Turbidity in Highway Construction Site Runoff: Preparing for Numerical Effluent Limits

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Abstract: A numerical turbidity limit that will affect highway construction sites to meet a standard turbidity value in the runoff was to be implemented in 2013. Although the limit appears to be deferred to future permits, this study addresses multiple turbidity issues that are relevant in implementations of numerical limits for construction storm water quality. Background turbidity maps are created to graphically present the natural turbidity background levels in the state of Texas, and those maps are compared with the proposed numerical limit; the median value map is interpreted as supportive of a regionally adjusted numerical limit. The water and solids color effect on turbidity measurement is evaluated, in addition to the use of sample dilution to extend instrument range. Substantial turbidity measurement differences between two different types of turbidimeters (field portable and bench) is explored, and a cause is postulated. Two construction sites were monitored to develop a reasonable protocol for self-reporting, should future permits require such activity. The results suggest that adjustable numerical limits should be used in future permits if such permits require monitoring; water and solids color effects are negligible for intended application; sample dilution can extend instrument range, but diluted samples under-report turbidity; and the selection of instrumentation is nontrivial. **DOI:** **10.1061/(ASCE)EE.1943-7870.0000805.** © *2014 American Society of Civil Engineers.*

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Introduction

The Texas Construction General Permit (CGP) is scheduled for renewal in 2013. Highway construction projects have to adhere to storm water pollution prevention standards promulgated by the U.S. Environmental Protection Agency (USEPA).

One potential component of the new standards was to monitor and self-report the storm water runoff from selected construction site discharge points. Contained within that proposed requirement was a numerical turbidity limit of 280 nephlometric turbidity units (NTUs) for all construction sites that disturb more than 10 acres at one time (USEPA 2009).

The numeric limit was stayed; as such, one could consider the issue null. However, the wording in the *Federal Register* clearly implies that at some time in the future a numeric limit will be issued.

"... Since the numeric portion of the rule was stayed, states are no longer required to incorporate the numeric turbidity limitation and monitoring requirements found at § 450.22(a) and § 450.22(b). However, the remainder of the regulation is still in effect and must be incorporated into newly issued permits. The purpose of this notice is to solicit new data from the public and request comment on a number of issues that the USEPA would like to consider in the *context of establishing numeric effluent limitations* for construction site stormwater discharges" ("Effluent Limitations" 2012; *Federal Register,* Vol. 77, No. 1, Jan. 3, 2012).

As of June 2012 the Texas CGP does not contain a monitoring requirement, undoubtedly a response to collective concern of the construction industry, facility owners, and the regulatory community to some of the issues identified in this paper and described in the *Federal Register.* However, a reasonable expectation for future permits is that turbidity monitoring will be required from highway construction sites (possibly without regard to best management practices technological capabilities); hence, the contents of this paper are relevant for these future conditions.

This remainder of this paper explores the feasibility and challenges anticipated with the use of turbidity as a regulatory tool in highway construction.

General Approach

This research assesses the applicability of turbidity as a storm water quality parameter for regulatory assessment of highway construction runoff controls by examining how the particular numerical value compares with existing spatially distributed turbidity values in Texas waters, examining the effects of water and solids color on turbidity measurements, and conducting a field monitoring study to develop a self-reporting protocol for sample collection and analysis employable by nonexperts in water quality analysis.

Geographic Theme Mapping

The spatially distributed background turbidity was determined by using the USGS National Water Information System website and *ArcGIS*. A total of 408 USGS stations in Texas with parameter code 00076 (turbidity in NTU) were identified. Without regard to season, the data for each station were analyzed to compute a minimum, maximum, and median value turbidity.

ArcGIS was used to create a map of the station locations within Texas using the NAD 1983 datum. The kriging algorithm

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in *ArcGIS* was used to produce three contour maps of turbidity: the minimum, maximum, and median turbidity. These maps were then interpreted in the context of the applicability of the 280 NTU limit as an achievable water quality goal, considering that the map values represent decidedly nonconstruction runoff contributions.

Turbidity Measurement Issues

Three general turbidity measurement issues were examined: the color (of water and solids), dilution (as a way to extend instrument range), and instrument selection (field portable versus laboratory).

Two different turbidimeters models were used: a Hach 2100N (Loveland Colorado) (lab instrument, 0–4,000 NTU range) and two identical Hach 2100P (field-portable instrument, 0–1,000 NTU range). There are other manufacturers of such instruments, but the comparisons in this paper should be interpreted as comparison of a field portable versus a same-manufacturer laboratory instrument.

The turbidity literature suggests that color affects measurements (Ginting and Mamo 2006; Gippel et al. 1991; Sadar and Engelhardt 2011; Downing 2005; Sutherland et al. 2000) in turbidimeters with a single-light detector because the samples that are darker in color will decrease the amount of scattered light reaching the detector (Sadar and Engelhardt 2011). Most field-portable meters are likely to be single-detector meters; hence, a set of experiments was conducted to examine the effect that water color might have on turbidity measurements (i.e., waters with high humic acids could be *clear* but have the color of tea), and a set of experiments to examine the effect that solids suspended in the water might have on turbidity measurements.

Water Color Experimental Procedure

A beaker was filled with 200 mL of tap water, and the turbidity of the pure tap water was measured in both the 2100P and 2100N turbidimeters. The turbidity of the tap water ranged from 0.14–0.18 NTU in the field 2100P turbidimeter and 0.12–0.16 in the 2100N turbidimeter. Next, 0.1 mL of blue food coloring dye was added to the 200 mL of tap water. Turbidity values for the 200 mL of tap plus 0.1 mL of blue dye sample were then measured in both turbidimeters. These steps were repeated and tested for the color blue using 0.2, 0.4, and 1.6 mL drops to 200 mL tap water. The procedure was then followed again for the colors yellow and green.

Solids Color Experimental Procedure

A lab experiment investigated the effects of a red and white precipitate on turbidity values. A red precipitate was chosen to reflect the red soils common in the Lubbock area and in other parts of Texas. The white precipitate was used to imitate the formazin standards used to calibrate the turbidimeters. 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 using a reaction with sodium chloride (NaCl) in deionized water. To keep the concentrations for each precipitate equal so as to reduce the effects of turbidity concentration, the target concentration for each precipitate was set at 300 mg/L in water to allow for enough precipitate to perform serial dilutions on the solution. Stoichiometry and solubility constants for each precipitate were used to predict the quantity of reactants that should form and the concentration of precipitate. The total solids procedure was used to determine the calculations' accuracy, and samples were tested for turbidity in the 2100P field turbidimeter and the 2100N lab turbidimeter (Clesceri et al. 1998).

Turbidity Measurement Issues—Dilution

In the course of this study, a few samples were found to be out of range of both turbidimeters. Determining the acceptability of dilution was necessary to extend the range of a turbidimeter as part of a field protocol on construction sites. Dilution would be important for self-reporting purposes to determine approximate turbidity levels in runoff. Therefore, lab tests were completed using both the field (2100P) and lab (2100N) turbidimeters. The field turbidimeter had a maximum range of 1,000 NTU with calibration standards set at 0.1, 20, 100, and 800 NTU. The lab turbidimeter had a range of up to 4,000 NTU with calibration standards set at 0.1, 20, 200, 1,000, and 4,000 NTU.

Dilution testing was performed on previously collected turbidity samples, one from the Marsha Sharp Freeway collected on May 11 and the samples from West Loop 289 to the playa collected on May 11 and March 4. The procedure calls for a measuring cup and bottled water, which would be cost-effective and easy to procure by construction companies. In addition, the dilution procedure was 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 supervisor's building on the construction site.

Turbidity Measurement Issues—Instrumentation

During the field-monitoring program, the lab and field turbidimeters reported different turbidity values. In general, the field 2100P turbidimeter read turbidity values almost twice as large as the lab 2100N turbidimeter. After determining that this variability was not caused by a calibration issue, further testing was completed.

To determine the differences in turbidimeters, two field 2100P turbidimeters were compared with the lab 2100N turbidimeter. Three runoff samples collected from highway construction sites were used in this experiment. Calibration of each turbidimeter was performed before testing the samples. Turbidity measurements were performed 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). Furthermore, each machine had the *signal averaging* and *automatic range* turned on. The lab turbidimeter had one extra function, *ratio,* which was also turned on because this turbidimeter had been reporting turbidity values above 100 NTU as out of range if this ratio function was turned off.

Pilot Field Monitoring Program

A pilot self-reporting turbidity monitoring program in Lubbock, Texas, involved two construction sites within an area that already had storm water pollution prevention plans (SW3Ps) in place: Marsha Sharp Freeway (MSF) and West Loop 289. Fig. 1 shows the location of both projects in Lubbock, Texas.

Figs. 2 and 3 show the actual discharging locations when project sample collection began and when analysis ended. 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 channel bottom had gabion-type walls and bottom. The culvert at the Marsha Sharp Location connected to the playa at the end of sample collection, which no longer provided a water-pooling site

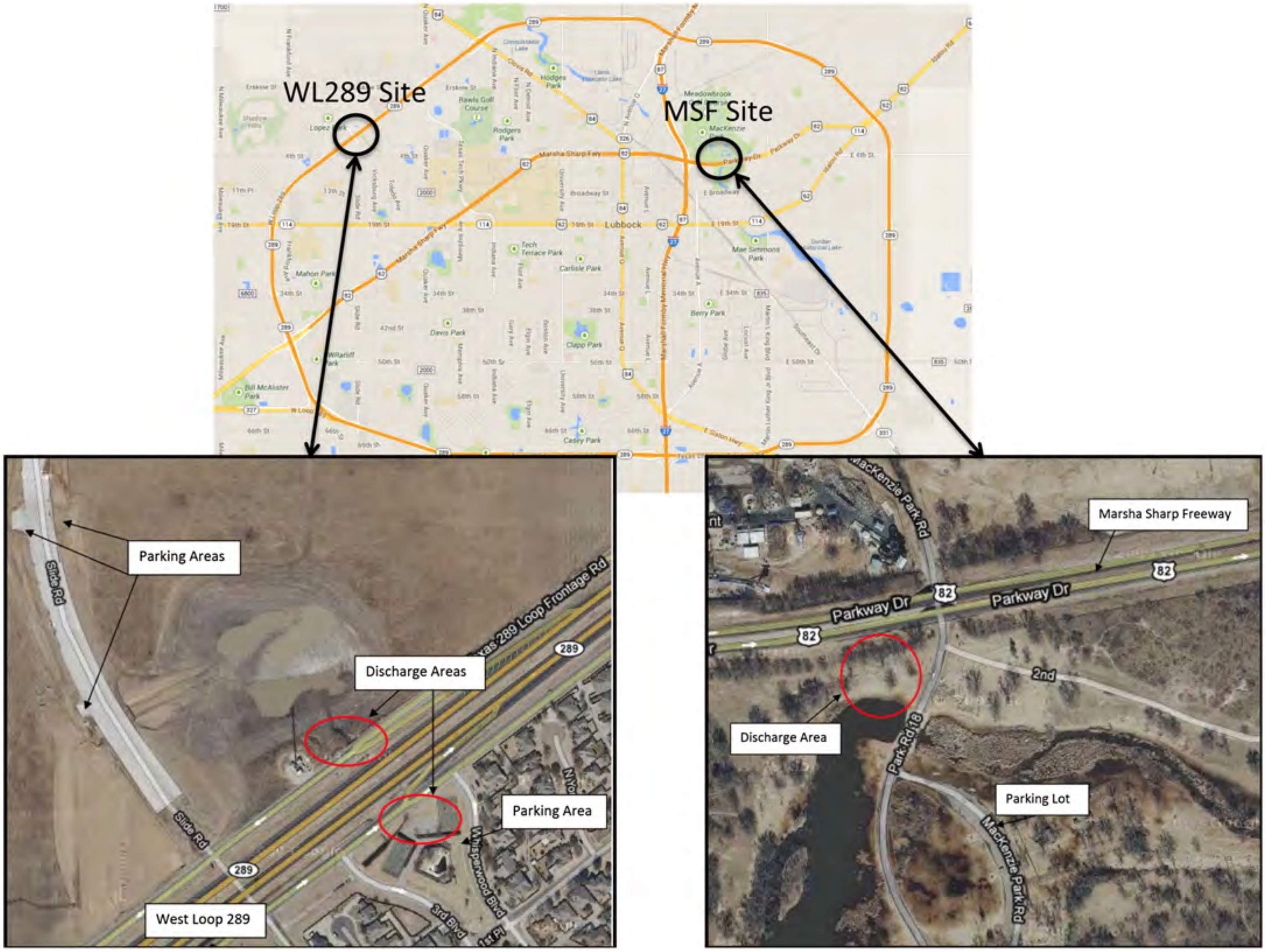

Fig. 1. Site map. Base map is from Google Maps (© Google 2013) [images are from Google Earth (© Google 2011)]

that allowed for collection at the beginning of the project. Instead, water samples were collected behind silt fences.

Samples were collected during or immediately after a storm event at the discharge point designated for each site from November 2010 through September 2011 or until the sites were seeded and no longer in the bare earth phase. Unfortunately, 2011 was the drought of record in Texas, so only four samples from the West Loop 289 site and five samples from the Marsha Sharp Freeway site were captured.

Results

Turbidity Theme Maps

The minimum turbidity values (map not shown) for most of Texas are below 25 NTU. There was one location in the Texas panhandle that had a value exceeding 500 NTU. Other parts of the state, such as central Texas, had minimum reported turbidity values below

Fig. 2. WL289 site discharging toward playa at beginning and end of construction (images by Holly L. Murphy)

Fig. 3. MSF site discharge location at beginning and near end of construction (images by Holly L. Murphy)

0.5 NTU. All three maps show this same trend of higher natural turbidity values in the panhandle (Murphy et al. 2011).

Fig. 4 displays the maximum observed background turbidity values found for Texas. The maximum value map shows more than half the state of Texas with turbidity values greater than 280 NTU. Maximum values above 280 NTU were common throughout the state. Houston and Dallas had maximum values reported between 650 and 2,000 NTU. Austin had one station with a maximum value greater than 2,000 NTU. The Texas panhandle had maximum values greater than 12,500 NTU for three stations (Murphy et al. 2011).

The median value map with turbidity values below a 280 NTU break is illustrated in Fig. 5. In the median value map, the entire state is below the 280 NTU break except for the one station in the panhandle. Most stations in central Texas had median turbidity values of less than 25 NTU with the exception of the Austin area, which had 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 exceeded 50 NTU for the median value (Murphy et al. 2011).

Insufficient data exist in the western portion of Texas to accurately understand the background turbidity values in this region of the state. Approximately 40 counties are located within the region designated as having no turbidity data available. Therefore, more sampling and data are needed because the current values in the western portion of Texas cause the maps to have large areas affected by one turbidity measurement, whereas the eastern portion of the state has many values to create the turbidity value maps.

Texas was not included in a 2002 study in which background turbidity ranges were collected from 27 states. All of these states reported a minimum turbidity equal to or less than 1.0 NTU. Maximum background turbidities of over 1,000 NTU have been reported in Arizona, Kentucky, Louisiana, North Carolina, Nebraska, New Mexico, Oregon, South Carolina, Utah, and Wyoming (Pruitt 2002). The ranges found in the background turbidity maps for Texas are reasonable in comparison.

Interpreting the median (and maximum) background maps, the proposed USEPA turbidity limit of 280 NTU is probably realizable throughout most of Texas, with an understanding that even marginal runoff management from construction sites would be compliant approximately half the time, and noncompliant approximately half the time. However, the western portion of the state, specifically the panhandle, has natural conditions that will most likely always fall above this proposed limit. The panhandle is known for dust storms and *muddy* rainfall.

Construction runoff was assumed to not be a factor in any of the measurements used to develop the background turbidity maps, and natural turbidity conditions in certain parts of the state are already

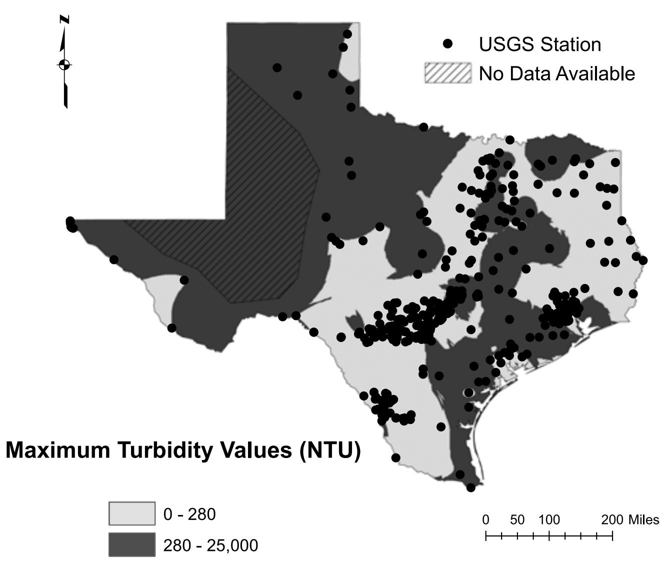

Fig. 4. Maximum value theme map (map data from USGS; base map from Esri *ArcGIS*)

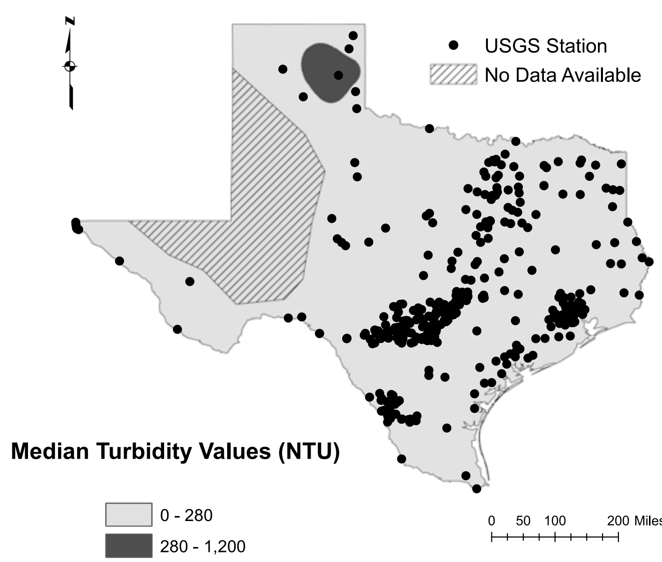

Fig. 5. Median value theme map (map data from USGS; base map from Esri *ArcGIS*)

at high numeric values (as compared with the proposed numerical limit).

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. In addition, regional adjustments may need to be allowed throughout the entire nation. Field data collected from construction site runoff that was commonly greater than 1,000 NTU supports the data collected from the USGS to create the maps.

Turbidity Measuring Factors

Color Effects on Turbidity

Colored water experiments in which dyes were added to otherwise clear water showed no significant change in turbidity; thus the color of otherwise clear water is not a factor of concern.

Sutherland et al. (2000) reported that the sensitivity of the backscatter sensor could vary by a factor of 10 from color effects; 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 used for instrument calibration; thus, only light-colored samples were able to record turbidity measurements close to those set by these standards (Downing 2005). Based on this literature, the authors anticipated that the white silver chloride would produce larger turbidity values than the darker red silver chromate.

The results for colored precipitates' effect on turbidity showed only minor differences in the turbidity per concentration results. For example, the red silver chromate precipitate had a 5.9 NTU/ppm value, and the white silver chloride had a 5.4 NTU/ppm value on the same instrument. In all cases examined, silver chromate produced larger turbidity readings per unit of concentration, which was unanticipated; however, the differences in these turbidity readings per unit of concentration values are probably not significant. Thus, like water color, the solids' color effects in natural Texas waters are negligible.

Dilution

Dilution was examined as a way to extend instrument range, so that self-reporting results could be recorded without upper detection censoring. The dilution approach used 2:1 serial dilutions, an easy method that could be employed by nonexperts.

The censoring issue is important to establish statistical structure of runoff turbidity, in addition to metering compliance. For example, a site that produces 1,001 NTU is a less *noncomplaint* outcome than 10,000 NTU, but with upper limit censoring such gradations of performance cannot be determined. The nonexpert application was deemed necessary for a self-reporting parameter. The 2:1 serial dilutions simply require three identical volume vessels (e.g., jars, cups) and were considered as a reasonable approach for possible implementation to extend turbidity values (Murphy 2011)

Table 1 illustrates the dilution results in both the 2100P field and 2100N lab turbidimeters. The estimated turbidity decreased with each serial dilution in both instruments. In the lab turbidimeter, the initial turbidity of the sample was approximately 1,900 NTU. After six serial dilutions, the estimated turbidity of the sample was approximately 900 NTU—a difference of approximately half the anticipated value of 1,900 NTU. The same behavior was exhibited with the field turbidimeter, in which the first measureable turbidity was 2,050 NTU and after four more dilutions, reached 1,300 NTU.

From these studies, dilution is not a desirable method to extend the range of a turbidimeter and should not be employed to determine turbidity values on highway construction sites to meet compliance limits. For construction site regulations, a turbidimeter with a range larger than the proposed turbidity limit is necessary.

If the desire exists to collect background turbidity data, numerical values would be necessary to extend current knowledge of background levels, and dilution measurements may be necessary. Dilutions may be performed for data collection simply to give an idea as to the value range of the collected samples. However, if dilutions are used to obtain background data, the sampler must remember that the dilution will under-report estimated turbidity values, and he or she should record that the sample was diluted.

The authors believe that diluted values should be determined and reported where practical. Even though dilution under-reports turbidity values, a biased numerical value is preferable to an *out-of-range* value, for performance evaluation of various storm water pollution prevention ***devices.***

Turbidimeter Variability

One of the most substantial issues identified in this portion of the research was the instrument variability. Typically, turbidity value differences between the 2100P field and 2100N lab instruments were consistently greater than 40%.

Table 2 lists the results of three sample analyses. Sample A was constructed to be out-of-range for the field instrument, and indeed the field instrument reported the out-of-range error code. However, Samples B and C are well within range of the field instrument, and the instrument reports nearly twofold the turbidity as that of the laboratory instrument.

One suggested reason for turbidity value differences in the two machines was the presence of color, which could increase or decrease turbidity in turbidimeters without a ratio function. However, these experiments with colored water and solids somewhat refute this explanation.

Turbidity value differences are not explainable 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' procedures for calibration (Hach 2003, 2008). Sample cells were cleaned and prepared in the same manner for

Table 1. Dilution on West Loop 289 to Playa Sample Collected on March 4, 2011

Dilution number	Field turbidimeter reading (NTU)	Lab turbidimeter reading (NTU)	Multiplier	Estimated turbidity in field (NTU) = (2) × (4)	Estimated turbidity in lab (NTU) = (3) × (4)
1	>1,000	1,888	1	—	1,888
2	>1,000	666	2	—	1,332
3	512	265	4	2,048	1,060
4	227	124	8	1,816	992
5	96.1	60.4	16	1,537.6	966.4
6	41.1	27.8	32	1,315.2	889.6

Table 2. Turbidity Variability between Instruments

Sample A			
Turbidimeter	Trial 1	Trial 2	Trial 3
Lab (NTU)	2,390	2,415	2,465
Field A (NTU)	E5	E5	E5
Field B (NTU)	E5	E5	E5
% difference in Fields A and B	—	—	—
% difference from average field to lab	—	—	—
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 Fields A and B	0	7	2
% difference from average field to lab	46	43	46
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 As and B	0	4	2
% difference from average field to lab	40	42	43

Table 3. Field Monitoring Turbidity Data

Date	Sample	Field (NTU)	Lab (NTU)
3/4/2011	MSF	—	21.6
	WL289, playa	—	1,889
	WL289, small tennis court	—	252
	WL289, large tennis court	—	60.2
5/11/2011	MSF	E5	2,205
	WL289, playa	>1,000	601
	WL289, small tennis court	449	226
	WL289, large tennis court	87.7	49.0
7/12/2011	MSF*	>1,000	>4,000
8/11/2011	MSF	E5	4,280
	WL289, playa	399	225
	WL289, small tennis court	353	170
	WL289, large tennis court	300	145
9/14/2011	WL289, playa	486	235
9/15/2011	WL289, small tennis court	51.0	32.2
	WL289, large tennis court	32.6	22.9
	MSF	425	238

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

each turbidimeter, and multiple measurements of each sample tested were taken. Therefore, interferences caused by improper cleaning or calibrations were ruled out as a possible source for the turbidity value differences between the two turbidimeters.

Consistent percent differences between the field and lab turbidimeters must be attributed to the turbidimeters' inherent operational properties or some other operator-induced systematic difference. The manufacturer also suggested that multiple detectors are likely to have the largest effect on how the turbidity measurements are affected and reported, but a more subtle difference may be in operation.

The instrument designer noted that the two instruments operate with a different measurement time interval: every 3 s for the laboratory instrument (2100N) and approximately 20 s for the field portable instrument (2100P). Hence, if the time of vial placement (assuming other sample preparation steps are identical) into the instrument and when the reading is reported by the instrument are not the same, then a measurement difference is anticipated, and can be substantial. Such differences are further expected if the sample contains rapidly settling materials such as sand with mean grain diameter in excess of 0.1 mm.

The variation between turbidimeter types (field or laboratory) is a topic that needs further examination if and when a numerical self-reporting limit is eventually established. Recent studies completed by the ASTM have resulted in new methods that may explain differences noted in this paper, and explicitly recommend technology for a particular type of result (e.g., regulatory versus scientific investigation). Specifically, ASTM D7315-12 provides a standardized test method appropriate for the waters described in this paper, and ASTM D7726-11 discusses particular technologies. Anderson (2005) also provides substantial guidance for instrument selection and field protocol development for scientific studies of turbidity, but provides little on comparative instrument selection. In the absence of such comparative instrument guidance, a specific set of manufacturer turbidimeters has to be chosen from a compliance standpoint when measuring turbidity values because one construction site may produce a sample that, when testing one kind of instrument, has a turbidity value below compliance limits. In contrast, if tested on a different kind of instrument and with the same sample, a turbidity value is produced above compliance. Operator training is also an important component, but the expectation of a skilled laboratory technician to collect and analyze daily samples on a construction site as part of a self-reporting exercise of a parameter that was selected for its comparative simplicity is unrealistic. One component of the work herein was to evaluate issues that would be associated with nonexpert users of the instruments.

Pilot Field Monitoring Data

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. Turbidity values observed in the construction runoff ranged from 20 NTU up to approximately 10,600 NTU. However, there was a difference in the 2100P field and 2100N lab turbidimeters. For all measurements, the field turbidimeter read larger values than the lab turbidimeter. A brief synopsis of the values collected for each sample collected is shown in Table 3. The samples collected on March 4 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 performed only in the lab turbidimeter.

For both sites, the field turbidimeter measurements ranged from 32.6 to over 1,000 NTU. The lab turbidimeter measurements ranged from 21.6 to >4,000 NTU. The discrepancy between the two machines was already addressed; however, it is apparent that field sites in West Texas with SW3Ps had turbidity values in the runoff exceeding the proposed 280 NTU, a result that was anticipated after interpretation of the median background map.

Conclusions

After studying the median background theme map, the once proposed USEPA turbidity limit of 280 NTU is probably achievable at half the time (as implied by a median) 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. If conditions occur in natural water bodies that produce turbidity values as 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, and would incur substantial societal costs. Therefore, this area would be in perpetual noncompliance—a strong argument that regional adjustments should be allowed. Also, it is the authors' belief that the next several years should be used to monitor the turbidity at construction sites without setting a numeric limit.

According to the literature, color can affect turbidity measurements, such that darker colors absorb light and decrease turbidity. White particles can produce a turbidity measurement up to 10 times larger than black particles; when comparing the white silver chloride with the dark red silver chromate, the silver chloride was expected to 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. Also, there was no significant difference for variations in colored water and, therefore, the color of otherwise clear water should not affect the turbidity values.

In this research, dilution was unable to accurately extend the range of a turbidimeter, and should be used with caution to determine turbidity values on highway construction sites for compliance limits. Diluted samples will under-report turbidity; as such, any numerical limit should be well within the reporting range of an instrument. The authors believe diluted samples have value in statistical characterization of turbidity and should be collected; at the very least, such samples will report the correct order-of-magnitude the turbidity level for a given water sample.

Finally, turbidity measurements can vary between different types of turbidimeters by almost a factor of two in the case of the 2100P and 2100N turbidimeters (field-portable and laboratory instruments, respectively). The differences are probably not manufacturer specific and could be a result of the time from vial placement into the instrument to the reading by the instrument. As for operating a turbidimeter to determine whether highway construction sites are within compliance levels for future turbidity limits, a specific set of turbidimeters and a precise instrument use protocol may have to be assigned by the USEPA to ensure that all construction sites are being held to the same standard. If one site has the 2100N turbidimeter and follows a reasonable interpretation of the instrument's instructions, a turbidity value will be reported at 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, whereas the other is in compliance.

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