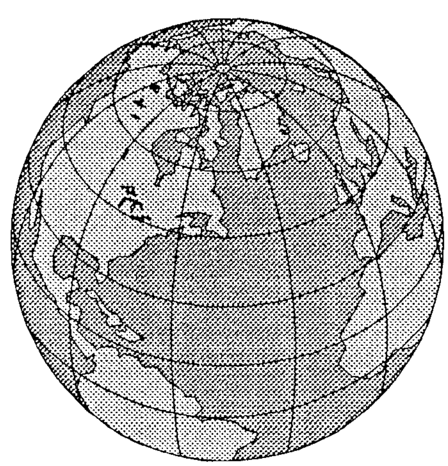
City of Winnipeg
Waterwork, Waste
and Disposal Department

Phase 1 Technical Memorandum for

Combined Sewer Overflow Management Study

EXPERIENCE ELSEWHERE

Technical Memorandum No. 6



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In Association With:

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DISCLAIMER

This Technical Memorandum is for information to the Phase 1 Workshop participants. It is a draft document intended for internal discussion and is not intended as a report representing the policy or direction of the City of Winnipeg.

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

This technical memorandum for the City of Winnipeg Combined Sewer Overflow Management Study was carried out to review the experience of other jurisdictions in combined sewer management. In order to provide the study with state of the art information on CSO control policies, practices and technologies experienced in other parts of Canada and the rest of the world, an extensive literature search was undertaken. Sources included on-line computer libraries (CISTI), the consultants' libraries and experience, and various conference proceedings.

Some 228 papers were classified according to their source and assigned a group reference number for use in this report. A brief review of each paper was presented including group reference, author, source, key words and phrases which characterize the work, and a concise summary if required. This information was then organized in tabular form to show which papers dealt with which aspect of CSO control, i.e., system type, feature, general subject material, policy information, soft and hard engineering, and operation and maintenance features.

Summaries of case studies were undertaken for municipalities which have carried out a CSO control plan and which were identified as having relevance to the City of Winnipeg CSO Management Study. The case study summaries include 10 in Canada, 12 in the U.S.A. and 4 in Europe. The case studies examined details regarding climatology, area characteristics, receiving waters, collection system, wastewater treatment, institutional jurisdiction and funding, and other issues. Also presented were CSO control objectives, technologies selected, cost and implementation details.

Key components of CSO control strategies were investigated in detail. These components included planning, control objectives, monitoring, modelling and control technologies.

CSO control approaches from a planning perspective were identified. The WPCF Manual of Practice on Combined Sewer Overflow Pollution Abatement suggests that "In many cases, it will be advantageous to approach plan development in phases with flexibility to alter the course based on the findings of each phase. Defining plan objectives... is an essential step". Ontario has recently released a draft CSO control policy which requires a planned approach by means of a Pollution Prevention and Control Plan (PPCP).

Flow monitoring is used as an investigative technique to identify the different components in sewage systems, including baseflow infiltration and inflow (I/I). The importance of installing, operating and maintaining/downloading a network of monitoring stations over several months to catch the system operation in all modes was highlighted.

CSO control approach objectives were identified as complex and often conflicting. A comprehensive planning approach to identify these objectives was recommended.

CSO modelling is a tool which is used to simulate the hydrology/hydraulics of a sewerage system with water quality aspects. For the City of Winnipeg, required model components identified included hydrology, water quality, hydraulics, storage/treatment, utilities and input/output. Criteria for the evaluation of available models were presented, and included, along with the technical aspects of each model, technical support, graphical user interface, cost, application, expansion and development capabilities and demonstration systems.

CSO Control alternatives were presented. Storage, in which CSO is retained for later return to a centralized WWTP or sent to a satellite treatment facility, was identified as an effective means of reducing CSOs. Real time control was described as the dynamic operation of collection systems by continually monitoring the system and using this information to make operational adjustments. The function of real time control systems is to fully utilize existing storage, conveyance and treatment capacity, thereby eliminating or postponing the need for capital improvements projects. Vortex regulators are described as reliable, flexible and low maintenance as an alternative for the effective and reliable regulation of flows in combined sewer systems. End of pipe alternatives considered include increasing the capacity of the existing treatment facility, diversion of flows to another treatment facility, solids separation devices, disinfection and screening devices. Sewer separation, both partial, which involves roads only, and full, which includes roads and house connections, was described. The disadvantages of sewer separation, and the difficulty in implementing full separation in developed cities was emphasized.

Best management practices (BMPs) were presented briefly. BMPs described include sewer flushing, catch basin cleaning, sewer system rehabilitation, inflow/infiltration control, street sweeping, control of de-icers, fertilizers and pesticides, discharge By-law review/implementation/enforcement, increase of pervious areas, industrial runoff control, enforcement of anti-litter laws, water conservation, and public education. Other BMPs generally known as stormwater management BMPs presented included inlet control, surface stormwater control, roof leader disconnection, infiltration trenches and basins, porous pavement and gutters, and erosion/sediment control.

A review of CSO/storm runoff control policies in North America and Europe was carried out.

There are as yet no Federal Regulations for the control of CSO in Canada. Several guidelines control CSO and stormwater discharges in Ontario. Recently, a draft CSO control guideline for Ontario was released, and these guidelines expected to be Regulation by the end of 1994. Policies considered include a minimum CSO control criteria. Interim Stormwater Quality Control Guidelines for New Development (Ontario) were released in July 1991. In Alberta, Manitoba and Nova Scotia, governments have acted to control CSO in the absence of a guideline. Alberta also has a governing Regulation and Guideline for stormwater (Stormwater Management Guidelines for the Province of Alberta). No other provinces have formal requirements for the control of stormwater.

In the U.S.A., the EPA has released a draft policy for combined sewer overflow control, which includes nine minimum controls in a two phased policy approach. The policy considers a CSO control program adequate if it meets any of several criteria, including a maximum of 4 overflows per year or elimination (or capture) of at least 85% of combined sewage by volume. Several states have taken the EPA policy and extended their requirements, including Ohio, Michigan, Minnesota and North Dakota. The EPA has included stormwater regulations as part of the Clean Water Act. The regulations are essentially intended to gather information on stormwater systems.

In Europe, no global policy for the control of CSO and stormwater exists. In some countries, pollution control policies exist for both combined and separated sewer systems. Details on sewer design, backwater protection, CSO control and stormwater quality were presented briefly for each of Belgium, Switzerland, Germany, Denmark, Spain, France, The Netherlands, Sweden, Finland and the United Kingdom.

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SECTION 1
INTRODUCTION

INTRODUCTION

1.1 GENERAL

The City of Winnipeg has initiated the study and development of a Combined Sewer Overflow (CSO) Management Strategy for the City. This study will result in the development of a framework for significant long-term environmental policies. A key outcome will be the establishment of a cost effective prioritized implementation plan for remedial work based on assessment of costs and benefits of practicable alternatives. This plan will be used by the City to develop and substantiate its position in the ongoing regulatory review process, ultimately looking to the execution of an approved plan.

As a requirement of the Combined Sewer overflow (CSO) Management Strategy Study for the City of Winnipeg, a comprehensive review of policies and practices relating to combined sewer overflow control and treatment implemented or proposed by municipalities in Canada, the United States and Europe, is to be undertaken. This review is required to ensure the implementation plan being developed for the City of Winnipeg takes into account current policies and practices as well as state-of-the-art technology. This task is to review the experience of other jurisdictions in combined sewer management to assess suitability and technologies for the Winnipeg situation.

This report presents the findings associated with the review of experience elsewhere.

1.2 SOURCES OF INFORMATION

Information relating to CSO control was obtained from the following sources:

- The Consultants' own library materials.
- Computerized data bases.
- Various government agencies in North America and Europe.
- Personal communication with various municipalities and levels of government.

The information collected is identified and discussed in later sections of this report.

1.3 LITERATURE SEARCH

A literature search was conducted by accessing Literature Review studies carried out by the Consulting Team for other projects and updating the previous searches with papers from current and pertinent conferences associated with CSO control. The previous Literature Review studies were carried out with data base searches which included:

- Canadian Institute for Scientific and Technical Information (CISTI)
- Engineering Index
- Current Technology Index

The literature search for this study includes only the most recent and relevant papers presented since 1980. CSO control technologies reported on prior to 1980 are considered to either be implemented and reported on more recently if found to be effective or have been implemented in association with some more recent advancements.

SECTION 2
DOCUMENTATION AND REVIEW OF INFORMATION

DOCUMENTATION AND REVIEW OF INFORMATION

2.1 CLASSIFICATION OF INFORMATION

For the purpose of this study, the papers and proceedings reviewed primarily focused on Combined Sewer Overflows (CSOs), the breadth of CSO impacts and management, combined sewers and, to a lesser extent, storm sewers and urban runoff, with regards to both quality and quantity aspects.

A total of 228 publications were assessed of which 203 came from 20 designated sources and 25 from undesignated sources. For ease of reference, they have been grouped according to source as follows:

Group Reference	Source	
A	Markham - International Symposium on Urban Hydrology & Municipal Engineering, June 1988.	18 papers
B	Publication - Design of Urban Runoff Quality Controls - Edited by Larry A. Roesner and others. Proceedings of Engineering Foundation Conference on Current Practice and Design Criteria for Urban Quality Control, Potosi, Missouri July, 1988.	2 papers
C	EPA Proceedings - SWMM Users Group Meetings, June 19-20, 1980; Sept. 28-29, 1981; April 12-13, 1984.	6 papers
D	Publication - Stormwater Detention Facilities edited by Wm. DeGroot. Proceedings of Engineering Foundation Conference Hennniker, New Hampshire, August 1982.	7 papers
E	Camp Dresser & McKee Inc.	2 papers

Group Reference	Source	
F	National Research Council (NRC)	5 papers
G	Boston - WPCF Speciality Conference Series Control of Combined Sewer Overflows, April 1990.	19 papers
H	Proceedings of the Third International Conference on Urban Storm Drainage Sweden, June 1984.	8 papers
I	Urban Stormwater Quality Enhancement - Source Control, Retrofitting & Combined Sewer Technology. Proceedings of Engineering Foundation Conference Davos Platz, Switzerland, October 1989.	9 papers
J	Osaka Japan Municipal Government Sewage Works Bureau.	3 papers
K	Washington - WPCF Annual Conference, October 1990.	3 papers
L	Pollution Control Planning Workshop Toronto, February 1987. Published as *Pollution Control Planning*, Editor William James	2 papers
M	Miscellaneous Sources	25 papers
N	Technical University of Nova Scotia (TUNS) Combined Sewer Overflow, May 1991.	7 papers
O	Emerging Technologies and Stormwater and Water Quality Management Modelling, Toronto February 1992. Published as *New Techniques for Modelling the Management of Stormwater Quality Impacts*, Editor William James	2 papers

Group Reference	Source	
P	Water Environment Federation (WEF) Speciality Conference Series Control of Wet Weather Water Quality Problems, May/June 1992.	7 papers
Q	Stormwater Management and Combined Sewer Control Technology Transfer Conference Ontario, January 1993.	7 papers
R	Stormwater and Water Quality Management Modelling Conference Toronto, February 1993. Published as *Current Practices in Modelling the Management of Stormwater Impacts*, Editor William James	3 papers
S	Water Environment Federation (WEF) Annual Conference and Exposition Anaheim, California October 1993.	8 papers
T	6th International Conference on Urban Storm Drainage (6 ICUSD) Edited by Jiri Marsalek and Harry Torno, September 1993.	78 papers
U	Annual Convention, Western Canada Water and Wastewater (formerly Sewage) Association, 1983, 1984, 1987, 1990, 1991, 1993	7 papers

The publications have been listed as follows:

- Group Reference Number
- Title
- Author(s)
- Source

2.2 *LITERATURE REVIEW*

The following pages present a review of selected technical papers since 1980 from sources described in Section 2.1. The format provides the Group Reference number, the number of the paper as selected from the proceeding, the author(s), the source, a number of key words or phrases to characterize the thrust and content of the paper and finally, a sentence or two to elaborate on the key if necessary.

SELECTED TECHNICAL PAPERS

A1 DEVELOPMENTS OF THE CANADIAN SWM TECHNOLOGY

by Paul Wisner
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: SWM - Detention - Treatment - Master Drainage Plans - Run-off - computer modelling

Outlines limitations of "surrogate objectives" versus ad hoc solutions in standardized policies.

A2 A PRAGMATIC APPROACH TO STORMWATER MANAGEMENT

by R.J. Shuttleworth
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: City of Brossard - surface water - design program - sump pumps - flooding protection -public consultation

A design program, S.I.R.D.U., developed by L'Universite de Montreal used to size piping and storage requirements. Substantial savings in installation costs of surface water drainage systems.

A3 STORMWATER MANAGEMENT ACROSS THE UNITED STATES

by David C. Roe
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: stormwater detention - retention - master plan - environmentally sensitive - controlling outlet flows

Facilities for commercial, institutional and governmental buildings.

A4 DISCUSSION & IMPLEMENTATION OF DETENTION SOLUTIONS FOR URBAN RUNOFF

by Mario Parente
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: detention facilities - urban runoff - quality - quantity - selection guidelines

Guidelines in the selection of a detention facility and four specific solutions.

A5 STORMWATER MANAGEMENT FOR COMMERCIAL & INDUSTRIAL DEVELOPMENTS

by Ken Collicott
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: commercial/industrial development - SWM - retention storage volumes - Ontario Regulatory Agencies

A6 CASE STUDIES OF DUAL DRAINAGE DESIGN WITH INLET CONTROL DEVICES IN METRO TORONTO

by Milos Jaukovic and Alan S. Lam
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: property damage - sewer back-up - dual drainage concept - public protection - environmental aspects - subdivision

A7 A CRITICAL REVIEW OF COMPUTER MODELLING

by C. Doherty
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: water resources - Ontario - hydrologic/hydraulic computer programs - user responsibilities and frustrations

A8 **STORMWATER MANAGEMENT - WHAT DO THE NUMBERS MEAN?**

by Christine Doody-Hamilton
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: pre design tools - solutions - policies - procedures - staff training

Refocus on overall watershed management objectives and physical site constraints, de-emphasize modelling techniques to maintain product quality.

A9 **COMPARISON OF DESIGN FLOOD METHODOLOGIES ON A SMALL RURAL WATERSHED IN SOUTHERN ONTARIO**

by Paul J. Pilon
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: design storm/flood techniques - (un)gauged watersheds - hydrologic practices

A10 **INTERNATIONAL RESEARCH & TRAINING CENTRE ON URBAN DRAINAGE (IRTCUD) & UDM DATA BASE ESTABLISHMENT ACTIVITIES & FUTURE PLANS**

by M. Radojkovic, C. Maksimovic, J. Despotovic & J. Petrovic
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: development - area of activity - future plans - rainfall-runoff

A11 **IMPORTANCE OF THE UDM RAINFALL-RUNOFF MEASUREMENTS FOR THE MUNICIPAL ENGINEER**

by J.F. Sabourin & P. Wisner
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: rainfall-runoff measurements - pitfalls - inadequate measurements

The UDM can become an international standard for new models.

A12 **THE NEED FOR MODELLING IMPROVEMENTS AND EXAMPLES FROM USA STUDIES**

by James E. Scholl
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: improvements - computer models - rainfall-runoff - studies - flows

HYMO program did not handle a mixture of pervious and impervious surfaces when the impervious percentage exceeded 30%.

A13 **APPLICATION OF REGIONALIZED UNIT HYDROGRAPHS & STORMWATER MANAGEMENT PROJECTS IN SWITZERLAND**

by David Consuegra & Rudolf Gloor
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: stormwater management - master drainage - hydrographs

Development of simple techniques to calculate runoff hydrographs is necessary.

A14 **RIVER IMPACT OF COMBINED SEWER OVERFLOWS: UK DEVELOPMENTS**

by J.M. Tyson and I.T. Clifforde
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: sewer overflows - sewage systems - quality models - flow models -structural integrity - hydraulic adequacy

Early approaches to regulate CSO performance were all directed from sewer design considerations.

A15 **HIGHLIGHTS OF STUDIES ON COMBINED SEWER OVERFLOWS IN QUEBEC**

by P. Lavallee
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: storm sewer discharges - sewer network - overflows - wastewater management - treatment plants

Five different types of projects were conducted in the Province.

A16 **PUBLIC PARTICIPATION IN THE DESIGN OF SWM FACILITIES**

by S.A. McKelvie
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: stormwater management - enhance - recreational facilities - local residents

This paper discusses several of these projects which have been successful from a water management point of view as well as from a public perspective.

A17 **ECOLOGICAL ASPECTS FOR THE DESIGN OF STORMWATER MANAGEMENT STORAGE**

by Dimitry D. Stone & Alan S. Lam
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: Two projects - Toronto area - collaboration - engineers - biologists - stormwater management - control - public - protection - fish habitat - wetlands

The two projects are the Pickering Plains and Bayview Hills residential developments, respectively located in the Towns of Ajax and Richmond Hill.

A18 **LANDSCAPING STORMWATER MANAGEMENT FACILITIES**

by Paul D. Ferris
International Symposium on Urban Hydrology and Municipal Engineering (June 1988)

KEY: architect - development - timing - involvement - site engineering - planting design and safety

B1 **STATE PERSPECTIVE ON WATER QUALITY CRITERIA**

by Eric H. Livingston
Design of Urban Runoff Quality Controls

KEY: water quality standards - best management practices - conceptual program - modification -stormwater - pollution loading

The relationship between the implementation of best management practices (BMPs) and water quality criteria is explored with emphasis on how Florida's stormwater regulatory program was established.

B2 **INSTITUTIONAL ASPECTS OF STORMWATER QUALITY PLANNING**

by Nancy W. Schultz and Ronald L. Wycoff
Design of Urban Runoff Quality Controls

KEY: implementation - programs - control - urban areas - effectiveness - motivations - responsible agencies

The study locations for stormwater runoff quality control programs were Chicago, Seattle, Milwaukee, St. Louis, Santa Clara Valley and Boston.

C1 **COMBINED SEWER SYSTEM ANALYSIS USING STORM AND SWMM FOR THE CITY OF CORNWALL**

by John C. Anderson
Proceedings Stormwater Management Model (SWMM) User Group Meeting (June 1980)

KEY: plant expansion - control techniques - minimize - overflow loadings - treatment - effectiveness

Further analysis to assess the hydraulic operation of the system for individual storm event operation was undertaken using the SWMM program.

C2 **AN INTEGRATED MODELLING APPROACH FOR EVALUATING CSO TREATMENT ALTERNATIVES**

by Arthur M. Dee
Proceedings Stormwater Management Model (SWMM) User Group Meeting (September 1981)

KEY: methodology - models - selection criteria - integrate -

The models integrated in the study were the SWMM Runoff model (U.S. EPA), the Mixed-Flow sewer model (University of Minnesota), and the RECEIV-II river model (Raytheon).

C3 **EVALUATION OF RELIEF ALTERNATIVES FOR COMBINED SEWER SYSTEMS**

by A. Ashamalla & M. Ahmad
Proceedings Stormwater Management Model (SWMM) User Group Meeting (September 1981)

KEY: City of Edmonton - modified version - relief concepts - surface - subsurface constraints
relief sewers - conveyance - overflows - minimize - storage

Among many relief concepts, two concepts proved to be the most feasible for the complex Edmonton system, considering the constraints in the already built-up area.

C4 **INVESTIGATION OF MANAGEMENT ALTERNATIVES FOR CSO'S FOR THE CITY OF HAMILTON**

by Dale Henry and Wm. James
Proceedings Stormwater Management Model (SWMM) User Group Meeting (September 1981)

KEY: RUNOFF - EXTRAN - catchment - channels and conduits - model - pollution - minimize - optimization

The stormwater conveyance network for Hamilton consists of five different transport systems, each distinctly different and requiring unique pollution abatement solutions.

C5 **HYDRAULIC MODELLING WITH SWMM IN AN UNSTEADY PRESSURE FLOW REGIME**

by James D. Parry and Thomas P. Finn
Proceedings Stormwater and Water quality Model Users Group Meeting (April 1984)

KEY: simulate - conduit - surcharging - tidal - storm events

The paper discusses the use of the SWMM (Version III) model to simulate a large, highly developed drainage system in the City of Norfolk, Virginia.

C6 **USING A TIMEX-SINCLAIR 1000 MICROCOMPUTER FOR REAL-TIME CONTROL OF CSO'S**

by Mark Stirrup & Wm. James
Proceedings Stormwater Management Model (SWMM) User Group Meeting (April 1984)

KEY: flow control - communicate - raingauges - flowgauges - interface - linear transfer

The computer communicates with on-site raingauges and flowgauges through a specially developed input/output interface.

D1 **PLANNING CONSIDERATIONS FOR DETENTION BASINS**

by Ernest F. Coff
Stormwater Detention Facilities

KEY: inflow loadings - inflow mechanics - outflow structures - aesthetic enhancement

Detention basins can be a valuable tool for reducing constituent loads in storm runoff.

D2 **ANALYSIS OF DETENTION BASINS IN EPA NURP PROGRAM**

by Eugene D. Driscoll
Stormwater Detention Facilities

KEY: results - variable - pollutant loads - evaluate - controlled - uncontrolled - urban runoff - design requirements

D3 **STORMWATER DETENTION PONDS FOR WATER QUALITY CONTROL**

by Clifford W. Randall
Stormwater Detention Facilities

KEY: incorporated - flood management - strategies - utilization - management principles - pond design

Detention pond utilization and management principles for water quality control are discussed.

D4 **URBAN RUNOFF POLLUTANT REMOVAL BY SEDIMENTATION**

by Clifford W. Randall, Kathy Ellis, Thomas J. Grizzard and William R. Knocke
Stormwater Detention Facilities

KEY: settling tubes - runoff samples - settling columns - culverts - experiments - reductions - pollutants - flocculant particles

Runoff samples used in the settling columns were collected from culverts draining three different shopping mall parking lots.

D5 **LAKE ELLYN AND URBAN STORMWATER TREATMENT**

by Donald L. Hey
Stormwater Detention Facilities

KEY: water quality - suspended solids - reduced - heavy metals - nutrients - immobilized

D6 **WATER QUALITY ENHANCEMENT THROUGH STORMWATER DETENTION**

by William G. Smith
American Society of Civil Engineers

KEY: storage - stormwater runoff - sewer overflows - pollutants - enhancement techniques

Urban stormwater is emerging as a significant source of surface water pollution in the United States.

D7 **WATER QUALITY ENHANCEMENT DESIGN TECHNIQUES**

by Richard H. Kropp
Stormwater Detention Facilities

KEY: deterioration - stormwater management - preventive control - detention facilities - particulate pollutant - regulatory programs - quantity - quality management

E1 **MODELLING RECEIVING WATER IMPACTS FROM COMBINED SEWER OVERFLOWS USING AN EMPIRICAL APPROACH**

by Thomas Hruby, Mark Carroll and Mitchell Heineman
Camp Dresser & McKee Inc.

KEY: New Bedford, Mass. - frequency - quality - criteria - resource areas - transport - dilution - parameters - models

New Bedford's CSOs were aggregated into six geographically-based groups for the purpose of modelling impacts in the receiving water.

E2 **NUMERICAL CSO MODELLING FOR DEVELOPING DISCHARGE CURVES TO MEET NPDES PERMIT REPORTING REQUIREMENTS**

by Robert J. Kapner and Phillip J. Biagiarelli
Camp Dresser & McKee Inc.

KEY: advantages - limitations - simulate - precipitation - hydraulic characteristics - antecedent - regression analysis - peak hourly intensity - total rainfall

Application of this approach to the combined sewer system in the City of Lowell, Massachusetts, is given as a case study.

F1 **STORMWATER POLLUTION CONTROL STRUCTURAL MEASURES**

by E. John Finnemore
The Journal of the Environmental Engineering Division (August 1982)

KEY: storage - wet-weather/dry-weather - treatment facilities - cost-effective - studies - demonstrate - concepts - computerized control - flexibility

Case studies of three very promising, constructed and operating structural measures for controlling combined sewer overflow pollution demonstrate concepts.

F2 **APPLICATION OF TRANSIENT MIXED-FLOW MODEL TO THE DESIGN OF A COMBINED SEWER STORAGE-CONVEYANCE SYSTEM**

by Charles C.S. Song, James A. Cardle, Gerald C. McDonald and Alfred J. DeYoung
1982 International Symposium on Urban Hydrology, Hydraulics and Sediment Control.

KEY: storage - conveyance - tunnel system - hydraulic design - simulating - mixed flow - pressurized flow - reducing - maximize - minimize - pressure

This paper describes the hydraulic design procedures for the new tunnel system using the newly developed transient mixed-flow model.

F3 **WATER QUALITY ENHANCEMENT THROUGH STORMWATER DETENTION**

by William G. Smith
American Society of Civil Engineers

KEY: surface water - pollution - storage - stormwater - sewer overflows - discharge

Water quality enhancement techniques include sedimentation, infiltration/percolation, biological treatment and disinfection.

F4 **STORM AND COMBINED SEWERS: PART OF THE TREATMENT PROCESS**

by Richard Fields
Water Engineering and Management, USA (January 1982)

KEY: maintenance - management - collection systems - drainage - pollution control - regulatory inspections - catchbasins

The benefits of combined sewer over separate sewer systems is outlined from an economic and environmental aspect.

F5 **WATER RESOURCES FOR CHICAGO - HISTORY AND FUTURE**

by Forrest C. Neil and Frank E. Dalton
Journal of the Water Resources Planning and Management Division

KEY: collection systems - discharge - diverted - tributary - canals - sewage treatment - flood control

The paper outlines the history of Chicago's growth and problems encountered with sanitary drainage and water collection systems.

G1 **THE PAPERDEGAT BASIN CSO ABATEMENT PROJECT**

by Robert Gaffoglio, Ram Patel & Robert Smith
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: pollutant - sewer overflow - concentrated - drainage area - water quality - alternatives - screening - swirl concentrators - detention - treatment - hydrodynamic models - outfall weir - storage

To meet water quality standards, a combination of detention and treatment was required.

G2 **ENVIRONMENTAL CONSEQUENCES OF CSO CONTROL ALTERNATIVES**

by Pamela Heidell
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: storage - treatment facility - tunnels - near-surface storage - environmental effects

This paper presents a summary of the key environmental issues associated with the storage options proposed.

G3 **MASSACHUSETTS WATER RESOURCES AUTHORITY COMBINED SEWER OVERFLOW FACILITIES PLAN: AN OVERVIEW**

by Daniel J. Murray Jr.
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: water basins - pollution loads - stormwater runoff - atmospheric deposition - control technologies - expanded alternative - limited alternative

The plan relates to the clean up of Boston Harbour and its tributaries.

G4 **FACTORS TO CONSIDER IN NEGOTIATING NPDES PERMITS FOR COMBINED SEWER OVERFLOWS: LEGAL AND LIABILITY ISSUES**

by J.C. Hall and E.D. Eilbott
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: strategy - discharge - unlawful - technology-based - water quality-based - pollutant control - pretreatment programs

The paper outlines several actions for CSO discharges to ensure they are incompliance with NPDES permit issuance to establish proper CSO requirements and limit potential liability.

G5 **CSO EXPERIENCE IN MICHIGAN - A CONSULTANT'S PERSPECTIVE**

by J.W. Hubbell
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: optimizing operation - developing - implementing - control program - retention - treatment - runoff - quality - quantity - treatment basins - cost effective - efficient

Impacts of CSO discharge on receiving waters are often difficult to accurately quantify because of the variation in quantity and quality of runoff from urban areas.

G6 A NEW LOOK AT SEWER SEPARATION FOR CSO CONTROL

by Carl Johnson
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: stormwater capacity - reduces infiltration - treatment system - pollutant reduction - coliform - screening facilities

The effectiveness in removing pollutants by sewer separation is a linear production function with pollutant reduction proportional to the amount of area separated.

G7 SEATTLE METRO'S COMBINED SEWER OVERFLOW CONTROL PROGRAM PLANNING AND IMPLEMENTATION

by J.B. Lampe and G.K. Sreifers
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: secondary treatment - system-wide reduction - evaluation - control methodologies - sewer separation - computer simulation

G8 A 100 - YEAR MASTER PLAN FOR CINCINNATI'S COMBINED SEWER SYSTEM

by L. Roesner, T. Saygers and G. Rowe
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: infiltration - inflow - pollutants - catchment areas - system improvements - overflow frequency - storage facilities - water quality

Recommendations made consist of an immediate and long term plans for CSO control.

G9 DESIGN OF CSO ABATEMENT FACILITIES IN NEW YORK CITY

by H. Moutal, R. Gaffoglio and G. Apicella
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: studies - storage facility - retention basins - floatable material - swirl concentrators

Due to the flat sewer slopes in New York city, it was found that a lift station would be required to lift waste to the interceptor level.

G10 BENEFITS OF THE PROACTIVE APPROACH FOR CSO CONTROL IN CHATTANOOGA

by J. Aldrich, D. Kurz and B. Cunningham
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: requirements/policies - control measures - compliance schedule - monitoring/modelling -nonpoint pollutants - stormwater runoff - stormwater management

The CSO Control Strategy is to be implemented through permitting strategies prepared by the State and system-wide CSO management plans.

G11 DEVELOPMENT OF A COMBINED SEWER OPERATIONAL PLAN FOR EAST LANSING , MICHIGAN

by B. Koltz, R. Martin and P. Ebervz
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: system inventory - administrative controls - maintenance program - control strategy - implementation schedule - offline storage

G12 DESIGN EXPERIENCE WITH 80 MGD GERMAN VORTEX SOLIDS SEPARATOR FOR TREATMENT OF FIRST FLUSH AT THE MAIN TP, BURLINGTON, VERMONT

by W. Pisano, N. Thibault and G. Forbes
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: solids separator - Fluidsep - intermediary - treatment - sedimentation tank

A new advanced solids separator device called the "Fluidsep" is discussed in this paper.

G13 INNOVATIVE REGIONAL WET WEATHER PROGRAM (FOR OAKLAND, CALIFORNIA)

by M.J. Wallis, E.H. McCormick and M.M. Campos
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: wastewater overflows - infiltration/inflow - computer modelling - flow motoring - sub-basins - capital improvement

It was found that although most of the sanitary and storm sewers have been separated, over 18% of the rain falling gets into the sanitary sewer system.

G14 A FLOOD RELIEF AND CSO STUDY FOR THE CITY OF SARNIA, ONTARIO

by B.J. Greck
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: location - magnitude - basement flooding - runoff - inlet control - sewer separation - sewer improvements

The 2, 5 and 10 year flooding levels of protection were investigated with the 10 year level selected.

G15 CSO ABATEMENT USING SWIRL CONCENTRATORS

by J.M. Gavin, R. Srinivasaraghavan, A.P. Trelewicz and V. Sinopoli
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: swirl concentrators - chlorination - intensity mixing - gravity distribution - holding tanks

This paper deals with the design of treatment facilities at North Yonkers Pumping Station to treat the overflows.

G16 INNOVATIVE TECHNIQUES FOR FLOW MONITORING IN COMBINED SEWER OVERFLOWS

by G.E. Kurz, S.E. Sirkin, J. Burns and J.A. Aldrich
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: Chattanooga, Tennessee - catchment - weirs - tide gates - Manning's equation - continuity equation

A field monitoring program was established to monitor three CSOs.

G17 PEAK FLOW IMPROVEMENTS AVOID OVERFLOWS

by P.S. Arora, J. Zink and M.R. Morlino
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: Dallas - Trinity River - hydrograph analysis - forcemain - pumping facilities - temporary storage

The design objective selected was to capture for later treatment all the wet weather flows above the maximum treatment rate of the plant.

G18 DROPSHAFTS FOR CONVEYANCE OF COMBINED SEWER OVERFLOWS TO TUNNELS

by D.E. Westfall
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: variable discharge - entrained air - headloss - subatmospheric - direct drop - vortex

G19 RISK ASSESSMENT: A TOOL TO DEFINE ENVIRONMENTAL AND HUMAN HEALTH EFFECTS OF URBAN RUNOFF AND COMBINED SEWER OVERFLOWS

by S.F. Munger and R.D. Cardwell
WPCF Specialty Conference On Control Of CSO's, Boston (April 1990)

KEY: Lake Union, Washington - lead - copper - hazard assessment - derivation - water quality
toxic chemicals - stormwater chemistry - public education - household hazardous materials

The approach taken was to select representative chemicals found in both storm drain discharges and CSOs and to predict their concentrations along paths of environmental exposure.

II1 **<u>THE NATIONWIDE URBAN RUNOFF PROGRAM (NURP) "ADAPTED FROM FINAL REPORT OF NURP - EXECUTIVE SUMMARY</u>**

by H.C. Torno.
Proceedings of the Third International Conference on Urban Storm Drainage, Sweden June (1984)

<u>KEY</u>: urban runoff - pollutant loads - rivers & streams - control effectiveness

The overall goal of NURP was to provide information to decision makers with the rational basis for determining whether or not urban runoff is causing water quality problems and, if it is , to help make policy decisions for control.

II2 **<u>THE OVERFLOW FREQUENCY AS A CRITERION FOR THE DESIGN COMBINED SEWER SYSTEMS</u>**

by Prof. J. Berlamont and M. Smites
Proceedings of the Third International Conference on Urban Storm Drainage, Sweden June (1984)

<u>KEY</u>: mean annual overflowing - peak overflow - pollution emission model - overflow frequency

It is noted that in Belgium and the Netherlands, the overflow frequency from combined sewer systems is used as a design criterion.

II3 **<u>ESTIMATION OF QUALITY AND POLLUTION LOAD OF COMBINED SEWER OVERFLOW DISCHARGE</u>**

by W. Hogland, R. Berndtsson and M. Larson
Proceedings of the Third International Conference on Urban Storm Drainage, Sweden June (1984)

<u>KEY</u>: City of Malmo, Sweden - pollution load - computer models - quality - sediment

A wide range of statistical analyses were performed on the data obtained for both within and between separate CSO events.

II4 **<u>CHARACTERISTICS OF COMBINED SEWER RUNOFF</u>**

by W.F. Geiger
Proceedings of the Third International Conference on Urban Storm Drainage, Sweden June (1984)

<u>KEY</u>: Munich-Harlaching - correlations - suspended solids - total organic carbon

Total suspended solids, BOD, COD, total organic carbon, kjeldahl-nitrogen and phosphorus, were monitored on a regular basis.

II5 **<u>THE PHYSICO-CHEMICAL SPECIATION OF ZINC, CADMIUM, LEAD AND COPPER IN URBAN STORMWATER</u>**

by G.M. Morrison and G. Svensson
Proceedings of the Third International Conference on Urban Storm Drainage, Sweden June (1984)

<u>KEY</u>: U.K. - Sweden - catchments - impervious - residential - multi-storey

The major findings of the study show that both the Swedish and U.K. catchments have consistent distribution of the four metals.

II6 **<u>REDUCTION OF OVERFLOW POLLUTANT LOADS FROM COMBINED SEWERAGE SYSTEM</u>**

by Dr. H.F. Kaltenbrunner
Proceedings of the Third International Conference on Urban Storm Drainage, Sweden June (1984)

<u>KEY</u>: Netherlands - surface waters - operations - difficulty - treatment - control facilities - concentration - composition - emerging technologies

The paper summarizes the CSO problems encountered in the Netherlands with 90% of the sewerage system being combined systems and discharging mainly into eutrophic, semi-stagnant bodies of water.

H7 **EXPERIMENTAL SYSTEM FOR REDUCTION OF URBAN STORM RUNOFF**

by S. Fujita
Proceedings of the Third International Conference on Urban Storm Drainage, Sweden June (1984)

KEY: Tokyo, Japan - permeable pavement - infiltration inlet - infiltration trench - infiltration curb - circuitous sewer pipe

The two components of the E.S.S. are infiltration and storage.

H8 **COMBINED SEWER ANALYSIS FOR THE CITY OF MALMO**

by J. Larsson and B. Persson
Proceedings of the Third International Conference on Urban Storm Drainage, Sweden June (1984)

KEY: Sweden - policies - plan - efficiently - formulated - integrated - SWMM - EXTRAN model - flood control

A study was conducted of the turbine Watershed which covers an area of 25 km^2 and half of the city population.

I1 **STORMWATER QUALITY INSTITUTIONAL CONSIDERATIONS**

by J.E. Jones and D.E. Jones
Proceedings of the Engineering Foundation Conference on "Union Stormwater Quality Enhancement - Source Control, Retrofitting and Combined Sewer Technology", Davos Platz, Switzerland (October 1989)

KEY: legislators/politicians - regulators - engineering consultant - project proponents - institutional policies

It is felt that relatively little attention has been paid upon the legal, social, economic and other institutional factors that determine the success or failure of a project.

I2 **STORMWATER REGULATIONS AND STANDARDS, INTRODUCTION**

by P. Harremoes
Proceedings of the Engineering Foundation Conference on "Urban Stormwater Quality Enhancement - Source Control, Retrofitting and Combined Sewer Technology" Davos Platz, Switzerland (October 1989)

KEY: interceptors - pollution discharged - critical flow - horizontal interceptors - policy - pollutant runoff - water quality

The paper presents a summary of a report to the Danish Environmental Protection Agency related to stormwater problems.

I3 **STORMWATER REGULATIONS FROM LOCAL GOVERNMENTS' VIEW**

by L.S. Tucker, ASCE Member
Proceedings of the Engineering Foundation Conference on "Urban Stormwater Quality Enhancement - Source Control, Retrofitting and Combined Sewer Technology" Davos Platz, Switzerland (October 1989)

KEY: United States - FWPCA - permits - USEPA - Congress - permit application requirements civil action

The paper examines the background, status and enforcement provisions of the stormwater permit program from the local government viewpoint.

I4 **SWEDISH TRENDS IN CSO PLANNING AND CONTROL**

by J. Larsson and J. Falk
Proceedings of the Engineering Foundation Conference on "Urban Stormwater Quality Enhancement - Source Control, Retrofitting and Combined Sewer Technology" Davos Platz, Switzerland (October 1989)

KEY: Sweden - historical trends - stormwater discharges - separation - stormwater management - flow equalization - sewer renovation

The authors predict that the trends in the 1990's will be towards flow equalization, sewer renovation, source control and real time control.

I5 MANAGEMENT STRATEGIES TO CONTROL INDUSTRIAL DISCHARGES TO COMBINED SEWER OVERFLOWS AND SEPARATE STORM SEWERS

by K. Weiss and H. Thron
Proceedings of the Engineering Foundation Conference on "Urban Stormwater Quality Enhancement - Sewer Control, Retrofitting and Combined Sewer Technology" Davos Platz, Switzerland (October 1989)

KEY: on-site controls - collection system controls - Best Management Practices (BMPs)

I6 REAL TIME CONTROL OF COMBINED SEWERS: A U.S. VIEW

by C.G. Chantrill
Proceedings of the Engineering Foundation Conference on "Urban Stormwater Quality Enhancement - Sewer Control, Retrofitting and Combined Sewer Technology" Davos Platz, Switzerland (October 1989)

KEY: control storage facilities - reduce overflow - microcomputer technology - control strategies - minimize pollution

Real time control of combined sewers is seen as a major option to curb pollution from surface water runoff.

I7 EQUIPMENT AND INSTRUMENTATION FOR CSO CONTROL

by H. Brombach
Proceedings of the Engineering Foundation conference on "Union Stormwater Quality Enhancement - Source Control, Retrofitting and Combined Sewer Technology", Davos Platz, Switzerland (October 1989)

KEY: storage capacity - tube-type - circular - stormwater overflow tanks - controllers - siphons
helical bends - anti-return flaps - tipping flushers

The author discusses the equipment and instrumentation installed at 9,000 storm overflow tanks in West Germany.

I8 NON-STRUCTURAL MEASURES TO MINIMISE CSO EFFECTS

by F. Sperling
Proceedings of the Engineering Foundation Conference on "Urban Stormwater Quality Enhancement - Source Control, Retrofitting and Combined Sewer Technology", Davos Platz, Switzerland (October 1989)

KEY: combined sewage flow - pollution concentrations - chemical dosing - oxygenation of rivers
retention of organisms

In Germany, the Federal Water Act demands the obtaining of a permit for wastewater and industrial discharges.

I9 THE REGULATION OF CSO'S AND STORM WATER IN THE UNITED STATES

by J.R. Elder
Proceedings of the Engineering Foundation Conference on "Urban Stormwater Quality Enhancement - Source Control, Retrofitting and Combined Sewer Technology", Davos Platz, Switzerland (October 1989)

KEY: amended - CWA - implementation - NPDES - EPA - implement national strategies -

This paper outlines the strategies associated with the regulation of CSOs and storm water discharges.

J1 IMPROVEMENT OF THE COMBINED SEWER SYSTEM BY USING THE LARGE-SCALE TRUNK SEWER

by Toshinori Nakagawa
Osaka Sewage Works Bureau

KEY: trunk sewers - overflow pollution control - Hirano Sewage Area - tunnel tank sewers - underground pumping station - zig zag aprons

To relieve extensive flooding experienced in several drainage areas, large stormwater trunk sewers are being constructed.

J2 **TREATMENT OF WET WEATHER INFLUENT IN COMBINED SEWER SYSTEM USING SLOPING-PLATE SEDIMENTATION TANKS**

by Hitoshi Murakami, Takashi Abe, Junji Hatoko
Osaka Sewage Works Bureau

KEY: Camp's Theory - effluent - measurements - effective - design maintenance - suspended solids

A great deal of data were also obtained concerning the design and maintenance of the sloping-plate sedimentation tank.

J3 **PRESENT STATUS & COUNTERMEASURES FOR URBAN FLOOD IN OSAKA CITY**

by Planning Department
Osaka Sewage Works Bureau

KEY: actual drainage capacity - method of calculation - Naniwa Grand Floodway - relief trunk sewers - pumping stations - stormwater runoff control -

K1 **EXPERIENCES IN THE OPERATION OF A REAL TIME PROCESS CONTROL CSO FACILITY**

by D.M. Hudson and R.E. Crowl
WPCF Annual Conference, Washington, D.C. (October 1990)

KEY: Northeast Ohio - automated regulators - sensing elements - computer control centre - velocity probes - reliability - sensitivity

To assist in the operation of the sewer system computer programs have been developed.

K2 **MOP FOR THE DESIGN AND CONSTRUCTION OF URBAN STORMWATER MANAGEMENT SYSTEMS PUBLISHED BY THE WATER POLLUTION CONTROL FEDERATION**

WPCF Annual Conference, Washington, D.C. (October 1990)

KEY: legal - financial factors - surveys - hydrological/hydraulic aspects - retention facilities

A draft copy of the Manual of Practice (MOP) for the design and construction of urban stormwater management systems was obtained and reviewed.

K3 **REAL TIME CONTROL IN THE CITY OF CORNWALL**

by M. Parente and V. Polyakova
WPCF Annual Conference, Washington, D.C. (October 1990)

KEY: St. Lawrence River - suspended solids - control system - control centre - dedicated telephone lines - pre-set hydraulic gradeline

To account for flow increase due to sewage system expansion, it was required to increase the sewage plant capacity to 36 MIGD.

L1 **EVALUATION OF ALTERNATIVES**

by Eugene D. Driscoll, William James
Pollution Control Planning, compiled by William James from Pollution Control Planning Workshop, Toronto, (February 1987)

KEY: performance of controls - impacts on receiving waters - site information - CSO flows & loads - stormwater runoff - CSO quality characteristics

Condensed overview of results from several EPA programs and the Nationwide Urban Runoff Program (NURP).

L2 **PACKAGING OF A PCP - TORONTO AREA WATERSHED MANAGEMENT STUDY**

abstracted by Don Weatherbe from *Humber River Water Quality Management Plan, 1986* of the Toronto Area Watershed Management Study, Ontario Ministry of the Environment
Pollution Control Planning, compiled by William James from Pollution Control Planning Workshop, Toronto, (February 1987)

KEY: CSO frequency - computer simulation - control options costing - water quality management plan - pollutant loadings - cause and effect relationships

M1 **RECTANGULAR SHAFT CONFIGURATION FOR STORM SEWAGE OVERFLOW STRUCTURES**

by R. Burrow and K.H.M. Ali
Institution of Civil Engineers Proceedings (September 1988)

KEY: chamber retention volume - retention efficiencies - storage provision

The performance of this structure is verified by its improved particle retention efficiencies over a typical stilling pond chamber of similar dimensions being employed in sewerage practice.

M2 **ESTIMATING INPUT HYDROGRAPHS TO A COMBINED SEWER**

by D.A. Rhodes
Institution of Civil Engineers Proceedings (September 1987)

KEY: inverse rating - downstream - upstream - storm runoff - dry weather flow - impermeable area

This technical note describes a simple approximate method of calculating input hydrographs to a combined sewer, which can be a useful complement to a detailed upstream catchment model.

M3 **FLOW AND STORAGE CONTROL IN A COMBINED SEWER**

by D.A. Rhodes
Water Pollution Control , U.K. (1985)

KEY: spare capacity - WASSP - reduce - frequency - vulnerability - suspended solids

This paper discusses the use of the interceptor sewer to the Rushmoor Treatment Plant in Telford as an on-line tank so as to reduce the volume of storm sewage discharge to the River Tern.

M4 **STORMWATER COMBINED SEWAGE POLLUTION ABATEMENT**

by Richard P. Traver
Reviewed by the Technical Council of Research, ASCE (May 1982)

KEY: BMPs - attenuation - porous pavements - erosion control - lower costs - unquantified - difficult

This paper addresses the problem and characterization of stormwater and combined sewage impacts upon our nation's receiving waters while presenting various levels of pollution control technology.

M5 **STORAGE OF COMBINED SEWER OVERFLOW AND URBAN STORMWATER: AN OVERVIEW**

by Peter Stahre
American Society of Civil Engineers

KEY: flow equalization - storage basins - technical configuration - outflow

Flow equalization involves the combination of a storage basin within a sewer system in order that peak flows can be reduced.

M6 **THE PERFORMANCE OF AN OFF-SEWER STORM-SEWAGE TANK**

by R.J.A. Henderson
Water Pollution Control, U.K. (1981)

KEY: Bannockburn - conventional manner - first flush - analytical analysis -

The storm-sewage tank in Bannockburn was selected as the site for a research project to quantify some of the benefits ascribed to the use of storage tanks at storm-sewage overflows.

M7 **THE USEPA OFFICE OF RESEARCH AND DEVELOPMENT'S VIEW OF COMBINED SEWER OVERFLOW CONTROL**

by R. Field
Proceedings of the Third International Conference on Urban Storm Drainage, Sweden (June 1984)

KEY: source control - land management - collection system controls - storage - treatment

The paper address the program initiated by the EPA's Storm and Combined Sewer Program (SCSP).

M8 **OPTIMIZATION OF URBAN WATER POLLUTION CONTROL ALTERNATIVES**

by R. Wycoff, J. Scholl and S. Carpenter
Proceedings of The specialty Conference - Water Forum, San Francisco (August 1981)

KEY: COST program - economically optimum - wet-weather - dry-weather - overall pollution control

M9 **CONTROL PLAN FOR SEATTLE METRO'S CSOs**

by Dordon Culp, John Lampe and Paula Arsenault
Water/Engineering and Management, Volume 135, No. 9 (September 1988)

KEY: SACRO & SACE models - baseline conditions - secondary systems - sewage - stormwater - control measures

The general approach was to develop typical dry-weather sewage flows and stormwater characteristics by land use type.

M10 **FLOW BALANCING SYSTEM FOR STORMWATER AND COMBINED SEWER OVERFLOW**

by P.H. Stevers
Water and Pollution Control (November/December 1984)

KEY: Sweden - New York - cells - floating pontoons - polyethylene floats - concrete weights

In this approach, a flow balancing method was developed that utilized the recipient water body as a balancing medium for the CSO or stormwater.

M11 **EVALUATION OF THE PERFORMANCE OF A COMBINED SEWER OVERFLOW RETENTION TANK**

by W. Wong and G. Zukovs
Ontario Ministry of the Environment, Research Publication No. 90 (July 1982)

KEY: Borough of York - storage capacity - rainfalls - flows - water quality - storm events - inflow - inexpensive - reducing pollution

During the summer periods (June to October) in 1977 and 1978, field monitoring programs were undertaken.

M12 **USE OF SWIRL CONCENTRATOR FOR COMBINED SEWER OVERFLOW MANAGEMENT**

by Dary Heinking and Nathan Wilcoxon
Journal WPCF, Volume 57, No. 5 (May 1985)

KEY: Decatur, Illinois - secondary treatment - higher flow - tank volume - accommodate greater volume - wastewater

Swirl concentrator recommended because of its ability to allow much higher flow rates for a given surface area and tank volume than those of more conventional settling tanks.

M13 **INNOVATIVE SYSTEM SAVES MONEY**

Anonymous
National Engineer V.91 (May 1987)

KEY: Milwaukee - tunnels - vortex generator - dropshafts - trash racks - frictional contact - de-aeration chamber

In the system proposed, dropshafts are used to divert sewage from the collection system to the tunnels.

M14 **TUNNEL AND RESERVOIR PLAN SOLUTION TO CHICAGO'S COMBINED SEWER OVERFLOW BASEMENT FLOODING AND POLLUTION**

by W.A. Bergman and D. H. Kapadia
Can. Journal of Civil Engineering, Volume 15, No. 3 (June 1988)

KEY: TARP - tunnels - storage reservoirs - limestone quarries - water pollution control - urban flood control - computer modelling - reduction - basement flooding

This system employs a system of tunnels through solid rock below the community to capture combined sewer overflows.

M15 **THE CSO PARTNERSHIP: CITIES JOIN FORCES ON COMBINED SEWERS**

by M. Oakley and C.F. Foster
Water Environment & Technology (November 1989)

KEY: United States - SRF - water quality - municipal authorities - education - meaningful legislation - CSO issue - sleeping giant

M16 **DEVELOPMENT & EVALUATION OF A RUBBER "DUCK BILL" TIDE GATE**

by Peter A. Freeman, Angelika B. Forndran & Richard Field
Environmental Protection Agency

KEY: New York City - RTG - inflow - tidal waters - improved performance - capability self-cleaning - reliability - installation - hydraulic performance

Results of the project indicate that the RTG can provide low maintenance and reliable performance as a cost effective alternative to conventional tide gates.

M17 **THE MAGNITUDE OF IMPROPER WASTE DISCHARGES IN AN URBAN STORMWATER SYSTEM**

by Stacy D. Schmidt and Douglas R. Spencer
WPCF Journal (July 1986)

KEY: Ann Arbor, Michigan - NPDES - stormwater runoff - treatment contaminated stormwater - source control - illegal waste

This study demonstrated that direct connection of individual, commercial and industrial pollutant discharges to the storm drain system is a major contributor of urban nonpoint pollution.

M18 **DISTRICT OF COLUMBIA - CSO ABATEMENT PROGRAM - COST-EFFECTIVE PROGRAM TO IMPROVE WATER QUALITY IN THE ANACOSTIA, POTOMAC AND ROCK CREEK**

Anonymous
District of Columbia & O'Brien & Gere

KEY: minimal modification - maximize capacity - telemetry system - unmanned facility - swirl concentrators - neutralization system - BMPs - inflatable weirs

A major facility planning effort was conducted with funding support from the U.S. EPA under the Construction grants program.

M19 **<u>DEMONSTRATION OF THE FLOW BALANCING METHOD FOR COMBINED SEWER OVERFLOW ABATEMENT IN ESTUARINE WATERS</u>**

by Angelika Forndran, Richard Field, Karl Dunkers
WPCF Conference (1989)

KEY: Fresh Creek, New York City - tidal estuary - volume discharged - flow behaviour - floatables discharged - freezing - storm conditions -

This paper presents monitoring procedures used to evaluate the system performance.

M20 **<u>IMPLEMENTATION OF A CSO ABATEMENT PROGRAM FOR BURLINGTON, VERMONT</u>**

by Robert C. Ganley, Dwight A. MacArthur & Eugene J. Formes
WPCF Conference (1989)

KEY: Lake Champlain - quality - screening - swirl vortex separator

Sampling and analysis of CSO characteristics, abatement alternatives, and storage vs. treatment combinations are all presented.

M21 **<u>EVALUATION OF FACILITY IMPROVEMENT ALTERNATIVES IN AN URBAN WASTEWATER CONVEYANCE SYSTEM</u>**

by Robert Swarner, Edward Speer, Zdenko Vitasovic
Metro Seattle

KEY: computer program - rainfall/runoff model - control algorithm - optimum regulator - hydraulic simulation

The information resulting from these analyses was useful in equipping the engineers and planners in Metro to make better decisions regarding modifications to the sewer system.

M22 **<u>COMPUTER-ASSISTED OPERATIONAL CONTROL STRATEGIES ALLOW EXPANSION OF INTERCEPTOR/TREATMENT NETWORK WITHOUT ADDITIONAL OPERATORS</u>**

by Jane M. Rozga, Michael J. Wallis and Randall Raines
East Bay Municipal Utility District (EBMUD)

KEY: analysis - control strategies - computer simulations - computerized control system activation/deactivation

Computer simulations of the performance of expanded facilities allowed the development of an operating strategy to balance all performance objectives.

M23 **<u>URBAN DRAINAGE DESIGN GUIDELINES APRIL 1987</u>**

by 4 Ontario Ministries (MOEE, MNR, MTO, MMA), Association of Conservation Authorities, MEA, and Urban Development Institute, Ontario

KEY: park detention - ponds - quality control - roof ponding, seepage trenches

The guidelines also cover Foundation Drain Collector Systems (FDC) but use of this approach has been limited to date.

M24 **<u>COMBINED SEWER OVERFLOWS IN ONTARIO, CANADA - AN OVERVIEW</u>**

by W.W.S. Gray, B. Chakraburtty and Adrian W. Coombs
Water Pollution Control Federation (October 1989)

KEY: quantity - quality - methods - detention - treatment

M25 **<u>EXISTING SEWER EVALUATION & REHABILITATION</u>**

by the American Society of Civil Engineers Water Pollution Control Federation

KEY: flow monitoring - sewer rehabilitation - I/I

N1 **URBAN RUNOFF AND COMBINED SEWER OVERFLOWS - SCOPE OF THE PROBLEM**

by Don Weatherbe
Technical University of Nova Scotia (TUNS) Combined Sewer Overflow, (May 1991)

KEY: pollutant characteristics - environmental & public health effects - regulatory aspects - control objectives & options

CSO's drawn from a number of studies in North America. Emphasis on Remedial Action Plans and Pollution Control Plans.

N2 **STATE OF THE ART IN COMBINED SEWER OVERFLOW TECHNOLOGY**

by William C. Pisano
Technical University of Nova Scotia (TUNS) Combined Sewer Overflow, (May 1991)

KEY: control measures - sewer flushing - urban SWM - vortex valves & separators - tankage concepts & equipment

N3 **COMBINED SEWER TANK - TORONTO - DESIGN**

by Mario Parente
Technical University of Nova Scotia (TUNS) Combined Sewer Overflow, (May 1991)

KEY: public beaches - DORSCH (QQS) model - lake currents - alternative modelling

Discussion of operation, maintenance and monitoring of tank storage facility.

N4 **CASE STUDY - COMBINED SEWER OVERFLOW FACILITIES - BOSTON**

by Clifford W. Bowers
Technical University of Nova Scotia (TUNS) Combined Sewer Overflow, (May 1991)

KEY: recreational use waters - dry weather overflow control - SWMM/QUALIIe modelling - storage

BMP analysis of CSO volume and event reduction, estimated capital cost and estimated annual operation and maintenance cost for meeting water quality standards.

N5 **REMEDIAL MEASURES FOR SEWER BACK-UP & CSO CONTROL**

by Paul Theil
Technical University of Nova Scotia (TUNS) Combined Sewer Overflow, (May 1991)

KEY: case studies, Toronto/Sarnia - inlet control - detention facilities (tanks/in-line storage) - retention ponds - basement flooding

Sewer separation versus inlet control less effective, more expensive and may not completely reduce CSO's when downspouts connected.

N6 **CITY OF KINGSTON POLLUTION CONTROL PLAN**

by G. Zukovs, P. Cheung
Technical University of Nova Scotia (TUNS) Combined Sewer Overflow, (May 1991)

KEY: water quality - pollution control - servicing - surface runoff - CSO's - level of control for a waterbody - O&M costs

Methodology of identifying and quantifying sources of pollution and determining their transport characteristics through the receiving waters.

N7 A PRIORITIZATION PLAN FOR NEW BEDFORD CSOs

by Gary W. Mercer
Technical University of Nova Scotia (TUNS) Combined Sewer Overflow, (May 1991)

KEY: water quality & quantity sampling - 35 CSO's - control alternatives - modelling (SWMM)

Control alternatives examined were sewer separation, storage and pumpback, satellite treatment, screening and disinfection, and increased conveyance to the treatment plant; of which the first two were selected.

O1 MICROCOMPUTER-BASED REAL TIME CONTROL (RTC) OF CSOs IN AN INDUSTRIALIZED CITY

by Mark Stirrup, Mark Robinson
New Techniques for Modelling the Management of Stormwater Quality Impacts, compiled by William James from Emerging Technologies and Stormwater and Water Quality Management Modelling Conference, Toronto (February 1992)

KEY: combined sewers - real-time control - stormwater runoff - demonstration system project -Hamilton, Ontario

This paper reviews the following components of Hamilton's RTC demonstration project: development and operation of a real-time rainfall and flow monitoring network and telemetry system; continuous modelling of the catchment using the PCSWMM3 RUNOFF and TRANSPORT modules; design and installation of a microcomputer-based controller and software for real-time control of CSO regulator.

O2 GIS BASED HYDRAULIC MODEL PICTURES THE INTERCEPTOR FUTURE

by Uzair M. Shamsi, Albert A. Schneider
New Techniques for Modelling the Management of Stormwater Quality Impacts, compiled by William James from Emerging Technologies and Stormwater and Water Quality Management Modelling Conference, Toronto (February 1992)

KEY: Geographic Information System - hydraulic capacity - ultimate development - SWMM - Allegheny County Sanitary Authority - combined sewers

This interceptor serves over 90% of the Chartiers Creek watershed, itself enveloping all or portions of 23 municipalities, 12 boroughs and 10 townships. Of the 56 tributary areas, 22 have combined sewers.

P1 A QUALITY ASSESSMENT OF DYNAMIC SEPARATION - THE UK EXPERIENCE

by G.W. Fagan
WEF Speciality Conference Series - Control of Wet Weather Water Quality Problems, Indianapolis (May/June 1992)

KEY: dynamic separation - Storm King™ Overflow - model tests - pollutant reduction

P2 MEASUREMENT OF COMBINED SEWER OVERFLOW DISCHARGES AND RIVER WATER QUALITY RESPONSES DURING A STORM

by Karl R. Kopec, Scott T. Girman, Victor J. Bierman, Jr.
WEF Speciality Conference Series - Control of Wet Weather Water Quality Problems, Indianapolis (May/June 1992)

KEY: South Bend, Indiana - sampling - flow monitoring - recreational/salmonoid waterway - rainfall criteria - SWMM model

P3 MARINE CSO IMPROVEMENTS; BRIDGEPORT, CONNECTICUT

by Andrew S. Abate, David J. Anderson
WEF Speciality Conference Series - Control of Wet Weather Water Quality Problems, Indianapolis (May/June 1992)

KEY: overflow regulators - separate sewers - treatment plant capacity - in-system storage - tidal inflow

Old, urban area with about 3880 acres of combined sewers; 38 of 94 outfalls with elevations below normal high tide.

P4 **RAINFALL-INDUCED SEPARATE SEWER OVERFLOWS VERSUS COMBINED SEWER OVERFLOWS**

by Donald F. Geisser, Michael D. O'Neill, Francis J. DeOrio
WEF Speciality Conference Series - Control of Wet Weather Water Quality Problems,
Indianapolis (May/June 1992)

KEY: rainfall-induced overflows - separate sewers - combined sewers - activation mechanism -monitoring/sampling program - water quality impacts - modelling (SWMM)

P5 **BOSTON HARBOUR PROJECT - CSO PEAK SHAVING FEASIBILITY STUDY**

by John A. Lager, Cheryl A. Breen
WEF Speciality Conference Series - Control of Wet Weather Water Quality Problems,
Indianapolis (May/June 1992)

KEY: WWTP design - CSO facilities plan - integrated approach - design flows/loads - "split-flow" treatment - costing

Impact of new flow data was enhanced by fast-track construction activities which have increased pumping capacities, increased wet weather intercept, and decreased extraneous inflows.

P6 **DEVELOPMENT OF A MULTIPLE-PHASE TUNNEL AND CAVERN PLAN FOR COMBINED SEWER OVERFLOW CONTROL**

by Edward H. Burgess, Larry A. Roesner
WEF Speciality Conference Series - Control of Wet Weather Water Quality Problems,
Indianapolis (May/June 1992)

KEY: Cincinnati - frequent CSOs - control alternatives - tunnels - innovative design - cost recovery - phased implementation

Tunnel to provide 127 MG storage and diversion of captured overflows. A deep cavern facility will provide an incremental 271 MG storage.

P7 **SYSTEMWIDE INFILTRATION/INFLOW EVALUATION TWIN CITIES METROPOLITAN AREA**

by David J. Bennett and Wayne B. Rikala
WEF Speciality Conference Series - Control of Wet Weather Water Quality Problems,

KEY: interceptors - treatment - flow monitoring - sewers - inflow/infiltration control

Q1 **A MUNICIPAL PERSPECTIVE ON STORMWATER MANAGEMENT AND COMBINED SEWER CONTROL**

by M.A. Price, P. Cookson, J. Minor
Stormwater Management and Combined Sewer Control Technology Transfer Conference,
Ontario (January 1993)

KEY: project approval - government agencies - develop implementation guidelines - support agencies

Q2 **CHARACTERIZATION OF STORMWATER & CSOs IN THE METRO TORONTO RAP**

by Michael D'Andrea
Stormwater Management and Combined Sewer Control Technology Transfer Conference,
Ontario (January 1993)

KEY: pollutant characterization, nonpoint source pollution, stormwater, combined sewer overflows

Summaries of mean contaminant concentrations are compared to dry weather discharges from sewer outfall, WPCPs and provincial water quality criteria

Q3 **COMBINED SEWER OVERFLOW GUIDELINES AND COSTS IN ONTARIO**

by Jonathan P'ng
Stormwater Management and Combined Sewer Control Technology Transfer Conference, Ontario (January 1993)

KEY: Combined sewer overflows - policy - guidelines - Ontario - costs - control criteria - EXSUDS

Summary of recent work done in the development of a provincial guideline.

Q4 **ADVANCED HIGH RATE TREATMENT FOR CSO CONTROL IN METROPOLITAN TORONTO**

by George Zukovs, W.C. Pisano, R.M. Pickett, P. Chessie
Stormwater Management and Combined Sewer Control Technology Transfer Conference, Ontario (January 1993)

KEY: combined sewer overflow - high rate treatment - vortex separator - sedimentation - disinfection

Application of the technology to five major overflow sites in the Don Sewershed.

Q5 **REAL TIME CONTROL TO PREVENT CSOs IN SEATTLE AND HAMILTON-WENTWORTH**

by Zdenko Vitasovic, Mark Stirrup
Stormwater Management and Combined Sewer Control Technology Transfer Conference, Ontario (January 1993)

KEY: combined sewer overflow - hydrologic and hydraulic simulation models, real time control

Discussion of requirements for developing and implementing a RTC System.

Q6 **REVIEW OF STORAGE METHODS TO PREVENT COMBINED SEWER OVERFLOWS**

by William C. Pisano, George Zukovs, Gabriel Novack, Nick Grande
Stormwater Management and Combined Sewer Control Technology Transfer Conference, Ontario (January 1993)

KEY: storage - near surface - tunnel - sediments - maintenance

Storage methods surveyed include: tanks, retention and detention, storage basins, combinations of high rate treatment with storage, tunnels and pontooned water based storage.

Q7 **SEWAGE TREATMENT IN WET WEATHER TO PREVENT CSOs AND BYPASSES**

by D. Thompson, Z. Georgousis, J. Bell, L. Sterne, D. Chapman
Stormwater Management and Combined Sewer Control Technology Transfer Conference, Ontario (January 1993)

KEY: step feed - storm flow control - stormwater management - bypass - combined sewer overflow

Results of implementation of step feed control at the Hamilton, Woodward Avenue WPCP (North Plant).

R1 **HYDRAULIC AND POLLUTANT MODELLING OF CSOs USING SWMM's EXTRAN BLOCK**

by Robert J. O'Connor, Guy Apicella, Frederick Schuepfer, James Zaccagnino, Les Kloman
Curent Practices in Modelling the Management of Stormwater Impacts, compiled by William James from Stormwater and Water Quality Management Modelling Conference, Toronto (February 1993)

KEY: pollutant post-processing program - EXTRAN - SWMM RUNOFF block - New York City - CSO abatement study - in-line storage weir

Using the Storage Pumping Model (SPM), storage of CSO was modelled. The SPM provided the flow and pollutant data necessary for assessment of CSO abatement alternatives.

R2 **COMPARISON OF TWO METHODS OF END-OF-PIPE CONTROL FOR CSO AND STORMWATER**

by Mario Conetta, Werner Wichmann, Mario Parente
Curent Practices in Modelling the Management of Stormwater Impacts, compiled by William James from Stormwater and Water Quality Management Modelling Conference, Toronto (February 1993)

KEY: control/treatment of stormwater runoff - CSOs - intercept - tunnel storage - subsurface storage tanks - environmental impacts - capital cost - O&M requirements - flexibility

R3 **COMPUTERIZED ANALYSIS OF RAINFALL RECORDS TO DETERMINE DESIGN STORM FOR CSO ABATEMENT**

by C. Wayne Dillard, George E. Kurz, John S. Crane
Curent Practices in Modelling the Management of Stormwater Impacts, compiled by William James from Stormwater and Water Quality Management Modelling Conference, Toronto (February 1993)

KEY: design storm - CSO abatement - rainfall analysis - limit overflows by a number

When control requirements are stated in terms of allowable overflows or discharges, rather than in terms of containment or conveyance of a specific storm event, selection of the design storm is not so easily determined. The methodology allows creation of intensity-duration-frequency curves for recurrence intervals of less than one year.

S1 **COST-EFFECTIVE SEPARATION OF COMBINED SEWERS TO MAXIMIZE THE UTILIZATION OF EXISTING INFRASTRUCTURE**

by Michael P. Hartford
Water Environment Federation (WEF) 66th Annual Conference and Exposition
Anaheim, California (October 1993)

KEY: Beverly, Mass. - dual use of interceptor - solids deposition - structural integrity - reduction of CSO pollutant loads

An innovative design concept to construct a carrier pipe, for sanitary wastewater flow, along the invert of a combined flow interceptor thereby providing separate flow conveyance in a single pipe.

S2 **LEWIS STREET CSO DIVERSION STRUCTURES AND TUNNEL - NASHVILLE'S FIRST PROJECT TO INTERCEPT AND STORE CSO FLOWS**

by Earl R. Mayo
Water Environment Federation (WEF) 66th Annual Conference and Exposition
Anaheim, California (October 1993)

KEY: intercept/store combined sewage flows - tunnel - detention basin - diversion structures

S3 **MODIFIED CSO CONTROL PLAN SAVES PEORIA $30 MILLION**

by Richard B. Helm, Gene Hewitt, Daniel R. Good
Water Environment Federation (WEF) 66th Annual Conference and Exposition
Anaheim, California (October 1993)

KEY: CSO - discharges - swirl concentrators - controls - sewers - system performance

S4 **CSO FACILITY DESIGN UNDER THE NEW USEPA CONTROL POLICY**

by Robert Gaffoglio, Les Kloman, Robert D. Smith, Peter J. Young, John St. John
Water Environment Federation (WEF) 66th Annual Conference and Exposition
Anaheim, California (October 1993)

KEY: US Environmental Protection Agency - draft CSO control policy - Clean Water Act - rational approach - minimum and long term control planning

S5 **BOSTON WATER AND SEWER COMMISSION COMBINED SEWER OVERFLOW MONITORING PROJECT**

by Lisa D. Eggleston, Brian P. Sullivan, Paul W. Keohan, Anthony M. Omobono
Water Environment Federation (WEF) 66th Annual Conference and Exposition
Anaheim, California (October 1993)

KEY: CSO - monitoring - modelling - reporting - compliance

Findings from the field monitoring component provided insight into drainage area characteristics, system hydraulics, tidal influence, storage and capacity.

S6 **IMPLEMENTING PREDICTIVE CONTROL TO REDUCE CSOs IN SEATTLE**

by Robert Swarner, Edward Speer, Marc Gelormino, N. Lawrence Ricker
Water Environment Federation (WEF) 66th Annual Conference and Exposition
Anaheim, California (October 1993)

KEY: collection system - real-time control - optimization - CSO - model predictive control - discrete control - in-line storage

Off-line and on-line testing and control has been valuable in modifying and tuning the control program to improve results. Function weightings, parameters, correlations and problem solving were evaluated and effected during testing.

S7 **SWIMMING IN MIDWESTERN TOWN: CSO INVESTIGATIONS IN SMALLER COMMUNITIES USING SWMM**

by Dante T. Zettler, Jeffrey D. Sharon, Robert W. Frutchey
Water Environment Federation (WEF) 66th Annual Conference and Exposition
Anaheim, California (October 1993)

KEY: CSO - combined sewer system - modelling - SWMM - EXTRAN - small systems - case studies

S8 **MEASURING UP: KEY ELEMENTS OF SUCCESSFUL FLOW MONITORING**

by James C. Graham
Water Environment Federation (WEF) 66th Annual Conference and Exposition
Anaheim, California (October 1993)

KEY: flow monitoring - sanitary sewer systems - DATA - device - application - theory - analysis

T1 **DEVELOPING A STRATEGY FOR ASSESSING COMBINED SEWER OVERFLOWS**

by C. Jefferies, E. Langlands, and P. Dugard
6 ICUSD page 42

KEY: United Kingdom - impacts - controls

A strategy for assessing CSOs is presented for application in the United Kingdom. The strategy includes sewer and river impact monitoring, and rules for CSO improvements and sewer rehabilitation.

T2 **STOCHASTIC ANALYSIS OF DISSOLVED OXYGEN DEPLETION IN RIVERS RECEIVING COMBINED SEWER OVERFLOWS**

by K. Schaarup-Jensen, T. Hvitved-Jacobsen and A. Dahl
6 ICUSD page 48

KEY: impacts - dissolved oxygen - model - Denmark

The Monte-Carlo method is used in a dissolved oxygen model DOSMO, as an add-on to the MOUSE modelling system. A case study is presented showing impacts in a statistical format of CSOs from a catchment in Denmark.

T3 **A CONJUNCTIVE ANALYSIS OF CSOs AND RECEIVING WATER CURRENT MAGNITUDE AND DIRECTION**

by K. Bedford, O. Wai, D. Podber, J. Yen, and L. Regenmorter
6 ICUSD page 54

KEY: impact - model - Lake Erie

An analysis of CSO impacts from Cleveland, Ohio, in Lake Erie is presented, relating rainfall event size and wind speed.

T4 **RECEIVING WATER QUALITY MODELLING IN CLEVELAND, OHIO FOR CSO CONTROL PLANNING**

by L. Regenmorter, J. Yen, and B. Yingling
6 ICUSD page 60

KEY: impact - model - SWMM - Lake Erie

A model configuration linking storm sewer models, combined sewer models and receiving water models is presented. The EPA SWMM model blocks, RUNOFF, TRANSPORT and EXTRAN were used for the sewer systems and receiving streams, while a large lake model LEIFS was used to represent Lake Erie.

T5 **STUDY OF BACTERIA IN THE DETROIT RIVER ASSOCIATED WITH COMBINED SEWER OVERFLOWS**

by J.A. McCorquodale, S.P. Zhou, Z. Ji, J. Marsalek, and G. Johnson
6 ICUSD page 66

KEY: impacts - bacteria - monitoring - model - KETOX - Detroit River

Results of a monitoring program and model prediction using the hydrodynamic model, KETOX, are presented.

T6 **MODELLING OF IMPROVEMENTS OF BATHING WATER QUALITY BY REDUCTION OF CSO's**

by J.J. Linde-Jensen, M. Jensen, and A. Dahl
6 ICUSD page 72

KEY: impacts - bacteria - model - MOUSE-SAMBA - Denmark

A bacterial receiving water model, an add-on to the MOUSE-SAMBA, system is presented. The model produces time series and statistics of E. Coliform bacteria in bathing beaches to determine and compare different control options.

T7 **IMPACT OF WET WEATHER DISCHARGES IN THE RIVER SEINE: MAJOR WATER QUALITY PARAMETERS**

by J.M. Mouchel, and L. Simon
6 ICUSD page 200

KEY: impacts - dissolved oxygen - monitoring - BOD - Seine River

A major monitoring effort to determine impacts of CSOs from the City of Paris is presented. Results for dissolved oxygen, BOD, ammonia, and organic nitrogen are presented.

T8 **THE EFFECT OF AN URBAN DRAINAGE SYSTEM ON RECEIVING WATER QUALITY**

by R. Lammersen
6 ICUSD page 206

KEY: impacts - monitoring BOD - dissolved oxygen - Innerste River

Results from monitoring of CSO's, treatment plant effluents, and runoff from separate systems are presented for the River Innerste in Germany.

T9 URBAN RUNOFF IMPACT OF HEAVY METALS ON RIVER SEINE SUSPENDED SOLIDS

by A. Estebe, J. Flores-Rodriguez, L. Lebreton, J.M. Mouchel, and D.R. Thevenot
6 ICUSD page 218

KEY: impacts - monitoring - suspended solids - metals - Seine River

Data is presented on the monitoring methods for suspended solids which were analyzed for metals cadmium, copper, lead and zinc. Metal concentrations were much higher in the area affected by CSOs.

T10 HYSTEM-EXTRAN - IMPROVEMENTS TO EPA - EXTRAN

by L. Fuchs and C. Scheffer
6 ICUSD page 237

KEY: model - real-time-control - SWMM-EXTRAN

Modifications to the SWMM-EXTRAN model are presented that make it useful for real-time-control applications.

T11 HYDRAULIC MODELLING OF COMBINED SEWER INTERCEPTORS

by E.H. Burgess, L.A. Roesner, and C.J. Cantrell
6 ICUSD page 255

KEY: model - SWMM-EXTRAN

The general approach for applying the hydrodynamic model EXTRAN to an interceptor sewer system during wet weather is discussed.

T12 XP-EXTRAN THE NEXT GENERATION UNSTEADY FLOW ROUTING SYSTEM

by A. Goyen, R. Dickinson, and G. Thompson
6 ICUSD page 269

KEY: model - EP-EXTRAN

Modifications to EPA's SWMM-EXTRAN are presented that make the model user friendly.

T13 HYDRODYNAMIC WATER QUALITY SIMULATION WITH DYNAMO

by D. Wittenberg
6 ICUSD page 336

KEY: dissolved oxygen - model - QUAL2

An application of the modified QUAL2 model called DYNAMO is presented for a river in Germany receiving CSOs.

T14 TRANSFER OF COMBINED SEWER OVERFLOWS IN THE SEINE RIVER

by L. Simon and J.M. Mouchel
6 ICUSD page 342

KEY: hydrodynamic model - receiving water - dye studies

Field work, including dye injection studies are presented as a means of developing hydraulic characteristics of the river. The model is used to predict CSO impacts in the River Seine below Paris.

T15 THE USE OF METAL BIOINDICATORS TO ASSESS THE IMPACT OF COMBINED SEWER OVERFLOWS ON THE RIVER SEINE

by S. Fraboulet, R. Mulliss, J. Flores-Rodriguez, J.M. Mouchel, M. Revitt, E. Garnier-Zarli and D. Thevenot
6 ICUSD page 500

KEY: biomonitoring - metals

The results of a biomonitoring program to assess impacts of CSO discharges are presented for metals lead, copper, zinc, and cadmium.

T16 **<u>RECEIVING WATER PROTECTION AT WET WEATHER</u>**

by V. Krejci, W. Schilling and S. Gammeter
6 ICUSD page 506

<u>KEY</u>: ecological effects - dissolved oxygen - ammonia

A case is made for inclusion of a receiving water protection strategy as part of a pollution control program based on considerations of the ecological problems in the receiving stream.

T17 **<u>IMPORTANCE OF RECEIVING WATER MORPHOLOGY AND HYDROLOGY WITH RESPECT TO COMBINED SEWER OVERFLOWS</u>**

by M. Grottker and S. Gammeter
6 ICUSD page 512

<u>KEY</u>: impacts - benthic community - morphology

The authors present a method for analyzing morphology and hydrologic impact on benthic communities. These factors had more importance in determining the health of communities in the example presented, than did the impact of CSOs.

T18 **<u>CHARACTERIZATION OF URBAN NONPOINT SOURCE DISCHARGES IN METROPOLITAN TORONTO</u>**

by M. D'Andrea and D.E. Maunder
6 ICUSD page 524

<u>KEY</u>: monitoring - characterization impacts - Toronto - metals - PAHs - organochlorine

Results from an extensive monitoring program of stormwater and CSO outfalls in the Toronto waterfront are presented for conventional parameters, metals, organochlorines and PAHs.

T19 **<u>COHESIVE SEDIMENT EROSION IN COMBINED SEWERS</u>**

by R.M. Ashley, D.J.J. Wotherspoon, B.P. Coghlan and E. Ristenpart
6 ICUSD page 644

<u>KEY</u>: sediment depository scour - suspended solids

The authors present field results and data to support a proposed model of sediment movement in combined sewers.

T20 **<u>DEVELOPMENT OF MEASUREMENT AND MONITORING STATION FOR STORMWATER IN COMBINED SEWER SYSTEM</u>**

by T. Sakakibara, K. Sasbe, S. Tanaka, and T. Masaki
6 ICUSD page 676

<u>KEY</u>: monitoring - statistical correlation - characterization - Japan

Results from monitoring of CSO are presented for conventional parameters metals, coliforms and hexane. Relationships are presented between several of the parameters.

T21 **<u>UNCERTAINTY OF QUANTITY AND QUALITY DATA MEASURED IN A COMBINED SEWER</u>**

by M. Uhl
6 ICUSD page 682

<u>KEY</u>: monitoring - uncertainty - Germany

Different statistics are presented of the variability of quantity and quality data from a CSO monitoring program in Germany as measures of uncertainty.

T22 **IMPACT OF RAINFALLS ON SELF-CLEANING PHENOMENA IN COMBINED SEWERS**

by P. Blaszczyk
6 ICUSD page 857

KEY: sediments - scouring - characterization

Sediment scour or self-cleaning in egg shaped sewers was studied and related to sewer slope, average velocity and depth of sewage. Increased flow during rain events did not effect the self cleaning phenomenon.

T23 **BUILD-UP AND EROSION OF SEDIMENT DEPOSITS IN COMBINED SEWER NETWORKS**

by A. Bachoc, D. Laplace and D. Dartus
6 ICUSD page 863

KEY: sediments - characterization

Basic sediment characteristics and sewer geometry are related to the buildup and wash out of sediments in combined sewers.

T24 **FLUID SEDIMENT MOVEMENT AND FIRST FLUSH IN COMBINED SEWERS**

by R.M. Ashley, S. Arthur, B.P. Coghlan and I. McGregor
6 ICUSD page 875

KEY: sediments - first flush - characterization

Sediment transport phenomena in combined sewers is investigated.

T25 **MODELLING OF STORMWATER QUALITY IN COMBINED SEWERS**

by J.W. Davies
6 ICUSD page 1254

KEY: model - characterization - quality - sediments

The author describes a model used for routing of pollutants, including gross solids, in combined sewer systems.

T26 **DETAILED COMBINED SEWER OVERFLOW SIMULATION REGARDING NEW GERMAN GUIDELINES A 128**

by T.G. Schmitt
6 ICUSD page 1260

KEY: model - guidelines - Germany

A new German CSO control guideline is described. Three applications are presented describing the model procedures.

T27 **MODELLING THE VARIABILITY OF DOMESTIC DRY WEATHER FLOW IN COMBINED SEWER NETWORKS**

by D. Butler and N.J.D. Graham
6 ICUSD page 1266

KEY: model - dry weather flow

The model FLUSH is presented with capability to predict variability in sewage flows in dry weather.

T28 **STOCHASTIC SIMULATION OF DRY WEATHER PROCESSES IN URBAN DRAINAGE SYSTEMS**

by K. Scholz
6 ICUSD page 1272

KEY: model - sediments - stochastic - dry weather flow

Stochastic techniques are used to model the dry weather sewage components during wet weather.

T29 INFLUENCE OF COMBINED SEWER NETWORK PROPERTIES ON CHARACTERISTICS OF OVERFLOW LOAD

by J. Beichert
6 ICUSD page 1278

KEY: sediment - sewer network - dry weather flow

Sewer network characteristics are used to estimate sediment loadings in CSOs.

T30 SETTLEABLE SOLIDS OUT OF A COMBINED SEWER SYSTEM - SETTLING BEHAVIOUR, POLLUTION LOAD, STORMWATER TREATMENT

by S. Michelbach and C. Wohrle
6 ICUSD page 1284

KEY: sediment - sedimentation - treatment

Relationships between solid fractions determined by settling velocity and the content of various pollutants are presented.

T31 DEVELOPMENT AND APPLICATION OF A GENERAL SIMULATOR FOR RULE BASED CONTROL OF COMBINED SEWER SYSTEM

by C. Jakobsen, O.B. Hansen and P. Harremoes
6 ICUSD page 1357

KEY: real time control - model - MOUSE-SAMBA

The model SAMBA-CONTROL is described for use in analyzing and optimizing control strategies for sewer systems, treatment plants and receiving waters.

T32 A EUROPEAN CONCEPT FOR REAL TIME CONTROL OF SEWER SYSTEMS

by S. Lindberg, J.B. Nielson and M.J. Green
6 ICUSD page 1363

KEY: real time control - MOUSE - model

The MOUSE modelling package is described along with four pilot projects where the model is being applied.

T33 NEW TOOLS FOR IMPLEMENTING REAL TIME CONTROL IN SEWER SYSTEMS

by W. Gonwa, A.G. Capodaglio and V. Novotny
6 ICUSD page 1375

KEY: real time control - model

A general overview paper describing requirements for successful applications, including robustness, inplementability, applicability, adaptability, and objective function and constraints. The paper also presents an evaluation of RTC mathematical techniques that form the basis of different approaches.

T34 FEASIBILITY OF OPTIMIZATION METHODS FOR REAL TIME CONTROL OF URBAN DRAINAGE SYSTEMS

by R. Rohlfing
6 ICUSD page 1381

KEY: real time control - model - EXTRAN

A procedure for optimizing operation of a combined sewer system, including consideration of measurement uncertainties is presented.

T35 **ON THE USE OF OPTIMIZATION TECHNIQUES FOR URBAN DRAINAGE OPERATION**

by F. Nelen
6 ICUSD page 1387

KEY: real time control - model - LOCUS

A real time control model, LOCUS, is described, along with an idealized case study.

T36 **COMPARISON OF OPTIMISATION ALGORITHMS TO DETERMINE CONTROL STRATEGIES IN UDS**

by A. Khelil, B. Knemeyer and J. Dehnhardt
6 ICUSD page 1395

KEY: real time control - optimization

Different optimization algorithms are presented and their effectiveness compared.

T37 **LEARNING ALGORITHMS IN A RULE BASED SYSTEM FOR CONTROL OF UDS**

by A. Khelil, A. Heinemann and D. Muller
6 ICUSD page 1401

KEY: real time control - rules

A rule based system coupled with the ability to improve performance by learning from past experience.

T38 **OPTIMIZATION OF STORAGE/TREATMENT SCHEME FOR COMBINED SEWER OVERFLOWS**

by A. Ashamalla, T. Bowering and M. Parente
6 ICUSD page 1409

KEY: storage - treatment - optimization - QQS - Toronto

The procedure used to derive the least cost alternative for meeting CSO control criteria in Ontario is presented. The Dorsch QQS model was used in hydraulic and water quality simulations.

T39 **OPTIMAL CAPACITY EXPANSION OF SEWAGE COLLECTION AND TREATMENT SYSTEM CONSIDERING COMBINED SEWER OVERFLOWS**

by A.E. Armijos, L. Smith and D.I. Smith
6 ICUSD page 1415

KEY: optimization - storage - treatment - model - Niagara Falls

A method for deriving optimal storage and treatment capacities for a CSO system is described.

T40 **IMPROVEMENT OF COMBINED SEWER SYSTEM BY NEWLY INSTALLED STORAGE PIPES**

by M. Yasumoto, T. Hatano and G. Matsuda
6 ICUSD page 1421

KEY: storage pipes

Different arrangements of large pipes installed to correct CSO problems are compared.

T41 **CHARACTERISTIC STORAGE TANK - THE EXPERIENCE IN NAGOYA**

by T. Ochi
6 ICUSD page 1427

KEY: storage tank

Various examples of storage tanks are described- used for control of combined sewer overflows and capture of first flush stormwater.

T42 **COST ANALYSIS OF DIFFERENT METHODS OF CLEANING CSO AND WASTE WATER EQUALIZATION TANKS**

by N. Grande and G. Novack
6 ICUSD page 1438

KEY: storage tanks - costs - maintenance

Different methods of cleaning sediment from combined sewage storage tanks are presented. The automatic tipping bucket flushing system is the most favored.

T43 **COMBINED SEWER OVERFLOW ABATEMENT WITH STORAGE FACILITIES**

by P.D. Hughes, V.F. Coletti and D.M. Heiser
6 ICUSD page 1446

KEY: storage - Chattanooga

The design of storage facilities to achieve 85% control of CSO volume is described.

T44 **DEVELOPMENT OF A CATCHMENT SIMULATOR AS AN ON-LINE TOOL FOR OPERATING A WASTEWATER TREATMENT PLANT**

by L.G. Gustafsson, D.J. Lumley, B. Persson and C. Lindeborg
6 ICUSD page 1508

KEY: model - real -time-control - MOUSE - Sweden

Various blocks of the MOUSE model package are described in an application of real-time-control for a city in Sweden.

T45 **FITASIM - A SIMULATOR FOR THE REAL-TIME-CONTROL OF URBAN DRAINAGE SYSTEMS**

by T. Einfalt
6 ICUSD page 1514

KEY: real time control - model - FITASIM

The simulation model, FITASIM, used off-line for the pre-planning phase of a real-time-control project is presented.

T46 **DERIVATION OF IF-THEN-ELSE RULES FROM OPTIMISED STRATEGIES FOR SEWER SYSTEMS UNDER REAL TIME CONTROL**

by M. do Ceu Almeida and W. Schilling
6 ICUSD page 1525

KEY: real time control - model - MOUSE

Rules for determining an optimal CSO operating strategy are defined. An application in Lisbon using the MOUSE system is described.

T47 **REAL TIME CONTROL IN A PIPE TO MINIMIZE THE CSO**

by C. Jakobsen, N.K. Andersen, P. Harremoes and P.S. Nielsen
6 ICUSD page 1531

KEY: real time control - model - MOUSE

A real time control proposal is analyzed for a simple storage system using the MOUSE package.

T48 **THE RELATIONSHIP BETWEEN FIELD AND MODEL STUDIES OF AN HYDRODYNAMIC SEPARATOR COMBINED SEWER OVERFLOW**

by P.D. Hedges, P.E. Lockley and J.R. Martin
6 ICUSD page 1537

KEY: treatment - sediment - vortex

The performance of the English hydrodynamic separator (Vortex) is presented in both model and field trials.

T49 **COMPARATIVE LABORATORY STUDY OF SWIRL, VORTEX AND HELICAL SEPARATORS**

by Z. Konicek and J. Marsalek
6 ICUSD page 1543

KEY: treatment - sediment - vortex - helical bend

The performance of two vortex separator designs, the American swirl concentrator, and the German design (Fluidsep) are tested in a lab, along with the helical bend separator.

T50 **A SIMPLIFIED METHOD TO EVALUATE CONTROL EFFECTS OF COMBINED SEWER OVERFLOW**

by M. Kume, S. Saito and K. Yoshimoto
6 ICUSD page 1549

KEY: storage - treatment

A simplified model which analyses continuous annual hydrographs of combined sewer flow is used to optimize storage and treatment.

T51 **RISK ANALYSIS AND REAL TIME OPERATION OF SEWER SYSTEMS, EXPERIENCE FROM THE USER'S PERSPECTIVE**

by J.M. Delattre
6 ICUSD page 1609

KEY: real time control - operation

The impact of instrument and human error in operation of a RTC system is described. Risk analysis methods are presented.

T52 **IMPLEMENTATION OF REAL TIME CONTROL IN BARCELONA'S URBAN DRAINAGE SYSTEM**

by J.L. Quer, P. Malgrat and J. Marti
6 ICUSD page 1621

KEY: real time control - operation - Barcelona

The different phases of development and implementation of a RTC system for Barcelona are described.

T53 **FEASIBILITY PLANNING OF A REAL TIME CONTROL SYSTEM IN THE CITY OF ZURICH, SWITZERLAND**

by B. Huber, M. Antener, W. Schilling and M. Grottker
6 ICUSD page 1627

KEY: real time control - planning - Zurich

A case study of the development and implementation of a RTC system is described.

T54 **URBAN DRAINAGE OPERATION - CONTROL OF PUMPED SEWER SYSTEMS DURING HEAVY STORM EVENTS**

by E. van Leewen and K.J. Breur
6 ICUSD page 1639

KEY: real time control - pumping - Rotterdam

A case study of real time control.

T55 **CONTROL STRATEGY OF DISCHARGE PUMP AND WATER GATE IN URBANIZED LOWLAND AREA FOR FLOOD PROTECTION AND WATER QUALITY MANAGEMENT**

by Y. Kido, T. Morioka and A. Miichi
6 ICUSD page 1645

KEY: real time control - storage - treatment - Osaka

A case study of a RTC system proposed for operating under different flow regimes.

T56 **OPERATIONAL EXPERIENCE WITH VORTEX SOLIDS SEPARATORS FOR COMBINED SEWER OVERFLOW (CSO) CONTROL**

by W.C. Pisano and H. Brombach
6 ICUSD page 1651

KEY: treatment - vortex - sediment

Results from laboratory and full scale installations of the Fluidsep vortex solids separator are presented.

T57 **DEMONSTRATION OF ADVANCED HIGH RATE TREATMENT FOR CSO CONTROL IN METROPOLITAN TORONTO**

by G. Zukovs and W.C. Pisano
6 ICUSD page 1657

KEY: treatment - vortex - storage - Toronto

The proposed demonstration project using a vortex separator (Fluidsep design) in conjunction with storage, sedimentation and disinfection is described. Costs and performance of the system, applied to a large drainage area is estimated.

T58 **A QUALITY ASSESSMENT OF DYNAMIC SEPARATION - THE UK EXPERIENCE**

by G.W. Fagan
6 ICUSD page 1663

KEY: treatment - vortex - United Kingdom

The performance of the Storm King solids separator is described, and results provided for several applications.

T59 **HIGH RATE TREATMENT OF COMBINED SEWER OVERFLOW IN COLUMBUS, GEORGIA**

by M.C. Boner, D.R. Ghosh, S.P. Hides and B.G. Turner
6 ICUSD page 1671

KEY: treatment - vortex - storage - Columbus

The results of a demonstration project using a StormKing vortex separator and a storage tank/clarifier in series is described.

T60 **REDUCTION OF COMBINED SEWER OVERFLOW POLLUTION BY COMBINATION OF SWIRL CONCENTRATOR AND DETENTION BASIN**

by A. Himmel and W.F. Geiger
6 ICUSD page 1677

KEY: treatment - vortex - storage - efficiency

The results of the testing a full scale and lab scale facility are presented. Different methods for measuring efficiency are described.

T61 **COMBINED SEWER OVERFLOW (CSO) GUIDELINES AND COSTS IN ONTARIO**

by J.C. P'ng, W.Y. Liang and D.J. Henry
6 ICUSD page 1702

KEY: guidelines - costs - Ontario

Ontario's proposed control guidelines require a pollution prevention and control plan, and provide for a minimum control criteria of 90% volumetric control, with more stringent requirements for beach protection. Control costs using different approaches to meet the guidelines are presented.

T62 **ADVANCED REQUIREMENTS FOR CSO's: A PROPOSAL OF A GERMAN ATV WORKING GROUP**

by F. Sperling
6 ICUSD page 1721

KEY: guidelines - Germany

The principals for an ecologically based methodology for adopting CSO control requirements are discussed.

T63 **POLLUTION CONTROL PLANNING EXPERIENCE IN ONTARIO**

by J. Antoszek, D. Henry and J. P'ng
6 ICUSD page 1717

KEY: planning - Ontario

Ontario's municipal pollution control planning program is discussed. Several case studies involving municipalities with CSO problems are presented.

T64 **MIXED SYSTEMS OF COMBINED AND SEPARATE DRAINAGE CAUSING PROBLEMS ON PLANNING AND OPERATION**

by D.T. Kollatsch
6 ICUSD page 1733

KEY: separation - Germany - partially separated - combined sewers - combinations - comparison

T65 **IMPROVEMENT OF AN URBAN DRAINAGE SYSTEM BASED ON AN INTEGRATED INTERDISCIPLINARY APPROACH**

by D. Wittenberg and D. Borchardt
6 ICUSD page 1739

KEY: integrated approach - STP - sewer system - receiving water

An integrated analysis of controls for the sewer system, treatment plant and receiving water is presented for Bremen.

T66 **REHABILITATION CONCEPT FOR EMSCHER-SYSTEM**

by D. Londong and M. Becker
6 ICUSD page 1744

KEY: integrated - rehabilitation

An integrated plan to control CSO's includes construction of new storage and treatment facilities. A feature of the plan is that the urban rivers will be rehabilitated to their natural state.

T67 **COMBINED SEWER AREA STUDY - CITY OF OTTAWA**

by A.R. Perks, T.J. Cover, G. Zukovs and B. Byce
6 ICUSD page 1774

KEY: storage - separation - Ottawa

A case study of combined sewer control alternatives is presented, which considered local storage, tunnel storage and sewer separation as options.

T68 **SEDIMENTATION IN STORAGE TANK STRUCTURES**

by V.R. Stovin and A.J. Saul
6 ICUSD page 1799

KEY: storage tank - sedimentation

The paper presents results from laboratory testing of the sedimentation tank operating under simulated wet weather conditions.

T69 **LABORATORY STUDY OF THE GROSS PARTICULATE RETENTION PERFORMANCE OF LARGE SCALE MODEL CSO STRUCTURES**

by S.J. Ruff, A.J. Saul, M. Walsh and M.J. Green
6 ICUSD page 1811

KEY: storage tank - sedimentation - treatment

A laboratory setup for testing CSO control structures, including different types of sedimentation tanks and vortex solids separators is described.

T70 **ELEMENTS FOR SIZING OF DECANTERS FOR DEPOLLUTION OF URBAN WET WEATHER DISCHARGES**

by A. Saget, G. Chebbo and A. Bachoc
6 ICUSD page 1817

KEY: storage tank - sedimentation - treatment

Basic performance and sizing of sedimentation tanks related to settling velocity thresholds is discussed.

T71 **COMBINED SEWAGE PRECIPITATION - A METHOD OF REDUCING THE COMBINED SEWAGE SURPLUS LOAD**

by F. Schweer
6 ICUSD page 1823

KEY: sedimentation - treatment - chemical addition - filtration

The experiments with chemical addition to combined sewage to enhance solids removal through precipitation and coagulation are presented. Results of filtration of the effluent is also presented.

T72 **A CASE STUDY OF CSO POLLUTION CONTROL IN THE UK**

by B. Crabtree, R. Gent, M. Becker and P. Davis
6 ICUSD page 1842

KEY: planning - models

Results of simulations using several models used in the UK are presented including MOSQITO, CARP, WASSP, MIKE, and WALLRUS.

T73 **COMBINED SEWER OVERFLOW CONTROL AND STORMWATER MANAGEMENT IN CANADA'S GREAT LAKES CLEANUP FUND**

by D.G. Weatherbe and I.G. Sherbin
6 ICUSD page 1848

KEY: planning - treatment - Ontario

A demonstration program for stormwater management and combined sewer overflow control is described. A real time control demonstration and a high rate treatment demonstration are described.

T74 **NEW CONCEPT FOR CSO REGULATION ENFORCEMENT**

by M. Figge and W. Geiger
6 ICUSD page 1866

KEY: model - monitoring

A system of online monitoring of facilities, coupled with a simulation model is used to establish control criteria.

T75 **STRATEGIC SCREENING OF POLLUTION CONTROL ALTERNATIVES FOR THE CITY OF SARNIA**

by H.G. Fraser, K. Stevens and S. Troxler
6 ICUSD page 1872

KEY: integrated approach - storage - Sarnia

A case study of a pollution control plan is presented for Sarnia. Various combined sewer control options are presented, with storage tanks being recommended.

T76 **CONTROL PROGRAM FOR THE COMBINED SEWER SYSTEM IN STOCKHOLM**

by K. Bennerstedt and L. Kjellson
6 ICUSD page 1884

KEY: planning - Stockholm - MOUSE

The program for control of CSOs in Stockholm is presented. The program includes construction of storage tanks as well as monitoring of system performance, and simulation using MOUSE.

T77 **ADVANCED INTEGRATED MONITORING AND CONTROL OF MUNICIPAL WASTE WATER SYSTEMS**

by A. Lynggaard-Jensen and P. Harremoes
6 ICUSD page 1927

KEY: real time control - monitoring - integrated - MOUSE

An integrated operation of the sewer system and treatment plant is described, using the MOUSE package of models, for Aalborg, Sweden.

T78 **TECHNOLOGICAL AND SANITARY ASPECTS OF THE RECIPROCAL IMPACTS OF THE COMBINED SEWER, WASTEWATER TREATMENT PLANT AND RECEIVING WATER**

by R. Arsov
6 ICUSD page 1950

KEY: real time control - sedimentation

A procedure for calculating mass loads of sediment in CSOs, and resulting impacts on the sewage treatment plant and receiving water is presented.

U1 **THE OPERATION AND MAINTENANCE OF STORMWATER DETENTION FACILITIES**

by J.E. Hodgson, M.J. Stalker
35th Annual Convention, Western Canada Water and Sewage Conference (September 1983)

KEY: Stormwater detention ponds - water quality considerations

U2 **SEWER AND WATERMAIN REPLACEMENT USING INSERTED POLYETHYLENE PIPE "RELINING"**

by Hank St. Onge
36th Annual Convention, Western Canada Water and Sewage Conference (September 1984)

KEY: Retrofitting - relining - aging sewers

U3 **PLANNING URBAN INFRASTRUCTURE REHABILITATION - A RATIONAL APPROACH**

by K. Foster and T. Burke
39th Annual Convention of the Western Canada Water and Wastewater Association, Saskatoon (October 1987)

KEY: Hydraulic and structural performance - sewers - watermains - hydraulic assessment

U4 **<u>HIGHLANDS TRUNK COMBINED SEWER UPGRADING</u>**

by W. Pelz and S. Fernando
42nd Annual Convention of the Western Canada Water and Wastewater Association (Regina 1990)

KEY: sewage collection system - basement flooding - system analysis

U5 **<u>SEWER UPGRADING IN BUILT-UP RESIDENTIAL AREAS, LAGO LINDO SUBDIVISION, EDMONTON, ALBERTA</u>**

by F. Wu and B. Harvey
42nd Annual Convention of the Western Canada Water and Wastewater Association (Regina 1990)

KEY: Sanitary sewer system - basement flooding - system analysis

U6 **<u>TYLEHURST SEWER RELIEF AND POLLUTION ABATEMENT STUDIES, CITY OF WINNIPEG, MANITOBA</u>**

by C. Macly and A. Nagy
43rd Annual Convention of the Western Canada Water and Wastewater Association (Winnipeg 1991)

KEY: Combined Sewer - hydraulic upgrading - discretized computer simulation model

U7 **<u>SEWAGE FLOW METERING AND ANALYSIS FOR A REGIONAL SEWAGE SYSTEM</u>**

by G. Thompson and K. Delaronde
45th Annual Conference of the Western Canada Water and Wastewater Association, Saskatoon (October 1993)

KEY: Peak flows - storms - by-pass volumes - collection systems

CITY of WINNIPEG MANAGEMENT STUDY
LITERATURE REVIEW

			SYSTEM TYPE		SYSTEM FEATURE							SUBJECT MATERIAL: GENERAL						POLICY				SOFT ENG'G		HARD ENGINEERING					OPERAT'L MAINTEN.	
PUBLICATION REFERENCE	COUNTRY	LOCATION	COMBINED	STORM	CATCHMENT	COLLECTION	OVERFLOWS	DETENTION / STORAGE	TREATMENT	DISCHARGE	RECEIVING WATERS	HISTORY	PHILOSOPHY	PLANNING	CONTROL ALTERNATIVES	SEWER SEPARATION	RESEARCH / TRAINING	GENERAL	PERMITTING	QUALITY STANDARDS	MONITORING	MODELLING	INVESTIGATIONS	PIPES	TUNNELS	OVERFLOWS	DETENTION FACILITIES	TREATMENT FACILITIES	REAL TIME COMTROL	MAINTENANCE PROGRAM
A1	CAN		X	X	X	X	X	X	X	X	X	X	X	X						X		X	X							
A2	CAN	Quebec		X		X		X						X								X								X
A3	USA			X	X			X		X												X					X			
A4	CAN		X	X				X					X	X								X					X			
A5	CAN			X				X						X	X												X			
A6	CAN			X		X	X							X								X								
A7	CAN			X		X																X								
A8	CAN		X	X		X																X								
A9				X	X																	X								
A10	International			X	X												X					X								
A11	CAN			X	X																	X								
A12	USA			X	X																	X								
A13	SWITZ.			X	X									X																
A14	UK		X			X	X				X	X	X							X		X							X	X
A15	CAN	Quebec	X			X	X				X																		X	
A16	CAN			X			X						X														X			
A17	CAN			X		X						X																		
A18	CAN			X				X						X																
B1	USA		X	X		X				X			X						X	X										X
B2	USA			X	X									X						X										
C1	CAN		X						X													X					X	X		
C2	USA		X		X	X			X	X					X							X					X	X		
C3	CAN		X			X									X															
C4	CAN		X	X	X	X		X														X					X		X	
C5	USA			X		X																X								
C6	CAN		X				X														X	X				X			X	
D1	USA			X				X						X													X			X
D2	USA		X	X				X											X	X							X			
D3	USA			X				X						X						X							X			
D4	USA			X				X	X											X			X							
D5	USA			X				X													X									
D6	USA		X	X			X	X																				X		
D7	USA			X				X							X															
E1	USA		X								X									X		X								
E2	USA		X				X				X								X			X								
F1	USA		X				X	X	X				X														X	X	X	
F2	USA		X					X														X			X		X	X		
F3	USA		X	X				X																			X			
F4	USA		X	X									X																	X
F5	USA		X	X		X		X				X						X							X		X			
G1	USA		X					X	X												X	X								
G2	USA		X					X	X						X					X					X					
G3	USA		X					X							X					X		X					X	X		
G4	USA		X				X													X										
G5	USA		X					X	X	X	X									X							X			
G6			X	X		X										X														
G7	USA		X	X		X									X							X								
G8	USA		X			X								X								X								
G9	USA		X				X	X																			X	X		
G10	USA		X				X								X			X	X	X		X								
G11	USA		X			X	X	X	X						X				X											X
G12	USA		X						X																			X		
G13	USA	Oakland		X		X								X										X						
G14	CAN	Sarnia	X				X	X														X					X			
G15	USA	NY (Yonkers)	X						X																			X		
G16	USA	Chattanoga	X																		X									
G17	USA	Dallas	X					X																			X			
G18	USA		X				X																			X		X		
G19	USA	Washington	X	X			X	X															X				X			
H1				X	X			X	X	X	X									X										
H2	BELG / NETH		X				X						X																	
H3	SWE	Malmo	X				X															X								
H4	GER	Munich	X			X																	X							
H5	UK / SWE	London		X	X	X																	X							
H6	NETH		X																				X							
H7	JAP	Tokyo		X		X																	X							
H8	SWE	Malmo	X											X								X	X							
I1	USA	Denver	X	X										X				X		X										
I2	DEN		X				X							X				X		X										

CITY of WINNIPEG MANAGEMENT STUDY
LITERATURE REVIEW

PUBLICATION REFERENCE	COUNTRY	LOCATION	SYSTEM TYPE: COMBINED	SYSTEM TYPE: STORM	SYSTEM FEATURE: CATCHMENT	SYSTEM FEATURE: COLLECTION	SYSTEM FEATURE: OVERFLOWS	SYSTEM FEATURE: DETENTION / STORAGE	SYSTEM FEATURE: TREATMENT	SYSTEM FEATURE: DISCHARGE	SYSTEM FEATURE: RECEIVING WATERS	GENERAL: HISTORY	GENERAL: PHILOSOPHY	GENERAL: PLANNING	GENERAL: CONTROL ALTERNATIVES	GENERAL: SEWER SEPARATION	GENERAL: RESEARCH / TRAINING	POLICY: GENERAL	POLICY: PERMITTING	POLICY: QUALITY STANDARDS	POLICY: MONITORING	SOFT ENG'G: MODELLING	SOFT ENG'G: INVESTIGATIONS	HARD ENGINEERING: PIPES	HARD ENGINEERING: TUNNELS	HARD ENGINEERING: OVERFLOWS	HARD ENGINEERING: DETENTION FACILITIES	HARD ENGINEERING: TREATMENT FACILITIES	OPERAT'L MAINTEN.: REAL TIME CONTROL	OPERAT'L MAINTEN.: MAINTENANCE PROGRAM
I3	USA																													
I4	SWE																													
I5	USA																													
I6	USA	Seattle/Ohio																												
I7	GER																													
I8	GER																													
I9	USA																													
J1	JAP	Osaka																												
J2	JAP																													
J3	JAP																													
K1	USA	NE / Ohio																												
K2	USA																													
K3	CAN	Cornwall																												
L1	USA	Lancstr/Rich																												
L2	CAN	Toronto																												
M1	UK																													
M2	UK																													
M3	UK																													
M4	USA																													
M5	SWE																													
M6	UK																													
M7	USA																													
M8																														
M9	USA																													
M10	SWE/US/CAN																													
M11	CAN																													
M12	USA																													
M13	USA																													
M14	USA																													
M15	USA																													
M16	USA																													
M17	USA	Ann Arbor																												
M18	USA																													
M19	USA	N.Y.																												
M20	USA	Vermont																												
M21	USA	Seattle																												
M22	USA	San Francisco																												
M23	CAN																													
M24	CAN	Ontario																												
N1	USA / CAN																													
N2																														
N3	CAN	Toronto																												
N4	USA	Boston																												
N5	CAN	Ontario																												
N6	CAN	Kingston																												
N7	USA	New Bedford																												
O1	CAN	Hamilton																												
O2	USA																													
P1	UK																													
P2	USA	Indiana																												
P3	USA	Connecticut																												
P4																														
P5	USA	Boston																												
P6	USA	Cincinnati																												
Q1																														
Q2	CAN	Toronto																												
Q3	CAN	Ontario																												
Q4	CAN	Toronto																												
Q5	USA / CAN																													
Q6																														
Q7	CAN	Hamilton																												
R1	USA	New York																												
R2																														
R3																														
S1	USA	Mass.																												
S2	USA	Nashville																												
S3	USA	Peoria																												
S4	USA																													
S5	USA	Boston																												

CITY of WINNIPEG MANAGEMENT STUDY

LITERATURE REVIEW

			SUBJECT MATERIAL																											
			SYSTEM TYPE		SYSTEM FEATURE							GENERAL						POLICY				SOFT ENG'G		HARD ENGINEERING					OPERAT'L MAINTEN.	
PUBLICATION REFERENCE	COUNTRY	LOCATION	COMBINED	STORM	CATCHMENT	COLLECTION	OVERFLOWS	DETENTION / STORAGE	TREATMENT	DISCHARGE	RECEIVING WATERS	HISTORY	PHILOSOPHY	PLANNING	CONTROL ALTERNATIVES	SEWER SEPARATION	RESEARCH / TRAINING	GENERAL	PERMITTING	QUALITY STANDARDS	MONITORING	MODELLING	INVESTIGATIONS	PIPES	TUNNELS	OVERFLOWS	DETENTION FACILITIES	TREATMENT FACILITIES	REAL TIME COMTROL	MAINTENANCE PROGRAM
S6	USA	Seattle																												
S7	USA																													
T1	UK																													
T2	DEN																													
T3	USA	Ohio																												
T4	USA	Lake Erie																												
T5	USA	Detroit River																												
T6	DEN																													
T7	FRA	Paris,Seine R																												
T8	GER	Innerste Riv.																												
T9	FRA	Paris,Seine R																												
T10	USA																													
T11	USA																													
T12	USA																													
T13	GER																													
T14	FRA	Seine River																												
T15	FRA	Seine River																												
T16																														
T17																														
T18	CAN	Toronto																												
T19																														
T20	JAPAN																													
T21	GER																													
T22																														
T23																														
T24																														
T25																														
T26	GER																													
T27																														
T28																														
T29																														
T30																														
T31																														
T32	EUROPE																													
T33																														
T34																														
T35																														
T36																														
T37																														
T38	CAN	Toronto																												
T39	CAN	Niagara Falls																												
T40	JAPAN																													
T41	JAPAN	Nagoya																												
T42																														
T43	USA	Chattanooga																												
T44	SWEDEN																													
T45																														
T46	PORTUGAL	Lisbon																												
T47																														
T48																														
T49																														
T50																														
T51																														
T52	SPAIN	Barcelona																												
T53	SWITZ	Zurich																												
T54	HOLLAND	Rotterdam																												
T55	JAPAN	Osaka																												
T56																														
T57	CAN	Toronto																												
T58	UK																													
T59	USA	Georgia																												
T60																														
T61	CAN	Ontario																												
T62	GER																													
T63	CAN	Ontario																												
T64	GER																													
T65	GER	Bremen																												
T66																														
T67	CAN	Ottawa, Ont.																												
T68																														
T69																														
T70																														
T71																														

			SUBJECT MATERIAL																											
			SYSTEM TYPE		SYSTEM FEATURE							GENERAL						POLICY				SOFT ENG'G		HARD ENGINEERING					OPERAT'L MAINTEN.	
PUBLICATION REFERENCE	COUNTRY	LOCATION	COMBINED	STORM	CATCHMENT	COLLECTION	OVERFLOWS	DETENTION / STORAGE	TREATMENT	DISCHARGE	RECEIVING WATERS	HISTORY	PHILOSOPHY	PLANNING	CONTROL ALTERNATIVES	SEWER SEPARATION	RESEARCH / TRAINING	GENERAL	PERMITTING	QUALITY STANDARDS	MONITORING	MODELLING	INVESTIGATIONS	PIPES	TUNNELS	OVERFLOWS	DETENTION FACILITIES	TREATMENT FACILITIES	REAL TIME CONTROL	MAINTENANCE PROGRAM
T72	UK													■								■								
T73	CAN	Ontario	■	■			■							■															■	
T74							■												■		■	■								
T75	CAN	Sarnia													■												■			
T76	SWEDEN	Stockholm	■				■								■						■	■					■			
T77	SWEDEN	Aalborg	■			■			■												■	■							■	
T78			■				■		■	■	■																		■	
U1				■				■	■																		■	■		
U2			■			■																		■						■
U3			■	■		■								■									■							■
U4			■			■								■									■							
U5			■			■								■									■							
U6	CAN	Winnipeg	■			■			■													■								
U7			■			■																	■							

2.3 REPRESENTATIVE CASE STUDIES

2.3.1 General

The following case studies in Tables 1 through 5, provide some insight into the parameters, objectives, remedies and costing of CSO projects undertaken in North America and the UK. The 26 case studies selected for inclusion possess some common element or similarity to Winnipeg's CSO Management Study and outline the experiences of other municipalities. There are 3 sets of tables; Canada, USA and UK / Europe, each 'set' is comprised of 5 tables with the following headings.

TABLE 1	Municipality Characteristics	• Climatology	- No. Rain Events - Total Volume (mm) - Comments
		• Area Characteristics	- Major Sub-basin - Total hectares - Hectares served by combined sewers - Population - Comments
		• Receiving waters	
TABLE 2	Municipality Infrastructure	• Collection System	- Regulators (No., Type) - Interceptors/Pumping
		• Wastewater Treatment	- Type - Capacity (m^3/d) (Average, Peak)
TABLE 3	Municipality Institutional	• Jurisdiction • Funding • Flooding • Beach • Public Health • Water Quality • Other	
TABLE 4	Municipality CSO Control Technologies	• Objectives • Flow Reduction • Storage • Treatment • Operation • Other	
TABLE 5	Municipality Implementation	• Cost • Period • Comment	

Table 1

Municipality	Characteristics								
	Climatology			Area Characteristics					Receiving Waters
	No. Rain Events	Total Volume (mm)	Comments	Major Sub-basin	Area (hectares)			Comments	
					Total	Combined	Population		
CANADA									
Cornwall	80		• Simulation period of 10 years of actual precipitation • Hydraulic analysis using severe historical storm	• combined sewers within older section of city with sanitary sewers for new developments	1,720	496	46,000 (1980)	• upstream terrain relatively flat, middle topography higher, terrain by pumping station rolling (all relative to Riverside Interceptor)	• St. Lawrence River - major waterway; receives stormwater, WPCP effluent, CSOs and industrial wastewater
Borough of East York, Ontario	12	24.94 (event period only)	• For purpose of calibrating computer model (1976) • 7 months simulation period (1979 - seasonal statistical average precipitation)	• Don River Watershed • 5 storm • 3 CSO - Cadorna, South-East, Leaside North	1,191	463.1	45,000 (1981)	• rolling terrain downhill from study area to Lake Ontario • Don River *valley* through area to Lake	• local watercourses; West Don River, East Don River, Massey Creek, Don River • Lake Ontario
Edmonton	62	325	• Spring/fall wet periods • Summer generally dry	• North and South combined sewer area	31,250	5,000	627,000	• Combined system services City core developed between 1903 and 1960	• North Saskatchewan River
Hamilton	88	638	• Spring/fall frontal storms • Summer has dominant thunderstorms	• Red Hill Creek • Chedoke Creek • Hamilton Harbour	11,600	5,400	43,000	• Niagara Escarpment bisects the City in an east to west direction in its lower third	• Hamilton Harbour • Cootes Paradise has high wildlife sanctuary potential
Kingston	87	542		• Little Cataraqui • Great Cataraqui • Lake Ontario		607 636 789	60,500	• Generally flat to mildly rolling • Terrain rises from Lake Ontario Shoreline	• Lake Ontario bounds southern portion of Kingston • Little Cataraqui Creek is western boundary • Great Cataraqui River is western boundary • Majority discharge into Lake Ontario or Great Cataraqui
London								• mildly rolling terrain	• North Thames, South Thames & Thames Rivers • Urban streams with multiple inputs including WPCP, Storm and CSO
Ottawa	87 (10 months)	620 (10 months)	• Critical events summer thunderstorms and large volume spring rain/melt events	• All combined areas flow to treatment plant	16,052	1,974	44,780 served by combined sewers 308,366 (1991)	• Mildly rolling terrain • Very steep valley at Ottawa River	• Ottawa River major receiver with fisheries and recreation potential • Rideau River slow moving eutrophic stream having recreational potential

Table 1

Municipality	Characteristics								
	Climatology			Area Characteristics					Receiving Waters
	No. Rain Events	Total Volume (mm)	Comments	Major Sub-basin	Area (hectares) Total	Area (hectares) Combined	Population	Comments	
CANADA									
Scarborough	66	465	• Frontal storms more probable in spring and fall • Summertime thunderstorms can be critical	• Victoria Park • Godfrey Fowler		213 622	535,000	• Areas have been partially separated. CSO discharges are generally made to storm outlets	• Lake Ontario • Massey Creek relatively limited stream
St. Catharines				1. Port Weller 2. Port Dalhousie	2,800 2,500		124,689 (1991) City of St. Catharines	• Mildly rolling terrain • Steep valley to Twelve Mile Creek	• Twelve Mile Creek - rapidly flowing urban stream with industrial, CSO stormwater and upstream rural inputs. Martindale pond at terminus of Twelve Mile Creek is important recreational site • Lake Ontario
City of Toronto			• 20 years of rainfall records: used representative precipitation from 4 years, April through November (2 years average: 1 extreme dry, 1 extreme wet)	• Lake Ontario • Don River • Humber River	4,760 3,134 224	2,568 632 ---	599,000 (1991)	• 47 CSO outfalls	• Lake Ontario • Humber River • Don River
Vancouver	137	1,062	• Bi-seasonal rainfall pattern divided between wet winter and relatively dry summer	• Vancouver sewerage area • Fraser sewerage area • Westridge (Burnaby) • New Westminster		9,170 920		• Combined sewers serve parts of three communities in the Greater Vancouver Area including City of Vancouver, New Westminster and Burnaby.	• Vancouver Harbour • Fraser River • Burrard Inlet • English Bay high recreation potential • False Creek sensitive area
Windsor	84	643	• Critical events summer thunder storms	• Little River • West Windsor	4,320 3,500	342 (combined) 1,115 (partly combined) 3,500	72,100 served by combined sewers 190,954 (1991)	• Very flat topography falling gently to Detroit River • Detroit River elevation varies creating backwater on outfalls	• Little River/urban stream with multiple inputs including WPCP, Storm, CSO and industrial (historical). Habitat disturbed in lower reaches • Detroit River - major receiver although near shore impacts possible

Table 2						
Municipality	Infrastructure					
	Collection System			Wastewater Treatment		
	Regulators		Interceptors/Pumping	Type	Capacity (m^3/d)	
	No.	Types			Average	Peak
CANADA						
Cornwall	11	• Brookdale Avenue chamber - motorized sluice gate, adjustable overflow weir • remaining regulators - spill weir / orifice	• One major interceptor (Riverfront); main sewage pumping station, plus WPCP	Primary + chemical P-removal	37,483 (1969)	93,730 (hydraulic capacity)
Borough of East York, Ontario		• orifices and pipes	• Interceptors and WPCPs operated by Metro Toronto • Four trunks serving East York. • Contributes to two WPCPs: Metro Toronto Main Treatment Plant (Ashbridges Bay) North Toronto Sewage Treatment Plant	Secondary	816,480 34,095	3,079,296 34,095 (excess flow to main plant)
Edmonton	22 direct overflows 50 overflows to storm outfalls	• Weirs, orifices, Brown and Brown regulators	• Two major interceptors service north and south combined areas	Goldbar WWTP Secondary	310,000	960,000 (short term - primary)
Hamilton	> 100 structures 22 major overflows	• weirs, orifice plates, fixed sluice gates, controlled sluice gates	• Western Interceptor and Redhill Creek Interceptor • Main pump station at WPCP	Woodward Avenue WPCP - Secondardy + Phosphorus Removal	409,000	615,000 (short term - 1 to 3 hours)
Kingston	45	• Weirs • Orifices	• Major interceptors alo*p2090XOntario Shoreline and north end of City • Interceptors feed River Street Pumping Station. All flows pumped across Great Cataraqui to WPCP. • Six minor pump stations	Primary + Chemical Addition	61,000	
London	100	• side spill weirs • direct overflow • flap gate • Milwaukee gate	• Six main trunk sewers • One pumping station. Pumps into open channel and into Dingman Creek	Secondary • Adelaide • Greenway • Oxford • Pottersburg • Vauxhall		peak Q (ML/d) 27.3 134.2 10.0 28.2 20.9

Table 2						
Municipality	Infrastructure					
	Collection System			Wastewater Treatment		
	Regulators		Interceptors/Pumping	Type	Capacity (m^3/d)	
	No.	Types			Average	Peak
CANADA						
Ottawa	11	• Brown & Brown • Side spill weirs	• One main interceptor receiving flows from seven major trunks. • WWTP pump station receives main interceptor flows. • Two other trunk sewers flow by gravity to WWTP.	Secondary	2,494,800	6,123,600
Scarborough	17	• Weirs, orifices, sluice gates	• Two major interceptors, Victoria Park/Gidfrey - Flowler • Three pump stations	Metro Main WPCP Activated Sludge + Phosphorus Removal	818,000	1,364,000
St. Catharines Port Weller Port Dalhousie				 Secondary Secondary	 68,000[1] 61,000[1]	 137,000[1] 123,000[1]
City of Toronto	27 control chambers	• combinations of fixed weirs and/or motorized sluice gates	• Interceptors and WPCPs operated by Metro Toronto • Five major wastewater intercepting sewers (3 central/western, 2 eastern portions of City) • Contributes to three WPCPs: Main Sewage Treatment Plant (MTP), Humber Treatment Plant (HTP), North Toronto Treatment Plant (NTTP)	MTP - secondary HTP - secondary NTTP - secondary	816,480 473,000 34,095	3,079,296 34,095
Vancouver	53	• Weirs, orifice plates, radial gates	• Six major interceptors • Seven major pumping stations (GVRD) plus three major municipal stations	Iona Island WWTP Primary + Disinfection		1,516,000
Windsor Little River	6 (outlets)	• side spill weirs • pumped overflow	• Four major trunk sewers • One trunk sewer pump station • WWTP pump station	Secondary		
West Windsor	24 + storm relief overflow	• side spill weirs/orifice • automated sluice gates	• One major interceptor with pump station • WWTP pump station • A number of major storm relief sewers intercept combined flows at multiple points upstream of regulators	Primary + Chemical Addition		

Notes: 1. In the process of being upgraded

Table 3

Municipality	Institutional: Jurisdiction	Institutional: Funding	Issues: Flooding	Issues: Beach	Issues: Public Health	Issues: Water Quality	Issues: Other
CANADA							
Cornwall	• City of Cornwall	• Provincial & Municipal Sewage Works Programmes		St. Lawrence River beaches	Impact of wet/dry weather overflows	• poor process performance; industry contributed 8% of daily average flows • MOEE concerned re impact of overflows on near shore areas of St. Lawrence River	• Reduce industrial effluent concentrations to within by-law limits
Borough of East York, Ontario	• Borough of East York (by-law for sanitary/storm systems use) • Regional Municipality of Metropolitan Toronto (collection & treatment of sanitary sewage) • Province of Ontario	• Borough of East York • Municipality of Metropolitan Toronto • Ontario Ministry of Transportation & Communication	several years of basement and street flooding		WPCP effluent bacterial contamination		• Leachate • Undersized sewer network
Edmonton	• City	• Funded through utility revenues	Local flooding	None	Limited concern	Concern regarding CSO loadings of pollutants	• CSO loadings compared to other sources such as WWTP and storm runoff
Hamilton	• Region of Hamilton-Wentworth owns and operates regulators, interceptors and WPCP • City of Hamilton owns collectors	• Funded through utility revenues • Small grants available from province	Some localized flooding	N/A	Concerns regarding aquatic recreation in Cootes Paradise	Hamilton Harbour is a RAP area with defined water quality goals. CSO management is considered important in meeting these goals	
Kingston	• City owns and operates all facilities	• Funded through City tax revenues • Ontario provides small grant	Some localized flooding	Lake Ontario beaches major issue	Beach related	Little Cataraqui prime wetland	
London	• City owns and operates all facilities	• Funded through Regional tax revenues and utility rates	Basement flooding Some surface flooding			• MOEE and Upper Thames River Conservation Authority (UTRCA) continually monitor effluent. • Primarily bacteria and floatables	• Odour compliance
Ottawa	• Region of Ottawa-Carleton owns and operates selected trunks, interceptor sewer selected regulators and WPCP • City of Ottawa owns and operates combined collection system, selected trunks and regulators	• Funded through Regional tax revenues • Ontario provides small grant	Some localized basement flooding	Rideau River beaches	No explicit concerns other than beach related	Primarily bacteria and floatables	• Fisheries impacts on Ottawa River
Scarborough	• Municipality owns/operates collection system including regulators • Metro owns trunk sewers, interceptors and WPCP	• Utility rates • Small grants from Metro for sewer separation	Local flooding	None	General concern in Massey Creek	General concern in Massey Creek and Lake Ontario	

Table 3

Municipality	Institutional: Jurisdiction	Institutional: Funding	Issues: Flooding	Issues: Beach	Issues: Public Health	Issues: Water Quality	Issues: Other
CANADA							
St. Catharines Port Weller Port Dalhousie	• Region of Niagara owns and operates WPCPs and pumping stations and trunk sewers with capacities > 170 L/s • City operates all other facilities including regulators	• Funded through Regional Tax revenues • Ontario provides small grant	Some localized basement flooding	Lake Ontario beaches	No explicit concerns other than beach related	Primarily bacteria and floatables	• Sediment quality in Martindale pond
City of Toronto	• City of Toronto • Agencies: - Municipality of Metropolitan Toronto - Ontario Ministry of Energy and the Environment (MOEE) - Ministry of Natural Resources (MNR) - Metropolitan Toronto and Region Conservation Authority (MTRCA)	• City of Toronto • MOEE	Flooding of lower reaches of the Don River	Eastern and Western Beaches closings	Bacteria criteria for beach area of 100/100ml	Aquatic habitats requiring sediment control	• fisheries • aesthetics in Harbour area with sediment control for long range
Vancouver	• Overflows, trunks and pumping facilities are jointly owned by the City and Greater Vancouver Regional District	• Funded through utility revenues • Small grants from province	Local flooding	English Bay, False Creek (aquatic recreation), Westridge	Concerns in connection with beach areas	Concern regarding CSO impacts on area receivers	• Clark Drive overflow of particular concern, has resulted in legal action under Fisheries Act
Windsor	• City owns and operates all facilities	• Funded through City tax revenues • Ontario provides small grant	Localized flooding in both basins	None	No explicit concerns other than bacteria	RAP has identified bacteria as concern on Detroit River	

Table 4						
	CSO Control	Technologies				
Municipality	Objectives	Flow Reduction	Storage	Treatment	Operation	Other
CANADA						
Cornwall	• Minimize overflow frequency to 1 per year • consolidate overflow sites • evaluate pollutant loadings	• Eliminate all but 3 regulator chambers • 1 overflow point at Brookdale Avenue • Intercept flow at 2 other locations equal to 10 x DWF	• Use existing storage in Riverfront interceptor (10,100 m^3 of storage)	• Expansion of WPCP capacity to 109,000 m^3/d peak wet weather flow and 54,550 m^3/d average flow • Expanded pumping capacities	• Real Time Control System in 2 phases: I - continuous observation of system responses II - automatic control of Brookdale Ave. gate	• Industrial sewer use controls • Enhanced street sweeping
Borough of East York, Ontario	• Meet appropriate regulatory requirements • Optimize use of new storm sewers for flood relief	• Eliminate dry weather sewage flow from 15 outfalls identified by MOEE	• Stormwater detention facilities • Detention tanks for combined sewage			• Modelling • BMP's • Sewer separation for flood relief
Edmonton	• Loading reduction selected pollutants	• City in early stages of formulating strategy. Considering storage and real time and control options				
Hamilton	• One event per year for sensitive areas • Four events per year for areas adjacent to industrial land-use	• Limited roof leader removal in areas of basement flooding	• Tank and tunnel storage including equalization at the WPCP	• Expansion of Woodward Avenue WPCP • Stormwater treatment from new developments	• Regular modifications to increase capture • Short term plan improvements to enhance peak processing capacity	• Real time control of system operations
Kingston	• Lake Ontario one overflow/summer • Little and Great Cataraqui existing level of control	• Limited separation, very localized	• Major tank storage plus local super pipes	• Stormwater treatment for beach area outfalls Cl_2/$DeCl_2$	• Some pumping capacity improvements	• NA
London	• Pumping station designed for 1 bypass per year	• Storm water management on private property - roof storage	• Underground storage in oversized pipes • Some surface storage (not practical)	• No treatment	• Some weir adjustments on the river	
Ottawa	• Objective for region under review • City objectives 90% volumetric or 4 overflows per year for Ottawa River and one overflow per year for Rideau River	• Some ongoing separation	• City proposes major tunnel storage • Regional program under development	• No additional treatment envisages		• Water efficiency
Scarborough	• One overflow per year	• Sewer separation major alternative	• Considered but not important	• None	• Some inlet controls and roof leader disconnection	
St. Catharines	• Recommended program designed for one overflow per summer season • Stormwater criteria of maximum 4 discharges per summer to beach areas	• Roof leader and I/I control • Some limited separation	• Tunnel and tank storage	• Upgrade capacity of WPCPs to manage return flows from storage	• Some weir adjustments	• Relief sewers and pumping station upgrades

Table 4						
	CSO Control	Technologies				
Municipality	Objectives	Flow Reduction	Storage	Treatment	Operation	Other
CANADA						
City of Toronto	• CSO limit 1 event per year to environmentally sensitive areas • 90% volumetric reduction of pollutants at other receiving waters • Control and treatment of stormwater	• Promote infiltration (pavers, soak away pits) • roof leader disconnection	• Storage tunnels (length 16.4 kms; 617,000 m^3) • 3 storage tanks (8,000; 2,250 and 600 m^3)	• new 86,400 m^3/d treatment facility with associated pumping station. Requires primary treatment only	• Metro Toronto responsible for treatment • Tunnel operation / maintenance require further study	• management alternatives (in place) • water quality monitoring for storm
Vancouver	• Seasonal site specific objectives by GVRD • Province wants ultimate elimination of all CSOs	• Vancouver (City) favours sewer separation	• Tank and tunnel storage have been proposed	• GVRD is examining high rate satellite treatment for remote CSOs	• GVRD plans to implement a limited real time control system to operate selected gates	
Windsor	• Range of overflow targets evaluated for Little River • West Windsor control targets will be established from receiving water analysis	NA	NA	NA	NA	NA

Table 5			
Municipality	Implementation		
	Cost	Period	Comments
CANADA			
Cornwall	$7.8 Million (1980)	Operational since 1989	• Storage and treatment capital items only. Cost mainly associated with treatment plant expansion ($500,000 for interceptor modification and instrumentation).
Borough of East York, Ontario	$6 Million (1986) (Recommended works)	Recommendations only	• For trunk sewer improvements and new sewer construction • Study complete and recommendations reported
Edmonton	Studies not yet completed		
Hamilton	Between $190 million and $250 million depending upon alternative and level of control	Not specified but a twenty year time frame was discussed	
Kingston	$16.8 million	14 years	• Program tailored to City of Kingston expenditure capability.
London	NA	NA	
Ottawa	Total cost not available until after Regional study complete	20 - 25 years	• City of Ottawa has completed studies and will proceed with tunnel storage • Region has study presently underway
Scarborough	$7.1 million (1986) inclusive of storage	No implementation period specified	
St. Catharines	$91 Million (1990)	20 - 25 years	• The City of St. Catharines has embarked on some smaller projects. No action as yet by City or Region on major CSO control works.
City of Toronto	$370 Million (1991 dollars) (Stormwater Control $1.9 Million of total)	25 years	• 6 phase implementation of 1 or 6 years duration on prioritized objectives • water quality criteria beyond City's jurisdiction for Western beaches and lower Don River
Vancouver	Studies not yet completed		
Windsor	NA	NA	• CSO control deferred until City wide assessment of pollution control priorities can be made.

Table 1

Municipality	Characteristics								
	Climatology			Area Characteristics					Receiving Waters
	No. Rain Events	Total Volume (mm)	Comments	Major Sub-basin	Area (hectares)			Comments	
					Total	Combined	Population		
U S A									
Boston	122	1,031	• Steady precipitation throughout year. Rain at worst, once per week • Intense Summer thunderstorms	1. Alewife/Mystic River 2. Lower Charles River 3. Inner Harbour Basin 4. Dorchester Bay Basin 5. NePonset Estuary Basin		377 1635 2370 } 555 } 64	75,380 115,600 532,800 3,600 (1990)	• Terrain sloping from north to river areas to east • Flat downtown area on north and south • Logan airport, east Boston peninsula to north • Downtown towers to west, level harbour facilities to south, flat developed area all around bay • Gently sloping land to river, rocky outcrops	1. ***Alewife River*** - Urban stream, heavily developed, some channelization. Receives stormwater as tributary to Mystic River ***Mystic River*** - As Alewife, controlled by Eherhart Bay. Used for pleasure craft. Has major dock facilities below dam. 2. ***Lower Charles*** - Controlled by a dam which creates Back Bay; used for rowing, pleasure boating; heavily used banks (pedestrian) 3. ***Inner Harbour*** - Receives stormwater, borders all downtown, harbour area, airport; fully channelized, built-up shores; heavy shipping traffic 4. ***Dorchester Bay*** - Fully developed shoreline, quite a few beaches, pleasure boating 5. ***NePonset Estuary*** - Urban stream, tidal, marshlands at areas to outlet
Chicago				• Mainstream • Calumet • O'Hare • Des Plaines	225,330 (total area)	57,705 23,517 6,838 9,065	2,039,000 278,000 7,000 198,000 (population equivalent)		• Lake Michigan • Chicagoland Waterway System: - Des Plaines River - Chicago Sanitary and Ship Canal - Little Calumet River - Higgins Creek

Table 1

<table>
<tr><th rowspan="4">Municipality</th><th colspan="10">Characteristics</th></tr>
<tr><th colspan="3">Climatology</th><th colspan="6">Area Characteristics</th><th rowspan="3">Receiving Waters</th></tr>
<tr><th rowspan="2">No. Rain Events</th><th rowspan="2">Total Volume (mm)</th><th rowspan="2">Comments</th><th rowspan="2">Major Sub-basin</th><th colspan="3">Area (hectares)</th><th rowspan="2">Comments</th></tr>
<tr><th>Total</th><th>Combined</th><th>Population</th></tr>
<tr><td colspan="11">U S A</td></tr>
<tr><td>Cincinnati</td><td>122</td><td>1,031</td><td>• Winter (October-March)/ Summer (April-September) precipitation frequency and volumes similar
• Generally low intensity long duration (>6 hrs) events
• Intense summer thunderstorms</td><td>1. Mill Creek
2. Little Miami
3. Muddy Creek</td><td>29,526
12,432
5,439</td><td>12,173
3,626
3,367</td><td>492,441 (1986)
167,080 (1986)
92,687 (1986)</td><td>• Rolling terrain rising approximately 500 ft. from Ohio River to inland plateau
• Ohio River and some tributaries experience typical 4 m change in stage</td><td>• Mill Creek - urban stream channelized in portions of lower reaches; receives stormwater, WWTP effluents CSO and leachates
• Duck Creek - heavily channelized urban stream
• Little Miami - state resource water
• Rapid Run Creek - urban streams heavily impacted by sewer construction (habitat) no base flow in upper reaches
• Ohio River - major waterway (~590 cms summer flows)</td></tr>
<tr><td>Detroit</td><td>NA</td><td>785mm average annual</td><td>• Winter (Dec-Mar), lows -3°C Summer (May-Aug), highs 24°C Generally low intensity, long duration events. Some summer thunderstorms</td><td>Eight major districts: Rouge, Hubbell, East Jefferson, Southfield, Baby Creek, Central, Conner Creek, Fox Creek</td><td>36,260 City of Detroit</td><td></td><td>4.3 million (Detroit City) 4.3 million (Metropolitan area)</td><td>• Terrain is generally flat, rising about 27m in 16 km</td><td>• Rouge River
• Detroit River</td></tr>
<tr><td>Fall River</td><td></td><td></td><td>• Thunderstorms</td><td>• Taunton River
• Mount Hope Bay
• Quequechan River</td><td>2,800</td><td></td><td>95,000</td><td>• Wide, rocky ridge sloping to Mount Hope Bay</td><td>• Mount Hope Bay
• Taunton River - some tidal effects
• Quequechan River small lakes above enclosed conduit through city core</td></tr>
<tr><td>Milwaukee</td><td>NA</td><td>760mm average annual rainfall</td><td>• Winter (Oct-Mar), lows -4°C Summer (June-Aug), highs 24°C Generally low intensity, long duration events. Intense summer thunderstorms</td><td></td><td>24,993</td><td></td><td>650,000 (City of Milwaukee) 1.6 million (Metropolitan area)</td><td></td><td>• Lake Michigan
• Milwaukee, Minnickinnic and Menomonee Rivers</td></tr>
<tr><td>Portland, Oregon</td><td>62</td><td>950</td><td>• Winter months generally have more frequent storms and greater rainfall depth.</td><td>• One major basin tributary to Columbia Boulevard WTP
• 42 sub-basins with CSO</td><td>33,400</td><td>11,900</td><td>288,300 (served by combined sewer)</td><td>• Part of the area rests in an alluvial deposit</td><td>• Willamette River, Columbia Slough</td></tr>
</table>

Table 1

Municipality	No. Rain Events	Total Volume (mm)	Climatology Comments	Major Sub-basin	Area (hectares) Total	Area (hectares) Combined	Population	Area Characteristics Comments	Receiving Waters
	Characteristics								
	Climatology			**Area Characteristics**					
U S A									
Providence,RI			• Critical events in summer, spring run-off	• Seekonk River • Providence River • Woonasquatucket R. • Moshassuck River	3,600		150,000	• Rolling terrain sloping to all river valleys	• Seekonk and Providence Rivers - tidal • Woonasquatucket and Moshassuck Rivers - small through dense urban development
San Francisco			• Regular, year round rainfall	City of San Francisco - Peninsula	5,200		680,000	• Rolling, hilly terrain rising to central twin peaks	• Pacific Ocean • Golden Gate • San Francisco Bay
Municipality of Metropolitan Seattle	150	890mm annual average mostly in winter	• Winter (Jan-Feb), lows 5°C Summer (Apr-Sept), highs 18°C		26,305		500,000 (City of Seattle) 2.6 million (Seattle area)		• Lake Washington • Elliot Bay (Puget Sound)

Table 2

Municipality	Infrastructure					
	Collection System			Wastewater Treatment		
	Regulators		Interceptors/Pumping	Type	Capacity (m^3/d)	
	No.	Types			Average	Peak
U S A						
Boston	16 30 41 4 10	• Alewife/Mystic Rivers } • Lower Charles River } overflow weirs • Inner Harbour Basin } tidal gates • Dorchester Bay Basin } sluice gates • NePonset Estuary }	• A total of twenty-nine major interceptors for all sub-basins • Five major pump stations 2 conveying dry weather flows, 3 provide relief during wet weather: Alewife (DWQ); Charlestown (DWQ) and New East Boston Pumping Station (WWQ) in Inner Harbour Basin; Calf Pasture Pumping Station (WWQ) and Union Park St. Pumping Station (WWQ) in Dorchester Bay Basin • Two wastewater treatment facilities: Deer Island (4 tributary headworks) and Nut Island • Six CSO treatment facilities:	Secondary	4,536,000	
Chicago	343 95	• intercepted CSO outfalls • to be captured by Tunnel and Reservoir Plan (TARP)	• Mainstream tunnel interceptor system (50 km long)(255 CSO outfalls) • Calumet tunnel interceptor system (14.7 km long)(76 CSO outfalls) • O'Hare tunnel interceptor system (10.6 km long)(27 CSO outfalls) • Des Plaines tunnel interceptor (5.6 km long)(80 CSO outfalls) • Three pumping stations (Mainstream, Calumet, O'Brien)	MWRDGC's Stickney WRP Calumet WRP ***All Advanced Secondary*** James C. Kirie Water Reclamation Plant MWRDGC's Stickney WRP	6,146,280 (total treatment capacity)	
Cincinnati						
Mill Creek	158	• Drop grate with connecting pipe • Brown & Brown (float/gate)	• Six major interceptors; one interceptor pump station with WWTP • Mill Creek regulators affected by Ohio River backwater • Five major interceptors; one interceptor pump station plus WWTP	Secondary	1,858,636	5,148,158
Little Miami	59	• Drop grate with connecting pipe • Brown & Brown • Sluice gates	• Little Miami regulators affected by Ohio River backwater • Four major interceptors • Six interceptor pump stations plus WWTP	Secondary	514,816	859,288
Muddy Creek	20	• Drop grate with connecting pipe	• Ohio River affects regulators along shoreline interceptors	Secondary	170,344	329,331
Detroit	76 45 22 2 2	• overflow points • float controlled regulators • diversion weirs • sluice gates • orifice regulators • Brown & Brown, McNulty Engineering	• 4,720 km of sewers • WWTP	Secondary	3,028,328	
Fall River	19	• weirs	• Waterfront interceptor • Quequechan Valley interceptor	1 secondary plant	189,271	
Milwaukee			• South Shore WWTP • Jones Island WWTP	Secondary Secondary	1,324,894 946,353	
Portland, Oregon	55	• Diversion dam, drop structure	• Eight major interceptors plus 2 tunnels • Five major pump stations	CBWTP is a secondary facility using conventional activated sludge	608,000	1,140,000 (primary)

Table 2

Municipality	Infrastructure					
	Collection System			Wastewater Treatment		
	Regulators		Interceptors/Pumping	Type	Capacity (m^3/d)	
	No.	Types			Average	Peak
U S A						
Providence, RI	65		• Blackstone Valley interceptor • Moshassuck Trunk • Pleasant Valley Trunk • Allens Avenue interceptor	2 secondary plants	302,833 832,790	
San Francisco	41		• Crosstown tunnel • Four treatment plants • Four additional facilities • Four pump stations	2 secondary plants 2 wet weather primary facilities Southeast: - secondary - wet weather North Point: - primary wet weather Richmond-Sunset: - primary Oceanside: - secondary - primary wet weather	 321,760 794,936 567,812 83,279 386,112 1,525,520	
Municipality of Metropolitan Seattle	19	• In-line sluice gates	• 160 km pipe from 300mm to 40m • 13 pump stations • West Point • Renton	 Secondary Secondary		

Table 3

Municipality	Institutional: Jurisdiction	Institutional: Funding	Issues: Flooding	Issues: Beach	Issues: Public Health	Issues: Water Quality	Issues: Other
U S A							
Boston	• The Massachusetts Water Resources Authority owns and operates the Trunk Sewer system, pump stations, CSO facilities and the treatment plants • The Boston Water and Sewage Commission operates some of the regulators	• Funding is by EPA grant • Massachusetts DEP funding • User fee levees	Some localized basement flooding	Dorchester Bay beaches	Public health concerns re CSO inputs into all area waterways	Concern for all area waterways, particularly for bacteria and floatables	• Aesthetics • Local fishing • General Massachusetts Bay concerns
Chicago	• Metropolitan Water Reclamation District of Greater Chicago (MWRDGC)	• USEPA Clean Water Act grant • Illinois EPA funding • MWRDGC	Flood control to be under Chicagoland Underflow Plan (CUP) Basement flooding		Pollution to area waterways Contaminated backflows to Lake Michigan	Concern for chemical water quality	• Aquatic life and habitat
Cincinnati	• Cincinnati Metropolitan Sewer District owns and operates trunks, pumping stations, regulators, interceptors and WPCPs	• Funded through utility rates	Some localized basement flooding	No beach issues	Public health concerns regarding CSO inputs into small urban streams	Ohio EPA concerned regarding CSO impacts on all urban streams	• Odour complaints • Aesthetics impacts from CSO debris
Detroit	• Detroit Water & Sewerage Department owns and operates trunks, pumping stations, sewers, regulators, interceptors and sewage treatment plants within the City of Detroit	• 90% EPA • 10% DWSD • Research and demonstration project		None		Lake Erie Report identified Detroit CSO as a major contributor to pollution of Lake Erie	
Fall River	• The CSO Program is directed by the City of Fall River Sewer Commission who also manage the treatment plant	• Some funding by state grant, most funding under negotiation	Some street ponding	No beach issues	Shellfishing closures.	Bacteria	• Aesthetics • Fisheries
Milwaukee	• Milwaukee Metropolitan Sewerage District owns and operates trunks, pumping stations, sewers, regulators, interceptors and sewage treatment plants	• 1/3 EPA • 1/3 State • 1/3 MMSD	Some localized flooding during heavy rains	Lake Michigan beaches	Ordered to abate CSO by Federal District Court. Court expanded common law of nuisance to remedy a pollution problem.	Dissolved oxygen impacts in Milwaukee River and fecal coliform concentrations following wet weather discharges	
Portland, Oregon	• City jurisdiction within urban service area boundary	• Utility rates	• None noted	No beach areas but concern over water recreation	Public health concern in relation to recreation	Water quality in Columbia Slough major issue. Concern over aquatic habitat	• Aesthetics concern in core area
Providence, R.I.	• The CSO program is directed by the Narragansett Bay Commission who manage the treatment plants and trunk sewer system.	• Some funding by state grant, most funding under negotiation	Not a major issue	No beach issues	Shellfishing closures.	Bacteria	• Aesthetics • Fisheries

Table 3

Municipality	Institutional		Issues				
	Jurisdiction	Funding	Flooding	Beach	Public Health	Water Quality	Other
U S A							
San Francisco	• The Clean Water Program is managed by the Clean Water Enterprise, which is the largest division in the City of San Francisco Public Works Department. The Bureau of Water Pollution Control is also involved.	• Funded by a combination of Federal and State grants and local sewer revenue bonds	Not a major issue	Water contact recreation and beach use available	Concern about beach and shellfishing closures.	Bacteria, floatables, oil and grease	• Aesthetics • Fisheries
Municipality of Metropolitan Seattle	• Metro owns and operates large trunks, pumping stations, regulators, interceptors and sewage treatment plants	• local	NA	Lake Washington & Elliot Bay beaches		Contaminated sediments in Elliot Bay	

Table 4

Municipality	CSO Control Objectives	Technologies: Flow Reduction	Storage	Treatment	Operation	Other
USA						
Boston	• Will follow EPA guidelines of 4 overflows per year	• Some sewer separation • I/I control • Sewer rehabilitation	• Present scheme identified tunnels and near surface storage • Some additional separation • Tunnels presently under review and will probable not be used	• The extensive expansion of the Deer Island Treatment Plant as part of the Boston Harbor clean up includes CSO treatment to the primary level	• CSO mitigation intended to capture all but four overflows by storage and transport to treatment	
Chicago	• Eliminate CSO contaminated waterway back-flows to Lake Michigan • Clean-up of inland waterways • Provide an outlet for flood waters (reduce basement flooding)	• Upgrading of local combined sewer systems	• Local open surface reservoir storage • Relief tunnels • 174.4 km tunnels in phase 1 of TARP	• Three aerated reservoirs	• Municipal CSO outfalls are connected to TARP phase 1 tunnels. CSO then pumped to 3 existing treatment plants • Flood relief via 33.6 km of relief tunnel, conveyed to aerated reservoirs	
Cincinnati	• Original objective one overflow per year with all captured flows receiving secondary treatment • Objectives are now being revised in light of new US EPA policies. New objectives will be stream specific	• Limited (spot) road drainage separation • RDI/I programs for roof leader removal in separated areas	• Major tunnel storage schemes • Some use of regional tank storage	• Expansion of central treatment • One satellite facility at Daly Road (Mill Creek basin)	• Increase in interceptor flow capture through weir and orifice adjustments	
Detroit	• Minimize CSO by maximizing in-system storage		• 567,812 m^3 in-system storage available through remote control of regulators and pump stations • additional 113,562 m^3 obtained by adding inflatable dams and in-pipe control gates		• Operators from a centralized control room, manually control pump stations and regulators by monitoring weather radar, a rain gauge network and sewer system levels	• Before program, a 12.7mm rainfall would cause a CSO. With control, now able to capture up to 34.3mm rainfall
Fall River	• Reduce overflows to meet Massachusetts DEP and USEPA regulations • Provide secondary treatment as much as is possible	• Some I/I work	• Tunnel storage and conveyance	• Additional grit facilities	• All CSO captured into tunnel • One emergency overflow	

Table 4

Municipality	CSO Control Objectives	Technologies: Flow Reduction	Technologies: Storage	Technologies: Treatment	Technologies: Operation	Technologies: Other
U S A						
Milwaukee	• Reduce overflows from an average of 50 per year to 2 per year	• Reduce infiltration where cost effective	• 27.4 km of deep tunnel providing 1,208,813 m^3 of storage	• Expanded South Shore plant 907,200-1,360,800 m^3/d • Expanded Jones Island plant 680,400-1,134,000 m^3/d	• Computerized system automatically diverts wet weather flow to deep tunnels through 17 drop structures. Automatic de-watering of tunnels following wet weather events	• Constructed 177,171 m^3 detention tank to intercept overflow from 231 ha combined sewer area
Portland, Oregon	• Columbia Slough 3 overflows/10 years • Willamette River 96% overflow volume reduction	• Use infiltration sumps for flow reduction • Selected separation including removal of piped streams	• Tunnel conveyance and storage • Regional tank storage	• Wet weather treatment facilities		• Stormwater treatment through wetlands
Providence, R.I.	• Reduce overflows to meet USEPA and RIDEM regulations • Provide secondary treatment as much as is possible	NA	• Major tunnel, some tank storage	• No additional facilities	• All CSO captured into tunnel • 3 emergency overflows	
San Francisco	• Reduce overflows from 80 to 8 or less per annum • Captured flows receive secondary or primary treatment depending on location	NA	• Tunnel storage, conveyance conduit, consolidation conduit, various CSO facilities	• Plants increased as defined earlier to treat CSO	• CSO captured to limit system overflows at treatment plants	
Municipality of Metropolitan Seattle	• Use in-system storage to minimize CSO • Study recommended reduction of overflows by 75% to 2 per year through partial separation of 3,642 ha				• Computerized system automatically opens and closes regulators and operates pump stations based on real-time simulation model	

Table 5

Municipality	Implementation		
	Cost	Period	Comments
U S A			
Boston	Present cost $1,100 million (1990)		• Due to high cost MWRA has commissioned new studies. Flows have been revisited.
Chicago	$3.7 billion (1991)	1986 - present	• System almost completely operational
Cincinnati	$1.9 billion (1991)	> 40 years	• Due to high cost and emerging regulatory requirements Cincinnati MSD has commissioned new planning study which is revisiting original plan
Detroit	$4 million (1971)	2 years	• Some parts of operation abandoned because operators were too busy to take action during rain events. Automatic operation is necessary.
Fall River	$100 million	20 - 25 years ±	• Design pending
Milwaukee	$1.6 - $1.8 billion	15 years	• Work essentially complete, system operating
Portland, Oregon	$950 million (1993)	Completion by 2013	
Providence, R.I.	$400 million	20 - 25 years ±	• Tunnel 1st phase pre-design underway
San Francisco	$340 million	20 - 25 years ±	• System in place
Municipality of Metropolitan Seattle	Sewer separation estimated at $175 million	No time schedule set	• In-system storage in operation since 1973. Sewer system model development continued through 1988 and data was integrated with the real-time SCADA system

2.4 OVERVIEW OF SELECTED TECHNOLOGIES

2.4.1 CSO Control Approaches - Planning

For the purposes of this review, planning refers to the sequence of activities leading to decisions on a control program. Different approaches to establishing a CSO control plan can be followed. The work plan for CSO control should be flexible allowing for modifications as the study proceeds. The following discussion reviews approaches elsewhere that reinforce our approach or might suggest modifications.

A good guide for CSO planning can be found in the WPCF Manual of Practice on Combined Sewer Overflow Pollution Abatement (WPCF, 1989). This document provides chapters on Choosing the Approach for Plan Development and Plan Development and Selection.

> "In many cases, it will be advantageous to approach plan development in phases with flexibility to alter course based on the findings of each phase. Defining plan objectives...is an essential step."

The establishment of plan objectives is inseparable from establishing the approach of carrying out the plan. Plan objectives are based on the environmental setting, regulatory setting, infrastructure setting and socio-political setting.

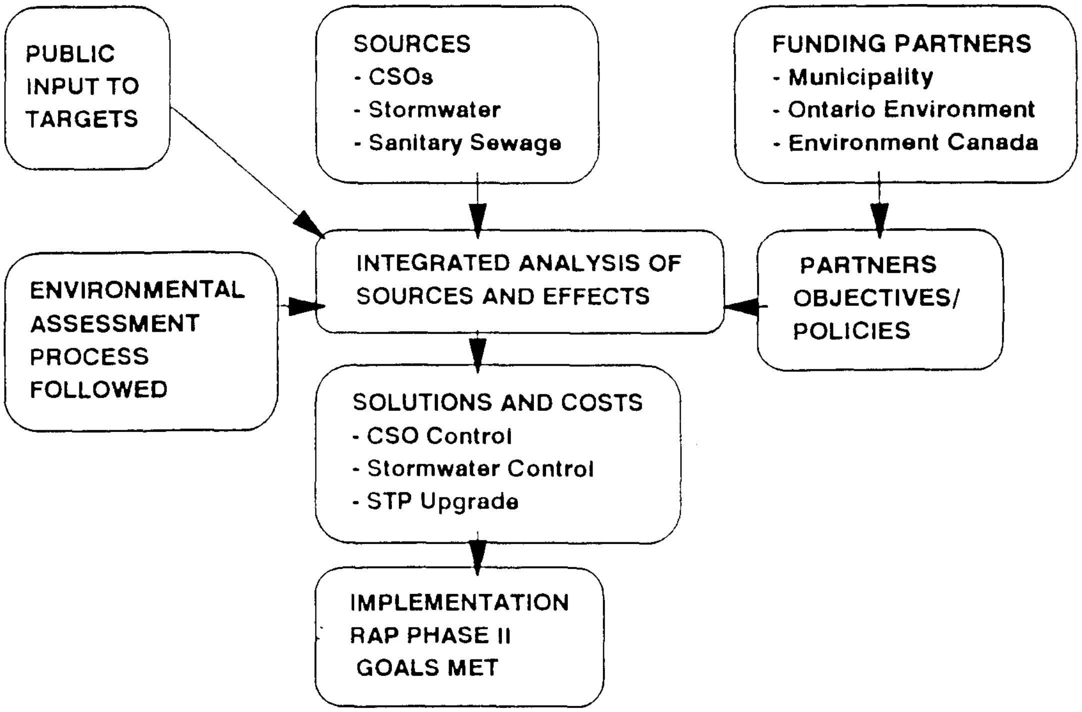
The environmental setting refers to water body characterization, aquatic life characterization, meterological conditions, and identifying constraints to improvements. The plan development and results must conform with the regulatory setting. Regulations may affect the plan process and involvement of participants, determine fixed objectives for control, or mandate receiving water standards to be met. The infrastructure elements (collection system, treatment system, related infrastructure plans such as road reconstruction) and their condition can affect plan development. The socio-political setting affects the plan and its direction and the degree of public involvement in the program.

Ontario has funded pollution control plans for several years, and recently identified that they would be required under a draft CSO control policy (described below in Section 3). In keeping with the trend towards pollution prevention as well as control, these are now known as Pollution Prevention and Control Plans (PPCP). The draft CSO policy has this to say about the PPCPs:

Every municipality with combined sewer areas will be required to develop a Pollution Prevention and Control Plan with the following components.

- The PPCP shall consist of all practical measures to eliminate dry-weather overflows and minimize wet weather overflows.
- The PPCP shall contain an implementation plan with cost estimates and schedule.
- The PPCP shall contain a thorough documentation of the combined sewer system.

POLLUTION CONTROL PLANNING PROCESS



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- Through the PPCP each municipality shall demonstrate that a combined sewer system, including the regulators, and associated treatment facilities are adequate for the transmission and treatment of all dry weather flows for the design population. Where elements of the sewer system or the treatment facility are found to have inadequate capacity for the above mentioned purpose, additional sanitary servicing should be curtailed and the municipality would upgrade the inadequate facilities.
- The PPCP shall include pollution prevention and water efficiency programs, preferably through By-laws, for the reduction of extraneous flows (infiltration and inflow).
- The PPCP shall establish the baseline annual CSO volume and frequency which is defined as the annual volume and frequency estimated to occur based upon the existing sewer system and the historical rainfall record.

Figure 1 indicates the organization of a PPCP. Recently, Pollution Control Plans have received joint funding from the Province and Environment Canada's Great Lakes Cleanup Fund for municipalities in areas of concern on the Great Lakes (Weatherbe and Sherbin, 1993). (Areas of concern are designated by the Great Lakes Water Quality Board of the International Joint Commission as locations that have impaired water uses and, under the terms of the Canada-U.S. Great Lakes Water Quality Agreement, require remedial action plans (RAPs) to be developed).

Figure 1 Pollution Control Planning Process followed in Ontario

In Ontario, combined sewer control projects are subject to the provincial environmental assessment process. Under the Class Environmental Assessment for Municipal Water and Wastewater Projects (Municipal Engineers Association, June, 1993), Pollution Control Plans are considered to be Master Plans. If a Master Plan is developed, then the environmental assessment process is significantly simplified and shortened for subsequent projects that implement the Plan. The Plan development process must incorporate the **five key principles of successful environmental planning** identified in Ontario's Environmental Assessment Act, as follows:

1. Consultation with affected parties early on, such that the planning process is a cooperative venture.
2. Consideration of a reasonable range of alternatives.
3. Identification and consideration of the effects of each alternative on all aspects of the environment.
4. Systematic evaluation of alternatives in terms of their advantages and disadvantages, to determine their net environmental effects.
5. Provision of clear and complete documentation of the planning process followed, to allow traceability of decision-making with respect to the project.

2.4.2 CSO Control Approaches - Objectives

It is difficult to separate the consideration of the control technologies from the performance objectives. Comprehensive planning studies allow the two to be considered concurrently.

The importance of comprehensive planning in developing a control strategy for combined sewer overflow control must be emphasized. In order to design control structures for combined sewer systems, it is first necessary to understand the operation of the elements. The conveyance capacity of sewer elements may be unevenly distributed, with bottlenecks causing unnecessary overflows or basement flooding. These issues require the application of a hydraulic model of the system in the development of a control program.

In addition, the complex and often conflicting objectives must be balanced in a cost effective manner. For example, the objective of flood relief is satisfied by releasing more flows, which directly conflicts with the environmental objective of reducing overflows. The location of storage and treatment elements can affect the costs and performance significantly. The technical and economic compromises are best done with the involvement of the interest groups represented by the levels of government and the public. The selection of appropriate technology for each municipality is dependent on local environmental conditions.

The resolution of local water pollution problems often requires consideration of controls for stormwater and partially treated sanitary sewage. The environmental and economic objectives considered together, with the aid of hydraulic models can indicate the most cost effective combination of controls.

In the almost complete absence of Canadian national or provincial regulatory objectives for CSO control (see sections following dealing with regulations) performance objectives for combined sewer control are usually derived locally. Examples of performance objectives used in North American cities include:

Reduction of overflows to a specified number of events per year, such as 1 or 4 events as is often used in Ontario studies

Achievement of a percentage volumetric control, defined, for example, as 90% of the combined sewage volume must receive adequate treatment.

Pollutant load reduction, applicable to a specific pollutants that are problems locally

Requirement that overflows receive specific minimum treatment, such as removal of coarse solids and floatable materials through the use of coarse screening, or use of disinfection.

Meeting an objective in the receiving water, such as a bacterial health standard at a bathing beach, or phosphorous levels in a lake.

Achievement of a degree of protection from basement flooding, usually defined as a return frequency associated with rainfall events, such as a two year to ten year storm.

Sewer separation as an objective in itself.

In this context, it is difficult to establish an overall environmental objective for CSO control. Indeed, as described in the regulatory section, in Canada, the tendency has been to carry out comprehensive studies, and accept the compromises that are arrived at locally. The technologies that are followed locally depend on the objective set and priorities established locally, and the available funding. The performance of the overall system then becomes paramount in the control strategy, not individual elements.

2.4.3 CSO Treatment Options

Introduction

Various unit operations have been demonstrated as potential CSO treatment options including dissolved air flotation, dual media high rate filtration and high gradient magnetic separation. However, for various reasons, these operations are not amenable to the intermittent, heavy shock loadings typical of CSO flows. Practically, the only operations with full scale application for high rate CSO treatment are screening, sedimentation, vortex solids separation, combined vortex separation/storage, and disinfection. The following discussion reviews North American and European operational experiences with these processes (sedimentation

2.4.3 *CSO Treatment Options*

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Screening

Screen systems have been used as the sole form of treatment or as pretreatment to enhance or protect downstream treatment operations. Screens are classified according to opening size, as follows:

• Bar screens	> 1 inch openings
• Coarse screens	3/16 - 1 inch openings
• Fine screens	1/250 - 3/16 inch openings
• Micro screens	< 1/250 inch openings

The first two types are generally used for pretreatment while fine and micro screens are typically employed at WWTP or centralized CSO treatment facilities. Solids removal occurs by two mechanisms: straining by the screen and filtering by the mat deposited by inlet straining.

For remote satellite operations, mechanical coarse screening is the most practical screening method. All screens require cleaning and are susceptible to clogging, tearing and mechanical failure, particularly as the design removal size is decreased (WPCF, 1989). Capital costs for recent screening facilities have ranged from $10,000 to $15,000 per USMGD (significantly higher costs have also been reported). Annual operating costs are generally $0.10 to 0.25 per 1,000 USG treated.

In Utoy, Atlanta, five separate screening/disinfection facilities were recently installed. The objective is to remove floatables and other solids larger than 3/8" diameter and reduce fecal coliforms. Coarse screening is the first operation, and uses front return climber type 1.5" bar screens. Fine, travelling water screens are employed for secondary screening. Flows in excess of design flows bypass screening through a baffled overflow to capture floatables. Screened flows are finally disinfected via chlorination. Facility design is such that screened flows can be deflected into deep tunnel storage at a later date. Average treatment costs are about $12,000 per USMGD.

Sieves

Rotating drum screens or sieves are used in CSO control programs to treat overflow from CSO storage tanks. Preventing the escape of aesthetically unpleasant floatables such as condoms, syringes and vials from CSO tanks is a relatively new application for this technology.

Slotted aperture openings 2-4 mm in width capture floatables on the surface of the rotating drum, which is cleaned automatically by a brush system when headloss across the unit reaches a predetermined level. After tank drawdown, a tipping flusher clears accumulated floatable material on the floor of the sieve chamber into the foul sewer draining to the downstream WWTP. Typical design capacity of a 1.5 m diameter, 5 m long drum is about 30 USMGD for axial discharge units. Large aperture, transverse discharge sieves of the same length can convey flows up to 130 USMGD. Emergency bypass troughs are usually incorporated in most designs.

The first U.S. installation of rotary sieves has been proposed for a major overflow in Hartford, Connecticut. Design flows for that facility are 115 to 140 USMGD. The estimated footprint of the \$0.5 million facility (1994 US dollars) is 150 m^2. Operational experience is rather limited because sieves have only been used in CSO control since 1992. A 12 month German demonstration study reported high removals of unsightly floatables (condoms, plastics strips and cigarette butts) and a "filtering" effect of the sieve due to the matting of toilet paper on the drum surface, resulting in much finer solids capture. Sieves in general will accept high hydraulic surficial loadings, giving rise to very compact facilities. Disadvantages of sieve systems are the need for external power and regular maintenance.

Vortex Technologies

Three types of vortex separators are in use today for CSO control programs. These are the "Swirl Concentrator" developed by the U.S. EPA; the "Fluidsep" developed by Dr. Brombach in Germany; and the "Storm King" developed in the U.K. by Hydro Research.

Swirl Experience

All Swirl concentrator installations in the US (of which there are 19 having a total design of flow capacity of 888 USMGD) were designed as stand-alone, off-line devices, with the exception of one. Several demonstration and full-scale Swirl facilities have achieved good solids removals during first-flush but none have achieved substantial removals when operated at design loadings (typically 50,000 - 65,000 USG/d.sq.ft.). Only oversized units have shown good removal. These results indicate that EPA's design handbook for Swirl concentrators prescribes vessel sizes and dimensions that are in general adequate.

At the Decatur, Illinois Swirl concentrator installation, pollutant removals for TSS and BOD_5 were calculated over a range of flows and for three intervals, namely, the entire storm, the duration of the storm less first flush, and first flush only. As seen in the following table, performance efficiency is strongly related to flow magnitude (Category B results would be typical for the intended process scheme, since first-flush is to be captured in retention storage with the remainder directed to the Swirl). The data show that the US Swirl is capable of substantial removal of first-flush contaminants but removal during other intervals is greatly reduced. As well, when discharge exceeds about 40% of design flow, performance declines significantly.

McKinley Avenue First Flush Treatment Facility: Decatur, Illinois. Summary of Swirl Concentrator Evaluation (7/26/87 - 9/29/87)			
Event Date	**Average Flow MGD**	**TSS (%)**	**BOD (%)**
A. Mass Pollutant Removal Effectiveness - Entire Storm			
8/08/87	10.1	33.1	44.4
9/16/87	13.1	16.4	42.7
9/29/87	24.0	23.2	NA
7/26/87	31.4	22.9	13.1
B. Mass Pollutant Removal Effectiveness - Exclude First Flush			
8/08/87	9.3	36.7	44.8
9/16/87	15.0	33.9	41.1
9/29/87	26.4	5.7	9.3
7/26/87	32.4	5.2	0.1
C. Mass Pollutant Removal Effectiveness - Only First Flush			
8/08/87	9.0	43.6	43.8
9/16/87	9.8	80.6	45.0
9/29/87	10.4	32.6	43.9
7/26/87	26.5	56.4	34.2

Costs for two US Swirl installations (Toledo and Washington) were $22,000/USMGD and $41,000/USMGD (1994 US dollars).

Storm King Experience

As of 1992, the only full-scale North American Storm King installation was the 3 unit facility in Gander, Newfoundland, which is used in lieu of primary clarification. The Storm King was demonstrated at Wards Island WWTP in New York City but at average surficial loadings of 22,000 USG/d.sq.ft. achieved only minimal treatment. When loadings were reduced to 3,000 to 7,000 USG/d.sq.ft, TSS and phosphorus removals exceeding 85% were reported (NN Hydroynamic, 1990).

Numerous recent Storm King installations exist in the U.K. Diameters are usually 4 - 10 foot range. Peak flows in larger units range from 1-100 USMDG with corresponding surficial loadings ranging from 10,000 to 30,000 USG/d.sq.ft. At one facility, TSS and COD removals were only 6% and 7%, respectively, at a loading of 2,200 USG/d.sq.ft. Performance objectives across the U.K. ranged from an equivalent cost effective alternative to 0.4" bar screen up to meeting effluent discharge requirements of 100 mg/L BOD and 60 mg/L SS (CH2M Hill Engineering Ltd., 1991).

Fluidsep Experience

As of 1992, the new Fluidsep solids separator design has been adopted for 15 U.S. and European CSO control facilities totalling 1.5 USBGD in design capacity. Many of these facilities involve the Fluidsep coupled with conventional storage.

In 1987, the first prototype Fluidsep facility was installed in Tengen, Germany. Over four years, the operational reliability and removal effectiveness of the two 10 foot diameter Fluidsep units was evaluated. Total design peak flow is 19.4 USMGD (one year return period storm event). Design hydraulic loading for each unit is 144,000 USG/d.sq.ft. (all of the US Fluidsep and US Swirl installations have design loadings of 30,000 - 90,000 USG/d.sq.ft.).

Maximum allowable underflow rate is 0.81 USMGD; underflow is throttled by vortex valves and discharged to a trunk sewer to centralized WWTP. Average dry weather flow is 0.19 USMGD.

It was determined that 52% of annual inflow was captured (in the underflow) and diverted to WWTP, with the remainder overflowing to a nearby stream. In four years of operation, 80 CSO events occurred but no untreated bypasses, failures or blockages were reported. The Fluidsep configuration also generated about 6,400 ft^3 of storage during wet weather upstream of the separator (ie. in-line) and within the separator vessel.

With respect to removal efficiency, settleable solids removal ranged from 29% at an average loading of 30,000 USG/d.sq.ft. to 97% at average loadings of 8,500 USG/d.sq.ft. Underflow settleable solids concentrations were, on average, about twice those of the overflow. Underflow/overflow solids ratios at peak flow were just under the average. Model simulations over the long term predicted wet weather solids and COD removals of 70-78%. The facility's success was attributed to a combination of the high ratios of flow interception, in-system storage, and the Fluidsep's treatment capacity.

Two new evaluations of US Fluidsep installations are currently underway in Decatur, Ill and Saginaw, MI (Pisano and Brombach, 1993).

Summary of Vortex Removal, Efficiency & Costs

Depending on hydraulic loading, vortex separators can provide treatment ranging from "preliminary" (removal of floatables, heavy grit, and 10-15% TSS) to "primary (removal of floatables, grit, and 30-50% TSS). Preliminary treatment can still be achieved by stand alone separators at loadings of 40,000 - 80,000 USG/d.sq.ft.

Generally speaking, properly designed vortex separators can remove 15-35% suspended solids, with higher removals during "first flush" periods. Solids removal decreases with increasing flow rate and increases with more "gritty" particle grain distributions. Removal of particles with settling velocities less than 0.1 cm/sec is minimal.

Combined Vortex Separator with Near-Surface Storage

Vortex separator with near surface storage are being applied in tandem. In most configurations, flows are pretreated via vortex separators prior to detention storage. Vortex underflows are directed to retention storage or to centralized WWTP, if capacity exists. This arrangement is believed to reduce maintenance costs associated with cleaning sediment and debris from large storage tanks. Other advantages are the small footprint, and the system's ability to remove visuals floatables and heavy grit from CSO at very high loadings.

The McKinley Avenue facility in Decatur, Illinois uses a combination of a Swirl concentrator with storage. Diverted CSO is first mechanically screened and the first 0.5 USMG or first-flush is directed into a 0.63 USMG first-flush retention tank. Excess flows are diverted to a Swirl Concentrator. Illinois State Standards require secondary treatment of one year, one hour storm first-flush CSOs (first flush volume is defined as CSO with contaminant concentrations greater than long term averages). The 25 foot diameter Swirl discharges treated flow to a nearby creek while underflow drains to a pumping station, where it is pumped either to the interceptor (if capacity available) or to the first flush tank. All flows beyond the Swirl design flow of 40 USMGD are bypassed directly to the creek. First-flush solids removal efficiency was very good (40-80%) but performance dropped at higher flows and when averaged over the entire storm. Total facility costs (including grading, piping and outfalls, screening, etc.) were $51,000 USMGD or about $3,100 per acre of tributary area served (1994 US dollars). Total site area required was 1.5 acres.

Disinfection

Disinfection can remove greater than 99.99% (4 logs) of fecal coliforms in CSOs and should be used in conjunction with some form of upstream solids removal to be cost effective. Disinfection is often the only CSO treatment for extreme flows which have bypassed upstream treatment operations. Liquid chlorination with sodium hypochlorite, with or without dechlorination is the most common approach used. It is recommended that bench studies be undertaken to determine appropriate contact times and dosages. In a Toronto demonstration study for CSO control, four log reduction of fecal coliforms was achieved with a 20 minute contact time and dosage of 3 mg/L chlorine as Cl_2. The some reduction in fecal coliforms was also achieved via UV irradiation at a dose of 65,000 μw-sec/cm^2. No clear preference for either type of disinfection was identified, although capital costs for UV disinfection were higher (Pisano and Zukovs, 1992).

Conventional contact times of 15-30 minutes may not be economical. Contact times may be reduced by employing higher mixing intensities and/or higher chlorine dosages to yield the same CT value. Typical costs for chlorine disinfection of CSOs with 5-10 minute contact time and dosage of 15 ppm are $4,600/USMGD (1994 US dollars). In a comparison of the disinfection effectiveness of a sedimentation/mixing process and vortex separator/storage treatment, it was found that the later provided more efficient CSO disinfection. Fecal coliform reduction of log 4.4 was observed in the vortex process for a seven minute contact time with 8 mg/L chlorine dosage (Ghosh et al., 1992).

STEP FEED OPERATION OF CENTRALIZED TREATMENT PLANTS

Principles

In most instances, the storm flow capacity of centralized WWTPs is limited by the ability of the secondary clarifiers to separate mixed liquor from the clarified effluent. Secondary clarifier capacity has been directly related to mixed liquor settling velocity in addition to clarifier surface area. Sludge settling velocity, in turn, generally increases as the concentration of the sludge decreases. Step feed operation of conventional activated sludge plants takes advantage of this relationship. By introducing influent along the length of the aeration basin, rather than just at the upstream end, the MLSS concentration in the downstream portion of the basin is reduced, resulting in lower solids loadings to the clarifier and higher sludge settling rates. The net effect is increased plant storm capacity.

Step feed operation also improves the plant's operational flexibility and is typically less expensive than adding aeration basins and/or final clarifiers. Some decay in effluent quality may be observed because of reduced contact time between substrate and plant biomass. The amount of solids carry over and ammonia bleedthrough tends to increase as the point of feed addition is moved further down the aeration basin. Other operating parameters which affect solids distribution in the aeration basin and thus the effectiveness of step feed operation include the sludge recycle rate, the influent flow rate and the number of passes in the basin. As recycle rates and influent rates increase, downstream MLSS concentrations increase. On the other hand, increasing the number of passes results in lower downstream MLSS levels and thus more hydraulic capacity.

When considering retrofitting a plant for step feed operation, several factors need to be examined. Hydraulic limitations in feed channels need to be checked under various operational modes and flowrates. The capacity of return activated sludge pumps need to be checked to ensure they can pump the increased sludge volume, resulting from decreased underflow concentrations. Basins without individual passes will require installation of baffles and the aeration system may require modification or expansion (Thompson et al, 1991).

Experience With Step Feed Operations

In a preliminary evaluation of step feed operation of five Ontario WPCPs, estimated storm capacities increased from 22% to 90%, compared to storm capacities observed during conventional operation. The average capacity increase was 57%. These increased capacities correspond to flows ranging from 2.7 to 4.0 times the average design flow, with an average of 3.2 times ADF (Thompson et al, 1991). A potential drawback resulting from these higher flows is the reduction in the plant's hydraulic capacity safety factor. Therefore, the amount of available capacity for step feed operation will be specific for each plant.

Step feed operation appears to be a cost-effective means of increasing treatment capacity. Depending on the modifications required, it is estimated that installation costs would range from virtually nothing to $1,400/USMGD (1994 US dollars). Moderate modifications, for example entailing conversion of complete mix tanks to tanks in series would cost between $200 and $900/USMGD. It should be emphasized that these unit costs were based on a limited investigation and should be used only for order of magnitude cost estimates.

2.4.4 Flow Monitoring

Since 1972 strong emphasis has been placed on sewer rehabilitation to reduce the hydraulic loads placed on treatment plants from excessive infiltration and inflow (I/I). The documentation of the non-existence or possible existence of excessive I/I in each sewer system tributary to a treatment works is required under The Water Pollution Control Act Amendments (Public Law 92-500, October 18, 1972) and the Rules and Regulations for Sewer Evaluation and Rehabilitation (40 CFR35.927) in the U.S.[1]

Flow monitoring as an investigative technique is an effective way to evaluate the quantity of flow passing a critical point in the system and serves to determine and isolate areas where I/I exists. Volumes monitored consist of baseflow infiltration and inflow (I/I) and once separated and quantified, can be used in various analyses pertaining to the integrity, capacity characteristics and variations of flow components in the system. All I/I analyses from flow monitoring data should recognize the impact of rainfall events, groundwater levels, antecedent soil and weather conditions and monitoring schedules on the overall component flows. In order to extrapolate data to un-monitored catchments, sites should be selected where possible, to represent typical conditions. Consider land use (residential, industrial, commercial or institutional), drainage/catchment areas and population.

Providing the flow data collected at each site represents the hydraulic reality of that site (i.e. there is a high level of confidence in the equipment and the data), a meaningful flow balance can determine sections where significant quantities of wastewater flows are lost or gained. The use of high density monitoring will quickly eliminate any catchments that do not exhibit high I/I from future study.

The most comprehensive and valuable results are obtained by installing, operating and maintaining/downloading a network of monitoring stations over a period of several months to capture the system operation in all modes and under as many varying conditions as possible.

[1] EPA Handbook - Sewer System Infrastructure Analysis and Rehabilitation, United States Environmental Protection Agency

The field monitoring program for the Boston Sewer and Water Commission for CSOs was conducted during dry weather as well as following wet weather events. The prime focus was to collect real time data from the flow monitoring to provide the necessary calibration and verification data to develop a mathematical model of the system.

The continuous flow metering over the course of the 2 year study within the CSO regulator systems was conducted using Montedero-Whitney Q-Loggers. The meters were equipped with MVP depth and velocity sensing probes which were upgraded to the Sonicstar probes further into the project. Because many of the regulator systems were expected to react very quickly to rainfall and consequently discharge an overflow, the flow meters were set up to take readings every 5 minutes. It was also important for the meters to be capable of measuring both depth and velocity so that discharge rates could be reported instantaneously. In some cases it was more beneficial to install two meters in one location rather than placing the meters in two individual locations.

The WPCF Manual of Practice discusses flow measurement techniques and the design of a system monitoring program. The following listing excerpts some common techniques with a brief outline of the pros and cons.

Weirs: <u>advantages</u> - low cost, easy to install, easy to obtain flow by standard equations, nomographs etc.
<u>disadvantages</u> - fairly high head loss, must be periodically cleaned, accuracy affected by excessive approach velocities and debris, may be difficult to make accurate manual measurement in sewers because of limited access.

Flumes: <u>advantages</u> - self-cleaning to a certain degree, relatively low head loss, accuracy less affected by approach velocity than weirs, data easily converted to flows using tables or nomographs.
<u>disadvantages</u> - high cost, difficult to install

Dye-dilution/chemical tracers: <u>advantages</u> - no entering of manholes, saves time and provides instantaneous flow data on many sewer sections, independent of sewer site, dimensions, velocities and surcharging.
<u>disadvantages</u> - samples must be analyzed as soon as possible (most dyes decay in sunlight), temperature corrections may be required, instrumentation is expensive, dye is expensive, need at least 100 sewer diameters for dye mixing before sampling.

Velocity: Measured by portable current meters, velocity probes; magnetic, Doppler ultrasonic, a hot-wire anemometer for spot velocity checks or a less satisfactory surface float.

There are automatic flow meters with capabilities to record depth, sense the wastewater surface with a probe, a bubbler sensor, pressure sensors, floats, ultrasonic devices, velocity and capacitance/electronic recorders.

On the practical side, although flow monitoring equipment needs vary widely depending on the size of the discrete sub-system being investigated, typical equipment needs for one such sub-system will include (but is not limited to):

- 2-3 fully automatic recording flow meters
- 1-2 velocity meters
- 1-2 depth sensors
- 2-3 20 to 76cm (8 to 30 in) weirs
- camera and film
- 1-2 tipping bucket rain gauges
- miscellaneous sewer and manhole sampling and access equipment

All flow monitoring will require a regular maintenance program to check batteries, current flow conditions, manual depth at an inspection, note equipment problems, note recorder time versus actual time. This all defines the quality of the final product. Flow monitoring is essential in characterizing wastewater flows that occur in sanitary sewers during both dry and wet weather conditions and in identifying specific areas with the worst I/I problems.

2.4.5 CSO Modelling

The following sections present the principal modelling goals, the major components of a CSO model, a brief description of various modelling packages available and comments on the evaluation and selection process for a modelling system for the City of Winnipeg.

Modelling Objectives

The primary goals of a modelling system includes:

- Creating a user friendly environment for CSO modelling.

- Developing a CSO model that simulates all collection facilities and their interaction.

- To develop a modelling tool that will assist in the development and evaluation of operational strategies and control measures.

- To develop a modelling tool to evaluate the water quality impact of operational strategies and control measures.

Model Components

Models that would meet the City of Winnipeg's needs should include six basic components:

- Hydrology
- Water Quality

- Hydraulics
- Storage/Treatment
- Utilities
- Input/Output

For the City of Winnipeg each of these components are necessary to satisfy the primary modelling goals. A sophisticated modelling system is required to simulate the hydrology/hydraulics with suitable water quality and data management utilities and user friendly input/output interface. A model should facilitate the following activities:

- Generation of inflow hydrographs from drainage basins to be used in the hydraulic model.

- Determination of the hydraulic performance of existing collection facilities using single event analysis (design storms).

- Estimation of CSO frequencies and volumes at any CSO outfall using continuous modelling.

- Evaluation of proposed stormwater and/or CSO control measures (e.g. sewer separation inlet controls, storage) with respect to quantity and quality control.

- Evaluation of operational changes to collection facilities.

- Determination of the static and dynamic operation of the combined sewer system (major collectors, interceptors, weirs, gates, orifices, storage, pump stations, etc.).

- Preparation of model input data and analysis of simulation results.

Advanced features beyond many hydrologic/hydraulic models include:

- Water quality modelling and links to receiving water quality models.

- Links to GIS or equivalent data management system.

- Links to Real Time Control (RTC) systems including SCADA networks.

CSO Model Software

The following are brief descriptions of various modelling packages presently available that possess the level of computational sophistication required for the City of Winnipeg.

A. US EPA's Stormwater Management Model (SWMM)

SWMM is perhaps the best known and most widely used urban drainage model available in the public domain. SWMM consists of separate computational modules, including:

- RUNOFF
- TRANSPORT
- EXTRAN
- STORAGE/TREATMENT
- STATISTICS
- Various utility functions

The SWMM RUNOFF module generates surface runoff and pollutant washoff from user supplied rainfall hyetographs, based on land use, topography, and antecedent conditions. Flows and pollutants can be routed through a simple gutter/pipe network using the non-linear reservoir method. The RUNOFF module can be run in single event or continuous mode (compatible with AES data format). The RUNOFF module transfers simulated hydrographs and pollutographs for all outlets (or inlets if no downstream pipes are presents) through a disk file. This file, a SWMM interface file, can be used as input to any of the other SWMM computational modules.

Routing hydrographs and pollutographs through the sewer system may also be accomplished by the TRANSPORT or EXTRAN modules. In instances where the sewer network contains large conduits, unusually shaped conduits or diversion structures, TRANSPORT and EXTRAN are preferable to the simple routing provided in RUNOFF.

The routing algorithm employed by SWMM TRANSPORT utilizes a kinematic wave approach. As such, backwater effects are not fully modeled, and downstream conditions are assumed to have no effect on upstream computations. Static diversion structures can be represented by three different types of simple flow dividers. Input hydrographs can be entered by the user or read from previously created RUNOFF interface file. TRANSPORT can be run continuously at using a variable computational timestep. Flow hydrographs and pollutographs generated by TRANSPORT can be transferred to other SWMM modules through the SWMM interface file.

SWMM EXTRAN is a fully dynamic flow routing model which employs an explicit finite difference solution to the St. Venant equations. It can simulate looped or dendritic sewer networks, both open channel and surcharged flow, tidal conditions, backwater, flow reversal, simple static flow control structures (e.g. weirs and orifices), pumps, and storage facilities. EXTRAN does not permit simulation of dynamic control structures (e.g. motorized sluice gates or radial gates) that are required in a RTC system. However, there are indirect modelling techniques that can be used to simulate basic dynamic gates as in a RTC system. The explicit solution employed by EXTRAN, restricts the model to very small computational timesteps (often 10 seconds or less) to ensure computational stability. This restriction makes the model unsuitable for long-term simulations.

The STORAGE/TREATMENT block can simulate the routing of flows and pollutants through a dry or wet weather storage/treatment plant containing a number of units or processes.

SWMM's popularity and wide use has resulted in a number of after market software products to be developed to assist in the review of simulation results. Most of these products are related to post processing of the EXTRAN model results.

Recently, software developed by XP-Software has integrated all the EPA SWMM modules into one graphical environmental called XP-SWMM/EXTRAN. XP-SWMM encompasses data entry, run-time graphics and post processing of results in graphical form. The graphical shell maintains an internal database which integrates spatial data including the system connectivity, node location, object types etc. with attribute data entered via graphical dialogues. At the time of model execution, all required data is extracted from the databases and assembled in the format required by the SWMM program. Following a simulation, flow hydrographs and/or the HGL can be reviewed through the graphical interface. XP-SWMM represents a major advancement in the accessibility of SWMM to technical people not usually involved in modelling. XP-SWMM has undertaken improvements to the EPA SWMM modules to correct historical program problems as well as to make the module features consistent (i.e. the number of pollutants). XP-SWMM is proprietary and the source code is not available; however, XP-Software is providing full support services and are capable of customizing or modifying the XP-SWMM modelling system. XP Software have made numerous computational improvements and added new features to all of the SWMM modules. One improvement to TRANSPORT includes the ability to supply a user defined discharge curve where there is a flow split. This is particularly useful for continuous simulation of CSO regulators where the throughflow varies with the inflow rate.

B. QUALHYMO

QUALHYMO was developed in 1983 (A.C. Rowney, C.MacRae) as a planning model for continuous water quality /quantity simulation. Several updates have been carried out. The latest versions will be available in May 1994. The model is presently being marketed by the Technical University of Nova Scotia (TUNS).

The model is capable of continuous simulation of:

i) rainfall/runoff (quantity and/or quality);
ii) detention pond routing;
iii) river routing;

iv) soil freeze-thaw
v) snowmelt and snow removal/disposal; and
iv) evapotranspiration

over a period of indefinite length (limited only by available disk space). This the model can be used on a discrete event or multi-event basis.

Constituents which can be simulated are:

i) stormwater runoff (flow rate and volume);

and optionally none or any combination of,

ii) pollutants exhibiting first order decay, or characteristics simulated using a rating curve, and/or

iii) sediments (in up to 5 size fractions) characterized by discrete particle settling, and/or

iv) instream erosion indices based on cumulative excess boundary shear stress.

It is noted that in principle appropriate pollutant or flow records obtained elsewhere (monitoring or other simulation models) can be routed through ponds or river reaches by the model.

Although the code and details of pollutant generation used in QUALHYMO are particular to this model, the basic algorithms are conceptually related to a number of other models, such as STORM, SWMM and HSPF.

Components are of a physical system which can be simulated are:

i) catchments,
ii) detention ponds,
iii) river reaches which may have junctions and bifurcations (flow splits).

In principle, a system comprised of any combination and any number of the above components can be simulated, provided that:

i) Each component of the system and the system as a whole can be described as 'one-way' or 'non-feedback'.

ii) At most six flow/quality components are simultaneously active, i.e. the model can store up to six flow/quality time series at any one time. A seventh series must overwrite one of the first six series.

iii) At most twelve boundary station shear stress series can be simultaneously active.

Looping networks, or ponds where outflow depends on water depth in the receiving channel, are examples of situations which might not be well represented in this model. A dendritic river network with channels adequately represented by uniform flow conditions will typically be appropriate for application of QUALHYMO.

C. STORM "Storage, Treatment, Overflow, Runoff Model", Corps of Engineers

STORM has been widely used throughout North America in the planning of CSO and stormwater controls. As a continuous water quantity/quality model it is capable of representing the following processes:

- rainfall, snowmelt
- runoff
- dry weather flow
- pollutant accumulation and washoff
- land surface erosion
- treatment rates
- detention storage

STORM is computationally simpler than other CSO model software. This simplicity makes STORM useful in the planning process for the evaluation of various storage/treatment options as the data needs, set up time and computational time is greatly reduced.

STORM is limited as there is no hydraulic simulation, or flow routing, component. As well, only one regulating point or catchment can be simulated at a time. STORM has been customized by others to overcome some of these restrictions by providing the capability of flow routing and linked catchments.

As a public domain model little coordinated development work has been undertaken on STORM and technical support is limited.

D. Wastewater Treatment Plant Models

GPS-X is a dynamic modelling system for the design, operation and control of wastewater treatment plants under dynamic conditions. GPS-X provides access to a comprehensive library of 50 unit processes including:

- Preliminary treatment models
- Primary settler models
- Aerobic biological treatment models
- Anaerobic biological treatment models
- Equalization basins, flow splitters, flow combiners and pumping stations
- Final settlers
- Disinfection (Cl_2)
- Filtration
- Chemical P removal

GPS-X can reproduce the behaviour of virtually any flow scheme and reactor type (e.g. CSTR). In addition, the model can simulate a number of biological system control strategies (e.g. SRT control). The model is a true simulator in that simulations can be viewed in real time and interrupted/restarted to observe the impact of variable changes upon model outputs. The GPS-X can be employed as a single event or continuous model. The program has a powerful integral interface (Screen Oriented Modelling Interface - SOMI) which allows the user to configure the treatment processes on a screen drawing board using icons and through a series of pull down menus to enter all the necessary unit process parameter and physical data. The menuing system also allows control of the simulation including real time interrupts to modify analysis conditions. GPS-X also has data management and presentation capabilities. Supported data management functions include file import, saving and editing. Data presentation capabilities include X-Y plotting of state and input/output variables, scroll (time series) plots of key variables and probability plots (e.g. distribution of effluent pollutant concentrations). The GPS-X also has an integral report generator for producing data tables.

A number of ancillary programs are available for GPS-X to enhance its ease of use, to make it accessible through a PC and to link model state variable and input/output data to observe data (SCADA). The program SIMWORKS is a PC resident "front end" GPS-X. SIMWORKS can be used for model setup, editing and viewing of data files and to access AutoCAD drawings of the treatment plant. SIMWORKS resident on PCS in other parts of the divisional network could be used to readily access GPS-X.

GFX is a program designed to aid in plotting and viewing time series data. GFX was specifically designed for analysis of wastewater treatment plant SCADA data. Implementation of GFX-X would allow simultaneous viewing of simulated and observed data. This capability would directly link the simulation capabilities of GPS-X with the SCADA system. Depending upon the manner of GFX implementation of the network key SCADA stations could be provided with process analysis capability.

E. Runstdy

Calgary based Reid Crowther Consultants have undertaken the development of a hydraulic model called RUNSTDY. RUNSTDY is based on a dynamic wave routing model called UNSTDY. Reid Crowther has developed a Windows type graphical interface for RUNSTDY which includes graphical representation of a collection system as well as dialogue boxes for data input. The interface is able to provide complete review of simulation results. Presently, Reid Crowther is developing a hydrologic module to work with RUNSTDY as an alternative to using SWMM RUNOFF. An unique feature of RUNSTDY is the ability to dynamically view the simulation and make dynamic changes to the network (ie. change gate setting or pumping rate) during a simulation, this provides a RTC feature to the model. Presently, water quality and treatment can not be simulated using RUNSTDY.

RUNSTDY employs a fully implicit finite difference scheme to solve the St. Venant equations. RUNSTDY is suitable for simulating dendritic sewer networks, free surface and surcharged flows, flow reversals, overflow weirs, pumping stations, lateral inflows, control gates, storage facilities, and various discharge and pressure head boundary conditions. Reid Crowther has significantly updated the model for application to their system, including the capabilities to simulate looped sewer networks, multiple downstream boundary conditions, supercritical flows, radial gates, siphon weirs, orifices, pumping station interconnections, and in-line and off-line storage.

To enhance the long-term simulation capability of RUNSTDY, a variable time step has been incorporated. This permits the use of large timesteps (eg. 30 minutes) during dry weather conditions and smaller timesteps (eg. 5 minutes) for use during storm conditions. This greatly reduces the processing time for continuous simulations. Another new feature added to the model is the capability to read and write interface files in the format used by SWMM4. This permits RUNSTDY to route hydrographs generated by the SWMM RUNOFF or TRANSPORT modules.

The main advantage of RUNSTDY is its implicit numerical solution scheme, which reduces computational instabilities and permits the use of much larger computational timesteps. Coupled with the variable timestep capability, RUNSTDY is well suited to long-term continuous simulation or single event analysis.

At this time there are no support services provided for RUNSTDY other than through the consultant.

F. MOUSE - Danish Hydraulic Institute (DHI)

MOUSE (**MO**delling of **U**rban **SE**wers) was released as a commercial product in 1985. It was developed jointly by DHI, the Department of Environmental Engineering at the Technical University of Denmark, and two private Danish companies. In Europe, MOUSE is one of the most widely used tools for the analysis of urban drainage systems. DHI is responsible for the continuous ongoing development, marketing and distribution of MOUSE. MOUSE is available for PCs running DOS or UNIX, and the most common UNIX workstations.

MOUSE comprises a number of computational modules of varying sophistication, permitting the simulation of overland flows, inflows and infiltration, pipe flows, and pollution leads. MOUSE provides the following facilities:

- An interactive menu-based system for data manipulation and program execution;
- A database for catchment and pipe system data;
- A database for rainfall and other time series data;
- Routines for tabulating and graphing input and output data;

- Computational modules for generalized hydrologic modelling (MOUSE-NAM), generalized hydraulic modelling (MOUSE-PIPE), and pollution load modelling (MOUSE-SAMBA).

The hydrologic model (MOUSE-NAM) includes the simulation of both direct surface runoff and indirect runoff (infiltration/inflow) for time varying historical rainstorms.

The hydraulic model (MOUSE-PIPE) simulates unsteady flow through pipes, manholes and hydraulic structures, using the St. Venant equations. The model is well suited to the analysis of complex looped sewer systems including overflows, storage basins and pumping stations. It can also be used to model open-channel networks and tunnel systems. MOUSE-PIPE provides three different hydraulic computation methods. The kinematic wave approach assumes a balance between friction and gravity forces, and thus cannot simulate backwater effects. The diffuse wave approach includes the hydrostatic gradient in its solution, and thus accounts for backwater effects and pressurized flow. The Dynamic wave approach employs the full flow momentum equation, including acceleration forces, providing the capability to simulate even very fast transients within the system. In the existing version of MOUSE, flow control routines will be enhanced to include operation of weirs and sluice gates, and a more flexible operation of pumps.

The pollution transport model (SAMBA) is used for the analysis of pollution loads from a simplified approach to simulate long-term pollution loads from CSOs. A time-area formulation is combined with simplified routing routines for surface runoff and pipe flow.

As MOUSE has been developed using modules it is possible to implement only those modules that are required allowing the level of implementation to evolve as there is a need.

DHI has undertaken the development of a software line for use in the design, implementation and testing of Real Time Control Systems. The first versions of this software was completed in 1992 and further testing and development are underway.

MOUSE and its related computational software modules are proprietary and source code is protected by DHI.

G. WALLRUS-SPIDA - HR Wallingford

WALLRUS is a suite of programs for the design and analysis of dendritic urban drainage systems. The package consists of four different modules which may be purchased either individually, or in various combinations:

- WALLRUS-VIS
- MicroRAT
- Hydrograph Method
- WALLRUS-SIM
- SPIDA

WALLRUS-VIS is a graphical visualizer for the WALLRUS computational modules. The modelled sewer system can be displayed in high resolution colour graphics, and data and model results can be presented for any pipe or node in the system.

MicroRAT is a microcomputer implementation of the modified rational method, which can be used to design pipes and channels in the sewer system. The Hydrograph Method can be used to design pipe and channel sizes in larger sewer systems.

WALLRUS-SIM computes discharges and water levels in existing sewer systems. The program performs best for steep dendritic sewer networks. Accuracy in flatter networks is maintained by using the free surface backwater option. For very flat or looped sewer systems, SPIDA should be used. WALLRUS-SIM has the ability to calculate pollution loading at overflows and outfalls. It is possible to interrupt the simulation at any point and change the simulation time, as well as altering other parameters that have been selected.

SPIDA is a detailed hydraulic simulation model for computing flows, surcharging, and flooding in any urban drainage network. It is especially designed to analyze looped sewer networks with flat or reverse gradients where the direction of flow may reverse. SPIDA solves the St. Venant equations of flow continuity and momentum. SPIDA has an automatically adjusted timestep to preserve a consistent level of computational accuracy regardless of how rapidly the flow is varying. SPIDA can model a variety of ancillary structures such as CSOs, storage tanks, pumping stations, etc. In SPIDA, it is already possible to interrupt a simulation and open or close gates or turn pumps on or off. A RTC driver is under development with a French partner. SPIDA is regarded as a complete state-of-the-art hydraulic simulation tool. HR Wallingford is planning to extend the program even further with WALLRUS-SIM, a full Graphical User Interface (GUI), and a RTC driver. SPIDA with the RTC option uses information about the location and operation of ancillary structures to simulate the dynamic behaviour of a sewer system during an event in real time. The user enters this information in the form of rules which link sensors, control devices and regulating structures. SPIDA is being used by most of the United Kingdom's Water Companies, the Hong Kong government, and some cities in France and Belgium (Price, 1993).

WALLRUS and SPIDA have been developed by HR Wallingford for widespread commercial distribution. Source code is not available.

Evaluation

The above modelling systems represent the most versatile simulation packages available to municipalities today. In all cases the Winnipeg collection systems and facilities can be modelled using any or combinations of these models for hydrologic, CSO and detailed hydraulic analysis. However, not all of the models have the ability to simulate water quality. RTC simulation is a relatively new demand made of CSO models and few modelling systems have advanced to the point where RTC can be accurately simulated.

Given that all the modelling systems satisfy the basic technical needs of the City, the evaluation and selection process needs to be based on other factors. Although the technical aspects of a model are important, of equal importance are the following:

- Technical support
  - Local technical support
  - Responsive technical support
  - Public domain code or propriety

- Graphical User Interface (GUI)
  - Pre/post processing of data
  - Data and file management
  - Negotiating through the system

- Cost
  - Hardware
  - Software
  - Training
  - Technical support

- Application
  - Ease of use, learning curve
  - GUI, I/O features
  - Execution times
  - Special technical features (i.e. dynamic controls, water quality, etc.)
  - Track record of model(s), past experience

- Expansion and Development
  - Future expansion of the system to include other functions (i.e. links to real time control, GIS, CAD, etc.)

- Demonstration System
  - Period of time to work with each system.

Each of the above items will play an important role in the final evaluation and selection of a modelling system.

2.4.6 CSO Control Technologies

2.4.6.1 Storage

Introduction

Storage can be employed to retain CSO flows for later return to a centralized wastewater treatment plant (WWTP) for detention with sedimentation before discharge to receiving waters or with other unit processes in a satellite treatment facility. Evaluation of storage options should consider what level of CSO treatment is desired and whether treatment will occur at centralized or satellite facilities. When stored

CSOs are treated centrally at existing WWTPs, storage simply acts to dampen wet weather flows, and provide flow equalization. In Ontario, storage requirements of 3-7 mm/ha are usually required in order to meet CSO control criteria, which range from 90% volumetric capture each year to permitting only one untreated overflow event per recreational season.

Storage facilities can be classified as either in-line, which have no pumping requirements or off-line, in which inflow and outflow is by gravity or pumping. Operation of storage facilities (i.e. timing and pattern of flow release) can be manual or automatic, relying on continuous monitoring of inflow rates and downstream pipe and treatment capacities.

In-Line Storage

In-line or in-pipe storage takes advantage of unused existing storage capacity of combined sewer trunks and interceptors by restricting flows at the regulator or overflow point, causing wastewater to backup in upstream lines. In-line basins may also be employed. Combined sewer trunks will generally convey flows between 50 and 500 times dry weather flow (DWF), while interceptors can carry flows in the range of 2 to 10 times DWF. Thus, during most storms, considerable unused capacity exists in these conduits. In-pipe storage is the most economical storage option and should be considered first.

Costs for in-pipe storage systems in the U.S. have ranged from $0.10 to $1.20 per USG (1994 U.S. dollars). Seattle's 17.8 US MG in-pipe storage system costs $18.5 million to build and $550,000 per year for operation and maintenance. Automated regulators accounted for roughly half of the capital expenditure, with the control and monitoring system accounting for the remainder, (EPA, 1977).

Regulators

Effective in-line storage is accomplished by the activation of system weirs, gates, vortex valves, inflatable dams, control of pumping, etc., to regulate the effluent rate from the sewer system to treatment facilities and also to regulate overflows.

Off-line Storage

In a recent review, Pisano et al. (1993) described the following off-line storage methods which are currently in practice:

- upstream, shallow stormwater tanks;
- upstream, contaminated, near-surface storage;
- downstream, contaminated, near-surface tanks;
- shallow and deep tunnel schemes; and
- pontooned water-based storage.

The following discussion includes a description of each method, typical costs, applications and preliminary design considerations.

Upstream stormwater tanks are actually a form of inlet control, since they restrict inflow to existing catchbasins. Instead, street runoff is diverted overland to new catchbasins which are connected to shallow, off-line storage tanks. Vortex throttles located in wet pits are used for controlled bleed back into the sewer system. Tanks are situated underground behind curbs in alleys, or in open park areas, making this method ideal for congested residential areas where there is no other effective means of creating near-surface storage. However, space limitations in such areas and the need for inlet and outlet gravity control limits the amount of storage generation to about 100-200 cubic feet per acre. Build up of heavy sediment layers in the tanks is prevented by placing double catchbasins with over-sized sumps immediately prior to the inlet. The sumps capture most of the grit and settleable material and are typically cleaned twice a year. Tank cleaning with firehoses is usually performed annually, with access provided by several entry manholes.

Upstream stormwater tanks are widely used in the U.K. and have been installed in Cleveland, Chicago and Decatur, Ill. Unit storage costs for the 200 shallow tanks in the greater Cleveland area have ranged from $1.60 to $3.00/USG (1994 US dollars).

Upstream contaminated (ie. combined sewage) near-surface tanks are further classified as either first-flush tanks or settling tanks. The former are used when the time of concentration within the catchment is 15 minutes or less. When storm flows exceed about twice dry weather flow, tank storage fills. Overflows are set upstream to prevent mixture of overflowing volumes with first flush contents. The median size for first flush tanks is 0.12 USMG with sidewater depths averaging about 10 feet. Over 12,000 such tanks have been installed in Europe (10,000 of which are in Germany). Roughly 40% of German installations use downstream vortex flow throttles for outflow control and all include an emergency bypass within the throttle chamber. About 24% serve large areas, and provide detention treatment, but the bulk are located in small widely scattered villages. Settling tanks are used when a pronounced first flush is not expected and function similarly to a primary settling tank. A recent development is the employment of an "air-regulated siphon" for upstream overflow control. This equipment can significantly reduce construction costs by shortening weir length. North American experience with upstream near-surface storage is very limited.

Downstream near-surface storage is more common in North America (there are about 30 installations). The greatest number are located in Michigan where capture of the one year, one hour storm with secondary treatment of returned flows is the new performance standard for CSO control. Tank sizes generally range from 1-4 USMG (storage volume/acre ranges from 300-1,000 ft^3). Consequently, the tank footprint tends to be large. Other concerns which have been raised are the maintenance (cleansing) requirements and high return solids loadings on the downstream WWTP.

Detention-Mode Storage

Storage facilities can also be designed to operate in a flow-through detention mode in addition to providing CSO retention for later return to a WWTP. When retention capacity is exceeded, overflow occurs and some sedimentation treatment is provided.

Conventional sedimentation basins handling CSO at loadings of 1,000 - 2,000 USG/d sq. ft. (ie. loadings typically seen in WWTPs) can generally remove 55 to 65% suspended solids without chemical addition (or settleable solids removal of 75 to 85%). However, CSO detention facilities are typically designed with overflow rates of 3,000 - 5,000 USG/d.sq.ft. At these design flows solids removals is much lower (usually less than 20%; treatment would consist of heavy grit and floatables removal. Increasing tank size to reduce loading rates may not be economical since it has been shown than removal efficiencies per unit volume decrease as tank size increases (WPCF, 1989).

Addition of coagulants to improve solids removal in conventional primary treatment is a proven technique. Addition of ferric chloride and polymer have resulted in average solids removals as high as 80% during sustained loadings of 2,800 USG/d.sq.ft. However, operational experience with coagulants in detention storage of CSOs is very limited.

Design Considerations

Several preliminary design considerations should be addressed for the design of storage facilities. The biggest challenge in CSO storage tank design is to provide storage and effective sedimentation and at the same time optimize self-cleansing, in order to reduce maintenance costs.

Considerations for storage designs are:

- Internal Division of Tanks
- Floor Design
- Ventilation/Odour
- Disinfection
- Flow Controls
- Cleansing
- Costs

SUMMARY

Storage facilities are an effective means of reducing CSOs. In-line storage is very cost-effective for creating relatively small amounts of storage. Shallow stormwater tanks are ideal for congested areas but only provide minimal storage. Upstream, near-surface storage is commonly used in Europe to provide detention treatment, particularly to capture first-flush flows. Larger downstream tanks are more common in the US than the upstream variety but require a large footprint and regular maintenance. Cleansing of large tanks remains problematic but sediment flushing tank systems show promise and are gaining popularity. Solids removal in CSO detention facilities tends to be minimal because of the high surficial loading rates at design flows. Tunnel storage systems are comparable in cost to large near-surface tanks and can be utilized to connect discontinuous congested areas and convey CSO to centralized treatment.

2.4.6.2 Real Time Control

Introduction

Municipal sewage collection systems have traditionally been operated in a static mode, with the result that optimal performance occurs only in one operational situation, namely, design conditions. In contrast, collection systems using real time control systems (RTCS) operate dynamically by continuously monitoring the system and using this information to make operational adjustments. The function of RTCSs is to fully utilize existing storage, conveyance, and treatment capacity, thereby eliminating or postponing the need for capital improvement projects. The following discussion reviews the key features of several successful RTC installations.

Practical Experience With RTC

Interest and research activities in RTC of collection systems began in the late 1960s. Despite this attention, only 18 installations exist across North America and Europe, based on a 1992 survey by Gonwa and Novotny (1993). Table 1 summarizes the salient features of seven such installations. The Table and related discussion is based largely on the findings of the previously mentioned survey.

The operational objectives of different RTC installations tend to differ slightly in terms of priorities, even though they were all intended to optimize collection system performance. A common objective is to equalize in-system storage (as a percentage of full volume) throughout the collection system. Another common approach is the "system works" objective, which finds a system which works according to design criteria (reasonable set points are determined by single event modelling and trial and error). The most common methodology for operation appears to be following: treat at maximum capacity, fill storage as long as there is room and overflow to receiving waters once storage is full. Regardless of the objective method adopted, pump-down of the collection system whenever a storage event is forecasted can be practised with good results. Multi-objective control, although technically feasible, is rarely practised.

In terms of levels of control and automation, local automatic control is most common, followed by supervisory local control. Although global automatic control is often designed, it is rarely achieved in practice. In some cases, failure to operate the sewer system as intended in the design may be due to long delays in "turning on" the system (for example, because of insufficient operator training). In other cases, the system has never been operated as designed because of reluctance on the part of operational personnel to modify operational procedures. The authors cited three common reasons for this reluctance:

- inadequate benefits to justify the increased complexity
- better performance by humans than by computers, and
- mistrust of automatic computer control.

It is anticipated that the growing interest in RTC technology will ultimately lead to further installations with greater capabilities, including fully automated control. RTC has become a standard alternative when considering planning and feasibility studies for CSO control. The low cost CSO storage and improved system flexibility offered by RTC systems make this technology very appealing. Overcoming human reluctance in adopting dramatically different operating procedures appears to be a major obstacle to successful RTC installation. The high degree of complexity in system design may limit its application to those municipalities with significant technical resources, competence in computer systems and sufficient motivation.

Table 1
Summary of Important Features of RTC Collection Systems

Location	Date of Original RTC Installation	Number of Control Stations	Global Control (intended in design)	Mode of Control (implemented)	Operational Objective	Level of Success
Seattle, Washington	1973	19 Regulators 13 Pumping Stations	Yes	Regulator: local automatic; Pumping station: remote automatic or supervisory	Multi objective	Reduction in CSO volumes of 7.5% (for 1990 RTC upgrade)
Milwaukee, Wisconsin	1986	43 Interceptors 4 Pumping Stations 30 Weirs	Yes	Local and remote automatic	"System works"	Less local flooding; increased inline storage increased operational flexibility
Detroit, Michigan	Early 1980s	7 Regulators 7 Pumping Stations	Yes	Manual	Treat at maximum capacity, etc[3]	Increased inline storage (interceptors pumped down prior to storms)
Vancouver, British Columbia	N/A	N/A			"System works"[2]	N/A
Cleveland, Ohio	1970	29 Regulators			Minimize contaminant loadings to receiving waters	50% reduction CSO volumes
Seine-Saint-Denis, France	Early 1970s	N/A			Flood protection / CSO control	N/A
Salmo, Sweden	1989	2 Regulators			Flood protection / CSO control	50% reduction in CSO volumes and events (predicted)

Notes:
1. Common objectives of multi-objective control are: minimize flooding, minimize overflow volumes, maximize energy consumption.
2. See accompanying text for description of "system works".
3. Objective is to treat a maximum capacity, fill storage, and then overflow to receiving waters when storage is full.

2.4.6.3 Vortex Regulators

Principles

Effective and reliable regulation of flows in combined sewer systems is a prerequisite for all forms of CSO control. Because of their reliability, flexibility, and low maintenance compared to conventional regulation devices, vortex throttle regulators are becoming increasingly popular in CSO control. In western Europe and North America, there are about 8,000 such installations with capacities from 0.5 to 300 cfs.

The basic principle of vortex throttling is that changes in pressure head at the inlet causes the flow regime within the unit to switch back and forth from orifice flow to vortex flow. During vortex mode, flow in the throttle forms a smooth, hollow vortex and exits as a hollow jet. The typical flow characteristic curve for a vortex valve is shaped like a sawtooth. On rising head, flow initially increases rapidly to a defined peak; this is the orifice flow stage. Further increases in head cause a transition in flow regime and a reduction in discharge until "kick-back" is reached. At this point stable vortex flow is achieved. Beyond that point, discharge increases at a slower rate and eventually levels off, in the same fashion as occurs in a typical orifice plate.

Recent advances and variations in vortex throttle design have further improved performance. The addition of venting has enhanced the reproducibility and accuracy of throttling. Under lab conditions, it has been shown that maximum hydraulic braking occurs with a smooth, well-defined and centrally aerated vortex (contrary to the popular notion that the vortex valve is a turbulence throttle). It was found that hydraulic braking could also be improved by replacing the flat cover plate with a smooth dish-shaped plate, which are also lighter and stronger. In response to a need for throttled control with feedback (originally for small, downstream flow-sensitive situations) two new feedback vortex throttle systems were developed. The main advantage of such a system is the large aperture opening, particularly during low flows. Flows as low as 0.5 cfs can be throttled of nominal head (4-6 feet) with aperture openings of 5-6" allowing good passage of solids and debris. Since it was developed seven years ago, over 250 such configurations have been installed and operated successfully, provided competent technicians are available for servicing.

Experience with Vortex Throttles

Unlike conventional mechanical float-operated devices, vortex throttles contain no moving parts which can fail, nor does it require an energy supply (except for the electronic feedback version). The technology's simplicity has resulted in excellent reliability and low maintenance requirements. Large aperture openings, relative to conventional devices such as pinch valves and sluice gates, means that solids and debris are more easily passed at low flows. However, cloggage in small units (less than 0.5 cfs) does occur. Experience suggests that contouring and tapering the inlet to accelerate flow will limit deposition and cloggage during low flow conditions.

Another advantage of vortex throttles is the high degree of flexibility in operation. Flow capacities and head allowances are easily adjusted by changing orifice inserts and, to a lesser extent by altering certain geometrical parameters. Typical designs have a pronounced braking effect (due to the "sawtooth" flow characteristic) but horizontally-arranged designs (Figure 2) behave such that the change from orifice to vortex flow is smoothed out (ie. monotonic). Finally, vortex throttles are relatively inexpensive compared to conventional flow controllers. In Saginaw, Michigan, the largest U.S. system-wide configuration of vortex throttles was installed between 1984 and 1986. Twenty-one of the City's 34 regulation chambers were retrofitted with vortex devices, replacing mechanical float-operated throttles, at a total cost of $1.2 million. At least 6 MG of in-line transient storage was created as a result and wet weather phosphorus loadings to the Saginaw River were reduced an estimated 15-20%.

2.4.6.4 Inlet Control

Inlet control is sometimes referred to as source control. It is achieved by restricting the inlets to the conveyance system at the source of the runoff. Typical locations where inlet control has been effectively used are rooftops, parking lots, industrial yards or specifically designed surfaces.

Introduction

The objective of inlet control is to restrict the input of surface stormwater runoff to underlying sewers without causing adverse street surface ponding or overland flow. In most cases, inlet controls alone are insufficient to solve serious CSO problems but can play a useful role in a broader CSO control program.

Types of Inlet Controls

The most common method of inlet control is catchbasin restriction devices. These flow controllers are used either to create temporary street storage or to induce overland flow from sensitive areas to more attractive capture points, such as nearby separated storm sewers.

Flows into catchbasins and other inlet structures can be restricted at or near the catchbasin grating. This type of restriction is generally achieved by mounting plates on top or below the grating, effectively reducing the grate size or by mounting horizontal orifice plates just below the grating. Grate restriction, however, results in decreased capture for all sizes of flows, even for small events during which the piping system has adequate capacity. Another disadvantage is the tendency for debris to become lodged in the closed section of grating. Horizontal plate restrictors require removal before the catchbasin can be cleaned, resulting in higher maintenance costs.

Alternatively, flow can be restricted by orifices placed over or in the catchbasin outlet. This approach offers several advantages. Grating capture is not affected by low flows. The restricting device is easily installed and does not present any impediment to basin cleaning. Also, orifice devices tend to function properly with debris in the basin. "Hanging trap" units, which consist of a horizontal submerged orifice in the outlet leader and vortex valves are two examples of this technology.

A minimum orifice size of 3-4 inches is usually required to prevent clogging. Orifice fouling has also been associated with inlets without sumps and with inlets with limited sump depth. In a study which examined the reliability of various restriction devices, it was found that vortex valve controllers were nearly clog-free. The cloggage potential of all devices tested was found to be highest during conditions of high basin turbulence due to the increased likelihood of debris passing into the orifice (Wisner, 1985). The hanging trap system has also been shown to be very resistant to leaf cloggage are the most cost-effective and are easily installed and replaced.

Inlet Control Experience in North America

Approximately 3,000 vortex inlet devices have been installed in the U.S., mostly in Cleveland and Portland, Maine and another 500 in Canada. Most of these installations are situated in separated or "over and under" collection systems. Combined sewer applications of vortex devices tend to use orifice diameters in the range of 3" to 4" and have been designed for release rates between 0.25 and 0.50 cfs. German designs have proven effective for release rates as low as 0.13 cfs.

In Parma, Ohio and Skokie, Illinois, catchbasin restriction devices are employed together with speed humps. Eighty such systems have been installed, providing low cost, controlled street storage. The cost-effectiveness of catchbasin controls is also demonstrated in Boston, where four vortex controllers are being used to induce surface gutter flow on Westmoreland Street down to an existing separate system on Adams Street. This approach saved roughly $120,000 in construction costs for sewer separation.

In Laval, Quebec, catchbasin restrictors are used for "flow slipping" runoff, which would otherwise be captured by existing, combined sewer laterals, down to the local receiving water.

About 2,300 horizontal plate restrictors have been installed in an around Saginaw, Michigan in order to reduce basement flooding in combined sewered areas.

2.4.6.5 End of Pipe Treatment

Control and treatment of CSOs can be effected in a number of ways as outlined below. As more flow is being intercepted for treatment the existing treatment facilities would have to be expanded or new treatment facilities built.

Increase Capacity of Existing Treatment Facility

Treatment of wastewater, including stormwater, could be undertaken at a centralized location by increasing the capacity of the existing treatment facility.

Diversion of Flows

Diversion of flows to another existing available treatment facility could be used to reduce overflows.

Solids Separation Devices

End of pipe treatment can be undertaken for individual outfalls or by the combination of two or more outfalls where feasible. Devices such as Swirl Concentrators, Fluidseps (German designed Swirl Concentrator) and Helical Bend Flow Regulators are commonly used to separate solids from the wastewater prior to discharge to receiving waters. These devices require room near the outfall which may not always be available.

Disinfection

Disinfection is used to reduce the concentration of pathogens in wastewater prior to discharge to receiving waters. When used in conjunction with upstream solids removal, such as solids separation devices, disinfection can remove greater than 99.99 percent of total coliforms.

Various disinfections are available for treatment of effluent. These include chlorination, ultraviolet light, ozone and bromine chloride. Should solid separation devices be considered, disinfection will be necessary to reduce coliform levels especially for outfall near beaches.

Screening Devices

Screening can provide high-rate separation of solids from wastewater. Various types of screens used such as mechanically cleaned permanent screens, travelling screens or drum screens. Screens are designed to remove a given particle size and are very effective in removing solids of the design size or larger.

2.4.6.6 Sewer Separation

Sewer Separation is considered for areas where combined sewers still exist, particularly in the downtown area. Full separation (road and house connections) are considered for appropriate areas. However, with the increasing concerns regarding the quality of stormwater runoff and the receiving waters, the advantages and disadvantages of carrying out this program are controversial.

Sewer separation is extremely difficult and very expensive in a developed city because of the narrow and over-crowded utility corridors. Full separation is normally carried out over a long period of time and private connections can only be separated with redevelopment. However, separation will reduce the amount of stormwater entering the combined sewers and therefore reduce the potential for CSO.

2.4.7 Management Alternatives

2.4.7.1 Best Management Practices

Best Management Practices are associated with the maintenance of combined and stormwater sewer systems.

2.4.7.2 *Sewer Flushing*

Sewer flushing restores the capacity of sewers with the removal of settled sediments. Quality improvements will also be realized with the removal of settled material from the system. Sewer flushing is indicated for flat sewers where the operating velocity is not sufficient to keep sediments in suspension and therefore convey them with each runoff event.

2.4.7.3 *Catch Basin Cleaning*

Catch basin cleaning serves to remove pollutants from the watershed rather than allowing them to overflow to the receiving water with CSO during a runoff event.

2.4.7.4 *Sewer System Rehabilitation*

Sewer system rehabilitation is generally carried out to enhance structural capability, restore flow carrying capacity and to reduce extraneous flows entering the sewer. Rehabilitation methods include spot repairs, cutting of roots and protruding connections, and various insertion lining methods.

2.4.7.5 *Inflow/Infiltration (I/I) Control*

I/I control reduces the amount of inflow and infiltration into combined sewers, thus reducing the volume of CSO during a runoff event, and also reduces the volume of flow to the plant for treatment. Sources of removable infiltration include leaking sewers, services and manholes. Inflow sources include foundation drains connected to the combined/sanitary sewer system and illegal connections of catch basins to sanitary sewers. Connection of foundation drains to sanitary sewers is, however, acceptable in order to provide a high level of protection from the fluctuation of the hydraulic grade line of storm sewers which can lead to structural damage to buildings. (As of 1991, the Ontario Building Code will not permit foundation drains from new developments to be connected to sanitary sewers.)

2.4.7.6 *Street Sweeping*

Street sweeping removes from the catchment surface debris and pollutants which would normally wash off of the streets into combined or storm sewers and possibly overflow to receiving waters.

2.4.7.7 *Control of Deicers*

Control of deicers removes pollutants such as chlorides at source to reduce pollutants discharged to the receiving water. Alternate deicers with fewer environmental impacts are being developed, but currently are not economically comparable to chlorides.

2.4.7.8 Control of Fertilizers and Pesticides

Control of fertilizers and pesticides removes these pollutants at source to prevent them from entering receiving waters. The majority of fertilizers and pesticides, if properly applied, are reasonable innocuous to the environment, but should regardless be applied as a last resort and sparingly.

2.4.7.9 Discharge By-Law Review/Implementation/Enforcement

Discharge By-Laws stipulate that undesirable industrial and residential flows cannot be discharged to the sewer system. By-Law review, implementation and enforcement ensures that By-Laws are equitable, effective and being adhered to.

2.4.7.10 Increase Pervious Areas

An increase in pervious areas in a watershed can help to reduce the amount of runoff which that area produces. Control of lot densities is a specific means of increasing pervious areas. Increases in pervious areas can only be achieved in re- or new development areas.

2.4.7.11 Industrial Runoff Control

Runoff from industrial areas may contain the residue from chemicals that are spilled during handling and storage. Gasoline and oil spills are typical pollutants often found in service areas. Industrial runoff control requires that the runoff from these areas be intercepted and the pollutants separated from the runoff and disposed of elsewhere.

2.4.7.12 Enforce Anti Litter Laws

A number of localized sources may contribute to water pollution, including animal, pet and bird faeces, boats, people, refreshment stands, etc. The enforcement of anti-litter laws can assist in reducing these non point sources of pollution.

2.4.7.13 Water Conservation

Water conservation, whether residential, commercial or industrial, reduces the amount of dry weather flow in the sewer system thereby theoretically providing more capacity for stormwater and reducing volume of CSO. Most municipalities will be practising water conservation for its own sake, so any benefits on CSO control will be realised.

2.4.7.14 Public Education

Public education with respect to the uses and impacts of discharges to storm, sanitary and combined sewers, as well as the issues and constraints associated with available alternatives can greatly assist a government endeavouring to implement pollution control.

SECTION 3
CSO REGULATORY GUIDELINES

URBAN DRAINAGE REGULATORY PROGRAMS

3.1 URBAN DRAINAGE CONTROL IN CANADA

3.1.1 CSO Control Programs in Canada

All provinces of the nation have municipalities served by combined sewers. Most do not allow construction of new combined sewer systems. Control programs are underway in some municipalities based on the need to control basement flooding, and in some cases, environmental concerns. Only one province, Ontario, is developing a formal control policy (as described below), although there are examples where other provincial governments have acted to control combined sewer overflows in specific cases. The Manitoba Clean Environment Commission has required Winnipeg to develop a CSO control program. In Halifax, with the support of the federal government and the Province of Nova Scotia, the proposed construction of a sewage treatment plant includes some controls on CSOs.

3.1.1.1 Ontario's Proposed Combined Sewer Overflow Control Program

Ontario currently has no formal CSO control policies. The Ministry of Environment and Energy does encourage development of comprehensive pollution control plans (PCPs) to consider integrated control of point and non point sources within a municipality. A recent paper (P'ng *et al*, 1993) outlined a guideline approach for CSO control which is under consideration for adoption as a policy, possibly to be incorporated into future MISA regulations for the municipal sector.

The policies being considered include a minimum CSO control criteria, a requirement for completion of pollution prevention and control plans, and the consideration of higher levels of control based on attaining water quality-based standards.

The minimum CSO control criteria proposed are that:

- No overflows of untreated sanitary wastewater are allowed during dry-weather periods except under certain emergency conditions.
- Each municipality shall make maximum use of the collection system for storage and maximize the flow to the sewage treatment plant (STP) for treatment.
- Where possible, the STPs shall be modified to implement Step Feed operation or be otherwise optimized to maximize the storm flow treated at the STP.
- Each municipality shall be required to control 90% of the average annual wet weather flow (stormwater) plus the dry weather flow. This contained volume is to receive a minimum overall treatment level equivalent to primary treatment.

- Wet weather-induced bypasses at STPs are to be considered the same as CSOs. They shall be subject to the same volumetric and minimum treatment conditions as above.
- New storm drainage systems will not be permitted to connect to existing combined systems except where evaluations (documented as part of a PPCP study) indicate that circumstances allow no other practical alternative.
- Development of a comprehensive Pollution Prevention and Control Plan (PPCP).

Additional controls for CSOs beyond the minimum criteria may be required on a case-by-case basis in areas where there are local water quality concerns or water uses are impaired as a consequence of CSOs. In cases where CSOs are one of the many sources contributing to water use impairment, the required solution has to deal with all of the pollutant sources.

The level of CSO control is site-specific and is dictated by local water quality objectives. The case of beaches impaired by CSOs should receive special consideration. The criterion for body contact recreation shall be maintained for at least 90% of the season from June 1 to September 30 on the average. There should be not more than two or three CSOs per season on the average. The contained volume is to receive the minimum level equivalent to primary treatment plus disinfection.

3.1.2 Stormwater Management in Canada

In reviewing practices in different provinces it was found that formal requirements at the provincial level were limited to Ontario and Alberta, described in the following sections. In many other locations, local requirements for stormwater controls are found, primarily based on design standards for property protection. In some municipalities, stormwater control ponds are constructed as an alternative to expansion of existing storm sewers, purely on economic grounds. It is often less costly to build a stormwater detention pond, than to expand or build a new storm sewer to an adequate receiver.

3.1.2.1 Stormwater Management in Ontario

All sewage works including storm sewers and stormwater management ponds require a Certificate of Approval under the Ontario Water Resources Act. There are no requirements in the Act or in guidance for stormwater management systems to be built for any purpose other than property protection or conveyance. However, general prohibitions against discharge of substances which may impair the quality of the water are used as justification by reviewers of development proposals in requiring controls on a case-by-case basis.

Ontario has published *Interim Stormwater Quality Control Guidelines for New Development* (1991). The goal of these guidelines is the protection and enhancement of pre-development hydrologic and water quality regimes. The key requirements of the guidelines are:

- Buffer zones along the stream corridor, to provide a protective barrier to intercept pollutants and assist in infiltration;

- Stormwater control systems to capture most of the runoff for quality control or infiltration;
- Sediment controls in all phases of construction.

The document, prepared jointly by the Ministries of Natural Resources and Environment and Energy, provides municipalities, proponents and reviewers with information on quality control approaches. The guidelines are meant to be used in several ways. They can be adopted as requirements in official plans or By-laws of municipalities, or attached as approval conditions by government agencies in reviewing development proposals. There are specific guidelines for volumetric control and buffer zones for watercourses that are widely applied in Ontario. Specifically for:

cold water fisheries	30 m buffer zone and volumetric control of runoff from 25 mm of daily precipitation.
warm water fisheries	15 m buffer zone and volumetric control of runoff from 13 mm of daily precipitation.

The Ministry of Natural Resources has asked for specific conditions to be placed on discharges for control of stormwater discharges with elevated temperatures, based on the need for protection of cold water fisheries.

The Ministry of Environment and Energy has issued effluent limits regulations for industrial sectors under the Environmental Protection Act in its Municipal Industrial Strategy for Abatement (MISA) program. These regulations are primarily for control of point sources; however, they also require industries to develop a storm water control study. A protocol is defined in the regulations (*Storm Water Control Study Protocol,* Ontario Ministry of the Environment, August 1992) that outlines the steps in developing a control program, including: exemption criteria, information collection requirements describing the site and stormwater characteristics, stormwater impacts, prevention and control information, stormwater control program, and monitoring requirements.

The Environmental Assessment Act (Ontario) requires an environmental assessment of certain undertakings or development projects in the public sector. This applies to the construction of storm sewer systems by municipalities, and by private developers, if the public agency (the municipality) will end up taking ownership. These projects follow a simplified assessment under the *Class Environmental Assessment for Municipal Water and Wastewater Projects* (Municipal Engineers Association, June, 1993). The more complex the project, the more detailed the review that takes place. For example, projects with new outfalls to a watercourse require the most complete review. The more complex projects go through a 5 phase process in the assessment, which includes public participation. The phases are:

Phase 1 - Problem identification
Phase 2 - Identification of alternate solutions
Phase 3 - Identification of alternate design concepts
Phase 4 - Complete Environmental Study Report (ESR)
Phase 5 - Detailed design

The review and resulting measures to mitigate against adverse effects take into account the concerns of agencies such as Ministry of Environment and Energy and the Ministry of Natural Resources. Of interest in the recently updated Class EA is the added emphasis on stormwater management projects. In addition the Class EA recognizes the municipal planning and design processes and the development of long range multi-disciplinary plans, such as subwatershed plans.
The Topsoil Preservation Act (Ontario) enables municipalities to enact a By-law for control of topsoil and specifically for sediment and erosion control. The Town of Aurora, a rapidly urbanizing municipality near Toronto, has enacted such a By-law. This By-law requires developers to submit a sediment and erosion control plan prior to being granted a permit to begin construction activities. The topsoil removal permit is the prime vehicle for implementing sediment and erosion control requirements. The By-law includes enforcement options. In many other municipalities, a sediment and erosion control plan is required as a condition of approval for the development issued under the Planning Act; however, the enforcement is not as effective as when the municipality enacts its own By-law.

The City of Etobicoke, part of Metropolitan Toronto, has adopted a new storm water management policy which addresses water quality concerns. The goals of the policy are:

1. To minimize the risk and threat to life and destruction of property from urban runoff.

2. To protect, and wherever possible, enhance the quality of storm water runoff into the receiving waters.

3. To protect and enhance the functionality of the City's waterways.

4. To re-establish the natural hydrologic cycle as much as possible.

5. To implement the Storm Water Management Program with due regard for the ecosystem.

In implementing the program, Etobicoke has instituted a unique system for rehabilitation of old storm sewer systems. They have constructed an underdrained storm system that allows water to exfiltrate to the groundwater. The system is designed to operate as normal storm drainage system, if the flows are excessive, or if the exfiltration system becomes plugged. A similar design is used in areas with clay soils. In this system, the water is filtered through the gravel filled trench and collected for discharge in the conventional storm system. Both of these designs are constructed in the right-of-way, with no additional land required. Etobicoke estimates that the cost is only 10% higher than a conventional storm sewer system. Etobicoke has also initiated rehabilitation of urban watercourses.

3.1.2.2 Stormwater Management in Alberta

Alberta's new Environmental Protection and Enhancement Act which came into force in September 1993 provided for new regulations for Municipal Wastewater and Storm Drainage. The regulation defines the storm drainage system to include components for collection, storage and disposal of storm drainage, including storage management and treatment facilities that buffer the effects of peak runoff or improve the quality of the storm water. Design standards are set in the regulation by reference to a document entitled *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage*. Detailed guidelines are provided in another document, *Stormwater Management Guidelines for the Province of Alberta*. In making application for approval of facilities, the information that must be submitted with the application, among other things, includes:

- an indication of the effect that the proposed construction will have on the quantity and quality of storm drainage being handled by the storm drainage system
- details and plans of topsoil conservation for a storm sewer that falls within the meaning of "pipeline"
- type and quantities of any proposed treatment chemicals
- review of the proposed monitoring systems to ensure compliance with storm drainage quality limits (where applicable) and to measure the rate of release of storm water from the management or treatment facilities
- assessment of any cumulative environmental impacts resulting from the proposed activities

To date, no water quality limits have been placed on stormwater facilities. However, for the developing areas around the two largest municipalities, Calgary and Edmonton, the province has been requiring the inclusion of stormwater retention ponds, sized according to criteria included in the guidelines document for rate of runoff control. The retention or wet ponds are preferred over other means such as detention ponds, because of the enhanced water quality improvement expected. In the Calgary area, discharges from new developments to the Bow River are controlled to protect a significant fishery.

3.2 URBAN DRAINAGE CONTROL PROGRAMS IN THE UNITED STATES

3.2.1 Combined Sewer Control Program

3.2.1.1 National CSO Control Program of EPA

Combined sewer overflow control is recognized as a major expense in the United States. According to the 1992 Needs Survey, $41.2 billion or 30% of the total costs identified for wastewater treatment needs is required for CSO control. Under the EPA draft policy for combined sewer overflow control, municipalities with combined sewer overflows (CSOs) will be required to install nine minimum controls, eliminate or relocate CSOs that discharge to sensitive areas, evaluate CSO control alternatives, and develop a long-term CSO control plan. The control program will be incorporated into the permitting process, i.e. National Pollution Discharge Elimination System (NPDES) of the Clean Water Act. The policy is expected to be incorporated into the reauthorized Clean Water Act in 1994. (At the time of writing, May, 1994, there are three versions of the CWA, the House version, the Senate version, and the Administration version, each with slightly different provisions for CSO control).

The nine minimum controls are:

1. Proper operation and regular maintenance programs for the sewer system and CSO points.
2. Maximum use of the collection system for storage.
3. Review and modification of pretreatment programs.
4. Maximization of the flow to the wastewater treatment plant.
5. Prohibition of CSO discharges during dry weather.
6. Control of the solid and floatable materials in CSO discharges.
7. Pollution prevention programs that focus on containment reduction activities.
8. Public notification to ensure adequate information on CSO occurrences and CSO impacts.
9. Monitoring CSO controls to effectively characterize their impacts and efficiency.

The policy requires a two phased approach. In the first phase, the municipalities must characterize their combined sewer system, demonstrate the implementation of the nine minimum controls and develop a long term CSO control plan. In developing the long term plan, attention should be paid to sensitive areas, and the development of alternative ways to achieve the goals in a cost effective manner. In evaluating CSO control alternatives, either a presumptive or a demonstration approach is allowed. In the presumptive approach, the plan presumes that the CSO control program is adequate if it meets any of the following criteria:

- For urban areas, no more than 4 overflows per year with an allowance for up to two additional overflows per year
- The elimination or capture for treatment of at least 85% combined wastewater (by volume) on an annual average basis.
- The elimination or reduction of no less than the mass of pollutants identified as causing water quality impairment, or the mass of pollutants associated with 85% combined wastewater (by volume).

The demonstration approach provides for a site specific plan to be developed that meets water quality standards locally.

In the phase II of the NPDES permit process, the permitting authority will establish an implementation schedule and develop monitoring and performance criteria.

3.2.1.2 Ohio CSO Control Program

The State of Ohio has proposed a comprehensive CSO Control Strategy, which takes elements from and extends the proposed EPA policy discussed above (January, 1994). The strategy starts with a statement of goals:

1. Discharges from combined sewer overflows shall not cause or contribute to violations of water quality standards or impairment of designated uses.

2. During wet weather, the total loading of pollutants discharged from the entire wastewater treatment system shall be minimized; and the discharge of pollutants from CSOs should not increase above current levels.

3. Combined sewer overflows shall be eliminated when this is a cost effective, economically achievable control option, and when it does not cause new or significantly increased overflows elsewhere in the system.

Water quality standards referred to in the goals include chemical, bacteriological and biological criteria. Each municipality must prepare a Combined Sewer System Operational Plan, which, among other things, indicates how the community will comply with the nine minimum control measures identified in the EPA policy (above).

In implementing the measure to maximize flow through the sewage treatment plant during wet weather, Ohio will rewrite the discharge permits to allow this, such that the effluent standards, normally based on average dry weather flows and performance, are adjusted for wet weather conditions. A procedure for wet weather stress testing is provided to establish maximum flows.

Ohio also requires that a Long Term Control Plan be developed. If the system discharges to less sensitive waters, the Operational Plan described above, plus monitoring may be sufficient. However, if the CSO system affects more sensitive waters, such as defined State Resource Waters, bathing waters, or public water supply, then a more detailed plan is required. The Long Term Control Plan contains the following elements:

1. Characterization and monitoring of the collection system and overflows. This could include monitoring of the receiving waters.
2. Identification of sensitive waters impacted by CSOs.
3. Evaluation of control alternatives.
4. Cost/performance evaluation.
5. Revision to the CSO Operational Plan.
6. Maximizing treatment of wet-weather flows at the wastewater treatment plant.
7. Implementation schedule.
8. Public participation.

3.2.1.3 CSO Control in Michigan

The Michigan control program follows the general outline of the EPA policy; however, it has evolved through several examples in response to local water quality problems. The specific controls are specified in discharge permits issued to individual municipalities. These reflect local conditions, including economics, and are subject to negotiations. The examples appear to recognize the existence of a first flush, or at least reflect the realities of cost effective treatment systems. Examples include the permit for the City of Grand Rapids in which "adequate treatment of CSO" is defined:

> Adequate treatment is defined as minimizing combined sewage discharges, by ensuring that discharges occur only in response to rainfall events or snowmelt conditions, including:
>
> 1. Retention, for transport and treatment, flows generated during storms up to and including the one-year one-hour storm event; or otherwise ensuring that discharges will not cause a violation of water quality standards;

2. Providing the equivalent of primary treatment of all flows greater than the one-year one-hour storm event (30 minutes detention or equivalent treatment, skimming and disinfection); or otherwise ensuring discharges will not cause a violation of water quality standards;

3. Providing treatment for flows in excess of the ten-year one-hour storm event to the extent possible with facilities designed for lesser flows.

In another examples, Saginaw's permit requires "..total storage for the retention of the one-half inch, one hour storm event, two thirds of which will be provided for settling, skimming, and disinfection".

3.2.1.4 Combined Sewer Control in Minnesota and North Dakota

Municipalities on the Red River, upstream from Winnipeg in the United States were contacted to establish their CSO status (Robert Skrentner, EMA Services Inc., Personal Communication, 1994). The results are as follows:

Moorhead, MN Moorhead completed separating their sewers in the late 1960s. They were required to do this by the Minnesota Pollution Control Agency. Moorhead's population is around 32,000, so they are under the size limit that would require permitting under EPA's storm water regulations.

Contact: Bob Zimmerman, City of Moorhead, MN, (218) 299-5390

Fargo, ND Fargo is just finishing separating their sewers. The Denver Region of EPA offered 75% funding and gave low interest loans for the remainder, which the City took advantage of. The city covered its share by assessing each lot $2500. They used block grants and a 1% sales tax for street improvements to help offset the cost.

North Dakota has no requirements for CSO control, separation or stormwater treatment.

Fargo has a population of 75,000, with another 25,000 in surrounding counties. They will fall under the EPA stormwater regulations and thus be required to obtain a permit. They are working on an approach for stormwater control which should be available by early 1995.

Contact: Pat Zavoral, City of Fargo, ND, (701) 241-1545

Grand Forks, ND Grand Forks completed separating their sewers in 1986.

Since their population is less than 50,000 population, they will not be affected by the EPA stormwater regulations.

Contact: Kenneth Vein, City Engineer, Grand Forks, ND, (701) 746-2630

3.2.2 *Stormwater Quality Control Program*

EPA has included stormwater regulations in the Clean Water Act since 1973, and updated these requirements in the 1987 reauthorization. The 1987 Clean Water Act established phased permit application requirements, deadlines and permit compliance conditions for different categories of storm water discharges. In 1990, EPA published its final rule for discharge permit applications for storm water discharges associated with industrial activity, and large and medium sized municipal separate systems. EPA has also issued guidance manuals for assistance in preparing permit applications. The basic steps in each application include:

- General information describing the owner and site.
- Establishment of legal authority of the municipality to: prohibit/limit discharges from industrial activity to storm sewers; to prohibit illicit discharges to storm sewers; to control discharges from spills, dumping and illegal disposal; enter into joint agreements; and, to require compliance with all ordinances and regulations which control discharges.
- Identification of sources
- Characterization of discharges
- Description of existing management programs such as structural and source controls, maintenance measures and inspection methods to detect illicit discharges
- Fiscal resources dedicated to storm water programs.

The final stormwater rule requiring permits includes construction activities in the definition of industrial activities. Construction activity is defined as including clearing, grading, and excavation activities for areas larger than five acres. As part of the permit application process, the owner of the construction site must develop a storm water pollution prevention plan, which includes sediment and erosion control measures during construction, and long term measures to stabilize and control runoff from the site.

3.3 *URBAN DRAINAGE POLICIES FOR CONTROL IN EUROPE*

3.3.1 *General Comments*

Urban drainage and pollution control are conflicting objectives in combined sewer systems (CSS). The interpretation of various European CSO policies might be easier to understand if they are seen in the light of the respective urban drainage policies and the liability problem when it comes to backwater, surcharge and flooding.

In most European countries there are both CSS and separate sewer systems (SSS). Generally, there are more SSS to be found
- in Northern countries
- in smaller towns
- in newer towns
- in new (suburban) developments of cities.

In some countries pollution control policies exist for both SSS and CSS.

3.3.2 Overview

The following overview section addresses 4 major questions for each of ten European countries.

Belgium (only Flemish Region)
Switzerland
Germany (federal plus some states)
Denmark
Spain
France
The Netherlands (federal plus some provinces)
Sweden
Finland
United Kingdom (without Scotland)

1. How are CSS/SSS designed with respect to urban drainage ?
   - **Sewer Design**
2. What are the consequences of backwater/flooding in basements?
   - **Backwater Protection**
3. How are CSO's controlled?
   - **CSO Control**
4. How are storm sewer discharges from SSS controlled?
   - **Stormwater Quality**

3.3.2.1 Belgium

Sewer Design

- traditionally combined system used, new systems are separate except in rural areas
- new regulation since 1988 ("AW/88-3" published by Ministry of Public Health of the Flemish Region)
- design return periods "drastically" reduced in AW/88-3
- methods used: rational, pseudo rational, Vicari, TRRL
- block rain T=1(..2) years for SSS, T=2(..5) years for CSS
- IDF-curve developed for one rain station ("Ukkel") representing the whole Flemish region,
- areal reduction factors after Fruhling
- runoff coefficient 0.8 for impervious areas
- design evaluation using dynamic routing and no specific model imposed

Backwater Protection
- no information available

CSO Control
- 2 times to maximum of 5 times DWF passed forward to TP
- CSO should be restricted to meet specific needs of receiving water
- if BOD is restricted: 7 CSO events per year are not to be exceeded
- basinwide evaluation of all pollutant sources with models such as QUAL II
- in-pipe storage is applied to reduce CSO, also off-line storage, disconnection of impervious areas, infiltration, on-site storage

Stormwater Quality
- no information available, probably included in basinwide evaluation of pollutant sources

3.3.2.2 Switzerland

Sewer Design
- 80% combined systems
- the respective municipality is responsible for definition of drainage comfort (municipality chooses recurrence interval T)
- traditional method is block rain/quasi-rational method with T = 5a in smaller towns, T = 10a in medium towns, T = 10..20a in cities
- new (1989) recommendation by VSA (Swiss WEF): restrict frequencies of "full pipe flow" or "flow level at basement level" or "surcharge", use hydrologic/hydrodynamic models

Backwater Protection
- municipalities sometimes require backwater valves
- soil drainage pipes around houses are often connected to (mostly combined) sewers, massive infiltration/inflow problems
- consequently very weak dry weather sewage
- since 1989 connection of drainage pipes to CSS is prohibited, but it will take a long time before effects are significant with respect to I/I quantities.

CSO Control
- Cantons (Provinces) are responsible (among others they specify the sensitivity parameter U)
- pass-on flow at CSO: $Q_{crit} = A_{red}(U - V_{upstream})\ 45/(t_f + 30)$ where

  U receiving water sensitivity parameter $V_{up}(20..50)$
  V_{up} upstream sewer inline volume in m^3/ha_{red}
  t_f flow time to CSO in min

- CSO control mostly by detention ponds, 3 types:
  first flush holding tanks Vol = f(U,t_f, DWF, slope)
  settling throughflow tanks Vol = f (surface load, t_f, flow velocity within tank, tank proportions, slope)
  combined first flush/settling tanks (only if $U > 30$)
- some experiments with sieves and screens, more frequently used lately
- pond construction phases out because subsidies will be no longer available after 1995
- since 1991 stormwater infiltration mandatory (federal law)

Stormwater Quality
- no general regulations
- tendency to connect hazard areas to combined systems
- preference to combined system

Specific Remarks on Switzerland

In Switzerland the procedures for general urban drainage master planning have been radically changed in the new guideline (1989). Simultaneously, a new federal law demands all clean sewage to be infiltrated, only exceptionally can it be discharged to sewers. Formerly this was exactly formulated the other way around.

The old Swiss CSO control approach was similar to the old German approach. Today it is recommended that the CSO problem is always locally assessed in terms of receiving water requirements. A CSO control approach has to be accompanied by assessments and measures for I/I reduction, surface use, structural sewer renovation, receiving water use, surface runoff infiltration and emergency measures. Any mix of measures is applicable provided the goals are reached. These goals are negotiated between the Canton and the respective municipality.

3.3.2.3 Germany

Sewer Design
- traditional method is block rain/quasi-rational method with T = 1a up to T = 5a in cities, higher T for special hazard structures (e.g. underpasses)
- city is responsible
- recently after supreme court verdict (1989): restrict frequencies of surcharge after local risk-benefit evaluations, use hydrologic/hydrodynamic models

Backwater Protection

- municipalities always require backwater valves
- municipalities define a "backwater level" up to which a house owner has to protect himself/herself by backvalves, pumps etc., usually this is street surface level
- soil drainage pipes sometimes hooked to combined and storm sewers, strictly forbidden to connect to sanitary sewer.

CSO Control

- so far 10,000 detention ponds in place (V = 10-30 m^3/ha_{red}), many with some form of real time control
- 10 billion, DM invested for tanks, i.e. 135 Canadian $/cap.
- various tank types throughflow, by-pass, settling, first-flush holding, etc.
- hardly any experience with other measures of quality control
- pass-on flow at CSO without storage: $Q_{crit} = A_{red}(7{,}5\ldots15\ l/s.ha_{red})$

Stormwater Quality

- no countrywide regulations, sedimentation ponds in some cases and some states ("Bundeslander")

Recently, the German WEF (ATV) has released a new guideline (A128) for CSO control. Formerly, CSO tanks had to be built to hold 90% of the annual BOD in the combined sewage during wet weather in the system. It was regarded that this could be achieved by holding 70% of the annual combined sewage in the system.

The new guideline follows a different approach. The idea is to have a CSS that discharges the same annual COD load as a separate system. The procedure starts by computing the annual COD load of an imaginary SSS. Then an imaginary tank is placed before the treatment plant and dimensioned so that it only discharges the same COD load. In all but simple cases this is done by pollutant transport models. Then the tank volume is distributed in the system at real CSO locations. Existing volume (in or off-line) can be taken into account. Volume activated by real time control can also be taken into account. Finally the re-designed system is simulated using the same rain data as above to show that the discharged pollution load is less than allowed.

The new guideline is likely to be adopted by most German states. It has the advantage that the construction of tanks as the only applicable measure is no longer necessary. Other forms of CSO control can be applied as well.

3.3.2.4 Denmark

Sewer Design

- <fewer than 50% of sewer systems are CSS
- use historical rain series and hydrologic/hydrodynamic models, design for full pipe flow with T = 2a up to T = 10a

Backwater Protection

- some communities require backwater valves if basement level is below sewer level

CSO Control

- since 1983 four complexity levels of evaluation
- simplest level (tables) only in exceptionally simple cases
- other levels used models of various sophistication
- higher level = individual quantification of CSO discharge effects in receiving waters (e.g. long term computation of oxygen depletion), computed with MOUSE/SAMBA/DOSMO
- criterion: frequency of low oxygen level in receiving water
- no routinely accepted CSO technology yet, measures to be used include swirl separator, ponds, real time control, etc.

Stormwater Quality

- sedimentation ponds required at every major stormwater outlet (recently issued requirement)

3.3.2.5 Spain

Sewer Design

- city is responsible
- no traditional rules
- tendency to use T = 10a for design storm and the rational method

Backwater Protection

- community is not responsible for backwater
- at some places frequent flooding, but no liability problems reported ("people are used to flooding")

CSO Control

- no regulation nor is it common practice
- tendency to apply dilution concept (i.e. overflow if sanitary sewage is diluted 3..4 times by stormflow

Stormwater Quality - unknown in Spain

3.3.2.6 France

Sewer Design

- generally applied return period for design storm T = 10a (official rule of 1977)
- can be varied between 2a (suburbs) and 20a (downtown), but usually the T = 10a rule is applied
- many existing sewers have much smaller capacity

Backwater Protection

- if basement flooding is due to surface flows the sewer agency is responsible, has to show that sewer is designed properly
- if basement flooding is due to backwater the homeowner is responsible, since flap valves are mandatory
- court decisions tend to protect homeowners
- since 1983 flooding insurance is available, provided the storm was "exceptional", definition of "exceptional" seems to be highly political, based on victims, flooded area, damage, newspaper reports (!)

CSO Control

- the law requires to agree locally on quality criteria (Department is in charge)
- common practice is to set CSO regulators to 3 times peak dry weather flow
- problem is more emphasized recently because of public awareness

Stormwater Quality

- no specific law except for receiving water quality standard
- practice is to use treatment plant effluent quality standards also for storm outlet quality
- emissions of visible and/or accidental pollutant discharges into storm sewers are prosecuted

3.3.2.7 Netherlands

Sewer Design

- the Cities are responsible for drainage
- Dutch sewer systems are networks of storage pipes emptied by pumps, >85% combined systems
- almost all sewage has to be pumped because there is literally no gradient available
- design variables are treatment and storage capacities, using the "Kuiper's graph" or "dot graph", based on one 37 year series of rainfall records
- surcharge of streets is accepted 10..30 min every two years, calculated using a specific runoff of 60..90 l/s.ha
- for storm sewer design also 60..90 l/s.ha is applied

Backwater Protection

- municipality is responsible for construction and maintenance
- practically, juridical action after backwater is hardly successful, so the homeowner carries the risk

CSO Control

- Dutch Provinces are in charge of water pollution control including CSO, have delegated this task to water authorities
- design of drainage and quality control can hardly be separated, since Dutch systems are functioning as underground storage ("communicating pipes")
- allowable overflow frequency is negotiated with Provinces (typically 3..10/yr)
- old design parameter was the theoretical ("Kuiper's") overflow frequency, usually 5..10 per year with approximately 3 times DWF pumped to treatment (DWF = 10-12 l/cap.h)
- after nationwide project on effects of CSO on receiving waters was finished, new standards are defined: By 1998 all CSS have to be upgraded to have 7 mm of inline storage, 0,7 mm/h so-called "pump-overcapacity" (i.e. extra treatment capacity at wet weather) and 2 mm of settling storage for all CSO leaving the system.

Stormwater Quality

- so-called "improved SSS" are mandatory, i.e. SSS where the first flush of stormwater pollutants is discharged into the sanitary sewer by means of connecting pipe to the sanitary sewer and a very low threshold weir in the storm sewer.
- in the stormwater sewer >4mm storage and in the sanitary sewer 0,3 mm/h pump overcapacity (for the first flush connection) has to be provided.

3.3.2.8 Sweden

Sewer Design

- CSS only in old towns/cities
- regulated in so called "P 28" document issued by Swedish Water and Waste Water Works Association (about 1985)
- basic rule: for combined sewers use design storm of T = 5a and rational formula,
- for pumped areas use T = 10a
- for storm sewers use T = 2a
- under discussion is concept of maximum flooding frequency with T = 10a

Backwater Protection

- traditionally communities were not liable for backwater damage caused by storm of T>5a
- now community has to prove that sewers have been designed after P 28

CSO Control

- CSO rarely specifically addressed, tendency to go for separation
- CSO restrictions issued by water quality agency together with operating requirements of treatment plants
- in large cities storage tunnel concept (e.g. Stockholm, Goteborg), real time control (Malmo)

Stormwater Quality

- surface runoff infiltration at source is regarded as good alternative
- each "big" outlet is regarded individually
- sedimentation tanks are sometimes applied

3.3.2.9 Finland

Sewer Design

- for combined sewers use design storm of T = 3a and rational formula
- for areas with bigger hazards use T = 5..10a
- for storm sewers use T = 2a
- major reference is a book by Kaupunkiliiton of 1979

Backwater Protection

- community is liable for backwater damage if sewers are not designed properly
- no insurance against backwater damage possible in Finland

CSO Control - dilution concept with 5..10 times dilution ratio

Stormwater Quality - apparently not regarded as a problem today

3.3.2.10 United Kingdom

Sewer Design

- apparent priority order of objectives: 1. public health/flooding, 2. structural integrity, 3. receiving water quality
- use full pipe flow with T = 2a return period and the Wallingford model all over the country
- occasionally T = 1..5a (Price)
- T = 10a for combined, T = 2a for separate systems (Ellis)
- "flood frequency performance criterion": return period of flooding mostly T = 35a, for some land uses 10..50a
- financial constraints prohibit frequent application of criteria above
- cost-effectiveness/benefit analysis recommended

- if ponds are used for quantity control prescribed recurrence intervals for flooding of ponds are:
  storm/underground T = 1..5a
  storm/surface T = 5..30a
  combined/underground T = 2..10a
  combined/surface T = 10..50a
- set of 6 methods (manual) and 3 models (computer) recommended for given catchment size (Hydraulics Research report no. 1363)

Backwater Protection

- Water Companies (formerly Water Authorities) are responsible (and liable?) if backwater damage appears increasingly often

CSO Control

- very general "consent" with the "Control of Pollution Act, Part II" of 1974 ("COPA-II"): outfalls should only work during rainfall
- nationwide rules as draft (National River Authority 3/1993):

  1. low significance if dilution >8:1 at 5% low flow in receiving river: apply "formula A" design concept: carry-on flow [l/day] = mean DWF + 1350 times population equivalents + 2 times industrial effluent

  2. medium significance if 2:1 <dilution< 8:1 and >2000 pop. equiv.: apply simple models and max. admissible BOD levels in rec. water

  3. high significance if dilution <2:1: apply complex models

- recommended receiving water criteria for T = 1 yr, d = 6h:DO>3,5 mg/l and tot. $NH4<5$ mg/l
- tank size V = (3 Q sanitary + 3 Q industry + Q infiltrated) times 2 h
- max flowthrough tanks = 6 DWF (settling), surplus directly via CSO
- very often carry-on flow is only slightly more than 1 DWF in existing old systems
- withhold debris > 6mm

Stormwater Quality

- no rules nor guidelines
- tendency for separate systems in new developments with discharge limited by ponds
- quality control in separate systems seems to be controversial, only oil interceptors generally accepted
- sedimentation in ponds is viewed as being more a nuisance than a benefit
- recently more attention is given to quality considerations

3.3.3 European Policies

Only very recently a first European Standard (EN 752) was released that regulates questions above. The general idea is that locally accepted policies can be further applied and that EN 752 has to be applied only if no other rules exist. Hence, formally all national etc. guidelines will remain valid. However, it is only logical that courts will adopt the European guidelines in their decisions if they deviate from the local guidelines. The importance of the European Standards will therefore in fact become larger than it appears today.

EN 752 is very specific about design storm frequencies for urban drainage systems and allowable flooding frequencies. A table is given that demands flooding frequencies from 1 in 10 down to 1 in 50 years. This is problematic in a number of countries already.

However, other than originally discussed, EN 752 does not include any very specific numbers and demands on stormwater CSO control. The respective paragraphs read like introductions in a text book for an introductory course on sanitary engineering. The only numbers given are "may be" - settings of CSO; of 5-8 DWF or critical rain intensities of 10 - 30 $l/s.ha_{red}$ for pass-on flows. Quote "Associated storage in, for example, a detention tank...can greatly reduce the environmental impact of stormwater outflows". Most of the cited national regulations on CSO go very much further in their specifications, as can easily be seen from the information described above.

SECTION 4
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REFERENCES

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SECTION 3

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