conductivity, dissolved oxygen (DO), salinity, water temperature and velocity, percent H⁺ ions (pH), and total suspended solids (TSS) may also strongly influence biota and overall stream health. For this reason, the physical properties of a stream system are commonly monitored to provide a basis for water quality analysis. All of the physical aspects in one way or another define the watershed and can, with long-term studies, give an estimate of the health of the watershed (Wagner 2006). If DO is too low, then fish and other aquatic creatures living in the stream that require oxygen to survive will not have enough oxygen to effectively breath. Based on the California State Water Resources Control Board (SWRCB) a level of six milligrams per liter of dissolved oxygen in the water is considered to be dangerously low for organisms to survive on (Kapahi 2006). Similarly, if salinity, temperature and pH are too high or too low, then the aquatic community in the stream or river may be forced out or replaced by other competitors and the community will transition over to a different set of species in the community.

Finally water velocity and total suspended solids also have an effect on the survival of certain organisms within the community. These two aspects of the watershed vary from location to location even within the body of the main stream. Certain fish and other organisms have adapted to live in certain water velocities. The majority of, if not all, river fish are sleek of body and have strong tail fins to be able to swim against strong currents (Breitburg, 1988). However, the velocity of a stream can be suddenly changed

by canalization or the formation of irrigation ditches that take water out and/or return water to the main stem. This change might then allow invasive species to potentially relocate within the river watershed and displace or at the least compete with the native biota.

The return flows from irrigation drainage ditches can also lead to a change in TSS. With more irrigation ditches being used as conduits to return agricultural drainage to points along the main stream, the concentration of TSS in a river can greatly increase if the ditches contain a lot of agricultural soil from the runoff. This can lead to the death of some river fish because the more suspended solids in a river the higher the turbidity will be (Breitburg 1988). The turbidity of a river influences the effectiveness of fish as visual predators within streams or rivers. For example, the Benedict Estuarine Research Lab led by Dr. Breitburg showed that with increased TSS, striped bass larvae consumed approximately forty percent fewer copepods than when TSS was left alone (Breitburg 1988).

In June of 2006, Herrera Environmental Consultants, Inc. presented a list of available options for reducing the impacts of irrigation ditches on Mission Creek, after they had been asked to look into the effects of irrigation return flows into Mission Creek. One of the aspects that was looked at by HEC Inc. was TSS and, based on their results, it appears that downstream of the confluence where the irrigation return flow ditch meets with Mission creek, TSS had increased in comparison to upstream of the confluence.

To further research the impacts of irrigation ditches on creeks at specific confluence areas I surveyed three creeks within the Lake county region, including Mission Creek, Post Creek, and Spring Creek, which is a tributary for South Crow Creek.

For each system, I surveyed the natural stream above and below the return flow point of the irrigation ditch. In addition I sampled a point in the irrigation ditch just prior to its confluence and an upstream site in the irrigation ditch as the canal initially receives its water. I collected water samples to test for the nutrients nitrogen, in the forms of nitrate and ammonia, and phosphorus in the forms of free floating phosphorus and phosphate, in the water, and recorded data on the physical aspects of the creeks such as flow, TSS, conductivity, DO, salinity, temperature, and pH . My expectation is that the irrigation ditch return flow will increase nutrient concentrations on the chemical and physical aspects of the three systems that they flow into.

Methods

Water samples were collected for nutrient analysis and physical parameters were measured at four locations, from three stream/irrigation drainages. This included sampling nutrients and physical parameters of the stream into which each irrigation ditch drained as well as the feeder locations for the irrigation ditches. Sampling took place fifty meters both upstream and down stream of the confluence and approximately twenty meters into the irrigation ditch just prior to its confluence. Additionally to capture how nutrients change from the beginning of an irrigation feed to the end of the ditch, where H₂O has come in and out of the irrigation canals, I sampled feeder canals close to the point of divergence from a natural stream or from the reservoir that it is flowing from. Sites were selected based on access granted by either CSKT tribal land or private landowners. My sites included irrigation drainages that fed into Mission Creek, Post Creek, and Spring Creek, which is a tributary of South Crow Creek. To test if usage of

the irrigation ditches by the farmers and cattle grazers in the area changes over the course of the summer, the nutrients and physical parameters that were collected twice with a two week waiting interval between sample collection times. Sample times ranged from July 2nd to July 8th for the first week of collection and then once more from July 23rd through July 29th.

In each creek, both up- and downstream, irrigation return ditch and irrigation feeder ditches were sampled for water velocity and flow, total suspended solids, dissolved oxygen, salinity, conductivity, pH, water temperature as well as tested for concentrations of NO₃, NH₃, P and PO₄³⁻. Velocity of the water was measured using a meter tape, a stopwatch and a couple of oranges. Water velocity was measured just below the surface of the water because oranges have a partial negative buoyancy, meaning that the oranges center of gravity is just below the surface of the water yet is still buoyant enough to float at a constant level with out sinking. By measuring out a set distance with the meter tape [fifteen meters when possible, but at some locals ten meters was required for use because of bends in the creek, and on one local a distance of one meter was required due to heavy macrophyte growth in the irrigation canal], and timing how long it takes the orange to float the given distance, I can use the formula

$$v = d / t$$

to determine the velocity of the water where 'v' is the water's velocity, 'd' is the distance the orange traveled, and 't' is the time in seconds that it took the orange to travel the given distance.

Total suspended solids, or TSS were measured by collecting 200mL of sample water in medium sized nalgene containers. The nalgene containers were first dried in a

heating oven to eliminate any moisture that might have been collected at the bottom of the container and then weighed. After the 200mL of sample water was collected into the containers, the water was allowed to sit for a few days to let all the suspended particles settle in the bottom. The water was then gently poured off the top until the particles started to stir. Then the rest of the water and container was placed into the heating oven once more and the water was allowed to evaporate off leaving the suspended solids at the bottom of the nalgene container. The container was then reweighed with the left over solids after the container had had a chance to cool off. The original weight of the container without the suspended solids was subtracted from the new weight to determine the mass of the suspended solids.

DO, salinity, conductivity, and water temperature were measured using a YSI model 85 meter with multiprobe. Before the aspects can be recorded however, the elevation, as read from a GPS or map, of the location is needed to calibrate the probe for variations that can arise from different elevations. The probe of the meter was placed approximately ten centimeters under the surface of the water and measurements were taken at three areas within each location. After the aspects had been measured and recorded, a pH meter was placed just below the surface of the water to measure the percent of H^+ ions.

To measure the concentration levels of the chemicals in the water I used a DR/890 Colorimeter from HACH®. Specifically, to test for nitrates, and nitrogen in the form of nitrate, I used the cadmium reduction method using powder pillows from the HACH® manual. This method tested for mid range concentrations between 0 to 5.0 mg/L NO_3 in water, wastewater and seawater. Nitrate is reduced to nitrite while in contact with

cadmium in a reduction tube and the nitrite is measured calorimetrically (Taylor, 2006). Based on initial trials that demonstrated high variation in nitrate measurements, this test was performed three times at each site. This variation comes from how vigorous one shakes the vials, if all the powder is emptied into the sample, and other possible errors. For this procedure, 10mL of water were placed into four sample cells, one for the control, and three for the redundancy. A NitraVer 5 Nitrate Reagent Powder Pillow was opened at one corner and the contents poured into one sample cell of 10mL of sample water. The cell was then shaken for one minute and then allowed to sit for five minutes while the reaction takes place. During the five minutes, the control cell was placed into the DR/890 Colorimeter and the meter was zeroed. After the five minutes of reaction time was up, the cell was wiped with a glass cleaner to remove fingerprints from the shaking and then placed in the meter to be read. This is repeated twice more with the other two sample cells.

To test for nitrogen in the form of ammonia, I used the Salicylate method from the HACH® manual. This method tests the low range of ammonia levels from 0 to 2.50 mg/L NH_3 in water, wastewater, and seawater using Test 'N Tubes, which contain AmVer Diluent Reagents. The Salicylate method was very stable based on initial replicates and thus only one measurement was needed unlike the nitrate midrange test. Two Test 'N Tubes were needed for this test, one as a control and one for the sample. In the control tube, 2mL of distilled water was mixed with the AmVer Diluent reagent, while in the sample tube, 2mL of sample water was mixed in. After the water, distilled and sample, was mixed with repeated pipetting, the contents of one Ammonia Salicylate reagent powder pillow and one Ammonia Cyanurate reagent powder pillow were poured

into each sample tubes. These tubes were then shaken until the contents were thoroughly mixed and then left to sit for twenty minutes while the reaction took place. After twenty minutes, the control tube was wiped down with a glass cleaning rag and then placed into the DR/890 Colorimeter to provide a zero. After the meter was zeroed, the sample tube was cleaned and placed into the meter to be read.

To test for phosphorus, the Orthophosphate, or sometimes called the Ascorbic acid, method from the HACH® manual was used. This method tests for a range of 0 to 2.50 mg/L PO_4^{3-} and P. As with the ammonia test, this test, based on initial trials, was very stable and thus only needs to be done once per site to get an accurate reading. Two sample cells were filled with 10mL sample water, and the control was placed off to the side until needed for zeroing. The contents of one PhosVer 3 Phosphate powder pillow was emptied into the 10mL of sample water and was then shaken for fifteen seconds to mix the contents. The sample was then allowed to sit for two minutes to allow for reaction time, during which the control was placed into the DR/890 Colorimeter for a zero. After the sample had been allowed to sit for two minutes, the vial was wiped down and cleaned to remove fingerprints, and placed in the meter to be read.

The data were analyzed using SYSTAT Version 9, 1998. The three different stream systems, for data analysis reasons, were considered replicates during the statistical testing. The four different site types and the two different sample times were tested for significance in comparison using a two-way ANOVA to test the different aspects measured in direct comparisons to site type and sample times, as well as test for an interaction between the two parameters. When SYSTAT showed that sample times were not significantly different in either a direct comparison or in an interaction with site type,

the two times were then averaged and then ran in a one-way ANOVA to test the significance of site type.

Results

In the creek, both up- and downstream, and in the irrigation feeder, average flow varied from 3.07 m³/s to 3.25 m³/s. However in the irrigation return ditch, the average flow was lower at 0.06 m³/s (Fig. 1). Total suspended solids were one of the few physical aspects tested for that was significantly different when comparing site types. Irrigation ditches and downstream portions of the creek from the convergence are significantly different from one another and from the other two site types ($p = 0.012$, $df = 3$, $F = 4.691$) (Fig. 2). TSS was most highly concentrated in the irrigation ditch, while the next highest concentration of TSS was in the downstream locale. Upstream of the creek and the irrigation feeders were not very different from one another. Besides site type TSS concentrations varied with flow. The regression when comparing flow to TSS showed a significant negative relationship ($y = -0.155x + 1.806$, $df = 1$, $R^2 = 0.330$) (Fig. 3).

Flow also affected concentration levels of phosphate (PO_4^{3-}) in the different sites with marginal significance ($P = 0.055$, $df = 3$, $F = 4.104$). As with TSS, the coefficient for the linear regression between PO_4^{3-} was negative ($y = -0.085.x + 0.65$, $df = 1$, $R^2 = 0.157$) (Fig. 4).

I sampled dissolved oxygen at each of the sites using the YSI meter. The concentration levels of DO were about the same in the creek, both up- and downstream of the confluence. However, the irrigation feeder was slightly lower than the creek, while

the irrigation return ditch was much lower than the other three. Measurements were taken in milligrams per liter.

Temperature is slightly lower in both stream sites than the irrigation canals (Figure 6). Water temperature was recorded in degrees Celsius. Conductivity was measured in microseamens using the YSI meter at each of the sites. As with all of the measurements taken with the YSI meter, conductivity was only measured once at each site, so no statistics could be run against it. Based on the graph, conductivity stayed relatively similar between the creek and the irrigation ditch (Figure 7). However, in the irrigation feeder location, the average conductivity was dramatically less than in the other three. It should also be noted that while salinity was tested only once, it is certain that there is significantly no difference between the sites. Salinity stayed at a constant 0.1ppt for all of the sites (Figure 8). While the creek and the irrigation feeder are relatively buffered, the irrigation return flow is almost a full fold difference in pH level (Figure 9).

The chemical compound ammonia (NH_4) was found to not vary significantly across the sites ($P = 0.216$, $df = 3$, $F = 1.623$) (Fig. 10). Phosphate, when did vary significantly between site types ($p = 0.029$, $df = 3$, $F = 3.708$) (Fig. 11). Free-floating phosphorus was significantly higher in the irrigation return ditch ($p = 0.041$, $df = 3$, F -ratio = 3.307 (Fig. 12). Nitrate had a p value of 0.055 ($df = 3$, $F = 3.134$). Nitrate was also significantly affected by an interaction between sample time and site types ($p = 0.014$, $df = 3$, $F = 4.858$) (Fig. 13).

Discussion

As expected, total suspended solids, phosphorus, and phosphate were higher in the irrigation ditch than in any other site type. This was expected due to agricultural runoff bringing in sediments from tilled and crop ground, as well as washing in phosphorus and phosphate in from animal waste, or from synthetic fertilizer. As Wallace and Batchelor (1997) suggest, during a storm or irrigation overflow, soil can be washed off of the land and into the irrigation ditches causing an increase in suspended solids in the water. They also mention that synthetic fertilizers used in today's crop production contain high levels of phosphorus and phosphates.

What was not expected were the low levels of ammonia and nitrate found in irrigation ditches. Similar to phosphorus and phosphate, concentration levels of ammonia and nitrate should increase during a storm or irrigation overflow, and yet I found the exact opposite in the irrigation ditches that were sampled. The natural waste of cows on a farm contain high levels of nitrate and ammonia and when the storm or overflow comes through, that waste is going to be shifted and moved into the irrigation canals (Kleinman, 2005). I was unable to make a reasonable argument for why this trend appeared in the irrigation ditches. Some suggestions made were that overall, nitrogen is limited in terrestrial systems, even in systems with agricultural usage or that possibly before the location of sampling where the nutrients flow into the irrigation ditch contained terrestrial plants that might have been taking up all of the nitrogen before it reached the irrigation ditch.

A piece of interesting data is the relationship between flow and TSS as well as the relationship between flow and PO₄. Normally, as flow increases, the ability for the water

to hold more suspended solids also increases. However, the flow data collected shows that the slower irrigation ditches actually contains the highest amounts of suspended solids. The same goes for the relation between flow and PO₄, the concentration of PO₄ is also higher in the slow irrigation ditches rather than the high flow sites of the creeks and irrigation feeders.

Based on the data, it is evident that the irrigation ditches have serious water quality problems. The absence of higher concentrations of ammonia and nitrate is strange to see, even if it is a good result in terms of environmental impact, when considering that while high levels of nitrogen can be bad for a system, low levels of the nutrient can also cause problems for the biological health of the stream when it comes time to sample the macroinvertebrates and macrophyte population.

A continued survey of the creeks and their irrigation return flow ditches should be put into place to monitor the quality of the water and to test for other aspects beyond those of this project. Also, more than just one convergence point along the creeks should also be inspected to get a better understanding of the entire creek system as well as comparing the headwaters of the creeks to the downstream portions for comparison.

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Figures

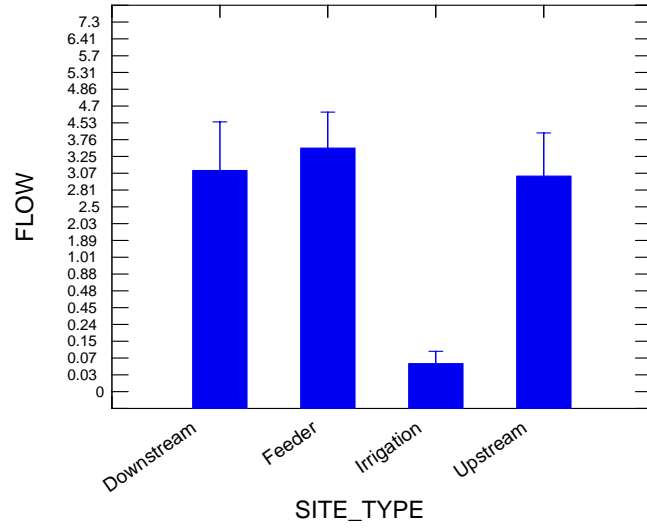


Figure 1 Site type in relation to Average Flow

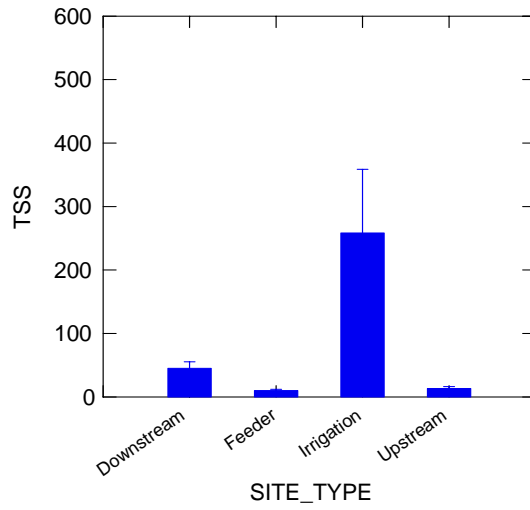


Figure 2 Site type in relation to Average TSS

Plot of Residuals against Predicted Values

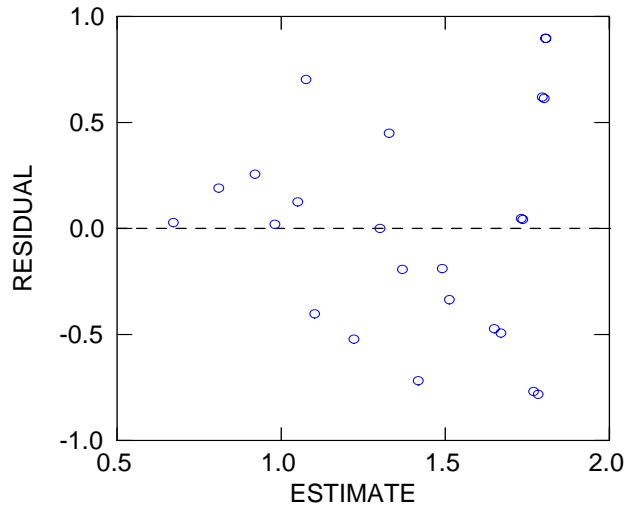


Figure 3 Regression between Flow and TSS

Plot of Residuals against Predicted Values

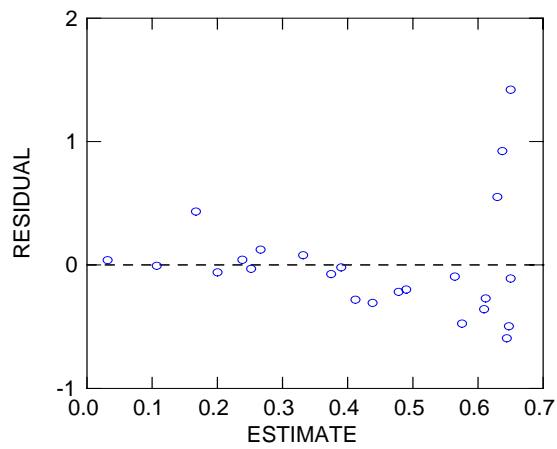


Figure 4 Regression between Flow and PO4

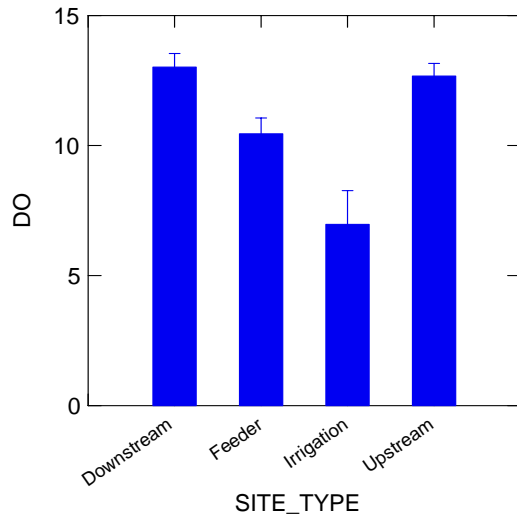


Figure 5 Site type in relation to Dissolved Oxygen

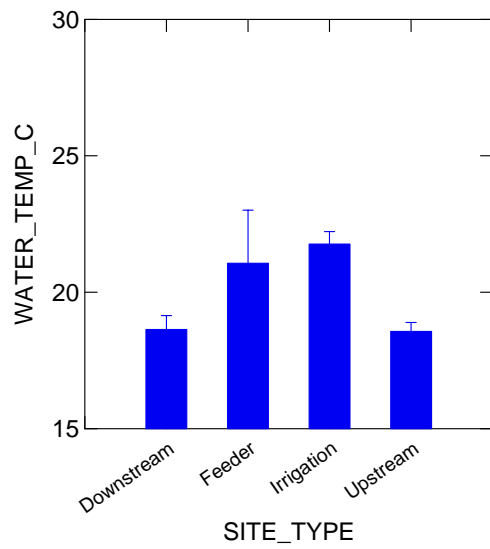


Figure 6 Site type in relation to Water Temperature

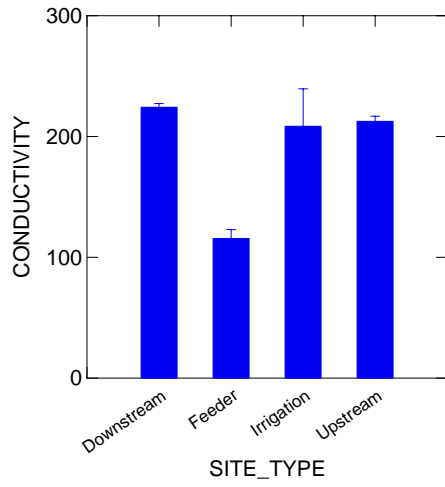


Figure 7 Site type in relation to Conductivity

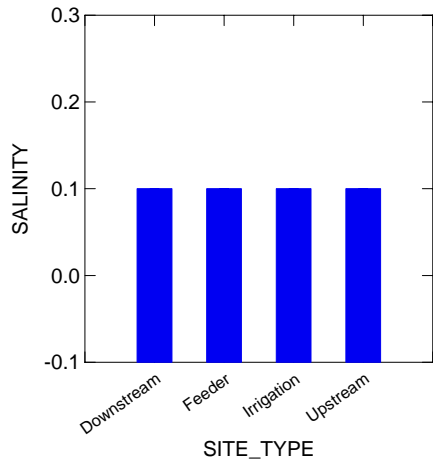


Figure 8 Site type in relation to salinity

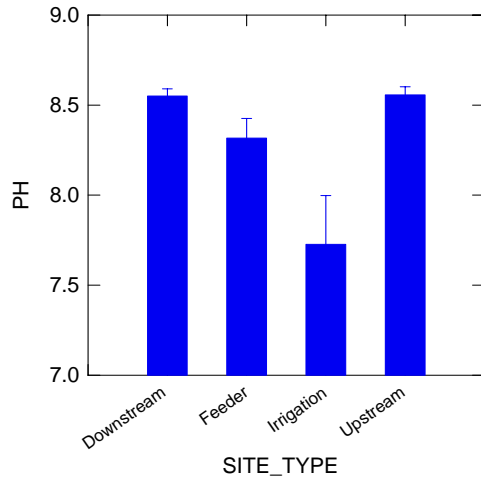


Figure 9 Site type in relation to pH.

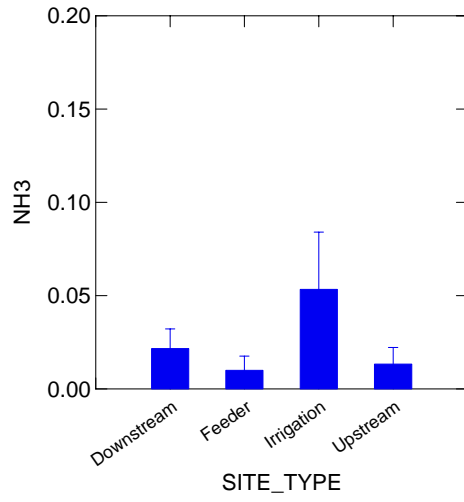


Figure 10 Site type in relation to Ammonia

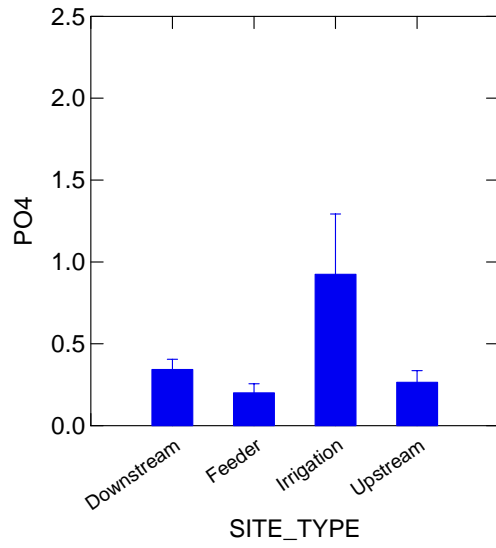


Figure 11 Site type in relation to phosphate

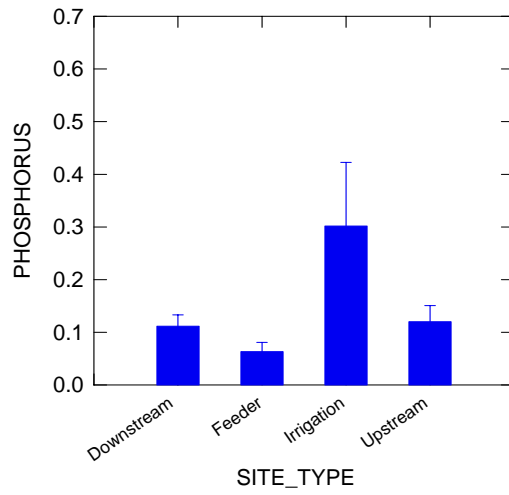


Figure 12 Site type in relation to Phosphorus

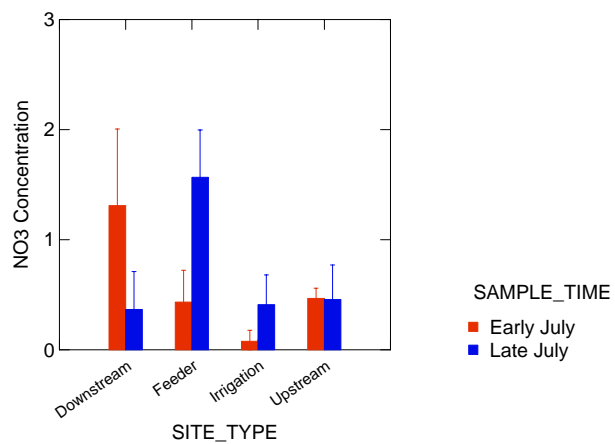


Figure 13 Site type in relation to NO3