THE EFFECT OF ROAD CROSSINGS ON NORTHERN MICHIGAN STREAM MORPHOLOGY

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Abstract

The purpose of this study is to see if culverts at road crossings significantly alter stream characteristics and functionality, and to determine whether or not future building alternatives should be sought. I measured the flow, temperature, and dissolved oxygen of the water at three, 5-meter intervals before and after passing through the culvert and measurements inside the culvert as well to see if these impacts were distinguishable. This study suggests that culverts were indeed impacting these stream characteristics and some of those impacts were dependent on the characteristics of the culvert design. With these findings, my study suggests that this form of infrastructure alters these basic stream characteristics and should be investigated further to determine whether these alterations contribute to changes in sedimentation, habitat distribution, and overall function of the stream system as a whole.

Introduction

As human development advances, so do its impacts on the environment (citation needed). Beyond global climate change, the automobile has necessitated vast transportation infrastructure projects across the U.S. to accommodate access to all areas (citation needed: Truman highway project). However, the impacts of such infrastructure projects were not analyzed until much later (cite needed).

One such example is steel culverts used to allow streams and rivers to flow under the roads. These culverts come in many forms with different structural materials, however most are cylindrical in shape made from corrugated steel. Additionally, this type of culvert contains ridges along the inside, creating small crevices across the span of the culvert. The purpose of these culverts is to allow water to flow freely under the road, accounting for both minimum and maximum flow periods throughout the year to avoid flooding and road washout. This is achieved by proper culvert construction and design to ensure proper culvert diameter, quantity, and height placement, and other specifications to achieve maximum efficiency (Piehl, Pyles, and Beschta 2007).

Despite the intent of ensuring flow capacity, studies have found that this was not always the case and that improper culvert design can create problems to humans. In a study by Piehl, Pyles, and Beschta, culverts in western Oregon were analyzed based on their capacity to handle 25-year peak flow. They found that over 40% of the culverts studied were far below this standard. Substandard culvert design can potentially create costs for governments both in the form of increased infrastructure costs due to flooding, road washouts, and road erosion (2007).

Additionally, improper culvert design can affect the natural stream fauna of all shapes and sizes. Gibson, Haedrich, Wernerheim studied the affect that these improperly designed culverts in Labrador, Newfoundland, CA had on fish habitat. They found that 53% of the culverts studied posed problems for salmon passage (2011). Moreover, a study by Warren and Pardew found that compared to other types of infrastructure, culverts posed as the biggest barriers to passage of many small fish species. Also, Blakely, Harding and McIntosh found that culverts dramatically affect aquatic insect populations. The study showed that given the presence of a culvert, the longitudinal population distribution was altered so that fewer larvae were found upstream than downstream (2006).

Most studies performed on culverts focused on passage and distribution of species. However, these culverts may impact basic stream water chemistry and physical characteristics that may affect stream systems on a much broader level. Measuring temperature, dissolved oxygen, and flow rate will determine if stream water is altered within the immediate area of the site and therefore affect the overall functionality of streams, creating a much broader impact to the environment.

Materials and Methods

This study was conducted at various sites in northern Michigan's Lower Peninsula where metal culverts were used at road crossings. Six sites were chosen based on three factors. First, to understand its natural characteristics, the culvert needed to be unobstructed, or at least minimally, by debris and rocks. Second, the stream needed to meet minimum flow levels to better distinguish flow change. Therefore streams of orders 2 and higher were targeted. Third, accessibility to all nine points of measurement was required, which meant that there was a maximum flow and maximum depth based on my ability to safely take measurements at each point. Measurement points were at 15m, 10m, 5m, and 0m upstream of the culvert, the culvert midpoint, and 0m, 5m, 10m, and 15m downstream of the culvert. These measurement points were determined by using a forest field tape measure extending from the edge of the culvert to the separate points and marked off using caution flags.

At these nine points, measurements of water flow (m/s) were taken using a Marsh McBiney Flowmate, model 2000 flowmeter. The instrument was attached to a metal pole that allowed me to adjust the height of the meter to measure the flow consistently at 60% of stream depth. Additionally, the Quanta Hydrolab was used at each measurement point, submerged just below the surface of the water, to measure temperature (°C), specific conductivity (microSiemens per centimeter), dissolved oxygen (mg/L), and pH (units).

To measure the characteristics of the culvert itself, I used a 3m long, extendable metal rod, marked at every half meter to measure the culvert diameter, Additionally, a tape measure was used to find the length of the culvert from end to end.

Results

After measuring for the listed variables at six different sites, general trends in the data have occurred.

Temperature

At most sites, the temperature of the water was altered as it went through the culvert. Through linear regression analysis of the temperature change at each site, I found that each site had a significantly altered temperature after passing through the culvert, with the highest p-value at 0.0122.

When looking at the amount sunlight lost during the time spent inside the culvert, as a function of culvert length and flow rate, there is a significant positive relationship.

Dissolved Oxygen

The dissolved oxygen is typically increased as it flowed through the culvert.

Third, the speed of the water spikes as it goes through the culvert and then returns back to original speeds by 15m downstream.

Fourth, there is a proven correlation between flow and dissolved oxygen

Discussion

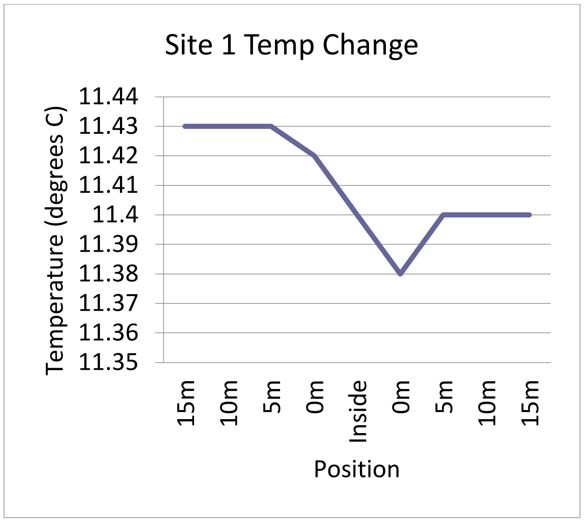
The results suggest that the presence of culverts does indeed alter the stream characteristics. The change in temperature can most likely be attributed to the loss of light available to heat the water, which means that the longer the time spent in the culvert, the colder the water became. There were sites, however, for which the temperature actually increased. This can possibly be attributed to the early time during which the measurements at these sites were taken; the peak sunlight hours in the afternoon would have created a greater dichotomy between covered and uncovered waters.

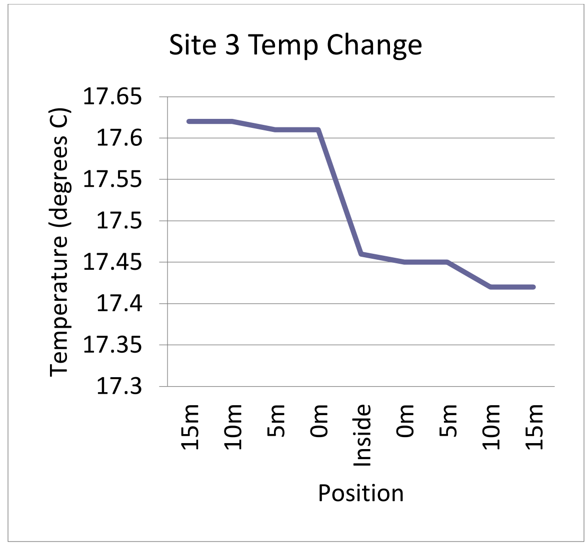
Additionally, the rapid change of flow from culvert funneling greatly affected the characteristics of the water. As described earlier, the amount of time the water was inside of the culvert determined the temperature change. But the residence time of the water is a function of the speed of flow.

Future study:

rusty culverts

pooling from flow change


Site 1 Temp Change
Temperature (degrees C)
11.44
11.43
11.42
11.41
11.4
11.39
11.38
11.37
11.36
11.35
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position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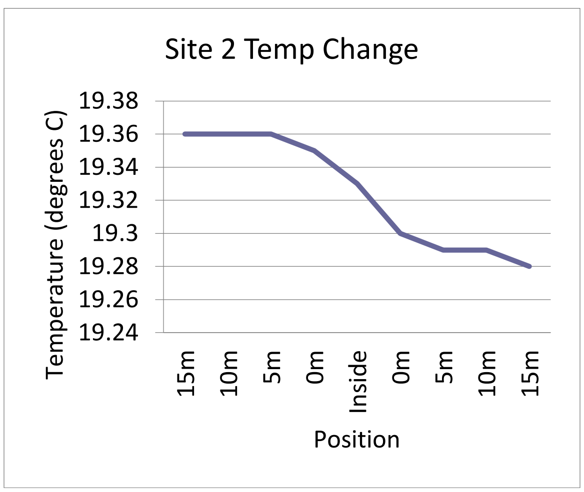
Temperature (degrees C)
17.65
17.6
17.55
17.5
17.45
17.4
17.35
17.3
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position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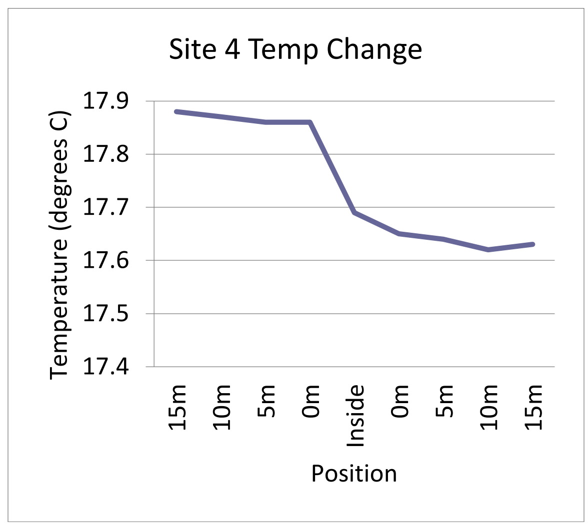
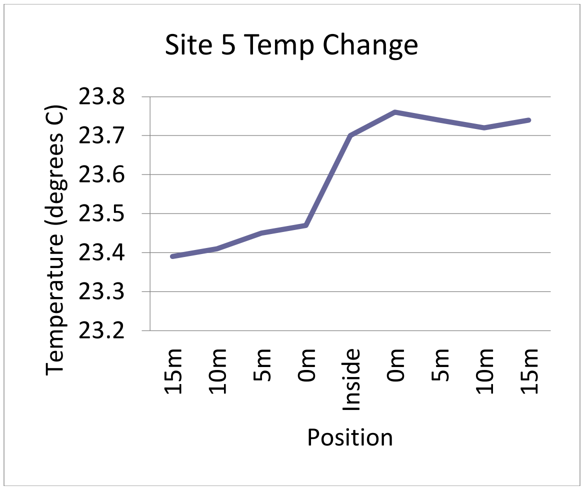
Temperature (degrees C)
19.38
19.36
19.34
19.32
19.3
19.28
19.26
19.24
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position


Site 4 Temp Change
Temperature (degrees C)
17.9
17.8
17.7
17.6
17.5
17.4
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position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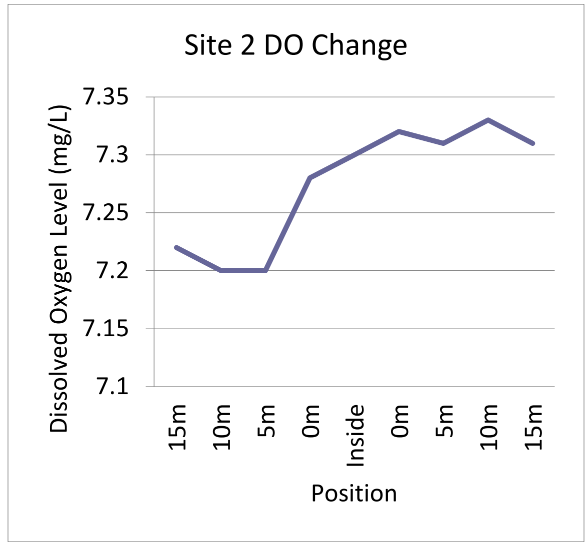
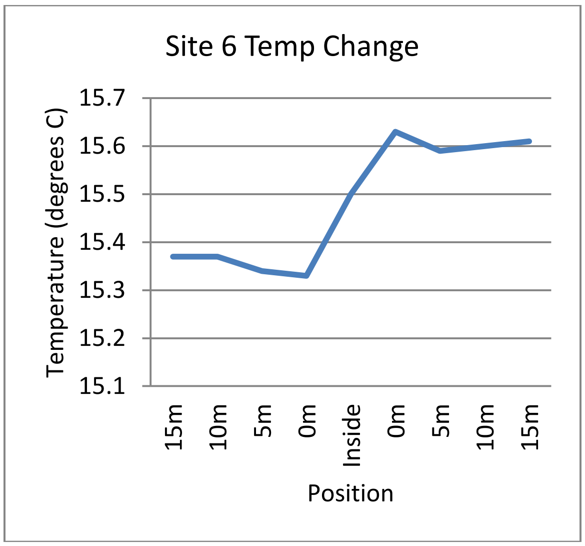
Temperature (degrees C)
23.8
23.7
23.6
23.5
23.4
23.3
23.2
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position


Site 2 DO Change
Dissolved Oxygen Level (mg/L)
7.35
7.3
7.25
7.2
7.15
7.1
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position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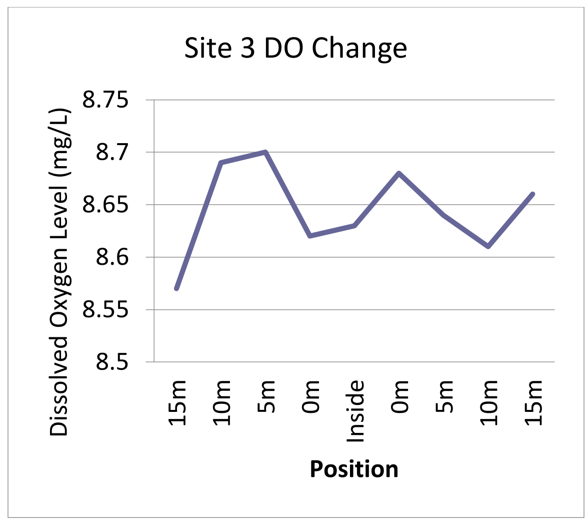
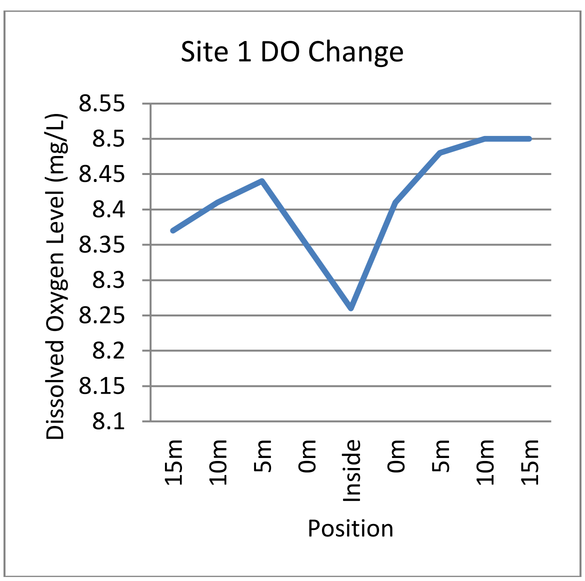
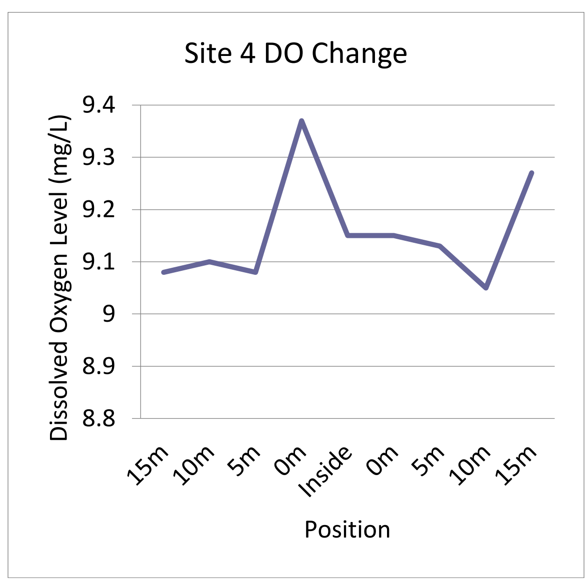
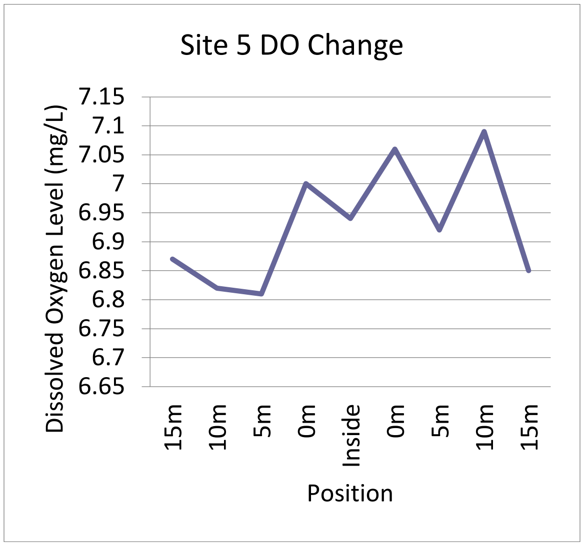
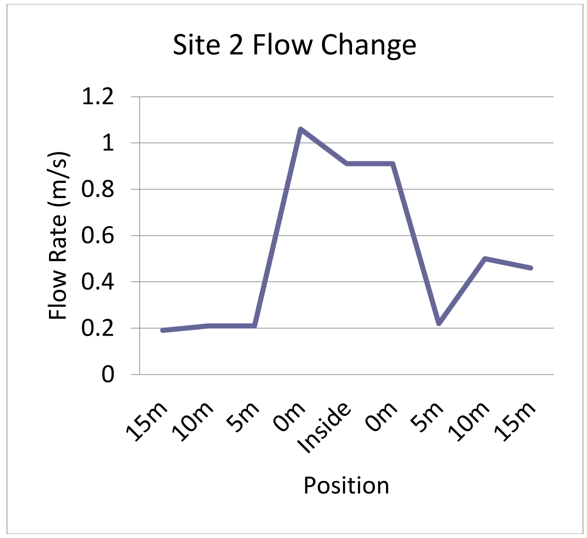
Temperature (degrees C)
15.7
15.6
15.5
15.4
15.3
15.2
15.1
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position

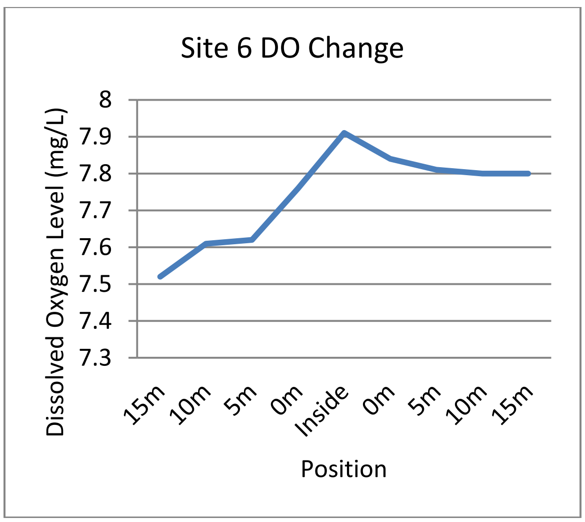

Site 3 DO Change
Dissolved Oxygen Level (mg/L)
8.75
8.7
8.65
8.6
8.55
8.5
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position

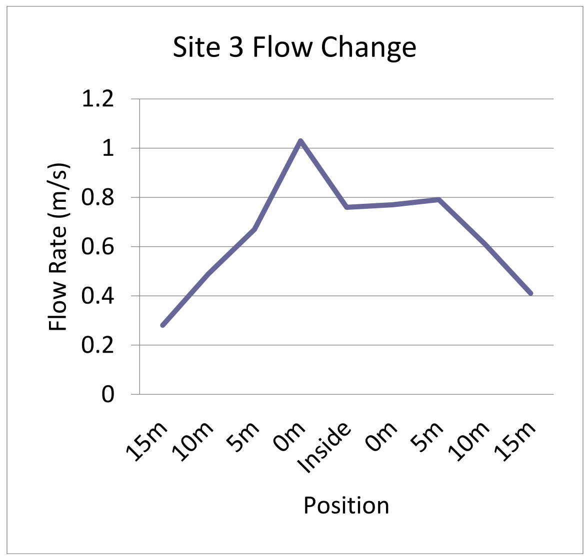

Site 1 DO Change
Dissolved Oxygen Level (mg/L)
8.55
8.5
8.45
8.4
8.35
8.3
8.25
8.2
8.15
8.1
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position

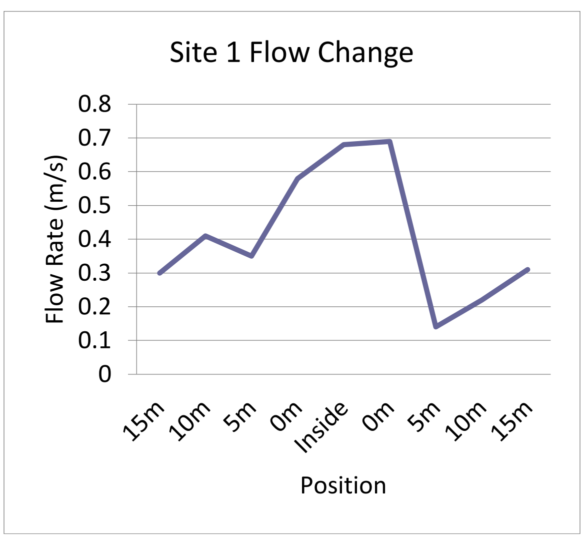

Site 4 DO Change
Dissolved Oxygen Level (mg/L)
9.4
9.3
9.2
9.1
9
8.9
8.8
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position

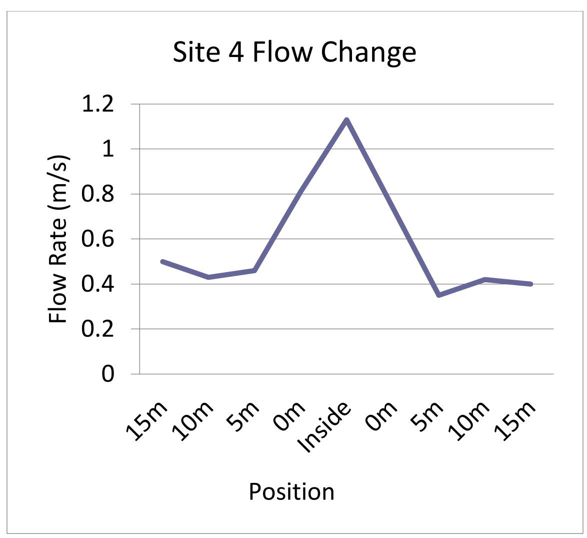

Site 5 DO Change
Dissolved Oxygen Level (mg/L)
7.15
7.1
7.05
7
6.95
6.9
6.85
6.8
6.75
6.7
6.65
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position

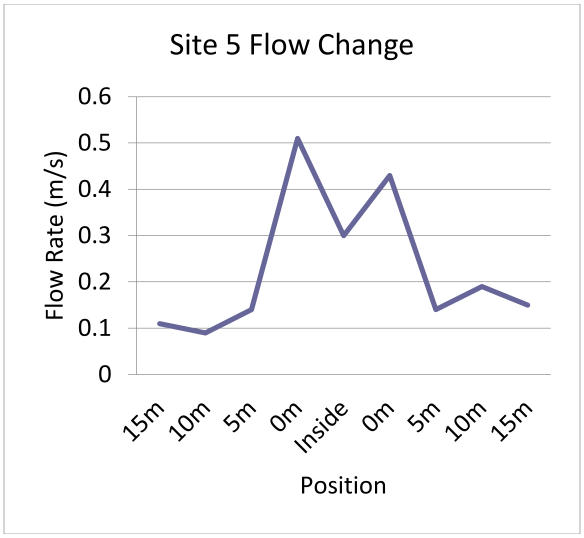

Site 2 Flow Change
Flow Rate (m/s)
1.2
1
0.8
0.6
0.4
0.2
0
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position

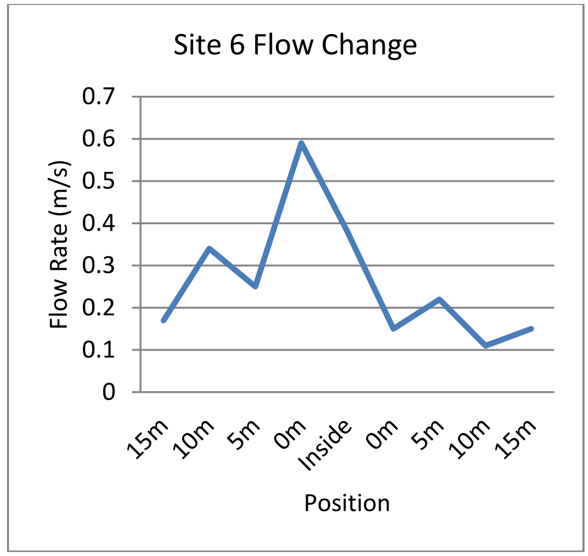

Site 6 DO Change
Dissolved Oxygen Level (mg/L)
8
7.9
7.8
7.7
7.6
7.5
7.4
7.3
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position

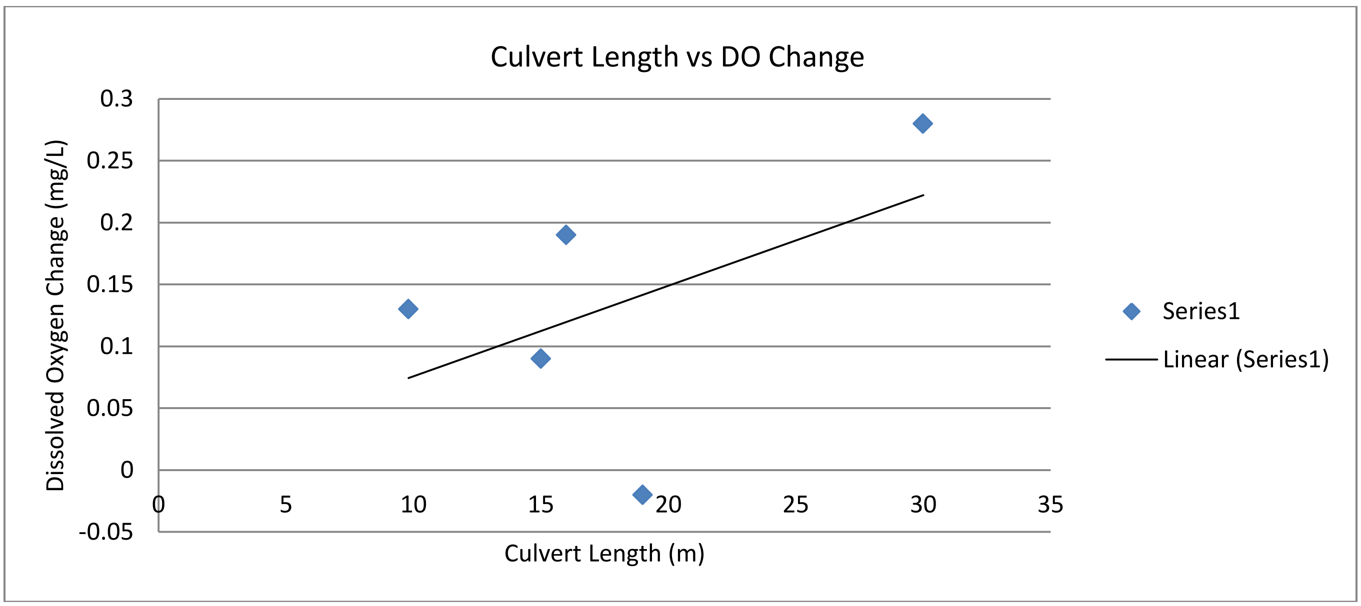

Site 3 Flow Change
Flow Rate (m/s)
1.2
1
0.8
0.6
0.4
0.2
0
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position

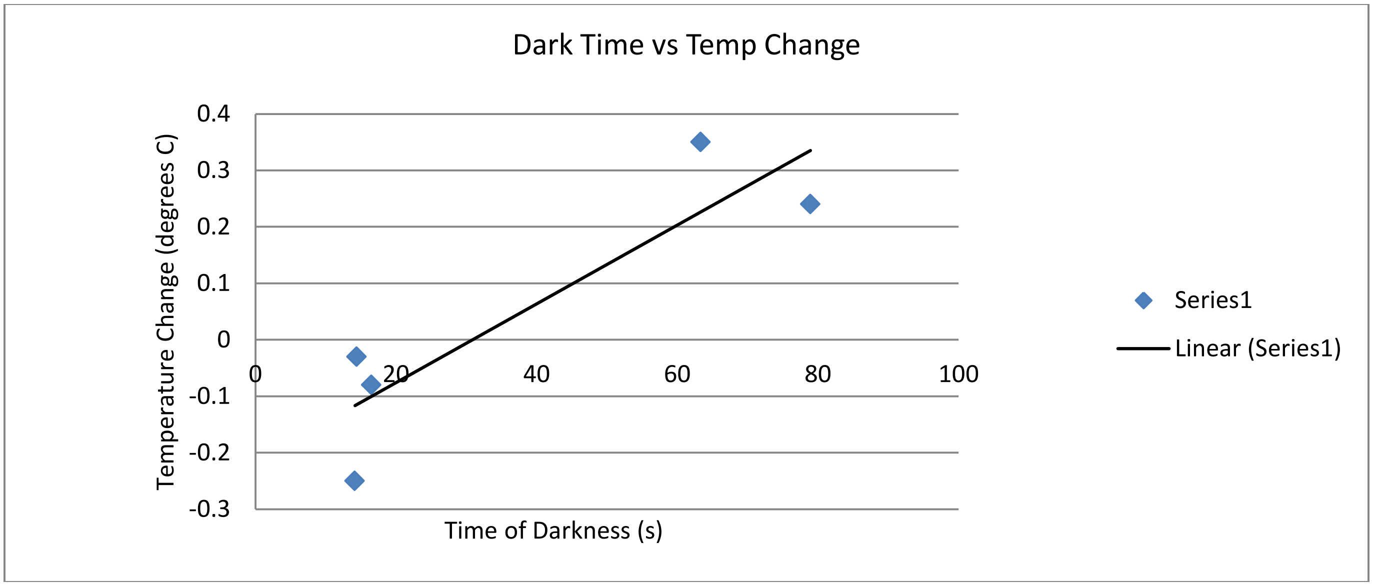

Site 1 Flow Change
Flow Rate (m/s)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position


Site 4 Flow Change
Flow Rate (m/s)
1.2
1
0.8
0.6
0.4
0.2
0
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position


Site 5 Flow Change
Flow Rate (m/s)
0.6
0.5
0.4
0.3
0.2
0.1
0
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position


Site 6 Flow Change
Flow Rate (m/s)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
15m
10m
5m
0m
Inside
0m
5m
10m
15m
Position


Culvert Length vs DO Change
Dissolved Oxygen Change (mg/L)
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
5
10
15
20
25
30
35
Culvert Length (m)
Series1
Linear (Series1)


Dark Time vs Temp Change
Temperature Change (degrees C)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
0
20
40
60
80
100
Time of Darkness (s)
Series1
Linear (Series1)

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