**Ashland Creek E. Coli 2012 to 2016**

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## Abstract

Bacteria concentration specifically *E. coli* has become a major issue in Oregon's Rogue Valley. High levels of *E. coli* in a water source can lead to health risks. The purpose of this study is to examine the continued affects the TID (Talent Irrigation Ditch) is having on Ashland Creek E. Coli levels. Using test results from the City of Ashland performed regularly since 2011 we were able to show the affects of TID water on Ashland Cr. Like the previous study done by Rogue River Keeper the TID appears to be the major contributor to E. Coli in the creek. The E. Coli concentrations in the ditch increase as it runs through city limits from Tolman Creek Rd. Further studies need to be conducted in order to rule out other potential sources. Steps have been taken by the city to reduce this risk however further actions are required. These include education of the public, piping of the entire ditch, more doggy waste stations, and further studies to rule out other potential sources.

**Introduction**

Bacteria concentration, specifically *Escherichia coli* (commonly known as *E. coli*), has become a concern in the Rogue Valley (RVCOG, 2003). The purpose of this study is to follow up on a previous study that was completed and published by Rogue River keeper, in collaboration with Southern Oregon University's Biology Department. The study involved bacteria concentrations in Ashland Creek. Current practices in Ashland were also analyzed to determine the quality of management practices implemented by the City. Basic guidelines are laid out by the EPA for the state of Oregon in regards to bacteria levels allowed in the waters. *E. coli* has the capability to cause human health issues, and in many cases water that passes through an urban watershed like Ashland, can become contaminated with fecal coliform and *E. coli* as well as many other pathogens which thrive in urban environments. Elevated Bacteria are in many ways linked to anthropocentric activities, and surface water running through a populated area is directly affected (Marion et al., 2016).

According to data taken by the Department of Environmental Quality (aka DEQ) there are hundreds of miles of streams and rivers in the Rogue Basin that exceed Oregon State water quality standards for *E. coli*. Many of these waterways in the basin are on the Clean Water Act's 303(d) water quality impaired list for *Escherichia coli* (English et al., 2010). High levels of bacteria in the water in Ashland Creek, prevents residents from recreating in those waters, due to the risk of contracting a water borne disease from the contaminants. The study will help to determine whether our bacteria management plan established by the City is working on Ashland Creek, and if not, to suggest alternative methods that could potentially be implemented. This information will be useful for City officials to better understand how our infrastructure, specifically the Talent Irrigation Ditch (henceforth referred to as TID), is affecting the water chemistry of the creek, as well as ways to limit potential public health concerns. This study will focus on unsafe levels of bacteria as established by the State in relation to human health regulations created by the EPA. The area along Ashland Creek specifically the upper portion that runs through Lithia Park, is a very popular location to recreate for Rogue Valley residents. These activities include swimming, wading, hiking, dog walking and much more making it an ideal area to examine the affects *E. coli* can have over an extended period.

**What is E. Coli?**

*Escherichia coli* is a commonly occurring single celled organism in lakes, streams, and rivers. *E. coli* is present in the intestines of warm blooded mammals. It is responsible for helping our intestines function properly and it is crucial for us to remain healthy. *E. coli*, along with other bacteria in our bodies, provide us with many important vitamins. (RVCOG, 2003). Some strains of the bacteria, however, may cause infections and are harmful to humans.

**Why Should We Care?**

High levels of bacteria in our streams increase many pathogen's abilities to propagate and thrive within open water sources. Pathogens are organisms that can contaminate a source making the water non-potable for humans and other animals if consumed. If high levels of *E. coli* are present in a water source the risk of encountering these harmful microorganisms is increased. There are a wide verity of pathogens including, but not limited to, several strains of viruses, bacteria, protozoa, and a variety of worms. In short, all these organisms have the potential to cause disease in humans. For these reasons, routine testing of recreational waters has been common practice for many years, and in the 1980's the presence of *Escherichia coli* was designated as the new standard test for monitoring water quality indications by the USEPA.

In 1986, the Environmental Protection Agency established that *Escherichia coli* should be used in place of fecal coliform bacteria in State recreational water quality standards as a better indicator of fecal contaminations. This decision followed an epidemiological study where *E. coli* concentration was proven to be a better predictor of swimming related gastrointestinal illness. The study showed it was more affective in water quality testing than fecal-coliform concentration (Francy et al., 1993). By examining other studies and management plans set forth by other municipalities to deal with bacteria, we can further understand our own obstacles and implement new policies and practices that are more efficient. Having a strong understanding of how E. Coli behaves and when it is most likely to occur, will have many benefits for small community like Ashland. The most obvious benefit to regulating bacteria levels in a municipality would be for human health concerns as well as concern for the ecosystem, which can become vulnerable and unproductive in areas known for high levels of bacteria.

***E. Coli* Testing Criteria**

Testing for *E. coli* allows authorities to inform the public of safety concerns before they swim or fish in a specific body of water. Regular testing of these sites will ensure healthy recreational activities. In highly contaminated areas the risk of getting an illness is increased. Children and the elderly are the most susceptible to harmful microorganisms and other bacteria. Common illnesses that occur from contaminated water ways are: gastrointestinal illnesses, upper respiratory illnesses, and infections. One way to avoid some of these consequences is to rinse off after meeting a contaminated water source. Another would be to know the conditions of the water in the area (RVCOG, 2003). There is a website known as “swim safe” that indicates whether it is safe to swim in the lakes and rivers in Oregon. This website was put together by a private entity known as Rogue River keeper and it allows you to go out and recreate without worrying about water borne illnesses. Public closures are an inconvenience for everyone, yet every summer one occurs in the Rogue Valley (RVCOG, 2003). If a creek or lake doesn't meet water quality standards, then the local agencies and media will be notified and the stream may be closed for use by the public (RVCOG, 2003). Identifying sources of bacteria is vital for authorities across the state and the country. It allows them to effectively target management strategies and, in theory, it allows them to reduce bacteria inputs into a watershed. Measuring *E. coli* in local streams, lakes, and rivers is important because it is an indicator for testing water quality for human use. *E. coli* in the environment dies at about the same rate as other pathogens making it extremely important to understand how *E. coli* reacts to an environment. Microbes like *E. coli* are also comparable when it comes to the water filtration process (RVCOG, 2003). Such similarities create endless options on how to study both bacteria and pathogens.

**TID**

The Talent Irrigation district is an essential part of the Ashland community and has been for decades. The purpose of the TID is to bring water to those allocated as well as to irrigate and offer services for new farms and ranches. TID in this study refers to the open ditch that runs from Buckhorn Springs Road, West to Ashland and ending at the TID outfall in Ashland Creek just above the playground and wading area.

**Ashland Creek Bacteria Practices**

The current *E. coli* management practices in our area are as follows: Multiple entities are involved when it comes to Ashland Oregon. The three major entities are Rogue River keeper, Ashland Parks and Recreation, and the City water department. All three of these organizations test water in our area for bacteria, from approximately May to October, to determine whether our water in this case specifically Ashland creek is safe to recreate in. The EPA has set forth a standard for bacteria management for the state of Oregon that these agencies follow. Bacteria concentration in the state may not exceed 406 organisms per 100 ml using the MPN, CFU, or other methods of testing approved by the EPA (Borok, 2016). The organizations in Ashland use this very method. The samples are taken frequently and an arithmetic mean of the MPN is calculated which cannot be greater than or equal to 126 org/100 ml sample. These are the general guidelines used by the city of Ashland. While talking with these agencies we found out that *E. coli* testing done by the city and private entities is not required. Medford one of Ashland's neighbor cities does very little to no bacteria testing and apparently have a, "don't ask don't tell" policy. This may work for the residents of Medford, but Ashland residences greatly value their recreation areas and enjoy being able to cool off in Ashland Creek during a hot summers day.

**Relevant Literature**

Bacteria is influenced by meteorological conditions and land-use characteristics. However, this relationship between the two is not fully understood. Using a Bayesian over dispersed Poisson models, the combined effects of temperature, rainfall, and land-use characteristics on fecal coliform concentration were quantified with predictive uncertainty, and the sources of variability were assessed. The model indicated that temperature had more of an effect on forest-dominated terrain versus urban dominated areas. The results suggest that seasonally dependent processes, including surface runoff, are important factors that regulate fecal coliform concentration in streams (Cha et al., 2016). This information shows the relationship between a healthy environment and healthy water. They found that when an area was predominantly forest, the effects of temperature had less of an effect on the streams.

Land uses have a direct effect on water quality (Derlet et al., 2016). A common land use around Ashland is cattle. Just East of Ashland, there are multiple cattle operations that operate near various water sources. An experiment was done in New Zealand dealing with a similar issue. In this case, the researchers wanted to understand the effects dairy cows had on streams when they cross them. The cows in this study defecated 50 times more per meter of stream crossing then anywhere on the raceway (The area in which the cows are contained). The results showed that cattle accessing streams caused direct water contamination (Davies-Colley et al., 2004). Taking cows out of the equation would have major water quality benefits. Unfortunately, this most likely will not happen, therefore an understanding of how livestock affects the ecosystem is imperative. This will allow ranchers to implement fixes which could decrease the damage done to a water source. Another experiment preformed in the Southwest on rangeland showed similar results. Carries out by a Texas Agricultural Experiment Station researcher, Dr. John Siji intended for it to be a showcase study for Texas. His team has been measuring water quality on rangelands, hoping to lay out a plan for land owners and ranchers to prevent contaminations (Texas A&M University, 2006). A similar plan could be implemented in Jackson County. It is a simple equation: when cows are near water they contaminate it. A closer to home example would be the study which examined backcountry lakes in the Sierra Nevada mountains. This study took five years to provide a longitudinal assessment of acquiring disease from the Sierra Nevada Wilderness area lakes and streams. By using coliforms as an indicator, they could show that there is a correlation between the use of an area and the level of coliform. Surface water from watersheds directly below cattle rangeland and those used by pack animals have a high risk for coliform. Water from wilderness day hiking sites or backpacking areas poses far less of a threat for contaminants such as coliform. (Derlet et al., 2016) This information can be used to better understand the impacts residents of Ashland have on the watershed, specifically regarding their actions in the upper watershed. It also brings up an interesting question about the effects Mount Ashland is having on the water shed. A common theme appears in the literature on land use. Where there is livestock or pack animals, there is a higher count of bacteria and a higher chance of contracting a water borne illness. Luckily, few large animals reside in the upper watershed and no livestock grazes there. Other effects on water quality come from populated areas, as well as man-made infrastructure.

It is widely known that storm water drainage has an impact on the health of a tidal system. Due to this, contaminations in the upper drainage basins can affect the lower estuaries and tidal creeks. These areas in many cases act as receiving waters. In this study, they are examining the importance of drainage basin sediments and the relationship it must *E. coli* within a watershed. This would be a valuable study to replicate in Jackson County, specifically in Ashland's watershed. The experiment utilized varying grain size and organic content to examine the influence of physical characteristics on bacterial prevalence. Results suggest that the host source may be more important to initial bacterial colonization, while the physical characteristics better explain extended *E. coli* persistence. The findings also suggested an indirect control of water column bacterial concentration by sediment type and erodibility (Curtis & Trapp, 2016). In other words, sediment matters when it comes to *E. coli* and its persistence to live in a specific area. In Oregon, Coastal streams GIS was used to predict pathogen indicator counts. Many layers were used within the software, and the idea was to understand the issue regionally to provide a procedure to decrease the problem. They found in the study that the most important predictors on bacteria count, were forest and riparian zones, cattle activities, and urban land use. The research in this model shows a linkage between anthropogenic activities and bacteria levels (Pettus et al., 2015).

**Methodology**

The data analyzed in this study was collected through standard *E. coli* sampling practices set forth by the EPA. It was collected over a five-year period from 2012 to 2016 by the city of Ashland. Sterile 100ml sample jars were used to take the samples from the two locations of interest. The samples from Ashland Creek were taken at the swimming reservoir and the playground between May and October. Multiple samples were taken to come up with an arithmetic mean for each set of data. Once the tests were taken in the field they were brought back to the lab where the following methods were used. An indicator growth medium was added into each sample, shaken up, and sealed into individual packets. The test kits used are the same ones used by most water quality managers and government agencies throughout the U.S. The samples were placed in the incubator for eighteen hours after the medium completely dissolves. After eighteen hours, the kits can be examined, and the data taken. The process involves counting the individual small wells and large wells to determine if they have grown bacteria. By applying a black light to the samples, counting how many individual wells have grown bacteria, is straight forward due to the florescent properties in the indicator growth medium. For analyzing *E. coli* tests, the most probably number is used or the MPN. The data used for this study was taken by the Ashland Parks and Recreation Office. By analyzing this data as well as the current practices used for managing *E. coli* in our area we were able to follow up on the previous study done on Ashland Creek by SOU and RRK. The numbers were inserted into excel, and using SPSS we could draw conclusions which will be discussed in detail. The methods we used to understand current practices were simple, we spoke with Ashland Parks and Recreation, as well as Rogue River-keeper and could put together what our city agencies as well as private entities are doing to manage the amount of *E. coli* in our watershed.

Our secondary data was originally collected by the city. It was then sent over to us by parks and recreation. The data was analyzed and the following tests were then run in SPSS. A paired two sample T-test for discharge and a linear regression test.

Rejection criteria:

- R value equal to or greater then 0.50 will be considered as showing greater then significantly weak correlation and will be counted as "yes, showing correlation."
- if 3/5 or more studies indicate a significantly weak/no correlation (<0.050) only then will the null hypothesis be accepted.
- Extreme outlier data points (above 900 org/100mls) will be removed to prevent type I errors from significantly impacting data analysis. Observations have shown that extremely high E. coli levels did not accrue naturally, and at least one was a septic leak, which caused an accidental point source contamination.

SEE APPENDIX FOR TABLES AND GRAPHS

**Results**

The results showed a significant relationship between discharge of the TID and *E. coli* levels at the playground which is below the TID outfall. We believe some of the errors in our analysis may have come from extreme outliers in the data. This information forced us to reject the Null that there is no significant statistical relationship between the TID discharge and mean *E. coli*, and except the alternative, that there is a significant statistical relationship between the two. The discharge results showed that as discharge increases in the TID so did the *E. coli* below the outfall at the playground. We were also able to determine that discharge did not have an affect on the reservoir *E. coli* levels.

**Discussion**

In the end the results of our analysis showed some statistical relationship between the discharge of the TID and the E. coli levels at the playground near Ashland Creek. We were not able to find a correlation between TID discharge and the swimming reservoir. This leads us to believe that the reservoir *E. coli* levels are not directly affected by the TID. On the other hand, the area in the stream below the outfall was correlated leading us to believe that the TID is continuing to have negative affects on the water chemistry of Ashland Creek. In order make it a stronger correlation, outliers will need to be removed. A future study could also test sites within the ditch itself to further show its effects on the creek. The discharge data was very interesting, because it shows what may occur during a storm event and how we can control these unwanted inputs. The most affective treatment for this problem would be to pipe the TID which would require a lot of money of community support. Another alternative is to continue educating the people on the ditch and the affects dumping waste into it may have. Overall the problem does not appear to be very extreme however due to climate change, and rising stream temperatures, we will surely continue to see elevated *E. coli* levels in the future.

**Thanks**

Rogue River keeper, a local organization that protects our watershed for making the study possible, especially Frances Oyung, Program Coordinator at Rogue River keeper as well as our project mentor.

Susan Dyssegard at Ashland Parks and Recreation for getting us the data and Jeff Mack for also consulting with us.

Libby at North Mountain Park Nature Center.

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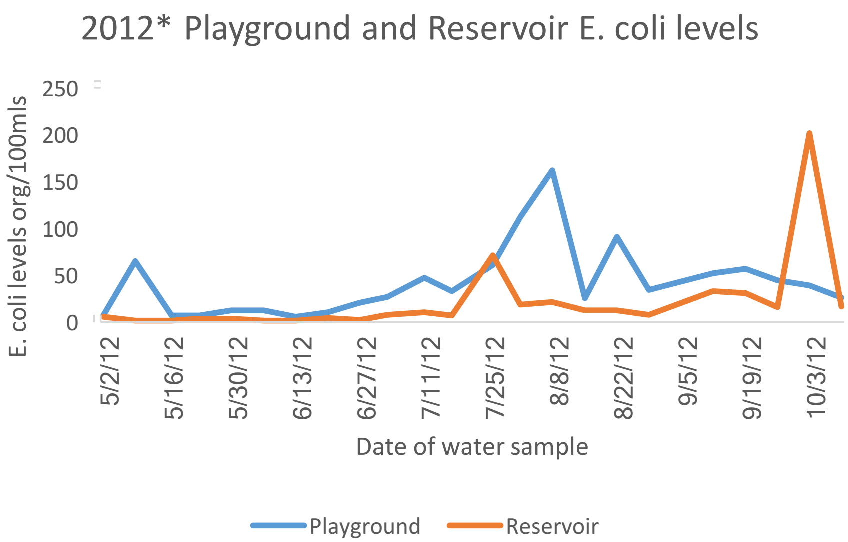
# APPENDIX

Graph 2012.0
E. coli levels (org/100mls) for both swimming reservoir (above TID) and playground (below TID). The data from 9/5/2012 and its extreme outlier (1732.9 playground; 6.3 reservoir) have been removed to maintain the overall scale; The reason for the dramatic spike in playground E. coli is unknown, but it was short lived.




| Regression Statistics | |
|---|---|
| Multiple R | 0.125 |
| R Square | 0.015 |
| Adjusted R Square | -0.033 |
| Standard Error | 38.996 |
| Observations | 22 |

Table 2012.0
Linear regression between playground and reservoir E. coli levels. The $R^2$ of .015 shows us that there is no correlation and the levels of significance of .576 (found on table 2012.1) tells us that even if there was a correlation it is not significant enough to reject the null hypotheses.

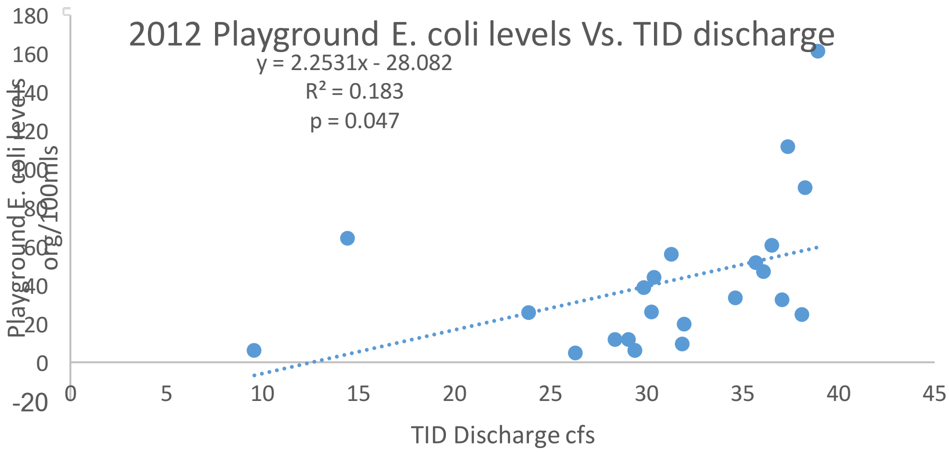
| ANOVA | | | | | |
|---|---|---|---|---|---|
| | df | SS | MS | F | Significance F |
| Regression | 1 | 490.436 | 490.4362 | 0.322 | 0.576 |
| Residual | 20 | 30413.971 | 1520.698 | | |
| Total | 21 | 30904.407 | | | |

Table 2012.1
This ANOVA is part of the linear regression ran between the playground and reservoir E. coli levels. For more information please see table 2012.0.

Graph 2012.1

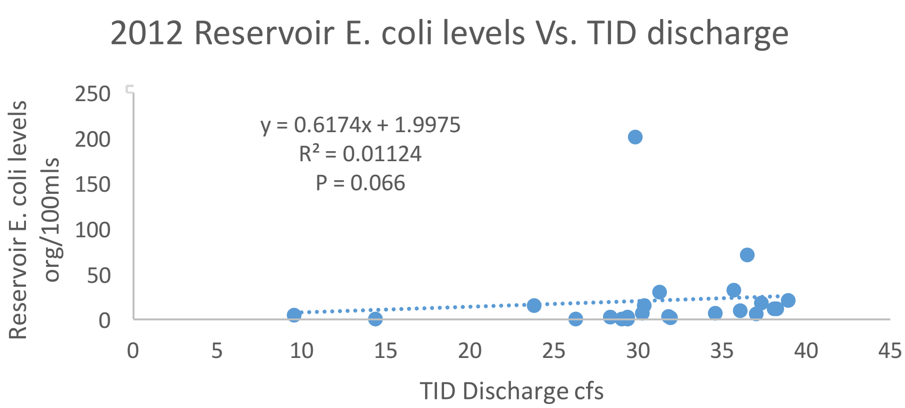
This graph shows the linear regression ran between playground E. coli levels and the DIT discharge just above the playground. The regression line shows that there is a correlation between E. coli levels and discharge coming from the TID. this is quantified by the equation at the top left corner of the graph, with a P value of .047 we accept the alternative hypotheses.

* The data from 9/5/2012 and its extreme outlier (1732.9 playground; 6.3 reservoir) have been removed to maintain the overall scale; The reason for the dramatic spike in playground E. coli is unknown, but it was short lived.




Graph 2012.2

This graph shows the linear regression between reservoir E. coli levels and TID discharge. The regression line being almost flat shows that there is no correlation between the reservoir and discharge levels. * The data from 9/5/2012 and its extreme outlier (1732.9 playground; 6.3 reservoir) have been removed to maintain the overall scale; The reason for the dramatic spike in playground E. coli is unknown, but it was short lived.



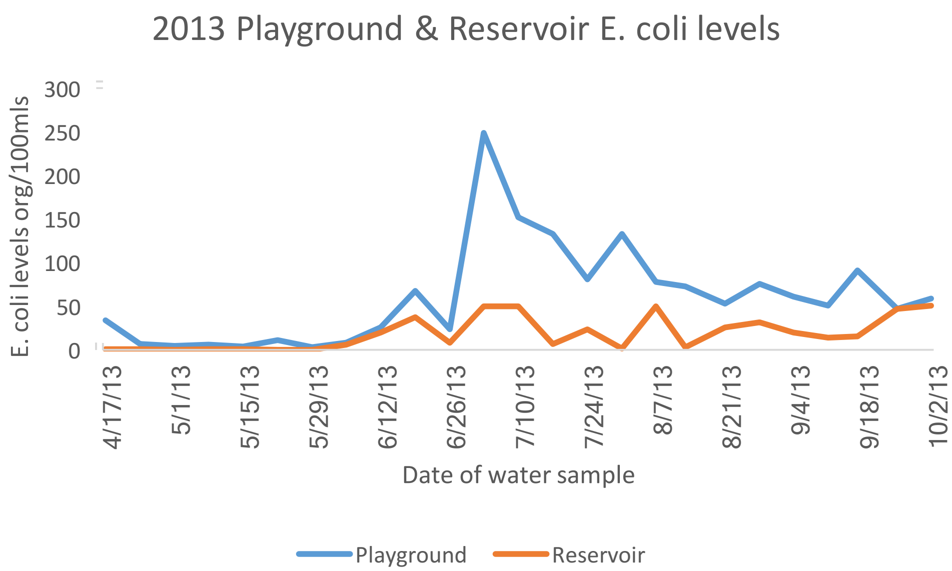
| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| | Discharge | Reservoir |
| Mean | 31.749 | 21.722 |
| Variance | 32.811 | 1862.107 |
| Observations | 22 | 22 |
| Pearson Correlation | 0.070 | |
| Hypothesized Mean Difference | 0 | |
| df | 21 | |
| t Stat | 1.090 | |
| P(T<=t) one-tail | 0.143 | |
| t Critical one-tail | 1.720 | |
| P(T<=t) two-tail | 0.287 | |
| t Critical two-tail | 2.079 | |

Table 2012.3
This paired two sample t-test was used to determine the P value using the two-tail result (.287) and a P value chart we find the P value to be (.066).

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| | Discharge | Playground |
| Mean | 31.749 | 42.868 |
| Variance | 32.811 | 1471.638 |
| Observations | 22 | 22 |
| Pearson Correlation | **0.398** | |
| Hypothesized Mean Difference | 0 | |
| df | 21 | |
| t Stat | **-1.430** | |
| P(T<=t) one-tail | 0.083 | |
| t Critical one-tail | 1.720 | |
| P(T<=t) two-tail | 0.167 | |
| t Critical two-tail | **2.079** | |

Table 2012.2
This paired two sample t-test was used to determine the P value using the two-tail result (.167) and a P value chart we find the P value to be (.098).

Graph 2013.0
E. coli levels (org/100mls) for both swimming reservoir (above TID) and playground (below TID).



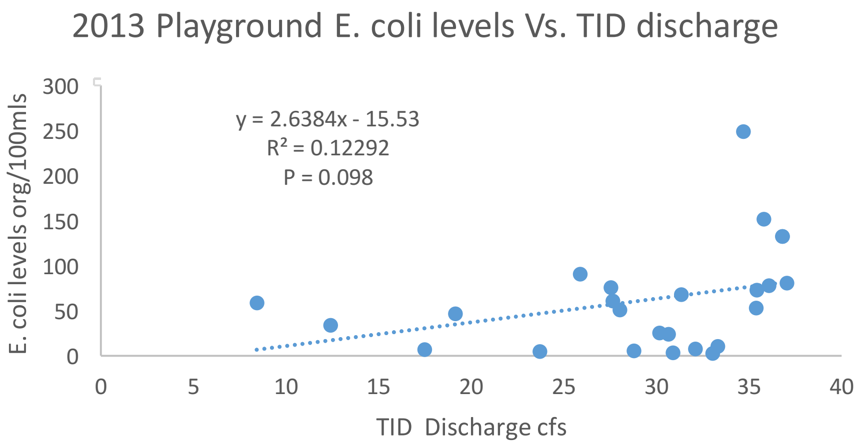

| Regression Statistics | |
|---|---|
| Multiple R | 0.538613823 |
| R Square | 0.29010485 |
| Adjusted R Square | 0.257836889 |
| Standard Error | 50.77797136 |
| Observations | 24 |

Table 2013.0
Linear regression between playground and reservoir E. coli levels. The $R^2$ of .290 shows us that there is no correlation and the levels of significance of .006 (found on table 2013.1) tells us that there is a significant correlation to reject the null hypotheses.

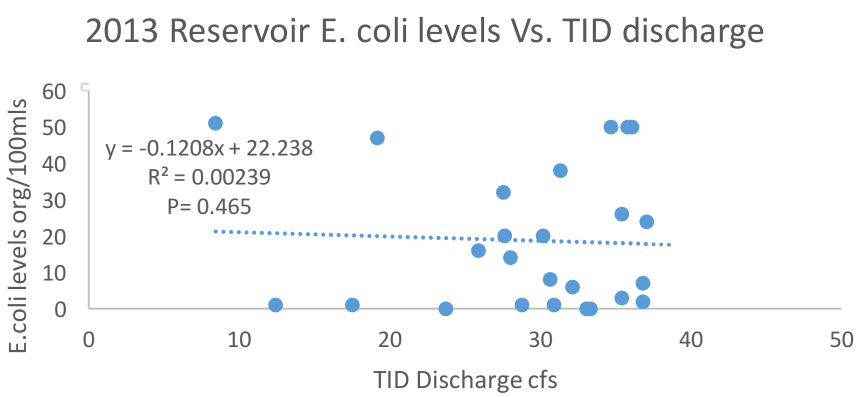
| ANOVA | | | | | |
|---|---|---|---|---|---|
| | df | SS | MS | F | Significance F |
| Regression | 1 | 23181.106 | 23181.106 | 8.990 | 0.006 |
| Residual | 22 | 56724.852 | 2578.402 | | |
| Total | 23 | 79905.958 | | | |

Table 2013.1
This ANOVA is part of the linear regression ran between the playground and reservoir E. coli levels. For more information please see table 2013.0.

Graph 2013.1
This graph shows the linear regression ran between playground E. coli levels and the DIT discharge just above the playground. The regression line shows that there is a correlation between E. coli levels and discharge coming from the TID. this is quantified by the equation at the top left corner of the graph, with a P value of .098 we accept the null hypotheses.




Graph 2013.2
This graph shows the linear regression between reservoir E. coli levels and TID discharge. The regression line being almost flat, with a slight decline even, shows that there is no correlation between the reservoir and discharge levels.



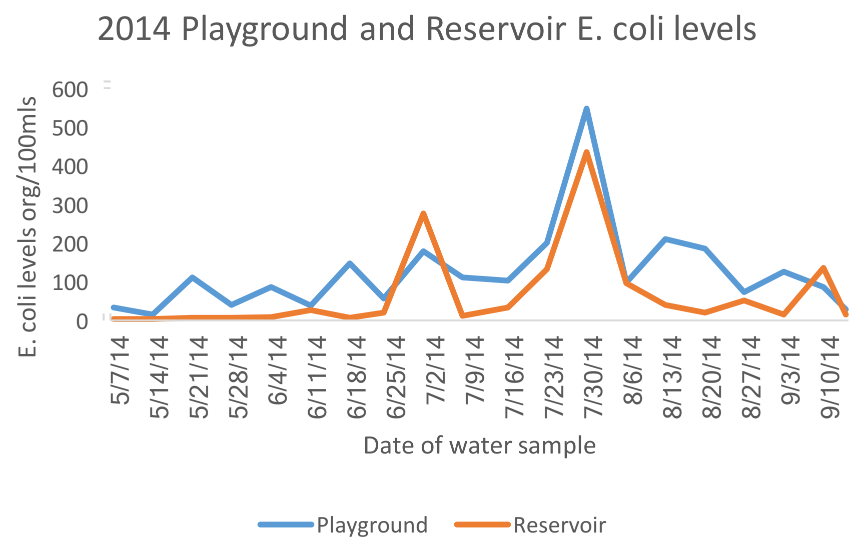
| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| | Playground | *Discharge* |
| Mean | 62.458 | 29.824 |
| Variance | 3474.172 | 49.252 |
| Observations | 24 | 24 |
| Pearson Correlation | **0.345** | |
| Hypothesized Mean Difference | 0 | |
| df | 23 | |
| t Stat | **2.809** | |
| P(T<=t) one-tail | 0.004 | |
| t Critical one-tail | 1.713 | |
| P(T<=t) two-tail | 0.009 | |
| t Critical two-tail | **2.068** | |

Table 2013.3
This paired two sample t-test was used to determine the P value using the two-tail result (.009) and a P value chart we find the P value to be (.098).

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| | Reservoir | *Discharge* |
| Mean | 19.458 | 29.824 |
| Variance | 363.476 | 49.252 |
| Observations | 24 | 24 |
| Pearson Correlation | -0.156 | |
| Hypothesized Mean Difference | 0 | |
| df | 23 | |
| t Stat | -2.381 | |
| P(T<=t) one-tail | 0.012 | |
| t Critical one-tail | 1.713 | |
| P(T<=t) two-tail | 0.025 | |
| t Critical two-tail | 2.068 | |

Table 2013.4
This paired two sample t-test was used to determine the P value using the two-tail result (.025) and a P value chart we find the P value to be (.465).

Graph 2014.0
E. coli levels (org/100mls) for both swimming reservoir (above TID) and playground (below TID).



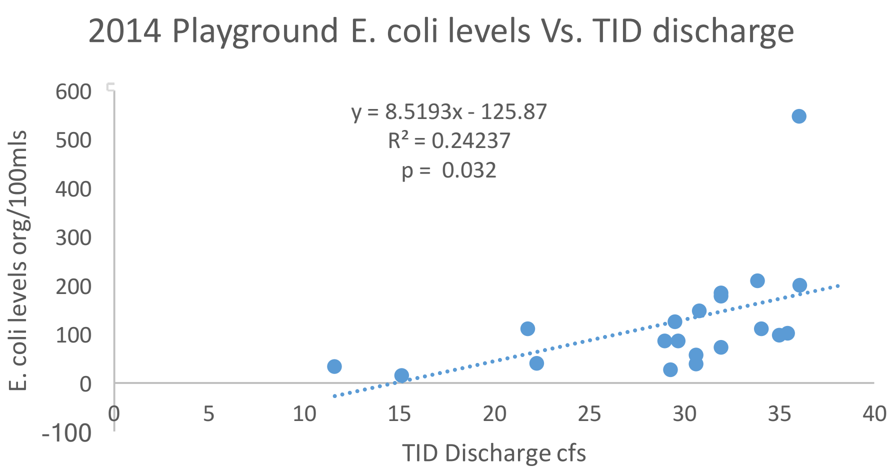

| Regression Statistics | |
|---|---|
| Multiple R | 0.812 |
| R Square | 0.659 |
| Adjusted R Square | 0.639 |
| Standard Error | 70.262 |
| Observations | 19 |

Table 2014.0
Linear regression between playground and reservoir E. coli levels. The $R^2$ of .659 shows us that there is no correlation and the levels of significance of .853 (found on table 2014.1) tells us that even if there was a correlation it is not significant enough to accept the null hypotheses.

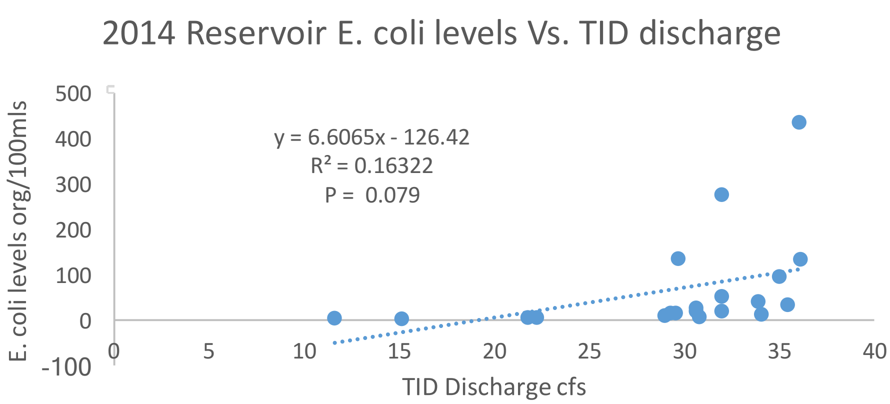
| ANOVA | | | | | |
|---|---|---|---|---|---|
| | df | SS | MS | F | Significance F |
| Regression | 1 | 162856.802 | 162856.802 | 32.988 | 0.853 |
| Residual | 17 | 83925.934 | 4936.819 | | |
| Total | 18 | 246782.736 | | | |

Table 2014.1
This ANOVA is part of the linear regression ran between the playground and reservoir E. coli levels. For more information please see table 2014.0.

Graph 2014.1
This graph shows the linear regression ran between playground E. coli levels and the DIT discharge just above the playground. The regression line shows that there is a correlation between E. coli levels and discharge coming from the TID. this is quantified by the equation at the top left corner of the graph, with a P value of .032 we reject the null hypotheses.




Graph 2014.2
This graph shows the linear regression between reservoir E. coli levels and TID discharge. The regression line does show some correlation, but with a P value of .079 we must accept the null hypotheses.



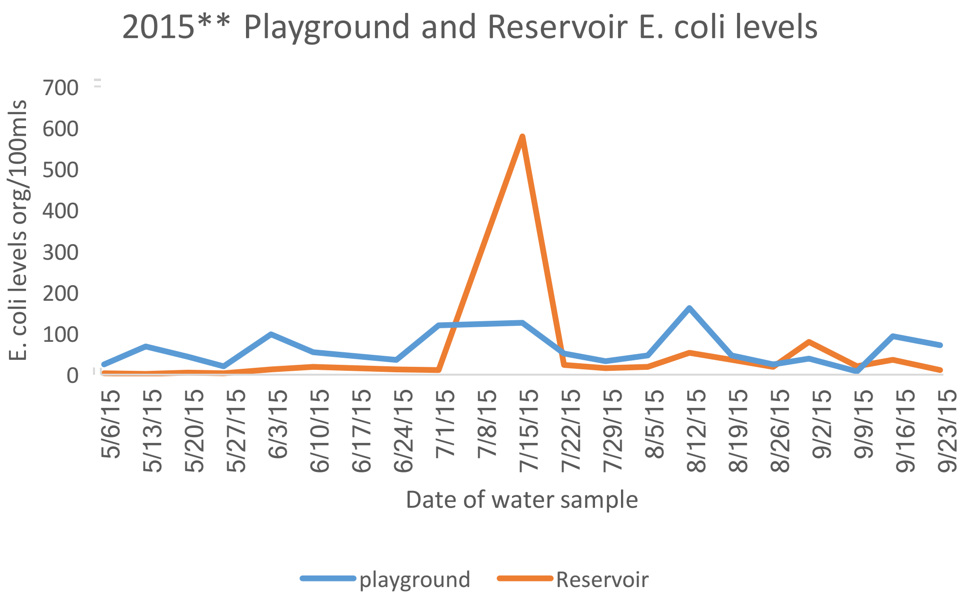
| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| | Playground | Discharge |
| Mean | 128.526 | 30.239 |
| Variance | 13710.152 | 29.002 |
| Observations | 19 | 19 |
| Pearson Correlation | **0.492** | |
| Hypothesized Mean Difference | 0 | |
| df | 18 | |
| t Stat | **3.740** | |
| P(T<=t) one-tail | 0.000 | |
| t Critical one-tail | 1.734 | |
| P(T<=t) two-tail | 0.001 | |
| t Critical two-tail | **2.100** | |

Table 2014.3
This paired two sample t-test was used to determine the P value using the two-tail result (.001) and a P value chart we find the P value to be (.032).

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| | Reservoir | Discharge |
| Mean | 70.526 | 30.239 |
| Variance | 12430.70 | 29.002 |
| Observations | 19 | 19 |
| Pearson Correlation | 0.412 | |
| Hypothesized Mean Difference | 0 | |
| df | 18 | |
| t Stat | 1.605 | |
| P(T<=t) one-tail | 0.062 | |
| t Critical one-tail | 1.734 | |
| P(T<=t) two-tail | 0.125 | |
| t Critical two-tail | 2.100 | |

Table 2014.4
This paired two sample t-test was used to determine the P value using the two-tail result (.125) and a P value chart we find the P value to be (.079).

Graph 2015.0
E. coli levels (org/100mls) for both swimming reservoir (above TID) and playground (below TID). The data from 7/8/2015and its extreme outlier (980 playground; 8840 reservoir) have been removed to maintain the overall scale; The reason for the dramatic spike in E. coli is from a septic tank that leaked into the reservoir on 7/6/2015.



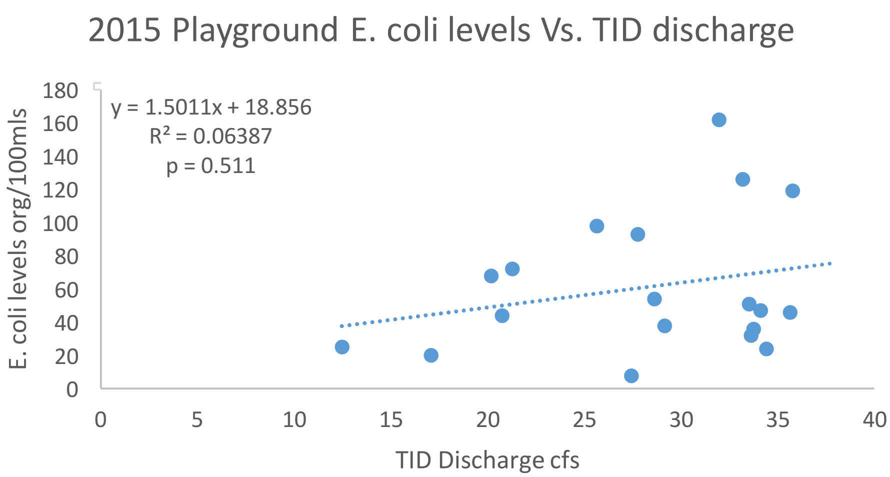

| Regression Statistics | |
|---|---|
| Multiple R | 0.402 |
| R Square | 0.162 |
| Adjusted R Square | 0.109 |
| Standard Error | 38.951 |
| Observations | 18 |

Table 2015.0
Linear regression between playground and reservoir E. coli levels. The $R^2$ of .109 shows us that there is no correlation and the levels of significance of .097 (found on table 2015.1) tells us that even if there was a correlation it is not significant enough to reject the null hypotheses.

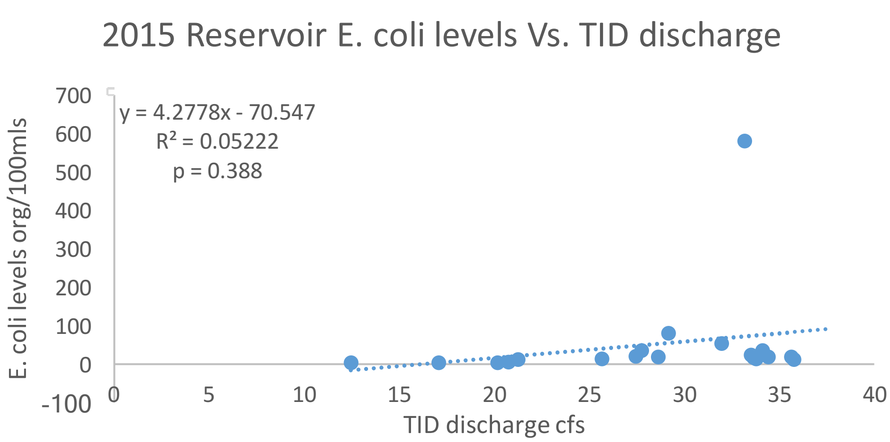
| ANOVA | | | | | |
|---|---|---|---|---|---|
| | df | SS | MS | F | Significance F |
| Regression | 1 | 4701.771 | 4701.771 | 3.098 | 0.097 |
| Residual | 16 | 24275.339 | 1517.208 | | |
| Total | 17 | 28977.111 | | | |

Table 2015.1
This ANOVA is part of the linear regression ran between the playground and reservoir E. coli levels. For more information please see table 2015.0.

Graph 2015.1
This graph shows the linear regression ran between playground E. coli levels and the DIT discharge just above the playground. The regression line shows that there is a correlation between E. coli levels and discharge coming from the TID. this is quantified by the equation at the top left corner of the graph, with a P value of .511 we accept the null hypotheses.




Graph 2015.2
This graph shows the linear regression between reservoir E. coli levels and TID discharge. The regression line does show some correlation, but with a P value of .388 we must accept the null hypotheses.



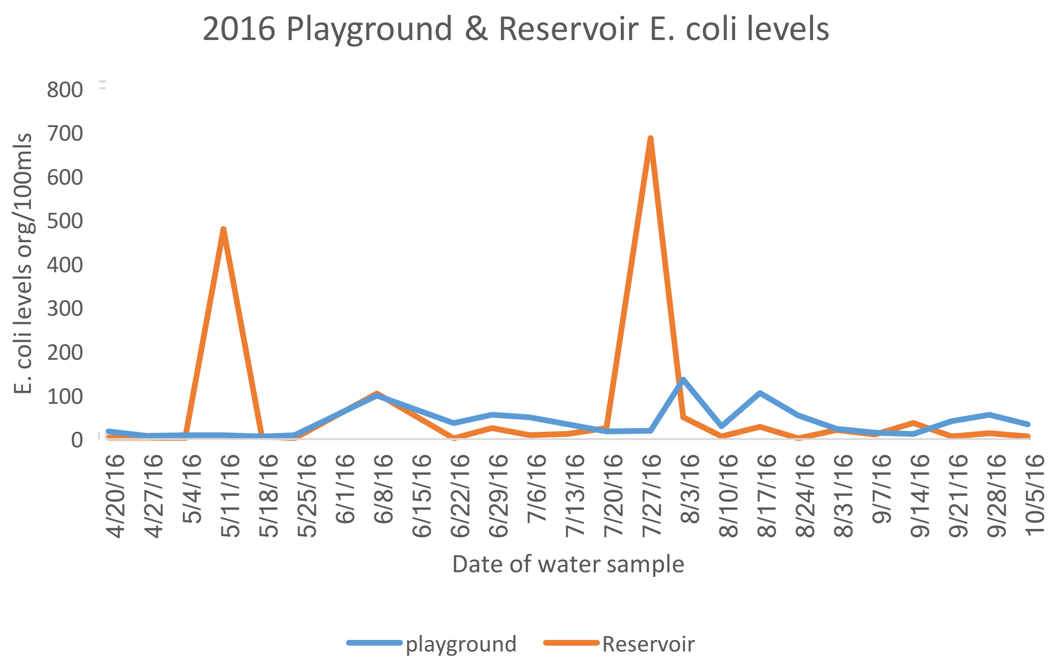
| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| | playground | discharge |
| Mean | 63.222 | 29.092 |
| Variance | 1704.535 | 35.188 |
| Observations | 18 | 18 |
| Pearson Correlation | **#N/A** | |
| Hypothesized Mean Difference | 0 | |
| df | 17 | |
| t Stat | **3.555** | |
| P(T<=t) one-tail | 0.001 | |
| t Critical one-tail | 1.739 | |
| P(T<=t) two-tail | 0.002 | |
| t Critical two-tail | **2.109** | |

Table 2015.3
This paired two sample t-test was used to determine the P value using the two-tail result (.002) and a P value chart we find the P value to be (.511).

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| | reservoir | discharge |
| Mean | 52.777 | 29.092 |
| Variance | 17603.712 | 35.188 |
| Observations | 18 | 18 |
| Pearson Correlation | 0.216 | |
| Hypothesized Mean Difference | 0 | |
| df | 17 | |
| t Stat | 0.764 | |
| P(T<=t) one-tail | 0.227 | |
| t Critical one-tail | 1.739 | |
| P(T<=t) two-tail | 0.455 | |
| t Critical two-tail | 2.109 | |

Table 2014.4
This paired two sample t-test was used to determine the P value using the two-tail result (.455) and a P value chart we find the P value to be (.388).

Graph 2016.0
E. coli levels (org/100mls) for both swimming reservoir (above TID) and playground (below TID).




| Regression Statistics | |
|---|---|
| Multiple R | 0.132 |
| R Square | 0.017 |
| Adjusted R Square | -0.031 |
| Standard Error | 35.592 |
| Observations | 22 |

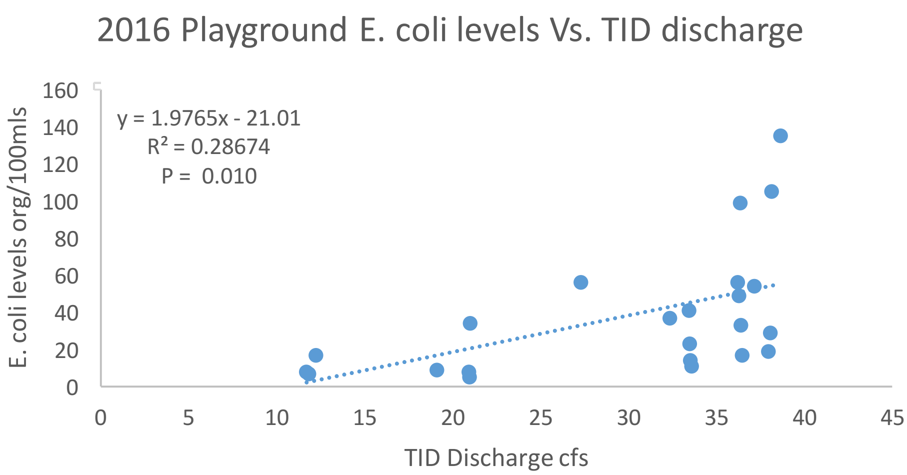
Table 2016.0
Linear regression between playground and reservoir E. coli levels. The $R^2$ of .017 shows us that there is correlation and the levels of significance of .556 (found on table 2016.1) tells us that it is not significant.

| ANOVA | | | | | |
|---|---|---|---|---|---|
| | df | SS | MS | F | Significance F |
| Regression | 1 | 454.249 | 454.249 | 0.358 | 0.556 |
| Residual | 20 | 25337.069 | 1266.853 | | |
| Total | 21 | 25791.318 | | | |

Table 2016.1
This ANOVA is part of the linear regression ran between the playground and reservoir E. coli levels. For more information please see table 2016.0.

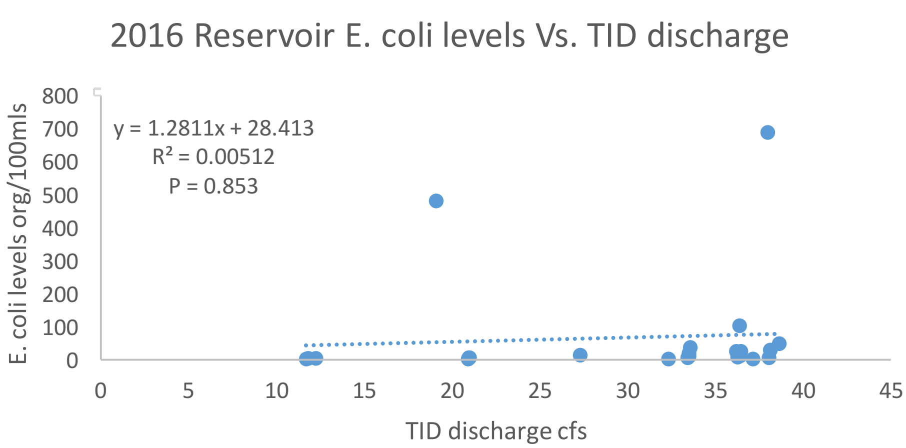
Graph 2016.1

This graph shows the linear regression ran between playground E. coli levels and the DIT discharge just above the playground. The regression line shows that there is a correlation between E. coli levels and discharge coming from the TID. this is quantified by the equation at the top left corner of the graph, with a P value of .010 we reject the null hypotheses.




Graph 2016.2

This graph shows the linear regression between reservoir E. coli levels and TID discharge. The regression line being almost flat shows that there is no correlation between the reservoir and discharge levels. with a P value of .853 we must accept the null hypotheses.



| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| | playground | discharge |
| Mean | 38.590 | 30.474 |
| Variance | 1228.158 | 76.531 |
| Observations | 22 | 22 |
| Pearson Correlation | **0.532** | |
| Hypothesized Mean Difference | 0 | |
| df | 21 | |
| t Stat | **1.217** | |
| P(T<=t) one-tail | 0.118 | |
| t Critical one-tail | 1.720 | |
| P(T<=t) two-tail | 0.236 | |
| t Critical two-tail | **2.079** | |

Table 2016.3
This paired two sample t-test was used to determine the P value using the two-tail result (.236) and a P value chart we find the P value to be (.010).

| t-Test: Paired Two Sample for Means | | |
|---|---|---|
| | | |
| | Reservoir | discharge |
| Mean | 69.318 | 30.474 |
| Variance | 29191.084 | 76.531 |
| Observations | 22 | 22 |
| Pearson Correlation | 0.041 | |
| Hypothesized Mean Difference | 0 | |
| df | 21 | |
| t Stat | 1.067 | |
| P(T<=t) one-tail | 0.148 | |
| t Critical one-tail | 1.720 | |
| P(T<=t) two-tail | 0.297 | |
| t Critical two-tail | 2.079 | |

Table 2014.4
This paired two sample t-test was used to determine the P value using the two-tail result (.297) and a P value chart we find the P value to be (.853).