The Seattle System - Real "Real Time Control"

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Introduction

During the past few years, Real Time Control (RTC) of conveyance systems has been emerging as an attractive alternative in efforts to reduce CSO problems. Although there are still only a few implementations of RTC technology for sewerage systems throughout the world, these include several large systems.

The basic concept behind RTC of sewer systems is fairly straightforward: the conveyance system is controlled in real time with the objective of maximising the utilisation of in-line storage available within the system. The cost of the control system is often only a fraction of the cost required for alternatives that include construction of new storage facilities. Such savings were clearly demonstrated in the application of RTC to a large urban system in Seattle, Washington.

Seattle Program

The Municipality of Metropolitan Seattle, commonly referred to as Metro, is a public agency that operates and maintains a network of large sewers and interceptors as well as several wastewater treatment plants in the greater Seattle area. Since its inception in the late fifties, Metro has reduced the amount of CSOs in the Seattle metropolitan area from an estimated 20-30 billion gallons per year to the level of 2 billion gallons per year in the mid-eighties. This reduction in yearly CSO volumes was accomplished by implementing a number of CSO projects including separation, storage, and real time control.

Metro's combined sewer system conveys wastewater to the West Point Treatment Plant. The system serves an urban area of 270 km^2 and includes about 160 km of interceptor sewers ranging from 300mm to 3.6 m in diameter. The system includes 13 pumping stations and 18 regulator stations. Regulator stations are control structures that consist of vertical in-line sluice gates which can be closed in order to regulate the flow going into the interceptor and to store wastewater temporarily in the trunk sewers. At most regulator stations, outfall gates can be opened to release wastewater to the adjacent bodies of water, so that backups into low connections can be avoided. Overflow weirs are located in the trunk sewers, usually upstream of gates, to prevent backups and flooding into low sewer connections.

In 1985 Metro was facing a set of challenges familiar to many municipalities: heightened public concern about CSOs, and increased pressure to be cost effective and "do more with less". Metro's CSO abatement program included a number of capital improvements projects, and a plan for the development of a real time control system.

The idea of applying RTC to the Metro's sewerage system gained considerable momentum after a cost benefit analysis was conducted at the onset of the project. This analysis (Sewell and Schultz, 1986) indicated that the cost of developing a real time control system would be between $0.21 and $0.35 per gallon/year, while the cost of building storage facilities to provide equivalent reduction would be between $1.50 and $2.00 per gallon/year.

In order to design a control strategy, it was necessary to test and evaluate different control scenarios and their impact on the operation of the conveyance system. Control strategies could not be tested on the real system - the idea of applying untested procedures to the real system was not only an unacceptable risk, but was also highly impractical. The operation of different control strategies had to be evaluated under various conditions, including storm events of different intensities. Such conditions would be impossible to generate within a reasonable time frame on the actual system. For this reason, mathematical modelling became the obvious answer and a critical part of the project.

The basic approach to designing the control strategy is shown in Figure 1. The mathematical models were used encapsulate and represent the behaviour of the real system, and control algorithms were superimposed on the mathematical models of the conveyance system.

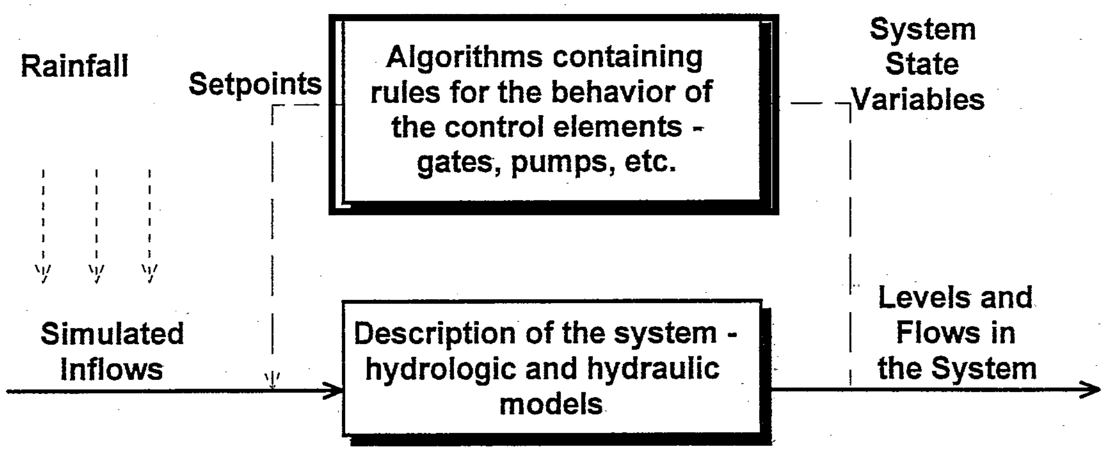

Figure 1. Conceptual approach to RTC development

This approach allowed the design team to simulate different operating conditions and observe impacts of control strategies on performance of the system without having to manipulate the actual physical facilities. More detail of the model set-up is presented in Figure 2.

Considering the challenges, costs, and risks of software development, Metro investigated the possibility of acquiring software to achieve the project goals. The result of the literature search (Schilling, 1984) indicated that at that time, no other city successfully implemented fully automatic real time CSO control to a large urban system. There was no clear blueprint for success that could be followed. The nature of the problem was quite specific, and an integrated solution ready to be "plugged in" was simply not available "off the shelf" on the commercial software market.

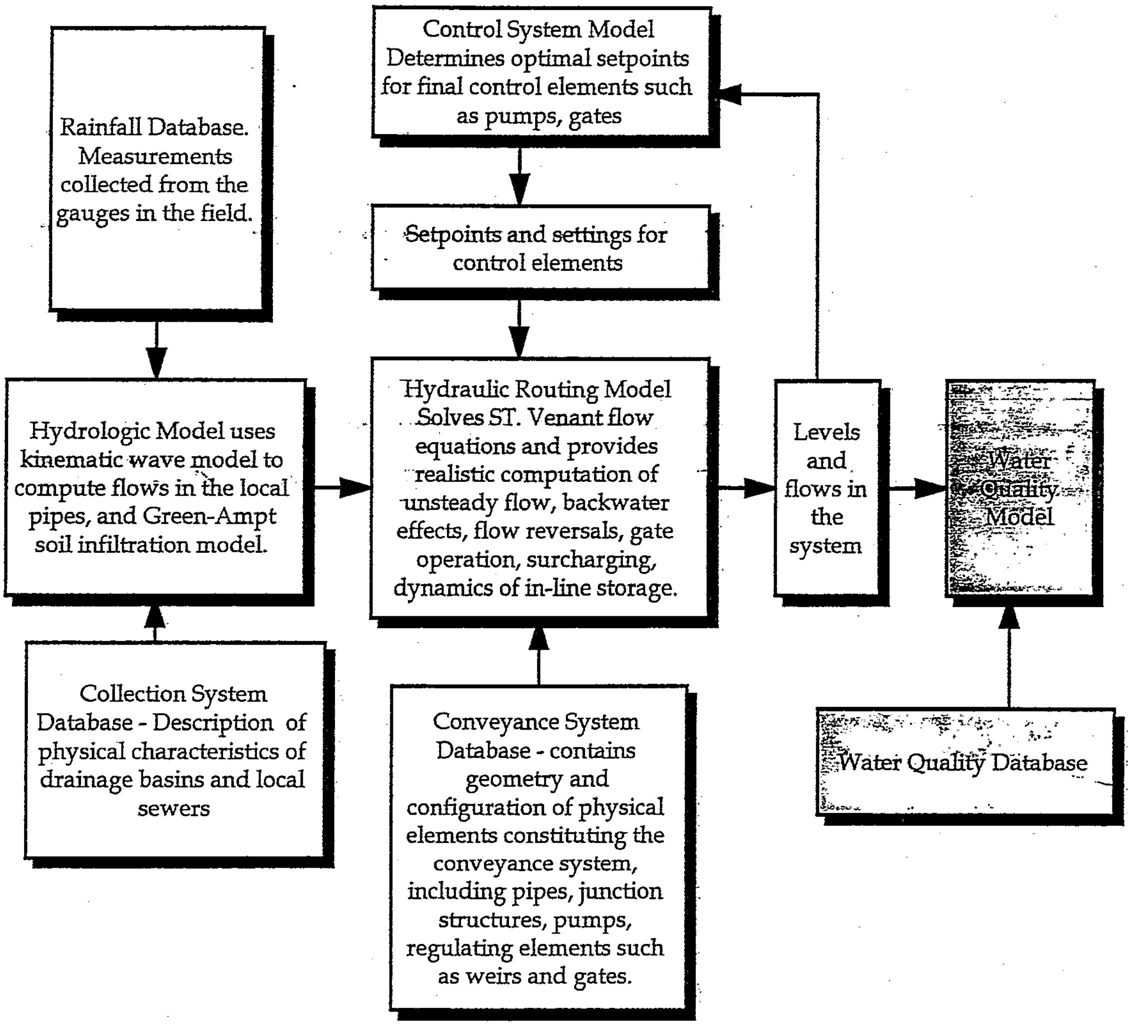

Figure 2. Modelling system components

The search did uncover several valuable pieces that could be integrated into the overall solution. Metro acquired the following modules:

1) Hydraulic Routing model developed at Colorado State University (Book, 1980). This model solves the St. Venant equations of continuity and momentum for each segment of the pipe and simulates all conditions of gradually varied flow, including backwater flow. The model can simulate surcharge conditions, which occur frequently during storm events.

2) Although a Runoff model obtained from Colorado State University provided a good starting point, the Runoff/Transport model was largely developed by Metro project staff. This model computes the amount of flow entering the large trunks and interceptors of the West Point conveyance system. The output from the Runoff/Transport model was connected to the Routing model at 250 points where the local sewer networks enter the main interceptor system.

The goals of the RTC system are usually defined within the objective function of the control system. The objective function can vary according to the nature of the system and the operational goals of the municipality. Some examples of the components making up the objective function include the following:

- minimising the number of spill events

- reducing discharges to sensitive areas
- minimising the overall volume of discharge during a storm
- increasing Mean Time Between Failure on control components
- avoiding surcharge conditions
- equalising flows to the treatment plant
- minimising energy consumption
- isolating a part of the system for maintenance

In Metro's case the objective function included more than a single component, and the priority of the components varied according to the system state. For example, during low dry weather flows the priority for saving energy was high while during heavy storms the concern for discharge levels had the highest priority.

Seattle Metro's Real Time CSO Control project was completed for $2.9 million, which was $1.4 million under the original project budget of $4.3 million. The modelling work actually accomplished was beyond the original project scope, and included a complete modelling environment that includes hydraulics, hydrology, sewer inventory, and a demographic database.

The real time control strategy has been completed and is now fully operational. The improvements in control practices resulted in CSO reduction of approximately 200 million gallons per year. In 1992, Metro received the national award for innovation in operational practices from the American Metropolitan Sewers Agencies Association (AMSAA) for this project.

References:

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Schilling, W., (1984) "Application of Real Time Control in Combined Sewer Systems", report to Department of Civil Engineering, Colorado State University

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Session 2- Chairman Peter Myerscough Yorkshire Water
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Question Michael Reeves Integrated Hydro Systems
The 7 design events you used to test the system how were they chosen ?
Answer
These were the standard events that Seattle Metro used and they were the easiest to cross reference. The storms represented a wide range with the biggest being a 1 in 20 year event. There was no spatial variation in the storms as this would complicate the comparison though in reality it would give bigger benefit in the control system.
Question Barry Luck Mc Dowels Ltd.
How confident would you be with an RTC system to achieve absolute standards of say 3 spills per bathing season ?
Answer
I am very confident with the tools and methodology to design the system. With the goals you describe you may choose a different approach to optimisation not use the linear optimisation.
Question Barry Luck Mc Dowels Ltd.
If you optimise but can't meet the standards you may need to supplement with major civils works where do you start with so many possibilities ?
Answer
In Seattle RTC was only 10% of the problem. All the storage available is fully utilised. There is little room for a lot of structures the tools are used to identify the best capital investment from all of the possibilities.
Question Charles Ainger Montgomery Watson
Query on the data collection , are you using just level or level and flow ?
Answer
Only using level , we wanted to use flow , we tested 4 manufacturers equipment for 3 months and then decided to stick with level only and derive flow from system geometry. The big issue was reliability and we were not confident with the velocity measurement to control 18 structures and 13 pumping stations. We were worried about data security.
I noticed you used RTC to reduce energy consumption. What percentage of the system storage do you feel it was safe to use for this purpose ?
Answer
We had a survey done on the available storage but I do not have the figures with me. The climate in Seattle is such that there are several months a year when rain is very unlikely and this helps.
Written Question Elaine Scott Rotherham Technical Consultancy
What provision is made for Fail Safe models if power fails?
Has a total failure been modelled ?
Answer
The whole system was designed with multiple redundancies. To date there have been no complete power failures.