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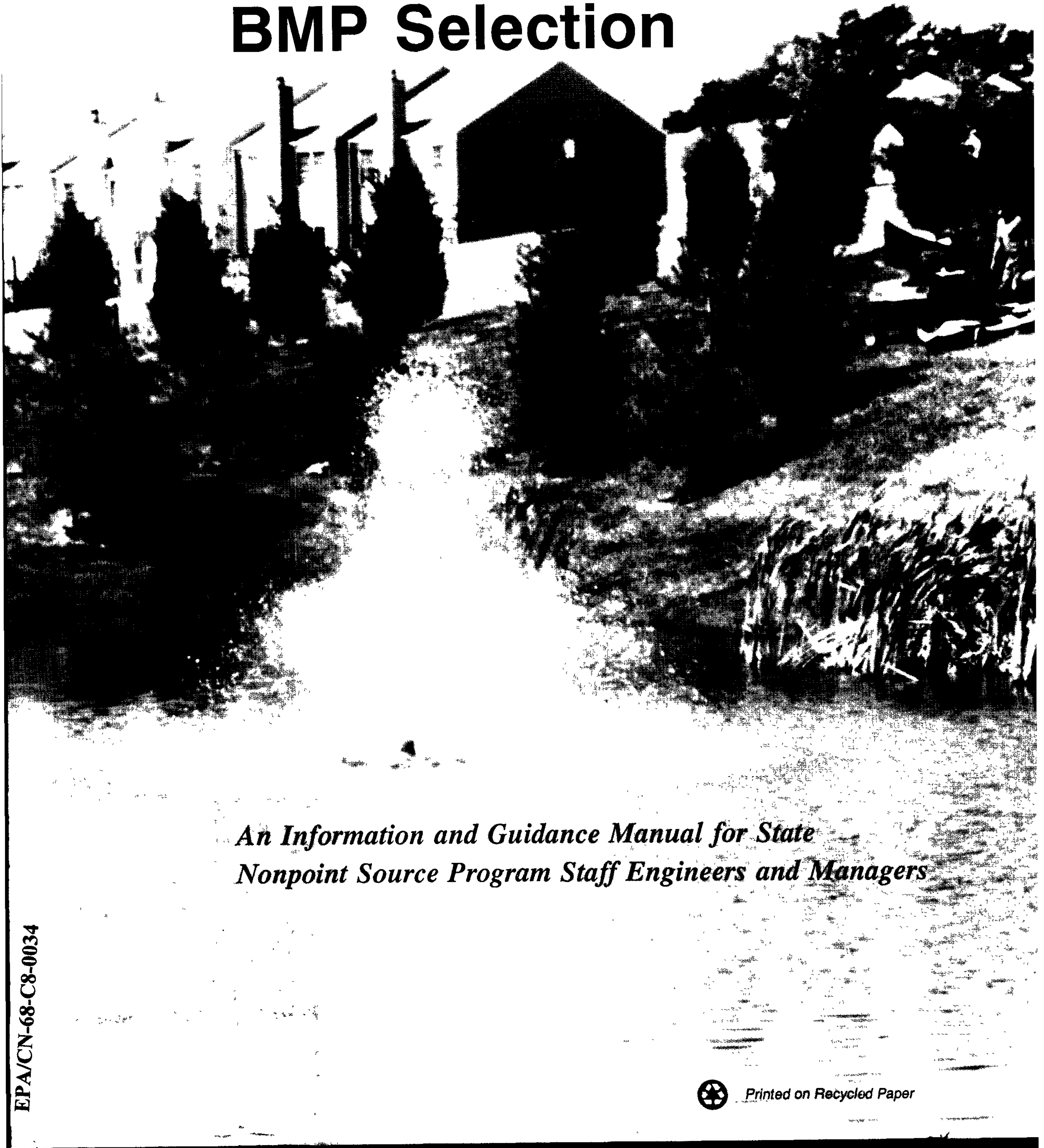
Urban Targeting and BMP Selection



An Information and Guidance Manual for State Nonpoint Source Program Staff Engineers and Managers

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Urban Targeting and BMP Selection

An Information and Guidance Manual for State Nonpoint Source Program Staff Engineers and Managers

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Acknowledgements

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Foreword

Urban runoff is a major issue in most urban and suburban areas, because of the potential for urban runoff to deliver pollutants to nearby receiving waters and cause flooding. Historically, urban runoff abatement efforts have concentrated on the techniques to control the loss of property and lives due to downstream flooding. The 1987 amendments to the Clean Water Act brought the issue of urban runoff quality to the forefront when it established two programs to assist the States and municipalities in abatement of urban runoff water quality problems: Section 319 (Nonpoint Source Control) and 402 (Stormwater Permitting).

In order for urban jurisdictions to focus limited financial and technical resources in an effective and efficient manner they must be able to relate identified or suspected water quality problems to source areas in an integrated approach. In many jurisdictions, sufficient resources may not be available immediately to implement all of the urban runoff nonpoint source controls needed to correct the documented water quality needs. Therefore, a staged implementation approach of a comprehensive management program based upon technical economic and timing considerations is appropriate. In response to the State and municipalities need for guidance on how to target controls, U.S. EPA, Region V has attempted to provide a rational basis for ranking different areas that need control within a jurisdiction. This manual is to assist State and local agency personnel in targeting areas within their jurisdiction. The Manual consolidates existing information and develops a noncomputerized methodology for targeting areas for control.

This manual is the first in a series of technical documents the U.S. EPA, Region V will cosponsor. Our objective is to facilitate technology transfer and the exchange of information. Future technical transfer efforts will include a stormwater handbook, a Great Lakes Nonpoint Source Symposium, a workshop on monitoring the effectiveness of best management practice implementation, and an urban nonpoint source control workshop.

Within each EPA Region, appropriate efforts are coordinated by the Nonpoint Source Coordinator. Contact your regional coordinator for information on nonpoint source management activities in your State, and for publications such as this manual. Comments or questions concerning this manual should be forwarded to Tom Davenport, of my staff.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

There is general agreement as indicated in State 305(b) reports, nonpoint source (NPS) Assessment Reports, and in the proposed Stormwater NPDES permitting requirements that urban runoff can be a significant contributor to degraded water quality in receiving waters. Management programs implemented by municipalities can prevent further deterioration,or improve receiving water quality for existing urbanized areas. For newly developing areas, such programs can protect existing water quality.

The focus on implementation of appropriate urban NPS management programs is at the local level, as federal legislation and state stormwater management planning efforts stipulate that a municipality is responsible for the quality and quantity of runoff within its jurisdiction. Large and medium municipalities will be required to respond initially to these issues in the context of the stormwater permit program. Other urban jurisdictions will face these requirements after 1992. Independent of the implications for urban NPS management associated with stormwater NPDES Permits, many municipal areas will be required to develop management programs in response to initiatives instituted by individual States

1.2 NEED FOR TARGETING TO PRIORITIZE EFFORTS

All municipalities are encouraged to initiate action to implement some baseline measures that will help to regulate pollutant discharges from stormwater runoff. There are many management actions that can be considered that are low in cost, utilize existing municipal activities, can be applied jurisdiction-wide, and/or address priority sources of pollutants. Early action is particularly appropriate in the case of areas undergoing a high growth rate with new areas coming under development, or older ones being redeveloped. There are often unique opportunities in such situations, in terms of institutional and cost factors, to address the NPS issues effectively.

Whether the impetus originates at the local level, or as a necessary response to Federal or State mandated programs, it is likely that in many cases, after appropriate baseline measures have been implemented, there will be a need to target specific parts of the overall area for initial attention in continuing management efforts. In some situations, sufficient resources may not be available to implement all of the controls that may be desirable. In other cases, a staged approach to the implementation of a comprehensive management program may be appropriate. For either of these possibilities, there is a need to target the available resources and to prioritize the control program based on site specific conditions, so that the greatest water quality benefit is realized for the resources expended.

1.3 ORGANIZATION OF MANUAL

This manual consolidates existing information and describes a methodology for targeting urban areas for control. It is designed to assist State and local agency personnel in targeting areas within their jurisdiction for priority in the development and implementation of NPS management programs. The following topic areas related to NPS pollutant discharges from urban areas are addressed:

1. The nature and characteristics of urban runoff, and the types of water quality problems that are most likely to occur. (Chapter 2)

2. The types of best management practices (BMP's) that are appropriate for control of NPS pollutant loads from urban and developing areas, and guidance for their selection. (Chapter 3)
3. A procedure for prioritizing urban areas for the application of controls beyond the baseline measures initially applied on a jurisdiction-wide basis.. (Chapter 4)

This manual has a technical orientation with a level of detail appropriate for local and state agency use for management program development or assessment. The information and procedures presented are at a level of detail considered to be suitable for developing local planning strategies for controlling the quality of urban runoff and associated receiving water effects. The material presented does not provide comprehensive and exhaustive treatment of technical aspects. For more detailed information, selected references are provided.

CHAPTER 2
URBAN NONPOINT SOURCE POLLUTANTS

Urban runoff quantity and quality are significantly affected by watershed development and, in particular, drainage systems that are constructed for human safety, health, and convenience. Urbanization alters the natural vegetation and natural infiltration characteristics of the watershed, causing runoff from an urban area to have a much higher surface flow component, a much smaller interflow component, and a somewhat reduced baseflow component. Urbanization also can cause water quality problems because activities associated with urbanization create sources of pollutants (e.g., automobile emissions) for surface runoff. Thus urbanization tends to increase runoff and pollutant loadings to the receiving water body. Specifically, some effects of urbanization are to:

- increase peak discharges (typically by about two to five times)
- increase runoff volume from a given storm (volume increases of 50% or more are common)
- decrease the watershed response time (the time of concentration)
- reduce streamflow in dry weather periods (especially during prolonged dry spells; urbanization can actually cause small headwater perennial streams to become ephemeral)
- increase runoff velocity during storms
- increase the discharge of pollutants
- significantly modify the type and nature of pollutants

The following sections discuss these effects and provide methods of estimating those effects (runoff volume and water quality) that are required for the targeting methodology presented in Chapter 4.

2.1 URBAN RUNOFF HYDROLOGY

2.1.1 Regional Precipitation Characteristics

Precipitation causes runoff which in turn mobilizes and transports pollutants from the urban area to the receiving water. Storm event characteristics and patterns vary considerably in different regions of the country, and can influence the nature and extent of the receiving water impacts. For example, in the East and Southeast, short duration - high intensity summer thunderstorms tend to increase the erosion potential compared to the Pacific Northwest, where the prevailing rainfall pattern is one of longer duration - low intensity events. Receiving water impacts are also affected by the characteristics of the receiving water body. In streams and rivers, water quality effects are associated with the individual storm events; whereas in the case of lakes and impoundments, the impact produced is usually the result of the cumulative effect of NPS discharges over an extended period of time. Regions with greater annual precipitation amounts will contribute higher pollutant loadings to these waterbodies than areas with low annual precipitation.

A recent EPA study characterizes storm event properties that are useful for preliminary planning assessments (Driscoll et al., 1989). Table 2-1 tabulates the statistics of a set of storm event properties for various rain zones shown in Figure 2-1, based on the analysis of rain gage data for the locations shown on the map.

FIGURE 2-1. RAIN ZONES OF THE UNITED STATES.

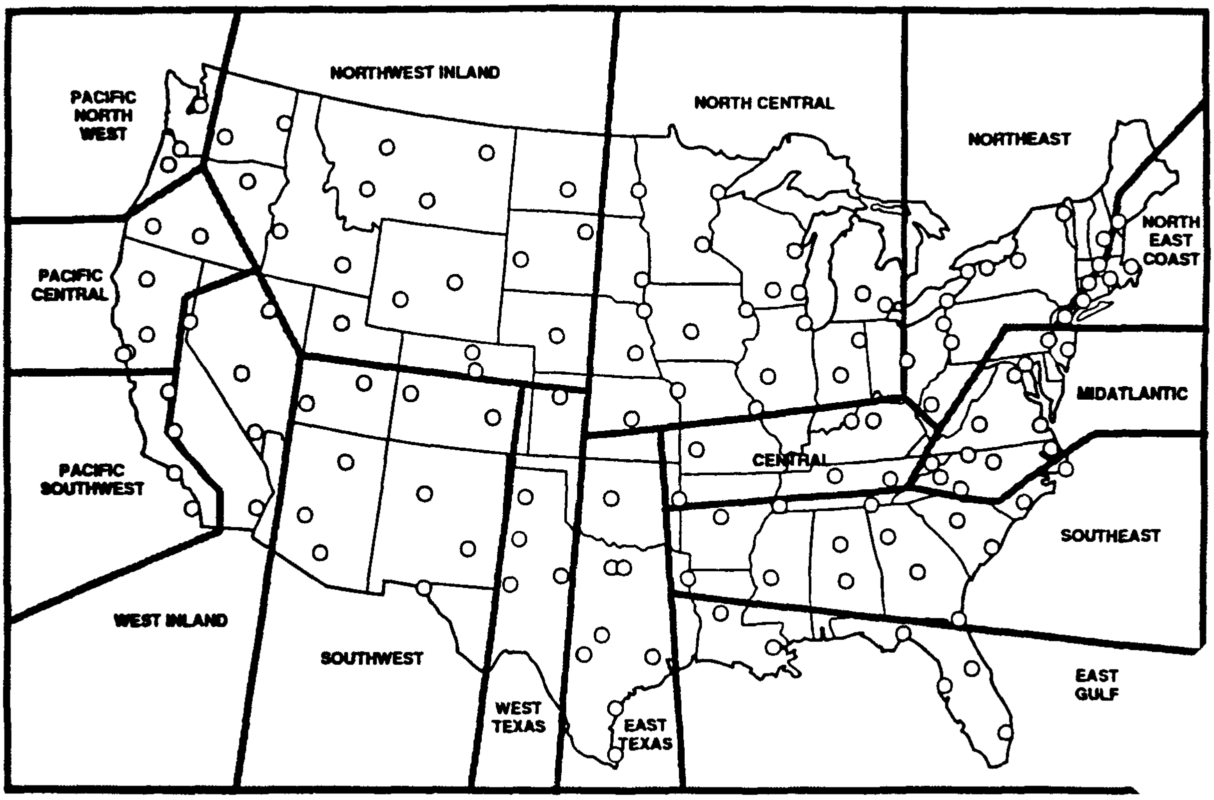


TABLE 2-1. TYPICAL VALUES OF ANNUAL STORM EVENT STATISTICS FOR RAIN ZONES

RAIN ZONE	Annual Statistics: No. of Storms Avg	COV	Precip Avg (in)	COV	Independent Storm Event Statistics: Duration Avg (hrs)	COV	Intensity Avg (in/hr)	COV	Volume Avg (in)	COV	DELTA Avg (hr)	COV
NORTH EAST	70	0.13	34.6	0.18	11.2	0 81	0.067	1.23	0.50	0.95	126	0.94
NORTH EAST - COASTAL	63	0.12	41.4	0.21	11 7	0 77	0.071	1.05	0.66	1.03	140	0.87
MIDATLANTIC	62	0.13	39.5	0.18	10.1	0 84	0.092	1.20	0.64	1.01	143	0.97
CENTRAL	68	0.14	41.9	0.19	9.2	0.85	0.097	1.09	0 62	1.00	133	0.99
NORTH CENTRAL	55	0.16	29 8	0.22	9.5	0.83	0.087	1.20	0.55	1 01	167	1.17
SOUTHEAST	65	0.15	49.0	0.20	8.7	0.92	0.122	1.09	0.75	1.10	136	1.03
EAST GULF	68	0.17	53.7	0.23	6 4	1.05	0.178	1.03	0.80	1.19	130	1.25
EAST TEXAS	41	0.22	31.2	0.29	8.0	0 97	0.137	1.08	0 76	1.18	213	1.28
WEST TEXAS	30	0.27	17.3	0.33	7.4	0.98	0.121	1.13	0.57	1.07	302	1.53
SOUTHWEST	20	0.30	7.4	0.37	7.8	0.88	0.079	1.16	0.37	0.88	473	1 46
WEST INLAND	14	0.38	4.9	0.43	9.4	0.75	0 055	1.06	0.36	0.87	786	1.54
PACIFIC SOUTH	19	0.36	10.2	0.42	11.6	0.78	0.054	0.76	0.54	0.98	476	2 09
NORTHWEST INLAND	31	0.23	11.5	0.29	10 4	0.82	0.057	1.20	0.37	0.93	304	1.43
PACIFIC CENTRAL	32	0.25	18.4	0.33	13.7	0.80	0.048	0.85	0.58	1.05	265	2.00
PACIFIC NORTHWEST	71	0.15	35.7	0.19	15.9	0.80	0.035	0.73	0.50	1.09	123	1 50

COV = Coefficient of Variation = Standard Deviation / Mean
DELTA = Interval between storm midpoints

Specific information on the individual sites is provided in the referenced document. The data presented is based on those storm events that produce storm volumes greater than 0.1 inch, because experience indicates that very small storms do not produce runoff. As a result, the statistics shown are for runoff-producing storm events. For these events the annual statistics show the average and year-to-year variability (expressed as the coefficient of variation) of the number of storms per year and the annual precipitation volume. The "event" statistics show the average and variability of the characteristics of individual storms. These data indicate significant regional differences which must be taken into account in NPS assessments. For example, as discussed earlier, note the four-fold difference in average storm intensity between the Pacific Northwest (0.035 in/hr) and the Southeast (0.122 in/hr).

2.1.2 Estimating Runoff Volume

Percent Imperviousness

An important element in targeting watersheds for control is the runoff volume from the respective watersheds within a jurisdiction. The following describes various simplified methods that may be used for estimating runoff volume.

The single most important factor in determining the quantity of runoff that will result from a given storm event is the percent imperviousness of the land cover. Other factors include soil infiltration properties, topography (which defines watershed slopes and depression storage capacity), vegetative cover , and antecedent conditions.

Impervious areas include paved streets, sidewalks, driveways, parking areas, rooftops, patios, decks, and similar man-made structures. Obviously, the extent of imperviousness is a function of local development customs and zoning requirements such as lot sizes, single- or multiple-level construction, preferences for garages, use of alleyways, curb and gutter versus swale drainage, and similar factors. Such customs vary widely across the country due to climate, land cost, and a host of other reasons. Even within a given region or municipality, they are typically not uniform and may vary by land use and, even within a given land use, by the age of the development or its location within the city.

Given the importance of percent imperviousness in NPS assessments, it is strongly recommended that the percent imperviousness for a given study area be determined from site specific information. For example, the impervious area can be estimated from site plans, maps, and aerial photographs. This method does involve some degree of uncertainty (for example, rooftops may or may not drain to other impervious areas). An alternative or complimentary method would treat the percent imperviousness as a "calibration factor" to be determined utilizing a simple runoff model and rainfall and runoff records.

For preliminary screening purposes, prior to obtaining detailed site specific information, initial estimates of percent imperviousness can be made based upon land use category. While useful for larger urban areas where things tend to "average out," caution is called for in inferring such values for small specific sites. Use local data where there is any question.

The largest single land use in most metropolitan areas is residential, which typically accounts for between 50% and 70% of the total area. Lacking any other information, it is suggested that an initial estimate of 60% be used. If population data are available, an estimate of the percent imperviousness can be obtained using the following expression (Shelley, 1988):

$$PI = 9(PD)^{0.5} \qquad (2\text{-}1)$$

where

PI = percent imperviousness [%]
PD = population density [persons/acre]

Note that the population density can be estimated by first determining the population from census data or other sources and dividing this by the area of the residential land use. Equation (2-1) is based upon extensive examination of all residential land use sites in the NURP and USGS runoff data bases.

Commercial land use typically represents from 5% to 15% of the total urban area; a value of 10% is suitable as a first approximation. The imperviousness of commercial areas varies considerably, from around 50% for shopping malls with considerable landscaping and associated undeveloped space to over 90% for central business districts. In the absence of specific information, the use of 75% to 80% impervious area is suggested for commercial land use.

Industrial land use will vary considerably with the region of the country and the nature of the community, being rather high for older, heavily-industrialized communities. Typical values range from 10% to 20% of the total urban area; with 15% recommended for use as a first approximation. Here also, the percent imperviousness varies considerably, but often is between 40% and 70%. A preliminary estimate of 55% to 60% impervious area is suggested for use in lieu of site specific data.

The land use for the remaining portions of the urban area consists largely of open areas such as parks, golf courses, cemeteries, and undeveloped land. Typically, this land use category is around 15%, and this value is suggested as a preliminary estimate. Here also, the percent imperviousness can vary widely (from 5% to over 40%); a value between 10% to 20% is a reasonable first estimate.

The foregoing procedure can be used to arrive at a composite estimate of overall percent imperviousness for an urban area, by developing a weighted average based upon allocating the total urban area to the four major land uses just discussed and using the preliminary percent imperviousness estimates as suggested. To illustrate, consider a medium sized urban area with a population density of 9 persons per acre.

Land Use	% of Total Area	% Impervious	Net Impervious Fraction
Residential	60%	27%	0.162
Commercial	10%	75%	0.075
Industrial	15%	55%	0.0825
Open/Other	15%	15%	0.0225
TOTAL IMPERVIOUSNESS			0.342

This value of 34.2% imperviousness is in the typical range of 30% to 35% for moderate sized urban areas and is a reasonable first approximation.

Runoff Coefficient

The runoff coefficient is the measure of the watershed response to rainfall events. It is a dimensionless number obtained by dividing the total storm runoff by the total rainfall volume.

Thus,

$$Rv = Qs / I \qquad (2\text{-}2)$$

where

Rv = the runoff coefficient [dimensionless]
Qs = runoff [inches]
I = rainfall [inches]

For a given site, the value for Rv will vary from event to event depending upon the characteristics of the rainfall event (intensity, duration, etc.) as well as the antecedent conditions. However, the variability can be statistically characterized from which mean seasonal or annual values can be estimated. From site to site, the variability in Rv can largely be attributed to differences in the percent imperviousness. Thus, a method is needed for estimating Rv based upon the percent imperviousness. As a very simplistic first approximation, the percent imperviousness can be used as the estimate of the runoff coefficient, with a lower bound of around 0.1 and an upper bound of around 0.95. Thus, in the example just cited, the runoff coefficient would be taken to be 0.342.

An alternative and preferred method for estimating the runoff coefficient from the percent imperviousness utilizes the following regression equation (Shelley, 1988):

$$Rv = 0.050 + 0.009\ (PI) \qquad (2\text{-}3)$$

where

PI is estimated from land use information (as in the above table) or from population density (Equation 2-1).

The correlation coefficient for the regression is 0.71, indicating that over 70% of the variance between Rv and percent impervious is explained by the regression. For the example just discussed, the refined estimate of the runoff coefficient would be:

$$0.358 = [0.050 + (0.009)(34.2)]$$

Given a rainfall event of a certain size, Rv *is used to estimate the runoff volume that* will result. This is the general approach used to estimate runoff quantity. It must be emphasized again that this approach only provides an estimate for the wet weather runoff portion of the urban runoff flow. Dry weather and base flow contributions, to the extent that they are present, must be determined from site-specific information.

2.2 URBAN RUNOFF WATER QUALITY

2.2.1 Pollutants in Urban Runoff

The net effect of urbanization is to increase pollutant runoff loads by at least an order of magnitude over pre-development levels. The impact is felt not only on adjacent streams and lakes, but also on downstream receiving waters. The following discussion identifies the principal types of pollutants found in urban runoff and describes their potential adverse effects on receiving waters.

Sediment : Suspended sediment concentrations and mass loads are the highest of any of the pollutant types discharged by urban runoff. Sediment has both short- and long-term impacts on receiving waters. Among the immediate adverse impacts of high concentrations of sediment are increased turbidity, reduced light penetration, reduced prey capture for sight feeding predators, clogging of gills/filters of fish and aquatic invertebrates, reduced spawning and juvenile fish survival, and reduced angling success. Additional impacts result after sediment is deposited in slower moving receiving waters and include smothering of the benthic community, changes in the composition of the bottom substrate, more rapid filling of small impoundments (necessitating more frequent dredging), and reduction in aesthetic values. Sediment having a high organic or clay content is also an efficient carrier of trace metals and toxicants. Once deposited, pollutants in these enriched sediments can be remobilized under suitable environmental conditions, posing a risk to benthic and other aquatic life.

Oxygen Demanding Substances : Decomposition of organic matter by microorganisms depletes dissolved oxygen (DO) levels in receiving waters, especially slower moving streams and lakes and estuaries. There are several measures of the degree of potential DO depletion, the most common of which are the Biochemical Oxygen Demand (BOD) test and the Chemical Oxygen Demand (COD) test. Both of these tests have problems associated with their use in urban runoff, but it is clear that urban runoff can severely depress DO levels after large storms.

Nutrients : The levels of phosphorus and nitrogen in urban runoff can lead to accelerated eutrophication in downstream receiving waters. Generally, phosphorus is the controlling nutrient in freshwater systems. The greatest risk of eutrophication is in urban lakes and impoundments with long detention times (say two weeks or greater). Surface algal scums, water discoloration, strong odors, depressed oxygen levels (as the bloom decomposes), release of toxins, and reduced palatability to aquatic consumers are among the problems encountered. High nutrient levels can also promote the growth of dense mats of green algae that attach to rocks and cobbles in shallow, unshaded headwater streams.

Heavy metals : Heavy metals are of concern because of their toxic effects on aquatic life and their potential to contaminate drinking water supplies. The heavy metals having the highest concentrations in urban runoff are copper, lead, and zinc with cadmium a distant fourth. However,when inappropriate connections between sanitary and storm sewers are present, other heavy metals such as arsenic, beryllium, chromium, mercury, nickel, selenium, and thallium can be found. A large fraction of the heavy metals in urban runoff are adsorbed to particulates and thus are not readily available for biological uptake and subsequent bioaccumulation. Also, the typical periods of exposure are those of urban runoff events (typically under 8 hours), which are much shorter than the exposure periods used in bioassay tests (typically 24 to 96 hours for toxicity testing). Nonetheless, it is likely that the heavy metals in urban runoff are toxic to aquatic life in certain situations, particularly for the more soluble metals such as copper and zinc. Compared to risks to aquatic life, human health risks appear to be more remote.

Bacteria : Fecal coliform levels in urban runoff usually will exceed public health standards for water contact recreation and shellfish harvesting. Furthermore, because bacteria multiply faster during warm weather, it is not uncommon to find a twenty-fold difference in bacterial levels between summer and winter in colder climates. The substantial seasonal differences do not correspond with comparable variations in urban activities, which suggests that in addition to temperature effects, sources of coliform unrelated to those traditionally associated with human health risk may be significant. Thus, despite the high numbers of coliforms found in urban runoff, in the absence of contamination from sanitary sewage, the health implications are unclear. The current literature suggests that fecal coliform may not be useful in identifying health risks from urban runoff pollution.

Oil and Grease : Oil and grease contain a wide variety of hydrocarbon compounds, some of which (e.g., polynuclear aromatic hydrocarbons) are known to be toxic to aquatic life at low concentrations. Hydrocarbons are often initially found as a rainbow colored film or sheen on the water's surface. Other hydrocarbons, especially weathered crankcase oil, appear in solution or in emulsion and have no sheen. However, hydrocarbons have a strong affinity for sediment, and much of the hydrocarbon load eventually adsorbs to particles and settles out. Hydrocarbons tend to accumulate rapidly in the bottom sediments of lakes and estuaries, where they may persist for long periods of time and exert adverse impacts on benthic organisms. The precise impacts of hydrocarbons on the aquatic environment are not well understood. Bioassay data which do exist are largely confined to laboratory exposure tests for specific hydrocarbon compounds. Remarkably few toxicity tests have been performed to examine the effect of urban runoff hydrocarbon loads on aquatic communities under the typical exposure conditions found in urban streams.

Other Pollutants : Other toxic chemicals are rarely found in urban runoff from residential and commercial land use areas in concentrations that exceed current water quality criteria. Pesticide concentrations in runoff from such areas, when they are found at all, tend to be near their detection limits. However, it should be noted that there has been relatively little sampling of runoff from industrial areas, where toxic compounds might be expected to be more prevalent.

2.2.2 Characterizing Urban Runoff Water Quality

Pollutant concentrations in urban runoff vary considerably, both during the course of a storm event as well as from event to event at a given site, from site to site within a given city, and from city to city across the country. This variability is the natural result of high variations in rainfall characteristics, differing watershed features that affect runoff quantity and quality, and variable antecedent conditions. In many situations, where within-event variability is not important, the event mean concentration or EMC (defined as the total constituent mass discharge divided by the total runoff volume) is frequently used as a representative measure of pollutant concentration. The event mean concentration values at a given site tend to be well represented by a lognormal probability distribution, and the varying values for pollutant EMCs in runoff can be characterized by a mean (or median) and coefficient of variation for the site.

The lognormal distribution has been used to characterize water quality because it has a number of important benefits (WCC, 1989), including:

- Concise summaries of highly variable data can be developed and the variability can be quantified and dealt with appropriately.
- Comparisons of results from different sites, events, etc. are convenient and more easily understood.
- Statements can be made about frequency of occurrence, i.e., one can express how often values will exceed various magnitudes of interest.
- A more useful and informative method of reporting data than the use of ranges is provided; one that is less subject to misinterpretation.

- A framework is provided for examining the transferability of data in a quantitative manner.

The median EMC for a site (the site median or SMC) measures the central tendency or the EMC for which half of the runoff events are higher and half are lower. The coefficient of variation is a dimensionless measure of variability computed by dividing the standard deviation by the mean. The appropriate statistic to employ for comparisons between individual sites or groups of sites is the median value, because the median is less subject to distortion by the one or a few very large values. However, for computations and analyses that develop or use mass loads, (such as annual pollutant loads), the mean value is the appropriate statistic. For a lognormal distribution, there is a defined relationship between the mean and median values. Data summaries presenting median values (such as in the NURP report) can be converted to mean values by the expression below. The mean is calculated by multiplying the median by the square root of one plus the square of the coefficient of variation, i.e.,

$$\text{Mean} = \text{Median} * [1+CV^2]^{0.5} \qquad (2\text{-}4)$$

Based upon the results of considerable analysis of the NURP data, it was determined that geographic location, land use category, rainfall characteristics, and other factors did not adequately explain the site-to-site variability of site median concentrations. Therefore, the SMC data for all urban sites were pooled and examined statistically. It was found that the lognormal distribution was also an adequate representation of this pooled data set. The results, given in Table 2-2, are based on the results obtained by the NURP study. Since the targeting methodology presented later uses a comparison of pollutant mass loads, approximate mean values for runoff concentrations have been listed. The mean of the EMC values are listed for the median urban site in the NURP data set, along with the values for the 10th and 90th percentile sites. That is, 10% of the urban sites are expected to have a mean EMC concentration that is either lower or higher than the corresponding percentile values.

The Table 2-2 results are presented to provide an indication of the range of the concentrations of the indicated pollutants that may be present at an urban site. For constituents that do not appear in Table 2-2, the NURP data base was too sparse to allow the analytical treatment just described, and local estimates must be provided. Similarly, the availability of local data can provide a basis for refining runoff concentration estimates.

The primary purpose for presenting this data is to provide background reference information, and to convey a sense of the variability of urban runoff quality. In the targeting methodology described in Chapter 4, this data has been used as a guide in selecting reasonable approximate concentration levels. The actual concentration value selected for the targeting analysis is unimportant, because no attempt is made to predict actual loads. Only the *relative* differences between concentrations for different land use types are a factor in the methodology.

2.2.3 Sources of Urban Runoff Pollutants

Erosion : Soil erosion can be an important source of pollutants in runoff from urban areas, either because of stream bank erosion or as a result of the disturbance of land surfaces. For example, initial clearing and grading operations during construction expose much of the surface soils. Unless adequate erosion controls are installed and maintained at the site, large quantities of sediment can be delivered to the stream channel, along with attached soil nutrients, organic matter, and other adsorbed pollutants. Uncontrolled

TABLE 2-2. WATER QUALITY CHARACTERISTICS OF URBAN RUNOFF

Constituent		Mean Concentration in Runoff		
		10th Precentile Urban Site	For Median Urban Site	90th Precentile Urban Site
TSS	(mg/l)	35	125	390
BOD	(mg/l)	6.5	12	20
COD	(mg/l)	40	80	175
Tot. P	(mg/l)	0.18	0.41	0.93
Sol. P	(mg/l)	0.10	0.15	0.25
TKN	(mg/l)	0.95	2.00	4.45
NO3-N	(mg/l)	0.40	0.90	2.20
Tot. Cu	(μg/l)	15	40	120
Tot. Pb	(μg/l)	60	165	465
Tot. Zn	(μg/l)	80	210	540

construction site sediment loads on the order of 40 tons/acre/year and higher have been reported (Novotny and Chesters, 1981; Wolman and Schick, 1967; Yorke and Herb, 1976 and 1978). Such loads are one to two orders of magnitude higher than from agricultural or stabilized urban land uses respectively.

Atmospheric Deposition : A significant source of pollutants in urban areas is atmospheric deposition in the form of both wetfall and dryfall. In almost all cases, some of the pollutants from atmospheric sources are trapped and remain on the land surface, rather than washing off in ordinary storm events. If source control of atmospheric deposition is desired, control strategies based on automobile and industrial emission controls are required.

Construction Materials : The various surfaces of the urban landscape are another major source of pollutants. Metals, for example, are a common element in many urban structures, such as flashing and shingles, gutters and downspouts, galvanized pipes, metal plating, paints, wood preservatives, etc. Over time, these surfaces corrode, flake, dissolve, decay, or are subject to leaching thereby allowing metals to be carried away in urban runoff. The process is often exacerbated by the acidity of the rainfall.

Manufactured Products : The use of a variety of manufactured products represents a source of some pollutants in urban runoff. For example, most copper found in urban runoff originate from various anthropogenic sources including oxides and sulfates of copper used for insecticides, algicides, and fungicides. Copper is frequently incorporated into paints and wood preservatives to inhibit growth of algae and invertebrate organisms. Copper salts are used in water supply systems for controlling biological growths. Primary sources of copper in industrial wastewater are metal process pickling and plating baths. Other sources include mine drainage, pulp and paper mills, fertilizer manufacturing, petroleum refining, and certain rayon processes. Copper is used in the automobile industry in brake linings, clutch facings, and certain tire compounds. Smelters may release copper to the atmosphere which is eventually returned to surface waters. The variety of potential sources for copper explains why it is almost invariably found in urban runoff at levels of concern.

Many pollutants which derive from manufactured products are toxic or hazardous materials. The more significant potential sources of some of these substances are given in Table 2-3. Note that automobile use contributes significantly to many of these constituents. Polycyclic aromatic hydrocarbons (PAHs), the most commonly detected toxic organic compounds found in urban runoff (EPA, 1982), originate from oil and combustion products. Phthalate esters, a relatively common toxic organic compounds, are derived primarily from plastics. Pentachlorophenol, also frequently found, comes from wood preservatives.

Plants and Animals : Other sources of pollutants that accumulate and subsequently wash off urban surfaces include plant debris (leaves, etc.) and animal excrement which in natural systems are recycled. For example, trees and shrubs deposit pollen and leaves which, no longer able to be converted to humus on the forest floor, enter into urban runoff. During the growing season, nutrients leach from tree leaves and stems during storms and are quickly conveyed to the stream if the ground is saturated or the tree's drip line extends over an impervious area.

Non-Stormwater Connections : An important potential source of toxic and other pollutants in urban runoff is through non-stormwater discharges to stormwater drainage systems. Inadvertent or deliberate discharges of sanitary sewage and industrial waters to storm drains has been identified as a widespread and serious occurrence. The detection and elimination of such discharges is a major focus of the NPDES Stormwater Permit program.

TABLE 2-3. POTENTIAL SOURCES OF TOXIC AND HAZARDOUS SUBSTANCES IN URBAN RUNOFF

	AUTOMOBILE USE	PESTICIDE USE	INDUSTRIAL/OTHER USE
Heavy Metals			
Copper	metal corrosion	algicide	paint, wood preservative electroplating
Lead	gasoline, batteries		paint
Zinc	metal corrosion tires, road salt	wood preservative	paint, metal corrosion
Chromium	metal corrosion		paint, metal corrosion electroplating
Halogenated Aliphatics			
Methylene chloride		fumigant	plastics, paint remover solvent
Methyl chloride	gasoline	fumigant	refrigerant, solvent
Phthalate Esters			
Bis (2-ethyhexyl) phthalate			plasticizer
Butylbenzyl phthalate			plasticizer
Di-N-butyl phthalate		insecticide	plasticizer, printing inks paper, stain, adhesive
Polycyclic Aromatic Hydrocarbons			
Chrysene	gasoline, oil, grease		
Phenanthrene	gasoline		wood/coal combustion
Pyrene	gasoline, oil, asphalt	wood preservative	wood/coal combustion
Other Volatiles			
Benzene	gasoline		solvent
Chloroform	formed from salt, gasoline & asphalt	insecticide	solvent, formed from chlorination
Toluene	gasoline, asphalt		solvent
Pesticides and Phenols			
Lindane (gamma-BHC)		mosquito control seed pretreatment	
Chlordane		termite control	
Dieldrin		insecticide	wood processing
Pentachlorophenol		wood preservative	paint
PCBs			electrical, insulation

As an illustrative example of how heavy metals can enter flows from industrial areas, consider the use of heat exchangers in plating tanks at metal finishing and electro-plating shops. It is not uncommon to have condensate return lines discharge directly to storm drains. As long as the heat exchangers are intact, this operating condition has no impact on discharge water quality. However, heat exchangers used in such applications typically develop pin-hole leaks, and as a result, plating solutions with high heavy metal concentrations can leak into the storm sewer system. In other instances, what is believed by a manufacturing firm to be non-contact cooling water, and appropriate to discharge to a storm drain, may in reality be a process cooling water with a significant concentration of heavy metals and other pollutants.

Cross-connections delivering sanitary sewage to storm drains can, like industrial contamination, occur in many different ways. There was a case reported where the sanitary lines from a high rise building were tied into the storm drain rather than the sanitary sewer. Locations with hydraulically overloaded sewage treatment plants or undersized sewers may provide relief points that transfer excess flow into storm drains. This type of situation is more likely in areas with aging sewer systems with excessive infiltration/inflow.

Accidental Spills : Another source of pollutants in urban runoff is accidental spills. Here, virtually any pollutant can be found, depending upon the nature of the spill. Deliberate dumping into storm sewers and catch basins (used crankcase oil is especially common) is yet another common source. Leaking underground storage tanks, leachate from sanitary landfills and hazardous waste treatment, storage, and disposal sites can also contribute to pollutants in storm sewers.

This discussion of sources of urban runoff pollutants indicates the types of activities that are believed to be the principal generators of urban runoff pollution. Once a particular receiving water body or segment of concern has been identified, there is an obvious need to identify the areas that contribute to it. As a rule of thumb, greater concentrations of pollutants will be found in urban runoff from industrial areas and older parts of the city. Given the role of the automobile in generating pollutants within the urban landscape, areas of high automobile density can be expected to have increased levels of pollution. The need to look for cross-connections and other illegal or inappropriate connections to separate storm drains cannot be overemphasized.

2.3 RECEIVING WATER PROBLEMS

2.3.1 Water Quantity Problems

The two principal concerns relating to the quantity of stormwater runoff are the total volume of runoff discharged, and the peak rates of flow that are produced. Problems associated with runoff quantity include flooding and erosion/sedimentation impacts. Historically, drainage has been the principal local-level concern regarding urban runoff. Flooding concerns can be divided into two basic categories; nuisance flooding and major flooding. Nuisance flooding (e.g., temporary ponding of water on streets, road closings, minor basement flooding), rarely affects the entire urban populace and is seldom life-threatening. Nonetheless, the concerns of affected citizens commonly requires that local action be taken to minimize the recurrence of such events. Such mitigation activities are usually locally determined, funded, and implemented because the affected public and government decision makers perceive and concur that such flooding constitutes a problem. Catastrophic flood events, on the other hand, have to be thought about differently for several reasons:

- They typically affect the majority of the urban populace.
- Mitigation measures often involve engineering improvements extending well beyond local jurisdictions.
- Mitigation measures often cost more than the local community can afford. In such cases, water quantity problems are readily observable, the degree of damage as well as the benefits of alternative flood control projects can be estimated. Thus, decision makers face a relatively low risk in prescribing courses of action and justifying the associated costs in light of the benefits. As will be discussed later, decision making in the case of water quality concerns is less straightforward.

Erosion concerns may be the result of a relatively short-term condition produced by disturbance of the land surface during construction activity, or a longer term condition of stream bank erosion and scour and deposition of the stream bed produced by peak flow rates. Although erosion and sedimentation are storm-event related, their resultant problems are not exclusively either water "quantity" problems or water "quality" problems. When sediment loads from undeveloped areas are discharged into receiving waters, the effects are primarily physical and only secondarily chemical, because the mineral constituents which make up the primary sediment load are relatively benign in most cases. Among the physical problems in receiving waters subjected to increased sediment loads are:

- Excess turbidity reduces light penetration, thereby interfering with sight feeding and photosynthesis.
- Particulate matter clogs gills and filter systems in aquatic organisms, resulting, for example, in retarded growth, systemic disfunction, or asphyxiation in extreme cases.
- Benthal deposition can bury bottom dwelling organisms, reduce habitat for juveniles, and interfere with egg deposition and hatching.
- degradation of general habitat.

Urbanization accelerates erosion through alteration of the land surface. Disturbing the land cover, altering natural drainage patterns, and increasing imperviousness all increase the quantity and rate of runoff, thereby increasing both flooding and erosion potential. Furthermore, the sedimentation products that result from urban activities are generally not as benign as the natural mineral sediments which result from soil erosion from undeveloped areas. Atmospheric deposition (associated with industrial and energy production activities) and added surface particulates (resulting from tire wear, automobile exhaust, road surface decomposition, and the like) are incorporated in the sediments discharged from urbanized areas. Their effects on receiving waters tend to be more chemical than physical. This is also true of natural mineral sediments that become contaminated by the adsorption of toxics and other chemicals present in the urban environment.

2.3.2 Water Quality Problems

The following are three considerations in evaluating water quality problems in surface waters subjected to urban runoff.

- the nature of the designated *beneficial uses* , e.g., drinking water supply, recreation, fisheries, wildlife and associated *water quality objectives.*
- *water quality characteristics*, i.e., the physical, chemical, and biological data resulting from analytical determinations made in the field or laboratory.

- *ecological effects* associated with a discharge, e.g., toxicity, carcinogenicity, disease, eutrophication, altered vegetation and succession, reproductive disorders, etc.

Water quality is what is typically measured, although laboratory and in situ toxicity testing using representative aquatic species is a tool for addressing ecological effects. Ecological effects determine how well a designated beneficial use is met. Although Congress has established fishable and swimmable waters as a goal, water quality planning activities will be more cost effective when the specific beneficial uses are supported by the local community. This is because the determination of the most appropriate beneficial use is strongly influenced by local attitudes, beliefs, needs and expectations. Unlike water quantity problems, water quality problems tend to be elusive because their definition involves subjective considerations. Also water quality problems are often not immediately obvious and are less dramatic than floods. They also tend to vary markedly with locality and geographic regions within the country.

For evaluating urban runoff impacts, three possible approaches for identifying the presence of a problem can be considered.

1 Actual impairment or denial of a designated beneficial use;

2 Violation of a water quality criterion;

3 Local public perception and concern.

The first type of problem would be where a determination has been made that some specific use, such as shellfishing, should be attained but that present aquatic tissue contamination is such harvesting and eating the organisms poses a health risk causing shellfishing to be banned for part or all of the year.

The second type of problem refers to violations of an applicable water quality criterion. An example would be a case where some measure of water quality characteristics (e.g., trace metal concentration) exceeds recommended or mandatory levels for the receiving water classification (e.g., EPA toxic criteria for aquatic life). This problem definition is less exact than the preceeding problem definition in that the receiving water classification may not be appropriate, the beneficial use may not be impaired or denied, and the water quality criteria associated with that classification may or may not be overly conservative or directly related to the desired use.

The third basis for problem identification involves public perception. This may be expressed in a number of ways, such as telephone calls to public officials complaining about receiving water color, odor, or general aesthetic appearance. Public perception of receiving water problems is highly variable, further complicating this level of problem definition.

The foregoing approaches provide a framework which permits water quality problems associated with urban runoff to be defined in a way that will assist in the formulation of a management plan, the implementation of an effective control strategy, and establishing a means of assessing its effectiveness.

2.3.3 Examples of Urban Runoff Receiving Water Impacts

Stormwater discharges into urban streams can dramatically change the character of a stream as it passes through an urban area. Some examples of the nature of the problems that can be produced, based on actual cases reported in the literature, are described below.

These cases provide background on the types of things to look for in a local assessment of the significance of urban NPS discharges.

In-stream monitoring of Village Creek in Birmingham, Alabama (Water Quality Engineers, 1981) provides a classic example of stream degradation due to intense urban development. At the stream's origin at Roebuck Springs, the creek has excellent physical and chemical characteristics, supporting watercress and other vegetation. By the time the stream passes under Vanderbilt Road it has turned grey-green and has an oily sheen and contains significant debris. Further downstream at the western limits of Birmingham, the creek is dark green, has a putrid odor and contains considerable oil and grease. At this point the creek is often anaerobic and contains no fish or other biological life. This study found that, on an annual basis, more than 90 percent of the copper loadings, more than 75 percent of the chromium and zinc loadings, and about 40 percent of the lead loadings originated from urban runoff.

A study (Dong et al., 1979, and Southeastern Wisconsin Planning Commission, 1976) of the Menomonee River near Milwaukee, Wisconsin indicated that the upper, more rural reaches of the river had an average of 40 times more fish than the lower, urbanized reach. The urban segments of the river supported a significantly reduced and scattered fish population and some segments were virtually devoid of even very pollution tolerant species. These conditions are the combined result of higher concentrations of toxic pollutants and poorer habitat conditions resulting from increased flow velocities and channelization. Further, the watershed benthic community is in "poor" condition in the urban area. The Menomonee study concluded that a relatively small degree of urbanization, less than 20 percent, is sufficient to cause significant receiving water degradation.

Studies at other locations have produced results similar to those cited above. Interestingly, toxic pollutants or long-term oxygen depletion has been found to cause more serious receiving water problems than short-term, event-related oxygen depletion or other concentration excursions. The accumulation of toxics in sediments and their subsequent movement through the food chain is especially pronounced in urban receiving waters. Studies on the Saddle River near Lodi, New Jersey (Wilber and Hunter, 1980) found significant enrichment of heavy metals (two to seven times) in lower Saddle River sediments (affected by urbanization) as compared to upper rural reaches. Similar results were found in a stream near Champaign-Urbana, Illinois (Rolfe and Reinhold, 1977), where the upper two inches of sediment in an urban stream reach had much higher lead concentrations (almost 400 ug/g) than sediments in the rural stream reaches. Species diversity of plants and animals were found to be lower in urban streams as compared to streams in rural areas. This impact is likely to be influenced by habitat and temperature changes, as well as pollutant levels.

Long-term biological, chemical, and physical investigations of Coyote Creek near San Jose, California (Pitt and Bozeman, 1982) revealed distinctive urban-rural differences in the composition and relative abundance of aquatic biota. A comparison of urban Kelsey Creek to rural Bear Creek near Bellevue, Washington (Pitt and Bissonette, 1984; Perkins, 1982; Scott et al. 1982) indicated significant interrelationships among the physical, biological, and chemical characteristics. The urban creek was significantly degraded when compared to the rural creek, but it still supported a limited and unhealthy salmon fishery. Most fish in the urban creek had respiratory anomalies attributed to carcinogens in the water associated with urban runoff. Although Kelsey Creek did not appear to be as polluted as some of the urban creeks cited earlier, flooding caused by increased runoff from urban development increased dramatically, with the result that the large amounts of toxic pollutants discharged to the stream during wet weather, were diluted to very low concentrations by the increased runoff volumes. The large flows that produced habitat problems diverted attention away from the long-term toxic accumulation potential and to the physical effects of accelerated runoff. The dilemma here is that if the flows were to be reduced in order to improve habitat conditions, the stream's assimilative capacity would decline, and the effects of toxic pollutants could become even more pronounced.

As the foregoing examples indicate, urban runoff can produce both water quantity and water quality problems, and the two are often interrelated. The water quantity problems include but are not limited to flooding, streambank erosion, habitat impairment and altered salinity. The water quality problems depend on (i) the type of receiving water involved (stream, lake, etc.) and its characteristics, (ii) the beneficial use or uses to be protected, and (iii) the specific pollutants involved. These in turn depend upon the intensity and the nature of the activities in the urbanized watershed.

CHAPTER 3
BMPs FOR CONTROL OF URBAN NPS

The term BMP, or Best Management Practice, has gained wide acceptance as a general term designating any method for controlling the quantity and quality of stormwater runoff. For the purposes of this manual, a "best management practice" (BMP) is considered to be either (1) a practice (routine procedure) that reduces the pollutants available for transport by the normal rainfall-runoff process, or (2) a device that reduces the amount of pollutants in the runoff before it is discharged to a surface water body.

It is almost impossible technically and economically to completely eliminate NPS pollutant discharges to a receiving water body. Realistic objectives of an urban stormwater management program include : (1) to establish baseline controls to reduce pollutants in stormwater runoff; (2) to establish controls for priority sources of pollutants; (3) to sufficiently reduce pollutant levels to eliminate or mitigate an existing water quality problem; and (4) to avoid the creation of a future problem where none exists now.

This chapter identifies and presents an overview of the different types of BMPs that may be considered in the development of urban stormwater management plans. Sufficient information is provided to support a planning level assessment of control options, but other appropriate studies and reports should be reviewed for additional detail on design, installation and operating aspects of specific BMPs. The chapter organization is structured to address BMP types individually, but in practice, BMPs can and should be considered in combination. Some examples include vegetated filter strips for pretreatment of inflows to infiltration systems, and detention basins to reduce sediment loads to a wetland. The specific characteristics of the site will determine the BMP types and combinations that are most appropriate in each case.

Institutional aspects of the development of an effective urban stormwater management program are not emphasized in this manual, but planning activities must include a recognition of the need to develop an understanding of the issues at several levels of local government, and provide support for the resolution of institutional issues. This may involve the identification of the relationships between stormwater management plan features and existing programs, plans and activities of City Managers, Planning Directors, and Public Works Directors, whose departments and responsibilities will provide the institutional framework for implementation of many of the important elements of a stormwater management plan.

3.1 TYPES OF URBAN BMPs

Effective techniques for the control of nonpoint runoff pollutant discharges from urban areas are identified below. These techniques are grouped into four categories, based on the operating principle or the physical mechanism that reduces the amount of runoff pollutants discharged to surface waters.

- **Detention basins** - The term "detention" applies when the runoff is temporarily stored and, apart from relatively minor incidental losses due to evaporation or percolation, is subsequently discharged to a surface water. Control results from a reduction in pollutant concentrations due to settling during the period the runoff is detained.

- **Retention devices** - The term "retention" applies when runoff is permanently captured so that it never discharges directly to a surface water. The usual mechanism by which stormwater controls permanently "capture" surface runoff is by infiltration. These techniques are often referred to as infiltration BMPs.

- **Vegetative controls** - Vegetative controls provide contact between stormwater runoff and vegetated areas and accomplish pollutant removal by a combination of filtration, sedimentation and biological uptake that reduce pollutant concentrations, and/or by a reduction in runoff volume due to infiltration or evapo-transpiration. Figure 3-1 provides a schematic illustration of various types of vegetative BMPs that can be considered in urban areas.

- **Source controls** - Source Control techniques include any practice that either (1) reduces the amounts of accumulated pollutants on the land surface available for washoff by rainfall, or (2) regulates the amount of impervious area to reduce the portion of rainfall that will appear as runoff, or (3) excludes inappropriate discharges to storm drains.

There is no generic method by which these different control techniques can be ranked either qualitatively or quantitatively. Site-specific conditions determine which practices are best, and even whether a particular approach is appropriate. Key factors that influence the suitability of a particular BMP include the following.

- **Drainage area served** - The feasibility of a particular control measure depends on the drainage area. There tend to be upper and/or lower bounds of the urban drainage area that can be served with a particular control practice. These bounds are based on design features and size requirements, as well as the operating characteristics of the BMP. Figure 3-2 presents a number of BMPs and the associated range of feasible drainage areas.

- **Soil permeability** - The soil type, which effectively governs the long-term percolation rate, is an important feature, which can limit the applicability of a technique at a site. Figure 3-3 illustrates typical ranges of infiltration rates associated with different soil types and their impact on the feasibility of different BMPs.

- **Local acceptance** - The acceptability of particular types of BMPs in different urban areas may vary considerably and will influence selection.

- **Other restricting factors** - In addition to the factors discussed above, Figure 3-4 summarizes several other factors that typically limit the applicability of a control practice.

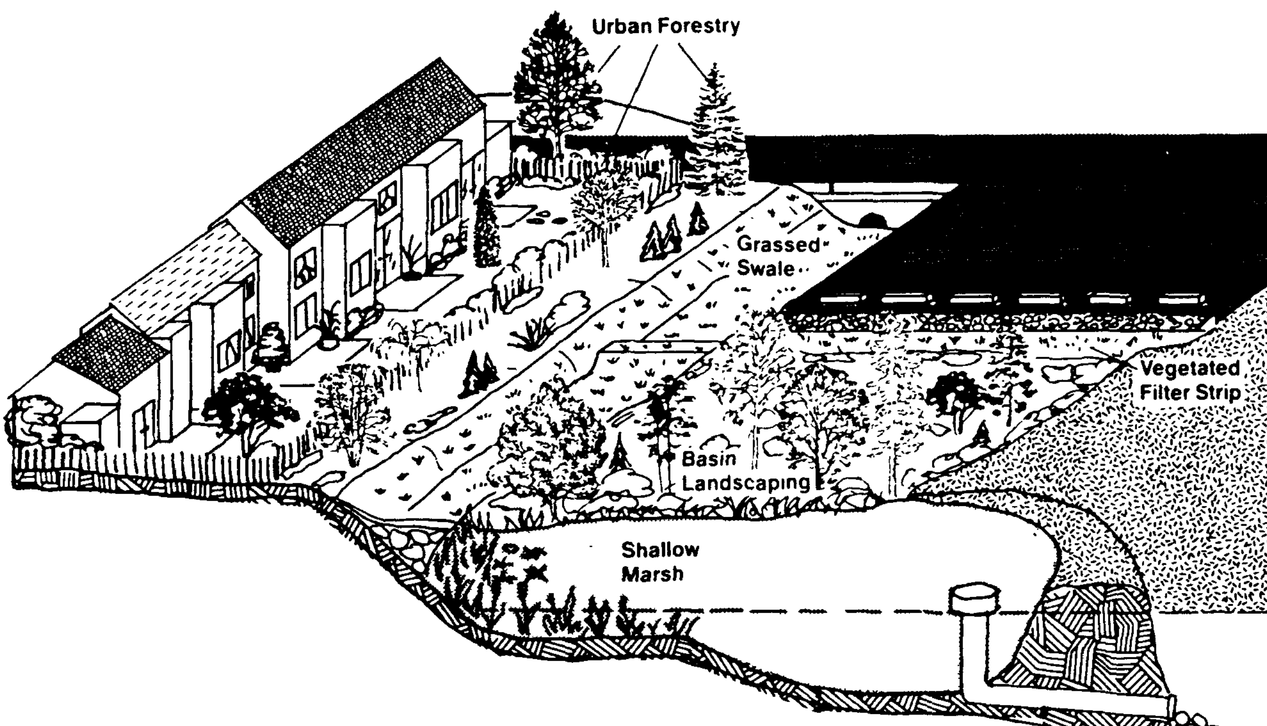
Consideration of the factors discussed above will usually permit a planner to significantly reduce the choice of control practices appropriate for a detailed evaluation.

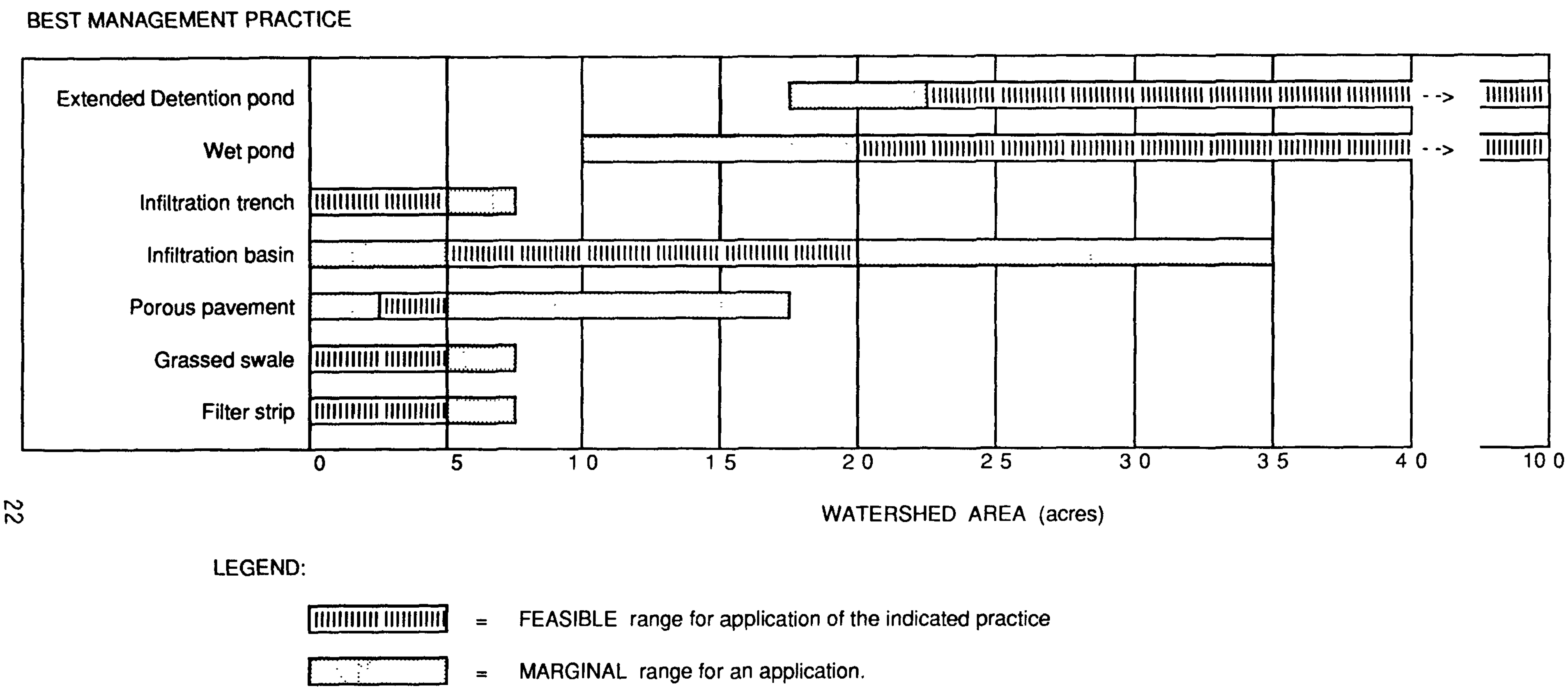
The following sections discuss each of the BMP categories identified above. The level of detail is limited to that considered appropriate for a planning-level assessment of the general features of a NPS urban pollutant control program. An annotated list of selected references is provided for a detailed evaluation. Key design features of the different control techniques are identified, but it should be recognized that other variations are possible. The discussion is limited to the size of a device and the density or intensity of application of a source control practice, because these factors are most important at the planning or

From: CONTROLLING URBAN RUNOFF: A Practical Manual for Planning and Designing Urban BMPs.

Source: Schueler (1987)

FIGURE 3-1. SCHEMATIC ILLUSTRATION OF VEGETATIVE BMPs.





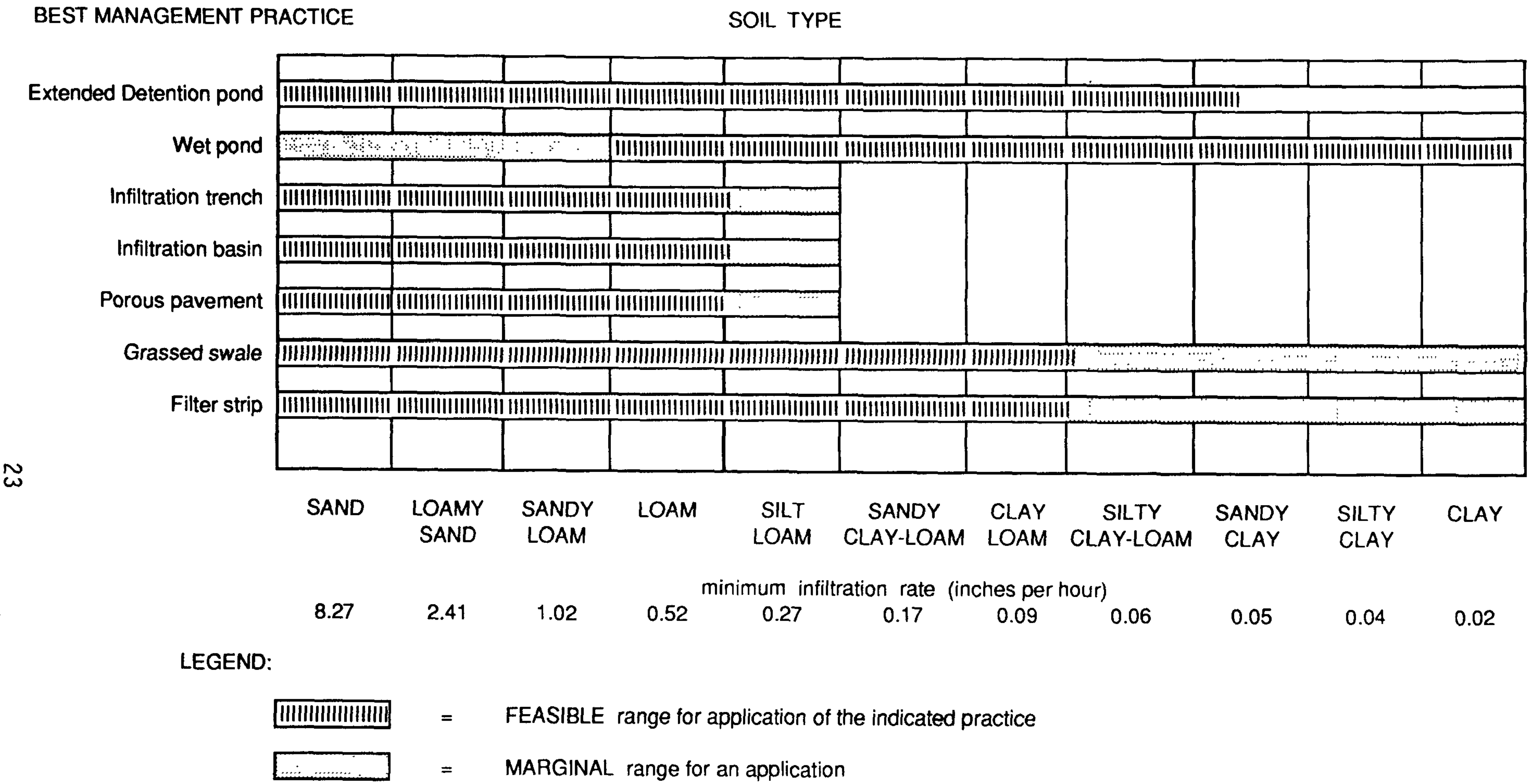
LEGEND:

= FEASIBLE range for application of the indicated practice

= MARGINAL range for an application.

Source: Schueler (1987)

FIGURE 3-2. FEASIBLE BMP TYPES FOR DIFFERENT SIZES OF WATERSHED



Source: Schueler (1987)

FIGURE 3-3. RESTRICTIONS FOR APPLICATION OF BMPs BASED ON SOIL PERMEABILITY

BMP	SLOPE	HIGH WATER TABLE	CLOSE TO BEDROCK	NEAR TO FOUNDATIONS	SPACE REQUIRE-MENTS	MAXIMUM DEPTH	RESTRICT LAND USES	HIGH SEDIMENT INPUT
Extended Detention pond	+++	+++	+/-	+++	---	+++	+++	+/-
Wet pond	+++	+++	+/-	+++	---	---	+++	+/-
Infiltration trench	---	---	---	---	+++	---	+++	---
Infiltration basin	+/-	---	---	+/-	+/-	---	+++	---
Porous pavement	---	---	---	---	---	---	---	---
Grassed swale	---	---	+/-	+/-	+++	+++	---	---
Filter strip	+/-	+/-	+/-	+/-	+++	+++	+/-	---

LEGEND:

+++ (shaded) = GENERALLY NOT A RESTRICTION

+/- = CAN BE OVERCOME WITH CAREFUL DESIGN

--- = MAY PRECLUDE USE OF THE BMP

Source: Schueler (1987)

FIGURE 3-4. OTHER COMMON RESTRICTIONS FOR BMPs assessment stage. Many of the detailed design and implementation features are critical to the ultimate success of a program, but are generally beyond the scope of a planning level assessment. Similarly, the discussion of performance is limited to the range in removal efficiency that can be achieved by a BMP type. Finally general benefits and common limitations or constraints of the particular practice are discussed briefly.

3.2 DETENTION BASINS

The dominant treatment mechanism is the reduction of pollutant concentrations by sedimentation, so that this practice is most effective for suspended solids and the fraction of a pollutant associated with particulate matter. For example, most of the lead that is present in urban stormwater is present in particulate form. The soluble fraction of total lead is typically on the order of only about 10 percent, and as a result the removal efficiency for lead in comparable to that for sediment. In contrast, as much as 40 or 50 percent of a pollutant such as copper in runoff may be present in a dissolved form, and not susceptible to removal by sedimentation.

Although the main benefit results from the reduction of pollutants concentrations in the runoff, water quality impacts may also be reduced by the delayed release of stormwater runoff volumes. The resulting reduction in peak discharge flows will tend to reduce stream bank erosion and place less stress on the physical habitat. A slower release of stormwater to a flowing stream may also result in lower concentrations of runoff pollutants in the stream because of higher dilution in the stream.

Depending on the design of the inlet and outlet structures, detention basins can be classified into the following three categories.

> **Dry ponds** - These are basins with the outlet located at the bottom. They are almost always dry, except infrequently and for relatively short periods following larger storm events. The outlet size is restricted to limit the maximum flow rate. Dry ponds are used for flood and erosion control and are not effective for water quality control purposes. They may often be retrofitted to achieve water quality control.
>
> **Wet ponds** - These basins employ outlet structures designed to maintain a permanent pool of water. They can provide high removal efficiencies for particulates, and have also been observed to be effective in significantly reducing soluble nitrogen and phosphorus concentrations by means of biological activity such as algal growth in the pool of water.
>
> **Extended detention dry ponds** - These basins employ an outlet structure that will cause most storms to pond in the basin. Following a storm these basins drain in about 24 to 40 hour and will be dry at all other times. The outlet structures may be either perforated risers or subsurface drains. They provide a practical technique for retrofitting dry ponds to obtain water quality benefits, and can provide particulate (and the associated pollutant) removal efficiency equivalent to that for wet ponds.

3.2.1 Design Features

Pollutant removal efficiency of an otherwise properly designed and maintained detention basin may be influenced by seasonal factors such as algal growth, shoreline vegetation, and ice formation. However, overall efficiency is determined principally by the size of the basin (the available storage volume provided) relative to the amount of runoff it receives during storm events. For any storm event, the volume of runoff will depend primarily on the size of the contributing drainage area, and the proportion of impervious area. The latter is influenced by land use. Since performance of a basin will vary with storm size, pollutant removal estimates reflect the long-term average removal efficiency over all storms.

A variety of basin sizing rules are in current use, depending on the experience and/or preference of the jurisdiction. In some of the agencies that have been active in the implementation of urban stormwater controls for a number of years, the sizing rules have changed over time, or alternate rules have been adopted for different situations. There is no generally accepted rule or standard for the size of a detention basin. Four commonly used basin sizing rules are discussed below.

Design storm basis - Basin volume is set equal to the runoff produced by a specified design storm. For example, the 1 year or the 2 year, 24 hour duration storm event is sometimes used to specify the size of an extended detention basin where a reduction of flooding and peak flow are important. The volume of rainfall must be converted to the amount of runoff it will produce, and this will vary with the land use distribution (percent impervious area) of the watershed.

First flush basis - Basin volume is designed to store 1/2 inch of runoff per impervious acre of the contributing watershed. This is the most common rule, but the same rule, using 1 inch, is sometimes used. This rule is attractive, because it is simple to use and apply.

Mean storm volume basis - Basin volume is specified as a multiple of the mean runoff volume of all storms. The value of mean runoff is determined by a statistical analysis of the rainfall records. This method has the advantages of being able to base the size on the desired level of performance, and to account for regional rainfall characteristics. For example, the storm that produces 1/2 inch of runoff per impervious acre is a more frequent event in the southeast, than it is in the midwest, and there would be corresponding differences in the long-term pollutant removal efficiencies for otherwise similarly sized basins in the two regions. For some jurisdictions, this approach has been used (with local rainfall characteristics) to determine the storage volume required to produce a particular performance level (e.g., 70% TSS (Total Suspended Solids) reduction), and then translated to a simple-to-apply sizing rule for everyday use.

Residence time basis - Basin volume is designed to provide a specified residence time. Where this is used, long residence times (typically 14 days) are used. This rule generally results in larger basins that provide higher levels of reduction of most pollutants. However the principal objective is to enhance the removal of soluble nutrients by improving conditions favorable for growth of algae and aquatic plants.

A comparative evaluation of the above four approaches to determine basin size can be obtained by the approximate ratio of the basin volume (VB) and the mean runoff volume (VR). This requires an appropriate analysis of the rainfall record and the characteristics of the contributing drainage area. For different regions of the country, the rainfall volume for the mean storm event ranges from about 0.2 to 0.5 inches. This can be taken as an approximation of the runoff volume if we consider only the impervious acres. On this basis, a basin with a VB/VR ratio of 1.0 would provide between 700 and 1800 cubic feet of storage per impervious acre in the watershed. Note that the design volume of a basin is directly proportional to the value of VB/VR. Approximate values of VB/VR for different basin sizing rules are presented in Table 3-1.

TABLE 3-1

RATIO OF BASIN VOLUME TO THE MEAN RUNOFF VOLUME FOR DIFFERENT DESIGN RULES

RULE	CHARACTERISTIC VALUE	VOLUME RATIO (VB/VR)
First flush	1/2 inch per impervious acre	1 to 2
Mean storm volume	1 inch per impervious acre	2 to 4
Residence time	14 day residence time	4 to 5
Design storm	1 year storm	7 to 8
Design storm	2 year storm	8 to 9

Note in general the larger the basin volume, the greater the removal efficiency. However basins with VB/VR ratios larger than 2.5 or 3 yield diminishing returns.

3.2.2 Performance

Depending on the size selected, wet ponds and extended detention ponds can reduce suspended solid concentrations in stormwater runoff by 50 to 95 percent. Removal efficiency for other pollutants is generally proportional to the pollutant fraction associated with (adsorbed on to) the particulates. For screening level analysis, approximate removal ranges that can be expected for detention basins are shown in Table 3-2. The performance levels shown are estimates of the approximate order of the removal efficiency for different pollutant types and basin sizes. Note that there are very limited data available on the removal of bacteria. The high removal efficiencies shown in Table 3-2 may be deceptive, because the water quality criteria levels are very low relative to the concentrations usually present in stormwater.

3.2.3 Advantages and Limitations

Advantages:

- Detention basins are effective runoff control devices, and there is an appreciable body of experience that attests to their performance capabilities, and provides a source of guidance for many important design details.

- They are suitable for relatively large drainage areas, and can be readily incorporated into the overall plans for new developments.
- Properly designed detention basins can enhance the value of the surrounding property.

TABLE 3-2

TYPICAL PERCENT POLLUTANT REMOVED FOR DIFFERENT RATIOS OF BASIN VOLUME TO MEAN RUNOFF VOLUME

POLLUTANT	PERCENT REMOVAL FOR INDICATED VB/VR			
	1	2.5	5	7.5
Suspended solids	50-60	70-80	85-90	90-95
Organics (BOD, COD)	25-30	35-40	40-45	45-50
Total N and total P	30-40	40-50	50-60	60-70
Lead	45-50	60-70	70-80	80-90
Other heavy metals	30-35	40-45	40-50	45-60
Bacteria	about 90 percent to about 99 percent			

TABLE 3-3

TYPICAL PERCENT POLLUTANT REMOVAL FOR RETENTION DEVICES

POLLUTANT	PERCENT REMOVAL FOR INDICATED SIZE		
	1/2 inch per impervious acre	1 inch from total area	2 yr runoff vol
Suspended solids	75	90	99
Organics (BOD, COD)	70	80	90
Total N and total P	45-55	55-70	60-75
Heavy metals	75-80	85-90	95-99
Bacteria	75	90	98

- Existing dry ponds, previously installed for flow control, can often be economically converted to serve as extended detention basins and provide water quality control.

Limitations:

- It is important to note that detention basins can become unsightly if routine maintenance is not performed.
- Removal of accumulated sediments will be required after 10 to 20 years of service, and can be quite expensive.
- The availability of sufficient land area at an appropriate location in the watershed can be a problem.
- Finally, it is usually difficult and often impossible to construct detention ponds in an existing built-up area.

3.3 RETENTION DEVICES

Retention or infiltration devices enable a fraction of the runoff volume to percolate into the ground, and hence reduce the discharge to a surface water body. Consequently, the removal efficiency is the same for all pollutants, and is proportional to the percentage of the total runoff volume that infiltrates. Many of the pollutants in urban runoff are effectively trapped in the upper soil layers, and do not reach the subsurface aquifer. This filtration or adsorption mechanism is particularly effective in the case of suspended solids, bacteria, heavy metals and phosphorus. Note that some of the percolating runoff may reach the surface water body, usually after a considerable delay, and after being "treated" by contact with the soil. Retention devices can be classified into the following three categories.

Infiltration basins - These are relatively large open depressions, produced by either natural site topography or by excavation, in which runoff is temporarily stored while percolation occurs through the bottom or the sides. Outlet devices to allow overflow of excess inflows are generally provided but are elevated so to maximize the storage volume. Infiltration basins are normally designed so that any stored runoff will percolate in no more than a day or two. Thus such basins are generally dry.

Infiltration trenches and dry wells - The design of infiltration trenches and dry wells is similar. The major difference is in the size and the configuration. These are essentially excavated holes filled with coarse aggregate and then covered. Drywells are used primarily for roof drainage from residential and commercial sites. Trenches or modifications of trenches serve larger drainage areas, and are particularly applicable for streets and parking lots in commercial areas.

Porous pavement - The main practical application is for parking lots. Heavy traffic and heavy loads that would tend to occur in most streets would compact the surface and reduce the infiltration rate over time. Also, the vacuum sweeping to remove fine sediments from the pavement, that is an important recommended maintenance procedure, is most realistic for parking lot areas.

3.3.1 Design Features

Key design factors that determine performance are the hydraulic conductivity of the underlying soil and the size of the device relative to the contributing drainage area. In this case, the size refers to the surface area available for percolation, and to the storage volume. Examples of typical sizing rules that have been applied include the following:

- Storage volume for 1/2 inch of runoff per impervious acre, or storage volume for 1 inch of runoff from the entire watershed. These rules are usually applied for infiltration trenches. Generally, trenches are made relatively wide and shallow, and percolation rates range from 0.5 to 1 inches per hour.

- Storage volume equal to the volume of runoff from a 2 year storm. This sizing rule is usually limited to infiltration basins, and makes assumptions comparable to the preceeding rule.

- Percolating area and storage volume may be determined by analyzing the rainfall records and soil percolation rates for the site or area.

3.3.2 Performance

For retention basins, "treatment rate" can be thought of as the product of the percolation rate and the available percolating area. Performance improves as the treatment rate increases and efficiency can be enhanced by the amount of storage volume provided. If large runoff volumes do not have time to drain between storms, basin performance may decrease because the soil column does not dry out during the period between storms.

Depending on the size and the soil characteristics, infiltration devices are capable of achieving removal efficiencies up to 99 percent. The removal of pollutants for different sizes and designs in the Maryland-Northern Virginia area are listed in Table 3-3. Note that the indicated performance can be expected to differ for areas with different rainfall and soil types, but the indicated efficiencies are typical of infiltration BMPs.

3.3.3 Advantages and Limitations

Advantages:

- Infiltration devices are capable of very high pollutant removals.
- In many cases they can be built in developed areas.
- In addition to water quality control, they also reduce stormwater runoff to surface water bodies during and after storm events and provide desirable subsurface recharge resulting in an increase in low, dry-weather stream flows. This has the desirable effect of reducing flow variations in streams.

Limitations:

- A variety of site specific factors (impermeable soils, high water table, bedrock, etc) restrict the applicability of this type of BMPs.
- Care during installation is necessary to prevent compaction of soil by construction machinery, or the sealing of infiltration surfaces by sediment generated during construction activities.

- Even during normal operating conditions, infiltration devices require pretreatment (e.g., grass filter strips, geo-textile cloth) to reduce the amount of coarse sediment reaching the infiltration surface.

3.4 VEGETATIVE CONTROLS

Vegetative BMPs include a variety of landscaping arrangements that serve to increase the contact of rainfall and stormwater runoff with appropriate types of vegetation. Vegetative control practices have the ability to reduce pollutant discharges by reducing the quantity of runoff through enhanced infiltration, and to reduce concentrations through a combination of filtration, sedimentation and biological uptake. The major types of vegetative BMPs include the following.

Basin landscaping - Basin landscaping can be addressed during early development of a watershed and can have a significant effect on the control of NPS pollutants. The objectives of basin landscaping include but are not limited to minimization of impervious surface area; protection and utilization of existing wetlands; provision for green-belt buffers along stream banks; routing of runoff flow through vegetated areas and away from erosion-prone steep slopes. Careful selection of vegetation most suitable for site conditions has an important bearing on physical appearance and the long-term performance of basin landscaping.

Wetlands - As part of site landscaping, it is possible to create new shallow marsh wetlands specifically designed to operate as an urban runoff control measure. In rare cases, there may be an existing wetland of appropriate type, size and location, to warrant its consideration as a BMP for urban runoff, provided that the wetland is not itself degraded as a result. In such cases, issues that will be difficult to resolve with current knowledge, such as the potential of urban runoff flows or pollutants to damage the existing wetland ecosystem, need to be addressed.

Grassed swales - Grassed swales are a shallow grass covered channel, rather than a buried storm drain, that is used to convey stormwater. Grass channels are mostly applicable in residential areas. They require shallow slopes, and soils that drain well. Often grassed swales are used to provide "pretreatment" of runoff to other controls, particularly infiltration devices.

Filter strips - These are similar in concept to grass swales, but are designed to distribute runoff across the entire width and result in an overland sheet flow. These strips should have relatively low slopes, adequate length, and should be planted with erosion resistant plant species. They are often used as pretreatment for other BMPs, for example, by being placed in the flow path between a parking lot and an infiltration trench.

3.4.1 Design Features

Performance of vegetative controls is strongly influenced by the depth and velocity of flow through or across the device (determined by slope and flow distribution), and by contact time (determined by the length of the flow path). Soil with higher infiltration rates, and the use of small check dams to produce temporary ponding of runoff improves performance by enhancing the infiltration rates. Care in selecting plant species appropriate for site specific conditions, and routine maintenance to maintain optimum height are important maintenance requirements.

3.4.2 Performance

The pollutant reduction capabilities of vegetative controls are not documented as well for the other types of BMPs. Available information suggests that under favorable conditions, vegetative controls can achieve moderate removals of particulates such as sediment and heavy metals. They are generally not effective in reducing nutrients.

Many of the important design features are determined by physical characteristics of the site, over which the planner or designer has little or no control. Thus, both the applicability and the degree of performance that can be expected are highly site-specific.

3.4.3 Advantages and Limitations

Advantages:

- The costs for vegetative controls tend to be lower than those for detention and infiltration practices.
- With appropriate planning and design, they can enhance the visual attractiveness of a site.
- Vegetative controls are usually most appropriate to provide pretreatment of runoff in order to improve the operation and maintenance of other BMPs.

Limitations:

- Vegetative controls are usually not adequate to serve as the only runoff control practice for a site.
- The overall pollutant reduction that can be obtained from vegetative practices is usually limited, and depends to a substantial degree on the physical characteristics of individual sites.
- Seasonal differences in performance can be important. Removal effectiveness for some pollutants can be markedly different during growing and dormant periods.
- Information on removal efficiencies for the range of conditions that might be encountered is relatively limited.

3.5 SOURCE CONTROLS

This category of BMPs includes any practice that (a) reduces the amounts of accumulated pollutants on the land surface available for washoff by rainfall, or (b) regulates the amount of impervious area to reduce the amount of runoff, or (c) excludes inappropriate discharges from storm drains.

Source controls address one or more of the above objectives. Depending on the basic nature of a practice, it may apply at a local level or on an areawide basis. In most cases, a management plan will incorporate an array of different source controls that are applicable for the area. All source controls involve each of the following "implementation" aspects, to a greater or lesser degree.

Education - Since many source control practices require either active public participation, or general public acceptance, public education elements are an important feature. Developing a public understanding of the need for an action, the benefit it can produce, and the pertinent details of its implementation, will be critical to success, and will require a specific program element that addresses this requirement.

Regulation - In many cases appropriate legal authority will have to be developed and assigned to an appropriate agency. There may be a need for redefining roles or establishing new agencies or departments. For example, an appropriate regulation against a particular form of pollutant discharge and legal enforcement authority may exist. If however, the enforcement authority resides in the Police Department, the situation may fall so far down on the priorities dictated by the general mission of a police agency, as to preclude any realistic expectation of active enforcement. This is an example of one of the variety of issues that may not be apparent in a simple listing of the elements of a particular NPS control action, and will have to be resolved.

Guidance - For some source controls, specific formal technical guidance may have to be developed and distributed to assure effective implementation. Examples include details of erosion control practices, oil separators that may be required for service stations, or detention facilities for new residential developments.

3.5.1 Design Features

There is no consistent way to characterize the salient design features of the variety of different types of practices that can be included in the source control BMP category. An important factor is the "application density". This generally (depending on the nature of the particular practice) addresses how actively, frequently and/or thoroughly the practice is pursued, and over how much of the total urban area it is applied. For example, the frequency at which each catch basin is cleaned; the number of streets or parking areas that are swept and how often the sweeper returns to a particular location are examples of application density, and ultimately of how effective a source control practice will be in reducing NPS pollutant loads from an overall urban area.

Source controls that have broad general applicability are identified below, with examples of some of the more important elements that are necessary for effective implementation. The list is not exhaustive; local situations can be expected to suggest other practices that are not included in this discussion. In addition, some of those that have been included in the list may not be applicable in all areas.

A. Exclude Inappropriate Discharges to Storm Drains

- **Eliminate illicit or inappropriate connections** - This is one of the more important source controls. The proposed stormwater permit regulations emphasize the detection and elimination of non-stormwater discharges to storm drainage systems. Elements of such a measure include the following:
  - Research, strengthen (if necessary), and enforce existing regulations which give local jurisdictions the legal authority to eliminate cross-connections that result in sanitary sewage or industrial wastewater entering the storm drainage systems.
  - Reevaluate previous decisions to allow certain relatively clean waters to be discharged to the stormwater system.
  - Ensure existing spill response measures consider impacts on water quality.

- Develop and implement an aggressive field program to search for, detect and control domestic, commercial or industrial cross-connections and illegal dumping.
- Develop and implement an aggressive field program to search for, detect, and control sanitary sewer leaks and areas where surcharging or overflows would be most likely to occur.

- **Prevent rainfall and runoff from contacting potential contaminants** - This is a well established standard practice that has obvious benefit. It applies primarily to industrial or commercial sites.
  - Educate regarding the need to keep rainfall and runoff from contacting potential contaminants. Describe typical examples of the problem and practical solutions.
  - Develop and implement regulations to require covers for outdoor storage areas that contain contaminants. Keep runoff from passing over areas that contain contaminants. Emphasize good housekeeping for open loading-unloading areas.
  - Develop and implement an aggressive field program to search for, detect and correct situations where rainfall or runoff presently contact potential contaminants.

- **Encourage proper use and disposal of materials by homeowners** - The contaminants addressed by this control activity include materials such as fertilizers, pesticides and herbicides, oil and antifreeze, paints, and solvents. Specific actions for preventing the discharge of household contaminants include the following.
  - Educate regarding the proper storage and use of fertilizers, herbicides and pesticides; application methods, rates and frequency appropriate for the area; and the potential environmental damage that can be caused by these materials. Identify alternative methods for controlling insects and weeds (e.g., physical controls, biological controls, less toxic chemicals).
  - Educate regarding the need to keep oils, paints and similar contaminants out of storm drains; the potential environmental damage that can be caused by these materials; and acceptable disposal methods.
  - Develop and implement programs and set up receiving facilities and procedures for specific pollutants such as crankcase oil, pesticide or paint containers, and other potentially harmful chemicals. Recycle if possible. The success of such a practice depends on the number and location (convenience) of stations and the awareness of the community about the effect of pollutants on the environment.
  - Research, strengthen (if necessary), and enforce existing regulations which give local jurisdictions the legal authority to prevent improper disposal of pollutants into storm drainage systems.
  - Label storm drain inlets and provide signs along the banks of drainage channels and creeks explaining the environmental impacts of dumping wastes.

- **Develop and implement an aggressive field inspection program.**
  - Search for, detect and prevent dumping or routinely discharging pollutants into storm sewers, drainage channels and urban streams.

- Look for runoff or spill problems when conducting fire inspections.

B. Reduce Street and Land Surface Sources of Pollutants -

- **Control littering and improper waste disposal practices** - In addition to its pollution control benefits, an effective litter control program will improve the general aesthetic appearance of the area. Because such programs have easily achieved public acceptance, with visible effects, they can assist in developing interest and acceptance of other BMPs where the relation between practice and benefit may be less obvious. Specific actions might include the following.
  - Educate regarding the NPS pollution impacts that result from littering and improper waste disposal practices.
  - Research, strengthen (if necessary), and enforce existing regulations which give local jurisdictions the legal authority to control littering and the improper disposal of potentially harmful or aesthetically objectionable materials.
  - Provide litter bags for use in cars. Work with citizen action programs to facilitate efforts to report littering incidents and illegal dumping.
  - Develop and implement regularly scheduled cleanup days and corresponding curbside collection of trash and household debris.
  - Provide, collect and maintain an adequate number of litter receptacles in strategic public areas, and during major public events.
  - Coordinate with efforts (by others) to establish practical controls regarding potentially harmful packaging of consumer products.

- **Control animal wastes** - The specific practices considered should consider both household pets and where appropriate, suburban livestock such as horses and chickens.
  - Educate regarding the need to clean up and properly dispose of pet wastes, and where appropriate, the need for proper management of wastes from suburban livestock and agricultural operations in the watershed.
  - Provide informational signs and dispense doggie litter bags in parks and other selected areas.
  - Implement and enforce leash laws and pet waste cleanup ordinances in selected public-use areas.

- **Improve the maintenance of major paved areas** - Activities in this category include both physical repairs to maintain pavement surfaces in good condition so that pavement debris and degradation products are not washed into storm drains, and street cleaning practices that remove litter and externally generated dust and associated pollutants that accumulate on paved surfaces.
  - Improve pavement repair and maintenance programs on streets and parking areas (e.g., fill potholes, seal cracks, apply surface treatments).
  - Develop and implement sufficiently intensive street sweeping programs for strategic locations. For example, paved surfaces in central business districts, shopping malls, major parking lots and industrial areas tend to produce more concentrated surface sources of heavy metals, oil and similar contaminants.

- Implement street parking regulations (e.g., alternate side parking days) where necessary for effectiveness of street sweeping programs.

- **Institute programs to remove accumulations of litter and debris** - Floatables and accumulations of debris represent an important aesthetic problem for urban streams in many areas.

  - Sponsor periodic stream bank cleanup programs to remove accumulations of litter and debris in urban streams or on their banks. Floatable materials often accumulate behind roadway culverts. Encourage participation by suitable community groups (e.g., Boy Scouts, etc.). Coordinate with Public Works Departments for hauling and disposal of removed materials.
  - Provide for routine sweeping of streets that border urban stream courses, and/or other targeted areas , e.g., certain parking lots.
  - Provide surveillance and enforce regulations against dumping.

- **Institute environmentally protective road maintenance practices** - Certain routine practices that are known to have adverse environmental effects should be examined and modified to the extent possible.

  - Calibrate road deicing spreader equipment to avoid excessive application rates.
  - Cover salt storage areas.
  - Consider use of alternate materials in select areas.
  - Consider use of low maintenance vegetation instead of herbicide use.

- **Control airborne pollutants** - A significant source of many of the pollutants present in urban stormwater runoff is the deposition of atmospheric particles that originate from a variety of sources, on land surfaces in the urban area. Source control activities that can address this situation include the following.

  - Educate regarding the relationship between air pollution and NPS water quality problems, and the need to coordinate with programs (by others) that seek to reduce particulate atmospheric emissions of pollutants from individual, public, commercial and industrial sources.
  - Educate regarding the potential benefits of reduced automobile use by various means (e.g., ride sharing, carpooling, public transportation), and the importance of frequent vehicle inspection and maintenance efforts to reduce atmospheric emissions.
  - Educate regarding the proper operation of fireplaces and wood burning stoves to minimize the emissions of particulate matter.
  - Cooperate with public transportation agencies, public agency motorpools, and public works departments to provide effective air pollution controls on publicly owned vehicles and motorized equipment, and, where practical, on the use of alternative clean-burning fuels.

C. Control Erosion -

- **Control erosion at construction sites** - These actions suggested here are directed at the control of erosion from land disturbed during construction, or the prevention of eroded materials from leaving the site.

- Educate architects, engineers, contractors, and public works personnel about the need for and practical methods for erosion control, sediment control, groundwater disposal, and site waste management and disposal.
- Develop and implement effective erosion and sediment control regulations, and requirements for corresponding construction inspection programs. These should apply to public-sector as well as private-sector construction programs.
- Develop and implement improved erosion and sediment control policies in the environmental elements of all general Plans (develop and adopt General Plan amendments, when needed).
- Adopt policies that require all CEQA compliance documents and all site development plans to explicitly address the topics of erosion potential, proposed erosion and sediment control plans, and enforceable mitigation measures to minimize environmental impacts.
- Require contractors to post bonds to cover potential damages from erosion or sediment deposition.
- Institute an active construction site inspection and enforcement program.

• **Control erosion of undeveloped land and park land** - These efforts are directed at the control of erosion from essentially undisturbed urban land areas, to reduce potential adverse impacts on urban water bodies.

  - Educate public works personnel and managers of parks and open-space lands about the need for and practical methods for erosion control and sediment control.
  - Develop and implement programs to actively search for, identify, evaluate, and prioritize erosion problems on undeveloped land, park land or open-space urban land use areas.
  - Develop and implement programs to work with landowners, tenants, and public agencies to apply practical erosion and sediment control practices.
  - Develop and implement practical programs for revegetating and otherwise restoring eroding areas (e.g., areas damaged by fires, off-road vehicle use).
  - Educate managers and users of park lands and open-space lands concerning the need to restrict off-trail activities. Establish and enforce practical, site-specific regulations to control harmful off-trail activities.

D. Implement Land Use Planning -

• **Implement Zoning regulations** - Appropriate zoning ordinances may be used in sensitive areas to provide for development patterns that are compatible with control of NPS discharges and the protection of receiving waters.

  - Zone to limit dwelling unit density and control the amount of on-site pollutants generated and control the amount of runoff by limiting the impervious surface area created.
  - Restrict development adjacent to streambanks. Require vegetated buffer strips along streambanks.
  - Restrict development on sites with soils and slopes that are susceptible to serious erosion.

- **Limit the directly connected impervious area** -
  - Develop planning guidelines illustrating favorable development techniques.
  - Use grass swales for drainage in preference to curbs and gutters and piped drains, where feasible.
  - Encourage use of cluster housing, buffer strips, open space, or other patterns that reduce the quantity of runoff from the site.
  - Avoid direct connection of roof leaders to drain pipes or paved surfaces.
- **Require physical controls for new developments** -
  - Require the installation of detention basins or infiltration devices as BMPs for the control of the quality and/or quantity of runoff and for control of peak flows on all new development sites.
  - Develop specific guidelines for design and construction of these devices.
  - Provide for the necessary supervision, inspection and enforcement of regulations to insure compliance.

E. Other Control Measures -

- **Control oil and grease** - Automobile operation and maintenance is the principal source of oil and grease that can result in objectionable films and sheens on the surface of receiving waters. Fractions that remain in solution may contribute toxic contaminants. Food service facilities may contribute animal fats and greases (vs hydrocarbon based) to runoff.
  - Educate regarding the effective use of "housekeeping" practices, oil and grease traps, the use of adsorbents and cleaning compounds for controlling oil and grease at gas stations, automotive repair shops, parking areas, commercial and industrial facilities, and food service facilities.
  - Educate regarding the need to provide adequate and sufficiently frequent vehicle inspection, and to maintain efforts to reduce leakage of oil, antifreeze, hydraulic fluid, etc.
  - Research, strengthen (if necessary), and enforce regulations which give local jurisdictions the legal authority to require oil and grease controls in areas that are significant sources (e.g., gas stations, automotive repair shops, parking areas, commercial and industrial facilities, and food service facilities).
  - Develop technical guidance that will facilitate efforts by responsible parties to comply with regulations requiring oil and grease controls (e.g., oil traps, plate separators, synthetic adsorbent material, grassed swales).
- **Control leaks from gasoline, fuel oil, and chemical storage tanks** - The actions listed can help to control pollutant contributions from leaking storage tanks.
  - Educate regarding the environmental impacts that result from leaks and spills from gasoline, fuel oil, and chemical tanks, above and below ground.
  - Coordinate with efforts (by others) to intensify the implementation of existing regulations which call for improved design of new tanks,(e.g., double walls, monitoring facilities); replacement of tanks over a specified age; self-

monitoring programs; and implementation of a strategically focused spot-check program to search for, identify, test, and control leaking storage tanks.

- **Intensify the maintenance and repair of stormwater drainage systems** - These actions are directed at removing the pollutants that tend to be retained, and accumulate at specific locations in the stormwater drainage system.
    - Determine the effectiveness of increasing the frequency of cleaning out storm sewer inlets, catchbasins, storm sewer pipes and drainage channels in areas where sediments, debris, or floatable materials tend to accumulate. Develop and implement improved programs where appropriate.
    - Develop and implement an aggressive field program to search for, test, remove, and properly dispose of sediment deposits in drainage channels and streams, which contain relatively high concentrations of pollutants.
    - Develop and implement a program which provides a means of recording the observations of field inspection and maintenance personnel, so that this information can be used to help locate the sources of pollutants.

- **Address indirect sources of sewage to stormwater drainage systems** - There are conditions or situations which make it possible for sanitary sewage to contaminate stormwater other than by direct piping connections.
    - Improve sanitary sewer maintenance where necessary to control excessive exfiltration.
    - Consider instituting a septic tank certification and inspection program.

3.5.2 Performance

While all of these practices will reduce water pollution, the current state of the art precludes accurate estimates of the effect such practices may have on area-wide pollutant loads or to problems in specific water bodies. There is considerable uncertainty associated with the ability to quantify load reductions. In addition, even assuming performance levels could be defined, estimating the extent to which the public at large applies a practice will generally be very difficult.

3.5.3 Advantages and Limitations

Advantages:

- Some source control actions will be very visible and will involve high level of public awareness and involvement. They can help to generate a sense of active community participation in an overall NPS control program, and may help secure the implementation of other, less obvious, elements of a management plan.
- In addition to reducing pollutant discharges to water bodies, many will have attendant aesthetic or cosmetic benefits.

Limitations:

- Adoption (with or without enforcement) of the necessary ordinances may create negative public reactions that may have an adverse effect on other areas of the program.

- In most cases, there is no reliable way to estimate the effect of a particular source control measure on the urban NPS pollutant loads.
- Effectiveness of a practice depends on the degree to which it is applied and the geographical extent of the application. Even with appropriate regulations in place, there is no positive assurance of compliance to the extent desired.
- Developing and assigning the necessary legal authority, and adding new responsibilities to established public agencies whose budget, experience, and priorities may not relate directly to NPS control may be difficult to resolve.

CHAPTER 4
TARGETING TO PRIORITIZE URBAN AREAS FOR CONTROL

4.1 INTRODUCTION

This chapter presents a ranking procedure for identifying the area (or areas) within an urban jurisdiction where it is most appropriate to focus additional stormwater pollutant control efforts, after jurisdiction-wide baseline controls and priority sources have been addressed. Technical, economic and timing considerations usually require a staged management effort in reaching water quality goals. The methodology ranks areas relative to the other areas in the jurisdiction and is not intended to imply that areas receiving lower ranking do not require controls.

A large urban jurisdiction will commonly involve a network of streams differing in size, use and sensitivity to urban runoff, and which receive discharges from different parts of the jurisdiction. A few of these may have greater local importance than others because of the nature and visibility of the resource, or the type or level of the its use. In addition some urban NPS control practices will generally apply to the entire jurisdiction (e.g., an anti-litter ordinance), but in many cases the control choices will tend to be either site-specific or land use-specific. For example appropriate pollutant control practices for industrial areas will usually be quite different than those suitable for residential areas. Further, factors such as topography, soil conditions, land availability and cost will often influence the selection of controls even for similar land uses in different parts of the jurisdiction.

For large urban areas it may be necessary to develop a targeting procedure for implementing stormwater controls for the following reasons:

- Once jurisdiction-wide, baseline actions have been applied, the implementation of additionsl stormwater controls over the entire urban jurisdiction, all at once is not usually possible . Thus a phased approach will generally be necessary.
- Development of a rational basis for ranking different areas within the jurisdiction will be desireable.
- Accounting for relevant site-specific attributes and documenting the decision process is necessary. This will be particularly useful for describing the specific targeting decisions to the public
- Assist the urban jurisdiction in meeting the requirements of Sections 319 and 402 of the Clean Water Act.

4.2 ELEMENTS OF THE TARGETING PROCEDURE

The procedure described in this chapter provides a way to prioritize urban watersheds so that a stormwater program can be sequentially implemented based on general and site-specific considerations. The approach described assumes that appropriate jurisdiction-wide measures have been identified and are being applied, and that any priority sources of pollutants are independently addressed. The procedure for prioritizing additional efforts consists of the following elements:

1. Identify discrete watersheds within the overall urban area, and the corresponding receiving stream segment. The necessary information could be developed from topographic or drainage system maps.

2. Determine relevant physical characteristics and other attributes of each watershed, and of the receiving stream segment.

3. Tabulate pertinent data in summary form.

4. Complete a "targeting table" by assigning a relative ranking value to each attribute. Assign weights to the attributes to reflect their relative importance in the local decision process.

5. Prioritize urban drainage areas in accordance with the resulting weighted sum of ranks.

There is no standard or generally accepted set of attributes that are used for establishing priorities for NPS control programs. A few attributes which are generally important are presented in Section 4.3. Note that any additional attributes that may be appropriate to consider for the local situation should be added to the procedure. The relative importance of each factor is accounted for by assigning different weights to each factor.

4.3 FACTORS USED FOR PRIORITIZATION

The factors in the ranking process are discussed below.

Waterbody Importance - This factor describes the general importance, and the ability of the waterbody to support a variety of beneficial uses. Since aquatic life populations and diversity as well as citizen use are likely to be greater for large streams (or lakes) with appreciable amounts of water than for very small water bodies with low flows and small surface areas, flow or watershed size can be used as a surrogate for waterbody importance. Since measured flow data is not likely to be available at all points of interest, total drainage area of the watershed upstream of the location of interest can be used for comparison purposes. Absolute values of drainage area are thus assigned an appropriate rank in the 1 to 9 range. Note the larger the stream size (drainage area) is, the higher is the rank.

Type of Use - This factor is selected to provide a comparative measure of the importance based on the primary type of beneficial use of the waterbody. The following beneficial uses are suggested for use in this ranking factor. The list below indicates two possible ways of ordering relative importance *for local ranking*.

RANK	BENEFICIAL USE		
HIGH	contact recreation		aquatic life
	non-contact recreation	OR	contact recreation
	aquatic life		non-contact recreation
LOW	urban drainage		urban drainage

The order selected would be one that reflected local values and issues. Bear in mind that the rank a particular use is assigned for this targeting exercise is not a statement of concern for fish vs people or vice-versa. The rank values (1-9) assigned could be given a wide difference where one or another had a high degree of local importance, and only slightly different (or similar) values in cases where use types were of equal importance.

Status of Use - This factor accounts for the present status of beneficial uses of the water body. There are different, but equally reasonable, rationales that can be applied to rank the relative importance of the desired use.

It can be reasoned that an EXISTING use in fairly good condition (or a presently good but merely threatened water), should have a lower priority than one for which the use is present but IMPAIRED. The philosophy would be to give highest priority to rectifying obvious problems, assuming that there would then be time for later actions to polish up the only slightly impacted areas. This implies that the highest rank would be assigned to a use whose degree of impairment is so great that it is effectively DENIED.

However, it is also reasonable to embrace a scheme that would assign higher ranks to uses that are presently in good condition or are only somewhat IMPAIRED, than to the real problem areas with DENIED uses. The philosophy here would be to give highest priority to protecting what we have and correcting the small problems, and then tackle the difficult ones further down the road. The relative ease and cost of reclaiming the IMPAIRED use might be such that demonstrable control program benefits would be achieved more rapidly, and there might be a greater impact on health and safety (if there is, in fact, no actual use of the denied resource).

Level of Use - Although the waterbody importance factor affects the level of use, this independent factor is included to make an important additional distinction that recognizes local factors. There will be cases where even a stream that would otherwise be considered quite small, will have a disproportionately high level of use, e.g., a small stream that flows through a park or recreational area and is popular with children for wading. The assigned rank for this factor should be based on whether the level of use is low, moderate or high - relative to the other waterbodies in the target area.

Pollutant Loads - The difference in annual pollutant load contributed by runoff from the different watersheds can be used as a surrogate for the potential to cause water quality problems that result in the impairment of a beneficial use. The procedure described below for estimating these loads, can be used for a comparative evaluation of pollutant sources for a screening type analysis.

Note that the procedure is not designed to estimate actual loads for the area. To do so accurately would require considerable site-specific refinements in site characterization and more elaborate analysis procedures. Nor is the procedure designed to provide an indication of actual water quality impacts. Different analysis procedures would be required depending on whether the water body in question was a stream, lake, estuary or coastal water body. In addition, streams quality responds to the transient event-to-event inputs, much more than to annual mass loads. The load estimates for the purpose of developing a relative rank, are suitable for this purpose, but are not at all adequate for reliable pollutant loading estimates or receiving water impact assessments.

The pollutant mass load in urban runoff is determined by (i) the amount of rainfall (ii) the total area of the watershed, and (iii) the distribution of land use types in the watershed. The rainfall can be assumed to be the same in all parts of the urban jurisdiction. The land use type influences the typical fraction of impervious surface area, which in turn determines how much of the rain is converted to surface runoff. Land use also influences the average concentration of a pollutant in the runoff.

The annual rainfall typical for the urban jurisdiction will normally be known. However the exact value assigned will not be important because the comparison to be made is one of relative differences between different watersheds in the jurisdiction. For the same reason, it is not important for the pollutant load comparisons, whether or not the use affected is largely seasonal in nature.and influenced by seasonal differences in rainfall. The suggested procedure (used in the example later) is to base comparative loads on 1 inch of rainfall. This is completely arbitrary, but it simplifies the arithmetic. Annual precipitation, or precipitation volume in a critical season, could also be used.

The total area and the distribution of land use categories for each urban watershed being considered, must be extracted from local maps. Table 4-1 provides typical values for impervious fraction and pollutant concentration in urban runoff (in milligrams per liter), for selected land use categories. It also lists values for runoff coefficient (Rv), which is computed from the impervious fraction, and represents the fraction of the rainfall that becomes surface runoff.

The values for the percentage of impervious area for different land use classifications presented in Table 4-1, are based on data from EPA's NURP program, and are suitable for a screening type analysis. However, they should be modified as appropriate if local information is available, or if site-specific factors are likely to modify them. Note that the NURP study was not designed to provide definitive information on the differences between land use types, and provided no information on industrial runoff.

TABLE 4-1

TYPICAL VALUES OF PERCENT IMPERVIOUS AREA
AND POLLUTANT CONCENTRATIONS

			POLLUTANT CONCENTRATION (mg/l)			
LAND USE	% IMP	Rv	TSS	TP	O&G	Cu
Open -Developing	5	0.1	150	0.800	0	0.010
Open- Park	5	0.1	50	0.800	0	0.010
Resid - LOW DENS	20	0.2	100	0.600	5	0.030
Resid - HIGH DENS	50	0.4	90	0.400	10	0.040
Commercial	90	0.8	80	0.200	15	0.050
Industrial	70	0.6	120	0.200	20	0.050

A variation in concentration with land use is also shown in Table 4-1. This is based on judgement concerning the relative differences that are likely to be associated with the general differences in the land uses. The values shown are considered appropriate for an analysis designed to estimate a relative comparison of mass loads. In particular, the values shown for industrial land use should be used with caution, because they are very sensitive to the type of industrial activity.

Runoff concentrations are listed for only four pollutants. However, in this screening analysis, these can be used as surrogates for other pollutants for which data may not be readily available. The following relationships will generally apply. Total Suspended Solids (TSS) can serve as a general surrogate for sediment deposition and siltation in streams and lakes. Total Phosphorus (TP) can be used to reflect the discharge of nutrients and their contribution to eutrophication potential. Oil and Grease (O&G) can be used as a surrogate for the potential for problems associated with degraded aesthetic values. The heavy metal Copper (Cu) can be used as a surrogate for potential toxic impacts on aquatic life.

The mass load (pounds) of a pollutant from runoff is computed by :

$$M = RainV * Rv * Area * Conc * 0.227 \qquad (4.1)$$

where:

M	=	mass load [pounds]
RainV	=	rainfall amount [inches]
Rv	=	runoff coefficient [unitless]
Area	=	drainage area [acres]
Conc	=	average concentration in runoff [mg/l]
0.227	=	unit conversion factor

If the rainfall amount used is the annual rainfall, the load computed would be pounds per year. However, since the analysis requires only comparative loads, a rainfall amount of 1 inch can be used for convenience. Loads should be computed for each land use within a watershed, and then combined to provide the total watershed pollutant mass load to be used for comparison. Rank values would be assigned to each watershed based on the range of mass values computed.

Implementability of Controls - This factor is designed to reflect the fact that an effective management program may be easier to implement for certain watersheds than for others. The prioritization scheme takes this into account. Differences may be based on institutional factors, existing ordinances, or technical factors. For example, it will usually be much easier to implement effective runoff controls for a newly developing area, than to retrofit controls in an existing central business district. Similarly, control requirements may be institutionally easier to implement for an industrial area than for scattered residential areas.

4.4 DESCRIPTION OF TARGETING PROCEDURE

A rank between 1 and 9 is assigned to each of the above factors to reflect increasing value or importance of the selected factor. It is emphasized that in each case, the rank is not an absolute measure of importance, but rather a comparative measure. Rank values are assigned so that the higher the value, the higher will be the priority for action. Scale ranges other than 1 to 9 could obviously be used as well. Very high ranges (e.g., 0 to 100) imply an ability to make fine distinctions and gradations that will not usually be possible. A very small range (e.g., 1 to 3) may represent the realistic level at which distinctions can be made in a screening analysis of this type, but constrains the sensitivity of the comparisons. The range of 1 to 9 is suggested as a reasonable compromise.

It is recognized that some factors will be more important than others. The relative importance of different factors is accounted for by assigning different weights to each factor.

This helps to avoid the choice of factors from forcing the results in a particular direction. The assignment of weights also permits the emphasis of locally important considerations. For example, if the planning body determined that it was most important to get some type of implementation program started at an early stage, the "ability to implement" factor could be given a high weight. In a case where the main concern is the violation of water quality standards for fishable, swimmable waters, the relative weights would emphasize the "use status" and "pollutant load" factors. It is not really important what the sum of the weights add up to, since it is relative scores that matter.. However, it is suggested that factor weights be assigned so that they add up to 100 (as in 100%). This will help in balancing the assignment of relative importance to the different targeting factors, and help assure that absolute scores that result from different trials are all on a common basis

It is important to bear in mind that there is a considerable subjective element involved in the selection of factors, and in the assignment of ranks and relative weights. Presumably these will be developed as a result of group discussions involving interested parties. The methodology presented here provides a useful framework for balancing priorities and forming a collective judgement.

The targeting procedure is best illustrated by an example. Figure 4-1 presents a schematic illustration of a hypothetical urban jurisdiction. Watersheds and land use types are delineated and their spatial relationship to important use locations are shown.

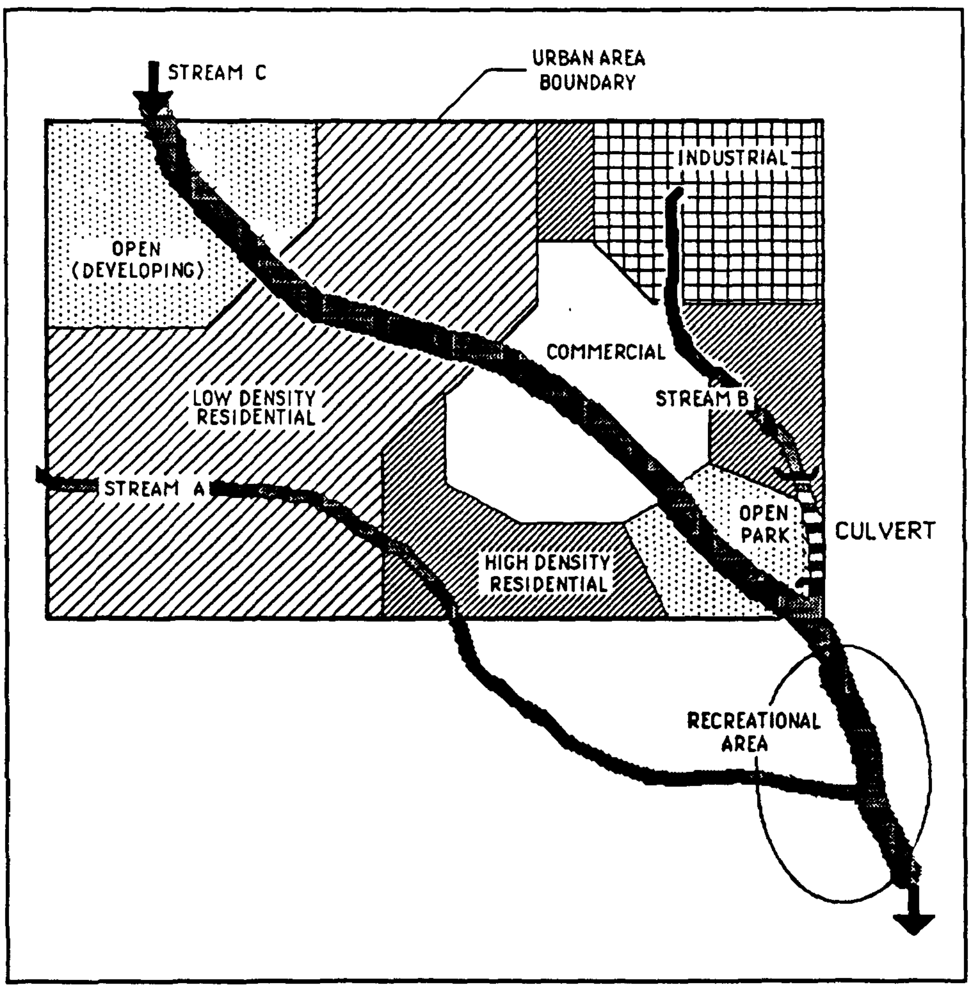


FIGURE 4-1 SCHEMATIC REPRESENTATION OF URBAN AREA

TABLE 4-2. CHARACTERISTICS OF URBAN AREA AND ESTIMATED RUNOFF CONCENTRATIONS.

LAND USE	Rv	Avg CONC in Runoff mg/l TSS	O&G	TP	Cu	DRAINAGE AREA IN ACRES STREAM A	STREAM B	STREAM C	URBAN TOTAL
INDUSTRIAL	0.6	120	20	0.20	0.05	0	150	0	150
COMMERCIAL	0.8	80	15	0.20	0.05	10	80	110	200
RESIDENTIAL - HD	0.4	90	10	0.40	0.04	100	100	50	250
RESIDENTIAL - LD	0.2	100	5	0.60	0.03	200	0	200	400
OPEN - DEVELOPING	0.1	150	0	0.80	0.01	0	0	150	150
OPEN - URBAN PARK	0.1	50	0	0.80	0.01	0	0	50	50
TOTAL URBAN AREA						310	330	560	1200
UPSTREAM DRAINAGE AREA						600	0	20,000	20,600
TOTAL DRAINAGE AREA						910	330	20,560	21,800

TABLE 4-3. ESTIMATED TSS LOADS FOR THE TARGETED AREA.

LAND USE CATEGORY	TSS LOAD (pounds per inch of rain) STREAM A	STREAM B	STREAM C	URBAN TOTAL
INDUSTRIAL	0	2452	0	2452
COMMERCIAL	145	1162	1598	2906
RESIDENTIAL - HD	817	817	409	2043
RESIDENTIAL - LD	908	0	908	1816
OPEN - DEVELOPING	0	0	511	511
OPEN - URBAN PARK	0	0	57	57
WATERSHED TOTAL	1870	4431	3482	9784
WATERSHED RANK VALUE	1.7	4.1	3.2	9.0

Table 4-2 presents a summary of the information that describes the urban area and the runoff concentrations assigned for the different land uses in the urban area. The runoff coefficient (Rv) is computed from the percentage of impervious area as described earlier in Chapter 2. The percent impervious area must be estimated from appropriate local maps or inspections, or from the approximate relationship described in Chapter 2.

Mass loading results for total suspended solids are presented in Table 4-3. These loads are computed using Equation 4.1, based on one inch of rainfall, and using the assigned areas, runoff coefficients and concentrations that were summarized in Table 4-2. The pollutant load is computed for each land use category, in each watershed. Individual watershed components are summed to provide a total for each stream. This table organization permits a direct visual indication of the differences between stream totals, and the contributions of the different land use types.

Each stream load is converted to a rank values at the bottom of Table 4-3, which will become its assigned value for the *pollutant load* factor in the overall ranking procedure. The rank values for any stream (X) is computed as its ratio to the load from the total urban watershed.

$$\text{rank X} = \text{rank MAX} \ (\text{load X} / \text{load MAX})$$

The overall urban total load (load MAX) is assigned a rank value of 9 (rank MAX) and the other streams are assigned rank values on the basis of their ratio to the total.

To illustrate the use of the prioritization scheme, rank values have been assigned for each of the targeting factors and entered as shown in Table 4-4. For this hypothetical case, the considerations described below are assumed to be the result of a consensus reached in planning discussions, and the basis for the rank values assigned . Bear in mind that there are no "correct" or "incorrect" rules or rationales for assigning rank values, or weighing the importance of different factors. There is a substantial subjective element involved, and the rationale applied will vary with the local situation. For purposes of illustrating the procedure, we assume that the determinations indicated below represent the collective judgement of the local group involved in the targeting analysis.

- Ranks for the *stream importance* factor, represented by stream size , are assigned in proportion to the total drainage area (urban and upstream) providing flow to the stream.
- *Beneficial use type* ranks are based on providing a mid-range ranking value to stream A, whose actual use is a habitat for aquatic life, with little or no direct human contact. (Alternatively,if runoff quality impacts were not considered to present a significant threat to human health, and protection of aquatic life was considered the highest valued beneficial use, then a higher rank value would be assigned to stream A.).

  Stream B is assigned a low rank on the basis that, although water quality is the poorest, the stream is viewed primarily as an urban drain. In effect, reclaiming this stream is given a much lower priority than protecting or improving other streams in the area.

  Stream C, and the downstream combination of all the urban streams, are assigned a high rank because of the active recreational use of the water at the city park and the downstream recreational area. The high visibility and social value of these facilities make the protection of their primary use an important issue.

TABLE 4-4 PRIORITIZATION ANALYSIS FOR URBAN AREA TARGETING

URBAN WATERSHED	STREAM SIZE	USE			POLLUTANT LOAD TSS	ABILITY TO IMPLEMENT	TARGET SCORE
		TYPE	STATUS	LEVEL			
WEIGHTS	25	10	10	5	25	25	100
WATERSHED A	4	5	7	4	1.7	5	4.08
WATERSHED B	2	2	2	1	4.1	7	3.73
WATERSHED C	8	8	2	6	3.2	3	4.85
TOTAL URBAN WATERSHED	8	8	5	8	9.0	2	6.45

TARGET SCORE = WEIGHTED AVERAGE OF RANK POINTS

$$= \frac{\text{SUM (RANK SCORE * WEIGHT)}}{\text{SUM (WEIGHTS)}}$$

- *Beneficial use status* ranks are based on the following reasoning.

  Streams A's use is still a viable one, but is somewhat impaired, and it is felt that it can be improved and protected by control of the runoff loads. It is assigned a high rank compared to the others.

  Streams B receives a low rank for two different reasons. Stream B has had poor quality water for so long that the denial of any use other than conveyance of drainage water has long been accepted. There is no current biota or human contact to be protected. The part flowing through the city park is in a buried culvert.

  Stream C is given a low rank for a completely different reason. The quality is still good. The value of pollution prevention to avoid degradation is not being dismissed, but rather a judgement is made that current status of the use is such that the need for action on this stream is less pressing.

  The combined total watershed flow below town is ranked higher than C. Quality is somewhat poorer (because it is affected by the loads coming from A and B). A use status rank between A and C is assigned.

- *Use level* ranks are a reflection of the relative number of people using or affected by the different stream segments. The total urban watershed is assigned the highest rank because the indicated recreational area there is popular and heavily used.

  Stream C is ranked slightly lower, but relatively high, because it is the main stream flowing through the town, is visible from many areas, and protection of its aesthetic appearance is considered desirable.

  Stream A is next lower on the scale principally because it runs through a low density residential area, and only a small portion of the local population comes in contact with it.

  Stream B receives the lowest rank because few even see it and no one actually uses it.

- *Pollutant load* ranks are assigned in proportion to the loads from each area that were developed on Table 4-2, as described earlier. TSS has been used as the general indicator of runoff pollutants for illustrative purposes. The analysis would be repeated using the other pollutants to determine whether the targeting decision is affected by the choice, since each is reflective of a different type of impact. For example, the concern stated above for protecting the aesthetic quality in Stream C and at the recreational area would be best indicated by evaluating the same type of comparison results using the Oil&Grease surrogate pollutant.

  The total watershed has the highest rank because it reflects the loads from all the others.

  Stream B has the second highest loading rank because of the high imperviousness and concentrations of the industrial and commercial areas it contains. This is followed by C which has a large area and significant commercial land use. Moderately sized Stream A with essentially all residential use, has the lowest rank.

- *Ability to implement* ranks assume that control would be easiest to apply in watershed B, because a major part of the area is industrial. Watershed C and the total urban watershed are given lower ranks than A because there is a greater area to control. In practice, physical factors such as steep slopes, high groundwater, rock, etc. would also influence the rank value assigned.

For the illustrative analysis, equal weights are assigned to the four factors. Since beneficial use has three sub-categories, weights are assigned so that they total to 25 to be consistent with the others.

On the basis of the site data and the series of value judgements discussed above, the prioritization results shown by Table 4-4 suggests that pollutant controls be applied first to watershed C, then to A, and finally to B. Although the "total urban area" has the second highest score, it implies control of the entire urban area.

With the use of this targeting methodology, sensitivity analyses are easy to perform and are recommended. In addition to repeating the analysis with other pollutants as mentioned earlier, the ranks (or weights) can be modified to determine the sensitivity of the targeting decision. For example, if all uses were considered equally important, and in about the same condition (good or poor) then zero weights could be assigned to everything but pollutant loads. In this case, the higher loads from watershed B would put it at the top of the targeting list.

4.5 DISCUSSION

There is no "magic formula" that can be applied that will "decide" for a user, the most appropriate priority to assign for a general implementation program. The degree of subjectivity in assigning both rank values and weights will be apparent as the targeting procedure is applied. The principal value of a formal procedure for an analysis with this unavoidable degree of subjectivity, is that it provides a way to document the decision process. Equally useful is the fact that it provides a framework to organize the thought process and provides a structure to the intermediate decision elements that determine the relative importance of different factors in the local situation.

Some urban jurisdictions will have relatively unique features that cannot be realistically reflected in a generalized procedure. In such a case, additional factors may be added to the assessment.

Similarly, the procedure could be made more complex in terms of the estimation of loads and relating them to the nature and severity or the water quality impact they cause. This consideration was rejected in the interest of keeping the procedure simple, and because value judgements on elements that are not subject to formal computation are also important in the targeting process.

Some judgement is required in the interpretation of the computed pollutant loads. They should not be used to infer either the presence or absence of an actual problem, which will also depend on a number of other factors. The loads computed are based on an arbitrary one inch of rainfall in an attempt to emphasize that they reflect only the comparative pollution potential of the different areas.

The rank values developed for this factor, which are based on pollutant load contributions from the different watersheds, will be quite different depending on the pollutant selected for analysis. This can be inferred by inspecting the relative differences in runoff concentrations listed in Table 4-2, for the different pollutants. For example it can be seen that for Oil&Grease industrial and commercial runoff contributions are dramatically different than residential inputs. They can be expected to make a greater contribution to aesthetic-type problems. Residential lawns and vegetated undeveloped areas, on the other hand, will tend to be more significant sources of nutrients.

The accuracy of the concentration relationships presented in Table 4-2 will obviously influence the rank values developed for this factor. The ratios shown are reasonable, based on interpretation of available data, but by no means absolute. This uncertainty is compensated for by the fact that estimated loading comparisons are only one of a suite of different factors that are used in establishing an overall targeting priority scheme. In cases where the pollutant loading factor will have a dominant influence on the priorities, it will be well to refine the Table 4-2 estimates with local data.

Pollutant loadings have virtually no effect on certain classes of problems commonly associated with urbanization. Examples include habitat modification, loss of natural wetland areas, and channelization of streambeds produced by physical site alterations. In such cases, the pollutant loading factor would be assigned an appropriately low weight. Adding an appropriate ranking factor that would reflect these issues (either an additional one, or as a substitute for the pollutant load factor) should be considered.

With regard to the weighting of the different ranking factors, note that there is no absolute necessity to assign weights so that they add up to a total of 100 as suggested. Any value would work equally well since we are comparing relative scores. Apart from simplifying the arithmetic, the use of a value like 100 (or 1000) for a consistent total weight will help a user keep in mind that is a *relative* weight (or relative degree of importance) that is being assigned to a ranking factor. If the importance of a particular factor is increased by giving it a greater weight, the emphasis is relative to and at the expense of the other factors, one or more of which should be reduced accordingly. Thus, while the total weight matters not at all for any single analysis, it is important to provide a consistent basis when the analysis considers testing the relative importance of the different factors.

The targeting procedure presented in this manual does not address the follow-on steps of determining what to do and where to start in the prioritized watershed. Such determinations will be highly site-specific. Some background has been provided in Chapter 3, which will be helpful in getting started. Nor does it address other closely related issues which should nevertheless receive adequate attention. A formal procedure is desireable for tracking implementation progress and related water quality benefits that accrue. Progress in the implementation of NPS control actions, and changes in the community through growth and development will result in a changing situation, which in time may be sufficient to warrant modifications to the prioritization scheme developed by the targeting analysis. Periodic reassessment of management plans and updating of targeting results will be important elements of an effective program.

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