33

Quality of Urban Runoff

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33.1 Urban Runoff

Urban runoff is a major environmental concern. The old paradigm of only controlling flow to mitigate flood damage must be extended to incorporate preventing deterioration of water quality. For the purposes of this chapter, **urban runoff** is water flowing because of urbanization and may occur from the following sources: stormwater runoff, combined sewer overflows, sanitary sewer overflows, publicly owned treatment works and industrial outfalls, and/or miscellaneous runoff. There are other sources of runoff that contribute to the deterioration of water quality, including agricultural runoff, but those are not considered urban sources. The major volume of urban runoff is composed of water that flows from landscaped areas, driveways, streets, parking lots, roofs, and from other impervious surfaces.

This chapter provides an overview of the sources of urban runoff in terms of quantity and quality, discusses water quality regulations and criteria, and shares best management practices, which often require detailed modeling of the urban system. Relevant investigations carried out by various agencies are included, such as NURP (National Urban Runoff Program, EPA, 1983). The TMDL (Total Maximum Daily Load) program is discussed and should be viewed as a management practice to control the quality of urban runoff (EPA, 2000c).

Before considering the impacts of pollution on urban water quality, the effect of urbanization on the hydrologic cycle must be investigated. As watersheds become urbanized, hydrological characteristics drastically change. Urbanization can result in the following changes of a catchment's hydrologic cycle (WEF/ASCE, 1998):

- reducing the degree of infiltration and increased runoff volumes resulting from surface changes (altered grading, form, or cover);
- changing the available depression storage because of re-grading;

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* Due to the untimely death of Dr. Wukasch, this chapter was completed by his co-authors and was reviewed by Reggie Baker of the Indiana Department of Environmental Management.

- changing evapotranspiration as vegetative cover is removed; and
- reducing the residence time of water in a catchment as a result of increased impervious areas or the construction of efficient sewer systems.

Clearly, the main cause for increased quantity of runoff when considering similar catchments in urban and rural areas is the increased impervious surface. Land use changes with urbanization cause average curve numbers and runoff coefficients to increase and the time of concentration to decrease. (A table of runoff curve numbers can be found in Chapter 32, "Urban Drainage".) The relationship between runoff coefficient (event runoff volume divided by event rainfall volume) and percent impervious area has been widely studied. A 1994 study of 40 runoff-monitoring sites in the U.S. indicated that percent watershed imperviousness is nearly equal to the runoff coefficient, and becomes a more perfect indicator of percent runoff as imperviousness increases (Schueler, 1994).

The different hydrologic responses of developed urban areas when compared to natural or rural settings are worth considering. Increased flow velocities are generated as excess water flows more rapidly over impervious surfaces. Runoff volume from an impervious parking lot is 20 times that which results from a 1% impervious measure of the same flow length and slope (Schueler, 1994). The susceptibility of sensitive catchments to development is further shown as an urban catchment generated over 250 times the peak flow and over 350 times the suspended sediment as compared to a 20% larger rural catchment (Cherkauer, 1975).

Point Sources

The terms point and nonpoint source have been used to identify types of pollution in urban runoff. The current statutory definition of a **point source** as defined by the Water Quality Act (U.S. Congress, 1987) is:

> The term "point source" means any discernable, confined and discrete conveyance, including but not limited to any pipe, ditch channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged. This term does not include agricultural, stormwater, and return flows from irrigated agriculture.

Typically, point source pollution can be traced to a single point such as a pipe or outfall. The main components of urban runoff that are identified as point sources of pollution are **publicly owned treatment works** (POTWs) and industrial outfalls, stormwater outfalls, **combined sewer overflows** (CSOs), and **sanitary sewer overflows** (SSOs).

Historically, substandard effluent quality from POTWs and industrial facilities was a common occurrence. However, as a result of increased awareness and stricter regulations, effluents have become controlled under permits and mandates. A widespread implementation of advanced treatment methods at POTWs and industrial facilities has resulted in a higher quality of effluent. Approximately 16,000 POTWs and tens of thousands of industrial facilities discharge treated wastewater in the U.S. Although the wastewater has been treated, many pollutant residuals remain in the effluent and are considered continuous point sources of pollution.

The improved quality of treated municipal and industrial wastewater effluent has caused other point sources of pollution to be scrutinized. Much attention has been shifted to point sources that intermittently "overflow" such as CSOs and SSOs. There are many possible reasons that may cause sewer systems to overflow untreated wastewater into a receiving body and are as follows (EPA, 2001a and 2001c):

- Infiltration and Inflow: flow that infiltrates through the ground into leaky sewers during large rainfall events and flow from various diffuse sources such as broken pipes.
- Undersized Systems: pumps and sewer piping inadequately sized to handle system demand resulting from increased urbanization.
- Equipment Failures: pumps and controls either fail or are inoperable due to power outages.
- Sewer Service Connections: old or damaged sewer service connections to houses and buildings.
- Deteriorating Sewer Systems: may result from improper installation and maintenance.

FIGURE 33.1 Map showing prevalence of CSOs in U.S. (EPA, 2001a).

Combined sewers were designed to convey a mixture of stormwater, infiltration, miscellaneous runoff, and raw sanitary sewage. During dry conditions, wastewater is directed to a POTW for treatment. However, in wet weather periods the design capacity of the combined sewer system can be exceeded. Excess water is then discharged through a CSO directly to a receiving body such as a stream, river, lake, or ocean. Communities with CSOs are typically found in older cities located in Northeastern and Great Lakes regions of the U.S. Figure 33.1 not only shows a distribution of cities in the U.S. with active CSOs, but also provides an idea of which areas are most vulnerable to pollution from CSO discharges (EPA, 2001a).

It is estimated that combined sewers serve 950 communities with about forty million people in the U.S. Some cities have as many as 280 outfalls. CSOs discharge toxic materials, solids, and bacterial and viral pathogens at potentially harmful levels into receiving bodies, which may be used for recreation or drinking water. An estimated total of 15,000 CSO discharges occur annually (EPA, 2001a).

Problems with sanitary sewers also pose a threat to human health and the environment. Since sanitary sewers are designed only to convey raw municipal wastewater to POTWs, SSOs can release raw sewage wherever sewer pipes travel enroute to the treatment facility. Due to the nature of the waste discharged from SSOs, exposure could result in sickness or death caused by pathogens and toxins. It is estimated that over 40,000 SSO events occur in 18,500 municipal sewers in the U.S. annually (EPA, 2001c).

Nonpoint Sources

All sources of pollution not defined as point sources are thereby nonpoint sources. **Nonpoint source** pollution comes from many diffuse sources. Some examples of nonpoint source pollution include agricultural runoff, urban runoff from sewered and unsewered communities, construction site runoff, septic tanks, wet and dry **atmospheric deposition**, and any other activities on land that generate runoff (Novotney et. al, 1994). Nonpoint source pollution is the main reason that 40% of the surveyed water bodies in the U.S. are not suitable for basic uses such as fishing and swimming (EPA, 1997a). Three main sources of nonpoint source pollution that contribute to urban runoff are stormwater runoff, shallow groundwater runoff, and miscellaneous runoff.

Stormwater runoff is defined as surface water runoff that flows into receiving bodies or into storm sewers. Currently only a small percentage of communities in the U.S. have stormwater runoff treatment initiatives. Stormwater runoff poses a special concern given that pollutants buildup during dry weather periods and then **washoff** following runoff events.

TABLE 33.1 Comparison of Areal Loadings of Pollutants From a Hypothetical American City of 100,000 People in tons per year (Pitt and Field, 1977)

Pollutant	Stormwater	Raw Sewage	Treated Sewage
Total Solids	17,000	5200	520
COD	2400	4800	480
BOD_5	1200	4400	440
Total Phosphorus	50	200	10
TKN	50	800	80
Lead	31	—	—
Zinc	6	—	—

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Shallow groundwater runoff is considered a nonpoint source of pollution given that any contaminant in contact with subsurface water may potentially be transported to receiving water bodies. Although this transport process appears slow, it may actually be accelerated as groundwater seeps onto impervious surfaces or infiltrates into faulty sewer systems. This form of nonpoint source pollution has been linked to groundwater contamination. A major nonpoint source of pollution in shallow groundwater deposits occurs due to flawed decentralized wastewater systems.

Decentralized wastewater systems are more commonly referred to as septic systems, private sewage systems, or individual sewage systems. A septic system works by retaining heavier solids and lighter fats, oils, and grease and discharging partially clarified water to a distribution and soil infiltration system. When these systems fail, it is often unnoticed and can become a significant nonpoint source concern. States report failed septic systems as the third most common source of groundwater contamination. Malfunctioning septic systems have been questioned as a potential source of contamination of drinking water that is estimated to cause 168,000 viral and 34,000 bacterial infections annually (EPA, 2000b).

Other contributions to nonpoint source pollution in urban runoff can be classified as miscellaneous runoff sources. Examples include excess water runoff from car washing or over watering of landscaped areas. Other sources consist of flushing fire hydrants, rubbish water leaking from trash, and improperly discarded oils. These sources are considered a major component of nonpoint source pollution, which carry pollutants and pose a threat to the quality of urban runoff.

33.2 Quality of Urban Runoff

The EPA recognizes that urban runoff is the leading cause of current water quality problems in the U.S. Table 33.1 provides a comparison of pollutant loadings from a hypothetical American city of 100,000 people. The data show that loadings from stormwater exceed that of the treated sewage.

Point Source Pollution

Although combined sewer systems can contain highly diluted sewage during wet weather flows, the overall quality of discharged water remains low. A 1978 investigation by the EPA provided an analysis of pollutants caused by CSOs. Table 33.2 shows nationwide average characteristics of CSOs. Pollutant concentrations are lower than typical raw wastewater composition, but the numbers exceed water quality criteria and pose an environmental threat to receiving waters. The investigation showed that CSOs contribute 15 times the lead and suspended solids of secondary wastewater treatment discharge. In addition, coliform bacteria are present in high quantity, potentially causing waterborne diseases in receiving communities.

Nonpoint Source Pollution

Nonpoint source pollution generated from various diffuse sources includes many pollutants, which are finally deposited into lakes, rivers, wetlands, coastal waters, and possibly underground aquifers. These pollutants include (EPA, 1997a):

TABLE 33.2 Nationwide Average Characteristics of CSOs (EPA, 1978)

Parameter	Average Concentration
BOD_5 (mg/l)	115
Suspended solids (mg/l)	370
Total Nitrogen (mg/l)	9–10
Phosphate (mg/l)	1.9
Lead (mg/l)	0.37
Total Coliforms (MPN/100 ml)	10^2–10^4

- Excess fertilizers and pesticides from residential areas – These compounds when conveyed downstream can contribute to algal blooms and other environmental nuisances caused by **eutrophication**.
- Oil, grease and toxic chemicals from urban runoff generated from residential or industrial activities – Oils and grease can leak onto road surfaces to be discharged into storm sewers or carried by rain or snowmelt directly to surface waters.
- Sediment from construction sites and other urban activities are eroded from the land and transported to surface waters. This causes gradual sediment deposition in streams and lakes.
- Salt and other deicing compounds that could either be distributed on roads or stored in an urban area. Melted snow containing salts or other deicing compounds can produce high sodium and chloride concentrations in ponds, lakes and bays. This could also cause fish kills.
- Heavy metals which come from various sources including the natural ones, such as minerals, sand, and rock, can degrade water quality and cause detrimental effects on aquatic life and water resources including groundwater aquifers. Industrial runoff also contributes a high concentration of heavy metals.
- Animal droppings, grass clippings and other urban wastes contribute bacteria and nutrients that lead to degradation of receiving waters.
- Other constituents deposited by atmospheric deposition. The acidic nature of urban rainfall can lead to damages in urban infrastructure and vegetation.

All pollutants contained within stormwater runoff such as toxic chemicals, heavy metals, nutrients, litter, sediments, and other constituents can pose a threat to human health and the environment.

Figure 33.2 shows the ubiquitous nature of nonpoint source of pollution resulting from urbanization. Collectively, nonpoint sources can potentially result in toxic, nutrient, and pathogenic pollutions in addition to causing negative aesthetic impacts on communities (Walesh, 1989).

Nationwide Urban Runoff Program (NURP)

NURP (EPA, 1983) provided a comprehensive investigation of the quality of urban runoff and was based on an extensive study conducted from 1978 to 1983 by the EPA and U.S. Geological Survey (USGS). The program included 2300 storm events at 81 sites in 22 different cities throughout the U.S. The principal conclusions quoted from NURP's Executive Summary are:

1. Heavy metals (especially copper, lead and zinc) are by far the most prevalent priority pollutant constituents found in urban runoff.
2. The organic priority pollutants are detected at lower concentrations than heavy metals.
3. Coliform bacteria are present at high levels in urban runoff and can be expected to exceed EPA water quality criteria during and immediately after storm events in many surface waters, even those providing a high degree of dilution.
4. Nutrients are generally present in urban runoff.

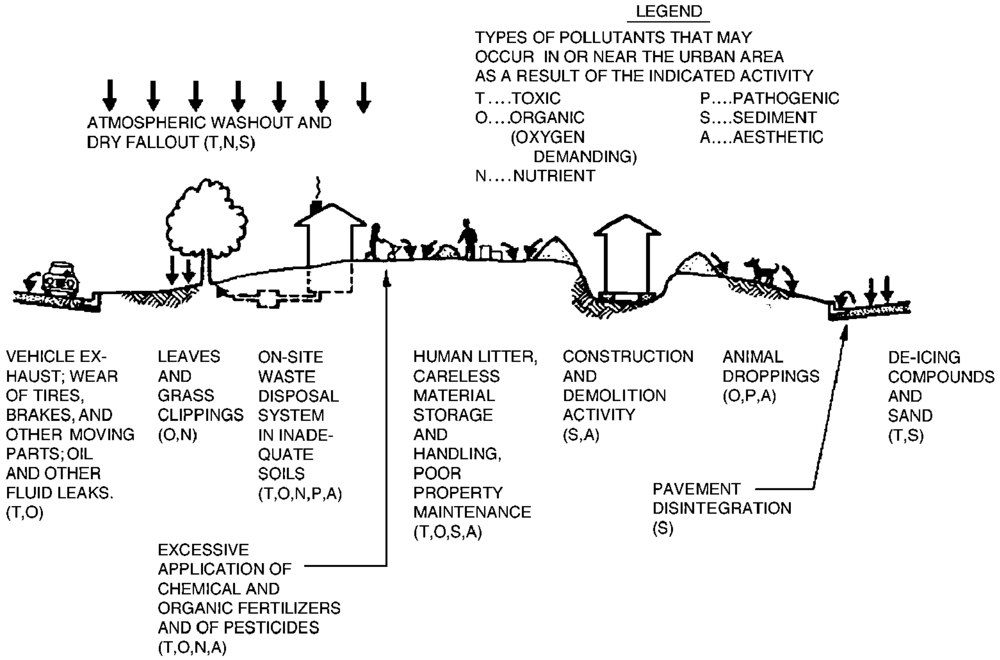

FIGURE 33.2 Nonpoint source pollution as a result of urbanization (Walesh, 1989).

5. Oxygen-demanding substances are present in urban runoff at concentrations approximating those in secondary treatment plant discharges.
6. Total suspended solids concentrations in urban runoff are fairly high in comparison to treatment plant discharges.

The EPA adopted the following constituents as standard pollutants to characterize the quality of urban runoff:

TSS = Total Suspended Solids
BOD = Biochemical Oxygen Demand
COD = Chemical Oxygen Demand
TP = Total Phosphorus (as P)
SP = Soluble Phosphorus (as P)
TKN = Total Kjeldahl Nitrogen (as N)
NO_{2+3}-N = Nitrite and Nitrate (as N)
Cu = Total Copper
Pb = Total Lead
Zn = Total Zinc

Using the above constituents, the study characterized the quality of urban runoff in the U.S. based on **event mean concentrations (EMC)**. EMC is the average pollutant concentration in runoff generated from a storm event. The results consist of flow-weighted average concentrations. Table 33.3 shows water quality characteristics of urban runoff based on a median and a coefficient of variation of the established EMCs. The report recommended using the data for planning purposes as a description of urban runoff characteristics.

Taking the above data and converting them to mean values produces Table 33.4, which shows EMC mean values used in load comparison. The mean range is shown for both the median and 90th percentile urban site. The difference in means reflects the dependence of the mean value on the coefficient of variability used. Load comparison values indicate a combination of the previous two columns.

TABLE 33.3 Water Quality Characteristics of Urban Runoff

Constituent	Event-to-Event Variability in EMCs (Coef Var)	Site Median EMC	
		For Median Urban Site	For 90th Percentile Urban Site
TSS (mg/l)	1–2	100	300
BOD (mg/l)	0.5–1.0	9	15
COD (mg/l)	0.5–1.0	65	140
Tot. P (mg/l)	0.5–1.0	0.33	0.70
Sol. P (mg/l)	0.5–1.0	0.12	0.21
TKN (mg/l)	0.5–1.0	1.50	3.30
NO_{2+3}-N (mg/l)	0.5–1.0	0.68	1.75
Tot. Cu (μg/l)	0.5–1.0	34	93
Tot. Pb (μg/l)	0.5–1.0	144	350
Tot. Zn (μg/l)	0.5–1.0	160	500

Source: U.S. EPA, 1983, Vol. 1, Table 6–17, pp. 6–43.

TABLE 33.4 EMC Mean Values Used in Load Comparison

Constituent	Median Urban Site	Site Median EMC	
		90th Percentile Urban Site	Values Used in Load Comparison
TSS (mg/l)	141–224	424–671	180–548
BOD (mg/l)	10–13	17–21	12–19
COD (mg/l)	73–92	157–198	82–178
Tot. P (mg/l)	0.37–0.47	0.78–0.99	0.42–0.88
Sol. P (mg/l)	0.13–0.17	0.23–0.30	0.15–0.28
TKN (mg/l)	1.68–2.12	3.69–4.67	1.90–4.18
NO_{2+3}-N (mg/l)	0.76–0.96	1.96–2.47	0.86–2.21
Tot. Cu (μg/l)	38–48	104–132	43–118
Tot. Pb (μg/l)	161–204	391–495	182–443
Tot. Zn (μg/l)	179–226	559–707	202–633

Source: U.S. EPA, 1983, Vol. 1, Table 6–24, pp. 6–60.

TABLE 33.5 Annual Urban Runoff Loads (Kg/Ha/Year)

Constituent	Site Mean Conc. (mg/l)	Residential	Commercial	All Urban
Assumed Rv		0.3	0.8	0.35
TSS	180	550	1460	640
BOD	12	36	98	43
COD	82	250	666	292
Total P	0.42	1.3	3.4	1.5
Sol. P	0.15	0.5	1.2	0.5
TKN	1.90	5.8	15.4	6.6
NO_{2+3}-N	0.86	2.6	7.0	3.6
Tot. Cu	0.043	0.13	0.35	0.15
Tot. Pb	0.182	0.55	1.48	0.65
Tot. Zn	0.202	0.62	1.64	0.72

Note: Assumes 40-inches/year rainfall as a long-term average.
Source: U.S. EPA, 1983, Vol. 1, Table 6–25, pp. 6–64

By choosing the appropriate rainfall and land use data and selecting the EMC value from Table 33.4, the mean annual load can be estimated for the urban runoff constituents. Table 33.5 shows annual urban runoff loads for different types of urban developments based on a 40-in. per year rainfall.

TABLE 33.6 Comparison of the Strength of Point and Nonpoint Urban Sources

Type of Wastewater	BOD$_5$ (mg/l)	Suspended Solids (mg/l)	Total Nitrogen (mg/l)	Total Phosphorus (mg/l)	Lead (mg/l)	Total Coliforms (MPN/100 ml)
Urban stormwater[a]	10–250 (30)	3–11,000 (650)	3–10	0.2–1.7 (0.6)	0.03–3.1 (0.3)	10^3–10^8
Construction site runoff[b]	NA	10,000–40,000	NA	NA	NA	NA
Combined sewer overflows[a]	60–200	100–1100	3–24	1–11	(0.4)	10^5–10^7
Light industrial area[c]	8–12	45–375	0.2–1.1	NA	0.02–1.1	10
Roof runoff[c]	3–8	12–216	0.5–4	NA	0.005–0.03	10^2
Typical untreated sewage[d]	(160)	(235)	(35)	(10)	NA	10^7–10^9
Typical POTW effluent[d]	(20)	(20)	(30)	(10)	NA	10^4–10^6

Note: () = mean; NA = not available; POTW = Publicly owned treatment works with secondary (biological) treatment.

[a] Novotny and Chesters (1981) and Lager and Smith (1974).

[b] Unpublished research by Wisconsin Water Resources Center.

[c] Ellis (1986).

[d] Novotny, et al. (1989).

Comparison of Pollution Sources

Results and conclusions from the NURP investigation clearly show the high concentration of pollutants generated during wet weather flow. Exact loadings from different nonpoint sources can be analyzed and compared to that of point sources, such as CSOs, SSOs and treated wastewater effluent. Table 33.6 comparatively provides additional information on the relative strengths of potential sources of point and nonpoint source pollution within an urbanized area.

The one issue that remains critical is whether pollution exceeds water quality criteria recommended by the EPA and enforced by state agencies. The next section will provide an overview of the water quality regulations set forth for the protection of water bodies and present water quality criteria, which can be compared to runoff pollution results.

33.3 Water Quality Regulations and Policies

Water quality regulations in the U.S. have evolved over the last 30 years. The following is a summary of a few relevant federal regulations as they impact urban runoff:

- Federal Water Pollution Control Act of 1972 (PL 92–500) and the Clean Water Act (CWA) Amendments of 1977 (PL 95–217): Under Section 208 of the Act, any discharged point source pollution into navigable waters is prohibited unless allowed by an NPDES permit. The law gave EPA the authority to set effluent standards on a technology basis.
- Safe Drinking Water Act (SDWA) of 1974 (PL 93–523) and 1986 Amendments regulate injection of wastewater into groundwater aquifers. Further, it requires communities with groundwater supply to develop a Wellhead Protection Plan (WHPP). The plan calls for the delineation of potential sources of contamination. See also Chapter 34, “Groundwater Engineering”.
- Resource Conservation and Recovery Act (RCRA) of 1976 (PL 94–580) and Hazardous Waste Amendments of 1984 (PL 98–616) mandate the protection of the environment from accidental or unregulated spills of hazardous substances and leading underground storage tanks.

The Federal Water Pollution Control Act of 1972 and Amendments (CWA) in 1977 provided much of the regulations concerning urban runoff, and govern pollutants discharged in streams, rivers, lakes, and estuaries. The Clean Water Act maintains that all U.S. waters must be "fishable and swimmable" at all times. Recent amendments enacted in 1987 under the Water Quality Act (PL 100–4) provided many provisions to previous regulations due to the remaining water quality problems. These provisions include:

- Establishing a comprehensive program to control toxic pollutants.
- Requiring states to develop and implement additional programs to control nonpoint source pollution.
- Authorizing a total of $18 billion in aid for wastewater treatment assistance.
- Authorizing additional programs and modifying previous ones to control water pollution in key water-resource areas including the Great Lakes.
- Revising regulatory, permit, and enforcement programs.

Receiving Water Guidance

The National Urban Runoff Program (EPA, 1983) provided principle conclusions to the impact of urban runoff on receiving waters. The effects of urban runoff on receiving waters depend on the type, size, and hydrology of the water body, the urban runoff quality and quantity, and water quality criteria for specific pollutants. NURP's principle conclusions for rivers, streams, lakes, estuaries, and groundwater, quoted from the executive summary, are:

Rivers and Streams

1. Frequent exceedances of heavy metals ambient water quality criteria for freshwater aquatic life are produced by urban runoff.
2. Although a significant number of problem situations could result from heavy metals in urban runoff, levels of freshwater aquatic life use impairment suggested by the magnitude and frequency of ambient criteria exceedances were not observed.
3. Copper, lead and zinc appear to pose a significant threat to aquatic life uses in some areas of the country. Copper is suggested to be the most significant of the three.
4. Organic priority pollutants in urban runoff do not appear to pose a general threat to freshwater aquatic life.
5. The physical aspects of urban runoff, e.g., erosion and scour, can be a significant cause of habitat disruption and can affect the type of fishery present. However, this area was studied only incidentally by several of the projects under the NURP program and a more concentrated study is necessary.
6. Several projects identified possible problems in the sediments because of the build-up of priority pollutants contributed wholly or in part by urban runoff. However, the NURP studies in the area were few in number and limited in scope, and the findings must be considered only indicative of the need for further study, particularly as to long-term impacts.
7. Coliform bacteria are present at high levels in urban runoff and can be expected to exceed EPA water quality criteria during and immediately after storm events in most rivers and streams.
8. Domestic water supply systems with intakes located on streams in close proximity to urban runoff discharges are encouraged to check for priority pollutants which have been detected in urban runoff, particularly organic pollutants.

Lakes

1. Nutrients in urban runoff may accelerate eutrophication problems and severely limit recreational uses, especially in lakes. However, NURP's lake projects indicate that the degree of beneficial use impairment varies widely, as does the significance of the urban runoff component.
2. Coliform bacteria discharges in urban runoff have a significant negative impact on the recreational uses of lakes.

TABLE 33.7 Recommended Water Quality Criteria of Freshwater for Selected Point and Nonpoint Source Pollutants (Adapted from EPA 1986 and 1991)

Pollutant	Acute (short-term) L.O.E.L.	Chronic (long-term) L.O.E.L.
Ammonia (μg/L)	15.7	3.9
Copper (μg/L)	18	12
Lead (μg/L)	82	3.2
Zinc (μg/L)	320	47
Bacteria – *E. Coli*	126 per mL	
Suspended solids	Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10% from the seasonally established norm for aquatic life.	
DO (mg/L)	6.5	4.00
Nitrates/nitrites	10 mg/L for water supply	
Phosphorus	0.10 μg/L (elemental) for marine or estuarine water	

Note: L.O.E.L = Lowest Observed Effect Level

Estuaries and Embayments

1. Adverse effects of urban runoff in marine waters will be at highly specific local situations. Though estuaries and embayments were studied to a very limited extent in NURP, they are not believed to be generally threatened by urban runoff, though specific instances where use is impaired or denied can be of significant local and even regional importance. Coliform bacteria present in urban runoff is the primary pollutant of concern, causing direct impacts on shellfish harvesting and beach closures.

Groundwater Aquifers

1. Groundwater aquifers that receive deliberate recharge of urban runoff do not appear to be imminently threatened by this practice at the two locations where it was investigated.

The conclusions provided by the NURP program for receiving waters can be viewed as recommendations for the abatement of pollution on receiving water bodies in an attempt to meet water quality standards.

Water Quality Criteria (WQC)

The EPA under section 304 of the Clean Water Act (CWA) has developed recommended water quality criteria. The criteria should provide guidance for states in selecting quality standards. The standards can be used in implementing limits based on environmental programs, such as NPDES permits. Recommended water quality criteria for selected pollutants are shown in Table 33.7.

Quality of urban runoff data given by the NURP and other investigations present a range of pollutants, but show high concentrations of metals, suspended solids, nutrients and bacteria. The recommended water quality criteria can be compared to the quality of urban runoff. A noticeable gap exists between runoff concentrations and water quality criteria. This shows that additional control and treatment is needed to improve the quality of receiving waters, which requires the development of management practices and control plans.

33.4 Modeling

The development of control plans or management practices for urban catchments requires a detailed understanding of all the inputs to urban runoff quality within the watershed. Modeling allows for a greater comprehension of the integrated urban water system. For situations that are best approached through modeling, the following rationales may be considered (WEF/ASCE, 1998):

- Characterize temporal and spatial details of quality and quantity of urban runoff;
- Perform frequency analysis to determine return periods for urban runoff quality parameters such as concentrations and loads;
- Determine configurations for urban runoff control options with regard to magnitude and location;
- Provide a drive for a receiving water quality model with quality and quantity of urban runoff as inputs; and
- Provide input for cost to benefit analyses.

Modeling Categories

When considering urban runoff quality, modeling can be useful in a planning, design, or operational situation. Three general modeling categories are available for approaching situations and are as follows (EPA, 1995a):

- Land Use Loading Models: These models provide pollutant loading as a function of the distribution of land use within the watershed. In this approach, water quality parameters may either be represented as constant concentrations or as unit loadings. Overall runoff quality is determined as a weighted sum of characteristic concentrations for the catchment.
- Statistical Methods: Often called the EPA Statistical Method, this technique is a more sophisticated rendering of Land Use Loading Models discussed above. It recognizes that Event Mean Concentrations (EMCs) are not constant but rather are distributed log normally. Combining the EMC distribution with distributed runoff volumes will yield the load distribution.
- Buildup/Washoff Models: These models attempt to simulate the "buildup" process where pollutants collect during dry weather periods and then "washoff" during storm events. By considering time periods, rainfall events, and management practices, the basic processes that control the quality of urban runoff can be investigated. For additional information on buildup/washoff models, see for example Novotny and Chesters (1981) or Delleur (1998).

Data

Regardless of the selected modeling approach, two types of data will be necessary. First, fundamental input data such as rainfall information, land slope, and water quality data will be necessary to compile most models. Potential sources for necessary water quality modeling data are contained in Table 33.8. Additionally, individual state agencies (such as departments of natural resources, departments of environmental management, or EPA) may be able to provide guidance on data collection. The second type of data represents the quality and quantity parameters the model attempts to characterize. It should be collected from sites within the modeled catchment and is used for the calibration of modeling results.

Point Source Models

Models analyzing point and nonpoint source pollution have been developed. Most point source modeling techniques are designed for modeling stormwater and combined sewer overflows. The Storm Water Management Model (SWMM) is a widely used model, which provides a complete simulation of the hydrologic, hydraulic, and environmental aspects of urban drainage systems. SWMM was developed in the 1970s for the EPA, is public domain, and is frequently updated. It performs both continuous and single-event simulation throughout the model and can perform quantity and quality modeling in detail. Each block of the model can simulate an aspect of urban runoff and jointly the model simulates the integrated urban water system. Figure 33.3 provides a schematic of principal blocks in the SWMM program. Other models of similar capabilities have been developed to simulate combined sewer systems and their effects on receiving waters. Such models include Statistical by EPA, STORM by HEC (Hydrologic Engineering Center) and others developed by various agencies. In some cases a particular model to be used may be specified. Given the dynamic nature of modeling and software development, evaluation of several models is necessary to ensure an appropriate model is selected. The MOUSE system (1992) is

TABLE 33.8 Data types and possible data sources (EPA, 1997b)

		Source	
Data Type	Federal Agencies	State Agencies	Local Groups
Land Geometry	USGS US Army Corps of Eng. Division/District Offices EPA	Special studies	Planning agencies
Stream Flow	USGS gage records and low flows (available through EPA)	Publications on low flows Basin plans	Universities Planning agencies
Water Quality Data	EPA STORET USGS US Fish & Wildlife Service	Regulatory agencies TMDL studies State Department of Health	Studies by regional planning groups Discharger's studies Universities
Wastewater Loads	EPA Permit Compliance System (PCS)	Discharge Monitoring Reports (DMR)	Municipal and industrial discharger's plant records
Nonpoint source loads	EPA STORET, USGS and US Fish and Wildlife Service; urban runoff data available from EPA NURP; precipitation and meteorological data available from NOAA National Climatic Weather Center; land use data from USGS; soil characteristic data from USDA Soil Conservation Service	Urban runoff data from special studies; precipitation and meteorological data from State planning agencies and local airports; land use data from State planning, agricultural and geological agencies.	Urban runoff data from regional, city and country studies; precipitation and meteorological data from local and county planning agencies and local airports; land use and soils characteristics data from regional and county planning, agricultural, and geological agencies.

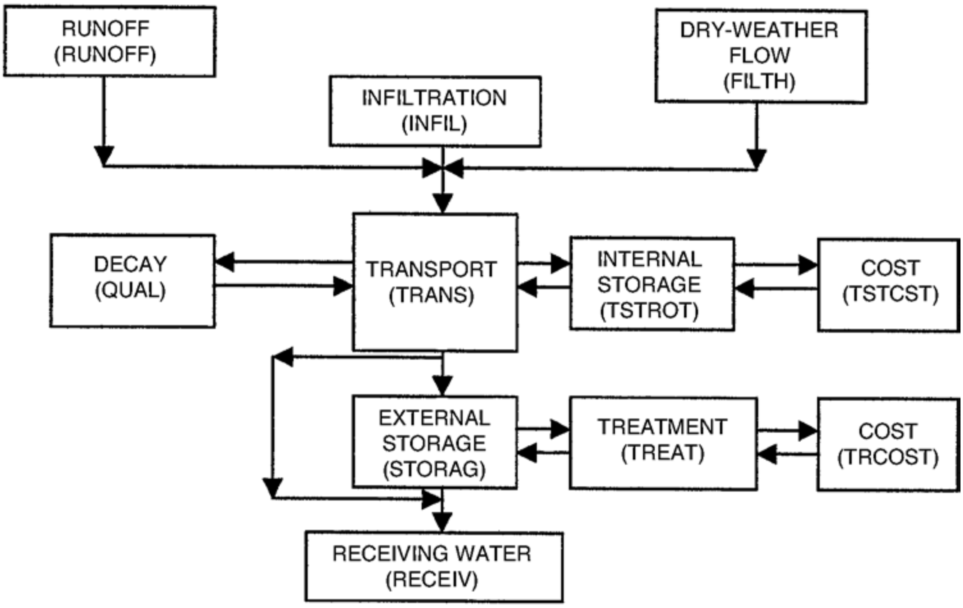

FIGURE 33.3 Components of the Storm Water Management Model (SWMM). Subroutines are in parentheses (EPA, 1971).

frequently used in Europe. Harremoës and Rauch (1996) and Krejci (1998) have advocated the integrated design and analysis of drainage systems, including sewers, treatment plants, and receiving waters.

Nonpoint Source Models

Nonpoint source modeling is a relatively new and rapidly evolving practice as much focus is being shifted towards eliminating nonpoint source pollution to improve water quality. Traditionally, models have focused on estimating the quantity of peak flow. However, much has been done recently to estimate the quality of runoff and receiving waters. A number of models have been developed to estimate and analyze urban nonpoint source pollution, and the following is a brief list of popular models:

- Storage-Treatment-Overflow-Runoff Model (STORM) (ACE, 1974)
- Stormwater Management Model (SWMM) (Huber and Dickinson, 1988)
- Hydrologic Simulation Program-FORTRAN (HSP-F) (Bicknell et al., 1997).

The above models were developed to analyze water pollution from nonpoint urban sources. Due to the geo-spatial variation involved with nonpoint source modeling, an additional tool is needed to further represent constituents over the watershed. Hence, the model can be linked to a geographic information system (GIS). Integrating the nonpoint source model with a GIS tool can provide many benefits including (Bhaduri, 2000):

- model-estimated nonpoint source pollution areas can be identified over the watershed;
- the integrated tools can produce useful information on changes in water quality following implementation of pollution reduction approaches; and
- it can also evaluate alternative management practices for the control of nonpoint source pollution.

The long-term hydrologic impact assessment (L-THIA) model has been developed to estimate the effect of urbanization on the quality of runoff and receiving waters. The nonpoint source model is based on the curve number (CN) method for estimating the quantity and quality of runoff. The model has been integrated with Arc/INFO software as a GIS (Geographic Information System) application. Figure 33.4 shows components of the L-THIA/GIS applications and steps involved in the analysis.

Modeling Considerations

The following fundamentals should be considered regardless of the model chosen or the type of pollution modeled (WEF, 1989 and WEF/ASCE, 1998):

- Develop a clear statement of the project objective. The need for quality modeling should be confirmed to prevent unnecessary modeling.
- The simplest model that will satisfy all project objectives should be chosen. A screening model, such as a statistical or regression method, may help determine if the problem calls for more complex models.
- Use a quality prediction approach that is consistent with available data.
- Predict only the quality parameters that are needed to analyze the problem. For example, do not use storm specific EMCs when the analysis only requires information to a seasonal or annual detail.
- When a model is chosen, perform a sensitivity analysis to become acquainted with the model.
- Have one data set available for calibration of the model and another to verify results obtained.

33.5 Best Management Practices

The gap between water quality criteria and pollutant concentrations found in urban runoff illustrates the urgent need to develop strategies to control runoff and improve quality of receiving waters. Regulations and public awareness have lead to the initiation of best management practices (BMPs) to provide comprehensive solutions.

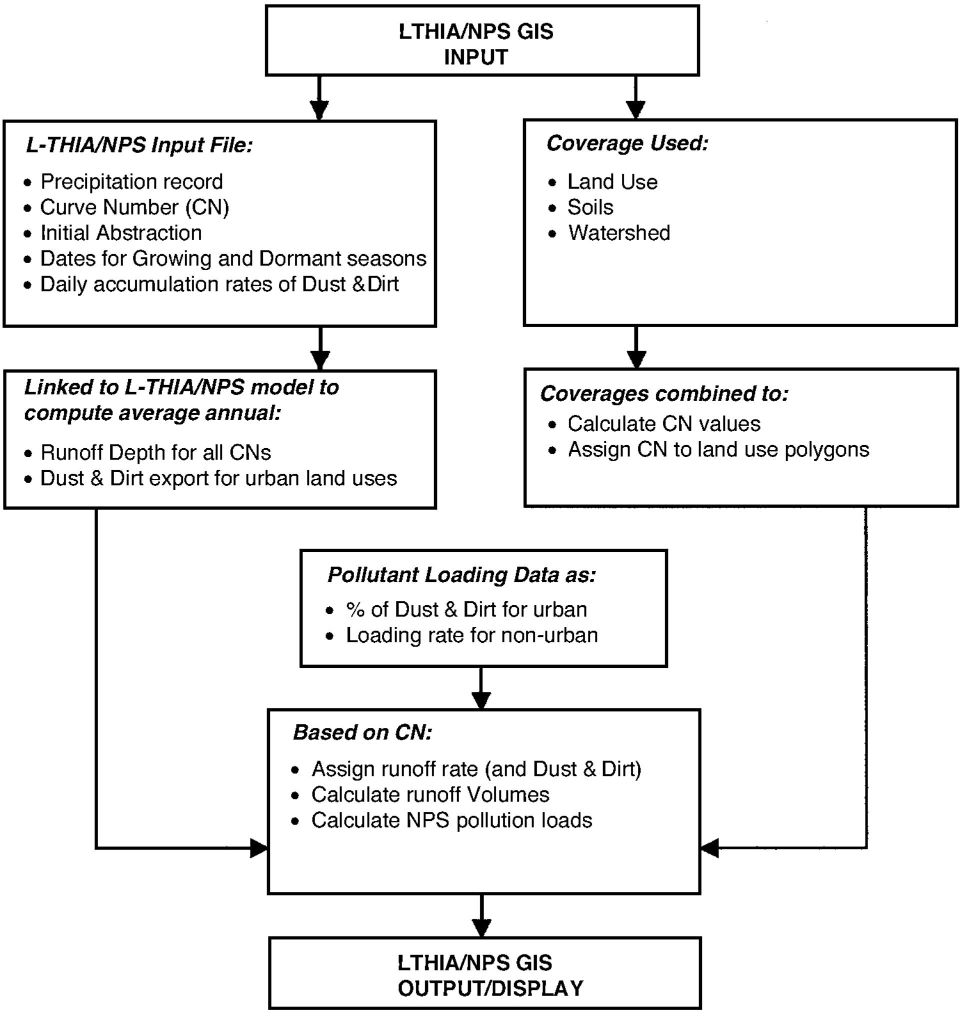

FIGURE 33.4 Components of L-THIA/nonpoint source (NPS) GIS applications and general steps involved in an analysis (Bhaduri et al., 2000).

A BMP can be viewed as a device, practice, or method for removing, reducing, or preventing stormwater runoff pollutants from reaching receiving waters (URS/ASCE/EPA, 1999). Selecting a best management practice involves technical and non-technical considerations. While technical issues are usually considered first, the non-technical issues can present many challenges. Major non-technical selection issues include federal, state, and local regulations, perceived water problems, uses of receiving water bodies, cost, and community perception. Technical issues include source control, local climate, design storm size, soil erosion, stormwater pollutant characteristics, multi-use management facilities, maintenance, and physical and environment factors (slope, area required, soil, water availability, aesthetics and safety, and additional environmental conditions) (WEF/ASCE, 1998).

Point Source Programs

The EPA has established a water quality based Combined Sewer Overflow Control Policy to serve as the framework for the control of CSOs through the NPDES (National Pollution Discharge Elimination System) permitting program. The policy encourages adoptions of overflow controls based on community need while meeting local environmental objectives. The fundamental principles are as follows (EPA, 1994):

1. clear levels of control to meet health and environmental objectives;
2. flexibility to consider the site-specific nature of CSOs and find the most cost-effective way to control them;
3. phased implementation of CSO controls to accommodate a community's financial capability; and
4. review and revision of water quality standards during the development of CSO control plans to reflect the site-specific wet weather impacts of CSOs.

EPA guidance documents for the Policy are continuously published and updated. Under the Policy, the first deadline occurred in 1997 requiring communities with CSOs to implement nine minimum technology-based controls. It was determined that implementation of the controls would reduce the prevalence and impacts of CSOs and would not require significant engineering studies or major construction. The nine minimum controls (NMC) are (EPA, 1995b):

1. Proper operation and regular maintenance programs for the sewer system and the CSOs
2. Maximum use of the collection system for storage
3. Review and modification of pretreatment requirements to assure CSO impacts are minimized
4. Maximization of flow to the publicly owned treatment works for treatment
5. Prohibition of CSOs during dry weather
6. Control of solid and floatable materials in CSOs
7. Pollution prevention
8. Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts
9. Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls

The Policy also requires the development of a comprehensive Long Term Control Plan (LTCP). The LTCP should be integrated with review and revision of water quality standards. The following steps and Fig. 33.5 are useful in developing an effective LTCP that will ensure measures will be sufficient to meet water quality standards provided in EPA guidance documents (EPA, 2001a).

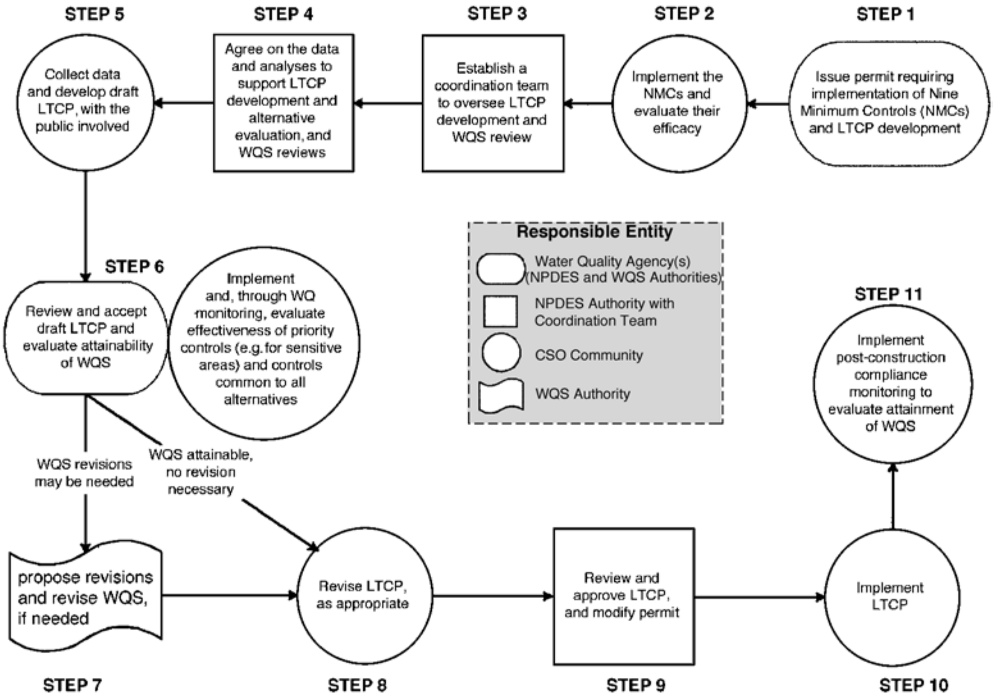

FIGURE 33.5 Steps for developing an effective long-term control plan (EPA, 2001a).

Step 1: Issue permit requiring implementation of the NMCs and LTCP. A permit or other enforceable mechanism requiring immediate action by the CSO community is issued the NPDES authority.

Step 2: Implement NMCs and evaluate their efficacy. The CSO community should evaluate the early level control of the NMCs in managing the number and quality of overflows. Ultimately the NMCs should be incorporated into the LTCP.

Step 3: Establish a coordination team to oversee LTCP development and WQS. The NPDES forms a team that will direct the development of a draft LTCP, promote timely discussion, and provide technical assistance. The coordination team should at minimum include decision-making representatives from the CSO community, State Water Director, and NPDES authority.

Step 4: Agree on the data and analyses to support LTCP development and alternative evaluation and WQS reviews. This step works toward early agreement on the planned process (i.e., milestones and dates) and scope of the LTCP. Additionally, type and amount of data and analyses necessary for control alternatives and water quality standards should be determined.

Step 5: Collect data and develop draft LTCP with public involvement. Following data collection, a draft LTCP is developed which evaluates the cost, feasibility, performance, water quality benefits, and sensitivity for each control. Other sources of pollution are identified that influence CSO receiving water quality.

Step 6: Review and accept draft LTCP and evaluate attainability of WQS. A draft LTCP is submitted to the NPDES authority and the State Water Director for review. The CSO community works with the reviewing agency to confirm the basis of the LTCP is acceptable to achieve WQS. Draft LTCP is revised if insufficient.

Step 7: Propose revisions and revise WQS if needed. To reach this step, all involved decision-making parties have agreed that the LTCP contains adequate data and information for the selection of CSO controls and needed WQS revisions have been identified. The state should quickly seek to revise WQS.

Step 8: Revise LTCP as appropriate. The CSO community would have to revise the draft LTCP if the WQS decisions differ from those anticipated or if the previously implemented controls have not performed as predicted.

Step 9: Review and modify LTCP and modify permit. The NPDES authority coordinates that review of the revisions and, if appropriate, approves the final LTCP. An enforceable permit is then issued requiring implementation of the approved LTCP.

Step 10: Implement LTCP. Approved control measures are implemented and approved operations plans and post-construction compliance monitoring program is carried out.

Step 11: Implement post-construction compliance monitoring to evaluate attainment of WQS. Monitoring data will be used to support changes to the operations plan if it is shown that implemented control measures are contributing to the non-attainment of WQS.

A similar policy (currently in the form of a rule) has been submitted by the EPA for SSO control. The rule seeks to revise existing NPDES permit regulations to improve the operation of municipal sanitary sewer collection systems, reduce the frequency and occurrence of sanitary sewer overflows, and provide more effective public notification when SSOs do occur. The rule largely addresses SSOs and will reduce overflows, provide better information for local communities, and extend lifetime for sanitary sewer systems. Requirements of the proposed rule quoted from the EPA include (EPA, 2001c):

- *Capacity Assurance, Management, Operation, and Maintenance Programs*. These programs will ensure that communities have adequate wastewater collection and treatment capacity and incorporate many standard operation and maintenance activities for good system performance. When implemented, these programs will provide for efficient operation of sanitary sewer collection systems.
- *Notifying the Public and Health Authorities*. Municipalities and other local interests will establish a locally tailored program that notifies the public of overflows according to the risk associated with specific overflow events. EPA is proposing that annual summaries of sewer overflows be made available to the public. The proposal also clarifies existing record-keeping requirements and requirements to report to the state.

- *Prohibition of Overflows*. The existing Clean Water Act prohibition of sanitary sewer overflows that discharge to surface waters is clarified to provide communities with limited protection from enforcement in cases where overflows are caused by factors beyond their reasonable control or severe natural conditions, provided there are no feasible alternatives.
- *Expanding Permit Coverage to Satellite Systems*. Satellite municipal collection systems are those collection systems where the owner or operator is different than the owner or operator of the treatment facility. Some 4800 satellite collection systems will be required to obtain NPDES permit coverage to include the requirements under this proposal

Total Maximum Daily Loads

Section 303 (d) of the Clean Water Act requires states to identify problem water bodies and develop **total maximum daily loads (TMDLs**), which set the maximum amount of pollution that a water body can receive without violating CWA water quality standards. The load includes end-of-pipe pollutants from point sources and nonpoint sources. Therefore, if nonpoint source pollution cannot be reduced, then more treatment is required for wastewater and more control is required for combined sewer systems. This is in response to the over 300,000 rivers and shoreline miles and five million acres of lakes across the U.S. that have been identified as polluted. The EPA defines a TMDL as a “pollution budget” and asserts that applicable water quality standards can be attained and maintained. If a state fails to develop TMDLs for their water bodies, the EPA is required under section 303 (d) of the Act to develop a priority list for the state and make its own TMDL determination. The EPA affirms that the TMDL rule will provide a comprehensive list of all U.S. polluted waters, require states to clean up polluted waters with cost-effective measures, and assure that TMDLs include implementation plans with defined milestones and timelines (EPA, 2000c).

This TMDL control is likely to impact Midwestern states affected by CSOs as well as CFOs (confined feeding operations). The program requires an analysis of the watershed including developing a model to provide an accurate assessment of the pollution present within the watershed. A TMDL will consider all sources contributing to the depletion of water quality within the watershed. Therefore, developing load allocations for a TMDL plan is a critical process. Figure 33.6 illustrates the appropriate steps taken in developing load allocations for the implementation of a TMDL plan. As shown in the figure, when information needed to develop load allocations is not present, the TMDL process becomes very complicated and additional time is required (EPA, 2000c).

Components of a TMDL plan include identification of polluted waters, clean-up schedule, the TMDL program, and an implementation plan. The following are the elements of a TMDL program (EPA, 2000c):

- water body name and location, pollutant(s), and water quality standard;
- amount of pollutant allowable to meet standards, load reduction needed to meet standards, sources of pollutant, wasteload allocation for point and nonpoint sources, and an implementation plan;
- factor of safety to account for seasonal and other variations; and
- public feedback and involvement prior to submission.

The implementation plan accounting for all sources of pollution will include (EPA, 2000c):

- a list of actions needed to reduce loadings and a schedule of implementation;
- “reasonable assurances” that actions will be implemented (an NPDES permit is an assurance for point sources. For other sources, load allocations in a TMDL must apply to the pollutant, be implemented expeditiously, be accomplished through effective programs, and be supported by adequate water quality funding.);
- a monitoring plan with milestones;
- plans for revising the TMDL if no progress is made; and
- water quality standards must be met within 10 years.

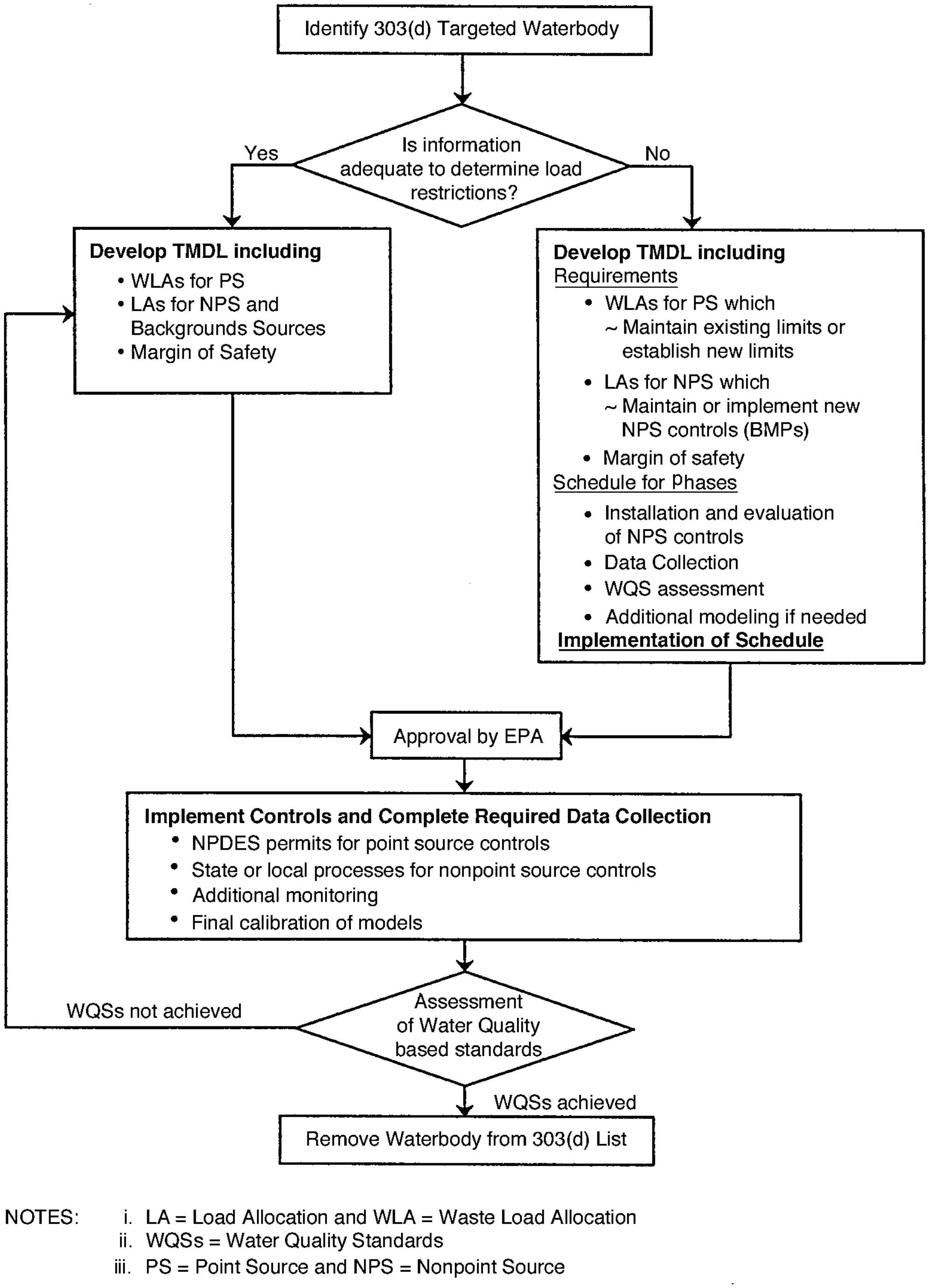

FIGURE 33.6 Flow chart showing steps taking in the development of a TMDL plan (EPA, 2000c).

A TMDL plan may require additional control measures (such as structural measures) to retrieve the quality of a waterbody to the specified criteria. The monitoring plan used to collect data will continue to assess the quality of the watershed. A waterbody is removed from the 303(d) list upon meeting water criteria. Otherwise, the TMDL must be modified by gathering additional data and information (EPA, 2000c).

Nonpoint Source Programs

A few selected nonpoint source programs are detailed below as they apply to the reduction of nonpoint source pollution.

The nonpoint source program (EPA, 2000a) is a state level program that focuses on educating the general public and implementing control measures termed BMPs to reduce nonpoint source pollution. In 1987, Congress enacted Section 319 of the Act to control nonpoint source pollution. Under Section 319, EPA provides technical and program assistance along with funding to the states. The National Monitoring Program (NMP) by the EPA as part of Section 319 establishes that the EPA shall collect information and make the following available:

- information concerning the costs and efficiencies of BMPs for the reduction of nonpoint source pollution; and
- data showing the relationship between water quality and implementation of various management practices.

The two objectives of Section 319 are to evaluate the effectiveness of watershed technologies designed to control nonpoint source pollution, and to improve the understanding of nonpoint source pollution.

Coastal Zone Management and Reauthorization Act (CZARA) of 1972 and Amendments of 1990 required coastal states and territories to develop programs to protect coastal water from runoff pollution. The program is administered by EPA and the National Oceanic and Atmospheric Administration.

The National Pollution Discharge Elimination System (NPDES) required municipal and industrial stormwater discharges to submit an NPDES permit under Phase I (1990) of Section 402 of the Clean Water Act. Phase I included municipalities with population over 100,000 and industrial stormwater discharges including construction sites of 5 acres or more. Phase II (1999) required municipalities with populations of less than 100,000 associated with commercial operations and light industries to develop stormwater management plans (EPA, 2000d).

Intermodal Surface Transportation Efficiency Act (ISTEA of 1991) is designed to improve the quality and condition of national highways and transportation systems. The act provided provisions for the mitigation of water pollution due to highway runoff.

Other nonpoint source programs include the National Estuary Program (NEP) established by the CWA and the pesticides program under the Federal Insecticide, Fungicide and Rodenticide Act. NEP focuses on pollution in high priority estuaries. The pesticides program concentrates on pesticides threatening surface and ground waters.

Structural Measures

The control of point and nonpoint source pollution may require the use of a structural measure. A structural measure is a strategy for control of the quality and quantity of urban runoff. Such measures impose additional capital and annual operations costs plus maintenance costs.

Various structural measures used to control urban runoff have evolved over the years in light of the recent regulations. Table 33.9 summarizes the opinions of senior stormwater quality management professionals about the design robustness of various stormwater quality controls. The effectiveness of such measures is site specific, and the removal of constituents from urban runoff depends on environmental and physical factors.

Wetlands can act as water retention facilities due to their capacity to store water. For example, a 1-acre wetland with a depth of 1 foot can hold over 330,000 gallons of water. Wetlands can provide several functions including water quality improvement, flood storage and the routing of stormwater runoff, cycling of nutrients and other material, habitat for fish and wildlife, recreational activities, education and research, and landscape enhancement. Performance has varied based on the location, type of wastewater, wetland design, climate, weather disturbance, and daily or seasonal variability. Therefore, it is very difficult to predict the performance of any given wetland system. Constructed wetlands can be surface flow,

TABLE 33.9 Robustness of Best Management Practice Design Technology (WEF/ASCE, 1998)

Type	Hydraulic Design	Removal of Constituents in Stormwater: Total Suspended Sediments and Solids	Dissolved	General Performance
Swale	Moderate-high	Low-moderate	None-low	Low
Buffer strip	Low-moderate	Low-moderate	None-low	Low
Infiltration basin	Moderate-high[a]	High	Moderate-high	Moderate
Percolation trench	Low-moderate[a]	High	Moderate-high	Moderate-high
Extended detention	High	Moderate-high	None-low	Moderate-high
Wet retention pond	High	High	Low-moderate	Moderate-high
Wetland	Moderate-high	Moderate-high	Low-moderate	Low-High[b]
Media filter	Low-moderate	Moderate-high	None-low	Low-moderate
Oil separator	Low-moderate	Low	None-low	Low
Catch basin Inserts	Unknown	NA[d]	NA	NA
Monolithic porous pavement[b]	Low-moderate	Moderate-high	Low-high[c]	Low-moderate
Modular porous pavement[b]	Moderate-high	Low-high	Low-high[c]	Low-high[c]

[a] Weakest design aspect, hydraulic or constituent removal, governs overall design robustness.

[b] Robustness is site-specific and maintenance dependent.

[c] Low-moderate whenever designed with an underdrain and not intended for infiltration and moderate-high when site specific permit infiltration.

[d] Not applicable.

subsurface flow, or a hybrid system. Subsurface flows have been proved to provide the highest removal efficiencies due to the presence of a substrate system, but are more expensive than surface wetlands.

Communities have several alternatives when controlling excessive flows while maintaining water quality criteria. Rehabilitation of sewers may improve the system, but will not provide additional capacity. Equalization basins are a viable alternative when CSOs and SSOs present a quality and quantity problem for a community. The combined flow is stored in the basin during wet weather flow and then discharged to the treatment plant during low peak periods. This provides for a consistent composition of wastewater (i.e., flow and constituents). An equalization basin can also store stormwater, which eventually may be discharged to a treatment plant or treated through a different system. The basin is typically designed to handle the first burst of stormwater, which carries the highest concentration of pollutants. This assures that overflow from the basin does not contribute a significant amount of pollution.

The majority of point source control practices target combined sewers. The type of CSO pollution abatement technology used may depend upon climate, topography, geologic conditions, and receiving water criteria of a particular location. A combination of technologies is often used. Most CSO structural practices can be grouped into the following four categories: offline storage/treatment, treatment, inline storage/control, and miscellaneous BMPs (WEF, 1989). Offline storage and treatment technologies divert combined flows into holding devices separated from the main flow and hold them until treatment capacity is available. In some cases, solids and floatables are removed during holding. CSO treatment facilities typically remove solids and floatables, chlorinate, and achieve some BOD removal. Inline storage and control methods work to store and divert flows online to ensure all combined flow is treated. Various best management practices, such as diversion weirs and system cleaning and rehabilitation, have been used successfully to control CSOs.

Defining Terms

Atmospheric deposition — The settling of pollutants by wind from various sources such as traffic, construction, and industrial sites.

BMP — Best Management Practice.

CFO — Confined Feeding Operation.

CSO — Combined Sewer Overflow.
CWA — Clean Water Act.
CZARA — Coastal Zone Management and Reauthorization Act.
EPA — Environmental Protection Agency.
Eutrophication — Excess nitrogen and phosphorus caused by over-fertilization. This can lead to algae blooms and other environmental problems.
Event mean concentration — The average pollutant concentration during the runoff caused by a storm event.
ISTEA — Intermodal Surface Transportation Efficiency Act.
LTCP — Long-Term Control Plan.
NEP — National Estuary Program.
NMP — National Monitoring Program.
NMC — Nine Minimum Controls.
Nonpoint source — A source of pollution, which is not considered point, generated from stormwater runoff, agricultural runoff and other sources of runoff.
NPDES — National Pollution Discharge Elimination System.
NURP — Nationwide Urban Runoff Program (EPA, 1983).
Point source — A source of pollution, which is usually traced to a pipe or outfall, such as CSOs, SSOs, POTWs, etc.
POTW — Publicly Owned Treatment Works.
Sewer infiltration — Flow that enters into the sewer system from underground sources, such as groundwater.
Sewer inflow — Flow that leaks into the sewer system from various diffuse sources.
SSO — Sanitary Sewer Overflow.
SWMM — Storm Water Management Model.
TMDL — Total Maximum Daily Load.
Urban runoff — All waters generated from urbanization including, but not limited to, stormwater runoff combined and separate sanitary overflows, and miscellaneous runoff.
Washoff — Amount of pollutant entrained by runoff from urban surfaces.
WQC — Water Quality Criteria.
WQS — Water Quality Standards.

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Further Information

The EPA Website (www.epa.gov/owow) has additional information on CSOs, SSOs, point and nonpoint source pollution, regulations, NPDES program, TMDL Program, NURP, BMPs and other related topics.

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