WASHINGTON STATE DEPARTMENT OF ECOLOGY

Interim Report:

Stormwater Quality Survey of Western Washington Construction Sites

September 2004

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WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Interim Report:
Stormwater Quality Survey of
Western Washington Construction Sites

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Table of Contents

Page

List of Figures and Tables ii
Abstract iii
Acknowledgements iv
Introduction 1
Methods 3
- Criterion for Time of Sampling 3
- Sampling Design 4
- Site Selection 5
- Field Methods 8
- Laboratory Methods 8

Data Quality 9
Results 11
Discussion 15
- Receiving Water Turbidity 15
- Site Characteristics and Turbidity 15
- Comparison of Precipitation with the Historic Record 16
- Soil Permeability and Expected Runoff 16
- Comparisons of Turbidity Indicators 20

Conclusions 23
Recommendations 24
References 25

List of Figures and Tables

Page

Figures

Figure 1. Study Area 2

Figure 2. A Transparency Tube 4

Figure 3. Outcomes of 57 Construction Sites Selected for the 2003-2004 Sampling Season 6

Figure 4a. Maximum Surface Soils Permeability and Facility Locations, Thurston County 17

Figure 4b. Maximum Surface Soils Permeability and Facility Locations, Pierce County 18

Figure 5. Soil Permeability for Western Washington 19

Figure 6. Field Turbidity versus Laboratory Turbidity Results 20

Figure 7. Transparency Tube Results versus Laboratory Turbidity Results 21

Figure 8. Total Suspended Solids Results versus Laboratory Turbidity Results....................22

Tables

Table 1. Sampling Plan Summary for the Two-Year Study 5

Table 2. Active Construction Sites Visited, 2003-2004 Sampling Season....................7

Table 3. Sample Size, Container, Preservation, and Holding Time by Parameter 8

Table 4. Analytical Methods....................8

Table 5. Precision Data 10

Table 6. Turbidity at Discharge and Upstream and Downstream of Discharge 12

Table 7. Site Characteristics 13

Abstract

This report presents first-year results of a two-year survey of construction stormwater sites in western Washington. The purpose of the study is to evaluate the quality of stormwater discharged from construction sites during the winter wet season when potential impacts are greatest.

Under the NPDES and State Waste Discharge General Permit program, the Washington State Department of Ecology has regulated discharges associated with construction activity since 1992. Data representative of typical construction stormwater discharges in western Washington have not been available. This survey was initiated to obtain representative data to characterize stormwater discharged from construction sites.

Forty-two construction sites were visited as potential sampling locations. Samples were collected and measurements made from the 11 sites that were actively discharging. These 11 sites were in Pierce and Thurston counties. Upstream and downstream receiving water samples also were collected from three of the 11 sites.

Turbidity ranged from 2.4 to >1000 NTU. Over 90% of the discharges ranged from 14 to 240 NTU. Comparisons are made between three methods for determining or estimating turbidity.

The low incidence of active construction sites discharging runoff (26%) during the first year of the study is attributed, in part, to the permeable soils of western Washington, as indicated by soil permeability maps. Lower than typical groundwater tables resulting from below average precipitation also may have been a factor.

Field turbidity determinations with a ratio-type nephelometer were found to be as precise and accurate as laboratory turbidity. Transparency was found to be a good surrogate for turbidity in western Washington for estimated turbidity values below 300 NTU. Total suspended solids is not a valid surrogate for turbidity determinations.

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Introduction

Under the NPDES and State Waste Discharge General Permit program, the Washington State Department of Ecology (Ecology) has regulated discharges associated with construction activity since 1992. During this time, stormwater sampling and analysis has been conducted only on certain sites when it was necessary to address specific water quality issues. Data representative of a wider range of construction stormwater discharges in western Washington have not been available.

This study was initiated to obtain representative data to characterize stormwater discharged from construction sites during the winter wet season when discharges and potential impacts are greatest. The survey-level data developed in this study will be useful to state and local government agencies involved in the permitting and inspection of construction activities as well as to construction operators and their consultants who develop Stormwater Pollution Prevention Plans.

Because fewer sites than planned were sampled during the first season, the study will be continued for a second year. The results of the first season of sampling are presented and evaluated in this interim report. A final report will be published in the fall of 2005 following the results of additional sampling during the second year of this study.

Figure 1 shows the study area. This study was limited to western Washington because it has a distinctly different climate and soil characteristic than the eastern portion of the state. Western Washington has wet winters with saturated soils and a high potential for erosion problems. Most of the state's construction activity is taking place in western Washington. Also, logistical limitations favored limiting this study to the western portion of the state.

As a result of limitations in the availability of sampling personnel, only Thurston and Pierce counties were sampled during the first sampling season. The study area is planned to be expanded to include King and Snohomish counties during the second year of this study.

The principal objective of the study is to survey stormwater discharge quality from western Washington construction sites. The impact of an array of site characteristics on construction stormwater turbidity is also explored. Other objectives include comparing methods for measuring turbidity. Potential correlations between total suspended solids (TSS) and transparency tube readings with laboratory turbidity measurements are evaluated. A transparency tube is a simple device for visually assessing light transmission. Both a field and laboratory turbidimeter (nephelometer) are used in this project to measure turbidity. Closeness between the two instrument models was assessed.

Results of the first year of sampling as well as discussions of the season's precipitation, soil permeability, and comparisons of turbidity indicators are presented in this report.

Figure 1. Study Area. Shaded areas are counties to be included in the study.

Methods

Criterion for Time of Sampling

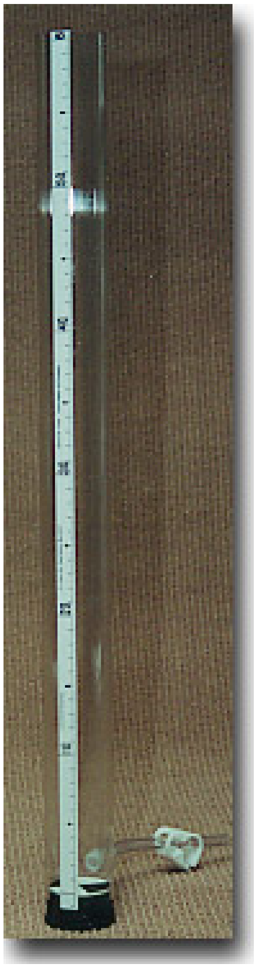
The sampling season for this study is November 1 to April 30. This corresponds to the winter wet season when stormwater discharges from construction sites are most common. The criterion for collection of a sample is the occurrence of stormwater discharge from a site.

In most parts of the United States, storm events are discrete, following periodic weather systems. For this reason it is commonly considered appropriate to sample during individual storm events. In western Washington, however, winter wet-weather storm events often overlap, so that long periods of precipitation, days and even weeks at a time, characterize the precipitation pattern. For this reason, sampling during the wet season in western Washington can take place during long, continuous, or nearly continuous, precipitation events.

For some forms of stormwater sampling, the "first flush" (first discharge of stormwater after a period of dry weather) is considered the worst case. The first period of precipitation after a period of dryness can wash off and entrain contaminants that have accumulated during the dry weather period. This first flush may contain high concentrations of pollutants.

For construction sites, first flush is not considered to be necessarily the worst case, as soil erosion is the principal cause of high contaminant concentrations, particularly the soil particles affecting turbidity as measured in this study. This, in addition to the overlapping nature of storms in western Washington, is the basis for the decision that stormwater sampling for this project is to take place not as associated with individual rain events or during any particular portion of a rain event. Instead, sampling is to occur throughout the wet weather season at any time that a facility is discharging stormwater.

Sampling Design



Field turbidity measurements were made and grab samples were collected for turbidity and TSS laboratory analyses at each site.

The field nephelometer used was a Hach 2100P ratio type. The laboratory nephelometer used for this study was also a Hach ratio-type instrument. Turbidity measurements in the field were paired with samples for laboratory turbidity analysis so that results from the two instruments could be compared.

A transparency tube was also used to make a quantified estimate of transparency from each discharge, by simple, visual means. A transparency tube is a simple field device used to estimate the transparency of a water column by noting the depth at which a black and white secchi disk affixed to the bottom of the clear tube is no longer visible. The transparency tube measurements were paired with turbidity measurements so that a comparison could be made between transparency tube results and conventional turbidity readings, and a correlation between the two could be developed.

Figure 2. A Transparency Tube.

In addition to determining turbidity and TSS of stormwater discharges from construction sites, receiving water turbidity upstream and downstream of each discharge was measured to provide an indication of the impacts of discharges on receiving water turbidity. Turbidity downstream was measured from the bank from which the discharge was taking place, sufficiently away from the bank to obtain samples where the receiving water was free-flowing rather than stagnant. Measurements were taken 100 feet downstream from the discharge point, as determined by pacing, or as close to 100 feet as practical. Downstream turbidity was also measured at a site along the bank, a distance three times the width of the receiving water from the discharge. For construction projects where stormwater discharges to a storm drain rather than directly to receiving water, receiving-water data were not collected.

Table 1 summarizes measurements and samples planned for this project, including 20% of samples as replicates for quality assurance. Only one sample was collected or field measurement made at each location where a sample was obtained, except when a field replicate was taken as a second sample or measurement. All transparency determinations were made twice, the second reported as a field replicate result.

Table 1. Sampling Plan Summary for the Two-Year Study.

Construction site discharge	Number of sites	
	Small sites (< 20 acres)	Large sites (20 acres or greater)
Laboratory		
Turbidity	22	22
Turbidity, field rep	4	4
TSS	22	22
TSS, field rep	4	4
Field		
Turbidity	22	22
Turbidity, field rep	4	4
Transparency	22	22
Transparency, field rep	22	22

Receiving water (for all-sized construction sites)*	Number of sites		
	Upstream of discharge	100 feet downstream of discharge	3x stream width downstream of discharge
Laboratory			
Turbidity	up to 44	up to 44	--
Turbidity, field rep	9	9	--
Field			
Turbidity	up to 44	up to 44	up to 44
Turbidity, field rep	9	9	9

* Because discharges from some sites enter a storm drain or the affected receiving water is otherwise unavailable for sampling, the number of sites for field analysis will be fewer than 44.

Site Selection

The aim of the study is to sample stormwater discharges from 44 construction sites in four western Washington counties over a two-year period. The counties, King, Snohomish, Pierce, and Thurston, represent a variety of geographic areas from Puget Sound to the Cascade Crest, and include construction sites from urban, suburban, and rural areas. The four counties include most construction permits issued in the state, roughly 580 of 800 sites.

Site selection was stratified so that the number of sites to be sampled in each county was roughly proportional to the number of permits in the county to provide for spatial representativeness. In addition, site selection was stratified by site size, with equal numbers (22) sites selected in each of two size ranges to provide for sufficient data to characterize sites within each size category. During the first year of the study, as a result of an unexpected lack of personnel, sites in Thurston and Pierce counties only were selected. Of the 57 sites selected, only 11 were discharging and were sampled.

Within each county and size range, sites were selected at random from those with construction permits listed in the Ecology WPLCS database. The county and latitude/longitude of each site were noted. To prevent bias in site selection, no preference was given to sites that discharge to surface water. Only active sites are included in the study. An active site is defined for this study as one in a stage between initial ground clearing and final site stabilization.

Sites were categorized as being in one of two size ranges:

1. Less than 20 acres
2. 20 acres or larger

The Quality Assurance Project Plan for this survey study called for the sampling of 44 sites (Golding, 2003). A total of 57 sites were selected at random for visits during the 2003-2004 wet season. Figure 3 summarizes the outcome of the site visits.

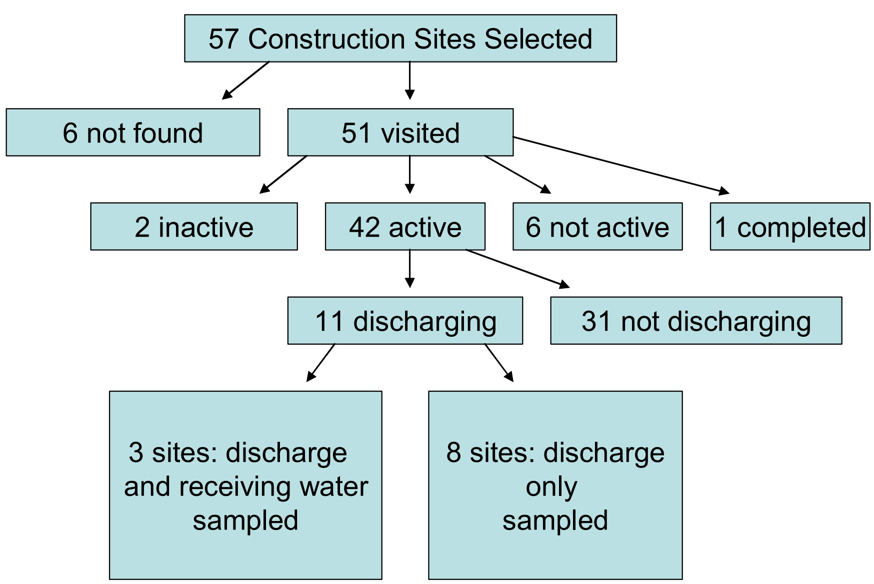


Figure 3. Outcomes of 57 Construction Sites Selected for the 2003-2004 Sampling Season.

Of the 57 sites selected, 51 were visited. Forty-two of these were active. Eleven of the active sites were discharging while 31 were not. The large number of sites not discharging was unexpected and is, in part, responsible for the continuation of the study into a second year. The active sites are summarized in Table 2 and shown in Figures 4a and 4b. Only two of the 11 discharging sites were located in Thurston County, reflecting the small number of construction stormwater permits issued there.

Table 2. Active Construction Sites Visited, 2003-2004 Sampling Season.

	Site name	Lat.; Long.; GPS datum NAD 27	County
1	Bethel Kapowski Elementary School	47º 00.750’ N; 122º 17.675’ W	Pierce
2	Tri Way Cooper Crest	47º 04.075’ N; 122º 56.949’ W	Thurston
3	Capstone Homes	47º 10.178’ N; 122º 18.208’ W	Pierce
4	Point Defiance Park Zoo	47º 18.237’ N; 122º 31.022’ W	Pierce
5	Chaffy The Ridge at Glacier Creek	47º 08.138’ N; 122º 19.128’ W	Pierce
6	Pelzel Village	47º 09.102’ N; 122º 25.234’ W	Pierce
7	Slavic Church	47º 15.019’ N; 122º 17.301’ W	Pierce
8	Wittenburg Estates	47º 06.965’ N; 122º 20.384’ W	Pierce
9	Bowlin Plat	47º 09.786’ N; 122º 24.586’ W	Pierce
10	Portland Avenue Business Park	47º 09.190’ N; 122º 24.204’ W	Pierce
11	Henderson Ave./ I-5 Interchange (Plum St.)	47º 07.788’ N; 122º 53.443’ W	Thurston

Field Methods

Table 3 lists sample sizes, containers, preservation, and holding times for the study parameters.

Table 3. Sample Size, Container, Preservation, and Holding Time by Parameter.

Parameter (analyte)	Sample size	Container	Preservation	Holding time
Turbidity	500 mL	500 mL w/m poly	cool to 4º C	48 hours
TSS	1000 mL	1000 mL w/m poly	cool to 4º C	7 days

Laboratory Methods

Table 4 shows the laboratory procedures used in the study. All samples were analyzed at Ecology's Manchester Environmental Laboratory.

Table 4. Analytical Methods.

Analyte	Analytical method
Turbidity	Standard Method 2130
TSS	Standard Method 2540D

Data Quality

Field replicates and laboratory duplicates allow for a determination of sampling and analytical error. Table 5 shows the results of replicates and duplicates from the first season of sampling. Relative percent differences (RPDs) are shown in Table 5.

Laboratory and field turbidity replicates and duplicates showed high precision, with all but one RPD below 8%. This indicates that the use of both laboratory and field turbidimeters provided precise results.

All but two of the transparency field replicate results had RPDs within 9%. Two of the nine field replicates showed less precision, with RPDs in the 22-29% range. This indicates adequate precision for the use of transparency tubes to estimate results. The transparency test results may have been less precise than the replicates indicate because replicates were not made under a variety of lighting conditions. The highest RPDs occurred with transparency tube results of 4 cm or below.

TSS replicates resulted in RPDs lower than 10%, indicating good precision. Lab duplicate TSS results also showed good precision, with duplicate sample results within 1 mg/L of sample results. The high RPDs of 66.7% and 18.2% for the lab duplicates should not be interpreted as indicating low precision because they are a consequence of the samples having low TSS values, close to the 1 mg/L reporting limit for TSS.

Table 5. Precision Data.

Laboratory Turbidity (NTU)			Field Replicates			Lab Duplicates		
Site	Station	Date	Sample 1	Sample 2	RPD	Sample 1	Sample 2	RPD
Bethel Kapowski Sch	upstream	1/28/04	--	--	--	9.6	9.5	1.0 %
Tri Way Cooper Crest	discharge	2/25/04	--	--	--	150	140	6.9%
Capstone Homes	discharge	1/15/04	--	--	--	240	240	0.0%
Pelzel Village	upstream		7.5	7.4	1.30%	7.5	7.4	1.30%
	100' down	1/28/04	26	27	3.8%	--	--	--
Wittenburg Estates	discharge	3/3/04	--	--	--	14	14	0.0%
Portland Ave Bus Pk	discharge	4/20/04	2.6	2.5	3.9%	2.5	2.6	3.9%
Henderson Ave Intchg	discharge	4/21/04	15	15	0.0%	--	--	--

Field Turbidity (NTU)			Field Replicates		
Site	Station	Date	Sample 1	Sample 2	RPD
Tri Way Cooper Crest	100' down	2/25/04	11.8	12.1	2.5%
	3x width	2/25/04	18.2	18.7	2.7%
Pelzel Village	discharge	1/28/04	45.3	42	7.6%
	100' down		25.6	25.7	0.3%
	3x width		24.5	21.7	12.1%
Slavic Church	discharge	1/15/04	68.1	67.7	0.9%
Wittenburg Estates	discharge	3/3/04	12.4	12.2	1.6%
Bowlin Plat	discharge	4/6/04	20.2	20.5	1.5%
Portland Av Bus Pk	discharge	4/20/04	2.37	2.23	6.1%
Henderson Ave Intchg	discharge	4/21/04	14.4	14.2	1.4%

Transparency (cm)			Field Replicates		
Site	Station	Date	Sample 1	Sample 2	RPD
Bethel Kapowski Sch	discharge	1/28/04	6.4	7.0	9.0%
Tri Way Cooper Crest	discharge	2/25/04	0.6	0.8	28.6%
Capstone Homes	discharge	1/15/04	5.5	5.6	1.8%
Point Defiance Zoo	discharge	1/29/04	4.0	3.2	22.20%
Chaffy at Glacier Cr	discharge	1/30/04	6.4	6.2	1.6%
Pelzel Village	discharge	1/28/04	18.9	18.8	0.05%
Slavic Church	discharge	1/15/04	10.8	10.6	1.9%
Wittenburg Estates	discharge	3/3/04	59	59	0.0%
Bowlin Plat	discharge	4/6/04	29.9	30.2	1.0%

TSS (mg/L)			Field Replicates			Lab Duplicates		
Site	Station	Date	Sample 1	Sample 2	RPD	Sample 1	Sample 2	RPD
Bethel Kapowski Sch	discharge	1/28/04	114	104	9.2%	--	--	
Tri Way Cooper Crest	discharge	2/25/04	26	28	7.4%	--	--	
Pelzel Village	discharge	1/28/04	15	14	6.9%	--	--	
Bowlin Plat	discharge	4/6/04	--	--	--	--	--	
Portland Av Bus Pk	discharge	4/20/04	--	--	--	1	66.7%	
Henderson Av Intchg	discharge	4/21/04	--	--	--	6	18.2%	

NTU = nephelometric turbidity units
TSS = total suspended solids
RPD = relative percent difference

Results

Data from the 11 visits to discharging sites are summarized in Table 6.

Turbidity, the principal parameter used to characterize overall stormwater discharge quality, varied considerably over the 11 sites sampled, from 2.23 to >1000 NTU. Nine of the 11 discharging sites had discharges with turbidities ranging from 14 to 240 NTU.

TSS also varied considerably, from 2 to 876 mg/L. Nine of the 11 discharging sites had discharges with TSS ranging from 5 to 114 mg/L.

Site characteristics as noted on field forms are summarized in Table 7. In general, sites of less than 20 acres discharged less turbid stormwater than did sites of 20 or more acres. The sample size is insufficient to conclude that this trend is significant.

Table 6. Turbidity at Discharge and Upstream and Downstream of Discharge (NTU)

Site name	Date	Sample location	Field turbidity	Lab turbidity	Turbidity tube	TSS	Upstream field	Upstream lab	100' down-stream field	100' down-stream lab	3x width downstream	Stream width (ft)
Bethel Kapowski Sch.	1/28/04	silt fence	174	150	6.4; 7.0	114; 104	9.81	9.6; 9.5	45.0	39.0	64.7	2.5
Tri Way Cooper Crest	2/25/04	pipe from silt fence	151;151 2nd: 1000	150; 140	7.2; 9.9	26; 28	17.6; 17.6	18	11.8; 12.1	14	18.2; 18.7	6
Capstone Homes	1/15/04	pond dis.	231	240; 240	5.5; 5.6	62	--		--		--	--
Point Defiance Zoo	1/29/04	3 storm drains at site	>1000 160 316	900	4; 3.2	876	--		--		--	--
Chaffy the Ridge at Glacier Creek	1/30/04	silt fence pond dis. silt fence	198 168 193	189	6.4; 6.2	46	--		--		--	--
Pelzel Village	1/28/04	pond dis.	45.3; 42.0	55	18.9; 18.8	15; 14	6.46; 6.30	7.5; 7.4	25.6; 25.7	26; 27	24.5; 21.7	3
Slavic Church	1/15/04	small pond	68.1; 67.7	70	10.8; 10.6	20	--		--		--	--
Wittenburg Estates	3/3/04	pond dis./ silt fence	12.4; 12.2 85.0	14; 14	59; 59	9	--		--		--	--
Bowlin plat	4/6/04	under silt f.	20.2; 20.5	20	29.9; 30.2	51	--		--		--	--
Portland Ave. Business Park	4/20/04	pond dis.	2.37; 2.23; 2.45	2.5;2.6 2.6	60+ 60+	2	--		--		--	--
Henderson Ave/ I-5 Interchange	4/21/04	pond dis.	14.4; 14.2 14.2	15;15	60+ 60+	5; 6						

Table 7. Site Characteristics (*Discharge turbidity: high ≥ 150 NTU; medium > 30 but < 150 NTU; low ≤ 30 NTU)

Site name	Type of project	Disch turbidity* (source)	Overall size	Disturbed area	Stage of construction	Well drained?	Protected inlets?	Pond present?	Ground covered?	Silt fence breached?
Bethel Kapowski Sch.	school expansion	**high** (from silt fence)	>20	100%	initial BMPs	yes/no	no	no	no	yes
Tri Way Cooper Crest	multi res	**high** (from silt fence)	20 or more	100%	mass grading	yes	yes	yes	no	yes
Capstone Homes	multi res	**high** (from pond)	19	100%	temp stab	yes	no	yes	most	recently
Point Defiance Zoo	park & zoo	**high** (unprotected drains)	>20	15	initial BMPs	yes	no	no	66%	no fencing where needed
Chaffy the Ridge at Glacier Crk.	multi res	**high/high** (pond/silt fence)	>20	>20	initial BMPs	yes	n/a	yes	yes	yes
Pelzel Village	multi res	**medium** (from pond)	5-20	100%	final	yes	yes	yes	no	no
Slavic Church	church	**medium** (inadequate pond)	<20	25-33%	final/finish	yes/no	yes	yes	no	no
Wittenburg Estates	multi res	**low/medium** (pond/silt fence)	16	14	temp stab	no	yes	yes	no	yes
Bowlin plat	multi res	**low** (groundwater under silt fence)	5-20	100%	final finish	yes	n/a	no	no	yes
Portland Ave. Business Park	commerc.	**low** (from pond)	2	0.2	final finish	yes	yes	yes	yes	no
Henderson Ave/ I-5 Interchange	highway/ transp	**low** (from pond)	not known	now known	temp stab	yes	no	yes	yes	no

BMPs = best management practices

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Discussion

Receiving Water Turbidity

Two of the three sites for which upstream and downstream receiving water turbidity was measured showed higher turbidities downstream, 3-5 times higher than the upstream turbidity (Table 6). The third site is believed to have had an inflated upstream turbidity value resulting from seepage of turbid construction site water upstream.

The turbidity upstream of the Bethel Kapowski discharge was 9.81 NTU while the turbidity 100 feet downstream was 39.0 NTU. Pelzel Village receiving water turbidities were 6.4 NTU upstream of the discharge and 25.6 NTU 100 feet downstream. These increases in turbidity downstream, 29.2 and 19.2 NTU, were greater than the 5 NTU increase allowed by state water quality standards.

Site Characteristics and Turbidity

In Table 7, the turbidities of discharges shown in Table 6 are summarized by categorizing each as "high," "medium," and "low." For the purposes of this categorization, high turbidity is defined as ≥ 150 NTU, medium turbidity is defined as > 30 but < 150 NTU, and low turbidity is defined as ≤ 30 NTU.

The turbidities of discharges as categorized in Table 7 can be considered with respect to the site characteristics summarized in the table. Stage of construction appears to correlate with discharge turbidity. Projects that were in the final/finish grading stage showed lower discharge turbidities than sites in earlier stages of construction. The presence of a pond for storing stormwater prior to discharge was also associated with lower discharge turbidities. Two of five sites without a pond showed high discharge turbidities while two of three sites with low discharge turbidities had ponds. The site with low discharge turbidities and no pond was in the final/finish grading stage of construction, and the discharge was from a spring rather than rainfall runoff. Other site characteristics shown in Table 7 could not be correlated with discharge turbidity, 11 sites being an insufficient sample size to evaluate secondary variables.

One important variable not considered in Table 7 is extent of rainfall prior to sampling. Sites were visited, however, only when rainfall was considered to be of an extent that would make discharges likely. That 31 of the 42 active sites visited were not discharging suggests that the sites included in the first year of study were built with sufficient storage for the rainfall encountered, and/or that the soils provided for rapid infiltration.

Comparison of Precipitation with the Historic Record

With only 26% (11 of 42) of active sites discharging when visited, it is of interest to determine whether a low amount of precipitation during the 2003-2004 study period was a contributing factor. A comparison was made between precipitation during weekdays throughout the November-April sampling season and weekdays during potential historic sampling seasons. Precipitation data for the Olympia Airport and McChord Air Force Base in Tacoma were obtained from the University of Washington Earth Climate and Weather internet site.

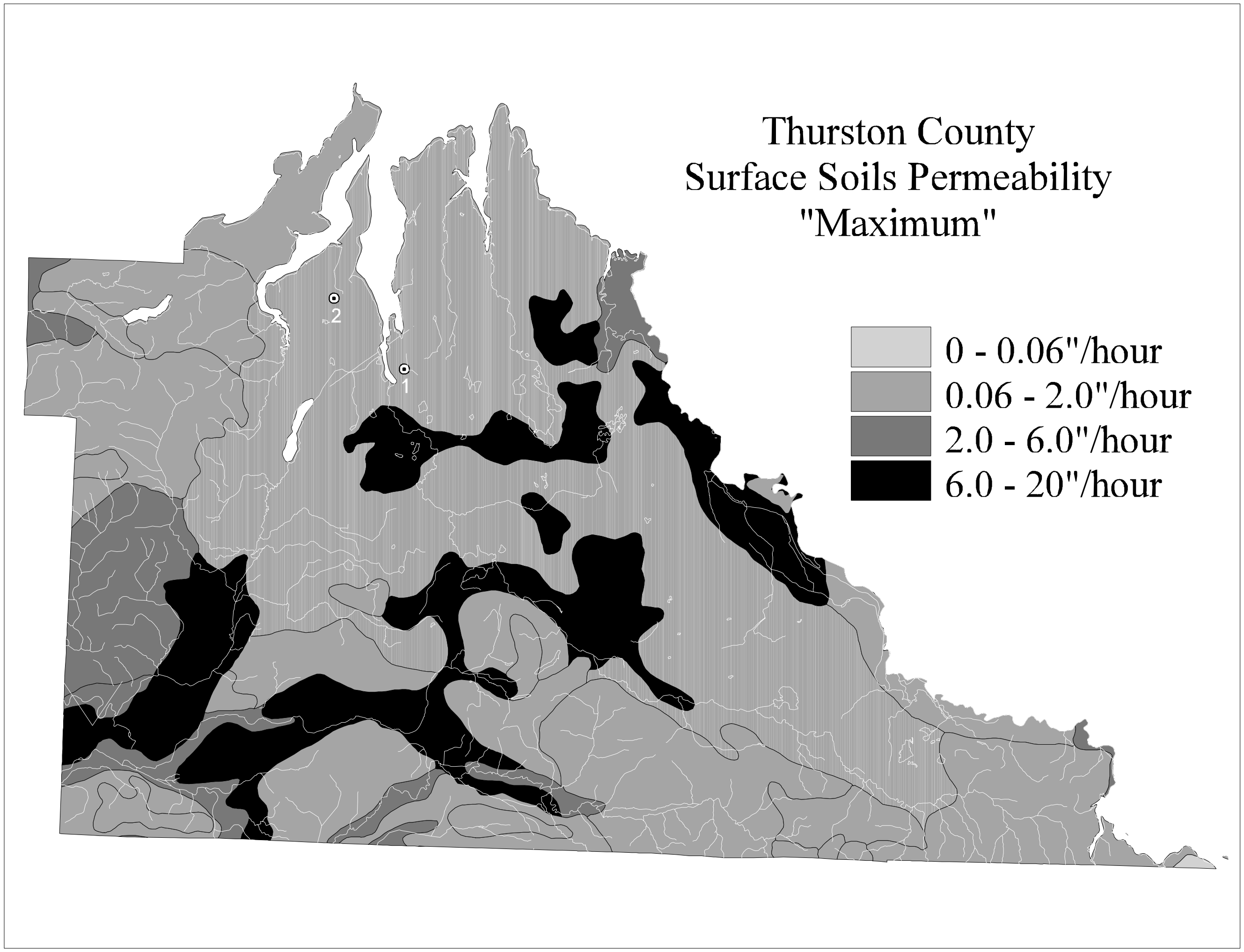
During the 2003-2004 November-April sampling season, there were 46 days in Olympia with at least 0.1 inches of rainfall and 34 days in Tacoma. This compares with a 1999-2004 historic mean of 50.2 days in Olympia and a 1996-2004 historic mean of 46 days in Tacoma. While rainfall was lighter than the historic record during the 2003-2004 sampling season, with a combined average of 17% fewer days of 0.1 inch or greater rainfall, there was not a sufficient shortfall to fully account for the low incidence of discharging active construction sites.

Soil Permeability and Expected Runoff

With only 26% (11 of 42) of active sites discharging when visited, soil permeability was considered as a causal factor in the low incidence of surface runoff. Soil permeability for western Washington was mapped using Arcview and data from the State Soil Survey (STATSGO). Figures 4a and 4b show soil permeability for Thurston and King counties. These counties have maximum permeabilities almost entirely above 0.6 inches per hour, high enough to account for much of the low incidence of surface runoff. The western portions of Snohomish and King counties, where population and construction is greatest in extent, also have highly permeable soils.

Figure 5 shows soil permeabilities for western Washington. Other than the Olympic Mountains and portions of the northwestern Olympic Peninsula, soils with low permeability (mostly exposed unweathered bedrock), occur only in the Cascade Mountains, where they are interspersed with coarse material with high permeability. Construction activity in western Washington can be expected to take place on soils of 0.6 inches/hour permeability or greater, sufficient for infiltration of runoff in construction sites with even a relatively small amount of storage.

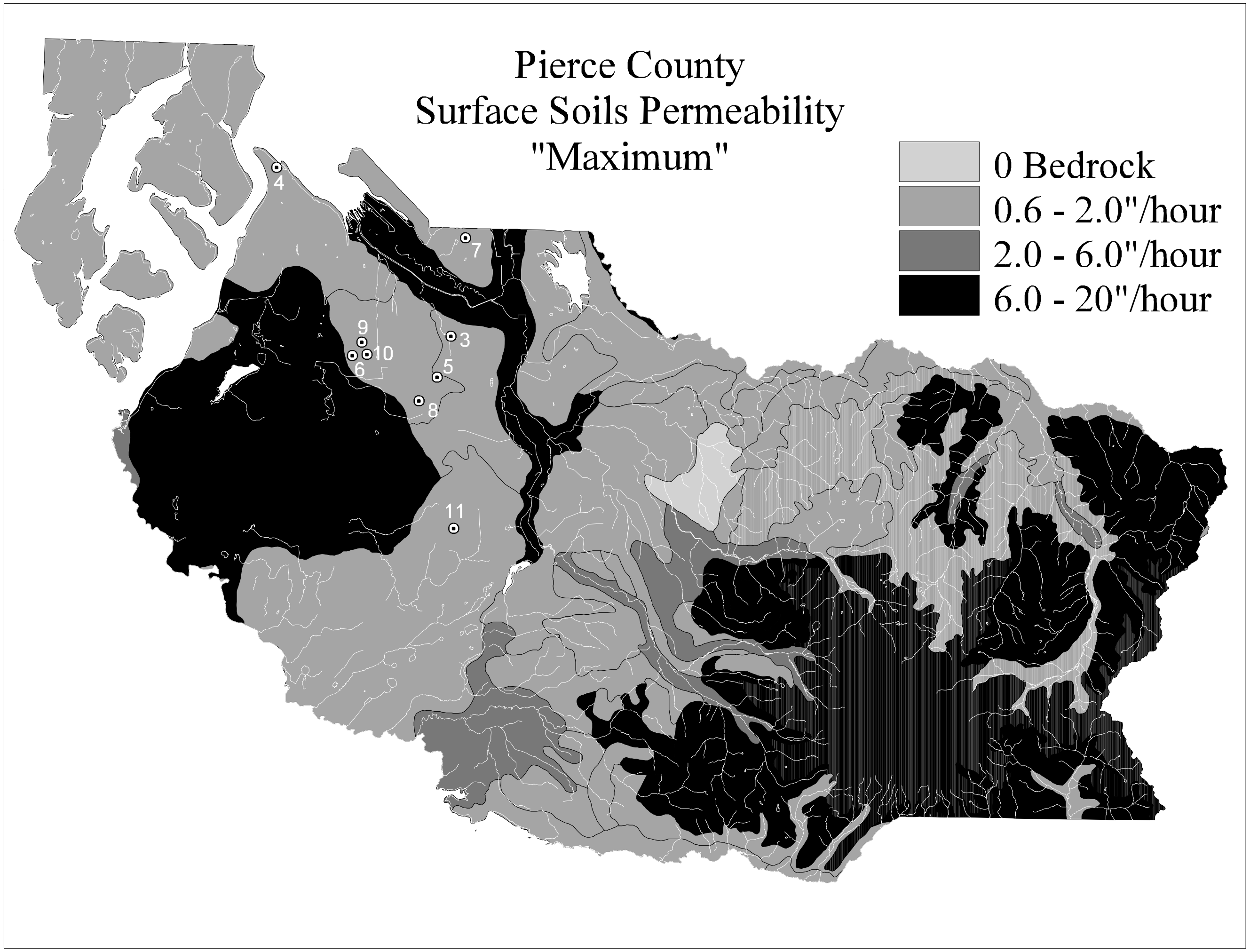
Infiltration rates are affected by groundwater elevation as well as soil permeability. High water tables, often associated with precipitation, prevent infiltration. For this reason, even in cases where soils are permeable, runoff may occur. The lower than average precipitation during the 2003-2004 sampling season may have resulted in lower water tables and a lower frequency of discharge.



Facility Locations

1. Henderson Ave/
   I-5 Interchange
2. Tri Way Cooper Crest

Figure 4a. Maximum Surface Soils Permeability and Facility Locations, Thurston County.



Facility Locations

3. Capstone Homes
4. Point Defiance Zoo
5. Chaffy at Glacier Crk.
6. Pelzel Village
7. Slavic Church
8. Wittenburg Estates
9. Bowlin plat
10. Portland Av. Bus. Pk.
11. Bethel Kapowski Sch.

Figure 4b. Maximum Surface Soils Permeability and Facility Locations, Pierce County.

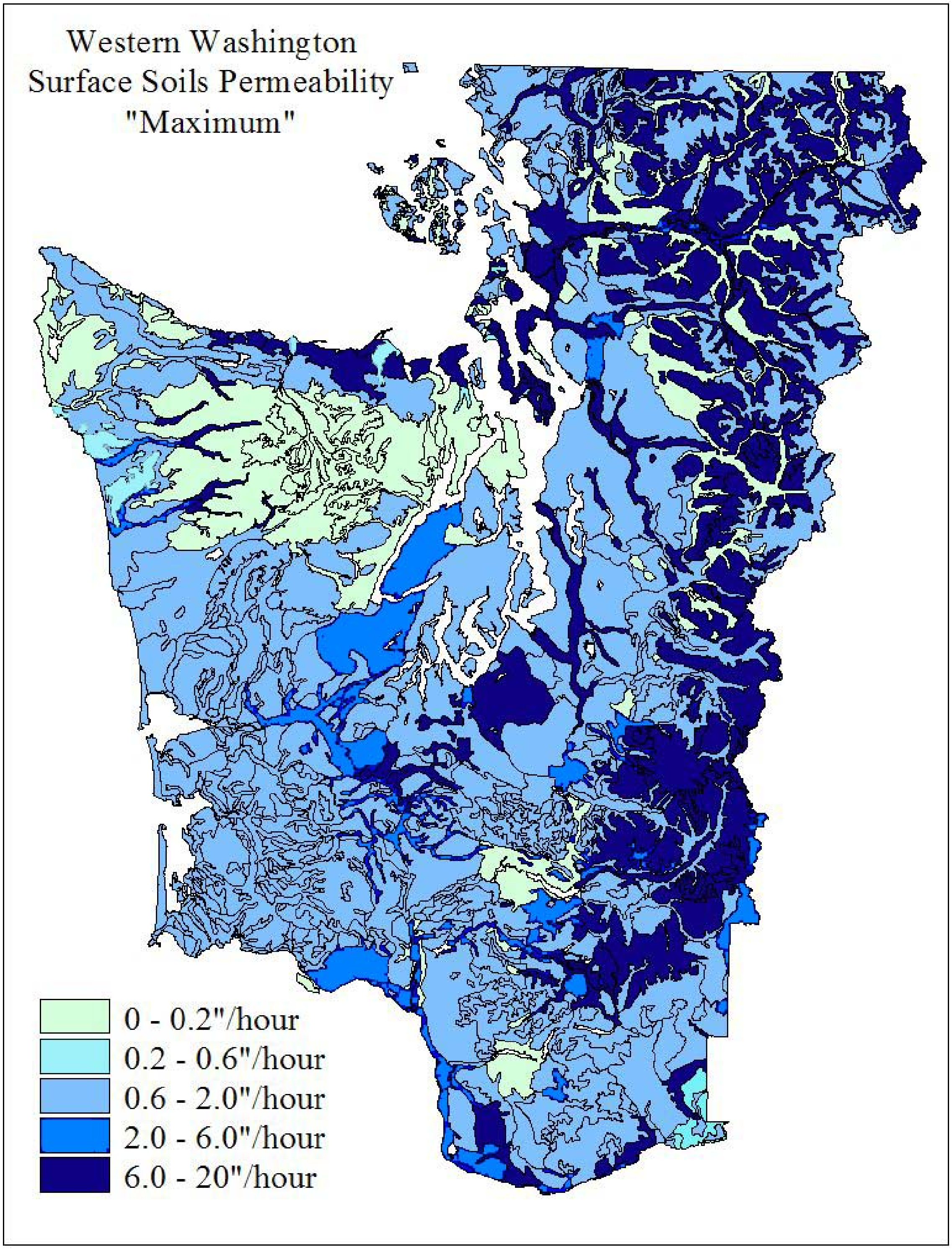


Figure 5. Soil Permeability for Western Washington.

Comparisons of Turbidity Indicators

The turbidity of discharges and receiving waters measured in the field was compared with that determined in the laboratory (Figure 6). It was anticipated that the results would correlate well because both instruments were ratio-type and of the same manufacturer. A correlation coefficient of 0.995 ($r^2 = 0.9902$) shows that the correlation between field and laboratory measurements was excellent.

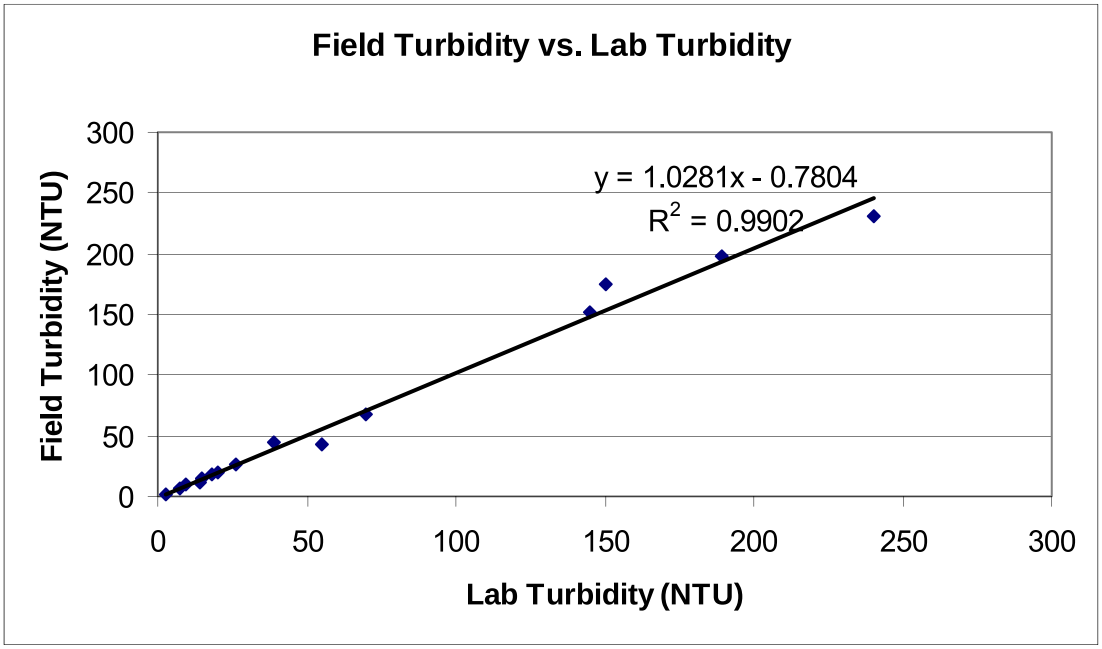


Figure 6. Field Turbidity versus Laboratory Turbidity Results.

Turbidity was compared with transparency tube results (Figure 7).

Using a power series, transparency tube results were found to correlate well with turbidity results. The correlation coefficient was 0.966 ($r^2 = 0.9336$), indicating good correlation between the two. A statistical t-test shows a significant correlation at the 99.9% level of confidence.

This high degree of correlation indicates that transparency tube measurements, with the equation above applied, result in good approximations of turbidity. However, correlations are poorer for turbidities of greater than about 250 NTU. This is because, as can be seen in Figure 7, the curve becomes fairly flat beyond 250 NTU. Also, as was noted in the Data Quality section of this report, transparency tube results became imprecise for results of 4 cm or less. This, combined with the flat slope of the transparency-turbidity curve for 250 NTU or higher, leads to the conclusion that transparency results corresponding to 250 NTU or higher should not be translated to turbidity but instead interpreted as >250 NTU.

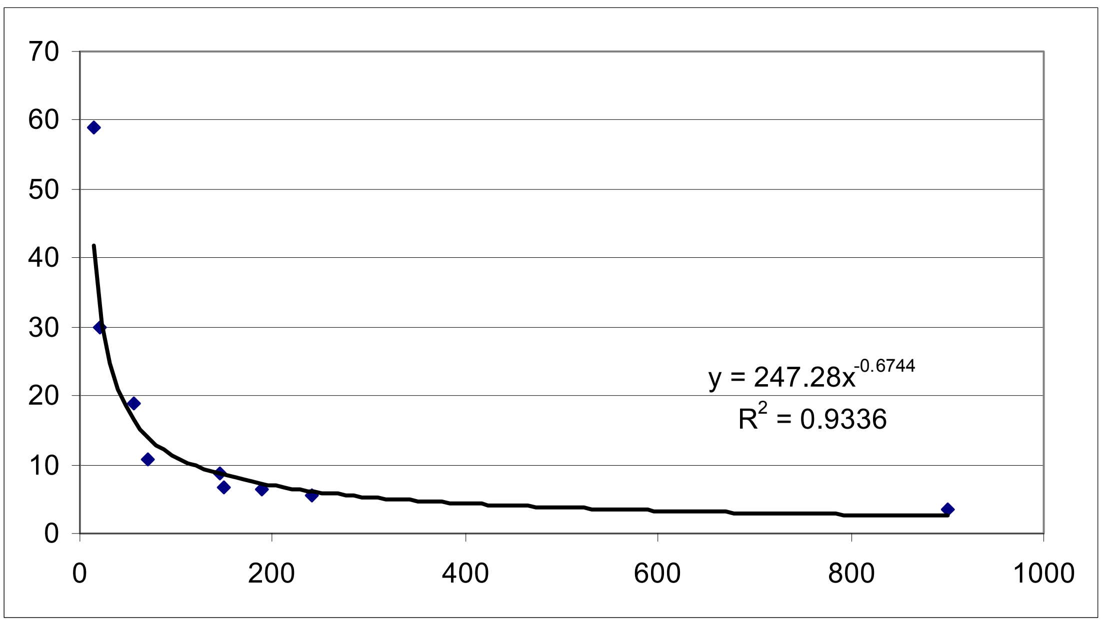


Figure 7. Transparency Tube Results versus Laboratory Turbidity Results.

The correlation between transparency tube and turbidity measurements applies only to the soils of the sites included in the first year's study. That is, only sites from two counties were involved in the correlation. The correlation between transparency tube and turbidity measurements for locations outside of the study area is unknown. It can be expected that varying soil types in different geographical areas may result in poorer correlations than those obtained in this study. Because of this and because two different properties are involved (transparency versus light scatter), it cannot be assumed that the above correlation applies to the entire state of Washington.

The possibility of a correlation between TSS and turbidity was also explored, although a good correlation was not anticipated. TSS, a measure of total suspended solids concentrations, may be expected to relate somewhat to turbidity, though particle size, while having a potentially large effect on turbidity measurements, does not enter into TSS determinations. Figure 8 shows the relationship between the TSS concentrations obtained and turbidity.

The correlation coefficient between TSS and turbidity was 0.637 (r^2 = 0.4055), indicating the lack of a correlation between TSS and turbidity. The presence of two of ten points far from the best-fit line in Figure 8 shows that TSS cannot be used as a surrogate for turbidity.

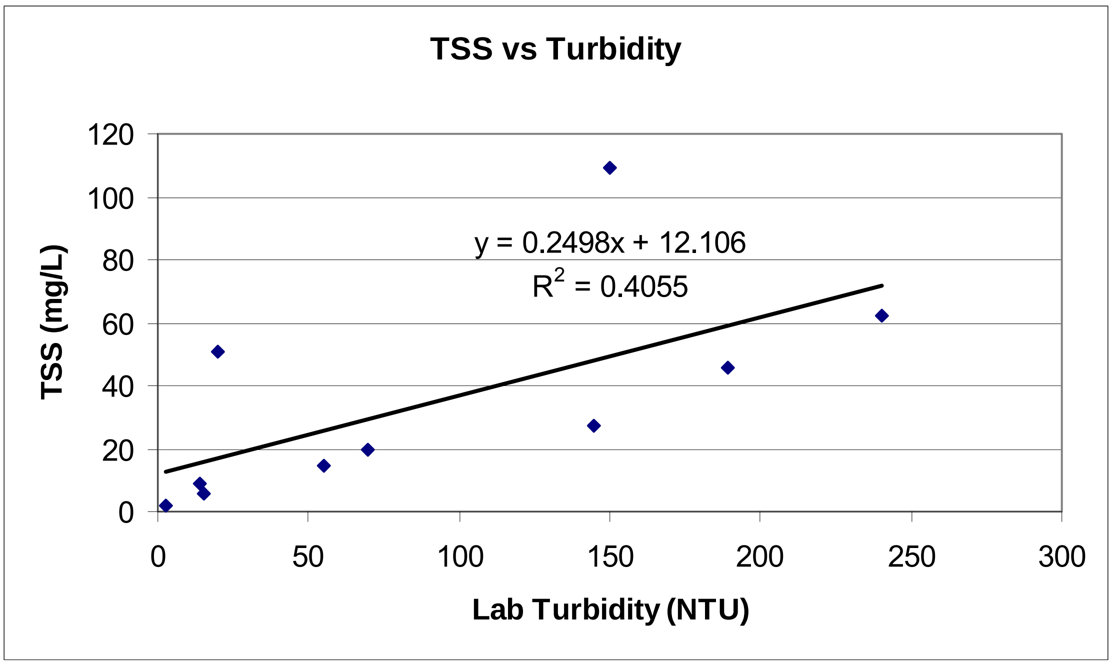


Figure 8. Total Suspended Solids Results versus Laboratory Turbidity Results.

Conclusions

Data from 11 construction sites that were discharging runoff, of 42 active sites visited, showed turbidities ranging from 2.4 to >1000 NTU, over 90% of the sites in the range of 14 to 240 NTU. More data are needed to adequately characterize stormwater discharges from western Washington construction sites.

The finding of considerable turbidity downstream at two sites suggests that turbidities downstream of construction site discharges may commonly be greater than the 5 NTU increase allowed by state water quality standards. Data from additional construction sites are needed to more fully evaluate impacts on receiving waters.

The low incidence of active construction sites discharging runoff (26%) during the first year (2003-2004) of the study is not the result of the somewhat lighter than average precipitation during the study period or the presence of large stormwater retention facilities at the sites, but of the high permeability soils in regions of western Washington where construction mostly takes place.

Field turbidity determinations with a ratio-type nephelometer were found to be as precise and accurate as laboratory turbidity.

Transparency was found to be a good surrogate for turbidity, for estimated turbidity values below 250 NTU. The correlation developed applies only to turbidity in Thurston and Pierce counties, though it may have applicability for much of western Washington. The second year of data from four counties is expected to verify this.

TSS is not a valid surrogate for turbidity determinations.

Recommendations

Recommendations resulting from this first year of the study are as follows:

- For the second year of the study, phone calls to construction operators should be made well in advance of each potential visit to explain the nature of the project, verify the active status of the site, and obtain driving directions.
- Because of the low cost of laboratory turbidity analyses, it is suggested that laboratory turbidity analysis be continued during the second year of the study.
- The effects of site characteristics on the turbidity of construction site discharges should be reevaluated when additional data are collected during the second year of the study.
- The effects of construction site stormwater discharges on receiving water turbidity should be reevaluated with additional data from the second year of the study.

References

APHA/AWWA/WEF, 1995. Standard Methods for the Examination of Water and Wastewater, 19th Edition. American Public Health Association, American Water Works Association, Water Environment Federation.

Ecology, 1992. Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC.

Ecology, 2001. Stormwater Management Manual for Western Washington, Vol. II. Water Quality Program, Washington State Department of Ecology, Olympia, WA. Publication No. 99-12. http://www.ecy.wa.gov/biblio/9912.html

Golding, S., 2003. Quality Assurance Project Plan: Stormwater Quality Survey of Western Washington Construction Sites. November 2003. Publication No. 03-03-111. http://www.ecy.wa.gov/biblio/0303111.html

University of Washington Earth Climate and Weather, 2004. http://www-k12.atmos.washington.edu/k12/grayskies/nw_weather.html