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ENVIRONMENTAL RESEARCH BRIEF

Storage/Sedimentation Facilities for Control of Storm and Combined Sewer Overflows: Design Manual

Joyce M. Perdek*, Richard Field*, and Shih-Long Liao**

Abstract

This report describes applications of storage facilities in wet-weather flow (WWF) control and presents step-by-step procedures for the analysis and design of storage-treatment facilities. Retention, detention, and sedimentation storage are classified and described. International as well as national state-of-the-art technologies are discussed.

Retention storage facilities capture and dispose of stormwater runoff through infiltration, percolation, and evaporation. Detention storage is temporary storage for stormwater runoff or combined sewer overflow (CSO). Stored flows are subsequently returned to the sewerage system at a reduced rate of flow when downstream capacity is available, or the flows are discharged to the receiving water with or without further treatment. Sedimentation storage alters the wastewater stream by gravity separation. The stormwater runoff and CSO must be characterized to estimate the efficiency of any sedimentation basin.

The detailed design methodology for each type of facility presented in the report includes the following steps: identifying functional requirements; identifying site constraints; establishing basis of design; selecting a storage and/or treatment option; and conducting a cost analysis.

This research brief summarizes a 1997 revision of an earlier unpublished report of the same title. The original report was prepared between September 1979 and October 1981 by Metcalf & Eddy, Inc., under the sponsorship of the U.S. Environmental Protection Agency's Office of Research and Development in Cincinnati, OH, in partial fulfillment of Contract No. 68-03-2877. The 1997 revision is being released currently to provide information to communities in support of their stormwater and CSO management efforts. Despite the revision, some of the content may no longer be entirely current. The authors of the full report are W. Michael Stallard, William G. Smith, Ronald W. Crites, and John A. Lager. Copies of the report are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Introduction

Among the earliest examples of public works are urban drainage systems designed to convey urban storm flow or WWF away from populated areas to receiving waters. WWF may consist of stormwater alone, or it may consist of both stormwater and sanitary or domestic wastewater in combined sewer systems, which is known as CSO. Common elements of a typical combined sewer system, generally found in older cites, are illustrated in Figure 1.

Discharges from WWFs conveyance systems have significant impacts on receiving-water quality. Recognition of their significance has increased as the quality of effluents from municipal wastewater treatment plants has improved as a result of the Clean Water Act. National cost estimates for controlling pollution from WWFs are substantial. The cost of meeting water quality standards for stormwater discharges has been projected to be as high as $400 billion in capital costs and $540 billion/year in operation and maintenance (O&M) costs. Capital costs for CSO abatement are estimated to be more than $50 billion for eleven hundred communities served by combined sewer systems.

The variable nature of WWFs makes controlling them difficult. Transport and treatment facilities for controlling excess WWF,

*National Risk Management Research Laboratory, Edison, NJ
**Oak Ridge Institute for Science and Education, Edison, NJ

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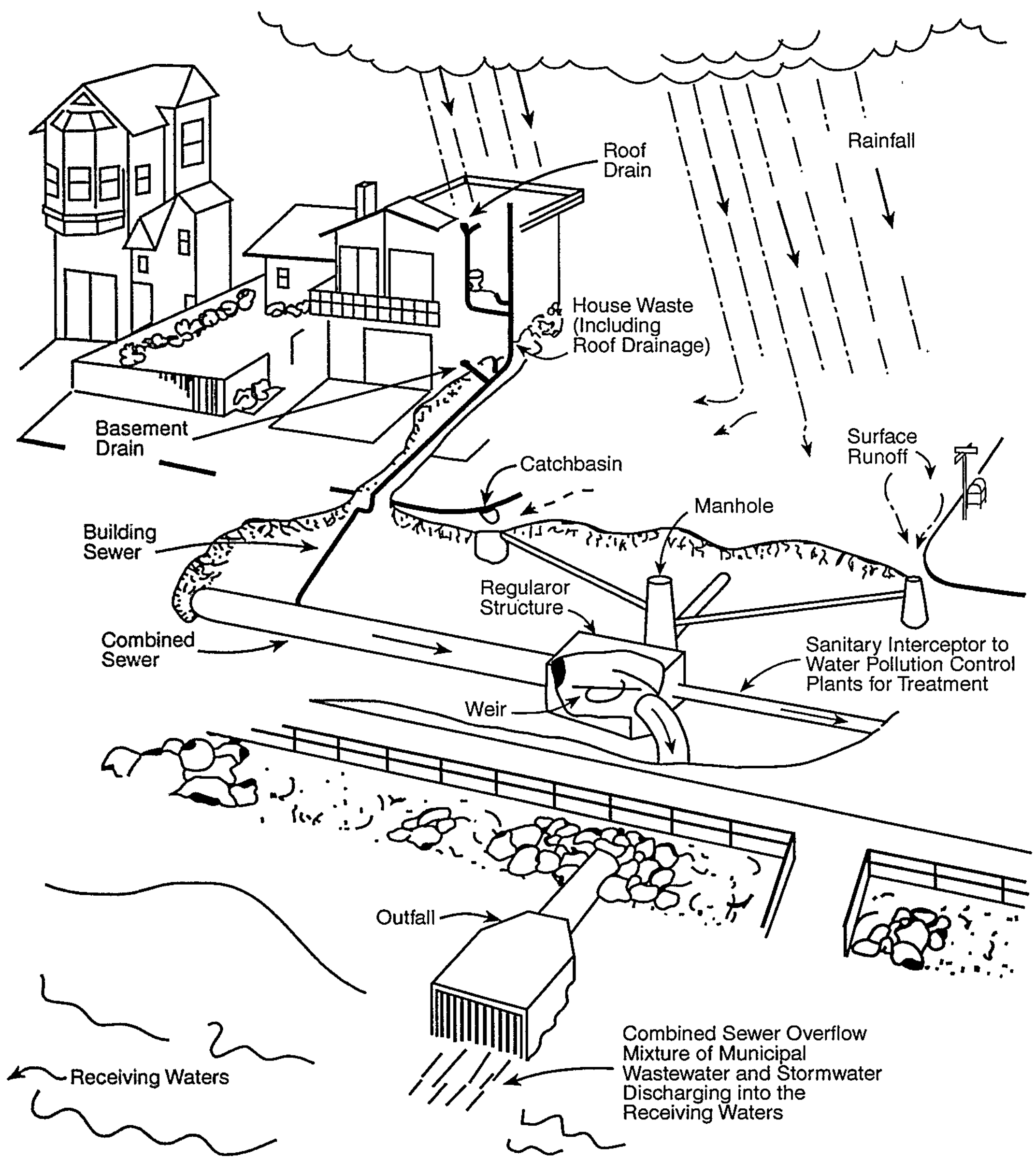

Figure 1. Common Elements of a Combined Sewer System.

which generally are designed to handle medium-intensity, medium-duration storm-flow volumes, frequently are idle during dry periods and overflow during large storms. Temporary storage of excess WWF can be an effective and economical method of controlling flooding and pollution. Excess WWF stored during large storms or during more intense rainfall periods can be released slowly when capacity in the drainage and treatment system is available. As a result, overflows occur less often.

Planning Methodology

The solution to WWF problems is most often a combination of various best management practices (*i.e.*, nonstructural and low-structurally intensive alternatives) and unit process applications (*i.e.*, physical treatment for removal of settleable and suspended solids and floatable material). Storage and/or sedimentation facilities are and should be the backbone of such an integrated WWF management plan. The following aspects of planning a storage/sedimentation facility are described: (1) general planning conditions, (2) establishment of goals, (3) planning methodology, (4) cost optimization methodologies, (5) storage-volume determination methods, and (6) effect of storage and/or sedimentation.

General planning conditions include determining whether storage/sedimentation is the best solution for dealing with the problems involved in terms of the type of WWF and the treatment goals. The feasibility of locating such a facility must be examined. Treatment goals include, but are not limited to, the maximum number of yearly overflow events, maximum overflow volume, and desired detention time.

The basic planning methodology includes the following steps: (1) identify functional requirements, (2) identify site constraints, (3) establish basis of design, (4) select storage and/or treatment option, (5) estimate costs and cost sensitivities, (6) check that facilities satisfy objectives, and (7) refine and complete or modify and repeat. A typical design methodology for source control options is illustrated in Figure 2. The methodology used to evaluate the optimum cost of storage and/or sedimentation facilities depends on the purpose of the facility: flow control only, or a combination of flow control and pollutant reduction. The Mass-Diagram Method and Production Theory Method are described in the manual.

In determining storage volumes, the effect of different possible combinations of storage and/or sedimentation design parameters (*e.g.*, settling time and facility size) on flow control must be determined. Methodologies for approaching these calculations include the following: desktop hand computations; statistical analysis of rainfall and flow data; simple, continuous simulation of WWF systems; and detailed, continuous or single event simulation of WWF systems. Deciding on the approach to be used depends on the size and complexity of the drainage area and/or sewerage system. For small and simple systems, hand computations can be used. For detailed systems, computerized continuous simulated models can be used.

To evaluate the different storage/sedimentation alternatives, the degree to which each alternative achieves the goals developed must be compared. Cost and performance of each should be considered. Thus, the best apparent alternative should be the most cost-effective one meeting the technical goals established at the lowest cost.

The process of integrating WWF control into a pollution control system involves initial planning where existing facilities are identified and goals are determined. Additional steps then involve selecting control methods that are both applicable and compatible to the existing facilities and established goals. These steps are to (1) identify existing system and needs, (2) establish system needs, (3) identify applicable control alternatives, and (4) determine control method compatibility.

Facility Design

Storage/sedimentation facility design procedures for both combined sewer and separate storm sewer systems are discussed in detail in the manual. The main steps to be followed in designing these systems are (1) problem identification, (2) data needs, (3) determination of the pollution load, (4) identification of the flood control and pollutant removal objectives, (5) control optimization, (6) pollutant budget analysis, (7) operating strategy for design, and (8) instrumentation and control strategy for operation.

Design of Retention Storage Facilities

Stormwater retention is the storage of excess runoff for complete removal from the surface drainage and discharge system. The water collected percolates through the bottom of the retention facility and may reach the groundwater. Stormwater retention facilities may take a variety of forms such as ponds and perforated culverts. This section describes design procedures and operation considerations for the most common retention storage facility types — dry and wet ponds.

Size and location are important design considerations for both types of ponds. Size requirements include not only volumetric

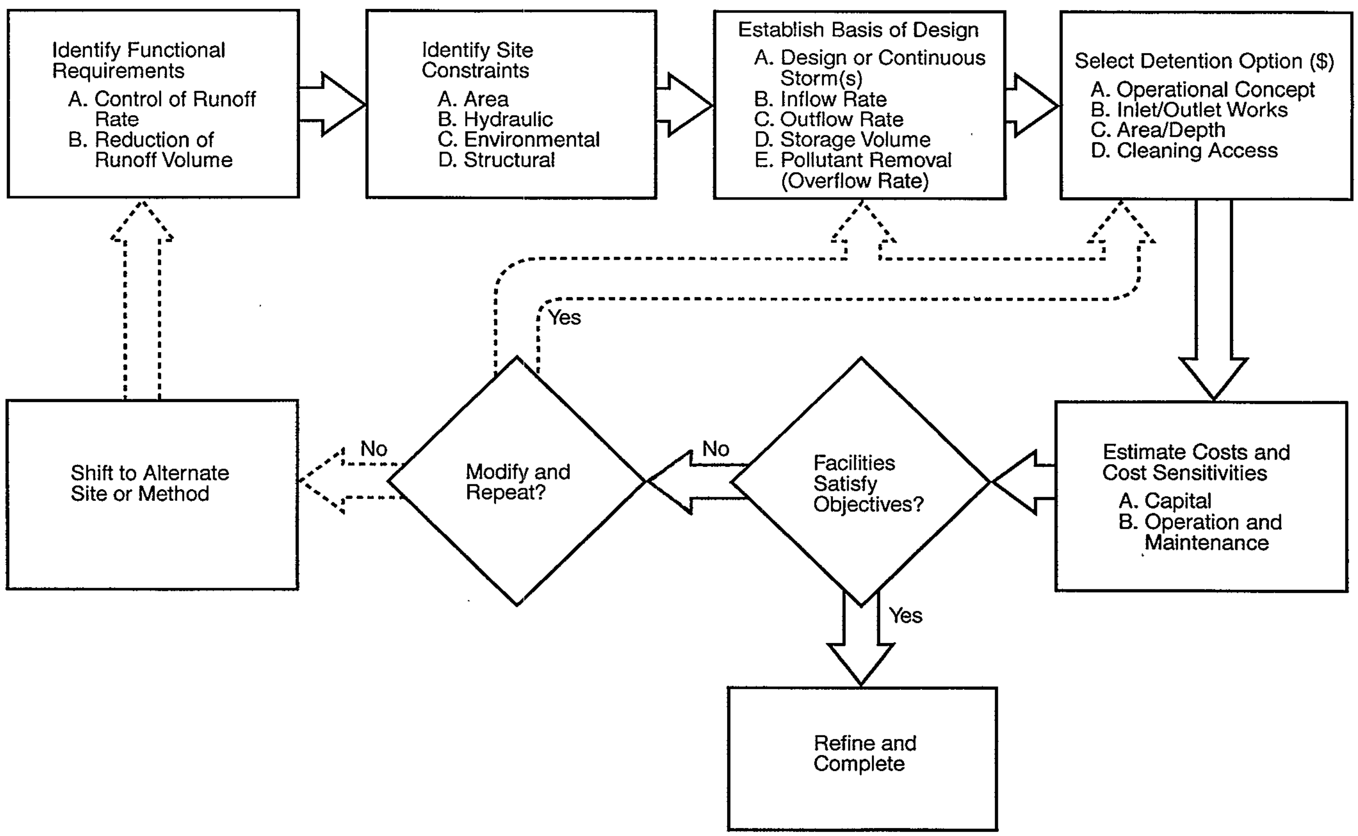

Figure 2. Source Control Design Methodology.

capacity but also both surface area and soil interface area requirements. The pond configuration depends on (1) the runoff storage volume needed; (2) the surface area, configuration, and weir length required to assure adequate settling during sedimentation operation; (3) the surface area needed for adequate transfer of oxygen into the pond water to allow aerobic decomposition of organic pollutants; (4) the soil-water interface area needed for adequate percolation of stored runoff between storm events; and (5) the area needed to serve whatever dual uses the basin may have. The suitability of a site within a drainage area for locating a retention pond facility depends on (1) site availability, (2) compatibility of surrounding land uses with a stormwater retention facility and its other functions, (3) the area required, (4) soil permeability, (5) tributary catchment size, and (6) its relationship to other sewer or drainage facilities.

The procedure presented for design of retention facilities consists of the following steps: (1) quantify functional requirements, (2) identify waste load and flow reduction, (3) determine preliminary basin size, (4) identify feasible pond sites, (5) investigate most promising sites, (6) establish basin sizes, (7) design solids removal facilities, and (8) determine pond configuration. The approach, which should make use of existing experience, known concepts, or developed theories, must be integrated to insure that the desired functions of the ponds (sediment removal, infiltration and percolation, flood control, or flow reduction) are compatible with the type of flow reaching the pond (stormwater runoff or CSO) and any other multi-use aspects (recreation, irrigation, aesthetics, etc.). In actual practice, retention ponds are very seldom used for CSOs because the organic solids tend to seal the pond bottom and reduce the soil infiltration capacity.

The efficiency of retention ponds in reducing stormwater pollutant loadings depends heavily on the underlying soil as a treatment medium. The mechanisms of removal include settling, filtering, biological activity, coagulation, adsorption, and chemical reaction. The major operational problems with ponds center around handling captured solids. Other operational concerns are the inlet and outlet structures, maintenance of vegetative cover through alternating wetting and drying periods, insect control, odor control, and maximizing availability of the pond for alternative uses. Cost curves for pond construction are presented in the manual. Operational costs are site specific.

Design of Detention Facilities

Detention storage delays excess runoff and attenuates peak flows in the surface drainage system. During peak flows, detention storage holds excess water until the inflow decreases and releases it during low-flow periods. Because of sedimentation that occurs during detention, detention storage in tanks or basins can also be considered a treatment process for high storm flow volumes that create tank or basin overflow. Site constraints to be considered for detention storage facilities include tributary area, topography, local land use, and area available for the structure or basin.

Types of detention storage include onsite and in-system. Onsite detention is the detention of stormwater or CSO at the source before it reaches a sewer network or receiving water. Onsite detention occurs in natural ditches, open ponds or basins, rooftops, parking lots, or recreational facilities. In-system detention storage holds storm flow either in series or in parallel within the collection system. In-system detention storage includes inline storage and offline storage. Inline storage can be accomplished by using the available volume in trunk sewers, interceptors, wet wells and tunnels to store excess WWF. Excess flows are stored off line in open or uncovered basins, caverns, mined labyrinths, and lined or unlined tunnels. Functionally, the application of onsite detention differs little from in-system storage other than the location where the storage occurs. However, while onsite detention is used primarily to minimize the cost of constructing new storm sewers to serve a developing area, in-system storage is generally used to decrease the frequency and volume of overflows from combined sewer systems.

Factors to be considered in the design of onsite storage facilities are (1) tributary area, (2) storage area and volume, (3) structural integrity, and (4) responsibility of the owner. Factors to be considered in the design of in-system detention storage facilities are (1) size and slope of sewers, (2) peak flow rates, (3) controls required for system operation, and (4) resuspension of sediment.

The design methodologies for onsite storage and in-system storage are very similar and combined together in the discussion presented in this section of the manual. The design procedure described consists of the following steps: (1) identify functional requirements, (2) identify site constraints, (3) establish basis of design, (4) select storage options and locations, (5) estimate costs, and (6) complete design.

The construction costs for in-system storage have been reported for selected demonstration sites. However, they are highly site specific. Costs also vary considerably depending on the complexity of the flow regulators and control systems. Detailed O&M cost data are limited. O&M costs must be estimated for specific facilities from the operation plan and maintenance schedule.

Design of Sedimentation Facilities

Storage/sedimentation is the most commonly and perhaps most effectively practiced method of urban CSO and stormwater runoff control in terms of the number of operating installations and length of service. Conversely, storage/sedimentation is frequently criticized for lack of innovation because of its simplicity and high cost due to size and structural requirements.

The report presents detailed design considerations and procedures for downstream storage/sedimentation basins, which are illustrated by example and through references of designed and operated facilities. Cost information is also provided. Examples of representative CSO storage/sedimentation basins and auxiliary support facilities are shown in Figure 3.

Functionally, the applications of downstream storage/sedimentation facilities vary from essentially total containment, experiencing only a few overflows per year, to flow-through treatment systems where total containment is the exception rather than the rule. For total containment, the major concerns are the large storage volume, the provisions of dewatering, and post-storm cleanup. For flow-through treatment systems, performance hinges on treatment effectiveness and design considerations including loading rates, inlet and outlet controls, short circuiting, and sludge and scum removal systems. In the case of offline facilities, the option exists to selectively capture the portion of storm flow with the highest pollutant load, referred to as the first flush, and bypass the balance of the flow to avoid the discharge of much of the pollution.

Factors to be considered in the design of storage/sedimentation facilities include the following: (1) storage volume, (2)

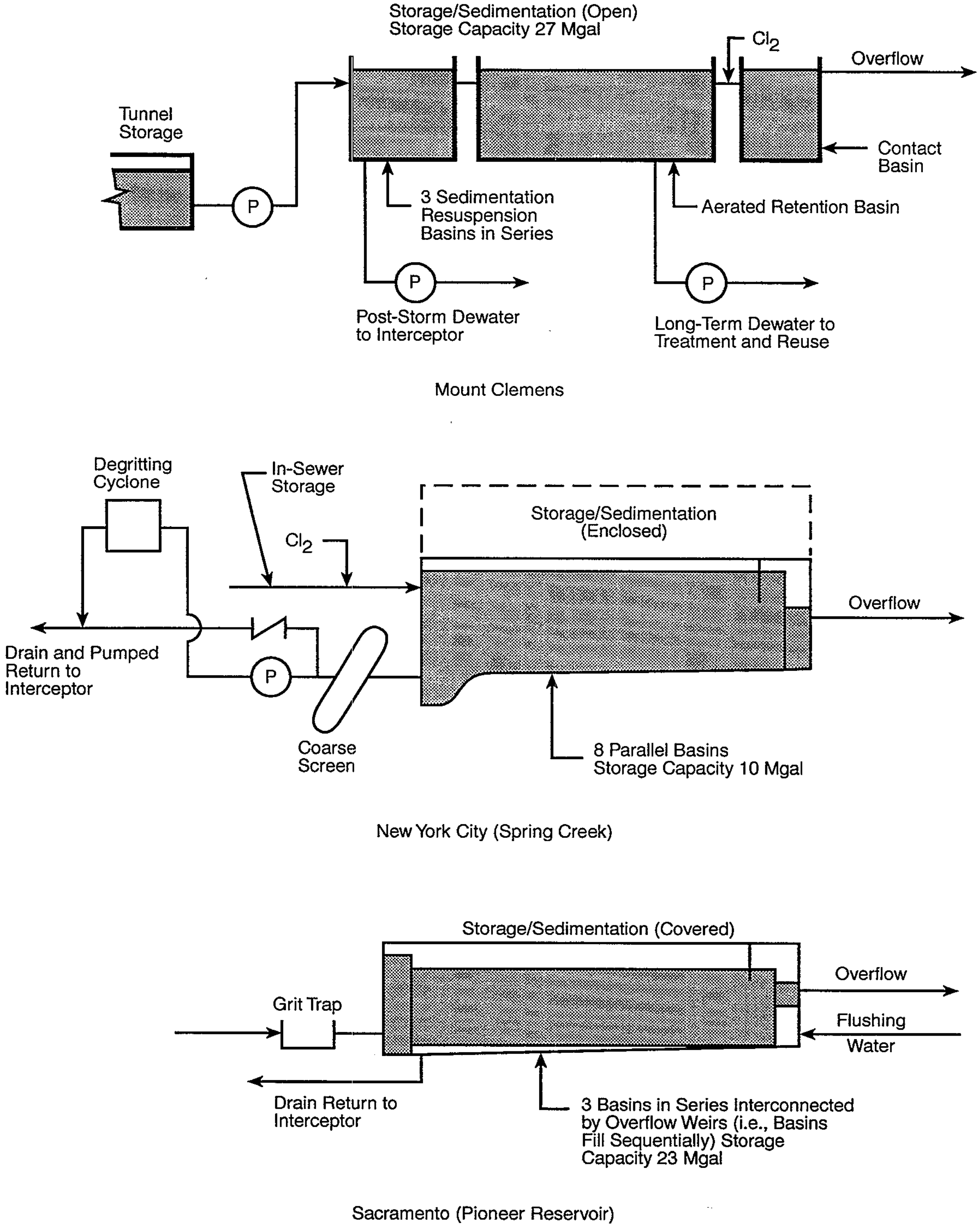

Figure 3. Representative CSO Storage/Sedimentation Basins and Auxiliary Support Facilities.

treatment efficiency, (3) disinfection, and (4) site constraints. The following sedimentation facility design procedures are (1) identify functional requirements, (2) identify site constraints, (3) establish basis of design, (4) select sedimentation facility configuration, (5) identify and select pretreatment, (6) detail auxiliary systems, (7) estimate costs and cost-effectiveness analysis, and (8) complete design.

The major O&M goal of downstream storage/sedimentation basins is to provide a facility that is available to its full design capacity as long as needed. Secondary goals include clear, prompt, and complete records of performance, reliability to provide for real location of personnel and facilities in non-storm periods, and dual-use operations such as backup treatment and/or flow equalization for dry-weather plants. The O&M requirements and procedures should be developed from the operational plan; there are no industry-wide standards.

International Perspective

The application of storage/sedimentation controls for urban WWF problems is not unique to the United States. In this era of excellent communications and increasing technology sharing on an international scale, similar approaches are found in many areas of the world. Several technologies developed internationally are introduced below. The review includes flow-control devices developed in Sweden, Denmark, and Germany; an in-receiving water flow balancing system developed and applied in Sweden; and an innovative self-cleaning storage/sedimentation basin used in Zurich, Switzerland.

For certain cases, the flow from storage/sedimentation facilities can be controlled by means of specially designed flow-control devices, which provide more effective flow control than can be accomplished with conventional static devices. Four devices are described. An advanced static device, the Steinscruv flow regulator, developed in Sweden in the 1970s by Stein Bendixsen, consists of a stationary, anchored, screw-shaped plate that is installed in a pipe. In that part of the plate which fits against the bottom of the pipe, there is a bottom opening to release a specified base dry-weather flow. The Hydrobrake, developed in Denmark in the mid-1960s, is used to control outflows from storage structures. Hydrostatic pressure associated with the water level controls the rate of flow through this device. A device with a similar operating principle, the Wirbeldrossel or turbulent throttle, developed in Germany in the mid-1970s, also regulates flow from a storage facility. Another flow regulator valve, developed in Sweden in the late 1970s, is a central outlet pipe surrounded by a pressure chamber filled with air. Water pressure on the upper portion of the device displaces the fabric at the outlet, which controls the discharge volume.

The Flow Balance Method, an innovative approach to urban WWF treatment for the protection of lakes, has been developed and applied at several locations in Sweden by Karl Dunkers. The Flow Balance Method, which is also being used in other locations, uses a portion of receiving-water volume within a hanging curtain to store runoff, while allowing for suspended solids sedimentation, before discharge. A schematic of the system is shown in Figure 4.

Typically, removal of settled solids from an inline storage facility has been a problem that requires an auxiliary flushing system of some sort. An innovative approach to eliminating this problem has been implemented in Zurich, Switzerland. A continuous dry-weather channel, which is an extension of the tank's combined sewer inlet, is formed by a number of parallel grooves connected at their end points similar to the configuration shown in Figure 5. Any solids that have settled in the basin during its storage operation are resuspended by the channelized high-velocity flow during the drawdown following a storm event.

Reference

Stallard, W.M., W.G. Smith, R.W. Crites, and J.A. Lager. *Storage/Sedimentation Facilities for Control of Storm and Combined Sewer Overflows: Design Manual,* **EPA/600/R-98/006 PB98-132228.** Cincinnati, OH: U.S. Environmental Protection Agency, 1998.

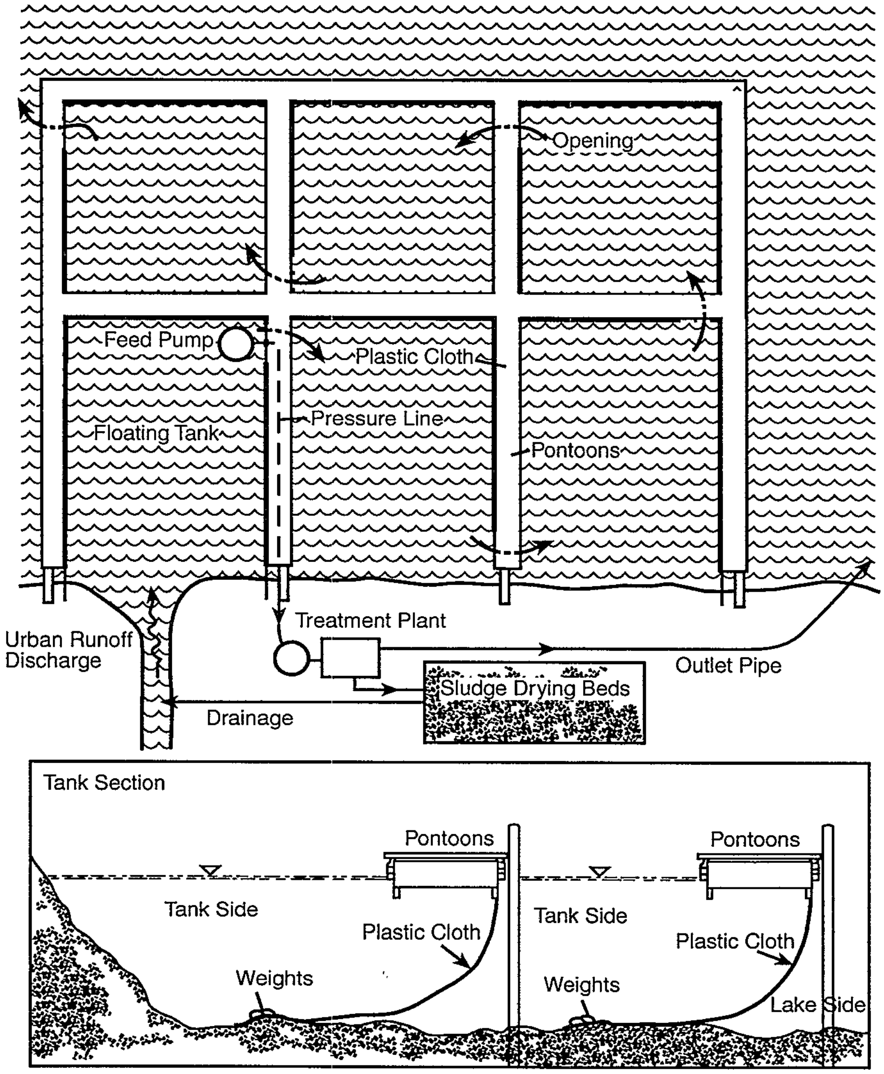

Figure 4. Schematic of Pontoon Tank System at Lake Tehorningen, Sweden.

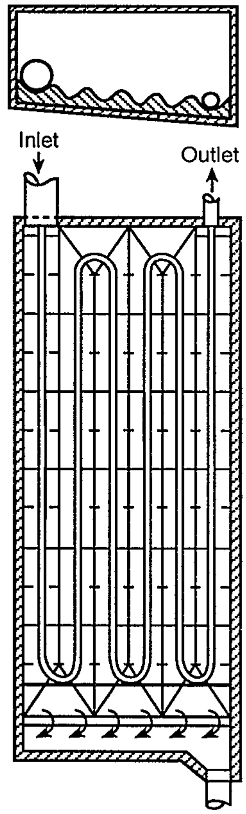

Figure 5. Self-Cleaning Storage/Sedimentation Basin used in Zurich, Switzerland.

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