Title

Effectiveness of stormwater best management practices along the Southeast Expressway, Boston, Massachusetts

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Publication Date

2001-09-24

EFFECTIVENESS OF STORMWATER BEST MANAGEMENT PRACTICES ALONG THE SOUTHEAST EXPRESSWAY, BOSTON, MASSACHUSETTS

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Abstract: Suspended particulate matter transported from roadway surfaces represents one of the most substantial sources of non-point source pollution in highway runoff. In addition to increasing turbidity and depositional loading, suspended sediment can retain and transport other pollutants to receiving water bodies. Roadway suspended solid loads may be reduced by using Best Management Practices (BMPs) for stormwater. Non-structural BMPs involve the removal of particulate matter from roadway surfaces prior to runoff transport (e.g., street sweeping), whereas various structural BMPs involve end-of-pipe devices that remove suspended solids prior to discharge to receiving waters. Two types of structural BMPs, a deep-sumped hooded catch basin and three 1500-gallon offline water quality inlets (WQIs), were investigated to assess their effectiveness in reducing highway contaminant concentrations along the Southeast Expressway in Boston, Massachusetts. Automatic monitoring techniques were used to characterize the temporal and spatial variability in suspended sediment transport through each structural BMP. The effectiveness of each BMP in reducing suspended sediment loads was assessed using a mass balance approach. The suspended sediment removal efficiency for the catch basin and two 1500-gallon WQIs was 39, 35, and 28 percent, respectively. The particle size distribution of the suspended sediment entering the structural BMPs indicated more than half of the suspended sediment in highway runoff was material less than .062 millimeters (mm) in diameter (sand/silt break). However, particle-size analysis of retained bottom sediment from three WQIs at the conclusion of the study indicated that an average of 74 percent of retained sediment particles were greater than .062 mm in diameter. About 92 percent of the material found in the deep-sumped hooded catch basins was comprised of these larger particles. The primary factor controlling the suspended sediment removal efficiency of each structural BMP was residence time. For example, the average removal efficiency of the WQIs during storms with rainfall depths less than 0.2 inches was 43 percent. This increased efficiency was a function of residence time rather than from “active” stormwater treatment. Flows from small storms simply displaced previously collected stormwater in which the suspended sediments had time to settle during the static antecedent period. The capture efficiency of suspended sediment was further reduced by re-suspension of fine-grained sediments within the WQIs, as well as from high flows bypassing the WQIs. Re-suspension also occurred within the catch basin. Moreover, collection of floatable debris at the outlet of a WQI suggests that floatable debris also was not indefinitely retained by either structural BMP. Due to the exorbitant costs of more frequent clean-up efforts (e.g., street sweeping, and clean-out of catch basins and WQIs) or more WQIs along the Southeast Expressway, source control measures are the most practicable means of reducing Suspended Sediment Concentration (SSC) loading from the highway. Future research includes developing a model that estimates contaminant loading from highway runoff, and evaluating conventional as well as innovative WQIs with real-time, flow-weighted sampling to assess whether their performance justifies their widespread use, especially along roadways.

Introduction

Suspended particulate matter transported from roadway surfaces represents one of the most substantial sources of non-point source pollution in highway runoff (Young and others 1996). In addition to increasing turbidity and depositional loading, suspended sediment can retain and transport other pollutants to receiving water bodies.

A common Best Management Practice (BMP) used by state highway agencies to reduce the impacts of stormwater runoff is to divert runoff collected from highway surfaces to detention basins or water quality swales where suspended sediments are captured and allowed to settle out. However, where highways cross through urbanized areas, the necessary space for such structural BMPs is seldom available. As a consequence, industry has created various types of structural BMPs, commonly called water quality inlets that can be installed underground and integrated within the existing drainage system. These devices are generally set off-line, contain two or three serial chambers designed to settle grit, and in theory capture oil and grease. The effectiveness of these BMPs is limited by the site-specific particle size distribution and quantity of the source material.

The U.S. Geological Survey, in cooperation with the Massachusetts Highway Department (MassHighway), began a study in November 1998 to determine the effectiveness of current BMPs in reducing suspended solid loads along the Southeast Expressway (Interstate Route 93) in Boston, Massachusetts. The Southeast Expressway, typical of heavily used highways within urban and industrialized areas, runs through the coastal zone watershed of Dorchester Bay in South Boston. During 1994, in an effort to remove contaminants from the highway runoff, five offline WQIs were integrated into the drainage system of the Expressway which runs adjacent to Dorchester Bay, as well as to two public beaches: Malibu and Tenean.

The BMPs examined in this study include a single, deep-sumped, hooded catch basin and three 1500-gallon offline WQIs. The effectiveness of each structural BMP was estimated by monitoring the water quality and quantity of stormwater at the inlet and the outlet of each device. At the end of the monitoring period, each device was drained and the captured material was measured and quantified. The monitoring results provide State and municipal highway planners with specific information regarding the current quality and quantity of highway runoff from major urban highways and the scientific basis for future consideration and application of these BMPs. Monitoring methods developed during this study also may be useful for evaluating the effectiveness of new BMPs.

Objectives

The purpose of this report is to describe the following: effectiveness of each structural BMP along the Southeast Expressway in reducing SSC loads and debris loads; document the monitoring methods used to evaluate each BMP; and estimate SSC loads from the highway within the Study area.

Study Area

The study area includes about 2 miles of the Southeast Expressway from the Neponset River to Savin Hill in South Boston (see figure 1). The highway section (including ramps) within the study area represents about .06 percent (34.6 acres) of the total watershed (approximately 58,000 acres) of Dorchester Bay.

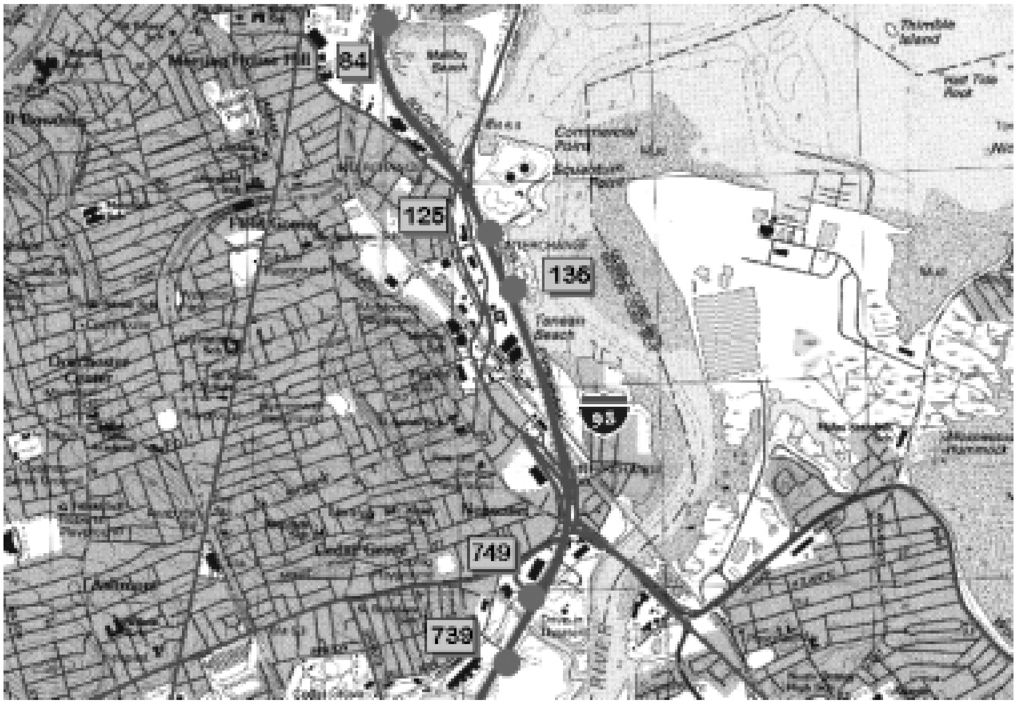

Fig. 1. Map of study area

Primary treatment for highway stormwater runoff was provided by 209 catch basins containing hinged cast-iron hoods over the outlet, 184 had 4-ft deep sumps (i.e., “grit” storage below the outlet pipe), and the remaining 25 had 3-ft sumps. The purpose of the catch basin hoods is to retain floatable debris at the water’s surface. The hoods encapsulate the entire outlet opening and extend down to about 0.5 ft below the bottom of the outlet pipe.

One three-chambered 4500-gallon offline WQI and four two-chambered 1500-gallon offline WQIs provided additional stormwater treatment. WQIs are large cast-concrete containers, sub-divided by one or more baffles, and buried beneath the land surface next to the highway. Each WQI included a bypass pipe that limited the amount of flow through the device using a diversion weir positioned near the inlet of the WQI. Although this design feature allows untreated stormwater to bypass the WQI, it theoretically prevents extreme flows from flushing (re-suspending) captured materials from the WQI. The stormwater "treatment train" of the catch basins to the WQI to the outfall pipe is depicted in figure 2.

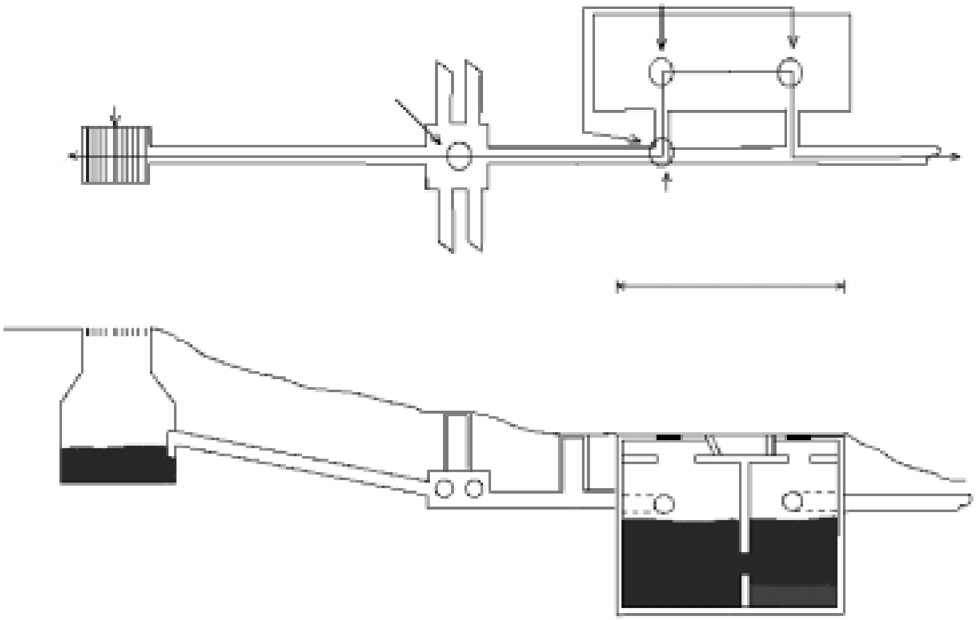

Fig. 2. Diagram of the stormwater "treatment train" of the catch basin.

Methods

Automatic monitoring techniques were used to characterize the temporal and spatial variability in suspended sediment transport through each structural BMP. Water-quality samples of Suspended Sediment Concentration (SSC) and continuous measurements of BMP water level and velocity (as well as site precipitation, site air temperature, specific conductance, and water temperature) were collected from April 1999 through June 2000 for the deep-sumped hooded catch basin and the 1500-gallon WQI at Station 136, and from August 1999 through June 2000 for the 1500-gallon WQI at Station 739 (see Figure 1 for WQI locations). These two WQIs received flow from 8 and 12 catch basins, respectively. During rainfall events highway runoff was collected flow-proportionally at the inlet and outlet of each structural BMP by automatic samplers under data logger control.

Solid phase concentration values in water may be determined by the Suspended Sediment Concentration (SSC) or the Total Suspended Solids (TSS) method. Although SSC and TSS are often used interchangeably in the literature to describe the total concentration of suspended solid-phase material, the analytical methods differ and can produce substantially different results (Bent and others 2000). The SSC method (American Society for Testing and Materials 2000) uses standardized procedures and equipment to measure all of the sediment and the net weight of the water-sediment mixture to calculate concentration, whereas the TSS method (American Public Health Association, American Water Works Association, and Water Pollution Control Federation 1995) requires analysis of a sub-sample extracted from the original sample. Contrary to the literal description, SSC include clays, silts, sands, gravels, asphalt particles and other road surface debris, and organic and synthetic materials. Although analytical uncertainties for each method are similar, errors that occur during processing of TSS samples can be large because agitation of a sample containing sand-size materials generally does not produce representative aliquots and can under-represent the true sediment concentration (Gray and others 2000). Therefore, the SSC method was chosen to measure the solid-phase concentrations to provide the most accurate assessment of BMP efficiencies. Samples were analyzed for SSC and particle size at the USGS Kentucky District Sediment Lab (Guy 1970; Sholar and Shreve 1998).

A total of 74 and 59 events produced measurable runoff during the monitoring period at Stations 136 and 739, respectively. SSC samples were collected at the inlets and outlets of the two WQIs and the catch basin during 53, 49, and 32 storms, respectively. Any lack of sampling was due to equipment malfunctions or shallow water depths from very small flows (i.e., light rainstorms). Nonetheless, the relatively high number of sampled storms has generated stormwater data with good statistical confidence.

Sampler intakes were fixed to static mixers at each sampling point with the exception of the catch basin inflow sampler, which was connected to a stormwater collection structure mounted below the trash bars of the catch basin. Sampler intakes were orientated in a horizontal and downstream direction (as depicted in figure 3). This configuration minimized debris accumulation by forming a small eddy at the intake, which envelops the sand particles and thus allows the sampler to collect a more representative sample of the coarse particle load (Edwards and Glysson 1999). The static mixer provided a secure and consistent mount for the sampler intake, reduced transport velocity, and provided agitation to produce a sample that represented the average SSC.

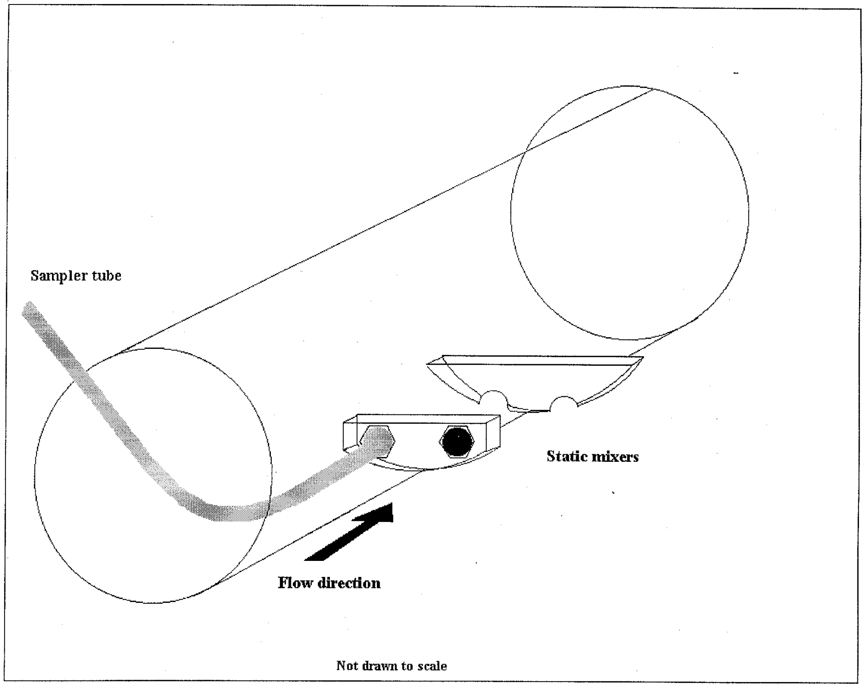

Fig. 3. Schematic diagram of a static mixer

Bottom sediment samples were collected from three WQIs (at Stations 136, 739, and 749) in November 1998, and December 1999 through January 2000. Bottom material depths were measured in each structural BMP prior to the first scheduled cleaning, during bottom material sample collection, and at the conclusion of the monitoring period. These samples were collected in the deep-sumped hooded catch basin and each chamber of the WQIs. Bottom sediment samples were wet-sieved into size classes less than .062 mm in diameter, between .062 mm and 2.00 mm in diameter, and greater than 2.00 mm in diameter.

Quality control procedures for the USGS Kentucky District Sediment Laboratory are described in Sholar and Shreve (1998). Quality control data indicated that most data were within the accumulative uncertainties of the various measurement, sampling, and analytical processes. However, the data indicated that particles greater than .062 mm in diameter were not evenly distributed throughout the water column at the inlet of the WQIs. Therefore, in order to avoid overestimating inlet loads, an adjustment equation was developed that normalized the mean SSC within the water column at the sample intake location of the WQIs.

Findings

BMP Treatment Efficiency

The overall monitoring period efficiency for the deep-sump hooded catch basin was about 39 percent. An estimated 234 Kg of solids was retained by the catch basin. There was no substantial difference between the catch basin outlet suspended sediment load, several weeks before and after annual catch basin cleaning. This finding indicated that the volumes of retained bottom material in the catch basins located within the drainage areas of Station 136 and 739 were not sufficient to substantially impact catch basin performance.

The overall monitoring period efficiency for the WQIs at Station 136 and 739 was 35 and 28 percent, respectively. The WQIs retained 477 Kg and 190 Kg of solids, respectively. In the combined treatment system in this study, where catch basins provide primary suspended sediment treatment, the WQIs reduced the initial pavement SSC by about an additional 19 percent (assuming an average catch basin efficiency of 39 percent). The efficiency computed using the measured quantity of material retained at the conclusion of the monitoring period and the total outflow load was 32 and 24 percent, respectively. The small difference between the two methods used to estimate the efficiency of the WQIs suggests that the adjustment equation used to normalize the inflow loads was reasonable. The estimated mass balance difference was within the accumulative uncertainties of the various measurement processes.

Discrete inlet suspended sediment sample concentrations for the WQIs and the deep-sumped hooded catch basin ranged from 8.5 to 7,110 mg/L and 32 and to 13,600 mg/L, respectively. Discrete outlet SSCs ranged from 5 to 2,170 mg/L and 26 to 7,030 mg/L, respectively. The median suspended sediment inlet and outlet Event Mean Concentrations (EMCs) for the WQIs at Stations 136 and 739 were estimated to be 333 and 150, and 145 and 96 mg/L, respectively. The lower suspended sediment EMCs at Station 739 was likely a function of a greater portion of the drainage perimeter being isolated from the earth shoulder resulting in less erosion onto the pavement. The median suspended sediment inlet and outlet EMCs for the deep-sumped hooded catch basin was estimated to be 280 and 195 mg/L, respectively.

Particle Size Distribution

During this study, the structural BMPs only were able to capture relatively coarse-grained particles. For example, more than 90 percent of the particles in typical WQI outlet samples were less than .062 mm in diameter. However, the particle size distribution of bottom sediments varied substantially between the deep-sumped hooded catch basin and three offline WQIs (see figure 4). Bottom sediments in the catch basin were coarse-grained (using weighted averages, about 83 and 92 percent was greater than 0.25 and .062 mm in diameter, respectively), whereas the sediment in WQIs was generally finer-grained (about 50 and 85 percent was greater than 0.25 and .062 mm, respectively). The primary chamber of the WQIs contained higher concentrations of coarse material (about 89 percent was greater than .062 mm), while finer and less dense particles were found in the second chamber (about 60 percent was greater than .062 mm), which suggests that particles in the smaller size range located in chamber one were re-suspended during flow events. However, it is unlikely that particles less than .062 mm in diameter were deposited during flowing conditions because it can take an hour to several days for particles in this size class to settle under static conditions. Thus, the occurrence of bottom material in this particle range was likely a result of static particle settling that occurred subsequent to each storm.

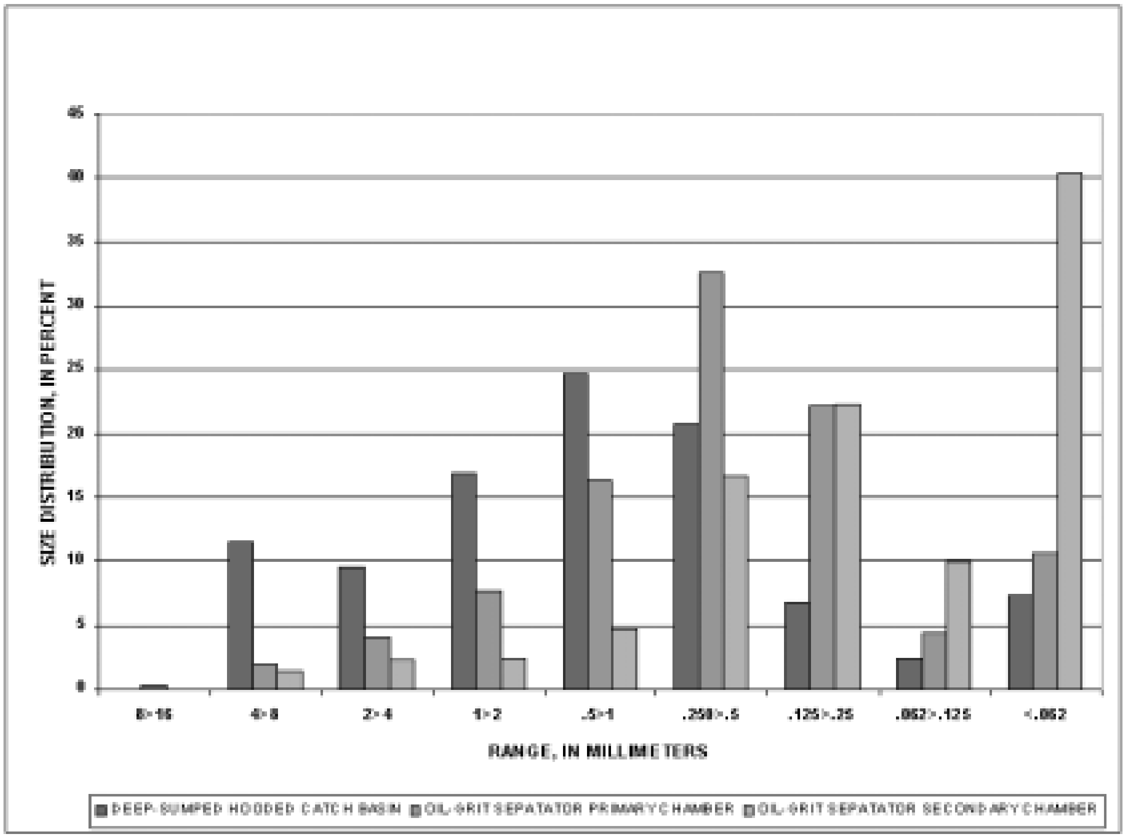

Fig. 4. Weighted average particle size distribution of bottom sediment

Figure 5 depicts the median (and variability) ranges of the suspended sediment fraction greater than .062 mm in diameter, from the inlet and outlet samples of each structural BMP. Based on 17 samples taken during six storms, generally 80 percent of the suspended sediment in highway runoff (i.e., catch basin inlet flow) consisted of material less than .062 mm. This is consistent with the findings of other studies. Yousef and others (1991) reported 70 to 80 percent of the particles in highway runoff were less than .088 mm in diameter. Prych and Ebbert (1986) noted most of the suspended material was less than .062 mm in diameter for many urban runoff conditions.

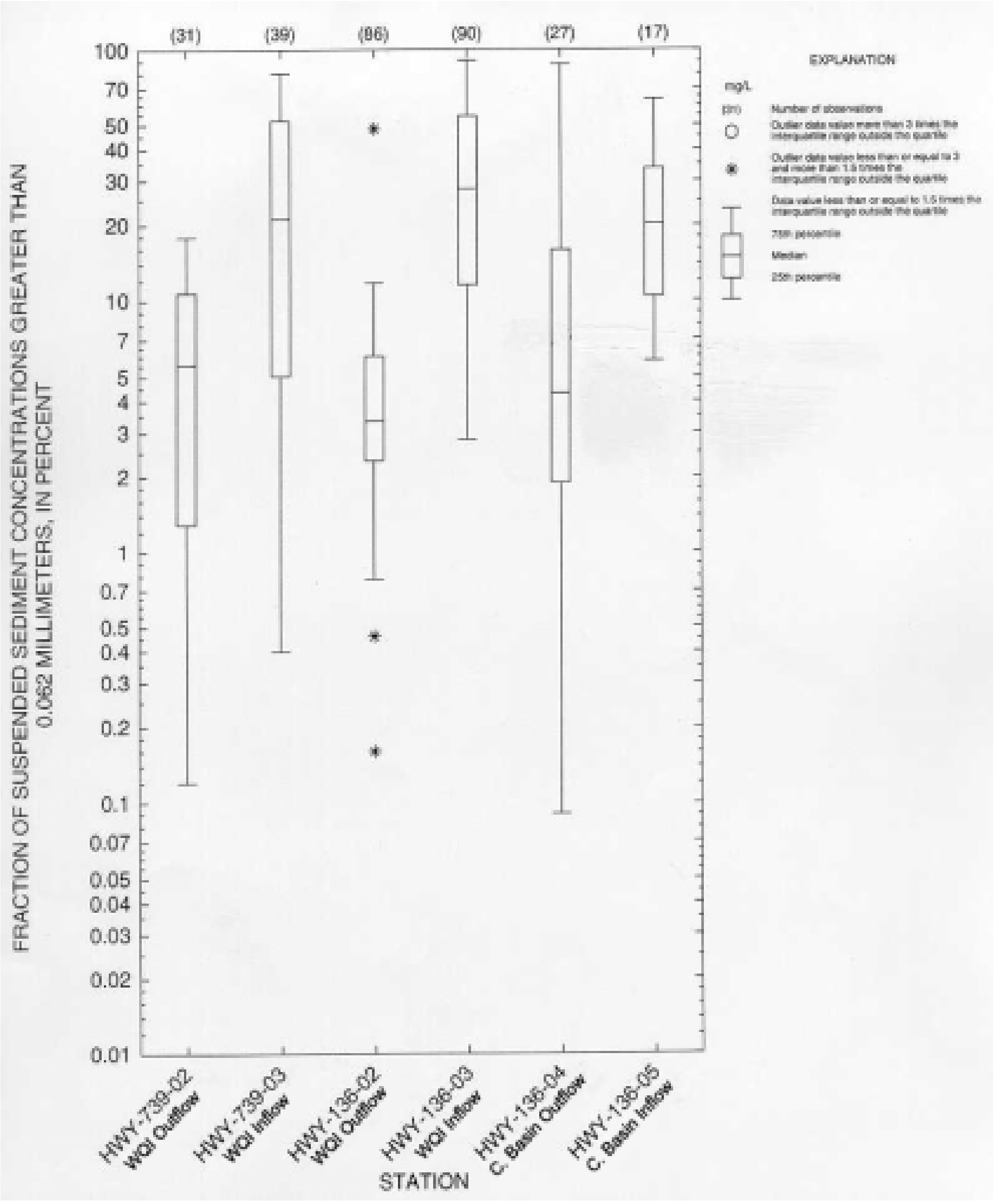

Fig. 5. Particle size distribution of suspended sediment samples

In this combined system, the deep-sumped hooded catch basin and offline WQI efficiencies were inversely related. Catch basin SSC removal efficiency decreased with an increase in discharge (i.e., flow) resulting from a decreased settling time. Conversely, the WQI performance improved with an increase in discharge despite a decrease in residence time. This was due, in part, to a change in the particle size distribution during periods of greater flows. During low flow, larger particulate matter settled in the catch basins while the finer material exited to the WQI. While the 1500-gallon WQI volume was greater than that of a single catch basin, the combined flow from multiple catch basins discharged to each WQI thereby reducing the settling time and inhibiting the capture of fine material. However, as flow increased, roadway suspended sediment and particle size tended to increase as coarse material was discharged from the catch basin, subsequently increasing the WQI performance.

Residence Time

The primary factor controlling the suspended sediment removal efficiency of each structural BMP was residence time. Intense flows also affected the efficiency, but to a lesser extent. The ability of the WQIs to reduce suspended sediment, characteristic of what is found along the Southeast Expressway was limited because the average particle size was less than .062 mm in diameter and the average structural BMP residence time ranged from about one hour to less than a minute. Although the 1500-gallon WQI volume was greater than that of a single catch basin sump (approximately 67 gallons), combined flows from multiple catch basins fed each WQI increasing flow and reducing settling time thereby inhibiting capture of fine material. This point is illustrated in Figure 6. Since settling velocities for urban and highway sediments can range from .03 to 65 feet per hour (Dorman and others 1996), then fine sediment particles require several days under static conditions to completely settle out.

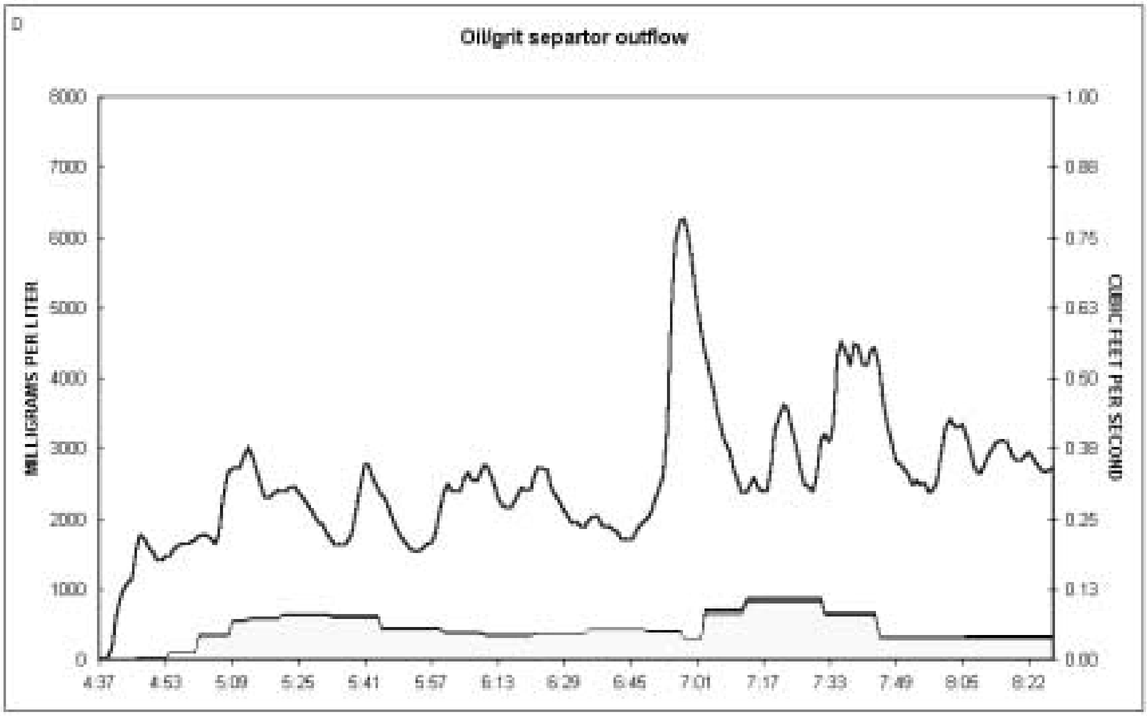

Fig. 6. Suspended sediment concentration and associated particle size

This effect of settling time becomes clear when examining the data. For example, the average removal efficiency of the WQIs during storms with less than 0.2 inches was 43 percent. This increase in efficiency is a function of residence time and not a function of active treatment of the stormwater. Flows from small storms displaced previously collected stormwater where the suspended sediments were reduced from settling during the static antecedent period. Consequently, the average event efficiency ranged from about 32 to 81 percent when the same storms were sorted according to the antecedent period ranging from less than a day to nearly six days (see Figure 7). During this study, the median antecedent dry period was about 4.5 days.

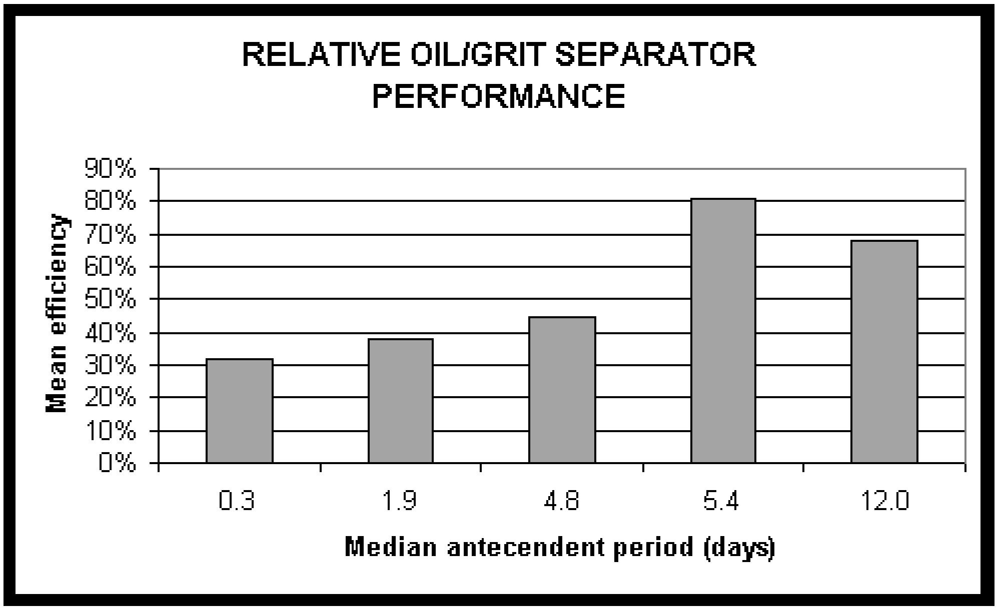

Fig. 7. The relation of antecedent dry period to precipitation events

Storm characteristics also influenced treatment efficiency by affecting the hydraulic detention time, catch basin turbulence, and the mobilization of roadway suspended sediment. The average catch basin residence time was about one hour, however, residence times as low as 37 seconds occurred during brief periods of peak flow. The catch basin lacked sufficient residence time, even during flows as low as .03 cfs, to retain suspended sediment less than .062 mm in diameter. Particles less than .062 mm in diameter retained in the deep-sumped hooded catch basin were the result of static settling. In general, the catch basin retained high-density medium and coarse-grain particles. Thus, the performance of the catch basin increased when these respective particle sizes were mobilized in storm flows. Catch basin performance declined as flows increased, catch basin turbulence increased, and residence time decreased. Lager and others (1977) found a 93 percent reduction in catch basin performance with respect to small particles (.25 to .10 mm in diameter) over a flow range of .25 to 6.3 cfs in a clean catch basin, but only a 60 percent reduction in catch basin performance with respect to heavy solids (greater than .25 mm in diameter).

Sediment Re-suspension

Previous studies found re-suspension to be a common problem of WQIs that were not located off-line (Schueler and Shepp 1993). By locating the WQI off-line, untreated stormwater can bypass the WQI during high flows and reduce the potential for flushing captured materials. In this study, bypass loads accounted for approximately three percent of the total suspended sediment load for each WQI. Bypass flow began to occur near 0.4 and 1.9 cfs at Station 136 and 739, respectively. The difference between the points where bypass flow began to occur for each station was attributed to the dissimilarity in the diversion weir height.

Re-suspension of bottom sediments was caused by excessive turbulence within the catch basin during peak flows. The literature suggests that re-suspension occurs when the level of retained material approaches or exceeds 50 percent of the catch basin sump depth. In simulated tests, the accumulation of bottom material in catch basins did not affect suspended sediment removal efficiencies until 40 to 50 percent of the storage depth was filled (Lager and others 1977). In this study, re-suspension was detected during several events although the volume of bottom sediment retained in the catch basin was less than 25 percent at the conclusion of the monitoring period. Figure 6 illustrates the re-suspension of SSC within the catch basin at Station 136 as it flows through the BMPs during a storm event. The frequency of cases where re-suspension was detected did not increase with an increase in captured sediment. The estimated amount of re-suspended sediment represented 18 percent of the catch basin's final retained suspended sediment load.

The WQIs' capture efficiency of suspended sediment also was reduced by the re-suspension of fine grain sediments, as well as by the bypassing of SSC within especially high flows. Despite the presence of a bypass pipe, previously captured fine bottom sediments were re-suspended and discharged from the WQIs nine and seven times at Stations 136 and 739, respectively. Re-suspension was detected at five-minute rainfall intensities and storm flows greater than .04 inches and about 0.46 cfs at each station, respectively. Storm flows from the WQI at 136 and 739 exceeded 0.46 cfs 33 and 22 times, respectively, during the monitoring period (the Station 136 WQI exceeded this threshold 24 times during the same operating period as Station 739). The amount of re-suspended sediment estimated for both WQIs represented about eight percent of the final retained suspended sediment loads. The frequency of cases where re-suspension was detected did not increase with an increase in captured sediment in either WQI. However, the level of captured sediment in chamber two of each WQI was several inches below the baffle.

The estimated quantity of suspended sediment in flows that bypassed the WQIs at Station 136 was about 20 percent higher than the amount of fine-grained sediment that was re-suspended and flowed out of the WQI. The inverse was true for Station 739 where the amount of bypassed suspended sediment was about 16 percent less than the amount of re-suspended sediment. This is logical considering that bypass flow occurred more frequently at the Station 136 WQI. Without the ability to limit flow to less than 0.46 cfs through the device, changes in the diversion weir height would not substantially affect the device performance. If the weir were raised, fine sediments – representing a relatively small fraction of the retained bottom material composition – would be re-suspended; and if the weir were lowered, a portion of coarse sediments -- readily mobilized during peak flows and retained by the WQI -- would bypass the device.

Debris Capture

Analysis of bottom material samples indicated that “floatable” debris was able to circumvent the catch basin hood and the WQI baffles. The relative ability of a WQI to retain large buoyant particles was further documented by attaching a debris collection device to the outlet headwall at Station 739. The quantity of material collected, for a total of 12 events, increased with an increase in peak discharge. About 71 percent (by mass) of the total debris collected was associated with runoff events where bypass flow occurred, which were exceptionally high runoff events. The quantity of material contained in the bypass flow, as opposed to the quantity of material passing through the WQI, was not determined. The quantity of floatable debris retrieved from the collection structure during the two-month period represented about 23 percent of the total estimate of floatable debris retained in the WQI after 10 months of operation. If the two storms where bypass flow occurred—and their associated debris load—are excluded, then the relative debris estimate is reduced to about eight percent of the total WQI capture estimate.

Although visual observations suggested the WQIs were at least temporarily effective at removing floatable debris, the distribution of potentially floatable debris in bottom materials relative to each chamber and the quantity of debris collected at the WQI outlet indicated the devices can only be effective if regular cleaning is performed. Moreover, the absence of debris in the deep-sumped hooded catch basin at the conclusion of the monitoring period and the large quantity of floatable debris found in each WQI suggested the catch basin hoods were not effective in reducing floatable debris.

Total SSC Loading

Suspended sediment loads for the entire study area were estimated based on the long-term average annual precipitation and the estimated inlet and outlet loads of the two 1500-gallon WQIs. The estimated annual suspended sediment load for the entire study area was about 29,000 Kg. Approximately 24,000 Kg discharged near Malibu Beach and Tenean Beach embayments and the remaining 5,000 Kg discharged to land surface where it infiltrated into the ground. These loads do not include an estimated 2,000 Kg of sediment retained by the five WQIs.

The findings of this study on the effectiveness of deep-sumped hooded catch basins and 1500-gallon WQIs in removing SSC from stormwater were based on the physical and environmental conditions occurring during the monitoring period. Many of the conditions at this site (e.g., daily traffic volume) were unique within the State of Massachusetts. Findings on other highway locations that have stable shoulders, lower traffic volumes, and different particle size distributions may be different.

Recommendations

Since it is not practicable to clean structural BMPs, or conduct street sweeping much more frequently, or install many more of these devices, then SSC source control is the most practicable approach. These methods are summarized below.

1. Catch basin cleaning, and street sweeping, should occur during Spring in order to avoid high-intensity rainfalls, characteristic of summer thunder storms, that re-suspend particles and/or mobilize sediments in the gutters to receiving waters.
2. In an effort to prevent erosion of the roadway shoulder (i.e., where the pavement edge meets the adjacent soil) onto the highway, and to enhance the effectiveness of street sweeping, a low-lying berm should be installed along this area of the Southeast Expressway. An alternative might be to grade the shoulder to an elevation below the edge of the pavement in order to prevent erosion onto the highway.
3. Consider significant reductions in sand application for snow and ice control. Sand probably provides minimal improvement for traction control along this highway anyway due to pulverizing (Comfort and Dinovitzer 1997) and blow-off (Nixon 2001). Road salting alone should be the primary emphasis along this highway, especially since the Expressway is immediately adjacent to a saltwater embayment.
4. Use more efficient maintenance equipment, such as vacuum pump trucks for cleaning out catch basins, in order to minimize the opportunity for re-suspension of captured sediments.
5. Apply more emphasis to litter pick-up efforts. This includes more signage and enforcement for littering, as well as other public outreach and educational efforts (e.g., public service announcements).

Future Research

1. Further work is needed to characterize the concentrations of the whole range of contaminants (e.g., nutrients, metals, hydrocarbons, and bacteria) in highway runoff that adequately accounts for rainfall intensity, antecedent conditions, particle sizes, traffic volume, pavement area, and flow. These factors have been shown to influence the estimates for contaminant loading from highway runoff. With this information, based on real-time flow-weighted data, a model could be developed that would more accurately estimate contaminant loading from highway runoff.
2. There should be an investigation into the degree to which bacteria survive and propagate in catch basins and WQIs. The static pool within these BMPs is generally dark (no light penetration), thermally stable, nutrient enriched, and free from predation. These factors may enhance the growth of fecal bacteria (Schueler 1999). The effectiveness of WQIs and catch basins in reducing fecal indicator bacteria concentrations is likely poor because bacteria share the same settling characteristics as particles less than .062 mm in diameter. Absolute bacteria removal in each BMP is dependent on the fecal indicator bacteria survivability prior to the subsequent event and the potential for exportation during the subsequent event.
3. Evaluate the effectiveness of hoods in capturing floatables; investigate the use of different types; what are their benefits/costs and to what degree do they interfere with maintenance and/or the drainage function of the catch basin.
4. Due to their limited water quality benefits, innovative water quality inlets should be more comprehensively evaluated before their widespread use. Such evaluations, employing the sampling methodologies described herein, will demonstrate the cost-effectiveness of these BMPs (i.e., determine if the environmental benefits exceed the costs of installation and maintenance). This information will provide a basis for their use by community planners, water managers, and others interested in storm water management.

Acknowledgements: The author of this paper would like to thank Kirk Smith of the U.S. Geological Survey, the principal investigator for this Study. His methods and thoroughness, in collecting and analyzing stormwater data, sets a standard for all future stormwater studies. I would also like to thank the Federal Highway Administration for the Study's funding, as well as all those from MassHighway who provided logistical support for this Study. In particular, Tom Lemeisz of the District 4 Maintenance Office gave essential assistance by providing periodic traffic control and structural BMP cleaning.

Biographical Sketch: Since 1993, Henry L. Barbaro has served as the Supervisor of the Wetlands & Water Resources Section within the Massachusetts Highway Department. Since the mid-1990s, Henry has been a leader in formulating statewide policy for stormwater management. He also is a member of the Stormwater Advisory Committee for the Massachusetts Department of Environmental Protection (DEP).

Before his experience with MassHighway, Henry worked for 3 years with the Wetlands Conservancy Program of DEP. He also has more than 5 years experience as a regional planner in Vermont and New Hampshire. In addition, Henry holds an M.S. in Natural Resource Planning from the University of Vermont, and a B.S. in Environmental Science from the University of Massachusetts in Amherst.

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