Appendix B

Details of Initial BMP Selection and Evaluation

Evaluation of Best Management Practices for Michigan Department of Transportation

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INTRODUCTION

This report presents an overview of our assessments and investigations of appropriate structural and non-structural Best Management Practices (BMPs), which may be applicable to the Michigan Department of Transportation (MDOT) activities. In early 2000, a detailed matrix of the BMPs evaluated was presented to MDOT. The matrix was generated from detailed investigation of nation-wide urban and particularly Department of Transportation (DOT) BMP programs and pilot studies. Following review of this matrix, MDOT provided specific comments on each BMP. The short report presented here provides a brief summary of this initial investigation, a revised matrix based on the comments received from MDOT, and finally our recommendations.

ORIGINAL BMP MATRIX

The original list of BMPs presented to MDOT in early 2000, is attached to Appendix A. The matrix includes an overall and preliminary investigation of all possible urban runoff control BMPs, which could be applicable to MDOT activities. The matrix includes structural and non-structural BMPs, as well as BMPs currently being tested in pilot studies by California Department of Transportation (Caltrans). Information such as BMP description, limitations, benefits, pollutant removal efficiency (based on actual monitoring data), capital costs, and O&M costs is included. It should be noted that the information presented was retrieved from data available at the time of the matrix was generated. Costs presented are from 1999 unless indicated otherwise. The detailed information provided was intended to familiarize the reader with current nationwide practices, as well as pilot studies being conducted in evaluating Best Management Practices (BMPs).

REVISED BMP MATRIX

Following the review of the original BMP, MDOT provided specific comments on each BMP based on applicability to their operations and activities. As a result, many of the original BMPs were deleted from the original list. A revised list, including the approved BMPs and BMPs with limited use, is provided in Appendix B. The following is a brief outline of the structural BMPs, which MDOT did not object to and regarded as being appropriate for its activities:

Infiltration Trench is a gravel-filled trench designed to infiltrate storm water into the ground. Typically infiltration trenches can only capture a small amount of runoff, and therefore, may be designed to capture the first flush of the runoff event. For this reason, they are typically used with other BMPs, such as detention basins to control peak flows.

Ponds (Basins) are designed to capture a storm water runoff volume, hold this volume and infiltrate it into the ground over a period of days. Basins are typically not designed to retain a permanent pool of water.

Infiltration Drainfields are infiltration systems that capture a volume of runoff and infiltrate it into the ground. The system consists of a pretreatment structure, a manifold system, and a drainfield.

Concrete Grid Pavements are lattice grid structures with grassed or pervious material placed in the grid openings. Their use, however, is generally restricted to parking areas and driveways.

Wetlands (constructed) consist of a rectangular basin with a forebay and wetland vegetation area. The forebay traps floatables and the larger settleable solids, facilitating maintenance, as well as protecting the wetland vegetation.

Biofilters are of two types: swales and strips. Vegetated Swales are vegetated shallow channels with a dense stand of vegetation covering the side slopes and channel bottom that treat concentrated flows. Infiltration (Vegetative Filter) Strips are densely vegetated, uniformly graded areas that intercept sheet flow and are usually placed parallel to the contributing surface.

Dry Detention Basins are basins that are dry between storms. During a storm the basin fills. A bottom outlet releases the storm water slowly to provide time for sediments to settle.

Catch Basin Inlet Devices are devices that are inserted into storm drain inlets to filter, or absorb sediment, pollutants, and oil and grease. These devices are typically placed at locations with a high potential for contamination.

In addition to the above structural BMPs, MDOT approved of the following non-structural and erosion control BMPs:

Non-structural BMPs:

- Minimizing Effects from Highway Deicing
- Employee Training
- Litter Control
- Identify and Prohibit Illegal or Illicit Discharges to Storm Drains
- Street Sweeping
- Clean and Maintain Storm Drain Channels
- Clean and Maintain Storm Inlet and Catch Basins
- Snow and Ice Control Operations

Construction BMPs:

Temporary Seeding of Stripped Areas

- Mulching and Matting
- Plastic Covering

FURTHER RECOMMENDATIONS

In the time following the development of the original matrix, many of the listed BMPs have been the focus of further tests and have been additionally implemented in different urban watersheds throughout the nation. New and updated information on the effectiveness of these BMPs in removing urban type of pollutants may be available. It is recommended that the matrix be further updated with new information including updated costs, limitations, and advantages. The construction and maintenance costs should be further investigated based on updated information from manufacturers, as well as recent cost information for the similar constructions and maintenance activities in the area.

As mentioned previously, in the recent years Caltrans and UCLA have been conducting focused pilot studies on specific structural BMPs. The results from UCLA studies may be available now and Caltrans pilot study results should become available in late 2001, and 2002. It is recommended that MDOT take advantage of the results of these comprehensive pilot studies before spending resources on costly BMP efforts and programs.

In addition, it is recommended that the approved BMP matrix be used as a decision making tool for planning of appropriate BMPs. A decision-making process could be established to prioritize various sites with appropriate BMPs. The main criteria in the BMP prioritization should be water quality improvement. However, a ranking or weighing criteria could be applied to the limitations, benefits, pollutant removal efficiency, capital costs, and O&M costs and used in the decision-making process.

Finally, it is recommended that MDOT take a proactive role in testing some of the approved BMPs on site- specific areas before the actual implementation of them. Different types of investigations may be conducted to better understand MDOT pollutant load contributions, as well as pollutant behavior/dynamics. To gain further knowledge of BMP effectiveness in control of pollutants, the promising structural BMPs, are recommended to be further tested in controlled pilot studies.

APPENDIX A

Original BMP Matrix

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Infiltration - a family of treatment systems in which the majority of the runoff from small storms is infiltrated in the ground rather than discharged into a surface water body. (1)					
Infiltration Trench - is an excavated trench (3 to 12 feet deep), backfilled with stone aggregate, and lined with filter fabric. (23) It is used to treat a small portion of the runoff by detaining storm water for short periods until it percolates down to the groundwater table. (21) Useful life is usually around 10 years. (20)	*potential loss of infiltrative capacity. (1) *applicability depends on specific site characteristics/opportunities (slope, soil types, proximity to water table). (23) *potential groundwater contamination. (1) *not suitable for sites that contain chemical or hazardous material. (23) *may need to be preceded by appropriate pretreatment. (23) *relatively short life span. (23)	*efficient removal of pollutants. (1) *can recharge groundwater supplies. (2) *provides localized streambank erosion control. (2) *easy to fit into unutilized areas of development sites. (2) *an effective runoff control. (1) *increases baseflow in nearby streams. (23) *Low land use requirement. (20)	* nitrogen compounds 40% to 80%. (2) * phosphorus compounds 40% to 80%. (2) * combined nitrogen and phosphorus compounds 45% to 75% (depending on design). (8) * total suspended solids 75%. (20) *total phosphorous 60%. (20) * total nitrogen 55%. (20) *COD 65%. (20) * Lead 65%. (20) * Zinc 65%. (20)	* $4,900/acre (prorated using ENR index from 1992 cost). (5) * $3.6 to $10.70/cubic feet storage (prorated using ENR index from 1986 cost). (20)	* $1,800/acre/year (prorated using ENR index from 1992 cost). (5) * 9% of Capital Cost (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Pond (Basin) - consist of shallow, flat basins excavated in pervious ground, with inlet and outlet structures to regulate flow. (19) Useful Life is usually around 25-years. (20)	*potential loss of infiltrative capacity. (1) *low removal of dissolved pollutants in very coarse soils. (1) *possible nuisance (odor, mosquito). (2) *frequent maintenance requirement. (2) *risk of groundwater contamination. (1) * High land use requirement. (20)	*achieves high levels of particulate pollutant removal. (1) * can recharge groundwater supplies. (2) *an effective runoff control. (1) *can serve tributary areas up to 50 acres. (1) *provides localized streambank erosion control. (2) *cost effective. (2)	* nitrogen compounds 40% to 80%. (2) * phosphorus compounds 40% to 80%. (2) * combined nitrogen and phosphorus compounds 45% to 75% (depending on design). (8) * total suspended solids 75%. (20) *total phosphorous 65%. (20) * total nitrogen 60%. (20) *COD 65%. (20) * Lead 65%. (20) * Zinc 65%. (20)	* $36,900/million gallons (prorated using ENR index from 1992 cost). (5) * $0.60 to $1/cubic feet storage (prorated using ENR index from 1986 cost). (20)	* $1,200/million gallons/year (prorated using ENR index from 1992 cost). (5) * 7% of Capital Cost (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Porous Pavement - is an alternative to conventional pavement whereby runoff is diverted through a porous asphalt layer and into an underground stone reservoir. (10) Useful life is around 10 years. (20)	*potential loss of infiltrative capacity. (1) *75% failure rate due to clogging, resurfacing or just failure after construction. (10) *high maintenance – requires special vacuum sweeping or jet hosing. (10) *may require twice as much material as without porous pavement to achieve the needed strength. (10) *unsuitable in fill sites and steep slopes. (5) *potential risk of groundwater contamination. (1) *limited efficiency (6 months). (23)	*achieves high levels of pollutant removal. (1) *groundwater recharge. (2) *localize streambank erosion control. (2) *reduced land *consumption. (2) *elimination of curbs and gutters. (2) *safer driving surface. (2)	* nitrogen compounds 60% to 80%. (2) * phosphorus compounds 40% to 80%. (2) *nitrogen and phosphorus compounds 45% to 75% (depending on design). (8) * sediment 82 to 95%. (23) * total phosphorus compounds 65%. (23) * total nitrogen compounds 80 to 85%. (23) * total suspended solids 90%. (20) *total phosphorous. 65% (20) * total nitrogen 85%. (20) *COD 80%. (20) * Lead 100%. (20) * Zinc 100%. (20)	* $123,000/acre (prorated using ENR index from 1992 cost). (5) * $2.10/square feet (prorated using ENR index from 1987 cost) (incremental cost beyond the conventional asphalt pavement). (20)	* $250/acre/year (prorated using ENR index from 1992 cost). (5) * $0.14/square feet/year (prorated using ENR index from 1987 cost). (incremental cost beyond the conventional asphalt pavement). (20)
Concrete Grid Pavement – are lattice grid structures with grassed or pervious material placed in the grid openings. (1) Useful life is usually around 20 years. (20)	*require regular maintenance. (20) *not suitable for high traffic areas. (20) *potential groundwater contamination. (20) *only feasible where soil is permeable. (20)	*groundwater recharge. (20) *can provide peak flow control. (20)	*total nitrogen 90%. (20) * total phosphorus compounds 90%. (20) * total suspended solids 90%. (20) *COD 90%. (20) * Lead 90%. (20) * Zinc 90%. (20)	* $1.7 - $3.5/ft^2 (prorated using ENR index from 1981 cost) (incremental cost beyond the conventional asphalt pavement) (20)	* -$0.07/ft^2 feet (prorated using ENR index from 1981 cost) (incremental cost beyond the conventional asphalt pavement) (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Infiltration Drainfields – a system composed of a pretreatment structure, a manifold system, and a drainfield. (28)	*high maintenance when sediment loads are heavy. (28) *short life span if not well maintained. (28) *not suitable in regions with clay or silty soils. (28) *anaerobic conditions could clog the soil. (28) *potential groundwater contamination. (28)	*groundwater recharge. (28) *used to control runoff. (28)	* depends on design – little monitoring data currently available. Potentially 100% of pollutant could be prevented from entering surface water. (28)	Approx. $72,000 for a drainfield with dimensions: 100 ft long, 50 feet wide, 8 feet deep with 4 ft cover. (28)	
Wet Detention Ponds – small artificial impoundments with emergent wetland vegetation around the perimeter designed for the removal of particulate matter and dissolved nutrients. (19) Useful life is around 50 years. (20)	*maintaining oxygen supply in the pond. (1) *need of supplemental water to maintain water level. (1) *land constraints, infeasible in dense urban areas. (1) *local climate might affect biological uptake. (27) *eventual need for costly sediment removal. (2) *potential nuisance (mosquito, odor, algae). (2) *potential stratification and anoxic conditions. (27)	*achieves high levels of soluble and organic nutrient removal. (2) *creation of local wildlife habitat. (2) *decrease potential for downstream flooding. (27) *recreational and landscape amenities. (2) *decrease potential downstream stream bank erosion. (19)	* nitrogen 20% to 60%. (2) * phosphorus 40% to 80%. (2) * nitrogen & phosphorous 30% to 70% (depending on volume ratio). (8) * total suspended solids 50% to 90% (27) & 60% (20). * total phosphorus 30% to 90% (27) & 45% (20). * total nitrogen 35%. (20) * soluble nutrients 40% to 80%. (27) * lead 70% to 80% (27) & 75% (20). * zinc 40% to 50% (27) & 60% (20). * COD 40%. (20)	$17.50 to $35 per cubic meter of storage area (27)	3 to 5 percent of construction cost per year (27)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Wetlands - constructed wetlands are a single stage treatment system consisting of a forebay and micro pool with aquatic plants. They remove high levels of particulate, as well as some dissolved contaminants. (19) Useful life is around 50 years. (20)	*need of supplemental water to maintain water level. (1) *potential nutrient release in the winter. (19) *reduction in hydraulic capacity with plant growth. (19) *wetland area less than 2% of watershed area. (10) *potential groundwater contamination. (26) * high land requirements. (20)	*passive recreation and wildlife support. (1) *improve downstream water and habitat quality. (26) *flood attenuation. (26) *achieves high levels pollutant removal. (1)	* total suspended solids 67% (26) & 65% (20). * total phosphorus 49% (26) & 25% (20). * total nitrogen 28% (26) & 20% (20). * organic carbon 34%. (26) * COD 50%. (20) * petroleum hydrocarbons 87%. (26) * cadmium 36%. (26) * copper 41%. (26) * lead 62% (26) & 65% (20). * zinc 45% (26) & 35% (20). * bacteria 77%. (26)	$26,000 to $55,000 per acre of wetland. (26)	2 percent of construction cost per year. (26)
Biofilters - Systems designed to pass storm water runoff slowly over a vegetated surface in the form of a swale or strip to filter pollutants and to infiltrate the runoff. (19)					

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Bioretention – system designed to treat runoff. The runoff is conveyed as sheet flow to the treatment area, which consists of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants. (33)	*cold climate may hinder infiltrative capacity. (33) *not suitable for slopes greater than 20 percent. (33) *clogging may occur in high sediment load areas. (33)	*enhance quality of downstream water bodies. (33) *improves area's landscaping. (33) *provide shade and wind breaks. (33)	* total Phosphorus 70 to 83%. (33) * metals (copper, lead, zinc) 93 to 98%. (33) * TKN 68% to 80%. (33) * total suspended solids 90%. (33) * organics 90%. (33) * bacteria 90%. (33)	$500 for new development of a bioretention, $6,500 for retrofitting a site into a bioretention area (33)	

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Vegetated Swale – is a broad, shallow channel (typically trapezoidal shaped) with a dense stand of vegetation covering the side slopes and bottom. (29) Useful life is around 50 years. (20)	generally incapable of removing nutrients. (2) *can become drowning hazards, mosquito breeding areas. (29) not appropriate for steep topography, very flat grades. (29) tributary area limited to a maximum of 5 acres. (19) difficult to avoid channelization. (19) *ineffective in large storms due to high velocity flows. (29)	design to convey runoff of 2 year storm, with freeboard of 10 year storm. (19) * low land requirement. (20) suitable for small residential areas. (1) can removes particulate pollutants at rates similar to wet ponds. (1) *reduction of peak flows. (29) *lower capital cost. (29) *promotion of runoff infiltration. (29) * low land requirements. (20)	* nitrogen 0 to 60% (2) * total nitrogen 10%. (20) * phosphorus 0 to 60% (2) * total phosphorus 9% (29) & 20% (20). * COD 25%. (20) * oxygen demanding substances 67%. (29) * total suspended solids 81% (29) & 60% (20). * nitrate 38%. (29) * hydrocarbons 62%. (29) * cadmium 42%. (29) * lead 67% (29) & 70% (20). * zinc 71% (29) & 60% (20). * copper 51%. (29)	* $6.80 to $12.50 per linear foot (prorated using ENR index from 1987 cost). (29) * $10.80 to $63.40 per linear foot (prorated using ENR index from 1991 cost). (29) * typical total for a 1.5 ft. deep, 10 ft wide, 1,000 ft long Low - $8,100 Moderate - $14,870 High - $21,640 Prorated using ENR index from 1991 cost). (29)	* $0.73 - $0.95 per linear foot (prorated using ENR index from 1991 cost). (29) * $1/linear foot 9prorated using ENR index from 1987 cost). (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Infiltration (Vegetative Filter) Strip - are broad surfaces with a full grass cover that allows storm water to flow in a relatively thin sheets (21) Useful life is around 50 years (20).	*sheet flow may be difficult to attain. (1) *not appropriate for steep slopes. (19) *tributary area limited to 5 acres. (19)	*suitable for parking lots. (1) *slows runoff flow. (1) *removes particulate pollutants. (1)	* nitrogen 0 to 40%. (2) * phosphorus 0 to 40%. (2) * total suspended solids 65%. (20) * total phosphorous 40%. (20) * total nitrogen 40%. (20) * COD 40%. (20) * lead 45%. (20) * zinc 60%. (20)	* $3,100/acre (prorated using ENR index from 1992 cost). (5)	* $310/acre/yr (prorated using ENR index from 1992 cost). (5) * $139 to $1,100/acre/year (prorated using ENR index from 1987 cost). (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Extended Detention Basins - consist of a settling basin with an outlet sized to remove particulate matter by slowly releasing accumulated runoff over a 24 to 40 hour period. "Dry" detention basins may be designed to empty between usages. (19) Useful life is usually 50 years. (20)	*occasional nuisance in inundated portion. (19) *inability to vegetation may result in erosion and re-suspension. (1) *limited orifice diameter precludes use in small watersheds. (1) *requires differential in elevation at inlet and outlet. (1) *frequent sediment maintenance. (19) * High land requirement. (20)	*creation of local wildlife habitat. (2) *recreational use in inundated portion. (2) *can remove soluble nutrients by shallow marsh or permanent pool. (2) *suitable for sites over 10 acres. (10) *temporary storage of runoff. (1) *no need of supplemental water. (1) *protection for downstream channel erosion. (2)	* nitrogen 20% to 60%. (2) * phosphorus 20% to 80% (2) & 10% to 30%. (10) * nitrogen and phosphorus 30% to 70% (depending on volume ratio). (8) * soluble nutrients – low or negative. (10) * total suspended solids 45% (20) & 88% (44). * nitrate 15% (44). * nitrite 61% (44). * oil and grease 56%. (44) * fecal coliform 45%. (44) total petroleum hydrocarbons 17% to 20%. (44) * TKN 40%. (44) * ammonia 5%. (440 *total phosphorous 25% (20) & 57% (44). * total nitrogen 30%. (20) *COD 20% (20) & (44). * lead 20% (20) & 55% (44). * zinc 20% (20) & 47% (44). * chromium 68%. (44) * copper 37%. (44) * nickel 62%. (44)	$123,000/million gallons (prorated using ENR index from 1992 cost). (5)	* $1,230/million gallons/year (prorated using ENR index from 1992 cost). (5) * 4% of capital cost. (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Modular Treatment Systems StormTreat™ System (STS) – treatment technology consisting of a series of sedimentation chambers and constructed wetlands. The 9.5 feet diameter recycled polyethylene modular treats storm water with sedimentation chambers, where pollutants are removed through sedimentation and filtration, then the water is conveyed to a surrounding constructed wetland. Vegetation in the wetland varies depending on local conditions. Because the system is relatively new, there is no data available on lifetime of the system. It is estimated that the plants and the gravel in the system need to be replaced every 10-20 years. (32)	*may require modifications to function in different environments. (32) * relatively new and remains to be tested in different geographical locations.	*protect groundwater by removing pollutants prior to infiltration. (32) *high removal rates. (32) *spill containment feature. (32) *soil types and high water table won't limit effectiveness. (32)	* fecal coliform bacteria 97%. (32) * total suspended solids 99% (32) * COD 82%. (32) * total dissolved nitrogen 77%. (32) * phosphorus 90%. (32) * total petroleum hydrocarbons 90%. (32) * lead 77%. (32) * chromium 98%. (32) * zinc 90%. (32)	$4,900 per unit + $500 to $1,000 installation cost + $350 to $400 for additional material (32)	$80 to $120 per tank for removal of sediment (32)
Hydrodynamic Separators – are flow-through structures with a settling or separation unit to remove sediments and other pollutants that are widely used. With proper upkeep, useful life is over 30 years. (25)					
Downstream Defender™ - designed to capture settleable solids, floatables and oil and grease. It utilizes a sloping base, a dip plate and internal components to aid in pollutant removal. (25)	* requires frequent inspections and maintenance is site-specific. (25)		Can achieve 90% particle removal for flows from 0.75 cfs to 13 cfs (25)	$10,000 to $35,000 per pre cast unit (23)	

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Continuous Deflection Separator (CDS) - pre cast units placed downstream of freeway drain inlets to capture sediment and debris. These underground units create a vortex of water that allows water to escape through the screen, while contaminants are deflected into the sump. (21)	* suitable for gross pollutant removal. (21)	. intended to screen litter, fine sand and larger particles. (21) . act as a first screen influence for trash and debris, vegetative material, oil and grease, heavy metals. (21)	oil and grease – 77% (34)	$2,300 to $7,200 per cubic feet second capacity (23)	
Continuous Deflection Separator (CDS) with Sorbents. Application of different types of sorbents in the CDS units. *OARS*™ - is a rubber type off sorbent (34) *Rubberizer* – is composed of a mixture of hydrocarbon polymers and additives (34) *Aluminum Silicate*: - *Xsorb*™ is made from a natural blend of silica minerals, which when expanded in our unique manufacturing process, make a white granular material that absorbs spills instantly on contact (web) *Sponge Rok*™ - primarily sold as a soil bulking agent (34) *Nanofiber*™ - is a polypropylene adsorbent (34)	* requires frequent inspections and maintenance is site-specific. (25)	*sorbents remove many times their own weight (34) *could be used oil spill control. (34)	OARS: oil and grease - 82%, 83%, 86%, 94% (34) Rubberizer: oil and grease 86%. (34) Xsorb: oil and grease 79%. (34) Sponge Rok: oil and grease 41%. (34) Nanofiber: oil and grease 87%. (34)		

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Stormceptor® - This system is a stormwater interceptor that efficiently removes sediment and oil from stormwater runoff and stores these pollutants for safe and easy removal. Units are available in prefabricated sizes up to 12 feet in diameter by 6 to 8 feet deep. They re designed to trap and retain a variety of non-point source pollutants, using a by-pass chamber and treatment chamber. A fiberglass insert separates the upper (by-pass) and lower (separation/holding) chambers. (25)	* requires frequent inspections and maintenance is site-specific. (25)	*use for redevelopment projects of more than 2,500 sq. feet where there was no pervious storm water management. (25) *projects that double the impervious layer. (25) *easy to design in new or retrofit applications. (35) *inexpensive to service and maintain. (35) *internal bypass prevents release of trapped pollutants. (35) *Ideal for highways, industrial properties, gas stations, parking lots and sites where there is a potential for oil or chemical spills.	* total suspended solids 80%. (35) * free oils 95%. (35) * oil 98.5%. (36) * inorganic sediment 80%. (36) * organic sediment 70%. (36) * total suspended solids 51.5%. (36) * oil and grease 43.2%. (36) * zinc 39.1%. (36) * total organic carbon 31.4%. (36) * chemical oxygen demand 26.0%. (36) * lead 51.2%. (36) * chromium 40.7%. (36) * copper 21.5%. (36) * iron 52.7%. (36) * calcium 17.9%. (36)	$7,600 to $33,560 per unit (23)	$1,000/year per structure (23)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Vortechs™ - a major advancement in oil and grit separator technology, Vortechs units removes grit, contaminated sediments, heavy metals, and oily floating pollutants from surface runoff. It is a stormwater treatment system consisting of four structures to treat stormwater: a baffle wall, a grit chamber, an oil chamber and a flow control chamber. This system combines swirl-concentrator and flow-control technologies. (25)	*most effective when separation of heavy particulate or floatable from wet weather runoff. (25) *suspended solids are not effectively removed. (25) * requires frequent inspections and maintenance is site-specific. (25)	*suited for areas with limited land available (25) *good for "hotspots" such as gas stations (high concentrations). (25) *able to treat runoff flows from 1.6 cfs to 25 cfs. (25)	* total suspended solids 84%. (37)	$10,000 to $40,000 per unit (not including installation) (23)	
Multi-Chambered Treatment Trains (MCTT) - consist of a three treatment mechanisms in three different chambers. 1) catch basin - screening process to remove large, grit sized material, 2) settling chamber - removing settleable solids and associated constituents with plate separators and sorbent pads, 3) media filter - uses a combination of sorption (layers of sand and peat covered by filter fabric) and ion exchange for the removal of soluble constituents. (21)	*high maintenance – require renewing sorbent pads, removing sediment, replacing clogged media. (21)	*treats storm water at critical source areas with limited space. (21)	* toxicity 70% to 100%. (24) * chemical oxygen demand 0% to 100% (24) * total suspended solids 70% to 90% (24)	* approx. $375,000 to $900,000 (depending on drainage area)	
Media Filtration – these are usually two or three stage constructed treatment systems, composed of a pretreatment settling basin and a filter bed containing filter media (and a discharge chamber). (19)					

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Sand Filter - the filter is designed to hold and treat the first one half inch of runoff and the pollutant removal ability of the sand filter has been found to be very good. (3)	*not effective treating liquid or dissolved pollutants (19) .routine maintenance requirement. (19) .significant headloss. (19) .severe clogging potential. (19) *media may be replaced 3 to 5 years. (30) *climate conditions may limit filter's performance. (30)	.high removal rates for sediment, BOD, and fecal coliform bacteria. (30) *can reduce groundwater contamination. (30) .requires less land, can be placed underground. (19) .suitable for individual developments. (1) .minimum depth of 18 inches. (1) .tributary areas of up to 100 acres. (19)	* fecal coliform 76%. (30) * BOD 70 %. (30) * total suspended solids 70 %. (30) * total organic carbon 48%. (30) * total nitrogen 21%. (30) * total phosphorus 33%. (30) * Lead 45%. (30) * zinc 45%. (30) * iron 45%. (30)	* $18,500 (1 acre drainage area) (1997). (30) * $6,940 to $11,600 (less than 1 acre – cast in place) (prorated from 1997 prices using ENR index). (30)	* sand filter vault $1,790 (prorated from 1997 prices using ENR index). (18) * sand filter basin $3,370 (prorated from 1997 prices using ENR index). (18) * 5 percent of the initial construction cost. (30)
Activated Carbon - has long been used in the chemical process industry and in hazardous waste cleanup as an effective method for removing trace organics from a liquid. (3)	*heavy maintenance requirement. (19) *severe clogging potential. (19) *limited by the number of adsorption sites in the media. (3) *small net surface charge and ineffective at removing free hydrated metal ions. (3)	*can be placed underground. (19) *less space required. (1) *effective in removing trace organics from liquid. (3) *suitable for individual developments. (1)		* $1/lb or $315/cy (prorated from 1997 prices using ENR index). (18)	

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Composted Leaves - made from yard waste, primarily leaves, have been advertised to have a very high capacity for adsorbing heavy metals, oils, greases, nutrients and organic toxins due to the humic content of the compost. (3)	*heavy maintenance requirement. (19) *severe clogging potential. (19) *in some cases, negative removal efficiencies with increased loads have been reported. (22)	*can be placed underground. (19) *no vegetation required. (19) *smaller land area required. (3) *suitable for individual developments. (1)	* total suspended solids 84% (3), -155% to 72% (22). * petroleum hydrocarbons 87% (3), 4% to 64% (22). * chemical oxygen demand 67% (3), 32% to 38% (22). * total Phosphorus 40% (3) & -320% to 28% (22). * TKN –133% to 43%. (22) * fecal coliform 6% to 80%. (22) * oil and grease 0% to 44%. (22) * total petroleum hydrocarbons 33% to 64%. (22) * ammonia 41% to 64%. (22) * nitrate –172% to 7%. (22) * nitrite –233% to 29%. (22) * chromium 0% to 25%. (22) * copper 67% (3) & 4% to 9% (22). * zinc 88% (3) & 46% to 65% (22). * aluminum 87%. (3) * nickel 33% to 50%. (22) * lead 0% to 17%. (22) iron 89%. (3)	* $130/cy (prorated from 1997 prices using ENR index). (18) * $27,000 to treat 1 cfs (prorated from 1998 prices using ENR index). (22)	* $2,400/year (prorated from 1998 prices using ENR index). (22)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Peat Moss - is partially decomposed organic material, excluding coal that is formed from dead plant remains in water in the absence of air. The physical structure and chemical composition of peat is determined by the types of plants from which it is formed. Peat is physically and chemically complex and is highly organic. (3)	*heavy maintenance requirement. (19) *severe clogging potential. (19) *can have a high hydraulic conductivity. (3)	*can be placed underground. (19) *no vegetation required. (19) *smaller land area required. (3) *polar and has a high specific adsorption for dissolved solids. (3) *excellent natural capacity for ion exchange. (3) *excellent substrate for microbial growth and assimilation of nutrients and organic waste material. (3)		$25 to $105/cy (prorated from 1997 prices using ENR Index). (18)	
Peat-Sand Filter - man made filtration device, has good grass cover on the top underlain by twelve to eighteen inches of peat. The peat layer is supported by a 4-inch layer of peat and sand mixture, which supported by a 20 to 24 inch layer of fine to medium sand. Under the sand are gravel and the drainage pipe. (3)	*heavy maintenance requirement. (19) *severe clogging potential. (19)	*can be placed underground. (19) *less space required (1) *suitable for individual developments. (1) *works best during growing season as grass cover can provide additional nutrient removal. (3)	* suspended Solids 90% (3) & 80% (20). * total phosphorus 70% (3) & 50% (22). * total nitrogen 50% (3) & 35% (20). * BOD 90%. (3) * bacteria 90%. (3) * trace metals 80%. (3) * lead 60%. (20) * zinc 65%. (20) * COD 55%. (20)	$6.50 per cubic foot of material (prorated from 1990 prices using ENR index). (20)	7 % of construction cost. (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Water Quality Inlets – commonly known as oil/grit or oil/water separators. These devices typically consist of a series of chambers, a sedimentation chamber, an oil separation chamber and a discharge chamber. (31) Useful life is usually 50 years. (20)	*limited drainage area (1 acre or less). (31) *high sediment loads can interfere ability to separate oil and grease. (31) *limited hydraulic and residual storage. (31) *frequent maintenance. (31) *residual may be considered too toxic for landfill disposal. (31) *recommended oil/water separators are used for spill control as their primary application. (42) *re-suspension of pollutants. (36) * small flow capacity. (31)	*reduction of hydrocarbon contamination. (31) *effectively trap trash, debris, oil and grease (31) *ideal for small, highly impervious area. (31) *ideal for maintenance stations. (36) * low land requirement. (20)	* sediments 20% to 40%. (31) * efficiency directly proportional to discharge rate. (31) * total suspended solids 15% to 35%. (20) * total phosphorous 5%. (20) * total nitrogen 5% to 20%. (20) * COD 5%. (20) * lead 15%. (20) * zinc 5%. (20)	$5,900 to $18,900 for cast in place water quality inlets (prorated from 1993 prices using ENR Index). (31)	
Catch Basin Inlet Devices - devices that are inserted into storm drain inlets to filter or absorb sediment, pollutants, and oil and grease (21)	* not feasible for larger than 5 acres. (20)	* high removal efficiency for large particles and debris for pretreatment. (20) * low land requirement. (20) * flexibility for retrofit of existing systems. (20)			
Stream Guard Inserts - are sock-type inserts that allow collected water to filter through the geotextile fabric. (21)	*maintenance includes removal of sediment and debris. (21)	*configured to remove sediment, constituents adsorbed to sediment, and oil and grease. (21)		approx. $50,000 to $100,000 per catch basin. (21)	
Fossil Filter Inserts - are trough-type of inserts filled with granular amorphous alumina silicate media. Removes pollutants through sorption. (21)	*maintenance includes removal of sediment and debris. (21)	*configured to remove sediment, constituents adsorbed to sediment, and oil and grease. (21)		approx. $50,000 to $100,000 per catch basin. (21)	

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
OARS™ - is a rubber type of sorbent insert (34)			* free oil and grease 88% to 91%. (39) * emulsified oil and grease 3%. (39)		
Nanofiber™ - is a polypropylene adsorbent type of insert. (34)			* free oil and grease 86%, 92%, 78%, 85%. (39)		
Aluminum Silicate: *Xsorb*™ is made from a natural blend of silica minerals, which when expanded in the unique manufacturing process, makes a white granular material that absorbs spills instantly on contact. *Sponge Rok*™ - primarily sold as a soil bulking agent (34)			* free oil and grease 88%, 91%, 94%, 89%. (39) * emulsified oil and grease 0%. (39)		
Curb Inlet Drain Diaper Insert – sorbent type diaper placed at the catch basin insert. (40)				$125 per unit. (40)	
Storm Clenz Filter and Multi Cell Flow Through Filter – developed by Best Management Technologies, the filters are used typically in maintenance facilities and staging areas were sediment and hydrocarbons are present. (41)				* multi cell flow through filters - $786 to $1233 depending on pipe size (6" to 12") * storm clenz filters - $339 to $702 depending on filter insert size. (41)	* flow through filter absorbents $24 to $44 depending on size. * storm clenz absorbents $24 to $ 54 depending on size. (41)
Some Examples of Temporary Erosion and Sediment Control BMPs – (typically used during construction activity)					

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Temporary Seeding of Stripped Areas - The establishment of a temporary vegetative cover on disturbed areas by seeding with rapidly growing plants. This provides temporary soil stabilization to areas, which would remain bare for more than seven days where permanent cover is not necessary or appropriate. (42)	*Temporary seeding is only viable when there is a sufficient window in time for plants to grow and establish cover. During the establishment period the bare soil should be protected with mulch and/or plastic covering. (42) *If sown on subsoil, growth may be poor unless heavily fertilized and limed Because over-fertilization can cause pollution of stormwater runoff, other practices such as mulching alone may be more appropriate. The potential for over-fertilization is an even worse problem in or near aquatic systems. (42) *Once seeded, areas cannot be used for heavy traffic. (42) *May require regular irrigation to flourish. Regular irrigation is not encouraged because of the expense and the potential for erosion in areas that are not regularly inspected. The use of low maintenance native species should be encouraged, and planting should be timed to minimize the need for irrigation. (42)	*This is a relatively inexpensive form of erosion control but should only be used on sites awaiting permanent planting or grading. Those sites should have permanent measures used. (42) *Vegetation will not only prevent erosion from occurring, but will also trap sediment in runoff from other parts of the site. (42) *Temporary seeding offers fairly rapid protection to exposed areas. (42)			

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Mulching and Matting - Application of plant residues or other suitable materials to the soil surface. This provides immediate protection to exposed soils during the period of short construction delays, or over winter months through the application of plant residues, or other suitable materials, to exposed soil areas. Mulches also enhance plant establishment by conserving moisture and moderating soil temperatures. Mulch helps hold fertilizer, seed, and topsoil in place in the presence of wind, rain, and runoff and maintains moisture near the soil surface. (42)	*Care must be taken to apply mulch at the specified thickness, and on steep slopes mulch must be supplemented with netting. (42) *Thick mulches can reduce the soil temperature, delaying seed germination. (42)	*Mulching offers instant protection to exposed areas. (42) *Mulches conserve moisture and reduce the need for irrigation. (42) *Neither mulching nor matting require removal; seeds can grow through them unlike plastic coverings. (42)			
Plastic Covering - The covering with plastic sheeting of bare areas, which need immediate protection from erosion. This provides immediate temporary erosion protection to slopes and disturbed areas that cannot be covered by mulching, in particular during the specified seeding periods. Plastic is also used to protect disturbed areas, which must be covered during short periods of inactivity to meet November 1 to March 31 cover requirements. Because of many disadvantages, plastic covering is the least preferred covering BMP. (42)	*There can be problems with vandals and maintenance. (42) *The sheeting will result in rapid, 100 percent runoff, which may cause serious erosion problems and/or flooding at the base of slopes unless the runoff is properly intercepted and safely conveyed by a collecting drain. This is strictly a temporary measure, so permanent stabilization is still required. *The plastic may blow away if it is not adequately overlapped and anchored. (42) *Ultraviolet light can cause some types of plastic to become brittle and easily torn. (42) *Plastic must be disposed of at a landfill; it is not easily degradable in the environment. (42)	*Plastic covering is a good method of protecting bare areas, which need immediate cover and for winter plantings. (42) *May be relatively quickly and easily placed. (42)			

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O&M Cost (approximate)
Alum Injection-Alum injection is the addition of alum to storm water which causes fine particles, suspended in the storm water, to flocculate and settle out. (45)	*Alum injection is an experimental practice. (45) *In addition to maintenance, alum injection requires ongoing operation. (45) *Alum injection cannot control storm water flows. (45) *Chemicals added during the alum injection process may have negative impacts on downstream waters. (45) *The precipitates produced from the alum treatment increase the solids that must be disposed of. (45)	Alum injection is a effective method to remove suspended particles in the storm water that may be difficult to remove via other methods.	TSS-95-99% removal (46) TP-85-95% removal (46) -37% removal (47) Ortho-Phos-90-95% (46) -42% (47) TN-60-70% (46) -52.2% (47) Fecal Coliform-99% (46) Heavy Metals-50-90% (46) Zinc-41% (47) Ammonia-(24.5)	$135,000 to $400,000 (45)	$6,500 to $25,000 per year
Green Parking-Green parking refers to several techniques applied together to reduce the impervious area. Green parking techniques limit the number of parking spaces, limit the dimensions of those spaces, utilize alternative pavers in overflow areas. Bioretention areas treat the runoff. (45)	The primary limitations include the applicability, cost, and maintenance of green parking. (45)	The benefits include the reduction of imperviousness and treatment of storm water. (45)	Bioretention is the primary method of removing pollutants in the grassed parking system. Bioretention removal rates are discussed previously in this table.	No Information	No Information

Nationwide Examples of Source Control (Non-Structural) Best Management Practices (BMPs)

Source Control (5)	Benefit (5)	Capital Cost (5)	O & M Cost (5)
Minimizing Effects from Highway Deicing			
Public Education (billing inserts, news releases, radio announcements, school programs)	*Can reduce improper disposal of paints and chemicals.	$200,000/yr (1992)	$257,000/yr (1992)
Employee Training – teaches employees about storm water management, potential sources of contaminants, and BMPs. (43)	*Low cost and easy to implement storm water management BMPs. (43)		
Litter Control	*Reduce potential clogging. *Proper disposal of paper, plastic and glass.	$20 per trash cans (1992)	$16/acre/yr (1992)
Recycling Program	*Reduction in potential clogging and harmful discharge.	$200,000/yr	$350,000 per 300,000 people
"No Littering" Ordinance	*Prevents litter from enter storm drain.	$20,000	potential self supporting
Identify and Prohibit Illegal or Illicit discharge to Storm Drain	*Halt hazardous and harmful discharge.	$2/acre (assumes 1 system monitored every 5 sq. miles)	$50/acre/yr (assumes TV inspection) $0.83/acre/yr
Street Sweeping – Two types of street sweepers are available for removal of solids from highway surfaces. The commonly used design is a mechanical street cleaner that combines a rotating gutter broom with a large cylindrical broom to carry the material onto a conveyor belt and into a hopper. The vacuum assisted sweepers, found to potentially remove more fine particles from the impervious surface, are impracticable due to their slow speed in highway maintenance operations. (42)	*Reduction in potential clogging storm drain material. *Some oil and grease control.	N/A	
Sidewalk Cleaning	*Reduction of material entering storm drain.	N/A	$60/acre/yr
Clean and Maintain Storm Drain Channels	*prevent erosion in channel. *improve capacity by removing sedimentation. *remove debris toxic to wildlife.	N/A	$21/acre/yr
Clean and Maintain Storm Inlet and Catch Basins - Inlets, catch basins, and manholes are to be periodically inspected and cleaned out using a vacuum truck. (42)	*removes sedimentation. *may prevent local flooding.	N/A	$21/acre/yr

Snow and Ice Control Operations - Snow control operations consist of removing accumulated snow from the traveled way, shoulders, widened areas and public highway approaches within the right-of-way. (42)	*Removes snow/ice before it requires ice control operations. (42)		
Clean and Inspect Debris Basin	*flood control. *proper drainage and prevent flooding.	N/A	$21/acre/yr
Spill Response and Prevention Plan (46)	*can be highly effective at reducing the risk of surface and ground water contamination. (46)	No Information	No Information
Used Oil Recycling Program (46)	*reduces the risk of groundwater and surface water contamination, but can become hazardous waste if mixed with other materials. (46)	N/A	Recovery service charge $79-$179 (46)
Materials Management Plan (46)	*Identifies hazardous and non-hazardous materials in the facility. (46) *Assures that all containers have labels. (46) *Identifies hazardous chemicals that require special handling, storage, and disposal (46)	No Information	No Information
BMP Inspection and Maintenance Plan (46)	*A regular inspection and maintenance program will maintain the effectiveness and structural integrity of the BMPs. (46)	N/A	$150-$9,000 depending on the BMP.
Storm Drain Stenciling (46)	*Educates the general public that the storm drain discharges into a natural waterbody. (46)	Mylar Stencils-$0.45 per lineal inch (46) Ceramic tiles $5-$6 each (46) Metal stencils-$100 or more (46)	No Information
Green Parking (46)	*Promotes infiltration and filtering of Stormwater. (46)	No Information	No Information
Alum Injection (46)	*Alum injected into stormwater forms precipitates that combine with heavy metals and phosphorus creating a floc. The floc is inert and stable. (46)	Cost ranges from $135,000 to $400,000 depending on the size of the watershed. (46)	$6,500 to $25,000 (46)

1. Camp Dresser & McKee, et al. 1993. *California Storm Water Best Management Handbook.* Prepared for Storm Water Quality Task Force. 4-8:4-77, 5-3:5-69.
2. Scheuler, Thomas R. 1987. *Controlling Urban Runoff: A Practice Manual for Planning and Designing Urban* BMP's. Prepared for Washington Metropolitan Water Resources Board. 2.11:2.14, 5.1:7.25.
3. Pitt, R. et al. "The Use of Special Inlet Devices, Filter Media, and Filter Fabrics for the Treatment of Storm Water." 9pp.
4. Eisenberg, Olivieri & Associates. 1996. *Guidance for Monitoring the Effectiveness of Storm Water Treatment Best Management Practices*. Prepared for the Bay Area Storm Water management Agencies Association. 5-6:5-7.
5. JMM. 1992 *A Study of Nationwide Costs to Implement Municipal Storm Water Best Management Practices*. Prepared for the Water Resources Committee American Public Works Association Southern California Chapter. 4-3:4-14.
6. Maine Department of Environmental Protection. *Environmental management: A Guide for the Town Officials*. 16, 27.
7. Denver regional Council of Government. *Nonpoint Source Demonstration Project*. 7:14.
8. Environmental Protection Agency, 1990. *Urban Targeting and BMP Selection*. 25:31.
9. Strecker, Eric W. 1993. *Assessment of Storm Drain Sources of Contaminants to Santa Monica Bay*. 21:28, 32.
10. Metropolitan Washington Council of Governments. 1992. *A Current Assessment of Urban Best management practices*. 7:13, 23:29, 55:69, 105:109.
11. Unocal. "More Down to Earth Talk from Unocal - Best Management Practices."
12. The Fertilizer Institute. 1985. Symposium: "Plant Nutrients Use and the Environment."
13. The Fertilizer Institute. 1988. *Best Management Practices*.
14. 1994. *Report of the Technical Advisory Committee for Plant Nutrient Management*. 17:18.
15. Virginia State Water Control Board Planning Bulletin 321. 1979. *Best Management Practices Handbook: Urban*. III-1:III-9, III-45:III-48, III-63:III-69, III-163:III-229.
16. California Department of Transportation Environmental Program. 1997. *Statewide Storm Water Management Plan*. B-14:B-53, C-1:C-22.
17. Caltrans Compost Storm Water Filters (CFSs), Bonita Canyon & North Hollywood Maintenance Yard. 1998. Table 9-15.
18. Minton, Gary R. "Storm Water Treatment by Media Filter." Dec. 11-12, 1997.
19. Ventura Countywide Storm Water Quality Management Program. "Draft Land Development Guidelines."
20. Environmental Protection Agency. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*.
21. Caltrans. Storm Water Program. *BMP Retrofit Pilot Studies, Technical Information*. 1999.
22. Caltrans. *Compost Storm Water Filters (CSFs), Bonita Canyon & North Hollywood Maintenance Yard 1997/1998 Wet Season, Post Sampling Summary Report*. 1998.
23. Environmental Protection Agency. 1999. *Infiltration Trench.* EPA 832-F-99-019.
24. Flan, Daryl R. and Himat Solanki. "Removal Efficiencies of Stormwater Control Structures."
25. Environmental Protection Agency. 1999. *Hydrodynamic Separators.* EPA 832-F-99-017.
26. Environmental Protection Agency. 1999. *Storm Water Wetlands.* EPA 832-F-99-025.

27. Environmental Protection Agency. 1999. *Wet Detention Ponds.* EPA 832-F-99-048.
28. Environmental Protection Agency. 1999. *Infiltration Drainfields.* EPA 832-F-99-018.
29. Environmental Protection Agency. 1999. *Vegetated Swales.* EPA 832-F-99-006.
30. Environmental Protection Agency. 1999. *Sand Filters.* EPA 832-F-99-007.
31. Environmental Protection Agency. 1999. *Water Quality Inlets.* EPA 832-F-99-029.
32. Environmental Protection Agency. 1999. *Modular Treatment Systems.* EPA 832-F-99-044.
33. Environmental Protection Agency. 1999. *Bioretention.* EPA 832-F-99-012.
34. Stenstrom, Michael K. and Sim-Lin Lau. "Oil and Grease Removal by Floating Sorbents in a CDS Device." University of California, Los Angeles, 1998.
35. Stormceptor Performance Testing Results. http://www.stormceptor.com/monitor.html
36. Westmount Shopping Centre and Conventry University Testing Results.
37. Caltrans. Highway Design Manual. *Chapter 890 – Storm Water Management*. Table 892.3.1999.
38. Allen, Vaikko P. Results from the Vortechs Stormwater Treatment System Monitoring Program at Del-Orme Publishing Company, Yarmouth, Maine. 1998.
39. Environmental Protection Agency and American Society of Civil Engineers. National Stormwater Best Management Practices (BMP) Database. Version 1.0, June 1999.
40. Lau, Sim-Lin and Michael K. Strenstrom. "Catch Basin Inserts to Reduce Pollution from Stormwater." Comprehensive Stormwater and Aquatic Ecosystem Management Conference, Auckland, NZ, February 22-26, 1999.
41. Petro-Marine Co. Curb Inlet Drain Diaper Insert. Contact Ronald Isaacson. 28 Buckley Road, Marlboro, NJ 07746.
42. Best Management Technologies Brochure. Contact Rod Butler. 23 Balwin Ave, Crockett, CA 94525.
43. Washington State Department of Transportation. Highway Runoff Manual. February 1995.
44. Environmental Protection Agency. 1999. *Employee Training.* EPA 832-F-99-010.
45. Caltrans. El Toro Detention Basin Storm Water Monitoring 1997/1998 Wet Season, Post Sampling Summary Report. 1998.
46. Environmental Protection Agency. 2002. www.epa.gov/npdes/menuofbmps/index.htm

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Los Angeles Area														
Bio Strip - are broad surfaces with a full grass cover that allows storm water to flow in a relatively thin sheets.	Altadena Maint Station	$218,000	1.7	1.0	1.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC1, REC2
Infiltration Trench -a trench is a depression used to treat small drainage areas by detaining storm water for short periods until it percolates to the groundwater table.	Altadena Maint Station	(built w/ bio strip)	1.7	1.0	1.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC1, REC2
Bio Strip	I-605/SR91	$193,000	0.5	1.0	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Bio Swale - are vegetated conveyance channels (typically trapezoidal shaped) wheere storm water flow passes through the grass at a specific depth.	I-605/SR91	(built w/ bio strip)	0.2	1.0	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR
Bio Swale	Cerritos Maint Station	$59,000	0.4	1.0	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR
Bio Swale	I-5/I-605	$97,000	0.7	1.0	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR
Bio Swale	I-605/Del Amo Ave	$124,000	0.7	1.0	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Infiltration Basin - a basin is a depression used to treat larger drainage areas by detaining storm water for short periods until it percolates to the groundwater table.	I-605/SR91	$273,000	4.2	1.0	0.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR
Drain Inlet Insert (stream guard)(a) - sock type inserts that allow collected water to filter through the geotextile fabric.	Las Flores Maint Station	$88,000	0.2	1.0	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD
Drain Inlet Insert (fossil filter) - trough type inserts filled with granular amorphous alumina silicate media.	Las Flores Maint Station	(built w/ DII (a))	0.8	1.0	0.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD
Drain Inlet Insert (stream guard)(a)	Rosemead Maint Station	$65,000	0.3	1.0	0.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, GWR, REC1, REC2, WARM
Drain Inlet Insert (fossil filter)	Rosemead Maint Station	(built w/ DII (a))	1.2	1.0	0.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, GWR, REC1, REC2, WARM

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Drain Inlet Insert (stream guard)(a)	Foothill Maint Station	$68,000	0.2	1.0	0.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, GWR, MUN, REC1, REC2, WARM
Drain Inlet Insert (fossil filter)	Foothill Maint Station	(built w/ DII (a))	1.6	1.0	0.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, GWR, MUN, REC1, REC2, WARM
Extended Detention Basin* - is a depression lined with either vegetated soils or concrete.	I-5/I-605 Intersection	$142,000	6.8	1.0	5.3	1998-1999	2	-89 to -71	-84 to 23	N/A	N/A	-84 to -81	-83 to -92	RARE, REC1, REC2, SPWN, WILD, GWR
Extended Detention Basin*	I-605/SR91 Intersection	$137,000	0.8	1.0	1.2	1998-1999	3	-86 to -58	-54 to 2	N/A	N/A	15 to 222	-8 to 339	RARE, REC1, REC2, SPWN, WILD, GWR

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Media Filter* - designed removes fine sediment and particulate pollutants through two concrete lined vaults (sedimentation vault and filtering vault). Three filter types 1) Austin - open topped, 2) Delaware - closed topped, 3) canister - uses pearlite/zeolite media.	Eastern Reg. Maint Sta	$341,000	1.5	1.0	1.9	1998-1999	1	-34	112	N/A	N/A	10	108	WILD, GWR, REC2, WARM
Media Filter*	Foothill Maint Station	$479,000	1.8	1.0	3.0	1998-1999	2	-42 to –34	285 to 289	N/A	N/A	-7 to 83	42 to 140	WILD, GWR, MUN, REC1, REC2, WARM
Media Filter	Termination Park & Ride	$450,000	2.8	1.0	3.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR
Media Filter	Paxton Park & Ride	$331,000	1.3	1.0	1.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	GWR, REC2

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Multi-Chambered Treatment Train - Three chamber mechanism 1) catch basin, which functions primarily as a screening process, 2) settling chamber, which removes settleable solids with plate separators and sorption pads, 3) media filter, which uses a combination of sorption (through layers of sand and peat covered by filter material) and ion exchange.	Via Verde Park & Ride	$375,000	1.1	1.0	1.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, WET, GWR, REC1, REC2, WARM
Multi-Chambered Treatment Train	Metro Maint Station	$893,000	4.6	1.0	6.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	GWR, REC1, REC2, WARM
Multi-Chambered Treatment Train	Lakewood Park & Ride	$456,000	1.9	1.0	2.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	RARE, REC1, REC2, SPWN, WILD, GWR

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Continuous Deflection Separator - a pre cast underground unit placed downstream of freeway drain inlets to capture sediment and debris. The unit creates a vortex of water that allows water to escape through screens, while contaminants are deflected into a sump, and later removed.	I-210/Orcas Ave	$62,000	1.1	1.0	0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, GWR, REC1, REC2, WARM
Continuous Deflection Separator	I-210/Filmore St	$63,000	2.5	1.0	0.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	WILD, GWR, REC1, REC2, WARM
Media Filter (compost)[2]	N. Hollywood Maint Sta	$40,000	3.0	0.7	1.0	1997-1998	5	-155	7	29	38 [4]	28 [4]	43	-
Media Filter (compost)[2]	Bonita Canyon		1.7	0.8	6.0	1997-1998	5	72	-172	-233	-1633	-320	-133	-
Extended Detention Basin [3]	El Toro		68	0.8	30.4	1997-1998	5	88	15	61	22	57	40	RARE, REC1, REC2, SPWN, WILD, GWR

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
San Diego Area														
Extended Detention Basin	I-5/Manchester (east)	$369,000	4.8	1.3	4.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC1, REC2, BIOL, EST, WILD, RARE, MAR, MIGR
Extended Detention Basin	I-5/SR56	$166,000	5.3	1.3	5.7	1998-1999	5	23 to 80	-100 to 64	-	-	-65 to 68	-84 to 43	BIOL, EST, MAR, MIGR, RARE, REC1, REC2, SHELL, WILD
Extended Detention Basin	I-15/SR78	$855,000	13.4	1.9	9.5	1998-1999	4	45 to 72	-240 to 58	-	-	-299 to -62	-101 to 19	AGR, COLD, MUN, REC1, REC2, WARM, WILD
Infiltration Basin	I-5/La Costa (west)	$241,000	3.2	1.3	3.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	BIOL, EST, MAR, MIGR, RARE, REC1, REC2, WARM

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Wet Basin - a basin consisting of a permanent pool of water surrounded by a variety of wetland plant species.	I-5/La Costa (east)	$694,000	4.2	1.3	2.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC1, REC2, BIOL, EST, WILD, RARE, MAR, MIGR
Media Filter (pearolite/zeolite)	Kearny Mesa Maint Sta	$340,000	1.5	0.9	2.7	1998-1999	3	-27 to 20	5 to 29	-	-	-115 to 46	5 to 32	REC2, WARM, WILD
Media Filter (sand type II)	Escondido Maint Station	$451,000	0.8	1.0	2.2	1998-1999	3	0 to 66	11 to 70	-	-	-23 to 70	56 to 84	MUN, AGR, REC1, REC2, WARM COLD, WILD
Media Filter (sand type I)	La Costa Park & Ride	$242,000	2.8	0.9	2.3	1998-1999	3	54 to 98	-98 to 4	-	-	-113 to 26	-28 to 38	BIOL, EST, AMR, MIGR, RARE, REC1, REC2, WARM
Media Filter (sand type I)	SR78/I-5 Park & Ride	$231,000	0.8	1.0	2.7	1998-1999	2	54	-313	-	-	-7 to 28	7 to 11	BIOL, MAR, RARE, REC1, REC2, WARM, WILD

Caltrans - Best Management Practices Pilot Studies [1]														
								Removal Efficiency %						
BMP Type	Site Location	Approximate Construction Cost	Drainage Area (acres)	Design Storm (in.)	Design Peak Flow (cfs)	Wet Season	Number of Storms	TSS	Nitrate	Nitrite	Dissolved Phosphorous	Total Phosphorus	TKN	Beneficial Uses
Bio Swale	SR78/Melrose Dr	$156,000	2.4	1.2	6.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	AGR, OMD, REC1, REC2, WARM, WILD
Bio Swale	I-5/Palomar Airport Rd	$142,000	2.3	N/A	3.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC2, WARM, WILD
Bio Strip	Carlsbad Maint Sta (west)	$196,000	0.7	N/A	1.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC2, WARM, WILD
Infiltration Trench/Strip	Carlsbad Maint Sta (east)	(built w/ bio strip)	1.7	1.3	2.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	REC2, WARM, WILD

1. Caltrans. BMP Retrofit Pilot Studies: Technical Information. 1999. This information is preliminary and will be verified later.
2. Caltrans. Compost Storm Water Filters (CSFs), Bonita Canyon & North Hollywood Maintenance Yard, Storm Water Monitoring. 1998.[3.] Caltrans. El Toro Detention Basin, Storm Water Monitoring. 1998.
4. Dissolved Phosphorus higher than Total Phosphorus concentrations, due to results from storm 4. Without storm 4, efficiencies are -36% for dissolved phosphorus and 7% for total phosphorus.
N/A - Not Available at this time. * Preliminary Information.

APPENDIX B

MDOT APPROVED BMPS

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Infiltration - a family of treatment systems in which the majority of the runoff from small storms is infiltrated in the ground rather than discharged into a surface water body. (1)					
Infiltration Trench - is an excavated trench (3 to 12 feet deep), backfilled with stone aggregate, and lined with filter fabric. (23) It is used to treat a small portion of the runoff by detaining storm water for short periods until it percolates down to the groundwater table. (21) Useful life is usually around 10 years. (20)	*potential loss of infiltrative capacity. (1) *applicability depends on specific site characteristics/opportunities (slope, soil types, proximity to water table). (23) *potential groundwater contamination. (1) *not suitable for sites that contain chemical or hazardous material. (23) *may need to be preceded by appropriate pretreatment. (23) *relatively short life span. (23)	*efficient removal of pollutants. (1) *can recharge groundwater supplies. (2) *provides localized streambank erosion control. (2) *easy to fit into unutilized areas of development sites. (2) *an effective runoff control. (1) *increases baseflow in nearby streams. (23) *Low land use requirement. (20)	* nitrogen compounds 40% to 80%. (2) * phosphorus compounds 40% to 80%. (2) * combined nitrogen and phosphorus compounds 45% to 75% (depending on design). (8) * total suspended solids 75%. (20) *total phosphorous 60%. (20) * total nitrogen 55%. (20) *COD 65%. (20) * Lead 65%. (20) * Zinc 65%. (20)	* $4,900/acre (prorated using ENR index from 1992 cost). (5) * $3.6 to $10.70/cubic feet storage (prorated using ENR index from 1986 cost). (20)	* $1,800/acre/year (prorated using ENR index from 1992 cost). (5) * 9% of Capital Cost (20)
Pond (Basin) - consist of shallow, flat basins excavated in pervious ground, with inlet and outlet structures to regulate flow. (19) Useful Life is usually around 25-years. (20)	*potential loss of infiltrative capacity. (1) *low removal of dissolved pollutants in very coarse soils. (1) *possible nuisance (odor, mosquito). (2) *frequent maintenance requirement. (2) *risk of groundwater contamination. (1) * High land use requirement. (20)	*achieves high levels of particulate pollutant removal. (1) * can recharge groundwater supplies. (2) *an effective runoff control. (1) *can serve tributary areas up to 50 acres. (1) *provides localized streambank erosion control. (2) *cost effective. (2)	* nitrogen compounds 40% to 80%. (2) * phosphorus compounds 40% to 80%. (2) * combined nitrogen and phosphorus compounds 45% to 75% (depending on design). (8) * total suspended solids 75%. (20) *total phosphorous 65%. (20) * total nitrogen 60%. (20) *COD 65%. (20) * Lead 65%. (20) * Zinc 65%. (20)	* $36,900/million gallons (prorated using ENR index from 1992 cost). (5) * $0.60 to $1/cubic feet storage (prorated using ENR index from 1986 cost). (20)	* $1,200/million gallons/year (prorated using ENR index from 1992 cost). (5) * 7% of Capital Cost (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Concrete Grid Pavement – are lattice grid structures with grassed or pervious material placed in the grid openings. (1) Useful life is usually around 20 years. (20)	*require regular maintenance. (20) *not suitable for high traffic areas. (20) *potential groundwater contamination. (20) *only feasible where soil is permeable. (20)	*groundwater recharge. (20) *can provide peak flow control. (20)	*total nitrogen 90%. (20) * total phosphorus compounds 90%. (20) * total suspended solids 90%. (20) *COD 90%. (20) * Lead 90%. (20) * Zinc 90%. (20)	* \$1.7 - \$3.5/ft^2 (prorated using ENR index from 1981 cost) (incremental cost beyond the conventional asphalt pavement) (20)	* -\$0.07/ft^2 feet (prorated using ENR index from 1981 cost) (incremental cost beyond the conventional asphalt pavement) (20)
Infiltration Drainfields – a system composed of a pretreatment structure, a manifold system, and a drainfield. (28)	*high maintenance when sediment loads are heavy. (28) *short life span if not well maintained. (28) *not suitable in regions with clay or silty soils. (28) *anaerobic conditions could clog the soil. (28) *potential groundwater contamination. (28)	*groundwater recharge. (28) *used to control runoff. (28)	* depends on design – little monitoring data currently available. Potentially 100% of pollutant could be prevented from entering surface water. (28)	Approx. \$72,000 for a drainfield with dimensions: 100 ft long, 50 feet wide, 8 feet deep with 4 ft cover. (28)	
Wetlands - constructed wetlands are a single stage treatment system consisting of a forebay and micro pool with aquatic plants. They remove high levels of particulate, as well as some dissolved contaminants. (19) Useful life is around 50 years. (20)	*need of supplemental water to maintain water level. (1) *potential nutrient release in the winter. (19) *reduction in hydraulic capacity with plant growth. (19) *wetland area less than 2% of watershed area. (10) *potential groundwater contamination. (26) * high land requirements. (20)	*passive recreation and wildlife support. (1) *improve downstream water and habitat quality. (26) *flood attenuation. (26) *achieves high levels pollutant removal. (1)	* total suspended solids 67% (26) & 65% (20). * total phosphorus 49% (26) & 25% (20). * total nitrogen 28% (26) & 20% (20). * organic carbon 34%. (26) * COD 50%. (20) * petroleum hydrocarbons 87%. (26) * cadmium 36%. (26) * copper 41%. (26) * lead 62% (26) & 65% (20). * zinc 45% (26) & 35% (20). * bacteria 77%. (26)	\$26,000 to \$55,000 per acre of wetland. (26)	2 percent of construction cost per year. (26)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Biofilters - Systems designed to pass storm water runoff slowly over a vegetated surface in the form of a swale or strip to filter pollutants and to infiltrate the runoff. (19)					
Vegetated Swale – is a broad, shallow channel (typically trapezoidal shaped) with a dense stand of vegetation covering the side slopes and bottom. (29) Useful life is around 50 years. (20)	*generally incapable of removing nutrients. (2) *can become drowning hazards, mosquito breeding areas. (29) *not appropriate for steep topography, very flat grades. (29) *tributary area limited to a maximum of 5 acres. (19) *difficult to avoid channelization. (19) *ineffective in large storms due to high velocity flows. (29)	*design to convey runoff of 2 year storm, with freeboard of 10 year storm. (19) * low land requirement. (20) *suitable for small residential areas. (1) *can removes particulate pollutants at rates similar to wet ponds. (1) *reduction of peak flows. (29) *lower capital cost. (29) *promotion of runoff infiltration. (29) * low land requirements. (20)	* nitrogen 0 to 60% (2) * total nitrogen 10%. (20) * phosphorus 0 to 60% (2) * total phosphorus 9% (29) & 20% (20). * COD 25%. (20) * oxygen demanding substances 67%. (29) * total suspended solids 81% (29) & 60% (20). * nitrate 38%. (29) * hydrocarbons 62%. (29) * cadmium 42%. (29) * lead 67% (29) & 70% (20). * zinc 71% (29) & 60% (20). * copper 51%. (29)	* $6.80 to $12.50 per linear foot (prorated using ENR index from 1987 cost). (29) * $10.80 to $63.40 per linear foot (prorated using ENR index from 1991 cost). (29) * typical total for a 1.5 ft. deep, 10 ft wide, 1,000 ft long Low - $8,100 Moderate - $14,870 High - $21,640 Prorated using ENR index from 1991 cost). (29)	* $0.73 - $0.95 per linear foot (prorated using ENR index from 1991 cost). (29) * $1/linear foot 9prorated using ENR index from 1987 cost). (20)
Infiltration (Vegetative Filter) Strip - are broad surfaces with a full grass cover that allows storm water to flow in a relatively thin sheets (21) Useful life is around 50 years (20).	*sheet flow may be difficult to attain. (1) *not appropriate for steep slopes. (19) *tributary area limited to 5 acres. (19)	*suitable for parking lots. (1) *slows runoff flow. (1) *removes particulate pollutants. (1)	* nitrogen 0 to 40%. (2) * phosphorus 0 to 40%. (2) * total suspended solids 65%. (20) * total phosphorous 40%. (20) * total nitrogen 40%. (20) * COD 40%. (20) * lead 45%. (20) * zinc 60%. (20)	* $3,100/acre (prorated using ENR index from 1992 cost). (5)	* $310/acre/yr (prorated using ENR index from 1992 cost). (5) * $139 to $1,100/acre/year (prorated using ENR index from 1987 cost). (20)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Dry Detention Basins - consist of a settling basin with an outlet sized to remove particulate matter by slowly releasing accumulated runoff over a 24 to 40 hour period. "Dry" detention basins may be designed to empty between usages. (19) Useful life is usually 50 years. (20)	*occasional nuisance in inundated portion. (19) *inability to vegetation may result in erosion and re-suspension. (1) *limited orifice diameter preclude use in small watersheds. (1) *requires differential in elevation at inlet and outlet. (1) *frequent sediment maintenance. (19) * High land requirement. (20)	*creation of local wildlife habitat. (2) *recreational use in inundated portion. (2) *can remove soluble nutrients by shallow marsh or permanent pool. (2) *suitable for sites over 10 acres. (10) *temporary storage of runoff. (1) *no need of supplemental water. (1) *protection for downstream channel erosion. (2)	* nitrogen 20% to 60%. (2) * phosphorus 20% to 80% (2) & 10% to 30%. (10) * nitrogen and phosphorus 30% to 70% (depending on volume ratio). (8) * soluble nutrients – low or negative. (10) * total suspended solids 45% (20) & 88% (44). * nitrate 15% (44). * nitrite 61% (44). * oil and grease 56%. (44) * fecal coliform 45%. (44) total petroleum hydrocarbons 17% to 20%. (44) * TKN 40%. (44) * ammonia 5%. (440 *total phosphorous 25% (20) & 57% (44). * total nitrogen 30%. (20) *COD 20% (20) & (44). * lead 20% (20) & 55% (44). * zinc 20% (20) & 47% (44). * chromium 68%. (44) * copper 37%. (44) * nickel 62%. (44)	$123,000/million gallons (prorated using ENR index from 1992 cost). (5)	* $1,230/million gallons/year (prorated using ENR index from 1992 cost). (5) * 4% of capital cost. (20)
Catch Basin Inlet Devices - devices that are inserted into storm drain inlets to filter or absorb sediment, pollutants, and oil and grease (21)	* not feasible for larger than 5 acres. (20)	* high removal efficiency for large particles and debris for pretreatment. (20) * low land requirement. (20) * flexibility for retrofit of existing systems. (20)			

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Curb Inlet Drain Diaper Insert – sorbent type diaper placed at the catch basin insert. (40)				$125 per unit. (40)	
Some Examples of Temporary Erosion and Sediment Control BMPs – (typically used during construction activity)					

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Temporary Seeding of Stripped Areas - The establishment of a temporary vegetative cover on disturbed areas by seeding with rapidly growing plants. This provides temporary soil stabilization to areas which would remain bare for more than seven days where permanent cover is not necessary or appropriate. (42)	*Temporary seeding is only viable when there is a sufficient window in time for plants to grow and establish cover. During the establishment period the bare soil should be protected with mulch and/or plastic covering. (42) *If sown on subsoil, growth may be poor unless heavily fertilized and limed Because over-fertilization can cause pollution of stormwater runoff, other practices such as mulching alone may be more appropriate. The potential for over-fertilization is an even worse problem in or near aquatic systems. (42) *Once seeded, areas cannot be used for heavy traffic. (42) *May require regular irrigation to flourish. Regular irrigation is not encouraged because of the expense and the potential for erosion in areas that are not regularly inspected. The use of low maintenance native species should be encouraged, and planting should be timed to minimize the need for irrigation. (42)	*This is a relatively inexpensive form of erosion control but should only be used on sites awaiting permanent planting or grading. Those sites should have permanent measures used. (42) *Vegetation will not only prevent erosion from occurring, but will also trap sediment in runoff from other parts of the site. (42) *Temporary seeding offers fairly rapid protection to exposed areas. (42)			

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Mulching and Matting - Application of plant residues or other suitable materials to the soil surface. This provides immediate protection to exposed soils during the period of short construction delays, or over winter months through the application of plant residues, or other suitable materials, to exposed soil areas. Mulches also enhance plant establishment by conserving moisture and moderating soil temperatures. Mulch helps hold fertilizer, seed, and topsoil in place in the presence of wind, rain, and runoff and maintains moisture near the soil surface. (42)	*Care must be taken to apply mulch at the specified thickness, and on steep slopes mulch must be supplemented with netting. (42) *Thick mulches can reduce the soil temperature, delaying seed germination. (42)	*Mulching offers instant protection to exposed areas. (42) *Mulches conserve moisture and reduce the need for irrigation. (42) *Neither mulching nor matting require removal; seeds can grow through them unlike plastic coverings. (42)			
Spill Response and Prevention Plan (46)	*Requires a well-planned and clearly defined plan. *May require training *Equipment must be readily available. (46)	*can be highly effective at reducing the risk of surface and ground water contamination. (46)	N/A	No Information	No Information
Used Oil Recycling Program (46)	*Oil may easily become contaminated during collection making it a hazardous waste. (46)	*reduces the risk of groundwater and surface water contamination, but can become hazardous waste if mixed with other materials. (46)	N/A	N/A	Recovery service charge $79-$179 (46)
Materials Management Plan (46)	No Information	*Identifies hazardous and non-hazardous materials in the facility. (46) *Assures that all containers have labels. (46) *Identifies hazardous chemicals that require special handling, storage, and disposal (46)	N/A	No Information	No Information

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
BMP Inspection and Maintenance Plan (46)	Materials needed for emergency structural repairs may not be easily obtainable and may require stockpiling. (46)	*A regular inspection and maintenance program will maintain the effectiveness and structural integrity of the BMPs. (46)		N/A	$150-$9,000 depending on the BMP. (46)
Storm Drain Stenciling (46)	*Paint will weather away a short period of time and decals may need replaced if vandalized or improperly installed. (46)	*Educates the general public that the storm drain discharges into a natural waterbody. (46)	N/A	Mylar Stencils- $0.45 per lineal inch (46) Ceramic tiles $5-$6 each (46) Metal stencils- $100 or more (46)	No Information
Green Parking (46) This BMP will be experimental for MDOT until it is proven valuable and cost effective.	*Applicability(46) *Cost *Maintenance	*Promotes infiltration and filtering of Stormwater. (46)	N/A	No Information	No Information
Alum Injection (46) This BMP will be experimental for MDOT until it is proven valuable and cost effective.	*Experimental practice(46) *Involves on-going operation in addition to maintenance(46) *Does not control flows(46) *Chemicals may have negative impacts downstream(46) *Precipitates must be disposed of. (46)	*Alum injected into stormwater forms precipitates that combine with heavy metals and phosphorus creating a floc. The floc is inert and stable. (46)	Removal efficiency varies greatly by study and pollutant. The removal efficiency is uncertain at this time. (46)	Cost ranges from $135,000 to $400,000 depending on the size of the watershed. (46)	$6,500 to $25,000 (46)

Nationwide Examples of Treatment Control (Structural) Best Management Practices (BMPs)					
Treatment Control (Source)	Limitations	Benefits	Removal Efficiency	Capital Cost (approximate)	O & M Cost (approximate)
Plastic Covering - The covering with plastic sheeting of bare areas, which need immediate protection from erosion. This provides immediate temporary erosion protection to slopes and disturbed areas that cannot be covered by mulching, in particular during the specified seeding periods. Plastic is also used to protect disturbed areas, which must be covered during short periods of inactivity to meet November 1 to March 31 cover requirements. Because of many disadvantages, plastic covering is the least preferred covering BMP. (42)	*There can be problems with vandals and maintenance. (42) *The sheeting will result in rapid, 100 percent runoff, which may cause serious erosion problems and/or flooding at the base of slopes unless the runoff is properly intercepted and safely conveyed by a collecting drain. This is strictly a temporary measure, so permanent stabilization is still required. *The plastic may blow away if it is not adequately overlapped and anchored. (42) *Ultraviolet light can cause some types of plastic to become brittle and easily torn. (42) *Plastic must be disposed of at a landfill; it is not easily degradable in the environment. (42)	*Plastic covering is a good method of protecting bare areas, which need immediate cover and for winter plantings. (42) *May be relatively quickly and easily placed. (42)			

Nationwide Examples of Source Control (Non-Structural) Best Management Practices (BMPs)

Source Control (5)	Benefit (5)	Capital Cost (5)	O & M Cost (5)
Minimizing Effects from Highway Deicing			
Employee Training – teaches employees about storm water management, potential sources of contaminants, and BMPs. (43)	*low cost and easy to implement storm water management BMPs. (43)		
Litter Control	*Reduce potential clogging. *proper disposal of paper, plastic and glass.	$20 per trash cans (1992)	$16/acre/yr (1992)
Identify and Prohibit Illegal or Illicit discharge to Storm Drain	*halt hazardous and harmful discharge.	$2/acre (assumes 1 system monitored every 5 sq. miles)	$50/acre/yr (assumes TV inspection)
Street Sweeping - Two types of street sweepers are available for removal of solids from highway surfaces. The commonly used design is a mechanical street cleaner that combines a rotating gutter broom with a large cylindrical broom to carry the material onto a conveyor belt and into a hopper. The vacuum assisted sweepers, found to potentially remove more fine particles from the impervious surface, are impracticable due to their slow speed in highway maintenance operations. (42)	*reduction in potential clogging storm drain material. *some oil and grease control.	N/A	$0.83/acre/yr
Clean and Maintain Storm Drain Channels	*prevent erosion in channel. *improve capacity by removing sedimentation. *remove debris toxic to wildlife.	N/A	$21/acre/yr
Clean and Maintain Storm Inlet and Catch Basins - Inlets, catch basins, and manholes are to be periodically inspected and cleaned out using a vacuum truck. (42)	*removes sedimentation. *may prevent local flooding.	N/A	$21/acre/yr

Snow and Ice Control Operations - Snow control operations consist of removing accumulated snow from the traveled way, shoulders, widened areas and public highway approaches within the right-of-way. (42)	*removes snow/ice before it requires ice control operations. (42)		