TECHNICAL MEMORANDUM

Nonstructural Stormwater BMP Assessment Work Order 145 31 043

Prepared for

City of Portland Bureau of Environmental Services

May 2006

Note:

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Prepared for

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Introduction

The City of Portland was issued its first National Pollutant Discharge Elimination System (NPDES) municipal separate storm sewer system (MS4) stormwater permit in September 1995 by the Oregon Department of Environmental Quality (DEQ). The permit was renewed in March 2004. DEQ then released a revised permit in response to a permit reconsideration in July 2005. The City of Portland, along with its two current co-permittees (the Port of Portland and Multnomah County), have developed stormwater management plans (SWMPs) that describe measures the communities will implement to improve stormwater quality. These measures, commonly known as best management practices (BMPs), can be classified as either structural or nonstructural. Structural BMPs include facilities such as stormwater detention ponds and oil-water separators. Nonstructural BMPs include measures such as public education and street maintenance. The NPDES permit requires the city to evaluate the effectiveness of both structural and nonstructural BMPs and to establish benchmarks for water quality to demonstrate that the pollution reduction efforts are working. The nonstructural measures, in particular, have been difficult to quantify and incorporate into benchmarks.

Under work order 145 31 043, Herrera Environmental Consultants, Inc. (Herrera) reviewed a spreadsheet model (the Watershed Treatment Model [WTM]) for potential use in evaluating BMPs used in the City of Portland's watershed management program, conducted a brief literature review, and prepared this technical memorandum to summarize the findings and recommend an approach for meeting the city's permit obligations. The memorandum also identifies areas where data are lacking and additional study is warranted.

This study focused on evaluating models that can be used to evaluate the following nonstructural BMPs identified in the City of Portland Stormwater Management Plan (Portland 2006):

- Downspout disconnection
- Residential education
- Maintenance and cleaning of MS4 system components
- Street cleaning
- Catch basin cleaning
- Erosion prevention and sediment control
- Vegetative management plan for parks (to reduce fertilizer and pesticide use)
- Education for city employees
- Industrial permitting for outfalls
- Program to eliminate illicit discharges
- Pesticide-free parks
- Education for business and industry
- Spill response program
- Control of erosion from construction sites
- Reduction in stormwater from new developments
- Land use zoning for environmental protection

- Naturescaping
- Tree planting.

This report discusses the results of an evaluation of WTM, presents information obtained from published literature that could be used to fill data gaps in WTM, and compares the WTM approach with the approach of the City of Portland's existing GRID model to determine which model better meets the needs of the city.

Evaluation of Watershed Treatment Model

The approach used by the WTM spreadsheet was evaluated for a number of factors, including ease of use, flexibility, ability to model physical conditions present within Portland's watersheds, the ability to model operation and maintenance methods and specific BMPs used by the City of Portland, and the ability to include the interaction of multiple BMPs in use together. The pros and cons of the WTM are evaluated in this section.

The WTM approach for modeling effectiveness of nonstructural BMPs would work reasonably well in Portland, especially in small watersheds with only one type of structural BMP. The cost of WTM is negligible (\$25), but it would require significant labor to enter and maintain the data needed for WTM. For larger, complex watersheds, the city's existing model (GRID) appears to be easier to use and maintain in terms of tracking pollutant and BMP information, provided its current, effluent-based approach is modified to better represent nonstructural BMPs. A brief synopsis of GRID is provided below for the purpose of comparison to WTM.

The GRID model, which is based on a geographic information system (GIS), is used to estimate pollutant concentrations and loads in stormwater. The model divides the entire city into a grid of 100-square-foot cells and assigns attributes to each of the cells, such as land use and rainfall. Based on these attributes, the GRID model can calculate the percentage of impervious surface and pollutant concentrations and generate runoff volumes and pollutant loadings for each cell. A pollutant-reduction factor for BMP effluent concentrations can also be applied to each cell to reflect the effectiveness of stormwater BMPs. The individual cells can be aggregated into a drainage basin to calculate the average pollutant concentration or total pollutant load for that basin. The GRID model can account for pollutant removal due to structural BMPs such as ponds and water quality swales and nonstructural BMPs such as public education and street sweeping. Currently, however, only effectiveness information for structural BMPs is available.

The WTM spreadsheet and its associated documentation (Center for Watershed Protection 2001), were reviewed to determine whether they could be used to better estimate pollutant loads in Portland and to incorporate the performance of both structural and nonstructural BMPs. WTM was developed for the Chesapeake Bay region, using climate, water quality, and BMP performance data generated in that region; however, these parameters can be revised by the user to apply the model to other regions.

Several factors were considered to determine whether WTM meets the City of Portland's needs:

- Ease of use
- Flexibility of the model
- Climate, soils, demographics
- Land use characteristics
- Operation and maintenance methods used by City of Portland
- BMPs used by City of Portland
- Interactions of multiple BMPs.

Ease of Use

The WTM spreadsheet is fairly simple and can be used by anyone who is familiar with Microsoft Excel. It contains worksheet pages for the following:

- Primary pollutant sources
- Secondary pollutant sources
- Existing management practices
- Future management practices
- Future land use
- New development
- Discounts for existing practices
- Discounts for future practices
- Existing loads
- Loads with future practices
- Loads including growth
- Summary sheet of pollutant loads.

The spreadsheet cells are color-coded into those that require user input, those with default values (that may be changed by the user), and those that should "generally not be changed," including those with "bottom line" loads.

A slight criticism of the WTM spreadsheet configuration is the fact that although the colorcoding does cue the user about which cells should "generally not be changed," none of the cells are protected. It is almost certain that some user will inadvertently change a crucial formula and cause problems, which may not be readily apparent. At a minimum, the formulas on the loading and summary pages should be protected.

The model authors have tried to simplify a difficult topic by providing guidance in the WTM in the form of simple tables to help determine many of the model inputs. In most instances, this is successful. However, there are still some poorly documented assumptions, such as Table 8.1 in the WTM User's Manual, indicating "removal rates adjusted based on best professional judgment."

Flexibility of Watershed Treatment Model

All of the input cells, coefficients, and formulas in the model can be changed by the user. The formulas are simple bookkeeping equations containing only basic math functions. They are relatively easy to understand and modify.

The model computes annual pollutant loads using the Simple Method (Schueler 1987), essentially flow multiplied by the pollutant concentration. The model currently estimates total suspended solids, nutrients, and bacteria concentrations but does not estimate metals, petroleum

derivatives, or other parameters that are included in Portland's MS4 permit and total maximum daily loads (TMDLs). These other parameters could be added but would require substantial reworking of the spreadsheet.

The model does not calculate individual particle sizes, including only a single value for the concentration of total suspended solids as a surrogate for all particle sizes. Tracking only total suspended solids means there is no way to accurately model multiple BMPs in a series, since most BMPs preferentially remove the heavier particulates, leaving behind an increasingly large proportion of fines that will not settle out. On the other hand, WTM does address instream erosion and sediments, albeit in a simplified manner.

The WTM incorporates a concept called "discounts" that enhances the model's flexibility. These are most apparent in the structural stormwater management practices, where a discount or decrease in a BMP's efficiency is calculated for incomplete capture of the stormwater, poor design, or inadequate maintenance. For nonstructural measures, discount factors may include awareness, willingness to participate, and enforceability.

The educational programs, for instance, contain two types of discount factors. Treatability factors depend on the ability of the program to be implemented and discount factors depend on the way in which the program is implemented. The educational lawn care formulas below are an example of the way this "implementation effectiveness" concept is applied in the WTM.

Example – Residential Education

Lawn Care

 $R_L = A_L \; Ff_1f_2$

Where:

- R_L = Reduced Pollutant Load from Turf Grass (lbs/year)
- A_L = Residential Lawn Area (acres)
- F = Fertilization Rate (lbs/acre/year) [The model assumes 150 lbs/acre/year for nitrogen and 15 lbs/acre/year for phosphorus]
- f_1 = Fertilizer Reduction (Fraction) [The model assumes 50 percent reduction]
- f₂ = Applied Fertilizer "Lost" to Runoff and Percolation (fraction) [The model assumes nitrogen losses of 25 percent and phosphorus losses of 5 percent]

Residential lawn area is calculated as:

 $A_{\rm L} = A_{\rm RE} (1 - I_{\rm RE}) f_3$

Where:

 A_{RE} = Area of Residential Land (acres)

- I_{RE} = Imperviousness of Residential Land (fraction)
- f₃ = Fraction of Residential Pervious Surfaces in Lawns [assume 80 percent of residential pervious surfaces are managed as turf]

Combining these two equations,

 $R_L = A_{RE} (1-I_{RE}) F f_1 f_2 f_3$

Other assumptions:

Treatability –
78 percent of individuals fertilize their lawn, 65 percent of those
people "over fertilize" (more than twice per year) –
0.78*0.65=0.50 or a 50 percent treatability factor
Discount factors –
D1 – where the information is coming from (for instance, the recall
rate from a television ad is assumed to be 40 percent,
newspaper is 30 percent, and a brochure is only 8 percent)
D2 – Willingness to change behavior is 70 percent]

The WTM does not allow for a range of values for pollutant loading. Since the values are determined based on many assumptions, some quantification of the uncertainty involved in the projections might be useful if an increase in pollutant loading is measured from one year to the next. The increase may just be natural variation around an otherwise declining trend in loading.

Physical Conditions in City of Portland's Watersheds

WTM was developed for the east coast and a number of parameters should be changed to reflect Portland conditions. Infiltration rates, soil enrichment factors, percentage of households owning dogs, and other factors would all need to be changed to reflect Portland characteristics. The model documentation provides guidance for doing this, but some factors may require additional calculations. Reasonable changes should be well documented.

Some of the default values in the WTM (pollutant loading and impervious cover, for example) are based on land use. Because these values were developed for use in New England, their applicability should be verified for the City of Portland. If necessary, they can be changed by the user. In addition, there are many parameter values that are not included with the model and have to be entered specifically for the City of Portland, among them the rate of urban infill.

Operations and Maintenance Methods Used by City of Portland

The effectiveness of many BMPs depends upon how well they are maintained. The pollutant removal percentages used by WTM for stormwater BMPs are median values from a selected BMP database, put together by Winer (2000). Unfortunately, most monitoring tends to occur on new facilities, when most BMPs are functioning at maximum effectiveness. Some vegetated facilities may improve with time due to improved vegetation density and soil structure. However the main method of pollutant removal is adsorption to the soil and those "adsorption sites" tend to get filled up. Oberts (1997) found pollutant removal efficiencies decreased from 20 to 65 percent for a wetlands treatment system after 10 years. The WTM does include several discount factors, which account for incomplete storm capture, and poor design or maintenance. The maintenance levels specified for use in deciding the maintenance discount factor are based on having a program in place rather than actual maintenance frequency. The lowest discount factor (0.5) is probably above current maintenance levels for a number of Portland facilities including catch basins and detention ponds.

BMPs Used by City of Portland

The WTM does not include all of the BMPs that the City of Portland is currently implementing or proposing to implement in the future. Therefore, many additional items would need to be added to the model for it to be useful. For example, the City of Portland has a nonstructural BMP in place to reduce fertilizer and pesticide use on city properties. This BMP is not included in the WTM. Neither are a number of low-impact development techniques such as planter boxes and ecoroofs.

A number of the equations used to calculate pollutant loadings in the model are based on demographic assumptions which are not necessarily valid for the City of Portland, with its younger, more urban population. This population typically has a higher level of environmental awareness. For instance, the WTM uses an equation to determine reduction in nutrient loading from lawn care based on public education. This equation assumes a certain rate of fertilizer application, a certain reduction rate, and a participation rate based on the number of people who were reached by the education program.

Many of the BMPs that the City of Portland has implemented cannot be quantified and entered into the model, yet do result in effective protection of water quality in receiving waters. Effective spill response, for example, may prevent an environmental disaster, but WTM isn't designed to take credit for pollutant control at the source for sporadic events.

One of the biggest shortcomings of the model is the lack of verifiable documentation. There simply is not much data available for many of these measures, especially nonstructural BMPs, so a lack of data is expected. However, even the references that are cited in the WTM Users Manual often do not have the exact numbers used in WTM. Values used in the model were

apparently extrapolated in some fashion from the references, leading to reasonable doubt as to the accuracy and confidence associated with the coefficients suggested for the model.

Interactions of Multiple BMPs

Like most models, the WTM does not accurately take into account the effects of several BMPs acting together to remove pollutants from the same volume of runoff. For example, if the City of Portland is conducting street sweeping and catch basin cleaning, the actual reduction in loading from the catch basin will be less than a stand-alone catch basin because the street sweeping will have already removed a fraction of the total suspended solids and associated pollutants that would have otherwise have been trapped by the catch basin. The WTM cannot accurately quantify the effectiveness of BMPs in a sequence like this. However, its method of dealing with nonstructural (sweeping) and structural (catch basin) BMPs is more robust than some models.

In the example above, street sweeping followed by catch basin cleaning, the model first subtracts a mass load assumed to be removed by the sweeping. The model then applies the percent load reduction assumed for the catch basin cleaning to the remaining mass load. WTM can use this approach for a subset of four stormwater treatment practices and seven prevention practices. However, the model documentation also acknowledges two simplifying assumptions:

- Within a subwatershed, structural treatment practices do not act in series.
 For example, removal from one pond will not affect the removal of another.
- Pollution prevention measures are distributed evenly throughout the watershed, so that the load reduced by a treatment practice can be subtracted from the total subwatershed stormwater load.

In other words, the selected pollution prevention measures (nonstructural BMPs) are additive; the treatment practices (structural BMPs) are not. The city has indicated that less than 5 percent of the city's area has structural BMPs, but the city needs to confirm how many situations in the city would be affected by multiple treatment practices and whether this shortcoming is significant. (The city's current emphasis on using effluent limitations is incompatible with the above approach as will be detailed in the discussion section below.)

Literature Review

The literature review was designed to answer several questions. Is the WTM methodology based on sound assumptions? Does WTM agree with other published studies? Is the city's existing GRID model a better fit for the city's objectives? Can the literature fill in any model gaps to better estimate pollutant loadings from Portland?

Sources of nonstructural stormwater BMP effectiveness information include documents provided by the city, documents referenced in the WTM (Center for Watershed Protection 2001), documents referenced in the Association of Clean Water Agencies BMP Effectiveness Study database (ACWA 2005), and additional literature gathered from Internet sources.

The literature review confirmed that BMP effectiveness documentation is scarce for all but one of the nonstructural BMPs of interest to the city. The exception is street sweeping, for which many studies have been conducted, although many street sweeping studies have relied on modeled data rather than physical monitoring data. The following sections summarize the documents reviewed for each of the BMPs of interest.

Downspout Disconnection

Schueler (1995a) summarized the results from other studies on roof runoff pollutants. His summary shows that roof runoff contains metal pollutants, the concentration dependent on the type of roofing material. The majority of the values given were for industrial areas with metal roofs; there was also one residential area shown.

A literature review conducted by Herrera for Seattle Public Utilities (Herrera 2005a) concluded that the concentration of metals from rooftops varied tremendously and were dependent on the type of roof material (see Table 1). Both this study and the Schueler study illustrate that, contrary to popular wisdom, roof runoff is not always much cleaner than street runoff. Thus, disconnecting downspouts may provide substantial benefits in terms of water quality as well as reducing the quantity of runoff.

Public Education

To quantify the effectiveness of public education in reducing nutrient loading, the WTM used values obtained from surveys of the public. Swann (1999), for instance, surveyed residents in the Chesapeake Bay area to determine their attitudes and practices regarding nutrient producing behaviors. This study also surveyed 50 nutrient education programs from across the country to determine types of outreach techniques employed, number of people reached and effectiveness of the outreach program. In addition, there was a detailed assessment of public attitude surveys that were concerned with nutrients or nonpoint pollution.

Roof and Gutter/ Downspout Material	Total Copper (µg/L)	Dissolved Copper (µg/L)	Total Lead (µg/L)	Dissolved Lead (µg/L)	Total Zinc (µg/L)	Dissolved Zinc (µg/L)
Metal roof with various gutter/downspout materials	4.8 - 355	2-7	2.9 - 302	n.d. – 35	101 – 43,667	82 - 11,900
Number of data points	6	3	11	3	11	3
Nonmetal roof with metal gutter/downspout	71 - 842	n.d.	4.9 - 1,420	n.d.	10 - 3,800	n.d.
Number of data points	4	0	6	0	6	0
Nonmetal roof and gutter/downspout	7.6 – 18	n.d.	2.7 – 37	n.d.	9.0 - 104	n.d.
Number of data points	3	0	3	0	3	0
Nonmetal roof with unknown composition gutter/downspout	6.0 - 6,817	0.1 – 128	8.0 - 510	0.06 - 2.73	36 - 2,998	8.4 - 909
Number of data points	11	4	14	4	14	4
Acute water quality criteria ^a		8.9 - 32.7		30.1 - 136.1		63.6 - 105.9

Table 1.Concentration ranges of total and dissolved metals in roof runoff from various
roof materials compared to Washington state water quality criteria.

^a Range represents criteria for waters with hardness values from 50 to 200 mg/L as CaCO₃.

Note: Concentrations are from several published reports and are reported in geometric means, mean EMCs, medians; and some are estimates from published graphs.

n.d. = no data available.

Source: Herrera (2005a).

Using the data from Swann (1999) requires many assumptions about the accuracy of the surveys due to potential inconsistencies in the responses of the survey participants (i.e., survey results are self-reported, with no way of validating the accuracy of responses). In addition, many of the surveys did not take place in the Pacific Northwest so it is possible that the results would vary depending on differences in regional attitudes.

Taylor and Wong (2002) reviewed literature relating to nonstructural stormwater BMPs. A portion of the literature review was related to public education and values, and many articles were cited that could potentially be useful for quantifying public education as a method for reducing pollutant loading. However, once again, the majority of the numbers in this literature review were self-reported based on public surveys.

The number recommended for use by the City of Portland Bureau of Environmental Services for the percentage of the public who change their habits based on educational programs (8 percent) comes from public relations outreach performed by Clean Water Services (Jockers 2005). Clean Water Services found that after sending out over 3,000 brochures, they had an 8 percent return rate asking for more information. A more generalized print/radio campaign about using native plants yielded 7,200 responses (website visits). Considering Clean Water Services' customer base of 480,000, this is a response rate of 1.5 percent. These response rates seem a better

indication of behavioral change than the relatively high numbers cited in the survey of awareness, especially since they required at least a minimal effort to ask for additional information, and changing habits would require effort.

Street Sweeping

Estimated pollutant reduction values for street sweeping are summarized in Table 2 and described below. Several documents were reviewed that presented estimated annual pollutant loading reduction values for street sweeping programs. Studies by Pacific Water Resources (2001, 2004a, 2004c), Sutherland (1991), Sutherland et al. (1998), and TetraTech and Pacific Water Resources (2001) used the SIMplified Particulate Transport Model (SIMPTM) to estimate annual pollutant loads. Other studies, including those by Martinelli et al. (2002), Sutherland (1991), and USGS (2002), presented estimated pollutant removal values based on pollutant concentrations. One study presented pollutant removal values in terms of areal load reduction (Wong and Walker 1999). A common criticism of many of these studies is that they use older street sweeping equipment. Ongoing studies, such as the one for Seattle Public Utilities presented at the Oregon Association of Clean Water Agencies, Stormwater Summit (Felstul 2006) may better reflect continuing improvements in street sweepers.

Catch Basin Cleaning

A fact sheet on catch basin cleaning from U.S. EPA (1999) states that past studies have reported that up to 57 percent of coarse solids (sands or coarser) and 17 percent of biological oxygen demand (BOD) are removed by catch basins. This fact sheet also stated that a catch basin should be cleaned when the depth of the deposits is greater than or equal to the one-third of the depth from the basin to the invert of the lowest pipe or opening into or out of the basin.

Mineart and Singh (2000) summarized a study conducted by them at Woodward-Clyde Consultants in Alameda County, California. The study compared debris from residential, commercial, and industrial storm drain inlets and determined whether frequent catch basin cleaning would remove more stormwater pollutants. It appears that monthly cleaning removes three to six times as much pollutant mass on an annual basis. Table 3 summarizes the results of the study, which seem to indicate that although more frequent cleanings remove more sediment, there is a point of diminishing returns. Monthly cleaning does not remove three times as much sediment as quarterly cleanings, for instance. For industrial catch basins, the optimal cleaning frequency appears to be between quarterly and semiannual; for residential catch basins, the optimal frequency appears to be annual. For commercial catch basins, the optimal frequency is semiannual.

Study	Reported Efficiency Value(s)	Reported as	Type of Sweeper	Sweeping Frequency	Geographic Region	Land Use / Road Surface Information	Other Notes
Martinelli et al. (2002)	Variable results	Pollutant concentration mg/L	Schwarze Industries EnviroWhirl EV2	19.5% of the area was swept every week and the full 34% was swept every other week	Milwaukee County, Wisconsin	Urban Highway (with an ADT of 133,900), concrete surface (last resurfaced mid 1990's), good condition	Paired basin approach; the concentration of pollutants exported in runoff were directly measured. Only the shoulder areas of the basin were swept, which amounted to 34% of the test basin.
Pacific Water Resources, Inc. (2004a)	The percent reduction varied depending on land use, type of sweeper used and number of sweepings per year.	Annual TSS load reduction as a percentage	Model used the efficiency associated with the Schwarze EV Envirowhirl	Model shows results for 6, 12, 23, 49, 87, 174 times per year	Yakima County, WA	Various Land Uses (including industrial, commercial, and single family residential).	Values simulated using SIMPTM
Pacific Water Resources, Inc. (2004b)	The percentage depended on the manufacturer, model and type of sweeper but ranged from 86.3 to 99.6%	Pick-up efficiency of street dirt as a percentage	Elgin Mechanical, Elgin Vacuum, Elgin Regenerative, Mobile Mechanical, Schwarze Mechanical, Schwarze Regenerative, Tennant Mechanical, Tymco Regerative.	One pass of the sweeper over a known amount of street dirt	Seattle, WA	Airplane hangar with pavement that had been sealed with a smooth rubber based coating, no curbs or roadway barriers, dry conditions	Several sweepers were used in a controlled setting. The street dirt used was a simulant. The pick-up efficiencies were very high because test conditions were ideal.
Pacific Water Resources, Inc. (2004c)	Varied depending on traffic volume, pavement types and percent compliance.	Percent reduction for TSS, total chromium, total copper, total lead, total zinc, total nitrogen, total phosphorus	Mechanical, Regenerative air, Schwarze	Various – results were modeled	Israel; Highway	Both traditional and porous asphalt pavements under low- and high-traffic volumes	Values simulated using SIMPTM

Table 2. Reported values for pollutant reduction resulting from street sweeping.

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Table 2 (continued).	Reported	values for pollutant	reduction resulting	from street sweeping.
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Study	Reported Efficiency Value(s)	Reported as	Type of Sweeper	Sweeping Frequency	Geographic Region	Land Use / Road Surface Information	Other Notes
HDR (1993)	Sweeping effectiveness varied depending on method used. The results are reported as the average pickup efficiency: 1) 39.8% 2) 45.5% 3) 74.2% tandem cleaning is the most effective, followed by heavy flush cleaning.	TSS reported in lbs per curb mile	Three methods were used: 1) mechanical sweeping with light flush (standard practice) 2) mechanical sweeping with heavy flush 3) tandem (mechanical sweeper followed by a vacuum sweeper)	Once a month	Portland, OR	Residential	Sampling to verify sweeper effectiveness. In addition data are provided for particulate sizes and associated pollutants (lbs/year).
Sutherland et al. (1998)*	TSS - 45-70% Copper – 20-60% Phosphorus - 35-60% Lead - 30-60% Zinc - 25-55%	Expected annual pollutant load reduction	SIMPTM was used to model the results	Modeled for several frequencies: twice weekly, weekly, biweekly	Seattle, WA	Port of Seattle marine cargo handling and storage facility	Values simulated using SIMPTM. In addition to annual percent removal, data are provided for dissolved loads, suspended loads, and total loads (lbs/year).
TetraTech, Inc. and Pacific Water Resources, Inc. (2001)	Varied depending on site and type of sweeper.	Solids removed in both percent reduction and lbs/year			Michigan		Values simulated using SIMPTM
USGS (2002)	Varied based on sweeping frequency and model used.	Percent removal TSS, fecal coliform bacteria, total phosphorus, lead	SWMM was used to model the results	Various frequencies modeled. Results shown from 1 to 30 days between cleanings	Lower Charles River watershed, Massachusetts	Single-family residential	Values simulated using SWMM

ADT = average daily traffic count SIMPTM = SIMplified Particulate Transport Model SWMM = Stormwater Management Model TSS = total suspended solids

		Removal E	ffectiveness	
Land Use	Cleaning Frequency	Pounds Per Cleanout	Pounds Per Year	– Type of Catch Basin
Industrial	Monthly	15	180	Drop inlet 41 inches long, 25
	Quarterly	33	130	inches wide, and 16 to 54 inches
	Semi-annual	55	100	deep
	Annual	30	30	
Residential	Monthly	10	100	
	Quarterly	8	35	
	Semi-annual	17	30	
	Annual	62	60	
Commercial	Monthly	10	120	
	Quarterly	13	50	
	Semi-annual	45	85	
	Annual	70	70	

Table 3.Results of study of catch basin cleaning frequency (Alameda County,
California).

Note: The effectiveness values were estimated from a graph provided in the study. Source: Mineart and Singh 2000.

Pitt (1988) reported that cleaning catch basins twice per year in a Bellevue study was optimal, reducing total residue by 10 to 25 percent. Pitt (1999) evaluated the effectiveness of three types of catch basins in a residential area in Stafford Township, New Jersey. The types of catch basins that were evaluated were: conventional catch basins with sumps, filter fabric units, and coarse filter units. This study showed that catch basins could remove around 30 percent of the solids. The catch basin with the sump was the only device that showed significant removals for several pollutants. Some of the results are shown in Table 4. The study also showed that although catch basins collect larger particles, they allow over 90 percent of the more contaminated finer particles (<100 micrometers) to pass through the outlet. The study indicates that catch basins will collect sediments until they reach about 60 percent of the total sump capacity (about 0.3 meters under the outlet).

	Total Solids	Suspended Solids	Turbidity
Range	0 - 50%	0 - 55%	0 - 65%
Average	22%	32%	38%

Source: Pitt 1988

The effectiveness of deep-sumped hooded catch basins in reducing concentration of suspended sediment was discussed in Smith (2002). It was determined that the catch basin performance

declined as flow increased, catch basin turbulence increased and retention time decreased. Some storms showed that outflow loads of suspended sediments were higher than the inflow loads due to the resuspension of sediments. It was suggested that when 50 percent of the catch basin is full then sediments are resuspended. In general, catch basins did not retain particles less than 0.062 millimeters in diameter even during low flows (0.03 cubic feet per second) but retained high density, medium and coarse grained particles. The operating efficiency for the catch basin was 39 percent for the 14-month period of the study.

In a study completed by Caltrans (2003) effluent was monitored from catch basins that were cleaned and catch basins that were not cleaned. The catch basins in this study were all along a freeway in Los Angeles County, California. The samples were analyzed for a wide range of pollutants over a 5-year period. Catch basins were cleaned three times per season at approximately 6-week intervals. The statistical analysis showed that there is not a significant difference in the effluent concentration of total suspended solids from cleaned and uncleaned catch basins. There was also no significant difference between the effluent concentration of cleaned and uncleaned catch basins for total metals, dissolved metals and nutrients. However, in the 5 years monitored at least 16,029 kilograms of debris was removed from the cleaned catch basins.

A spreadsheet model previously created for the City of Portland (Felstul 1994) calculated that catch basin effectiveness was highly dependent on the cleaning frequency. A comparison of cumulative removal values predicted by the model and values reported for a number of communities served by Clean Water Services in Washington County, Oregon, showed some variation; however, they fit the general sigmoidal curve generated by the model (Figure 1).



Figure 1. Cumulative pollutant removal by catch basins.

However, looking at the instantaneous removal may be more appropriate for judging how often a catch basin should be cleaned. Figure 2 shows that if a typical catch basin is not cleaned at least annually, it provides virtually no pollutant removal. The modeling also showed that cleaning the catch basin more frequently than once every 3 months provides little additional benefit. The results of this model are similar to those of Mineart and Singh (2000) shown in Table 3, that is, semiannual cleaning (shown at 9 months in Figure 2) appears optimal for an average catch basin.



Figure 2. Instantaneous pollution removal by catch basins.

Herrera understands that the City of Portland is very limited in its catch basin cleaning program. The city currently cleans catch basins in three sections a year. With 300 sections in the city, this means an individual catch basin is cleaned approximately once every 100 years (Hottenroth 2006). (Clogged catch basins will likely be cleaned more frequently and those with no problems, less frequently.) The lack of cleaning means that most catch basins in Portland are probably removing little or none of the sediments moving through them, instead of the 40 to 60 percent indicated above.

Control of Erosion from Construction Sites

Brown and Caraco (1997) cited several articles which determined that erosion and sediment control practices at construction sites are not very effective. The authors of this article mentioned several reasons why these practices are not effective, and listed 10 ways to improve the implementation of erosion and sediment control practices. The WTM assumes that if all these items are used, the program will be effective in removing 70 percent of the sediment from a construction site compared to a site without erosion and sediment control practices. Using this value for efficiency assumes that all construction sites implement all aspects of the erosion and sediment control plan perfectly.

In 1994, Patterson conducted a study looking at erosion control practices at construction sites in North Carolina. Throughout this study, construction sites were visited to determine if erosion control practices had been adequately installed and maintained. The erosion control discount factors in the WTM came from the results of this study. This study is very limited in that it only looked at erosion control in North Carolina. It is questionable whether the results of the study are directly applicable to erosion control practices in Oregon.

Schueler (1997) describes several ways to improve the trapping efficiency of sediment basins at construction sites. He also cites an article that gives sediment removal efficiencies for some of these improvements.

Nutrient Control

Schueler (1995b) summarized several studies showing the nitrate-leaching potential from turf grass in different scenarios. The results depended on the type of fertilizer, how much water the grass was receiving, the soil type, and the application rate of fertilizer.

Discussion

The decision about what methodology is best for estimating pollutant removal for nonstructural BMPs used in Portland should take into account the available literature and the relative merits of the city's current GRID model approach versus the WTM approach.

Effectiveness of Nonstructural BMPs

The brief literature review completed for this memorandum confirmed that published data for nonstructural BMPs are much scarcer than that for structural BMPs. The published data on nonstructural BMP effectiveness that are available are mostly for maintenance-type activities, such as street sweeping and catch basin cleaning. The data on public education or behavior-changing activities were much less quantifiable.

The lack of published data and difficulty measuring the effectiveness of individual nonstructural BMPs are the main reasons that another Portland area agency, Clean Water Services, has decided to use a lumped approach. This lumped approach looks at the combination of BMPs in use when their stormwater permit was first issued and the water quality measured at that time and compares it to the current water quality and BMPs. The improvement is assumed to be due to the entire package of BMPs. While this approach could potentially be flawed, it markedly simplifies the assessment of BMP effectiveness, but does not determine which BMPs are doing the most to reduce pollutant loads. The results are also not transferable to other locations or BMP combinations due to the lack of underlying data and the generally lower concentrations found during Clean Water Services' monitoring as compared to all of the other jurisdictions (Strecker et al. 1997).

Almost all of the data available for nonstructural BMPs are in the form of mass loadings or mass removal. Even street sweeping and catch basin cleaning, the areas with the most published information, have virtually no data on how those BMPs affected effluent concentrations. It clearly is easier to measure how many dump trucks were filled with swept material than to collect water quality samples downstream of the sweeping. It is often assumed that the removed mass can be multiplied by a calculated runoff volume to yield the resulting reduction in pollutant concentrations. However, this approach assumes that all of this removed material would have entered the runoff, which is often not the case.

A study evaluating the effect of street sweeping on stormwater runoff quality using several paired catchments and a new generation street sweeper is currently underway in Seattle. However, the results of this study by Herrera for Seattle Public Utilities will not be available for another year. The same is true for another study planned for Olympia, Washington, which also will address street sweeping effectiveness.

Comparison of GRID and WTM

Overall Methodology

Both the GRID and WTM approaches are essentially pollutant-tracking methods that use simple percent reduction values. There are no empirical or deterministic removal equations in the model. The user inputs the estimated effectiveness. The two models differ in a number of ways, however, including how they calculate effectiveness and in their level of geographic resolution.

The WTM approach calculates pollutant reduction based on mass loading. This allows it to combine estimates of nonstructural effectiveness (mass prevented from entering the stormwater system) with estimates of structural effectiveness (percentage of mass treated and removed from the stormwater system). However, WTM cannot model the interaction of multiple structural BMPs.

The GRID model currently is only used to model the effectiveness of structural BMPs using effluent concentration to judge effectiveness. However, it has the capacity to model nonstructural BMPs using reduction in mass loadings. It deals with multiple structural BMPs by selecting the most effective BMP in terms of lowest effluent concentrations. It ignores the potential additional removal provided by the less effective BMPs.

GRID has a much higher resolution, using 100-square-foot grid cells rather than an entire watershed or drainage basin as does WTM. WTM therefore cannot break out the BMPs into specific areas of the city. This limits WTM's usefulness in identifying pollutant-generating "hotspots" in the city and targeting BMPs for these areas.

Approach for Nonstructural BMPs

A number of factors indicate that the GRID model may provide the better framework for use in Portland. Both GRID and WTM are bookkeeping models, GRID provides more resolution, and Portland already has the GRID model constructed for the city. (The effort to incorporate the required information into a separate WTM spreadsheet for each subbasin in the city would be tremendous.) WTM is also limited in the types of pollutants it tracks. It deals only with total suspended solids, phosphorus, nitrogen, and bacteria. GRID can more easily accommodate metals and other pollutants.

However, the approach currently used with GRID also has several shortcomings, one of which is the reliance on effluent concentrations. This makes calculations easier by essentially sidestepping the issue of interactions between multiple BMPs. However, it makes it more difficult to do things such as incorporate nonstructural measures, for a number of reasons, not all of them technical. One alternative is to create a matrix of BMP interactions and assign effluent concentrations to every combination that exists within the city. This would better capture the BMP interactions, but is considerably more complicated than the simple, effluent-based approach. The effluent-only methodology is based on the presumption that a lower limit exists for each type of BMP, below which the effluent concentration cannot be reduced. The effluent concentration is considered to be independent of influent concentration and of the exact configuration of the structural BMP (i.e., a pond is a pond). However, the effluent quality of a number of BMPs is highly dependent on the influent quality, as the Caltrans study (Caltrans 2004) showed. The particular configuration of the BMP is also important, as is whether the BMP is well-maintained or not. The effectiveness of these BMPs may be better judged by the mass removed or the percent reduction in concentration. In this respect, the WTM approach with discount factors better reflects reality. Applying discount factors to the effluent approach, while not impossible, is more problematic because by definition, the effluent concentration represents the irreducible, lowest concentration achievable.

One advantage to using the discount factor concept is that it allows the city to claim improvements in water quality by improving or increasing maintenance in future years. Using only an irreducible effluent limit for a BMP means there is no way to improve on that removal efficiency even if the maintenance effort is substantially increased in future years.

Selecting only the BMP that has the lowest reported effluent concentrations makes it easier to calculate effectiveness, yet also means there is no reason to use multiple BMPs, such as public education, street sweeping, catch basins, and a detention pond. The whole treatment train concept of BMPs is negated in favor of simply choosing the most effective BMP, usually the structural measure, and ignoring the others. That will almost certainly be the argument of anyone looking to keep costs for stormwater management low. The City of Portland is looking at ways to account for BMP treatment trains.

The effluent-only approach ignores other benefits that the "less-effective" BMPs provide. In the example above, the other three measures help reduce loading to the pond and are easier to implement than frequent pond cleaning. They also are more visible measures of cleaning and help build public support. For instance, catch basins are one of the least effective BMPs in terms of effluent concentration, yet they are present throughout the city. It is not possible to install detention ponds in most neighborhoods and, in aggregate, catch basins remove a large mass of sediments.

To summarize, although the GRID framework of cells and their associated attributes provides greater resolution and may even require less time to calculate, its current effluent-only methodology presents a number of problems, including incorporation of the effects of nonstructural BMPs. In this instance, the WTM approach of subtracting mass loads from preventive (nonstructural) measures and then applying a reduction factor that is tempered by "discounts" seems to work better. However, by incorporating nonstructural BMPs, allowing the use of mass load reductions, and using discount factors or similar measures, the GRID model will be able to overcome these shortcomings.

Model Recommendation

The City of Portland should use the GRID model framework, but with pollutant loads instead of effluent concentrations for nonstructural elements. To accommodate multiple BMPs, both structural and nonstructural, the city should use a matrix of potential BMP combinations and conditions to look up effectiveness values. The nonstructural BMPs would be considered source control and would provide a mass reduction "off-the-top" from the total pollutant load. The structural measures would provide treatment down to an effluent limit considered typical of that type of facility (i.e., pond, vegetated swale, or sedimentation manhole). The matrix should be based on a concept similar to WTM's discount values. This approach would blend many of the strengths and overcome some of the weaknesses of the two modeling approaches.

If the city has a strong desire to use the effluent approach for both structural and nonstructural BMPs, the lookup matrix could be configured to list effluent concentrations for selected nonstructural BMPs in addition to the structural ones. The nonstructural effluent values would need to be calculated from the mass removal rates presented in the literature, as direct measurement of effluent concentrations has not been reported for most nonstructural BMPs.

Recommended BMP Effectiveness Values and Data Gaps

Herrera and city staff met on December 12, 2005, to discuss the draft of this technical memorandum. Several decisions were made at that meeting.

The city will continue to use the GRID model framework to evaluate pollutant loading and removal rates. The GRID model provides more detail than the WTM model. It is based on the city's GIS coverage and can be easily updated as zoning or other information changes.

The city will continue to estimate the effectiveness of structural BMP controls based on effluent concentrations. The effectiveness of nonstructural controls, however, will be based on reductions in load (i.e., percent removal). This methodology is similar to that used by the WTM model. It is based on treating the nonstructural BMPs as source controls, subtracting the reduction in pollutant loads from the initial concentration. The structural BMPs are considered treatment measures whose effectiveness is based on effluent quality. It was acknowledged at the meeting that there are some problems with this approach, mainly in overlapping treatment between structural and nonstructural BMPs, but it was felt these concerns were minor since less than 5 percent of the Portland's drainage area is treated by structural BMPs.

The city, therefore, needs pollutant load reduction values for the nonstructural BMPs that can be entered into the GRID model. The city supplied additional material on previous estimates of load reductions made for Portland, as well as detailed information on data inputs for the GRID model. Herrera supplemented that information with suggested values from the WTM model and the results of previous studies to produce a spreadsheet table of nonstructural BMP effectiveness. A printout is included as Appendix A. A narrative explaining the derivation of the table numbers is included as part of the appendix.

The nonstructural BMP table is set up by land use to make incorporation into the GRID model straightforward. Each BMP section contains, as appropriate, rows with set values and formulas, rows that can be modified by the user, and rows containing calculated pollutant load reductions. Additional columns are provided so the user can modify data for future years. Subsequent pages of the spreadsheet contain information from the first page of data compiled by land use.

The spreadsheet table is essentially a simple model intended to serve as a "pre-processor" to prepare data for entry into the GRID model. A number of data gaps still exist and are indicated in the table. It is hoped that by working through the table to determine reasonable increases in city programs such as tree planting or catch basin cleaning, the city can use the spreadsheet to help determine achievable benchmarks over the course of the city's NPDES permit.

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APPENDIX A

Output from NonStructural Spreadsheet Model

modifiable rows

need addtl d

	Existing	Year 1	Year 2	Year 3	Year 4	Year 5
Single-family residential						
Lawn Care						
Description						
Fertilization Rate - Nitrogen (lbs/acre/year)	150	150	150	150	150	150
Percent of fertilizer lost to runoff and percolation - Nitrogen	25%	25%	25%	25%	25%	25%
Fertilization Rate - Phosphorus (lbs/acre/year)	15	15	15	15	15	15
Percent of fertilizer lost to runoff and percolation - Phosphorus	5%	5%	5%	5%	5%	5%
Fertilizer Reduction – due to educational program	50%	50%	50%	50%	50%	50%
Percent of residents that fertilize their lawn who over-fertilize	50%	50%	50%	50%	50%	50%
Modifiable						
Cumulative number of property owners reached	1000	1000	2000	4000	6000	8000
Lawn area per property owner (acres)	0.00574	0.00574	0.00574	0.00574	0.00574	0.00574
Willingness to change behavior	8%	8%	8%	8%	8%	8%
Pollutant Reduction						
Nitrogen load reduction (lbs/pervious acre/year)	0.750	0.750	0.750	0.750	0.750	0.750
Total nitrogen load reduction (lbs/yr)	4.3	4.3	8.6	17.2	25.8	34.4
Phosphorus Load Reduction (lbs/pervious acre/year)	0.015	0.015	0.015	0.015	0.015	0.015
Total phosphorus load reduction (lbs/yr)	0.09	0.09	0.17	0.34	0.52	0.69
Naturescaping						
TSS load reduction (mg/l)	900	900	900	900	900	900
Average lot size (sf)	5000	5000	5000	5000	5000	5000
Percent of lot with bare soil (area that can be treated)	0.05	0.05	0.05	0.05	0.05	0.05
Area that can be treated per house(sf)	250	250	250	250	250	250
P = annual precipitation depth (inches)	36	36	36	36	36	36
P_j = factor that correct for storms that produce no runoff	0.9	0.9	0.9	0.9	0.9	0.9
Rv = runoff coefficient = 0.05 + 0.009 + * I	0.50	0.50	0.50	0.50	0.50	0.50
I = percent of catchment that is impervious	50	50	50	50	50	50
C = reduction in pollutant EMC (mg/L)	900	900	900	900	900	900

POLLUTANT LOAD REDUCTION	CALCULATIONS
	0111000110110

modifiable rows

need addtl d

	Existing	Year 1	Year 2	Year 3	Year 4	Year 5
A = contributing area (acres)	0.01	0.01	0.01	0.01	0.01	0.01
L (lbs) = 0.23 * P * Pj * Rv * C * A	19	19	19	19	19	19
Modifiable						
Cumulative number of people reached through program	4071	4071	5000	6000	7000	8000
Percent of people reach who implement naturescaping	30%	30%	30%	30%	30%	30%
Pollutant Reduction						
TSS load reduction (lbs/ pervious acre/year)	5.77	5.77	5.77	5.77	5.77	5.77
Total TSS reduction (lbs/yr)	135	135	166	199	232	265
Number of people who will implement naturescaping	1221	1221	1500	1800	2100	2400
Pet Waste						
Description						
Waste Production (lbs/dog/day)	0.32	0.32	0.32	0.32	0.32	0.32
Fecal Coliform (billion colonies/lb)	10	10	10	10	10	10
Percent of pollutant delivered to stream (fecal coliform)	35%	35%	35%	35%	35%	35%
Nitrogen (lbs/lb)	0.23	0.23	0.23	0.23	0.23	0.23
Percent of pollutant delivered to stream (nitrogen)	25%	25%	25%	25%	25%	25%
Phosphorus (lbs/lb)	0.01	0.01	0.01	0.01	0.01	0.01
Percent of pollutant delivered to stream (phosphorus)	75%	75%	75%	75%	75%	75%
Conversion Factor (days/year)	365	365	365	365	365	365
Number of single family residential households with dogs	25000	25000	25000	25000	25000	25000
Percent of dog owners who walk and don't clean up after their dog	20%	20%	20%	20%	20%	20%
Modifiable						
Cumulative number of people reached through program	1000	1000	2000	2000	2000	2000
Willingness to change behavior	8%	8%	8%	8%	8%	8%
Pollutant Reduction						
Fecal Coliform Reduction (billion colonies per year)	6540.8	6540.8	13081.6	13081.6	13081.6	13081.6
Phosphorus Reduction (lbs/year)	14.016	14.016	28.032	28.032	28.032	28.032
Nitrogen Reduction (lbs/year)	107.456	107.456	214.912	214.912	214.912	214.912

POLLUTANT LOAD REDUCTION CALCULATIONS		modifiable rows				need addtl d	
	Existing	Year 1	Year 2	Year 3	Year 4	Year 5	
Downspout Disconnect - Residential							
Description							
Building footprint (square feet)	1500	1500	1500	1500	1500	1500	
Rooftop (acres)	0.034435262	0.0344353	0.0344353	0.0344353	0.0344353	0.0344353	
Total Cu (lb/impervious acre of roof)	0.11616	0.11616	0.11616	0.11616	0.11616	0.11616	
Total Pb (lb/impervious acre of roof)	0.17424	0.17424	0.17424	0.17424	0.17424	0.17424	
Total Zn (lb/impervious acre of roof)	1.21968	1.21968	1.21968	1.21968	1.21968	1.21968	
Modifiable							
Portion of roof disconnected	60%	60%	60%	60%	60%	60%	
Number of households participating	22400	22400	23000	23000	23000	23000	
Pollutant Reduction							
Total Cu (lbs/year)	53.76	53.76	55.2	55.2	55.2	55.2	
Total Pb (lbs/year)	80.64	80.64	82.8	82.8	82.8	82.8	
Total Zn (lbs/year)	564.48	564.48	579.6	579.6	579.6	579.6	
SFR TOTALS (LBS/YR)							
TSS	134.9	134.9	165.7	198.8	232.0	265.1	
ТР	14.1	14.1	28.2	28.4	28.5	28.7	
TN	111.8	111.8	223.5	232.1	240.7	249.3	
Cu	53.8	53.8	55.2	55.2	55.2	55.2	
Pb	80.6	80.6	82.8	82.8	82.8	82.8	
Zn	564.5	564.5	579.6	579.6	579.6	579.6	
Fecal Coliform Reduction (billion colonies per year)	6540.8	6540.8	13081.6	13081.6	13081.6	13081.6	

Multi-family residential

Lawn Care Description

|--|

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	Existing	Year 1	Year 2	Year 3	Year 4	Year 5
Fertilization Rate - Nitrogen (lbs/acre/year)	150	150	150	150	150	150
Percent of fertilizer lost to runoff and percolation - Nitrogen	25%	25%	25%	25%	25%	25%
Fertilization Rate - Phosphorus (lbs/acre/year)	15	15	15	15	15	15
Percent of fertilizer lost to runoff and percolation - Phosphorus	5%	5%	5%	5%	5%	5%
Fertilizer Reduction – due to educational program	50%	50%	50%	50%	50%	50%
Percent of residents that fertilize their lawn who over-fertilize	50%	50%	50%	50%	50%	50%
Modifiat	ole					
Cumulative number of property owners reached	100	100	100	100	100	100
Acres of lawn per property owner (ft2/acre)	0.02296	0.02296	0.02296	0.02296	0.02296	0.02296
Willingness to change behavior	8%	8%	8%	8%	8%	8%
Pollutant Reduction	0 n					
Nitrogen load reduction (lbs/pervious acre/year)	0.750	0.750	0.750	0.750	0.750	0.750
Total nitrogen load reduction (lbs/yr)	1.7	1.7	1.7	1.7	1.7	1.7
Phosphorus Load Reduction (lbs/pervious acre/year)	0.015	0.015	0.015	0.015	0.015	0.015
Total phosphorus load reduction (lbs/yr)	0.03	0.03	0.03	0.03	0.03	0.03
Downspout Disconnect - Multi-Family Residential						
Description						
Building footprint (square feet)	15000	15000	15000	15000	15000	15000
Rooftop (acres)	0.344352617	0.3443526	0.3443526	0.3443526	0.3443526	0.3443526
Total Cu (lb/impervious acre of roof)	0.11616	0.11616	0.11616	0.11616	0.11616	0.11616
Total Pb (lb/impervious acre of roof)	0.17424	0.17424	0.17424	0.17424	0.17424	0.17424
Total Zn (lb/impervious acre of roof)	1.21968	1.21968	1.21968	1.21968	1.21968	1.21968
Modifiat	ole					
Portion of roof disconnected	60%	60%	60%	60%	60%	60%
Number of buildings participating	100	100	100	100	100	100
Pollutant Reduction	0 n					
Total Cu (lbs/year)	2.4	2.4	2.4	2.4	2.4	2.4
Total Pb (lbs/year)	3.6	3.6	3.6	3.6	3.6	3.6
Total Zn (lbs/year)	25.2	25.2	25.2	25.2	25.2	25.2

modifiable rows

need addtl d

	Existing	Year 1	Year 2	Year 3	Year 4	Year 5
MFR TOTALS (LBS/YR)						
TSS						
TP	0.03	0.03	0.03	0.03	0.03	0.03
TN	1.72	1.72	1.72	1.72	1.72	1.72
Cu	2.40	2.40	2.40	2.40	2.40	2.40
Pb	3.60	3.60	3.60	3.60	3.60	3.60
Zn	25.20	25.20	25.20	25.20	25.20	25.20
Fecal Coliform Reduction (billion colonies per year)						

Transportation

Street Sweeping

Residential						
Frequency (times per year)	б	6	6	6	12	12
lane miles swept	10000	10000	10000	10000	10000	10000
acres per lane mile	1.21	1.21	1.21	1.21	1.21	1.21
TSS removal (lbs/acre/year) - see notes on Trans page	20.9	20.9	20.9	20.9	29	29
TSS removal (lbs/lane mile/yr)	25.33	25.33	25.33	25.33	35.15	35.15
Pollutant removal	l					
TSS removal (lbs/year)	253333	253333	253333	253333	351515	351515
TP removal (lbs/year)	538	538	538	538	747	747
Cu removal (lbs/year)	34	34	34	34	47	47
Pb removal (lbs/year)	73	73	73	73	101	101
Zn removal (lbs/year)	101	101	101	101	140	140
Industrial						
Frequency (times per year)	6	6	23	23	23	23
lane miles swept	5000	5000	5000	5000	5000	5000
acres per lane mile	1.21	1.21	1.21	1.21	1.21	1.21

	modifiable rows

need addtl d

	Existing	Voor 1	Voor 2	Voor 3	Voor 1	Voor 5
TCC removed (lbc/core/veer) and refer on T_{result} in sec.	51.7	1 car 1 51 7	112 A	112 A	112 A	112 A
TSS removal (lbs/acre/year) - see noies on Trans page	51.7	31.7	112.4	112.4	112.4	112.4
Dollutont removal (IDS/Iane mile/yr)	02.07	02.07	130.24	130.24	130.24	130.24
	212222	212222	(01010	(91010	(91010	(01010
TSS removal (Ibs/year)	313333	313333	081212	081212	081212	081212
P removal (Ibs/year)	666	666	1448	1448	1448	1448
Cu removal (lbs/year)	42	42	92	92	92	92
Pb removal (lbs/year)	90	90	196	196	196	196
Zn removal (Ibs/year)	125	125	272	272	272	272
Commercial						
Frequency (times per year)	49	49	49	49	49	49
lane miles swept	10000	10000	10000	10000	10000	10000
acres per lane mile	1.21	1.21	1.21	1.21	1.21	1.21
TSS removal (lbs/acre/year) - see notes on Trans page	128.6	128.6	128.6	128.6	128.6	128.6
TSS removal (lbs/lane mile/yr)	155.88	155.88	155.88	155.88	155.88	155.88
Pollutant removal						
TSS removal (lbs/year)	1558788	1558788	1558788	1558788	1558788	1558788
TP removal (lbs/year)	3312	3312	3312	3312	3312	3312
Cu removal (lbs/year)	210	210	210	210	210	210
Pb removal (lbs/year)	449	449	449	449	449	449
Zn removal (lbs/year)	622	622	622	622	622	622
Catch Basin Cleaning						
Average frequency (vr)	0.01000	0.01000	0.10000	0.10000	0.10000	0.10000
Number of catch basins in city	50000	50000	50000	50000	50000	50000
Amount of sediment removed per catch basin (lbs)	35	35	35	35	35	35
Sediment Load Reduction (lbs/year/CB)	0.35	0.35	3.5	3.5	3.5	3.5
Phosphorus Load Reduction (lbs/year/CB)	0.0003003	0.0003003	0.0030030	0.0030030	0.0030030	0.0030030
Cu Load Reduction (lbs/year/CB)	0.0000117	0.0000117	0.0001166	0.0001166	0.0001166	0.0001166
Pb Load Reduction (lbs/year/CB)	0.0000420	0.0000420	0.0004200	0.0004200	0.0004200	0.0004200
Zn Load Reduction (lbs/year/CB)	0.0000644	0.0000644	0.0006440	0.0006440	0.0006440	0.0006440

5

need addtl d

		Existing	Year 1	Year 2	Year 3	Year 4	Year 5
Pollu	itant removal						
TSS removal (lbs/year)		17500	17500	175000	175000	175000	175000
TP removal (lbs/year)		15.015	15.015	150.15	150.15	150.15	150.15
Cu removal (lbs/year)		0.58275	0.58275	5.8275	5.8275	5.8275	5.8275
Pb removal (lbs/year)		2.1	2.1	21	21	21	21
Zn removal (lbs/year)		3.22	3.22	32.2	32.2	32.2	32.2
Maintenance and cleaning of MS4 components							
Sumps and manholes cleaned		922	922	922	922	922	922
Feet of culvert cleaned		21232	21232	21232	21232	21232	21232
Feet of ditch cleaned		11727	11727	11727	11727	11727	11727
Ditch (cubic feet of sediment removed)		11727	11727	11727	11727	11727	11727
TSS removed (lbs/yr)		1289970	1289970	1289970	1289970	1289970	1289970
TP removal (lbs/year)		1107	1107	1107	1107	1107	1107
Cu removal (lbs/year)		43	43	43	43	43	43
Pb removal (lbs/year)		155	155	155	155	155	155
Zn removal (lbs/year)		237	237	237	237	237	237
Tree planting along transportation corridors							
Mature tree diameter		30	30	30	30	30	30
Area covered by tree canopy (ft2)		707	707	707	707	707	707
Percent of area that is impervious		50%	50%	50%	50%	50%	50%
Potential impervious area disconnected (acres)		0.008	0.008	0.008	0.008	0.008	0.008
Deciduous interception efficiency		10%	10%	10%	10%	10%	10%
	Modifiable						
Cumulative number of trees planted		5000	5500	6000	6500	7000	7500
Polluta	int Reduction						
Total area effectively disconnected (acres) TSS removal (lbs/year)		4.06	4.46	4.87	5.27	5.68	6.09

TRANSPORTATION TOTALS (LBS/YR)

		n	nodifiable rows		
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need addtl d

	Existing	Year 1	Year 2	Year 3	Year 4	Year 5
TSS	2142955	2142955	2668333	2668333	2766515	2766515
TP	4532	4532	5448	5448	5657	5657
TN						
Cu	288	288	342	342	356	356
Pb	614	614	739	739	767	767
Zn	851	851	1027	1027	1066	1066
Fecal Coliform Reduction (billion colonies per year)						
<u>City Wide Measures</u>						
Erosion from construction sites						
Pre-construction inspections	3660	3660	3660	3660	3660	3660
Interim compliance inspection (during construction)	657	657	657	657	657	657
Permanent erosion control measure inspections (building final)	3539	3539	3539	3539	3539	3539
Final erosion control inspection (5 months after building final)	2489	2489	2489	2489	2489	2489
Effectiveness of soil and erosion control	70%	70%	70%	70%	70%	70%
Fraction of building permits regulated	100%	100%	100%	100%	100%	100%
Fraction of practices installed	70%	70%	70%	70%	70%	70%
Fraction installed/maintained properly	60%	60%	60%	60%	60%	60%
TSS load without erosion control						
Pollutant Reduction						
TSS load reduction (lbs/yr)	0	0	0	0	0	0
New developments and redevelopments						
Illicit discharge						
Number of illicit discharges removed per acre inspected	0.05	0.05	0.05	0.05	0.05	0.05
Spill response program						

POLLUTANT LOAD REDUCTION CALCULATIONS		modifiable rows			need addtl d		
	Existing	Year 1	Year 2	Year 3	Year 4	Year 5	
CITY WIDE MEASURES TOTALS (LBS/YR)							
TSS							
TP							
TN							
Cu							
Pb							
Zn							
Fecal Coliform Reduction (billion colonies per year)							

Commercial

Education for businesses (P2 program)

Total number of businesses (per year)	25	25	25	25	25	25
Percent of businesses that implemented practices due to the program	10%	10%	10%	10%	10%	10%
Number of business involved	2.5	2.5	2.5	2.5	2.5	2.5
Standard number of acres per site	3.5	3.5	3.5	3.5	3.5	3.5
Total acres of land program applied to	8.75	8.75	8.75	8.75	8.75	8.75
TSS load reduction (lbs/yr)	750	750	750	750	750	750
Heavy Metals load reduction (lbs/yr)	2.68	2.68	2.68	2.68	2.68	2.68
Phosphorus load reduction (lbs/yr)	2.46	2.46	2.46	2.46	2.46	2.46
COMMERCIAL MEASURES TOTALS (LBS/YR)						
TSS	750	750	750	750	750	750
TP	2.46	2.46	2.46	2.46	2.46	2.46

- TN
- Cu Pb

Zn

Fecal Coliform Reduction (billion colonies per year)

POLLUTANT LOAD REDUCTION CALCULATIONS modifiable rows need addtl d Existing Year 1 Year 2 Year 3 Year 4 Year 5 Industrial **Industrial Permitting** Number of sites inspected 143 143 143 143 143 143 Acres per site 3.5 3.5 3.5 3.5 3.5 3.5 500.5 Total acres inspected 500.5 500.5 500.5 500.5 500.5 TSS (lb/ac/yr) load reduction 61 61 61 61 61 61 Cu (lb/ac/yr) load reduction 0.2 0.2 0.2 0.2 0.2 0.2 Pb (lb/ac/yr) load reduction 0.26 0.26 0.26 0.26 0.26 0.26 Zn (lb/ac/yr) load reduction 0.36 0.36 0.36 0.36 0.36 0.36 TSS reduction (lbs/yr) 30530.5 30530.5 30530.5 30530.5 30530.5 30530.5 Cu reduction (lbs/yr) 100.1 100.1 100.1 100.1 100.1 100.1 Pb reduction (lbs/yr) 130.13 130.13 130.13 130.13 130.13 130.13 Zn reduction (lbs/yr) 180.18 180.18 180.18 180.18 180.18 180.18 **INDUSTRIAL MEASURES TOTALS (LBS/YR)** TSS 30530.5 30530.5 30530.5 30530.5 30530.5 30530.5 TP TN Cu 100.1 100.1 100.1 100.1 100.1 100.1 Pb 130.13 130.13 130.13 130.13 130.13 130.13 Zn 180.18 180.18 180.18 180.18 180.18 180.18

Fecal Coliform Reduction (billion colonies per year)

Parks and Public Facilities

Fertilizer reduction Description Fertilization Rate - **Nitrogen** (lbs/acre/year)

DLLUTANT LOAD REDUCTION CALCULATIONS		modifiable rows			need addtl d		
	Existing	Year 1	Year 2	Year 3	Year 4	Year 5	
Percent of fertilizer lost to runoff and percolation - Nitrogen	25%	25%	25%	25%	25%	25%	
Fertilization Rate - Phosphorus (lbs/acre/year)							
Percent of fertilizer lost to runoff and percolation - Phosphorus	5%	5%	5%	5%	5%	5%	
Fertilizer Reduction – due to educational program							
Park area (acres)							
Percent of park area that program is going to be applied to							
Pollutant Reduction							
Nitrogen load reduction (lbs/year)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Phosphorus load reduction (lbs/year)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Pesticide reduction							
Description							
Pesticide Application Rate - (lbs/acre/year)							
Percent of pesticide lost to runoff and percolation							
Pesticide Reduction							
Park area (acres)							
Percent of park area that program is going to be applied to							
Pollutant Reduction							
Pesticide Load Reduction (lbs/year)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Tree planting (watershed revegetation plan)							
Number of trees planted	99655	99655	105000	110000	115000	120000	
Linear feet of streambank	11353	11353	11353	11353	11353	11353	
Acres	80.5	80.53	84.85	88.89	92.93	96.97	
Rainfall (inches/year)	36	36	36	36	36	36	
CN before planting	74	74	74	74	74	74	
CN after planting	62	62	62	62	62	62	
Flow Reduction							
Reduced runoff (acre-inches)	2555	2556	2694	2824	2954	3083	
Reduced ruoff (acre-feet)	212.9	213.0	224.5	235.3	246.1	256.9	

POLLUTANT LOAD REDUCTION CALCULATIONS	FLOAD REDUCTION CALCULATIONS		modifiable i	need addtl d		
	Existing	Year 1	Year 2	Year 3	Year 4	Year 5
Education for City Employees						
Green Roofs						
PARKS AND PUBLIC FACILITY TOTALS (LBS/YR)						
TSS						
TP	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TN	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Cu						
Pb						
Zn						
Fecal Coliform Reduction (billion colonies per year)						

Non-Structural BMP Pollutant Reductions	Existing	Year 1	Year 2	Year 3	Year 4	Year 5
Portland Total (per year)						
TSS (lbs)	2174370	2174370	2699780	2699813	2798028	2798061
TP (lbs)	4548	4548	5479	5479	5688	5688
TN (lbs)	113	113	225	234	242	251
Cu (lbs)	444	444	500	500	513	513
Pb (lbs)	829	829	956	956	984	984
Zn (lbs)	1621	1621	1812	1812	1851	1851
Fecal Coliform Reduction (billion colonies)	6541	6541	13082	13082	13082	13082
Single-family residential subtotal (per year)						
TSS (lbs)	134.90	134.90	165.68	198.82	231.96	265.09
TP (lbs)	14.10	14.10	28.20	28.38	28.55	28.72
TN (lbs)	111.76	111.76	223.52	232.13	240.74	249.35
Cu (lbs)	53.76	53.76	55.2	55.2	55.2	55.2
Pb (lbs)	80.64	80.64	82.8	82.8	82.8	82.8
Zn (lbs)	564.48	564.48	579.6	579.6	579.6	579.6
Fecal Coliform Reduction (billion colonies)	6540.8	6540.8	13081.6	13081.6	13081.6	13081.6
Multi-family residential subtotal (per year)						
TSS (lbs)	0.00	0.00	0.00	0.00	0.00	0.00
TP (lbs)	0.03	0.03	0.03	0.03	0.03	0.03
TN (lbs)	1.72	1.72	1.72	1.72	1.72	1.72
Cu (lbs)	2.40	2.40	2.40	2.40	2.40	2.40
Pb (lbs)	3.60	3.60	3.60	3.60	3.60	3.60
Zn (lbs)	25.20	25.20	25.20	25.20	25.20	25.20
Fecal Coliform Reduction (billion colonies)	0.00	0.00	0.00	0.00	0.00	0.00

Appendix A - Output from Non-Structural Spreadsheet Model

Non-Structural BMP Pollutant Reductions	Existing	Year 1	Year 2	Year 3	Year 4	Year 5
Transportation subtotal (per year)						
TSS (lbs)	2142955	2142955	2668333	2668333	2766515	2766515
TP (lbs)	4532	4532	5448	5448	5657	5657
TN (lbs)	0	0	0	0	0	0
Cu (lbs)	288	288	342	342	356	356
Pb (lbs)	614	614	739	739	767	767
Zn (lbs)	851	851	1027	1027	1066	1066
Fecal Coliform Reduction (billion colonies)	0	0	0	0	0	0
City Wide subtotal (per year)						
TSS (lbs)	0	0	0	0	0	0
TP (lbs)	0	0	0	0	0	0
TN (lbs)	0	0	0	0	0	0
Cu (lbs)	0	0	0	0	0	0
Pb (lbs)	0	0	0	0	0	0
Zn (lbs)	0	0	0	0	0	0
Fecal Coliform Reduction (billion colonies)	0	0	0	0	0	0
Commercial subtotal (per year)						
TSS (lbs)	750	750	750	750	750	750
TP (lbs)	2	2	2	2	2	2
TN (lbs)	0	0	0	0	0	0
Cu (lbs)	0	0	0	0	0	0
Pb (lbs)	0	0	0	0	0	0
Zn (lbs)	0	0	0	0	0	0
Fecal Coliform Reduction (billion colonies)	0	0	0	0	0	0

Appendix A - Output from Non-Structural Spreadsheet Model

Non-Structural BMP Pollutant Reductions	Existing	Year 1	Year 2	Year 3	Year 4	Year 5
Industrial subtotal (per year)						
TSS (lbs)	30530.5	30530.5	30530.5	30530.5	30530.5	30530.5
TP (lbs)	0	0	0	0	0	0
TN (lbs)	0	0	0	0	0	0
Cu (lbs)	100.1	100.1	100.1	100.1	100.1	100.1
Pb (lbs)	130.13	130.13	130.13	130.13	130.13	130.13
Zn (lbs)	180.18	180.18	180.18	180.18	180.18	180.18
Fecal Coliform Reduction (billion colonies)	0	0	0	0	0	0
Parks/Public Facilities subtotal (per year)						
TSS (lbs)	0	0	0	0	0	0
TP (lbs)	0	0	0	0	0	0
TN (lbs)	0	0	0	0	0	0
Cu (lbs)	0	0	0	0	0	0
Pb (lbs)	0	0	0	0	0	0
Zn (lbs)	0	0	0	0	0	0
Fecal Coliform Reduction (billion colonies)	0	0	0	0	0	0

Appendix A - Output from Non-Structural Spreadsheet Model