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LITERATURE SUMMARIES PREPARED FOR A CSO GUIDANCE DOCUMENT

U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C.

September 28, 1989

1. An Analysis of the United States Environmental Protection Agency's Needs Survey (American Public Works Association), 1975.

2. Analyzing the Existing Collection System (Pisano), 1978-1981.

3. Assessment of Benefits Resulting from Control of Combined Sewer Overflows (Driscoll and Mancini), 1978.

4. Benefit Analysis for Combined Sewer Overflow Control (USEPA - Environmental Research Information Center), 1979.

5. Combined Sewer Overflow Abatement Alternatives - Washington, D.C. (Weston), 1970.

6. Combined Sewer Overflow Abatement Program, Rochester, New York (Drehwig, Murray, Carleo, Jordan), 1981.

7. Combined Sewer Regulator Overflow Facilities (American Public Works Association), 1970.

8. Control of Combined Sewer Overflows in Minneapolis-St.Paul (Tucker), 1971.

9. Countermeasures for Pollution from Overflows: The State-of-the-Art (Field, Lager), 1974.

10. Dry-Weather Deposition and Flushing for Combined Sewer Overflow Pollution Control (Pisano), 1979.

11. Methodology of Analysis for a Combined Sewer Overflow Abatement Program (Murphy), 1978.

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15. Retention Basin Control of Combined Sewer Overflows (Springfield Sanitary District), 1970.

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24. Use of Street Cleaning Operations in Reducing Urban Runoff Pollution (Pitt), 1978.

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26. Water Quality Characteristics of Storm and Combined Sewer Overflow (Ministry of Construction - Japanese Government), 1977.

AN ANALYSIS OF THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY'S NEEDS SURVEY

AMERICAN PUBLIC WORKS ASSOCIATION

August 1975

Public Law 93-243 directed the U.S. Environmental Protection Agency to conduct a survey in 1974 to determine the cost of wastewater facilities eligible for funding under PL 92-500. The National Commission on Water Quality retained the APWA Research Foundation to make an independent study of the procedures used by states and selected metropolitan communities to assess and report the cost estimates and to assemble data concerning industrial use of municipal treatment facilities, sludge disposal, and proposed financing of the construction program. The APWA study was not intended either to duplicate or to validate the results of the USEPA survey. Rather, the study was designed to add interpretation to the 1974 Needs Survey. This report presents the findings of the APWA study.

The APWA study reviewed state policies and procedures on non-federal financing of local sewer systems and treatment facilities, industry-municipal inter-relations on wastewater handling, private industry waste handling and disposal, non-utility private wastewater treatment needs, cost factors not included in the 1974 needs estimates but requiring consideration up to and after 1983, and opinions of state officials on the ability of public agencies to complete needed sewer system and treatment facilities by the deadlines established by PL 92-500. The APWA study also explored potential impacts of the major water quality controls stipulated by the Act on the state's surface water, groundwater, air, and land resources. In addition, the reported needs of representative metropolitan governmental units and their financing of required construction work were examined. The study identified areas where the 1974 Needs Survey reflects realistic Construction costs for projects required by PL 92-500 and ascertained how the states determined their needs. The study also evaluated the reasons for changes between the 1974 Survey and a previous survey conducted in 1973.

The study conducted by APWA included in-person interviews with 18 states and three (3) metropolitan areas. In addition, mail surveys were conducted in the remaining 32 states, the District of Columbia, Puerto Rico, the Virgin Islands, American Samoa, and the trust territory of the Pacific Islands.

The same needs categories which were used in the USEPA National Needs Survey for 1974 were used for this study. They include the following:

- Category I - Secondary Treatment and Best Practicable Waste Treatment Technology
- Category II - More Stringent Degrees of Treatment
- Category IIIA - Infiltration/Inflow Correction
- Category IIIB - Major Sewer System Rehabilitation
- Category IVA - New Collector Sewers and Appurtenances
- Category IVB - New Interceptor Sewers and Appurtenances
- Category V - Correction of Combined Sewer Overflows
- Category VI - Treatment and/or Control of Stormwater Discharges

The APWA study interviews and surveys covered the following information:

- Estimate of methods used by local authorities to develop cost estimates for the 1974 Needs Survey: for facilities with no needs, facilities for which 1973 cost estimates were reported, and facilities with updated or newly estimated needs for all categories.

- Reasons for new or updated costs in 1974 survey not included in the 1973 survey, increased facility capacities required, new facility processes required, other reasons for new or updated 1974 costs for all categories.

- Methods used by states for cost estimates and evaluation procedures: USEPA guidelines, state modifications of USEPA guidelines, state-developed guidelines for all categories.

- Basis for state variances from USEPA Guidelines for each category I - VI.

- Basis for state variances from engineering report estimates of local authorities for each category.

- Basis for 1974 Needs estimates: cost-effective analyses, engineering studies, USEPA guidelines, rough local estimates--for all categories.

- Anticipated needs not included in the 1974 Needs Survey but required to meet 1983 criteria, based on 1990 population estimates: upgrading of water quality standards, land needs for treatment facilities and disposal areas for effluent and sludge application, system rehabilitation needs (including treatment facilities), needs for privately owned (non-industrial) treatment system facilities, and facilities with undetermined needs--for all categories.

- State policies on disposal and treatment of industrial wastes: encouragement by states of joint municipal-industrial treatment facilities, requiring cost recovery systems for industrial waste handling to qualify municipal facilities for state aid, invoking USEPA guidelines on industrial wastes cost-recovery arrangements, status of cost-recovery arrangements in the states.

- Wastewater character and volumes produced by the ten major industries in each state: listing of major industries in order of importance, MGD flow, BOD and Suspended Solids loadings.

- Estimated trends in industrial wastes production - 1974/1977/1983: volumes of wastewaters produced, volumes anticipated to be handled by municipal facilities - for each of the ten major industries of each authority.

- Estimated construction cost of probable industrial wastewater treatment facilities - 1974 to 1983: for publicly owned plants handling industrial wastes, for industry-owned facilities, dependent upon whether cost of municipal systems handling industrial wastes was included in 1974 needs and percentage of Category I needs included in the 1974 survey.

- Basis for population estimates for 1990 by local authorities: USEPA regional estimates (Series E, Department of Commerce); state own population estimates, local or regional planning agency population studies and projections, or any combination of methods for estimating population trends.

- State estimates on progress in meeting goals of PL 92-500 for Categories I and II: numbers and capacities of facilities already completed, numbers and capacities of facilities to be completed by 1977, numbers and capacities of facilities to be under construction in 1977, numbers and capacities of facilities not yet begun in 1977, estimated cost of facilities to be completed between 1974 and 1977, and estimated cost of facilities to be under construction or not yet begun in 1977.

- State authorization of local financing requirements for Category I and Category II facilities: state aid arrangements, funds allocated for local water pollution control needs, types of taxes and/or other local funding methods for sewer systems and treatment works.

- Detailed information on state and local infiltration/inflow control actions (Category IIIA): allowable infiltration rates set by states for sewer design, estimates of actual infiltration rates experienced in sewer systems, amounts of infiltration that can cause sewer system and treatment plant problems, state regulations prohibiting inflow into sanitary sewers, status of local studies of infiltration/inflow problems, types of local corrective actions taken or contemplated to correct infiltration/inflow conditions - including sewer system rehabilitation, excess treatment facilities, percent of systems studied to determine cost of correction actions, and percent of total sewer systems requiring infiltration corrective actions.

- Miles of sewers in state requiring major rehabilitation (Category IIIB), due to: age of sewer system, defective workmanship or materials, chemical deterioration, establishment of state guidelines or criteria for major rehabilitation, and other causes.

- State policies and experiences on combined sewer overflows and corrective actions (Category V): state criteria on quality of combined sewer overflows, provisions to prevent or minimize overflows, state policies on elimination of combined sewer overflows, number of enforcement actions taken, methods and costs planned by the state for correction of overflow - sewer separation, treatment equivalent to primary plus disinfection, treatment equivalent to secondary, storage off- system or in-system, flow routing and other means, state policies permitting new or extensions of combined sewers, and amounts built from 1970 to 1974.

- State policies and procedures on storm water discharge elimination (Category VI): states' estimates for 1974 needs in terms of quality of storm water runoff, rainfall events covered by storm sewer design, establishment of state stormwater control criteria to guide local governments, state requirements for stormwater discharge control or treatment - including storage and controlled release, storage in-system with release to treatment equivalent to secondary treatment or other means.

- States' evaluation of the potential environmental impact of compliance with the goals of PL 92-500: as envisioned by the 1974 needs estimates on surface water, groundwater, air and land resources.

The findings of the APWA study by needs category are as follows:

Category I - Secondary Treatment and Best Practicable Wastewater Treatment Technology

- Population estimates seem high
- The extent of municipal facility use by industry is uncertain
- The cost of adequate sludge handling and disposal facilities has not been included in all cost estimates.
- High I/I flows may be included as the basis of facility design
- Costs for the facilities appear to be based generally upon engineering studies with well defined treatment requirements

Category II - More Stringent Treatment Required by Water Quality

- Population estimates seem high
- Assumptions concerning the level of treatment required are preliminary
- The extent of use of facilities of industry is uncertain
- High I/I flows may be included as the basis of facility design
- The cost of adequate sludge handling and disposal facilities has not been included in all cost estimates
- Uncertainty as to which facilities will be required to meet water quality requirements suggests that reported costs are questionable; costs may be high, low or accurate

Category IIIA - Correction of Infiltration/Inflow

- Few local authorities have conducted I/I studies
- Correctional cost versus cost of excess treatment capacity has not been determined for most systems.
- Where relatively high I/I rates are allowed, the cost of Category I and II facilities will be higher than where more strict standards are in effect.
- Total costs for Category IIIA appear to be low due to number of authorities not reporting costs for 1974

Category IIIB - Major Sewer Rehabilitation

- Total costs will not be known until I/I studies have been conducted
- Since many local authorities did not report costs in 1974, they are probably understated

Category IVA - New Collector Sewers

Methods used to obtain cost estimates appear reliable; however, some sewers reported in the Needs Survey may not be eligible for inclusion and high population estimates could have produced overstated costs.

Category IVB - New Interceptor Sewers

Methods used to obtain cost estimates appear reliable; however, the size and cost of systems is dependent upon the accuracy of population and industrial flow estimates for Category I and II facilities.

Category V - Correction of Combined Sewer Overflows

- Cost estimates may be high where they are based on sewer separation
- Many small local authorities apparently did not report their needs
- Sludge handling requirements were not always considered
- Control or treatment objectives are needed
- The net effect of the above factors could not be estimated

Category VI - Treatment and/or Control of Stormwater

- Estimates were missing from three states
- Control or treatment objectives are needed
- A significant portion of the costs reported were for storm sewers
- Costs are to be considered speculative and a first estimate

The analysis for state-reported data concerning the status of plans for construction of Category I and II treatment facilities indicated that 66 percent of the facilities would not be completed by 1977, but 24 percent of them would be under construction. In terms of capacity, 43 percent could be completed by 1977, 30 percent would be under construction, and 27 percent would not be started.

Adequate methods were not available to evaluate the potential environmental impacts of the pollution control program. However, the opinion of the key officials participating in the survey was that receiving surface waters would be generally improved and that groundwater and air resources would not be degraded by the construction of new facilities.

ANALYZING THE EXISTING COLLECTION SYSTEM

by

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1978-1981

The objective of this combined sewer management study was to study in fine detail the impact of potential structural and non-structural control options for an old combined sewer collection system and then to select the least cost program for that system. The same problem was analyzed from three alternative points of view: a) remedial system fixes; b) the vogue and prevailing 208 orientation of street sweeping/sewer flushing/roof top inflow control; and c) end-of-line detention storage. Beforehand It was believed that significant control of combined sewer overflows can in fact be accomplished through a purposeful effort in restoring the condition of the existing system and jointly maximizing any system control.

The principal motivation and emphasis of the study method was to demonstrate the feasibility and practicality of developing low-cost, non-structural solutions for mitigating the number and magnitude of combined sewer overflows from the prototype study area.

This study was extremely well-received by USEPA as a hallmark problem-solving investigation which demonstrated the clear and unmistakable need to thoroughly understand the piping system, optimize its performance and then consider additive control measures. The study was presented at several Combined Sewer Overflow Technology Transfers EPA sponsored between 1978-1981.

This project was described in the 1978 report to Congress on Control of Combined Sewer Overflow in the United States. It best signifies Environmental Design and Planning's cost-effective philosophical approach to combined sewer management planning. The following is excerpted from the report to Congress:

"The major objective of collection system management is to implement a continual remedial repair and maintenance program to provide maximum transmission of flows for treatment and disposal while minimizing overflow, bypass, and local flooding. It requires an understanding of how the collection system works and patience to locate unknown malfunctions of all types, poorly optimized regulators, unused in-line storage, and pipes clogged with sediments in old combined sewer systems.

The first phase of analysis in a sewer system study is an extensive inventory of data and mapping of flowline profiles. This information is then used to conduct a detailed physical survey of regulator and storm drain performance. In this detailed study, Pisano found that minor repairs of four overflow structures and several small alterations of storm sewer piping obtained a 43.9 percent reduction of the present BOD load due to combined sewer overflow at a cost of $26,000. An additional 23 percent BOD reduction was obtained at a cost of $4,678,000 using sewer flushing, street sweeping, inflow correction and storage. This type of sewer system inventory and study should be the first objective of any combined sewer overflow pollution abatement project."

ASSESSMENT OF BENEFITS RESULTING FROM CONTROL OF COMBINED SEWER OVERFLOWS

by

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EPA TECHNOLOGY TRANSFER SEMINARS ON COMBINED SEWER OVERFLOW ASSESSMENT AND CONTROL PROCEDURES

1978

The nature of surface water quality problems present around metropolitan areas is quite varied. Local factors have a predominant influence on the class of problem, its severity, and the specific source or sources which are contributing to the problem. The local factors which affect water quality include climate, geography, population, population concentration, the nature and degree of industrialization in an area, the receiving water system, its nature, size and hydrology; and the nature of the surrounding area - both upstream and downstream of the urban area itself.

The objective of water quality management, particularly facilities planning activities, is improvement in water use. The definitions of water quality problems used in 201 studies should be related to water uses. This type of water quality problem definition will provide a sound basis for focusing pollution control activities, facility evaluations and efforts to benefit estimates.

Facility plans must provide answers to three implicit questions which are raised by public administrators and citizens. These are:

- Why commit any resources at all to these water quality management activities?
- Why commit these resources now?
- Why commit these resources in the way recommended?

Estimates of water quality and water use benefits provides part of the information needed to answer these questions. The reason a community, a state or EPA would want to commit resources to water quality management activities, regardless of time frame, would be that the perceived benefits are larger than the anticipated costs.

A common element of all levels of benefit estimates is the ability to quantitatively project water quality impacts of pollution control activities. There are several methods of estimating the benefits of water quality management.

The first is Application of Available Technology. The essence of this approach is a fundamental assumption that the benefits to be derived from the proposed activities are so large that they will automatically justify the allocation of the required resources. The controlling factor is assumed to be the availability of technology for obtaining the water quality benefits.

A second measure which can be considered in benefit estimates concerns achievement of "water quality standards." The basic assumption is that standards are somehow tied to protection of certain water uses. A major requirement of this type of an evaluation is the ability to directly relate proposed pollution control activities to improvements in receiving water quality.

An additional level of resolution may be obtained through translating improvements in water quality into "Estimates of Increased Water Use Potential." Physical scales such as useable beach length and water surface area can be related to the number of individuals that could utilize those resources. Once the level of water quality improvement has been defined as suggested above, these factors may be used to estimate the potential increased water resource utilization that could be accommodated.

The final level of benefit analysis is the classical cost benefit analysis in which each anticipated water usage is assigned a dollar value as a measure of unit worth or willingness to pay. The actual projected usage in each water use category is multiplied by the unit value and the sum represents an estimate of the value of the total benefits. The benefit total value is compared to total costs.

The analysis of receiving water impacts is a common element to each of the benefit estimating techniques previously discussed.

Streams and rivers can often be characterized as one-dimensional flowing systems where dispersion of mass can be neglected. For a complete specification of stream responses to pollutant loads under these assumptions, the initial pollutant concentration, the reaction rate, and the river flow and cross-sectional areas must be defined. Concentrations are assumed to be constant throughout the depth and across the width of the receiving water. The receiving water geometry is, therefore, approximated by a series of constant geometry and constant flow segments. For a first assessment, a single segment model should be used with a spatially aggregated average stormwater load.

One or two spatial dimensions may be of importance in estuaries, although initial assessments may simplify the problem to a one-dimensional analysis. The primary difference between estuaries and the one-dimensional river flow situation is the dispersive mass transport due to tidal mixing. This forms an important transport phenomena in combination with to the net freshwater flow through the estuary and, as such, must be included specifically in the analysis.

Lakes and reservoirs can involve either two or three spatial dimensions. Initial assessments of long-term stormwater impacts in lakes and reservoirs may be made with a few simplifying assumptions. To determine the average concentration of slowly reactive constituents (i.e., dissolved solids, persistent organics, etc.), the water body may be assumed to be completely mixed.

The objective of a 201 Facilities Plan for CSOs should include the following elements. First, the need for controlling waste loads from each source should be assessed. The need should be defined in terms of sufficient impacts on receiving water quality which violate water quality standards and as a consequence impair or deny desired beneficial uses of the receiving water body. Secondly, where a need for CSO control has been established, the 201 planning effort should identify a control strategy for which cost-effectiveness is justified in terms of the receiving water benefits expected to accrue.

In order to determine receiving water impacts, it is necessary to identify the magnitude of the waste loads which enter the receiving water. The determination of point source continuous loads is straightforward, being defined by the volume and quality of the discharge. However, intermittent waste loads, which result from the rainfall process, are more difficult to characterize. The intermittent nature of rainfall, the number and wide spatial distribution of overflow points, and the variability in both size of storm event and pollutant concentrations found in runoff, make a definitive determination of such loads impractical, if not virtually impossible.

Once the magnitude of stormwater impacts on receiving water quality are estimated, control strategies for the reduction of these impacts may be analyzed. A variety of stormwater control alternatives are available. These are generally grouped into two types of approaches:

1. Structural, end-of-pipe treatment devices
2. Management practices

Structural, end-of-pipe alternatives include devices which capture and store runoff, such as interceptors and retention basins, and devices which reduce the pollutant concentration of runoff or overflows, such as screens, filters, concentrators, and disinfection systems. Management practices include source controls, such as street sweeping and erosion control; and collection system management techniques, such as sewer flushing and polymer injection to increase the flow capacity of the sewerage system. The projected improvement in receiving water quality due to the modification of stormwater loads represents the benefit of potential stormwater control actions.

BENEFIT ANALYSIS FOR COMBINED SEWER OVERFLOW CONTROL

TECHNOLOGY TRANSFER SEMINAR PUBLICATION
ENVIRONMENTAL RESEARCH INFORMATION CENTER
CINCINNATI, OHIO 45268

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April 1979

Approximately 40 million people (one-fifth of the nation's population) are served by combined sewers. There are between 1,100 and 1,300 combined sewer systems, covering an area of more than 2 and one-half million acres. Seventy-seven major cities, including 10 of the country's 14 largest have combined sewer overflow control needs of $50 million or more. They account for 96 percent of urbanized area combined sewer overflow control needs and 64 percent of national needs.

Some of the options for controlling combined sewer overflows, especially those involving the division of the combined sewers into separate storm and sanitary systems, necessitate monumental expenditures that severely strain local budgets and state construction grant allocations.

As a tool to relate proposed expenditure to anticipated benefit, a properly executed benefit analysis helps a municipality, and thus the U.S. government, avoid unnecessary costs. A benefit analysis provides justification for funding requested from the state and EPA, and it demonstrates to the taxpayers that their tax dollars are being used to achieve desirable objectives.

To succeed in obtaining approval and funding assistance for a combined sewer overflow (CSO) project, it is necessary to know the regulations and policies that have an impact on ultimate grant application approvals. A clear understanding should be developed at the beginning of the process, because the plans must provide special outputs and must meet a number of criteria peculiar to combined sewer overflow control planning.

In any well executed planning process in the public realm, there are two general principles regarding the preparation of objectives. First, the effort to define them should begin early in the project. Second, though decisions on objectives can be facilitated by the technicians and consultants who can suggest alternatives and indicate the range of choices, the actual choices must be made by elected officials. A third principle has applicability to many types of projects but is of critical importance to planning for control of pollution from combined sewer overflows. The tasks of developing a combined sewer overflow control program that will qualify for EPA approval and funding and then obtaining the funding as well as local support for the proposal will be immensely easier if the combined sewer overflow control objectives are related to benefits and expressed in such a way that measurement of benefit is made possible. It is the benefits that are the results of pollution abatement - the improvements expected in receiving water uses - that must be demonstrated. Because this is the case, it makes sense to select as pollution control objectives the maintenance of or improvement in specific beneficial uses.

The determination of both required and desired uses of local receiving water is only the beginning of the analysis necessary to plan for combined sewer overflow control projects that are to be funded by the federal government. One criterion for federal approval of combined sewer overflow projects is that the analysis must have "...demonstrated that the level of pollution control provided will be necessary to protect a beneficial use of the receiving water even after technology-based standards...are achieved by industrial point sources and at least secondary treatment is achieved for dry weather municipal flows in the area." Combined sewer overflow control must also be shown to be more cost effective than "the addition of treatment higher than secondary treatment for dry weather municipal flows in the area." Taken together, these criteria mean among other things, that in order for a CSO project to qualify for federal funding, the pollutants to be controlled must be identified with a specific beneficial use and that a primary contributor of that pollutant must be demonstrated to be combined sewer overflows.

Selecting from among the alternatives available for controlling combined sewer overflows does not enter the planning process until many decisions about desired benefits have been made and data gathering is quite far advanced. The water quality parameters associated with the desired beneficial uses provide the link between objectives and control alternatives. The objectives must first be translated into the water quality criteria necessary to protect the uses. Then the reductions in specific pollutant inputs required to meet the criteria can be calculated. With this work completed, two tasks remain: the development of a control strategy and the selection of control alternatives.

Technologies to control pollution from combined sewer overflow, many of which are also applicable to urban stormwater runoff, can be grouped in three main categories: source controls to reduce the amounts of pollutants entering the sewer system, collection system control to improve the system's effectiveness in storing and handling the flows, and off-line storage and treatment to remove pollutants from combined sewer flows. The control alternative selected for any given situation may include techniques from one or more of these groups.

Most source controls are non-structural in nature. The principle common to all of them is reduction of pollutant accumulation on impervious surfaces in the drainage basin or in portions of the collection system itself, so that pollutant loadings in combined sewer flows during storm events are lowered. Included under the category of source controls are: street cleaning, combined sewer flushing, and catch basin cleaning.

Techniques of collection system controls are intended to ensure that the sewer system operates as efficiently as possible and that maximum advantage is taken of any opportunities it offers for combined sewer overflow pollution reduction. All of these measures require detailed knowledge of the sewer system. Some are structural and some are nonstructural. Included under collection system controls are the following: existing system management, flow reduction techniques, sewer separation and in-line storage.

When the list of control alternatives has been narrowed down to those that look most promising, each should be tested again for effectiveness in providing the desired benefit--that is, in meeting the criteria to protect that benefit.

The analysis and planning for combined sewer overflow correction has rested solidly on a determination of desired or required beneficial uses of a receiving water body and the most cost effective controls that will result in these beneficial uses. The culmination of this process in a decision to proceed depends on the presentation of the answers to three basic questions:

- What are the benefits?
- How costly is the project?
- Do the benefits expected justify the commitment of public funds and other resources?

The key to a successful outcome of this stage is that the questions be answered in a clear, logical, and realistic manner. The dollar amounts involved in combined sewer overflow control projects are invariably large enough to attract more than casual interest. If it is not possible to demonstrate to the taxpayers a favorable relationship of benefits to costs, it is not likely that they will lend their support to the undertaking.

COMBINED SEWER OVERFLOW ABATEMENT ALTERNATIVES
WASHINGTON, D.C.

by

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THE WATER QUALITY OFFICE
ENVIRONMENTAL PROTECTION AGENCY

August 1970

Most United States cities today are served both by combined sewers and by separate sanitary and storm sewer systems. As determined from a 1967 survey sponsored by the Water Quality Office of the Environmental Protection Agency, approximately 29 percent of the total sewered population of the United States is served by combined sewer systems. Approximately three percent of the total annual flow of sewage and as much as 95 percent of the sewage produced during periods of rainfall is carried with combined sewer overflows to the surface waters.

The District of Columbia follows this pattern, with an area of approximately 20 square miles (one-third of the total area of the District) being served by combined sewers. The hydraulic capacity of the system is often exceeded during periods of precipitation, and raw sewage mixed with surface runoff is discharged to the watercourses of the District.

The Potomac Estuary is polluted and continues to experience problems with low dissolved oxygen, excessive algae growths, sediments, high concentrations of fecal bacteria and repulsive floating matter. All of these problems, except sediments, are complicated by combined sewers. Although combined sewer overflow adds to the sediment load, the primary source of sediment is the heavy silt load included in the runoff from areas with significant agricultural and construction activity. In addition to the effects of combined overflow on the Potomac River, overflows into Rock Creek detract from the natural and recreational features of this small, scenic stream flowing through the District.

After review and interpretation of pertinent information, four methods of abating pollution from combined sewer overflows appeared to offer sufficient promise to justify consideration as alternative approaches for the District:

1. <u>Sewer Separation</u>
   This alternative would completely separate storm and sanitary sewers.

2. <u>Storage Reservoirs</u>
Sufficient underground storage volume would be provided to hold the combined sewer overflows caused by each storm until the storm subsides and stored wastewater would then be pumped the back into the sewerage system for conveyance to a centralized treatment plant.

3. <u>Treatment at Overflow Points</u>
A treatment facility would be located at each existing overflow point, except where conditions either prevent this or dictate that certain overflow points be combined.

4. <u>Tunnels and Mined Storage</u>
Combined sewer overflow would drop through a vertical shaft down to an underground system of tunnels and mined storage. The tunnels would convey the overflow at high velocity to mined storage. After the storm subsides, the retained overflow would be pumped back into the regular sewers.

Cost is an essential factor in selecting the appropriate alternative for abating combined sewer overflows. In summary, the costs for each alternative were as follows:

1. Storage Reservoirs	\$5,560,000
2. Treatment at Overflow Points	\$6,820,000
3. Conveyance Tunnels and Mined Storage	\$3,500,000
4. Sewer Separation	Considerably greater than the above 3

To determine which of the feasible alternative approaches would offer the best opportunity for abatement of the combined sewer overflow problem requires careful consideration of many factors. Cost comparison obviously is essential, but there are other factors which also have a significant bearing on the selection of the most favorable plan. The most important of these other factors are reliability, flexibility, land requirements, public convenience, implementation, and solids disposal and gas production.

Each strategy offers a different level of costs, pollutant loadings, and benefits. While the selection of the appropriate strategy rested partially on factors beyond the scope of this study, the information presented within this article indicated that the appropriate District-wide solution would utilize mined storage and conveyance tunnels. The total project costs of the recommended alternative was estimated to be \$318,000,000 in 1970 .

COMBINED SEWER OVERFLOW ABATEMENT PROGRAM, ROCHESTER, N.Y.

VOLUME I: ABATEMENT ANALYSIS

by

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Pollution abatement analyses, conducted in conjunction with system network modeling studies and supported by combined sewer overflow (CSO) monitoring and sampling, were initiated with the ultimate goal of formulating a cohesive and workable Master Plan for CSO reduction and control in Rochester, New York. The Master Plan was developed in light of fiscal constraints, sewer system complexities, necessity for optimized benefits from minimal capital and operating expenditures, and best use policies for the affected receiving waters. The present methodology is considered applicable to other urban areas.

Overflow monitoring and sampling data from thirteen CSO locations within the Rochester, New York Pure Waters District collected during the period January through December, 1985 served as the basis for network modeling studies. Within each of these overflow discharge conduits, an electronic flow measuring system was installed to determine the hydrograph and thus the quantity of combined sewer overflow discharged from the tributary drainage area.

To collect the samples, samplers were installed at each of the overflow locations. Samples were collected at approximately 15-minute intervals unless the pumping distance dictated suction and purge times greater than 15 minutes. At the completion of an overflow event, the samples were collected and transported to the laboratory for analyses.

A system of 12 rain gauges was installed within the Rochester Pure Waters District. The location of each gauge was selected by dividing the District into 12 units of equal area. Within each of the units, a building of significant height (school, firehouse, pump station) with no observable influences from adjacent buildings or trees was selected for installation. The total system of gauges allowed an evaluation of differences of rainfall patterns and their possible effect on the intercepting sewer system.

The flow, analytical, and rainfall data that were monitored and recorded served two main purposes. First, the data was used directly in the calibration and verification process associated with the application of the SWMM. Secondly, much of the data was used for developing valuable relationships between rainfall and overflow quantity and quality through the use of statistical procedures.

In the overall effort to develop an abatement and management program for the combined sewer overflows, the physical characteristics of the entire study area were defined. A brief description of the scope of work outlined for the drainage areas surveys follows:

1) Each of the 13 CSO locations were divided into a maximum of sixty subcatchments ranging in size from ten to fifty acres. Division was made on the basis of land slope and zoning classifications such as residential, commercial, industrial, or open.

2) Each drainage area subcatchment was characterized by determining the average ground slope, percent of the area that is pervious and impervious, total area, average drainage width, total length of gutters, total number of catch basins and stored volume of each, the BOD_5 contained in the volume of stored water in those catch basins, and any available surface storage capacities.

3) The estimation of dry-weather flow for each subcatchment was made by collecting statistics as to the number of dwelling units, average number of people per unit, market value of average units, average family income, percent of units with garbage grinders, and information as to industrial process flows.

4) Other information required to complete the characterization of the drainage basin included total population, street cleaning frequency, average number of sweeper passes, and location of inlet manholes.

5) Information was obtained to characterize the sewer network including length of sewer conduits, conduit slope, type, size and roughness, and manhole invert and ground elevations.

The two models selected for demonstration and use in the evaluation of various combined sewer overflow abatement alternatives proposed under this program were the SWMM (II) and the Simplified Storm Model (7). The Simplified Stormwater Model was developed by Metcalf & Eddy, Inc. Each model was selected for a specific purpose. Preliminary screening of various abatement alternatives was accomplished with the use of the Simplified Stormwater Model, whereas, the SWMM was used to evaluate specific alternatives under the application of varying design storms.

There are three general approaches available for the control of stormwater and CSO discharges. A combination of storage and treatment can be applied through the use of structurally intensive measures to attain defined water quality standards. Secondly, the sources of the pollutants discharged into the sewer system can be addressed through the application of the Best Management Practices (BMP) concept. Thirdly, a combination of the two can be applied. In general, the most cost-effective abatement alternative will be the application of structural and nonstructural (BMP) measures.

For this article, the alternatives that were evaluated can be classified as nonstructural, minimal structural, and structurally intensive. The first two classes of abatement alternatives are those generally considered in developing a BMP program.

Nonstructural Alternatives

1) - Land Use Policies
   - Land use policies and sewer system maintenance procedures can significantly affect both the quantity and quality of combined sewer overflows.
2) - Street Cleaning Practices
3) - Increased Sewer Maintenance
   - Sewer maintenance has potential for not only reducing system flooding but also minimizing first flush effects.
4) - Land Use Planning
   - Increased imperviousness adversely affects the quantity and quality of stormwater and combined sewer overflow.
5) - Surface Storage

Minimal Structural Alternatives

1) Abandoned Treatment Facilities
2) Multi-Purpose Upstream Impoundment for Overflow Control
3) Use of In-System Regulators and Control Structures for Increased In-System Storage
4) Upgrading the Existing St. Paul Interceptor
5) Selective Blockage of High Impacting Combined Sewer Overflows
6) Selective Overflow Weir Evaluation
7) Regulator Capacity Evaluation

Structural Intensive Alternatives

Alternative 1: This alternative considered capturing the first-flush from all the river overflow sites and treating all post first-flush flows with primary swirl devices. The temporarily stored first-flush volume would be released back into the interceptor system on termination of system overflows.

Alternative 2: This alternative involved evaluating various storage and treatment options for capturing the total overflow to the Genesee River.

Alternative 3: The only difference between Alternatives 2 and 3 was the location of the treatment facility.

Alternative 4: This alternative is similar to Alternate 1 with the exception that the post first-flush would not be treated, but directly discharged to the river.

Alternative 5: Primary swirl concentrators would be located on each of the river overflow locations for treatment of the entire overflow volume.

Alternative 6: This alternative involved construction of an interceptor to convey overflows from the western portion of the collection system to the Cross-Irondequoit Tunnel. The latter facility served the eastern portion of the city and had in-system storage available.

Cost benefit analyses of all structurally intensive alternatives were conducted using optimum treatment process train configurations developed from pilot plant evaluations, as reported in Volume II of the project's report.

Based on the results of this investigation, the following conclusions were made.

General

1. A rigorous definition of the existing system of CSO and stormwater facilities is fundamental to the development of an abatement program. This definition includes the identification of major drainage basins, major trunk and intercepting sewers, and CSO and stormwater relief points.

2. The installation and proper maintenance of overflow monitoring instrumentation is essential for both receiving water problem definition and any subsequent sewer network and water quality model calibration and verification.

3. Accurate rainfall data collection and subsequent statistical analyses, including design storm definition and formulation, is essential in evaluating the response of the existing system as well as the effectiveness of various abatement alternatives.

4. Development of a methodology of approach and definition of applicable abatement alternatives early in the program ensures that the purpose of the study is not lost, and all data collection activities are conducted according to the required analyses.

5. SSM is capable of providing a preliminary screening of potential abatement alternatives involving a balance between storage and treatment.

6. SWMM (USEPA Stormwater Management Model-Version II) can project the urban storm runoff and quantities within acceptable confidence limits but is presently limited in its ability to simulate overflow quality.

7. Overflow quality can be better simulated through the application of statistical techniques using actual monitoring overflow data.

8. The ability to abate CSO pollution resulting from an infrequent design storm event will require the implementation of structurally intensive facilities, minimal structural improvements to the existing sewer system, or the implementation of nonstructural abatement alternatives, known as BMPs.

COMBINED SEWER REGULATOR OVERFLOW FACILITIES

AMERICAN PUBLIC WORKS ASSOCIATION DEPARTMENT OF THE INTERIOR

July 1970

PROGRAM NO. 11022 DMU

An in-depth investigation of combined sewer regulator practices was carried out by the American Public Works Association. The focus of this investigation was on design application, performance, operation and maintenance practices, and equipment. The study provided information upon which to base recommendations on the more effective use and management of existing regulator facilities and on maximizing the quality of wastes discharged to receiving waters. This report was dedicated entirely to regulator facilities and was not concerned with other aspects of combined sewer systems.

The findings and major recommendations of this study included the following:

- It is economically infeasible to apply expensive and sophisticated regulator devices in small regulator structures which handle flows of 2 cfs or less. Consolidation of small regulator-overflow locations would make it feasible to provide more effective control facilities.
- Regulators should be designed to control both quantity and quality of overflows. Too often, design is concerned only with the quantity of the overflow.
- Management of control for an entire sewer system could result in less overflows than would be seen in a system which has all independently controlled devices.
- Control systems should have the ability to direct excess flow in one part of a system to another part of the system which may have available capacity to handle the excess flow.
- Dynamic-type regulators, while more costly for initial installation, are better able to reduce overflows than static devices. This is a result of the dynamic regulators' ability to react to sewer system hydraulic conditions.

- Many existing dynamic-type regulators have been removed or disabled because of maintenance and repair costs. Each type of regulator should be given the attention required to achieve maximum performance (instead of being neglected).

- Regulator facilities should be designed such that they are easily accessible for routine maintenance purposes. Inaccessible regulator stations tend to discourage the frequency and effectiveness of inspections and maintenance.

- Training is extremely important for the proper operation of an overflow control device. Maintenance crews should be adequately staffed and provided with the necessary equipment and tools to service the equipment.

- Corrosion and wear can shorten the life of overflow control equipment. Adequate specifications must be prepared to address existing environmental conditions.

- Tide gates are often poorly located for maintenance purposes. Design should provide sufficient access.

- State water pollution control agencies have not exerted enough regulator control over sewer overflows.

- Manufacturers, officials, and designers should communicate more often on overflow matters. This would produce a better knowledge base for reducing overflows.

- A Manual of Practice has been developed on the design, operation, and maintenance of combined sewer overflow regulators and tide gates, as part of this study.

- Clogging is the most frequent cause of regulator malfunction. Maintenance should be designed to reduce these effects.

- Local jurisdictions should gather information on the frequency and extent of overflow events.

- European practices have been effective and should be studied for use in the United States and Canada.

CONTROL OF COMBINED SEWER OVERFLOWS IN MINNEAPOLIS-SAINT PAUL

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DEPARTMENT OF THE INTERIOR

October 1971

NTIS PB-212 903

This report represented one phase of a larger scale study which was designed to develop criteria and a rationale for the establishment of centralized metropolitan water intelligence systems in urbanized and urbanizing areas. This particular phase of the overall project (Phase I) was focused on real-time automation and control facilities for combined sewers. Basic objectives of Phase I were to:

- Investigate and describe modern automation and control systems for combined sewer systems,
- Develop criteria for managers, planners, and designers for the operation of combined sewer systems, and
- Study the feasibility of automation and control systems for combined sewer systems.

This report was prepared in connection with one task of Phase I, which examined existing planned automation and control systems. The planning, design, operation, and maintenance of computer controlled systems was studied. Regulators were redesigned and rebuilt; rainfall, water level, and water quality data were monitored and transmitted to computer based data logging and processing centers; and regulators, gates, and pumps were remotely controlled. These controls were not designed as integral parts of complete metropolitan systems, but were implemented to demonstrate concepts and hardware.

Existing overflow regulators were replaced with power operated gates at 16 key diversion locations. The new regulators will control flows and levels in the sewers by adjusting gate position (tied to a telemetering system). River water quality was also monitored at five (5) locations. The CSO control system had basically five (5) functions:

- Scan and print readings of river quality, regulator activities, interceptor conditions, and rainfall;

- Control regulator gate positions;

- Perform analyses of data;

- Provide an operational model that could aid the operator during rainstorm events; and

- Perform any other functions for management that would not affect performance during rainstorm events.

Data acquisition for the system program emphasized providing immediate information on river quality, including dissolved oxygen, chloride, ORP, pH, and temperature. Additionally, depth of flow in the trunk sewers, depth of flow in the overflow pipe, position of the regulator, and rainfall data were immediately available. Control functions included operating gates to predetermined set points based on system conditions. The main concerns of the operator were to prevent:

- surcharging of the trunk sewers
- excessive pressure buildup on the inflatable dams and gates.

Operation of the system, as of 1971, consisted only of deflating system dams (allowing an overflow) if system pressures became too high. No attempts were made to utilize the control system as a storage area for excessive combined sewer flows.

The demonstration project discussed in this article was a definite success insofaras demonstrated the feasibility of controlling of combined sewer overflows. Overflow regulators could be remotely controlled based on parameters monitored throughout the interceptor system. The conclusions stated, however, that the demonstration project was not being used up to its potential. No attempts were being made to optimize storage of combined sewage overflows in the interceptor system and the prediction model developed to assist an operator was not being used.

COUNTERMEASURES FOR POLLUTION FROM OVERFLOWS

THE STATE OF THE ART

by

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Control and/or treatment of stormwater discharges and combined sewer overflows from urban areas are problems of importance in the field of water quality management. Over the previous decade, much research effort was expended and a large amount of data was generated, primarily through the actions and support of the U.S. Environmental Protection Agency's Storm and Combined Sewer Research and Development Program.

Combined sewer overflows are major sources of water pollution, but even discharges of stormwater alone can seriously affect water quality. Current approaches involve control of overflows, treatment and combinations of the two. Control may involve maximizing treatment with existing facilities, control of infiltration and extraneous inflows, surface sanitation and management, as well as flow regulation and storage.

Examples of source controls include flow attenuation, erosion control, restrictions on chemical use (deicing compounds, pesticides), and improved neighborhood sanitation practices. The theory behind source controls is to limit the supply of contaminants. The benefits are not only reduced water pollution but also cleaner and healthier environments.

Examples of collection system controls include flushing, polymer feed, inflow/infiltration control, improved regulator devices, sewer separation, and remote monitoring/control systems. The emphasis, with the exception of sewer separation, is upon optimal utilization of the existing facilities.

Storage facilities possess characteristics which are also beneficial in stormwater treatment: 1) they are capable of providing flow equalization or attenuation and, in the case of tunnels, flow transmission; 2) they are simple to design and operate; 3) they respond without difficulty to intermittent and random storm behavior; 4) they are relatively unaffected by flow and quality changes; and 5) frequently they can be operated in concert with regional dry weather flow treatment plants for benefits during both dry and wet-weather conditions. Disadvantages of storage facilities include their large size, high cost, and dependency on other treatment facilities for dewatering and solids disposal.

Physical treatment processes in many ways are well suited to stormwater applications, particularly with respect to solids removal. These processes include sedimentation, dissolved air flotation, screening, filtration, and flow regulation. Handicaps appear to be sensitivities to flows and loadings, high maintenance requirements, and the absence of effective utilization between storms.

Biological treatment of storm wastewaters must overcome some serious drawbacks: 1) the biomass used to assimilate the waste constituents must either be kept alive during times of dry weather or allowed to develop for each storm event; and 2) once developed, the biomass is highly susceptible to washout by hydraulic surges or overload.

Physical/chemical processes are of particular importance to stormwater treatment because of their adaptability to automated operation, rapid startup and shutdown characteristics, and very good resistance to shock-loads. Drawbacks to physical/chemical treatment include high initial costs, high chemical requirements, and increased sludge (by dry weight) to be disposed of.

By far the most promising approaches to urban stormwater management involve the integrated use of control and treatment with an areawide, multidisciplinary perspective. Integrated approaches are notably demonstrated in programs underway in Chicago, San Francisco, Seattle, Washington, D.C., and Rochester, New York.

Two directions for further study were suggested: 1) Characterization and Evaluation: Simulation Models, Nationwide Assessment of Urban Runoff Impacts, Combined Sewage Sludge, Uniform Procedures for Analysis and Evaluation of Storm Flow Characteristics and Treatability, Flow Measurement, Consideration of Trace Pollutants, and Pathogen Detection, and 2) Control Methodology: New Sewer Design, Upstream Impoundment, Catch Basins, Runoff Attenuation by Porous Pavement, Dual Use Facilities, Swirl and Helical Separators, Comparisons of Screening Devices, Hydrologic-Hydraulic Design Rationale, and Beneficial Use of Stormwater.

A nationwide characterization and evaluation of the impact of new methods for the determination of pathogenic pollution would be required in addition to a reevaluation of disinfection requirements. Methods of controlling and treating heavy metals and organics found in runoff should be developed. Detention, both in-line and upstream, needs further development to optimize its effectiveness as a pollution abatement procedure.

Multi-billion dollar treatment plant upgrading and expansion programs now in progress throughout the country will do much to alleviate water pollution. However, means of mitigating the effects of urban runoff must also be found if we hope to abate the pollution in an optimal manner.

DRY WEATHER DEPOSITION AND FLUSHING FOR COMBINED SEWER OVERFLOW POLLUTION CONTROL

by

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This report summarizes the results of a two-year study aimed at addressing the feasibility, cost-effectiveness and ease of application of upstream solids control as an integral part of overall combined sewer management. The project was functionally divided into four major phases. The first three phases were intensive field engineering investigations, while the fourth phase was relegated to data reduction and desk-top analytical efforts.

In the first phase of field work, four test segments on different streets in the Boston sewerage system were field flushed over an extended period using different flushing methods. External sources of fresh water, as well as treated sewage, were used. The experiments were aimed at quantifying the effectiveness of flushing deposition accumulations from a single pipe segment on a routine basis, as well as roughly estimating deposition characteristics within collection system laterals. Removals of 75 to 90 percent for grit, organic and nutrient contaminants can be expected for single manhole to manhole small diameter combined and separated sewer laterals. All flushing methods yielded comparable flushing pollutant removals. The most effective flushing method was an application of about 50 cubic feet (1.42 cubic meters) of water, injected at discharge rates exceeding 0.5 cfs (14.4 liters per second).

The second phase of field work was concerned with the problem of flushing a long flat stretch of combined sewer laterals. Flushes were injected into the uppermost manhole and pollutant levels in the flush wave passing three downstream manholes were monitored. Work was divided into two subphases. Initially, pollutant removals over the three segments were determined for different flushing conditions established in the first manhole, providing insights into flushing effectiveness over three segments of pipe. The results of these experiments indicated that a single flushing at the upper end of the street was reasonably effective in removing most of the deposited load along the 675-foot (206 m.) stretch of 12-inch (30.5 cm.) combined sewer lateral. Next, settleability tests were performed for the purpose of crudely extrapolating how far beyond the

flushing monitoring manholes the materials would be carried. The experiments showed that heavier grit fractions would quickly resettle, leaving the lighter solid fractions in suspension. Roughly 20 to 30 percent of suspended solids and about half of the BOD and nutrient loads would remain in suspension after 30 minutes of settling time. Analysis of the heavy metals results from the settleability experiments indicated that about 20 to 40 percent of the heavy metals would not settle within two hours of settling.

In the final phase of field operation, an automatic sewer flushing module was designed, fabricated, installed, and operated on a single segment for an extended period. Flushed pollutant loads were determined for seven flushing events, and were comparable to removals noted in the first phase of work, where flushing was accomplished by manual means using a flush truck. The purpose of this work was to begin to develop operational experience using automated flushing equipment. The state-of-the-art with respect to operational automated flushing methods, equipment, and sensing interfaces has not been fully demonstrated at this point in time. The effort in this study is viewed as a pilot prototype investigation.

In the fourth phase, various predictive deposition loading and flushing criteria were generated from the large data base developed during the field programs. These formalisms allow for scanning of large-scale sewer systems to identify problem pipes with respect to deposition. The refined tools will allow for comparative analysis of upstream solids control vs. selected structural options to compare program efficiencies.

THE METHODOLOGY OF ANALYSIS FOR A COMBINED SEWER OVERFLOW ABATEMENT PROGRAM

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CHICAGO, ILLINOIS

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The Fifth Annual International Joint Commission (IJC) Report on Great Lakes Water Quality acknowledged the impact of urban runoff in the Great Lakes Basin:

> "The Commission believes that combined sewer overflows and stormwater flows from urban areas are reaching serious proportions and contribute significant amounts of a wide range of harmful substances in the Great Lakes."

Urban runoff is composed of two major components, stormwater and combined sewer overflow. Stormwater discharges consist of runoff from various impervious areas which have been contaminated by pollutants accumulated on the various surfaces due to chemical spillage, air pollution, atmospheric washout, the application of highway deicing agents, fecal matter of animal origin, and the accumulation of surface debris and litter. The combined sewer overflows contain stormwater and sanitary sewerage.

The problem of combined sewer overflows is extensive insofaras one-fifth of the nation's population is served by combined sewer systems. Furthermore, ten (10) of the nation's fourteen (14) largest cities are served by a combined system in whole or in part.

The objective of facilities planning is the development of cost effective, environmentally sound and implementable conveyance and treatment systems which will meet applicable requirements of Sections 201(g), 301, and 302 of PL 92-500.

Consistent with 40 CFR Part 35, Subpart E (Grants for Construction of Treatment Works - Federal Water Pollution Control Act Amendments of 1972) a facilities plan is to include:

- A description of the treatment works for which construction drawings and specifications are to be prepared,
- A description of the selected wastewater treatment system covering all elements of the system,
- Infiltration/inflow documentation,
- A cost-effectiveness analysis of the alternatives,
- Identification of effluent limitations (permit),
- Required comments or approvals of relevant state, interstate, regional and local agencies,
- Brief summary of pertinent public hearings or meetings, and
- Brief statement demonstrating the implementability of the project.

The facilities planning activities are essentially the same for conventional treatment facilities as for combined sewer overflow facilities. However, there were some difficulties in the planning process. As a result, EPA established certain specific policies (PRM 75-34 and PRM 77-4) which described how these issues were to be addressed in the facility planning for combined sewer overflow abatement facilities.

PRM 77-4 outlined a cost allocation procedure for multiple purpose projects, allowing EPA and the applicant to select the abatement alternative which offers the highest cost-effectiveness relative to pollution control. PRM 75-34 outlines the procedure to select the alternative and the sizing necessary to optimize the marginal cost/marginal benefit ratio of the abatement options.

In the process of conducting the Rochester, New York CSO study, a methodology for the analysis of CSO abatement alternatives was developed. The abatement alternative analysis involved the logical development of a data base which analyzed activities in fifteen major categories.

A number of points were stressed in the development of the methodology sequence. The first of these points was the need to define the applicable abatement alternatives very early in the program. This process ensure that the purpose of the study is not lost and all data gathering activities be conducted according to the required analyses.

Another important step was the calibration and verification of all models that were used for CSO analysis in the study area. The models selected for application were based on the urban area and collection system requirements as well as the objectives defined in the initial phase of the program. The Simplified Stormwater Model was used in the initial screening of alternatives. The final analysis was conducted on a selected number of abatement alternatives with the use of SWMM Version II. In conducting the network model activity, it became apparent that one should not use models which are more complex than the analysis requires. One should be certain to utilize the simplest model which will attain the defined objectives. It is for this reason that the Simplified Stormwater Model or an equivalent planning tool was recommended in the initial screening of alternatives, while the use of SWMM Version II was recommended in the final analysis of a select number of abatement alternatives.

The following major tasks are considered to be most important in the methodology necessary to develop a combined sewer overflow master plan: definition of program objectives, definition of existing conveyance and treatment systems, definition of drainage areas and their characteristics, review of the meteorological data base, selection of detailed network model to be utilized in the hydraulic analysis of the existing system and the proposed alternatives, initiation of the overflow and meteorological monitoring program necessary to augment the existing data base, establishing relevant abatement alternatives, use of a simplified stormwater model to evaluate the existing system - long-term simulation, initial evaluation of storage/treatment - capital intensive alternatives using the simplified stormwater model, calibration and verification of the detailed network model, application of the detailed network model to the preliminary evaluation of non-structural alternatives, selection and verification of wet weather quality predictive models, evaluations of applicable treatment processes, detailed analysis of the prime alternatives, development of the CSO abatement Master Plan.

In light of the very significant capital and operating costs associated with the implementation of capital intensive storage/treatment alternatives, a more exacting system analysis is necessary to evaluate the application of less capital intensive measures which may be particularly effective in optimizing the performance of the existing system. The methodology and tools of analysis are presently available which allow the development of a comprehensive and cost-effective combined sewer overflow abatement program.

PREVENTION AND CORRECTION OF EXCESSIVE INFILTRATION AND INFLOW INTO SEWER SYSTEMS

MANUAL OF PRACTICE

by the

AMERICAN PUBLIC WORKS ASSOCIATION

January 1971

As a result of a national study of the sources and prevention of infiltration and inflow, a Manual of Practice was proposed. The Manual is intended to serve as a guide to local officials in evaluating their construction practices, conducting surveys to determine the extent and location of infiltration and inflow, the making of economic analyses of the cost of excessive infiltration/inflow waters, and instituting corrective action.

"Infiltration" covers the volume of groundwater entering sewers and building sewer connection from the soil, through defective joints, broken or cracked pipe, improper connections, manhole walls, etc.

"Inflow" covers the volume of any kinds of water discharged into sewer lines from such sources as roof leaders; cellar and yard area drains; foundation drains; commercial and industrial so-called "clean water" discharges; drains from springs and swampy areas; etc. It does not include, and is distinguished from, "infiltration".

"Infiltration/Inflow" is the volume of both infiltration water and inflow water found in existing sewer systems, where the indistinguishability of the two components of extraneous waters makes it possible to ascertain the amounts of both or either.

Infiltration and inflow conditions have two characteristics in common, in that each problem is divided into two parts: prevention of excessive extraneous flows, and correction of conditions already imposed on existing sewer systems.

In the case of infiltration, prevention of excessive entries into new sewer systems depends on effective design; choice of effective materials of sewer construction; imposition of rigid specifications limiting infiltration allowances; and alert and unremitting inspection and testing of construction projects to assure tightness of sewers and minimization of infiltration waters.

Correction of infiltration conditions in existing sewer systems involves evaluation and interpretation of sewage flow conditions to determine the presence and extent of excessive extraneous water flows from sewer system sources, the location and gauging of such infiltration flows, and the elimination of these flows by various corrective, repair and replacement methods.

Prevention of excessive inflow volumes is a matter of regulating sewer uses and enforcement of such precepts and codes by means of vigilant surveys and surveillance methods. Correction of existing inflow conditions involves location of points of inflow connections; determination of their legitimacy or illicit nature; evaluation of the responsibility for correction of such conditions; establishment of inflow control policies where none have been in effect; institution of corrective policies and measures, backed up by investigative and enforcement procedures to make such policies potent.

The initial area of concern in reducing or eliminating infiltration involves the production of a pipe system and appurtenances which are water-tight and do not permit groundwater leakage. The realization of this objective begins during design. A number of preliminary activities are necessary to provide vital background information before any design decisions are made. Soil and groundwater conditions must be considered if the design for a proposed sewer system is to avoid infiltration. The four methods of obtaining the necessry design information include: reconnaissance (the gathering of available information on soils and groundwater conditions), subsurface investigations, lab testing, and in-situ testing.

Also, the above concern is important to improvements in pipe material which ensure that the designer can provide proper materials to meet rigid infiltration allowances.

The most critical factor relative to the prevention of infiltration in new sewers is construction. All of the currently manufactured pipes and joints are capable of being assembled into sewer systems with minimal infiltration. This capability must be coupled with good workmanship and adequate inspection.

The correction of infiltration involves a lengthy, systematic approach. The first step is to identify the system by obtaining maps of the sewer system. The maps should be analyzed to develop a series of small drainage areas. Next, identify the scope of infiltration by obtaining actual dry-weather and wet-weather flow measurements at key manholes. If the infiltration/inflow problem has been identified as rain-connected and the system is supposedly separate, a rainfall simulation in the storm sewers can help pinpoint the source. It is also very important that a physical survey of the sewer system be taken to check for the effects of poor soil conditions and groundwater conditions. Next, a planned sewer cleaning program should be established. Clean sewers are a necessary prerequisite for any television inspection program and also for any correction sealing procedures. As a result of the findings of the previous stages, the best utilization of television or photographic inspection can now be determined. Based on the results and recommendations of the inspection report, sound budgeting and planning for the restoration of the system can now be achieved.

Control of inflow, like control of infiltration, resolves itself into two practices: prevention of new inflows, and correction of existing inflows. Prevention involves exclusion of inflow connections by edict, and the rejection of any such flows when new structures are built, or when existing building operations are modified. Correction involves the location of existing sources and their elimination by physical separation of any such connections in accordance with set policies of the jurisdictions.

Guidelines have been given for the control of infiltration and inflow conditions. Each jurisdiction must determine its own policies and practices, using these indicators as to what can be accomplished by new criteria and actions.

RELATIONSHIP BETWEEN DIAMETER AND HEIGHT FOR THE DESIGN OF A SWIRL CONCENTRATOR AS A COMBINED SEWER OVERFLOW REGULATOR

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EPA 670/2-74-039

This report is a supplement to the report entitled "The Swirl Concentrator as a Combined Sewer Overflow Regulator Facility" which was published in September of 1972. The 1972 studies demonstrated that the swirl device was capable of removing floatable and suspended solids from sanitary sewage and stormwater. They established a suitable relationship between chamber depth and diameter and their effect on solids removal efficiencies. The purpose of this supplemental report was to investigate the depth to width ratio established by the 1972 report and to define the dimensions which would provide optimum construction economy and operating efficiency in terms of solids.

The studies for this report were conducted on a hydraulic model of the swirl concentrator at the LaSalle Hydraulics Laboratory in Montreal. The concentrator configuration was similar to that which was used in the 1972 study. The model diameter remained constant at 36 inches with a 20-inch diameter clear liquid overflow weir and a 24-inch diameter scum ring.

The variable factors chosen to provide the chamber depth-to-width relationships were weir height and the inlet pipe diameter. The study covered five rates of discharge, including the probable ranges that would be imposed on a full-scale unit. These flowrates on a 1:12 scale of laboratory model to prototype, were: 50; 100; 150; 200; and 300 cfs. Four inlet pipe diameters were studied: 3; 4; 5; and 6 foot. The inlet wastewater line was set at a slope of 1:1,000 to provide tangential flow of incoming liquid in the swirl concentrator chamber.

At least three weir heights, or chamber depths, were tested for each inlet pipe diameter. The range selected for the hydraulic study was: 6; 7; 9;, 11; and 13 feet.

The incoming wastewater was composed of water supplied from a constant level tank in the laboratory, and synthetic solids of proper composition injected into the inflow stream by a vibrating feed unit.

The clear water outlet from the swirl concentrator was through a 6-inch diameter pipe which was installed upward through the bottom of the model centerline. The height could be varied at will by adding or removing segments to or from the top of the pipe. The foul outlet consisted of a 2-inch diameter flexible tube, leading to a solids settling tower fitted with an adjustable level outlet pipe which could be raised or lowered to regulate the rate of discharge of the solids flow.

The grit increment of the synthetic solids injected into the stream flow to the swirl was assumed to have a specific gravity of 2.65 and a straight line grain size distribution was selected as a representative average of samples taken from existing combined sewer systems - from No. 70 to No. 10 sieve sizes. The concentration range was 20 to 360 mg/l.

The organic material contained in the flow to the swirl concentrator, was defined as having a specific gravity of 1.2 and a grain size distribution from less than 0.1 to 5 mm.

The floatable increment injected in the flow had a specific gravity of 0.9 to 0.998 and a size range from 5 to 25 mm. The concentration range was 10 to 80 mg/l.

The hydraulic model could not duplicate the variations in inflow rates and in combined wastewater solids concentration, which normally occurs in sewer system operations.

The pilot study which evaluated solids recovery for four sizes of inlet pipes and various weir heights produced the following conclusions:

- Design parameters can be definitively established, covering swirl concentrator chamber diameter, inlet pipe dimensions, and internal chamber facilities, to provide specific solids removal efficiencies for prototype combined sewer overflow systems.

- For chambers having a ratio of chamber diameter to chamber depth of 4 : 1 it was found that the depth had little effect on recovery rate. The same condition was found when the ratio of chamber diameter to inlet dimension was in the range of 6 : 1 or 7.2 : 1. When the ratio of chamber diameter to inlet dimension was increased to 9 : 1 or 12 : 1, the depth or weir height had more influence on recovery rates.

- For any given discharge the use of a smaller ratio of chamber diameter to inlet dimension results in lower inlet velocity and lower chamber area and volume. Hence for economy reasons, the designer should attempt to reduce this ratio as close to six as is possible with the use of the design curves given in this report.

- Where circumstances are not favorable for the standard design with a ratio of chamber diameter to depth of 4 : 1, it is possible to decrease the chamber depth to a value equal to the inlet dimension. This also results in an increase in the chamber diameter and chamber area. The chamber volume may also be somewhat affected either up or down by this change.

The report recommended that the swirl concentrator principle be utilized more extensively for the removal of solids pollutants of both inorganic and organic nature which are contained in combined sewer overflow wastes.

REMOTE CONTROL OF COMBINED SEWER OVERFLOWS

JAMES J. ANDERSON AND ROBERT L. CALLERY

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The Minneapolis - St. Paul combined sewer system was modified with the installation of a computer-assisted, real-time monitoring and remote control to reduce number and volume of combined sewer overflows. The combined sewers service area, some of which has been partially separated, is approximately 30 sq. miles (77.7 sq. km.). Initial sewer gauging had indicated that the 30 mile interceptor system conveyance capacity was not fully utilized during wet weather events. This was because of inflexible regulator devices, and non-uniform distribution of rainfall over the service area.

The control system was designed to provide variable flow control to the interceptor system, based on current conditions in the sewer system. Rain gauges, level sensors, and gate and dam sensing devices transmit information to a central control system over leased telephone wires. The amount of flow diverted to the interceptor is controlled by inflatable fabric dams and hydraulically operated gates.

Gates and dams may be controlled remotely by an internal program, or manually by an operator at a console. The position or pressure of each dam and gate is addressed, and brought back to the proper value if the position or pressure has changed. This control system has a mathematical model to assist the operator in anticipating sewer flow conditions, based on rainfall location and intensity, and to test a change in operation before initiating it. The control system cannot operate independently, because it does not have a feedback routine in the model. The operational strategy is to maximize downstream interceptor capacity, while preventing surcharging of trunk sewers. Costs for the system in 1969 included $500,000 for regulator modifications; $185,000 for the underground control vaults, polemount cabinets, telephone and the level gauging system; and $370,000 for the central computer, level transducers, telemetry, and supervisory contact equipments.

During 1969 and 1970, overflow events were reduced by 58 and 52 percent respectively. Duration was reduced by 88 and 84 percent. Snowmelt overflow events were virtually eliminated.

RETENTION BASIN CONTROL OF COMBINED SEWER OVERFLOWS

by

SPRINGFIELD SANITARY DISTRICT
SPRINGFIELD, ILLINOIS

for the

ENVIRONMENTAL PROTECTION AGENCY
WATER QUALITY OFFICE

August 1970

Storm overflow from combined sewers discharged through the Cook Street Pumping Station of the Springfield Sanitary District into Sugar Creek has resulted in repeated fish kills during previous years. A study was undertaken to evaluate the ability of a retention basin to prevent such deterioration of water quality. Anticipated possible effects of the basin include attenuation of peak flows, sedimentation, and biological degradation. An anticipated adverse effect of the retention basin was the discharge of algae synthesized in the basin. Performance of the lagoon during the 20-month period of observation indicated that it was successful in preventing severe deterioration of downstream water quality due to combined sewer overflows.

Performance of the lagoon was monitored by daily collection of composite samples from the lagoon influent and effluent and by grab sampling of stations in Sugar Creek above and below the point of lagoon discharge. Interpretation of the capabilities and limitations of the facility was limited by the lack of capability for measuring influent flow rate and the lack of influent and effluent samples collected at various periods during storms. Hence, it was not possible to conduct mass balance computations on the basin to determine its overall effectiveness. Best evidence of the efficiency of the facility was afforded by observation of the fact that incidence of fish kills was limited following installation of the retention basin.

While the movement of individual storm flows through the lagoon could not be traced, it was observed that the average annual reduction of BOD was 27 percent and total coliform reduction averaged 72 percent. However, during the period from June through October 1969, production of algae in the basin caused the effluent BOD to consistently exceed that of the influent. This observation was substantiated by the increase in suspended solids in the effluent during these periods, increased effluent pH and supersaturation of dissolved oxygen during periods of high radiant energy. It would appear that the suitability of retention basins of the type used at Springfield should be considered on an individual basis because of the possibility of adverse water quality conditions being created as a result of the release of high concentrations of algae during parts of the year.

Considerable reductions in the concentration of indicator organisms occurred in the retention basin, averaging 72 percent. However, influent total coliform density was high (averaging 1,250,000/100 ml) and thus the effluent coliform density was significant (353,000/100 ml).

While the analysis of the performance of the basin is limited on a quantitative basis, it was shown to be an adequate solution for the existing problem at Springfield, Illinois. Only one fish kill occurred during the period of study, and it happened during a period when the basin was drained for repair.

It was not possible to quantitatively determine the relative effect of the various mechanisms which could account for the basin's performance. Sedimentation can reasonably be accredited with some water quality improvement since sludge accumulated in the basin. However, the contribution of bacteria and algae synthesized in the basin to this sediment is not known. Similarly, the amount of biological degradation of soluble and colloidal organic material has not been established. It is postulated that an appreciable amount of the observed improvement could be attributed to retention of storm flow with slow release at diminished rates to the receiving stream.

The analysis of basin performance could not provide a rational basis for determining the desirable size of storm water retention facilities at other installations. This is because the available instrumentation did not afford a measure of influent flow rate and because a portion of high storm water overflows were bypassed and did not enter the retention facility. On the basis of an increase in biochemical oxygen demand during summer months, it was anticipated that difficulty might be experienced at certain installations because of deterioration of downstream water quality or because of aesthetic objection to the high algae densities. Sizing retention facilities clearly depends upon the water quality objective involved. For example, where appreciable reductions in the density of indicator organisms is necessary, retention times approximating those provided at Springfield would not be sufficient. An additional consideration in determining basin volume is the requirement for storage of solids retained in the basin.

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SEWER FLOW MEASUREMENT
A STATE-OF-THE-ART ASSESSMENT

by

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In order to characterize stormwater and combined sewer overflows and to facilitate the development, demonstration, and evaluation of treatment and control systems for combating the problem, it is necessary to have accurate and reliable determinations of the quantity and quality of the flows. Both the quantity and quality of urban stormwater runoff are highly variable and transient in nature, because of meteorological and climatological factors, topography, hydraulic characteristics of the surface and subsurface conduits, and land use activities. Conventional flow measurement devices and techniques have been developed mainly for the relatively steady-state flows as found in irrigation canals, sanitary sewers, and large streams rather than the highly varying surges encountered in storm and combined sewers.

Measurements of quantity of flow, usually in conjunction with sampling for flow quality, are essential to nearly all aspects of water pollution control. Research, planning, design, operation and maintenance, and enforcement of pertinent laws are activities which rely on flow measurement to be effective. For some activities, very precise, time synchronized, continuous flow records are needed. With others, occasional, fairly rough estimates of flow may suffice.

The various flow measuring devices and techniques are summarized in Table 1. These evaluations were made with a storm or combined sewer application in mind and will not necessarily be applicable for other types of flows.

A second table offers a comparison of some of the primary devices or techniques that are used to measure storm and combined sewer discharges. Each method is numerically evaluated in terms of its percent of achievement of several desirable characteristics. Dilution techniques as a class promise accuracy in a number of applications. They are probably most useful as a tool for in-place calibration of other primary devices. They have also been extremely useful for general survey purposes and have found some application when added to other primary devices during periods of extreme flow such as pressurized flow in a conduit that is normally open channel.

Acoustic open channel devices are dependent on the velocity profile a resultant requirement for several sets of transducers. They are presently justifiable for very large flows because of the expense involved.

The Parshall flume is a commonly used flow measurement device. The requirement for a drop in the flow is a disadvantage, and submerged operation may present problems at some sites. Known uncertainties in the head-discharge relations (possibly up to 5 percent), together with possible geometric deviations, make calibration in place a requirement for high accuracy. Palmer-Bowlus type flumes are very popular overall. They can be used as portable as well as fixed devices in many instances, are relatively inexpensive, and can handle solids in the flow without great difficulty.

All point velocity measuring devices were included in the current meter category. In the hands of an experienced operator, good results can be obtained. They are often used to calibrate primary devices in place or for general survey work. They are generally not suited for unattended operation in storm and combined sewer flows, however.

Electromagnetic flowmeters show considerable promise where pressurized flow is assured as do closed pipe acoustic devices. Neither can be considered portable if one requires that the acoustic sensors be wetted, a recommended practice for most wastewater applications.

Open flow nozzles and sharp-crested weirs are often used where the required head drop is available. Weirs will require frequent cleaning and are best used as temporary installations for calibration purposes. Flow tubes and venturies are only suitable for pressurized flow sites such as might be encountered, for example, at the entrance to a treatment plant.

Trajectory coordinate techniques, such as the California pipe or Purdue methods, require a pipe discharging freely into the atmosphere with sufficient drop to allow a reasonably accurate vertical measurement to be made, a situation not often encountered in storm or combined sewers. Slope area methods, as explained earlier, must generally be considered as producing estimates only and, consequently, should be considered as the choice of last resort.

TABLE 1 - FLOWMETER EVALUATION SUMMARY

	Range	Accuracy	Flow Effects on Accuracy	Gravity & Pressurized Flow Operations	Submergence or Backwater Effects	Effect of Solids Movement	Flow Obstruction	Head Loss	Manhole Operation	Power Requirements	Site Requirements	Installation Restrictions or Limitations	Simplicity and Reliability	Unattended Operation	Maintenance Requirements	Adverse Ambient Effects	Submersion Proof	Ruggedness	Self Contained	Precalibration	Ease of Calibration	Maintenance of Calibration	Adaptability	Cost	Portability
Gravimetric-all types	G	G	H	Y	L	H	H	H	P	M	H	H	P	Y	H	M	-	F	Y	Y	G	F	-	H	N
Volumetric-all types	P	G	H	Y	L	H	H	H	P	L	H	H	F	Y	H	M	-	F	Y	Y	G	F	-	H	N
Venturi Tube	P	G	S	N	L	S	S	L	P	L	H	H	G	Y	M	M	-	G	Y	Y	G	G	-	H	N
Dall Tube	P	G	S	N	L	M	S	L	P	L	H	M	G	Y	H	M	-	G	Y	Y	G	F	-	H	N
Flow Nozzle	P	G	S	N	L	S	S	M	P	L	H	M	G	Y	L	M	-	G	Y	Y	G	G	-	M	N
Orifice Plate	P	F	S	N	L	H	H	H	P	L	H	S	G	Y	H	M	-	F	Y	Y	G	P	-	L	Y
Elbow Meter	P	F	S	N	L	S	S	L	P	L	H	S	G	Y	L	M	-	G	Y	N	F	G	-	L	N
Slope Area	F	P	H	N	H	S	S	L	G	L	M	S	G	Y	L	M	-	G	Y	N	F	G	-	H	N
Sharp-Crested Weir	F	F	M	N	M	H	H	H	F	L	M	M	G	Y	H	M	-	G	Y	Y	G	P	-	L	Y
Broad-Crested Weir	F	F	S	N	H	H	H	M	G	L	M	H	G	Y	L	M	-	G	Y	N	F	F	-	L	N
Subcritical Flume	F	F	S	N	L	S	S	L	F	L	M	S	G	Y	L	M	-	G	Y	Y	G	G	-	M	N
Parshall Flume	G	F	S	N	M	S	S	L	F	L	M	M	G	Y	L	M	-	G	Y	Y	G	G	-	M	Y
Palmer-Bowlus Flume	F	F	S	N	M	S	S	L	G	L	S	S	G	Y	L	M	-	G	Y	Y	G	G	-	L	Y
Diskin Device	F	F	S	N	M	M	H	L	G	L	S	S	G	N	H	H	-	F	Y	Y	F	F	-	L	Y
Cutthroat Flume	G	F	S	N	L	S	S	L	P	L	S	S	G	Y	L	M	-	G	Y	Y	G	G	-	L	N
San Dimas Flume	G	F	S	N	L	S	S	L	F	L	S	S	G	Y	L	M	-	G	Y	Y	G	G	-	L	N
Trapezoidal Flume	G	F	S	N	L	S	S	L	F	L	S	S	G	Y	L	M	-	G	Y	Y	G	G	-	L	N
Type HS, H & HL Flume	G	F	S	N	H	M	S	H	G	L	M	M	G	Y	M	M	-	G	Y	Y	G	F	-	L	Y
Open Flow Nozzle	G	F	S	N	H	M	S	H	G	L	M	M	G	Y	M	M	-	G	Y	Y	G	F	-	L	Y
Float Velocity	G	P	H	N	L	S	S	L	G	L	S	S	G	N	L	H	-	G	N	-	-	-	-	L	Y
Tracer Velocity	F	F	M	Y	L	S	S	L	G	M	S	S	F	Y	M	S	-	F	N	N	G	G	-	H	Y
Vortex Velocity	P	F	S	N	L	H	H	L	P	L	H	H	F	Y	H	S	-	P	Y	Y	F	F	-	H	N
Eddy-Shedding	F	F	S	Y	L	M	M	L	G	L	S	S	F	Y	M	S	-	F	Y	Y	G	F	-	M	Y
Turbine Meter	P	F	S	N	L	H	H	M	P	L	H	M	F	Y	H	S	-	F	Y	Y	G	F	-	H	N
Rotating-Element Meter	F	F	S	Y	L	H	H	L	F	L	S	S	G	N	H	H	-	G	N	Y	G	G	-	L	Y
Vane Meter	P	F	S	N	L	M	H	L	F	L	S	M	G	Y	M	M	-	G	Y	Y	F	F	-	L	N
Hydrometric Pendulum	P	P	S	N	L	H	M	L	G	L	S	S	G	N	L	H	-	G	N	Y	F	F	-	L	Y
Target Meter	P	F	S	N	L	M	H	M	P	M	S	M	F	Y	H	S	-	P	Y	Y	G	F	-	H	N
Force-Momentum	P	G	S	N	L	H	M	L	P	H	H	H	P	Y	H	S	-	P	Y	Y	G	G	-	H	N
Hot-Tip Meter	F	P	S	Y	L	H	M	L	F	M	M	M	F	Y	H	H	-	F	Y	Y	G	F	-	H	N
Boundary Layer Meter	G	G	S	Y	L	S	S	L	P	M	M	M	F	Y	M	S	-	G	Y	Y	G	G	-	H	N
Electromagnetic Meter	F	G	S	Y	L	S	S	L	P	H	M	H	F	Y	H	S	-	F	Y	Y	G	G	-	H	N
Acoustic Meter	G	G	S	Y	L	M	S	L	F	M	M	M	F	Y	M	S	-	F	Y	Y	G	G	-	H	N
Doppler Meter	P	G	S	Y	L	H	S	L	F	M	M	M	F	Y	M	S	-	F	Y	Y	G	G	-	H	N
Optical Meter	F	P	S	N	L	S	S	L	F	L	S	S	G	N	L	H	-	G	N	Y	G	G	-	L	Y
Dilution	G	G	H	Y	L	S	S	L	G	M	S	S	F	Y	M	S	-	F	N	N	G	G	-	H	Y

Legend:

F - Fair
G - Good
H - High
L - Low
M - Medium or Moderate
N - No
P - Poor
S - Slight
Y - Yes

TABLE 2 - COMPARISON OF MOST POPULAR PRIMARY DEVICES OR TECHNIQUES

Primary Device or Technique	Desirable Characteristic (% of Achievement)								Comments
	Range	Uncalib. Accuracy	Head Loss	Free From Upstream Effects	Free From Downstream Effects	Solids Bearing Liquids	Portability	Unattended Operation	
Dilution	100	100	100	100	100	100	100	80	Especially useful as a calibration tool.
Acoustic (Open Channel)	100	100	100	60	90	95	80	100	Good in large flows but expensive.
Parshall Flume	90	95	80	90	80	90	70	100	Requires drop in floor.
Palmer Bowlus Flume	80	90	85	90	85	90	90	100	Good overall.
Current Meter	90	95	100	100	100	90	100	0	Results are very operator dependent.
Electromagnetic	50	100	100	100	100	100	0	100	Generally requires pressure flow
Acoustic (Pressure Flow)	100	100	100	60	90	95	0	100	Wetted transducers recommended.
Open Flow Nozzle	60	95	70	80	75	80	80	95	Good if head drop is available.
Sharp-Crested Weir	60	95	70	80	80	50	80	90	Will require frequent cleaning.
Flow Tube	50	100	95	40	100	95	0	100	Pressurized flow only.
Venturi Tube	20	100	90	70	100	90	0	100	Pressurized flow only.
Trajectory Coordinate	80	70	50	100	70	100	100	0	Requires free discharge.
Slope Area	80	50	100	20	100	100	100	0	Use as last resort.

STORAGE AND TREATMENT OF COMBINED SEWER OVERFLOW

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ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND MONTIRONIG

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The objective of this study was to demonstrate the feasibility and economic effectiveness of a combined wastewater overflow detention basin. Wastewater in excess of existing transportation/treatment system capacities overflows to a detention basin during wet weather, and is later treated during periods of low flow.

A paved asphalt detention basin with a storage volume of 8.66 acre feet was constructed at Chippewa Falls, Wisconsin to receive overflow from a 90 acre combined sewer area including all of the central business district. The system was designed so that the stored combined sewage could be pumped to the wastewater treatment plant when precipitation subsided.

Project construction began in October of 1967 and was completed in March of 1969. Total capital cost for the demonstration project was approximately $610,000. This cost can be subdivided into the following components:

Detention Pond Construction		$ 60,000
Pumping Station, Pond Structures, Piping		158,000
Combined Relief Sewer and Separate Sewer		223,000
Electrical Work		21,000
Treatment Plant Revisions		117,000
Land		2,000
	Total	$610,000

This study was conducted over the two-year time frame of 1969 and 1970. Results indicated several positive effects from installation of this basin. During 1969, due to dry weather, the pond received flow during only 16 events, but completely filled twice and overflow to the river occurred. During 1970, there were 46 discharges to the pond with only one overflow to the river. Over the study period, 37.75 million gallons of combined sewage (93.7 percent of the total discharge volume) were withheld from the river for subsequent treatment. This included 49,520 pounds of BOD_5 and 90,390 pounds of suspended solids which were withheld from the river and were subsequently treated. These loads represented 98.2 percent of the total BOD_5 and 95.8 percent of the total suspended solids which were contained in the overflows from the existing transport/treatment system.

There were no observed detrimental effects on treatment plant operation due to the increased intermittent flows from the detention pond. Although the basin is located in close proximity to the business district, no complaints were received regarding any phase of the pond operation. The overflow basin stored combined sewage for periods up to 14 hours without odors developing. Substantial relief from basement flooding in the downtown area was also observed as a result of the basin.

The estimated average operating and maintenance cost attributed to the storage basin system was $7,300 per year over the two year period. The largest portion of this annual cost (75 percent) was attributed to additional treatment plant operations while pumping and pond cleaning accounted for the remaining portions (7.5 percent and 17.5 percent respectively).

A STRATEGY FOR INTEGRATING STORAGE TREATMENT OPTIONS WITH MANAGEMENT PRACTICES

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COMBINED SEWER OVERFLOW ASSESSMENT AND CONTROL PROCEDURES
WINDSOR LOCKS, CONNECTICUT

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A methodology was presented to provide planners with a tool to develop preliminary cost estimates and strategies for wet-weather pollution control facilities. The primary emphasis was placed on procedures to integrate storage/treatment options with other management practices.

Previous assessments published by the authors indicated that nationwide capital costs for wet-weather pollution control ranged from $2.5 billion at 25 percent BOD control to $41.9 billion at 85 percent BOD control. The plotted curve of function of percent BOD removal is an exponential type curve. Graphical solutions were used by the authors to evaluate a wide range of wet-weather control options.

Wet-weather pollution control costs were estimated based on production theory and marginal cost analysis from economics. A seven-step graphical procedure was developed to produce this estimate. Production functions were established for street sweeping, combined sewer flushing, and storage treatment. A unit cost of $7.00 per curb mile was established for street sweeping and $11.78 per foot of sewer was established as a unit cost for sewer flushing. Unit costs for storage treatment were taken from existing EPA publications.

The methodology was applied to a hypothetical city of 1,000,000 people. Pollutant loads were estimated, and a control network consisting of street sweeping, sewer flushing and storage/treatment was analyzed. The results demonstrated that other management practices used in conjunction with storage/treatment can give a savings of 5 to 45 percent over storage/treatment alone.

The results of the paper represent simplified estimates of system savings and pollution control, however they do suggest that management practices should be considered as part of a stormwater pollution control package. The methodology was stated to be capable of estimating the costs and cost savings of pollution control management practices.

STREAM POLLUTION AND ABATEMENT FROM COMBINED SEWER OVERFLOWS

BUCYRUS, OHIO

FEDERAL WATER QUALITY ADMINISTRATION DEPARTMENT OF THE INTERIOR

by

BURGESS AND NIPLE, LIMITED

November 1969

This report presents the findings of a study conducted to evaluate the pollutional effects from combined sewer overflows on the Sandusky River at Bucyrus, Ohio. It also presents the benefits, economics, and feasibility of abating pollution from combined sewer overflows. The study compares physical sewer separation to alternate methods of reducing or eliminating the pollution resulting from combined sewer overflows. This study focuses on determining if there are methods of abating pollution from combined sewer overflows which would accomplish the task better than physical separation and at a lesser cost.

One of the primary objectives of the study was to determine the relationship of rainfall events to overflow events and the volume of flow in the Sandusky River. Historical records of rainfall and flow in the Sandusky River were evaluated along with data collected during the one-year study period. Weirs for measuring overflow volumes were installed at three locations. Samples were also collected at these locations to determine overflow characteristics and effects on the stream. From this information a two-year, one-hour design storm was selected for use in sizing intercepting devices and treatment facilities.

The city of Bucyrus is located near the upper end of the Sandusky River Basin which is tributary to Lake Erie. Bucyrus has an incorporated area of about 2,340 acres, a population of 13,000, and a combined sewer system with an average dry weather wastewater flow of 2.2 million gallons per day.

The results of the study show that any 20 minute rainfall greater than 0.05 inches will produce an overflow. The combined sewers will overflow about 73 times each year discharging an estimated annual volume of 350 million gallons containing 350,000 pounds of BOD and 1,400,000 pounds of suspended solids. The combined sewer overflows had an average BOD of 120 mg/l, suspended solids of 470 mg/l, total coliforms of 11,000,000 per 100 ml and fecal coliforms of 1,600,000 per 100 ml. The BOD concentration of the Sandusky River, immediately downstream from Bucyrus, varied from an average 6 mg/l during dry weather to a high of 51 mg/l during overflow discharges. The total coliforms varied from an average of 400,000 per 100 ml during dry weather to a high of 8,800,000 per 100 ml during overflow discharges.

Six methods of controlling the pollution from combined sewer overflows were evaluated for degree of protection, advantages, disadvantages and estimated costs. The methods evaluated are presented below with their associated costs.

. Complete Separation of Sanitary Wastewater and Stormwater	
- New Sanitary Sewer System	$9,300,000
- New Storm Sewer System	$8,800,000
. Interceptor Sewer and Lagoon System	
- Interceptor, Pump Station and Aerated Lagoon	$5,220,000
- Holding Tanks, Interceptor, Pump Station and Aerated Lagoon	$5,860,000
. Stream Flow Augmentation	$5,000,000
. Primary Treatment of Overflows	$8,810,000
. Chlorination of Overflows	$3,000,000
. Off-Stream Treatment	$1,700,000

Sewer separation was the most costly alternative to controlling combined sewer overflows and would only reduce the pollutants discharged to the river by 50 percent. In this report it was shown that the stormwater runoff from urban areas contains a significant amount of contaminants harmful to stream water quality. The degree of pollution from stormwater varies from that of very dilute sewage to strong sewage.

Construction and operation of the Interceptor and Lagoon System or Off-Stream Treatment would be the most economical method of reduction or controlling pollution from overflows.

The interceptor and lagoon system would be designed to protect the stream from all overflows from storms less than the two-year, one-hour storm. The lagoon could also provide tertiary treatment for effluent from the existing wastewater treatment plant. The Off-Stream Treatment Alternative involves construction of a pump station to divert the flow in the Sandusky River to lagoons for treatment during combined sewer overflows. This alternative would only provide downstream water quality protection and would not change the water quality in the river reach within the city.

Stream flow augmentation is a method of controlling pollution from overflows by providing sufficient dilution water from storage impoundments to maintain a desired concentration of dissolved oxygen downstream during overflows. This is not feasible at Bucyrus due to the lack of suitable reservoir sites.

Primary treatment of overflows is very costly and it would only reduce the waste loads discharged to the river by 50 to 70 percent.

Chlorination of overflows would reduce the bacteria count discharged to the river but would not significantly reduce the concentration of any of the other pollutants present in the combined sewer flows.

The study recommended two phases of construction. The first phase would involve construction of Off-Stream Treatment to include construction of a pump station, a low head dam, and a lagoon system. When it has been adequately demonstrated that the lagoon treatment is capable of providing the water quality protection required, the second phase would be constructed. The second phase would involve construction of the interceptor. The first phase would provide downstream water quality protection. The second phase would provide water quality protection for entire stream reach within Bucyrus and downstream.

This alternative is less costly than complete sewer separation and it provides treatment for storm runoff as well as sanitary flow. Sewer Separation would result in all urban storm runoff being directly discharged to the river.

SURFACE AND SUB-SURFACE DETENTION IN DEVELOPED URBAN AREAS: A CASE STUDY

by

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Stormwater detention facilities are technically sound, economically attractive, and environmentally acceptable elements in urban stormwater control systems serving newly developing areas. A potential, fundamentally different approach is retrofitting detention into an existing stormwater system. A carefully engineered runoff control system (RCS) including on-street storage and subsurface tank storage may be implemented to control the stormwater flow into a combined sewer system to mitigate basement flooding and control stormwater runoff to mitigate surface flooding.

Presented in this article is the process leading to and the status of an ongoing project incorporating surface and subsurface detention to prevent sewer surcharging and basement flooding in a completely urbanized 1,200-acre combined sewer service area in Skokie, Illinois. The Village of Skokie, Illinois, a northern suburb of Chicago, is within the service area of the Metropolitan Sanitary District of Greater Chicago (MSDGC). The 1200-acre Howard Street Sewer District (HSSD) is on the south side of the Village.

The fully developed district contains approximately 80 percent residential land use, 15 percent industrial and 5 percent commercial. The gross population density is approximately 15 people per acre. Average annual precipitation is about 34 inches and all seasons are marked by occasional intense storms. Runoff from these storms, particularly in the spring and summer, cause severe surcharging and basement flooding. For 1 hour, 1-, 10-, and 100-year recurrence interval rainfall events, rainfall amounts are 1.19, 1.94, and 2.80 inches respectively. For a 24-hour period, the 1-, 10, and 100-year amounts are 2.21, 3.86, and 6.70 inches respectively.

The HSSD slopes generally eastward along Howard Street, the main east-west artery, towards the North Shore Channel. Slopes vary from 0.1 to 1 percent and the overall slope of the district is 0.2 percent.

Surface drainage moves from front lawns, driveways, and alleys to the streets. Stormwater moves in gutters along the curb lines to the nearest inlets which are located at mid-block points and immediately outside of intersections.

Stormwater and sewage from the HSSD are conveyed to an interceptor owned and maintained by the MSDGC. Interception takes place at the east end of the HSSD near the North Shore Channel. The MSDGC has completed Phase I of the Tunnel and Reservoir Plan (TARP) which was scheduled to go into operation in early 1985. TARP was to increase the interceptor capacity and reduce overflows into the North Shore Channel. Although TARP will improve the outlet conditions for runoff events from the HSSD, it will not change flow capacities or conditions in most of the HSSD.

The MSDGC obtained funding for TARP form the USEPA and it appeared Skokie may be eligible for similar funding to be used for a conveyance system within the Village. The estimated cost for the conveyance system was $78,000,000 for the entire Village.

By 1981, it was evident that EPA funds for this plan would not be available. Another study was undertaken and it concluded with the idea of a system which would incorporate runoff control with surface and subsurface storage within the developed area.

The following design criteria were established at the beginning of the engineering process or evolved during the course of the process.

- Use the 10-year recurrence interval storm.
- Make maximum utilization of existing sewer system but reduce sewer surcharging to prevent sewage backup caused by overloading of the sewer system.
- Make maximum utilization of available street storage capacity without causing flood damage to adjacent property.
- Minimize flooding on state and county highways.
- Assume TARP is completed and the HSSD discharges into it.
- Utilize a gravity-operated system, in preference to a pumped system, and make minimal use of electrical and mechanical controls and equipment.

Watershed modeling and analysis was used to diagnose the hydrologic-hydraulic behavior of the HSSD. A three-phased approach was used in the watershed modeling and analysis.

Phase I was a static condition analysis which determined if flood levels on the North Shore Channel would cause basement flooding solely as a result of backwater. The analysis was conducted to determine if there were portions of the HSSD in which flood control could not be achieved by in-HSSD runoff control. The analysis concluded that there were no significant areas in which basement flooding would result solely from backwater of the North Shore Channel.

The intent of Phase II, Sewer Capacity Analysis, was to determine the maximum rate in which stormwater runoff could be released into the combined sewer system without exceeding the established surcharge level. The sewer capacity analysis was carried out using the computer program System Analysis Model (SAM), which permitted simulation of the entire HSSD and provided the computational means of accounting for system surcharges and hydraulic grade lines for each trunk and branch sewer.

Street Ponding Analysis, Phase III, determined the street ponding which would occur as a result of regulating the rate at which stormwater runoff could enter the combined sewer system. Overall, the street ponding analysis indicated that keeping water out of basements via surface and subsurface ponding was feasible but the number of streets subject to ponding would increase.

The recommended Runoff Control System consists of:

- 425 flow regulators functioning in conjunction with 215 berms.

- 12 subsurface storage facilities.

- 9,500 feet of 30-inch to 72-inch separate relief sewer for the commercial, downstream end of the HSSD.

The system would perform such that the average maximum depth of street ponding is approximately 0.7 feet measured from the gutter at the lowest point in the block and the average ponding duration is 5 hours under the design 10-year storm condition. The estimated late 1983 cost for the recommended runoff control system was $8.1 million or about 20 percent of the cost of a conventional runoff control system.

The recommended runoff control system was tailored to the unique combination of topographic, land use, hydrologic and hydraulic characteristics of the combined sewer service area in Skokie. However, the analytic techniques used, particularly the hydrologic-hydraulic computer models, and the surface and subsurface facilities and hardware employed are likely to be applicable to other fully developed urban areas experiencing sewer surcharging and other flooding problems.

THE SWIRL CONCENTRATOR AS A COMBINED SEWER OVERFLOW REGULATOR FACILITY

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In 1969-70 The American Public Works Association (APWA) Research Foundation carried out a national investigation of the means by which municipal jurisdictions in the U.S. and Canada regulate and control overflows from combined sewer systems, and of methods by which the pollutional effects of these discharges into receiving waters can be minimized.

The major finding of the study was that in American practice, little or no effort was made to improve the quality of the overflow liquids and, thereby, to reduce the pollutional impact on receiving waters. Regulators were only capable of controlling the quantity of overflows; and even this function had been carried out with only limited success. The investigation also disclosed that European practices emphasized improvement of the quality of storm overflows from combined sewers by various mechanical-hydraulic means. One of the methods of quality control being used in Bristol, England, was the so-called "vortex" device. The APWA study recommended that further research be conducted on new devices which could induce separation of solids from the liquid.

This led to the study of the swirl concentrator which is a modified version of the "vortex" device. This study found that a vortex flow pattern should be avoided when working with larger flows in minimum-sized chambers. However, it showed that inducing a swirl action in the wastewater was very effective in causing a liquid-solids separation.

The American Public Works Association, under contract with the City of Lancaster, PA, completed this study with the intent that Lancaster would construct a demonstration or prototype swirl concentrator. The study included hydraulic modeling studies conducted at the LaSalle Hydraulic Laboratory in Canada; and mathematical modeling to determine design relationships and the degree of efficiency which might be associated with construction of such facilities. The objectives of the study were to determine swirl concentration configurations, flow patterns, and settleable solids removal efficiency.

The device, as developed by the study, consists of a circular channel in which rotary motion of the sewage is induced by the kinetic energy of the sewage entering the chamber. Settleable solids underflow discharges through an orifice called the foul sewer outlet, located at the bottom and near the center of the chamber. Clarified liquid discharges over a circular weir around the center of the tank and is conveyed to storage treatment devices as required or to receiving waters. The concept is that the rotary motion causes the sewage to follow a long spiral path through the circular-chamber. A free surface vortex was eliminated by using a flow deflector, preventing flow completing its first revolution in the chamber from merging with inlet flow. Some rotational movement remains, but in the form of a gentle swirl, so that water entering the chamber from the inlet pipe is slowed down and diffused with very little turbulence. The particles entering the basin spread over the full cross section of the channel and settle rapidly. Solids are entrained along the bottom, around the chamber, and are concentrated at the foul sewer outlet.

The following conclusions were drawn from the hydraulic and mathematical modeling:

- The swirl concentrator is a practical, simple facility which offers a high degree of performance in reducing the amount of settleable solids contained in combined sewer overflows.

- The swirl concentrator is very efficient in separating both grit and settleable solids in their middle (>0.2 mm) and larger grain size ranges. By weight, these fractions represent about two-thirds of the respective materials in the defined combined sewer. Separation of the small grain sizes was less efficient, although still appreciable.

- The floatables trap and storage arrangements should capture most of the lighter than water pollutants and convey them to the foul sewer. Its dimensions are such that oversize floating objects would not be captured, and would tend to go over the effluent weir rather than stay in the chamber to clog the foul outlet.

- Both the floatables trap and foul outlet are easy to inspect and clean out if necessary, during dry weather flows.

- There must be sufficient hydraulic head available to allow flows to pass through the swirl concentrator facility without causing backups or flooding upstream in the system. Sufficient head should be available to operate the foul sewer discharge by gravity. If sufficient head is not available, the foul sewer discharge may require continuous pumping.

SWIRL AND HELICAL BEND POLLUTION CONTROL DEVICES

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In 1970, an EPA state-of-the-art report on regulators indicated that two British devices showed possibilities for application as combined sewer overflow regulators in the United States. These were the vortex-flow regulator, later called the swirl regulator/separator, and the helical bend regulator/separator. Both have been modified for adaptation to North American treatment practice.

The design criteria used for the English regulators differ from those used in North American practice, primarily in the ratio of wet-weather flow to dry-weather flow allowed to enter the interceptor for treatment. Thus, it was necessary to conduct hydraulic model studies to develop units for United States practice.

The swirl combined sewer overflow regulator/separator is of simple annular-shaped construction and requires no moving parts to achieve a relatively high degree of separation of settleable and floatable solids from a waste stream. While accomplishing the separation of solids, it also regulates the flow to the interceptor sewer system. Wastes are concentrated into what should be a more economical method to treat the waste stream. Treatment of the concentrate could be with either conventional wastewater treatment facilities or special combined sewer overflow treatment units.

The device consists of a circular channel in which rotary motion of the sewage is induced by the kinetic energy of the incoming sewage. Flow to the treatment plant is deflected and discharged through an orifice called the foul sewer outlet, located at the bottom and near the center of the chamber. Excess flow in storm periods discharges over a circular weir around the center of the tank and is conveyed to storage treatment devices as required or to receiving waters. The concept is that the rotary motion causes the sewage to follow a long spiral path through the circular chamber. A flow deflector prevents flow completing its first revolution in the chamber from merging with inlet flow. Some rotational movement remains, but in the form of a gentle swirl, so that water entering the chamber from the inlet pipe is slowed down and diffused with very little turbulence. The particles entering the basin spread over the full cross section of the channel and settle rapidly. Solids are entrained along the bottom, around the chamber, and are concentrated at the foul sewer outlet. Flow through the foul sewer outlet is limited to the hydraulic capacity of downstream facilities.

The device is essentially without moving parts and performs well under a variety of flow conditions. The primary features of the unit include: Inlet Ramp, Flow Deflector, Scum Ring, Overflow Weir and Weir Plate, Gutters, Downshaft and Secondary Overflow Weir.

Three flow quantities must be considered in the design: 1) the peak dry-weather flow; 2) the design flow, i.e., the flow for which the optimum treatment is desired; and 3) the maximum flow likely to occur through the chamber.

The following procedure should be used when designing a swirl regulator/separator.

1. Select design discharge
2. Select the recovery efficiency desired:
   - One of four performance efficiencies can be chosen - either 100, 90, 80 or 70 percent recovery of settleable solids
3. Find the inlet dimension--D_1, and chamber diameter--D_2
4. Check discharge range covered
5. Recovery rates
6. Foul discharge
7. Find dimensions for the whole structure
8. Geometry modifications
9. Foul discharge modifications

The location of the swirl regulator/separator is dependent upon the elevation of the combined sewer and the location of the interceptor sewer. In some instances, it may be feasible to construct the facility underground in the public right-of-way. The site should minimize construction of transition sewers from the collector and the clear overflow discharge to receiving waters.

The operation and maintenance requirements for swirl regulators/separators has been assumed to be constant for all sizes of units. Cleaning of the unit may be done with automatic washdown facilities. With these washdown facilities, only one or two special site visits to remove large objects can be anticipated.

Results from three demonstration units are available which have tended to validate the laboratory testing. The units which have been constructed include those by Onondaqa County (Syracuse), New York; Lancaster, Pennsylvania; and Boston, Massachusetts.

The experience of all three agencies with the operation of the swirl unit has been very good. Generally, operational problems which have become apparent have been due to design deficiencies.

Monitoring for treatment evaluation has been performed at the Syracuse facility. Efficiency has been calculated on the values based upon the laboratory work.

Relatively good SS removal efficiencies were determined over the entire storm flow range at the Syracuse prototype. Total mass loading and concentration removal efficiencies ranged from 33 to 82 percent and 18 to 55 percent, respectively, with flowrates from 0.54 cu m/min (0.2 mgd) to 20.5 cu m/min (7.6 mgd). Suspended solids influent concentrations greater than 250 mg/l generally resulted in removals of better than 50 percent of the total mass loading to the swirl.

Care must be taken in evaluating swirl solids treatability since under dry-weather flow conditions, all regulators are designed to deliver the entire flow volume and associated solids to the intercepting sewer until a predetermined overflow rate is reached.

If the swirl regulator was replaced by a conventional flow regulator, the net mass loading reductions (attributable to the SS conventionally going to the intercepted underflow) would have ranged from 17 to 64 percent as compared to a more effective range of 33 to 82 percent for the swirl.

Prototype analyses indicated BOD_5 removals of 50 to 82 percent for mass loading, and 29 to 79 percent in terms of concentration.

The helical bend combined sewer overflow regulator/separator consists of an enlarged section of the sewer which acts as a solids and floatables trap prior to diversion of the overflow to additional treatment or receiving waters. The device requires considerable space to construct. Operation and maintenance are minimized as there are no mechanical or moving parts within the device. The channel is curved to develop helical secondary motions within the flow. The helical motion effectively captures particles which have a greater settling velocity than the upward velocity of the helical motion. Relatively high velocities are achieved as the chamber empties to treatment at the end of the storm event which will remove deposited solids. Thus, the helical bend separator is unique in that most of the removed solids are released at the end of the storm event.

The helical bend combined sewer overflow separator was developed in Great Britain. The design developed for USEPA was based upon English experience as well as hydraulic and mathematical model studies. A demonstration unit has been installed (September 1979) in Boston, Massachusetts, where it was to be tested on both combined sewage and separate stormwater flows.

Available data indicates that the helical bend separator can be as efficient as the swirl separator/regulator. The helical bend separator compared to the swirl separator should have less head loss, may require less acquisition of additional right-of-way, and allows the short period of time at the end of the storm event. However, the cost of the device may be up to 50 percent more than an equivalent swirl separator/regulator and almost 3 times more than a swirl unit designed to remove 80 to 90 percent of the solids.

The location and depth of the combined sewer will determine the area required for its installation. The depth of the sewer may suggest that an underground chamber is appropriate. If this is the case or if adjacent land is expensive, it may be desirable to construct a chamber for the separator along the existing right-of-way of the sewer.

The available head at a specific site may be a critical factor in the choice of the specific type of combined sewer regulator to be used. The head loss must be considered for two conditions: 1) for periods of dry-weather flow, and 2) for periods of wet-weather flow. The available head during dry-weather flow will depend on the difference in elevation between the combined sewer and the interceptor that will convey the flow to the wastewater treatment plant. The available head during wet-weather flow will depend on the difference in elevation between the combined sewer and the water surface of the receiving stream.

The helical bend separator was tested extensively in Nantwich, England. The first full size unit has been built in Boston, Massachusetts. A purpose of the demonstration project was to compare the efficiency of the unit as compared to a swirl separator/regulator. The unit was to be tested on combined sewer overflows and stormwater discharges. Test results were not available at the time of preparation of the article. Construction costs were very low due to the fact that the unit was prefabricated from wood and is not intended for permanent use.

It appears that the principal advantages of the helical bend separator are the low head requirements and the discharge to treatment of the captured solids at the end of the storm event. The swirl regulator/separator in turn requires less space and should be less expensive to construct. Use of the swirl regulator/separator where insufficient hydraulic head is available for its normal mode of operation may require dry weather bypassing the device. As both units have been designed to minimize the cost of operation and maintenance problems, they are considered comparable.

URBAN RUNOFF POLLUTION CONTROL TECHNOLOGY OVERVIEW

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Control and treatment of stormwater discharges and combined sewage overflows from urban areas are problems of increasing importance in the field of water quality management. Over the past decade much research effort has been expended and a large amount of data has been generated, primarily through the actions and support of the U.S. Environmental Protection Agency's Storm and Combined Sewer Research and Development Program.

The program starts with "Problem Definition" broken into "Characterization" and "Solution Methodology".

The average BOD concentration in combined sewer overflow is approximately one-half the raw sanitary sewage BOD. However, storm discharges must be considered in terms of their shockloading effect due to their great magnitude. A not uncommon rainfall intensity of 1 inch/hour will produce urban flowrates 50 to 100 times greater than the dry-weather flow from the same area.

Approximately one-half of the stream miles in this country are water quality limited and 30 percent of these stream lengths are polluted to a certain degree with urban runoff. Therefore, secondary treatment of dry-weather flow is not sufficient to produce required receiving water quality; and control of runoff pollution becomes an alternate for maintaining stream standards. Accordingly, both water quality planning and water pollution abatement programs need to be based on an analysis of the total urban pollution loads.

Until the urban stormwater situation is analyzed and efficient corrective measures taken, there may be no point to seeking higher levels of treatment efficiency in existing plants.

The second area under Problem Definition, "Solution Methodology" naturally followed initial "Characterization" for providing a uniform and necessary background for the user community.

The first and most fundamental approach should be a more accurate assessment of the problem. Ideally, this should involve acquiring data on a city-wide basis for both dry-weather flow and wet-weather flow.

Integrated with a more accurate assessment is the consideration of cost-effective approaches to wet-weather flow pollution control.

User Assistance Tools are divided into "Instrumentation" and "Simulation Models".

The qualitative and quantitative measurement of storm overflows is essential for planning, process design, control, evaluation, and enforcement. "Urban intelligence systems" require real-time data from rapid remote sensors in order to achieve remote control of a sewerage network. Sampling devices do not provide representative aliquots, and in-line measurement of suspended solids and organics is needed. Conventional rate-of-flow meters have been developed mainly for relatively steady-state irrigational streams and sanitary flows and not for the highly varying surges encountered in storm and combined sewers.

The electromagnetic, ultra-sound, and passive sound flowmeters have been developed to overcome these adverse storm flow conditions. Passive sound instruments offer the additional benefit of extremely low power requirements rendering them amenable to installation at remote overflow locations and integration into city-wide, in-sewer, sensing, and control systems.

Math models are needed to predict complex dynamic responses to variable and stochastic climatological phenomena. Models have been subcategorized into three groups: 1) simplified for preliminary planning, 2) detailed for planning and design, and 3) operational for supervisory control.

The Storm Water Management Model (SWMM) provides a detailed simulation of the quantity and quality of stormwater during a specified precipitation event. Its benefits for detailed planning and design have been demonstrated and the model is widely used.

Wet-weather flow control can be assumed to involve aspects as follows. First, there is the choice as to where to attach the problem: at the source (e.g., the street, gutters, and catchment areas) by land management, in the collection system, or off-line by storage. Second, there is the choice of how much control or degree of treatment to introduce. Third, there is the impact assessment, public exposure, and priority ranking with other needs.

Land Management includes all measures for reducing urban and construction site stormwater runoff and pollutants before they enter the downstream drainage system. On-site measures include structural, semi-structural and non-structural techniques that affect both the quantity and quality of runoff.

Structural and semi-structural control measures require physical modifications in a construction or urbanizing area and includes such techniques as on-site storage, porous pavement, overland flow modifications and solids separation.

Non-structural control measures involve surface sanitation, chemical use control, urban development resource planning, use of natural drainage, and certain erosion/ sedimentation control practice.

The next category, collection system control pertains to those management alternatives concerned with wastewater interception and transport. These alternatives include sewer separation; improved maintenance and design of catch basins, sewers, regulators, and tide gates; and remote flow monitoring and control. The emphasis, with the inception of sewer separation, is on optimum utilization of existing facilities and fully automated control. Because added use of the existing system is employed, the concepts generally involve cost-effective, low-structurally intensive control alternatives.

Storage is perhaps the most cost-effective method available for reducing pollution resulting from combined sewer overflows and managing urban stormwater runoff. Furthermore, it is the best documented abatement measure in present practice.

Storage facilities possess many of the favorable attributes desired in combined sewer overflow control: 1) they are basically simple in structural design and operation; 2) they respond without difficulty to intermittent and random storm behavior; 3) they are relatively unaffected by flow and quality changes; and 4) they are capable of providing flow equalization and, in the case of sewers and tunnels, transmission.

THE USE OF STREET CLEANING OPERATIONS IN REDUCING URBAN RUNOFF POLLUTION

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In many cases, street cleaning operations can be used to reduce the amount of pollutants entering urban runoff. This paper described the effectiveness and cost characteristics of street cleaning operations. Information was summarized from many different studies conducted over the last 20 years, but was mostly based upon the results of a study completed for the Storm and Combined Sewer Section of the USEPA (Edison, New Jersey) entitled, Demonstration of Non-Point Pollution Abatement Through Improved Street Cleaning Practices.

This demonstration project included several hundred street cleaning tests conducted over a period of a year in San Jose, California. More than 20,000 samples were collected and analyzed in describing street surface loading conditions during specially scheduled street cleaning operations. Five different study areas were examined ranging from downtown commercial areas to suburban residential areas. The study areas ranged in size from 50 to 200 acres. This study was unique in that it measured the effectiveness of street cleaning over large areas under the influence of many real-world conditions, such as different land uses, variable street dirt loadings, changing weather characteristics, varying parked car conditions and different street surface pavement conditions. Previous street cleaning effectiveness studies only examined street cleaning equipment operating under very strictly controlled conditions in strip test or very small scale (about 40 foot cleaning paths) actual street and curb tests. Therefore, these results typically show the effectiveness of street cleaning operations to be somewhat less effective than under the earlier more controlled tests. However, street cleaning practices can be used to significantly reduce the quantities of some street surface contaminants in urban runoff, if the street cleaning program is adequately designed.

The type of street contaminants present are generally a function of local geological conditions, motor vehicle emissions and wear, and inputs from surrounding areas. Accumulation rates of street surface contaminants vary widely with geographical location, season, land use, traffic, and other conditions. Nationwide accumulation rates vary from 3 to 2700 lb/curb-mile/day with an average around 150 lb/curb-mile/day.

This study showed that higher concentrations of contaminants are seen with decreasing particle size. Additionally, typical street sweeping activities are most effective at removing larger size particles. Street cleaning is still an important control measure because the larger size particles are typically the most abundant and contain significant quantities of contaminants. The largest particles (>6370μ) had removal rates as high as 55 percent during this study.

Another important aspect of an effective street sweeping operation is to implement measures to eliminate parking interferences. This study found that the percent of total street solids loading removed by sweeping was negatively impacted by the percentage of curb length occupied by parked cars. Under most conditions, removal of parked cars during street sweeping operations can significantly improve the street cleaning effectiveness.

The San Jose study found the following removal rates and costs for several contaminants during the street cleaning operations:

	Average Removal (lb/curb-mile)	Average Unit Cost ($/lb removed)
Total Solids	200	0.08
TSS	100	0.16
BOD_5	12	1.34
Lead	0.80	20
Cadmium	0.002	8000

As shown, removal rates and costs vary widely for different types of surface contaminants.

Information from this study was presented in a generic manner that should be applicable to most areas of the country. Specific local monitoring activities are necessary before final design of an adequate street cleaning program can be completed.

USEFUL TECHNOLOGICAL INFORMATION ON SEWER FLUSHING

by

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Combined sewer systems are generally old, well constructed, but often because of neglect, function poorly, particularly during wet weather flow conditions. In the past, overflow regulation was often set to minimize retained wet weather flows for treatment even though there was ample hydraulic conveyance capacity. Many repairs and patchwork such as the connection of new separated areas into combined systems over the years have greatly confounded piping complexity. Understanding how the system works is no simple task. Sewer maps are generally old, piece meal, out-of-date, and difficult to use. Detailed operational information in a simple concise form simply does not exist.

Municipal maintenance funds are generally limited and are largely relegated to reaction policies such as cleaning clogged sewers. Active maintenance programs aimed at ensuring proper collection system performance during both dry and wet weather conditions are almost non-existant for most communities. The maintenance issue is further compounded by the fact that in many cities there is a functional division of responsibility and authority between upstream collection system control and management, and downstream overflow collection, conveyance, and treatment. The downstream authority generally views its mission as abating combined sewer overflows within the spatial limits of their jurisdiction. Downstream control generally means expensive structural programs. Institutional differences often preclude the downstream authority from assuming the role for active management of the upstream areas. The net result in many cases, is that both known and unknown upstream system problems having a high pollution control cost-effectiveness, often go undetected and uncontrolled, and management is focused instead on downstream solutions resulting in high program costs.

Putting aside institutional and jurisdictional issues, it is the author's belief that the financial interests of the federal government would be best served if in fact, Step 1 201 Combined Sewer Facilities Planning both mandated and funded for each and every facility study in reasonably sized communities, thorough and comprehensive sewer mapping activities, intensive physical surveys and measurement programs during all flow conditions for the entire sewerage system of concern. This assertior is based on the belief that there are unknown malfunctions of all types, poorly optimized regulators, unused in-line storage and pipes clogged with sediments in old combined sewer systems. Furthermore, detection and correction of these maladies would in fact, result in extremely cost-effective solutions for partial if not significant control of combined sewer overflow emissions. It is a further belief that wet weather emissions/water quality response measurement programs should then be instituted to ascertain whether further planning and additional control is necessary. In some situations it will be clear that additional control is necessary. In some situations it will be clear that additional management and control will be immediately necessary. For many small communities already faced with taxed financial resources for dry weather treatment, the measurement and wait/see option will be meaningful.

In short, combined sewer management planning should be "front-end" loaded with intensive mapping and field sleuthing and measurement activities. This proposition represents a fairly radical departure from current planning methodologies where often the orientation seems to be heading toward heavy "back-end" loaded SWMM modeling and "desk top" analysis efforts with inventory and survey efforts kept to a minimum. The author believes that a change in the opposition direction would be in the long run, be more cost-effective to the government, provided that the institutional and funding mechanisms can be resolved.

The findings of a recent section 208 combined sewer management study for portions of the sewerage system in the City of Fitchburg, MA demonstrate this viewpoint. The results showed that sewerage system remedial repairs and slight piping modifications were an order of magnitude less expensive than the nominal BMP practices of sewer flushing, street sweeping and catchbasin cleaning, and several orders of magnitude less than alternative structural options.

WATER QUALITY CHARACTERISTICS OF STORM AND COMBINED SEWER OVERFLOW

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In Japan as of 1975, 583 municipalities had sewage works. In 1976, 65 new municipalities were expected to begin wastewater treatment.

In Japan, many cities have combined sewer systems. According to a 1972 survey conducted by the Ministry of Construction, combined sewer systems accounted for 73 percent of the total sewered area, covering 69 percent of the total sewered population.

Many municipalities which have combined sewer systems have adopted separate sewer systems in new sewered areas, so the proportion of combined sewer systems is decreasing gradually. Nevertheless, the significance of the combined sewer overflow on the contribution to pollution loads in waters has not yet been reduced significantly. In large cities where steps toward improvement through secondary treatment have been made, the contribution for water pollution by combined sewer overflow will be increased more and more.

Large costs have stood in the way of changing combined systems to separate systems. Narrow width of road in densely populated areas, and the fact that stormwater from storm sewers itself is populated, have also limited separation. Converting to a separate system is not always considered to be the best solution.

Most of the measures taken or being planned to control the water pollution by combined sewer overflow are either detention or sedimentation of wet-weather overflow.

In Japan, there are three practical examples of measures to control water pollution due to combined sewer overflow, two in Osaka and one in Yokohama.

In 1975, the Osaka Municipal Government constructed a stormwater sedimentation tank consisting of two basins. The dimensions of each basin is 3.5m in width, 20.2m in length and 4.5m to 5.0m in depth. Four additional basins were to have been constructed. With all the basins complete, the storage capacity was estimated at 2,000m^3. This facility is the only example in Japan of measures against wet-weather overflow. In Osaka, flooding frequently occurs in lowlands because of marginal use of catch basins and settling due to excessive use of groundwater. In order to solve this problem, installation of a new interceptor was planned and has been underway since 1973. This trunk sewer is planned to control water pollution due to wet-weather overflow without detriment to the original purpose of flood control.

The Yokohama Municipal Government was in the process of constructing a stormwater sedimentation tank consisting of 18 6.0m wide by 35m long by 6.0m deep basins with a total capacity of 22,680m^3. These tanks are expected to reduce the pollution loads by 10 percent or more in SS and almost the same degree in BOD compared to sewer separation.

For the purpose of collecting extensive data on the characteristics of wet-weather combined sewage, 12 drainage areas different in drainage system and land use were selected as the study areas in 11 member municipalities.

Following is a list of survey areas and a brief explanation of each.

Combined Sewer Survey Areas:

A. Single-family residential area apart form the city's center
B. Populated urban area with a mixed variety of residential houses and stores
C. Area with small to medium factories, residential houses and stores
D. Area with residential zones and shopping quarters
E. Residential area on a terrace bordering on an urban area
F. Area with low-story and medium-story shopping quarters and amusement quarters
G. Area with low-story shopping quarters, amusement quarters, and medium-story business quarters.
H. Dense area packed with low-story residential houses, stores and factories mainly of textile and dyeing
I. Typical high-story civic and business center

J. Area with residential quarters, commercial quarters, wholesale markets and small factories along a trunk road
K. Suburban residential area on a terrace with many company-owned residential houses.
L. Amusement quarters

Separate Sewer Survey Areas:

M. Tier on the sea, with business quarters, commercial quarters, hotels, public facilities, government institutions, multi-family residential houses
O. Newly developed residential area on a suburban terrace, with single-family houses

In each survey area sewage flow was measured and once every 30 minutes sampling was conducted for water quality analysis.

Following are the water quality characteristics of respective survey areas in dry-weather and the factors which are considered attributable to them.

C. Industrial quarters count for 75 percent of total area, discharging high concentrations of heavy metals
E. Residential, but high in BOD, COD and SS
H. A good number of textile and dyeing factories in the area resulting in high BOD, COD and SS
I. Typical business quarters discharging weak effluents having a soluble-to-total BOD ratio of 14.4 percent
K. Low BOD; quantities of pipeline deposits are suspected
L. Densely built amusement quarters generating a large volume of sludge for the area; high BOD

While these areas have different characteristics, they also have something in common with each other:

a. VSS/SS is in the range of 0.63 to 0.88, except for one survey area.

b. Three survey areas (F, G, and L) show flow rate 10 to 30 percent less in winter than in summer, and an increase in BOD of 30 to 40 percent on the average in winter over summer.

c. No definite differences by land use are noticed.

Wet-weather surveys were conducted two to four times in each survey area.

The runoff coefficient is largely influenced by the impervious area ratio. Some survey areas had a large impervious area ratio of more than 90 percent. In these areas, the runoff coefficient is high. Taken altogether, the runoff coefficient lies in the range of 40 to 80 percent.

After a light rainfall, BOD, T-P and K-N become far larger in concentration than in dry weather. In the case of a large scale storm, the concentrations are reduced by dilution effects and the loadings are held within several times those in dry weather. Regarding SS, the reduction in concentration is far less than others even in the case of a large-scale rainfall. It remains almost the same as in dry weather. This shows that the bulk of SS was conveyed into the sewer from the ground surfaces.

The surveys on combined sewer overflow in the 12 representative cities in Japan have disclosed the following:

1. In wet weather, BOD, T-P and T-K are diluted significantly while SS remains the same.

2. In wet weather, water quality in the combined sewers seriously decreases.

3. In wet weather the combined sewers experience an increase in inorganic SS and at the same time an increase in refractory organics.