20

Connecting Pipes and Plants:

Concurrent Hydrodynamic Simulation of the Hydraulic Performance of a Collection System and a Wastewater Treatment Plant

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The City of Edmonton's Gold Bar Wastewater Treatment Plant (GBWWTP) is at the downstream end of a collection system servicing approximately 634,000 people plus industrial and commercial areas. The plant has a relatively flat hydraulic profile, such that the effluent weir on the primary tanks is 0.23 m above the invert of the incoming conduit. The effluent weir on the secondary clarifiers is only 0.38 m below the primary tank weir.

For years the hydraulic simulation of the collection system has proceeded on the assumption of a controlled head relationship at the headworks of the treatment plant. This has been a reasonable approach when evaluating the performance of the collection systems. However as work has progressed on the City's combined sewer overflow strategy and a preferred method of control is to convey more flow to the GBWWTP for treatment and expand treatment capacity, the hydraulic gradeline at the inlet, and the headworks of the plant become important elements. Without lowering the gradeline at the plant inlet, it is difficult to achieve the objective of treating a flow rate of 1600 ML/d on a sustained basis. Typically only during the largest events could such a high flow to the plant be possible and only for a short period of time. Therefore it was necessary to determine means of lowering the hydraulic profile at the headworks of the plant, and at the same time evaluating the system flows reaching the plant.

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To understand and evaluate the hydraulic relationship between the upstream collection systems and the GBWWTP a detailed hydraulic model of GBWWTP was developed and included as part of the collection system hydraulic model. The hydraulic model was constructed using the Danish Hydraulic Institute MOUSE model using approximately 150 elements to describe the various treatment and conveyance processes. This included grit tanks, screens, primary settling basins, bypasses, secondary aeration basins, secondary clarifiers, ultra violet disinfection, and outfall to the river. The combined collection and treatment plant model was used to simulate alternative flows scenarios to and through the treatment plant as part of a City wide CSO Strategy. Alternatives evaluated include increased pipe capacity in the downstream portions of the conveyance system, increased conduit capacity into the GBWWTP, and pressurized flow in the conveyance system.

20.1 Introduction

The City of Edmonton is located in the north-central part of the Province of Alberta, Canada, at approximately 54 degrees latitude. The City is serviced by 4,300 km of sewerage and drainage facilities, of which 930 km are combined sewers constructed between the years 1903 and 1960. The area serviced by combined sewers (about 5,000 ha) represents about 16% of the presently developed lands in the City. The service area includes the downtown core plus residences for about 27% of the City's present population of 634,000.

The major drainage system through Edmonton is the North Saskatchewan River. Within the City, the river is the receiving water body for six small tributary creeks, 214 storm outfalls, 19 CSOs and the secondary treated effluent from the City's Gold Bar Wastewater Treatment Plant (GBWWTP). The creeks, storm outfalls and CSOs discharge to the river during spring snowmelt and rainfall events. Other discharges occur from private industrial sources both in the City and further downstream.

To some extent during the 1950s, and exclusively since 1960, new development in the City has been serviced with separate sanitary sewerage and storm drainage systems. Today there are about 1,600 km of sanitary sewerage piping and about 1,800 km of storm drainage piping. During the 1950's, there appears to have been an emphasis on local flood control with the installation of interconnections between combined and sanitary sewer systems and adjacent storm drainage system at common manholes or as high level overflows. In 1994, there were 347 of these system interconnections documented (Ward et al., 1997); subsequently, the number was reduced to 188 by 1999 due to the expeditious remediation at sites providing no obvious flood control benefit.

On an annual basis, approximately 100 million m^3 of wastewater receives full treatment at the GBWWTP (Figure 20.1). In addition to the normal flows, the GBWWTP provides some treatment to 3.8 million m^3 (56%) of the 6.8 million m^3 of rainfall induced flows that enter the collection system during the recreation season (May 1 to October 31) in a typical year. Figure 20.2 shows the location of nineteen CSO structures where the remaining 3.0 million m^3 of rainfall induced flows discharge to the North Saskatchewan River. The largest single volume of CSO occurs at the Rat Creek site accounting for approximately 60% of the annual CSO volume. All the CSOs are downstream of the City's two water treatment plants, and as such, pose no direct threat to Edmonton's drinking water supply (Buie and Labatiuk, 1994). The City and Alberta Environmental Protection (AEP) recognize that CSOs are a concern and that CSO impacts on the environment should be mitigated. Annual CSO contaminant loadings of bacteria and nutrients to the North Saskatchewan River are second only to those from the GBWWTP. The loading issues from GBWWTP discharges are being addressed through implementation of ultraviolet disinfection and biological nutrient removal facilities.

To address the discharge of combined sewage, Drainage Services initiated a CSO Control Strategy in 1994. This resulted in the development of a CSO Early Action Control Plan (RCPL, 1997) and culminated in the development of a CSO Long Term Control Plan (UMA, TetrES and XCG, 1999). During the development of the plan, it became apparent that an important CSO control option would be to provide additional primary treatment at GBWWTP.

A base model of the City's collection system had been set up as early as 1991 on the basis of a controlled outlet from the downstream end of the system into the plant headworks. It was realized that a free outlet from the system into the plant did not exist as the effluent weir on the primary tanks is set at 0.23 m above the invert of the connecting conduits. Thus a backflow condition from the plant into the system occurs under base dry weather flow condition before the effect of wet weather flow is superimposed. It was not deemed necessary to assess the effect of the backflow and the hydraulic performance of the plant until the requirement to increase plant capacity was realized as a CSO Long Term Control Plan initiative. The issue then became how to increase flows through the plant without adversely affecting the downstream portions of the collection system.

To understand the backwater effects on the collection systems a model of the plant was set up and connected with the collection system base model. This chapter discusses the setup and calibration of the collection system and GBWWTP hydrodynamic models, and the application of these two models to resolve combined sewage discharge in the City of Edmonton.

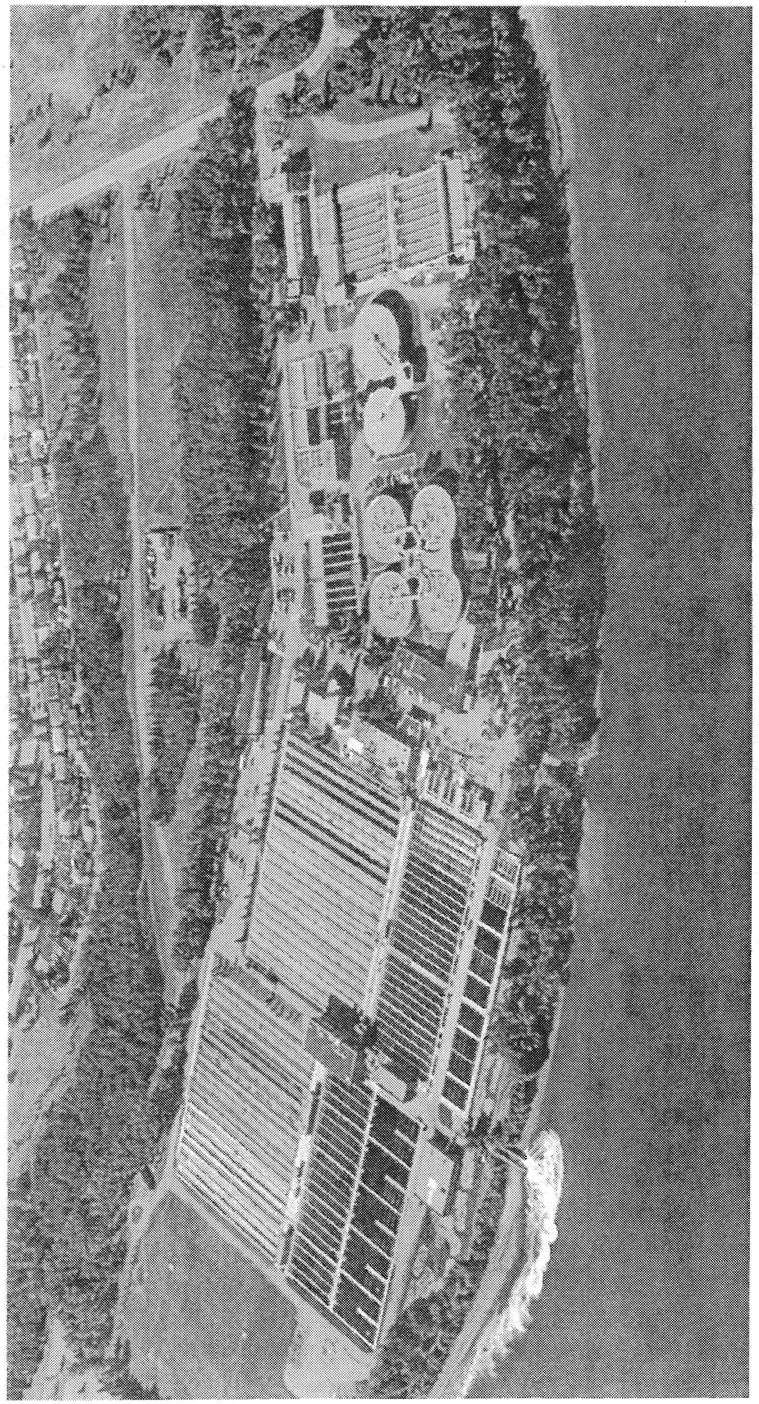

Figure 1

Figure 20.1 Gold Bar Wastewater Treatment Plant.

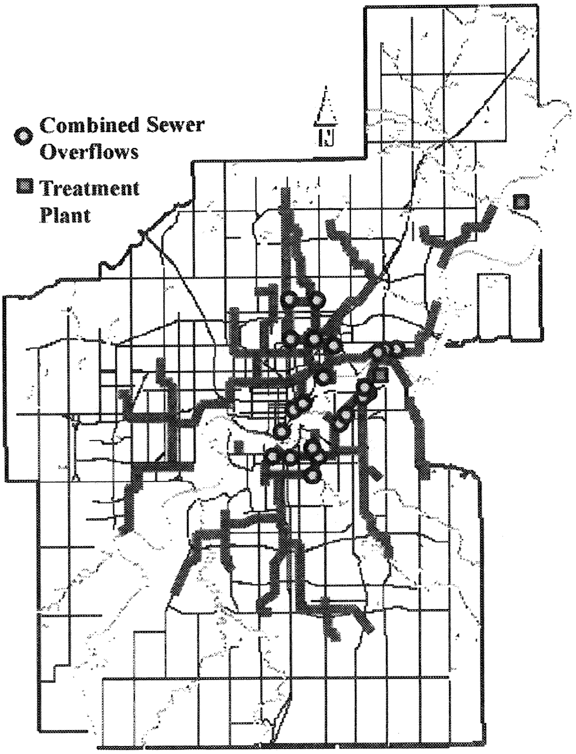

Figure 20.2 System schematic.

20.2 Conveyance System Model

Edmonton's collection system model is referred to as the Global Trunk Model. The Global Trunk Model was established to evaluate the operation of the City of Edmonton combined and sanitary sewer systems with the following objectives:

- capacity as related to its present level of service;
- the impact of sewer surcharging on local systems;
- controlling combined sewer overflows; and
- effects of the collection system on the GBWWTP.

The existing Global Trunk Model represents approximately 6.1% of the entire combined and sanitary collection sewers. These sewers are representative of the larger sewers in the system and are key segments of the collection system. Figure 20.2 shows the extent of the Global Trunk Model. The modeled system includes all facilities operational in the collection system in 1998.

The Global Trunk Model is a combination of SEWHYMO (Ward et al., 1994) for hydrology linked to the Danish Hydraulic Institute MOUSE model for detailed hydraulic computations. SEWHYMO was customized as a hydrologic model for the City of Edmonton and generates inflow hydrographs of dry weather and wet weather events for use in MOUSE. A conversion routine, developed by the Danish Hydraulic Institute, translates the SEWHYMO interface file into a format usable by MOUSE.

The hydraulic assessment of the existing system and various control measures were carried out using the Danish Hydraulic Institute MOUSE model. The model provides a stable platform, with real time control (RTC) modeling capabilities. MOUSE was used for single event analysis as well as continuous simulation of the recreation year (May through October). Single event analysis was used to provide a preliminary assessment of various options to facilitate more timely results. The continuous simulations were used in assessing alternativeplans.

The City has expended significant effort to calibrate and verify the Global Trunk Model using flow monitoring data collected since 1991 at in-pipe and CSO locations (City of Edmonton, 1995a and 1995b). The calibration/verification includes dry weather flow, infiltration, wet weather flow, CSO overflow frequency and volume. Figure 20.3 provides an example of the agreement between measured and modeled flows that has been observed throughout the sewerage system.

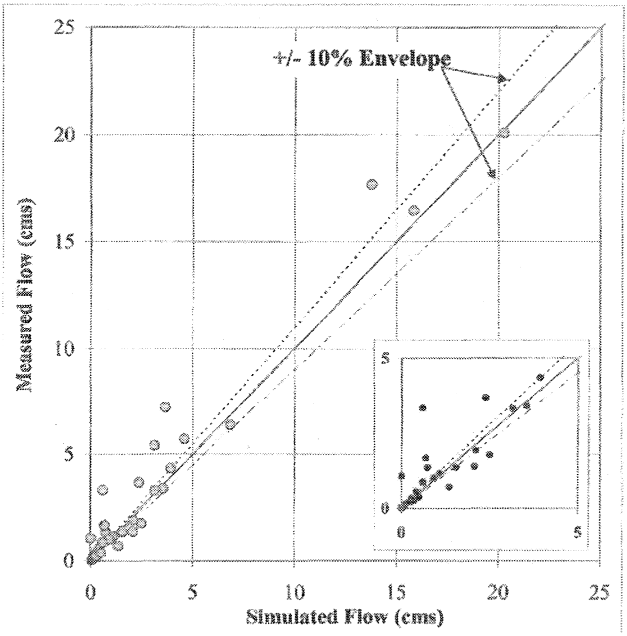

Figure 20.3 Global Trunk Model calibration: June 6 to 9, 1991.

The data in Figure 20.3 are peak flow comparisons between simulated and monitored flows at locations throughout the sewerage collection system. Some discrepancy is observed in peak flow calibration at flow rates less than 5m^3/s. The calibration in these areas, and the flow monitoring data are being confirmed.

20.3 CSO Long Term Control Plan

In the development of a CSO Long Term Control Plan, eight detailed alternatives were evaluated to arrive at a recommended plan. To select between each plan, detailed modeling and analysis of each of the plan options was performed. A value engineering exercise was then undertaken to select the preferred plan. The following describes the recommended CSO Long Term Control Plan (referred to as *Plan 5*) and the simulation results. The linkage to the downstream GBWWTP is then discussed with a description of plant hydraulics.

20.3.1 Plan 5

The selected CSO Long Term Control Plan consists of the following primary elements (as shown in Figure 20.4):

- in-system storage through RTC;
- expand GBWWTP to provide 1600 ML/d enhanced primary treatment, including disinfection;
- opportunistic sewer separation;
- complete Rat Creek river crossing and remove bulkhead at Hardisty; and
- Highlands system optimization.

The total cost estimate for this plan is in the order of $260 million.

The implementation of RTC's and the Rat Creek river crossing were simulated in the collection system model and are discussed below. The benefits of expanding primary treatment at GBWWTP and opportunistic sewer separation were initially assessed through spreadsheet analysis rather than hydraulic modeling.

In-system Storage Through RTC

The Early Action Control Plan proposed the implementation of RTC as a viable CSO alternative to take advantage of in-system storage (ISL, 1997). In the Edmonton sewerage system RTCs are proposed as fully automatic local control devices. These are gates installed in the sewer system responding to level information monitored in the sewers upstream and downstream of the gate.

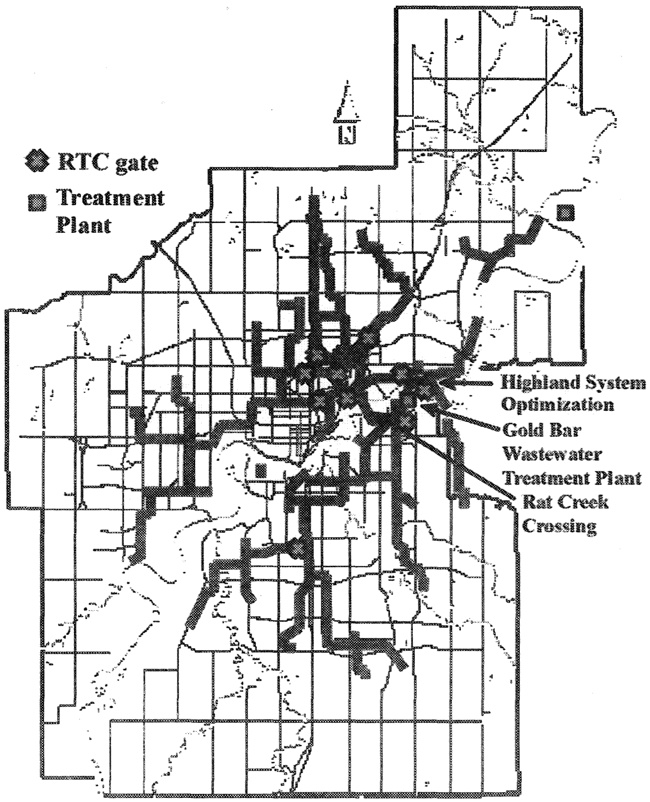

Figure 20.4 CSO long-term control Plan 5.

The benefits of RTC in controlling CSOs were evaluated utilizing the MOUSE model. Regulating gates that allow dry weather flow to be conveyed uninhibited were introduced at each of the potential sites as shown in Figure 20.4. As the flow levels increase resulting from a wet weather event, the control gate restricts the flow backing up excess flow in the upstream segment. At a critical flow elevation, unique to each location, the control gate begins to open releasing the stored flow. The gates are designed to open prior to affecting upstream pipe elements avoiding extreme surcharge conditions. If the critical elevation is not reached, the stored flow will eventually be drawn down during dry weather flow periods after an event.

In total, ten sites were considered. Upon review nine of the ten gates were modeled. For these gates, a simple two position operating strategy was adopted. The normal gate position was set to allow peak dry weather flows to pass through the gate without surcharge conditions. The second position of the gate was set as fully open. The gate was allowed to move to the fully open position only when the hydraulic grade line reached a critical elevation at a control node located upstream of the gate.

A more complex operating strategy was necessary for Gate #3 at Rat Creek. The control objective was to restrict the throughflow to a maximum of 4 m^3/s. To achieve this level of flow control during wet weather it was necessary to first restrict the flow by closing the gate in order to maximize the available storage. The gate opening was then regulated to maximize the in-system storage without adverse affects on upstream systems. Under dry weather conditions the gate would open sufficiently to pass the peak dry weather flow.

Simulation results determined that an annual CSO volume reduction of approximately 200,000 m^3 is achieved by the implementation of RTCs. This represents increasing the wet weather flow capture by approximately 3%. Work is ongoing regarding the pre-design of specific RTC sites with more detailed RTC modeling undertaken to refine actual operating strategies.

Rat Creek Crossing

The Rat Creek Crossing connects the north side and south side conveyance systems with an inverted syphon under the North Saskatchewan River (Figure20.4). The approximate length of the crossing is 950 m. Construction of this syphon provides an alternative route during wet weather flow for flows to be conveyed to the GBWWTP, thus relieving the north side CSOs.

Simulation results determined that an annual CSO volume reduction of approximately 40,000 m^3 is achieved by construction of the Rat Creek crossing. However the crossing in conjunction with expansion of GBWWTP primary capacity significantly reduces the total annual CSO volume by approximately 1.2 million m^3. This represents increasing the wet weather flow capture by approximately 18%.

20.3.2 Hydraulic Grade Line at GBWWTP

After *Plan 5* was selected as the preferred CSO Long Term Control Plan, additional components were identified to enhance the wet weather control performance of the plan. One of the issues identified with *Plan 5* was the ability to convey flows to the GBWWTP for treatment due to hydraulic gradeline restrictions at the downstream end of the collection system and in the plant.

The hydraulic gradeline at the GBWWTP has a significant backwater effect on the Highlands, Rat Creek and Hardisty CSO sites. The low grade drop through the plant, approximately 0.38 m, results in backflow in the collection system and the existing Highlands river crossing (a twin barrel inverted syphon). The backwater effects limit the collection system capacity to convey flows to the GBWWTP.

To better assess the situation, hydraulic modeling through the GBWWTP was therefore undertaken and linked to the collection system model. Various alternatives could then be simulated to reduce the hydraulic gradeline and optimize the Highlands system allowing conveyance of more flows to the plant.

20.4 Plant Hydraulics

Despite the complex treatment process of the GBWWTP, the physical configurations of most components in the plant such as treatment facilities, physical connections, inlet and outlet control devices conform to certain hydraulic elements that can be represented by or translated into basic hydraulic elements for computer model simulation. Basic plant hydraulics and process flow relationships of the GBWWTP are simplified and presented in Figure 20.5.

From a hydraulic perspective, raw sewage is received at the raw inlet chamber and diverted into a series of grit chambers, screen facilities and primary settling tanks. These are termed primary treatment processes. Effluent from the primary treatment process enters a number of aeration tanks and clarifiers for secondary treatment. Effluent from this process passes through the Ultra Violet facility for final disinfection before it is discharged into the North Saskatchewan River. The basic plant hydraulics have been incorporated into a GBWWTP hydraulic model. Major components included in the plant hydraulic model representing the current (1998) configuration include:

- the main sewer entering the plant (a twin 2.4 m by 2.0 m box section pipe at 0.08% slope);
- a raw inlet chamber with three main control gates;
- three main inlet channels below ground (south, central and north);
- five grit chambers (#1 to 5);
- two screen facilities before primary treatment;
- eight primary settling tanks (#1 to 8);
- eight aeration tanks (#1 to 8);
- two bio-reactors (#9 & 10);
- ten secondary clarifiers (#1 to 10);
- one UV facility with four inlet channels;
- three Venturi flumes at the inlet and one effluent flume near the plant outfall;
- two primary by-pass and one secondary by-pass locations;
- inlet control gates to most facilities;
- effluent troughs/ launders in primary settling tanks and clarifiers; and
- influent channels, effluent channels and underground pipes throughout the plant.

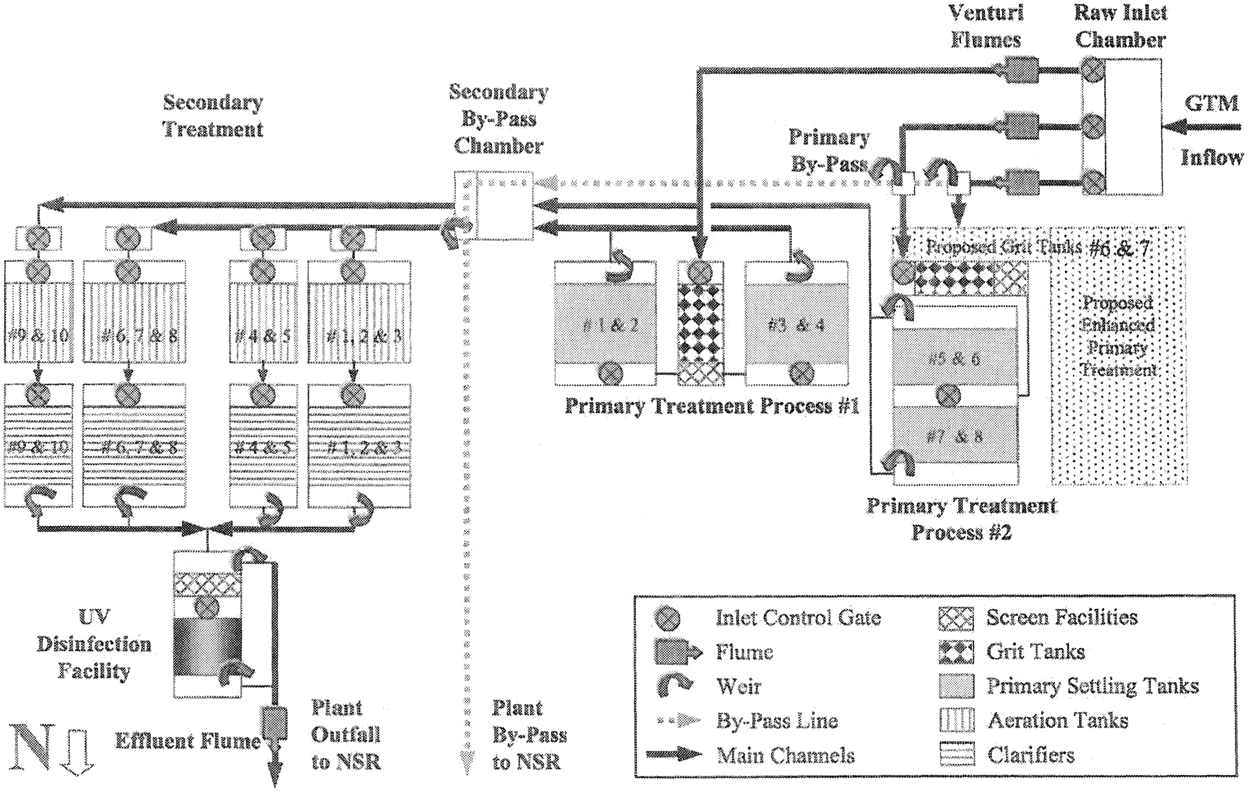

Figure 20.5 Hydraulic and process flow diagram of the GBWWTP.

Some of these structures or facilities are considered critical elements with respect to the hydraulic characteristics of the GBWWTP.

Flumes: the Venturi flumes and effluent flume were constructed to monitor raw sewage inflow and plant effluent respectively. These flumes have similar hydraulic characteristics to transverse broad crested weirs, and were therefore modeled as such.

Primary by-pass: if plant influent under wet weather flow conditions is greater than the primary treatment capacity, approximately 950ML/d (11.0 m^3/s), by-pass occurs in two of the three main inlet channels (north and central channel), preventing flooding of the primary treatment facilities. Bypass flows are conveyed straight to the river without any form of treatment.

Secondary by-pass: effluent from primary treatment is conveyed to the secondary by-pass chamber. If the flow is greater than the secondary hydraulic treatment capacity, 400 ML/d (4.6 m^3/s), a secondary by-pass occurs. If the secondary by-pass is not controlled properly, it may result in either too much overflow discharging into the North Saskatchewan River or flooding of the secondary processes adversely affecting the effluent water quality.

Slide gates: these gates were installed to control, manually or automatically, inflow to the following facilities: main inlet channels, grit tanks, screen facilities, primary settling tanks, aeration tanks, clarifiers, and UV facility. Proper level settings are required to control the inflow rate and backwater to upstream facilities.

Aeration tanks: inflow to the aeration process has to go through four passes in each tank for biological treatment before it enters the secondary clarifiers.

Effluent troughs/ launders: parallel troughs and launders are constructed near the surface of all primary settling tanks and clarifiers. Treated flow discharges to these launders and is conveyed to other facilities for further treatment. Weir length and crest level control the water depth in the tanks and the discharge rate.

Two new grit chambers (#6 & 7) are under construction and will become operational later in 1999. These will be connected to the north main inlet channel. This channel is included in the model, but is set up for plant expansion purpose and is not connected to any facilities in the 1998 baseline model. The impact of construction of these facilities on the hydraulic gradeline is discussed later.

20.4.1 Simulation Setup

Based on the structural drawings of the GBWWTP and site visit information describing the operational characteristics of the plant, a model schematic of the

GBWWTP was developed. The schematic representation only accounts for the hydraulic operation of the plant including the following:

- layout and connectivity of the system;
- hydraulic and process flow direction;
- basic and special hydraulic elements such as nodes, links, gates, weirs and flumes;
- possible connection of future facilities;
- system inflow, plant by-pass and plant outfall locations; and
- facility description.

Basic hydraulic elements included in the model are links, nodes, gates and weirs. In general,

- The raw inlet channels and other underground conduits are modeled as closed links with circular or rectangular sections.
- Flow channels and process tanks are modeled as open links. For example, process tanks in the model are represented by large open channels with shallow slopes.

In order to simplify the modeling process, some of the tanks adjacent to each other were considered as a single element in the hydraulic representation. Figure 20.6 shows the simplified hydraulic representation adopted.

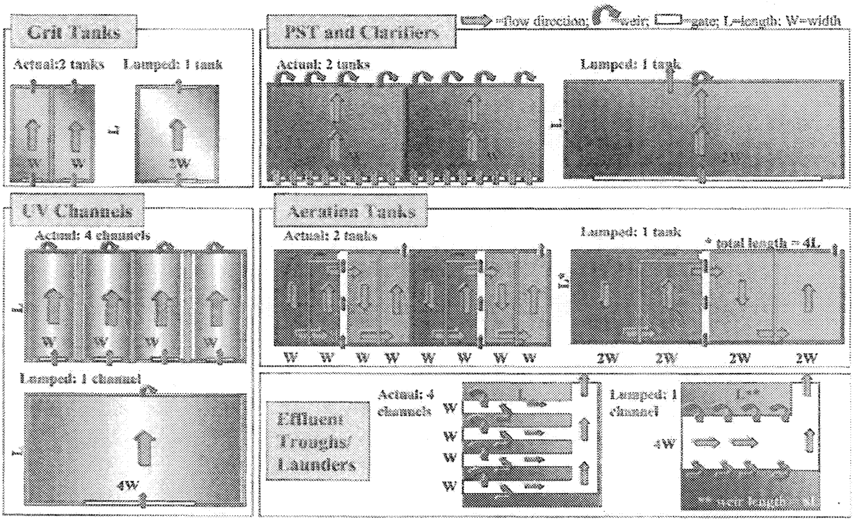

Figure 20.6 Hydraulic model system lumping.

The following elements were simplified as single elements:

- grit chambers # 1,2 & 3, and #4 & 5 were simulated as two tanks;
- primary settling tanks (PST)# 1 & 2, #3 & 4, #5 & 6, and #7 & 8 were simulated as 4 tanks;
- aeration tanks # 1,2 and 3, #4 & 5, #6, #7 & 8, and #9 & 10 were simulated as 4 tanks;

- secondary clarifiers # 1, 2 & 3, #4 & 5, #6, #7 & 8, and #9 & 10 were simulated as 4 tanks;
- ultra violet (UV) disinfection channels #1, 2, 3 & 4 were simulated as one channel; and
- parallel effluent launders in primary settling tanks and secondary clarifiers were lumped with the respective tanks.

From previous experience in the City it is expected that in most cases similar results will be obtained from a detailed or lumped system. If differences do occur, they can be easily minimized by changing one or more hydraulic parameters during the calibration process.

Simplification was also applied to the following control structures:

- Slide gates at each facility are lumped into one control gate. Gate opening positions are currently set at a fixed level for calibration purposes. It is possible to convert these to RTC settings based on levels and discharge measurements elsewhere in the system.
- Weir lengths of effluent troughs/launders in each primary settling tank and clarifier are calculated as the sum of all weirs on all sides of the facility.

The following special modeling techniques are applied for specific hydraulic elements:

- Storage/basin nodes, with depth/area relationship are assigned to large manhole shafts.
- Dummy storage nodes are created in order to represent the connection of two elements where no real manholes exist or a sudden change in conduit shape occurs. For example, a small channel connecting to a deep and wide open tank.
- The total length of each aeration tank is assumed to be the sum of all four passes in that tank. Friction loss due to the passes are reflected by adjusting roughness coefficient in the tanks during the calibration process.
- Without a detailed calculation of effective openings and flow characteristics, flow restriction caused by screen facilities are calibrated by adjusting the roughness coefficient in the channel representing these elements.
- Venturi and effluent flumes are modeled using equivalent hydraulic elements. Flow characteristics of these flumes are best described and modeled by equivalent transverse weirs.

To facilitate model calibration and to ensure stability, the various hydraulic elements were added in stages to develop a complete hydraulic representation of the plant. A plan view of the model network is shown in Figure 20.7, and a typical longitude profile view, from raw sewage inlet to plant outfall is shown in Figure20.8.

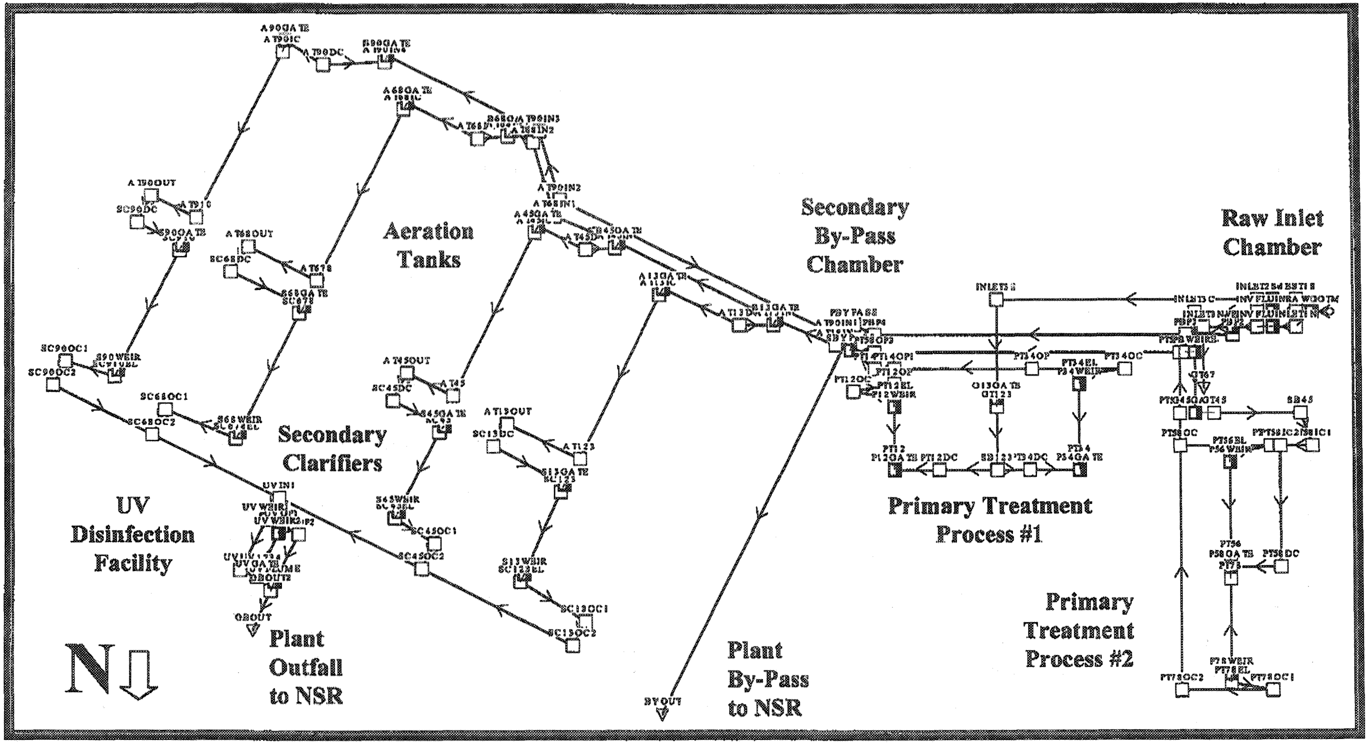

Figure 20.7 The GBWWTP hydraulic model network.

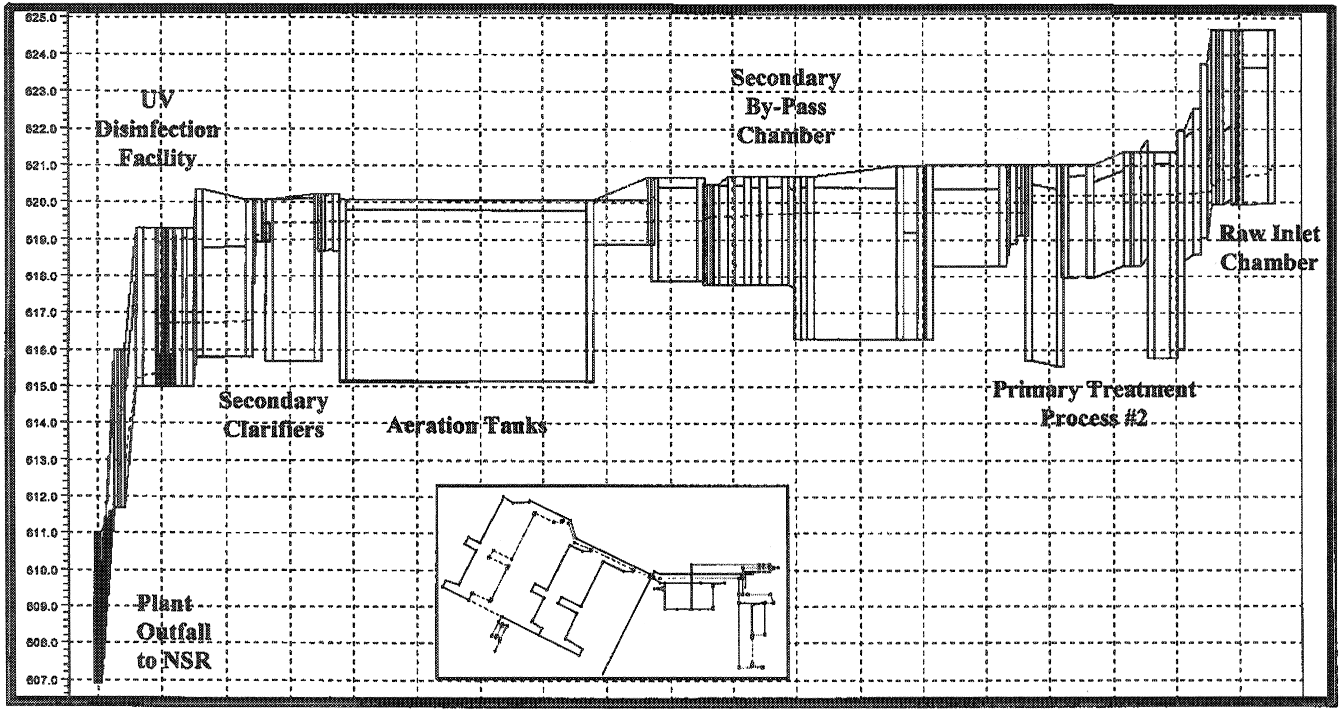

Figure 20.8 The GBWWTP hydraulic model typical longitude profile.

20.4.2 Calibration

Initially the GBWWTP network was tested and calibrated using various constant inflow rates for a 24-h period with a 10-s simulation time step. Hydraulic characteristics of each component in the model were examined and verified ensuring consistent results were obtained with previous steady state simulations through the plant using the HYDRO model. This model had previously been calibrated on the basis of field observations during rainfall events in 1993. However configuration of some components of the plant have changed since this time, including the addition of new facilities. Therefore the basis of calibration of the HYDRO model is not current.

Constant inflow rates utilized in the testing and calibration phases ranged from 150 to 1400 ML/d. Where:

- 150 ML/d (1.74 m^3/s) represents the capacity of primary settling tanks 1 & 2;
- 200 ML/d (2.31 m^3/s) represents the minimum dry weather flow (dry weather flow) to the plant;
- 300 ML/d (3.47 m^3/s) represents the capacity of primary treatment process 1 (primary settling tanks 1, 2, 3 & 4);
- 360 ML/d (4.17 m^3/s) represents the normal peak dry weather flow to the plant;
- 400 ML/d (4.63 m^3/s) represents the capacity of secondary treatment;
- 650 ML/d (7.52 m^3/s) represents the capacity of primary treatment process 2 (primary settling tanks 5, 6, 7, & 8);
- 950 ML/d (11.00 m^3/s) represents the total capacity of primary treatment; and
- 1400 ML/d (16.2 m^3/s) represents the maximum observed inflow to the plant due to a severe storm event on July 4, 1995.

Specifically, model calibration was performed to confirm the following plant hydraulics:

- process capacity at each unit;
- primary and secondary by-pass rate, volume and frequency;
- water levels at critical locations such as raw inlet, flumes, by-pass weirs, process tanks, and effluent launders;
- gate opening positions;
- flow restriction caused by screen facilities;
- time for tank filling; and
- flow balance at various locations.

During calibration, the following parameters had to be adjusted to achieve a reasonable comparison to the previous HYDRO modeling. These are the more sensitive components of the model to water level and flow adjustment:

- Water levels at critical locations and flow restriction characteristics at the screen facilities were calibrated by altering the channel roughness coefficients.
- Primary and secondary by-pass levels were calibrated by modifying the weir characteristics (length, crest level and discharge coefficient).
- Inflow rates and water levels at various process units were calibrated by changing the gate opening positions in the RTC file.
- Flow characteristics of the flumes were calibrated by adjusting parameters of the equivalent weir.

The GBWWTP model is hydraulically different from a conventional gravity drainage sewer model. Traditionally in a collection system model hydraulic stability can be achieved with minor adjustments to model configurations or hydraulic parameters. Where hydraulic instabilities are most likely to occur is in special structures such as storage tanks, with pump stations and other control points (i.e. weirs, orifice). The GBWWTP hydraulic model comprises many special control structures which inherently create instabilities. Instabilities in the GBWWTP were identified to be caused by the following conditions:

- large open tanks at shallow slopes;
- sharp changes in conduit shapes at connections, for example, connections between a small channel and a large tank; and
- large inflow to empty channels and tanks.

In the GBWWTP model, instability problems were resolved by modifying the following parameters:

- conduit length, slope and roughness,
- depth/area relationship of storage nodes,

Calibration of the MOUSE model to the HYDRO model produced good agreement in simulated water levels throughout the plant between the two different models. This is not a true calibration of the model as there is no direct comparison with monitored water levels throughout the plant. However for the purposes of the model setup, this calibration was deemed satisfactory, until level information is collected and further calibration performed.

20.4.3 Real Events

To further assess the model capabilities, simulations of real events were performed. The simulations were undertaken without the upstream collection model. Five storm events were used to simulate flow conditions through the plant as described in Table 20.1.

Figure 20.9 shows the peak flow hydraulic grade line profile through the plant and selected flow hydrographs for the July 4, 1995 event . For this simulation peak flows in various plant processes are shown in Table 20.2.

Table 20.1 Rainfall event statistics.

Date	Frequency	Duration
July 14, 1981	50 y	2-h
July 1, 1990	100 y	24-h
June 6, 1991	25 y	6-h
August 23, 1991	10 y	2-h
July 4, 1995	200 y	2-h

Table 20.2 Peak simulated plant flows (July 4, 1995).

Process	Peak Flow (ML/d)	Peak Flow (m^3/s)
Raw Inlet Chamber	1,310	15.2
South Venturi Flume	370	4.3
North Venturi Flume	940	10.9
Primary Bypass	200	2.3
Primary Process 1	370	4.3
Primary Process 2	740	8.6
Secondary Bypass	690	8.0
Secondary Treatment, UV Disinfection and Treated Effluent	420	4.9

From a review of Figure 20.9, it is apparent that the hydraulic gradeline is flat through the plant, even for flow rates greater than the plant capacity. At the peak of the storm event, the drop in simulated hydraulic gradeline through the plant between the north Venturi flume and the secondary clarifiers is 2.95 m.

20.5 Concurrent Simulation

All GBWWTP simulations presented have been on the basis of separate models of the collection system and the wastewater treatment plant. To simulate and analyze the systems together the GBWWTP hydraulic model is linked to the Global Trunk Model. This baseline model represents the 1998 configuration of a complete sanitary and combined trunk network including the GBWWTP.

20.5.1 Baseline Results

To assess the impacts of the GBWWTP and the effects of future modifications, simulations were performed of the same five storm events with the collection system model and the detailed wastewater treatment plant model as one hydraulic

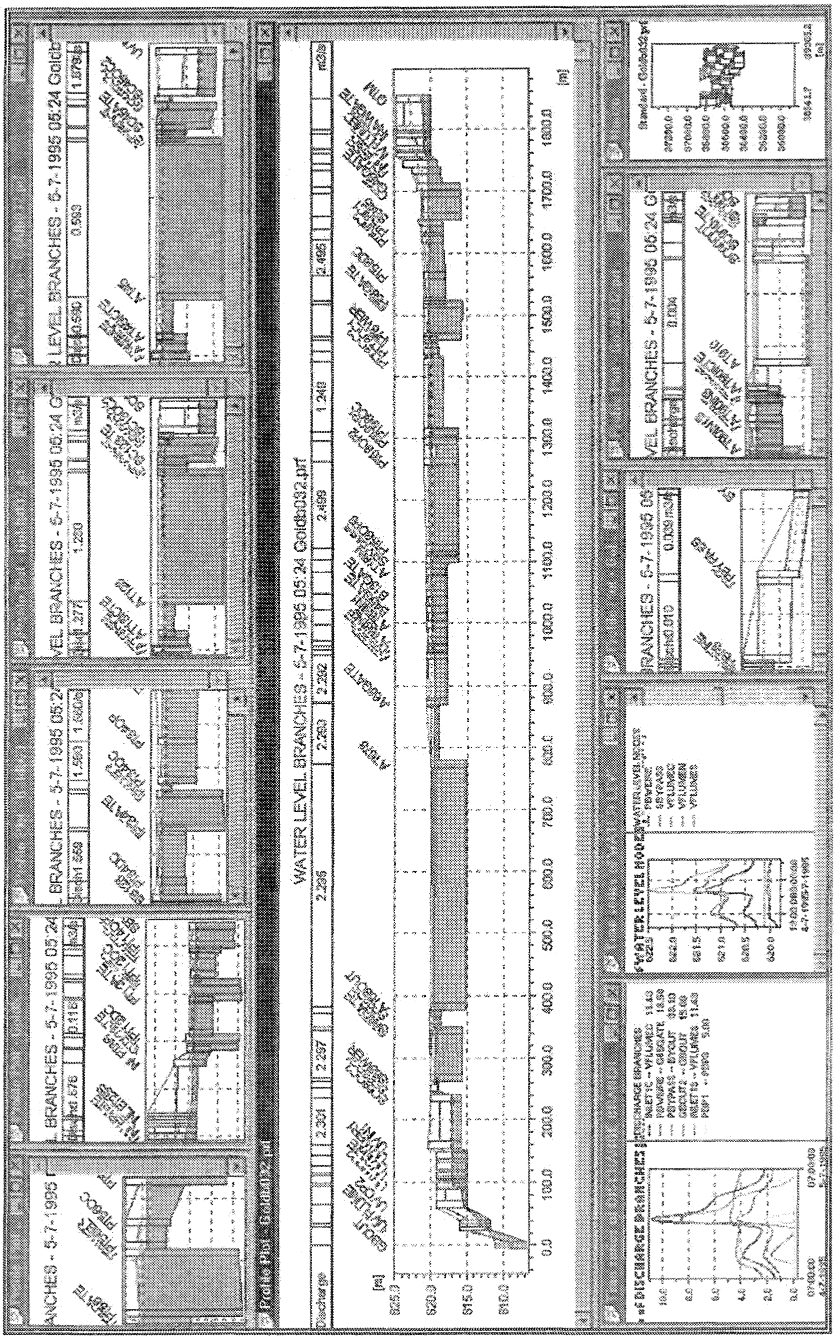

Figure 20.9 Hydraulic gradeline profile: July 4, 1995.

model. Comparisons of modeled CSO overflow volumes based on simulations with and without the detailed GBWWTP model for one storm event are shown in Table 20.3 for the event of June 6, 1991.

Table 20.3 CSO volume comparison with and without GBWWTP hydraulic model (June 6, 1991).

CSO Location	Collection System Model (m^3)	Collection System and GBWWTP Model (m^3)
Queen Elizabeth 1	80,110	80,220
Queen Elizabeth 2	6,630	6,600
Rossdale	31,560	31,560
Downtown	0	0
Mill Creek North	29,650	29,430
Mill Creek Central	19,460	19,470
Mill Creek South	160	150
Strathearn	16,490	16,470
Rat Creek	187,990	188,900
Kinnard	26,060	25,670
Hardisty	168,740	169,470
Capilano	0	0
Highlands	84,270	89,510
Beverly	10,100	9,820
Kennedale	0	0
CSO Total	661,220	667,270

Comparison of the two model setups indicate that there are similar CSO volumes predicted using either the collection system model or the collection system model with the GBWWTP model. However, reviewing the combined model results provided a better understanding of the backwater effects in upstream collection systems. It was observed that backwater from GBWWTP was primarily attributed to the hydraulic characteristics of the following elements:

- Venturi flumes;
- screen facilities;
- weir crest levels (especially in the secondary clarifiers); and
- gate opening positions.

20.5.2 Highlands System Optimization

For the CSO Long Term Control Plan, expansion of the enhanced primary treatment from the 950 ML/d to 1600 ML/d at the GBWWTP was proposed. Based on the system analysis results for this alternative, 1.78 million m^3 of CSO would overflow to the North Saskatchewan River annually. Of this volume, approximately 520,000 m^3 overflows at the Highlands CSO site, while the proposed treatment capacity of 1600 ML/d is not fully utilized. The bottleneck in the system was identified as the conveyance capacity of flows from the north side of the river to the GBWWTP on the south side.

In order to achieve full utilization of the treatment capacity, the optimization of the Highlands system was required. The performance of the Highlands, Rat Creek and Capilano CSOs are directly influenced by the hydraulic gradeline of GBWWTP and the relatively flat topography and the configuration of the conveyance system. Subsequently, the following three options for optimization of the Highlands system were identified for further evaluation:

1. Utilize the third inlet conduit at the GBWWTP.
2. Add a third pipe at the Highlands river crossing.
3. Seal the system resulting in pressurized flow.

Five additional options were considered but not evaluated in the model.

Option 1 refers to the three existing entrance channels inside the plant to convey flows through the primary tanks. The third entrance channel has never been used to date. However with the construction of grit tanks 6 and 7, the third channel will be connected to the plant. These facilities were therefore added to the detailed modeling to assess their impact on the hydraulic gradeline through the headworks and conveyance system. The simulation results with the inclusion of these tanks indicate a decrease in the hydraulic gradeline by as much as 0.9 m at the plant inlet. A comparison of the existing system with and without the new grit tanks and third conduit is shown in Table 20.4.

Table 20.4 Impact of grit tanks 6 and 7 on CSO volumes (June 6, 1991).

CSO Location	Collection System Model with GBWWTP (m^3)	Collection System Model with GBWWTP and New Grit Tanks (m^3)
Queen Elizabeth 1	80,220	81,180
Queen Elizabeth 2	6,600	6,600
Rossdale	31,560	31,560
Downtown	0	0
Mill Creek North	29,430	29,260
Mill Creek Central	19,470	19,450
Mill Creek South	150	130
Strathearn	16,470	16,470
Rat Creek	188,900	188,580
Kinnard	25,670	25,670
Hardisty	169,470	169,290
Capilano	0	0
Highlands	89,510	78,700
Beverly	9,820	9,820
Kennedale	0	0
CSO Total	667,270	653,710

The simulation results indicate a reduction in volume of 10,810 m^3 at the Highlands CSO is achieved for a single event analysis. This is the largest volume reduction achieved at any of the CSO sites, and is at the site most impacted by the backflow from the GBWWTP. Considering the new grit tanks are currently under construction their addition to the GBWWTP model were considered in the evaluation of the second and third options.

Table 20.5 provides a summary of the evaluation of the Highlands system optimization options at the Highlands CSO site. Option 2, which consists of adding a third 1500 mm diameter river crossing, was selected and used as the preferred approach. Option 3, the sealing of the system, was not considered given structural considerations of operating a pressure system. Reviewing the reduction in CSO volume shown in Table 20.5 it is evident that with the optimization of the Highlands system and the proposed plant upgrades, a significant reduction in CSO volume can be achieved at the Highlands CSO.

Table 20.5 Comparison of Highlands system optimization options (June 6, 1991)

Scenario	Highlands CSO Volume (m^3)
Baseline	89,510
Plan 5	84,980
Option 1	78,700
Option 2	2,430
Option 3	0

20.6 Conclusions

This chapter has demonstrated the application of hydrodynamic modeling techniques to the wastewater treatment plant process. Hydraulic gradeline profiles through the downstream portions of the collection system and the treatment plant have been simulated. These simulations have helped define, understand and evaluate alternative remedial measures aimed at lowering the gradeline, negating the impact of the treatment plant on the collection system.

In the analysis it is evident that there is minimal data for calibration of the water levels in the treatment plant. The calibration is based on previous modeling by the steady state HYDRO model, which was calibrated to measured water levels in the plant in 1993. As there have been plant process modifications since that time, there is a need to update the model calibration using current water levels throughout the plant

An extension of the GBWWTP hydraulic model to be considered is a link to a wastewater treatment plant process model. It has been demonstrated, as with most treatment pants, that a number of the control settings in the GBWWTP are based on process capacities not hydraulic constraints. A link between a process and hydraulic model would provide an overall solution to maximizing treatment plant operations in the future.

This modeling work has built on previous sewerage system modeling and assessment, including real time control simulations. In performing this detailed modeling the following challenges had to be overcome:

- Continuous simulation of six month rainfall periods through a complex model;
- Managing data output;
- Determining and simulating real time controls, including establishing and setting up the control logic; and
- Identifying and conceptualizing remedial measures for simulation.

To optimize the efforts required for this type of simulation exercise the following recommendations are suggested:

- Perform screening exercises using simplified modeling approaches to sort through many different options and components;
- Perform single event simulations, possibly even design storm comparison, to determine the relative benefit of varying options, before performing long term continuous simulation; and
- Add model components in small steps, especially for more complex elements, to ensure model stability for all items simulated.

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