Response to a 1:100 Year Rainfall Event

City of Lethbridge 2002 Flooding Investigation

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During a 65 h period in June, 2002 a total of 137 mm (5.4 in) of rain fell on the City of Lethbridge, representing a rainfall event greater than the City's 1:100 y return frequency.

Overloaded sewers created surcharged conditions throughout portions of the system leading to sanitary sewer backups, and, in three locations, to sanitary sewer overflows (SSO).

A situation analysis of this event required the distribution of a flooding questionnaire to City residents that provided key insights into the performance of the system and aided the subsequent sewer performance evaluation.

The performance of the sanitary sewer system was analyzed through the use of the RT-SWMM hydrologic / hydraulic model, which is slightly modified from the USEPA's SWMM to include additional model parameters to simulate dry weather flow sewage generation hydrographs for various land uses. Extraneous wet weather flows, or inflow and infiltration (I&I) into the sanitary sewer was simulated using SWMM's Runoff Block. ARCVIEW GIS was used to generate and present results from the modeling.

The sanitary sewage collection system model was calibrated to time-sensitive data that included Public Operations observations and measurements of manhole surcharging and overflows, wastewater treatment plant and lift station data, and results from the flooding questionnaire such as timing of sewage backups and basement flooding hydraulic grade lines.

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The RT-SWMM model was used to simulate the performance of the existing sanitary collection system in terms of observed system behavior, customer complaints and claims in order to provide a basis and scale on which “at-risk of flooding” residences could be measured and compared to the City’s desired level of service - 99.5% protection from sewer backup flooding. The model was also used to quantify the benefit (or relief of *at-risk* residences) that the City’s planned sanitary system improvements would have provided to the existing system during this or a similar rainfall event. The impact of future City development was also considered in this analysis.

7.1 Introduction

During the 66 hours between 2:00 am on June 8th, 2002 and 8:00 pm on June 10th, 2002 a total of 137 mm of rain fell on the City of Lethbridge, Alberta. This rainfall represents an event greater than the 1:100 y return frequency, and occurred during the wettest spring on record.

The main adverse effects of this rainfall were the hundreds of Lethbridge residences that experienced sanitary sewer backups into their basements and other types of flooding and related difficulties. The City of Lethbridge received 88 reports of stormwater seepage damage (due to basement foundation or wall cracking), 489 reports of sewer backups, and 435 other damage claims related to the storm.

Excess runoff created surcharge conditions through portions of the sanitary sewer and stormwater collection systems, which led to sanitary sewer backups and overland flooding. Surcharging of manholes in the sanitary collection system also led to three locations of sanitary sewer overflows.

As a result of this event, the City of Lethbridge commissioned an investigation to evaluate the performance of the stormwater and sanitary sewer systems. In addition to quantifying the nature and extent of problems, the study addressed the following questions:

- What were the key characteristics of the rainfall event, and what impact did prior rainfalls have on the response of the stormwater and sanitary collection systems?
- How did the various components of the stormwater and sanitary sewer systems perform during the storm event?
- Did the City respond appropriately to the operational challenges?
- How will ongoing and planned improvements help reduce the impacts of future rainfall events?

7.2 Historical Perspective on Local Flooding Occurrences

Prior to 1990, there is little evidence of widespread sewer backups in Lethbridge, although occasional instances did occur in those areas most prone to flooding today. From 1990 to 1994, however, the frequency of flooding and sewer backups increased, particularly in West and Southeast Lethbridge. Figure 7.1 shows the geographic location of the City of Lethbridge and the various City areas and neighbourhoods referred to in this chapter.

Figure 7.1 Location map.

In June 1995, more than 100 homes experienced sanitary sewer backups (primarily in Southeast Lethbridge). The City subsequently conducted two studies, *Relief of Southeast Sanitary Sewer Surcharging*, UMA Engineering Ltd. and MPE Engineering Ltd. (March 1995) and *City of Lethbridge Lot Drainage Study*, Associated Engineering Ltd. (1996) which identified that weeping tile infiltration was a major contributor to the severity of the flooding. The analysis of the June 1995 event resulted in the following five initiatives:

- Education efforts surrounding the issues of inflow and infiltration of rainwater and groundwater into the sanitary sewer system.
- Lot grading practices and construction standards in the City were permanently amended in an attempt to reduce the volume of rainwater entering the sanitary system via existing weeping tiles.
- New weeping tile connections to the sanitary sewer system were disallowed in favour of sump pump installations discharging to the ground surface or the storm system.
- Metal inserts, or tubs, were placed underneath “trapped low” sanitary sewer manholes submerged by street ponding during periods of rainfall in order to prevent large volumes of rainfall from entering the sanitary system.
- The Southeast Storage Tank was constructed adjacent to the Sugar Bowl. The tank was designed to provide temporary storage during times of peak sanitary sewer flows. When sewage levels in the trunk sewer adjacent to the Tank rise past a certain point, sewage spills over a weir into the Tank and is held there until sufficient downstream sewer capacity is available - at which time the Southeast Storage Tank is pumped into a trunk sewer manhole located on 19th Avenue South.

In 1997, the City began a comprehensive review of its water and sewer systems - kicking off the multi-year *Underground Infrastructure Master Plan (UIMP) Study* (Stantec Consulting Ltd., 2000). The objectives were to:

- conduct a detailed assessment of the condition of the existing water, sanitary sewer, and storm sewer systems,
- identify and prioritize optimized alternatives to refurbish, rehabilitate, and replace the existing infrastructure where necessary,
- create models for the City’s 20 y growth projections and future land use scenarios which will compute what impacts the various growth scenarios will have on the City’s existing underground infrastructure,

- develop a specific list of prioritized capital projects including their cost, the financing alternatives and the timing of implementation over the planning period, and
- develop a comprehensive underground infrastructure management system including the creation of computer models for the three systems, such that the Master Plan could be developed, implemented and updated.

During both 1997 and 1998, rainfall events occurred that elevated sewage levels to the point at which they spill into the Southeast Storage Tank.

With the generally drier conditions experienced during the summers of 1999 and 2000, fewer backups occurred.

By the year 2000, the UIMP Study was complete - having provided the City with a clear assessment of the existing system. The study identified 457 residences as being at risk of experiencing sanitary sewer backups during a peak design wet weather flow event. 25 locations throughout the City were identified as having high flooding potential as a result of stormwater from a 1:100 y rainfall event - the top 10 locations impacted 104 residences. The City's design standards were updated to account for the relatively high levels of observed inflow and infiltration, a common practice throughout North American municipalities affected by extraneous sewer inflows. In addition to identifying the above, the UIMP Study also used public participation to develop levels of service for all three systems. These goals were used to help define the extent of required improvement alternatives.

In 2000 the City implemented planning and design activities on a slate of over 25 priority water distribution, sanitary sewer, and stormwater management remediation projects which were identified in the UIMP Study (Stantec Consulting Ltd., 2000).

In 2001, the City began the multi-year construction of the C\$10.3M East Lethbridge Sanitary Sewer Upgrade, intended to relieve those areas facing the highest risk of sanitary sewer backups. However, the June 8-10, 2002 event occurred prior to the completion and commissioning of this important upgrade.

7.3 Situation Analysis

Prior to assessing the performance of the sewer systems, a situation analysis was conducted to develop a comprehensive understanding of the events surrounding the June 8-10 storm as well as those before and after the rainfall.

7.3.1 Antecedent Precipitation Conditions

The impact of any given rainfall event (in terms of inflow and infiltration rates) into the sanitary and storm sewer systems is influenced by past rainfall events and prior soil moisture conditions. Water-saturated soils generate higher volumes of runoff and contribute more extraneous flows to the sanitary sewer system than dry soils. Prior precipitation conditions were described by Alberta Environment (Water Supply Outlook for Alberta, 2002) as follows:

- Extremely dry spring and summer of 2001.
- Near normal winter precipitation (November 1, 2001 to April 30, 2002) was helped by precipitation in April that raised winter totals closer to normal values, particularly in southern Alberta.
- Two significant snowstorms occurred in May, 2002 generating above-normal precipitation.
- During May-June, 2002 records at Carway, Lethbridge and Medicine Hat were the wettest on record, while the record at Edmonton was the driest on record.

In reviewing flow records from the WWTP and prior rainfall events in 2002, it appears that antecedent soil moisture conditions contributed to the impact of the June 8-10 event.

7.3.2 Characteristics of the June 8-10, 2002 Event

Between 2:00 am on June 8th and 8:00 pm on June 10th a total of 137 mm rain fell on Lethbridge. Figure 7.2 depicts the rainfall hyetograph and cumulative precipitation over this time period. This hyetograph represents a much longer duration rain than is usual for Lethbridge's customary summer thunderstorms, which are short but torrential.

When data from the hyetograph is plotted on Lethbridge's standard rainfall intensity-duration-frequency (IDF) curves based on data from 1960 to 1990, the nature of the event can be further quantified as shown in Figure 7.3. While peak rainfall intensities over the 3-h and 6-h durations are less than a 2-y return period, the 24-h volume approaches the 25-y return period, and rainfall over the total storm duration exceeds the 100-y return period.

The June 8-10, 2002 event contributed to monthly precipitation in June 2002 being nearly 4 times normal, based upon 1961 to 1990 data (Water Supply Outlook for Alberta, Alberta Environment, 2002). It was extreme, presenting a greater load on Lethbridge's underground infrastructure than previously recorded events.

Figure 7.2 Hourly and cumulative rainfall for June 8-10, 2002.

7.3.3 Observed Effects of the June 8-10, 2002 Event

Observed and anecdotal data was collected from four primary sources:

1. *Observations by City of Lethbridge Public Operations Department and WWTP Employees.* Supervisory employees prepared a detailed summary and report of their field experiences and responses to the challenges of the rainfall and customer inquiries and complaints. This work created a database of 466 observations that are summarized in a geographic-coded timeline that was used in the verification of the model results of the sewer performance evaluation.
2. *Property Damage and Claims Related Data from the City of Lethbridge's Risk Management Department.* The data showed that seepage and sewer backup reports and claims were concentrated primarily in South Lethbridge - in general agreement with data from the Public Operations Department.
3. *Claim Location Data from Alberta Disaster Services.* The Province of Alberta (through Alberta Disaster Services) assisted more than 800 residents who experienced damage as a result of overland flooding (but not sewer backups) which is not generally insurable. To aid in the preparation of the 2002 Flooding

Figure 7.3 City of Lethbridge intensity-duration-frequency (IDF) curves and June 8-10, 2002 rainfall intensities.

Investigation (Stantec Consulting Ltd., 2002), Alberta Disaster Services provided a claim location map that was compared to other data sources.

4. *Observed, Anecdotal, and Other Data Received from the Public via the Flooding Questionnaire.* Over 400 respondents completed a detailed two page flooding questionnaire which addressed flooding location, age of residence, prior flooding history, flooding duration, and other details regarding private property flooding. 186 respondents indicated they experienced water seepage into their basement, while 246 indicated that a sanitary sewer backup occurred at their residence. South Lethbridge was hardest hit in nearly every category, the West side being a distant second for sanitary sewer backups, and North Lethbridge's only significant issue being basement water seepage.

The situation analysis revealed, in summary, that:

- Since 1990, the City of Lethbridge has experienced an increasing frequency and volume of sanitary sewer backups due to wet weather flows.
- From June 8-10, 2002 an extreme rainfall event occurred, which with wet antecedent soil and groundwater conditions negatively impacted parts of the stormwater and sanitary sewer collection systems. The stormwater system experienced issues with localized flooding and overland flows, while the sanitary sewer system was overwhelmed in many areas of the City.
- Record numbers of homeowners were affected, both in high risk and previously unaffected areas, resulting in property damage and claims against the City of Lethbridge.
- Over 400 flooding questionnaires received were invaluable determining the severity and nature of the sewer system performance during this significant rainfall event.

7.4 Stormwater and Sanitary Sewer Systems Performance

Lethbridge has two sewer systems; the sanitary sewer system conveys residential, commercial, and industrial wastewater to the WWTP for tertiary treatment prior to discharge into the Oldman River, while the storm sewer system manages and conveys stormwater directly to the Oldman River.

Both analyses were conducted using the RT-SWMM hydrologic / hydraulic model engine, a modified version of the USEPA SWMM engine. PCSWMM 2002 (Computational Hydraulics Inc., 2002) was used during this analysis as a front-end model interface in order to assist scenario management and output visualization.

The RT-SWMM model also includes a number of modifications to the original SWMM code that adds functionality and a change in modeling philosophy in order to represent and accurately simulate the two primary flow regimes inherent in a typical sanitary sewer system - dry weather flow (DWF) and wet weather flow (WWF) due to rainfall induced inflow and infiltration (RDII).

DWF components of the sanitary model are accommodated within the EXTRAN block where unit hydrographs are used to represent the diurnal sewage generation patterns characteristic of residential, commercial and industrial type land uses. D2 to D5 input lines are used to represent residential sewage generation rates for user-defined population densities and average per capita sewage generation rates that are assigned to model nodes - population peaking factor equations such as Harmon's Peaking Factor (Alberta Environmental Protection Design Guidelines) are also included, but are optional. D6 to D9 input lines are used to represent the sewage generation of commercial and industrial land uses by assigning a unit area flow hydrograph to the area of a sewershed designated to a model node.

The RUNOFF block in RT-SWMM was used to simulate the effects of extraneous wet weather flow. As the runoff block is normally used to generate surface runoff from a watershed entering into the storm sewer system, in order to use the RUNOFF block to generate inflow and infiltration volumes, the physical parameters and other hydrologic variables were modified for simulating extraneous flows. Extraneous WWF volumes were determined from historical flow monitoring data, and the rainfall data from a historical calibration event was used in the runoff block. The area parameter in the H1 input lines of the runoff block was established as a percentage of the physical sewershed area where this percentage was initially estimated by determining the ratio of extraneous flow volume to the total rainfall volume from flow monitoring data. Runoff block parameters were then modified until the model matched the total volume and shape of the monitoring data during the storm event. Surge gauges were also utilized to check the hydraulic gradeline levels in numerous locations across the City. The model was then verified and further calibrated to the June 8-10, 2002 rainfall event to time-sensitive data that included Public Operations observations and measurements of manhole surcharging and

overflows, WWTP and lift station data, and results from the Flooding Questionnaire such as timing of sewage backups and basement flooding hydraulic grade lines.

7.4.1 Storm Sewer Performance Evaluation

The storm sewer system for the City of Lethbridge covers an existing service area of approximately 3,600 ha. The minor system comprises some 300 km of storm sewer pipes ranging in size from 150 mm to over 2,000mm - designed to accommodate the 1 in 5 y design rainfall event. The major system consists of surface conveyances such as streets, open channels and depressions designed to convey and store rainfall events of larger magnitudes. The drainage system includes 5 lift stations, 15 ponds, and 18 outfalls (see Figure 7.4).

As described in section 7.3, the rainfall of the June 8-10, 2002 event was slow and occurred over a long duration at a relatively steady rate - a fact that allowed the storm system to perform quite well, as the design rainfall consists of an intense (100 mm/h), short duration (4 h) rainfall, typical of Lethbridge's summer thunderstorms.

Problems with the storm sewers were either operational in nature or were primarily overland flow related such as:

- trapped lows becoming activated,
- errant drainage patterns in partially completed areas under construction, and
- excessive ponding.

Examples of operational failures which occurred include a number of trapped lows which began to fill up with stormwater when catch basins became plugged, and the events which occurred at an overflowing stormwater wet pond.

Model results indicate that the minor system did not experience substantial surcharging. For example, Figure 7.5 is a profile of the Lakeview storm trunk, which flows at a mild slope until it begins its steeply-sloped descent to the Oldman River and passes under Scenic Drive South, at which point it becomes surcharged but does not overflow.

Comparing the results shown on this profile for both the June 8-10, 2002 rainfall and the current City of Lethbridge standard 1:5 y return frequency design rainfall event - the trunk is completely overwhelmed by the rapid rainfall of the design event, yet performed quite well during the June 8-10, 2002 event. This event did not exceed the design capacity of the storm sewer system.

Figure 7.4 Lethbridge storm sewer system schematic.

7.4.2 Sanitary Sewer Performance Evaluation

The sanitary sewer system consists of a total of 365 km of collection mains ranging in size from 100 to 1,000 mm. A total of 16 liftstations pump into 10.0 km of pressurized forcemains present in the system. As sewers reach the top of the Oldman River valley, a total of 12 km of siphons ranging from 200 mm to 600 mm convey the bulk flows to the WWTP as illustrated in Figure 7.6.

Figure 7.5 Lakeview storm sewer trunk profile.

Wastewater Treatment Plant Performance:

At the beginning of June, the diurnal dry weather flow pattern produced an average total plant inflow of about 30 MLD (*Ed. Note: 1 MLD = 11.5 L/s*). Rainfall in the first week of June produced peaked inflows up to 60 MLD, after which the diurnal pattern began to fall back towards its dry weather average. The average flow was 32.5 MLD, or about 10% over normal, when the June 8-10, 2002 rainfall occurred. This pattern was repeated again, as the impact of the major rainfall was still being felt when it next rained on June 17 - when a rainfall much smaller than the June 8-10, 2002 event caused peak flows nearly as extreme with the help of the wet antecedent conditions.

Figure 7.7 displays the measured plant inflows, computed base dry weather flows corresponding to the average days before the June 8-10, 2002 event, and the computed flows of the June 8-10, 2002 rainfall period. The model computes higher inflows to the plant than were possible to measure, as the main inflow channel at the WWTP becomes overloaded with flows in excess of 80 MLD, where excess flow is diverted over an emergency spill weir. The missing observed data was replaced by manual measurements taken by WWTP staff who monitored and measured the depth of flow diverted across the weir. These important measurements were used to approximate the peak flows in excess of 80 MLD as shown on Figure 7.7. The computed flows match the

Figure 7.6 Lethbridge sanitary sewer system schematic.

recession of the wet weather flows back to the dry weather flow pattern. The model was adjusted to be slightly conservative, for design purposes as shown by the computed inflows being approximately 10% higher than the measured inflows.

Based upon this data, it appears that approximately 7% of the total rainfall falling on the City was captured by the sanitary sewer system during this event. This is higher than the maximum envelope value of 5.5% obtained during the UIMP Study (Stantec Consulting Ltd., 2000) and the 4.4% calculated in the design of the Southeast Storage Tank (UMA Engineering Ltd., 1997) and is reflective of the extreme nature of this rainfall event.

Figure 7.7 Waste water treatment plant inflow comparison.

The WWTP was able to respond adequately to this sudden influx of rainwater, although minor flooding did occur and the treatment process was modified to handle the emergency sewage. No bypasses to the Oldman River occurred. Operations were complicated by a concurrent power failure, and some difficulties were experienced with the UV disinfection portion of the treatment chain.

Collection System Performance:

This event re-confirmed the fact that while the sanitary sewer system can adequately convey Lethbridge's dry weather sewer flows, the inflow and infiltration of excessive amounts of rainwater into the system can lead to overloaded sewers. Rainwater enters the sanitary sewer system through cracked pipes, leaky manholes, holes in submerged sanitary sewer manhole covers, and most significantly through directly-connected weeping tile systems in areas with high groundwater. In general, the river valley siphons and trunk sewers were hardest hit - while the collection sewers in the upstream portions of the system usually had 20% spare capacity, based on computed results. Unfortunately, all the City's flow monitors had been removed from the system for inspection and repair. As a result, no direct measurement of system flows in trunk and collection sewers was possible.

In many locations, sewer levels surcharged high enough to induce sanitary sewer backups into residential homes. The surcharging of manholes also led to three locations spilling an estimated total of 110,000 m³ of dilute sewage to the Oldman River valley.

To illustrate the extent of sanitary system surcharging, Figure 7.8 is a profile of the Lakeview Sanitary trunk, displaying the ground surface, pipe invert and obvert, and model results in the form of peak hydraulic gradelines.

Sanitary sewers are typically designed such that the peak hydraulic gradeline is confined below the pipe obvert. As surcharging levels rise in the system, residences are faced with increasing levels of flooding risk. For this study, the following general risk levels were defined, as shown in Figure 7.9:

- *Highly Probable*: Should sewage levels rise in manholes higher than 1.0m below the manhole rim elevation, sanitary sewer backups are considered highly probable.
- *Probable*: The risk of backup was considered probable with surcharging levels between 1.0m and 1.5m below the rim.
- *Possible*: The risk of backup was considered possible with surcharging levels between 1.5m and 2.0m below the rim.
- *Unlikely*: When surcharging does not rise higher than 2.0m below the rim, sewer backups become unlikely.
- *Not At Risk*: When levels do not rise higher than 2.5m below the rim it is felt that flooding risk is nearly zero, although the only way to eliminate all risk is to disconnect all extraneous flow sources from the system.

This spectrum of risk was evaluated across the City using detailed results from the June 8-10, 2002 rainfall simulation modeling, as the model results compared very closely with the observed occurrences in terms of timing, magnitude, and location. Figure 7.10 illustrates the spectrum of risk in the existing system in South Lethbridge during the rainfall event, with the known trouble spots being well represented by the model and as summarized below:

- *Highly Probable*: 167 homes
- *Probable*: 147 homes
- *Possible or Unlikely*: A further 1,256 residences are located in areas of *possible* or *unlikely* sewer surcharging as a result of insufficient system capacity,
- while 22,930 residences were found to be *not at risk* of flooding. This 98.7% reliability (number of protected homes divided by number of total homes) does not meet the initial 99.5% level of service target established by the public during the UIMP Study.

Figure 7.8 Lakeview sanitary sewer trunk profile.

Figure 7.9 Spectrum of flooding risk, relating modeled manhole surcharging to the degree of risk for residential basement flooding. Plots show depth against time. The vertical axes are in metres with values ranging from 0 m at the top (in 0.5 m increments). The maximum value varies between risk categories up to 4 m. Horizontal axes are in 12 h (1/2 day) periods.

Figure 7.10 South Lethbridge residences at risk, existing system.

Sewage Lift Station and Forcemain Performance:

During the June 8-10 event, two of City's liftstations in the Lakeview and Tudor neighbourhoods experienced difficulties, as evidenced by the wetwell level data and alarms received at the WWTP. These two liftstations were operating at their peak (two pumps operating) capacities at various times during the rainfall. With the pumps at capacity, any inflows higher than the capacity flow rate are stored in the pipes upstream of the facilities, creating a higher risk of surcharging and sewer backups.

The forcemains that carry sewage downstream from the liftstations eventually terminate in manholes, intermittently adding large volumes of pumped waste. In the case of the Lakeview liftstation, for example, surcharging occurred immediately downstream of the facility as a result of the short forcemain length and insufficient capacity at its outlet.

Storage Tank Performance:

The Southeast Storage Tank provides 4,700m³ of off-line storage for the Lakeview trunk sewer. The tank begins to fill when sewage levels in the trunk sewer spill over a weir located in the sanitary manhole at the intersection of 20th Avenue S. and 20th Street S., and is completely filled when sewage depths in the tank reach 4.5 m.

Figure 7.11 displays the observed and computed performance of the Southeast Storage Tank showing how inflows to the tank began very early in the storm, reached a peak inflow of 154 L/s, and caused the tank to fill completely around midnight on Saturday, June 8. The inflows to the tank slow as the tank fills, and drop to zero when the tank is full. The trace showing the measured depth in the tank proves that the tank filled quickly and stayed full until June 13, when pumps could finally empty the tank into downstream sewers without placing anyone at risk.

The model indicates that some time after the tank was full, in the early morning hours of June 10, loads on the system were sufficient to raise the peak hydraulic gradelines at the tank to within 0.5 m of the surface. In fact, at an upstream manhole the gradeline breached the surface creating an overflow from the system. Note that although computed depths did not precisely match measured depths, they do match the times to fill and empty the tank.

Also at this time, a physical piping failure occurred at the tank, dumping sewage into the dry portion of the station. This occurrence did not adversely affect performance since the tank pumps are not allowed to discharge until after a rainfall in any case.

Figure 7.11 Southeast storage tank performance during June 8-10, 2002..

The offline storage provided by the Southeast Storage Tank was ineffective at mitigating the impacts of this extreme rainfall event. The Southeast Storage Tank was designed to contain the flows from an August 1993 rainfall event (which was estimated to have a return period in excess of 100 years) and to limit surcharging to “acceptable levels for the 1:25 Chicago design event.” - *Relief of Southeast Sanitary Sewer Surcharging*, UMA Engineering Ltd. and MPE Engineering Ltd. (March 1995)

The limitation of wet weather flow storage solutions are also evident, in that constructed storage is usually a finite volume and offers little benefit once consumed. Based upon the current investigation and modeling results, it was determined that a larger tank approximately 13,600 m³ in size (which is three times the size of the existing Southeast Storage Tank) could have prevented the flooding which occurred in the Sugar Bowl area during the June event.

Design Rainfall Results

While analyzing the system using the June 8-10 rainfall is important, the City has established design guidelines that are more stringent than the demands represented by the June 8 to 10 rainfall.

The design rainfall event provides a higher level of protection to residents and is used to establish design parameters for new and retrofit infrastructure. When this event is run through the model, the percent utilization of full pipe capacity for sanitary sewers rise and manhole surcharging increases; a total of 674 manholes surcharge during the design event as compared to 633 during June 8 to 10.

7.5 Impact of Ongoing and Future Improvements

As the City investigated its underground infrastructure between 1997 and 2000 via the UIMP Study, numerous problem areas were confirmed and identified. Conceptual solutions to the worst of these problems were devised, prioritized, and conceptual costs developed.

When the Mayor Magrath Drive transportation network upgrade began, synergies were identified between planned underground improvements and the surface improvements. In particular, the diversion of sewer flows passing west under Mayor Magrath Drive was seen as a key component to include within the Mayor Magrath Drive Upgrade to eliminate underground construction following the roadway upgrade. As part of the functional planning for Mayor Magrath

Drive, several underground upgrade concepts from the UIMP Study were brought into the project and optimized, evolving into the East Lethbridge Sanitary Sewer Upgrade.

Many upgrades from the UIMP Study remain to be implemented, and further upgrades and future growth planning during the course of the Southeast Lethbridge Urbanization Plan have further refined these upgrades and added to the capital improvement program.

7.5.1 East Lethbridge Sanitary Sewer Upgrade

The initial mandate of this upgrade was simple: remove wet weather flows from the Lakeview Green Strip trunk sewer upstream of the Agnes Davidson neighbourhood. Given the relatively economical incremental costs of sewer pipe installations, it was decided to also remove all (dry and wet weather) Fairmont Park sewage flows, along with provisions for 100 L/s of new flows from expanded areas in the Southeast, thereby facilitating impact-free growth as development in this area has been limited due to sanitary sewer servicing constraints as a result of an overcapacity system.

Figure 7.12 shows the new deep gravity trunk delivering Fairmont Park sewage and new Southeast area sewage to a liftstation constructed just east of Mayor Magrath Drive on the Lakeview Green Strip. This liftstation is also designed to remove two-thirds of the peak wet weather flows (up to 200 L/s) from the Lakeview Green Strip trunk sewer. This liftstation, equipped with adequate backup pumps and emergency power, pumps sewage north to the 2nd Avenue North liftstation, which then pumps half of the sewage north to the WWTP while the other half spills into the adjacent gravity trunk.

When the model was run for the June 8-10 event with all of these upgrades operational, benefits were evident in both the upstream and downstream portions of the Lakeview Green Strip trunk sewer particularly around the Sugar Bowl. The upgrade relieves flow in the sewer downstream of Fairmont Park, which will reduce the flooding risk to residents in downstream neighbourhoods. The Southeast Storage Tank is expected to not be required to operate with this improvement in place, and if in operation will provide additional protection from private property flooding in the surrounding neighbourhood, due to the reduction of incoming flows.

Of primary importance, however, is the number of homes at risk of sewer backup following the completion of this upgrade:

- The number of *highly probable* backups drops from 167 residences to 28 residences, an 83% reduction.

Figure 7.12 Overview of East Lethbridge sanitary sewer upgrades.

- The number of *probable* backups drops from 147 residences to 63 residences, a 57% reduction.
- The total number of residences in the *possible* and *unlikely* categories drops from 1,256 to 838, a 33% reduction.
- 641 more residences indicate no risk at all.

One impact of this improvement is inevitable; loads on the WWTP will increase as sewage is prevented from spilling to the environment, kept out of

basements, and more effectively transmitted to the Plant. This may require a future upgrade to the WWTP inflow capacity.

7.5.2 Other Planned Improvements

In addition to the East Lethbridge Sanitary Sewer Upgrade, the UIMP Study has identified more than 25 additional prioritized capital improvements in the Stormwater and Sanitary Collection Systems for future construction. The goal of these improvements (which were designed using peak design flows rather than historical rainfall events) is to achieve the desired levels of service outlined in the UIMP Study, shown below in Table 7.1. As funding permits, these improvements are advanced from their current conceptual status through preliminary and detailed design phases, following which they are tendered and built.

While the proposed levels of service with respect to overflows, system tolerance, and extraneous flows were judged to be reasonable and attainable, there is a strong desire for the City of Lethbridge to reduce the number of homes affected to 0.5% of the 24,500 private households (about 123 residences).

Future stormwater improvements are targeted at reducing the flooding occurring at 25 locations around the City. The strategy for these improvements is simple - relocate the accumulated stormwater, moving any rainwater accumulations that threaten residences to locations where they cannot negatively impact City residents.

In addition to the components of the East Lethbridge Sanitary Sewer Upgrade that will be operational in November 2002, another eight system improvements were incorporated into the RT-SWMM model to determine their benefits in terms of reducing the potential for sewage backups, as indicated in Table 7.2 below. Given that with today's infrastructure 314 residences were at *highly probable* and *probable* risk levels during this three day event, it is reassuring to see that model results indicate that future improvements will reduce this total to only 11 *highly probable* locations and no *probable* locations. The City's desired levels of service for sanitary sewer backup prevention would be met and exceeded by the planned improvements, which would offer a reliability of 99.9%.

With all planned improvements complete, the 1:5 y design rainfall event is accommodated with an achieved reliability against probable flooding of 99.5%. With some further minor system alterations, exceeding the 99.5% standard is achievable beyond planned improvements.

Table 7.1 City of Lethbridge level of service criteria.

Customer	Capacity	Overflows	System Tolerance	Extraneous Flow
ISSUE	Sewer Backup Prevention	Frequency and Magnitude	Acceptable Quality	Tolerable Limits
Residential	Collect 100% of Dry Weather Flows and aim to protect, at a minimum, 99.5% of homes from sanitary flooding during peak wet weather flow events.	The City will not allow sanitary sewer overflows into the environment. However, during peak wet weather flow events, priority will be given to protecting residents from sanitary sewage flooding and backups.	The discharge of contaminants that may reduce the carrying capacity of the sanitary sewer system, such as grease, should not be accepted by the City. The City should actively pursue programs to eliminate these discharges.	Limit extraneous flows entering through manholes in stormwater ponding areas to 5%. On-lot contribution of extraneous flows from new developments will be unacceptable. Older neighbourhoods with high extraneous flows will be targeted for reduction through improved lot grading, roof leader extension, etc.
Industrial	X	X	X	X
Commercial	X	X	X	X
Institutional	X	X	X	X
Wastewater Treatment Plant	X	X	X	Optimum operations at the wastewater treatment plant would require limitation of the peak wet weather flow to 80ML/day. This is desirable if possible.
Alberta Environment	(AEP 7.1.1.4) The total peak design flow rates should be the sum of the peak dry weather flow rates as generated by the population and land use, and the rate of all extraneous flow allowances, as determined for the design contributing area.	Overflows of untreated sanitary wastes into the environment are not acceptable.	X	X

Figure 7.13 depicts the graphical locations of residences at risk in South Lethbridge with the completion of the East Lethbridge Sanitary Sewer Upgrade and all planned improvements.

Table 7.2 provides a summary of the model results identifying the number of residences at risk in the existing sanitary system, post East Lethbridge Sanitary Sewer Upgrade, and with all planned sanitary improvements in place. Similarly, Table 7.3 summarizes the number of residences at risk for the design rainfall.

Table 7.2 Estimated *At-Risk* Residences - June 8-10, 2002 rainfall event

Level of Risk	Depth of Surcharged Sewage Below Manhole Rim	Existing System of June 2002	With East Lethbridge Sanitary Sewer Upgrades	With All Planned Improvements
Highly Probable	0.0m - 1.0m	167	28	11
Probable	1.0m - 1.5m	147	63	0
Possible	1.5m - 2.0m	443	257	183
Unlikely	2.0m - 2.5m	813	581	455
Not at Risk	> 2.5m	22,930	23,571	23,851
Total residences =		24,500	24,500	24,500

Table 7.3 Estimated *At-Risk* residences - design rainfall event.

Level of Risk	Depth of Surcharged Sewage Below Manhole Rim	Existing System of June 2002	With East Lethbridge Sanitary Sewer Upgrades	With All Planned Improvements
Highly Probable	0.0m - 1.0m	324	90	75
Probable	1.0m - 1.5m	150	96	36
Possible	1.5m - 2.0m	576	507	317
Unlikely	2.0m - 2.5m	1,702	1,636	1,075
Not at Risk	> 2.5m	21,748	22,171	22,997
Total residences =		24,500	24,500	24,500

7.6 Summary and Conclusions

In completing the investigation, the project team responded to the original study questions as follows:

Figure 7.13 South Lethbridge residences at risk, post improvements.

7.6.1 What were the key characteristics of the rainfall event, and what impact did prior rainfalls have on the system?

For 66 h during June 8-10, 2002, an extreme rainfall event with an estimated return frequency in excess of 100 y occurred. This rainfall included the largest 1-d and 3-d rain volumes (for the April 1st to July 15th period) in more than a decade, and occurred during one of the wettest May to June periods on record. Despite the enormity of the event, the City's current standards still represent a more stringent design environment.

The cause of the flooding was antecedent late snowfalls and a storm the previous week, creating wet soil conditions, causing higher than normal levels of inflow and infiltration into the sanitary sewer system and therefore higher base flows just prior to the June 8-10 rainfall - an effect observed at the WWTP.

7.6.2 How did the various components of the stormwater and sanitary sewer systems perform during the storm event?

The rainfall of June 8 to 10 was slow and occurred over a long duration at a relatively steady rate; a fact that allowed the storm system to perform quite well, a marked difference from its performance during the intense rainfalls of typical summer thunderstorms. As a result, problems with the storm sewers were either operational in nature or were overland flow issues. The number of citizens affected by the storm sewer system was much lower than the number impacted by the sanitary sewer system.

The WWTP and its processes performed very well, handling dramatic increases in inflows without bypassing any flows to the Oldman River. The Plant's inability to measure extremely high inflows was evident.

The sanitary collection piping was overloaded in several areas. The river valley siphons experienced flows so high that two major overflows occurred. Major trunk sewers and considerable lengths of small diameter collection sewers were overloaded and surcharged, some to ground level. As a result, 314 residences were placed in a *highly probable* or *probable* flood risk situation during the June 8-10, 2002 storm. This level of performance does not meet the City's desired 99.5% reliability Level of Service, which equates to only having 123 homes at these levels of risk.

The Lakeview and Tudor lift stations both experienced temporary failures. It is believed that one pump at Lakeview clogged and that the forcemain discharge downstream of the lift station also induced flooding. The Tudor facility pumps could not discharge effectively given high surcharged sewer levels downstream.

The Southeast Storage Tank was ineffective in the face of the significant rainfall event which occurred during the June 8-10, 2002 event. This situation does not improve when the current City standard design rainfall event occurs, however the Tank does afford a level of localized flooding protection to some residences in the Sugar Bowl area.

7.6.3 How did the City respond to the operational challenges it faced?

While the City's Public Operations Department responded quickly and appropriately to the challenges of this event, this investigation suggests several possible improvements for future responses. An Emergency Response Plan should be formulated for future extreme rainfall events using the results of this investigation. This Plan should address expected "hotspot" locations, staffing levels, response plans, inter-department notification and communication protocols, data collection during the event, and should also contain a methodology for notifying and warning various neighbourhoods of increasing levels of sewer backup risk.

7.6.4 How will the ongoing and planned improvements help reduce the impacts of this and other future rainfall events?

Ongoing and planned improvements currently being readied by the City will substantially reduce the risk of sanitary sewer surcharging and basement backups. With the ultimate implementation of final versions of all these alternatives, levels of service in excess of 99.5% reliability will be reached.

The impact of future rainfall events will most likely occur within the context of a growing City of Lethbridge. Current planning and engineering analysis activities completed as part of the Southeast Lethbridge Urbanization Plan have provided a template for impact-free growth and evolving standards.

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