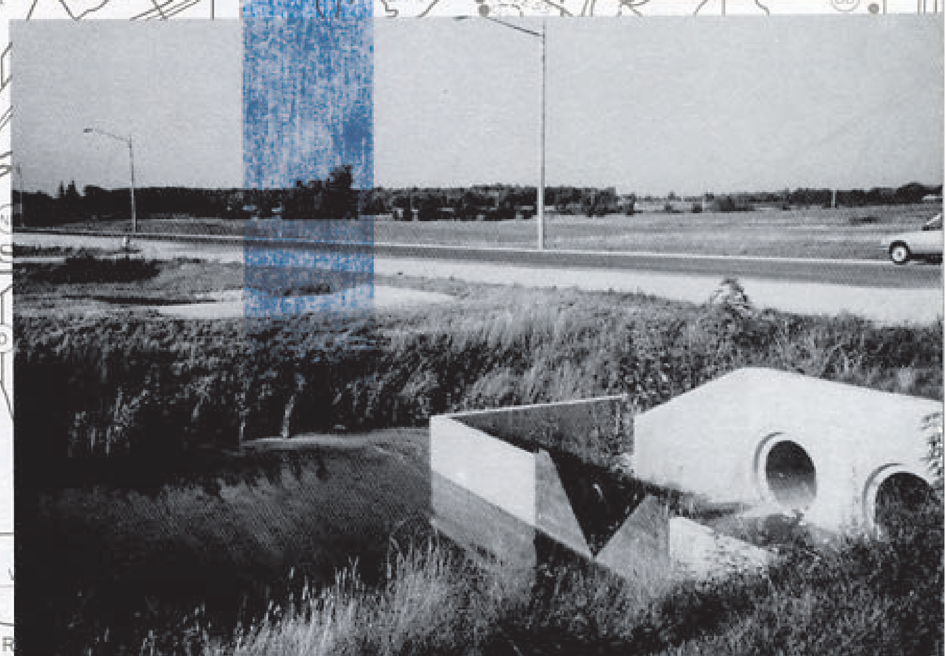
TECHNICAL REPORT NUMBER 31

COSTS OF URBAN NONPOINT SOURCE WATER POLLUTION CONTROL MEASURES



SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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Cover Photo Courtesy of University of Wisconsin-Extension.

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COSTS OF URBAN NONPOINT SOURCE WATER POLLUTION CONTROL MEASURES

Prepared by the

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SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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STATEMENT OF THE EXECUTIVE DIRECTOR

A need for improved information concerning the cost of controlling nonpoint sources of water pollution from both developing and developed urban land areas has been created by the shift which has occurred in urban stormwater runoff control strategy over the past decade. Historically, urban stormwater runoff was viewed as a problem requiring control of the peak rate of discharge of the runoff. Areawide water quality management plans developed in the 1970s for designated areas such as Southeastern Wisconsin identified urban runoff as a significant source of water pollution in urbanized or urbanizing watersheds. However, the measures which could be used to abate that source adequately were not at that time well understood and recommendations were made in the areawide water quality management plans for more detailed, second-level planning. Such second-level planning is now underway in portions of Southeastern Wisconsin and in the rest of the State. Much of this second-level planning is being conducted under the Nonpoint Source Water Pollution Abatement Program administered by the Wisconsin Department of Natural Resources.

The primary purpose of this report is to provide assistance in estimating the capital and annual operation and maintenance costs of urban nonpoint source water pollution control measures including: wet detention basins, infiltration trenches, infiltration basins, grassed swales, vegetated filter strips, porous pavement, catch basin cleaning, and street sweeping. Cost data are also presented for nine temporary construction erosion control measures: filter fabric fences, straw bale barriers, diversion swales, inlet protection devices, temporary seeding, mulching, sodding, sediment traps, and sedimentation basins.

The cost estimating procedures presented are appropriate for use in systems planning and preliminary engineering stages. The cost estimates can be readily modified to reflect known site conditions. The procedures and supporting data are not intended to be used in the final design stage, since local conditions and costs necessitate a very site-specific analysis at that stage.

It is the hope of the Commission staff that estimating procedures and supporting cost data presented in this report will be helpful to planners and engineers employed in both the public and private sectors in addressing the need for abatement of nonpoint sources of water pollution, and thereby protecting and enhancing the water quality of the lakes and streams of the Region.

Respectfully submitted,

Kurt W. Bauer
Executive Director

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INTRODUCTION

BACKGROUND

Government agencies, developers, and private landowners who implement urban nonpoint water pollution source control measures, including construction erosion control measures, will encounter costs for administration, planning and design, land acquisition, site preparation, site development, and operation and maintenance. The magnitude of these costs is dependent on a number of complex factors, including the local site conditions, type of control measure, existing and proposed future land uses, environmental considerations, public preferences, and degree of technical assistance available. Costs for these measures are often difficult to estimate because relatively few practices have been implemented in most urban areas and because the costs of those measures which have been installed have seldom been well documented.

The need for improved cost information concerning the control of nonpoint water pollution from both developing and developed urban land areas is emphasized by the shift which has occurred in urban runoff control strategy over the past decade. Historically, urban stormwater runoff was commonly viewed as a flooding and drainage problem. In the late 1970s, some areawide water quality management plans in designated areas such as southeastern Wisconsin identified urban runoff as a serious concern in urbanized or urbanizing watersheds.[1] However, the measures which could be used to reduce urban nonpoint pollution sources adequately were not at that time well understood and recommendations were set forth in those areawide plans for more detailed, second-level planning.

Research on the quality of urban runoff increased in the early 1980s, with much of the work conducted under the U. S. Environmental Protection Agency's Nationwide Urban Runoff Program.[2] This research enhanced the understanding of water quality-related urban runoff processes, helped to identify critical urban pollutants, and refined the then available quantitative estimates of the rates of pollutant loading from various land uses. Importantly, the research results helped quantify the water quality benefits of various nonpoint source control measures in urban areas. These results led, in turn, to the development of improved mathematical simulation models of urban runoff, such as the Illinois State Water Survey's <u>Illinois Urban Drainage Simulator-Quality</u> (ILLUDS-Q) and Wisconsin Department of Natural Resources' <u>Source Loading and Management Model</u> (SLAMM), which are capable of simulating pollutant loadings and the pollutant reduction benefits of various nonpoint source control measures.

Current urban runoff control strategy recognizes the need to address both the hydraulic and water quality impacts of urban development. The trend in controlling urban nonpoint sources of pollution is toward retaining or detaining urban stormwater runoff, where practical, at upstream locations. This strategy is based on the following water quality considerations, agreed on by most researchers to date:

1. Compared to other pollutant sources, developed urban land areas generally contribute higher loadings of metals and bacteria and more modest loadings of sediment, nutrients, and organic toxic contaminants. Construction site erosion, however, is a very high contributor of sediment loadings.

2. The most effective control measures in developed urban areas are generally those measures which utilize stormwater detention, retention, and infiltration. Street sweeping may be effective in removing pollutants from commercial and industrial

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[1] *SEWRPC Planning Report No. 30, <u>A Regional Water Quality Management Plan for Southeastern Wisconsin: 2000</u>, 1979.*

[2] *U. S. Environmental Protection Agency, <u>Results of the Nationwide Urban Runoff Program</u>, Vol. 1, <u>Final Report</u>, December 1983.*

land uses. Vegetative measures, such as filter strips, comprise an integral part of many urban measures. Properly designed conventional construction erosion control measures, such as temporary seeding, mulching, hay bales, silt fences, and sediment basins, can be effective in reducing the extremely high sediment loadings from construction activities.

3. Because many urban nonpoint source control measures either reduce the rate or the volume of runoff, or delay the arrival of runoff contributions at critical points downstream, it is essential that urban nonpoint source control measures be selected and designed, where practical, as part of a watershedwide stormwater management plan which addresses the impacts of both water quality and water quantity. Construction site erosion control measures, however, can be effectively carried out through the development and use of a construction erosion control ordinance and the handbook developed to implement the ordinance requirements.[3]

APPLICATION OF COSTS IN THE PLANNING PROCESS

The nonpoint source control measures presented in this report should not be indiscriminately installed wherever pollution sources are identified. Nonpoint source control measures in urban areas should be designed in the context of comprehensive stormwater management plans which address the complex relationships between hydrologic, hydraulic, and water quality-related factors. Special care must be taken to ensure that the selected nonpoint source control measures are compatible with the engineered stormwater drainage system facilities and capacities and also to avoid creating new drainage, flooding, or nuisance problems. Particular care must be taken in establishing property and street grades related to the stormwater management system so as to insure the development, over time, of an integrated system.

Urban nonpoint source control measures should be analyzed in the context of what may be regarded as a three-phase stormwater management planning process.

The first, or systems planning, phase concentrates on the definition and description of the drainage, flooding, and pollution problems to be addressed within a watershed and on the development and evaluation of alternative measures for resolution of those problems. Systems planning for resolving water pollution problems is intended to permit the selection of the most effective and desirable pollution control measures to resolve identified problems. With respect to nonpoint source pollution abatement, the systems level planning should be carried out in the context of comprehensive areawide plans for land use and the supporting public works systems. This ensures that the recommended measures for water quality problems will be compatible with, and properly reflect, land use, socioeconomic, and total environmental conditions and be compatible with other public works systems plans. A good example of a systems level plan is a stormwater management plan prepared for an entire subwatershed.[4] The degree of detail provided in system plans varies; some plans overlap the second, or preliminary engineering, phase of the planning process.

Implementation of a recommended systems-level plan requires that the technical, economic, environmental, and other features of specific facilities or measures recommended in the systems plan be reexamined in great depth and detail before implementation. The second, facilities planning or preliminary engineering, phase of the planning process begins where the systems planning phase ends and is properly

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[3] *League of Wisconsin Municipalities and Wisconsin Department of Natural Resources, Construction Site Erosion Control, Model Ordinance, January 1987, and Wisconsin Department of Natural Resources, Wisconsin Construction Site Best Management Practice Handbook, April 1989.*

[4] *Examples of systems level plans include SEWRPC Community Assistance Planning Report No. 173, A Stormwater Management Plan for the City of West Bend, Wisconsin, Vol. 1, Inventory Findings, Forecasts, Objectives, and Design Criteria, 1989, and Vol. 2, Alternatives and Recommended Plan for the Silver Creek Subwatershed, 1990; and Wisconsin Department of Natural Resources, The Oconomowoc River Priority Watershed Plan, 1986.*

carried out by the implementing units of government and the private property owners concerned. The preliminary engineering phase concentrates on the specific pollution control measures identified in the system-level stormwater management plan, and may involve the collection and analysis of more detailed data. This second phase, using more detailed site-specific data, determines the best way to implement each facility or measure recommended in the system plan. This preliminary engineering can be carried out for an individual component or for a logical set of selected components of the system plan, thus allowing implementation of the system plan incrementally over time. An example of a preliminary engineering analysis is the analysis of the location, size, preliminary design, and cost of a nonpoint source control measure, typically conducted, for budgetary purposes, by a municipal staff prior to preparing contract drawings and specifications. The preliminary engineering analysis frequently provides the basis for requesting proposals for final design from consultants

The third, or final design, phase is also carried out by the implementing units of government and the private property owners concerned. The final design phase consists of the development of the construction plans and specifications needed to implement the nonpoint source control measures concerned completely. The final design includes layout drawings, construction details, materials specifications, a schedule for construction, and logistical support arrangements. The final design serves as the basis for requesting bids from contractors to construct the desired control facilities or carry out the desired control measures.

The procedures of cost estimation set forth in this report are appropriate for the systems phase and the preliminary engineering phase of stormwater management planning. Using the procedures presented in this report, cost estimates can be modified to reflect known site conditions. However, these cost estimates are not intended to be used directly in the final, detailed design phase. Local labor and material costs and special design considerations require a more rigorous site-specific cost analysis in that final phase.

Unlike the other stormwater management measures, which are long-term and must be set in the context of land use and other public works systems, construction erosion control measures are ephemeral and site-specific. Thus, these construction erosion control measures are not normally analyzed in the three-phase stormwater management planning process. Rather, they are generally considered in the detailed design and construction phases of a development project. The cost estimating procedures reported in this report are appropriate for estimating the costs of construction erosion control plans prepared for a specific proposed subdivision or other major development project. More detailed cost estimates should be made by the contractors actually constructing the development.

SCOPE

The primary purpose of this report is to provide guidance for estimating the capital and annual operation and maintenance costs of urban nonpoint source control measures including: wet detention basins, infiltration trenches, infiltration basins, grassed swales, vegetated filter strips, porous pavement, catch basin cleaning, and street sweeping. Cost data are also presented for nine temporary construction erosion control measures: filter fabric fences, straw bale barriers, diversion swales, inlet protection devices, temporary seeding, mulching, sodding, sediment traps, and sedimentation basins.

Chapter II of this report describes the sources of information and general procedures for estimating the costs of the various pollution control measures. Chapter III describes the use and approximate pollutant removal effectiveness of the various urban nonpoint source control measures and presents cost data on each measure. The costs are apportioned by component, and a procedure for estimating the cost of each measure is presented. Chapter IV describes construction erosion control measures and attendant cost information and procedures for estimating costs of these measures. Chapter V, the final chapter, provides a summary of the report.

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Chapter II

COST ESTIMATING PROCEDURES

INTRODUCTION

The costs of urban nonpoint source and construction erosion control measures can vary substantially from one application to another. Costs are influenced by a number of complex factors, including site topography, soil conditions, rainfall characteristics, existing vegetative cover, time of year, type of construction equipment used, and governmental regulations. The cost estimating procedures presented in this report are based on typical unit costs. The validity of the unit cost approach, which is convenient and easy to apply, was improved by use of a statistical analysis of actual costs reported for several construction projects in Wisconsin.

Cost estimating procedures were developed for eight urban nonpoint source control measures: wet detention basins, infiltration trenches, infiltration basins, grassed swales, vegetated filter strips, porous pavement, catch basin cleaning, and street sweeping. Similar data are presented for nine temporary construction erosion control measures: filter fabric fences, straw bale barriers, diversion swales, inlet protection devices, temporary seeding, mulching, sodding, sediment traps, and sedimentation basins. Although many of these measures are in common use, some measures, such as porous pavement and infiltration trenches, have not been used extensively in Wisconsin to date.

PROCEDURES

To estimate the local costs of urban nonpoint source and construction erosion control measures, information was obtained from municipal, state, and federal governmental agencies, from private consulting firms, and from construction contractors operating in the State of Wisconsin as well as from a literature review. The information sources used to estimate unit construction costs are listed in Table 1.

Reported unit construction costs for each component or construction phase, such as vegetation clearing or soil excavation, were compiled and statistically analyzed to calculate the mean cost and the standard deviation.[1] The calculated mean unit construction costs and standard deviations are presented in Table 2. For certain components, primarily excavation, clearing, and grubbing, inordinately high reported unit costs were not used in the calculation of the means and standard deviations. Sites with severe limitations may entail high costs; such sites should be considered as unsuitable locations for nonpoint source control measures. Many such measures can readily fail if not carefully designed and suitably located. Where insufficient local cost data were available, the unit costs were estimated on the basis of data obtained for projects located outside the State of Wisconsin and on the basis of costs set forth in the literature.

The unit costs are used to calculate the total construction cost of installing various nonpoint source and erosion control measures. For each component, three unit construction costs are used in the cost calculation tables: a low, a moderate, and a high unit cost. The moderate cost is the statistical mean cost shown in Table 2, the low cost is the mean minus one standard deviation, and the high cost is the mean plus one standard deviation. Where appropriate, these unit costs were applied to various types or sizes of a control measure in order to help formulate a usable procedure to estimate the cost of the control measure.

When estimating the total capital cost of installing a nonpoint source or construction erosion control measure, the construction cost calculated by means of unit costs was increased by 25 percent to account for engineering, legal, and administrative fees and contingencies. The costs

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[1] *The standard deviation is a measure of the deviance of the data from the mean. A large deviance implies data with a high degree of variation. If the data are normally distributed, about 68.27 percent of the data will lie within (plus or minus) one standard deviation of the mean. Two standard deviations will include about 95.45 percent of the data, and three standard deviations will include 99.73 percent of the data.*

Table 1

SOURCES OF INFORMATION USED TO CALCULATE UNIT CONSTRUCTION COSTS

Information Source	Site Preparation	Site Development	Landscaping	Erosion Control	Street Sweeping and Catch Basin Cleaning
The Bruce Company of Wisconsin, Bid Tabulations and Plans for Grassman Greenway Improvement-Phase I, Madison, Wisconsin, March 1982	X	X	X	X	- -
City of Madison, Wisconsin, Bid Tabulations and Plans for Wexford Detention Project, June 1989	X	X	X	X	- -
City of Milwaukee, Wisconsin, Bureau of Budget and Management Analysis, Street and Alley Sweeping Utilization of Motorized Street Sweepers, May 1976	- -	- -	- -	- -	X
City of Milwaukee, Wisconsin, Bureau of Sanitation, Annual Report 1980	- -	- -	- -	- -	X
City of Milwaukee, Wisconsin, Bureau of Sanitation, Annual Report 1988	- -	- -	- -	- -	X
City of West Bend, Wisconsin, Contract Documents, Bid Tabulations and Plans for the Overall Industrial Park-South, Stormwater Management Facility, August 1986	X	X	X	X	- -
Crispell-Snyder, Inc., Bid Tabulations and Plans for:					
Meadowdale Farms, Pleasant Prairie, Wisconsin, February 1989	X	X	- -	X	- -
Detention Pond, Elkhorn, Wisconsin, July 1984	- -	X	- -	X	- -
Abbey Springs Detention Pond, Town of Walworth, Wisconsin, July 1985	- -	X	- -	- -	- -
Crispell-Snyder, Inc., Bid Tabulations and Plans for:					
Madsen & Lehner Detention Ponds, Mt. Pleasant, Wisconsin, September 1981	X	X	- -	X	- -
Westwood Estates, Mt. Pleasant, Wisconsin, June 1987	X	X	X	- -	- -
Denver Regional Council of Governments, Cost of Erosion Control Measures, May 1982	- -	- -	X	- -	- -
Donohue & Associates, Inc., Bid Tabulations for Lake Forest Stormwater Detention and Sedimentation Control, Town of Madison, Wisconsin, September 1981	X	X	X	- -	- -
Stormwater Management Feasibility Study for the City of Oconomowoc, April 1989	- -	X	X	- -	- -

Table 1 (continued)

Information Source	Site Preparation	Site Development	Landscaping	Erosion Control	Street Sweeping and Catch Basin Cleaning
Edgerton Contractors, Inc., Bid Tabulations for MMSD Bank Restoration on the Kinnickinnic River Downstream of S. 47th Street Extended, Milwaukee, Wisconsin, May 1988	- -	X	X	X	- -
Geo-Synthetics, Inc., Quotation Sheet for Erosion Blankets and Geotextile Fabric, August 1989	- -	- -	- -	X	- -
Goldman, Steven J., et al., Erosion and Sediment Control Handbook, 1986	- -	- -	- -	X	- -
Homburg-Olp Construction Company, Inc., Final Cost Sheet for the Swanton Greenway Improvement, Madison, Wisconsin, November 1982	X	X	X	X	- -
Howard Needles Tammen & Bergendoff, Final Cost Estimates for the MMSD Kinnickinnic River (South Branch) Improvements from S. 20th Street to S. 6th Street Milwaukee, Wisconsin, February 1988	X	X	X	X	- -
Mahoney, William D., ed., Means 1989 Building Construction Cost Data	X	X	X	X	- -
Marino Construction Company, Inc., Bid Tabulations for MMSD Bank Restoration on the Kinnickinnic River Downstream of S. 47th Street Extended Milwaukee, Wisconsin, April 1988	X	X	X	- -	- -
McMahon, Leonard, Dodge Heavy Construction Cost Data, Mid-1988	X	X	X	- -	- -
Means 1989 Heavy Construction Cost Data	X	X	X	X	- -
Metropolitan Washington Council of Governments, Evaluation of Costs of Stormwater Management Pond Construction and Maintenance, March 1983	- -	X	- -	- -	- -
Midwest Research Institute, Inc., Collection of Economic Data from NURP Projects-Final Report, March 1982	- -	X	- -	- -	X
North Carolina Department of Resources and Community Development, Nationwide Urban Runoff Program: Winston-Salem, October 1983	- -	- -	- -	- -	X

Table 1 (continued)

Information Source	Site Preparation	Site Development	Landscaping	Erosion Control	Street Sweeping and Catch Basin Cleaning
Pitt, Robert, Characterizing and Controlling Urban Runoff Through Street and Sewerage Cleaning, April 1985	- -	- -	- -	- -	X
Pitt, Robert and James McLean, Humber River Pilot Watershed Project-Final Report, Ontario Ministry of Development, June 1986	- -	- -	- -	- -	X
Ruekert and Mielke, Inc., Bid Tabulations for:					
Village of Mukwonago, Wisconsin, Industrial Park, June 1989	- -	- -	X	- -	- -
City of Cedarburg, Wisconsin, Jackson Street Relief Sewer, March 1989	X	X	- -	X	- -
Schueler, Thomas R., Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, July 1987	- -	X	X	- -	- -
Southeastern Wisconsin Regional Planning Commission, Technical Report No. 18, State of the Art of Water Pollution Control in Southeastern Wisconsin, Vol. 3, Urban Stormwater Runoff, July 1977	- -	X	- -	X	X
Southeastern Wisconsin Regional Planning Commission, Community Assistance Planning Report No. 173, A Stormwater Management Plan for the City of West Bend, Wisconsin, Vol. 1, Inventory Findings, Forecasts, Plan Objectives, and Design Criteria, Draft, March 1989	- -	X	- -	- -	- -
Southeastern Wisconsin Regional Planning Commission and Wisconsin Department of Natural Reources, Evaluation of Urban Nonpoint Pollution Management in Milwaukee County, Wisconsin, Vol. 2, Feasibility and Application of Urban Nonpoint Source Water Pollution Abatement Measures, 1983	- -	X	- -	- -	X
Terra Engineering and Construction, Final Cost Sheet-Plans for:					
Dairy Equipment Retention Basin-Phase I, Madison, Wisconsin, December 1982	X	X	- -	X	- -
Monroe Street-Aboretum Settling Basin, Madison, Wisconsin, June 1982	X	X	- -	X	- -
U. S. Environmental Protection Agency, Comparative Costs of Erosion and Sediment Control, Construction Activities, July 1973	- -	X	- -	X	- -

Table 1 (continued)

Information Source	Site Preparation	Site Development	Landscaping	Erosion Control	Street Sweeping and Catch Basin Cleaning
U. S. Environmental Protection Agency, <u>Control of Sediments Resulting from Highway Construction and Land Development Designs</u>, September 1971	--	--	--	X	--
U. S. Environmental Protection Agency, <u>Results of the Nationwide Urban Runoff Program</u>, Vol. 1, <u>Final Report</u>, December 1983	--	X	--	--	X
Wisconsin Department of Natural Resources, <u>Construction Site BMP Handbook</u>, Draft, February 1988	--	--	X	--	--
Wisconsin Department of Natural Resources, <u>Priority Watershed Management Plans</u> for:					
Black River, June 1983	--	X	--	--	--
Galena River, November 1979	--	X	--	--	--
Hay River, November 1979	--	X	--	--	--
Kewaunee River, April 1984	--	X	--	--	--
Lower Manitowoc River, October 1979	--	X	--	--	--
Oconomowoc River, March 1986	--	X	--	--	--
Turtle Creek, March 1984	--	X	--	--	--
Upper Sugar River, May 1979	--	X	--	--	--
Wisconsin Deptartment of Transportation, Bid Tabulations for:					
1988 Transportation Projects (48 projects)	X	X	X	X	--
1988 Construction Site Erosion Control Projects (48 projects)	--	--	--	X	--
Young, Kenneth and David Danner, <u>Urban Planning Criteria for Nonpoint Source Water Pollution Control</u>, Washington, D. C., Water Resources Research Center, March 1982	--	--	--	--	X

Source: SEWRPC.

of land and easement acquisition are not included in the cost estimates presented in this report since these costs are site- and project-specific.

Estimating the costs of operation and maintenance of a construction erosion or a nonpoint source control measure in an urban area is particularly difficult because few such costs have been documented and reported. The exceptions include street sweeping and catch basin cleaning, which have long been performed by municipalities. Operation and maintenance unit costs are presented in Table 3. Because of the limited data available, a single unit cost is presented for each component, rather than a range of costs. Where sufficient reported costs were unavailable, unit costs were estimated by the Regional Planning Commission staff.

The unit costs shown in Tables 2 and 3 were uniformly applied to estimate the total costs of the various control measures and to allow modification of the costs if site conditions are

Table 2

ESTIMATED UNIT CONSTRUCTION COSTS FOR NONPOINT SOURCE CONTROL COMPONENTS IN WISCONSIN

Component	Unit[a]	Number Reported Costs	Mean[b]	Standard Deviation[b]	Reported Range
Site Preparation					
Mobilization/Demobilization					
Light	LS	194	$ 274.00	$ 167.00	$50.00-1,500.00
Heavy	LS	- -	1,000.00	610.00	- -
Clearing	ID	74	$ 3.40	$ 1.40	$1.01-6.60
Southern Dry Forest	Acre	- -[c]	6,200.00	2,500.00	- -
Southern Mesic Forest	Acre	- -[c]	7,600.00	3,100.00	- -
Southern Wet Forest	Acre	- -[c]	15,600.00	6,400.00	- -
Northern Dry Forest	Acre	- -[c]	5,400.00	2,200.00	- -
Northern Mesic Forest	Acre	- -[c]	10,800.00	4,400.00	- -
Northern Wet Forest	Acre	- -[c]	18,700.00	7,700.00	- -
Shrub Communities and Grasslands	Acre	- -[d]	2,000.00	820.00	- -
Disturbed Woodlands	Acre	- -[e]	3,800.00	1,600.00	- -
Grubbing	ID	67	$ 4.60	$ 1.30	$2.00-6.60
Southern Dry Forest	Acre	- -[f]	8,300.00	2,300.00	- -
Southern Mesic Forest	Acre	- -[f]	10,300.00	2,900.00	- -
Southern Wet Forest	Acre	- -[f]	21,100.00	5,900.00	- -
Northern Dry Forest	Acre	- -[f]	7,300.00	2,000.00	- -
Northern Mesic Forest	Acre	- -[f]	14,600.00	4,100.00	- -
Northern Wet Forest	Acre	- -[f]	25,300.00	7,100.00	- -
Disturbed Woodlands	Acre	- -[e]	5,200.00	1,400.00	- -
General Excavation	CY	125	$ 3.70	$ 1.60	$0.90-6.90
Trench Excavation	CY	13	$ 5.60	$ 3.50	$1.50-12.00
Wetland Excavation	CY	24	$ 3.20	$ 1.00	$1.70-6.00
Rock Excavation	CY	11	$ 116.00	$ 38.10	$25.80-165.00
Place and Compact Fill	CY	- -[g]	$ 1.10	$ 0.50	- -
Level and Till	SY	- -[h]	$ 0.35	$ 0.15	- -
Grading	SY	- -[i]	$ 0.20	$ 0.10	- -
Site Development					
Crushed Stone Fill	Ton	12	$ 11.30	$ 9.20	$4.00-30.30
	CY	9	19.40	4.60	14.30-27.30
Riprap	Ton	7	$ 19.30	$ 5.70	$10.00-27.00
	CY	39	29.60	13.20	9.60- 49.50
Polyethylene Sheeting	SY	14	$ 1.70	$ 0.50	$1.00-2.00
Geotextile Fabric	SY	279	$ 2.00	$ 1.00	$0.50-10.00
Grade-Control Structure	Each	7	$ 6,230.00	$3,800.00	$1,184.00-11,100.00
Basin Inlet	Each	4	$ 5,740.00	$3,120.00	$1,208.00-7,869.00
Basin Outlet	Each	2	$ 6,760.00	$4,120.00	$3,850.00-9,680.00
Shallow Observation Well	VF	- -[j]	$ 160.00	$ 94.00	$95.00-280.00
Porous Pavement	SY	- -[k]	$ 9.70	$ 3.20	- -

Table 2 (continued)

Component	Unit[a]	Number Reported Costs	Mean[b]	Standard Deviation[b]	Reported Range
<u>Landscaping</u>					
Salvaged Topsoil	SY	61	$ 0.70	$ 0.40	$0.20-1.50
New Topsoil	SY	109	$ 1.70	$ 1.20	$0.20-8.50
Grass Seed	LB[l]	98	$ 9.90	$ 10.60	$3.30-50.50
	SY	10	0.20	0.10	0.10-0.50
Special Grass Seed[l]					
Prairie Grass and Forb	LB	3	$ 36.00	$ 29.90	$23.00-80.00
Native Seeding	LB	3	94.00	15.50	86.00-116.00
Wetland Cover Seed	LB	3	204.00	5.00	200.00-210.00
Wetland Plantings	Each	3	1.00	8.40	0.80-1.50
Wetland Rootstock	Each	3	0.90	0.30	0.60-1.20
Seed, Mulch, Fertilizer	SY	12	$ 0.30	$ 0.20	$0.20-0.70
Sod	SY	117	$ 2.40	$ 1.20	$1.40-10.10
Fertilizer[m]	CWT	127	$ 57.60	$ 52.50	$21.20-303.00
Landscaping, Etc.	Acre	- -[n]	$ 2,000.00	$1,000.00	- -
<u>Erosion Control</u>					
Hay Bales	Each	136	$ 9.20	$ 1.40	$5.00-12.00
Matting	SY	159	$ 1.20	$ 0.50	$0.80-6.00
Straw Blankets	SY	6	$ 2.60	$ 2.90	$0.70-8.30
Mulch	SY	91	$ 0.30	$ 0.20	$0.10-1.00
Sand Bags	Each	18	$ 5.30	$ 3.40	$1.00-10.00
Silt Fence	LF	290	$ 3.40	$ 1.10	$0.60-8.00
Silt Screen	LF	14	$ 14.50	$ 4.10	$2.50-19.00
Temporary Grass Seed	LB[o]	43	$ 4.60	$ 2.80	$1.50-10.00
	SY	8	0.10	0.10	0.10-0.20

NOTE: *All costs are reported in January 1989 dollars.* ENR CCI = 4734.

[a]*Unit abbreviations are as follows:*

LS = Lump Sum	*SY = Square Yard*	*CWT = 100 Pounds*
ID = Inch Diameter	*VF = Vertical Foot*	*LF = Lineal Foot*
CY = Cubic Yard	*LB = Pounds*	

[b]*Mean estimated from <u>Means 1989 Building and Heavy Construction Cost Data</u>. Standard deviation estimated by applying the same relationship to the mean as calculated for Mobilization/Demobilization-Light. On standard deviation, see footnote 1 in this chapter.*

[c]*Clearing costs for Wisconsin forest types are estimated by applying the stated mean inch-diameter clearing costs to the average biomass structure of typical stands of Wisconsin forest types, as set forth in John T. Curtis, <u>The Vegetation of Wisconsin</u>, 1959.*

[d]*Includes removal of all vegetative material, both above and below ground. Mean estimated using <u>Dodge Heavy Construction Cost Data</u>, mid-1988, and <u>Means 1989 Building and Heavy Construction Cost Data</u>. Standard deviation estimated by applying the same relationship to the mean as calculated for general clearing.*

Table 2 Footnotes (continued)

[e]*The above forests are natural, fully developed forest types in Wisconsin. For cost estimating purposes, disturbed woodlands are assumed to contain one-half the biomass of southern mesic forests.*

[f]*Grubbing costs for Wisconsin forest types are estimated by applying the stated mean inch-diameter grubbing costs to the average biomass of typical stands of Wisconsin forest types, as set forth in John T. Curtis, The Vegetation of Wisconsin, 1959.*

[g]*Mean estimated from Means 1989 Building and Heavy Construction Cost Data. Standard deviation estimated by applying the same relationship to the mean as calculated for general excavation.*

[h]*Mean estimated from SEWRPC Technical Report No. 18, State of the Art Water Pollution Control in Southeastern Wisconsin, Vol. 4, Rural Storm Water Runoff, December 1976. Standard deviation estimated by applying the same relationship to the mean as calculated for general excavation.*

[i]*Mean estimated using Dodge Heavy Construction Cost Data, mid-1988, and Means 1989 Building and Heavy Construction Cost Data. Standard deviation estimated by applying the same relationship to the mean as calculated for general excavation.*

[j]*Mean, standard deviation, and range estimated from T. R. Schueler, Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, July 1987.*

[k]*Costs given for porous pavement are the combined incremental costs above conventional asphalt pavement costs. The standard deviation is the sum of the standard deviations of the individual components. For incremental component cost breakdown, see Table 23.*

[l]*Seeding rates for general use lawns are:*
80 to 100 pounds per acre for flat areas
40 to 80 pounds per acre for slopes.
Wetland area seeding rates are:
80 pounds per acre
43,560 plants per acre or one plant per square foot.

[m]*Fertilizer applied at a rate of 500 pounds per acre.*

[n]*Estimate of miscellaneous costs such as ornamental landscaping, trails, and fences.*

[o]*Temporary seeding rate is 100 to 170 pounds per acre.*

Source: SEWRPC.

known. All costs are presented in January 1989 dollars. These costs may be updated by multiplying the cost by the current Engineering-News Record Construction Cost Index divided by 4,734, the average of the January 1989 Index values for Chicago and Minneapolis. The Construction Cost Index is not presented for any Wisconsin city in the Engineering-News Record; thus the Chicago and Minneapolis values were averaged to provide some reasonable cost index for Wisconsin. Such a procedure has been generally accepted and used in planning for long-term major public works projects in the Milwaukee area.

Table 3

ESTIMATED OPERATION AND MAINTENANCE UNIT COSTS FOR URBAN NONPOINT SOURCE CONTROL MEASURES

Description	Unit Cost	Source
Landscape Maintenance		
General Lawn Care (pesticides, fertilizers, watering)	$9.00 per 1,000 per square feet per year	SEWRPC
Lawn Mowing	0.85 per 1,000 square feet per mowing	Means 1989 Building Construction Cost Data, 1989
Grass Reseeding, with Mulch and Fertilizer	0.30 per square yard	Table 2
Grass Resodding	2.40 per square yard	Table 2
Structural Maintenance		
Basin Inlet Maintenance	3 percent capital cost per year	SEWRPC
Basin Outlet Maintenance	5 percent capital cost per year	SEWRPC
Periodic Inspections	$25 per inspection	SEWRPC
Infiltration Maintenance		
Minor Trench Rehabilitation	$3.80 per lineal foot (3-foot-deep by 4-foot-wide trench) $9.40 per lineal foot (6-foot-deep by 10-foot-wide trench)	Calculated from Table 2 costs
Major Trench Rehabilitation	$11.80 per lineal foot (3-foot-deep by 4-foot-wide trench) $50 per lineal foot (6-foot-deep by 10-foot-wide trench)	Calculated from Table 2 costs
Soil Leveling and Tilling	$0.35 per square yard	Table 2
Observation Well Monitoring	$100 per year	SEWRPC
General Operation and Maintenance		
Wet Basin Sediment Removal	1 percent capital cost per year	Metropolitan Washington Council of Governments, An Evaluation of the Costs of Stormwater Management Pond Construction and Maintenance, 1983
Infiltration Basin Sediment Removal	$4,211 per basin acre per year	Means 1989 Building Construction Cost Data; and SEWRPC
Wet Basin Nuisance Control	$200 per basin acre per year	Robert Pitt, Wet Detention Ponds, Wisconsin Department of Natural Resources, draft 1987; and SEWRPC
Basin Debris and Litter Removal	$100 per basin per year	SEWRPC
Swale Debris and Litter Removal	$0.10 lineal foot per year	SEWRPC
Porous Pavement Vacuum Sweeping and High Pressure Jet Hosing	$100 per acre per year	SEWRPC
Street Sweeping	$21.25 per curb-mile or $11.40 per cubic yard	Bureau of Sanitation, City of Milwaukee, Wisconsin, 1988 Annual Report

NOTE: All unit costs are presented in January 1989 dollars. ENR CCI = 4734

Source: SEWRPC.

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Chapter III

URBAN NONPOINT SOURCE CONTROL MEASURES

INTRODUCTION

For eight urban nonpoint source control measures, wet detention basins, infiltration trenches, infiltration basins, grassed swales, vegetated filter strips, porous pavement, catch basin cleaning, and street sweeping, this chapter presents a description of each measure; a discussion of its application and the advantages and disadvantages of its use; design and sizing guidelines; maintenance requirements; and pollutant removal effectiveness. Reported installation and maintenance costs are also listed. Finally, a procedure for estimating costs is set forth, which may be used to calculate both capital and annual maintenance costs for each control measure.

WET DETENTION BASINS

Wet detention basins can be one of the most effective measures in removing pollutant loadings from urban stormwater runoff. If properly sized and maintained, wet basins can achieve a high rate of removal of sediment, organic matter, nutrients, and metals. Sedimentation and biological uptake are the primary processes of removal.

The costs provided herein are intended to be used in urbanizing areas where a stormwater management system can be designed to incorporate wet detention basins. These costs are not suitable for estimating the cost for retrofitting detention storage in existing urbanized areas. Such costs are highly variable, based upon site-specific considerations and cannot be developed in the generalized manner presented herein. However, one analysis conducted by the Regional Planning Commission and presented in Appendix A indicates costs for retrofitting stormwater storage could range from $400,000 to $1,000,000 per acre of storage pond required, compared to $100,000 or less per acre, as set forth herein, for incorporation such ponds in newly developing areas.

Description

Wet basins without an outlet are referred to as retention basins; basins with an outlet are called detention basins. Perhaps more than any other urban nonpoint source control measure, wet detention basins require careful planning and site evaluation, thoughtful design, and regular maintenance. Improperly designed or sited wet basins can be more harmful than beneficial by exacerbating existing flooding and drainage problems or by destroying aquatic habitat. A typical wet detention basin is illustrated in Figure 1. Table 4 summarizes some design guidelines and criteria for enhancing the performance of wet detention basins.

Wet detention basins are unique in that they provide for multiple uses. Potential positive impacts of wet basins include achievement of a high level of pollution control, creation of waterfowl and wildlife habitat, provision of recreational opportunities, and landscape and aesthetic amenities. Wet basins may also provide peak flow-rate reductions and streambank erosion control benefits if the basins are designed to allow additional storage during a storm event. Potential negative impacts of wet detention basins include safety hazards, occasional nuisance problems, and relatively high maintenance requirements. In addition, because of the effects on water temperature, such basins may degrade downstream fishery habitats.

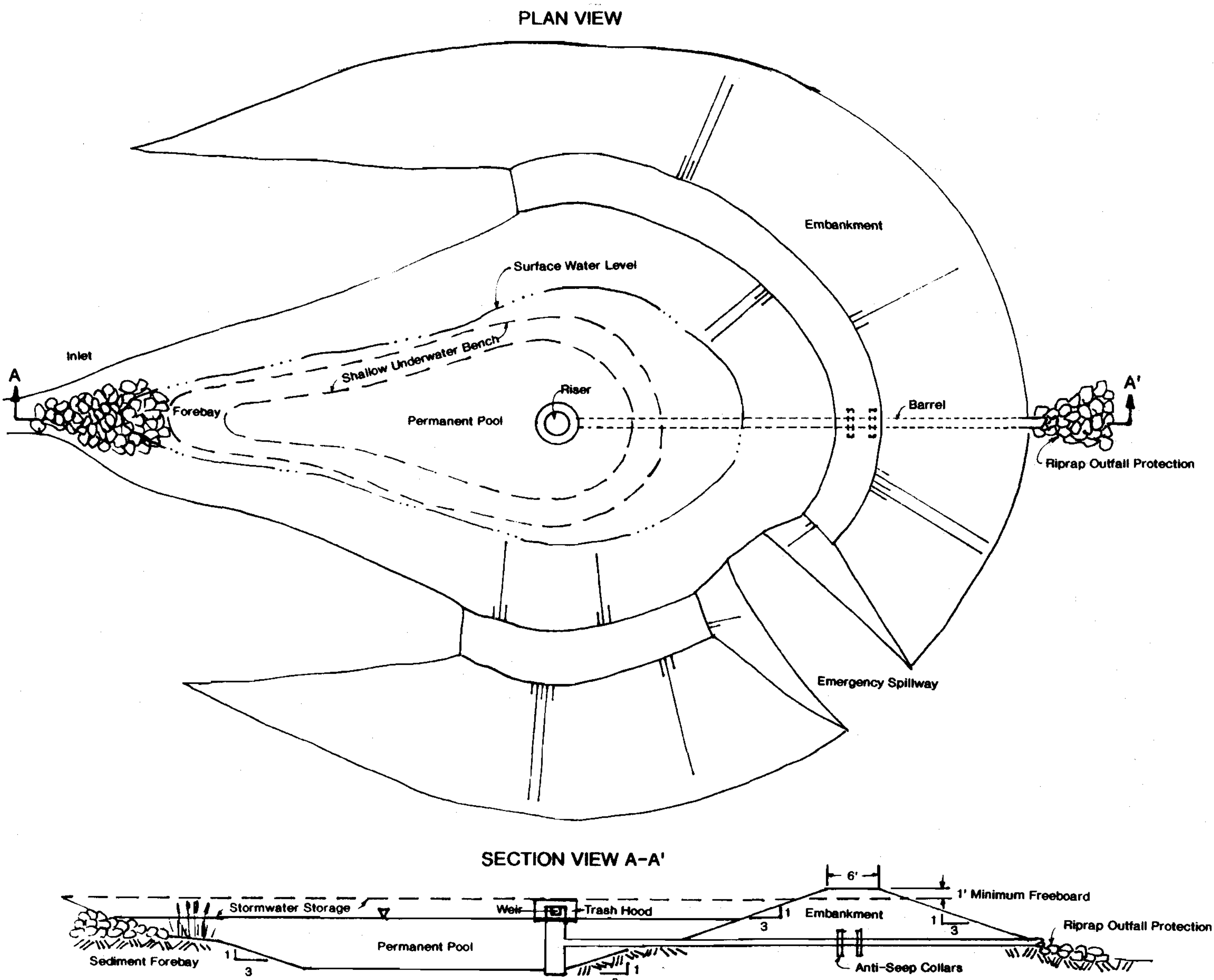
Compared to wet detention basins, dry detention basins, or those which do not contain a permanent pool of water, provide few water quality benefits because the detention time is often too short. The dry basins usually store water only during large storm events, and any sediments deposited in the basin are frequently flushed out during subsequent storm events.

Somewhat improved water quality benefits may be provided by extended detention basins. Extended detention basins are normally dry, but have special outlets which slow the release of impounded water. The extended detention basins may pose serious maintenance problems, are generally not aesthetically pleasing, and offer few multiple-use benefits.

Designing and sizing a wet detention basin, especially the outlet, requires careful analysis of the hydraulic impacts and water quality bene-

Figure 1

TYPICAL WET DETENTION BASIN



Source: SEWRPC.

fits. In general, larger wet basins remove a higher portion of the pollutants than do smaller basins. However, after a certain threshold size is reached, further removal by sedimentation is negligible. An upper limit on wet basin size may also be imposed by site constraints and by limits on available funding.

Figure 2 shows the estimated amount of various pollutants removed as a function of the ratio of the wet basin area to the tributary urban drainage area. The figure indicates that most of the water quality benefits are provided when the ratio of wet basin area to tributary drainage area reaches 0.4 or 0.5 percent. Maximum rates

Table 4

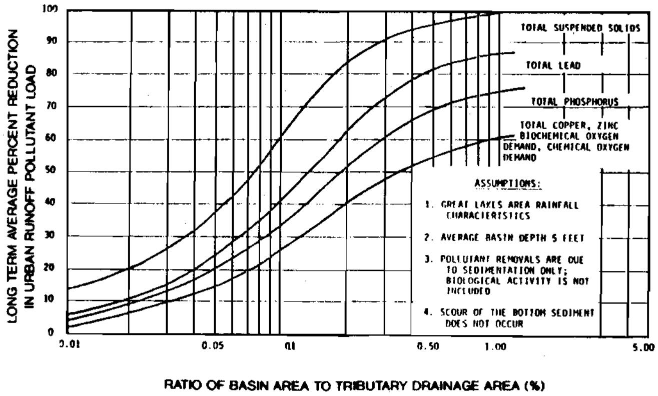
RECOMMENDED DESIGN GUIDELINES FOR ENHANCING THE PERFORMANCE OF WET DETENTION BASINS

Design Factor	Guidelines
Area	• Minimum: 0.25 acres • Select based on needed level of pollutant removal (see Figure 2 or use comparable technique)
Volume	• Minimum: 2.5 times the runoff volume generated by a mean storm event
Depth	• Basin depth when constructed: five to 10 feet • Dredge basin to maintain a minimum depth of three feet • Construct shallow underwater bench, with a minimum width of three feet, around basin perimeter for safety • Water depths should be shallower near inlet (unless a sediment forebay is provided) and deeper near outlet
Shape	• Wedge-shaped; narrowest at inlet and widest at outlet • Minimum length to width ratio: 3:1 • Irregular shape preferred
Excavated Side Slopes	• Minimum: 20:1 • Maximum: 3:1 for sand; 1:1 for peat; 2:1 for other soils • Flatter slope on shallow bench around perimeter
Outfall Design	• For a one-inch storm, basin should have average detention time of at least 24 hours • Minimum pipe diameter: four inches • Install trash racks or hoods to reduce clogging • Allow access for easy debris removal and maintenance • For lower maintenance, concrete pipes are preferred over corrugated metal pipes • Protect channel banks below basin to prevent erosion
Vegetated Buffer Strip	• Minimum width: 25 feet wide • Use water tolerant, low-maintenance vegetation • Establish artificial marsh vegetation near inlet and around at least 50 percent of basin perimeter
Embankment	• Overfill embankment by at least 5 percent to allow subsidence and settling • Provide at least one foot of freeboard above water surface with emergency spillway flowing at design depth. The minimum difference in elevation between the crest of the emergency spillway and the top of the embankment should be two feet • Use anti-seep collars to prevent seepage around outlet pipe • Minimum top width: six feet • Maximum side slopes: 2:1
Drainage Area	• Minimum: 10 acres
Site Access	• Reserve access site at least 10 feet wide, on a slope of 5:1 or less and stabilized to withstand the passage of heavy equipment

Source: U. S. Soil Conservation Service, 1989; Thomas R. Schueler, 1987; and SEWRPC.

Figure 2

POLLUTANT REMOVAL EFFECTIVENESS OF WET DETENTION BASINS IN THE GREAT LAKES AREA



Source: G. Driscoll, Nationwide Urban Runoff Program Retention Basin Analysis, 1983.

of removal are at least 85 percent for suspended solids and lead; 75 percent for total phosphorus; and about 60 percent for organic matter, zinc, and copper. Although not shown on the figure, lower removal rates, less than 50 percent, would be provided for bacteria and dissolved substances such as nitrates.

It is extremely important that both routine and periodic maintenance of wet detention basins be performed. Routine maintenance tasks include lawn and other landscape care, basin inspections, debris and litter removal, erosion control, and nuisance control. Periodic maintenance tasks include inlet and outlet repairs and sediment removal.

Inadequate maintenance of wet detention basins is common. The American Public Works Association reported that a survey of maintenance problems with wet basins indicated that the most serious problems, in descending order of severity, were excessive weed growth, erosion of grassed areas, excessive sediment accumulations, bank erosion, mosquito control, outlet blockages, and excessive algal growth.[1] A similar survey of wet basins conducted by the Northeastern Illinois Planning Commission found that 31 percent of the basins surveyed experienced erosion of the accumulated sediments, 13 percent had excessive weed growth, 10 percent had outlet blockages, and 10 percent experienced bank erosion.[2]

It is noteworthy that some of these problems, excessive sediment accumulations, weed growth, and algal growth, demonstrate that the wet basins were indeed removing pollutants by either sedimentation or biological nutrient uptake. A properly functioning basin can be expected to develop "problems" which will require maintenance. However, relatively simple and inexpensive design modifications can significantly reduce both the scope and cost of future maintenance activities.[3]

Increasing the storage volume of the wet basin, preferably through construction of a sediment forebay near the inlet, can reduce the frequency of sediment removal. Sediment removal costs can also be reduced by up to 50 percent if an onsite sediment disposal area is reserved. If the basin outlet is designed so that the basin can be completely dewatered, removal of sediments can be accomplished by mechanical excavation equipment, rather than by the more expensive hydraulic dredging equipment. With regard to the outlet structure, a reinforced concrete structure will require much less maintenance and have at least twice the longevity, as a corrugated metal outlet will. Grass mowing costs can be substantially reduced if the basin buffer is managed as a meadow, rather than as a lawn. Aggressive ground cover species such as crown vetch can stabilize an embankment and require little or no maintenance. And, of course, the most important design element related to maintenance is the provision of an adequate access way to allow passage of heavy equipment.

Reported General Costs

Unfortunately, few wet detention basins designed specifically for water quality improvement purposes have been constructed in Wiscon-

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[1]*American Public Works Association, Urban Stormwater Management, Special Report No. 49, Chicago, Illinois, 1984.*

[2]*D. W. Dreher, G. C. Schaefer, and K. L. Hey, Evaluation of Stormwater Detention Effectiveness in Northeastern Illinois, Northeastern Illinois Planning Commission, Draft, June 1989.*

[3]*T. R. Schueler and M. Helfrich, Design of Extended Detention Wet Pond Systems, Metropolitan Washington Council of Governments, Draft, 1989.*

Table 5

SUMMARY OF REPORTED COSTS OF WET DETENTION BASINS

Description	Capital Cost	Annual Operation and Maintenance Cost	Comments	Location	Reference[a]
Basin with a 20-Acre Drainage Area	Construction cost = $85V^{0.483}$ V = Basin Volume (cubic feet)	$1,870/basin	Excludes planning, design, administration, and contingencies	Montgomery County, Maryland	Metropolitan Washington Council of Governments, March 1983
Basin Capacities 1,000 to 1.0 Million Cubic Feet	Capital cost = $107.4V^{0.51}$ V = Basin Volume (cubic feet)	- -	Capital cost includes planning, design, administration, and contingencies	Washington, D. C., area	Metropolitan Washington Council of Governments, March 1983
Basin Size: a) 2,700 Gallons/Acre Served b) 13,600 Gallons/Acre Served c) 27,200 Gallons/Acre Served d) 40,700 Gallons/Acre Served e) 136,000 Gallons/Acre Served	 a) $311/acre served b) $1,038/acre served c) $1,470/acre served d) $2,076/acre served e)$6,228/acre served	 a) $61/acre served b) $52/acre served c) $52/acre served d) $52/acre served e) $43/acre served	Valid for basins serving ≤ 50 acres	General	SEWRPC Technical Report No. 18, July 1977
Pond Size: a) Six Acres b) 8.5 Acres c) 10 Acres d) 11.5 Acres	 a) $1,231,163/basin b) $1,281,757-2,151,978/basin c) $7,207,230/basin d) $1,204,538/basin	 a) $5,521/basin b) $2,096-3,064/basin c) $2,290/basin d) $10,288/basin	All basins drainage area ≤ 50 percent impervious. Basins a), b), and c) include discharge pump and canal. Basin d) percolates discharge	Fresno, California	Midwest Research Institute, March 1982
Basin Capacity of 6.5 Acre-Feet	$81,243/basin	$2,020/basin	- -	Tri-County, Michigan	Midwest Research Institute, March 1982
0.8-Acre Basin Serving a 160-Acre Drainage Area	$53,068/basin	$722/basin	Capital cost includes construction, materials, land, soil testing, and other indirect costs. Operation and maintenance cost includes labor, equipment, and disposal costs	Salt Lake County, Utah	Midwest Research Institute, March 1982
1,000- to 1.0-Million-Cubic-Foot Basin Serving a Drainage Area of 20 to 1,000 Acres	Capital cost = $108.36V^{0.51}$ V= Basin Volume (cubic feet)	Operation and maintenance cost is 5 percent of capital cost	- -	Washington, D. C., area	U. S. Environmental Protection Agency, December 1983
Basin Volumes V < 100,000 Cubic Feet	Capital Cost = $6.1V^{0.75}$ V = Basin Volume (cubic feet)	- -	Capital cost excludes engineering, administration, and contingencies	Washington, D. C., area	T. R. Schueler, July 1987
Basin Volumes V ≥ 100,000 Cubic Feet	Capital Cost = $34V^{0.64}$ V = Basin Volume (cubic feet)	- -	Capital cost excludes engineering, administration, land acquisition, and contingencies	Washington, D. C., area	T. R. Schueler, July 1987
Series of Nine Interconnected Basins	$51,900/basin	- -	25 percent of capital cost includes grading, drainage, and paving	Southern California	Robert Pitt, April 1987
Basin Volume: a) One Acre-Foot b) Three Acre-Feet c) Five Acre-Feet d) 10 Acre-Feet e) 20 Acre-Feet	 a) $19,504-45,580/basin b) $62,540-60,377/basin c) $94,022/basin d) $146,492/basin e) $227,900/basin	- -	Capital cost excludes land acquisition, engineering, administration, and contingencies	Southeastern Wisconsin	SEWRPC Community Assistance Planning Report No. 173, March 1989

NOTE: All costs updated to January 1989.

[a]*See Appendix C.*

Source: SEWRPC.

sin to date, and the costs of such basins have not been compiled and documented in the Midwestern states. The most extensive cost data available are for the Washington, D. C. area and for the State of California. The Metropolitan Washington Council of Governments has compiled extensive cost data and has developed procedures for estimating the costs of wet basins.

Table 5 presents a summary of the reported costs of wet detention basins. The table includes the costs of actual basins, as well as procedures which have been proposed to estimate the cost of basins. Both capital and operation and maintenance costs vary widely, depending on the location, the basin specifications, and the site conditions.

Table 6

ESTIMATED CAPITAL COST OF A 0.25-ACRE WET DETENTION BASIN

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization-Demobiliation-Heavy	Basin	1	$ 390	$1,000	$ 1,610	$ 390	$ 1,000	$ 1,610
Site Preparation								
Clearing[b]	Acre	0.50	$2,200	$3,800	$ 5,400	$ 1,100	$ 1,900	$ 2,700
Grubbing[c]	Acre	0.13	3,800	5,200	6,600	494	676	858
General Excavation[d]	Cubic yard	908	2.10	3.70	5.30	1,907	3,360	4,812
Place and Compact Fill[e]	Cubic yard	608	0.60	1.10	1.60	365	669	973
Site Development								
Salvaged Topsoil, Seed, and Mulch[f]	Square yard	1,089	$ 0.40	$ 1.00	$ 1.60	$ 436	$ 1,089	$ 1,742
Sod[g]	Square yard	121	1.20	2.40	3.60	145	290	436
Riprap[h]	Cubic yard	16	16.40	29.60	42.80	262	474	685
Basin Inlet	Basin	1	2,620	5,740	8,860	2,620	5,740	8,860
Basin Outlet	Basin	1	2,640	6,760	10,880	2,640	6,760	10,880
Landscape, Fence, etc.[i]	Acre	0.25	1,000	2,000	3,000	250	500	750
Subtotal	- -	- -	- -	- -	- -	$10,609	$22,459	$34,306
Contingencies, Engineering, Legal Fees, and Administration	Basin	1	25 percent	25 percent	25 percent	$ 2,652	$ 5,610	$ 8,577
Total[j]	- -	- -	- -	- -	- -	$13,261	$28,069	$42,883

[a]Basin has five-foot depth; 3:1 side slopes.

[b]Area cleared = 2 x basin area.

[c]Area grubbed = 0.5 x basin area (for embankment and spillway).

[d]Volume excavated = basin volume + 5 percent for spillway, inlet, outlet, etc.

[e]Volume of fill placed and compacted = 0.67 x excavation volume.

Source: SEWRPC.

[f]Seeded area = (area cleared - basin area) x 0.9.

[g]Area sodded = (area cleared - basin area) x 0.1.

[h]Riprap volume = basin area x 0.02 x 0.5 yard thick.

[i]Area landscaped = basin area.

[j]Add $14,200 if basin lining required.

Cost Estimates

The costs for wet detention basins can be divided into a number of components: mobilization and demobilization of heavy equipment, site preparation, site development, and contingencies. Site preparation includes clearing, grubbing, excavation, and placement and compaction of fill. Site development activities include placement of topsoil, seeding, sodding, mulching, placement of riprap, basin lining (if needed), construction of the inlet and outlet, and landscaping. In addition, the component costs were increased by 25 percent to allow for contingencies, planning, engineering, administration, and legal fees.

Table 2 presented the unit construction costs which were estimated for these components. Three unit costs, a low, a moderate, and a high cost, were used to calculate a probable range of costs for each component and to calculate a range of total basin construction costs.

Tables 6 through 9 present the calculated component and total capital costs for 0.25-, 1.0-, 3.0-, and 5.0-acre wet detention basins. The assumptions used to quantify each component are listed in the footnotes to the tables. Using the moderate cost estimates, the estimated capital costs range from a low of $28,000 for a

Table 7

ESTIMATED CAPITAL COST OF A 1.0-ACRE WET DETENTION BASIN

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization-Demobiliation-Heavy	Basin	1	$ 390	$1,000	$ 1,610	$ 390	$ 1,000	$ 1,610
Site Preparation								
Clearing[b]	Acre	2.0	$2,200	$3,800	$ 5,400	$ 4,400	$ 7,600	$ 10,800
Grubbing[c]	Acre	0.5	3,726	5,175	8,901	1,863	2,588	3,300
General Excavation[d]	Cubic yard	5,771	2.10	3.70	5.30	11,699	20,613	29,526
Place and Compact Fill[e]	Cubic yard	3,867	0.60	1.10	1.60	2,320	4,254	6,187
Site Development								
Salvaged Topsoil, Seed, and Mulch[f]	Square yard	4,356	$ 0.40	$ 1.00	$ 1.60	$ 1,742	$ 4,356	$ 6,970
Sod[g]	Square yard	424	1.20	2.40	3.60	581	1,162	1,742
Riprap[h]	Cubic yard	48	16.40	29.60	42.80	787	1,421	2,054
Basin Inlet	Basin	1	2,620	5,740	8,860	2,620	5,740	8,860
Basin Outlet	Basin	1	2,640	6,760	10,880	2,640	6,760	10,880
Landscape, Fence, etc.[i]	Acre	1	1,000	2,000	3,000	1,000	2,000	3,000
Subtotal	- -	- -	- -	- -	- -	$30,079	$57,506	$ 84,929
Contingencies, Engineering, Legal Fees, and Administration	Basin	1	25 percent	25 percent	25 percent	$ 7,520	$14,377	$ 21,232
Total[j]	- -	- -	- -	- -	- -	$37,599	$71,883	$106,161

[a]Basin has five-foot depth; 3:1 side slopes.

[b]Area cleared = 2 x basin area.

[c]Area grubbed = 0.5 x basin area (for embankment and spillway).

[d]Volume excavated = basin volume + 5 percent for spillway, inlet, outlet, etc.

[e]Volume of fill placed and compacted = 0.67 x excavation volume.

Source: SEWRPC.

[f]Seeded area = (area cleared - basin area) x 0.9.

[g]Area sodded = (area cleared - basin area) x 0.1.

[h]Riprap volume = basin area x 0.02 x 0.5 yard thick.

[i]Area landscaped = basin area.

[j]Add $56,600 if basin lining required.

0.25-acre basin to $342,000 for a 5.0-acre basin. The cost per acre of basin ranges from a low of $68,000 for a 5.0-acre basin to a high of $112,000 for a 0.25-acre basin.

The distribution of the component capital costs is largely a function of the basin area, as shown in Figures 3 and 4. For each wet basin size, the figures show the distribution of costs based on the moderate cost estimates presented in Tables 6 through 9. For very small basins, about 0.25 acre, the site development cost exceeds the site preparation cost, while for larger basins, the site preparation cost is much higher than the site development cost. The importance of the site preparation costs supports the conclusion that total basin costs are heavily dependent on site conditions, especially for larger basins. For example, a basin constructed in an existing depression with a natural inlet and grass cover may cost only a fraction of what a similar-sized basin would cost to construct on level, wooded land. For all basins, mobilization/demobilization of equipment accounts for less than 5 percent of the total capital cost and contingencies were assumed to be 20 percent of the capital cost of all basins.

Table 8

ESTIMATED CAPITAL COST OF A 3.0-ACRE WET DETENTION BASIN

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization-Demobiliation-Heavy	Basin	1	$ 390	$1,000	$ 1,610	$ 390	$ 1,000	$ 1,610
Site Preparation								
Clearing[b]	Acre	6.0	$2,200	$3,800	$ 5,400	$ 13,200	$ 22,800	$ 32,400
Grubbing[c]	Acre	1.5	3,800	5,200	6,600	5,700	7,800	9,900
General Excavation[d]	Cubic yard	21,260	2.10	3.70	5.30	44,646	78,662	112,678
Place and Compact Fill[e]	Cubic yard	14,244	0.60	1.10	1.60	8,546	15,668	22,790
Site Development								
Salvaged Topsoil, Seed, and Mulch[f]	Square yard	13,068	$ 0.40	$ 1.00	$ 1.60	$ 5,227	$ 13,068	$ 20,909
Sod[g]	Square yard	1,452	1.20	2.40	3.60	1,742	3,485	5,227
Riprap[h]	Cubic yard	145	16.40	29.60	42.80	2,378	4,292	6,206
Basin Inlet	Basin	1	2,620	5,740	8,860	2,620	5,740	8,860
Basin Outlet	Basin	1	2,640	6,760	10,880	2,640	6,760	10,880
Landscape, Fence, etc.[i]	Acre	3.0	1,000	2,000	3,000	3,000	6,000	9,000
Subtotal	- -	- -	- -	- -	- -	$ 90,089	$165,275	$240,460
Contingencies, Engineering, Legal Fees, and Adminstration	Basin	1	25 percent	25 percent	25 percent	$ 22,522	$ 41,319	$ 60,115
Total[j]	- -	- -	- -	- -	- -	$112,611	$206,594	$300,575

[a]Basin has five-foot depth; 3:1 side slopes.

[b]Area cleared = 2 x basin area.

[c]Area grubbed = 0.5 x basin area (for embankment and spillway).

[d]Volume excavated = basin volume + 5 percent for spillway, inlet, outlet, etc.

[e]Volume of fill placed and compacted = 0.67 x excavation volume.

[f]Seeded area = (area cleared - basin area) x 0.9.

[g]Area sodded = (area cleared - basin area) x 0.1.

[h]Riprap volume = basin area x 0.02 x 0.5 yard thick.

[i]Area landscaped = basin area.

[j]Add $169,800 if basin lining required.

Source: SEWRPC.

Table 9

ESTIMATED CAPITAL COST OF A 5.0-ACRE WET DETENTION BASIN

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization-Demobiliation-Heavy	Basin	1	$ 390	$1,000	$ 1,610	$ 390	$ 1,000	$ 1,610
Site Preparation								
Clearing[b]	Acre	10.0	$2,200	$3,800	$ 5,400	$ 22,000	$ 38,000	$ 54,000
Grubbing[c]	Acre	2.5	3,800	5,200	6,600	9,500	13,000	16,500
General Excavation[d]	Cubic yard	37,013	2.10	3.70	5.30	77,727	136,948	196,196
Place and Compact Fill[e]	Cubic yard	24,799	0.60	1.10	1.60	14,879	27,279	39,678
Site Development								
Salvaged Topsoil, Seed, and Mulch[f]	Square yard	21,780	$ 0.40	$ 1.00	$ 1.60	$ 8,712	$ 21,780	$ 34,848
Sod[g]	Square yard	2,420	1.20	2.40	3.60	2,904	5,808	8,712
Riprap[h]	Cubic yard	242	16.48	29.60	42.80	3,969	7,163	10,358
Basin Inlet	Basin	1	2,620	5,740	8,860	2,620	5,740	8,860
Basin Outlet	Basin	1	2,640	6,760	10,880	2,640	6,760	10,880
Landscape, Fence, etc.[i]	Acre	5.0	1,000	2,000	3,000	5,000	10,000	15,000
Subtotal	- -	- -	- -	- -	- -	$150,341	$273,478	$396,642
Contingencies, Engineering, Legal Fees, and Adminstration	Basin	1	25 percent	25 percent	25 percent	$ 37,585	$ 68,370	$ 99,161
Total[j]	- -	- -	- -	- -	- -	$187,926	$341,848	$495,803

[a] *Basin has five-foot depth; 3:1 side slopes.*

[b] *Area cleared = 2 x basin area.*

[c] *Area grubbed = 0.5 x basin area (for embankment and spillway).*

[d] *Volume excavated = basin volume + 5 percent for spillway, inlet, outlet, etc.*

[e] *Volume of fill placed and compacted = 0.67 x excavation volume.*

[f] *Seeded area = (area cleared - basin area) x 0.9.*

[g] *Area sodded = (area cleared - basin area) x 0.1.*

[h] *Riprap volume = basin area x 0.02 x 0.5 yard thick.*

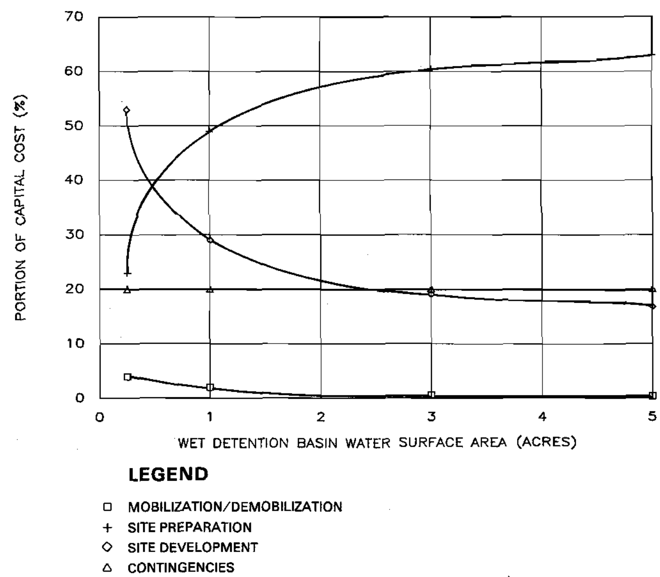
[i] *Area landscaped = basin area.*

[j] *Add $283,000 if basin lining required.*

Source: SEWRPC.

Figure 3

DISTRIBUTION OF WET DETENTION BASIN CAPITAL COSTS AS A FUNCTION OF BASIN SIZE



Source: SEWRPC.

Operation and maintenance costs of wet detention basins were calculated using the unit costs set forth in Table 3. Table 10 presents estimated costs for lawn care and mowing, sediment removal, inlet and outlet maintenance, nuisance control, debris and litter removal, basin inspection, and program administration. The estimated annual operation and maintenance costs range from $1,300 for a 0.25-acre basin to nearly $8,700 for a 5.0-acre basin.

The distribution of the component operation and maintenance costs also varies by basin area. Figure 5 illustrates the distribution of the operation and maintenance costs. As basin area increases, the portion of the total cost required for sediment removal, lawn care, and nuisance control costs generally increases, while the portion of the total cost required for inlet and outlet maintenance, debris and litter removal, and basin inspection and maintenance program administration decreases.

Based on the cost calculations presented above, cost curves were developed which may be used to estimate the capital costs and operation and maintenance costs of a wet detention basin. The costs are calculated as a function of the basin volume. These curves may be used to provide a preliminary estimate of a proposed basin's cost. Furthermore, the costs generated from the curves may be modified for known site-specific conditions by adjusting the component costs listed in Tables 6 through 10.

Figure 6 presents the capital cost curves for wet detention basins. Low, moderate, and high curves are presented to provide a probable range of costs. For comparison purposes, Figure 7 shows cost curves generated by other agencies or individuals. All curves were adjusted to January 1989 dollars. For wet basins less than 100,000 cubic feet, the SEWRPC moderate curve compares well with the other curves available. For larger wet basins, especially those greater than 200,000 cubic feet, the SEWRPC moderate costs are higher than those estimated by the U. S. Soil Conservation Service (SCS), 1977,[4] or by the Metropolitan Washington Council of Governments (WASHCOG), 1983.[5] However, a review of actual individual basin costs presented by the Metropolitan Washington Council of Governments indicated that the SCS, 1977, and WASHCOG, 1983, curves usually somewhat underestimated the actual costs of larger basins. The SEWRPC cost curves for larger basins are consistent with a cost estimating procedure developed by Wiegand et al., 1986,[6] for basins greater than 100,000 cubic feet. Wiegand et al., 1986, concluded that separate cost curves should be used for basins less than 100,000 cubic feet and for basins greater than 100,000 cubic feet.

Figure 8 presents the annual operation and maintenance cost curves for wet detention basins. Curves are presented for each maintenance component so that the estimated costs can

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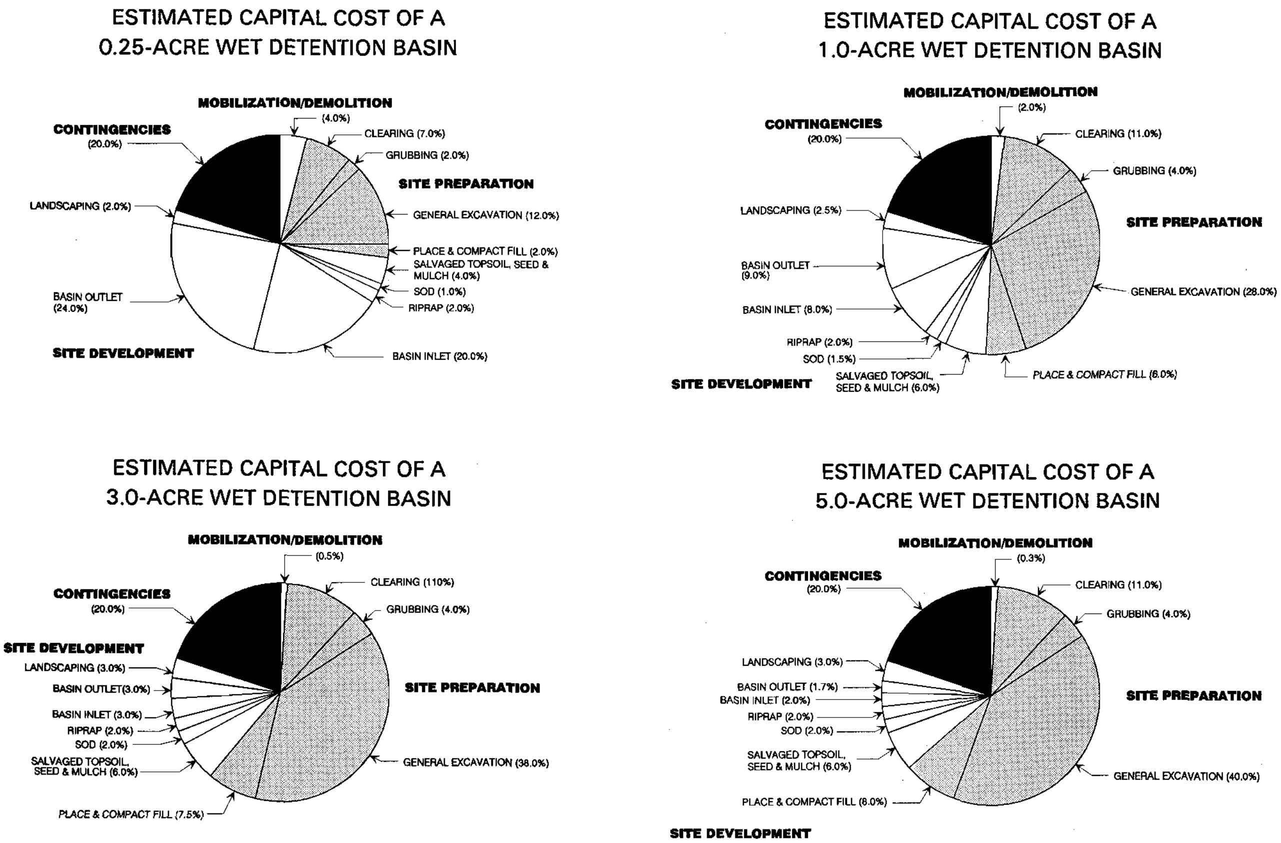
[4]*D. DeTullio and R. Thomas, Stormwater Management Cost Study, USDA Soil Conservation Service for Maryland-National Capital Park and Planning Commission, July, 1977.*

[5]*Metropolitan Washington Council of Governments, An Evaluation of the Costs of Stormwater Management Pond Construction and Maintenance, March 1983.*

[6]*C. Wiegand, T. R. Schueler, W. Chittenden, and D. Jellick, "Cost of Urban Runoff Quality Controls," Urban Runoff Quality-Proceedings of an Engineering Foundation Conference, Urban Water Research, ASCE/Hennider, New Hampshire, June 23-27, 1986.*

Figure 4

DISTRIBUTION OF WET DETENTION BASIN COMPONENT
CAPITAL COSTS AS A FUNCTION OF DETENTION BASIN SIZE



Source: SEWRPC.

be adjusted to account for known site problems or conditions. The Metropolitan Washington Council of Governments, 1983, estimated that annual operation and maintenance costs for wet detention basins generally range from 3 to 5 percent of the capital costs. This is consistent with the total annual operation and maintenance curve shown in Figure 8. The annual operation and maintenance cost for a 0.25-acre basin would approximate 4.7 percent of the estimated capital cost, while the annual operation and maintenance cost for a 5.0-acre basin would approximate 2.5 percent of the capital cost.

INFILTRATION TRENCHES

Infiltration trenches remove waterborne pollutants by capturing surface water runoff and filtering it through the soil. Infiltration trenches can effectively remove sediments, such as organic matter, nutrients, metals, and bacteria, although excessive sediment loadings can clog the trenches. In general, trenches are most effective at removing particulate pollutants or those pollutants which have an affinity for particles, and least effective at removing dissolved pollutants. Trapping, bacterial degradation, precipitation, and sorption onto soil particles are the primary processes of removal.

Description

An infiltration trench is an excavated trench that has been back-filled with stone aggregate, allowing accumulated water to seep into the underlying soil. A typical design of an infiltration trench is shown in Figure 9. The trenches are generally long and narrow, ranging in depth from about three to 12 feet. Typically, infiltration trenches are designed to serve drainage

Table 10

AVERAGE ANNUAL OPERATION AND MAINTENANCE COSTS OF WET DETENTION BASINS

Component	Unit Cost	Basin Surface Area (acres)				Comment
		0.25	1.0	3.0	5.0	
Lawn Mowing	$0.85/1,000 square feet	$ 74	$ 296	$ 889	$1,481	Maintenance area equals area cleared minus basin area. Mow eight times per year
General Lawn Care	$9.00/1,000 square feet/year	$ 98	$ 392	$1,176	$1,960	Maintenance area equals area cleared minus basin area
Basin Inlet Maintenance	3 percent of capital cost of inlet	$ 172	$ 172	$ 172	$ 172	- -
Basin Outlet Maintenance	5 percent of capital cost of outlet	$ 338	$ 338	$ 338	$ 338	- -
Basin Sediment Removal	1 percent of capital cost	$ 281	$ 719	$2,067	$3,421	- -
Debris and Litter Removal	$100/year	$ 100	$ 100	$ 100	$ 100	- -
Basin Nuisance Control	$200/acre of basin water surface	$ 50	$ 200	$ 600	$1,000	- -
Program Administration and Inspection	$50/basin/year, plus $25/inspection	$ 200	$ 200	$ 200	$ 200	Basins inspected six times per year
Total Annual Operation and Maintenance	- -	$1,313	$2,417	$5,542	$8,671	- -

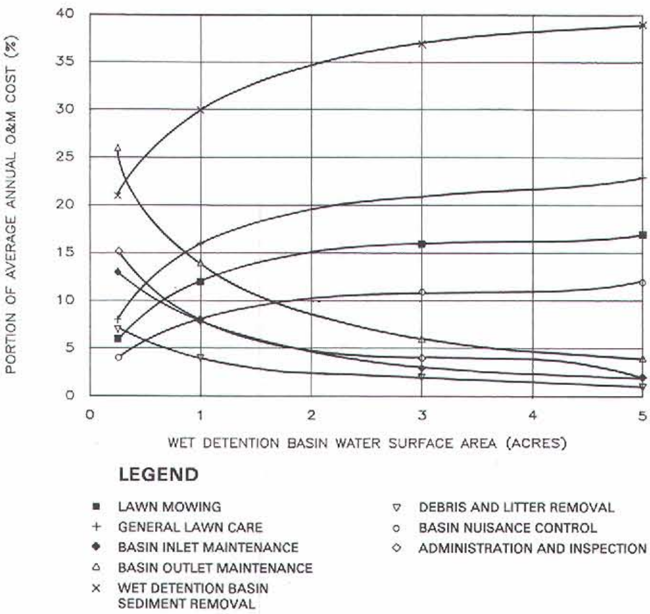
Source: SEWRPC.

areas of less than 10 acres; it is generally not economically feasible to infiltrate runoff from larger drainage areas in a trench. The surface of the trench can consist of stone or of vegetation with special inlets to distribute the water evenly. Table 11 summarizes some design guidelines and criteria for proper construction of a trench.

Infiltration trenches, like all infiltration practices, may also reduce the volume of stormwater runoff, provide groundwater recharge, and augment low stream flows. Infiltration practices can sometimes be used to limit peak stream flows at pre-development levels, thereby potentially reducing flooding, the size of downstream conveyance facilities, and streambank erosion problems. Infiltration trenches have a tendency to clog rapidly when sediment loadings are high and thus are better suited for application in fully developed and stabilized urban areas. The applicability of such trenches is limited by soil and groundwater conditions and there is a risk

Figure 5

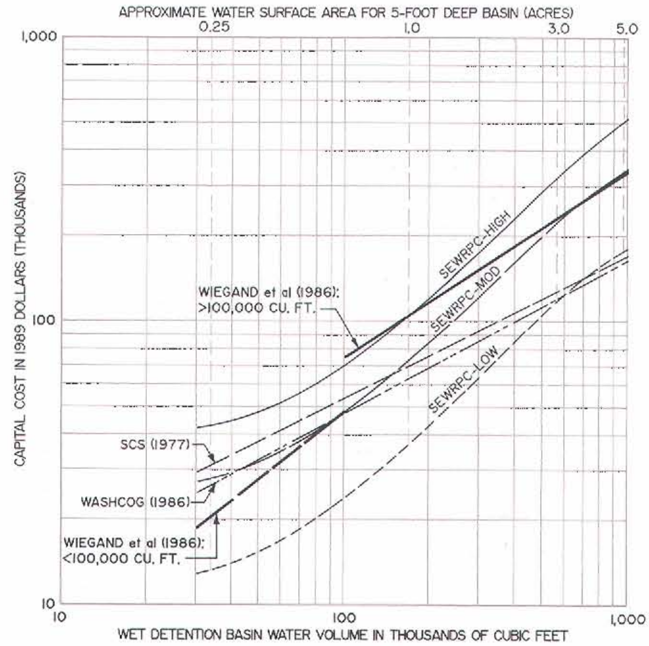
DISTRIBUTION OF WET DETENTION BASIN COMPONENT OPERATION AND MAINTENANCE COST AS A FUNCTION OF BASIN SIZE



Source: SEWRPC.

Figure 7

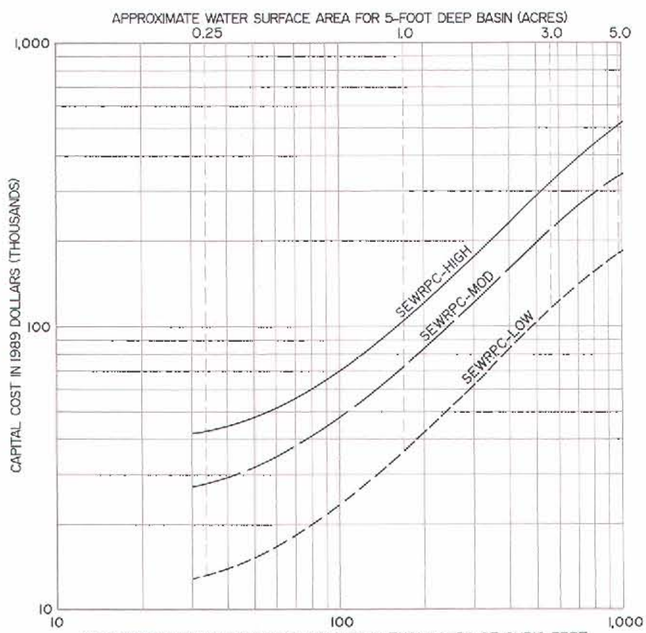
COMPARISON OF WET DETENTION BASIN CAPITAL COST ESTIMATING PROCEDURES: 1989



Source: SEWRPC.

Figure 6

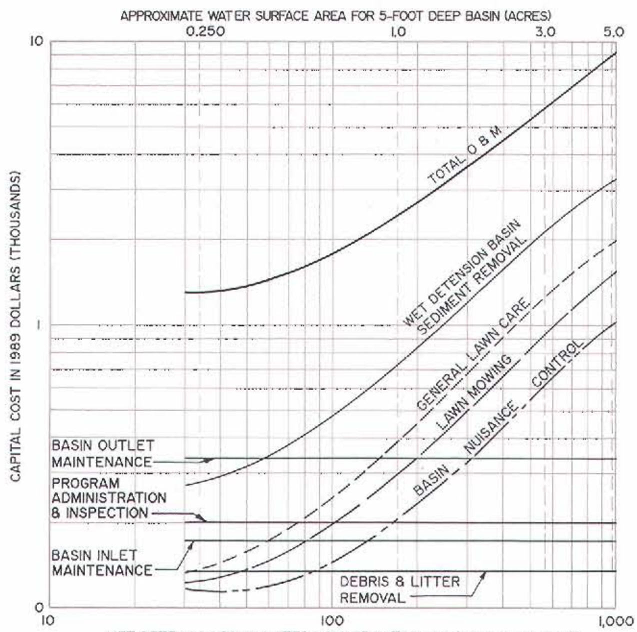
WET DETENTION BASIN CAPITAL COSTS: 1989



Source: SEWRPC.

Figure 8

WET DETENTION BASIN AVERAGE ANNUAL OPERATION AND MAINTENANCE COSTS: 1989



Source: SEWRPC.

of groundwater contamination. Moreover, in urban areas great care must be taken in the location of such trenches to avoid undue increases in the elevation of the groundwater table and attendant wet basements, excessive infiltration of clean water into sanitary sewerage systems, and failing foundations for pavements and structures.

In sizing an infiltration trench, it may be assumed that, with a stone aggregate diameter ranging from one to three inches, the void space will be about 40 percent. For water quality protection, the trenches should be designed to store the first 0.5 inch of runoff from the contributing drainage area—thereby capturing the "first flush," which generally contains the highest pollutant concentrations.

To determine whether trenches are operating properly, observation wells should be installed. An observation well, as also shown in Figure 9, may consist of a four- to six-inch-diameter perforated polyvinyl chloride (PVC) pipe set vertically on a foot plate. The well should have a secure removable locking cap. The well is intended to be used to monitor the water level in the trench after rainfall events. The well readings thus provide an indication of whether the trench is draining properly after a storm event. Inadequate drainage could be caused by clogging of the trench, inadequate soil permeability, or insufficient depth to groundwater, and would indicate the need for maintenance.

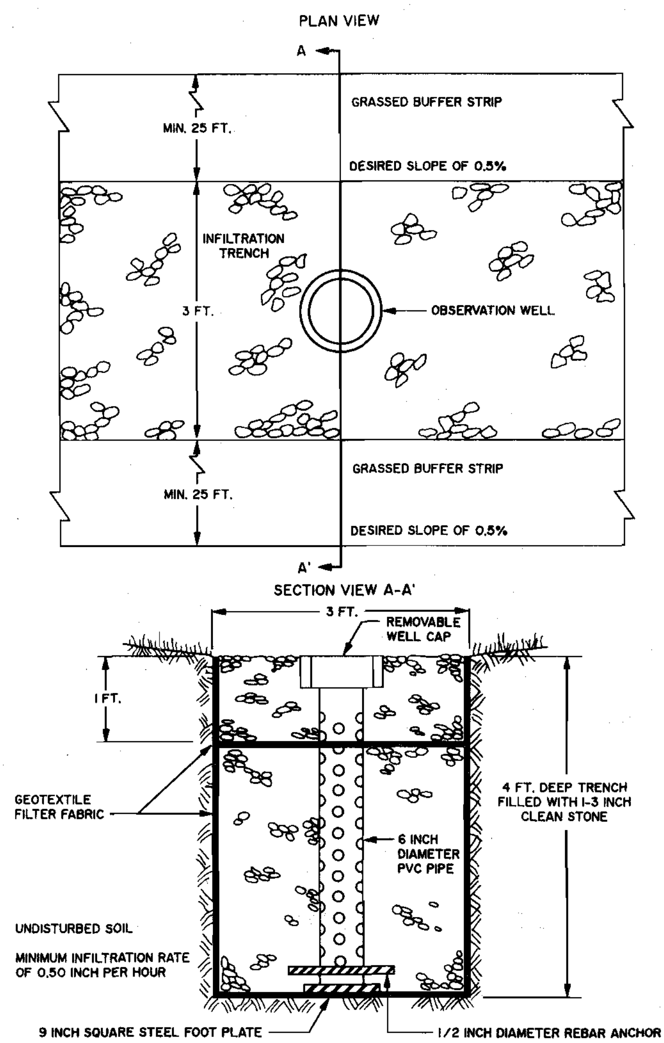
Filter fabric is required around the walls and, unless a sand filter is provided, over the bottom of the trench to prevent migration of fine soil particles into the stone voids. Filter fabric should also be placed horizontally about one foot below the surface of the trench to capture sediment and reduce clogging.

To prevent clogging and enhance the longevity of the trench, the entire drainage area should be stabilized prior to construction of the trench, and a minimum 25-foot-wide grass buffer-strip should be provided around the perimeter of the trench. The site should be graded to allow sheet flow across the buffer strip into the trench.

Infiltration trenches do not remove all of the pollutant loadings because only a portion of the runoff is captured by the trench, because some soluble pollutants pass through the soil layers,

Figure 9

TYPICAL INFILTRATION TRENCH



Source: SEWRPC.

and because some sediment-adsorbed pollutants will eventually be leached from the soil. These soluble and leached pollutants will seep either to the water table, or to a nearby groundwater discharge site such as a stream or wetland. Typical long-term pollutant removal rates for infiltration trenches are listed in Table 12. The removal rates vary with the pollutant considered, ranging from slightly less than 50 percent for total nitrogen to about 90 percent for sediment, certain metals, and bacteria.

Periodic maintenance of infiltration trenches is essential. Periodic maintenance tasks include inspections annually and after large storm events, vegetated buffer strip maintenance and

Table 11

DESIGN GUIDELINES FOR INFILTRATION TRENCHES

Design Factor	Guidelines
Site Evaluation	• Take soil borings to depth of at least five feet below bottom of trench to check for soil infiltration, depth to seasonally-high water table, and depth to bedrock • Minimum soil infiltration rate four feet below bottom of trench: 0.50 inch per hour • Avoid Hydrologic Soil Group C or D soils • Acceptable soil texture classes include sand, loamy sand, sandy loam, and some silt loams. Soils should have less than 20 percent clay and less than 40 percent silt and clay combined • Minimum depth to bedrock or seasonally-high water table: four feet • Minimum setback from water supply wells: 100 feet • Minimum setback from building foundations: 10 feet down-gradient; 100 feet up-gradient • Maximum ground slope of overall contributing drainage area: 5 percent • Avoid use in areas where the stormwater runoff is likely to contain high concentrations of soluble toxic substances
Drainage Area	• Maximum: 10 acres • Entire drainage area must be stabilized (either by vegetation or impervious surfaces), or divert stormwater away from trench until vegetative cover is established
Trench Drainage Time	• Maximum: 72 hours • Minimum: six hours
Trench Volume	• Minimum (with 40 percent void space): contain 0.5-inch runoff from contributing drainage area
Trench Depth	• Minimum: three feet • Maximum: 12 feet
Construction	• Excavate with light equipment to prevent compaction. Acceptable equipment includes small backhoes or wheel and ladder-type trenches. Unacceptable equipment includes bulldozers and front-end loaders • Place excavated soil at least 15 feet from trench • Line sides and bottom of trench with filter fabric (a six-inch layer of clean sand may be used on bottom of trench instead of filter fabric) • Place filter fabric horizontally one foot below surface of trench • Place stone aggregate in trench gently with backhoe and lightly compact with plate compactors
Stone Aggregate	• Clean and washed stone • Minimum diameter: one inch • Maximum diameter: three inches
Observation Well	• Anchor vertical four- to six-inch-diameter perforated PVC pipe • Cover well pipe with removable, locking cap
Grass Buffer Strip	• Minimum: 25 feet wide • Slope: Minimum, 0.5 percent; Maximum, 15 percent • Surround entire trench • Design so sheet flow, rather than channelized flow, travels over strip
Pretreatment of Runoff	• Pretreat runoff containing substantial amounts of sediment, oil, and grease in a grit chamber, sediment trap, or catch basin

Source: T. R. Schueler, 1987; B. W. Harrington, 1988; and SEWRPC.

Table 12

TYPICAL LONG-TERM POLLUTANT REMOVAL RATES FOR INFILTRATION TRENCHES AND BASINS

Pollutant	Typical Removal Rates (percent)
Sediment	75-90
Total Phosphorus	50-70
Total Nitrogen	45-60
Biochemical Oxygen Demand	70-80
Metals	75-90
Bacteria	75-90

Source: T. R. Schueler, 1987.

mowing, and rehabilitation of the trench when clogging begins to occur. Surface clogging can be relieved by replacing the top layer of the trench, including the filter fabric near the surface. Bottom clogging requires removal and replacement of all of the filter fabric and stone aggregate.

Reported General Costs

Few infiltration trenches have been constructed in southeastern Wisconsin. Using a unit cost range of $99 to $126 per cubic yard as estimated by the Northern Virginia Planning Commission, a 100-foot-long trench which is three feet deep and four feet wide would cost from $4,400 to $5,600; while this same trench would have an estimated cost of $3,200 using a cost procedure developed by Wiegand et al., 1986.

Few estimates are available on the cost of maintaining trenches. In general, it may be expected that the trenches will need to be rehabilitated, at a cost of about 20 percent of the capital cost, at five- to 15-year intervals. Overall maintenance costs were estimated by the Metropolitan Washington Council of Governments at 5 to 10 percent of the capital cost per year.[7] This estimate was based on a survey of six local and national agencies having organized stormwater management maintenance programs.

Cost Estimates

The costs for infiltration trenches can be divided into a number of components: mobilization and demobilization of equipment, site preparation, site development, and contingencies. Site preparation includes clearing, grubbing, and excavation. Site development activities include placement of filter fabric, placement of stone aggregate, installation of groundwater observation well, and establishment of a vegetative buffer strip. Contingencies include planning, engineering, administration, and legal fees.

Based on a review of the local unit costs reported in Appendix B, a low, moderate, and high unit cost was selected for each component by the Regional Planning Commission staff, in consultation with representatives of engineering firms and local agencies of government. These three unit costs for each component were used to calculate a probable range of capital costs for each component, and to calculate a range of total capital costs.

Tables 13 and 14 present the estimated unit costs and the calculated component and total capital costs for a three-foot-deep, four-foot-wide trench; and for a six-foot-deep, 10-foot-wide trench, respectively. Both trenches would be 100 feet long. The assumptions used to quantify each component are listed in the footnotes to the tables. The estimated capital costs range from $27 to $74 per lineal foot of trench for the smaller trench, and from $71 to $167 per lineal foot for the larger trench.

The distribution of the component capital costs varies slightly with the size of the trench, as shown in Figure 10. The figure shows the distribution of costs based on the moderate cost estimates presented in Tables 13 and 14. The site development cost exceeds the site preparation cost for both small and large trenches. Mobilization and demobilization of equipment accounts for 5 percent or less of the total capital cost and contingencies were assumed to equal 20 percent of the capital cost of all trenches.

Trench maintenance unit costs were also estimated. Table 15 presents selected unit costs for major and minor trench rehabilitation, buffer strip maintenance, trench inspection, and program administration. A single unit cost was selected for each maintenance component because little experience is available in the State. The estimated annual operation and maintenance costs range from $285 for three-foot-deep, four-foot-wide, 100-foot-long trench, to $615 for a six-foot-deep, 10-foot-wide, 100-foot-long trench.

[7] *Wiegand et al., 1986. op. cit.*

Table 13

ESTIMATED CAPITAL COST OF A THREE-FOOT-DEEP, FOUR-FOOT-WIDE INFILTRATION TRENCH[a]

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization/ Demobilization-Light	Trench	1	$ 107	$ 274	$ 441	$ 107	$ 274	$ 441
Site Preparation								
Clearing[b]	Acre	0.12	$2,200	$ 3,800	$ 5,400	$ 264	$ 456	$ 648
Grubbing[c]	Acre	0.01	3,800	5,200	6,600	38	52	66
Trench Excavation[d]	Cubic yard	43.3	2.10	5.60	9.10	91	242	394
Site Development								
Salvaged Topsoil, Seed, and Mulch[e]	Square yard	111	$ 0.40	$ 1.00	$ 1.60	$ 44	$ 111	$ 178
Sod[f]	Square yard	444	1.20	2.40	3.60	533	1,066	1,598
Crushed Stone Fill[g]	Cubic yard	43.3	14.80	19.40	24.00	641	840	1,039
Geotextile Fabric[h]	Square yard	171	1.00	2.00	3.00	171	342	513
Shallow Observation Well[i] ...	Vertical foot	4	66.00	160.00	254.00	264	640	1,016
Subtotal	- -	- -	- -	- -	- -	$2,153	$4,023	$5,893
Contingencies	Trench	1	25 percent	25 percent	25 percent	$ 538	$1,006	$1,473
Total	- -	- -	- -	- -	- -	$2,691	$5,029	$7,367

[a]*Trench has a 100-foot length.*

[b]*Area cleared = (trench width + 50 feet) x trench length.*

[c]*Area grubbed = (trench width x trench length).*

[d]*Volume excavated = trench volume.*

[e]*Area seeded = (area cleared - trench area) x 0.2.*

[f]*Area sodded = (area cleared - trench area) x 0.8.*

[g]*Volume of stone fill = trench volume.*

[h]*Geotextile filter fabric = 2(trench depth x length) + 2(trench width x length) + 10 percent.*

[i]*Depth of observation well = (trench depth + 1 foot).*

Source: SEWRPC.

The distribution of the component operation and maintenance costs varies by trench size, as shown in Figure 11. As the trench volume increases, the portion of the total maintenance cost required for trench rehabilitation increases.

Based on the unit costs presented above, cost curves were developed which may be used to help estimate the capital and operation and maintenance costs of various infiltration trench sizes. These curves should be used only to provide a preliminary estimate of a proposed trench cost. The costs are presented for a typical trench design as shown in Figure 8. For modified designs, the unit costs presented in Appendix B may be used to revise these costs.

Figure 12 presents the capital cost curves for infiltration trenches. Moderate unit costs were used to calculate the curves, which are shown for trench depths ranging from three to 12 feet and for trench widths ranging from two to 30 feet. Figure 13 presents the annual operation and maintenance cost curves for infiltration trenches.

INFILTRATION BASINS

Infiltration basins perform similar to infiltration trenches in removing water-borne pollutants by capturing surface water runoff and filtering it through the soil. Like trenches, infiltration basins are most effective at removing pollutants

Table 14

ESTIMATED CAPITAL COST OF A SIX-FOOT-DEEP, TEN-FOOT-WIDE INFILTRATION TRENCH[a]

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization/ Demobilization-Light	Trench	1	$ 107	$ 274	$ 441	$ 107	$ 274	$ 441
Site Preparation								
Clearing[b]	Acre	0.14	$2,200	$ 3,800	$5,400	$ 308	$ 532	$ 756
Grubbing[c]	Acre	0.02	3,800	5,200	6,600	76	104	132
Trench Excavation[d]	Cubic yard	222	2.10	5.60	9.10	466	1,243	2,020
Site Development								
Salvaged Topsoil, Seed, and Mulch[e]	Square yard	111	$ 0.40	$ 1.00	$ 1.60	$ 44	$ 111	$ 178
Sod[f]	Square yard	444	1.20	2.40	3.60	533	1,066	1,598
Crushed Stone Fill[g]	Cubic yard	222	14.80	19.40	24.00	3,286	4,307	5,328
Geotextile Fabric[h]	Square yard	388	1.00	2.00	3.00	388	776	1,164
Shallow Observation Well[i]	Vertical foot	4	66.00	160.00	254.00	462	1,120	1,778
Subtotal	- -	- -	- -	- -	- -	$5,670	$ 9,533	$13,395
Contingencies	Trench	1	25 percent	25 percent	25 percent	$1,418	$ 2,383	$ 3,349
Total	- -	- -	- -	- -	- -	$7,088	$11,916	$16,744

[a]*Trench has a 100-foot length.*

[b]*Area cleared = (trench width + 50 feet) x trench length.*

[c]*Area grubbed = (trench width x trench length).*

[d]*Volume excavated = trench volume.*

[e]*Area seeded = (area cleared - trench area) x 0.2.*

[f]*Area sodded = (area cleared - trench area) x 0.8.*

[g]*Volume of stone fill = trench volume.*

[h]*Geotextile filter fabric = 2(trench depth x length) + 2(trench width x length) + 10 percent.*

[i]*Depth of observation well = (trench depth + 1 foot).*

Source: SEWRPC.

which are attached to sediment particles or which have an affinity for particles. Trapping, bacterial degradation, precipitation, and sorption onto soil particles are the primary processes of removal. Infiltration basins differ from trenches in that the water is temporarily stored above grade, rather than in a rock filled trench, and therefore the full volume of the basin is available for storage.

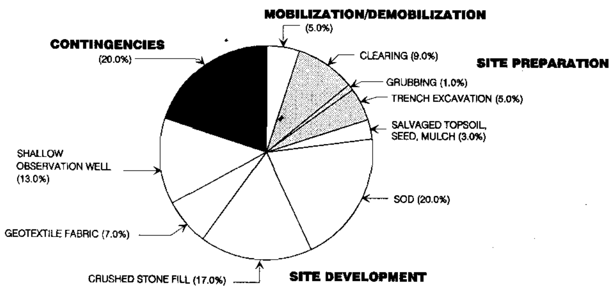
Description

An infiltration basin is a dry impoundment which is formed by excavation or by constructing an embankment. The basin typically does not have an outlet other than an emergency spillway to pass runoff volumes in excess of the design storm, but rather the captured runoff infiltrates through the permeable soils of the basin floor. An example of a typical design of an infiltration basin is shown in Figure 14. The floor of the basin is graded as flat as possible. A dense grass cover is established to promote infiltration, to increase the biological uptake of nutrients, to trap sediment particles, and to improve sediment drying by plant transpiration. Table 16 summarizes design guidelines and criteria for construction of an infiltration basin.

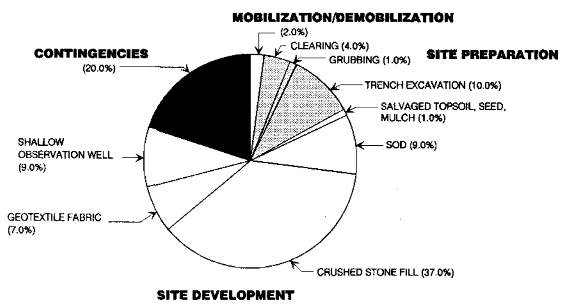
Figure 10

DISTRIBUTION OF INFILTRATION TRENCH COMPONENT CAPITAL COSTS AS A FUNCTION OF TRENCH SIZE

ESTIMATED CAPITAL COST OF A 3-FOOT-DEEP, 4-FOOT-WIDE INFILTRATION TRENCH



ESTIMATED CAPITAL COST OF A 6-FOOT-DEEP, 10-FOOT-WIDE INFILTRATION TRENCH

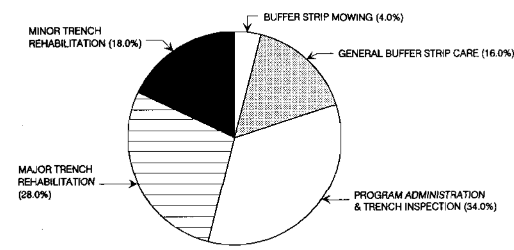


Source: SEWRPC.

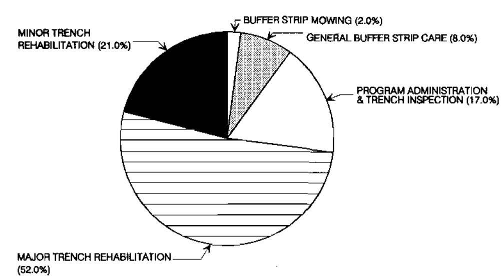
Figure 11

DISTRIBUTION OF INFILTRATION TRENCH COMPONENT OPERATION AND MAINTENANCE COST AS A FUNCTION OF TRENCH SIZE

ESTIMATED ANNUAL OPERATION AND MAINTENANCE COST OF A 3-FOOT-DEEP, 4-FOOT-WIDE INFILTRATION TRENCH



ESTIMATED ANNUAL OPERATION AND MAINTENANCE COST OF A 6-FOOT-DEEP, 10-FOOT-WIDE INFILTRATION TRENCH



Source: SEWRPC.

Table 15

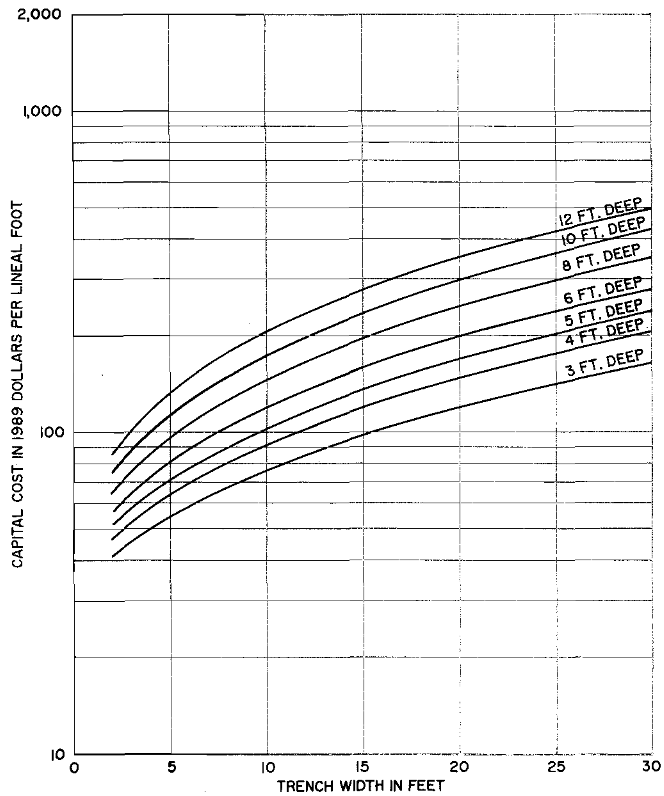
AVERAGE ANNUAL OPERATION AND MAINTENANCE COSTS FOR INFILTRATION TRENCHES

Component	Unit Cost	Trench Size: 100 Feet Long by Three Feet Deep by Four Feet Wide	Trench Size: 100 Feet Long by Six Feet Deep by 10 Feet Wide	Comment
Buffer Strip Mowing	$0.85/1,000 square feet/mowing	$ 10	$ 10	Maintenance area equals area cleared minus area grubbed. Mow twice per year
General Buffer Strip Lawn Care	$9.00/1,000 square feet/year	$ 45	$ 45	Maintenance area equals area cleared minus area grubbed
Program Administration and Trench Inspection	$25/inspection, plus $50/trench/year for administration	$100	$100	Inspect twice per year
Major Trench Rehabilitation	$0.40 to $19.00 per lineal foot at 15-year intervals	$ 79	$334	- -
Minor Trench Rehabilitation	$0.25 to $3.70 per lineal foot at five-year intervals	$ 51	$126	- -

Source: SEWRPC.

Figure 12

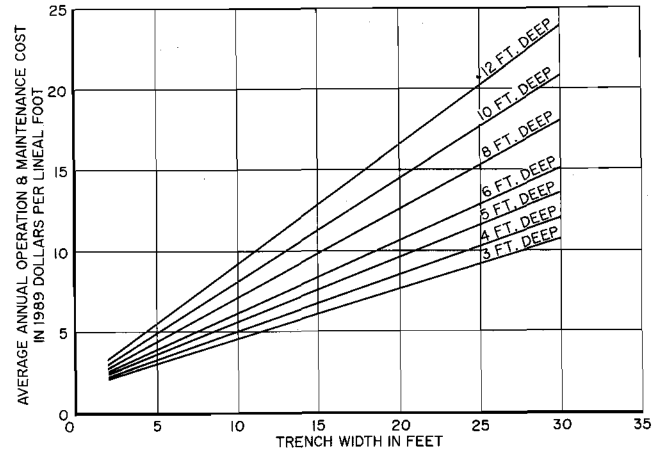
INFILTRATION TRENCH CAPITAL COSTS: 1989



Source: SEWRPC.

Figure 13

INFILTRATION TRENCH AVERAGE ANNUAL OPERATION AND MAINTENANCE COSTS: 1989



Source: SEWRPC.

Infiltration basins have the same site limitations as do trenches, and periodic inspections are needed to check for ponded water, vegetation damage, and soil erosion. The primary advantage of infiltration basins is a relatively low cost per unit volume of water stored and treated, compared to other infiltration systems. Observation wells are normally not needed for basins, unless groundwater samples are desired to check for contamination. Disadvantages of infiltration systems include a fairly high rate of failure due to unsuitable or clogged soils; the need for frequent cleaning and maintenance; nuisance problems such as odors, mosquitoes, and soggy ground; and potential contamination of the groundwater.

Although infiltration basins are sometimes sized to store and infiltrate the entire runoff volume generated from a storm as large as a two-year recurrence interval storm, basins may also be designed to accommodate only smaller storm events. During larger storm events, the basins would capture the initial "first flush" of runoff. At a minimum, all infiltration basins should be designed to store the first 0.5 inch of runoff from the contributing drainage area.

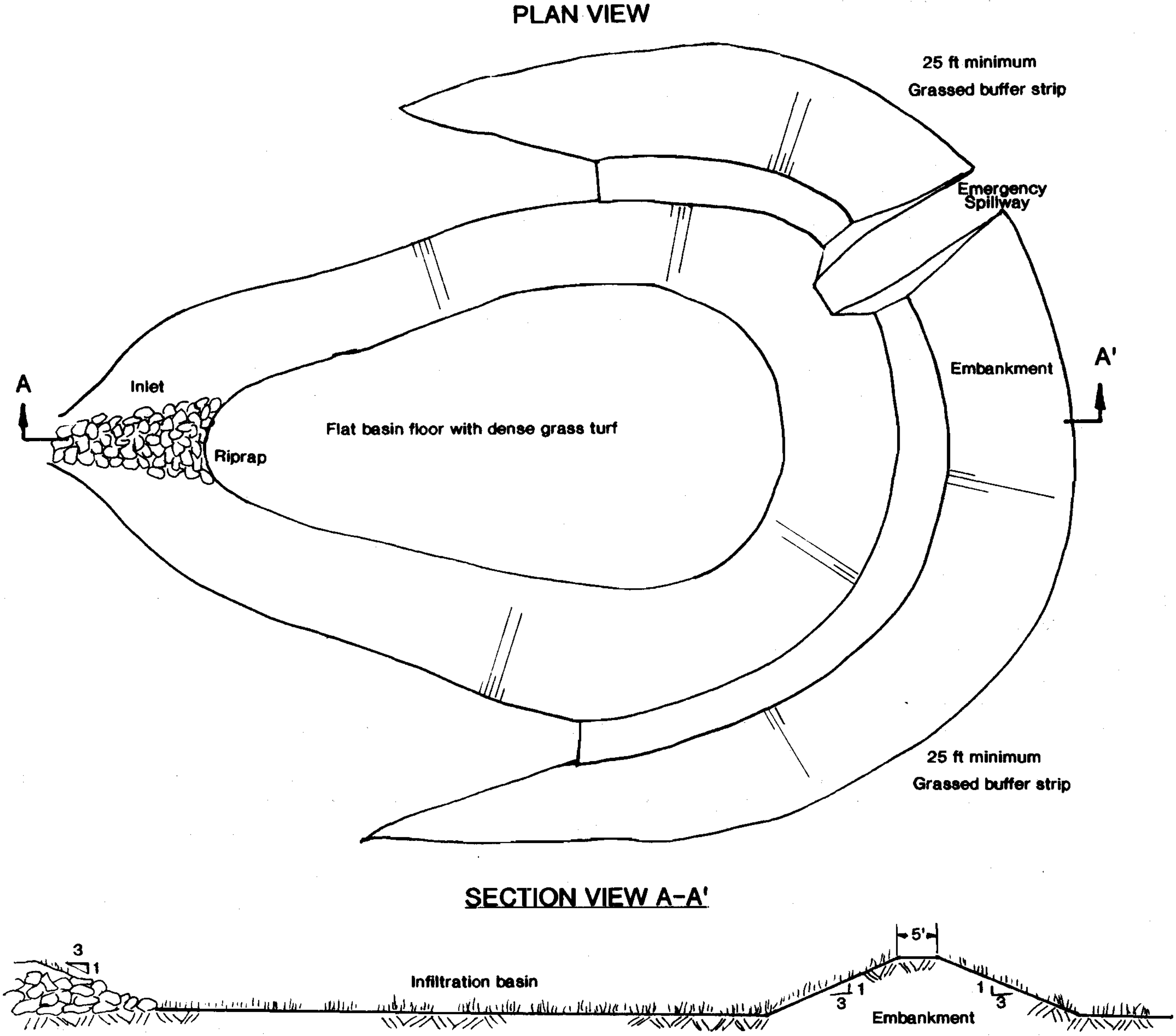
Excessive sediment loadings should not be discharged to the basin. The surface soils on the basin floor can be clogged by deposited sediments. A sediment trap may be constructed near the basin inlet to capture incoming sediment loadings. Once the soils are clogged, it is difficult to rehabilitate a basin because the native surface soils must be either deeply tilled or excavated and replaced, and the vegetation quickly reestablished. Clogged infiltration basins may also be converted into wet ponds.

Pollutant removal rates for infiltration basins are the same as for infiltration trenches, as presented in Table 11. As already noted, those rates range from slightly less than 50 percent for total nitrogen to about 90 percent for sediment, certain metals, and bacteria.

Careful construction and maintenance is essential for an infiltration basin. The State of Maryland reported that about 40 percent of the infiltration basins surveyed became partially or completely clogged within the first few years of operation—a failure rate higher than any other

Figure 14

TYPICAL INFILTRATION BASIN



Source: SEWRPC.

infiltration practice.[8] Failure was attributed to such factors as inadequate testing of soil infiltration rates, compaction of soils, or clogging by excessive sediment loadings. Periodic maintenance needs include inspections annually and after large storms, mowing of side slopes and basin floor at least twice per year to prevent woody growth, debris and litter removal, erosion control, and control of nuisance odor or mosquito problems. Deep tilling may be needed at five- to 10-year intervals to break up a clogged surface layer. The tilling would be followed by grading, leveling, and revegetating the surface. In some cases, perforated underdrain pipes may need to be installed to maintain adequate infiltration. Accumulated sediments may need to be removed by light equipment periodically.

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[8]*Maryland Water Resources Administration, Minimum Water Quality and Planning Guidelines for Infiltration Practices, Maryland Department of Natural Resources, Annapolis, Maryland, 1986.*

Table 16

DESIGN GUIDELINES FOR INFILTRATION BASINS

Design Factor	Guidelines
Site Evaluation	• Take soil borings to depth of at least five feet below bottom of basin to check for soil infiltration, depth to seasonally-high water table, and depth to bedrock • Minimum infiltration rate four feet below bottom of basin: 0.50 inches per hour • Avoid Hydrologic Soil Group C or D soils • Acceptable soil texture classes include sand, loamy sand, sandy loam, and some silt loams. Soils should have less than 20 percent clay and less than 40 percent silt and clay combined • Minimum depth to bedrock or seasonally-high water table: four feet • Minimum setback from water supply wells: 100 feet • Minimum setback from building foundations: 10 feet down-gradient; 100 feet up-gradient • Maximum ground slope of overall contributing drainage area: 5 percent • Avoid use in areas where the stormwater runoff is likely to contain high concentrations of soluble toxic substances
Drainage Area	• Maximum: 50 acres • Entire drainage area must be stabilized (either by vegetation or impervious surfaces), or divert stormwater away from basin until vegetative cover is established
Basin Drainage Time	• Maximum: 72 hours
Basin Capacity	• Minimum: contain and infiltrate 0.5-inch runoff from contributing drainage area
Basin Side Slopes	• Maximum: 3:1
Inlet	• Basin inlet should be constructed following wet detention basin guidelines set forth in Table 4 • The inlet should discharge at the same invert elevation as the basin floor • Where incoming sediment loadings are high, construct a sediment trap at inlet • Where inflow velocities are high, construct a riprap apron at inlet to dissipate the flow
Construction	• Excavate with light equipment with tracks or oversized tires to prevent soil compaction • After excavation, level basin floor and till with a rotary tiller or disc harrow to restore infiltration rates • The basin embankment and emergency spillway should be constructed following wet detention basin guidelines set forth in Table 4
Basin Vegetation	• Establish dense growth of water-tolerant, low-maintenance, rapid-germinating grasses on basin floor and side slopes • Remove all woody growth from basin floor and side slopes Trees and shrubs may be planted around perimeter of basin
Grass Buffer Strip	• Provide a minimum 25-foot-wide, well-vegetated buffer strip between the edge of the basin and any impervious surfaces
Access	• Provide a minimum 12-foot-wide access way to the basin floor that can withstand light equipment and that does not cross the emergency spillway

Source: T. R. Schueler, 1987, and SEWRPC.

Table 17

ENGINEERING FORMULA FOR ESTIMATING COSTS OF INFILTRATION BASINS

Capitol Cost	Annual Operation and Maintenance Cost	Location	Reference[a]
$C = \$4.16V^{0.75}$ Where, C = Capital Cost V = Basin Volume[b] in Cubic Feet	5 to 10 percent of basin cost Construction: 4 to 9 percent of basin capital cost	Washington, D. C. Metropolitan Area	Wiegand et al., June 1986
$C = \$73.52V^{0.51}$ Where, C = Capital Cost V = Basin Volume[b] in Cubic Feet	3 to 5 percent of basin construction cost; 2 to 4 percent of basin capital cost	Washington, D. C. Metropolitan Area	T. R. Schueler, et al., April 1985
$C = \$14.63V^{0.69}$ Where, C = Capital Cost V = Basin Volume[b] in Cubic Feet	3 to 5 percent of basin construction cost; 2 to 4 percent of basin capital cost	Washington, D. C. Metropolitan Area	T. R. Schueler, 1987
C = \$1.18(cubic foot)[c] Where, C = Capital Cost	\$0.15/cubic foot, or 13 percent of capital cost	City of Oconomowoc, Wisconsin	Donohue & Associates, Inc., April 1989

NOTE: All costs updated to January 1989.

[a] *See Appendix C.*

[b] *Applies to infiltration basins with a volume greater than 10,000 cubic feet.*

[c] *Calculated for a three-foot-deep infiltration basin.*

Source: SEWRPC.

Reported General Costs

Although many communities in Wisconsin contain internally-drained areas which serve to infiltrate stormwater, few engineered basins have been constructed. Thus, little is known about the construction and maintenance costs of such basins in the State.

Table 17 summarizes empirical formulae which have been proposed to estimate the cost of infiltration basins. Wiegand et al., 1986, concluded that the capital cost of an infiltration basin would approximate one-half the cost of a dry or wet detention basin of comparable volume, the detention basin cost being calculated from the reported costs for 53 such basins in the Washington, D. C. area. Schueler et al., 1985, proposed that the capital cost of an infiltration basin be estimated as 80 percent of the cost of a comparably-sized wet or dry detention basin, with Schueler's detention basin cost being derived from reported costs for 31 detention basins, also in the Washington, D. C. area. Wiegand and Schueler et al. agree that the cost of an infiltration basin is lower than for a stormwater detention basin because the infiltration basin would not require an outlet system. In a later study, Schueler, 1987, concluded that the capital cost of an infiltration basin should be

Table 18

ESTIMATED CAPITAL COST OF A 0.25-ACRE INFILTRATION BASIN[a]

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization/ Demobilization-Heavy	Basin	1	$ 390	$1,000	$1,610	$ 390	$ 1,000	$ 1,610
Site Preparation								
Clearing[b]	Acre	0.5	$2,200	$3,800	$5,400	$ 1,100	$ 1,900	$ 2,700
Grubbing[c]	Acre	0.13	3,800	5,200	6,600	494	676	858
General Excavation[d]	Cubic yard	834	2.10	3.70	5.30	1,751	3,086	4,420
Place and Compact Fill[e]	Cubic yard	559	0.60	1.10	1.60	335	615	894
Level and Till[f]	Square yard	1076	0.20	0.35	0.50	215	377	538
Site Development								
Salvaged Topsoil, Seed, and Mulch[g]	Square yard	1,210	$ 0.40	$ 1.00	$ 1.60	$ 484	$ 1,210	$ 1,936
Sod[h]	Square yard	1,210	1.20	2.40	3.60	1,452	2,904	4,356
Riprap[i]	Cubic yard	10	16.40	29.60	42.80	164	296	428
Basin Inlet[j]	Each	1	2,620	5,740	8,860	2,620	5,740	8,860
Landscape, Fence, etc.[k]	Acre	0.5	1,000	2,000	3,000	500	1,000	1,500
Subtotal	- -	- -	- -	- -	- -	$ 9,505	$18,804	$28,100
Contingencies	Basin	1	25 percent	25 percent	25 percent	$ 2,376	$ 4,701	$ 7,025
Total	- -	- -	- -	- -	- -	$11,881	$23,505	$35,125

[a]*Basin has a three-foot depth; 3:1 side slopes.*

[b]*Area cleared = 2 x basin area.*

[c]*Area grubbed = 0.5 x basin area (for embankment and spillway).*

[d]*Volume excavated = basin volume + 50 percent for spillway.*

[e]*Volume of fill placed and compacted = 0.67 x excavation volume.*

[f]*Area leveled and tilled = basin bottom area, (basin area - embankment side sloped area).*

[g]*Area seeded = 0.5 x area cleared.*

[h]*Area sodded = 0.5 x area cleared.*

[i]*Riprap volume = (number of inlets x 10 cubic yards).*

[j]*Assumed only one inlet needed.*

[k]*Area landscaped = area cleared.*

Source: SEWRPC.

calculated using a formula developed from an analysis of 40 extended detention dry basins. Unlike his 1985 report, Schueler, 1987, did not recommend reducing this cost to account for lack of an outlet. All three of these studies estimated that contingency fees would approximate 25 percent of the basin construction cost. Donohue & Associates, Inc., 1989, estimated a unit area capital cost for a three-foot-deep infiltration basin, apparently by calculating the cost of individual construction components.

Schueler et al., 1985, and Schueler, 1987, proposed that the annual operation and maintenance cost of an infiltration basin be estimated as 3 to 5 percent of the construction cost, or 2 to 4 percent of the capital cost. This cost estimate is the same as Schueler proposed for detention basins. Wiegand et al., 1986, recommended that a higher operation and maintenance cost be used for infiltration basins because of a more frequent need for lawn mowing and sediment removal. Wiegand et al., 1986, suggested that the annual operation and maintenance cost be estimated as 5 to 10 percent of the construction cost, or 4 to 9 percent of the capital cost. Unit operation and maintenance costs presented by Donohue & Associates, 1989, were even higher, representing about 13 percent of the capital cost.

Table 19

ESTIMATED CAPITAL COST OF A 1.0-ACRE INFILTRATION BASIN[a]

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization/ Demobilization-Heavy	Basin	1	$ 390	$1,000	$1,610	$ 390	$ 1,000	$ 1,610
Site Preparation								
Clearing[b]	Acre	2.0	$2,200	$3,800	$5,400	$ 4,400	$ 7,600	$ 10,800
Grubbing[c]	Acre	0.5	3,800	5,200	6,600	1,900	2,600	3,300
General Excavation[d]	Cubic yard	4,240	2.10	3.70	5.30	8,904	15,688	22,472
Place and Compact Fill[e]	Cubic yard	2,841	0.60	1.10	1.60	1,705	3,125	4,546
Level and Till[f]	Square yard	4,570	0.20	0.35	0.50	914	1,600	2,285
Site Development								
Salvaged Topsoil, Seed, and Mulch[g]	Square yard	4,840	$ 0.40	$ 1.00	$ 1.60	$ 1,936	$ 4,840	$ 7,744
Sod[h]	Square yard	4,840	1.20	2.40	3.60	5,808	11,616	17,424
Riprap[i]	Cubic yard	10	16.40	29.60	42.80	164	296	428
Basin Inlet[j]	Each	1	2,620	5,740	8,860	2,620	5,740	8,860
Landscape, Fence, etc.[k]	Acre	2.0	1,000	2,000	3,000	2,000	4,000	6,000
Subtotal	- -	- -	- -	- -	- -	$30,741	$58,105	$ 85,469
Contingencies	Basin	1	25 percent	25 percent	25 percent	$ 7,685	$14,526	$ 21,367
Total	- -	- -	- -	- -	- -	$38,426	$71,631	$106,836

[a]*Basin has a three-foot depth; 3:1 side slopes.*

[b]*Area cleared = 2 x basin area.*

[c]*Area grubbed = 0.5 x basin area (for embankment and spillway).*

[d]*Volume excavated = basin volume + 50 percent for spillway.*

[e]*Volume of fill placed and compacted = 0.67 x excavation volume.*

[f]*Area leveled and tilled = basin bottom area, (basin area - embankment side sloped area).*

[g]*Area seeded = 0.5 x area cleared.*

[h]*Area sodded = 0.5 x area cleared.*

[i]*Riprap volume = (number of inlets x 10 cubic yards).*

[j]*Assumed only one inlet needed.*

[k]*Area landscaped = area cleared.*

Source: SEWRPC.

Cost Estimates

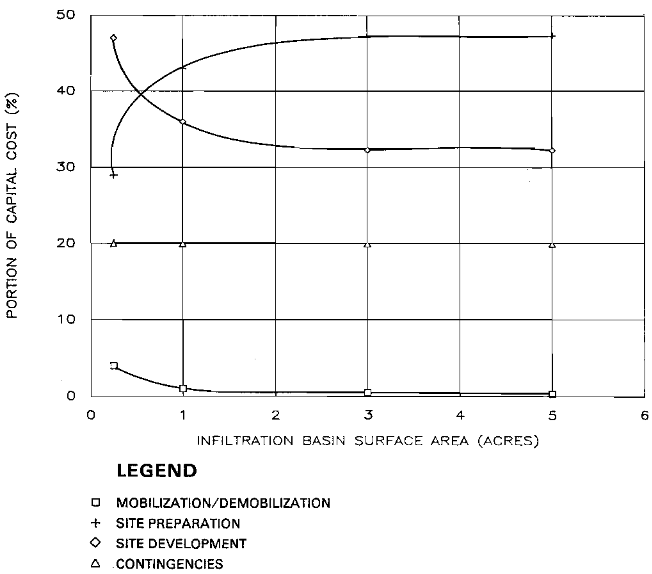
The costs for infiltration basins can be divided into a number of components: mobilization and demobilization of equipment, site preparation, site development, and contingencies. Site preparation includes clearing, grubbing, and excavation. Site development activities include construction of an inlet, possible installation of an underground drainage system, and establishment of vegetative cover. Contingencies include planning, engineering, administration, and legal fees.

Based on a review of the local unit costs report in Appendix B, a low, moderate, and high unit cost was selected for each component. These three unit costs for each component were used to calculate a probable range of costs for each component, and to calculate a range of basin total capital costs.

Tables 18 and 19 present the selected unit costs and the calculated component and total capital costs for a 0.25-acre infiltration basin and for a one-acre basin. Both basins would be three feet deep, and neither would contain an underground drainage system. The cost of an underground drainage system was not included because such systems are required only when the soils have marginal permeability. In those cases, it may be preferable to utilize a measure other than an infiltration basin—such as a wet pond—to

Figure 15

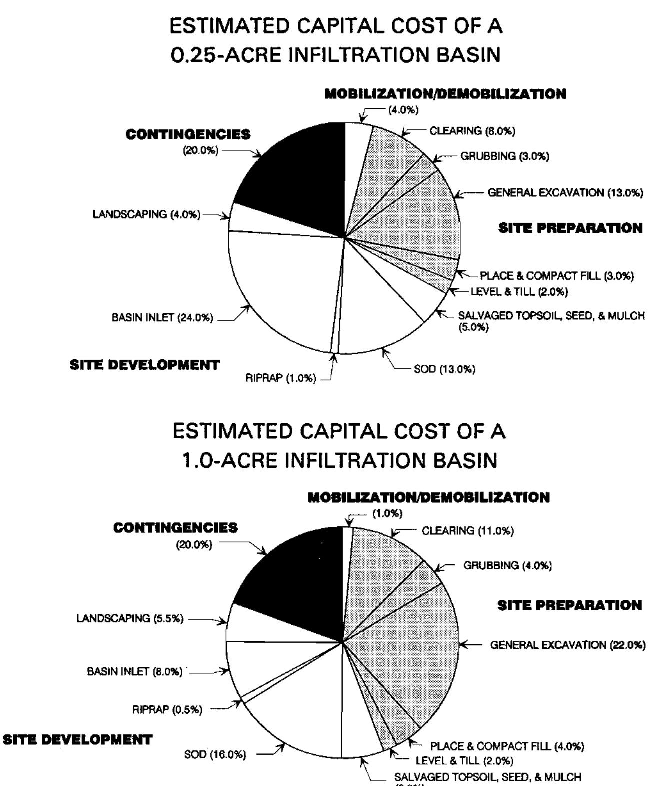
DISTRIBUTION OF INFILTRATION BASIN CAPITAL COST AS A FUNCTION OF BASIN SIZE



Source: SEWRPC.

Figure 16

DISTRIBUTION OF INFILTRATION BASIN COMPONENT CAPITAL COSTS AS A FUNCTION OF BASIN SIZE



Source: SEWRPC.

control pollution. The assumptions used to quantify each component are listed in the footnotes to the tables. The estimated capital costs range from \$12,000 to \$35,000 for a 0.25-acre basin; and from \$38,000 to \$107,000 for a 1.0-acre basin.

The distribution of the component capital costs varies with the size of the basin, as shown in Figures 15 and 16. The figures show the distribution of costs based on the moderate cost estimates presented in Tables 18 and 19. For very small basins—about 0.25 acre—the site development cost exceeds the site preparation cost; while for larger basins, the site preparation cost is slightly higher than the site development cost. For all basins, mobilization/demobilization accounts for less than 5 percent of the total capital cost and contingencies were assumed to equal 20 percent of the capital cost of all basins.

Table 20 presents estimated unit costs for each activity required for the long-term maintenance and operation of an infiltration basin. The estimated annual operation and maintenance costs range from \$917 for a three-foot-deep, 0.25-acre infiltration basin, to \$2,468 for a three-foot-deep, one-acre infiltration basin. As shown in Figure 17, the distribution of the component operation and maintenance costs varies slightly by basin size.

Based on the unit costs presented above, cost curves were developed which may be used to help estimate the capital and operation and maintenance costs of various infiltration basin sizes. These curves should be used only to provide a preliminary estimate of a proposed basin cost. The costs are presented for a typical basin design as shown in Figure 14. For modified designs, the unit costs presented in Appendix B may be used to revise these costs.

Figure 18 presents the low, moderate, and high capital cost curves for infiltration basins. The unit costs presented in Tables 18 and 19 were used to calculate the curves. The cost curves are presented for infiltration basins having a volume ranging from 30,000 to one million cubic feet. Figure 19 compares the SEWRPC capital cost curves to curves derived from cost estimating formulas proposed by Schueler et al., 1985, Schueler, 1987, Wiegand et al., 1986, and Donohue & Associates, Inc., 1989. The SEWRPC moderate and high cost curves are higher than any of the other curves. The SEWRPC cost

Table 20

AVERAGE ANNUAL OPERATION AND MAINTENANCE COST OF INFILTRATION BASINS

Component	Unit Cost	Basin Top Surface Area (acres)		Comment
		0.25	1.0	
Lawn Mowing	$0.85/1,000 square feet/ mowing	$148	$ 592	Maintenance area equals two times basin area. Mow eight times per year
General Lawn Care	$9.00/1,000 square feet/ year	$196	$ 784	Maintenance area equals two
Basin Inlet Maintenance	3 percent of inlet capital cost/year	$172	$ 172	- -
Soil Leveling and Tilling	$0.35/square yard	$ 38	$ 160	Basin bottom area leveled and tilled at 10-year intervals following sediment removal
Infiltration Basin Sediment Removal	$421.10/basin bottom acre/year	$ 84	$ 379	Assume a sediment layer of one foot removed at 10-year intervals
Basin Debris and Litter Removal	$100/year	$100	$ 100	- -
Grass Reseeding with Mulch and Fertilizer	$0.30/square yard	$ 29	$ 131	Area revegetated equals basin bottom area at 10-year intervals
Program Administration and Basin Inspection	$50/basin/year, plus $25/inspection	$150	$ 150	Basin inspected four times per year
Total Annual Operation and Maintenance	- -	$917	$2,468	- -

Source: SEWRPC.

curves represent the capital costs of constructing an infiltration basin on a flat woodland site. SEWRPC capital costs also include components such as basin bottom leveling and filling, and landscaping, that are not included in the other cost curves. For a given site, Table 2 may be used to eliminate unneeded components from the capital cost.

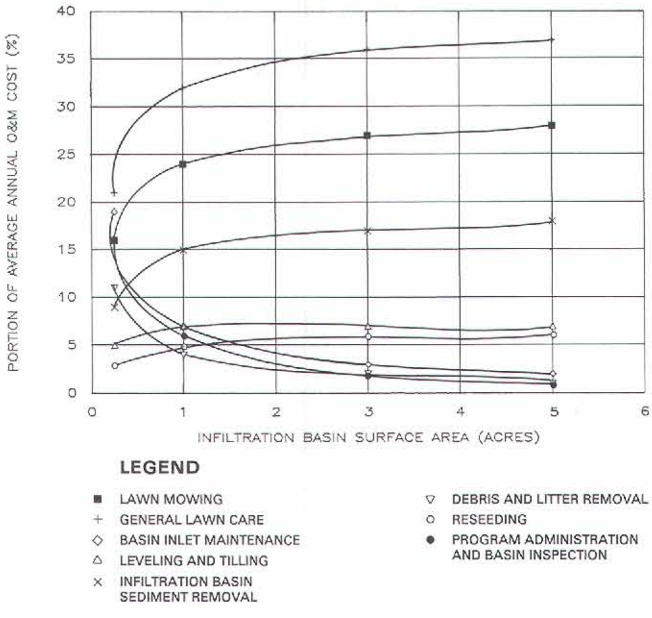
Figure 20 presents the annual operation and maintenance cost curves for infiltration basins. The average annual operation and maintenance costs derived from the cost curves would represent about 3 to 4 percent of the capital cost, which is consistent with operation and maintenance cost estimates proposed by Schueler et al., 1985, Schueler, 1987, and Wiegand et al., 1986. However, the SEWRPC costs are lower than those estimated by Donohue & Associates, Inc., who estimated the annual operation and maintenance costs as 13 percent of the capital cost.

POROUS PAVEMENT

Porous pavement, like other infiltration measures, removes waterborne pollutants by allowing stormwater runoff to filter through the underlying soil. Nearly all silt-sized and larger particles are trapped by the pavement itself, with

Figure 17

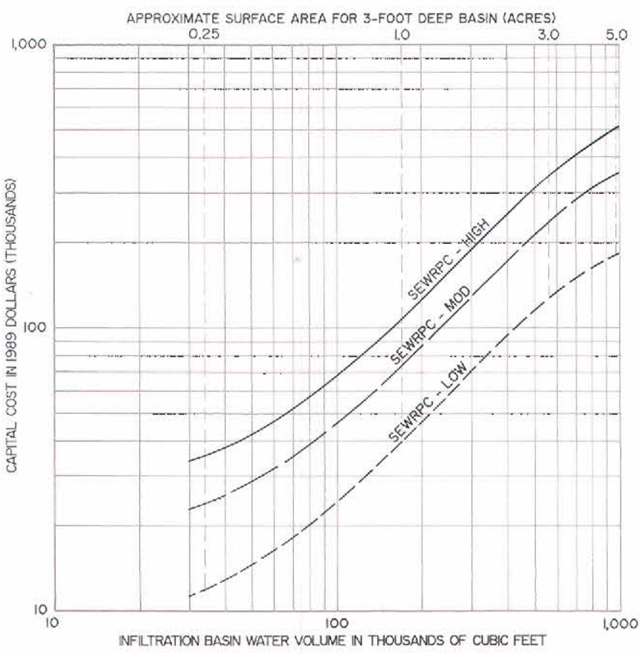
DISTRIBUTION OF INFILTRATION BASIN COMPONENT OPERATION AND MAINTENANCE COST AS A FUNCTION OF BASIN SIZE



Source: SEWRPC.

Figure 18

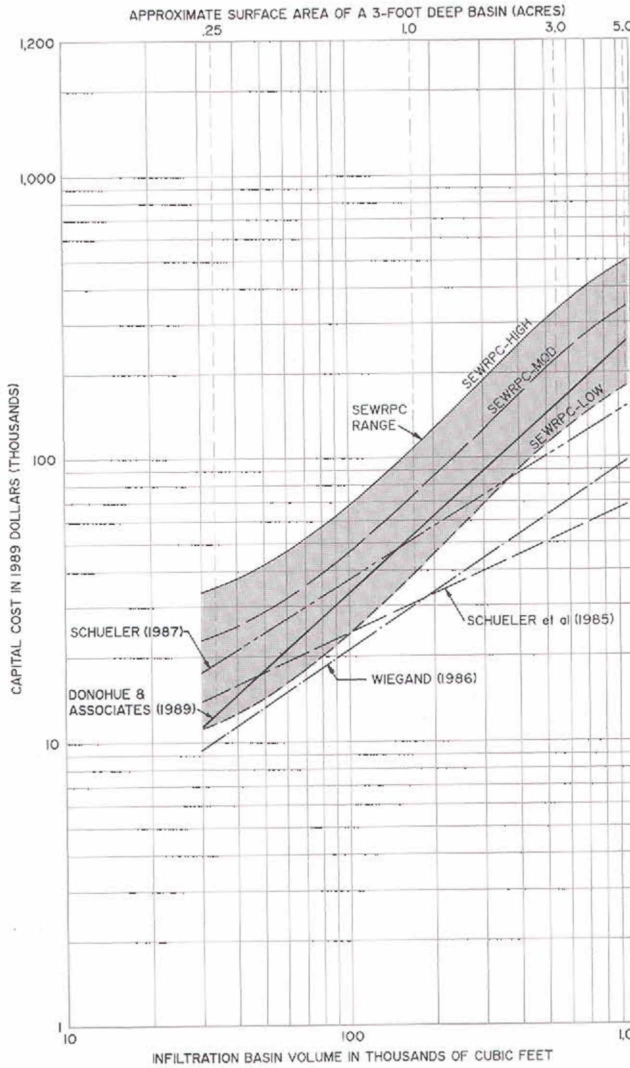
INFILTRATION BASIN CAPITAL COST: 1989



Source: SEWRPC.

Figure 19

COMPARISON OF INFILTRATION BASIN CAPITAL COST ESTIMATING PROCEDURES: 1989



Source: SEWRPC.

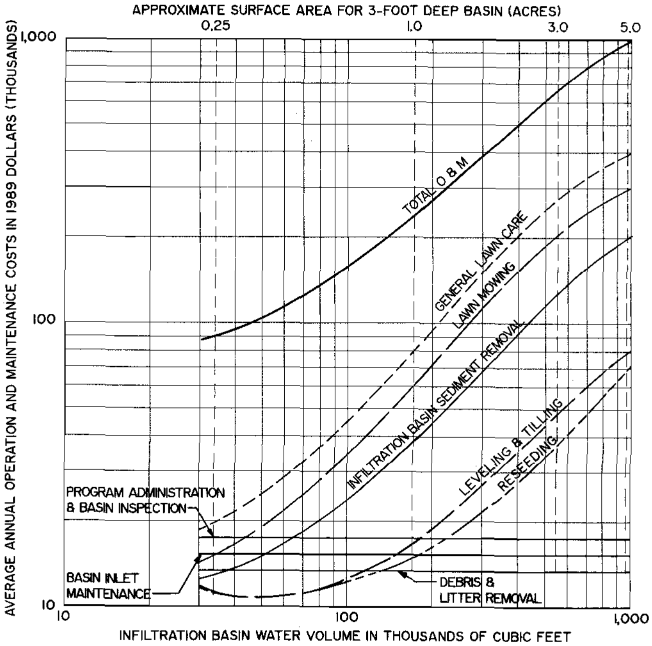
additional pollutant removal being provided by bacterial degradation, precipitation, and sorption within the underlying soil. The use of porous pavement is generally limited to low-volume parking lots, although runoff from rooftops and other adjacent impervious areas is sometimes conveyed to the porous pavement area.

Description

A porous pavement is constructed of a porous asphalt, or bituminous concrete, surface placed over a highly permeable layer of open graded

Figure 20

AVERAGE ANNUAL OPERATION AND MAINTENANCE COSTS OF INFILTRATION BASINS: 1989

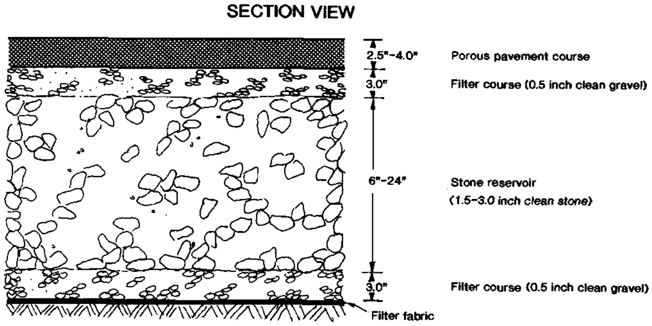


Source: SEWRPC.

Figure 21

TYPICAL CROSS-SECTION OF POROUS PAVEMENT

SECTION VIEW



Source: SEWRPC.

gravel and crushed stone. A filter fabric is placed beneath the gravel and stone layers to prevent the movement of fine soil particles into these layers. The porous asphalt is similar to conventional asphalt, except that fewer fines are used in the mix. Figure 21 illustrates a typical porous pavement cross section. Stormwater infiltrates through the pores of the 2.5- to 4.0-inch-thick porous asphalt layer into the void spaces of underlying gravel and stone layers. Runoff stored in the gravel and stone layer then infiltrates into the soil. If the infiltration rate of the soil is inadequate, perforated underdrain pipes can be placed in the stone layer reservoir. The collected water is then conveyed to a surface waterway. However, pollutant removal rates would be much lower than if the water was allowed to infiltrate into the soil. Table 21 summarizes design guidelines and criteria for construction of porous pavement.

Because the infiltration rate of the porous asphalt layer is very high, the storage capacity of a porous pavement system is dependent on the storage volume of the stone layer, or reservoir. The stone layer for a porous pavement is typically six to 24 inches thick. Porous pavements may not be as durable as conventional pavement because of an increased potential for drainage problems and freeze-thaw damage in cold climate areas. A modified form of porous pavement consists of open grid blocks, where sand or gravel is placed in the holes. Grass may be grown in the open spaces. Generally, porous pavements are applicable only in low-traffic areas such as storage areas, service roads, and low-volume parking lots.

The primary advantage of porous pavement is that driveways and parking areas can be put to dual use reducing land area requirements. Permeable soils are needed to allow percolation of the stored runoff, and the percolation requirements are the same as for other infiltration measures.

Porous pavement is considerably more costly then conventional pavements. Other disadvantages are a potential risk of clogging; the need for frequent cleaning; potential wear deterioration and strength problems if proper construction and maintenance guidelines are not strictly followed; and—like all infiltration measures—a potential risk of groundwater contamination. Groundwater contamination is a particular concern for those transportation-related pollutants—such as oil and gasoline—which can move readily through the soil. If the porous pavement does become irreversibly clogged, drain holes may have to be drilled into the surface, or the pavement may need to be replaced.

Pollutant removal rates for porous pavement are relatively high, as presented in Table 22. The removal rates range from 65 percent for total phosphorus to 99 percent for zinc.

Table 21

DESIGN GUIDELINES FOR POROUS PAVEMENT

Design Factor	Guidelines
Site Evaluation	• Take soil borings to depth of at least four feet below bottom of stone reservoir to check for soil infiltration, depth to seasonally-high water table, and depth to bedrock • Minimum infiltration rate four feet below bottom of stone reservoir: 0.27 inches per hour • Avoid Hydrologic Soil Group D soils • Maximum pavement slope: 5 percent • Minimum depth to bedrock and seasonally-high water table: four feet • Minimum setback from water supply wells: 100 feet • Minimum setback from building foundations: 10 feet
Drainage Area	• The conveyance of additional water to the pavement surface should be minimized. Stormwater runoff which is conveyed to the pavement should contain a low sediment concentration and pass through a minimum 25-foot-wide grass buffer strip • Control construction sediment loadings to the pavement surface
Traffic Conditions	• Use for low volume automobile parking areas and lightly used access roads • Avoid moderate to high traffic areas and all truck traffic • Post with signs to restrict the use of salt and sand for ice control, and to prevent truck traffic
Drainage Time for Design Storm	• Maximum: 72 hours • Minimum: 12 hours
Construction	• Excavate and grade with light equipment with tracks or oversized tires to prevent soil compaction • As needed, divert stormwater runoff away from planned pavement area to keep runoff and sediment away from site both before and during construction • Place filter fabric beneath stone and gravel layers to prevent upward piping of underlying soils • Place clean, washed, 1.5- to 3.0-inch aggregate in stone reservoir in lifts, and lightly compact. The gravel layers should be composed of clean, washed, one-half inch stone
Porous Pavement Placement	• Pavement laying temperature: 240° to 260°F • Minimum air temperature: 50°F • Compact with one or two passes of a 10-ton roller • Prevent any vehicular traffic on pavement for at least two days

Source: T. R. Schueler, 1987, and SEWRPC.

Like all infiltration measures, porous pavements require careful maintenance in order to prevent clogging of the system. Routine maintenance practices include vacuum sweeping the pavement at least four times per year, followed by high-pressure jet hosing, to keep the asphalt pores open; inspection of pavement surface annually and after large storms; prompt repair of cracks and potholes; and relief of local clogging by drilling small holes through the asphalt or installing drop inlets. Sand should not be applied to the street surface for ice control. Application of deicing salt should also be severely restricted because a surface crust may form, which would reduce infiltration, and because of a risk of groundwater contamination. Studies have indicated that snow- and ice-melt is more rapid on porous pavement than on conventional pavement. An observation well may be installed on the downslope end of a porous pavement area to

Table 22

POLLUTANT REMOVAL RATES FOR POROUS PAVEMENT

Pollutant	Removal Rates (percent)
Sediment	80-95
Total Phosphorus	65
Total Nitrogen	80-85
Organic Matter	80
Zinc	99
Lead	98

Source: T. R. Schueler, 1987.

monitor proper drainage of the stone reservoir layer following a storm event and, if necessary, to collect water quality samples.

Reported General Costs

Few porous pavement surfaces have been constructed in Wisconsin, and therefore local cost data are not available. Compared to conventional pavements, porous pavements entail additional costs for the excavation of the added depth for the stone reservoir, the placement of stone fill in the reservoir layer, the placement of filter cloth, the porous pavement layer itself, and possible overflow pipes, underdrain systems, grass buffer strips, and erosion and sediment control measures.

The Metropolitan Washington Council of Governments found that the cost of the porous asphalt layer itself was about 15 percent higher than the cost of conventional asphalt.[9] However, the incremental cost percentage increase for the total pavement system—including the underlayers—would be much greater than 15 percent. Overall, it was estimated that construction of a porous pavement parking lot would cost nearly $80,000 per acre more than construction of a conventional asphalt pavement parking lot.

Cost Estimates

Incremental costs for porous pavements—or the additional costs beyond that required for conventional asphalt pavements—can be divided into excavation, site development, and contingencies. Additional excavation is needed to accommodate the increased depth of the stone reservoir. Incremental site development components include the placement of stone fill in the reservoir layer, the placement of filter cloth, the construction of the porous pavement layer, and sometimes the installation of a supplemental overflow or drainage system, grass buffer strips, or additional erosion and sediment control measures. Contingencies include planning, engineering, administration, and legal fees. The contingencies would also include the extensive feasibility studies, inspections, and additional supervision needed to ensure a very high level of construction workmanship, which are essential for a successful porous pavement project.

Based on a review of the local unit costs report in Appendix B, a low, moderate, and high unit cost was selected for each component which entails an incremental cost. These three unit costs for each component were used to calculate a probable range of incremental capital costs for the construction of porous pavement surfaces.

Table 23 presents the selected unit costs and the calculated incremental component and total capital costs for the construction of a one-acre porous pavement parking lot. These costs are in addition to the typical cost of a conventional asphalt pavement parking lot. A conventional asphalt parking lot would entail a total capital cost of about $40,000 per acre. The estimated incremental capital costs for a porous pavement lot range from $40,000 to $78,000 for a one-acre parking lot. Thus, the cost of a porous pavement parking lot may be two to three times higher than the cost of a conventional asphalt pavement parking lot. Figure 22 shows the distribution of the incremental capital costs. In this example, it was assumed that a supplemental overflow or drainage system, grass buffer strips, and additional erosion and sediment control measures would not be required.

Porous pavement maintenance costs are estimated in Table 24. Incremental costs are presented for vacuum sweeping, high pressure jet hosing, and pavement inspections. Other maintenance activities are assumed to be the same as for conventional asphalt pavement. The total incremental maintenance cost is estimated at $200 per acre of porous pavement surface per year.

[9] *T. R. Schueler, 1987, op. cit.*

Table 23

ESTIMATED INCREMENTAL COST OF A 1.0-ACRE POROUS PAVEMENT PARKING LOT

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Site Preparation General Excavation[a]	Cubic yard	1,452	$ 2.10	$ 3.70	$ 5.30	$ 3,049	$ 5,372	$ 7,696
Site Development Geotextile Fabric[b] Crushed Stone Fill[c] Porous Pavement[d]	 Square yard Cubic yard Square yard	 5,082 1,452 4,840	 $ 1.00 14.80 0.50	 $ 2.00 19.40 0.75	 $ 3.00 24.00 1.00	 $ 5,082 21,490 2,420	 $10,164 28,169 3,630	 $15,246 34,848 4,840
Subtotal	- -	- -	- -	- -	- -	$32,041	$47,335	$62,630
Contingencies	Site	1	25 percent	25 percent	25 percent	$ 8,010	$11,834	$15,658
Total	- -	- -	- -	- -	- -	$40,051	$59,169	$78,288

NOTE: These costs would be in addition to the cost of a conventional asphalt pavement parking lot, which was estimated at $40,000 per acre.

[a] *Volume of incremental excavation = parking lot area x one foot.*

[b] *Area covered with filter fabric = parking lot area + 5 percent.*

[c] *Volume of incremental stonefill = parking lot area x one foot.*

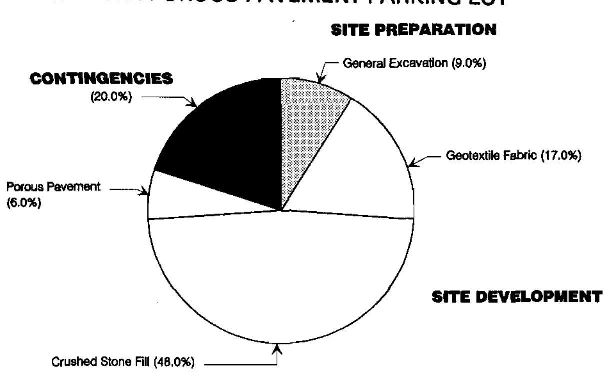
[d] *Area covered by porous pavement = parking lot area.*

Source: SEWRPC.

Figure 22

DISTRIBUTION OF POROUS PAVEMENT INCREMENTAL COMPONENT CAPITAL COSTS

ESTIMATED INCREMENTAL CAPITAL COST OF A 1.0- ACRE POROUS PAVEMENT PARKING LOT



Source: SEWRPC.

Based on the unit costs presented above, procedures were developed which may be used to estimate the incremental capital and maintenance costs of a porous pavement surface with various stone reservoir depths. These procedures may be used to provide a preliminary estimate of a proposed porous pavement cost. Figure 23 presents capital cost curves for porous pavement surfaces with 0.5-foot-deep, 1.0-foot-deep, 1.5-foot-deep, and 2.0-foot-deep stone reservoirs.

Low, moderate, and high unit costs presented in Table 23 were used to calculate the curves. Incremental annual maintenance costs are estimated to be $200 per acre per year, regardless of the depth of the stone reservoir.

GRASSED SWALE

Grassed swales are used to convey stormwater to another channel while avoiding erosion. Swales may be located and used to collect overland flows from areas such as front, side, and back yards, and to transmit the flows to a larger open drainage channel or stream, or to a subsurface conveyance system. Swales may also run parallel and adjacent to a roadway, providing longitudinal drainage. Roadside swales may be used to collect and convey stormwater runoff from the roadway and from adjacent tributary land areas. Swales may reduce runoff flows by allowing some water to infiltrate. Particulate pollutants are also filtered by the vegetation, and some biological uptake of nutrients may

Table 24

INCREMENTAL AVERAGE ANNUAL MAINTENANCE COST OF A POROUS PAVEMENT PARKING LOT

Component	Unit Cost	Porous Pavement Parking Lot	Comment
Vacuum Sweeping and High-Pressure Jet Hosing	$17/acre vacuum sweeping, plus $8.00/acre jet hosing	$100/acre/year	Vacuum and hose area four times per year
Inspections	$25/inspection	$100/acre/year	Inspect four times per year
Total	- -	$200/acre/year	- -

NOTE: These costs would be in addition to the annual maintenance cost of a conventional asphalt pavement parking lot.

Source: SEWRPC.

occur. Grassed swales can serve as integral parts of the minor stormwater drainage system of an area—replacing curb and gutter and storm sewer systems in low-density residential, industrial, institutional, and recreational areas. Larger swales can serve as integral parts of the major stormwater drainage system, conveying flows generated by storms as large as a 100-year recurrence interval storm event in some areas.

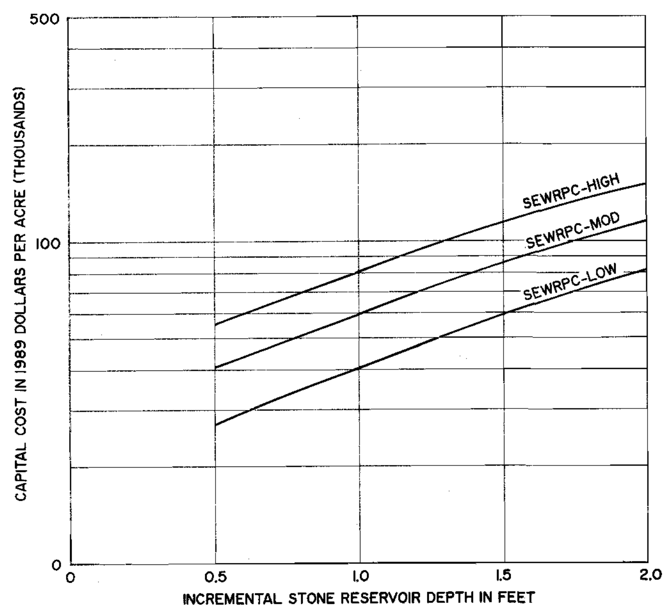
Description

A grassed swale is a natural or man-made grass-lined channel of parabolic or trapezoidal cross section used to convey stormwater. Figure 24 shows a typical grassed swale cross sections. Compared to engineered storm sewer systems, swales can produce lower peak runoff flows by reducing the velocity of flow—which increases the time of concentration, or detention, within the watershed—and by allowing some water to infiltrate. However, because of the concentrated flow conditions, the amount of infiltration and pollutant trapping that occurs is limited. Table 25 summarizes some design guidelines for grassed swales. Figure 25 shows swale top width as a function of swale depth and swale bottom width with an assumed side slope of 3:1.

The advantages of a grassed swale compared to a storm sewer system may include reduced peak flows, increased pollutant removal, and lower capital costs. Roadside swales are not usually practicable in higher density urban areas because each intersecting private driveway, as well as each public roadway, must be provided with a culvert to carry the drainage. As densities

Figure 23

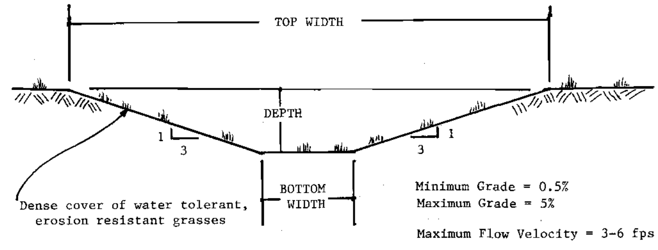
POROUS PAVEMENT PARKING LOT CAPITAL COST ESTIMATING PROCEDURES: 1989



Source: SEWRPC.

Figure 24

CROSS SECTION OF TYPICAL GRASSED SWALE



Source: SEWRPC.

Table 25

DESIGN GUIDELINES FOR GRASSED SWALES

Design Factor	Guidelines
Grade	• Minimum: 0.5 percent • Maximum: 5 percent • Provide grade control structures as necessary to reduce channel gradients and obtain flow velocities within acceptable limits • Where possible, swales should follow street alignments and gradients
Side Slopes	• Maximum: 3:1
Discharge Rate and Velocity	• Maximum peak-flow rate: accommodate peak runoff expected from at least a five-year, and preferably a 10-year, recurrence interval storm event • Maximum flow velocity: three to six feet per second (fps), depending on the type of vegetation
Vegetative Cover	• Establish dense cover of water-tolerant, erosion-resistant grass • Maintain vegetation at least six inches in height • For two-year recurrence interval storm flow, velocities less than three fps, establish vegetation with seeding and mulching; for flow velocities greater than three fps, establish vegetation with sodding • Where swales are to be located in existing wetland areas, establish wetland vegetation along the channel bottom
Soils	• Minimum permeability: 0.5 inches per hour • Till soil before grass is established to restore infiltration capacity
Depth to Groundwater and Bedrock	• Minimum: two feet

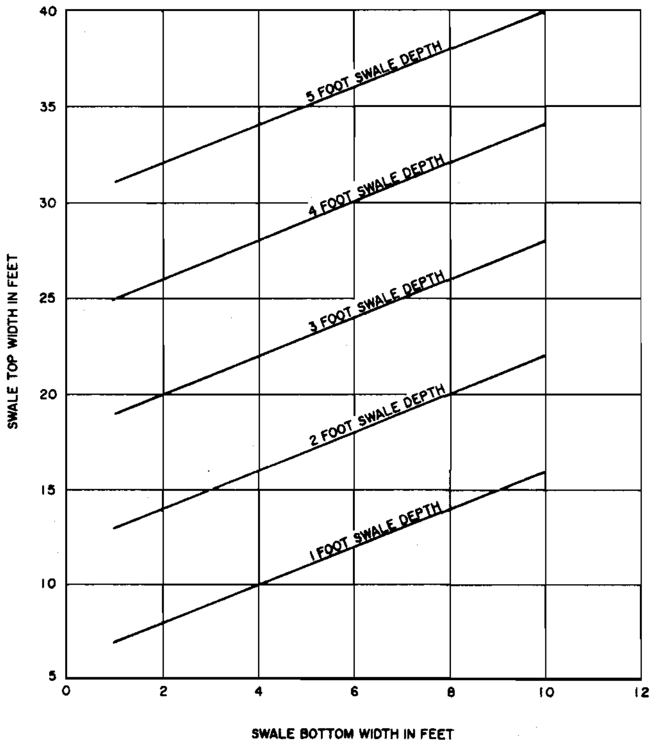
Source: T. R. Schueler, 1987, and SEWRPC.

increase, lot areas and widths decrease so that a point is reached where the provision of storm sewers becomes more economical, desirable, and maintainable than the provision of roadside swales and culverts. Swales are often not practical in areas with flat grades, in areas of steep topography, or in wet or poorly drained soils. Some swales, because of the need for attendant culverts, are prone to ice blockage during winter and early spring. Other disadvantages include restrictions on the amount of stormwater flow that can be conveyed; minimal water quantity and quality benefits when flow volumes or velocities are high; potential mosquito and odor problems; potential safety hazards; and generally higher maintenance costs than storm sewer systems. The land surface area required to construct roadside swales with adequate capacity is often not available in higher density urban areas. Roadside swales are generally not appropriate in areas currently served by storm sewers.

While some swales have been effective in removing pollutant loadings, other swales have performed poorly. Studies summarized by Schueler, 1987, indicate that swales with high-flow velocities, compacted soils, steep slopes or short grass height removed few pollutants. It may be assumed that properly designed grassed swales may achieve about a 25 percent reduction in particulate pollutants, including sediment and sediment-attached phosphorus, metals, and bacteria. Lower removal rates—probably less than 10 percent—may be expected for dissolved pollutants, such as soluble phosphorus, nitrate, and chloride.

Figure 25

RELATIONSHIP BETWEEN SWALE TOP WIDTH, BOTTOM WIDTH, AND DEPTH WITH AN ASSUMED SWALE SIDE SLOPE OF 3:1



Source: SEWRPC.

The primary objectives of swale maintenance are to maintain the hydraulic efficiency of the channel and to maintain a healthy, dense grass cover. Maintenance activities include clearing of debris and blockages, periodic mowing, spot reseeding or resodding, weed control, and watering during drought conditions. While mowing helps control weeds, improves hydraulic flows, and generally enhances aesthetics, grass heights should remain at six inches or greater in order to filter the runoff and slow the flow velocity enough to allow sedimentation and infiltration. Application of fertilizers and pesticides should be minimized.

Reported General Costs

Goldman et al., 1986, estimated the cost of a typical grassed swale at $5.30 per lineal foot. Donohue & Associates, Inc., 1989, calculated costs ranging from $6.40 to $11.20 per lineal foot for swales with 12- to 16-foot top widths. Schueler, 1987, estimated that a grassed swale with a 15-foot top width would cost from $4.90 to $9.00 per lineal foot.

Cost Estimates

The costs for grassed swales can be divided into a number of components: mobilization and demobilization of equipment, site preparation, site development, and contingencies. Site preparation includes clearing, grubbing, and excavation. Site development activities include the placement of topsoil, seeding, and mulching or the placement of sod, and the installation of grade control structures if needed. Contingencies include planning, engineering, administration, and legal fees.

Tables 26 and 27 present the selected unit costs and the calculated component costs and total capital costs for a 1.5-foot-deep swale with a bottom width of one foot and a top width of 10 feet; and for a three-foot-deep swale with a bottom width of three feet and a top width of 21 feet, respectively. Both swales would have a length of 1,000 feet, gradient of 2 percent and side slopes of three to one. The smaller swale (Table 26) would have a maximum discharge capacity of about 39 cubic feet per second (cfs), while the larger swale (Table 27) would have a maximum discharge capacity of about 340 cfs. The estimated capital costs range from $6,400 to $17,100 for the 1.5-foot-deep swale; and from $12,900 to $33,400 for the three-foot-deep swale.

The distribution of the component capital costs varies slightly with the size of the swale, as shown in Figure 26, which shows the distribution of costs based on the moderate cost estimates presented in Tables 26 and 27. The cost of excavation accounts for a much larger portion of the total cost of the three-foot-deep swale than of the total cost of the 1.5-foot-deep swale. For both swales, mobilization and demobilization of equipment accounts for 2 percent or less of the total capital cost and contingencies were assumed to equal 20 percent of the capital cost.

Swale maintenance costs are estimated in Table 28, which presents selected unit costs for debris removal, grass mowing, spot reseeding and resodding, weed control, swale inspection, and program administration. The estimated annual operation and maintenance costs range from $0.58 per lineal foot for the 1.5-foot-deep, 10-foot-wide swale, to $0.75 per lineal foot for the three-foot-deep, 21-foot-wide swale.

Table 26

ESTIMATED CAPITAL COST OF A 1.5-FOOT-DEEP, 10-FOOT-WIDE GRASSED SWALE[a]

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization/ Demobilization-Light	Swale	1	$ 107	$ 274	$ 441	$ 107	$ 274	$ 441
Site Preparation								
Clearing[b]	Acre	0.5	$2,200	$3,800	$5,400	$1,100	$ 1,900	$ 2,700
Grubbing[c]	Acre	0.25	3,800	5,200	6,600	950	1,300	1,650
General Excavation[d]	Cubic yard	372	2.10	3.70	5.30	781	1,376	1,972
Level and Till[e]	Square yard	1,210	0.20	0.35	0.50	242	424	605
Site Development								
Salvaged Topsoil, Seed, and Mulch[f]	Square yard	1,210	$ 0.40	$ 1.00	$ 1.60	$ 484	$ 1,210	$ 1,936
Sod[g]	Square yard	1,210	1.20	2.40	3.60	1,452	2,904	4,356
Subtotal	- -	- -	- -	- -	- -	$5,116	$ 9,388	$13,660
Contingencies	Swale	1	25 percent	25 percent	25 percent	$1,279	$ 2,347	$ 3,415
Total	- -	- -	- -	- -	- -	$6,395	$11,735	$17,075

[a]*Swale has a bottom width of 1.0 foot, a top width of 10 feet with 3:1 side slopes, and a 1,000-foot length.*

[b]*Area cleared = (top width + 10 feet) x swale length.*

[c]*Area grubbed = (top width x swale length).*

[d]*Volume excavated = (0.67 x top width x swale depth) x swale length (parabolic cross-section).*

[e]*Area tilled =* $\left(\text{top width} + \frac{8(\text{swale depth}^2)}{3(\text{top width})}\right)$ *x swale length (parabolic cross-section).*

[f]*Area seeded = area cleared x 0.5.*

[g]*Area sodded = area cleared x 0.5.*

Source: SEWRPC.

The distribution of the component operation and maintenance costs is only slightly dependent on the swale size. Figure 27 illustrates the distribution of the operation and maintenance costs. Lawn mowing and other lawn care measures are the most costly maintenance activities.

Based on the unit costs presented above, cost curves were developed which may be used to estimate the capital and operation and maintenance costs of various grassed swale sizes. These curves may be used to provide a preliminary estimate of a proposed swale cost. The costs are presented for a typical swale design as shown in Figure 24. For modified designs, the unit costs presented in Appendix B may be used to revise these costs.

Figure 28 presents the capital cost curves for grassed swales. Moderate unit costs were used to calculate the curves, which are shown for swale depths ranging from one to five feet and for bottom widths ranging from one to 10 feet. Top widths for these swales may be calculated using Figure 25. The capital costs shown on the curves range from about $8.50 to nearly $50 per lineal foot of swale. These cost are generally higher than the reported cost range of $4.90 to $11.20 per lineal foot. The SEWRPC cost estimates may be higher because they include the costs of

Table 27

ESTIMATED CAPITAL COST OF A 3.0-FOOT-DEEP, 21-FOOT-WIDE GRASSED SWALE[a]

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization/ Demobilization-Light	Swale	1	$ 107	$ 274	$ 441	$ 107	$ 274	$ 441
Site Preparation								
Clearing[b]	Acre	0.75	$2,200	$3,800	$5,400	$ 1,650	$ 2,850	$ 2,700
Grubbing[c]	Acre	0.50	3,800	5,200	6,600	1,900	2,600	1,650
General Excavation[d]	Cubic yard	1,563	2.10	3.70	5.30	3,283	5,783	1,972
Level and Till[e]	Square yard	2,420	0.20	0.35	0.50	484	847	605
Site Development								
Salvaged Topsoil, Seed, and Mulch[f]	Square yard	1,815	$ 0.40	$ 1.00	$ 1.60	$ 726	$ 1,815	$ 1,936
Sod[g]	Square yard	1,815	1.20	2.40	3.60	2,178	4,356	4,356
Subtotal	- -	- -	- -	- -	- -	$10,327	$18,525	$26,723
Contingencies	Swale	1	25 percent	25 percent	25 percent	$ 2,582	$ 4,631	$ 6,681
Total	- -	- -	- -	- -	- -	$12,909	$23,156	$33,404

[a]*Swale has a bottom width of 3.0 feet, a top width of 21 feet with 3:1 side slopes, and a 1,000-foot length.*

[b]*Area cleared = (top width + 10 feet) x swale length.*

[c]*Area grubbed = (top width x swale length).*

[d]*Volume excavated = (0.67 x top width x swale depth) x swale length (parabolic cross-section).*

[e]*Area tilled =* $\left(\text{top width} + \frac{8(\text{swale depth}^2)}{3(\text{top width})}\right)$ *x swale length (parabolic cross-section).*

[f]*Area seeded = area cleared x 0.5.*

[g]*Area sodded = area cleared x 0.5.*

Source: SEWRPC.

activities such as clearing, grubbing, leveling, tilling, and sodding which may not be included in many of the reported costs. These components may or may not be required at a given site, depending on the existing soil conditions, topography, and vegetative cover. For a given site, Tables 26 and 27 may be used to eliminate unneeded components from the capital cost.

Figure 29 presents the annual operation and maintenance cost curves for grassed swales. The average annual costs range from $0.50 to $1.07 per lineal foot of swale.

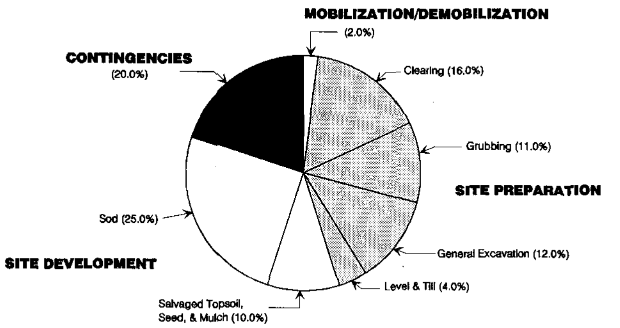
GRASSED FILTER STRIPS

Grassed filter strips differ from grassed swales in that the strips are designed to accommodate overland sheet flow, rather than channelized flow. Because the resulting flow velocities are lower, and a greater portion of the water volume is filtered, a properly designed grassed filter strip may be expected to provide a higher pollutant removal rate than a grassed swale. Stormwater sheet flow over the grassed strip is filtered by the vegetation, and a portion of the flow infiltrates into the soil.

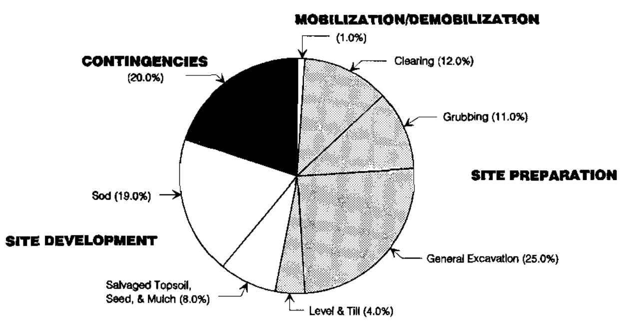
Figure 26

DISTRIBUTION OF GRASSED SWALE COMPONENT CAPITAL COSTS AS A FUNCTION OF SWALE SIZE

ESTIMATED CAPITAL COST OF A 1.5-FOOT-DEEP, 10-FOOT-WIDE GRASSED SWALE



ESTIMATED CAPITAL COST OF A 3-FOOT-DEEP, 21-FOOT-WIDE GRASSED SWALE

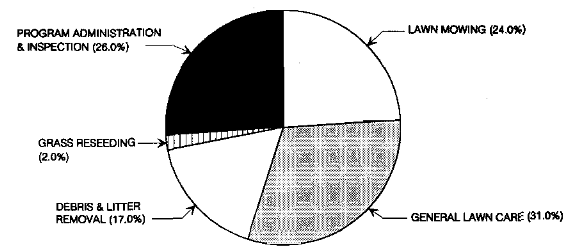


Source: SEWRPC.

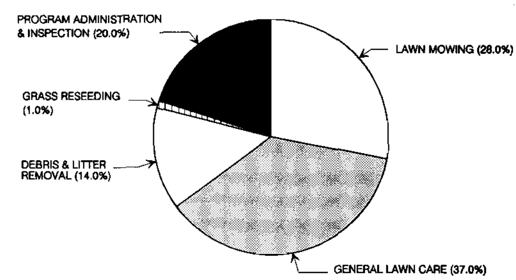
Figure 27

DISTRIBUTION OF GRASSED SWALE COMPONENT OPERATION AND MAINTENANCE COSTS AS A FUNCTION OF SWALE SIZE

ESTIMATED ANNUAL OPERATION AND MAINTENANCE COST OF A 1.5-FOOT-DEEP, 10-FOOT-WIDE GRASSED SWALE



ESTIMATED ANNUAL OPERATION AND MAINTENANCE COST OF A 3-FOOT-DEEP, 20-FOOT-WIDE GRASSED SWALE



Source: SEWRPC.

Description

A grassed filter strip is a relatively long and narrow piece of land, which is graded to a uniform, low slope and densely vegetated, usually with erosion-resistant grass species. Often, a level spreading device is provided to distribute the runoff evenly across the strip. A typical grassed filter strip is graphically illustrated in Figure 30. Table 29 summarizes design guidelines and criteria for construction of a grassed filter strip.

Grassed filter strips are often used to enhance the effectiveness and increase the longevity of other urban nonpoint source control measures. The strips are used to trap coarse sediments and prevent the clogging of infiltration basins and trenches and porous pavement systems. Grassed strips are also frequently provided around the perimeter of wet detention basins.

Although normally vegetated with grass, strips can also be planted with shrubs and trees to provide wildlife habitat, screening, and shading for streams. Some studies have shown that wooded filter strips retain higher levels of nutrients than do grassed strips.

The advantages of grassed filter strips are their low cost, ease of maintenance, modest land area requirement, and relatively high pollutant removal rates. Filter strips can be used in developed urban areas, construction sites, and even in areas where toxic pollutants are present in the runoff. While relatively narrow strips—about 25 feet wide—can effectively remove pollutant loadings, strips at least 600 feet wide can support a moderately diverse urban wildlife community, and a strip at least 1,000 feet wide is effective for screening purposes and for the preservation of scenery.[10]

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[10] *T. R. Schueler, 1987.*

Table 28

AVERAGE ANNUAL OPERATION AND MAINTENANCE COSTS FOR GRASSED SWALES

Component	Unit Cost	Swale Size (depth and top width)		Comment
		1.5 Feet Deep, One-Foot Bottom Width, 10-Foot Top Width	Three Feet Deep, Three-Foot Bottom Width, 21-Foot Top Width	
Lawn Mowing	$0.85/1,000 square foot/mowing	$0.14/lineal foot	$0.21/lineal foot	Lawn maintenance area = (top width + 10 feet) x length. Mow eight times per year
General Lawn Care	$9.00/1,000 square foot/year	$0.18/lineal foot	$0.28/lineal foot	Lawn maintenance area = (top width + 10 feet) x length
Swale Debris and Litter Removal	$0.10/lineal foot/year	$0.10/lineal foot	$0.10/lineal foot	- -
Grass Reseeding with Mulch and Fertilizer	$0.30/square yard	$0.01/lineal foot	$0.01/lineal foot	Area revegetated equals 1 percent of lawn maintenance area per year
Program Administration and Swale Inspection	$0.15/lineal foot/year, plus $25/inspection	$0.15/lineal foot	$0.15/lineal foot	Inspect four times per year
Total	- -	$0.58/lineal foot	$0.75/lineal foot	- -

Source: SEWRPC.

The primary disadvantage of grassed filter strips is a tendency for stormwater runoff to concentrate and form a channel, which essentially "short circuits" the filter strip. One study in Virginia estimated that 60 percent of agricultural filter strips were short-circuited.[11] Gully erosion can damage filter strips which are improperly designed or maintained, and strips subjected to excessive pedestrian or vehicular traffic.

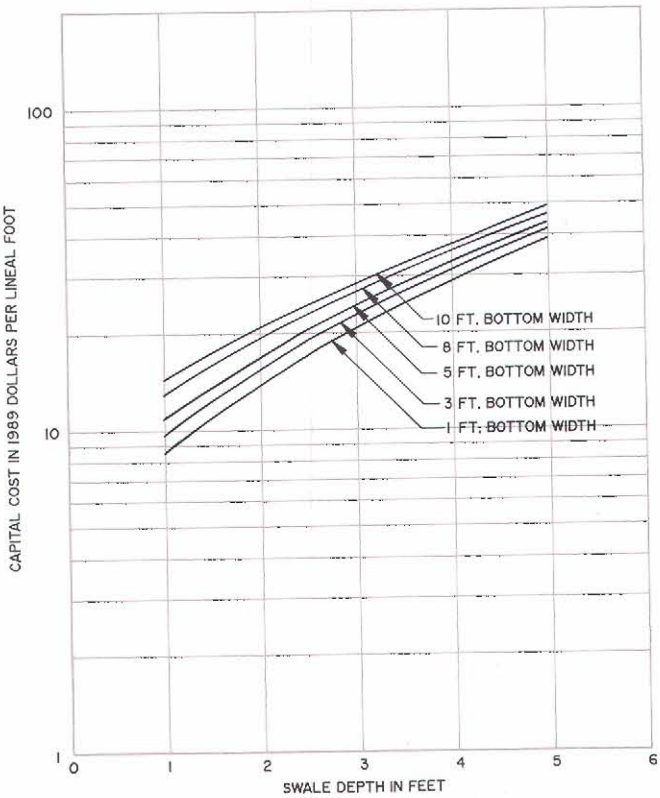
The rate of pollutant removal is a function of the length, slope, and soil permeability of the strip, the size and characteristics of the contributing drainage area, the type of vegetative cover, and the runoff velocity. Strips are very effective in removing sediment and sediment-associated pollutants such as bacteria, particulate nutrients, most pesticides, and metals. At least a 40 percent removal can be expected from strips as narrow as 25 feet, and strips 90 to 300 feet wide may be expected to remove essentially all of the sediment loading, depending primarily on the soil permeability. Figure 31 illustrates the removal of clay-sized particles by grassed filter strips as a function of the depth of water flow over the strip. Limited removal of soluble pollutants, primarily nutrients, results from uptake of pollutants by the plant roots. However, removal of soluble pollutants by filter strips is usually modest—less than 25 percent—because only a small portion of the runoff infiltrates into the soil.

Maintenance of a grassed filter strip includes management of a dense vegetative cover, and prevention of channel or gully formation. Frequent spot repairs, fertilization, and watering may be needed to support the dense growth. Exposed areas should be quickly reseeded or sodded. The strips should be examined annually for damage by foot or vehicular traffic, gully

[11] *Ibid.*

Figure 28

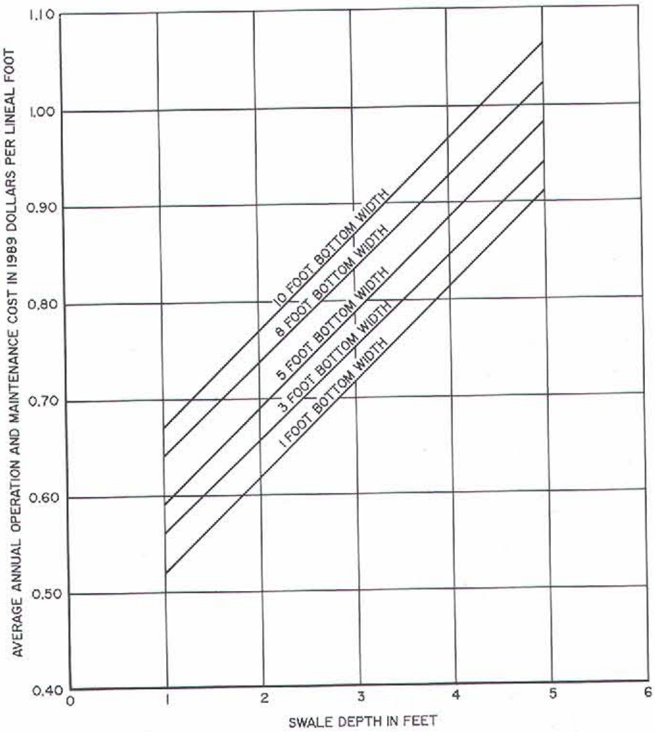
CAPITAL COSTS OF GRASSED SWALES: 1989



Source: SEWRPC.

Figure 29

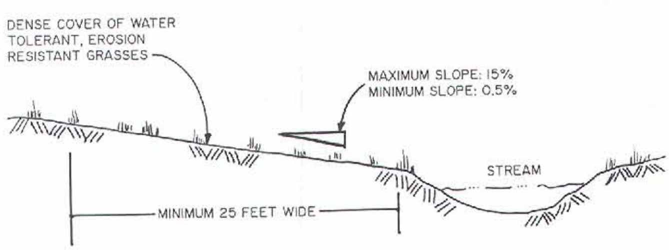
AVERAGE ANNUAL OPERATION AND MAINTENANCE COSTS OF GRASSED SWALES: 1989



Source: SEWRPC.

Figure 30

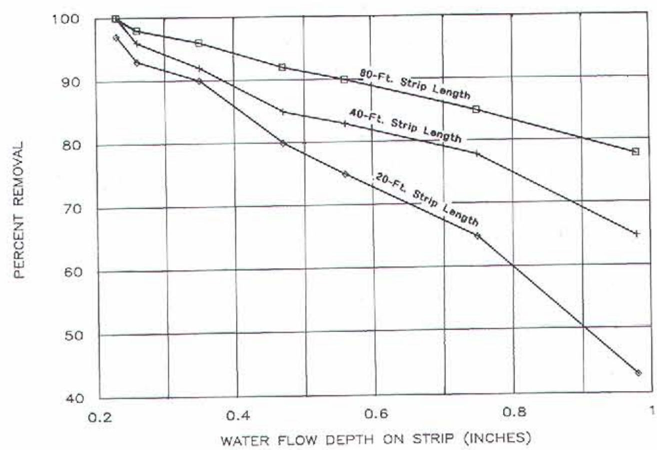
TYPICAL GRASSED FILTER STRIP LOCATED ADJACENT TO A STREAM



Source: SEWRPC.

Figure 31

REMOVAL OF CLAY-SIZED PARTICLES BY GRASSED FILTER STRIPS



NOTE: ANALYSIS ASSUMES A 1% SLOPE ON THE GRASSED STRIP. HIGHER REMOVAL RATES WOULD BE EXPECTED FOR SILT- AND SAND-SIZED PARTICLES. LOWER REMOVAL RATES WOULD BE EXPECTED FOR DISSOLVED POLLUTANTS.

Source: R. Pitt, Construction Site Erosion and Stormwater Management Plan and Model Ordinance, Wisconsin Department of Natural Resources, Draft, May 1985, and SEWRPC.

Table 29

DESIGN GUIDELINES FOR GRASSED FILTER STRIPS

Design Factor	Guidelines
Strip Alignment	• Upslope edge of strip should follow same elevation contour; that is, line of equal elevation • Upslope edge of strip should directly abut contributing impervious area, if present
Strip Width	• Absolute minimum: 25 feet • Preferred minimum: 50 feet, plus an additional four feet per each 1 percent of strip slope
Strip Slope	• Absolute maximum: 15 percent • Preferred maximum: 5 percent • Minimum: 0.5 percent • Steeper slopes require wider strips • Grade carefully to provide uniform slope and prevent concentration of runoff
Contributing Drainage Area	• Maximum: five acres • Provide level spreader, ditches, or trenches to distribute flow evenly, where necessary to prevent channelized flow

Source: T. R. Schueler, 1987, and SEWRPC.

erosion, damage to vegetation, and evidence of concentrated flows. Grass heights should remain at six inches or greater, where practicable, and applications of fertilizers and pesticides should be strictly limited to the minimum needed to maintain the vegetative cover.

Reported General Costs

Grassed filter strip costs were generally not reported in the literature reviewed because the cost was included in the cost of an adjacent primary structure—such as a detention basin or infiltration measure—or because a filter strip was considered to be part of the overall landscaping for a site. Donohue & Associates, Inc., estimated a capital cost of $0.28 per square foot.[12] Capital costs may be negligible when an existing grass or meadow area can be reserved at the site before development begins. Annual maintenance costs for grassed filter strips were not reported in the literature reviewed, but presumably would approximate the cost of general lawn care and maintenance.

[12] *Donohue & Associates, Inc., Stormwater Management Feasibility Study for the City of Oconomowoc, 1989.*

Cost Estimates

The cost for vegetated filter strips can be divided into mobilization and demobilization of equipment, site preparation, site development, and contingencies. Site preparation includes clearing, grubbing, and grading. Site construction activities include the placement of salvaged topsoil, seeding, mulching, and sodding. Contingencies include planning, engineering, administration, and legal fees.

Tables 30 through 32 present the selected unit costs, and the calculated component and total capital costs for 25-foot-wide, 50-foot-wide, and 100-foot-wide grassed filter strips—each strip being 1,000 feet long. The estimated capital costs range from $9.00 to $23 per lineal foot for a 25-foot-wide strip; from $17 to $43 per lineal foot for a 50-foot-wide strip; and from $32 to $82 per lineal foot for a 100-foot-wide strip.

The distribution of the component capital costs does not vary significantly with the width of the filter strip. Figure 32 shows the distribution of costs based on the moderate cost estimates presented in Tables 30 through 32. Clearing and grubbing (if required) and sodding account for the largest portions of the total cost. Mobilization and demobilization of equipment accounts

Table 30

ESTIMATED CAPITAL COST OF A 25-FOOT-WIDE GRASSED FILTER STRIP[a]

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization/ Demobilization-Light	Strip	1	$ 107	$ 274	$ 441	$ 107	$ 274	$ 441
Site Preparation								
Clearing[b]	Acre	0.7	$2,200	$3,800	$5,400	$1,540	$ 2,660	$ 3,780
Grubbing[c]	Acre	0.7	3,800	5,200	6,600	2,660	3,640	4,620
Grading[d]	Square yard	3,333	0.10	0.20	0.30	333	667	1,000
Site Development								
Salvaged Topsoil, Seed,and Mulch[e]	Square yard	1,667	$ 0.40	$ 1.00	$ 1.60	$ 667	$ 1,667	$ 2,667
Sod[f]	Square yard	1,667	1.20	2.40	3.60	2,000	4,001	6,001
Subtotal	- -	- -	- -	- -	- -	$7,307	$12,909	$18,509
Contingencies	Strip	1	25 percent	25 percent	25 percent	$1,827	$ 3,227	$ 4,627
Total	- -	- -	- -	- -	- -	$9,134	$16,136	$23,136

[a]*Grassed filter strip has a length of 1,000 feet.*

[b]*Area cleared = (strip width + 5 feet) x strip length.*

[c]*Area grubbed = area cleared.*

[d]*Area graded = area cleared.*

[e]*Area seeded = (area cleared x 0.5).*

[f]*Area sodded = (area cleared x 0.5).*

Source: SEWRPC.

Table 31

ESTIMATED CAPITAL COST OF A 50-FOOT-WIDE GRASSED FILTER STRIP[a]

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization/ Demobilization-Light	Strip	1	$ 107	$ 274	$ 441	$ 107	$ 274	$ 441
Site Preparation								
Clearing[b]	Acre	1.3	$2,200	$3,800	$5,400	$ 2,860	$ 4,940	$ 7,020
Grubbing[c]	Acre	1.3	3,800	5,200	6,600	4,940	6,760	8,580
Grading[d]	Square yard	6,292	0.10	0.20	0.30	629	1,258	1,888
Site Development								
Salvaged Topsoil, Seed, and Mulch[e]	Square yard	3,146	$ 0.40	$ 1.00	$ 1.60	$ 1,258	$ 3,146	$ 5,034
Sod[f]	Square yard	3,146	1.20	2.40	3.60	3,775	7,550	11,326
Subtotal	- -	- -	- -	- -	- -	$13,569	$23,928	$34,289
Contingencies	Strip	1	25 percent	25 percent	25 percent	$ 3,392	$ 5,982	$ 8,572
Total	- -	- -	- -	- -	- -	$16,961	$29,910	$42,861

[a]*Grassed filter strip has a length of 1,000 feet.*

[b]*Area cleared = (strip width + 5 feet) x strip length.*

[c]*Area grubbed = area cleared.*

[d]*Area graded = area cleared.*

[e]*Area seeded = (area cleared x 0.5).*

[f]*Area sodded = (area cleared x 0.5).*

Source: SEWRPC.

Table 32

ESTIMATED CAPITAL COST OF A 100-FOOT-WIDE GRASSED FILTER STRIP[a]

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Mobilization/ Demobilization-Light	Strip	1	$ 107	$ 274	$ 441	$ 107	$ 274	$ 441
Site Preparation								
Clearing[b]	Acre	2.5	$2,200	$3,800	$5,400	$ 5,500	$ 9,500	$13,500
Grubbing[c]	Acre	2.5	3,800	5,200	6,600	9,500	13,000	16,500
Grading[d]	Square yard	12,100	0.10	0.20	0.30	1,210	2,420	3,630
Site Development								
Salvaged Topsoil, Seed, and Mulch[e]	Square yard	6,050	$ 0.40	$ 1.00	$ 1.60	$ 2,420	$ 6,050	$ 9,680
Sod[f]	Square yard	6,050	1.20	2.40	3.60	7,260	14,520	21,780
Subtotal	- -	- -	- -	- -	- -	$25,997	$45,764	$65,531
Contingencies	Strip	1	25 percent	25 percent	25 percent	$ 6,499	$11,441	$16,383
Total	- -	- -	- -	- -	- -	$32,496	$57,205	$81,914

[a]Grassed filter strip has a length of 1,000 feet.

[b]Area cleared = (strip width + 5 feet) x strip length.

[c]Area grubbed = area cleared.

[d]Area graded = area cleared.

[e]Area seeded = (area cleared x 0.5).

[f]Area sodded = (area cleared x 0.5).

Source: SEWRPC.

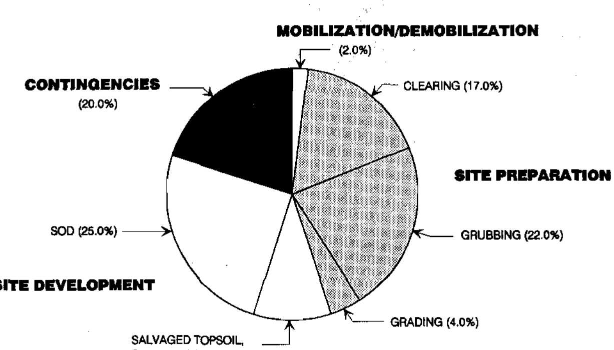
for about 2 percent of the total capital cost and contingencies were assumed to equal 20 percent of the capital cost of all strips.

Grassed filter strip maintenance costs are estimated in Table 33, which presents selected unit costs for grass mowing, spot reseeding and resodding, weed control, fertilization, and inspection. The estimated annual operation and maintenance costs range from $0.51 per foot for the 25-foot-wide grassed filter strip to $1.71 per foot for the 100-foot-wide strip.

The distribution of the component operation and maintenance costs slightly varies by strip width. Figure 33 illustrates the distribution of the operation and maintenance costs.

Figure 32

DISTRIBUTION OF GRASSED FILTER STRIP CAPITAL COST COMPONENTS



Source: SEWRPC.

Based on the unit costs presented above, cost curves were developed which may be used to estimate the capital and operation and maintenance costs of various sized grassed filter strips. These curves may be used to provide a preliminary estimate of a proposed strip cost. The costs, which are presented for a typical strip design as shown in Figure 30, may be revised by modifying the unit costs to reflect known site conditions. Figure 34 presents the capital cost curves for grassed filter strips. The curves are presented for strip widths ranging from 25 feet to 100 feet. Figure 35 presents the annual operation and maintenance cost curves for grassed filter strips.

Table 33

AVERAGE ANNUAL OPERATION AND MAINTENANCE COSTS FOR GRASSED FILTER STRIPS

Component	Unit Cost	Strip Width[a]			Comment
		25 Feet	50 Feet	100 Feet	
Lawn Mowing	$0.85/1,000 square feet/mowing	$0.17/lineal foot	$0.34/lineal foot	$0.68/lineal foot	Lawn maintenance area equals width times strip length. Mow eight times per year
General Lawn Care	$9.00/1,000 square feet/year	$0.23/lineal foot	$0.45/lineal foot	$0.90/lineal foot	Lawn maintenance area equals width times strip length
Grass Reseeding with Mulch and Fertilizer	$0.30/square yard	$0.01/lineal foot	$0.02/lineal foot	$0.03/lineal foot	Area revegetated equals 1 percent of lawn maintenance area per year
Filter Strip Inspection	$25/inspection	$0.10/lineal foot	$0.10/lineal foot	$0.10/lineal foot	Inspect four times per year
Total	- -	$0.51/lineal foot	$0.91/lineal foot	$1.71/lineal foot	- -

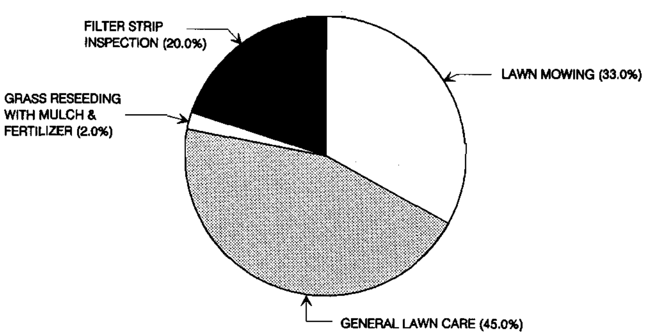
[a] *Assumes a filter strip length of 1,000 feet.*

Source: SEWRPC.

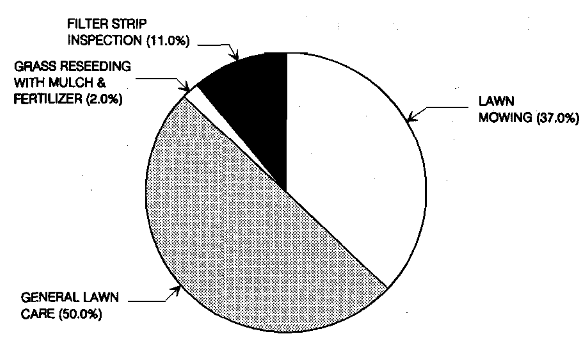
Figure 33

DISTRIBUTION OF GRASSED FILTER STRIPS COMPONENT OPERATIONS AND MAINTENANCE COST AS A FUNCTION OF FILTER STRIP SIZE

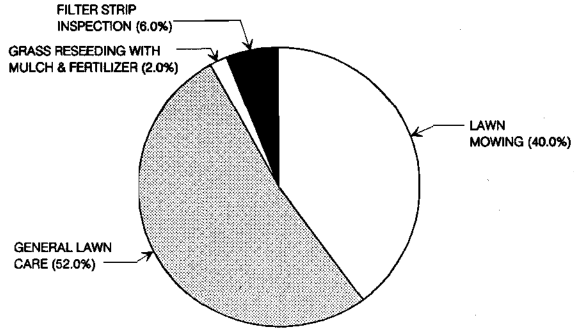
ESTIMATED ANNUAL OPERATION AND MAINTENANCE COST OF A 25-FOOT-WIDE GRASSED FILTER STRIP



ESTIMATED ANNUAL OPERATION AND MAINTENANCE COST OF A 50-FOOT-WIDE GRASSED FILTER STRIP



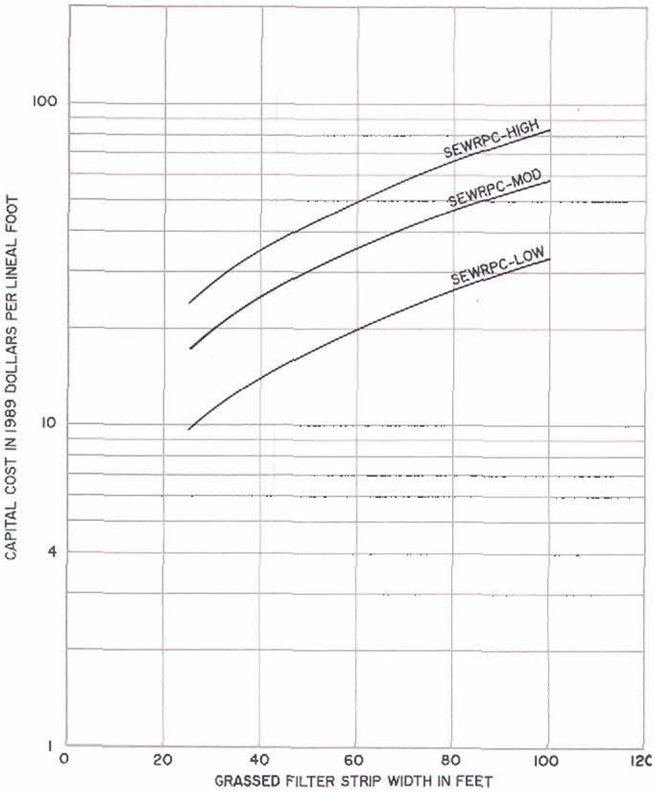
ESTIMATED ANNUAL OPERATION AND MAINTENANCE COST OF A 100-FOOT-WIDE GRASSED FILTER STRIP



Source: SEWRPC.

Figure 34

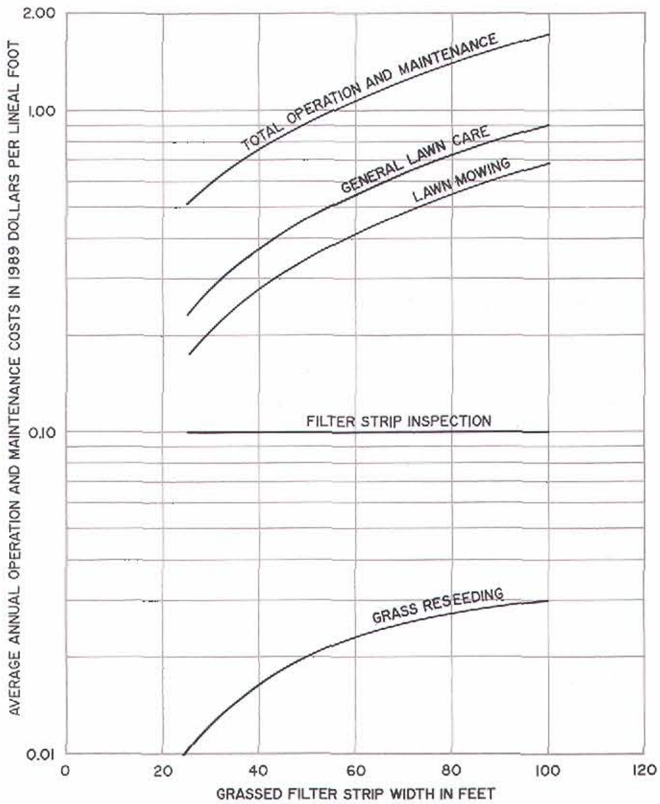
CAPITAL COSTS OF GRASSED FILTER STRIPS: 1989



Source: SEWRPC.

Figure 35

AVERAGE ANNUAL OPERATION AND MAINTENANCE COSTS OF GRASSED FILTER STRIPS: 1989



Source: SEWRPC.

STREET SWEEPING

Most street sweeping programs are designed primarily to improve aesthetics and prevent clogging of inlets and storm sewer systems. However, street sweeping can provide water quality benefits by removing pollutant loadings from the street surface before they are washed into a nearby waterway. Street sweepers are most effective at removing debris and large particles, and least effective at removing very fine particles. Unlike some other urban nonpoint source control measures, street sweeping can be readily applied in existing urban areas, including areas which generate high levels of toxic pollutants.

Description

Street sweepers are designed to dislodge debris and dirt from the street surface, transport it onto a moving conveyor, and deposit it into a storage hopper. The most common type of street sweeper is a mechanical sweeper, which uses a rotating gutter broom to transport particles from the gutter area into the path of a large cylindrical broom which rotates to carry the material onto a conveyor belt. Water is sprayed on the collected material to control resuspension of the fine particles. A second type of street sweeper is a vacuum sweeper, which uses gutter and main pickup brooms for dislodging and transporting street debris and dirt into the path of a vacuum intake, which carries the debris into the hopper. The collected dirt is sprayed with water and settles out in the hopper. A third type of street sweeper is a regenerative air system sweeper. These sweepers "blast" the dirt and debris from the street surface into the hopper, and the air is then vented through a dust separation system. A fourth type of street cleaner is a flusher, which uses water to flush the street dirt and debris towards, or into, the drainage system. In separate sewered areas, street flushing provides few water quality benefits because the pollutants are discharged to the receiving water body. The material collected by street sweepers is typically taken to a disposal site such as a sanitary landfill.

Street sweeping can be used to remove pollutants from urban areas served by streets with an urban cross section, that is, by streets with curbs and gutters. In areas served by streets with a suburban or rural cross section; that is, with road ditches in place of curbs and gutters, street sweeping may be used for aesthetic and litter control purposes, but the pollutant removal benefits of the sweeping are likely to be limited because the street debris and dirt would not be concentrated in a gutter area for effective pickup. In street sections with curb and gutter, no parked cars, smooth street surfaces, and moderate to heavy traffic volumes, from 70 to 80 percent of the street debris lies within six inches of the curb, and up to 90 percent lies within 12 inches.[13]

The establishment of a street sweeping program requires the purchase of equipment; the employment of operators and maintenance technicians for the equipment; and measures for disposal of the collected material. In addition to regular street sweeping, many municipalities utilize the sweepers for leaf collection, catch basin cleaning, construction site cleanup, and parking lot cleaning. Some municipalities contract with private firms for street sweeping services.

The number of street sweepers utilized in a street sweeping program, as well as the required operator and maintenance personnel, are dependent on the total number of curb-miles to be swept and on the desired frequency of sweeping. A 1975 American Public Works Association nationwide survey indicated that commercial and industrial areas are swept an average of one to three times per week, while residential areas are swept an average of about once or twice per month.[14] The survey indicated that the municipalities surveyed typically had one street sweeper for every 60 to 130 miles of curb in the municipality. Average street sweeping routes for an eight-hour shift ranged from 25 to 45 miles. During an average shift, about 15 cubic yards of material were collected per sweeper. The most common street sweeper hopper sizes were three and four cubic yards; therefore, about four or five loads were usually collected during each shift. Street sweepers typically had an economic life of eight to 14 years.

The effectiveness of street sweeping depends on the type and condition of the street pavements and on parking, traffic, and litter conditions in the municipality, as well as on the management and operation of the street sweeping program. Vehicles parked at curbs constitute the major obstacle to effective street sweeping. For example, if parked vehicles are located along 50 percent of the curb-length, only 15 percent of the street could be swept because of the additional length required for maneuvering around the parked vehicles. In addition, parked vehicles reduce the accumulation of particulates near the curb, resulting in higher loadings toward the middle of the street, which are more difficult to remove by sweeping. Street surfaces that are irregular, or that have many cracks, joints, and potholes are more difficult to sweep effectively than are those surfaces which are smooth and well-maintained. Rough textured street pavements have a more even distribution of debris across the street surface and may have from two to six times more debris on the street than do smooth textured street pavements. Traffic congestion may make street sweeping impractical because of the inability of the sweeper operator to maneuver the sweeper consistently along the curb and because of the potential for causing accidents. Streets subject to high traffic volumes may need to be swept during the evening or off-peak periods when traffic is at a minimum. Climate and weather, particularly snow and ice, restrict street sweeping in Wisconsin. Within southeastern Wisconsin, street sweeping is generally conducted from about the beginning of April through the end of November.

Street sweeping performance is also very sensitive to operator skill and to the level of sweeper maintenance provided. Inexperienced or poorly skilled operators may be unable to properly adjust the sweepers to optimize pollutant removal, may be unable to effectively maneuver around parked vehicles, and may improperly dispose of the collected materials.

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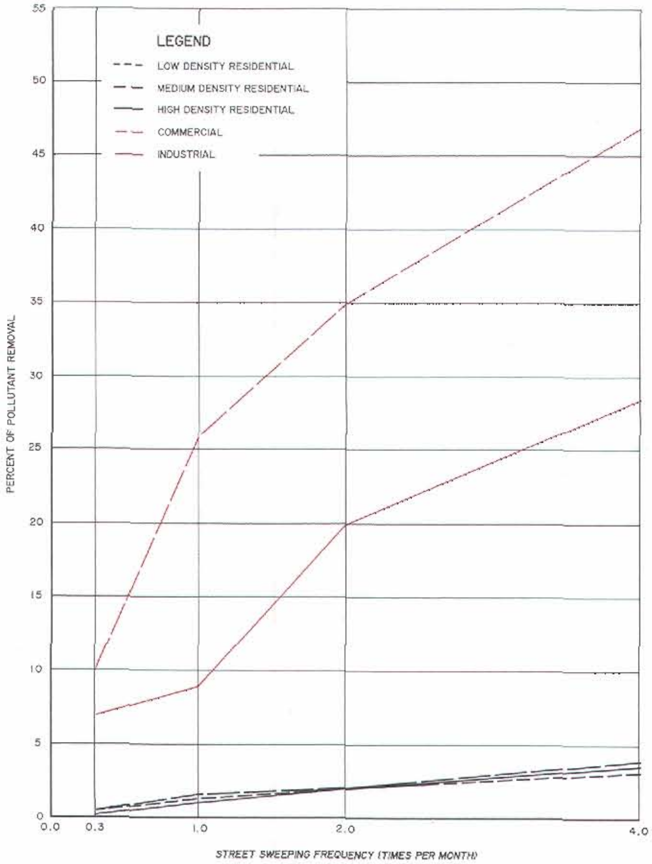
[13]*American Public Works Association, Street Cleaning Practice, 3rd Edition, R. R. Fleming, ed., Chicago, Illinois, 1978.*

[14]*Ibid.*

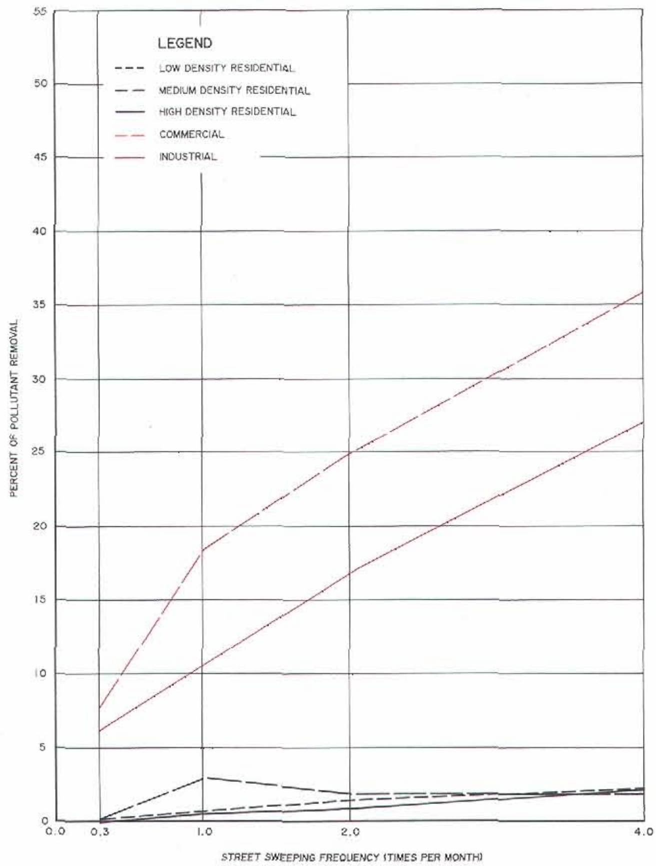
Figure 36

POLLUTANT REMOVAL EFFECTIVENESS OF STREET SWEEPING

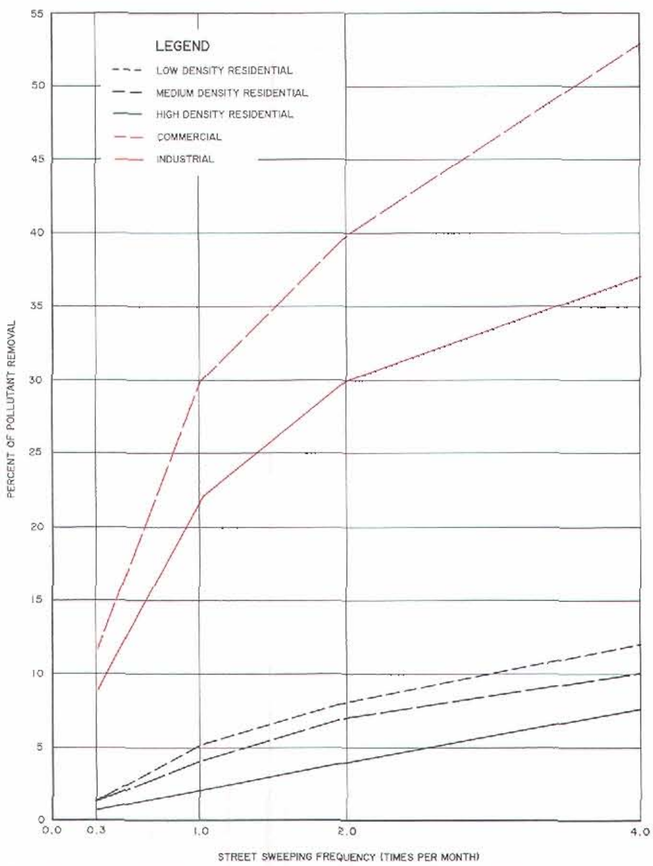
SEDIMENT



PHOSPHORUS



LEAD



Source: Wisconsin Department of Natural Resources.

The results of recent studies conducted under the Nationwide Urban Runoff Program sponsored by the U. S. Environmental Protection Agency, indicate that the overall water quality benefits of street sweeping are minimal.[15] It is likely that existing street sweeping programs in many communities achieve about a 10 percent reduction in solids loadings, compared to areas that are not swept at all.

Because of the extreme variability in urban runoff characteristics and site conditions, the research studies conducted under the Nationwide Urban Runoff Program were unable to clearly identify the differential water quality benefits of various street sweeping programs. Simulation model studies conducted by the Wisconsin Department of Natural Resources indicate that, as shown in Figure 36, intensive sweeping of commercial and industrial areas may provide significant water quality benefits, whereas, sweeping of residential areas may be ineffective.

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[15] *U. S. Environmental Protection Agency, Results of the Nationwide Urban Runoff Program, Vol. 1, Final Report, December 1983.*

Table 34

GUIDELINES FOR ENHANCING THE EFFECTIVENESS OF STREET SWEEPING PROGRAMS

Program Component	Guideline
Frequency of Sweeping	• As soon as snow and weather conditions permit in spring, conduct an intensive sweeping program to sweep residential streets at least three times and commercial and industrial streets six to nine times to reduce high spring street surface loadings • Conduct an intensive street sweeping program in fall to collect leaves and other vegetative debris • Increase the frequency of sweeping those streets which have high pollutant loadings—primarily industrial areas—and which now are not swept often because litter problems are not severe
Sweeping Equipment	• Use crimped wire or natural fiber brooms instead of plastic brooms, and maximize the broom pattern (The pattern is a measure of the pressure applied between the main pickup broom and the street surface. It is measured as the tangential length of main pickup broom in contact with the street surface.) • When new street sweepers are purchased, consider vacuum sweepers because some studies have indicated that vacuum sweepers remove a somewhat higher proportion of the fine particles and because vacuum sweepers can provide additional related uses such as leaf collection and catch basin cleaning. However, the replacement of still-effective mechanical sweepers with vacuum sweepers does not appear justified
Street Pollutant Loading Control	• Eliminate the temporary storage of leaves in the street. Store leaves on the grassed right-of-way or in bags • Establish a program for promptly sweeping special problem areas such as construction sites, special event areas, and high litter areas • Maintain streets and provide smooth surfaces wherever possible • Eliminate, or minimize, the duration of temporary storage of sweeper collected material on streets
Regulations and Education	• Develop, implement, and enforce regulations such as parking ordinances, litter control and trash and refuse storage ordinances, and construction erosion control ordinances • Educate and inform sweeper operators on methods to optimize pollutant removals. Emphasize those factors (sweeper speed, brush adjustment and rotation rate, sweeping pattern, maneuvering around parked vehicles, and interim storage and disposal methods) which have been shown to affect pollutant removal • Educate citizens and public officials on the multiple benefits of street sweeping, including aesthetics, water quality improvement, and air quality improvement by reducing fugitive dust emissions

Source: SEWRPC.

The pollutant removal effectiveness of a street sweeping program can often be significantly improved by modifying an existing program at modest additional cost. The effectiveness of a street sweeping program can generally be improved by increasing the efficiency of the sweepers to remove pollutant loads from the street surface, by optimizing the frequency and extent of sweeping, and by reducing the accumulation of pollutant loadings on the street surface. The applicability of these sweeping modification measures to an individual municipality is dependent on the physical characteristics of the area and on the existing sweeping program and related municipal operations. The evaluation of an existing street sweeping program requires a thorough understanding of local conditions that affect street sweeping effectiveness, and knowledge of the advantages and limitations of street sweeping methods and equipment. Table 34 presents some suggested guidelines for effective street sweeping programs.

Table 35

REPORTED COSTS OF STREET SWEEPERS

Sweeper Type	Manufacturer and Model	Capital Cost	Reference
Mechanical	Elgin Pelican	$65,000-75,000	Bruce Municipal Equipment, Inc., Menomonee Falls, Wisconsin
	FMC Vanguard 4000		
	Single broom	$ 89,225	Bark River Culvert & Equipment Company, Milwaukee, Wisconsin
	Double broom	93,550	
Vacuum	Elgin Whirlwind	$120,000	Bruce Municipal Equipment Inc., Menomonee Falls, Wisconsin
	VAC/ALL Model E-10		
	Single broom	$ 61,467	Bark River Culvert & Equipment Company, Milwaukee, Wisconsin
	Double broom	73,467	
Regenerative Air	Elgin Crosswind	$110,000	Bruce Municipal Equipment, Inc., Menomonee Falls, Wisconsin
	FMC Vanguard 3000SP		
	Single broom	$ 73,165	Bark River Culvert & Equipment Company, Milwaukee, Wisconsin
	Double broom	77,700	
	TYMCO Model 600	$ 87,000	Illinois Truck Equipment, Appleton, Wisconsin

Source: SEWRPC.

Reported General Costs

Street sweeping is a relatively labor-intensive operation which also requires a substantial investment in sweeper trucks, disposal facilities, and maintenance facilities. Mechanical street sweepers typically cost about $65,000 to $95,000, as presented in Table 35. Vacuum and regenerative air sweepers are generally more costly, with prices ranging up to $120,000 for vacuum sweepers, and up to $110,000 for regenerative air sweepers. In addition to capital and labor costs, street sweeping operations require funds for maintenance, parts and materials, fuel, and disposal fees. Table 36 presents street sweeping costs reported by the City of Milwaukee for 1976 through 1980, and for 1988. In 1988, the City of Milwaukee spent $2.1 million to sweep nearly 86,000 curb-miles, or about $25 per curb-mile swept. Most of the streets in the City of Milwaukee are swept about once per month. More frequent sweeping is conducted on some commercial streets. Figure 37 shows the distribution of the street sweeping costs reported by the City of Milwaukee. Wages and salaries account for the largest portion—34 percent—of the total cost.

Cost Estimates

Unit costs for existing street sweeping programs, which include both capital and operation and maintenance costs, are presented in Table 37. The costs per pound of solids collected are highly variable—ranging from $0.05 to $0.93 per pound. The pollutant loading rate on the street surfaces, the street conditions, sweeper equipment and method of sweeping, and weather conditions may all affect the quantity of solids collected. The costs per curb-mile swept range from $12.90 to $27.20 per curb-mile. The cost per hour of sweeping operation—ranging from $21.80 to $46.60 per hour—was less variable and more uniform than the cost per pound of solids collected. Of the above unit costs, the costs per curb-mile swept are probably the most useful because of the relative reliability with which the

Table 36

STREET SWEEPING COSTS FOR THE CITY OF MILWAUKEE, WISCONSIN: 1976-1988

Year	Curb-Miles Swept	Cubic Yards of Material Collected	Total Cost	Cost per Cubic Yard of Material Collected	Cost per Curb-Mile Swept
1976	57,299	55,804	$ 582,802	$10.44	$10.17
1977	58,283	39,670	611,766	15.42	10.50
1978	66,998	56,891	979,260	17.21	14.62
1979	63,757	55,823	936,783	16.78	14.69
1980	69,967	58,421	1,138,097	19.48	16.27
1988	85,628	159,908	2,144,656	13.42	25.05

NOTE: This table shows actual costs incurred. They are not updated to January 1989 dollars.

Source: City of Milwaukee and SEWRPC.

curb-miles swept can be measured and recorded. Thus, the cost estimates herein provided are based on curb-miles swept.

Figure 38 presents a capital cost curve which may be used to estimate the capital cost, and number of street sweepers, required to establish a new street sweeping program or expand an existing program. The cost generated from the curve may be adjusted if the assumptions listed on the figure are changed. For example, the costs would be one-half the indicated amount if the sweepers were operated for only one shift per day rather than for two shifts. The capital cost curve is based on an assumed street sweeper cost of $80,000 each.

Figure 39 presents annual operation and maintenance costs for street sweeping at a frequency ranging from once per month to three times per week. For general cost estimating purposes, it may be assumed that the cost would not vary significantly based on the land use adjacent to the street. However, it may be more expensive to sweep industrial and commercial streets than residential streets because of higher solids loadings on the industrial and commercial streets—which would increase disposal costs, and because of more severe problems with traffic and parked cars in these areas. The operation and maintenance costs include wages, equipment maintenance, fuel, and disposal costs.

CATCH BASIN CLEANING

Catch basin cleaning has historically been undertaken to remove accumulated debris to prevent clogging of downstream stormwater conveyance systems. The removal of decaying debris and highly polluted water from catch basins also has aesthetic benefits, prevents foul odors, reduces high pollutant concentrations during the "first flush" of a stormwater runoff event, and reduces overall pollutant loadings to the receiving water body. Because of the cost associated with the construction and cleaning of catch basins, and the potential negative impacts on water quality and odors if the basins are not adequately cleaned, catch basins are no longer commonly constructed as components of piped storm sewer systems.

Description

A catch basin is a stormwater runoff inlet equipped with a small sedimentation basin or grit chamber with a capacity ranging from 0.5 to 1.5 cubic yards. Stormwater runoff enters the catch basin through the surface inlet and drops to the bottom of the basin, where sediment and other debris transported by runoff are deposited and accumulate. A typical catch basin is shown in Figure 40. The primary purpose of the catch basin is to provide for removal of sediment and debris from stormwater runoff before it enters the subsurface conveyance system.

Table 37

REPORTED UNIT COSTS FOR STREET SWEEPING PROGRAMS

Cost Factor	Nationwide Urban Runoff Program (NURP) Studies: Milwaukee, Wisconsin	Winston-Salem, Forsyth County, North Carolina	San Francisco Bay Area, California	Champaign, Illinois	San Jose, California (Pitt, 1979)	City of Milwaukee (1988)	Mean of All Studies
Cost per Pound of Solids Collected	NA	0.17-0.93	0.12-0.34	NA	0.05-0.32	NA	0.32
Cost per Cubic Yard of Solids Collected	NA	NA	NA	NA	40.0	13.4	26.7
Cost per Curb-Mile Swept	25.0	17.9	12.9-19.4	14.3-18.0	27.2	25.0	21.2
Cost per Hour of Sweeping Operation . . .	36.0	21.8-46.6	NA	NA	29.7	NA	33.3

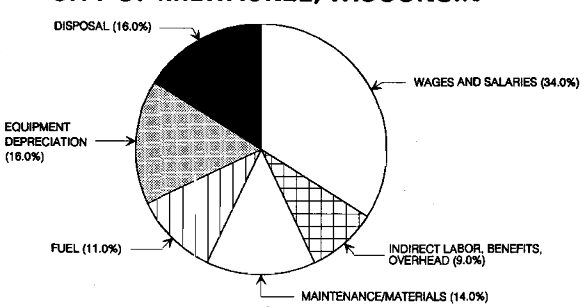
NA indicates data not available.

NOTE: All costs were updated to January 1989 dollars.

Source: SEWRPC.

Figure 37

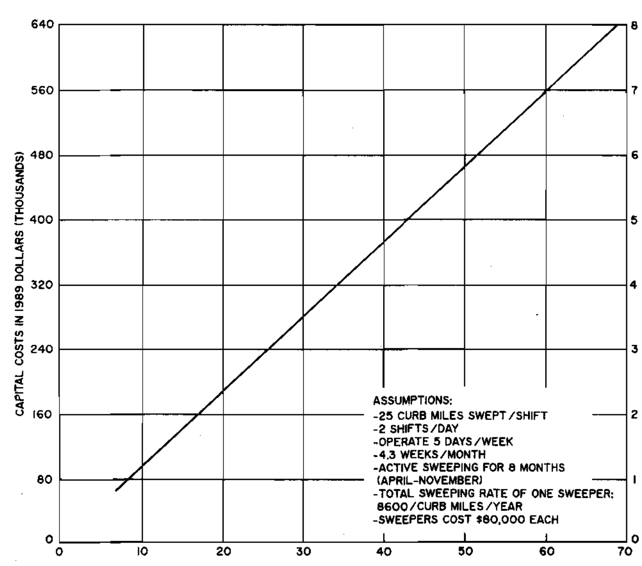
DISTRIBUTION OF ANNUAL STREET SWEEPING COMPONENT COSTS FOR THE CITY OF MILWAUKEE, WISCONSIN



Source: SEWRPC.

Figure 38

CAPITAL COST OF A NEW OR EXPANDED STREET SWEEPING PROGRAM

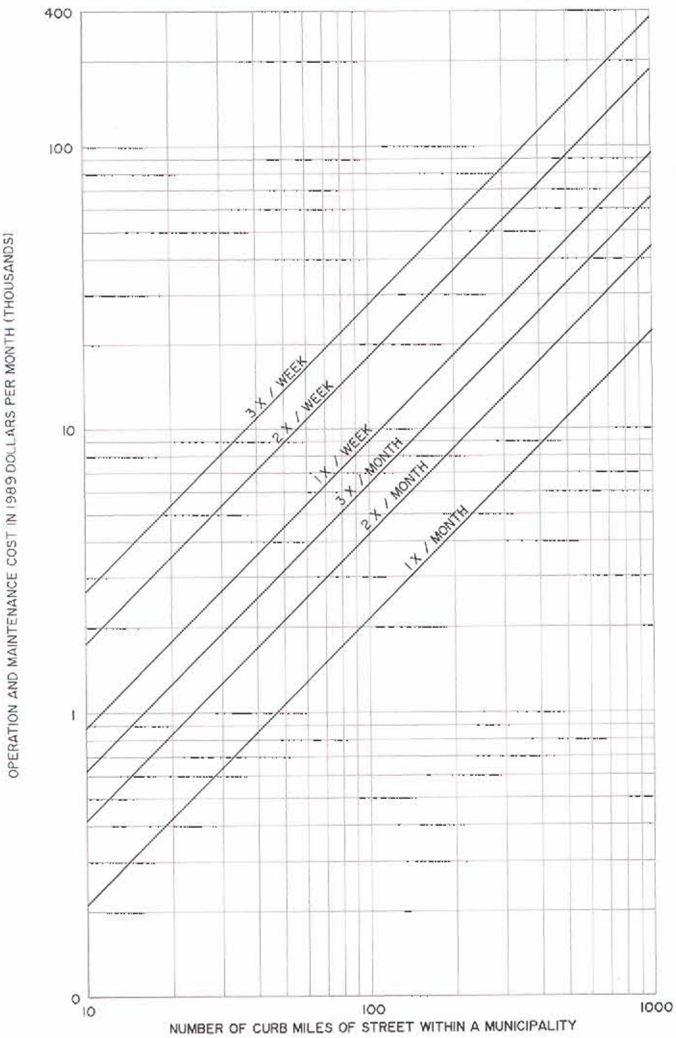


Source: SEWRPC.

Catch basins must be periodically cleaned to remove the sediment and debris which accumulates in the grit chamber. The basins can be cleaned either manually with a shovel or, by machine using a clamshell bucket or specially designed or modified equipment including bucket loaders, vacuum eductors, or vacuum attachments to street sweepers. Cleaning frequencies are generally determined by the availability of equipment and manpower, and by the level needed to prevent clogging of storm sewers. Cleaning frequencies in Wisconsin typically range from twice per year to once every three years. Material removed from catch basins is usually disposed of at landfills.

Figure 39

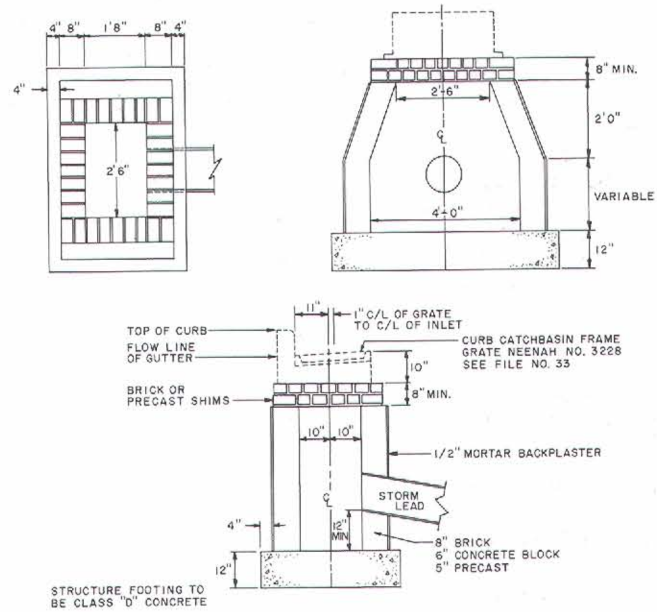
MONTHLY STREET SWEEPING OPERATION AND MAINTENANCE COSTS BASED ON CURB-MILES AND FREQUENCY



Source: SEWRPC.

Figure 40

TYPICAL STORMWATER CATCH BASIN



Source: *Standard Specifications for Sewer and Water Construction in Wisconsin, 4th Edition, March 1980.*

During storm events, some of the accumulated pollutants may be flushed from catch basins into the storm sewer system. Increasing the frequency of cleaning so that sediment and debris is removed when approximately 50 percent of the total grit chamber capacity is reached reduces the amount of sediments flushed into the storm sewers.

Although a variety of techniques are utilized to clean catch basins, labor-intensive manual cleaning methods are generally utilized in smaller communities, or for specialized situations in larger communities where vacuum systems or bucket machines cannot be utilized. The results of a 1973 survey by the American Public Works Association indicated that the majority of catch basins were cleaned with vacuum eductors or bucket machines. The survey indicated that an average of 10 basins could be cleaned per day by a three- to four-man manual cleaning crew; whereas, about 20 basins could be cleaned per day by a two-man crew using vacuum eductors or bucket machines. There are generally between 12 to 18 basins per curb-mile in urban areas which have catch basins.

The advantages of catch basin cleaning are that, where catch basins are present, the cleaning entails a relatively low cost; the aesthetic benefits resulting from debris removal and odor abatement are readily perceived by the public; and the cleaning can be easily conducted in both existing and new urban development in small as well as large communities. The disadvantages of catch basin cleaning are that only larger particles and debris are removed. Fine-grained sediments and dissolved pollutants, which cause most water quality problems, are not effectively trapped in a catch basin. Catch basins may be difficult to clean in areas with traffic congestion and parking problems; and cleaning is difficult during the winter when snow and ice are present. The material which accumulates in catch basins undergoes decay, and the first flush of stagnant water and debris by the stormwater runoff in a sewer system with catch basins that have not been properly cleaned may contain high concentrations of pollutants. Average concentrations of pollutants in catch basin liquid discharged during storm events have been reported to be similar to concentrations in raw sanitary sewage.

It is not possible, based on the data currently available, to quantify the water quality benefits to receiving waters of catch basin cleaning. Data collected as part of a Nationwide Urban Runoff Program project in Castro Valley Creek, California, indicated that basins which are cleaned either once per year or once every other year contained approximately 60 pounds of material each, although many catch basins have the capacity to hold over 1,000 pounds of material. The rate at which catch basins fill with debris, as well as the total amount of material which can be removed by different frequencies of catch basin cleaning are highly variable and cannot be readily predicted. In addition, some of the debris which is trapped in catch basins, such as rocks and cans, may not be considered water pollutants, although such debris may interfere with the use of the receiving waters.

Reported Costs

Capital costs for material and labor to install catch basins generally range from about $2,000 to $4,000 per basin. Cleaning costs for catch basins were estimated in three Nationwide Urban Runoff Program studies.[16] In Castro Valley, California, a cleaning cost of $7.70 per basin, or about $0.13 per pound of solids removed, was reported. In Salt Lake County, Utah, a cost of $10.30 per basin cleaned was reported. In Winston-Salem, North Carolina, a cleaning cost of $6.30 per basin was estimated. Basins in these studies were cleaned with a vacuum attachment to a street sweeper. Data from the City of Milwaukee, Wisconsin, indicated a catch basin cleaning cost with a vacuum attachment of about $0.09 per pound of solids removed. Cleaning catch basins manually by hand or with a clamshell bucket costs about twice as much as cleaning the basins with a vacuum attachment to a sweeper.[17]

Cost Estimates

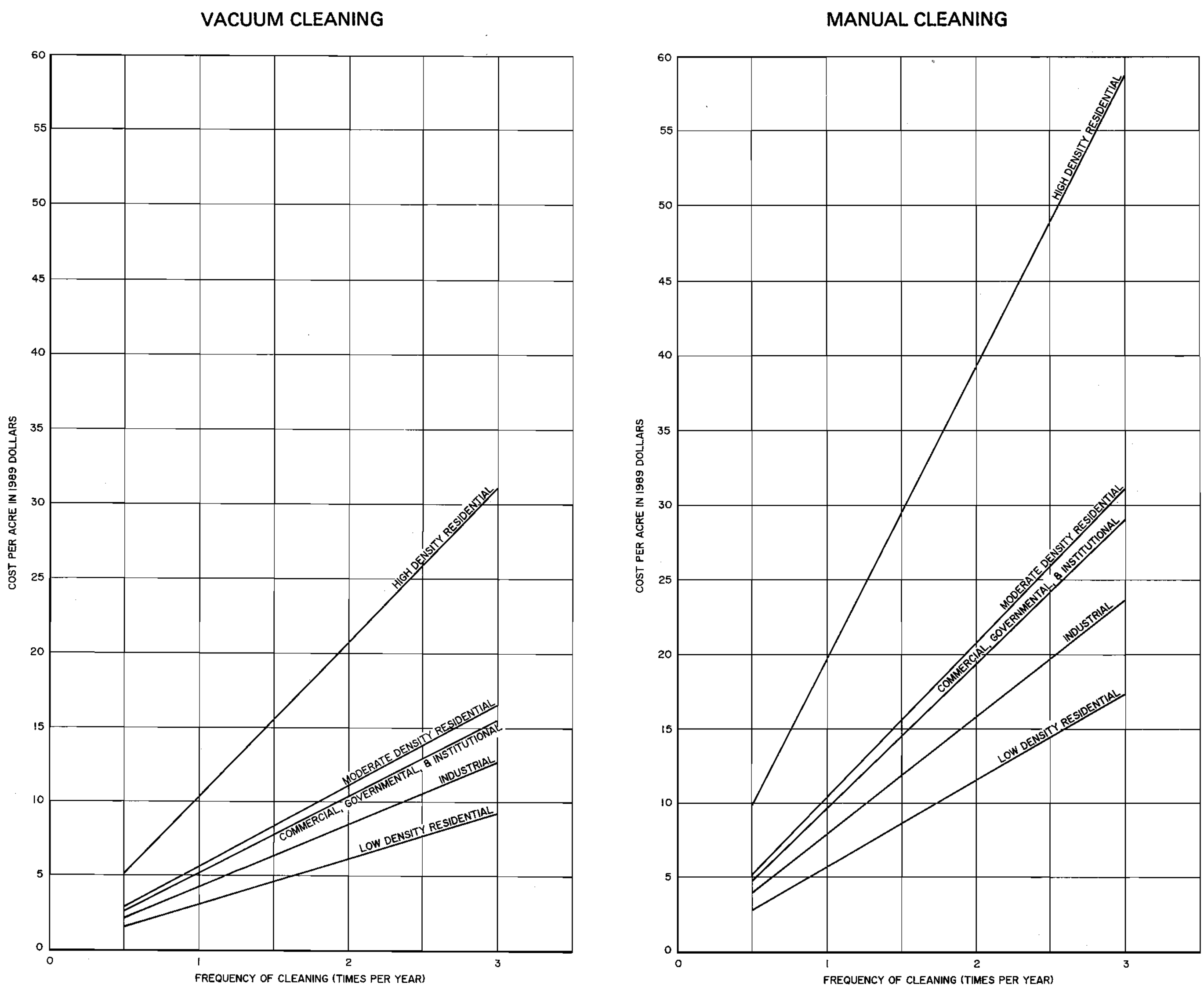
In those communities equipped with vacuum street sweepers, a cleaning cost of $8.00 per basin cleaned may be used. A cost of $15 per catch basin cleaned may be used for manual cleaning. Assuming an average density of 15 catch basins per lineal mile of street, and depending on the density of the street pattern, catch basin cleaning using attachments to a vacuum street sweeper may be expected to cost from $3.00 to $16 per acre of urban land, while catch basin cleaning by hand or by using a clamshell bucket may be expected to cost from $5.00 to $31 per acre. Figure 41 presents catch basin cleaning costs for low-, moderate-, and high-density residential land; for commercial, governmental, and institutional land; and for industrial land. The cost of catch basin cleaning, on a per acre basis, is highest for high density residential land because this land use typically has the densest street pattern.

[16]*Midwest Research Institute, 1982.*

[17]*SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control in Southeastern Wisconsin, Vol. 3, Urban Storm Water Runoff, 1977.*

Figure 41

CATCH BASIN CLEANING COSTS: 1989



Source: SEWRPC.

Chapter IV

CONSTRUCTION EROSION CONTROL MEASURES

INTRODUCTION

Land disturbance by urban development and construction projects often results in excessive stormwater runoff, erosion, and sedimentation. These impacts can be reduced by controlling the amount, rate, and direction of surface runoff; by protecting the land surface from the erosive forces of raindrops and flowing water; and by detaining surface runoff to trap sediments. Some of the urban nonpoint source control measures described above, such as wet detention basins, grassed swales, vegetated filter strips, catch basin cleaning, and street sweeping, can be used to control construction site erosion damages. These measures can continue to be used to abate nonpoint source pollution after the development is completed. Urban nonpoint source control measures which promote infiltration of stormwater, namely, infiltration trenches and basins, and porous pavement, should not be used at construction sites because the high sediment loadings will likely clog these systems. Several additional measures can be used to temporarily control erosion during the construction activity. These measures include filter fabric fences, straw bale barriers, diversion swales, inlet protection devices, temporary seeding, mulching, sodding, sediment traps, and sedimentation basins. These measures selected for detailed cost analysis are intended to be representative of the large and varied number of measures which could potentially be used to control erosion. Measures are often uniquely designed to accommodate the site-specific characteristics of a given site.

This study considered specific physical measures which may be placed at or near a construction land disturbance site to control erosion. A description of these temporary erosion control measures, along with pertinent cost information, is presented. In addition to these physical measures, a construction erosion control program for a particular development site may also include modifications to the sequence and timing of land disturbance activity, proper waste disposal, tracking control, and other measures which entail little or no cost.

DESCRIPTION

Temporary construction erosion control measures are designed and constructed to prevent erosion during particular phases of construction activity. To be effective, these measures must not interfere with the construction activity, the measures must be able to be installed quickly, and the measures must often be relocated or removed as the construction progresses. The construction erosion control program should be flexible enough to accommodate the continuous, almost daily, changes in a construction site. Regular repair and maintenance of the measures may be required during the period of construction.

In the absence of erosion control measures, sediment loadings contributed to nearby waterways from construction sites vary greatly, often exceeding, however, 20,000 pounds of sediment per acre of land per year. The effectiveness of individual erosion control measures similarly varies greatly. A well designed and implemented erosion control program may be expected to achieve about a 90 percent reduction in sediment loadings. The resultant sediment loading from a controlled construction site—perhaps 2,000 pounds of sediment per acre per year—is still about 10 times the sediment loading from developed medium- to high-density residential areas, and over four times the loading from uncontrolled cropland.

Table 38 summarizes some methods and criteria for designing construction erosion control measures. A particularly useful report for designing construction site erosion control measures in the southeastern Wisconsin area is the <u>Wisconsin Construction Site Best Management Practices Handbook</u>, published in 1989 by the Wisconsin Department of Natural Resources.

<u>Revegetation Measures</u>

Revegetation measures include temporary seeding, mulching, and sodding. These measures are intended to rapidly establish a vegetative cover on exposed soil surfaces. Vegetative cover may also reduce overland stormwater flow velocities on some sites.

Table 38

DESIGN METHODS AND GUIDELINES FOR CONSTRUCTION EROSION CONTROL MEASURES

Measure	Extent and Material	Dimensions	Drainage Area	Hydraulic	Avoid	Miscellaneous
Temporary Seeding	Place topsoil as needed to enhance plant growth. A loamy soil with an organic content of 1.5 percent or greater is preferred Use rapid-growing annual grasses, small grains, or legumes Apply seeds using a cyclone seeder, drill, cultipacker seeder, or hydroseeder	Place topsoil, where needed, to a minimum compacted depth of two inches on 3:1 slopes or steeper; and of four inches on flatter slopes	- -	Divert channelized flow away from temporarily seeded areas to prevent erosion and scouring	Heavy clay or organic soils as topsoil Hand-broadcasting of seeds (not uniform), except in very small areas Mowing temporary vegetation High-traffic areas	Use where vegetative cover is needed for less than one year Use chisel plow or tiller to loosen compacted soils As needed, apply water, fertilizer, lime, and mulch. Incorporate lime and fertilizer into top four to six inches of soil Plant small grains one inch deep. Plant grasses and legumes one-half inch deep
Mulching	Prefer organic mulches such as straw (from wheat or oats), wood chips, and shredded bark Commercial mats and fabrics may also be very effective Chemical soil stabilizers or binders are less effective, but may be used to tack wood fiber mulches	Application rates (per acre): straw, one to two tons; wood chips, five to six tons; wood fiber, 0.5 to one ton; bark, 35 cubic yards; asphalt (spray), 0.10 gallon per square yard After spreading mulch, less than 25 percent of the ground surface should be visible	- -	- -	- -	Mulch may be applied by machine or by hand Chemical mulches and wood fiber mulches, when used alone, often do not provide adequate soil protection Use nets or mats in areas subject to water flow Anchor mulch by punching into soil, or by applying chemical agents, nets, or mats Secure nets and mats with six inches or longer, No. 8-gauge or heavier, wire staples placed at three-foot intervals
Sodding	Sod should be machine-cut at a uniform thickness of one-half to two inches	- -	- -	In waterways, select plant types able to withstand design flow velocity	Gravel or nonsoil surfaces Unusually wet or dry weather Frozen soils Mowing for at least two to three weeks	Prior to laying sod, clear soil surface of debris, roots, branches, and stones bigger than two inches in diameter Sod should be harvested, delivered, and installed within 36 hours Lay sod with staggered joints along the contour Lightly irrigate soils before sod placement during dry or hot periods After placement, roll sod and wet soil to a depth of four inches On slopes steeper than 3:1, secure sod with stakes In waterways, lay sod perpendicular to water flow. Secure sod with stakes, wire, or netting
Filter Fabric Fence	Use commercial synthetic filter fabric or pervious sheet of polypropylene, nylon, polyester, or polyethylene Fabric should contain: Ultraviolet light inhibitors and stabilizers; 85 percent filtering efficiency; 30 pounds per linear inch tensile strength at 20 percent elongation Posts: Four-inch-diameter pine, or two-inch-diameter oak, or steel To reinforce fabric, use wire fence with a minimum of 14-gauge and a maximum mesh spacing of six inches. (Wire fence not needed if extra-strength fabric attached to posts with six-foot spacings.)	Post length: minimum of four feet Height of fence above ground: maximum of 24 inches Excavate trench four inches wide and eight inches deep. Backfill with compacted soil or gravel	Maximum: 0.25 acre per 100 feet of fence	Design for stability under a 10-year peak storm runoff Maximum depth of impounded water: 1.5 feet under design storm	Crossing streams, ditches, or waterways Attaching fabric to trees Slopes greater than 50 percent Slope lengths greater than 100 feet	Tie ends into landscape to prevent flow around fence ends Secure fabric to upslope side of posts Space posts a maximum of eight feet apart Drive support posts a minimum of 18 inches into ground Place fence on the contour, where practical

Table 38 (continued)

Measure	Extent and Material	Dimensions	Drainage Area	Hydraulic	Avoid	Miscellaneous
Straw Bale Barrier	Bales should be wire- or string-bound Anchor each bale with at least two wood or metal stakes	- -	Maximum unpaved: two acres Maximum paved: one acre	To prevent flow around barrier, elevation of top of straw bale at invert location in channel should be lower than the bottom elevation of the ends of the barrier	Intermittent and perennial streams	Install so bindings are oriented around sides, rather than top and bottom, of bale Fill gaps between bales with straw Entrench bale at least four inches into ground Place in single row lengthwise along contour for sheet-flow control; or perpendicular to contour for channel-flow control
Inlet Protection Devices Filter Fabric	Fabric criteria same as filter fabric fence above Stakes: wood or metal	Height above inlet: minimum 1.5 feet Stake length: minimum three feet Wood stake dimensions: two inches by four inches	Maximum: one acre per inlet	Inlet flows should not exceed 0.5 cubic feet per second	Drainage area slopes greater than 5 percent	Space stakes minimum of three feet apart Construct frame so that water can overtop fabric into inlet Bury fabric at least one foot into soil around frame and backfill
Straw Bale	Bales should be wire- or string-bound Anchor each bale with at least two wood or metal stakes	- -	Maximum: one acre per inlet	Inlet flows should not exceed 0.5 cubic feet per second	Drainage area slopes greater than 5 percent	Entrench bales at least four inches into ground Fill gaps between bales with straw Install so bindings are oriented around sides, rather than top and bottom, of bales
Concrete Block and Gravel	Place concrete blocks lengthwise around perimeter of inlet, with ends of blocks abutting Place wire mesh around outside of blocks Pile crushed stone or gravel against wire to top of blocks	Concrete blocks: 12 to 24 inches high Wire mesh: one-half-inch openings Crushed stone or gravel: one-half- to three-fourths-inch diameter	Maximum one acre per inlet, unless arrangements are made to remove accumulated sediment frequently	May be used where high flows are expected and where an overflow capacity is necessary to prevent ponding around structure	- -	Place gravel or crushed stone on 2:1 slope or flatter May be used in steeper sloped areas
Sod (permanent)	Place sod for a minimum distance of four feet around inlet	- -	Maximum: two acres per inlet Drainage area must be sodded or permanently seeded and mulched	Maximum design flow velocity over sod: five feet per second	Unstabilized construction sites	Lay all sod strips perpendicular to the direction of flow Stagger sod strips so that adjacent strip ends are not aligned
Diversion Swale	- -	Minimum height from channel invert to crest of dike: two feet Minimum width of dike: top, two feet; base, 4.5 feet	Maximum: five acres	Design for peak runoff from a 10-year storm Minimum freeboard: 0.3 foot Maximum design flow velocity: depends on soil and vegetation range: 1.5 to 5.0 feet per second Channel grade: 0.5 to 1.0 percent	Construction equipment traffic Sudden increases or decreases in swale grade	Side slope: maximum 3:1 Discharge diverted flow through a stabilized outlet Cover dike with sod or with seed and mulch Compact soil after shaping dike
Sediment Trap	Trap may be excavated, or constructed with an embankment Construct outlet of stone	Minimum volume: 1,800 cubic feet per acre of disturbed drainage area Maximum embankment height (above original ground surface): five feet Minimum embankment top width: five feet	Maximum: five acres	- -	Intermittent or perennial streams	Provide ready access for sediment removal and other maintenance Maximum embankment side slopes and excavated side slopes: 2:1 Provide emergency bypass for embankment
Sedimentation Basin	Basin may be excavated, or constructed with an embankment	Minimum basin size: 0.1 acre. Select size based on needed level of pollutant removal (see Figure 47) Minimum permanent water depth: three feet Minimum basin embankment top width: five feet	Maximum: 100 acres Minimum: five acres	Design for peak runoff from 10-year storm Minimum: one foot freeboard above emergency spillway Minimum outlet capacity: 0.2 cubic foot per second per acre of drainage area	Perennial streams	Provide ready access for sediment removal and other maintenance If possible, divert sediment-free runoff away from basin Minimum basin length to width ratio: 2:1

Table 38 (continued)

Measure	Extent and Material	Dimensions	Drainage Area	Hydraulic	Avoid	Miscellaneous
Sedimentation Basin (continued)	- -	- -	- -	- -	- -	To prevent blockage of a horizontal barrel pipe outlet, use minimum barrel size of eight inches for corrugated metal pipe or six inches for smooth pipe. Make cross-sectional area of vertical riser pipe 50 percent greater than horizontal barrel Use antiseep collar to reduce seepage around outlet pipe Maximum embankment side slopes: 2.5:1 Maximum basin side slopes: 3:1 Provide trash rack on outlet to prevent clogging Protect channel below basin to prevent erosion

Source: Wisconsin Department of Natural Resources, Wisconsin Construction Site Best Management Practice Handbook, 1989; North Carolina Sediment Control Commission, Department of Natural Resources and Community Development, Erosion and Sediment Control Planning and Design Manual, September 1988; Virginia Soil and Water Conservation Commission, Virginia Erosion and Sediment Control Field Manual, undated; and SEWRPC.

Temporary Seeding: The establishment of a temporary vegetative cover with appropriate rapid growing plants on disturbed soil areas can be accomplished by the drilling or broadcasting of seed either mechanically or by hand, or by hydroseeding. The soil must cover the seed to enhance germination. Hand broadcasting of seed is suitable for small areas, while machine broadcasting can cover larger areas with a uniform application of seed. Machine drilling, suitable only in gentle slope areas, distributes the seed in small furrows and provides maximum germination and growth. Hydroseeding, often used on long, narrow areas with steeper slopes and where access is limited, involves spraying a mixture of seed, fertilizer, and fiber mulch or chemical soil stabilizer onto the disturbed land surface.

Grass species sometimes used to provide temporary cover include wheat, oats, barley, rye, german or foxtail millet, annual ryegrass, and clover. Most of these species can be planted in spring, summer, or fall.

Proper maintenance of temporary seeded areas includes the use of mulch to prevent erosion of the soil and removal of newly planted seeds; fertilization; weed control; watering; and spot reseeding. Temporary seeded plants should generally not be mowed, but if mowing is required, the grass height should be retained at a minimum of three inches. Inspections should be made after each major rainfall until a good vegetative cover is established.

Mulching: Mulching involves the application of plant residues or other suitable material to disturbed soil surfaces to prevent water and wind erosion and reduce overland flow velocities. Used after seeding, the mulch fosters germination and plant growth by preventing the seeds from washing away, by increasing retention of soil moisture, and by providing insulation against extreme heat or cold. Mulch may also be applied to bare soil areas which cannot be seeded due to the season, and to areas which are frequently disturbed.

There are several types of mulch which utilize natural plant residue. The most commonly used mulch is straw, which is hand broadcast or blown onto a site. Other natural material mulches include wood chips, wood fiber, and corn stalks and cobs. The natural material mulches eventually biodegrade on the site. Hydromulching involves the uniform application of a plant residue mulch and a tacking agent in a slurry with water. Hydromulch can also be combined with seed and fertilizer. Jute matting is a heavy natural fiber net which covers and holds down mulch. The fiber net may also be bonded to a paper or plastic reinforcing net, and is then referred to as wood excelsior matting.

Various man-made materials are also used for mulching. Plastic and fiberglass nets may be used to hold down mulch. These nets are removed once a vegetative cover is established. Chemical and asphalt tacking agents can hold both mulch fibers and soil particles. Tacking agents are often used on steep, rocky slopes where other mulches and protective nets or mats are unsuitable.

Mulching requires little maintenance, other than site inspections after major rainfalls, and the placement of additional mulch if erosion starts to occur.

Sodding: The placement of grass sod on an exposed area immediately establishes a permanent vegetative cover on critical areas such as steep slopes, drainageways, and areas adjacent to buildings and pavement. The soil surface should be graded and cleared of stones, branches, and debris. The sod should be laid within 36 hours of cutting. The moist sod should be placed at right angles to the direction of stormwater flow. The sod may be secured by pegs on steep slopes and in waterways to prevent slippage. Common species of grass used for sod include Kentucky bluegrass, tall fescue, and Bermuda grass.

Special care is required after the placement of the sod because the root system will not adhere well for several weeks. Frequent watering will be required to provide adequate soil moisture. Minimum grass height should normally be maintained between two and three inches. After the first growing season, established sod will require fertilization and weed control.

Structural and Runoff Control Measures

Measures which intercept stormwater runoff to either convey it to a safe disposal area or to trap sediment particles include filter fabric fences, straw bale barriers, inlet protection devices, diversion swales, sediment traps, and sedimentation basins.

Filter Fabric Fence: A filter fabric fence is a temporary sediment barrier consisting of a synthetic filter fabric attached to posts and sometimes supported by a wire mesh. The bottom of the fabric is entrenched into the soil. A typical filter fence is shown in Figure 42.

The fence, usually less than three feet in height, is placed across, or at the base of, a slope or in a minor drainageway to intercept and detain sediment and slow runoff velocities. The fences can help control sheet and rill erosion, as well as erosion caused by small concentrated flows. Materials commonly used for a fence include polypropylene, nylon, polyester, and ethylene yarn. The silt fences normally have an effective life of six months to one year.

Maintenance of a silt fence includes regular inspections and spot repairs. Sediment deposits should be removed if the deposits reach one-half of the height of the fence. When the development is completed and the site stabilized, the fence should be removed and the accumulated deposits graded and seeded or sodded.

Straw Bale Barrier: Straw bales can be used to construct a temporary barrier placed across, or at the base of, a slope to trap sediment by detaining and filtering stormwater runoff. On a slope, the bales are placed parallel to contours, and firmly anchored, usually by wood stakes, to prevent displacement. To control channel flow, the bales are placed perpendicular to the contour. The bales are tied with twine or wire and placed in shallow trenches to prevent piping. A typical straw bale barrier is shown in Figure 43. The bales may be expected to have an effective life of three months to one year.

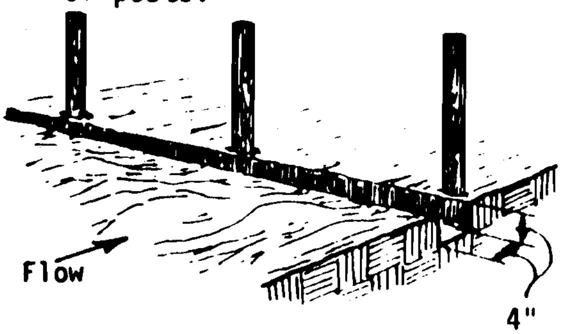
Maintenance of a straw bale barrier includes inspections and repair and replacement as necessary. Sediment deposits behind bales should be removed when one half of the bale is covered. After the development is completed, the bales should be removed and the accumulated deposits graded and seeded or sodded.

Inlet Protection Device: Various measures may be installed around storm sewer inlet structures to prevent clogging of the inlet and to reduce sediment loadings to the stormwater conveyance system. These measures may be constructed of straw bales, filter fabric or burlap, concrete blocks with wire screen and gravel, sod strips, or an inlet basket. The inlet basket is a metal frame and filter fabric liner placed within the inlet to reduce the inflow of sediment into the storm sewer. Figure 44 shows some typical inlet protection devices.

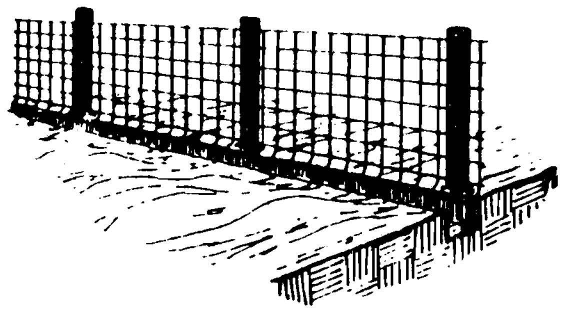
Figure 42

TYPICAL FILTER FABRIC FENCE

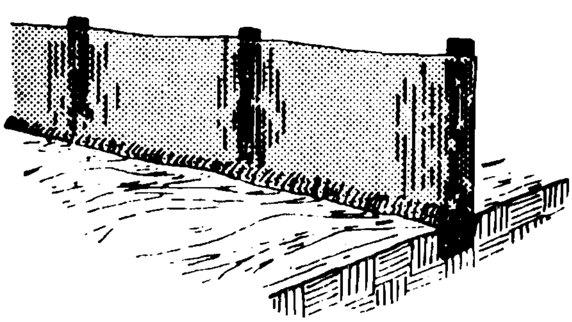
1. Set posts and excavate a 4"x4" trench upslope along the line of posts.



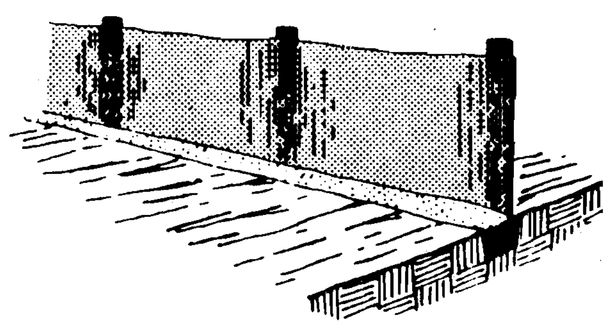
2. Staple wire fencing to the posts.



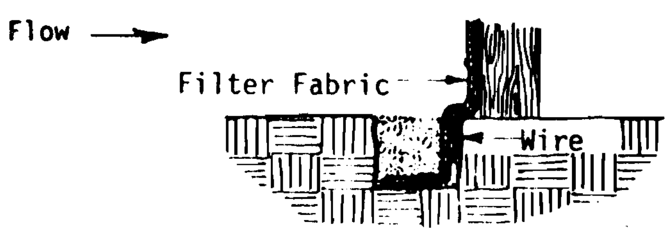
3. Attach the filter fabric to the wire fence and extend it into the trench.



4. Backfill and compact the excavated soil.



Extension of fabric and wire into the trench.



CONSTRUCTION OF A SILT FENCE

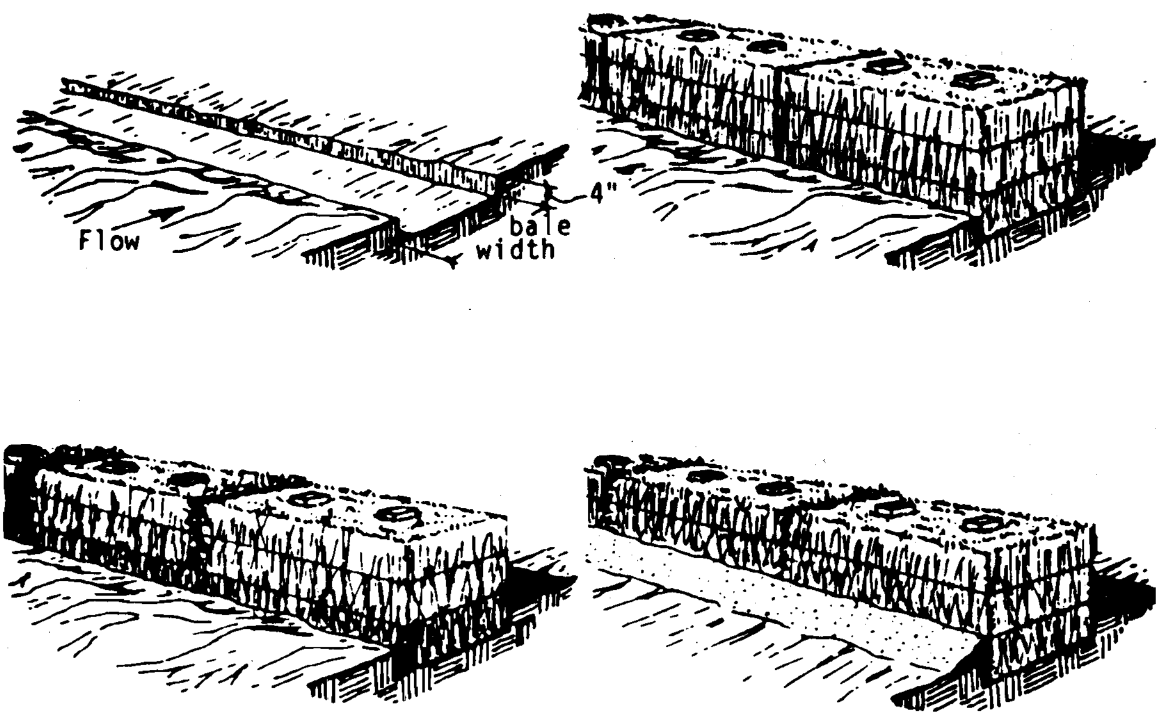
Source: Wisconsin Department of Natural Resources.

Figure 43

TYPICAL STRAW BALE BARRIER

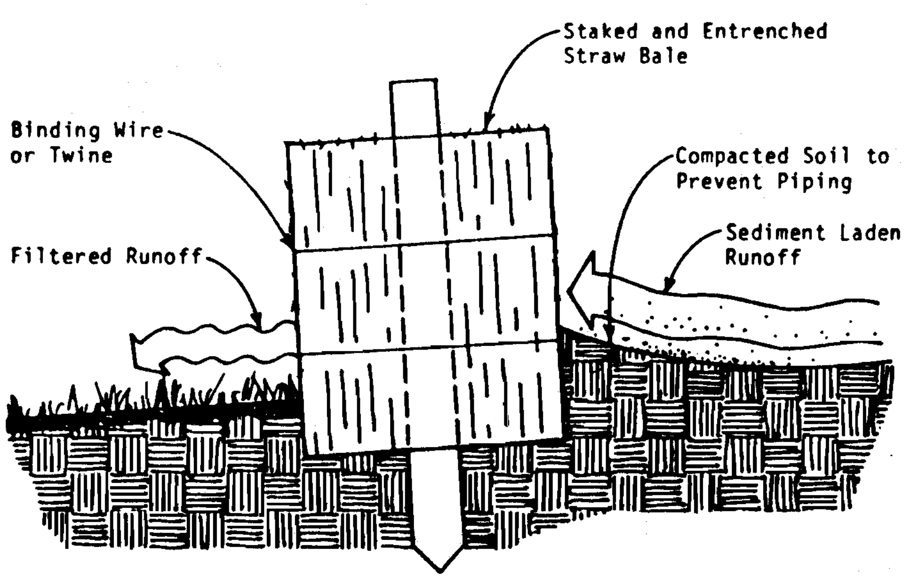
CONSTRUCTION OF A STRAW BALE BARRIER

1. Excavate the trench. **2. Place and stake straw bales.**



3. Wedge loose straw between bales.
4. Backfill and compact the excavated soil.

SECTION VIEW



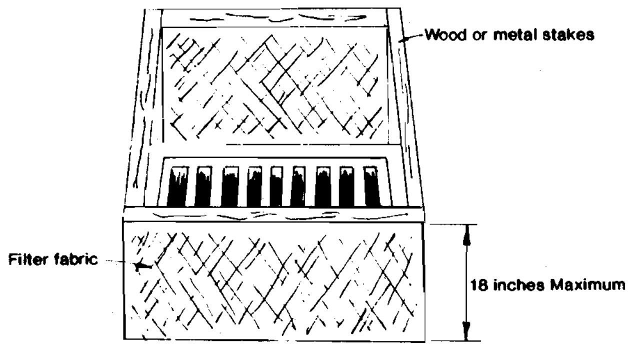
Source: Wisconsin Department of Natural Resources and North Carolina Department of Natural Resources and Community Development.

Figure 44

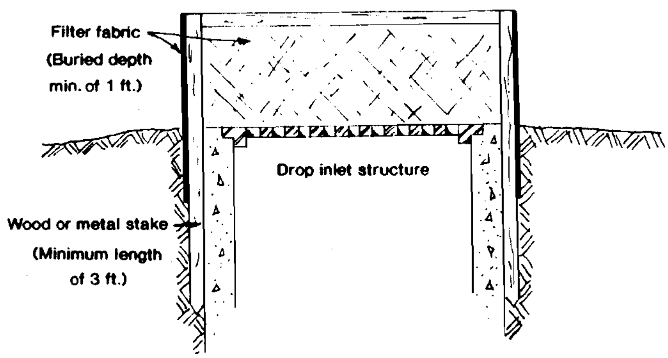
TYPICAL INLET PROTECTION DEVICES

FILTER FABRIC DEVICE

OBLIQUE VIEW

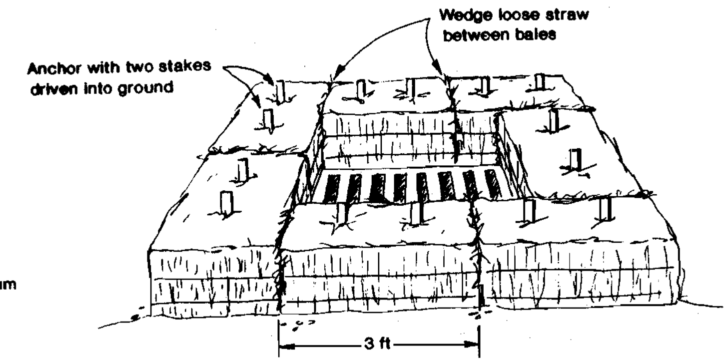


CROSS SECTION



STRAW BALE DEVICE

OBLIQUE VIEW



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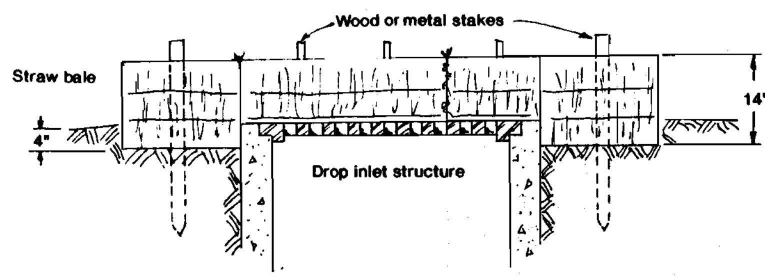
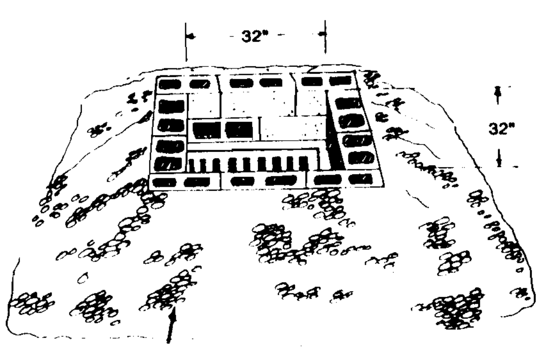
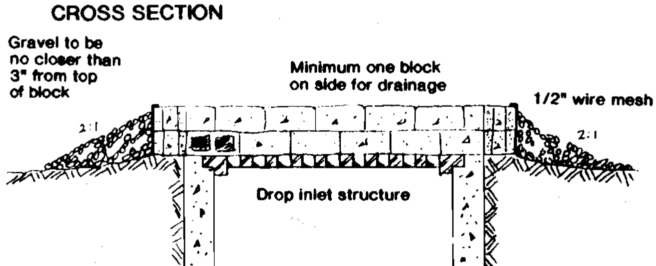


BLOCK AND GRAVEL DEVICE

OBLIQUE VIEW

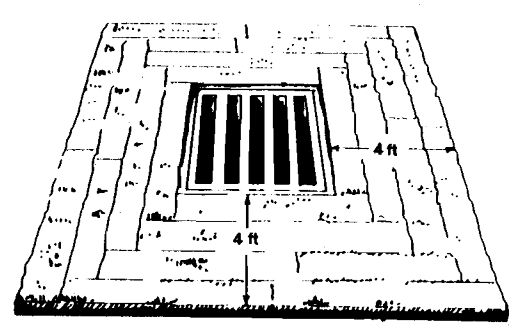


CROSS SECTION



SOD DEVICE

OBLIQUE VIEW



CROSS SECTION

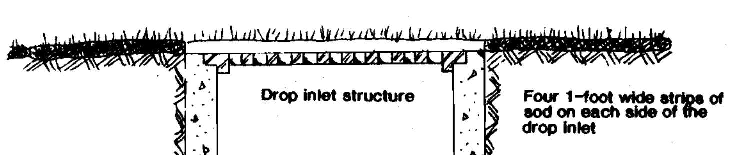
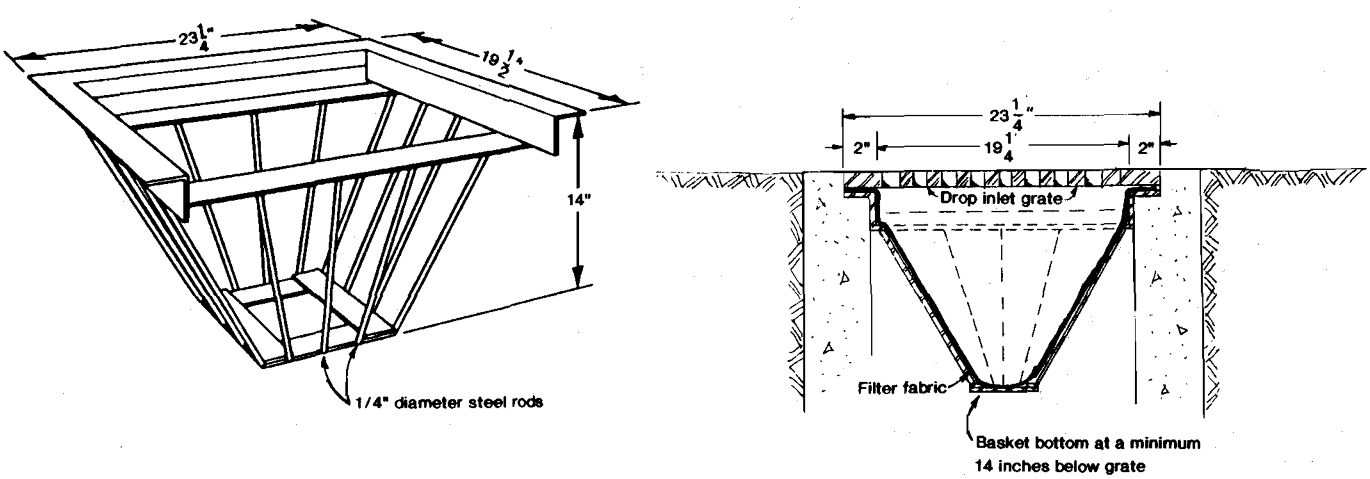


Figure 44 (continued)

INLET BASKET DEVICE

OBLIQUE VIEW

CROSS SECTION



Source: Wisconsin Department of Natural Resources, Metal-Era, Inc., and SEWRPC.

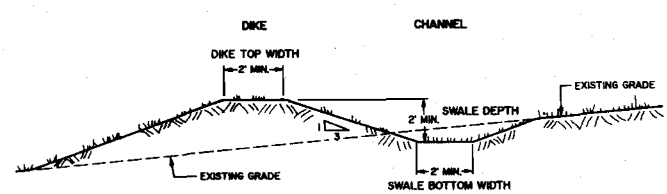
The devices should not cause ponding at the inlets, and they generally are not intended to protect inlets receiving large concentrated stormwater flows. Where practicable, the inlets protected should have a tributary drainage area of about one acre or less.

The maintenance requirements of an inlet protection device depend on the material used, but the overall inspection, repair, and sediment removal requirements would be similar to those described above for straw bale barriers and filter fabric fences. The inlet protection devices should be removed once the development site is stabilized so inflow rates are not impeded.

Diversion Swale: A diversion swale is a channel with an adjacent ridge on the downslope side, or simply a ridge of compacted soil installed immediately above a newly-constructed slope. When placed on a slope, the diversion reduces the uninterrupted slope length; when constructed above an exposed slope, the diversion intercepts the stormwater runoff from the upland area and diverts it to an acceptable outlet. Swales may also be used to divert runoff away from any critical, sensitive, or easily-eroded area, or to divert runoff towards a wet detention basin, sediment trap, or sedimentation basin. Swales designed for a construction site should generally serve a drainage area of five acres or less.

Figure 45

TYPICAL DIVERSION SWALE



Source: SEWRPC.

The swale should be constructed and fully stabilized prior to the onset of land disturbance activity. Maximum permissible design flow velocities for swales depend on the soil texture and the vegetative cover, but generally should range from 1.5 to 5.0 feet per second. Channel grades should typically range from 0.5 to 1.0 percent. Figure 45 shows a typical design of a diversion swale.

Diversions should be inspected after each major rainfall and repairs made immediately. Because of the channelized flow conditions, severe erosion problems can develop in damaged or poorly maintained swales. A dense vegetative cover should be maintained on the swale throughout the duration of the construction project.

Sediment Trap: A sediment trap is a small basin normally dry between storm events formed by excavation or by construction of an embankment to intercept sediment-laden runoff and retain a portion of the sediment. It is usually installed on a small drainageway, or at stormwater inlets or discharge sites. Drainage areas to a sediment trap are less than five acres. Depending on the soil and drainage conditions, some sediment traps can serve essentially as infiltration basins; however, in most instances, the traps require an outlet constructed of crushed stone which is part of the embankment. A typical sediment trap is shown in Figure 46.

The trap should be constructed and the embankment and adjacent land area stabilized prior to the onset of construction activity. The trap should be removed once construction is completed and the disturbed areas are vegetated.

A sediment trap should be inspected following major storm events. Sediment should be removed and the trap restored to its original dimensions when sediment fills one-half of the volume of the trap.

Sedimentation Basin: A sedimentation basin differs from a sediment trap in that the basin retains a permanent pool of water between storm events, and the basin serves a larger tributary drainage area—usually greater than five acres. Unlike a wet detention basin, a sedimentation basin is a temporary structure intended to remain in place only for the duration of the construction project. Since the basin provides only temporary protection, it may be possible to design it to permanently store the entire quantity of sediment which is generated during the construction phase, and the basin's life. When the construction is completed and the site stabilized, the remaining basin volume would be filled,and the area graded, seeded or sodded, and used for open space purposes. A typical sedimentation basin is shown on Figure 47.

A sedimentation basin should be inspected following major storm events. Because sediment loadings to the basin will be high, special care should be taken to ensure that the inflowing conveyance system and the basin outlet do not become obstructed or clogged with sediment. Accumulated sediment should be removed from the basin as necessary to maintain a minimum basin water depth of three feet.

REPORTED GENERAL COSTS

Table 39 presents a summary of reported costs of temporary seeding, mulching, sodding, filter fabric fences, and straw bale barriers. Extensive cost information on these erosion control measures were available from the Wisconsin Department of Transportation. Filter fabric fences average $3.40 per lineal foot; straw bale barriers entail an average cost of $9.20 per bale; mulching with straw typically costs about $0.30 per square yard; temporary seeding costs about $0.10 per square yard; and sodding may be expected to entail an average cost of $2.40 per square yard.

Few reported capital costs are available for inlet protection devices, diversion swales, sediment traps, and sedimentation basins. The U. S. Environmental Protection Agency reported that inlet protection devices constructed of straw bales may be expected to cost about $129 per inlet protected.[1] While the Denver Regional Council of Governments estimated an inlet protection device cost of $108 per inlet protected.[2] The Denver Regional Council of Governments estimated the capital cost of a diversion swale at $3.70 per cubic yard of soil excavated. The Denver study estimated that sediment traps may be expected to cost from $680 to $1,240 per acre of drainage area, while sedimentation basins may be expected to cost from $250 to $500 per acre of drainage area. The cost per drainage acre of a sediment trap is higher than for a sedimentation basin because the ratio of trap size to its drainage area is typically much greater than the ratio of basin size to its drainage area.[3]

If the measures are properly designed and the project is of sufficiently short duration (i.e., six to 12 months), very little maintenance may be required. However, when the construction period lasts for more than one year, or when the site

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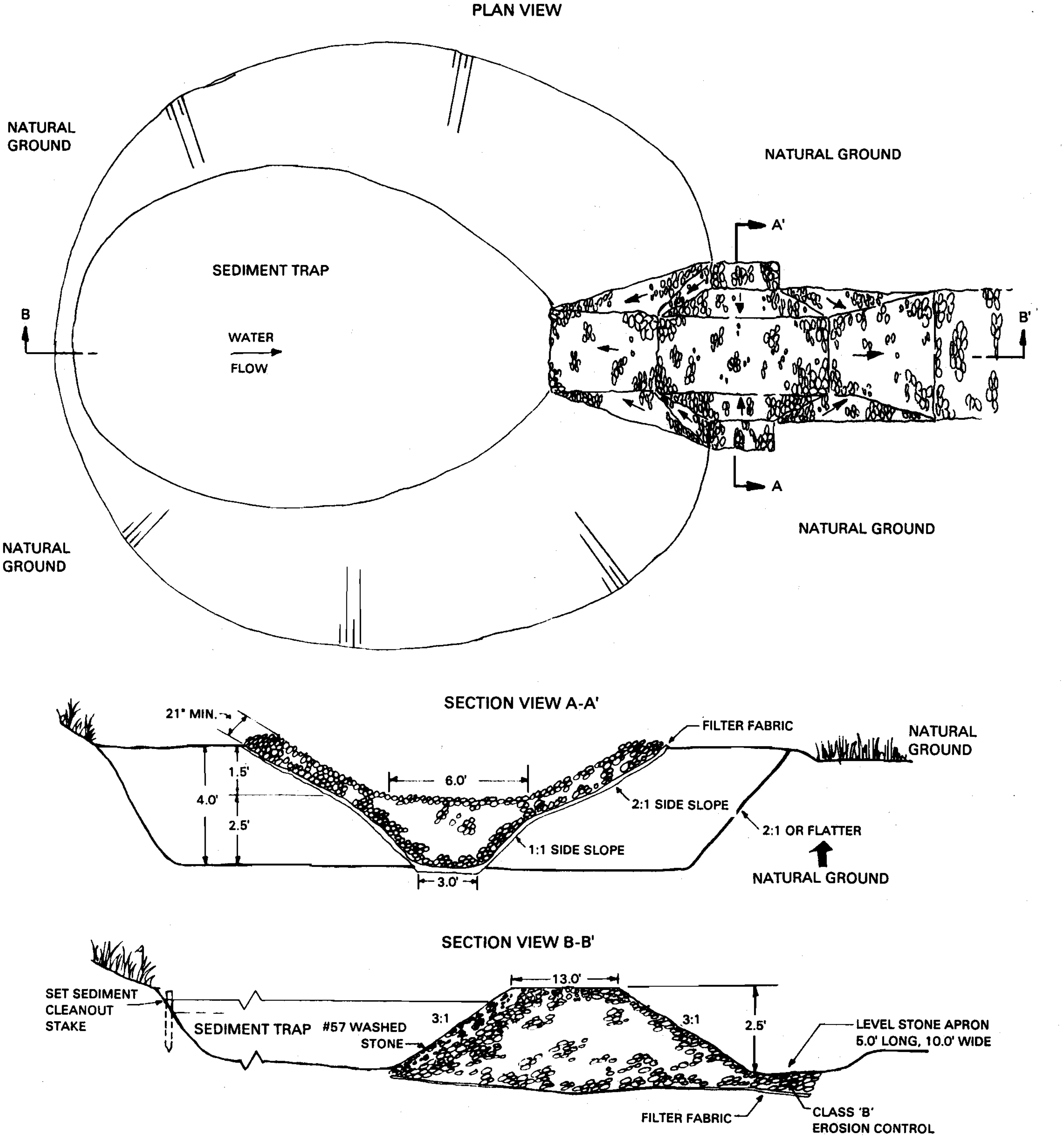
[1] *U. S. Environmental Protection Agency, Comparative Costs of Erosion and Sediment Control, Construction Activities, July 1973.*

[2] *Denver Regional Council of Governments, Cost of Erosion Control Measures, May 1982.*

[3] *Ibid.*

Figure 46

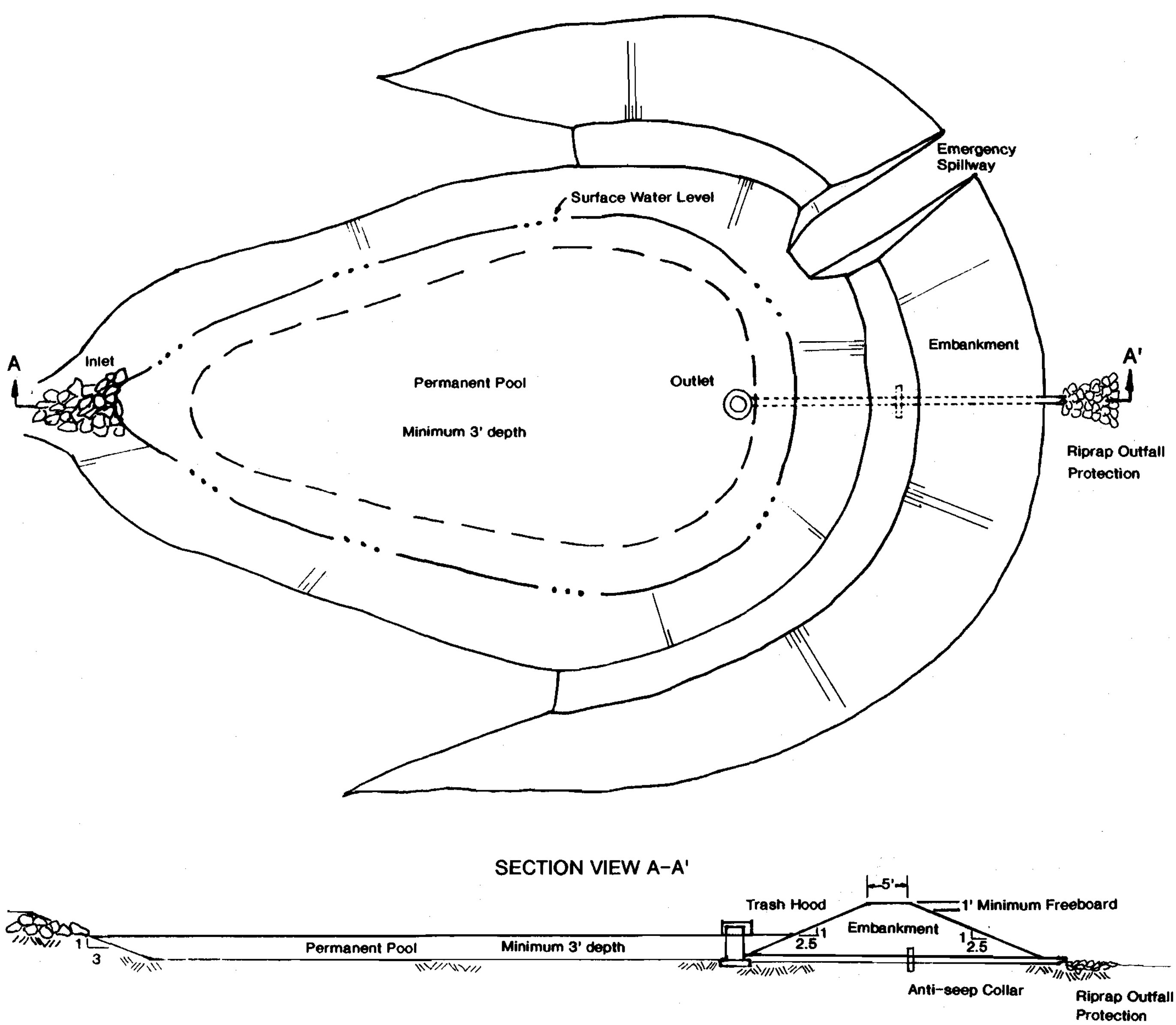
TYPICAL SEDIMENT TRAP



Source: Wisconsin Department of Natural Resources and SEWRPC.

Figure 47

TYPICAL SEDIMENTATION BASIN



Source: SEWRPC.

conditions increase the likelihood of severe erosion problems, some measures will require some degree of reconstruction, replacement, or sediment removal. Relatively few maintenance costs for construction erosion control measures have been reported in the literature. Seeded and sodded areas may require watering, fertilization, weed control and mowing. Some practices which trap sediment may require removal of the sediment in order to maintain their effectiveness. The Denver Regional Council of Governments estimated the annual maintenance costs of erosion control measures.[4]

[4]*Ibid.*

Table 39

REPORTED COSTS OF SELECTED CONSTRUCTION EROSION CONTROL MEASURES

Measure	Unit	Number of Reported Costs	Minimum	Maximum	Mean
Temporary Seeding	Square yard	8	$0.08	$ 0.12	$0.10
Mulching	Square yard	91	0.10	1.00	0.30
Sodding	Square yard	117	1.40	10.10	2.40
Filter Fabric Fence	Lineal foot	290	0.60	8.00	3.40
Straw Bale Barrier	Bale	136	5.00	12.00	9.20

Source: City of Madison, Wisconsin; City of West Bend, Wisconsin Crispell-Snyder Consulting Engineers; GeoSynthetics, Inc.; Hornburg Contractors; Ruekert & Mielke, Inc.; Terra Engineering; Wisconsin Department of Transportation; and SEWRPC.

Table 40

UNIT CAPITAL COSTS FOR SELECTED CONSTRUCTION EROSION CONTROL MEASURES

Component	Unit	Unit Cost		
		Low	Moderate	High
Temporary Seeding	Square yard	$ 0.05	$ 0.10	$ 0.20
	Pound	1.80	4.60	7.40
Mulching	Square yard	0.10	0.30	0.50
Sodding	Square yard	1.20	2.40	3.60
Filter Fabric Fence	Lineal foot	2.30	3.40	4.50
Straw Bale Barrier	Bale	7.80	9.20	10.60
Inlet Protection Device	Inlet	106.00	130.00	154.00

Source: SEWRPC.

Because the measures are designed for only temporary use, the maintenance costs are high, relative to the capital costs, when such measures must be used for an extended period of time. According to the Denver report, the annual maintenance costs for diversion swales and sediment traps may be expected to approximate 20 percent of the capital cost; the annual maintenance cost for a sedimentation basin about 25 percent of the capital cost; and the annual maintenance cost for filter fabric fences and straw bale barriers—neither of which should be used for more than a one-year period—is essentially 100 percent of the capital cost. Based on the unit costs for lawn care and mowing set forth in this report, the annual maintenance cost for an area vegetated with topsoil, seed, and mulch would approximate 15 percent of the capital cost; while the annual maintenance cost of an area vegetated with sod would approximate 5 percent of the capital cost.

COST ESTIMATES

Unit capital costs for temporary seeding, mulching, sodding, filter fabric fences, straw bale barriers, and inlet protection devices are presented in Table 40. For each measure, low, moderate, and high unit costs are presented. The costs for diversion swales, sediment traps, and sedimentation basins can be divided into site

Table 41

ESTIMATED CAPITAL COST OF A 1.5-FOOT-DEEP DIVERSION SWALE

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Site Preparation								
Excavation[a]	Cubic yard	11.81	$2.10	$3.70	$5.30	$ 24.80	$ 43.70	$ 62.59
Place and Compact Fill[a]	Cubic yard	11.81	0.60	1.10	1.60	7.09	12.99	18.90
Grading[b]	Square yard	144.4	0.10	0.20	0.30	14.44	28.88	43.32
Site Development								
Salvaged Topsoil, Seed, and Mulch[b,c]	Square yard	72.2	$0.40	$1.00	$1.60	$ 28.88	$ 72.20	$115.52
Sod[b,c]	Square yard	72.2	1.20	2.40	3.60	86.64	173.28	259.92
Subtotal	- -	- -	- -	- -	- -	$162.00	$331.00	$500.00
Contingencies	Swale	1	25 percent	25 percent	25 percent	$ 41.00	$ 83.00	$125.00
Total	- -	- -	- -	- -	- -	$202.00	$414.00	$625.00

NOTE: Swale height is from top of dike to bottom of channel. Dike top width equals channel bottom width of two feet. Swale has an assumed length of 100 feet with 3:1 side slopes.

[a] *Volume excavated = volume filled*

$$\underset{\text{[cubic yard]}}{\text{Volume}} = \frac{\underset{\text{(feet)}}{\text{swale length}}\left(\frac{\text{swale height (feet)}}{2} + \left[\begin{matrix}\text{dike top width (feet)}\\ \text{or channel bottom}\\ \text{width (feet)}\end{matrix} + \left(\frac{\text{swale height (feet)}}{2} \times \underset{\text{(H÷V)}}{\text{side slope}}\right)\right]\right)}{27}$$

[b] *Swale surface area*

$$\underset{\text{(square yard)}}{\text{Area}} = \frac{\left[\left(\underset{\text{(feet)}}{\text{dike top width}} + \underset{\text{(feet)}}{\text{channel bottom width}}\right) + 2\left(\underset{\text{(H÷V)}}{\text{side slope}} \times \text{swale height (feet)}\right)\right]\underset{\text{(feet)}}{\text{swale length}}}{9}$$

[c] *One-half of swale surface area is seeded; one-half is sodded.*

Source: SEWRPC.

preparation and site development components, as shown in Tables 41 through 47. Site preparation components include excavation, placement and compaction of fill, and leveling and grading. Site development components include placement of topsoil, seeding, sodding, mulching, inlets, and outlets. No costs are assumed for mobilization or demobilization of equipment because the equipment would be readily available on the construction site.

All capital costs include a contingency fee of 25 percent to account for planning, engineering, administration, and legal fees. Although many erosion control measures require little, if any, planning or engineering, the development and implementation of a construction erosion control plan for a particular construction project which conforms with a local construction erosion control ordinance may be expected to entail this additional cost.

Tables 41 and 42 present the calculated component and total capital costs for a 1.5-foot-deep diversion swale, and for a 3.0-foot-deep diversion swale, respectively. The estimated capital costs for a diversion swale range from $4.00 to $14 per lineal foot of swale.

Table 42

ESTIMATED CAPITAL COST OF A 3.0-FOOT-DEEP DIVERSION SWALE

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Site Preparation								
Excavation[a]	Cubic yard	36.11	$2.10	$3.70	$5.30	$ 75.83	$133.61	$ 191.38
Place and Compact Fill[a]	Cubic yard	36.11	0.60	1.10	1.60	21.67	39.72	57.78
Grading[b]	Square yard	244.4	0.10	0.20	0.30	24.44	48.88	73.32
Site Development								
Salvaged Topsoil, Seed, and Mulch[b,c]	Square yard	122.2	$0.40	$1.00	$1.60	$ 48.88	$122.20	$ 195.52
Sod[b,c]	Square yard	122.2	1.20	2.40	3.60	146.64	293.28	439.92
Subtotal	- -	- -	- -	- -	- -	$162.00	$331.00	$ 500.00
Contingencies	Swale	1	25 percent	25 percent	25 percent	$ 79.00	$159.00	$ 240.00
Total	- -	- -	- -	- -	- -	$397.00	$797.00	$1,198.00

NOTE: Swale height is from top of dike to bottom of channel. Dike top width equals channel bottom width of two feet. Swale has an assumed length of 100 feet with 3:1 side slopes.

[a] *Volume excavated = volume filled*

$$\underset{\text{[cubic yard]}}{\text{Volume}} = \frac{\underset{\text{(feet)}}{\text{swale length}}\left(\frac{\text{swale height (feet)}}{2} + \left[\begin{array}{c}\text{dike top width (feet)}\\ \text{or channel bottom}\\ \text{width (feet)}\end{array} + \left(\frac{\text{swale height (feet)}}{2} \times \underset{(H \div V)}{\text{side slope}}\right)\right]\right)}{27}$$

[b] *Swale surface area*

$$\underset{\text{(square yard)}}{\text{Area}} = \frac{\left[\underset{\text{(feet)}}{\text{(dike top width}} + \underset{\text{(feet)}}{\text{channel bottom width)}} + 2\left(\underset{(H \div V)}{\text{side slope}} \times \text{swale height (feet)}\right)\right]\underset{\text{(feet)}}{\text{swale length}}}{9}$$

[c] *One-half of swale surface area is seeded; one-half is sodded.*

Source: SEWRPC.

Tables 43 and 44 present the calculated component and total capital costs for a 1,000-square-foot, three-foot-deep sediment trap, and for a 5,000-square-foot, five-foot-deep sediment trap, respectively. The estimated total costs range from $600 for the 1,000-square-foot, three-foot-deep trap, to $4,400 for the 5,000-square-foot, three-foot-deep trap.

Tables 45, 46, and 47 present the calculated component and total capital costs for 0.1-acre, 0.25-acre, and 1.0-acre sedimentation basins, respectively. All basins would be constructed with a permanent pool water depth of five feet. The costs of revegetating the land area immediately adjacent to the basin are not included. The estimated capital costs range from $10,500 for a 0.1-acre basin to $49,000 for a 1.0-acre basin.

The distribution of the component capital costs for diversion swales, sediment traps, and sedimentation basins are shown in Figures 48, 49, and 50. The figures show the cost distribution based on the moderate cost estimates presented in Tables 41 through 47. Contingencies were assumed to equal 20 percent of the capital cost of all measures.

Table 43

ESTIMATED CAPITAL COST OF A 3.0-FOOT-DEEP SEDIMENT TRAP

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Site Preparation Excavation[a]	Cubic yard	117	$ 2.10	$ 3.70	$ 5.30	$246.00	$433.00	$620.00
Site Development Outlet Crushed Stone Fill[b] Filter Fabric[c]	 Cubic yard Square yard	 1.8 6.7	 $14.80 1.00	 $19.40 2.00	 $24.00 3.00	 $ 26.60 6.70	 $ 34.90 13.40	 $ 43.20 20.10
Subtotal	- -	- -	- -	- -	- -	$279.00	$481.00	$683.00
Contingencies	Swale	1	25 percent	25 percent	25 percent	$ 70.00	$121.00	$171.00
Total	- -	- -	- -	- -	- -	$349.00	$602.00	$854.00

NOTE: Trap has an assumed surface area of 1,000 quare feet.

[a]*Volume excavated = trap volume + 5 percent for outlet.*

[b]*Outlet has an average thickness of four feet, an average width of four feet, and 2:1 side slopes.*

Crushed stone fill volume (cubic yard) - trap depth (feet) x outlet thickness (feet) x outlet width (feet) / 27

[c]*Filter fabric lining under crushed stone (square yard) = (trap depth (feet) x 5) x outlet thickness (feet) / 9*

Source: SEWRPC.

Table 44

ESTIMATED CAPITAL COST OF A 5.0-FOOT-DEEP SEDIMENT TRAP

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Site Preparation Excavation[a]	Cubic yard	926	$ 2.10	$ 3.70	$ 5.30	$1,945.00	$3,426.00	$4,908.00
Site Development Outlet Crushed Stone Fill[b] Filter Fabric[c]	 Cubic yard Square yard	 3 11	 $14.80 1.00	 $19.40 2.00	 $24.00 3.00	 $ 44.40 11.00	 $ 58.20 22.00	 $ 72.00 33.00
Subtotal	- -	- -	- -	- -	- -	$2,400.00	$4,383.00	$5,013.00
Contingencies	Swale	1	25 percent	25 percent	25 percent	$600.00	$877.00	$1,253.00
Total	- -	- -	- -	- -	- -	$3,000.00	$4,383.00	$6,266.00

NOTE: Trap has an assumed surface area of 5,000 square feet.

[a]*Volume excavated = trap volume + 5 percent for outlet.*

[b]*Outlet has an average thickness of four feet, an average width of four feet, and 2:1 side slopes.*

Crushed stone fill volume (cubic yard) - trap depth (feet) x outlet thickness (feet) x outlet width (feet) / 27

[c]*Filter fabric lining under crushed stone (square yard) = (trap depth (feet) x 5) x outlet thickness (feet) / 9*

Source: SEWRPC.

Table 45

ESTIMATED CAPITAL COST OF A 0.1-ACRE SEDIMENTATION BASIN

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Site Preparation								
Excavation[a]	Cubic yard	462	$ 2.10	$ 3.70	$ 5.30	$ 970.00	$ 1,709.00	$ 2,449.00
Place and Compact Fill[b]	Cubic yard	310	0.60	1.10	1.60	186.00	341.00	496.00
Site Development								
Basin Inlet[c]	Basin	1	$1,310.00	$2,870.00	$4,430.00	$1,310.00	$ 2,870.00	$ 4,430.00
Basin Outlet[d]	Basin	1	1,320.00	3,380.00	5,440.00	1,320.00	3,380.00	5,440.00
Riprap[e]	Cubic yard	2.42	16.40	29.60	42.80	39.70	71.60	104.00
Subtotal	- -	- -	- -	- -	- -	$3,826.00	$ 8,372.00	$12,919.00
Contingencies	Basin	1	25 percent	25 percent	25 percent	$ 956.00	$ 2,093.00	$ 3,230.00
Total	- -	- -	- -	- -	- -	$4,782.00	$10,465.00	$16,149.00

NOTE: Basin has side slopes of 3:1 and a depth of five feet.

[a]*Volume excavated = basin volume + 5 percent for spillway, inlet, outlet, etc.*

[b]*Volume of fill = 0.67 x excavated volume.*

[c]*Temporary basin inlet cost = one-half of permanent wet detention basin inlet cost.*

[d]*Temporary basin outlet cost = one-half of permanent wet detention basin outlet cost.*

[e]*Riprap volume = basin area x 0.01 x 0.5 yard thick.*

Source: SEWRPC.

Table 46

ESTIMATED CAPITAL COST OF A 0.25-ACRE SEDIMENTATION BASIN

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Site Preparation								
Excavation[a]	Cubic yard	1,509	$ 2.10	$ 3.70	$ 5.30	$3,169	$ 5,583	$ 7,998
Place and Compact Fill[b]	Cubic yard	1,011	0.60	1.10	1.60	607	1,112	1,618
Site Development								
Basin Inlet[c]	Basin	1	$1,310.00	$2,870.00	$4,430.00	$1,310	$ 2,870	$ 4,430
Basin Outlet[d]	Basin	1	1,320.00	3,380.00	5,440.00	1,320	3,380	5,440
Riprap[e]	Cubic yard	6.1	16.40	29.60	42.80	100	181	261
Subtotal	- -	- -	- -	- -	- -	$6,506	$13,126	$19,747
Contingencies	Basin	1	25 percent	25 percent	25 percent	$1,627	$ 3,282	$ 4,937
Total	- -	- -	- -	- -	- -	$8,133	$16,408	$24,684

NOTE: Basin has side slopes of 3:1 and a depth of five feet.

[a]*Volume excavated = basin volume + 5 percent for spillway, inlet, outlet, etc.*

[b]*Volume of fill = 0.67 x excavated volume.*

[c]*Temporary basin inlet cost = one-half of permanent wet detention basin inlet cost.*

[d]*Temporary basin outlet cost = one-half of permanent wet detention basin outlet cost.*

[e]*Riprap volume = basin area x 0.01 x 0.5 yard thick.*

Source: SEWRPC.

Table 47

ESTIMATED CAPITAL COST OF A 1.0-ACRE SEDIMENTATION BASIN

Component	Unit	Extent	Unit Cost			Total Cost		
			Low	Moderate	High	Low	Moderate	High
Site Preparation								
Excavation[a]	Cubic yard	7,252	$ 2.10	$ 3.70	$ 5.30	$15,229	$26,832	$38,436
Place and Compact Fill[b]	Cubic yard	4,859	0.60	1.10	1.60	2,915	5,345	7,774
Site Development								
Basin Inlet[c]	Basin	1	$1,310.00	$2,870.00	$4,430.00	$ 1,310	$ 2,870	$ 4,430
Basin Outlet[d]	Basin	1	1,320.00	3,380.00	5,440.00	1,320	3,380	5,440
Riprap[e]	Cubic yard	24.2	16.40	29.60	42.80	397	716	1,036
Subtotal	- -	- -	- -	- -	- -	$26,464	$48,929	$71,395
Contingencies	Basin	1	25 percent	25 percent	25 percent	$ 5,293	$ 9,786	$14,279
Total	- -	- -	- -	- -	- -	$26,464	$48,929	$71,395

NOTE: Basin has side slopes of 3:1 and a depth of five feet.

[a] *Volume excavated = basin volume + 5 percent for spillway, inlet, outlet, etc.*

[b] *Volume of fill = 0.67 x excavated volume.*

[c] *Temporary basin inlet cost = one-half of permanent wet detention basin inlet cost.*

[d] *Temporary basin outlet cost = one-half of permanent wet detention basin outlet cost.*

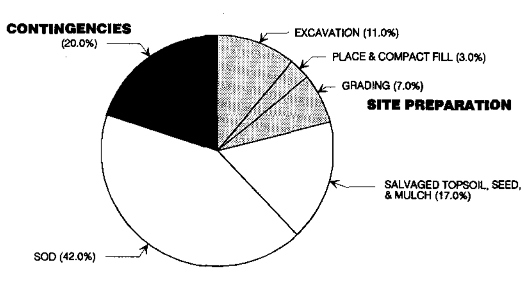
[e] *Riprap volume = basin area x 0.01 x 0.5 yard thick.*

Source: SEWRPC.

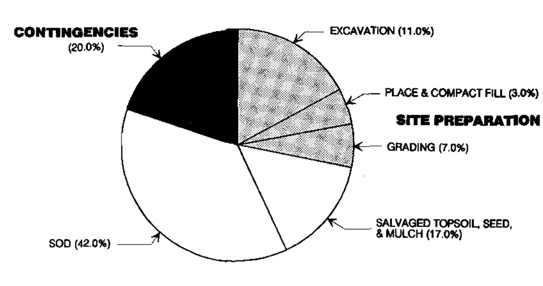
Figure 48

DISTRIBUTION OF DIVERSION-SWALE COMPONENT CAPITAL COSTS AS A FUNCTION OF SWALE SIZE

ESTIMATED CAPITAL COST OF A 1.5-FOOT-DEEP DIVERSION SWALE



ESTIMATED CAPITAL COST OF A 3.0-FOOT-DEEP DIVERSION SWALE

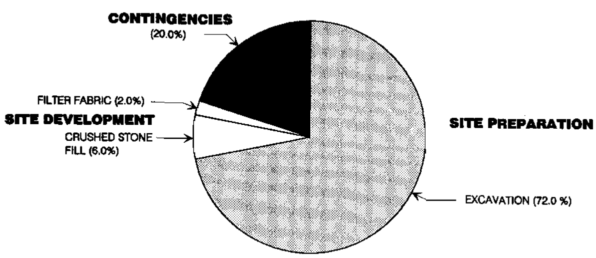


Source: SEWRPC.

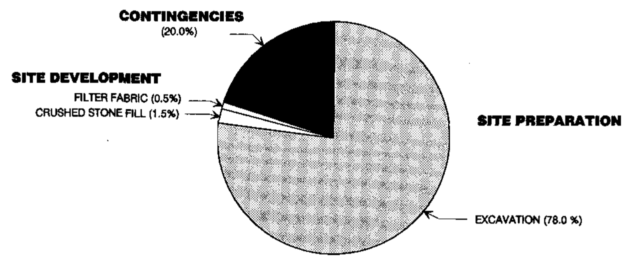
Figure 49

DISTRIBUTION OF SEDIMENT-TRAP COMPONENT CAPITAL COSTS AS A FUNCTION OF TRAP SIZE

ESTIMATED CAPITAL COST OF A 3.0-FOOT-DEEP SEDIMENT TRAP



ESTIMATED CAPITAL COST OF A 5.0-FOOT-DEEP SEDIMENT TRAP

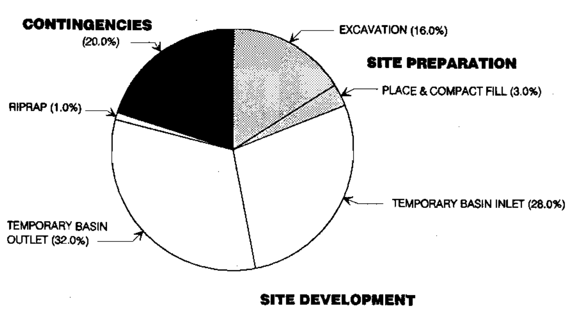


Source: SEWRPC.

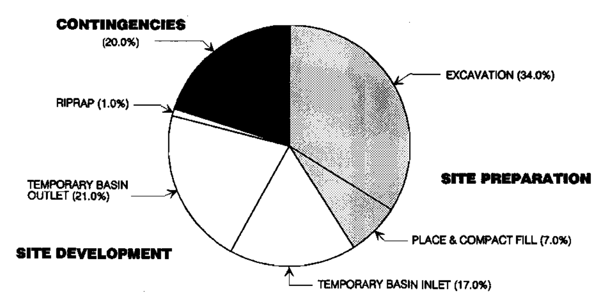
Figure 50

DISTRIBUTION OF SEDIMENTATION BASIN COMPONENT CAPITAL COSTS AS A FUNCTION OF BASIN SIZE

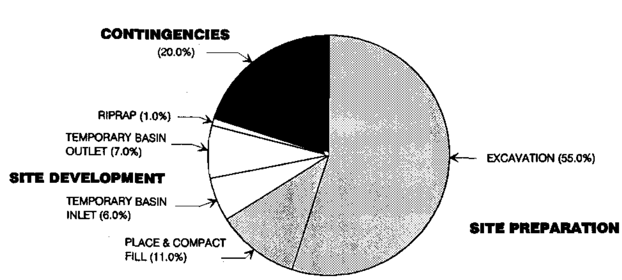
ESTIMATED COST OF A 0.1-ACRE SEDIMENTATION BASIN



ESTIMATED COST OF A 0.25-ACRE SEDIMENTATION BASIN



ESTIMATED COST OF A 1.0-ACRE SEDIMENTATION BASIN



Source: SEWRPC.

Table 48

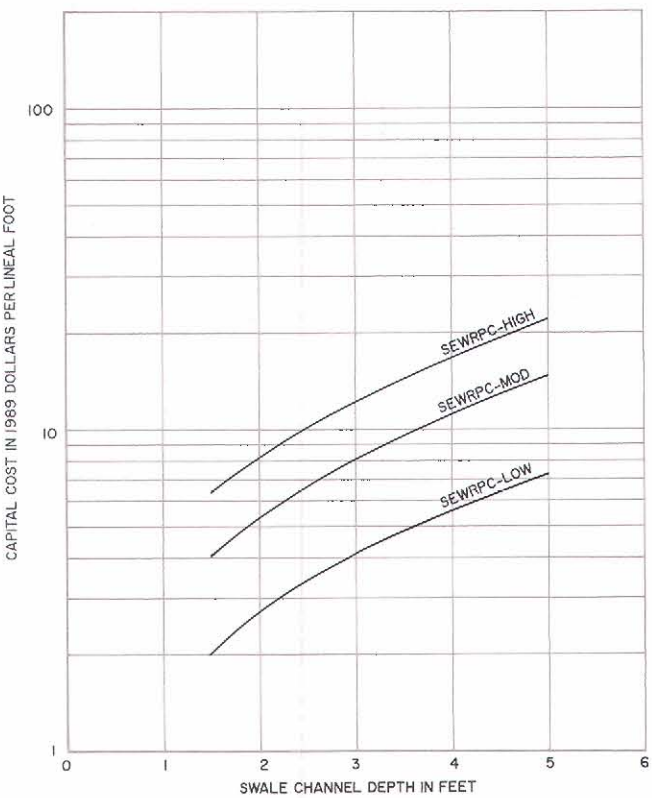
ANNUAL MAINTENANCE UNIT COSTS FOR CONSTRUCTION EROSION CONTROL MEASURES

Measure	Annual Maintenance Cost Expressed As Percentage of Capital Cost	Unit Annual Maintenance Cost
Temporary Seeding and Mulching	25	$0.12/square yard
Sodding	5	$0.12/square yard
Filter Fabric Fence	100	$3.40/lineal foot
Straw Bale Barrier	100	$9.20/bale
Inlet Protection Device	100	$123/inlet
Diversion Swale	20	$1.50-5.20/lineal foot
Sediment Trap	20	$1.00-1.80/lineal foot
Sedimentation Basin	25	$1.50-3.25/cubic yard

Source: SEWRPC.

Figure 51

CAPITAL COSTS OF DIVERSION SWALES: 1989



Source: SEWRPC.

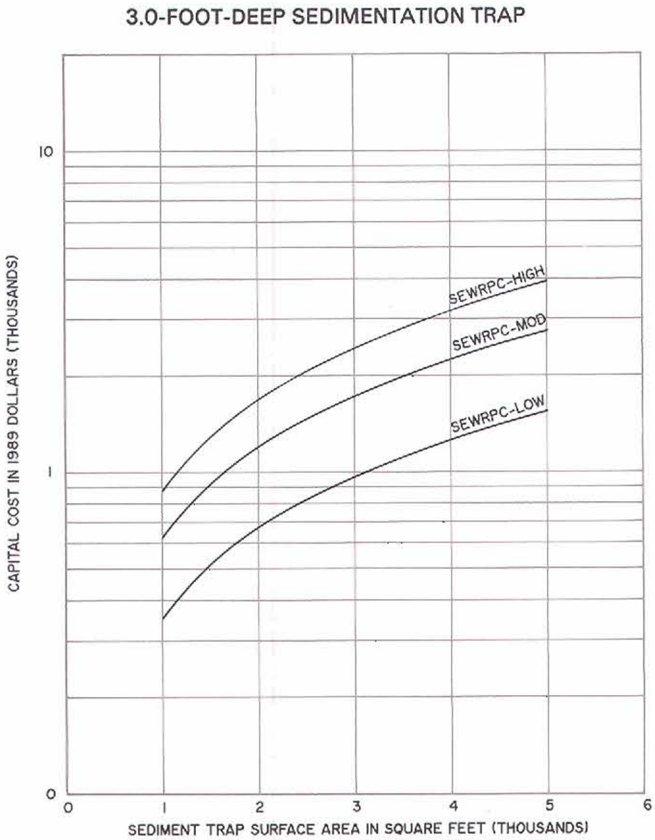
Table 48 presents estimated unit operation and maintenance costs for construction erosion control measures. These costs should only be applied when the construction period is expected to be longer than one year, or when there is an unusually severe potential for erosion.

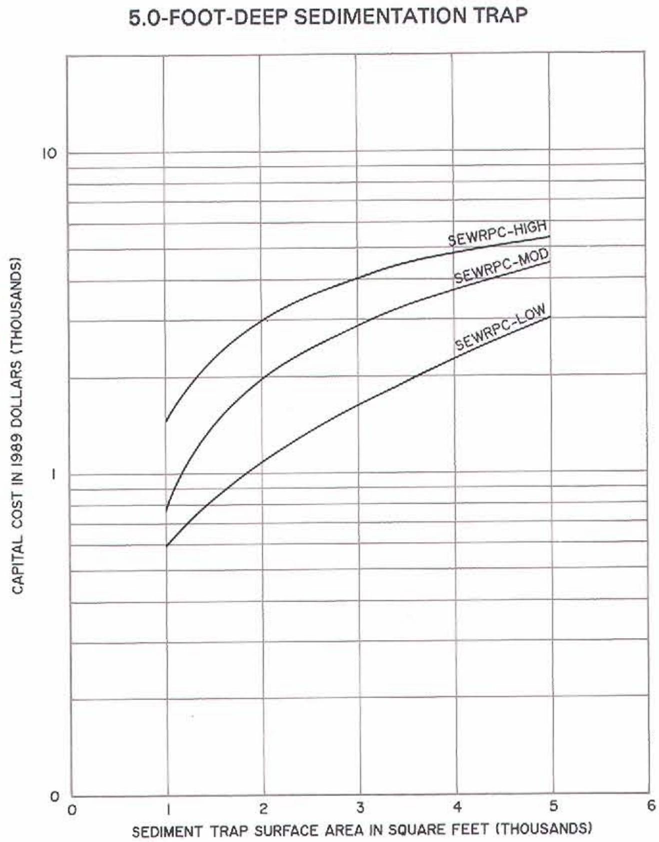
For filter fabric fences, straw bale barriers, inlet protection devices, temporary seeding, mulching, and sodding, the unit capital costs set forth in Table 40 may be used to estimate total capital costs. For diversion swales, sediment traps, and sedimentation basins, cost curves were developed which may be used to estimate total costs. Furthermore, the costs generated from the curves may be modified for known site conditions by adjusting the component costs presented in Tables 41 through 47.

Figure 51 presents the capital cost curves for diversion swales ranging in depth from one and one-half to five feet. Figure 52 sets forth the capital cost curves for 1,000 to 5,000 square feet, three- and five-foot-deep sediment traps. Capital cost curves for 0.1- to 1.0-acre sedimentation basins with a water depth of five feet are shown in Figure 53.

Figure 52

CAPITAL COSTS OF SEDIMENT TRAPS: 1989



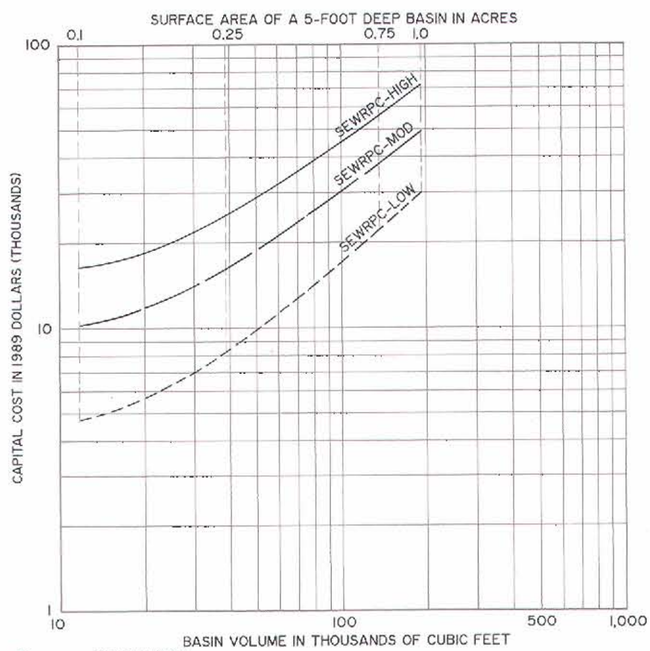


Source: SEWRPC.

Although, as noted above, properly designed construction erosion control measures may not require significant maintenance during the life of a typical construction project, some maintenance may indeed be required for construction projects which lasts for an extended time period (more than one year), when site restrictions limit the suitability of desired erosion control measures, or when an unusually large storm event—or series of storm events—occurs. In these cases, some replacement and maintenance may be required. Figures 54 and 55 present annual maintenance cost curves for diversion swales, sediment traps, and sedimentation basins. Other measures, such as filter fabric fences, inlet protection devices, and straw bale barriers, may require replacement and occasional sediment removal. A limited amount of lawn care—including mowing—may be required for areas seeded or sodded. Unit annual maintenance costs for these construction erosion control measures are presented in Table 48.

Figure 53

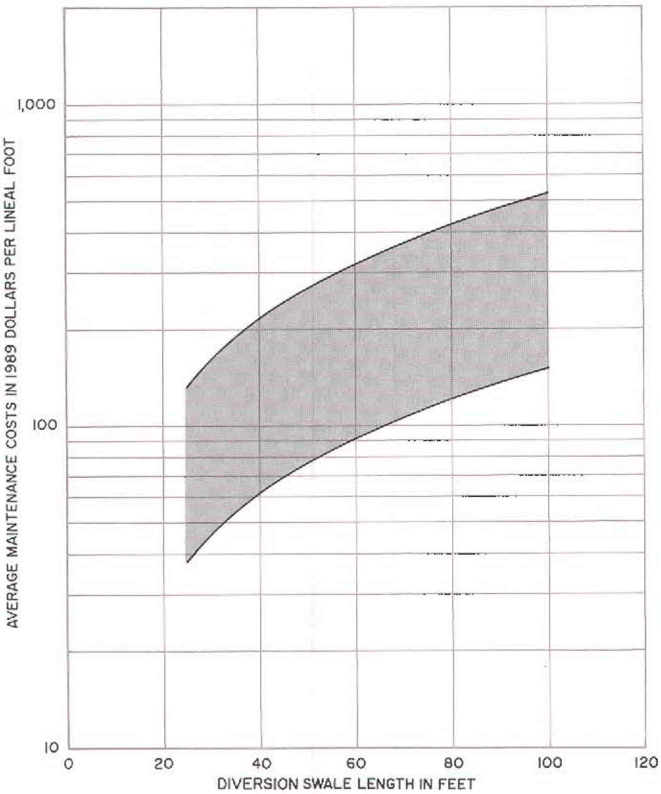
CAPITAL COSTS OF SEDIMENTATION BASINS: 1989



Source: SEWRPC.

Figure 54

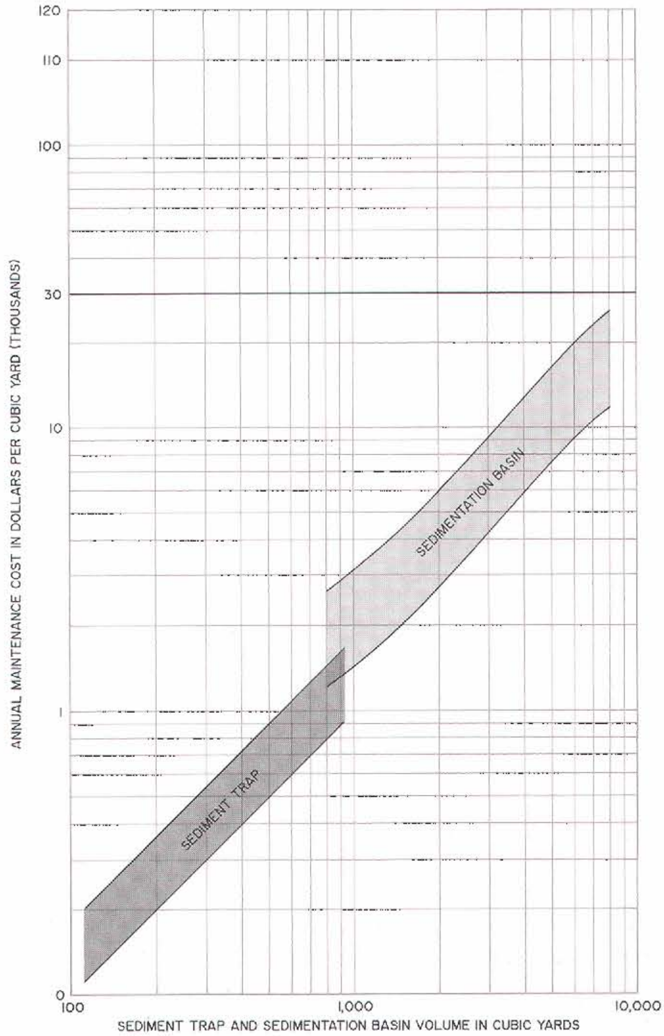
RANGE OF ANNUAL MAINTENANCE COSTS FOR DIVERSION SWALES: 1989



Source: SEWRPC.

Figure 55

ANNUAL MAINTENANCE COSTS FOR SEDIMENT TRAPS AND SEDIMENTATION BASINS: 1989



Source: SEWRPC.

Chapter V

SUMMARY

Descriptions and cost estimating procedures, based upon a unit cost approach, are presented for eight urban nonpoint source control measures: wet detention basins, infiltration trenches, infiltration basins, porous pavement, grassed swales, grassed filter strips, street sweeping, and catch basin cleaning; and for nine construction erosion control measures: temporary seeding, mulching, sodding, filter fabric fences, straw bale barriers, diversion swales, inlet protection devices, sediment traps, and sedimentation basins. The description of each measure includes a discussion of its application, advantages, disadvantages, design and sizing guidelines, maintenance requirements, and pollutant removal effectiveness. Reported total costs and unit costs for individual construction components are presented for each pollution control measure. Local unit costs were obtained from municipal, state, and federal governmental agencies, from private consulting firms, and from construction contractors operating within the State of Wisconsin, as well as from a review of the literature.

Based upon a statistical analysis of the reported costs obtained, low, moderate, and high unit costs were identified for each component. The application of the unit costs helped determine the portion of the total cost which would be required for each component. The unit costs were then utilized to develop cost estimating procedures for each measure which may be used to calculate a range of capital costs and annual operation and maintenance costs. The cost estimating procedures presented in this report, usually expressed as cost curves, allow calculation of the costs as a function of the size, or extent, of the measures.

The cost-estimating procedures are appropriate for systems level and preliminary engineering level stormwater management analysis and planning. The cost estimates can be readily modified to reflect known site conditions. However, these cost estimates are not intended to be used directly in detailed design, since local conditions and costs necessitate a more site-specific analysis.

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APPENDICES

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Appendix A

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION STAFF MEMORANDUM, FEBRUARY 9, 1990: "STORMWATER DETENTION COSTS IN EXISTING HIGHLY URBANIZED AREAS

INTRODUCTION

The costs of providing detention ponds in urbanizing areas is set forth in Chapter III of this report. As indicated in that chapter, the capital costs of the basins may be expected to range from $37,000 to $106,000 per acre of pond required using one-acre size ponds. While these costs are valid for use in urbanizing areas where the stormwater management system can be designed to incorporate the detention ponds as development takes place, the costs are not suitable for estimating the cost of retrofitting detention storage in existing highly urbanized areas. In order to provide an estimate of the cost that would be expected in an urbanized area, the Commission staff examined a typical urban area in the Lincoln Creek watershed. That area is generally bounded by N. Sherman Boulevard on the west, W. Capitol Drive on the south, N. 35th Street on the east, and Lincoln Creek on the north. The area is primarily in urban residential use except along W. Capitol Drive and N. 35th Street, where some commercial development exists. There is limited open space in the area, including open space areas between N. Montreal Street and N. Toronto Street, and at a school property located between N. 36th Street and N. Sercombe Road. The costs to provide approximately 5.0 acre-feet of detention storage in this area are considered in the following paragraphs in this memorandum.

ALTERNATIVES SUMMARY

Three alternative means of providing stormwater detention and sedimentation control were investigated for the Lincoln Creek-35th Street area. Under Option 1, it was assumed that detention would be provided on open space lands which could be purchased, using two 0.5-acre ponds, each providing about 2.5 acre-feet of storage. Under Option 2, it was assumed that structures would have to be removed in order to locate surface storage in a location which is most conducive to being compatible with the existing storm sewer system. This option used one 1.0-acre pond to provide 5.0 acre-feet of storage. Under Option 3, it was assumed that underground covered storage would be provided at five locations. The following summarizes the costs estimated under each of the three options. A more detailed description of each option is presented in the subsequent section and in the attachments to this memorandum.

Summary of Capital Costs for Detention Sedimentation in Highly Urbanized Areas

	Total Capital Cost
Option 1—Provision of Surface Detention Ponds Using Existing Open Space, Including Two 0.5-Acre Ponds	$400,000 to 450,000
Option 2—Provision of Surface Detention Storage Pond Using One 1.0-Acre Pond, Assuming Structure Removal at Optimum Location in the Stormwater Drainage System	$990,000 to 1,020,000
Option 3—Provision of Subsurface Storage at Five Locations	$1,000,000

Based upon a review of the above costs, it would appear that a range of $400,000 to $1 million, or an average cost of $700,000 per acre of storage, would be more appropriate for use in the urbanized areas.

OPTIONS CONSIDERED

Following is a brief description of each of the three options that were evaluated. Under the first option, two detention ponds would be provided: one on the school property just west of N. 36th Street and north of W. Hope Avenue, and one in the parkway between N. Montreal Street and N. Toronto Street. Each pond would cover about 0.5 acre and have about 2.5 acre-feet of storage. Two ponds were used to minimize the need to reroute storm sewers to and from the ponds and to limit the encroachment on the school athletic fields. The approximate location of these ponds, as well as the interconnecting storm sewers required to convey stormwater to and from the basins, is shown on the map attached hereto as Exhibit A. The costs for this option, including pond construction, connecting storm sewers, and land acquisition, are estimated to be between $400,000 and $450,000, as shown in Exhibit D.

Under Option 2, a single basin would be installed in the vicinity of N. 37th Street and Congress Street. This location is considered typical of the areas in the Lincoln Creek watershed. A single basin was used having a surface area of one acre and having about 5.0 acre-feet of storage but requiring about two acres of land including access, fencing, and buffer areas. This resulted in the need to remove eight homes and the costs reflect those home purchases, as well as structure removal and relocation costs. In addition, the costs for the interconnecting storm sewer modifications were included. The alternative is shown on the map attached hereto as Exhibit B. The cost for this option, including pond construction, connecting storm sewers, and land, is between $990,000 and $1,020,000, as shown in Exhibit D.

Under Option 3, subsurface storage would be provided at five locations within the watershed, as shown on the map attached hereto as Exhibit C. The estimated cost for this option is $1 million, including construction of the subsurface basins and street repair, as shown in Exhibit D. The unit cost approximated $7.50 per cubic foot. This compares favorably with the costs for underground storage reported in other documents, as shown below.

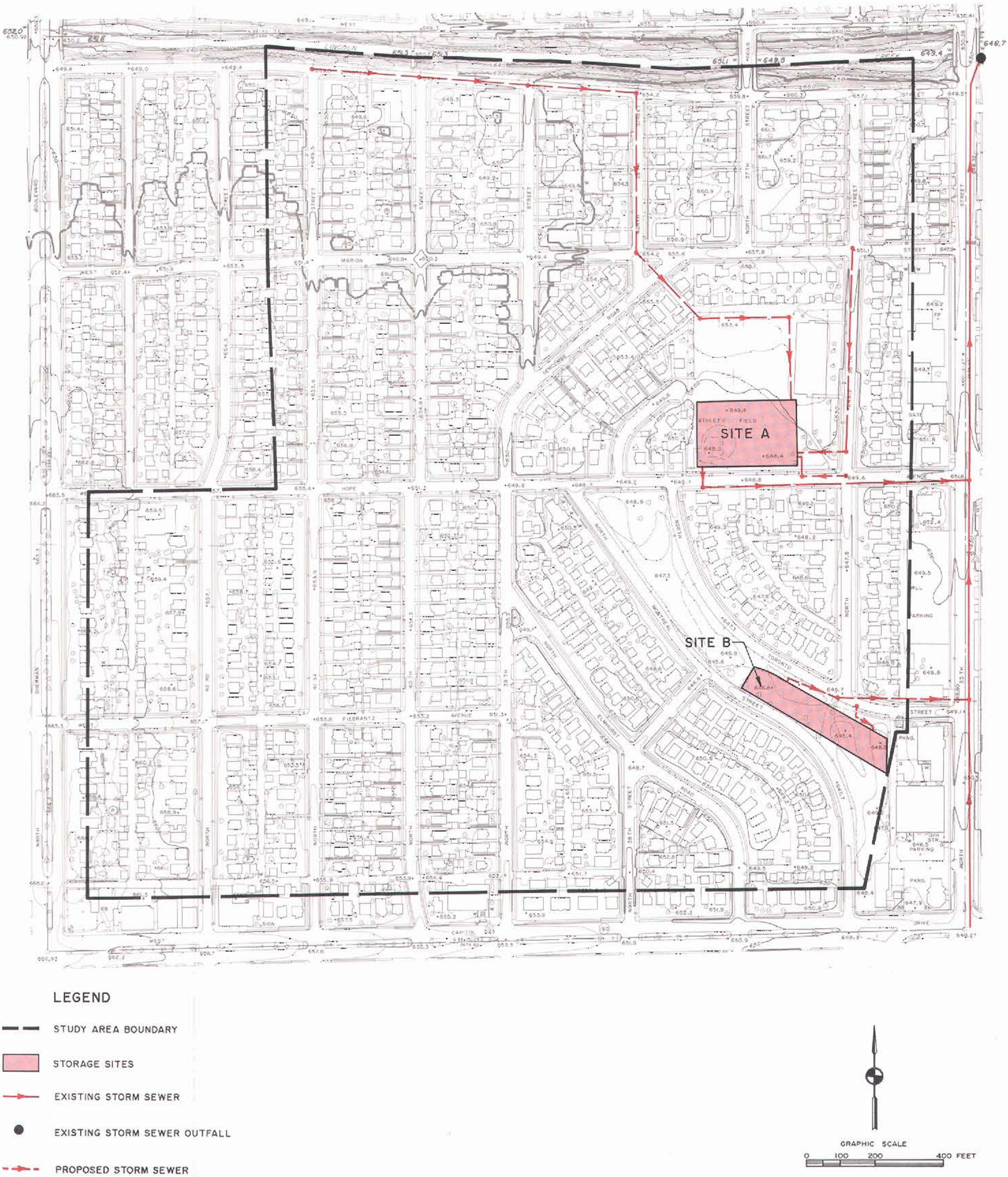
Description	Capital Cost per Cubic Foot	Reference
1. Underground Sedimentation Tank (assume six feet deep)	$7.70	Donohue & Associates, Inc., Stormwater Management Feasibility Study for the City of Oconomowoc, April 1989
2. Upsized Sewer Pipe, 96 Inch Diameter. Incremental Cost for New Sewer Construction	8.23	S. M. Luzkow, et al., "Effectiveness of Two In-Line Urban Storm Water Best Management Practices," 1981. Proc. International Symposium on Urban Hydraulics, Hydrology, and Sediment Control, Lexington, Kentucky, July 27-30, 1981
3. Concrete Storage Tanks Buried in Parks	4.34	SEWRPC Technical Report No. 18, State of the Art of Water Pollution Control in Southeastern Wisconsin, Vol. 3, Urban Stormwater Runoff, 1977
4. Subsurface Detention Tank to Store Combined Sewer Overflows (CSOs)	3.47	City of Milwaukee and Consoer, Townsend & Associates, Detention Tank for Combined Sewer Overflow, EPA-600 2-75-071, 1975

CONCLUSION

It would appear that the cost range of $400,000 to $1 million per acre of storage pond required should be used for highly urbanized areas, with an average of $700,000 per acre of storage pond. In urbanizing areas, the cost of $37,000 to $106,000 per acre of storage pond, plus land costs as set forth in the draft of Technical Report No. 31, is suitable.

Exhibit A

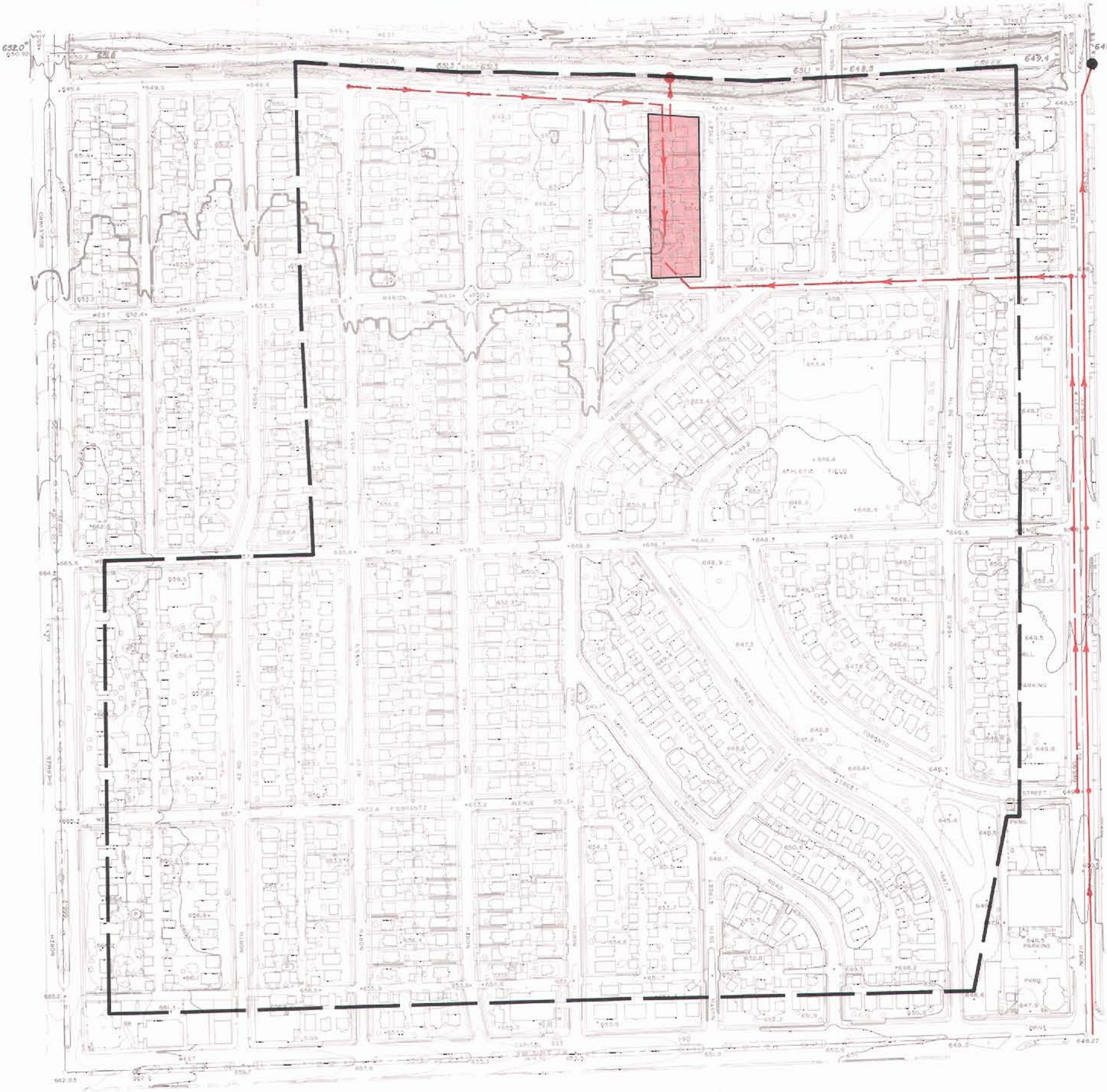
OPTION 1—TWO 0.5-ACRE SURFACE BASINS IN EXISTING OPEN SPACE AREAS



Source: SEWRPC.

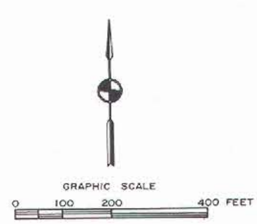
Exhibit B

OPTION 2—ONE 1.0-ACRE SURFACE BASIN IN CURRENTLY DEVELOPED LANDS



LEGEND

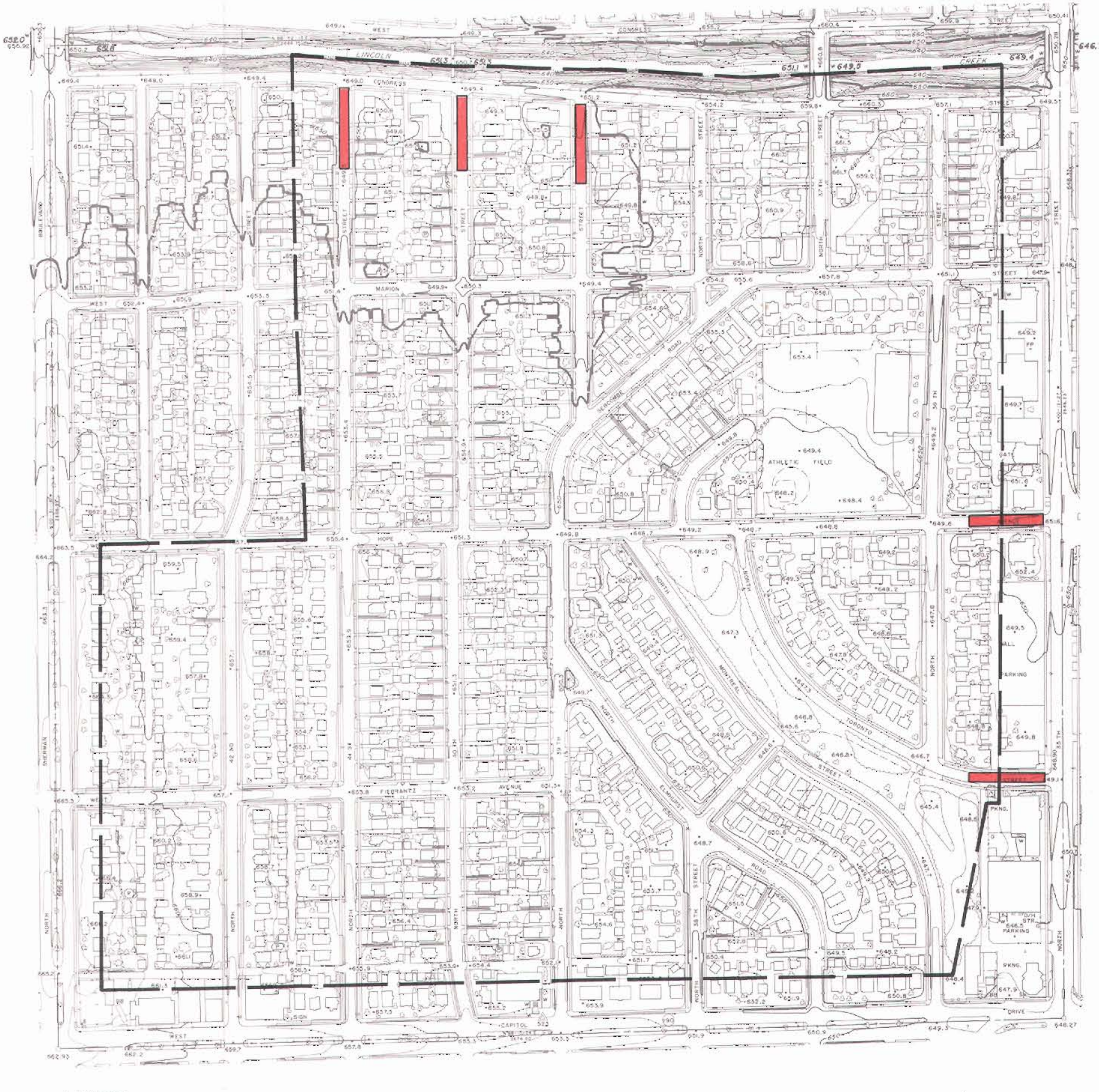
- STUDY AREA BOUNDARY
- STORAGE SITE
- EXISTING STORM SEWER
- EXISTING STORM SEWER OUTFALL
- PROPOSED STORM SEWER
- PROPOSED STORM SEWER OUTFALL



Source: SEWRPC.

Exhibit C

OPTION 3—FIVE SUBSURFACE SEDIMENTATION-FLOTATION BASINS



LEGEND

STUDY AREA BOUNDARY

SUBSURFACE STORAGE TANK SITES

GRAPHIC SCALE

0 100 200 400 FEET

Source: SEWRPC.

EXHIBIT D

COST DATA FOR STORMWATER DETENTION OPTIONS IN HIGHLY URBANIZED AREAS

February 9, 1990 Memo

Option 1—Two 0.5-Acre Surface Basins in Existing Open Space Areas

Capital Cost

1. Pond Construction per TR-31—Use Medium to High Range, Two at $50,000 to 75,000	$100,000 to 150,000
2. Connecting Storm Sewers and Intercepting Structures	199,700
3. Land Acquisition Assume Two One-Acre Sites at $10,000 each	20,000
4. Engineering and Contingencies Storm Sewer System (25 percent)	80,000
Total	$399,700 to 449,700
	Use $400,000 to 450,000 per acre of pond

Option 2—One 1.0-Acre Surface Basin in Currently Developed Lands

Capital Cost

1. Pond Cost per TR-31—Use Medium to High Range One at $72,000 to 106,000	$72,000 to 106,000
2. Connecting Storm Sewers and Intercepting Structures	168,700
3. Property Acquisition, Land Clearing, and Structure Removal	552,000
4 Engineering and Contingencies Storm Sewer System (25 percent)	198,000
Total	$990,700 to 1,024,700
	Use $990,000 to 1,020,000

Option 3—Five Subsurface Sedimentation-Flotation Basins (see Figure A-1)
Use Five Structures at 20,000 Cubic Feet Each

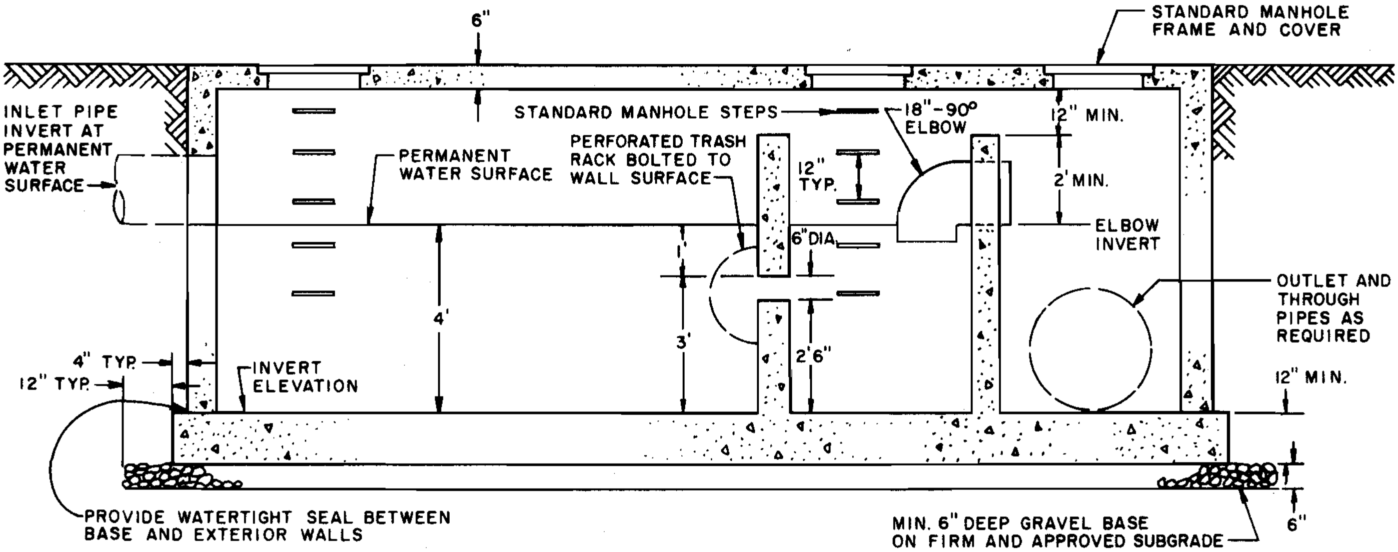
Cost per Basin

1. Excavation		$ 7,800
2. Pavement Removal	210 x 25 = 5,250 @ 4 =	21,000
3. Concrete		125,800
4. Access Manholes		5,000
5. Miscellaneous Interior Piping and Materials		5,000
6. Sewer Intercepting Structures		10,000
7. Engineering and Contingencies (25 percent)		42,000
Total		$211,100
		= $10.50/cubic feet for liquid volume
		= $750/cubic feet total volume
	For Five Basins ~	$1,000,000

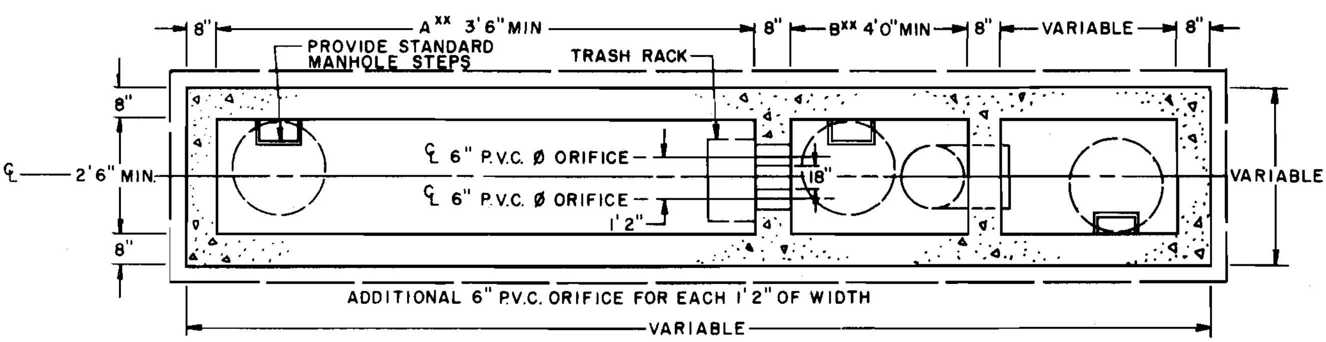
Figure A-1

TYPICAL STORMWATER SEDIMENTATION-FLOTATION BASIN

SECTION



PLAN



**WHEN COMBINED LENGTH OF OIL AND GRIT CHAMBERS EXCEEDS 12 FEET, A = 2/3 TOTAL AND B = 1/3 TOTAL.

Source: Montgomery County, Maryland; and SEWRPC.

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Appendix B

CONSTRUCTION COMPONENT UNIT COSTS FOR URBAN NONPOINT POLLUTION CONTROL MEASURES

Description	Unit	Installation Costs			Indirect Cost	Total Cost	Year of Cost	Comments
		Material	Labor	Equipment				
Site Clearing								
Clear and Grub								
Light	Acre	- -	$ 865.00	$ 850.00	$ 510.00	$ 2,225.00	January 1989	All trees are cut and chipped
Medium	Acre	- -	1,225.00	1,225.00	750.00	3,200.00		
Heavy	Acre	- -	2,875.00	2,850.00	1,725.00	7,450.00		
Clear and Grub								
Light	Acre	- -	$ 283.12	$ 365.00	$ 256.01	$ 904.13	Mid-1988	- -
Medium	Acre	- -	943.73	1,216.67	853.36	3,013.76		
Heavy	Acre	- -	3,147.20	4,144.00	2,863.99	10,155.19		
Clear Brush								
By Hand	Acre	- -	$1,125.00	$ 430.00	$ 620.00	$ 2,175.00	January 1989	- -
With Brush Saw	Acre	- -	540.00	205.00	305.00	1,050.00		
Clear Trees								
≤ 24 Inches	Each	- -	$ 118.87	$ 52.17	$ 86.25	$ 257.29	Mid-1988	- -
> 24 Inches	Each	- -	178.30	78.25	129.39	385.94		
Earthwork								
Grading								
By Hand	Cubic yard	- -	$ 40.64	- -	$ 30.66	$ 71.30	Mid-1988	- -
Dozer	Cubic yard	- -	0.46	$0.91	0.53	1.90		
Scraper								
≤ 1,000 Foot Haul	Cubic yard	- -	0.30	0.82	0.41	1.53		
> 1,000 Foot Haul	Cubic yard	- -	0.30	0.88	0.41	1.59		
Excavating								
To Five-Foot Depth	Cubic yard	$ 0.50	$ 5.33	$ 2.77	$ 4.70	$ 13.30	Mid-1988	- -
To 10-Foot Depth	Cubic yard	0.50	3.04	1.58	2.74	7.86		
By Hand	Cubic yard	- -	- -	40.64	30.66	71.30	Mid-1988	- -
Common Excavation	Cubic yard	- -	- -	- -	- -	$ 2.82 2.00-5.00	1983	Average Typical range
Excavation								
Loam, Sand, and Gravel	Cubic yard	- -	$ 0.24	$ 0.30	$ 0.24	$ 0.78	Mid-1988	Two-and-one-half cubic yard power shovel
Compacted Gravel and Till	Cubic yard	- -	0.26	0.33	0.27	0.86		
Hard Clay and Shale	Cubic yard	- -	0.32	0.40	0.33	1.05		
Excavation								
Loam, Sand, and Gravel	Cubic yard	- -	$ 0.17	$ 0.07	$ 0.07	$ 0.38	Mid-1988	Two-cubic-yard front end loader
Compacted Gravel and Till	Cubic yard	- -	0.18	0.07	0.16	0.41		
Hard Clay and Shale	Cubic yard	- -	0.23	0.09	0.19	0.51		
Excavation: Structure								
Backhoe								
Common Earth	Cubic yard	- -	$ 3.63	$ 4.78	$ 2.24	$ 10.65	January 1989	3/4 Cubic Yard Bucket
Common Earth	Cubic yard	- -	3.03	4.97	1.95	9.95		One-Cubic-Yard Bucket
Common Earth	Cubic yard	- -	2.27	4.44	1.54	8.25		1-1/2-Cubic-Yard Bucket
Common Earth	Cubic yard	- -	1.63	4.46	1.26	7.35		Two-Cubic-Yard Bucket

Appendix B (continued)

Description	Unit	Installation Costs			Indirect Cost	Total Cost	Year of Cost	Comments
		Material	Labor	Equipment				
Backfill By Hand								
Light Soil	Cubic yard	- -	$ 9.65	- -	$ 4.85	$ 14.50	January 1989	No compaction
Heavy Soil	Cubic yard	- -	12.25	- -	6.20	18.45		
Backfill: Compaction								
Light Soil Six Inches Deep								
Hand Tamp	Cubic yard	- -	$ 16.20	- -	$ 8.15	$ 24.35	January 1989	- -
Roller Compaction	Cubic yard	- -	12.06	$ 0.67	6.10	18.83		
Light Soil 12 Inches Deep								
Hand Tamp	Cubic yard	- -	13.61	- -	6.84	20.45		
Roller Compaction	Cubic yard	- -	11.25	0.45	5.68	17.38		
Heavy Soil Six Inches Deep								
Hand Tamp	Cubic yard	- -	18.80	- -	9.50	28.45		
Roller Compaction	Cubic yard	- -	14.66	0.67	7.45	22.78		
Heavy Soil 12 Inches Deep								
Hand Tamp	Cubic yard	- -	16.21	- -	8.19	24.40		
Roller Compaction	Cubic yard	- -	13.85	0.45	7.03	21.33		
Earth Fill								
Borrow Fill								
One Mile Haul	Cubic yard	$ 3.67	$ 0.44	$ 1.17	$ 0.72	$ 6.00	January 1989	Compact and shape
Select Fill								
One Mile Haul	Cubic yard	5.75	0.44	1.17	0.89	8.25		
> One Mile Haul	Mile	- -	- -	- -	- -	0.60		
Compacted Gravel Fill								
Four Inches Deep	Square feet	$ 0.11	$ 0.09	$ 0.01	$ 0.05	$ 0.26	January 1989	- -
Six Inches Deep	Square feet	0.17	0.10	0.01	0.07	0.35		
Nine Inches Deep	Square feet	0.25	0.12	0.02	0.09	0.48		
12 Inches Deep	Square feet	0.33	0.14	0.02	0.10	0.59		
Crushed Stone Fill								
1-1/2 Inches	Cubic yard	$ 14.00	$ 0.87	$ 2.34	$ 2.04	$ 19.25	January 1989	- -
3/4 Inches to 1-1/2 Inches	Ton	9.10	- -	- -	0.90	10.00		
Stone Fill								
One to Two Inches Deep	Cubic yard	- -	- -	- -	- -	$ 22.50 15.00-25.00	1983	Average Typical range
Stone Tamping	Cubic yard	- -	- -	- -	- -	$ 2.00	1983	Average
Pea Gravel Fill	Cubic yard	$ 14.40	$ 15.00	- -	$ 8.60	$ 38.00	January 1989	- -
	Cubic yard	- -	- -	- -	- -	7.50	1983	Average
Clean Washed Sand Fill	Square feet	$ 12.95	$ 0.87	$ 2.34	$ 1.94	$ 18.10	January 1989	- -
	Square feet	- -	- -	- -	- -	14.00	1983	Average
Hauling								
Off-Road								
1,000 Feet One Way	Cubic yard	- -	$ 0.23	$ 0.52	$ 0.29	$ 1.04	Mid-1988	- -
2,000 Feet One Way	Cubic yard	- -	0.27	0.67	0.54	1.28		
Over-Road								
1,000 Feet One Way	Cubic yard	- -	0.44	0.74	0.49	1.67		
2,000 Feet One Way	Cubic yard	- -	0.47	0.82	0.52	1.81		
Six Cubic Yard Dump Truck								
1/4 Mile Round Trip	Cubic yard	- -	0.59	1.12	0.04	2.11	January 1989	- -
1/2 Mile Round Trip	Cubic yard	- -	0.71	1.37	0.49	2.57		

Appendix B (continued)

Description	Unit	Installation Costs Material	Labor	Equipment	Indirect Cost	Total Cost	Year of Cost	Comments
Mobilization/Demobilization								
Shovel, Backhoe, or Dragline								
3/4 Cubic Yard	Each	- -	$ 39.00	$ 175.00	$ 41.00	$ 255.00	January	- -
1-1/2 Cubic Yard	Each	- -	47.00	210.00	48.00	305.00	1989	
Construction								
Pond Linings								
Plain PVC Sheets								
10 mils Thick	Square feet	$ 0.10	$ 0.54	- -	$ 0.35	$ 0.99	January	- -
20 mils Thick	Square feet	0.21	0.55	- -	0.37	1.13	1989	
30 mils Thick	Square feet	0.32	0.56	- -	0.39	1.27		
PVC Mineral Fiberback								
45 mils Thick	Square feet	$ 0.70	$ 0.57	- -	$ 0.43	$ 1.70	January 1989	- -
Waterproof Membrane								
Two-Ply	Square yard	$ 5.41	$ 10.16	- -	$ 8.80	$ 24.37	Mid-1988	- -
Three-Ply	Square yard	5.82	12.70	- -	10.80	29.32		
Filter Fabric								
Minimum	Square feet	$ 0.26	- -	- -	$ 0.03	$ 0.29	January	- -
Maximum	Square feet	0.30	- -	- -	0.03	0.33	1989	
Filter Cloth	Square feet	- -	- -	- -	- -	$ 2.71	1983	Average
						2.00-5.00		Typical range
PVC Pipe								
10-Foot Length								
Six-Inch Diameter	Lineal foot	$ 1.22	$ 1.32	- -	$ 0.79	$ 3.33	January	- -
Eight-Inch Diameter	Lineal foot	1.75	1.38	- -	0.87	4.00	1989	
10-Inch Diameter	Lineal foot	2.80	1.67	$ 0.26	1.12	5.85		
Six-Inch Diameter	Lineal foot	- -	- -	- -	- -	$ 10.00	1983	Average
						8.00-12.00		Typical range
Eight-Inch Diameter	Lineal foot	- -	- -	- -	- -	10.50		Average
10-Inch Diameter	Lineal foot	- -	- -	- -	- -	15.00		Average
Six-Inch Diameter	Lineal foot	$ 2.65	$ 0.79	- -	$ 1.15	$ 4.59	Mid-1988	- -
Eight-Inch Diameter	Lineal foot	4.48	0.83	- -	1.57	6.88		
10-Inch Diameter	Lineal foot	7.19	0.89	- -	2.17	10.25		
Perforated PVC Pipe								
10 Foot Length								
Four-Inch Diameter	Lineal foot	$ 0.57	$ 1.23	- -	$ 0.68	$ 2.48	January	- -
Six-Inch Diameter	Lineal foot	1.22	1.32	- -	0.79	3.33	1989	
Eight-Inch Diameter	Lineal foot	1.75	1.38	- -	0.87	4.00		
10-Inch Diameter	Lineal foot	2.80	1.67	$ 0.26	1.12	5.85		
Six-Inch Diameter	Lineal foot	$ 2.65	$ 0.79	- -	$ 1.15	$ 4.59	Mid-1988	- -
Eight-Inch Diameter	Lineal foot	4.48	0.83	- -	1.57	6.88		
10-Inch Diameter	Lineal foot	7.19	0.89	- -	2.17	10.25		
Six-Inch Diameter	Lineal foot	- -	- -	- -	- -	$ 10.00	1983	Average
						8.00-12.00		Typical range
Eight-Inch Diameter	Lineal foot	- -	- -	- -	- -	10.50		Average
10-Inch Diameter	Lineal foot	- -	- -	- -	- -	15.00		Average

Description	Unit	Installation Costs			Indirect Cost	Total Cost	Year of Cost	Comments
		Material	Labor	Equipment				
Reinforced Concrete Pipe (Class III)								
15-Inch Diameter	Lineal foot	$ 7.31	$ 2.06	$ 1.17	$ 3.32	$ 13.86	Mid-1988	Gasket joints eight-foot lengths
18-Inch Diameter	Lineal foot	9.08	3.31	1.88	4.81	19.08		
21-Inch Diameter	Lineal foot	10.73	3.42	1.95	5.24	21.34		
24-Inch Diameter	Lineal foot	15.20	4.14	2.36	6.81	28.51		
Reinforced Concrete Pipe (Class III)								
15-Inch Diameter	Lineal foot	$ 7.50	$ 3.15	$ 0.48	$ 2.37	$ 13.50	January 1989	Gasket joints
18-Inch Diameter	Lineal foot	9.45	3.67	0.56	2.87	16.55		
24-Inch Diameter	Lineal foot	14.80	5.50	0.85	3.85	25.00		
Riprap								
Broken Stone, Random Placement	Cubic yard	$ 9.20	$ 5.25	$ 6.35	$ 4.20	$ 25.00	January 1989	Machine placed for protection
3/8-1/4 Cubic Yard Pieces	Square yard	16.10	12.70	5.75	8.45	43.00		Grouted
18-Inch Minimum Thickness	Square yard	11.50	19.20	8.70	11.60	51.00		Not grouted
Porous Pavement								
Two-Inch-Thick Surface	Square yard	- -	- -	- -	- -	$ 6.60	1976	12-inch sub-base
Two to Four Inches Thick	Square yard	$ 1.58	- -	- -	- -	- -	1983	
Grassed Driveways (porous surfaces)	Cubic yard	- -	- -	- -	- -	$ 70.00	1976	Brick lattices, gravel filled, covered with top soil
Landscaping								
Sodding								
Level								
> 400 Square Yards	Square yard	$ 0.98	$ 0.85	$ 0.17	$ 0.56	$ 2.56	January 1989	- -
100 Square Yards	Square yard	1.36	1.07	0.22	0.70	3.35		
50 Square Yards	Square yard	1.95	1.14	0.23	0.80	4.12		
Slopes								
400 Square Yards	Square yard	1.03	1.19	0.24	0.72	3.18		
Seeding								
Mechanical Seeding	Acre	$410.00	$ 435.00	$ 165.00	$ 290.00	$ 1,300.00	January 1989	- -
	Square yard	0.08	0.09	0.03	0.06	0.26		
Fine Grade/Seed	Square yard	0.15	0.85	0.17	0.48	1.65		Includes fertilizer and lime
Push Spreader								
Grass Seed	1,000 square feet	$ 8.60	$ 0.67	$ 0.26	$ 1.22	$ 10.75	January 1989	- -
Limestone	1,000 square feet	2.05	0.67	0.26	0.58	3.56		
Fertilizer	1,000 square feet	5.40	0.67	0.26	0.92	7.25		
Level Areas	Acre	578.21	149.30	80.63	251.00	1,059.14	Mid-1988	- -
Sloped Areas	Acre	578.21	238.88	129.00	328.75	1,274.84		
Mulching								
Hay	Acre	$255.76	$ 74.65	$ 40.31	$ 118.50	$ 489.22	Mid-1988	- -
	Square yard	- -	- -	- -	- -	0.58	1983	Average
						0.25-1.00		Typical range

NOTE: Total cost includes operation and maintenance, taxes, insurance, and other contingencies.

Source: SEWRPC.

Appendix C

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