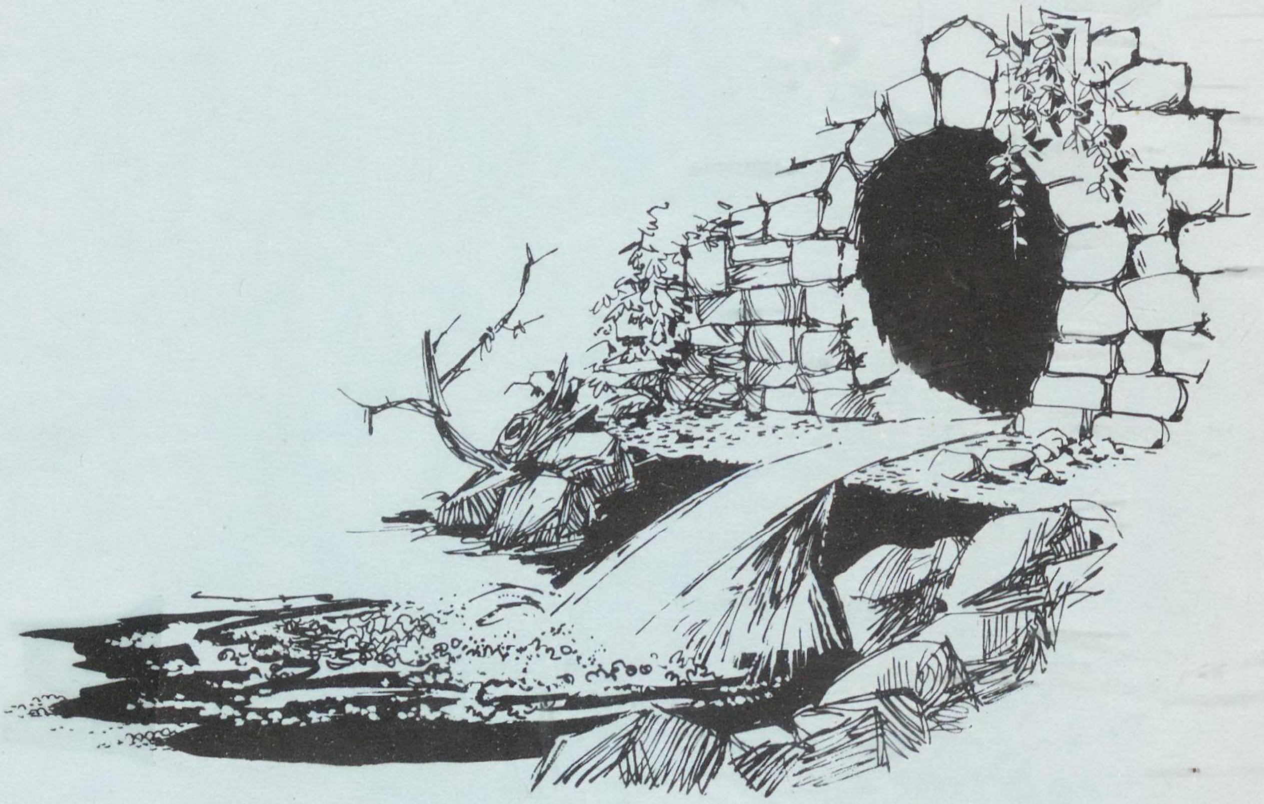
CLEAN WATER

Advances in Storm and Combined Sewer Pollution Control Abatement



ENVIRONMENTAL PROTECTION AGENCY • *RESEARCH & MONITORING*

ADVANCES IN STORM AND COMBINED SEWER POLLUTION ABATEMENT TECHNOLOGY*

by

Allen Cywin and William A. Rosenkranz**

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** Messrs. Cywin and Rosenkranz are, respectively, Deputy Director, Technology Division and Chief, Municipal Technology Branch of the Office of Research and Monitoring, Environmental Protection Agency.

ABSTRACT

Research, development and demonstration efforts sponsored by the Environmental Protection Agency since 1966 have resulted in advances in technology which can be applied as alternatives to sewer separation for abating pollution from combined sewers. The overall problem is caused by basic deficiencies in collection, transport and treatment systems, which must be corrected to provide truly efficient sewerage facilities. All the sewerage facilities (the system) must be evaluated in order to plan modifications which will provide the capability to adequately control and treat wastewaters during and immediately following storm events.

Control facilities such as in and off-system storage, flow regulation and routing, remote flow-sensing and control, coupled with treatment, are applicable solutions. Physical, chemical, biological and physical-chemical treatment methods are under investigation, with a screening, dissolved-air flotation process and a high-rate multi-media filtration process offering the best current potential for producing good quality effluents.

Requirements for control of pollution from combined sewer overflows are rapidly becoming more stringent. Control of pollution caused by urban storm water discharges is on the horizon.

INTRODUCTION

Identification of combined sewer overflows as a substantial pollution source having National significance was established in 1964[2]. The published report indicated that it would cost \$20 - \$30 billion to correct the problem, this estimate being based on reconstruction of the combined sewers so as to provide separate systems for sanitary sewage and storm waters, accepted practice at that time. The report also recognized that storm water is a significant source of pollution and that separation may not be an adequate solution. Exploration of alternative control measures was, therefore, recommended.

The Congress, in 1965, authorized a program[1] to develop and demonstrate ".....new or improved methods of controlling the discharge of untreated sewage or inadequately treated sewage or other wastes from sewers which carry storm water or storm water and sewage or other wastes." The research, development and demonstration program of the Environmental Protection Agency considers "urban runoff" pollution in three source categories; combined sewer overflows, storm water discharges and non-sewered urban runoff.

An updated estimate of remedial costs pertaining to combined sewer overflows compiled in 1967[3] indicated that a National separation program would cost \$48 billion. Use of alternative measures, based on overflow storage, was estimated to have the potential to reduce remedial costs to \$15 billion. It should be noted that the estimates contained in both of the studies excluded costs associated with abatement of pollution stemming from storm water discharges and non-sewered urban runoff.

RESEARCH, DEVELOPMENT AND DEMONSTRATION PROGRAM

Early assessment of the problem within the research, development and demonstration program indicated that the combined sewer overflow pollution problem is in reality a reflection of the inefficiencies inherent in our collection, transport and treatment systems.[(5)(30)]

Primary thrust of research, development and demonstration has been to identify system weaknesses and to develop and demonstrate the technology and hardware which can be utilized to improve operating efficiency and capabilities of sewer systems. This can be done only by considering the problem in the context of the entire system and by applying systems analysis techniques to define the scope of individual system problems, as a design tool for remedial action and facilities as well as to assist in the evaluation of installed facilities.

Recognize that the development of new and improved methods and the application of demonstrated technology must encompass at least two principal areas. The first of these, the total system approach, has already been mentioned. The second involves the sub-systems. Utilization of the total system approach to problem solving requires the availability of suitable subsystem or unit processes which can be wedded to form an entire operable system. Many different alternatives can be envisioned as potential solutions to combined sewer overflow problems. Most, however, are not applicable to all of the varied weaknesses within the entire system, therefore, the means to perform the wedding alluded to above must be developed. This we have attempted to do by means of mathematical simulation modelling. A storm water management model has been developed for the purpose of simulating the reaction of urban drainage systems during periods of rainfall. Since the model includes dry weather flow in the simulation of urban runoff, omission of a rainfall event(s) results in a simulation of system operation during dry weather periods. To evaluate overflow conditions, storm events selected for design purposes by the analyst or designer are programmed to the computer, along with detailed information concerning the physical characteristics of the system and other pertinent data. The model then produces hydrographs and pollutographs at selected points within the system for each time step. The reaction of the system to modifications such as installation of holding tanks, flow regulators, treatment facilities or other changes can be simulated. Costs of remedial measures can be included. This affords the designer the capability to select locations, capacity and needed efficiency of remedial facilities based on predicted system performance. The current generation of the model is single basin oriented, therefore, it must be run separately for each outfall.

The model also offers the capability of predicting the affect that system modifications will have on the receiving waters. Thus, the designer can fully apply his imagination, ingenuity and engineering knowledge to plan modifications and extensions to the system which offer the best pollution control capabilities at least cost. The four-volume Storm Water Management Model report (41) which contains a detailed description of the model, its general capabilities and a user's manual has been printed.

Application of total systems techniques to development of solutions to combined sewer overflow and storm water pollution problems requires knowledge of unit processes, methods and equipment which can be utilized to make modification feasible. The bulk of the research, development and demonstration effort is directed toward improving the state of the art so as to increase the arsenal of weapons that can be brought to bear on the problem.

Reporting on advances in technology in this complex technical area places the reporter in a minor dilemma because there is so much ground to cover. An important milestone has been reached in that we feel that sufficient advances have been made to permit the development and implementation of full-scale remedial programs.

Pertinent areas for research and development were identified [6] during the early stages of the research, development and demonstration program and were utilized to stimulate activity toward development of alternative control and treatment methods in a wide range of technical areas. Alternative methods have been pictured as falling into one or more of three principal categories (1) control (2) treatment and (3) combinations of control and treatment. These categories are further viewed as sub-systems or building blocks which are essential to the development of an efficient collection, transport and treatment system It must be emphasized that each outfall and each system must be evaluated individually in order to select and apply the control/treatment facilities on a cost-effecitve basis.

A fourth category, which includes those areas not specifically a part of the above categories, but important to each, has been labeled "miscellaneous". A better term might be "support areas". Development of the Storm Water Management Model, work on improved flow measuring methods, special engineering studies, literature abstracting, improved materials and construction practices and other general technical efforts supporting and contributing input to efforts in the first three referenced categories are included.

A brief look at these basic areas will serve to provide a status report on technology advances.

Control

Storage is the most common method applied for control of combined sewer overflows. Great Britain,[31] Germany[15] and other European countries, as well as the United States and Canada have utilized tank storage as a basic control method for many years. However, relatively few such tanks were installed in the United States prior to the existence of the current demonstration program. Columbus, Ohio, installed what are believed to be the first tanks in this country in 1932. Wayne County, Michigan, is currently devoting considerable effort in this direction.

Inclusion of storage as a part of the research, development and demonstration effort considers the capabilities of storage as a control means in the very broadest context--that is, all modes of storage are considered and are in the process of evaluation.

Types of storage facilities currently undergoing demonstration include:

* Concrete storage tanks
* Earthen (lined and unlined) retention basins
* Deep tunnels and mined caverns
* Utilization of available sewer system storage capacity
* Vertical, mined "silos"

Point of application of a storage facility is also a factor of importance to total system performance. Placement of a facility at the overflow point is an obvious potential selection. Such a choice must consider that of all potential locations in the system, the outfall site will require the largest storage capacity for effective control. It is also the location that, in most cases, will present the most difficulty in land availability and cost.

Other sites, function and types of storage should not be ignored. Placement of control structures at sites upstream of the outfall, in various portions of the drainage area should be explored. Off-system storage utilizing parks, golf courses, parking lots, play grounds, rooftops and similar areas can be employed. Location at key points in the system other than the outfall has the potential for making optimum use of sites within the watershed, with some potential for cost reduction. This is especially true if dual use of a site is feasible. Recreation facilities, parking areas, ornamental ponds and other secondary uses can be incorporated during the planning and design process. Imagination and ingenuity are very important to selection of alternatives and realization of the full potential of sites available.

By utilizing upstream sites it may be possible to use existing sewer capacity to better advantage and to improve transport efficiency.

Each community and each overflow site presents unique site characteristics which may control design. We have found storage costs on demonstration projects to range from $77,000 to $3,170,000 per million gallons capacity or, to put it another way, $151 to $42,000 per acre served. The need for careful site selection and design is obvious.

Examples of the application of storage taken from demonstration projects will illustrate some of the factors discussed above.

Figure 1 shows an asphalt lined retention basin constructed in Chippewa Falls, Wisconsin.(32) The basin receives combined sewage by-passed at a major pumping station during storm periods. Captured flow is returned to the system for transport to the City's activated sludge wastewater treatment plant following cessation of the storm. The facility has functioned very effectively since installation during 1969 and 1970, eliminating

59 discharges to the river from 62 overflows from storm events which occurred during the evaluation period. The basin serves a tributary combined sewer area of 90 acres and contains 3,487,000 gallons or $2,590 per acre served. Design was based on control of 1.6 inches of storm runoff.

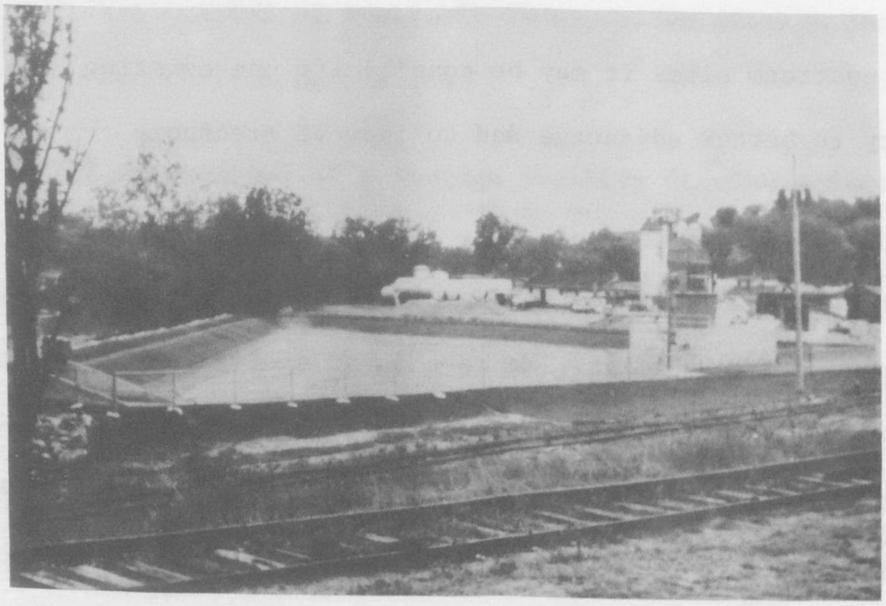

FIGURE I - Asphalt lined retention basin,
Chippewa Falls, Wisconsin

Figure 2 shows a holding facility in Milwaukee, Wisconsin. The 3.9 mg concrete tank is designed to control a part of the excess flow from a 570 acre portion (about one-fourth) of the combined sewer area in Milwaukee. Overflow events are anticipated to be reduced by 70 percent. Overflows that do occur from the tank are disinfected prior to discharge.

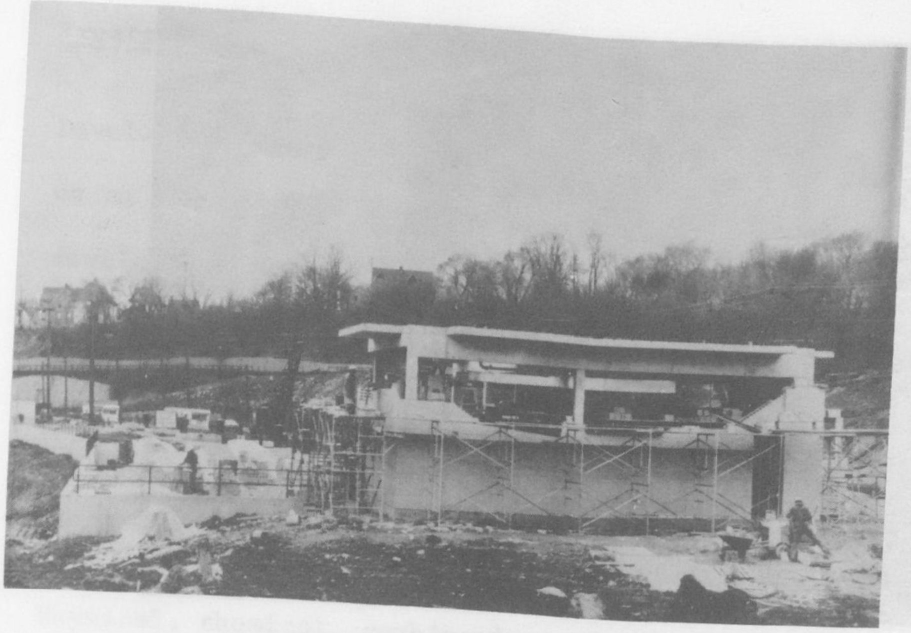

FIGURE 2 - Concrete holding facility under construction in Milwaukee, Wisconsin

The complexities of controlling overflows must be recognized in terms of the capabilities and inadequacies of the entire sewer system. Utilization of storage capabilities of the existing system, flow regulation and routing, remote flow and overflow sensing and telemetering, remote control facilities, off-system storage and others will soon be common practice. Figure 3 shows the central data logging and control center for the system of regulators and in-system control project in Seattle. A similar center at Minneapolis is shown in Figure 4. This type of positive management of sewer systems will become as necessary and sophisticated as similar controls for water distribution facilities, where entire systems are already remotely controlled.

FIGURE 3 - Display board and control panel, Seattle, Washington

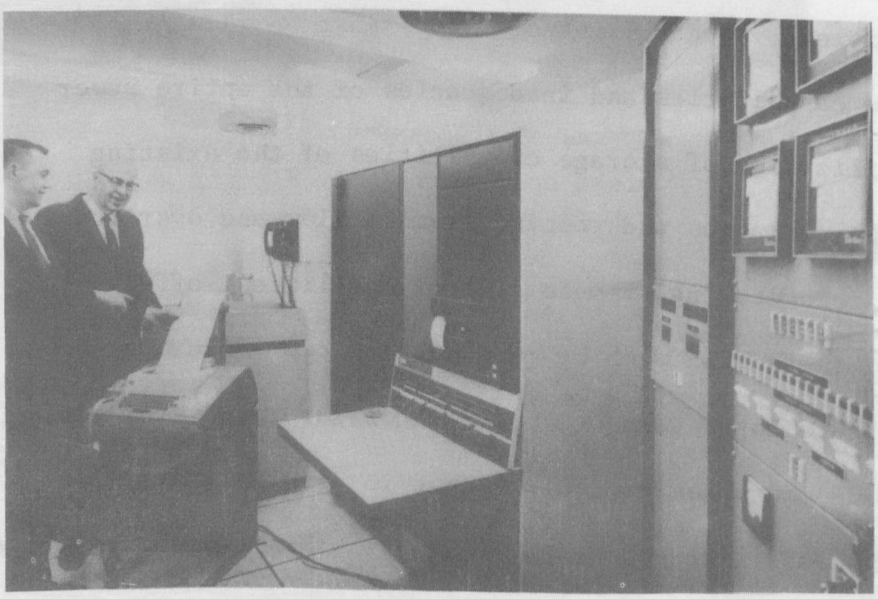

FIGURE 4 - Computer-assisted control room, Minneapolis-St. Paul, Minn.

Treatment

Development of the capability to treat extremely high flow rates on an intermittent basis is a primary objective of the research, development and demonstration program. Factors that must be considered include instantaneous flow rate, total volume to be treated, characteristics of the waste stream, and water quality standards or objectives for the receiving waters--which in turn determine the quality of effluent required.

Physical, chemical, combinations of physical-chemical and biological methods have been considered. Specific processes within these categories which have been investigated are:

Physical

1. Fine screening
2. Microstraining
3. Dissolved-air flotation
4. High-rate multi-media filtration
5. Ultrasonic filtration
6. Cyclonic and vortex separation
7. Tube settlers

Chemical

1. Polyelectrolyte sedimentation aids
2. Chemical oxidation
3. Disinfection--chlorination, ozonization

Physical-Chemical

1. Screening + dissolved-air flotation with flotation aids
2. Screening - chemical flocculation - sedimentation - high-rate filtration - carbon adsorption

Biological

1. High rate plastic and rock media filters
2. Bio-adsorption
3. Stabilization Ponds
4. Rotating Biological Contactor
5. Deep-tank aeration

Treatment methods can be utilized for at individual overflow points or as auxiliary facilities at the basic treatment works. The characteristics of the system will dictate the choice(s). Planning of control and treatment facilities must first evaluate the means for physically controlling the overflows. The capability of the basic treatment works to treat the excess flow on a complete or partial basis should be the second consideration. The means for treating controlled overflows at overflow points or by modifying the basic treatment works should be explored if the existing treatment works cannot adequately treat them. The possibilities of dual use deserves thorough consideration. A facility selected for treating overflows or by-passes may capably serve to upgrade treatment during normal flow periods.

Based on the methods which have thus far been demonstrated, the most applicable for treatment at overflow points include high-rate multi-media filtration and a combination of screening and dissolved-air flotation. Both have the capability of producing a high-quality effluent with design flow rates greatly exceeding those for more conventional waste treatment processes. Multi-media high-rate filtration has thus far been demonstrated at pilot scale to produce suspended solids removals ranging from 75 percent at a filtration rate of 24 gpm/sq.ft. to 87 percent at a filtration rate of 5 gpm/sq.ft. Reduction of Biochemical Oxygen Demand (BOD) has averaged 35 percent. Cost for this process is currently estimated to range from $50,000 to $80,000 per mgd capacity.

The capabilities of the screening-dissolved-air flotation process have been evaluated in a 5 mgd pilot plant in Milwaukee, Wisconsin, and are being further studied and evaluated in a 24 mgd facility constructed by the City of San Francisco.

Combinations of Control and Treatment

Each of the other methods listed can be used effectively under the proper conditions. Screening or microstraining, for example, can be applied as unit processes within a total treatment facility design. A storage or other control facility can include fine screening or microstraining treatment of flow from the facility when storage capacity is exceeded during a storm. The treated overflow can then be disinfected with a resulting effluent of high quality.

The required capacity for treating combined sewer overflows will exceed the capacity of the basic municipal wastewater treatment works--with few exceptions. Findings of the research, development and demonstration activity thus far indicate that there is little liklihood that a process will be developed which can directly handle the instantaneous flow rates generated by storm events. The coupling of control capabilities; such as surge basins, in-system storage and others; to form an operable system will be required. Sophisticated approaches to planning and design will be needed to accomplish this matching of sub-systems and formulation of a remedial plan for the community--large or small.

Combinations of control and treatment offer the designer additional options and flexibility in developing a remedial plan. The types of storage mentioned earlier, variable locations and operating modes for storage or other control methods and the wedding of control facilities with treatment provide the tools for corrective actions. Examples of a few of the possible combinations which can be considered include:

* Capture and retention followed by pump-back to the sewer system upon cessation of storm-generated flow

* Partial retention with short term sedimentation and disinfection of tank discharge

* Retention coupled with fine screening and disinfection of tank discharges

* Retention coupled with chemically assisted sedimentation

* Long-term retention and treatment of the stabilization pond type, including disinfection

Other combinations are also possible, but the above listing will serve to illustrate the broad potential and flexibility of storage as a control measure.

Figure 5 illustrates concrete tank construction. The facility shown was constructed by the Metropolitan District Commission of Boston to serve a combined sewer area in Cambridge. The facility is designed to receive combined sewer overflows and to provide short-term sedimentation and disinfection prior to discharge to the Charles River. Minimum retention time of 10 minutes is provided at a design flow of 233 mgd. This provides storage of 1.7 million gallons, which can be effective for small storms.

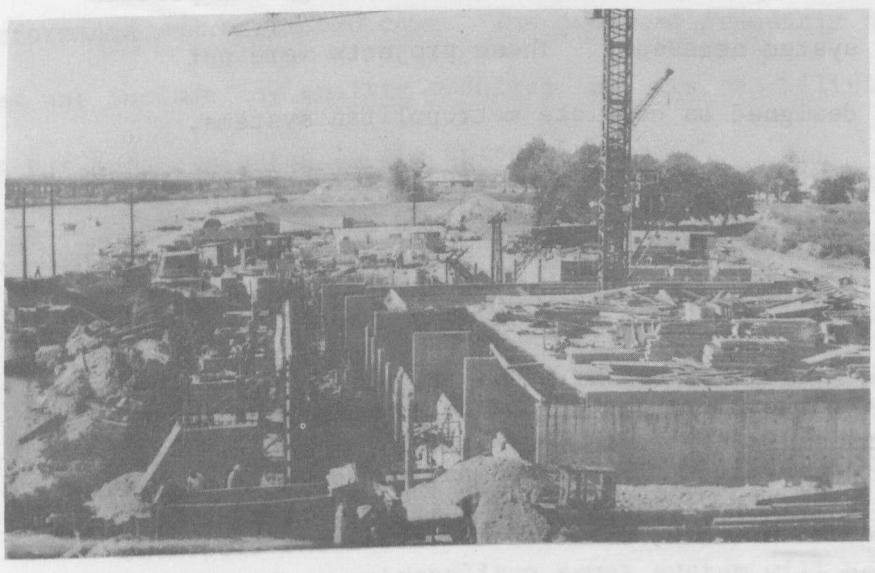

FIGURE 5 - Concrete tank construction of detention-chlorination facility, MDC, Boston, Mass.

Implementation Concepts

The total systems approach is rapidly emerging as the only problem solving technique which offers the potential for producing storm and combined sewer remedial programs that will be not only economically feasible, but will also be effective from a pollution control standpoint. This entails a detailed examination of the wastewater collection, transport and treatment system. Quality of overflows and other discharges must be determined. The collection and transport facilities cannot logically be considered separately from the treatment facilities because the net pollution control capability and operating efficiency requires that the units such as sewers, retention basins, regulating and pumping stations, flow and quality sensing devices, rain gages and others function effectively as a system.

The Detroit, Seattle and Minneapolis-St. Paul in-system control demonstration have shown that current technology can produce the type of system necessary. These projects were not necessarily designed as complete metropolitan systems. Instead, they were planned to demonstrate the concept and to evaluate the hardware and system function. This objective is being accomplished.

Improved techniques were needed for determining the reaction of a sewer system during storm periods and for predicting changes in system reaction in the event that control and treatment facilities are added to the existing system for the purpose of abating combined sewer overflow and storm water pollution.

The Storm Water Management Model mentioned earlier has this capability. The model, or modifications of it, has been used by several cities to assess their overflow problems in terms of quality and quantity as a tool in the remedial measure planning process and as a means for evaluating performance of installed facilities. It has been applied to areas as large as 20,000 acres and as small as 180 acres.

A similar approach has been developed recently in Germany.[39] Utilizing computerized mathematical modeling called the Hydrograph Volume Method, emphasis is placed on maintaining and improving the efficiency of the sewer system through system analysis and pre-planning system modifications. The entire drainage system is considered as a functional hydraulic unit, existing and projected flows are routed through the system to determine areas where improvements are or will be needed. Modifications can then be planned based on system performance and estimated cost. The model as presently developed does not include any quality modeling, and its capabilities have not yet been evaluated in the United States.

The next step in model development and use is expected to be two-fold: (1) simplification as much as possible without detriment to the output and (2) modification to make it more functional as a planning (optimization) tool. Eventually, it is anticipated that a model taylored and programmed for a specific municipal or metropolitan sewer system will be part of a centralized, decision-making and control center; where measured rainfall will be entered into the real-time data bank, system reaction predicted and system controls activated accordingly--on an automated basis.

Manpower Needs

The success of any urban runoff pollution control program adopted by a community, rests heavily on the human resources provided to operate and maintain the system. It must be pointed out that new manpower capabilities will be required. New, automated facilities will require specially trained personnel, such as instrument technicians, computer operators, and maintenance staff familiar with a higher level of equipment sophistication than generally employed today. Such improvements in staffing will be needed to augment but not to replace the typical labor force currently employed in this area.

Recognition of the changing needs in staffing and the improved training programs required to maintain and upgrade competency is an issue to bear in mind in formulating local programs.

The needs in this area will be substantial in terms of both numbers and capability. Recognition must be given to the personnel needs early in the planning and throughout complete development and implementation of the remedial program. The high level of capital investment in facilities must be protected and the system must operate at high efficiency levels.

Storm Water Discharges

Urban storm water has been found to be a signif·cant source of pollution. Long believed to be inconsequential (a reason used for separating sewers) we now know that the assumption that storm water is "clean" is erroneous. Data show that solids, both organic and inorganic; COD; BOD; bacteria; and nutrient concentrations are high enough to cause serious degradation of receiving waters. One only has to observe the materials on our streets to detect the reason. Illicit connections of sanitary and industrial sewers to storm drainage systems also play an important role in this area. Studies of storm water quality in Washington, D.C. (34), Durham, N.C. (35), Cincinnati, Ohio (25), Bucyrus, Ohio (36), and Chicago, Ill. (27)(40) have provided the bulk of the information on this subject in the United States. Studies in Sweden (33) have indicated that increases in traffic result in increased storm water contamination.

Research, development and demonstration efforts in the area of storm-generated wastewater discharges have thus far been concentrated primarily on combined sewer overflows because of the discharge of raw sewage that occurs. Data on storm water quality and results obtained from projects dealing with combined sewer overflows indicate that some of the control and treatment methods for combined sewer overflows can be utilized to abate storm water pollution as well. More work on this problem will be necessary in the near future.

Non-Sewered Runoff

Research, development and demonstration efforts related to non-sewered runoff are in the embryo stage. Airport runoff, road and street de-icing practices, urban erosion control and other technical areas will be explored by the storm and combined sewer research, development and demonstration program as resources permit.

Current Status

A question that should be asked and that must be answered is: what impact has the research, development and demonstration effort had on the pollution abatement programs and what is portended for the future?

Current impact can, perhaps, be identified by official actions taken. Recently published regulations pertaining to basin planning (for water pollution control, for example, require that "....storm water and mixed storm water and sewage shall be identified and reported separately in terms of frequency-volume relationships". This requirement, plus the requirement for quality measurements for all waste discharges contained in the same regulations, place a large responsibility on basin planning agencies for identification of both combined sewer overflow and storm water discharge pollution problems. Such information is, of course, necessary to the development of abatement plans.

The Federal Guidelines for Design, Operation and Maintenance of Wastewater Treatment Facilities require that excessive amounts of infiltration be identified and plans be developed for bringing the problem under control. The Guidelines also require that sewage by-passing be eliminated as far as possible and that consideration be given to ".....separation of combined systems, detention facilities or other alternative means* of control or treatment and disinfection of overflows". The intent is clear--control and treat combined sewer overflows.

Enforcement actions taken under the Federal Water Pollution Control Act, where combined sewers constitute a pollution source, have included control of pollution from overflows as a part of the required abatement action. The Great Lakes Enforcement Conference, for example, has set 1977 as the target date for bringing this problem under control.

State water pollution control agencies are becoming more aggressive in their requirements for abating combined sewer overflow pollution. State orders requiring separation or alternative corrective action are being issued.

Results of demonstration projects indicate that alternative methods can do a more effective job than will separation and at less cost. A study in Bucyrus, Ohio,[36] indicated that if combined sewers were separated, only 50 percent pollution reduction would be achieved due to the remaining storm water pollution. An alternate scheme utilizing an aerated lagoon to treat combined sewer overflows was estimated to provide a 95 percent reduction in pollution at about 60 percent of the cost of separation.

Implementation of new, innovative approaches must be accepted. An example of such a bold approach is the "Kingman Lake Project."[42] This EPA conceptual engineering study describes the reclamation of combined sewer overflows for utilization in a water oriented recreational facility in the heart of the Nation's Capitol.

*emphasis added

A 175 million gallon below-grade storage basin, coupled with a 50 mgd reclamation facility would provide fresh water for two 46-acre swimming and boating lakes.

Cost effectiveness of the project has been indicated to be 1.6 at an estimated total project cost of $45.2 million, with an estimated annual operating cost of $1,777,000.

Based on available and developing technology and the emphasis being placed on requirements for remedial action, it appears that near-future action in abatement of pollution from combined sewer overflows will be a reality. Prudent analysis of sewer system deficiencies and planning for system improvement will take full cognizance of this fact.

Since urban storm water has been identified as a significant pollution source,[(23-27)(33)(35)] evaluation of the total urban drainage system should take this into account, with the objective of developing plans for extensions and improvements to the storm drainage system in a manner which will permit the addition of future treatment facilities at least cost. Some urban areas already face rapid deterioration of lakes and ponds within their boundaries and will need to begin now to control pollution from storm water discharges.

Summary

In closing, several points should be re-emphasized. First, the combined sewer overflow problem exists because we in the water pollution control field have failed to recognize its extent and importance, but even more significant, we have failed to build and maintain wastewater collection, transport and treatment systems that are dependable and efficient.

The second point is that urban storm water discharges from both sewered and non-sewered sources are significant sources of pollution that should, and eventually must, be controlled.

The third and most important point is that traditional, staid, "off-the-shelf" engineering approaches must be abandoned in favor of innovative, imaginative problem analysis and planning directed toward the total urban drainage and treatment system. The system is only as good as its weakest point. Current and emerging technology provides the basic capability to solve the problems. Application of the best technology available must be adopted as standard practice.

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