Evaluation of Turbidity in Highway Construction Runoff in Texas

By

Holly Murphy

A Thesis

In

Civil Engineering

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

Master of Science

Approved

Theodore G. Cleveland
Co-chair

Audra N. Morse
Co-chair

Peggy Gordon Miller
Dean of the Graduate School

December, 2011

Acknowledgments

The research team at Texas Tech University would like to thank TxDOT for supporting this project financially. We would especially like to thank the Lubbock TxDOT district for their willingness to help and provide site locations for sampling. In particular, special thanks to Davis Melton for his great help throughout the project.

I would also like to thank Dr. Cleveland and Dr. Morse for their guidance throughout my time on the project. Their encouragement and motivation really helped me through. I would also like to thank my family and friends for all the laughter and support this past year and a half. Thank you all so much!

Table of Contents

Abstract

As the national Construction General Permit (CGP) comes up for renewal in 2013, the U.S. Environmental Protection Agency (EPA) wants to set a nationwide numeric turbidity limit for runoff. The ruling would affect any highway construction sites that disturb more than ten acres at a time. The current proposed turbidity limit is 280 NTU, and the Texas Department of Transportation (TxDOT) along with three universities in Texas are working together to collect and test current runoff from construction sites for turbidity to examine the achievability of the proposed limit and to support the selection of appropriate structural and chemical controls to limit runoff turbidity. In Lubbock, Texas two sites were monitored and samples were collected at the discharge points during rainfall events to determine the current turbidity values in runoff from sites with a Storm Water Pollution Prevention Plan (SW3Ps) already in place. Samples collected had a higher turbidity value than the current proposed limit set by the EPA.

List of Tables

List of Figures

Chapter 1 – Introduction

Background

As the Texas Construction General Permit (CGP) comes up for renewal in 2013, highway construction projects will have to adhere to new standards set forth by the US Environmental Protection Agency (EPA). One new standard includes a nationwide numerical turbidity limit for stormwater runoff from selected construction sites' discharge point. Currently, the standard is anticipated to be 280 NTUs (nephlometric turbidity units) for all construction sites that disturb more than 10 acres at one time (EPA, 2009). The particular nationwide numerical limit is controversial, and the ruling may change (EPA, 2009). The 280 NTU turbidity limit is still in discussion while data is being collected from highway construction projects around the state in order to better understand current runoff turbidity values.

Currently, Best Management Practices (BMPs) such as silt fences, rock-filter dames, ground treatments, tackifiers, and settling basins are the primary tools for decreasing the total amount of sediment in runoff from highway construction sites. Many studies have shown that the relative usefulness of these treatments varies and sometimes particular treatments do not work unless used in conjunction with another treatment. To address this multiple technology problem, the Texas Department of Transportation (TxDOT) wants to determine the appropriate BMPs that will allow them to meet the 280 NTU limit.

A relatively new product, polyacrylamide (PAM), has been discussed and tested as a possible ground treatment to reduce erosion and consequently turbidity values from construction runoff. As with other ground cover treatments, the usefulness and effectiveness of PAM is uncertain. The conditions of a construction site and PAM application frequency are anticipated to govern the effectiveness of PAM.

Objectives

In Texas, TxDOT has invested in research to respond to this nationwide turbidity limit. Three Texas universities: A&M University (TAMU), University of Texas in Austin (UT), and Texas Tech University (TTU) have been involved with collecting turbidity measurements from runoff at highway construction sites in the bare earth phase. The data collected will help TxDOT understand the range of runoff turbidity in different areas of the state and how turbidity may vary depending on soil properties in Texas. The work herein will provide recommended monitoring and sampling protocols that construction workers on site can follow for runoff sample collection and analysis of runoff turbidity in the construction site.

This thesis further examines if water color and/or the color of the suspended particles affects turbidity measurements. Dilution experiments were performed to determine if dilution was a reasonable solution to extend the range of an instrument for turbidity measurements. Lastly, background turbidity maps for the state of Texas were created to display the ambient turbidity conditions in state waters.

Scope and Limitations

The research in Lubbock, Texas involved two construction sites within an area that already had stormwater pollution prevention plans (SW3Ps) in place. Samples were only taken during or right after a storm event at the discharge point designated for each site. Therefore, possible runoff from other areas of the construction sites may not be characterized by the samples collected for measurement. Furthermore, stormwater runoff may vary throughout the course of a storm and therefore the turbidity could vary depending on the time of sample collection in relation to storm duration.

A major limitation in 2011 was the drought of record in Texas. Samples were intended to be collected November 2010 through September 2011 or until the sites were seeded and no longer in the bare earth phase. The drought resulted in only four samples from one site and five samples from the other site to be collected and measured for turbidity, resulting in limited data.

Organization

The remainder of this thesis is organized as follows. Chapter 2 presents background information on turbidity, PAM, and BMPs. The methodology is presented in Chapter 3. The results and discussion appear in Chapter 4. Chapter 5 discusses five topic specific experiments, and the summary and conclusions are discussed in Chapter 6. The appendices include data tables, calculations for experiments, and the attribute table used in ArcGIS to create background turbidity value maps for the state of Texas.

Chapter 2 – Literature Review

Turbidity

Turbidity is the "optical property of suspension with reference to the extent to which the penetration of light is inhibited by the presence of insoluble material – it is a function of both the concentration and particle size of the suspended sediment" (Weigel, 1984).

What Affects Turbidity?

Different types of soil, such as clay, silt, and sand, can have an impact on turbidity. Suspended clay and silt particles have low settling velocities, which impacts turbidity values for a given mass density in the slurry (Bhardway et al., 2009). Clay-sized particles are able to remain in suspension for weeks to months. In major water supply systems such as rivers and reservoirs, clay and other colloidal sized particles are the main threat to water supply clarity (LaHusen, 1994).

Organic material in a water column can increase the turbidity. By the organic cations attaching to clay particles, and stimulating precipitation of colloidal sized solids, turbidity increases (Weigel, 1984). During the summer months, particularly in lakes and rivers, phytoplankton and other microorganisms are major contributors to turbidity. During the winter, suspended mineral sediment is the main source of turbidity. Clay-sized particles and organic sediments affect turbidity year round (Curtiss, 1982).

Other factors affecting turbidity include intense rainfall and snowmelt. Turbidity increased significantly in Fir Creek, Oregon following an intense rainfall event (LaHusen, 1994). Heavy rainfall can have an effect on best management practices

(BMPs) on construction sites as well. If there is poor trap maintenance for a basin, turbidity can increase in the discharge (McCaleb et al., 2008). Silt fences may be overtopped in large rainfall events if not well maintained.

Effects of Color

The measured turbidity of a water sample can be affected by a number of different factors, one of which being color. Dark colors are known to absorb more light-waves, and bright colors reflect light-waves, which is the key concept behind how color can affect turbidity measurements. The nephelometric turbidity method is the most common measurement for turbidity and is based on a theory that as the particle concentration increases so does the light scattering intensity (Ginting et al., 2006 and Gippel et al., 1991). Color can affect turbidity measurements in turbidimeters with a single light detector because the samples that are darker in color will decrease the amount of scattered light that reaches the detector. There are turbidimeters that are equipped with multiple detectors to mitigate the color effect (Sadar et al., 2011).

In general, suspended or dissolved material dark in color and in high concentrations can decrease turbidity readings by absorbing light. Throughout a monitoring program, particle colors can change as the seasons change, which will influence turbidity measurements with backscatter sensors (used to detect the amount of light bouncing back due to particles in the air or water) to also change because of a color’s darkness level (Downing, 2005). The sensitivity of the backscatter sensor has been shown to vary by a factor of 10 from color effects (Sutherland et al., 2000). Simply put, a sample with white particles can produce a turbidity reading almost 10 times larger than a water sample with black particles of the same size and concentration. White formazin standards are primarily used for calibration, only light-colored samples will be able to record turbidity measurements close to those set by these standards (Downing, 2005).

One study using Munsell Soil Charts studied the effect of a soils hue, chroma, and value on optical backscatter sensors. Red, green, yellow, blue, black and white spray paints were used to color sediment samples for testing. The optical backscatter sensor's response was smallest for the black sample and increased, in order, to blue, yellow, red, green, and finally white, which had the largest response. When white sediment was added to the colored samples the response in the optical backscatter sensors increased, whereas the addition of black sediment decreased responses. From this study, it was concluded that the optical backscatter response was influenced by the Munsell value (blackness level) and not by hue (actual color) or chroma (richness or dullness of a color) (Sutherland et al., 2000).

The affect of color on turbidity can primarily be seen in the darkness of the color being tested. Colors that are closer to white in their value reflect light waves that would increase turbidity values. Reflecting light allows light waves to reach the detector plates in the turbidimeters. Darker colors, such as those with values closer to black, decrease turbidity by absorbing light and minimizing the amount of light that reaching the detector plates within a turbidimeter. More advanced turbidimeters are able to account for color changes in turbidity using multiple detectors.

State Regulations and Background Turbidities

There are currently regulations for municipal and industrial water supply treatment for turbidity in most states. The EPA's Water Quality Standards Criteria Summaries lists a summary for each state's turbidity limits and where they apply. Most states' turbidity requirements fall under one of the following categories:

- A numerical turbidity limit above background conditions
- Limits specified for specific water types based on use or geographical region
- Limits based on runoff generation location, i.e. highways, agricultural land, mining operations
- Percent increase above background conditions
- 30 day average turbidity limits with instantaneous maximum limit (Pruitt, 2002)

For Texas, the turbidity should not be substantially different from ambient conditions from waste discharges in to all streams (US EPA, 1980). The turbidity limitations mentioned here are not set standards for highway construction site runoff.

A few north-eastern states, such as Conneticut and Rhode Island, have a numeric turbidity limit of 5 NTU above background levels while southern states such as Mississippi have a limit of 50 NTU above background. Other states have set numeric limits between these values as well. Oregon was the only state that limited discharging water to a 10 percent increase above background conditions. Other states, such as Arkansas, Oklahoma, North Carolina, and South Carolina, have set different numeric limits above background turbidities based on the use or location of the water body (Pruitt, 2002).

For example, the North Carolina Administrative code 15A NCAC 02B.0211, states that runoff from a site must not exceed 50 NTU in streams not designated as trout waters and 10 NTU in streams and lakes designated as trout waters. For lakes without trout, turbidity should not exceed 25 NTU. However, if receiving waters have larger turbidity values than 50 NTU for streams, 25 NTU for lakes or 10 NTU for trout water, the runoff from a construction site should not exceed the current turbidity (Bhardwaj et al., 2008).

One study received turbidity background ranges from 27 states in 2002. All of these states reported a minimum turbidity equal to or less than 1.0 NTU. Only three states, Connecticut, New Hampshire, and Nevada had maximum background turbidities less than 100 NTU, while 18 states reported maximum turbidities over 500 NTU. Even more surprising, was that 10 of 27 states reported maximum background turbidities over 1000 NTU. These states are Arizona, Kentucky, Louisianna, North Carolina, Nebraska, New Mexico, Oregon, South Carolina, Utah, and Wyoming (Pruitt, 2002).

While most states currently have turbidity limits for municipal and industrial discharges, these standards can vary greatly in acceptable discharge turbidity values because of background conditions. Most states have a turbidity limit for municipal and industrial discharges that are a numeric limit or a percent increase above the background. Given the maximum background conditions reported by 27 states, some industries would be required to have their discharge water around 100 NTU while others could have turbidity limits greater than 100 NTU depending on where they were discharging.

Highway Construction Site Turbidity

The turbidity from a highway construction site during the bare earth phase can vary, commonly exceeding several hundred and often several thousand NTU even with proper BMPs (Hayes et al., 2005). At one site in North Carolina, the average turbidity measurements using silt fences and rock filter dams ranged from 210-14000 NTU with an average of 3813 NTU (McLaughlin et al., 2009a). With the amount of soil exposed to the elements, it is no surprise that turbidity could reach such a large value.

At the North Carolina site, background samples before the site was graded had an average turbidity of 589 NTU. Before construction took place and while the gravel load was undisturbed, samples from the site had an average turbidity of 1613 NTU (McLaughlin et al., 2009a). However, the addition of fiber check dams (FCDs) decreased the turbidity to 202 NTU and FCDs with polyacrylamide (PAM) lowered the turbidity to 34 NTU (McLaughlin et al., 2009b). Yet, not all construction sites have reported turbidities this high. Another site in North Carolina showed that the turbidity of untreated discharges only ranged from 220 to 260 NTU (Bhardwaj et al., 2008).

For a California study, turbidity measurements for construction sites and highway runoff were compared. Construction sites were reported of having a minimum turbidity of 15 NTU, a maximum of 16000 NTU and an average of 701 NTU. For highway runoff when in use the minimum turbidity was 9.9 NTU, the maximum was 140 NTU, and the average was 59 NTU (Kayhanian et al., 2010). For construction site runoff, the variability in the turbidity measurements from one storm event to another can be quite large.

Polyacrylamide – PAM

Chemistry

Polyacrylamide (PAM) is a synthetic polymer with a high molecular weight that can be either anionic, nonionic (neutral), or cationic with a number of different chain length combinations (Bhardwaj et al., 2008). Similar to polyethylene, the structure of PAM has a hydrogen on every other carbon that is replaced by an amide group in the form of $CONH_2$. The PAM molecule is further composed of repeating CH_2-$CH(CONH_2)$ units as shown in Figure 1 where the $CONH_2$ group can react with the same group of another molecule creating a link between them in the form of CONHCO (Shakhashiri, 2008).

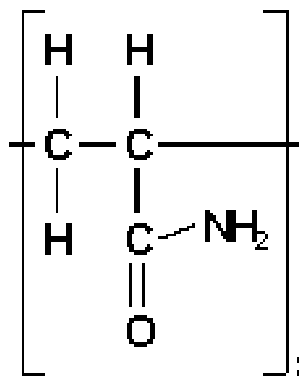

Figure 1. PAM's Molecular Structure (Image taken from Sojka, 2001)

Cationic PAMs have been known to have inferior performance compared to other forms of PAM because of their lower molecular weight. The molecular weight of a polymer can influence the adsorption and flocculation processes – as molecular weight increases so will polymer adsorption (Lentz et al., 2010). Along with molecular weight, temperature, pH, and ionic strength can impact the adsorption process. Hydrogen ion activity (pH) can affect the functional groups of PAM and the charging properties of the clay, affecting adsorption of the polymer (Atesok et al., 1988).

Adsorption of clay by PAM is thought to occur through hydrogen bonding. The charged functional group of the polymer aids in the adsorption step, typically at cation sites, until repulsive forces are too large and dispersion occurs. A study has shown that different PAMs can cause dispersion when applied above a certain maximum amount. For nonionic PAM a 200 mg/kg maximum was found and for anionic PAM, dispersion occurred above 50 mg/kg (Atesok et al., 1988).

How it Works

The basic principle to explain how PAM works is that it stabilizes the soil and prevents surface sealing, such that the soil was able to take in more water from rainfall events and therefore decrease the total runoff from an area (Shainberg et al., 1990). Researchers believe PAM increases the cohesive forces between soil particles at the surface in a thin layer (Lentz et al., 2010). Anionic PAM, the most commonly used form, binds to sediment mainly through cation bridging which produces flocs; this reaction is rapid and irreversible (Bhardwaj et al., 2008). Small amounts of Ca^{+2} in the water can cause the anionic surfaces of a soil to bridge with the PAM molecules allowing flocculation to occur (Sojka, 2001).

There are three different forms of PAM – powder, block, and emulsion – all with the same purpose of increasing flocculation to reduce turbidity (Bhardwaj et al., 2008). Studies have shown that PAM blocks are effective when applied under optimal conditions. Optimal conditions include keeping the blocks clear of sediment so that the storm water can make contact with the blocks and mix with the PAM. The blocks must stay moist between storm events (McLaughlin et al., 2009a), whereas the powder and emulsion forms of PAM need reapplication after every major storm event (McLaughlin et al., 2009b).

Adsorption of PAM on clay minerals can vary based on whether the polymer is anionic, cationic, or neutral, the dosage at which PAM is applied, and the pH. When low doses with the neutral polymer were applied, the clay/water sample appeared in its flocculated state with a clear supernatant. However, when the anionic polymer was applied in low doses, the sample was dispersed and formed a cloudy supernatant. Furthermore, for a neutral PAM, flocculation increased with an increase in the clay solution's pH when the initial concentration was low. With higher polymer dosage, flocculation did not vary with an increase in pH until the pH reaches 11, then PAM loses its ability to flocculate due to hydrolysis of the functional groups (Atesok et al., 1988).

How to Use PAM

Cationic and neutral PAMs are known toxicants, which should warrant caution from using them on a construction site discharging into water bodies because they can cause harm to aquatic life (Sojka, 2001). The California Stormwater BMP Handbook states that only the anionic form of PAM may be used (EC-13, 2003). This document also establishes guidelines for how to use PAM on construction sites.

First, PAM should never be applied to or allowed to directly enter a water body. When PAM is used on a slope, a sediment trap or basin must be located downstream to prevent discharge of PAM to a water body. PAM should preferably be applied to dry soil, but can be applied to wet soil if needed. For safety reasons, it is important to remember that PAM combined with water is very slippery, so caution should be used. Also, granular PAM loses effectiveness after sun exposure, so PAM should be kept out of the sunlight. In certain areas where tree foliage is rare, there would not be enough shade to allow for PAM to be placed outside. Lastly, the maximum rate that PAM should be applied to a site is ½ pound PAM per 1000 gallons water per 1 acre of bare soil. (EC-13, 2003).

Soil Impact

Soil texture and structure can have both positive and negative impacts on the effectiveness of PAM (Hayes et al., 2005). Because PAM is primarily used for clays, studies have investigated the reaction of PAM with the three categories of clay: montmorillonite, kaolinite, and illite. Montmorillonite is known for swelling. When water enters its layers, the montmonillonite layers separate easily. Kaolinite has layers held together through strong chemical bonds making it very stable and it does not expand significantly when wet. Illite’s layers are like montmorillonite, but there is potassium between each layer, which makes it stronger than montmorillonite, but weaker than kaolinite. Therefore illite expands slightly when wet (Coduto, 1999).

One study by Lentz et al. (2010) showed that for montmorillonite clays the order of adsorption was greatest in anionic PAM, followed by neutral PAM, and least in cationic PAM. Other previously reported studies found that cationic PAM had the greatest adsorption inmontmorillonite clays, and anionic PAM had the smallest adsorption (Lentz et al., 2010). Another study showed that neutral PAM causes flocculation in kaolinite soils at low doses, while the anionic PAM only produces dispersion (Astesok et al., 1988).

The kind of ions found in the three types of clays can impact the effectiveness of PAM, which are typically either calcium (Ca) or sodium (Na). The calcium ion has a double charge and small hydrated radius, which acts as a good bridge between anionic soil surfaces and PAM thereby increasing flocculation. Sodium ions have a comparatively large hydrated radius that prevents ion bridging, leading to dispersion instead of flocculation (Sojka, 2001).

A study by Bhardwaj et al. (2009) determined the different responses for the Ca and Na ions for each of the three clays using anionic PAM. The increase in flocculation was enhanced in the Ca-montmorillonite compared to the Na-montmorillonite at lower PAM concentrations, but as the concentration of PAM increased, flocculation decreased. For illite soils, PAM was shown to cause flocculation in Ca-illite better than Na-illite. The flocculation trend suggested that cation bridging was the primary way of bonding the anionic PAM to the negatively charged illite clay. Lastly, for kaolinite, PAM caused flocculation at only low concentrations and caused dispersion at higher concentrations. The results of this study show that PAM is affected by soil factors such as the “size and shape of the particles, their association, and orientation in solution” (Bhardwaj et al., 2009).

PAM Effectiveness

The effectiveness of PAM on highway construction sites is somewhat variable. After application at one site, PAM reduced turbidity for only two storm events but not after multiple events for any ground cover combination. Further, PAM only reduced turbidity when added to the mechanically bonded fiber matrix (MBFM) and the erosion control blanket (ECB) treatment, but only for the first rain event (McLaughlin et al., 2006).

When PAM was applied to bare soil by itself, turbidity was reduced, but not as much as just the ground cover. The average turbidity with just the PAM application was double the average turbidity for the ground cover applications with no PAM added (McLaughlin et al., 2006). However, PAM added to a straw mulch treatment was more effective than either PAM or straw mulch alone – the straw mulch and dry PAM reduced sediment loads by 92% and 82%. Yet, the PAM applied to the seed/mulch treatment did not have a statistical effect when compared to the seed/mulch alone (Hayes et al., 2005).

For slopes ranging from 20 to 50%, PAM added to a straw mulch/seed combination was ineffective at reducing turbidity significantly unless the application rate was 80 kg/ha. On slopes of about 6 to 9%, PAM reduced sediment yield at only 20 kg/ha (McLaughlin et al., 2006). On a 50% fill slope, PAM did not decrease turbidity by itself, but on a 20% cut slope, PAM reduced turbidity for first of six storms (Hayes et al., 2005).

Best Management Practices

Detention/Retention Basins

One common Best Management Practice (BMP) used on construction sites to reduce turbidity is detention/retention basins. Large well-stabilized basins with surface outlets are very efficient and have been known to achieve up to a 99% sediment capture efficiency. Sediment traps with gravel outlets were reported to trap 59-69% of incoming sediment for a 20 month time period. However, standard sediment traps (ST) often reported increases in turbidity measurements, and were deemed ineffective at turbidity control. Modified ST systems which include a forebay, porous baffles, PAM, and a floating outlet instead of a rock dam outlet, known as SkFBPam, were able to reduce turbidity 82-99% for three storm events (McLaughlin et al., 2009b).

One study by McCaleb and McLaughlin (2008) determined the effectiveness of five different types of basin setups. The first was the Skimmer Basin (skB), which retained 99.6% of sediment and had an average turbidity of 1070 NTU. The second was the standard trap (10ST), which retained 35% of sediment with an average turbidity of 2090 NTU. The standard trap with a standing pool retained 34% of sediment and had an average turbidity of 130 NTU. A basin sized for a 25-year recurrence storm (25ST) reported an average turbidity of 4410 NTU. Finally a standard trap with silt fence baffles (STSFB) was able to retain 45% sediment, but reported a 12640 NTU for the average turbidity. (McCaleb et al., 2008)

Often times a basin has to be modified from the standard to increase effective sediment capture. Energy dissipaters with a basin, such as baffles, reduce turbulence allowing sediment particles an increased opportunity to settle (Bhardwaj et al., 2008). Turbulence is a common occurrence that increases turbidity by prolonging particle suspension in the water column. A jute/coir baffle was one of the most effective baffles in reducing turbulence, capturing smaller sized particles, and thereby reducing turbidity. Whereas the silt fence was less effective because of the localized currents formed by the weirs and overtopping problems. Skimmers are also known for their effectiveness in increasing sediment capture. Modeling has shown that skimmers are superior in increasing sediment capture when compared to either bottom or full water column dewatering (Thaxton et al., 2005).

Ground Covers

Aside from retention/detention basins other BMPs are in practice and have been shown to reduce turbidity on construction sites. Straw, erosion control blanket (ECB), and mechanically bonded fiber matrix (MBFM) were all shown to reduce turbidity significantly. The presence of ground covers such as these were able to reduce turbidity by a factor of 4 compared to bare soil alone (McLaughlin, 2006). A seed and mulch ground cover treatment was able to reduce turbidity in 4 of 7 events and sediment losses in 4 of 6 events (Hayes et al., 2005).

One other ground cover, compost erosion control blankets (CECBs) were able to reduce the amount of runoff 65% compared to bare soil and 50% compared to a hydromulch treatment over a 12-month period. CECBs effectiveness can vary depending on the thickness applied. Total amount of runoff reduction increased with increasing CECB thickness for a given depth of rainfall where the magnitude of the runoff reduction decreased with increasing rainfall (Beighly et al., 2010).

Ground covers are common BMPs for construction sites, and they can substantially decrease erosion caused rainfall events and decrease turbidity values in the runoff leaving the site. Often the more ground cover treatments applied, the more effective the treatments will be in decreasing runoff turbidity. Combining treatments, such as the seed and mulch ground cover combination, can also effectively decrease erosion on site.

Currently, TxDOT in Lubbock has employed certain BMPs such as silt fences and rock-filter dams to control turbidity and sediment loss. The data collected on runoff turbidity exiting from one of the highway construction sites in Lubbock, TX will reflect the effectiveness of these BMPs. Chapter 3 discusses how samples were collected In Lubbock at two highway construction sites and how the samples were tested for turbidity and how measurements were recorded.

Chapter 3 – Methodology

Overview

Sampling was done at the discharge points located on the two TxDOT sites chosen in Lubbock, TX. The first site, located on the Marsha Sharp Freeway, with a watershed area of approximately 160 acres, depicted in Figure 1, had one discharge point while the second site located on the West Loop 289, with a watershed area of approximately 52 acres. Figure 2 shows the two discharge points to be sampled during a rain event. Grab samples were the means of collecting a water sample from each point. A clean collection bottle was the necessary tool in order to collect each grab sample.

Collecting a Sample

Once the discharge locations were established and a rainfall event occurred, the analyst(s) visited the site. With a clean collection bottle the analyst stood downstream of the discharging water with the bottle opening facing in the direction of the flow. The bottle was positioned above the ground in order to avoid disturbing the settled sediment and to reduce impacts to the turbidity measurement. For low flows, a scoop was used to capture a sample so that the bottom settlements were not disturbed, and for hard to reach locations, a pole was attached to a bottle to retrieve a sample, which are recommendations from other state protocols (Washington State, 2007). A single grab sample from each sampling location was considered sufficient.

Labeling the Samples

Before going out to each site, collection bottles were prepared for labeling. Labeled bottles had a strip of tape placed on the bottle, not the lid, with the sampling locations written in permanent marker on the tape for each of the four locations. After collecting a sample in the field, further information such as the date, time, and sampler's initials were added. The purpose of labeling the bottles was to avoid confusion in the lab so that the results were documented correctly. Labeling with tape, rather than labeling the bottle itself, allowed the bottles to be reused for another rainfall event after disposing of the samples.

Parking Locations

When visiting the sites, it was important to know where to park. For the Marsha Sharp Freeway location, there was a small parking lot in Mackenzie Park near the discharge point that provided a safe parking spot near the construction site. For the West Loop 289 site, Slide road provided adequate shoulder parking on access curbs both while this section of the road was closed and after it opened in order to reach the site discharging to the playa safely. For the discharge points to the tennis courts, a parking lot right near the site was used. Figures 2 and 3 show maps of the two locations with the parking areas and collection points labeled.

Figure 2. Marsha Sharp Freeway Location – Parking and Discharge Area (Data image captured July 2011 from Google images)

Figure 3. West Loop 289 Location – Parking and Discharge Areas (Data image captured July 2011 from Google images)

Sampling Locations

For the Marsha Sharp Freeway location, there were rills in the slope that led to a playa in Mackenzie Park. If water was flowing in these cracks, samples were collected. In most cases, when the storm did not produce enough rain for substantial runoff, a puddle formed at the bottom of the slope around a culvert or silt fence, and the samples were collected at this location. At the West Loop 289 site, samples were taken on the side that flowed into the playa, just where the water left the culvert and entered the stream bed.

This site was difficult to reach at times and required the use of a pole to reach the runoff stream. The other side of the Loop 289 project discharged towards neighborhood tennis courts is where grab samples were taken from as the water left the two culverts and formed puddles. The West Loop 289 location resulted in at least three samples collected for each rainfall event.

Figures 4 and 5 show the actual discharging locations when sample collection began and when testing ended. The sites changed between beginning and end of sample collection, which resulted in slight changes of how and where to take samples safely. Initially the culvert at the West Loop 289 location to the playa had a bare earth channel bottom. At the end of sample collection the culvert had a bottom with rocks and a wire mesh requiring the sampling personnel to use a pole to collect a sample inside the culvert. The culvert at the Marsha Sharp Location connected to the playa at the end of sample collection, which no longer provided a puddle that allowed for collection at the beginning of the project. Instead, puddles behind silt fences had to be used to collect samples.

Figure 4. West Loop 289 Discharge Location to the Playa

Figure 5. Marsha Sharp Freeway Discharge Location

Testing and Recording Turbidity

For this project, turbidity was measured using two machines. The Hach 2100P ISO was the portable turbidimeter taken in to the field, and had a range from 0-1000 NTU. The other turbidimeter, the Hach Model 2100N, was kept in the lab and used as soon as possible after collection, and had a range from 0-4000 NTUs. Sample preparation was the same for both instruments.

Preparing Sample Cells for Analysis

To prepare a sample, a clean sample cell was filled with water from the collection bottles to a line near the top of the sample cell. The analyst must remember during this process to avoid touching the sides of the sample cells during preparation, and if at all possible only touch the top and bottom of the cell. Once the cap was placed back on the sample cell, the cell was held by the cap while the outside was cleaned with a tissue. While still holding only the cap, a drop or two of silicone oil was applied to the outside of the sample cell and cleaned using the oiling cloth provided in the kit (Hach Company, 2003 and 2008).

When using the portable 2100P turbidimeter, the sample cell was prepared immediately after collection. The 2100N lab turbidimeter required the collection bottles to be shaken before the sample cells were filled because of a time lapse of transporting the collection bottles to the lab. For each sample used in the lab turbidimeter, the closed collection bottle was moderately shaken for ten seconds to resuspend settled particles. The bottle was then placed on a level surface for 30 seconds before the sample cell was prepared (Bhardwaj et al., 2008).

Turbidity Measurements

Before measurements were made in either one of the turbidimeters, the turbidimeters were calibrated according to the user manuals (Hach Company, 2003 and 2008). Once the turbidimeter was calibrated and the sample cell was prepared, the cell was placed into the respective turbidimeter with the arrow on the sample cell lined up with the notch in the turbidimeter. To read the turbidity, the machine was turned on and the range was set to automatic and the signal averaging setting was turned on. For the 2100N model in the lab, the ‘units’ key had to be pressed in order to provide measurements in NTU (this step was not necessary for the portable turbidimeter). The ‘read’ button was then pressed and the turbidity value recorded in the data sheet shown in Table 1 for each sample taken.

Table 1. Sample Data Sheet

Technician(s) Name:	
Date of Storm Event:	
Time Sample Collected:	
Location:	
Time Field Measurements Taken:	
Time Lab Measurements Taken	
Turbidity (NTU) in the field:	
Turbidity (NTU) in the lab:	

Once each data sheet was filled out, they were filed into a binder and transcribed into the main operator's lab notebook. Samples could then be stored at 4°C (39°F) for up to 48 hours if needed (Washington State, 2007).

Sample Photographs

Before samples were discarded, photographs of each sample were taken in the sample cells that they were prepared. To avoid variations in lighting, photographs were always done in the lab where the 2100N turbidimeter was located. After the sample had been read in the turbidimeter, it was placed on a sheet of white computer paper on the table with another sheet taped to the lab table behind it. The sample cell was placed in the middle of the paper on the table, and the picture was taken at approximately eye level to the sample cell. In order to avoid variations as the paper got older and discolored, new sheets of computer paper were used for different sampling days. Figure 6 provides a configuration example of the picture set-up.

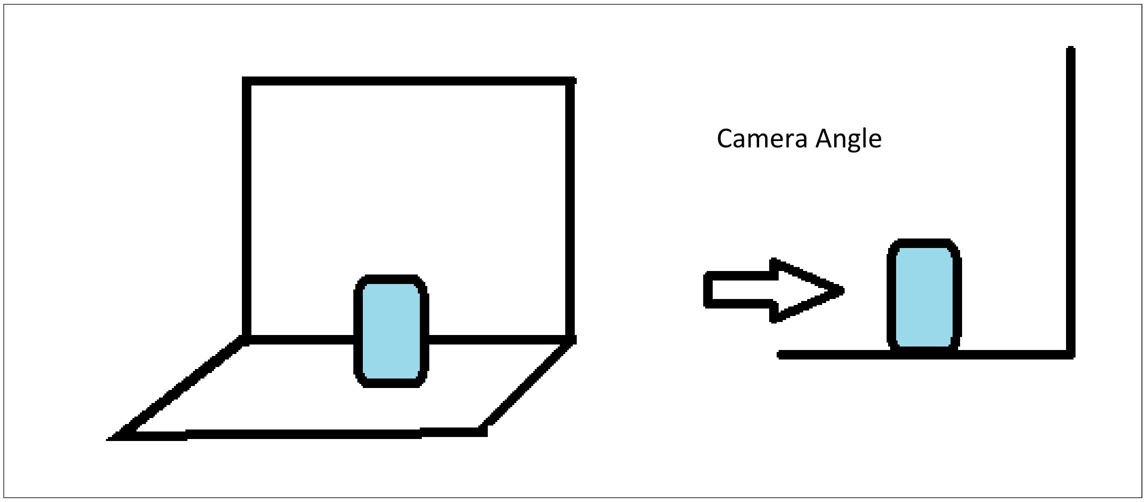

Figure 6. Camera Set-up

Pictures taken in the lab were then labeled. The pictures were downloaded to a computer and printed as soon as possible to avoid confusion of the sample pictures. The computer file name for each picture included the date (YYYYMMDD), location, and both turbidity measurements. For example, a sample taken on January 23, 2011 at the Marsha Sharp Freeway location, with turbidity measurements of 210 NTU in the field and 234 NTU in the lab – the file name for that picture would have been 20110123_MSF_210_234. For the West Loop 289 location use WL289 instead of the MSF (Marsha Sharp Freeway) example. A print out of each picture was kept directly behind the matching data sheet for that sample in the lab binder. The picture files were kept on the main operator’s project flash drive as well. If someone other than the main operator took the pictures, the files were e-mailed to him/her as soon as possible.

Sample Discarding

Once all necessary measurements and photographs were taken and recorded, the water samples in the sample cells and collection bottles were discarded. The samples were poured down the sink unless the lab room in which the operator(s) is working in stated otherwise. Both the sample cells and collection bottles were rinsed with distilled water from the water line. To turn the distilled water on, the pump by the sink had to be turned on and then the distilled water faucet could be used.

The bottles and cells were rinsed with three rinses – the collection bottles were filled approximately a quarter of the way and the cells were filled half way with distilled water. For each rinse the water was swished around in the bottle or cell, with the cap on, for approximately 10 seconds then poured down the sink. The collection bottles and samples cells were then placed back on the lab table to air dry with the lids set on paper towels.

Chapter 4 – Results and Discussion

Raw Sample Results

During the course of the study four rainfall events occurred that allowed for sample collection at both the Marsha Sharp Freeway and the West Loop 289 locations. March 4, May 11, and August 11, 2011 were the two days that samples were obtained for both. July 12, 2011 allowed for one sample to be collected from the Marsha Sharp Freeway location only. For the two times samples were collected at both sites, four total samples for each rainfall event were collected - one at the Marsha Sharp Freeway location and three at the West Loop 289 location. Table 2 shows a sample data sheet used for one of the samples.

Table 2. Sample Data Collection Sheet

Technician(s) Name:	Holly Murphy
Date of Storm Event:	5/11/2011
Time Sample Collected:	6:15 am
Location:	WL 289 – playa
Time Field Measurements Taken:	6:30 am
Time Lab Measurements Taken	10:30 am
Turbidity (NTU) in the field:	>1000
Turbidity (NTU) in the lab:	601

Turbidity values observed in the field ranged from 20 NTU up to around 10,600 NTU. However, there was a difference in the 2100P field and 2100N lab turbidimeter. For all measurements the field turbidimeter read larger values than the lab turbidimeter. A brief synopsis of the values read for each sample collected is shown in Table 3. The samples collected on March 4th were not collected by the main operator on the project, therefore, the sample collecting personnel did not have access to the field turbidimeter, and measurements were only performed in the lab.

Table 3. Overview of Sample Turbidity Values

Date	Sample	Field (NTU)	Lab (NTU)
3/4/2011	MSF	-	21.6
3/4/2011	WL289 - playa	-	1889
3/4/2011	WL289 - small tennis	-	252
3/4/2011	WL289 - large tennis	-	60.2
5/11/2011	MSF	E5	2205
5/11/2011	WL289 - playa	>1000	601
5/11/2011	WL289 - small tennis	449	226
5/11/2011	WL289 - large tennis	87.7	49.0
7/12/2011	MSF*	>1000	>4000
8/11/2011	MSF	E5	4280
8/11/2011	WL289 - playa	399	225
8/11/2011	WL289 - small tennis	353	170
8/11/2011	WL289 - large tennis	300	145
9/14/2011	WL289 - playa	486	235
9/15/2011	WL289 - small tennis	51.0	32.2
9/15/2011	WL289 - large tennis	32.6	22.9
9/15/2011	MSF	425	238

*A dilution series was performed on this sample in the lab machine only and produced a final 10,600 NTU reading

Photographs of each sample collected and tested are shown in Figures 7-11, sorted by date collected. These photographs provide a visual relationship between NTU value and the water quality. The figures also include the turbidity values for each sample with the field turbidimeter measurement labeled first followed by the lab turbidity measurement.

Figure 7. Samples Collected on March 4th, 2011

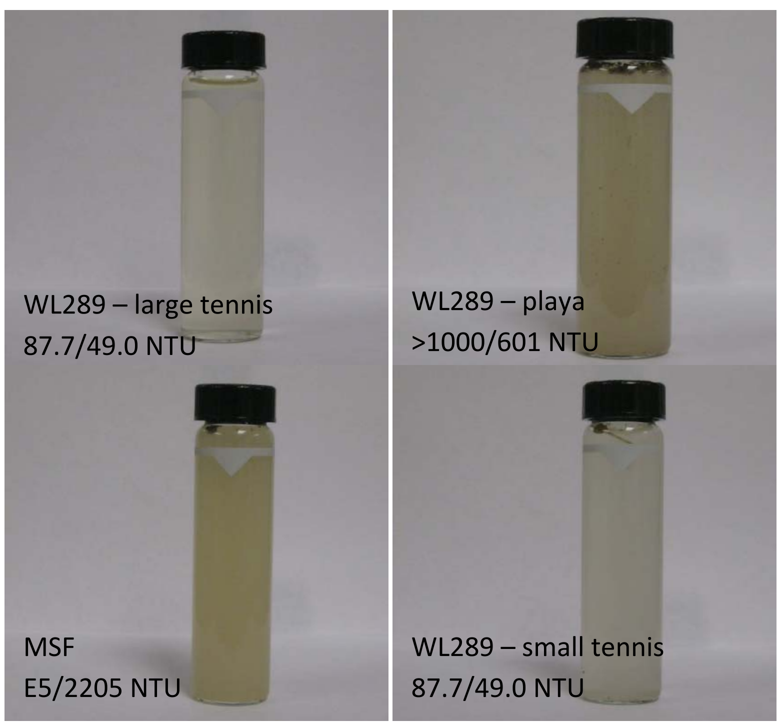

Figure 8. Samples Collected on May 11th, 2011

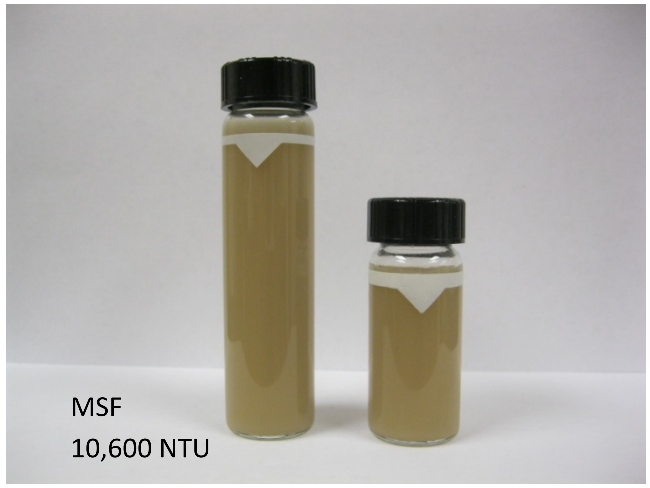

Figure 9. Sample Collected on July 12th, 2011

Figure 10. Samples Collected on August 11th, 2011

Figure 11. Samples Collected on September 15, 2011

Discussion

All measurements made with the 2100P field and 2100N lab turbidimeter varied, in that the field turbidimeter read almost twice as high as the lab turbidimeter in most samples tested. For the one sample from the WL289-playa taken on May 11th, the field turbidimter read the sample as out of range, or greater than 1000 NTU. However, the lab turbidimeter read the sample as 601 NTU, which is below 1000 NTU range of the field turbidimeter. Also, there was one instance when the field turbidimeter read an error of E5, despite multiple measurements of the MSF sample taken on May 11th. This E5 error message is related to an obstruction of light within the instrument according to the HACH turbidimeter manual (Hach Company, 2003).

When discussing this problem with a representative from HACH, it was said that this error was probably due to the presence of color – an explanation also given for the differences in turbidity readings between the two instruments. The MSF sample taken on May 11th had a higher turbidity than the rest (excluding the one taken on July 12th) and had a brighter appearance than the others. Therefore, this theory of the presence of color causing the error may be true. More detail on the machine differences is provided in Chapter 5.

Even with BMPs in place, turbidity values in the runoff from sites in the bare earth phase are at high numbers. For all results, except for the samples taken in at the West Loop 289 project site by the tennis courts, turbidity values were greater than 1000 NTU. The samples taken at the tennis courts could be considered direct runoff results from the site, puddles that formed by the culverts that lead from the neighborhood to the other side of the project out towards the playa or both. Still, these samples provide comparison of values in runoff from the sites to puddles that form near the site.

Chapter 5 – Topic Specific Experiments

Due to the drought in 2011, more topics involving turbidity were discussed and included for this project. Because the literature pointed out that the color of a sample can increase or decrease turbidity values, experiments were done to determine if the color of water and/or the color of the particles mattered. Also, the question of dilution for turbidity arose to extend instrument range, which led to a dilution experiment and written protocol for construction site workers. The background turbidity for the state of Texas was of importance in order to determine current water turbidity values around the state. Lastly, an instrument comparison between the two turbidimeters used in these projects is discussed. The order of the five topic specific papers is as follows:

1. Effect of Colored Water on Turbidity
2. Effect of Colored Precipitates on Turbidity
3. Dilution as a way to Extend the Range of a Turbidimeter
4. Background Turbidity Levels for the State of Texas
5. Instrument Variability Issues

Effect of Colored Water on Turbidity

Introduction

The presence of color has been known to have impacts on turbidity measurements. Darker colors absorb light so less light reaches the detectors in turbidimeters, thereby decreasing values. The opposite is true of lighter colors – light bounces off of light colors, increasing turbidity values (Sadar et al., 2011). The purpose of this study on the color of water is to determine water color may affect turbidity measurements. This study of the effect of colored water on turbidity evaluates colored tap water impacts on turbidity measurements in the absence of visible solids.

Methods

To determine if the color of water affected turbidity levels, experiments were completed for three colors: blue, yellow, and green. These colors were chosen because they were available as common food dye colors. For these experiments, 200mL of tap water for each color was needed. Once a beaker was filled with 200mL of tap water, the turbidity of the pure tap water was measured in both the 2100P and 2100N turbidimeters. After the values were recorded, the water in both of the vials was added back to the beaker. Special care was taken during this time to keep the vials clean as they would be used for each step for the color being tested as to avoid differences in sample cells from affecting turbidity measurements because the values were so low.

Next, one blue drop of food coloring dye was added to the 200mL of tap water. The drops used were equivalent to 0.1 mL per drop. The one drop sample was mixed in the beaker and then added to the same vials used for the tap water. Turbidity values were then measured in both turbidimeters and recorded. Again, the contents of the vials were emptied back into the beaker. One more drop was added to the 200mL of tap water to make the solution two drops of blue dye to 200mL water. The two drop solution was tested, recorded, and emptied back into the beaker. These steps were repeated and tested for the color blue using four drops to 200mL tap water and 16 drops to 200mL tap water.

Once the color blue had been tested, the beaker and vials were rinsed three times using deionized water. The procedure was then followed again for the colors yellow and red. An example of the table used for each color is shown below in Table 4. The “Field (NTU)” column refers to the turbidity measurements in the portable turbidimeter 2100P and the “Lab (NTU)” column refers to the measurements made in the 2100N turbidimeter.

Table 4. Sample Measurement Chart

COLOR:		
# of drops to 200mL tap	Field (NTU)	Lab (NTU)
0		
1		
2		
4		
16		

Results

For the color of water experiment results, data was recorded and shown below in graphical form in Figures 12 through 14 for the colors blue, yellow, and green. Lines were placed on each graph to show the original tap water’s turbidity value before colored drops were added for both turbidimeters. In general the presence of color had an approximate 20-50% increase on the turbidity value for the one, two, and four drop samples, and over 60% increase for the 16 drop samples. In most cases the field turbidimeter read a little higher than the lab turbidimeter. For Figure 12, both machines read the same value for the one and two drop samples of blue.

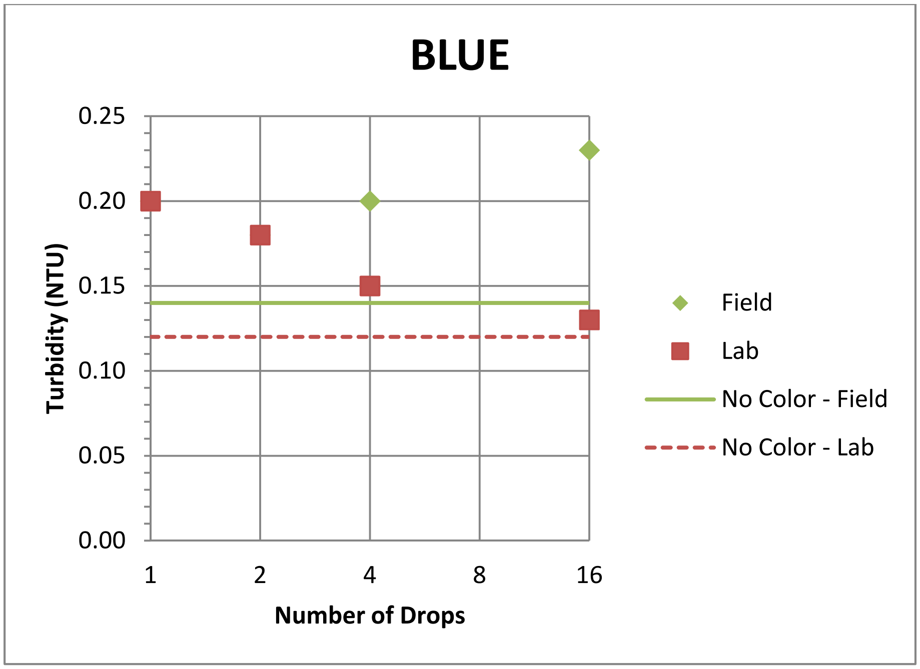

Figure 12. Graph Results for Blue Water

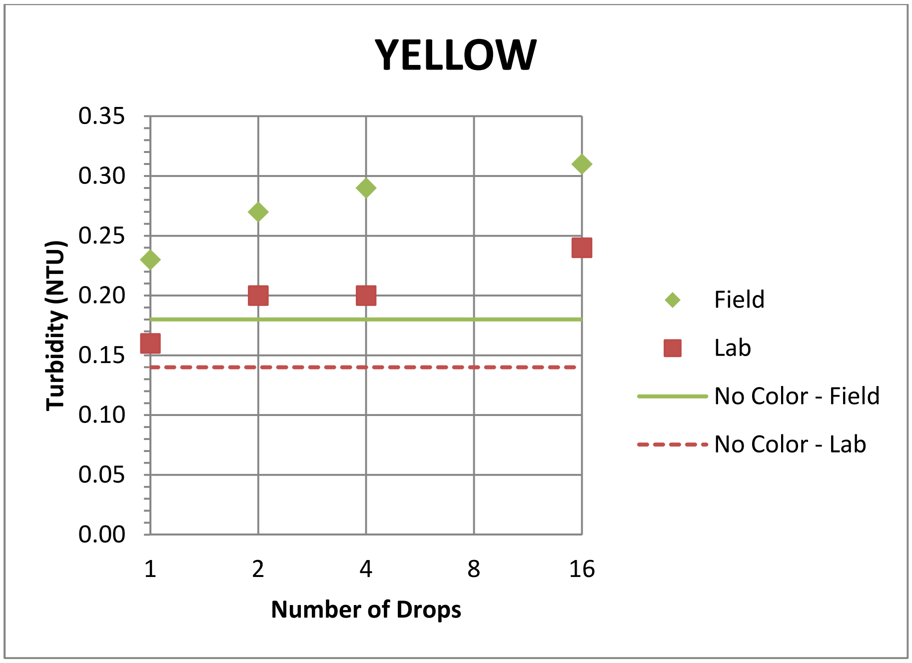

Figure 13. Graph Results for Yellow Water

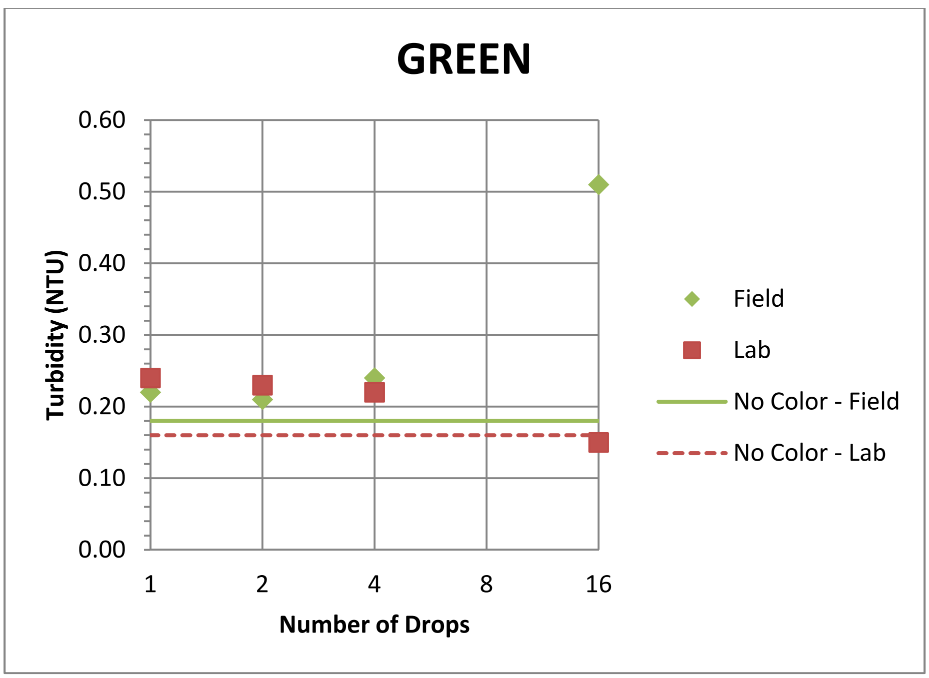

Figure 14. Graph Results for Green Water

For a visual description of the color of the water in terms of the number of drops for each color tested, refer to the next Figure 15. The pictures are ordered from one drop to 16 drops of food dye. The vials in the pictures were the actual vials used when making the turbidity measurements.

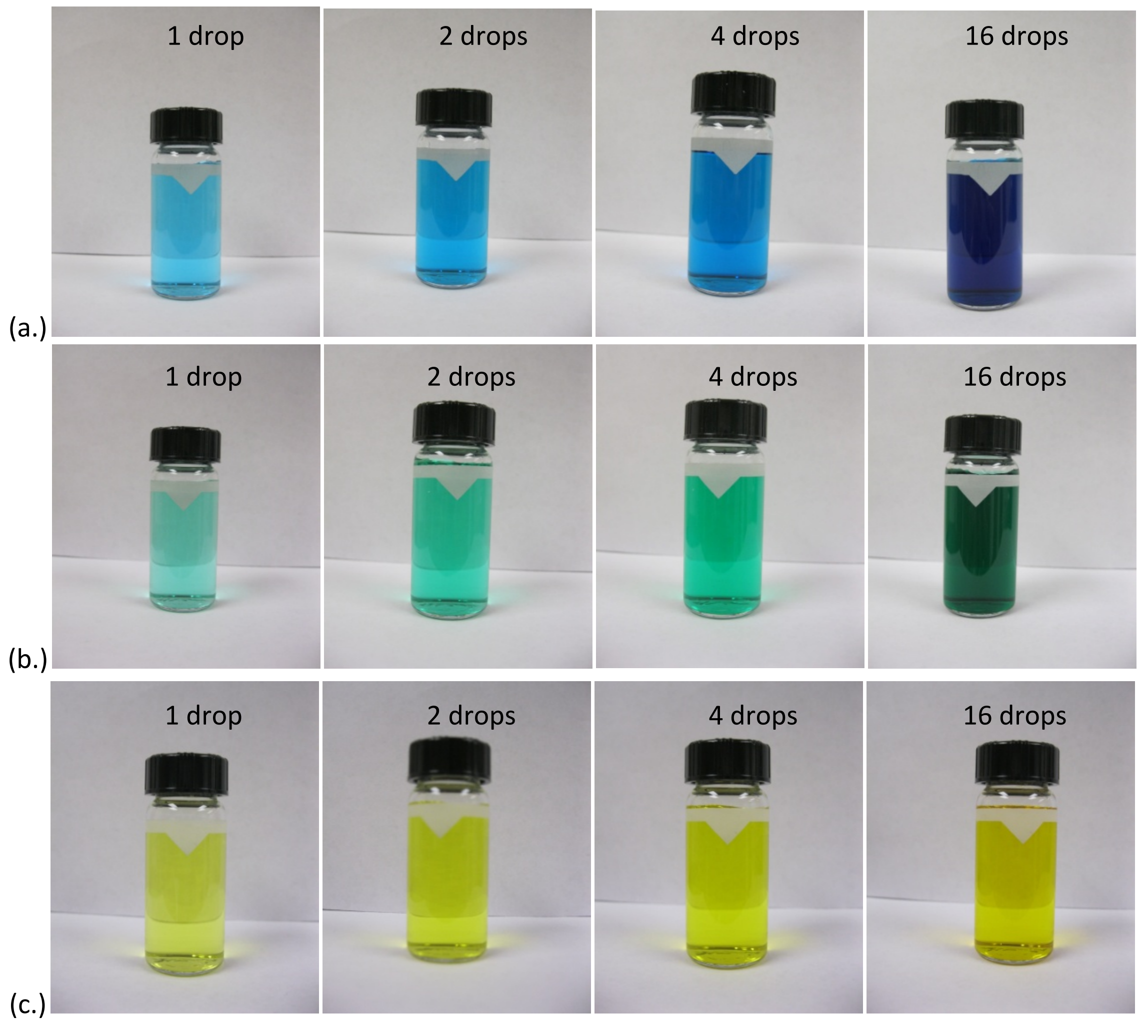

Figure 15. Color Variations for (a.) Blue Water, (b.) Green Water (c.) Yellow Water

Conclusions

The color of water has an effect on turbidity values, but it is minimal in such a way that the increase or decrease would not be noticeable in highly turbid water. Although there was a general increase in turbidity values as the number of drops increased for each color for the field turbidimeter, there was a decreasing trend in the lab turbidimeter for all colors except yellow.

These variations could be attributed to simply the water sample being tested. The tap water values with zero drops varied themselves between each color series by approximately 30% at most. Considering how minimal the increase or decrease in turbidity values due to water color, this is not a factor of concern when determining how much color may affect turbidity measurements of extremely turbid water samples when suspended solids are present.

Effect of Colored Precipitates on Turbidity

Introduction

Turbidity is the result of suspended sediments present in a water column. The variation in color of these sediments may have an effect on the turbidity measurement of a sample. Particles darker in color would absorb light and decrease turbidity results, while colors that are brighter would reflect light and increase turbidity measurements.

Turbidity has been shown to vary by a factor of 10 due to color effects (Sutherland et al., 2000). This means that white particles could produce a turbidity measurement 10 times larger than black particles of the same size and concentration. The formazin standards for calibrating a turbidimeter are bright white, which could alter the measurements for darker colored samples (Downing, 2005). The purpose of this experiment is to determine the effect of particle color on turbidity using solid precipitates formed in the lab.

Methods

A lab experiment was set up to determine the effects of a red and white precipitate on turbidity values. The red precipitate, silver chromate (Ag_2CrO_4) was formed by adding silver nitrate ($AgNO_3$) to potassium chromate (K_2CrO_4) in deionized water. Silver nitrate was also used to form the white precipitate, silver chloride (AgCl), and reacted with sodium chloride (NaCl) in deionized water.

To keep the concentrations for each precipitate equal so as to reduce turbidity concentration impacts, the target concentration for each precipitate was set at 300 mg/L in water to allow for enough precipitate to later perform serial dilutions on the solution.

Stoichiometry and solubility constants for each precipitate were used for each reaction to determine how much reactants should be added to form the correct concentration of precipitate. Figure 16 below shows the two reactions used in this experiment.

Red Precipitate: $AgNO_3 + K_2CrO_4 \rightarrow Ag2CrO_{4(s)} + 2KNO_3$

White Precipitate: $AgNO_3 + NaCl \rightarrow AgCl_{(s)} + NaNO_3$

Figure 16. Reactions used to form Precipitates

The total suspended solids (TSS) test procedure was applied to each solution after the precipitate was formed in order to determine if the calculations were correct and there was 300mg/L of each precipitate (Clesceri et al., 1998). The standard method however proved ineffective as both precipitates passed through the filter. Therefore, 200 mL of each solution was placed in a beaker to be put into the oven until all the water had evaporated. Measuring the beaker before and after would allow the total solids (TS) for each solution to be calculated. The researcher assumed in this experiment that TSS and TS were equal to each other because the precipitates was formed in the lab and should therefore have no other solids present. Samples were then tested for turbidity in the 2100P field turbidimeter and the 2100N lab turbidimeter. A dilution series test was then done for each sample.

Results

Once testing was completed it was found that the concentrations for the silver chromate and silver chloride were not equal. The red precipitate formed more solids than the white one. There was 620 mg/L of silver chromate and 415 mg/L of silver chloride.

The solutions tested for turbidity were taken from the same bulk solution that was used to test the 200 mL of each precipitate for TS so as to make later comparisons between turbidity values and concentrations. The turbidity results for each of the solutions made are shown in Tables 5 and 6. The "actual" turbidity measurements are the value shown by the turbidimeter for that dilution multiplied with the multiplier. The 2100P turbidimeter is the field turbidimeter and the 2100N turbidimeter is the lab turbidimeter.

Table 5. Silver Chromate Turbidity Dilutions

Silver Chromate Turbidity Dilutions					
Dilution #	Field (NTU)	Lab (NTU)	Multiplier	Actual Field (NTU)	Actual Lab (NTU)
1	E3	> 4000	1	-	-
2	E5	3149	2	-	6298
3	E5	1408	4	-	5632
4	460	598	8	3680	4784
5	118	205	16	1888	3280
6	71	50.7	32	2272	1622

Table 6. Silver Chloride Turbidity Dilutions

Silver Chloride Turbidity Dilutions					
Dilution #	Field (NTU)	Lab (NTU)	Multiplier	Actual Field (NTU)	Actual Lab (NTU)
1	E5	3362	1	-	3362
2	E5	1422	2	-	2844
3	563	575	4	2252	2300
4	276	298	8	2208	2384
5	155	164	16	2480	2624
6	95	75	32	3040	2400

For a visual representation of the solution color for each precipitate during the turbidity testing, refer to Figure 17 and 18. The figures are labeled with the dilution number and turbidity values that they correspond to in the previous tables.

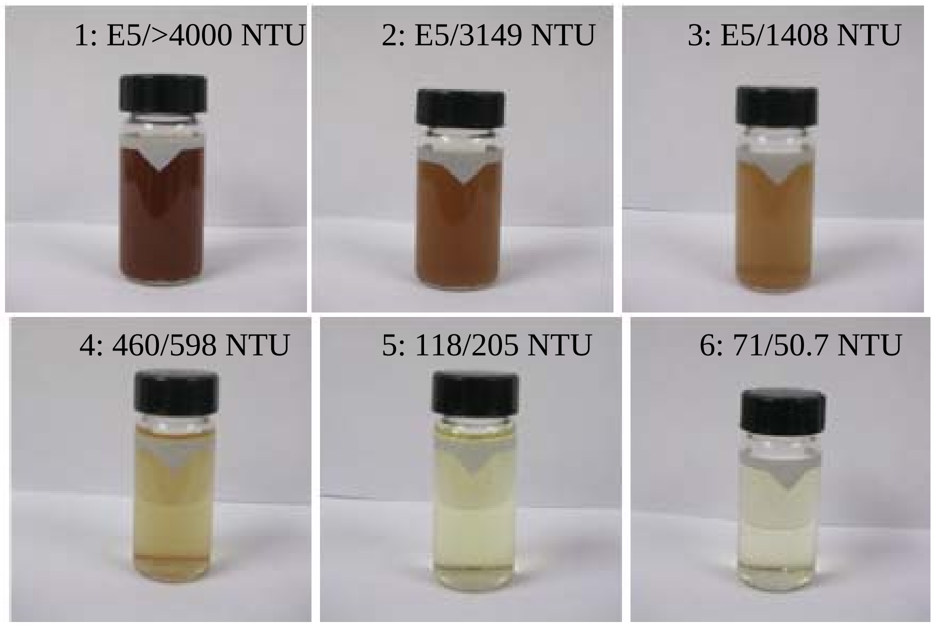

Figure 17. Silver Chromate Dilutions

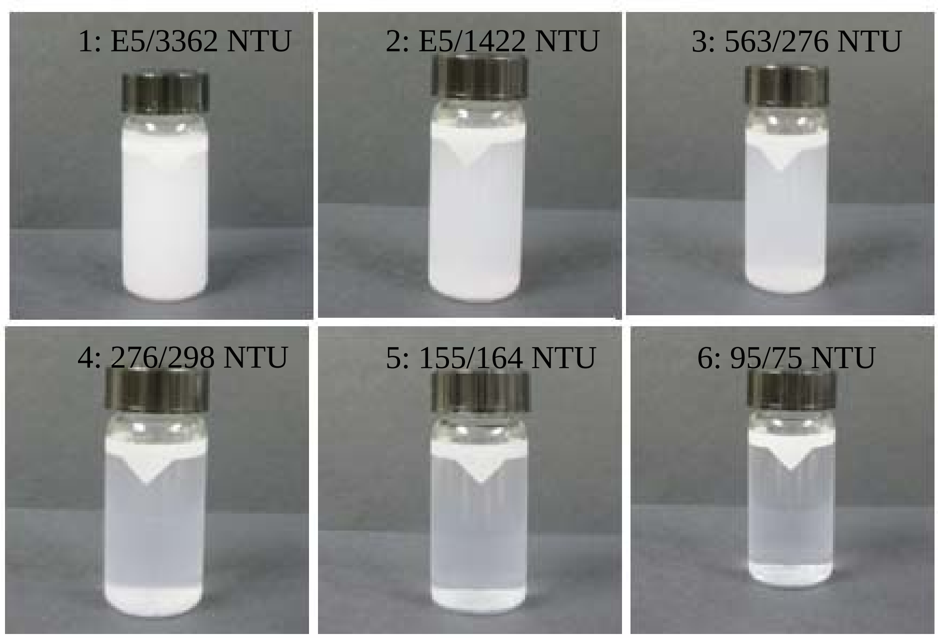

Figure 18. Silver Chloride Dilutions

Because the concentrations for each precipitate were different from each other the NTU per mg/L concentration for each field and lab turbidity measurement were calculated for each precipitate. The first turbidity value shown in the “actual” field or lab column was used because the turbidity values decreased with each dilution number and this value would represent the most accurate value of the original sample. Table 7 shows the comparisons of the NTU per mg/L value for each precipitate.

Table 7. Comparison of Red and White Precipitates

Precipitate	Field (NTU/(mg/L))	Lab (NTU/(mg/L))
Red Silver Chromate	5.9	10.2
White Silver Chloride	5.4	8.1
Percent difference between Red and White	9.4%	25.4%

Conclusions

The results show that the red and white color variation only contributes a minor difference in the field turbiditmeter but a larger difference in the lab turbidimeter based on the turbidity per concentration results. According to the literature, color can affect turbidity measurements, such that darker colors absorb light and decrease turbidity. If white particles can report a turbidity measurement up to ten times larger than black particles, it was expected when comparing the white silver chloride with the dark red silver chromate, that the silver chloride would report larger turbidity values per concentration. In this experiment, the opposite was true. The darker color, silver chromate, produced larger turbidity readings per unit of concentration.

The slightly higher turbidity per concentration for the red precipitate could be attributed to particle size. The red silver chromate precipitate had a larger sized diameter than the white silver chloride. This size difference was noticeable to the eye, but more so in the traditional TS procedure when all of the silver chloride passed through the 55 µm filter, while some of the silver chromate was retained on the same 55 µm filter. Further testing of this phenomenon is recommended to determine the true extent of the effects of particle color on turbidity measurements; however, the author believes color effects in natural Texas waters will be negligible unless truly “black” particles are encountered.

Dilution as a way to Extend the Range of a Turbidimeter

Introduction

There were times in the field when collected samples exceeded the range of the portable 2100P turbidimeter. For these instances, a procedure for sample dilution procedure was developed that would be easily performed by construction site workers. Further experimentation was completed to determine if a dilution procedure was an appropriate way to extend the range of a turbidimeter. The procedure calls for a measuring cup and bottled water which would be cost-effective and easy to attain for construction companies. Also, the procedure is simplified to using this measuring cup instead of a pipette for ease of going through the procedure either in the field or back at the foreman's building on site.

To determine the acceptability of dilution in regards to turbidity values, lab tests were completed using both the field (2100P) and lab (2100N) turbidimeters. Dilution testing was done on previously collected turbidity samples, one from the Marsha Sharp Freeway collected on May 11th and the samples from West Loop 289 to the playa collected on May 11th and March 4th. All dilution experiments in the lab were done following the "Turbidity Dilution Procedure to Extend Instrument Range" given in the next section.

Methods

Turbidity Dilution Procedure to Extend Instrument Range:

1. After collecting a sample, test turbidity in turbidimeter. Do not discard the turbidity sample in the collection bottle until all testing is complete.
2. If the turbidimeter returns a numeric value, record in CHART (shown in Table 1) for Step 1 under column (2) and complete the row calculations. Leave the other rows blank. If the turbidimeter returns an error notification record "ERROR" for Step 1 then continue this procedure.
3. Prepare a 1:2 dilution of the collected sample using Figure 19. (*See note at end of procedure.)

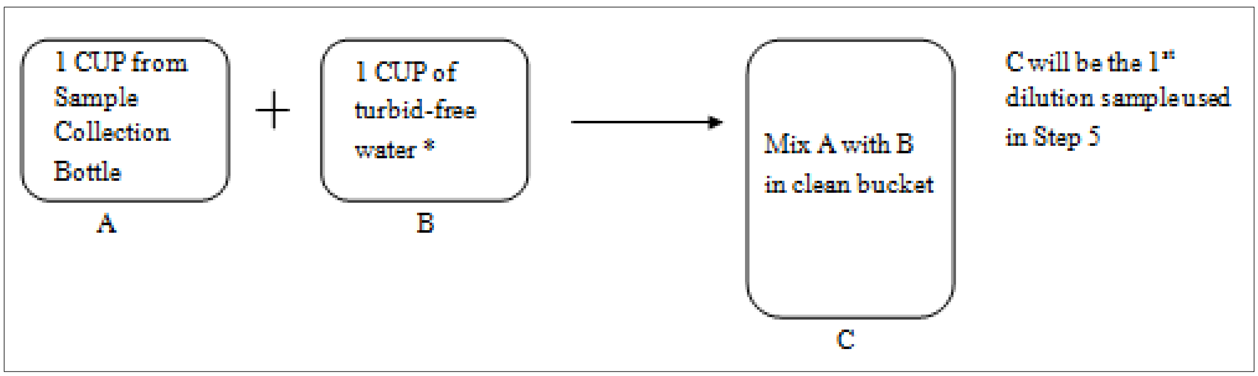

Figure 19. First Dilution

4. Test the 1st Dilution (C) in the turbidimeter.
5. If the turbidimeter returns a numeric value, record in CHART for Step 2 under column (2) and complete the row calculations. Leave the other rows blank. If the turbidimeter returns an error notification record "ERROR" for Step 2 then continue this procedure.
6. Prepare a 1:2 dilution of the 1st Dilution (C) using Figure 20.

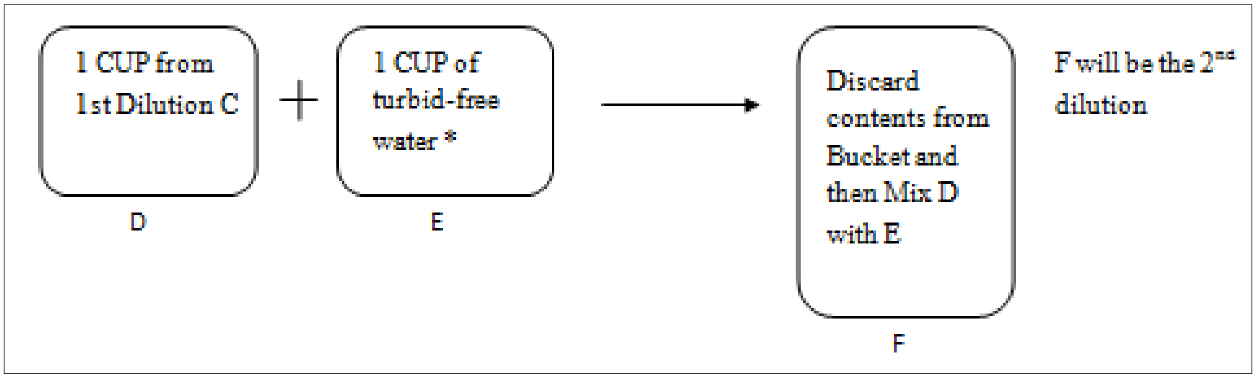

Figure 20. Second Dilution

7. Test the 2nd Dilution (F) in the turbidimeter.
8. If the turbidimeter returns a numeric value, record in CHART for Step 3 under column (2) and complete the row calculations. Leave the other rows blank. If the turbidimeter returns an error notification record "ERROR" for Step 3 then continue this procedure.
9. Prepare a 1:2 dilution of the 2nd Dilution (F) using Figure 21.

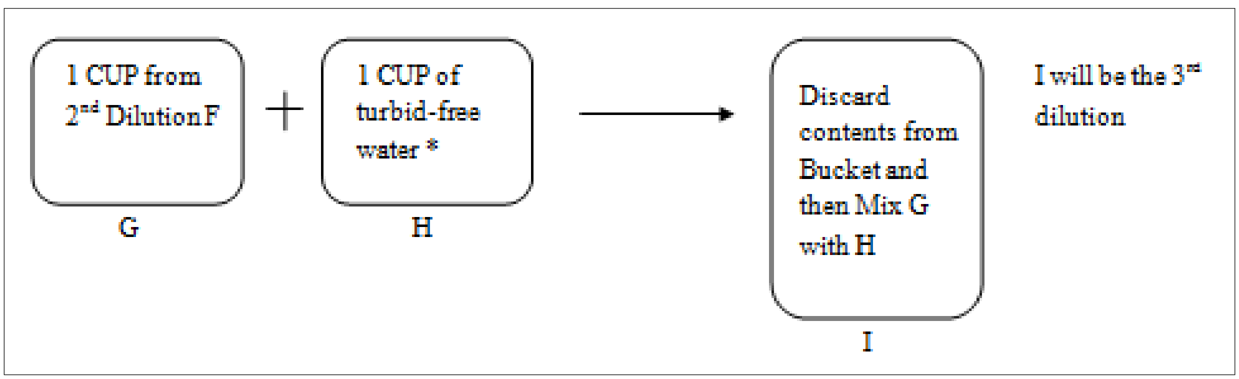

Figure 21. Third Dilution

10. Test the 3rd Dilution (I) in the turbidimeter.
11. If the turbidimeter returns a numeric value, record in CHART for Step 4 under column (2) and complete the row calculations. Leave the other rows blank. If the

turbidimeter returns an error notification record "ERROR" for Step 4 then continue this procedure.

12. Prepare a 1:2 dilution of the 3rd Dilution (I) using Figure 22.

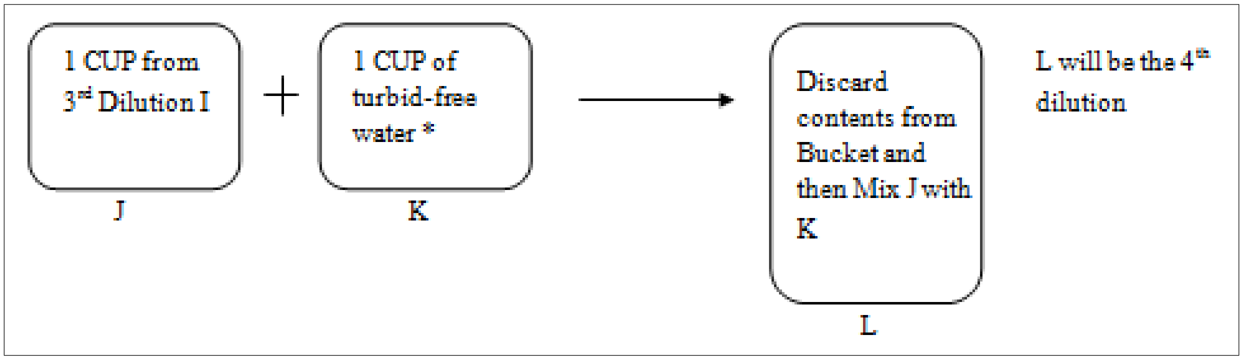

Figure 22. Fourth Dilution

13. Test the 4th Dilution (L) in the turbidimeter.
14. If the turbidimeter returns a numeric value, record in CHART for Step 5 under column (2) and complete the row calculations. Leave the other rows blank. If the turbidimeter returns an error notification record "ERROR" for Step 5 then continue this procedure.
15. Prepare a 1:2 dilution of the 4th Dilution (L) using Figure 23.

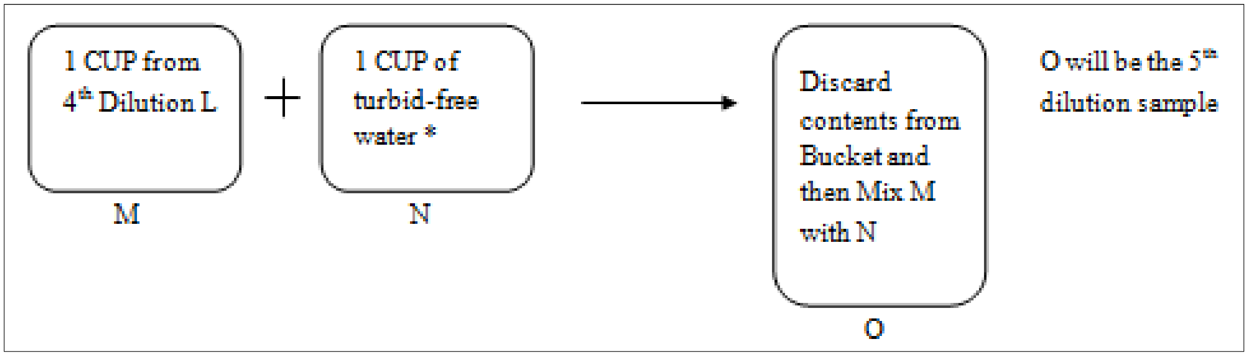

Figure 23. Fifth Dilution

16. Test the 5th Dilution (O) in the turbidimeter.
17. If the turbidimeter returns a numeric value, record in CHART (Table 8) for Step 6 under column (2) and complete the row calculations. If the turbidimeter returns an error notification record "ERROR" for Step 6 in column (2) and record " >32,000 " in column (4).

* Bottled drinking water should be used for turbid-free water unless otherwise specified, and is likely to be available on site.

Table 8. CHART - Turbidity Sampling Worksheet

Date:			
Time:			
Location:			
Sample No.:			
Name:			
(1)	(2)	(3)	(4)
Dilution Number	Turbidimeter Reading (Error or NTU value)	Multiplier	Actual Turbidity (NTU) = (2)x(3)
1		1	
2		2	
3		4	
4		8	
5		16	
6		32	

Results

Dilution experiments were performed on three of the samples collected in the field that were saved in a refrigerator in the lab. Table 9 through 11show the dilution experiment for each of the samples tested. Measurements in the field turbidimeter refer to measurements in the 2100P model and measurements in the lab turbidimeter refer to measurements in the 2100N model. The actual turbidities are the measurements made in the turbidimeter multiplied by the multiplier. The charts shown in the next few tables vary from the chart in Table 7 given for the dilution procedure because there were two turbidimeters used for this experiment. Therefore, two extra columns were needed to distinguish between the field (2100P) and lab (2100N) turbidimeters.

Table 9. West Loop 289 Sample to Playa on 3/4/2011

Sample:	WL289 - Playa on 3/4/11				
(1)	(2)	(3)	(4)	(5)	(6)
Dilution Number	Field Turbidimeter Reading (NTU)	Lab Turbidimeter Reading (NTU)	Multiplier	Actual Turbidity in Field (NTU) = (2)x(4)	Actual Turbidity in Lab (NTU) = (3)x(4)
1	>1000	1888	1	-	1888
2	>1000	666	2	-	1332
3	512	265	4	2048	1060
4	227	124	8	1816	992
5	96.1	60.4	16	1537.6	966.4
6	41.1	27.8	32	1315.2	889.6

Table 10. West Loop 289 Sample to Playa on 5/11/2011

Sample:	WL289 - Playa on 5/11/11				
(1)	(2)	(3)	(4)	(5)	(6)
Dilution Number	Field Turbidimeter Reading (NTU)	Lab Turbidimeter Reading (NTU)	Multiplier	Actual Turbidity in Field (NTU) = (2)x(4)	Actual Turbidity in Lab (NTU) = (3)x(4)
1	758	382	1	758	382
2	327	177	2	654	354
3	148	85.3	4	592	341.2
4	79.2	44.8	8	633.6	358.4
5	36.4	22.8	16	582.4	364.8
6	16.1	10.1	32	515.2	323.2

Table 11. Marsha Sharp Freeway Sample on 5/11/11

Sample:	MSF - puddle on 5/11/11				
(1)	(2)	(3)	(4)	(5)	(6)
Dilution Number	Field Turbidimeter Reading (NTU)	Lab Turbidimeter Reading (NTU)	Multiplier	Actual Turbidity in Field (NTU) = (2)x(4)	Actual Turbidity in Lab (NTU) = (3)x(4)
1	E5	2128	1	-	2128
2	>1000	790	2	-	1580
3	607	318	4	2428	1272
4	244	134	8	1952	1072
5	105	65.2	16	1680	1043.2
6	45.9	29.8	32	1468.8	953.6

After dilutions were analyzed for each of these samples it was decided that effects of settling were causing the turbidity to decrease. To address this problem, a chemical called sodium hexametaphosphate (SHMP) was added to ½ cup (125 mL) of each of the samples. SHMP is used in geotechnical practices to measure particle size distribution in clay samples. Applying SHMP to clay allows the clay to be suspended in a water column for particle size analysis (Kettler et al., 2001). For the dilution experiments, SHMP was added directly to the water with the sediment already in the water sample. SHMP was added in two doses, ½ tsp (2.5 mL) and 1 tsp (125 mL), to a ½ cup (125 mL) sample of turbid water. After the SHMP had dissolved, testing was then done on each sample the same way it was conducted on the samples without SHMP. Examples of the SHMP additions and how SHMP affected turbidity measurements during the dilution procedure are shown in Tables 12 through 17.

Table 12. West Loop 289 Sample to Playa on 3/4/2011 with 1/2 tsp SHMP

Sample:	WL289 - Playa on 3/4/11 with 1/2 tsp (2.5 mL) SHMP to 1/2 cup (125mL) sample				
(1)	(2)	(3)	(4)	(5)	(6)
Dilution Number	Field Turbidimeter Reading (NTU)	Lab Turbidimeter Reading (NTU)	Multiplier	Actual Turbidity in Field (NTU) = (2)x(4)	Actual Turbidity in Lab (NTU) = (3)x(4)
1	>1000	1235	1	-	1235
2	794	500	2	1588	1000
3	329	195	4	1316	780
4	149	103	8	1192	824
5	71.6	54	16	1145.6	864
6	36.2	29.2	32	1158.4	934.4

Table 13. West Loop 289 Sample to Playa on 3/4/2011 with 1 tsp SHMP

Sample:	WL289 - Playa on 3/4/11 with 1 tsp (5 mL) SHMP to 1/2 cup (125 mL) sample				
(1)	(2)	(3)	(4)	(5)	(6)
Dilution Number	Field Turbidimeter Reading (NTU)	Lab Turbidimeter Reading (NTU)	Multiplier	Actual Turbidity in Field (NTU) = (2)x(4)	Actual Turbidity in Lab (NTU) = (3)x(4)
1	>1000	1150	1	-	1150
2	782	455	2	1564	910
3	349	196	4	1396	784
4	158	102	8	1264	816
5	72.4	54.4	16	1158.4	870.4
6	35.8	28.4	32	1145.6	908.8

Table 14. West Loop 289 Sample to Playa on 5/11/2011 with 1/2 tsp SHMP

Sample:	WL289 - Playa on 5/11/11 with 1/2 tsp (2.5 mL) SHMP to 1/2 cup (125 mL) sample				
(1)	(2)	(3)	(4)	(5)	(6)
Dilution Number	Field Turbidimeter Reading (NTU)	Lab Turbidimeter Reading (NTU)	Multiplier	Actual Turbidity in Field (NTU) = (2)x(4)	Actual Turbidity in Lab (NTU) = (3)x(4)
1	508	275	1	508	275
2	236	130	2	472	260
3	94.1	62.9	4	376.4	251.6
4	39.9	29.3	8	319.2	234.4
5	19.2	15.1	16	307.2	241.6
6	10	7.8	32	320	249.6

Table 15. West Loop 289 Sample to Playa on 5/11/2011 with 1 tsp SHMP

Sample:	WL289 - Playa on 5/11/11 with 1 tsp (5 mL) SHMP to 1/2 cup (125 mL) sample				
(1)	(2)	(3)	(4)	(5)	(6)
Dilution Number	Field Turbidimeter Reading (NTU)	Lab Turbidimeter Reading (NTU)	Multiplier	Actual Turbidity in Field (NTU) = (2)x(4)	Actual Turbidity in Lab (NTU) = (3)x(4)
1	474	273	1	474	273
2	231	134	2	462	268
3	110	71.5	4	440	286
4	46.7	35.5	8	373.6	284
5	23.1	18.1	16	369.6	289.6
6	12.3	9.46	32	393.6	302.72

Table 16. Marsha Sharp Freeway Sample on 5/11/2011 with 1/2 tsp SHMP

Sample:	MSF - Puddle on 5/11/11 with 1/2 tsp (2.5 mL) SHMP to 1/2 cup (125 mL) sample				
(1)	(2)	(3)	(4)	(5)	(6)
Dilution Number	Field Turbidimeter Reading (NTU)	Lab Turbidimeter Reading (NTU)	Multiplier	Actual Turbidity in Field (NTU) = (2)x(4)	Actual Turbidity in Lab (NTU) = (3)x(4)
1	E5	1390	1	-	1390
2	837	491	2	1674	982
3	320	179	4	1280	716
4	130	82	8	1040	656
5	57.9	41.1	16	926.4	657.6
6	27.3	21.2	32	873.6	678.4

Table 17. Marsha Sharp Freeway Sample on 5/11/2011 with 1 tsp SHMP

Sample:	MSF - Puddle on 5/11/11 with 1 tsp (5 mL) SHMP to 1/2 cup (125 mL) sample				
(1)	(2)	(3)	(4)	(5)	(6)
Dilution Number	Field Turbidimeter Reading (NTU)	Lab Turbidimeter Reading (NTU)	Multiplier	Actual Turbidity in Field (NTU) = (2)x(4)	Actual Turbidity in Lab (NTU) = (3)x(4)
1	E5	1272	1	-	1272
2	833	462	2	1666	924
3	336	179	4	1344	716
4	127	81	8	1016	648
5	56.5	40.8	16	904	652.8
6	26.6	20.2	32	851.2	646.4

For most situations tested, dilution was shown to decrease actual turbidity values. As more dilutions were performed on the original sample, the smaller the “actual turbidity” measurements turned out to be compared to the original value. Therefore, dilution is not an acceptable method to extend the range of a turbidimeter. Reasons for this decrease in measurements are probably due to settling that occurs as each dilution is made. Instead of half of the sediment from one sample going to the next dilution step, less than half is going forward because some material is settling out in the process. This will cause the actual turbidity to decrease over each dilution made.

Originally, SHMP was meant to be added to clay soil samples prior to being suspended in water in order to perform particle size analysis. SHMP provided little help to suspend the particles in the water sample so as to prevent settling during testing because after SHMP was added settling could still be visibly seen. Adding more SHMP caused some SHMP to not dissolve, and settling could still be seen in the samples so more SHMP was not affective at slowing down settling. In this experiment, adding SHMP to a water sample with soil already present was not effective with either amount of SHMP added.

Conclusions

Dilution is not a desirable method to extend the range of a turbidimeter, and should therefore not be used to determine turbidity values on highway construction sites. However, if the turbidimeter on site has a range less than the proposed EPA turbidity limit (currently at 280 NTU), dilution may be necessary to determine if the sample is within the compliance limits. If the turbidmeter on site has a range larger than the limit, there is no need to go through dilutions if the sample exceeds the machine range because it is already known that the sample is above compliance limits anyway. For construction site regulations, a turbidimeter with a range larger than the proposed turbidity limit will be needed.

However, if the state of Texas wanted to collect background turbidity data, numerical values would be necessary to extend current knowledge of background levels, and dilution measurements may be used. Dilutions may be performed for data collection simply to give an idea as to the range the collected sample falls between. If a sample is diluted, it will be important to remember that the value recorded will probably not be a true representation of the samples' original turbidity and will be lower than the actual turbidity value. The numerical value that is collected for background informational purposes will still show approximately how large the turbidity is for a given water sample. This information would still be pertinent in the case of knowing approximate background levels in the use of either current highway construction.

Background Turbidity Levels for the State of Texas

Introduction

As the Texas Construction General Permit (CGP) comes up for renewal in 2013, highway construction projects will have to adhere to new standards set forth by the US Environmental Protection Agency (EPA). The new standard includes a nation-wide turbidity limit for stormwater runoff from these construction sites' discharge points. Currently, the standard being discussed is 280 NTUs (nephlometric turbidity units) for all construction sites that disturb more than 10 acres at one time (EPA, 2009). Since the idea of this ruling came into being, there has been much controversy, and this ruling may change as more information becomes available.

Pruitt (2002) examined background turbidity ranges from 27 states in the US. These 27 states all reported a minimum turbidity level less than or equal to 1.0 NTU. Connecticut, New Hampshire, and Nevada reported maximum turbidity values less than 100 NTU, while 18 other states reported maximum turbidities over 500 NTU. Maximum background turbidities over 1000 NTU were reported for Arizona, Kentucky, Louisiana, North Carolina, Nebraska, New Mexico, Oregon, South Carolina, Utah, and Wyoming. Because such large turbidities were found in existing water bodies around the US, Texas Tech University in cooperation with Texas A&M University, the University of Texas, TxDOT, and TCEQ is in progress, in part, to determine if this limit is reasonable in Texas.

Background turbidities around the state of Texas were collected and organized to create turbidity theme maps for the state. These maps help visualize the maximum, minimum, and median turbidity levels recorded for various water bodies within Texas. The authors believe that if there are areas in Texas where the water has a background turbidity value above the 280 NTU limit or any other proposed limit set by the EPA, then regionally based limits should be allowed.

Methods

Data Collection

The United States Geological Survey's (USGS) National Water Information System website and ArcGIS were used to analyze and display the background turbidities for water bodies in the state of Texas. USGS stations that had a data entry with parameter code 00076, had reported turbidity measurements of unfiltered water samples measured in NTU. The analysis identified 408 stations that had turbidity measurements. Some stations had only a single measurement while others had over 200 measurements. The database time period spanned from 1975 to 2004.

Each station's reported measurements were analyzed to compute a minimum, maximum, and median value of turbidity. Table 18 lists a portion of the results of such analysis; these results are then imported into a GIS, in this study ArcGIS 9.3 (ESRI, 2008).

Table 18. Sample of Attribute Table

STATION_ID	X LONGITUDE	Y LATITUDE	MAX	MIN	MEDIAN
08037000	-94.726111	31.457222	61.00	8.00	28.5
07297910	-101.413611	34.837500	23000.00	0.00	9.6
08178880	-99.069722	29.723611	240.00	0.20	1
08179000	-98.975833	29.675278	15.00	0.20	3.75
293736099034801	-99.064956	29.626422	0.20	0.20	0.2
293934098584801	-98.979806	29.659389	2.80	2.80	2.8
294243099073801	-99.127228	29.712189	25.00	25.00	25
294309099015701	-99.033000	29.719750	2.60	2.60	2.6
294425098495401	-98.832003	29.740883	16.00	16.00	16
294717099165301	-99.281972	29.788028	0.20	0.20	0.2
294815099343801	-99.574389	29.811186	0.36	0.36	0.36
08159165	-97.296667	30.305000	720.00	2.60	160
08159170	-97.327500	30.265000	530.00	7.60	160
08159180	-97.284167	30.241389	400.00	32.00	230
08159185	-97.317500	30.230278	130.00	3.60	66.8
08102500	-97.441111	31.070000	6.40	0.50	2.4

Map Production

ArcGIS (ESRI, 2008) was used to create a map of the stations' locations within Texas using the NAD 1983 datum. Figure 24 is a map of the stations. The figure shows a large area in the western portion of the state without any stations. This area was later blanked for the theme map contouring.

The kriging algorithm in ArcGIS was used to grid the station data for contouring and producing the three theme maps. These maps used the minimum, maximum, and median turbidity measurement for each station, and interpolated between stations to produce a raster image that could then be set by the analyst into a number of classifications to produce areas that fell within a specified range of turbidity values.

Figures 25, 26, and 27 are theme maps of the minimum, maximum, and median background turbidity values in Texas from 1975 to 2004. The theme maps all use eight classifications for the displayed turbidity ranges. Ranges were set using a quantile classification to assure an even number of raster cells in each class, then adjusted manually to make the classification breaks reasonable values. In addition, the EPA proposed numeric turbidity limit of 280 NTU was used as a break between the two ranges in each of the maps.

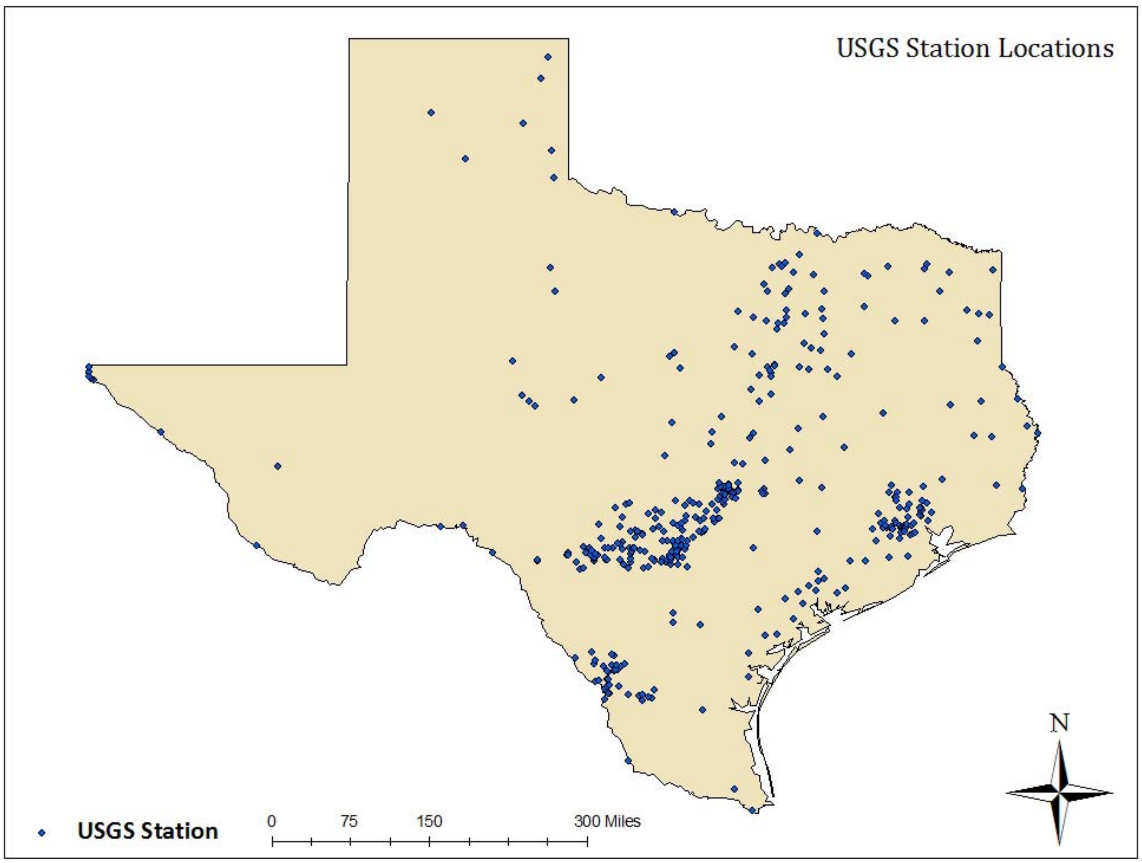

Figure 24. USGS Station Locations with Reported Turbidity Values

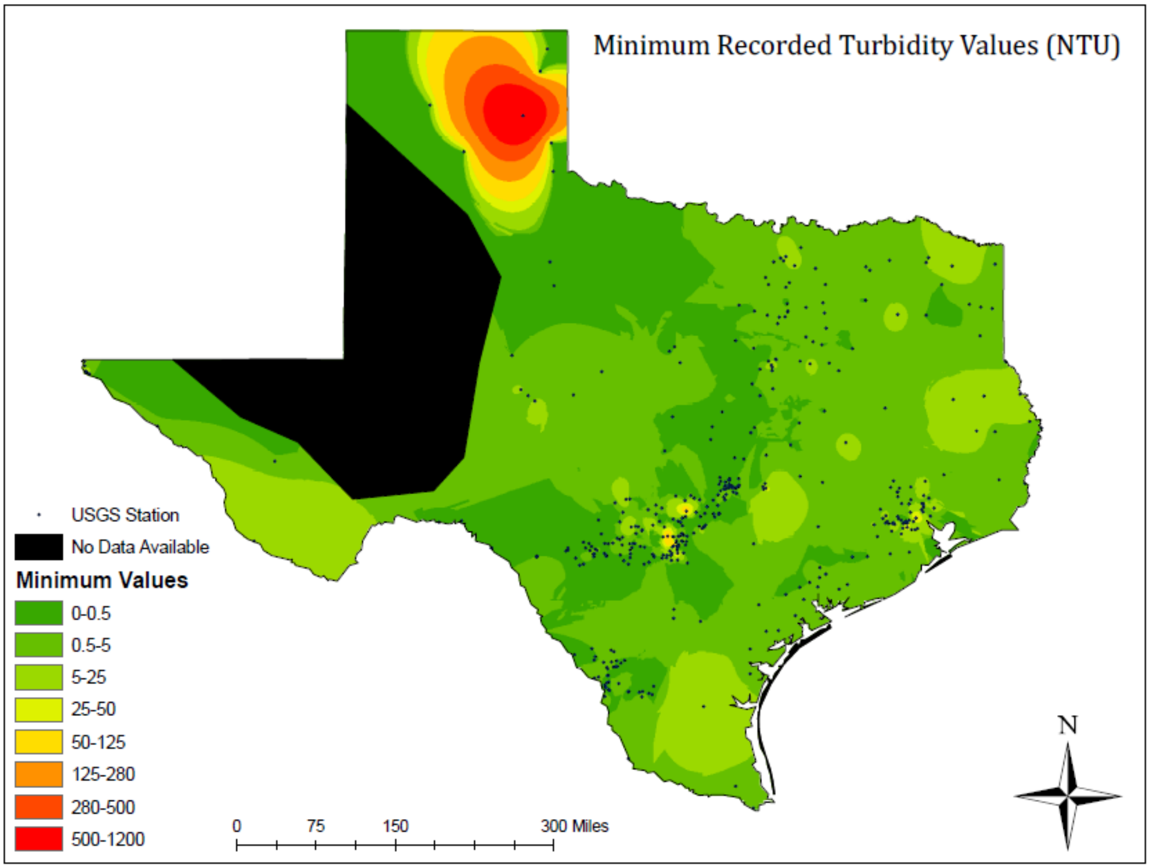

Figure 25. Minimum Recorded Turbidity Values (NTU) for the State of Texas

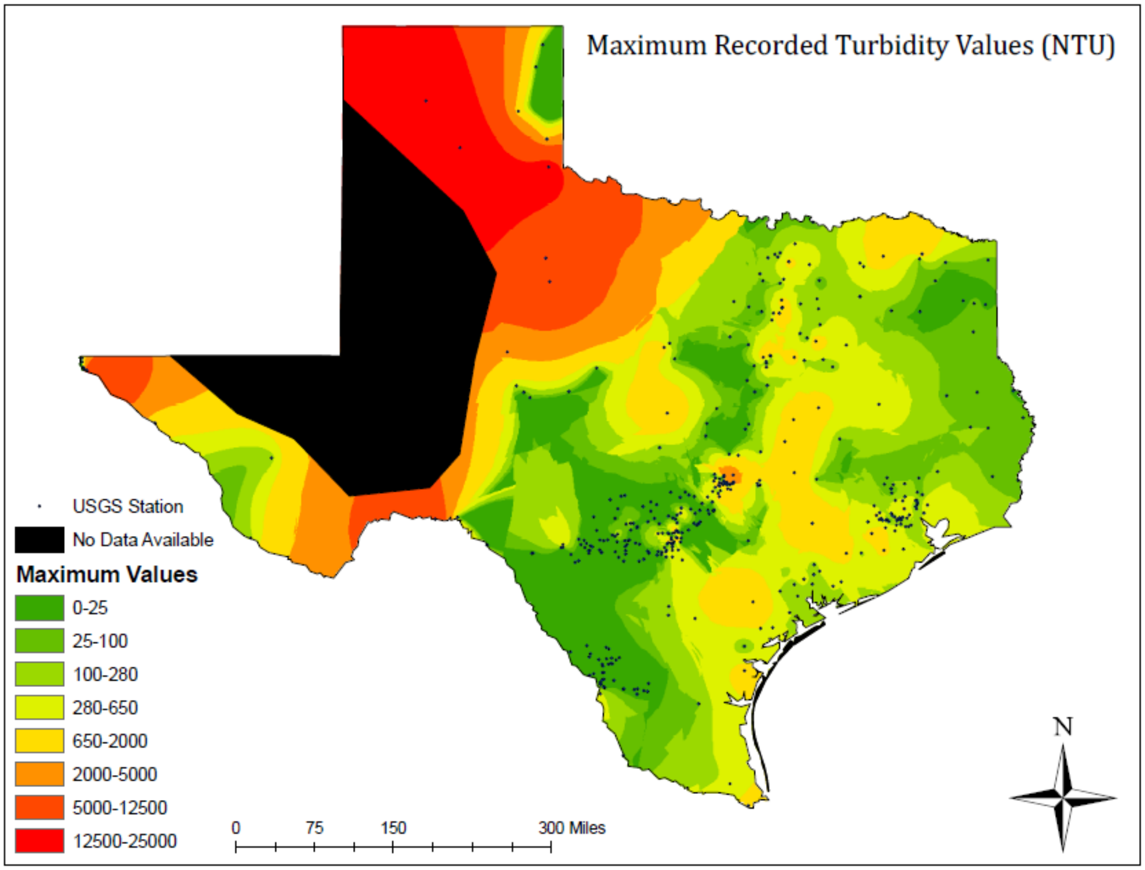

Figure 26. Maximum Recorded Turbidity Values (NTU) for the State of Texas

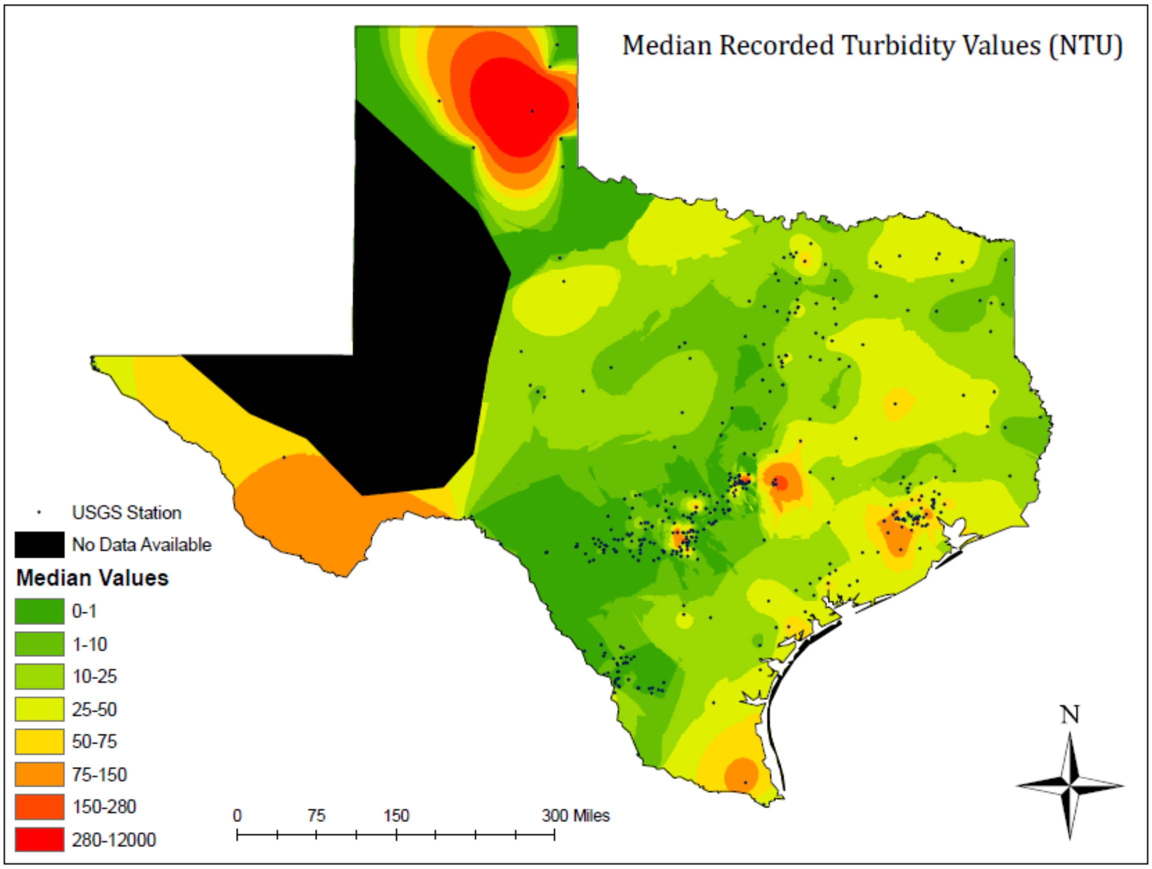

Figure 27. Median Recorded Turbidity Values (NTU) for the State of Texas

Results and Discussion

All three maps it show that the panhandle of Texas has a high natural turbidity value. Even on the minimum value map, values in the panhandle exceed 125 NTU. Other parts of the state such as central Texas can have a minimum reported turbidity below 0.5 NTU. Maximum values above 280 NTU are common throughout the state.

In the median value map, most stations in central Texas have turbidity values less than 25 NTU with the exception of the Austin area which has a median larger than 50 NTU. Along the Gulf Coast, median values are larger than 50 NTU, primarily in larger cities such as Houston. Most of west Texas exceeds 50 NTU for the median value.

There is insufficient data in the western portion of Texas. To accurately understand the background turbidity values in this region of the state, more sampling is needed.

Conclusion

Texas, as a whole, represents almost every physio-geographic feature found within the United States. There are mountains and deserts in the western portion of the state. Rolling hills are found in the center, and flat prairies in the panhandle. Coastal areas are along the Gulf Coast and the woods and forest region throughout the northeast. Varying topographies and climatic conditions such as these can influence turbidity in the state waters. These different regions could help further characterize similar physiological features turbidity backgrounds throughout the nation.

The turbidity values collected from USGS show the variation in turbidity among the state in natural conditions. Construction runoff was unlikely a factor in any of the measurements, and therefore natural turbidity conditions in certain parts of the state are already at high numeric values. If conditions are occurring as what is shown in the maps, then treating runoff water to cleaner than ambient conditions would be of negligible benefit assuming existing conditions are at natural equilibrium, but would incur substantial societal costs.

After studying the maps, the proposed EPA turbidity limit of 280 NTU is thought to be achievable throughout most of Texas. However, the western portion of the state, specifically the panhandle has natural conditions that will most likely always fall above this proposed limit. Therefore, this area may always be in perpetual noncompliance. For these reasons regional adjustments should be allowed for the sections of Texas where it may be nearly impractical to achieve a specified turbidity limit.

Instrument Variability Issues

Introduction

In Lubbock, Texas runoff samples from highway construction sites were collected and the turbidity value was measured. Two turbidimeters were used during this testing: the portable field 2100P and the lab 2100N. Differences in turbidity values were noted from the beginning of the project. To determine the extent of these differences, three runoff samples were tested in two field 2100P turbidimeters and in one lab 2100N turbidimeter.

The first difference noted had to do with the calibration standards. Both types of turbidimeters use formazin standards, but the values of each standard used during calibration vary. The field 2100P turbidimeter uses the standards <0.1 NTU, 20 NTU, 100 NTU, and 800 NTU and the lab 2100N turbidimeter uses the standards <1.0 NTU, 20 NTU, 200 NTU, 1000 NTU, and 4000 NTU. The largest notable difference, however, is how the turbidimeters measure turbidity. The 2100P model is only equipped with a 90 degree detector plate to catch scattered light waves, but the 2100N has multiple detector plates within the instrument (Hach Company, 2003 and 2008). Differences in turbidimeters could lead to measurement variability in turbidity values, and should not be overlooked.

Methods

To determine the differences in turbidimeters, two field 2100P were compared with the lab 2100N turbidimeter. Three runoff samples collected from highway construction sites that had been saved were used in this experiment. Sample A is from the WL289-playa collected on March 4th, sample B is from the WL289-small tennis collected May 11th, 2011 and Sample C is from the WL289-playa collected on May 11th, 2011.

Calibration of each turbidimeter was performed before testing each sample. Turbidity measurements were then made for each sample three times in each of the three turbidimeters. To avoid variations caused by time such as settling, sample cells were prepared right after the sample bottles were shaken and measurements were taken in each of the turbidimeters at the same time. Sample cells were then cleaned and prepared as the HACH manuals outlined (2003 and 2008). Further, each machine had the “signal averaging” and “automatic range” turned on. The lab turbidimeter had one extra function, “ratio”, which was turned on as well because this turbidimeter had been reporting turbidity values above 100 NTU as out of range if this “ratio” function was turned off.

Results

Tables 19 through 21 show the turbidity values for each sample in each turbidimeter. Sample A reported an E5 error in the field tubidimeters which is caused by a light interference, most likely caused by the soil type and/or color in the sample. Approximate percent differences between the field tubidimeters and the field and lab turbidimeters are also shown.

Table 192. Sample A's Turbidity Results

Sample A			
Turbidimeter	Trial 1	Trial 2	Trial 3
Lab (NTU)	2390	2415	2465
Field - A (NTU)	E5	E5	E5
Field - B (NTU)	E5	E5	E5
% difference in Field A and B	-	-	-
% difference from Average Field to Lab	-	-	-

Table 20. Sample B's Turbidity Results

Sample B			
Turbidimeter	Trial 1	Trial 2	Trial 3
Lab (NTU)	96	98.5	100
Field - A (NTU)	177	182	189
Field - B (NTU)	177	170	186
% difference in Field A and B	0%	7%	2%
% difference from Average Field to Lab	46%	43%	46%

Table 31. Sample C's Turbidity Results

Sample C			
Turbidimeter	Trial 1	Trial 2	Trial 3
Lab (NTU)	406	430	455
Field - A (NTU)	683	719	816
Field - B (NTU)	682	750	803
% difference in Field A and B	0%	4%	2%
% difference from Average Field to Lab	40%	42%	43%

For sample B and C, the differences in field turbidimeters were very minimal with the largest difference reported as 7%. Differences between the field and lab machines were greater than 40%. This result shows that the variations in turbidity measurements are due to the type of turbidimeter and how the turbidimeters operate, and not to sample preparation. When discussing this variability issue with a representative from HACH, the reason for differences in machines was explained to be due to the presence of color or the type of particles in the water which could influence turbidity values depending on how the turbidimeter operates.

Conclusions

Turbidity measurements can vary between different types of turbidimeters by almost a factor of two in the case of the 2100P and 2100N turbidimeters. Reasons for these differences could not be found in the way the samples were prepared or in how the analyst operated the turbidimeters. Calibrations were performed before each testing as explained in the manuals' procedure for calibration (Hach Company 2003 and 2008). Sample cells were cleaned and prepared in the same manner for each turbidimeter and multiple measurements of each sample tested were taken.

Consistent percent differences between the field and lab turbidimeters must therefore be a cause of the turbidimeters' inherent properties in how each one operates. The multiple detectors most likely have the largest impact on how the turbidity measurements are affected and reported. The variations in the calibration standards' values from one turbidimeter to the other may also have played a part in how high or low the turbidity of a sample is read.

Further work with HACH may be important in determining why these differences exist. As for operating a turbidimeter to determine if highway construction sites are within compliance levels for future turbidity limits, a specific turbidimeter may have to be assigned by EPA to assure all construction sites are being held to the same standard. If one site has the 2100N turbidimeter, they will report a turbidity value almost half of what a site with a 2100P turbidimeter would report for the same runoff sample – a difference that may cause one site to exceed compliance limits while others are below.

Chapter 6 –Conclusions

Summary

As the new CGP comes up for renewal, the US EPA will have a numerical turbidity limit for all sites that disturb more than 10 acres at a time to follow around the nation. Currently the proposed limit sits at 280 NTU; however, this may change as new findings and arguments come to surface such as the data presented in this thesis. To determine the current turbidity values from highway construction sites around the state of Texas, TxDOT enlisted three state universities to devise and carry out a sampling protocol. In Lubbock, Texas two sites were monitored and samples were collected during or after rainfall events to collect turbidity values in runoff. Because of a drought of record that affected the whole state, only four samples were taken at the West Loop 289 project site, and five samples were taken at the Marsha Sharp Freeway location during nine months. The samples collected at Marsha Sharp Freeway, however, did not visibly leave the site. Also, four studies were completed in relevance to turbidity throughout this project – dilution of samples, water color effect, particle color effect, and the background turbidity for the state of Texas. These studies help serve as background information for turbidity in Texas, and discuss special problems associated with turbidity measurements.

Conclusions

At the Marsha Sharp Freeway location, samples were collected in puddles as there was never enough precipitation to form actual streams from which to collect samples. For the March and May rainfall events, samples were collected from the discharging culvert where a puddle formed around the base before it was later connected to the playa at the end of the project and, therefore, would not be held to the new turbidity regulations. Once the culvert discharged directly to the playa, the rest of the samples were collected from a puddle that collected behind a silt fence. None of the actual samples were being discharged into the playa, and therefore the actual runoff coming from the site was not affecting state water bodies.

The West Loop 289 project actually discharged runoff to the nearest playa through a culvert and therefore, had an effect on the playa's turbidity level. Although, this playa through most of the year never actually contained water, except during rainfall events. The samples collected by the tennis courts at a large and small culvert that led from the neighborhood to the playa, were never from running streams, but simply puddles that formed by the culverts. During rainfall events, water was never flowing through these culverts.

Because of the lack of data caused by the drought and the small rainfall events, none of the samples collected were visibly running off into existing water with the exception of the WL289-playa samples that ran into a dry playa. However, water that was collected from the sites was typically above 1000 NTU (excluding the WL289-tennis-large and WL289-tennis-small). Even with BMPs in place, turbidity values run high in the runoff from a construction site in Lubbock, Texas. Setting a numeric turbidity limit at 280 NTU will cause an increase in construction cost in order to comply with this limit.

Also, there was a machine difference noted throughout all sample testing. The two machines reported different numbers for the same sample. The 2100P turbidimeter (field) reported a turbidity measurement almost two times higher than the 2100N (lab) for most samples. Causes could be attributed to color effects in the instruments, but the difference in turbidimeters is still uncertain as the same procedure used for calibrating each machine before use, cleaning vials, and sample preparation were the same for both. Calibration was not the cause of the difference in the machine readings since it was performed before each turbidity measurement. Because all turbidity measurements were done using the same cleaning and calibration procedure, the turbidimeter differences is believed to be an inherent function of how each turbidimeter operates.

Lastly, there was an initial interest in using PAM during this project to test the effectiveness of PAM in reducing turbidity values in runoff. The drought did not allow testing to be accomplished. However, there are a few concerns about using PAM in west Texas, such as exposure to sunlight which can cause PAM to lose effectiveness. Here in Lubbock, tree foliage is rare and PAM would therefore be exposed to the sun more often than not. If PAM is to be used as a BMP on construction sites, more work will need to be accomplished to determine the benefits of PAM in different areas of the country where soil types and sun exposure vary.

Future Work

This study provided a limited data on highway construction runoff's turbidity. In the future more sampling will need to be done to attain a comprehensive set of data across the state. Further, more areas of the state may need to be represented such as the western portion of the state. Soil conditions vary throughout the region and turbidity is affected by soil type so more water quality testing of runoff may provide helpful.

From the background maps of ambient turbidity conditions in Texas, more sampling will have to be done in the section of the state where there are currently no data points to analyze. Further data collection in these areas around the state with no turbidity data may provide a better understanding of the background turbidity values found throughout the state.

The machine differences also pose a problem with reporting turbidity values for a construction site. A future project to help determine why there are these differences along with how to address them may be necessary from a compliance point of view. As of now, one construction site might be in compliance of the EPA's proposed turbidity limit while another is not, simply because of the type of turbidimeters used at each site.

References

"Anionic Polyacrylamide." Horticultural Alliance, Inc, <http://www.hortsorb.com/PDFfiles/Acrylamide%20Tox.pdf> (Oct. 31, 2010).

Ashworth, J., Nijenhuis, R., Glowacka, B., Tran, L., and Schenk-Watt, L. (2010). “Turbidity and Color Correction in the Microtox Bioassay.” *The Open Environmental Pollution & Toxicology Journal*, 2, 1-7.

Atesok, G., Somasundaran, P., and Morgan, L.J. (1988). "Charge Effects in the Adsorption of Polyacrylamide on Sodium Kaolinite and Its Flocculation." *Powder Technology*, 54, 77-83.

Barron, Johnny. (2002). “Stream Sampling 101.” *The Journal for Surface Water Quality Professionals*, <http://www.stormh2o.com/forms/print-7447.aspx > (Sept. 15, 2010).

Beighley, Edward R., Scholl, Bryan, Faucette, Britt L., and Governo, Jason. (2010). “Runoff Characteristics for Construction Site Erosion Control Practices.” *Journal of Irrigation and Drainage Engineering*, 136(6), 405-413.

Bhardwaj, A. K., and McLaughlin, R.A. (2008). "Simple Polyacrylamide Dosing Systems for Turbidity Reduction in Stilling Basins." *Transactions of the American Society of Agricultural and Biological Engineers*, 51(5), 1653-1662.

Bhardwaj, A. K., McLaughlin, R.A., Shainberg, I., and Levy, G.J. (2009). "Hydraulic Characteristics of Depositional Seals as Affected by Exchangeable Cations, Clay Mineralogy, and Polyacrylamide." *Soil Science Society of America Journal*, 73(3), 910-918.

Burdick, Everette M. and Allen, James S. (1948). “Rapid Estimation of Citrus Peel Oil.” *Analytical Chemistry*, 20(6), 539-541

Clesceri, L.S., Greenber, A.E., and Eaton, A.D. (1998). “Physical and Aggregate Properties.” *Standard Methods for the Examination of Water and Wastewater: 20th Edition*. United Book Press, Baltimore, MD, 2-8 – 2-60.

Coduto, D.P. (1999). “Soil Composition.” *Geotechnical Engineering: Principles and Practices*. Prentice-Hall, Upper Saddle River, NJ, 125-128.

Curtiss, David A. (1982). "An Evaluation of Suspended Sediment and Turbidity in Cow Creek, Oregon." Tech. no. 82-364. U.S. Geological Survey, Portland, OR.

Downing, John. (2005). "Turbidity Monitoring." *Environmental Instrumentation and Analysis Handbook*, Randy D. Down and Jay H. Lehr, eds., Hoboken, NJ, 511-546.

EPA. (2009). "Effluent Limitations Guidelines and Standards for the Construction and Development Point Source Category." *40 CFR Part 450*. Federal Register, 74(229), 62995-63058.

ESRI. (2008). *ArcGIS*. Computer Software. Vers. 9.3.

Gippel, C.J., Rieger, W.J., and Olive, L.J. (1991). "The Effect of Particle Size and Water Colour on Turbidity." *International Hydrology and Water Resources Symposium*, Institution of Engineers, Sydney, Australia.

Ginting, Daniel, and Mamo, Martha. (2006). "Measuring Runoff-Suspended Solids Using an Improved Turbidometer Method." *Journal of Environmental Quality*, 35, 815-823.

Hach Company. (2003). *Portable Turbidimeter Model 2100P ISO Instrument and Procedure Manual*. Hach Company, Loveland, CO.

Hach Company. (2008). *Model 2100N Laboratory Turbidimeter Instruction Manual*. Hach Company, Loveland, CO.

Hayes, S. A., McLaughlin, R.A. and Osmond, D.L. (2005). "Polyacrylamide Use for Erosion and Turbidity Control on Construction Sites." *Journal of Soil and Water Conservation*, 60(4), 193-199.

Huber, E. and Frost, M. (1998). "Light Scattering by Small Particles." *Aqua*, 47(2), 87-94.

Kayhanian, Masoud, Murphy, Kevin, Regenmorter, Louis, and Haller, Richard. "Characteristics of Stormwater Runoff from Highway Construction Sites in California." *Storm Water Program,* <http://www.owp.csus.edu/research/papers/papers/PP006.pdf> (Sept. 9, 2010).

Kettler, T.A., Doran, J.W., and Gilbert, T.L. (2001). “Simplified Method for Soil Particle-Size Determination to Accompany Soil-Quality Analyses.” *Soil Science Society of America Journal,* 65, 849-852.

LaHusen, Richard G. (1994). “Variations in Turbidity in Streams of the Bull Run Watershed, Oregon, Water Years 1989-90.” Tech. no. 93-4045. U.S. Geological Survey, Vancouver.

Lentz, R.D., Sojka, R.E., and Carter, D.L. “Influence of Polymer Charge Type and Density on Polyacrylamide Ameliorated Irrigated Furrow Erosion.” *NWISRL Publications,* <http://eprints.nwisrl.ars.usda.gov/1060/1/789.pdf> (Oct. 27, 2010).

McCaleb, M. M., and McLaughlin, R.A. (2008). "Sediment Trapping by Five Different Sediment Detention Devices on Construction Sites." *American Society of Agricultural and Biological Engineers,* 51(5), 1613-1621.

McLauglin, Richard A., and Brown, T. Tabitha. (2006). "Evaluation of Erosion Control Products with and without Added Polyacrylamide." *Journal of the American Water Resources Association,* 42(3), 675-684.

McLaughlin, R. A., King, S.E., and Jennings, G.D. (2009). "Improving Construction Site Runoff Quality with Fiber Check Dams and Polyacrylamide." *Journal of Soil and Water Conservation,* 64(2), 144-154.

McLaughlin, R. A., Hayes, S.A., Clinton, D.L., McCaleb, M.S., and Jennings, G.D. (2009). "Water Quality Improvements Using Modified Sediment Control Systems on Construction Sites." *Transactions of the American Society of Agricultural and Biological Engineering,* 52(6), 1859-1867.

“Monitoring of Turbidity in Stormwater Runoff from Construction Activities.” *Vermont Department of Environmental Conservation,* <http://www.vtwaterquality.org/stormwater/docs/construction/sw_turbidity_monitoring_guidance.pdf> (Sept. 15, 2010).

Montgomery, Douglas C. (1997). “Design and Analysis of Experiments.” *Randomized Blocks, Latin Squares, and Related Designs,* John Wiley and Sons, NY, 171-227.

Moore, A. D., McLaughlin, R.A., Mitasova, H., and Line, D.E. (2007). "Calibrating WEPP Model Parameters for Erosion Prediction on Construction Sites." *American Society of Agricultural and Biological Engineers,* 50(2), 507-516.

Oregon. Department of Environmental Quality. (2005). “General Permit: National Pollutant Discharge Elimination System Stormwater Discharge Permit.” *Permit Number: 1200-C*. Oregon Department of Environmental Quality, Portland, OR.

Pitt, R. (2007). “Module 3: Water Sample Collection Methods.”*University of Alabama,* <http://rpitt.eng.ua.edu/Class/ExperimentalDesignFieldSampling/Module%203/M3%20Water%20Sample%20Collection%20Methods.pdf> (Sept. 9, 2010).

Pitt, Robert, Maestre, Alex, and Morquecho, Renee. (2004). “The National Stormwater Quality Database Version 1.1.” *University of Alabama*, <http://unix.eng.ua.edu/~rpitt/Research/ms4/Paper/Mainms4paper.html> (Sept. 9, 2010).

“Polyacrylamide EC-13." (2003). “California Stormwater BMP Handbook.” California Stormwater Quality Association, <http://www.cabmphandbooks.com/Documents/Construction/EC-13.pdf> (Oct. 31, 2010).

Pruitt, Bruce A. (2002). “Uses of Turbidity by States and Tribes.” *Proceedings of the Federal Interagency Workshop on Turbidity and Other Sediment Surrogates,* 31-46.

Sadar, Michael J., and Engelhardt, Terry L. “Determining Correlation of Nephelometric Turbidity Measurement to Suspended Solids in Industrial Samples.” *Hach Company*, < http://www.hach.com/fmmimghach?/CODE%3ATURBIDITYANDSUSPENDE1574%7C1> (Jan. 28, 2011).

Shainberg, I., Warrington, D.N., and Rengasamy, P. (1990). “Water Quality and PAM Interactions in Reducing Surface Sealing.” *Soil Science*, 149(5), 301-307.

Shakhashiri. (2008). "Chemical of the Week: Polymers." <http://www.scifun.org> (Nov. 28, 2010).

Sojka, R. E. (2001). "The Use of PAM - a Linear Polyacrylamide for Use in Irrigation Water." *National Alliance of Independent Crop Consultants.* <http://www.naicc.org/meeting/2001/UseofPAM.html> (Oct. 30, 2010).

Sutherland, T.F., Lane, P.M., Amos, C.L., and Downing, J. (2000). “The Calibration of Optical Backscatter Sensors for Suspended Sediment of Varying Darkness Levels.” *Marine Geology*, 162, 587-597.

Thaxton, C. S., and McLaughlin, R.A. (2005). "Sediment Capture Effectiveness of Various Baffle Types in a Sediment Retention Pond." *Transactions of the American Society of Agricultural Engineers*, 48(5), 1795-1802.

United States Environmental Protection Agency Office of Water Regulations and Standards. (1980). “Turbidity: Water Quality Standards Criteria Summaries - A Compilation of State/Federal Criteria.” Nalesnik Associates Incorporated, Washington D.C.

USGS Water Resources. “Water Quality Samples for Texas Grouped by County.” *USGS: Science for a Changing World*. < http://nwis.waterdata.usgs.gov/tx/nwis/qwdata?> (April 2011).

Washington State. (2007). “How to Do Stormwater Monitoring: A Guide for Construction Sites.” *Publication # 06-10-020.* Department of Ecology, WA.

Weigel, Jay F. (1984). “Turbidity and Suspended Sediment in the Jordan River, Salt Lake County, Utah.” *Tech. no. 84-4019.* Salt Lake City: U.S. Geological Survey.

Wilde, F.D., and Gibs, J. (2005). “6.7 Turbidity.” *National Field Manual for the Collection of Water-Qualit Data,* U.S. Geological Survey, Reston, VA.

Zaneveld, J.R., Spinrad, R.W., and Bartz, R. (1979). “Optical Properties of Turbidity Standards.” *SPIE Ocean Optics,* 208, 159-168.

Appendix A – Colored Water Effects on Turbidity Results

Table 22. Turbidity Values for Blue Water

COLOR: BLUE		
# of drops to 200mL tap	Field (NTU)	Lab (NTU)
0	0.14	0.12
1	0.20	0.20
2	0.18	0.18
4	0.20	0.15
16	0.23	0.13

Table 13. Turbidity Values for Yellow Water

COLOR: YELLOW		
# of drops to 200mL tap	Field (NTU)	Lab (NTU)
0	0.18	0.14
1	0.23	0.16
2	0.27	0.20
4	0.29	0.20
16	0.31	0.24

Table 24. Turbidity Values for Green Water

COLOR: GREEN		
# of drops to 200mL tap	Field (NTU)	Lab (NTU)
0	0.18	0.16
1	0.22	0.24
2	0.21	0.23
4	0.24	0.22
16	0.51	0.15

Appendix B – Calculations and Results for Precipitates' TSS

$AgNO_3 + K_2CrO_4 \rightarrow Ag2CrO_{4(s)} + 2KNO_3$

Want 300 mg/L (0.3 g/L) Ag_2CrO_4 to precipitate out

(0.3 g/L Ag_2CrO_4) X (1 mol/332 g Ag_2CrO_4) = 0.00090 mol/L Ag_2CrO_4

Ksp of Ag_2CrO_4 is $9.0x10^{-12}$

$Ksp = [Ag^+]^2[CrO_4^{-2}] = [2X]^2[X] = 4X^3$

$X = 1.31x10^{-4}$ mol/L → This is the solubility of Ag_2CrO_4

Total needed to make = 0.00090 mol + $1.31x10^{-4}$ mol = 0/001031 mol Ag_2CrO_4

Ag needed = (0.001031 mol Ag_2CrO_4) X (2 mol Ag / 1 mol Ag_2CrO_4) = 0.002062 mol Ag

CrO_4 needed = (0.001031 mol Ag_2CrO_4) X (1 mol CrO_4 / 1 mol Ag_2CrO_4) = 0.001031 mol CrO4

K_2CrO_4 needed = (0.001031 mol CrO_4) X (1 mol K_2CrO_4 / 1 mol CrO_4) X (194 g

K_2CrO_4 / 1 mol K_2CrO_4) X 1.2 excess = **0.24 g K_2CrO_4 needed**

$AgNO_3$ solution used was 1000 ppm = 1000 mg/L

(1000 mg/L Ag) X (1 g / 1000 mg) X (1 mol Ag / 108 g Ag) = 0.00926 mol/L Ag

Volume of $AgNO_3$ needed = C_fV_f/C_i (where C_f is 500 mL) = (0.002062 mol/L Ag) X (0.5 L + Vneeded) / (0.00926 mol/L Ag)

0.00926V = 0.001031 + 0.002062V → **Volume of $AgNO_3$ needed = 143 mL**

The actual TSS produced using the calculate values of chemicals to add is 620 mg/L compared to the desired 300 mg/L.

Table 25. AgNO3 TSS Results

Silver Chromate TSS	
Sample Volume (mL)	200
Tare Wt. (mg)	95082
Gross Wt. -103C (mg)	95206
TSS (mg)	124
TSS (mg/L)	620

$AgNO_3 + NaCl \rightarrow AgCl(s) + NaNO_3$

Want 300 mg/L (0.3 g/L) of AgCl to precipitate out

(0.3g/L AgCl) X (1 mol/143.5 g AgCl) = 0.00209 mol/L AgCl

Ksp of AgCl is $1.8x10\text{-}^{5}$

$Ksp = [Ag^{+}][Cl^{-}] = [X][X] = X^{2}$

$X = 1.34x10^{-5}$ → This is the solubility of AgCl

Total needed to make = 0.00209 mol + 0.0000134 mol = 0.00210 mol AgCl

Ag needed = (0.00210 mol AgCl) X (1 mol Ag / 1 mol AgCl) = 0.00210 mol Ag

Cl needed = (0.00210 mol AgCl) X (1 mol Cl / 1 mol AgCl) = 0.00210 mol Cl

NaCl needed = (0.00210 mol Cl) X (1 mol NaCl / 1 mol Cl) X (58.5 g NaCl / 1 mol NaCl) X 1.2 excess = **0.147 g NaCl needed**

$AgNO_3$ solution used was 1000 ppm = 1000 mg/L

(1000 mg/L Ag) X (1 g / 1000 mg) X (1 mol Ag / 108 g Ag) = 0.00926 mol/L Ag

Volume of $AgNO_3$ needed = C_fV_f/C_i (where C_f is 500 mL) = (0.00210 mol/L Ag) X (0.5 L + Vneeded) / (0.00926 mol/L Ag)

0.00926V = 0.00105 + 0.00210V → **Volume of $AgNO_3$ needed = 147 mL**

The actual TSS produced using the calculate values of chemicals to add is 415 mg/L compared to the desired 300 mg/L.

Table 26. AgCl TSS Results

Silver Chloride TSS	
Sample Volume (mL)	200
Tare Wt. (mg)	104789
Gross Wt. -103C (mg)	104872
TSS (mg)	83
TSS (mg/L)	415

Differences between Calculated values and TSS values found during the experiment could be attributed to volumetric measurement error when using the beakers. Below are the calculations for how much precipitate should have been produced for each reaction compared with what was produced.

$AgNO_3 + K_2CrO_4 \rightarrow Ag2CrO_{4(s)} + 2KNO_3$

> 0.24 g K_2CrO_4 = 240 mg K_2CrO_4
> 143 mL $AgNO_3$ at 1000 ppm
>
> 143 mL $AgNO_3$ X (1000 mg/L) X (1 L/1000 mL) = 143 mg $AgNO_3$
>
> Total Chemicals Added = 240 mg K_2CrO_4 + 143 mg $AgNO_3$ = **383 mg Chemicals** in 500 mL of DI water + 143 mL $AgNO_3$
>
> Should have produced **X**
> (383 mg chemicals added/643 mL total volume) = **X**/(200 mL of solution put in oven)
> **X = 119 mg $AgCrO_4$**
>
> TS results in lab for 200 mL of solution produced **83 mg $AgCrO_4$**
>
> Percent Difference = 30 %

$AgNO_3 + NaCl \rightarrow AgCl(s) + NaNO_3$

> 0.147 g NaCl = 147 mg NaCl
> 147 mL $AgNO_3$ at 1000 ppm
>
> 147 ml $AgNO_3$ X (1000 mg/L) X (1 L/1000 mL) = 147 mg $AgNO_3$
>
> Total Chemicals Added = 147 mg NaCl + 147 $AgNO_3$ = **294 mg Chemicals** in 500 mL of DI water + 143 mL $AgNO_3$
>
> Should have produced **X**

(294 mg chemicals added/647 mL total volume) = **X**/(200 mL of solution put in oven)
X = 90.9 mg AgCl

TS results in lab for 200 mL of solution produced **124 mg AgCl**

Percent Difference = 27 %

The percent differences are attributed to volumetric measurement error becase the expected amount for AgCl was 27% less than the actual TSS results while the expected amount for $AgCrO_4$ was 30% higher than the actual TSS results. Most beakers can vary by plus or minus 50 mL. Two beaker measurements were used – one to add 500 mL of DI water to either NaCl or K_2CrO_4 before the $AgNO_3$ was added, and the second beaker was used to place 200 mL of the solutions with the formed precipitates in the oven for TSS measurement. A volumetric measurement error in either one or both of the beakers could easily have affected the percent difference between how much precipitate was expected to form and how much precipitate was actually made.

Appendix C – Attribute Table for Background Turbidity Maps

Table 27. Attribute Table Used in ArcGIS to Create Background Turbidity Maps for Texas

STATION_ID	X	Y	NAD	MAX	MIN	MEDIAN
08037000	-94.726111	31.457222	27.00	61.00	8.00	28.5
07297910	-101.413611	34.837500	27.00	23000.00	0.00	9.6
08178880	-99.069722	29.723611	27.00	240.00	0.20	1
08179000	-98.975833	29.675278	27.00	15.00	0.20	3.75
293736099034801	-99.064956	29.626422	83.00	0.20	0.20	0.2
293934098584801	-98.979806	29.659389	83.00	2.80	2.80	2.8
294243099073801	-99.127228	29.712189	83.00	25.00	25.00	25
294309099015701	-99.033000	29.719750	83.00	2.60	2.60	2.6
294425098495401	-98.832003	29.740883	83.00	16.00	16.00	16
294717099165301	-99.281972	29.788028	83.00	0.20	0.20	0.2
294815099343801	-99.574389	29.811186	83.00	0.36	0.36	0.36
08159165	-97.296667	30.305000	27.00	720.00	2.60	160
08159170	-97.327500	30.265000	27.00	530.00	7.60	160
08159180	-97.284167	30.241389	27.00	400.00	32.00	230
08159185	-97.317500	30.230278	27.00	130.00	3.60	66.8
08102500	-97.441111	31.070000	27.00	6.40	0.50	2.4
08104100	-97.492222	31.001667	27.00	3.00	0.30	1.2
08177600	-98.545833	29.576389	27.00	85.00	17.00	50
08177700	-98.510000	29.498889	27.00	2700.00	0.30	180
08177800	-98.473889	29.473333	27.00	31.00	2.50	3.7
08177860	-98.478333	29.451111	27.00	5.40	0.40	3
08178000	-98.494722	29.409444	27.00	580.00	0.90	11.5
08178050	-98.494444	29.392778	27.00	98.00	0.30	6.9
08178300	-98.549722	29.458056	27.00	680.00	140.00	195
08178555	-98.492222	29.351389	27.00	680.00	60.00	120
08178620	-98.463056	29.590000	27.00	870.00	6.80	120
08178640	-98.441389	29.623056	27.00	1700.00	2.60	85
08178645	-98.428056	29.617778	27.00	130.00	2.90	24
08178690	-98.440278	29.526667	27.00	84.00	6.80	18
08178700	-98.430833	29.515833	27.00	3300.00	0.30	26
08178800	-98.412500	29.356944	27.00	550.00	0.70	7.65
08180700	-98.689444	29.334722	27.00	16.00	0.95	6
08180720	-98.641944	29.295000	27.00	6.70	6.70	6.7

STATION_ID	X	Y	NAD	MAX	MIN	MEDIAN
08180750	-98.638806	29.327972	83.00	1.60	1.60	1.6
08180800	-98.581111	29.261944	27.00	34.00	3.40	12
08181000	-98.627778	29.587222	27.00	230.00	180.00	205
08181400	-98.691389	29.578333	27.00	370.00	1.20	24
08181450	-98.600000	29.386667	27.00	190.00	17.00	130
08181480	-98.583889	29.329722	27.00	500.00	0.30	3.95
08181500	-98.490556	29.263889	27.00	450.00	1.80	15.5
08181800	-98.355556	29.221944	27.00	580.00	0.60	9
291720098422301	-98.706389	29.288889	83.00	0.24	0.24	0.24
292109098343001	-98.575000	29.352500	83.00	0.41	0.41	0.41
292624098335001	-98.563889	29.440000	83.00	0.10	0.10	0.1
292648098303401	-98.501111	29.446667	83.00	0.30	0.30	0.3
292648098303701	-98.501944	29.446667	83.00	1.50	1.50	1.5
292808098230101	-98.383611	29.468889	83.00	0.09	0.09	0.09
293100098225401	-98.373333	29.516667	83.00	0.21	0.21	0.21
293133098303201	-98.509444	29.526111	83.00	0.17	0.17	0.17
293504098332601	-98.557222	29.584444	83.00	0.11	0.11	0.11
293512098291701	-98.488056	29.586667	83.00	0.41	0.41	0.41
293525098213701	-98.360278	29.590278	83.00	0.15	0.15	0.15
293551098244801	-98.413333	29.597500	83.00	0.20	0.20	0.2
294300098402501	-98.674028	29.715000	83.00	3.60	3.60	3.6
300438098232401	-98.390611	30.077500	83.00	0.80	0.80	0.8
300828098305601	-98.516194	30.141361	83.00	0.90	0.90	0.9
300832098185201	-98.314389	30.142611	83.00	3.50	3.50	3.5
08095200	-97.469167	31.669444	27.00	26.00	0.50	4.4
07344210	-94.151389	33.304167	83.00	70.00	2.00	5.5
08078000	-95.320556	29.369167	27.00	340.00	0.90	29
08111000	-96.192222	30.869444	27.00	100.00	6.50	43
08212400	-98.135556	27.264167	27.00	81.00	20.00	30
08109800	-96.817222	30.407222	27.00	1900.00	1.20	20
08110000	-96.507222	30.321667	27.00	50.00	1.80	14
08103900	-98.036667	30.911389	27.00	26.00	0.10	0.6
08470400	-97.700278	26.173333	27.00	330.00	1.70	97
08475000	-97.454167	25.876389	27.00	860.00	0.50	25
07299540	-100.192778	34.569167	27.00	16000.00	0.60	5.2
08123850	-100.761667	32.053611	27.00	2300.00	0.50	19
08141500	-99.534444	31.834167	27.00	1.80	1.10	1.4
08058900	-96.608611	33.243889	27.00	410.00	1.10	14

STATION_ID	X	Y	NAD	MAX	MIN	MEDIAN
08059400	-96.482778	31.294444	27.00	1000.00	0.30	8.45
08061000	-96.475278	33.023611	27.00	17.00	2.20	3.8
07300000	-100.220556	34.957500	27.00	1600.00	0.70	3.25
08160700	-96.571111	29.719167	27.00	1600.00	1.10	26
08167500	-98.383333	29.860278	27.00	880.00	0.60	6.5
08167800	-98.179722	29.858889	27.00	22.00	0.70	2.6
293745098162001	-98.272222	29.629167	83.00	0.40	0.40	0.4
294137098093201	-98.158889	29.693611	83.00	8.60	8.60	8.6
294249098080301	-98.134444	29.713611	83.00	0.24	0.24	0.24
294300098080001	-98.137500	29.712778	83.00	0.05	0.05	0.05
294323098115101	-98.197500	29.723056	83.00	0.10	0.10	0.1
294344098253801	-98.427583	29.728972	83.00	0.20	0.20	0.2
294428098063701	-98.110278	29.741111	83.00	0.30	0.30	0.3
294650098265801	-98.453167	29.780778	83.00	0.30	0.30	0.3
294743098291801	-98.488333	29.795278	83.00	0.20	0.20	0.2
294918098330301	-98.551456	29.821878	83.00	0.30	0.30	0.3
295013098255201	-98.431483	29.836983	83.00	0.40	0.40	0.4
295352098071201	-98.120000	29.897778	83.00	0.20	0.20	0.2
295458098143001	-98.242694	29.916278	83.00	0.60	0.60	0.6
295555098222801	-98.374444	29.931944	27.00	94.00	94.00	94
08099100	-98.532778	32.173611	27.00	220.00	0.50	4.25
08099300	-98.604444	32.113889	27.00	910.00	0.40	7.2
08099500	-98.458889	31.957778	27.00	36.00	1.10	17
08136500	-99.919167	31.515833	27.00	42.00	1.20	16
08101000	-97.884722	31.284722	27.00	110.00	0.20	1.1
08049500	-96.994444	32.762500	83.00	750.00	0.20	10
08049600	-97.023056	32.584167	27.00	1400.00	0.80	32
08049850	-96.990000	32.651944	27.00	40.00	1.00	15.5
08049900	-96.982222	32.661944	27.00	1100.00	1.50	35
08057410	-96.735556	32.707500	27.00	110.00	2.00	13
07342500	-95.594722	33.356389	27.00	1000.00	0.90	31
08050500	-97.084722	33.386389	27.00	140.00	0.90	13.5
08051000	-97.012500	33.406389	27.00	180.00	14.00	46
08051130	-97.046944	33.350278	27.00	180.00	3.10	10
08051500	-97.179167	33.336111	27.00	170.00	1.40	12
08052700	-96.892500	33.283333	27.00	810.00	6.50	73
08053000	-96.960833	33.045556	27.00	370.00	1.00	7.9
08053500	-97.290278	33.118889	27.00	130.00	1.60	10

STATION_ID	X	Y	NAD	MAX	MIN	MEDIAN
08053800	-97.247778	33.020000	27.00	85.00	0.59	7.5
08055000	-97.012500	32.986944	27.00	77.00	0.86	5.3
08062500	-96.462778	32.426389	27.00	210.00	1.10	14
08063685	-96.738611	32.307500	27.00	250.00	0.60	10
08063800	-96.640000	32.243333	27.00	27.00	2.20	19
08364000	-106.540278	31.802778	27.00	13000.00	1.10	41.5
314908106342610	-106.573889	31.818889	27.00	21.00	21.00	21
314939106345210	-106.581111	31.827500	27.00	20.00	20.00	20
315035106352710	-106.590833	31.843056	27.00	17.00	17.00	17
315454106360610	-106.602222	31.915278	83.00	47.00	2.80	9.4
315807106361910	-106.605278	31.968611	27.00	190.00	6.90	43
08098290	-96.824722	31.133889	27.00	1000.00	0.50	21
08072300	-95.806667	29.743056	27.00	300.00	5.60	80
08114000	-95.757500	29.582222	27.00	890.00	0.40	82
08116650	-95.582222	29.349444	27.00	780.00	4.30	96
08117500	-95.893611	29.313333	27.00	200.00	0.40	45
08064700	-96.289722	31.848333	27.00	230.00	1.20	9.5
08188500	-97.384858	28.649286	83.00	1600.00	1.00	40
08173900	-97.450000	29.484167		30.00	3.60	9.1
07301200	-100.608889	35.329167	27.00	1200.00	1200.00	1200
07331600	-96.563056	33.818889	27.00	15.00	0.50	2.4
08050840	-96.806944	33.526111	27.00	320.00	3.10	30
08068740	-95.717500	29.958889	27.00	260.00	2.80	33
08069000	-95.428611	30.035556	27.00	300.00	3.90	70
08069200	-95.329722	30.030278	27.00	320.00	4.20	76
08072730	-95.686667	29.830556	27.00	800.00	4.50	80
08072760	-95.646389	29.866944	27.00	300.00	8.60	96.5
08073500	-95.605556	29.761667	27.00	460.00	3.80	61
08073600	-95.557500	29.761944	27.00	350.00	3.10	32.5
08073630	-95.539722	29.775556	27.00	90.00	1.90	24
08073700	-95.523333	29.746667	27.00	20.00	20.00	20
08074000	-95.408333	29.760000	27.00	160.00	2.10	69
08074145	-95.485833	29.858611	27.00	280.00	1.10	55.5
08074250	-95.469167	29.827778	27.00	310.00	1.00	18
08074400	-95.434444	29.804167	27.00	100.00	1.20	15
08074500	-95.396944	29.775000	27.00	470.00	0.40	27
08074540	-95.368056	29.792778	83.00	350.00	1.20	53
08074550	-95.368333	29.792500	27.00	350.00	0.60	46

STATION_ID	X	Y	NAD	MAX	MIN	MEDIAN
08074598	-95.358333	29.766389	27.00	150.00	10.00	82
08074610	-95.351944	29.765833	27.00	130.00	32.00	83.5
08074800	-95.561944	29.656389	27.00	690.00	3.60	115
08075000	-95.411944	29.696944	27.00	340.00	1.20	19
08075100	-95.356389	29.709722	27.00	190.00	50.00	110
08075400	-95.434444	29.618611	27.00	400.00	6.10	80
08075500	-95.289167	29.674167	27.00	300.00	2.40	30
08075650	-95.243611	29.676389	27.00	150.00	18.00	48.5
08075730	-95.216111	29.694444	27.00	200.00	5.00	63
08075760	-95.330556	29.806111	27.00	250.00	1.70	18
08075770	-95.267778	29.793056	27.00	300.00	1.40	19
08076000	-95.306667	29.918056	27.00	810.00	7.50	40
08076500	-95.034722	29.861667	27.00	300.00	1.10	25
08076700	-95.233056	29.836944	27.00	380.00	70.00	150
294617095390502	-95.651389	29.771389	27.00	380.00	1.60	67.5
294729095372502	-95.623611	29.791389	27.00	480.00	4.40	74
295516095080801	-95.135556	29.921111	27.00	81.00	2.50	24
295702095091401	-95.153889	29.950556	27.00	48.00	14.00	27
295902095074201	-95.128333	29.983889	27.00	80.00	2.50	26
300016095073401	-95.126111	30.004444	27.00	48.00	15.00	26
300158095074601	-95.129444	30.032778	27.00	73.00	4.70	26
300209095091201	-95.153333	30.035833	27.00	400.00	3.50	31
07346070	-94.345833	32.712778	27.00	42.00	3.00	14
07346085	-94.187778	32.696389	83.00	17.00	2.80	8.35
08158700	-98.007500	30.082500	27.00	580.00	0.10	0.9
08158800	-97.847778	30.085833	27.00	1200.00	0.00	30
08158810	-97.939722	30.155278	27.00	500.00	0.00	1
08158825	-97.861944	30.125278	27.00	280.00	5.20	65
08171000	-98.088611	29.994167	27.00	30.00	0.30	1.7
295108097591401	-97.987222	29.852222	83.00	0.17	0.17	0.17
295322097561000	-97.931667	29.892500	83.00	0.35	0.35	0.35
295322097561002	-97.930000	29.893333	83.00	0.18	0.18	0.18
295345098001001	-98.002778	29.895833	83.00	0.20	0.20	0.2
295406097551201	-97.920000	29.901667	83.00	0.10	0.10	0.1
300041097563901	-97.944167	30.011389	83.00	0.40	0.40	0.4
300516098113201	-98.191861	30.087547	83.00	1.00	1.00	1
300630098161001	-98.269464	30.108133	83.00	0.16	0.16	0.16
07228000	-100.370278	35.935000	27.00	130.00	0.20	6.05

STATION_ID	X	Y	NAD	MAX	MIN	MEDIAN
08062700	-96.102222	32.147500	27.00	360.00	0.50	50
08092000	-97.452500	32.150556	27.00	20.00	0.60	2.2
08092600	-97.366667	31.866667	27.00	4.90	0.50	1.8
08093160	-97.245556	31.977778	27.00	870.00	0.10	15
08093250	-97.149722	32.005556	27.00	870.00	3.40	28
08093260	-97.143889	31.995278	27.00	230.00	1.20	24.5
08093360	-97.202778	31.895278	27.00	120.00	2.30	29
08093500	-97.201111	31.844444	27.00	550.00	2.20	16
315518097123401	-97.209444	31.921667	27.00	25.00	25.00	25
08065350	-95.656111	31.338333	27.00	510.00	0.70	60
08370500	-105.606944	31.084722	27.00	950.00	1.40	54.5
07342470	-95.862500	33.219722	27.00	600.00	1.00	28
07342480	-95.915278	33.266389	27.00	410.00	2.00	33.5
08164000	-96.686111	28.959722	27.00	470.00	0.50	11.5
08164450	-96.546111	29.160000	27.00	170.00	0.70	11
08164500	-96.552222	29.025556	27.00	170.00	5.40	25
08164503	-96.468028	29.071858	83.00	300.00	1.10	28
285331096343501	-96.574722	28.894444	27.00	140.00	2.50	60.5
08039500	-94.151944	31.015000	27.00	100.00	1.30	3.3
08041000	-94.093056	30.355556	27.00	60.00	1.80	23
08431700	-104.001111	30.613333	27.00	150.00	1.00	75
08049580	-97.122778	32.490833	27.00	330.00	1.80	6.5
08061750	-96.503333	32.774167	27.00	230.00	1.50	11
08062000	-96.485000	32.638611	27.00	260.00	0.80	10.5
294718098443001	-98.741950	29.788203	83.00	0.10	0.10	0.1
295322098471401	-98.787578	29.889667	83.00	0.20	0.20	0.2
295709098535301	-98.898089	29.952611	83.00	0.70	0.70	0.7
295827098424301	-98.712306	29.974139	83.00	2.80	2.80	2.8
300044098471801	-98.788589	30.012481	83.00	1.80	1.80	1.8
295443099142301	-99.242028	29.916972	83.00	0.76	0.76	0.76
300235099205901	-99.351194	30.043217	83.00	0.90	0.90	0.9
300534099120401	-99.201358	30.092853	83.00	17.00	17.00	17
300559099084401	-99.145897	30.099731	83.00	0.30	0.30	0.3
291836100251501	-100.421111	29.309167	83.00	1.10	1.10	1.1
291837100251801	-100.421667	29.310278	83.00	0.08	0.08	0.08
291901100245301	-100.414722	29.316944	83.00	0.16	0.16	0.16
08103800	-98.016389	31.081667	27.00	16.00	0.30	2.4
08147000	-98.564167	31.217778	27.00	1500.00	0.40	23

STATION_ID	X	Y	NAD	MAX	MIN	MEDIAN
08066500	-94.850556	30.425000	27.00	120.00	0.50	9.5
08067500	-94.985556	29.972500	27.00	690.00	9.00	68
08070000	-95.103889	30.336389	27.00	88.00	6.00	26.5
08071280	-95.059722	30.109444	27.00	52.00	1.90	24
07235000	-100.275278	36.237778	27.00	5.60	5.60	5.6
08210000	-98.177778	28.427222	27.00	530.00	0.75	18
08151500	-98.669444	30.751111	27.00	160.00	0.40	4.35
08095300	-97.365556	31.509167	27.00	8.00	0.27	1.6
08095600	-97.193333	31.601111	27.00	41.00	0.90	7.2
08206600	-98.547222	28.467222	27.00	160.00	5.00	32
08206700	-98.545556	28.587222	27.00	240.00	2.60	10
07346000	-94.498611	32.749444	27.00	6.50	0.80	2.7
08162600	-96.170833	28.927778	27.00	300.00	2.00	24
08162700	-96.284722	28.863333	27.00	310.00	2.30	32
08180640	-98.812778	29.323889	27.00	12.00	0.50	2.5
08200000	-99.247689	29.570031	83.00	200.00	0.00	0.5
291222099095601	-99.165556	29.206111	83.00	0.47	0.47	0.47
291231098565901	-98.949722	29.208611	83.00	0.18	0.18	0.18
291358098531901	-98.888611	29.232778	83.00	0.06	0.06	0.06
291523099135401	-99.232222	29.256389	83.00	0.11	0.11	0.11
291743099081801	-99.139444	29.297500	83.00	0.50	0.50	0.5
291828098485301	-98.814722	29.307778	83.00	0.06	0.06	0.06
291943099163301	-99.278056	29.331944	83.00	0.08	0.08	0.08
292037098501201	-98.836667	29.343611	83.00	0.30	0.30	0.3
292037099082001	-99.138889	29.346944	83.00	0.04	0.04	0.04
292411099082701	-99.140833	29.403056	83.00	1.50	1.50	1.5
292556099065801	-99.116111	29.431944	83.00	0.06	0.06	0.06
292607098564101	-98.944722	29.435278	83.00	0.11	0.11	0.11
292656099000701	-99.001944	29.448889	83.00	0.48	0.48	0.48
292804099151301	-99.253611	29.467778	83.00	4.00	4.00	4
292853099084901	-99.146944	29.481389	83.00	0.60	0.60	0.6
292916099060301	-99.100833	29.487778	83.00	0.50	0.50	0.5
292924099044401	-99.078889	29.490000	83.00	0.50	0.50	0.5
292940099225101	-99.380833	29.494444	83.00	0.80	0.80	0.8
293231099165801	-99.282778	29.541944	83.00	0.46	0.46	0.46
293332099190301	-99.317500	29.558889	83.00	0.40	0.40	0.4
08106500	-96.946389	30.835000	27.00	950.00	0.50	55.5
08067650	-95.542778	30.341944	27.00	38.00	2.00	5.4

STATION_ID	X	Y	NAD	MAX	MIN	MEDIAN
08067900	-95.579000	30.253778	83.00	88.00	5.00	14
08068000	-95.456944	30.244444	27.00	120.00	1.80	19.5
08068090	-95.299722	30.085833	27.00	240.00	2.70	55.5
08068390	-95.491111	30.190556	83.00	36.00	4.40	11
08068400	-95.483611	30.191944	27.00	26.00	1.50	12.5
08068450	-95.481111	30.130833	27.00	18.00	1.00	4.5
08070200	-95.124167	30.145278	27.00	83.00	8.50	28.5
08070500	-95.302222	30.259444	27.00	110.00	3.90	20
07343850	-94.741667	33.275000	27.00	67.00	14.00	36
08063045	-96.814444	31.976944	27.00	960.00	1.40	23
08063100	-96.681111	31.938333	27.00	230.00	7.70	18
08063500	-96.421111	31.950556	27.00	200.00	1.70	16
08064100	-96.520000	32.198333	27.00	1100.00	0.40	33.5
08025307	-93.676389	31.156389	27.00	30.00	5.20	10
08026000	-93.519444	31.063889	27.00	40.00	0.20	4.45
08030500	-93.743611	30.303611	27.00	40.00	1.50	14.5
08211520	-97.501667	27.711111	27.00	960.00	1.50	29
08022040	-94.353333	32.327222	27.00	74.00	1.10	14
08045850	-97.651667	32.740278	27.00	200.00	0.50	12.45
07227500	-101.879167	35.470278	27.00	24000.00	3.00	60
08374200	-104.286111	29.519444	27.00	240.00	24.00	85
07343200	-95.062222	33.390556	27.00	1000.00	4.50	40
08188800	-96.884444	28.505556	27.00	300.00	0.90	38
08189200	-97.112222	28.303333	27.00	390.00	3.10	70
08189500	-97.278889	28.291667	27.00	640.00	0.60	12
08024300	-93.807222	31.528333	27.00	20.00	20.00	20
08038000	-94.304167	31.504167	27.00	72.00	10.00	27
08189800	-97.503611	28.046667	27.00	25.00	5.00	8
08022500	-94.006111	31.972222	27.00	50.00	2.00	15
08091000	-97.702222	32.258889	27.00	100.00	0.40	2.2
08461300	-99.168056	26.556944	27.00	35.00	0.70	5.8
08080500	-100.180278	33.008056	27.00	11000.00	0.40	50
08082000	-100.237778	33.333889	27.00	5600.00	0.00	3.2
08047000	-97.441667	32.665000	27.00	82.00	0.40	4.85
08048970	-97.264722	32.603333	27.00	14.00	3.20	8.6
08049700	-97.101667	32.580833	27.00	340.00	1.20	4.25
07343500	-95.092500	33.322222	27.00	90.00	5.10	37
07344500	-94.881944	33.020833	27.00	36.00	0.41	16

STATION_ID	X	Y	NAD	MAX	MIN	MEDIAN
08134000	-100.636667	31.592500	27.00	220.00	6.00	17
08135000	-100.447500	31.432500	27.00	28.00	6.50	13.5
313023100321101	-100.536389	31.506389	27.00	0.60	0.60	0.6
08154700	-97.784444	30.371944	27.00	3800.00	0.20	31
08154750	-97.790000	30.359444	27.00	2.00	0.20	1.5
08155200	-97.925278	30.296111	27.00	560.00	0.00	3.6
08155240	-97.844444	30.273889	27.00	500.00	0.20	17
08155260	-97.828611	30.270000	27.00	800.00	0.50	80
08155300	-97.801944	30.244444	27.00	2200.00	0.00	68
08155400	-97.771944	30.263333	27.00	370.00	0.19	47.5
08155500	-97.771111	30.263333	27.00	44.00	0.00	0.9
08156800	-97.750000	30.276389	27.00	4000.00	0.17	270
08157600	-97.753889	30.251944	27.00	200.00	0.80	28
08157700	-97.743611	30.247222	27.00	200.00	1.10	44
08158000	-97.694167	30.244444	27.00	280.00	0.10	1.5
08158050	-97.672222	30.263056	27.00	3300.00	0.40	240
08158200	-97.660278	30.375000	27.00	2600.00	0.50	2.6
08158600	-97.654722	30.283056	27.00	3100.00	0.20	190
08158640	-97.656667	30.266111	27.00	2100.00	1.70	4.6
08158840	-97.903056	30.208889	27.00	150.00	0.16	1.1
08158860	-97.831944	30.161944	27.00	160.00	2.00	55
08158920	-97.860000	30.235000	27.00	2600.00	0.00	50.5
08158922	-97.841111	30.226111	27.00	280.00	0.10	17
08158970	-97.732222	30.189167	27.00	1000.00	0.20	2.9
08159000	-97.688333	30.177778	27.00	820.00	0.20	6
301500097424801	-97.713833	30.250417	83.00	160.00	0.30	3
301546097445101	-97.747528	30.263056	83.00	490.00	0.40	5.25
301558097452201	-97.756222	30.266194	83.00	410.00	0.40	2.5
301712097470701	-97.785556	30.287333	83.00	66.00	0.20	2
301739097471201	-97.787222	30.294472	83.00	65.00	0.40	3.1
301926097502201	-97.843667	30.327167	83.00	30.00	0.30	1.6
302021097540001	-97.903528	30.335944	83.00	30.00	0.30	1.2
302043097472401	-97.790000	30.345278	27.00	120.00	0.30	2.7
302314097544901	-97.913889	30.387389	83.00	25.00	0.00	1.65
08033500	-94.399444	31.025000	83.00	100.00	11.00	29.5
08019500	-95.091389	32.603889	27.00	16.00	0.30	5.6
08190000	-99.996944	29.428333	27.00	600.00	0.00	0.6
08195000	-99.704444	29.488333	27.00	5.30	0.00	0.45

STATION_ID	X	Y	NAD	MAX	MIN	MEDIAN
08196000	-99.781111	29.504444	27.00	5.30	0.00	0.4
08198000	-99.492500	29.490833	27.00	2.00	0.00	0.5
291135099495001	-99.831667	29.190833	83.00	0.10	0.10	0.1
291238099464801	-99.780000	29.210556	83.00	0.30	0.30	0.3
291732099530601	-99.885000	29.292222	83.00	0.30	0.30	0.3
291840099382601	-99.640556	29.311111	83.00	0.16	0.16	0.16
291909099281001	-99.469444	29.319167	83.00	0.30	0.30	0.3
291937099280501	-99.468056	29.326944	83.00	0.08	0.08	0.08
292039099384401	-99.645556	29.344167	83.00	4.60	4.60	4.6
292103099380201	-99.633889	29.350833	83.00	0.11	0.11	0.11
292112099294801	-99.497778	29.355833	83.00	0.21	0.21	0.21
292310100011401	-100.020556	29.386111	83.00	0.30	0.30	0.3
292325099413101	-99.691944	29.390278	83.00	0.20	0.20	0.2
292346099594701	-99.996389	29.396111	83.00	0.30	0.30	0.3
292352099354501	-99.595833	29.397778	83.00	1.00	1.00	1
292447099371601	-99.621111	29.413056	83.00	0.40	0.40	0.4
292544099451001	-99.752778	29.428889	83.00	0.10	0.10	0.1
292651099401601	-99.671111	29.447500	83.00	0.10	0.10	0.1
292856099262201	-99.439444	29.482222	83.00	0.20	0.20	0.2
293711099320701	-99.535331	29.620300	83.00	0.35	0.35	0.35
08377200	-101.755556	29.780556	27.00	10000.00	0.10	80
08447410	-101.445833	29.802778	27.00	100.00	0.20	1
08450900	-101.040833	29.425000	27.00	12.00	0.10	0.8
08017410	-95.919167	32.806111	27.00	160.00	0.40	9.5
08450900	-101.040833	29.425000	27.00	12.00	0.10	0.8
08017410	-95.919167	32.806111	27.00	160.00	0.40	9.5
08164600	-96.818889	28.891111	27.00	170.00	0.25	27
08164800	-96.768611	28.725000	27.00	130.00	3.00	15
08176500	-97.012778	28.792778	27.00	240.00	0.40	22
08459200	-99.488333	27.400278	27.00	400.00	0.70	29
272352098585101	-98.980833	27.397778	27.00	1.40	1.40	1.4
272550098501601	-98.837778	27.430556	27.00	0.10	0.10	0.1
272636098531601	-98.887778	27.443333	27.00	0.10	0.10	0.1
272726099010001	-99.016667	27.457222	27.00	0.20	0.13	0.165
272749099100701	-99.168611	27.463611	27.00	0.14	0.14	0.14
272804098582001	-98.971667	27.468056	27.00	0.48	0.48	0.48
272813099093901	-99.160833	27.470278	27.00	0.16	0.16	0.16
272902099251601	-99.421111	27.483889	27.00	0.18	0.18	0.18

STATION_ID	X	Y	NAD	MAX	MIN	MEDIAN
272942099262001	-99.438889	27.495000	27.00	0.57	0.57	0.57
273145099285401	-99.481667	27.529167	27.00	0.14	0.14	0.14
273154099284801	-99.480000	27.531667	27.00	0.15	0.15	0.15
273232098490301	-98.817500	27.542222	27.00	0.15	0.15	0.15
273331099291701	-99.488056	27.558611	27.00	0.16	0.16	0.16
273455099175901	-99.299722	27.581944	27.00	2.00	2.00	2
273521099274101	-99.461389	27.589167	27.00	0.14	0.14	0.14
273533099260401	-99.434444	27.598611	27.00	0.12	0.12	0.12
273903099374501	-99.629167	27.650833	27.00	1.30	1.30	1.3
274012099343101	-99.575278	27.670000	27.00	1.20	1.20	1.2
274115099271301	-99.453611	27.687500	27.00	0.11	0.11	0.11
274122099261301	-99.436944	27.689444	27.00	0.25	0.25	0.25
274633099265401	-99.448333	27.775833	27.00	0.60	0.60	0.6
274759099273201	-99.458889	27.799722	27.00	7.10	7.10	7.1
274808099221301	-99.370278	27.802222	27.00	0.45	0.45	0.45
274828099190601	-99.318333	27.807778	27.00	0.15	0.15	0.15
274839099203401	-99.342778	27.810833	27.00	0.40	0.40	0.4
275125099155601	-99.265556	27.856944	27.00	0.30	0.20	0.25
275157099301801	-99.505000	27.865833	27.00	0.74	0.74	0.74
275223099235301	-99.398056	27.873056	27.00	1.00	1.00	1
275305099194201	-99.328333	27.884722	27.00	0.28	0.28	0.28
275332099132001	-99.222222	27.892222	27.00	0.22	0.22	0.22
275355099381701	-99.638056	27.898611	27.00	0.17	0.17	0.17
275631099372001	-99.622222	27.941944	27.00	0.18	0.18	0.18
275812099535801	-99.899444	27.970000	27.00	0.18	0.18	0.18
280034099220101	-99.366944	28.009444	27.00	2.00	2.00	2
280152099240901	-99.402500	28.031111	27.00	3.50	3.50	3.5
280318099400501	-99.668056	28.055000	27.00	0.30	0.30	0.3
08162000	-96.103611	29.308889	27.00	1000.00	0.30	32
07308500	-98.531389	34.110000	27.00	3300.00	0.30	42
08104700	-97.711111	30.661667	27.00	10.00	0.30	1.8
08105300	-97.585000	30.645833	27.00	540.00	0.40	5.75
08105700	-97.278611	30.694167	27.00	200.00	1.00	19
08018500	-95.485556	32.613611	27.00	70.00	7.90	24.5