The City of Winnipeg
Water & Waste Department

COCKBURN AND CALROSSIE
COMBINED SEWER RELIEF WORKS
CONCEPTUAL DESIGN REPORT

FINAL REPORT
MAY 2010

KGS GROUP CONSULTING ENGINEERS

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May 28, 2010

File No. 05-0107-14

City of Winnipeg
Water and Waste Department
110-1199 Pacific Avenue
Winnipeg, Manitoba
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ATTENTION: Mr. Charles Boulet, P.Eng.
Project Manager

RE: Cockburn and Calrossie Combined Sewer Relief Works
Conceptual Design Report

Dear Charles:

Please find enclosed four (4) copies of our final "Cockburn and Calrossie Combined Sewer Relief Works Sewer Relief and CSO Abatement Conceptual Design Report" for your use and records. The report has been updated in response to review comments received from the City, and this submission completes the first stage of the project.

We were pleased to have the opportunity to demonstrate our initiative and innovation in evaluating the options and integrating combined sewer overflow control options into the assessment. As demonstrated in this report, project consideration from a multiple-program perspective provides the potential for significant operational optimization and cost savings.

The traditional district evaluation concluded that there is a high benefit-cost ratio to support proceeding immediately with Cockburn and Calrossie, and in particular that the recommended works will alleviate the severely substandard level of service and high risk of flooding that currently exists in the Southeast Jessie area.

Our report recommends that the City proceed with a phased approach that will take immediate action to deal with the most severe basement flooding issues, and postpone the decision on integration with the Combined Sewer Overflow (CSO) program. The first phase involves immediate partial separation of Cockburn West, with relief of Cockburn East being deferred until a second phase when decisions on integration with the combined sewer program are finalized. This approach has the advantage of preserving all future options, without the commitment to decisions on CSO control at this time.

Based on recent discussions with the City, however, there has been more focus on consideration of the CSO program in addition to Basement Flooding Relief (BFR). On this basis, the City is considering the phased (expandable) separation of Cockburn West. This would allow for the City to relieve the severe basement flooding issues in Southeast Jessie, while following the City's anticipated guidelines for CSO control.

The costs for various options have been presented in 2007 dollars, which corresponds to when the original scope of work was completed and submitted to the City. We are recommending that an escalation factor of 1.09 (or 9% increase) be applied to these costs to obtain a reasonable estimate of the 2010 dollar values. This is based on an estimated construction inflation of 3% per year for the period 2007 to 2010.

Assuming the 9 % inflation increase, the following table summarizes the options described above in 2010 dollars.

Options	Cost (2010 dollars)
West Side – Partial LDS Separation	$24.2 Million
West Side – Phased (Expandable) LDS Separation)	$31.8 Million
West Side – Total LDS Separation	$40.5 Million

Finally, it should be noted that the Technical Memorandum, "Cockburn & Calrossie Combined Sewer Relief Works Fort Rouge Yards Addition", has been finalized and included as Appendix F of this report. The separate Technical Memorandum, "Cockburn & Calrossie Combined Sewer Relief Phased Separation Option", has also been finalized and is included in Appendix G, which describes the partial separation option that would provide for subsequent upgrading to complete separation.

It has been a pleasure to have the opportunity to provide our services on this very interesting project. We look forward to hearing from you on the results of the program prioritization and implementation scheduling and to offering our services for continuation of this project through implementation and the enhancement to city services that it brings.

Sincerely,

KGS Group

Dave MacMillan, P. Eng.
Project Manager

CH2M HILL

Ed Sharp, P.Eng.
CSO Alternatives – Relief Coordinator

ES/DBM
Enclosure

Winnipeg

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COCKBURN AND CALROSSIE
Combined Sewer Relief Works
Conceptual Design Report

Prepared for
City of Winnipeg Water and Waste Department

FINAL

May 2010

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EXECUTIVE SUMMARY

Background

The City of Winnipeg's current basement flood relief program was originally adopted in 1977, and was developed in response to the extensive property damage caused by intense summer rainstorms. The objective of the program is to bring all combined sewer districts to a 5-year level of protection with provision for relief of the districts to a 10-year level of protection at a future date. The Cockburn and Calrossie Combined Sewer Districts were identified by the Water and Waste Department in the planning report, *Basement Flooding Relief Program Review – 1986,* as districts where benefits could be realized through the implementation of relief works to reduce basement flooding.

Subsequent to the commissioning of the study for the Cockburn and Calrossie District, the City requested that the southeast portion of the Jessie Combined Sewer District, located south of Grant Avenue, also be included in the Cockburn and Calrossie study limits for basement flood relief consideration. This portion of the Jessie District was not relieved when the hydraulic relief for the remainder of the Jessie District was undertaken previously. The revised study to include Jessie has been referred to as the Cockburn and Calrossie and Southeast Jessie Combined Sewer District for this study.

The objectives of the study were:

- To evaluate the existing level of service for the sewer district and develop upgrading recommendations for basement flooding relief to a 5-year level of protection with provision for a ten-year level of protection at a future date.

- To assess the potential to control and reduce the annual number and volume of combined sewer overflows (CSO) to the river system. The current target used by the City is four overflows per recreational season.

The tasks undertaken to achieve the program objectives included:

- The collection of all relevant data on the existing combined sewer system, surface runoff conditions, lift station flow data and observed rainfall data.

- The development of a computer model to represent the hydrologic runoff process from rainfall and a hydraulic model of the combined sewer system to simulate sewer system flows.

- The calibration and verification of the runoff and sewer system hydraulic computer models to observed rainfall and water levels.

- The development of a computer model for dry weather flow and the calibration and verification of the model to recorded sewer flows.

- The assessment of the existing level of service for the sewer system.

- The preparation of alternative hydraulic relief measures to improve the existing level of service to the City standard of protection for the 5-year summer rainstorm.

- The identification of measures to reduce combined sewer overflows to the Red River to the City's future goal of a maximum of 4 overflows per recreation season.
- Preparation of a feasibility assessment for redirection of SEWPCC service area wet weather flows to the NEWPCC through a storage-transport tunnel.
- The assessment of the spring level of service protection with respect to the combined probability of spring rainfall and Red River flood levels.
- The determination of construction costs and benefits for each alternative relief measure in order to rank the projects on the basis of benefit-cost ratios.
- The selection of the most cost effective measure that satisfies both the hydraulic relief and pollution abatement objectives.

The scope of work was also expanded to evaluate land drainage options for the future Bus Rapid Transit System in the adjacent Fort Rouge Yards area.

Existing Level of Service

The hydraulic analysis of the combined sewer system showed that the existing sewer system did not have adequate capacity for the City's minimum accepted requirements of the basement flood relief program. The level of service for the district was shown to be less than the 2-year rainstorm for most of the Cockburn and Calrossie Districts, which is considerably less than the 5-year standard for the basement flood relief program. The Southeast Jessie area was found to be severely substandard, with less than a 1-year level of service, in spite of relief works having being installed in the majority of the Jessie District in the 1970's.

Future Development

As part of the review of the relief and separation alternatives, future development schemes for vacant lands were considered. These future development schemes were incorporated as part of the XP-SWMM models for relief and separation alternatives to assess their hydraulic impact on the sewer system.

A total of 4 locations with potential for future development have been considered in the study area:

- Fort Rouge Yards
- Winnipeg Humane Society
- Large Field Area North of Parker Avenue
- Land adjacent to Sobeys on Taylor Avenue

Relief Alternatives

The development of relief alternatives was initiated based on results obtained during the calibration of the model and the existing level of service evaluations, as well as discussions during the course of the study with the Water and Waste Department.

Relief piping alternatives for the Cockburn and Calrossie and Southeast Jessie Combined Sewer District included district wide combined sewer relief sewers (SRS), complete and partial land drainage separation, and complete wastewater separation, localized relief of Southeast Jessie and Cockburn East and a combination of combined sewer relief piping and land drainage separation for Cockburn West (“Hybrid Alternatives”).

The selection of a preferred alternative was largely based on the 1986 methodology set out in the 1986 Basement Flooding Relief Program Report prepared by the City of Winnipeg Water and Waste Department. Benefits were calculated based on the difference in average annual damage estimates before and after implementation of relief works. Average annual damages were determined through development of flood-frequency-damage curves, by applying unit damages to flooding predictions for various design storm events, for both the existing conditions and with relief in place. Costs for the benefit cost analysis were based on the average annual value of the capital upgrading cost. In order to provide a uniform benefits-cost comparison for the program, which extends over many years, the costs were standardized to 1991 values and the benefits to 1993-dollar values.

Although a number of district-wide and localized relief alternatives were considered, only district-wide relief alternatives, with Southeast Jessie included, were considered in the preferred alternative selection. Selection of district-wide alternatives has been the past practice in establishing the Basement Flooding Relief Program prioritization, leaving the localized alternatives for consideration once the district-by-district decisions have been made.

The recommended relief alternative conforming to the current Basement Flooding Relief program mandate for the Cockburn and Calrossie and Southeast Jessie district consists of a partial land drainage separation system. This alternative would require major pipes to collect the catchbasin flows. Nearly complete land drainage separation would be required for the Southeast Jessie area.

The comparative construction cost estimate for use in program prioritization is $11.9 million (1991 dollars) with a benefit-cost ratio of 1.7. The estimated construction cost in terms of 2007 dollars is $37.7 million. It should be noted that the benefit-cost ratio is based on costs and benefits exclusive of inlet restriction. Inlet restriction has long been recognized as a cost effective way to upgrade a sewer district that has been relieved from a 5-year to a 10-year level of protection, substantially enhancing the benefit-cost ratio. Technical issues with inlet restriction have more recently been identified however, which has precluded it from the evaluation.

The option of phasing in complete separation was assessed as an additional service subsequent to completion of the study. The concept would be to initially install partial separation to meet the basement flooding relief upgrading requirements, with the common elements being increased in size to accommodate future separation for the remainder of the district. Complete separation would provide enhanced basement flooding protection, and also practically eliminate combined sewer overflows. The analysis indicated that a premium of $11.5 million would be required for the initial phase, followed by $11.0 million to complete the separation at a later date (all in terms of $2007). From a basement flooding relief perspective, the initial premium would not add significantly to the basement flooding relief benefits, and would reduce the district Benefit-Cost ratio from 1.7 to 1.4. The concept would not be recommended from the basement flooding relief perspective, but would provide a viable option when jointly considering CSO control.

Spring Level of Protection

The spring level of flood protection was determined with the storm relief sewer option for relief works. Various combinations of Red River level frequencies and storm precipitation return periods for the April-May time frame were used to determine the combined probability of incipient flooding in the district during the spring period.

The model results for spring rainstorms showed that the runoff from the Cockburn and Calrossie combined sewer system for the storm relief sewer alternative would be stored within the existing and relief sewers for all rainstorms up to approximately the 35-year spring storm. Flood levels in the Cockburn and Calrossie Combined Sewer District were therefore independent of the downstream Red River water levels during spring.

The model results also showed that basement flooding during spring would only occur for the 50-year rainstorm at a location on Grant Avenue due to limited high-end sewer capacity. However, the sewer capacity was not affected by the downstream Red River level, even for the 50-year rainstorm.

The storm sewer relief alternative design would therefore have a minimum 50-year level of service for spring rainstorms.

CSO Analysis

The CSO analysis undertaken as part of the Cockburn and Calrossie project was considered as a secondary objective. The Basement Flooding Relief Program mandate is to mitigate basement flooding but because of the opportunity to achieve cost-effective benefits when considered jointly, the CSO evaluation was included in the scope of work. A cost-effectiveness curve was developed that identifies the incremental cost of CSO control implementation for the Cockburn and Calrossie districts and provided the basis for comparisons.

The traditional approach to basement flooding relief considers the impacts of implementation of CSO control subsequent to completion of the relief works. The impacts of implementing the recommended partial LDS alternative prior to CSO control are as follows:

- The recommended alternative would provide a positive impact on combined sewer overflow reduction. Under the alternative, thirty-nine percent of the surface runoff would be removed from the Cockburn combined sewer collection area and an immediate reduction in the number and volume of overflows would occur. However, the impact would be marginal in terms of meeting the long-term objective of four overflows.

- Significant combined sewer overflows would remain after implementation, and meeting future requirements would still require a CSO control program. The alternative is compatible with subsequent use of in-line storage for CSO control.

- Use of in-line storage in combination with the recommended partial LDS separation alternative would have a significant impact on reduction of combined sewer overflows. The number of overflows could be reduced from an average of 23 to less than 8 if in-line storage is maximized through use inflatable dams and real time controls. It would still be expected that off-line storage be required to reach the objective of four overflows.

- In-line storage has a number of unknowns and risks associated with it that must be resolved before it can be fully adopted. Supplemental alternatives, which would most likely involve off-line storage, would be required either in addition to or as a replacement for in-line storage.

Selection of an integrated relief and CSO control alternative provides the opportunity for joint optimization, which goes far beyond what can be achieved by considering each independently. The analysis indicated that if in-line storage cannot be used, or is to be supplemented by additional off-line storage, then the most cost effective option would be by a concept referred to as "sunken relief" piping. Under this option, portions of the relief piping would be enlarged and sunken (lowered in elevation). It would provide the hydraulic capacity for basement flooding relief and the necessary storage for CSO control, without the need for inflatable dams or other means of automated overflow control.

The installation of sunken relief piping with a new lift station would provide a reduction in overflows to an average of 4 per year at a cost of approximately $6.6 Million. The cost is about $25,000,000 less than proceeding with partial LDS separation and subsequently providing a combination of in-line and off-line CSO control.

Relief Program Integration with a CSO Tunnel

A feasibility assessment for redirection of the Cockburn and Calrossie districts, along with other adjacent districts, to the North End Pollution Control Centre (NEWPCC) through a storage-transport tunnel was included in the Cockburn and Calrossie study. It would essentially comprise the majority of CSO control for all combined sewers south of The Forks that are on the west side of the Red River.

The analysis concluded that based on the current level of understanding the costs of the tunnel alternative are in the same order of magnitude as the in-line and off-line combinations identified in the CSO Management Study illustrative program. The tunnel option has the additional advantage of not requiring use of conventional in-line storage with its more complex operation and inherent risks.

The NEWPCC interconnection would comprise one regional solution to a comprehensive CSO program. The option would complete the CSO program for the entire southwest combined sewer quadrant and would leave only the relatively minor Mager and Metcalfe Districts with combined sewer overflows south of The Forks. The alternative is also compatible with the North End Water Pollution Control Centre Master Plan that is currently in progress, and would not be expected to compromise integration into a citywide CSO program. It would provide benefits to the South End Pollution Control Centre (SEWPCC) by diverting wet weather flows to the NEWPCC. On this basis, it is recommended that further evaluation be undertaken to evaluate CSO alternatives for incorporation into the long term CSO master plan.

Fort Rouge Yards

The Fort Rouge Yards area was initially to be considered from two perspectives, firstly as vacant land being serviced as it currently is, and secondly, as developed land with the upgraded services being routed through Cockburn district. The impact of the development of Fort Rouge area was evaluated for the partial LDS separation alternative. The LDS separation option was most amenable to the development since the increased surface drainage can be conveyed without causing a detrimental impact to combined sewer overflows, with or without a stormwater retention pond.

Based on this preliminary assessment, it was determined that future development of the Fort Rouge Yards, if serviced by the recommended partial LDS alternative would add $1,750,000 to the cost of relief. The addition of the Bus Rapid Corridor would add an additional $520,000 cost. The development would increase the Cockburn lift station flow by approximately 50 percent, but would not reduce the level of service during flood conditions.

Additional services were assigned late in the Cockburn and Calrossie study to carry out a more comprehensive assessment of Fort Rouge Yards servicing to accommodate the Bus Rapid Transit corridor. The subsequent evaluation, reported on in an appendix to the conceptual study, concluded that the entire Fort Rouge Yards area could be serviced through an existing separate land drainage outfall on Glasgow Avenue. It was recommended that the internal drainage concept be proceeded with as it was not only cost competitive, but had the advantage of being totally independent of Cockburn and Calrossie construction, and avoided potential scheduling conflicts. The internal system was recommended to be sized to accommodate internal site development as well, with the only future impact to Cockburn being connection of sanitary sewer services.

Recommended Approach

It is recommended that the City proceed with a phased approach, with partial land drainage separation of Cockburn West proceeding immediately, and relief of Cockburn East being deferred until decisions on integration with the combined sewer overflow program are finalized.

The Cockburn and Calrossie conceptual study clearly identified benefits and a need to proceed with basement flooding relief:

- The high benefit-cost ratio (even without consideration of inlet restriction) on a district-wide basis supports its early prioritization.

- The Cockburn West relief works would alleviate the severely substandard level of service found in the Southeast Jessie area.

The study also identified substantial cost saving opportunities for integration of relief with CSO controls. The phased approach will provide a balance to both issues, by bringing the needed relief to most of the district, without compromising future potential CSO program integration benefits. Partial separation of Cockburn West is estimated to cost $22.2 million in terms of 2007 dollar values.

ACKNOWLEDGEMENTS

The KGS Group Team acknowledge with appreciation the contribution of the many individuals consulted in the course of the project

The project was especially assisted by the co-operation and contributions of the Steering Committee organized by the Water and Waste Department of the City of Winnipeg. The Committee, which was comprised of representatives of the Operations and Engineering Division of the Department, provided valuable information and guidance throughout the project.

- Charles Boulet, P.Eng. - Project Manager
- Grant Mohr, P.Eng.
- Bill Watters, P.Eng.
- Nick Szoke, P. Eng.
- Terry Josephson, P.Eng.
- Cynthia Wiebe, P. Eng.

STUDY TEAM

This study was conducted by KGS Group in association with CH2M Hill and Dillon.

The following key personnel were directly involved in the studies leading to the preparation of this report:

KGS Group

- Dave MacMillan, P.Eng. - Project Manager
- Brian Bodnaruk, P.Eng. - Specialist Advisor and Analytical Input into Overall Program
- Andrée Kirouac Huth, P.Eng. - Lead Modeller - CSO Management
- Fuad Curi, P.Eng. - SWMM Modeller - Basement Flooding Relief
- Mark Wilcox - Data Management
- Roy Houston, P.Eng. - Conceptual Relief Design

CH2M Hill

- Ed Sharp, P.Eng. - Lead Modeller - CSO Management
- Mario Parente, P.Eng. - Senior Technical Consultant
- Rayna Volden, P.Eng. - Specialist Advisor/Quality Control
- Dave Turcotte, P.Eng - SWMM Modeller
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- John Ewing, P.Eng. - Project Specialist Advisor and Conceptual Design, Fort Rouge Yards and Bus Rapid Transit System

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1.0 INTRODUCTION

1.1 BACKGROUND

The City of Winnipeg's current storm relief program was originally adopted in 1977, and was developed in response to the extensive property damage caused by intense summer rainstorms. The objective of the program is to bring all combined sewer districts to a five-year level of protection with provision for relief to a ten-year level of protection at a future date.

As part of the on-going storm relief program, the City requested the engineering services of KGS Group / CH2M HILL / Dillon for the design and implementation of storm sewer relief works for the Cockburn and Calrossie Combined Sewer Districts. The City of Winnipeg Water and Waste Department (WWD), identified these districts in the planning report, *Basement Flooding Relief Program Review – 1986,* as districts where benefits could be realized through the implementation of relief works to reduce basement flooding. As discussed in Section 5.0, the southeast part of the Jessie Combined Sewer District was also added to the project scope as it was not relieved as part of the Jessie Relief Project in the 1970s. Figure 1-1 shows the study boundary, including the Cockburn, Calrossie and Southeast Jessie Sewer Districts. The Fort Rouge Yards are also highlighted on this figure, as this area will be used for the development of the future South West Bus Rapid Transit (SWBRT) Corridor.

The 1986 relief scheme for the Cockburn and Calrossie Combined Sewer District included a number of storm relief sewers. Major trunk sewers were proposed along Jubilee Avenue and Sparling Avenue with sub-trunk sewers along Taylor Avenue and Harrow Street for the area west of Pembina Highway, and Cockburn Street for the area south of the CNR Fort Rouge Yards. The 1986 report indicated that the benefit-cost ratio for the Cockburn and Calrossie Districts was 1.04 (reference Table 3 of the report's Executive Summary).

Figure 1-1: Study Area

1.2 SCOPE OF WORK

The scope of work is based on the Terms of Reference dated August 2005, and discussions with Mr. Charles Boulet and Mr. Bill Watters of the Water and Waste Department. The intent of the preliminary design phase of the project is to develop a computer model of the sewer districts and alternative relief/separation options that provide the optimal hydraulic relief of the system at the lowest cost. Included in the preliminary phase is an assessment of the potential to control and reduce the annual number and volume of combined sewer overflows (CSO) to the river system. The current standard used by the City is four overflows per recreational season. The scope of work was further expanded to take into consideration the merits of building a storage transport tunnel to control CSOs and divert the flow to the North End Water Pollution Control Centre (NEWPCC).

1.2.1 Data Collection

This phase of the project involved the collection and review of all available information required to develop and calibrate a hydraulic model of the Cockburn, Calrossie and southeast part of Jessie Combined Sewer Districts. This included a review of database files, office files, reports, topography, existing facilities, future land use planning and the location and scope of various infrastructure renewal projects in the area. Where necessary, field surveys and investigations were conducted to verify existing conditions and to supplement available information.

The structural condition assessments of the major sewer trunks and outfalls were also reviewed. The sewer condition assessment was carried out using information retrieved from the City of Winnipeg Sewer Management System (SMS).

Finally, a review of the City's current level rainfall monitoring data and program for each sewer district was undertaken to determine its concurrence and acceptability.

1.2.2 Development of Hydraulic Model

The preliminary design Scope of Work focused on the development and simulation of a computer model (XP-SWMM software) to evaluate the existing combined sewer systems to a desired level of protection specified as a design storm frequency. The computation of sewer hydraulics in XP-SWMM is based on the EPA XP-SWMM EXTRAN model. Calibration and verification of the hydraulic model to rainfall and sewer level data gathered during real rain events was required.

The specified City of Winnipeg design criteria for the level of service is protection from summer-time basement flooding for the 5-year summer storm event by a piping system which can be upgraded to the 10-year event with supplemental work.

The recommended relief scheme was determined based on the following considerations:

- Was the most economical relief alternative that met the required design service levels.
- Partial and complete storm and sanitary sewer separation was included in the relief alternatives studied.
- Hydraulic relief must be compatible, if economically viable, with a sewer separation alternative.
- Recommended methods for hydraulic relief must not increase pollutant loadings to rivers and streams.
- The recommended relief system must be evaluated to identify any localized areas where partial relief could be implemented, resulting in a higher benefit-cost ratio for that area when compared to total district relief.

Street storage was initially to be included as part of the supplemental method to provide 10-year relief. However, based on discussions with the Water and Waste Department, the feasibility of implementing street storage through catchbasin inlet restriction has not yet been proven. For this reason, the City has advised that the 10-year design using street storage would not be considered in the Scope of Work for the project.

As part of the modeling exercise, a number of additional tasks and issues specific to the Cockburn, Calrossie and southeast part of Jessie districts were considered, including:

- A cursory review of the sewage lift station for condition assessment.
- An inventory of all buildings in each district to determine whether roof runoff is directly connected to the sewer system.
- The future development of the Fort Rouge Yards may result in increased rainfall runoff to the City's sewer system. The effect of the increased flow on the preferred scheme was evaluated and options were developed to accommodate the development scenarios. Once the pre-development economic relief works were determined, the effects of the proposed

development works were separately assessed. This included any modifications to the relief scheme, along with the associated costs.

- The City's future Bus Rapid Transit (BRT) System could also result in increased runoff to the Cockburn sewer system. The proposed Southwestern Transit Corridor is to be located along the CN tracks from Queen Elizabeth Way to Jubilee Avenue. An evaluation of the increased flow on the preferred scheme was undertaken. The effect of this increased flow scenario on the preferred scheme was evaluated and options developed to accommodate the flow scenarios.

- Subsequent to the initial Fort Rouge Yards evaluations, additional work was assigned for a more comprehensive evaluation of servicing options for both the BRT and vacant land development.

1.2.3 Hydraulic Analysis of Relief Schemes

Once the hydrologic/hydraulic model was developed, relief options were assessed, evaluated on both a district-wide and localized area. Recommendations for relief schemes were developed based on a benefit-cost analysis of the relief/separation alternatives. This is consistent with the Basement Flood Relief Program policy update by the City of Winnipeg. The 1986 Report requires qualification of benefits and costs. Benefits are determined based on the difference in average annual damages before and after the implementation of the relief works. Average annual damages are determined from flood frequency – damage curves computed on the basis of unit damages applied to predicted flooding for various storm events for existing and relieved systems. Average annual costs for an upgrading alternative are determined from the computed capital cost of the improvements.

Benefit-cost ratios were developed using 1991 costs and 1993 damages, as prescribed by the City. This is to allow for a common basis for comparison, as set-out in the report by Stantec Consulting Limited (2001). The recommended relief scheme is to be compared to relief projects from other sewer districts, to establish the implementation prioritization.

Spring flood protection levels with relief works, was also assessed to obtain a level of service up to the minimum 1 in 25 year level of protection. The Cockburn Flood Pump Station is located in the Cockburn Combined Sewer District and an assessment of the flood pumping capacity, station layout, and condition was also completed as part of this assignment.

The sewer condition report from the current sewer-cleaning program was reviewed and potential integration works identified. The results of this assessment are summarized on the sewer Management System Pipe Condition Assessment Drawing (Appendix B) and in Section 16.2.

1.2.4 CSO Analysis

The City of Winnipeg is striving to implement a program to reduce combined sewer overflows to receiving water bodies. Current long-term CSO control target objectives are to achieve an average of four overflows per recreation season (May 1st to September 30th, open-water recreation season). On this basis, a modeling methodology was developed to determine the number and volume of combined sewer overflows to the river system for the existing system and for the recommended relief works. A minimum of six hours between rainfall events was used to separate individual CSO events. The CSO analysis identified potential CSO control options to achieve the stated long-term CSO control target.

CSO control options were evaluated based on the 1992 representative year established by Wardrop Engineering Inc. (2002) under the CSO Management Study. The CSO analysis and development of control alternatives included the following:

- Raising of the existing weirs
- Determination of modifications to the interception/diversion rates
- Use of in-line storage with or without real time control
- Addition of off-line storage tanks
- An assessment of potential modifications to the recommended relief works to provide cost effective integration of CSO control measures with hydraulic options.
- If partial separation is a viable relief option, consideration of additional separation.
- Combinations of the above.

From the analysis, a CSO "cost-effectiveness curve" was developed, along with short and long-term CSO mitigation works staging considerations. For example, short-term staging would be the most cost effective works, which eliminates some CSO events, while longer-term staging would be additional works to reduce CSOs to the design value of four events per recreational season.

1.2.5 NEWPCC Interconnection

The methodology and merits of diverting flow from the South End Pollution Control Centre (SEWPCC) service area to the NEWPCC were considered as part of this study. The Cockburn Combined Sewer District provides one of the best locations for this physical interconnection since it falls within the SEWPCC service area but is adjacent to the NEWPCC service area.

A tunnel connection from Cockburn Station to River District Station was proposed and evaluated. The tunnel would provide CSO in-system storage for Cockburn and Calrossie, Baltimore, Jessie and River Combined Sewer Districts to meet the four-overflow criteria. It would also accomplish the objective of redirecting flow from the SEWPCC to the NEWPCC. The alternative was evaluated based on a comparison with other methods of CSO control for these districts.

2.0 XP-SWMM MODEL SETUP / BACKGROUND

2.1 DATA SOURCES

Data sources referenced as part of this project included the following:

- Various engineering study reports and documents obtained from the Water and Waste Department Resource Centre.
- Sewer and manhole data from the City's LBIS database.
- As-built drawings at key locations in the study area.
- Data from field investigations (i.e. Grant Park Shopping Centre, Parker survey, downspout survey forms, Pan Am Pool dye testing).
- Sewer monitoring data at 9 locations in the Cockburn District between April and November 2004.
- City of Winnipeg Rainfall Records (Summer 2004) – Lord Roberts School and Harrow School Rain Gauges.
- Water Consumption Records (City of Winnipeg, 2000).
- Flow rates at Cockburn Lift Station (1999, 2003 and 2004 – Winter months).
- DWF Additional Scope of Work – Additional 2006 monitoring.
- Outfall Condition Assessment (Carried out by KGS Group March 22nd, 2006).
- Groundwater cooling inputs along Grant Avenue.
- Information on sewer condition from City of Winnipeg Sewer Management System (SMS).
- Cost and benefit data.

These data sources will be referenced throughout this report. Details on some of the sources listed above are also provided in the following sections.

2.1.1 Sewer and Manhole Data

An XP-SWMM model was created of the existing sewer network for the Cockburn and Calrossie Combined Sewer Districts. Pipe and manhole data was input from the City's LBIS database, including manhole rim elevations, pipe diameters, as well as upstream and downstream pipe invert elevations. The nodes and links were georeferenced in the model. The corresponding "id" number from the LBIS data was also input in the XP-SWMM model, where applicable. Although they were not required for the analysis portion of this study, the as-built drawings were obtained from the City of Winnipeg for key locations in the study area for the final design of the relief alternatives to confirm the sewer and manhole data from the City's LBIS database.

Information related to sediment build-up in the sewers was available from the City's Sewer Management System (SMS). Since the sewers in the Cockburn Combined Sewer District were cleaned prior to the 2004 sewer monitoring program, the City recommended that this should not be incorporated in the XP-SWMM model. Sediment build-up in the sewers was therefore not considered for the calibration process.

2.1.2 Data From Field Investigations

The first and primary part of the field investigations involved determining the manhole rim elevations for specific manholes, where no information was available from the LBIS database. As part of this task, elevations were also recorded along numerous streets to confirm the direction of drainage. The surveyed manhole rim elevations were incorporated as part of the model, while the surveyed street elevations were used only as a reference in the subcatchment delineation process. The majority of these surveys were completed in January 2006.

Further field investigations involved the confirmation of drainage directions for various areas. For example, a detailed survey of the large field area between Parker Avenue and the CN tracks was carried out which showed that drainage was generally from North to South toward Parker Avenue. This survey also highlighted the large amount of depression storage that exists in this area, which results in a lower flow peak during rainfall. The direction of drainage was also confirmed at approximately 50% of the large apartment complexes along Grant Avenue. Based on field investigations carried out in March 2006, drainage from the apartment complexes is directed toward Grant Avenue.

At the Grant Park Shopping Centre, manhole covers were lifted to measure the pipe diameters in the parking lot. Although plan drawings of the shopping centre have been reviewed, there were no pipe diameters or manhole rim elevations specified on these drawings. Based on the field investigation, the diameters ranged from approximately 250 mm at the upstream end to 500 mm at the downstream end of the sewer network. An estimate of the manhole rim elevations was also made based on the difference in elevation between Grant Avenue and the parking lot for the Grant Park Shopping Centre.

A downspout survey was also undertaken to provide additional information on the drainage characteristics of a specified lot. A percentage was assigned to divide the drainage from the roof to the sewer and the lot. The surveys were carried out primarily in residential areas throughout the Cockburn and Calrossie Sewer Districts, and were used to estimate the percent imperviousness of catchments. The majority of the residential lots in the districts were reviewed as part of the survey.

Finally, an assessment was carried out of the 2 outfalls at the Cockburn Flood Pumping Station on March 22nd, 2006. The first outfall, referenced in the City of Winnipeg Flood Activity/Emergency Manual as RR-38, is associated with the flood pumping station and consists of a 1524 mm diameter CSP culvert. The second outfall, RR-39, is the gravity outfall associated with the Cockburn Lift Station combined sewer and consists of a 1675 mm diameter CSP culvert. During the inspection, both pipes were found to be in good condition, with no apparent deflections. A 1997 geotechnical inspection of the outfalls, also carried out by KGS Group, noted that the outfalls were at a low risk of failure.

The observations made during the outfall assessment on March 22nd, 2006 are included in Appendix A.

2.1.3 Groundwater Cooling

There are 3 known apartment locations on Grant Avenue that had been discharging groundwater into the sewer as part of an air conditioning system (#1025, #1055, and #1281 Grant Avenue). It should be noted that the flow rates at the #1025 and #1055 Grant Avenue locations were removed by June 2006 from the sewer system. The groundwater input to the combined sewer at the third apartment was reported to have been removed during the summer of 2006.

The estimated discharge at each of these locations was approximately 450 USGPM (28 L/s), which is similar to the estimate of 40 L/s that WWD anticipated. This estimate was based on information from KGS Group from their involvement in the removal of the groundwater discharge at #1025 and #1055 Grant Ave. The additional flow has been considered as part of the XP-SWMM model at the 3 locations for the calibration and verification process. Although this additional flow would have a significant effect on the dry weather flow, the effect would be minimal for wet weather flow. For example, for the calibration event, equivalent to approximately a 2-year magnitude, the wet weather flow peak ranges from 5 to 50 times greater than the groundwater cooling input. These flow inputs were excluded from the calibrated model for the existing level of service evaluation and the assessment of relief alternatives.

2.1.4 Sewer Management System

A review of the City of Winnipeg database, Sewer Management Systems (SMS), was carried out to retrieve information on sewer inspection data in the Cockburn, Calrossie and Jessie Sewer Districts. Figure B-1 in Appendix B shows the grade (SMG) assigned to the pipes in these districts. The pipes are assigned ratings of 1 to 5. A value of 1 is associated with a pipe that has no structural defects, while a value of 5 is associated with pipes that have already collapsed or that are excessively deformed or fractured.

Although this information was referenced as part of the relief alternatives, the hydraulic conditions in the model dictated in general the locations where relief piping was required.

2.2 SUBCATCHMENT DELINEATION

Using information gathered from the field investigations and surveys, data from the LBIS database on sewer directions and slopes, and ortho images, subcatchments were delineated for the Cockburn and Calrossie Sewer Districts. Subcatchments were also delineated in the southeast part of the Jessie District, when this area was added as part of the project scope. Figure 2-1 shows the subcatchments that were input into the XP-SWMM model.

Figure 2-1: Overview of Subcatchment Delineation Process

As shown on the figure, the subcatchment shape depends on the land type (e.g. residential or commercial) as well as the layout of the existing sewers. Flat roof areas are shown as hatched areas, which include the Grant Park Shopping Centre and the large apartment complexes along Grant Avenue. This area is shown in greater detail on Figure 2-2.

Figure 2-2: Large Roof Areas along Grant Avenue

Subcatchment parameters used in the model included the drainage area, slope, subcatchment width, and percent imperviousness of the catchment. The drainage area is a physical parameter based on the subcatchment boundary. Conversely, the subcatchment width, slope and percent impervious are model calibration parameters, which are adjusted within reasonable ranges to achieve model fit with observed flows and levels.

The width of the catchment depends on the catchment type, which can be characterized as a one-sided or a two-sided catchment. Drainage for a one-sided catchment flows from one side of the catchment to the other, while drainage from a two-sided catchment generally flows from both limits of the catchment toward a midpoint.

To determine the percent imperviousness of each subcatchment, sample calculations of different land use types (e.g. residential and commercial areas) were carried out. The impervious area included, streets, back lanes, and sidewalks. Only a portion of house roofs was considered impervious. Detailed downspout surveys conducted as part of this study generally showed that while the downspouts were disconnected from the sewer, the water was often directed onto sidewalks, driveways, and other impervious surfaces leading to the street or back lane sewer inlets. Based on the review, it was judged that only half of the roof area would be classified as impervious. Figure 2-3 shows an example of the sample calculations that were carried out to determine the percent imperviousness of a residential area. The blue-hatched sections (i.e. houses and streets) in the Figure show the impervious area.

Figure 2-3: Sample Calculations of Percent Imperviousness for Residential Area

Drainage inflow from subcatchments typically occurs through catchbasin leads, which are located between manhole locations. Therefore, in some cases, sewer inflow was input upstream or downstream of the actual input locations. Although this was not the exact location of the input, it was noted that not much effect occurs in the pipe length under consideration and would not be carried out downstream.

2.3 MODEL SET-UP

The land use in the Cockburn and Calrossie Sewer Districts consists of residential dwellings in the Lord Roberts area, south of the Fort Rouge Yards, and in the Ebby/Wentworth areas. Large apartment complexes are located along Grant Avenue near the Grant Park Shopping Centre, and are characterized by significant grassed pervious areas. Large commercial developments have also recently been constructed along Taylor Avenue for which open spaces are entirely paved impervious areas. Model parameters have been adjusted to reflect the difference in land use types.

In the residential areas, runoff enters the combined sewer system via street inlets as well as inlets located in back lanes, which are generally mid-block. The back lane inlets are connected to the combined sewers via pipes through private property. The runoff model was created with sewer inlets at each street or back lane, with the boundary of the subcatchment defined by the contributing area of the inlet. The subcatchment area was determined by using a combination of aerial photographs, information from the GIS database (e.g. manhole rim elevations), and information gathered as part of the field investigations.

The model was setup to include the Cockburn, Calrossie and southeast part of Jessie Sewer District. Although the Cockburn and Jessie Districts consist of a combined sewer system, the Calrossie District is a separated system with separate land drainage and wastewater sewers. The XP-SWMM model for the Calrossie District therefore consisted of the land drainage sewer system. Provisions were also made to include the Cockburn and Calrossie Interconnection as part of the XP-SWMM model, which is a WWS/CS to LDS cross-connection overflow located east of Calrossie Boulevard and Riverside Drive.

2.4 ROOF DRAINAGE

Roofs in residential areas were considered differently than the roofs of the large apartment complexes along Grant Avenue. Residential roofs with downspouts directed toward the lawn were treated as pervious areas while residential roofs with downspouts directly connected to the sewers or directed onto impervious surfaces were treated as impervious areas. Information gathered from the downspout connection surveys showed that the majority of the downspouts have been disconnected in the residential areas.

Further investigation of the apartment complexes along Grant Avenue showed that roof drainage was restricted significantly. For this reason and based on information from past studies (Independent Review of the Colony Combined Sewer District Storm Relief – 1998, Sewer Relief for Tylehurst Combined Sewer District – 1993, Strathmillan and Moorgate Combined Sewer Districts Sewer Relief and CSO Abatement Study - 2005), specific drainage characteristics were assigned to flat roof areas in the XP-SWMM model. These roof areas were considered to be impervious, but modeled as separate subcatchments to adequately represent the restriction of runoff into the sewer due to the roof orifices.

Model parameters adjusted to reflect the restriction of runoff from roofs included increasing the depression storage for impervious surfaces from 1.5 to 5 mm and decreasing the catchment slope from an average of 1.0% to 0.2%.

2.5 COST AND BENEFIT DATA

Costs and benefits used in this study were based on information provided by the City of Winnipeg, Water and Waste Department (WWD). Unit prices for relief/separation piping provided by the City were in 1991 dollars, while the benefit data recommended for this study was in 1993 dollars (Stantec 2001). It was requested that these data sources be used for the benefit-cost analysis to ensure that the results from this study would be based on a standardized approach for consistent results and comparison to other districts. A summary of the flooding damage estimates used for benefit calculation and the 1991 dollar unit prices is presented in Section 9.0.

In addition to the data required for the benefit-cost calculations, an estimate of the unit prices for relief/separation piping in 2007 dollars was made based on tender tabulations provided by the City from 13 bid opportunities between 2002 and 2006. Due to the variability in costs, only tender tabulations since 2005 were used.

Prices from all bidders were included in the comparison. Items having a similar description of work were compared and their average price was calculated. Some minor adjustments were made to the average costs to show a correlation between the diameter of pipe and cost. The tender evaluation showed that prices increased by 20 percent between 2005 and 2006, while a 6% increase in prices was assumed between 2006 and 2007. Additional costs associated with the relief/separation piping (i.e. televise, restore, manhole) were estimated based on experience and knowledge of current tender prices for these items. The unit prices for land drainage separation were assumed to be the same as for relief piping. The additional cost for reconnection of catchbasin leaders is required for land drainage separation, which is offset by not having to interconnect to the existing combined sewer, as is the case for relief piping. The final relief sewer construction costs are shown in 2006 and 2007 dollars in Table 2-1.

Table 2-1: Relief Sewer Construction Costs ($/m)

Diameter (mm)	Pipe (2006$)	Televise (2006$)	Restore (2006$)	Manhole (2006$)	Total (2006$)	Total (2007$)
300	$500	$10	$100	$120	$730	$770
375	$650	$10	$100	$120	$880	$930
400	$715	$10	$150	$120	$995	$1,055
450	$715	$10	$150	$120	$995	$1,055
525	$750	$10	$175	$120	$1,055	$1,120
600	$840	$10	$175	$120	$1,145	$1,200
750	$1,500	$10	$200	$160	$1,870	$1,980
900	$1,900	$10	$200	$160	$2,270	$2,410
1050	$2,600	$10	$225	$160	$2,995	$3,175
1200	$2,600	$10	$225	$160	$2,995	$3,175
1350	$2,800	$10	$250	$160	$3,220	$3,410

Notes:
1. Costs include manholes, televising, restoration, and minor drainage appurtenances but not major items such as chambers, outfalls, etc.
2. Sewer/catchbasin/service connections and connection abandonment are not included for relief sewer.
3. For regional streets, the costs should be increased by 15%.
4. Costs do not include engineering contingencies or overheads.
5. For pipe sizes greater than 1350 mm, a relationship was developed using the estimated costs for diameters less than 1350 mm.

The 2007 relief sewer construction costs were not used for the benefit-cost analysis but will be referenced in Section 14.0 of this report in the discussion of the preferred alternatives.

3.0 DRY WEATHER FLOW MODEL

3.1 INTRODUCTION

The basement flooding relief program is concerned with high rates of runoff while dry weather flow is normally of minor concern. The average dry weather flow (ADWF) for Cockburn and Calrossie for example has been measured at 0.024 m^3/s, (24 L/s) which compares to the peak 5-year storm runoff rate of 11.8 m^3/s (11,800 L/s), which is nearly 500 times the ADWF. The Cockburn and Calrossie project did, however, include dry weather calibration in the scope of work for the following reasons:

- Cockburn has a high incidence of dry weather overflows and calibration was proposed to increase the system understanding and provide an opportunity to identify and address anomalies.

- Dry weather flows are more significant for smaller runoff rates, and the accuracy of the CSO analysis and model calibration using smaller storms would benefit from quantification of the dry weather flows.

The dry weather flow calibration was undertaken based on system monitoring carried out by the City during the 2004 summer season. Automated monitors at nine locations collected sewer levels in the Cockburn collection system. Winter dry weather flow records and a short period of summer pump monitoring supplemented the data.

The calibration effort based on the 2004 data produced a reasonable estimate of the dry weather flow patterns, which was considered suitable for proceeding with the basement flooding relief analysis. There were, however, a number of unresolved discrepancies that could potentially impact the operation of the lift station and the incidence of overflows.

The City authorized additional investigation of dry weather flows and carried out a second flow-monitoring program in the fall of 2006. The discussion that follows addresses each of the evaluations independently.

The following section considers only dry weather flows, including domestic sewage and dry weather inflow and infiltration. Rainfall dependent inflow and infiltration (RDII) is also of interest for sewer separation alternatives, and is discussed in Section 8.3.

3.2 DRY WEATHER FLOW - 2004 MONITORING

3.2.1 Water Consumption Data

Water consumption was used as the basis to proportion wastewater flows to each of the modeled subcatchments. Water consumption records for the year 2000 for the Cockburn and Calrossie sewer district were available for use in this study. The data included annual water consumption volumes by address divided into residential, commercial and industrial categories. The annual water consumption is summarized in Table 3-1.

Table 3-1: Cockburn and Calrossie 2000 Water Consumption

User Type	Annual Consumption (L)	Average Flow Rate (L/s)	Percent of Total
Residential	628,200,000	20.0	75%
Commercial	200,000,000	6.3	23%
Industrial	12,400,000	0.4	2%
Total	840,600,000	26.7	100%

3.2.2 Population

Information for the study area population was obtained from the Government of Canada 2001 Census. The Cockburn and Calrossie districts include approximately 90% of the Grant Park, 35% of Lord Roberts, and 100% of the Ebby-Wentworth census area. The northern side of Grant Avenue is in the Rockwood census area and includes 21 multi-storey apartment buildings, which are also serviced by the Cockburn Sewer District. From the census data, the study area population was estimated to fall between 5,000 and 7,500, depending on the number of people inhabiting the large apartment buildings. A precise estimate would require identification of the number of residents per apartment, and was not carried out for this study. A population of 5,000 was assumed for the purpose of proportioning flow. The area has a total of 2,480 dwelling units. The number of single-family residential units was determined by a house count to be 1,149, leaving a total of 1,331 multi-family dwelling units.

A population density of 2.5 people per single-family dwelling was assumed. The population in the single-family residential category was therefore determined to be 2,872. The remaining population of 2,128 was assumed to be distributed between the apartment complexes, resulting in an average of 1.6 people per multi-family dwelling.

3.2.3 Cockburn Pump Station

The measured flow at the Cockburn lift station was provided for the years 1999, 2003 and 2004 for the winter months. This monitoring period represents the dry weather flow (DWF) period, as there would be no surface runoff during the winter. Table 3-2 presents a summary of the DWF over this period.

Table 3-2: Cockburn Lift Station Flow Monitoring

	Year	Set	Start of Range	End of Range	Weekly Volume (m^3)	Average Weekly Volumes (m^3)	Daily Volume (m^3)	Lpcd	Average Flow (L/s)
Winter	1999	1	1/4/1999	1/10/1999	16,405	16,344	2,344	469	27
Winter	1999	2	3/1/1999	3/7/1999	14,929		2,133	427	25
Winter	1999	3	1/18/1999	1/24/1999	17,697		2,528	506	29
Winter	2003	1	1/22/2003	1/28/2003	11,879	12,000	1,697	339	20
Winter	2003	2	1/26/2003	1/1/2003	12,121		1,732	346	20
Winter	2004	1	1/19/2004	1/25/2004	13,035		1,862	372	22
Overall Winter Average					**14,344**		**2,049**	**410**	**24**
Summer	2005	1	8/22/2005	8/25/2005	42,909		6,130	1227	71

The monitored dry weather flows ranged from a winter average of 27 L/s in 1999 to 20 L/s in 2003. This declining trend for water consumption is consistent with the citywide experience, which saw a peak water consumption use in the early 1990s. No significant land development occurred in the mostly built up area, which would impact water use, with the exception of commercial areas along Taylor Avenue. For the full period of record, the average weekly volume at the pump station including all winter data sets is 14,344 m^3, which is equivalent to an average flow of 24 L/s, or 410 litres per capita per day (Lcpd).

The summer flow rate at the lift station was only available for the August 22nd to 25th, 2005 period. The average summer flow, as listed in Table 3-2, was 71 L/s. Environment Canada weather records at the Winnipeg International Airport, however, showed that there were significant rain events before and during the period, and therefore the flows cannot be considered as representative summer dry weather flow.

3.2.4 Summer Flow Monitoring Data

The City of Winnipeg provided sewer flow monitoring data for 9 locations in the study area, as listed below (MH No. corresponds to the ID associated with the WWD GIS sewer manhole database) and shown on Figure 3.1:

- Hector – (MH No. 60009692)
- Nathaniel – (MH No. 60009584)
- Harrow and Hector – (MH No. 60009942)
- Guelph – (MH No. 60018522)
- Taylor – (MH No. 60010831)
- Cockburn and Rosedale – (MH No. 60010363)
- Riverside – (MH No. 0010349)

The 9 sites provided depth of flow from April to November 2004. For each of the monitoring locations, the data were analyzed and all days in which rainfall occurred were eliminated from the data set for the dry weather flow calibration.

The data were then analyzed and any anomalies in the data were eliminated. From the remaining data, a representative week of dry weather flow data was compiled for each monitoring location. The flow monitoring was analyzed and a typical 7-day dry weather flow pattern compiled.

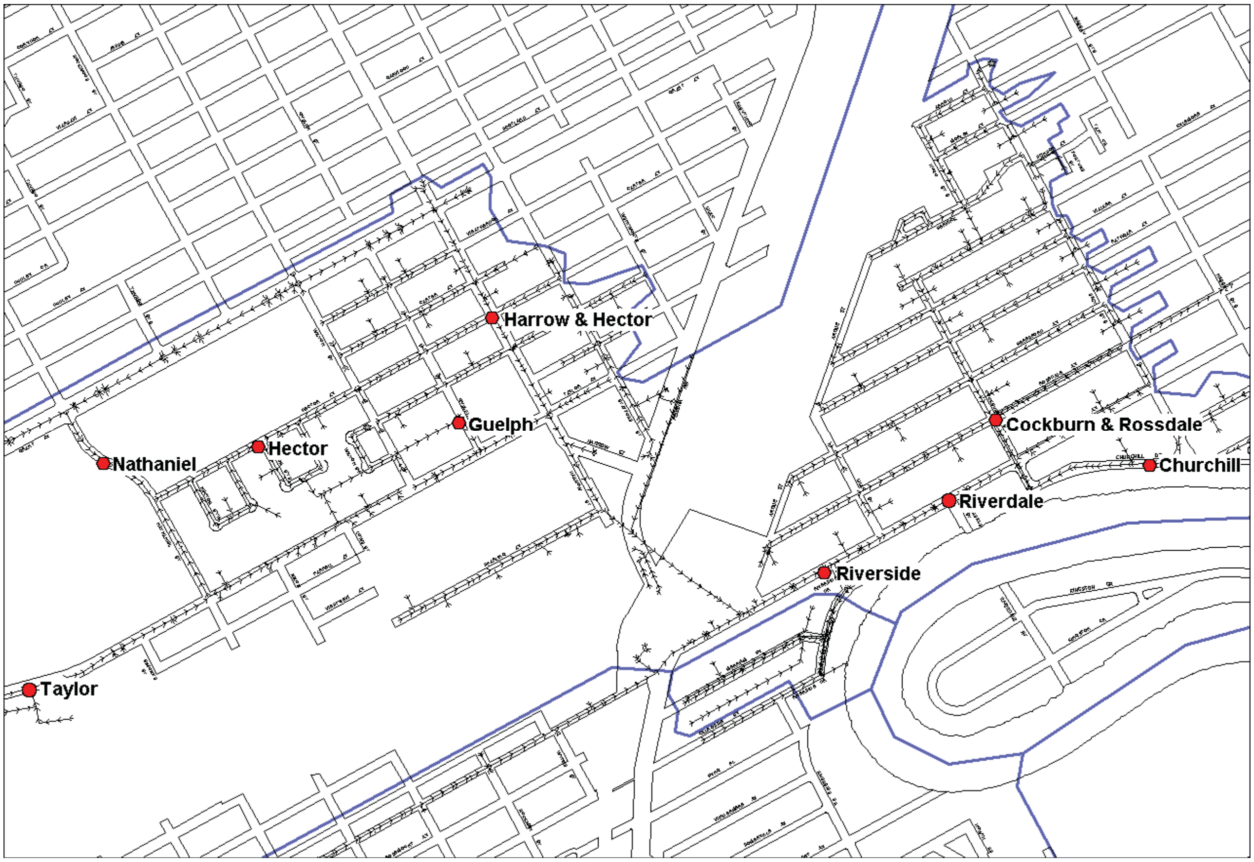


Figure 3-1: 2004 Sewer Monitoring Locations in Cockburn Combined Sewer District

3.2.5 Calibration Approach

The objective of the dry weather flow analysis was to develop a calibrated hydraulic model.

The planned approach was:

- Estimate the wastewater generation rate from the water consumption averages and apply it to each subcatchment in the model.
- Calibrate the dry weather flow model by comparing the water consumption rates for the entire sewer district to the lift station flow records, accounting for dry weather infiltration (base flow).
- Calibrate the summer dry weather flow by comparing the dry weather flows to summer monitoring data accounting for the increased rate of infiltration during the summer.

- Review the calibrated model in comparison to the monitored flows to identify anomalies such as from unaccounted for ground water inflow or infiltration.

The wastewater generation for each subcatchment was developed from the annual 2000 water consumption records. The wastewater generation rates were determined as presented in Table 3-3.

Table 3-3: Computed Wastewater Generation

User Type	Basis of Estimate	Estimated Population based input (Lcpd)	District Total (L/s)
Residential	Water consumption x 80%	275	15.9
Large Commercial	Water consumption x 80%	N/A	4.5
Small Commercial	Water consumption x 80%	9	0.5
Industrial	Water consumption x 80%	5	0.3
Other (Infiltration)		48	2.8
Total		410	24.0

The water consumption rates for all water users were multiplied by a factor of 80% to estimate the wastewater generation rate in litres per capita per day (Lcpd). This allowance was included to account for the fact that not all water consumed is returned to the sewer system.

Two dry weather flow inputs were entered into the model for each subcatchment. The large commercial wastewater generation rates were input into the actual subcatchments where the user is located. The second was a blend of the residential, small commercial, industrial and other categories, which totaled 337 Lpcd. The inflow for each subcatchment was calculated based on the per capita rate and the size of the subcatchment. The wastewater generation rates were applied as follows:

- The large commercial users accounted for 90 percent of the total commercial water consumption. The actual rates were input into each subcatchment for the large commercial users.

- Small commercial users represent the difference between the total commercial use of 6.3 L/s and large commercial use of 5.7 L/s, or a total of 0.6 L/s. At a ratio of 80% the wastewater generation from small commercial users was estimated to be 0.5 L/s, or an average of 9 Lpcd.

- The total industrial users in the area consumed 0.4 L/s, or an average of 5 Lpcd.

- Other sources were determined based on the difference between the known total district dry weather flow of 24.0 L/s and the sum of the known users. This amounted to 2.8 L/s and is attributed to winter ground water infiltration.

The dry weather flow generation method selected in XP-SWMM was the Direct Flow method, with the flow rate (litres/second), peaking factor and the pattern variation being input to the model. The pattern variation or diurnal pattern was entered based on previous experience for similar type areas. Figure 3-2 summarizes the temporal variation or diurnal pattern used for the study area.

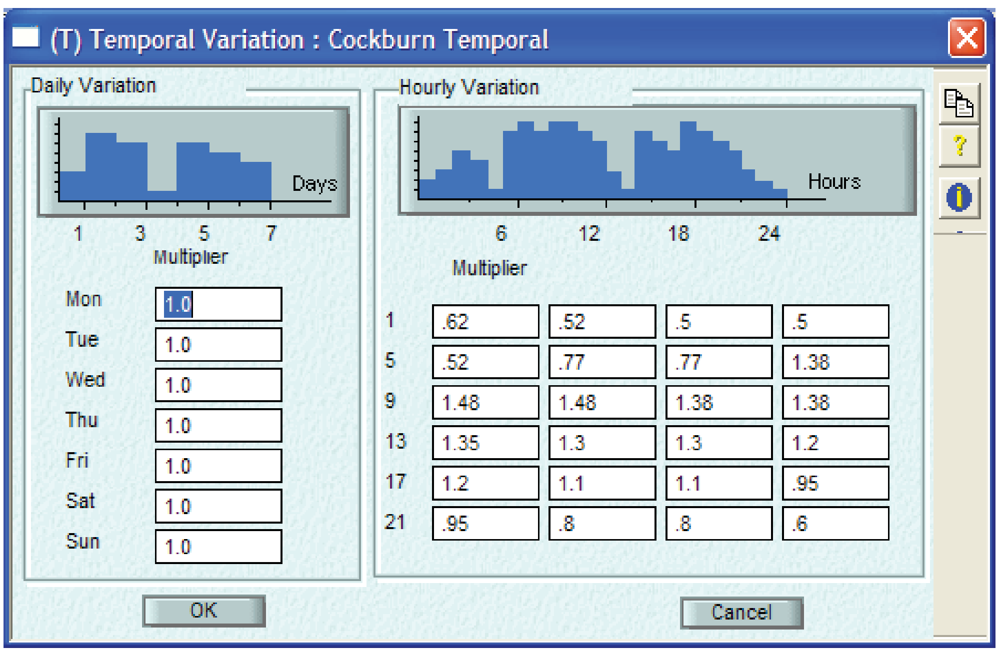


Figure 3-2: Temporal Variation (Diurnal Pattern)

As reported in Section 2.1.3, past studies have discovered that during the summer months the flow from well water was introduced into the sewage system via commercial cooling systems. Three locations, which once practiced well water-cooling, were identified to be #1025, #1055 and #1281 Grant Avenue. The City has reported that this practice was discontinued in 2006 but would have been contributing during the summer of 2004. The wastewater patterns and timing were unknown for the wells and they were not entered in the model as an inflow, but were to be used as a calibration input if a discrepancy was found between the model and field monitoring results.

3.2.6 Dry Weather Flow Model Calibration

The dry weather flow model calibration was undertaken on the basis of comparison of model output to recorded or known system information. Several attempts were made to confirm the model in comparison to the recorded system data. However, the extent and quality of monitoring information did not support a high level of confidence in the calibration.

The winter infiltration rates could not be estimated with any degree of confidence. Based on the water consumption approach and an assumed total dry weather flow at Cockburn Station of 24.0 L/s, the implied extraneous flow, which would be primarily attributed to infiltration, was 2.8 L/s. Since there was no way of validating the water to wastewater ratio, the infiltration rate could not be reliably determined. By example, the range in winter dry weather flows, determined on an annual basis at the Cockburn lift station, varied from 20 to 27 L/s, meaning the rate of infiltration could fall in a range from 0 to 5.8 L/s.

The pumping station data available for the summer period was very limited and prohibited an estimate of summer dry weather infiltration. The only data available was for a short duration and occurred over a period of rainfall, and therefore was determined to be unsuitable for summer dry weather flow calibration.

The water levels generated by the model were compared to actual monitored water level readings taken at the 9 sites during dry periods in the summer months. The model flows included the individual subcatchment inputs previously discussed. Figures 3-3 to 3-11 illustrate the monitored versus model depth of flow at the various monitoring locations.

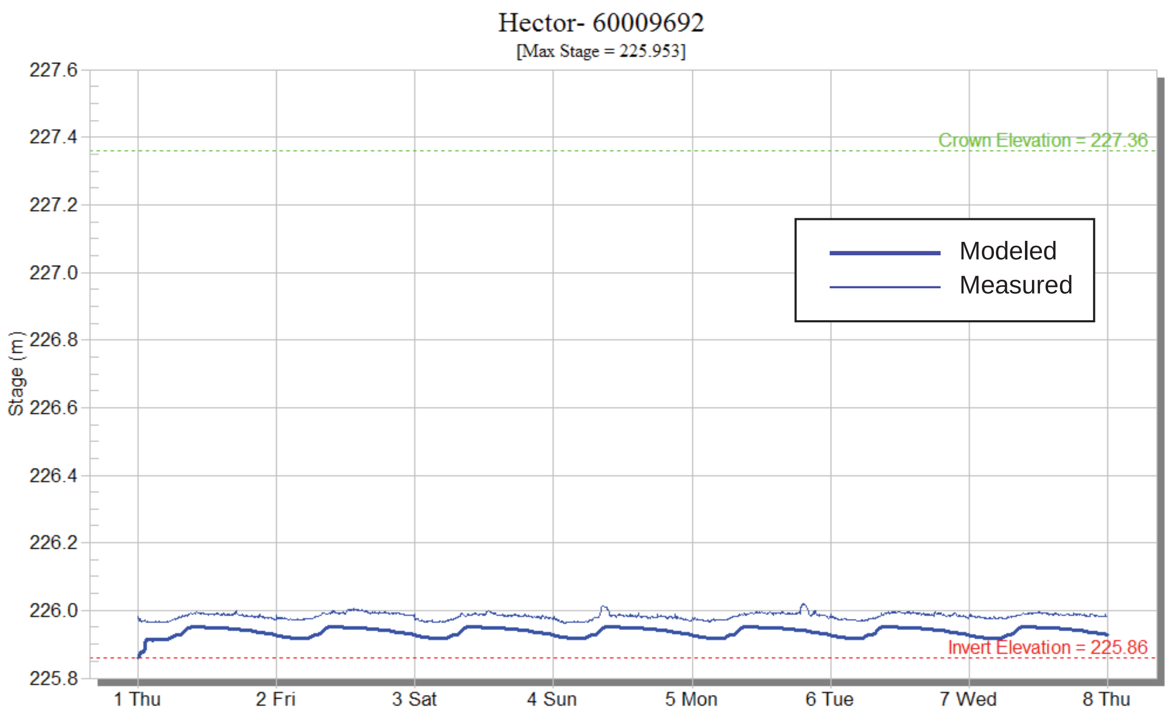


Figure 3-3: Comparison of Observed and Computed Levels at the Hector Gauge

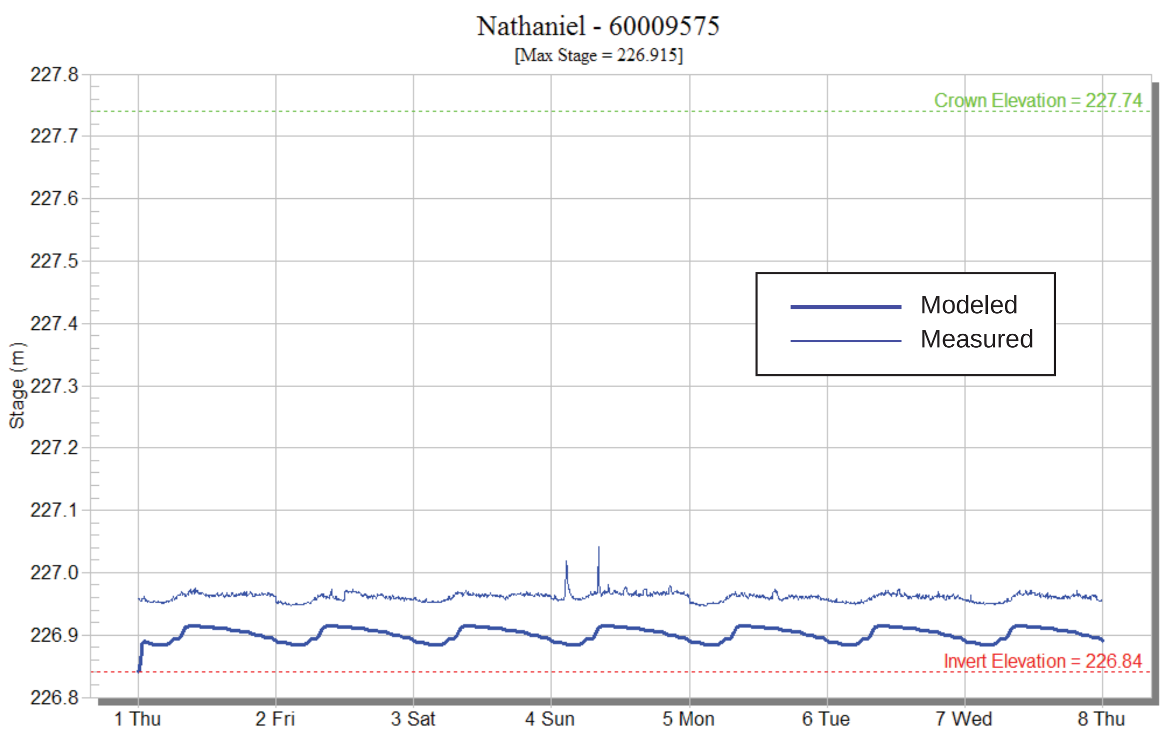


Figure 3-4: Comparison of Observed and Computed Levels at the Nathaniel Gauge

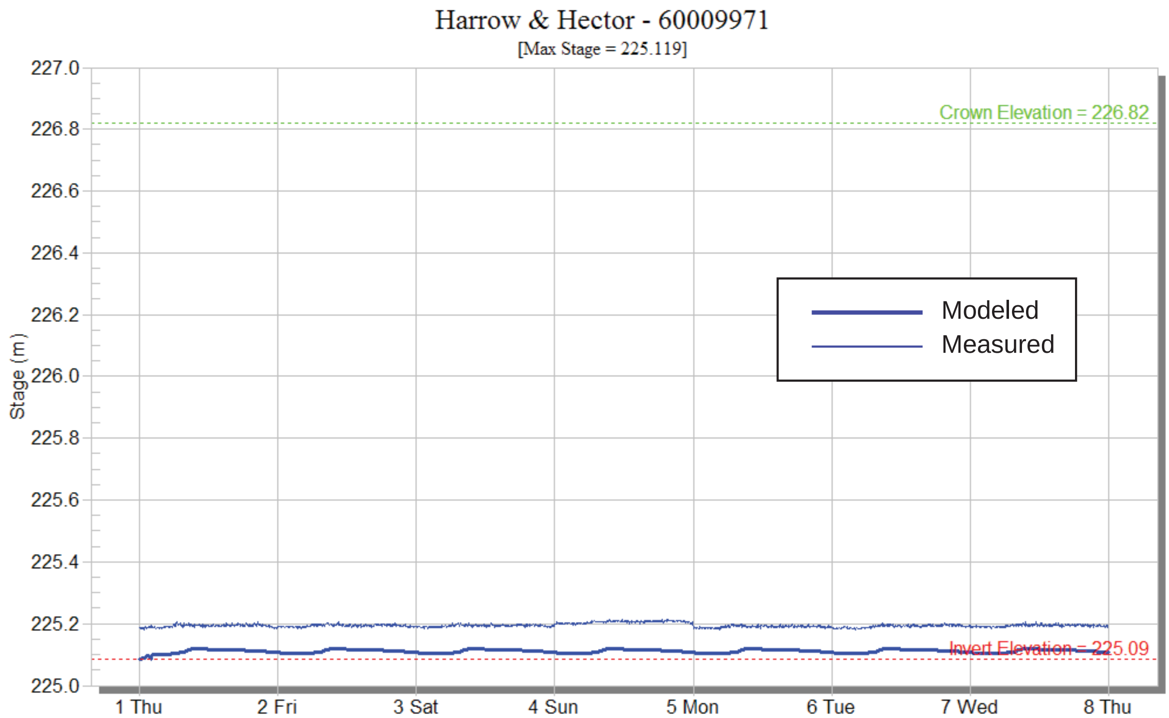


Figure 3-5: Comparison of Observed and Computed Levels at the Harrow & Hector Gauge

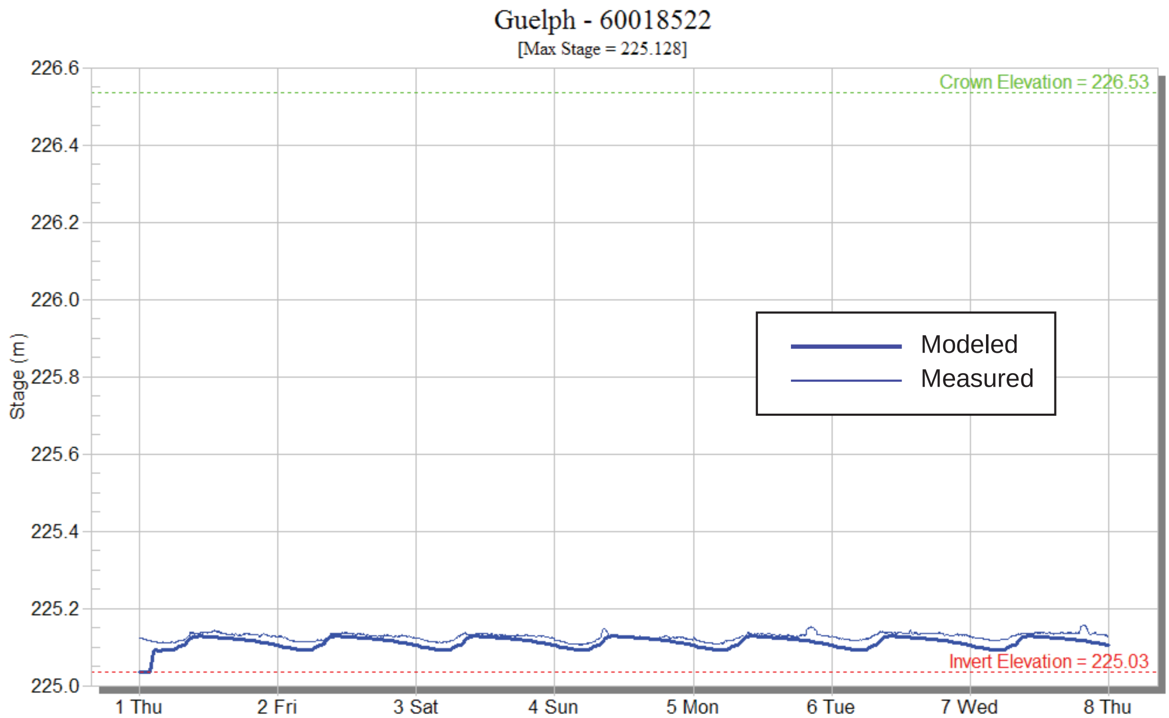


Figure 3-6: Comparison of Observed and Computed Levels at the Guelph Gauge

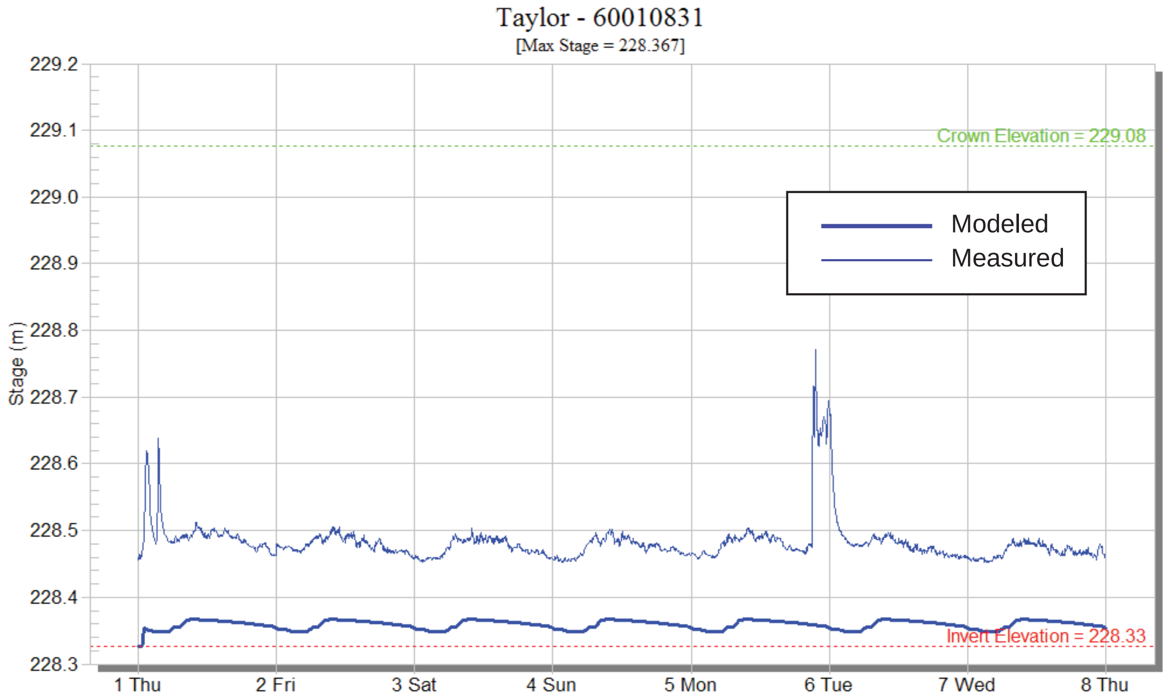


Figure 3-7: Comparison of Observed and Computed Levels at the Taylor Gauge

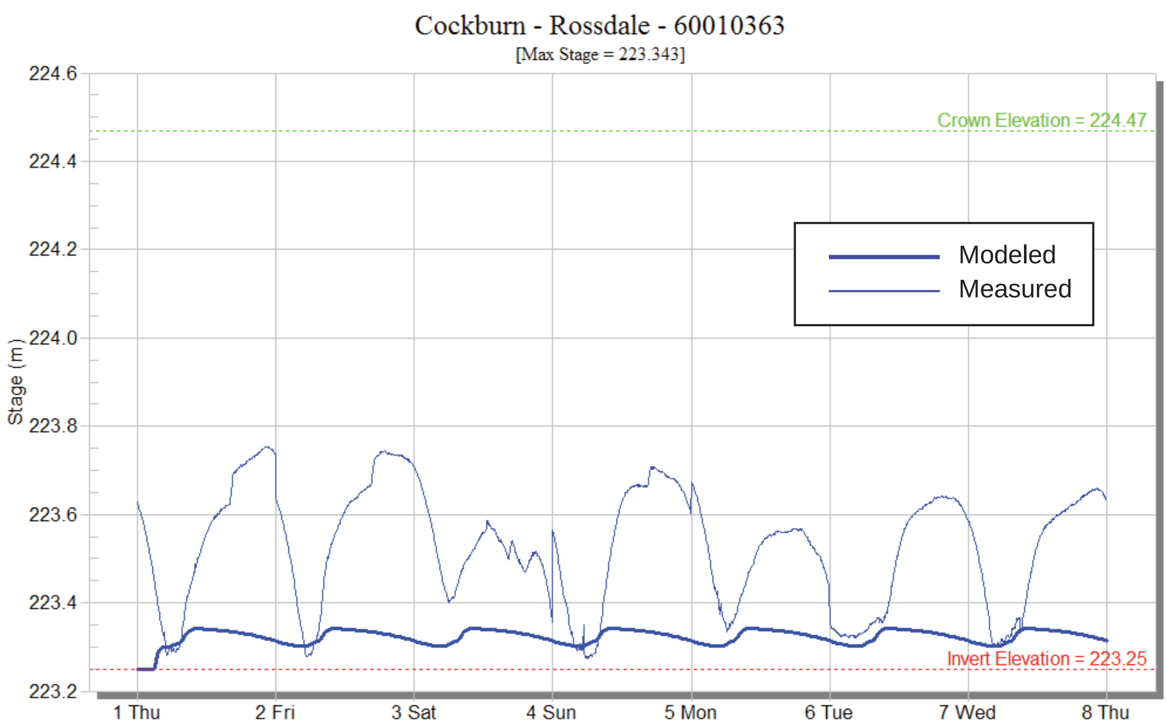


Figure 3-8: Comparison of Observed and Computed Levels at the Cockburn & Rosedale Gauge

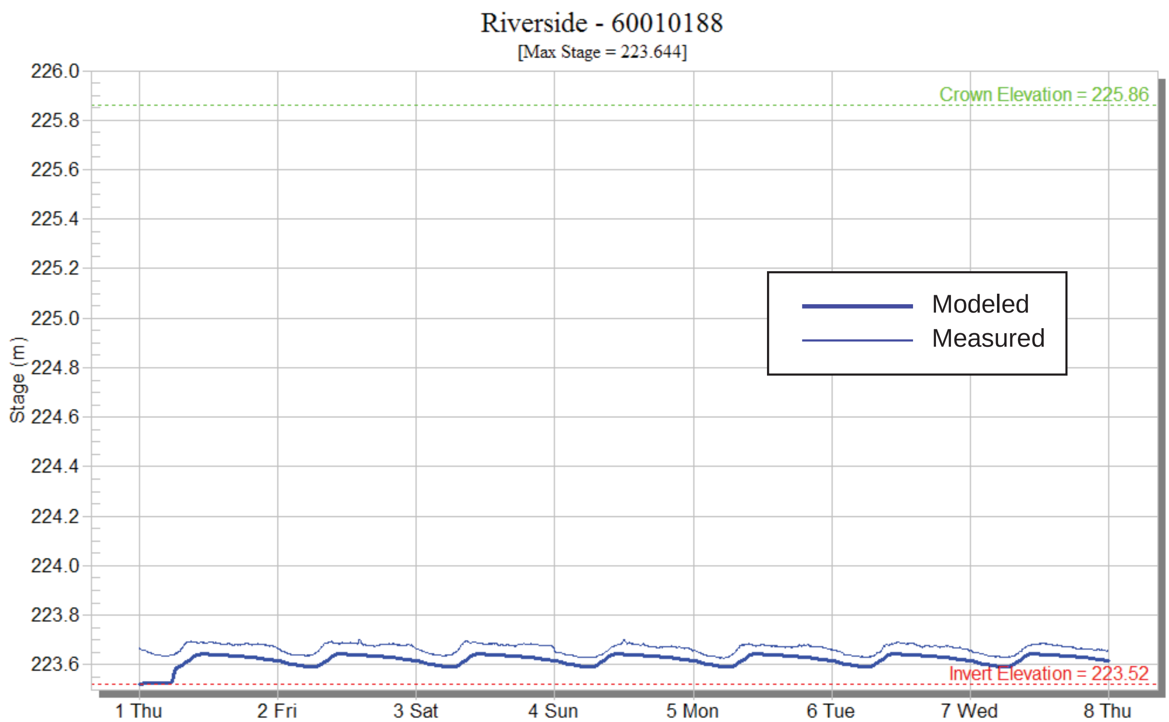


Figure 3-9: Comparison of Observed and Computed Levels at the Riverside Gauge

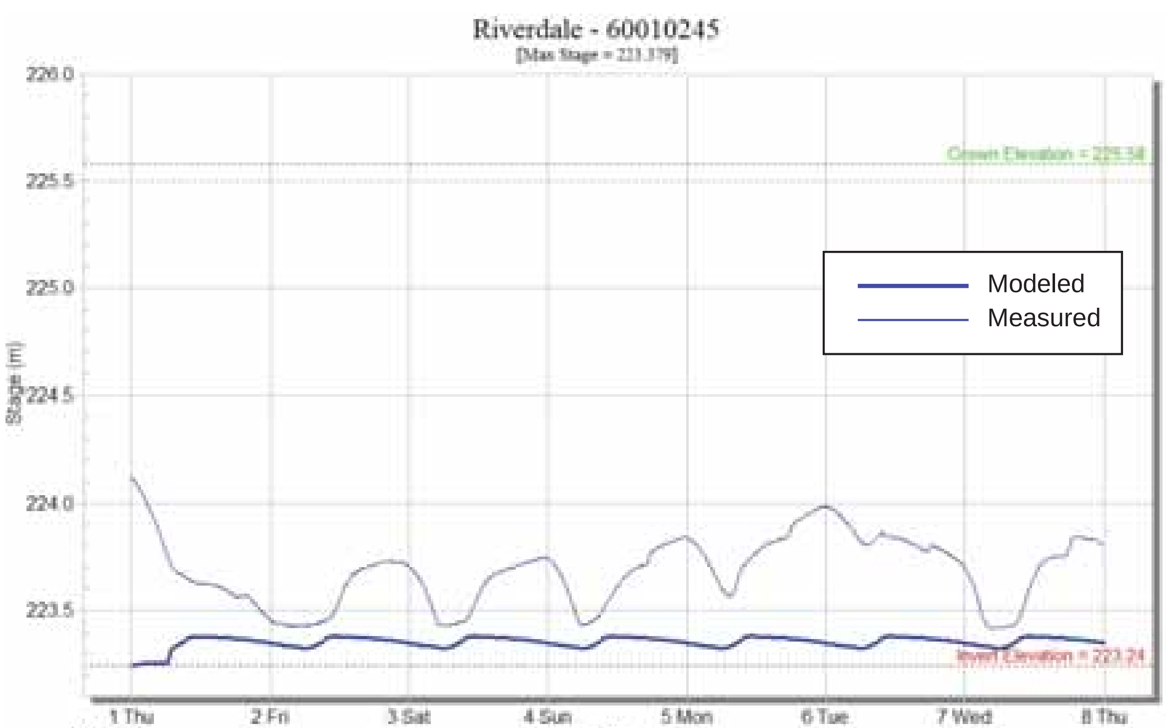


Figure 3-10: Comparison of Observed and Computed Levels at the Riverdale Gauge

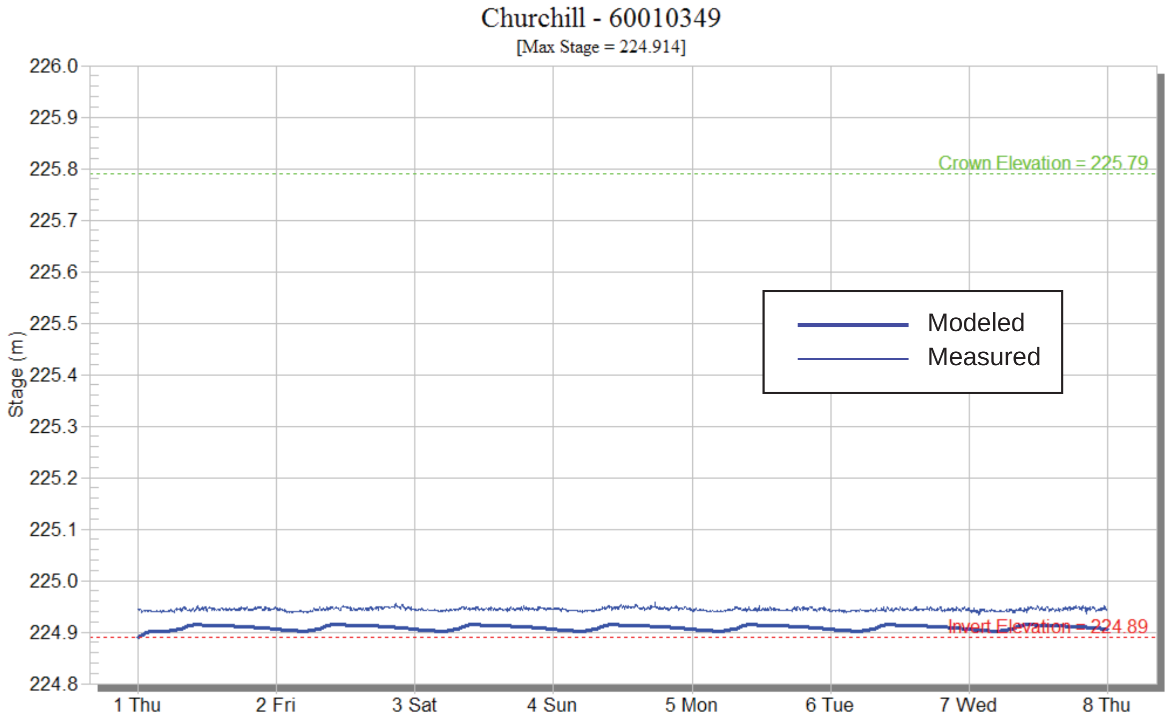


Figure 3-11: Comparison of Observed and Computed Levels at the Churchill Gauge

The depth of flow comparison shows a fairly good correlation for the area west of Pembina Highway. Hector and Guelph modeled depths are very close to recorded, while Harrow/Hector and Nathaniel model depths are somewhat lower than recorded. The Taylor modeled level is substantially less than the measured one. The reason for the large discrepancy could not be determined with the existing information. The piping system for this western area combines into a single conduit, which crosses Pembina Highway and the railroad. The Riverside monitoring location is located in the downstream pipe, with the modeled and recorded depths having a very good correlation.

Three depth monitors were located in the area east of Pembina Highway. Review of the depth recordings for Riverdale and Cockburn sites suggested that lift station backwater levels influenced the recorded water depths. Both locations show a recorded diurnal pattern of increasing levels throughout the day, and decreasing levels overnight. The peak levels at both locations were in the range of the normal summer river water level (223.7 m), which suggests they were at a sufficient level to cause a discharge to the river through the flap gate. The probable cause of this pattern was the inability of the lift pumps to dewater the sewage collected in the system. As the rate of inflow exceeded the capacity of the lift pumps, the level in the wet well would increase backing up into the combined sewer. This level appears to have increased above the weir crest without causing a dry weather overflow for this district since the normal summer river level is above the weir height and would have keep the flap gate closed.

The modeling exercise could not reproduce the monitored results. The capacity of the lift station pumping at the time of the monitoring was 73 L/s, which should have been sufficient capacity to keep up to the projected dry weather inflows. The observed increase in water levels in the combined sewer would have resulted from either this capacity not being available, the inability of the system to deliver the flow to the pumps, or higher than projected inflows. Pumping records that were available during the summer period could not be used to validate the station information since they were recorded during periods of rainfall.

The other depth monitor in the eastern area was located on Churchill Drive where the modeled level shows a poor correlation to the measured values. As with the western area, model adjustments were ineffective at producing model calibration with any degree of confidence.

The impact of the well discharges was not evident from the monitoring results. The 9 monitoring locations were analyzed, however no obvious increases in depth of flow could be attributed to well water. The wells would only be expected to be operational during hot weather, and the operation may have been intermittent, but in any case was not evident from the sewer gauging results.

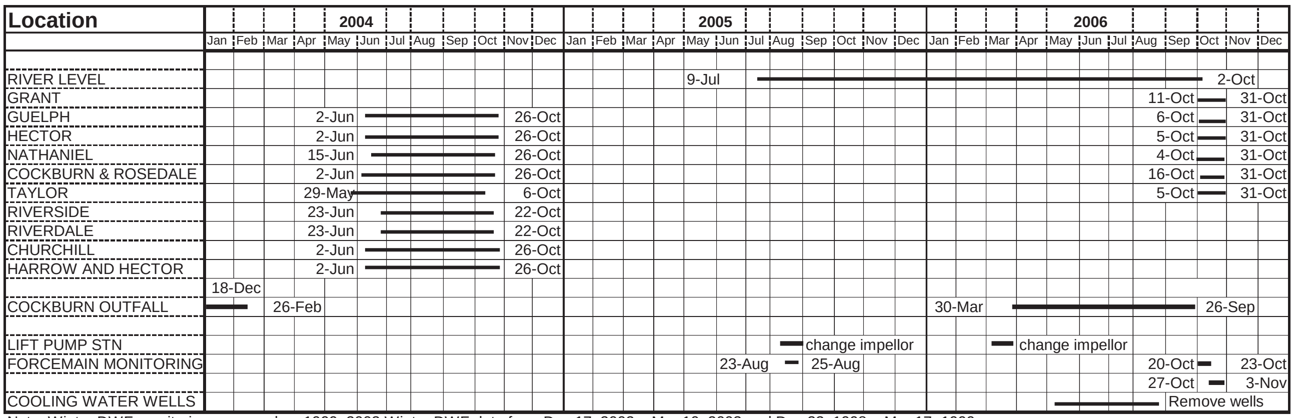
3.2.7 2004 - Model Calibration Summary

The 2004 based dry weather model produced a system response that was expected to be a reasonable representation of actual conditions for the purpose of runoff calibration. As previously identified, discrepancies in depths of flow which impact dry weather overflow analyses were unresolved. Several model adjustments were made in an attempt to improve the calibration, however they had limited impact on the dry weather flow depths. The depth of flow does not vary significantly with changes to the rate of flow at the sewer depths being encountered. More accurate information using flow rather than depth information would improve the calibration. Remaining discrepancies may include suspected localized flow variations, an increase in infiltration under summer conditions, and unaccounted for sediment build-ups or other blockages in the sewers.

The 2004 dry weather flow calibration was used for subsequent relief piping alternatives.

3.3 DRY WEATHER FLOW – 2006 SUPPLEMENTAL MONITORING

Additional flow monitoring was carried out during 2006 to increase the level of understanding of the dry weather flow conditions. A timeline of the entire Cockburn monitoring programs is shown in Figure 3-12.



Note: Winter DWF monitoring program has 1999, 2003 Winter DWF data from Dec.17, 2002 ~ Mar.10, 2003 and Dec.23, 1998 ~ Mar.17, 1999.

Figure 3-12: Schedule of Cockburn and Calrossie Site Activities

The 2006 monitoring program included:

- A strap-on doppler flow meter on the Cockburn lift station discharge forcemain
- Six depth monitors re-installed in the collection system
- Acquisition of data from the area-velocity meter installed downstream of the Cockburn weir
- Acquisition of river level data.

The Cockburn lift station flow meter was installed from October 20th to October 23rd, 2006. There was no wet weather during or immediately preceding the period, and the river levels were low, which suggests it is reasonably indicative of a typical summer dry weather flow pattern.

The 2006 summer DWF pattern is plotted along with the 2004 winter DWF in Figure 3-13. The summer flow pattern shows the same diurnal variation as the winter but is consistently higher by approximately 10 L/s, increasing the ADWF from 24 to 34 L/s. This is in most likelihood because of the summer groundwater infiltration rate received from weeping tiles and pipeline and manhole cracks and joints. River intrusion would not occur during this period because of the lower Red River levels during winter through the control of the locks at Lockport.

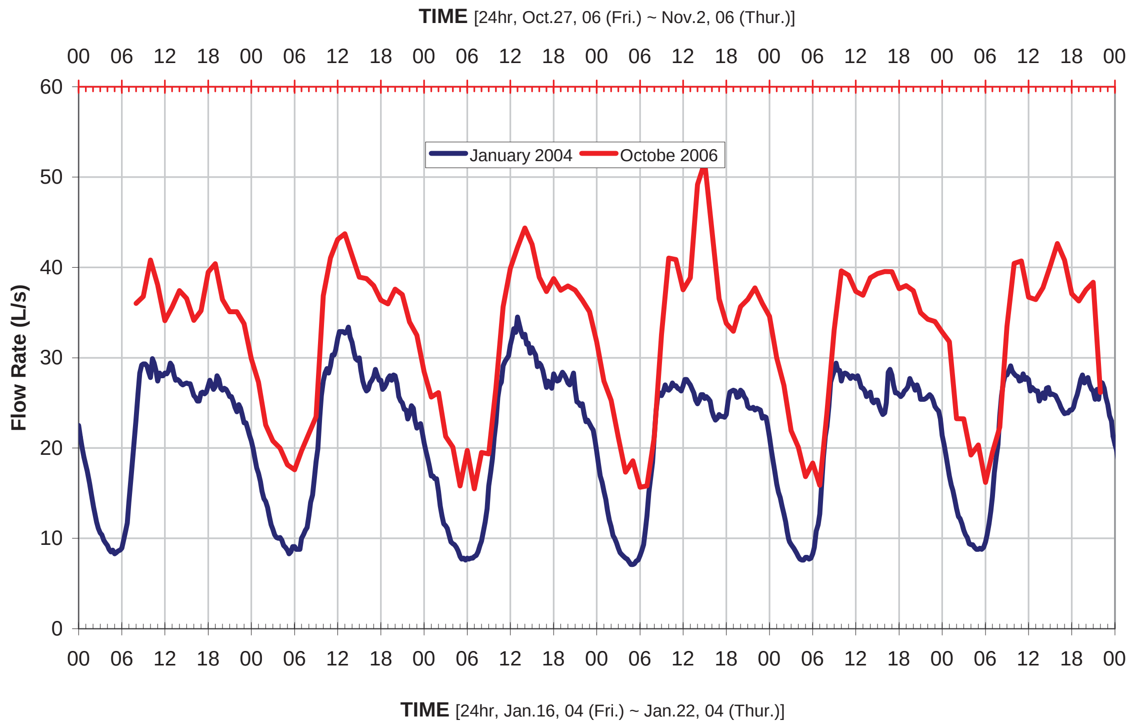


Figure 3-13: Cockburn Lift Station DWF - October 2006 and January 2004

The 2006 summer monitoring information is also plotted along with the 2005 summer DWF results in Figure 3-14. The 2005 results were impacted by rainfall and are as expected, higher than the 2006 flows, which were not impacted by wet weather. It should also be noted that the three groundwater cooling wells were not disconnected until 2006, and therefore they may have contributed to the 2005 flows. The impact of the rainfall presented in the figure was not determined. However, by observation, the ADWF during this period would be at least 60 L/s.

At a DWF rate of 60 L/s, the Cockburn pumping rate of 73 L/s at the time would not have been able to keep up with the diurnal peaks, which could provide an explanation for the discrepancy noted previously for the 2004 Cockburn and Riverdale monitoring locations.

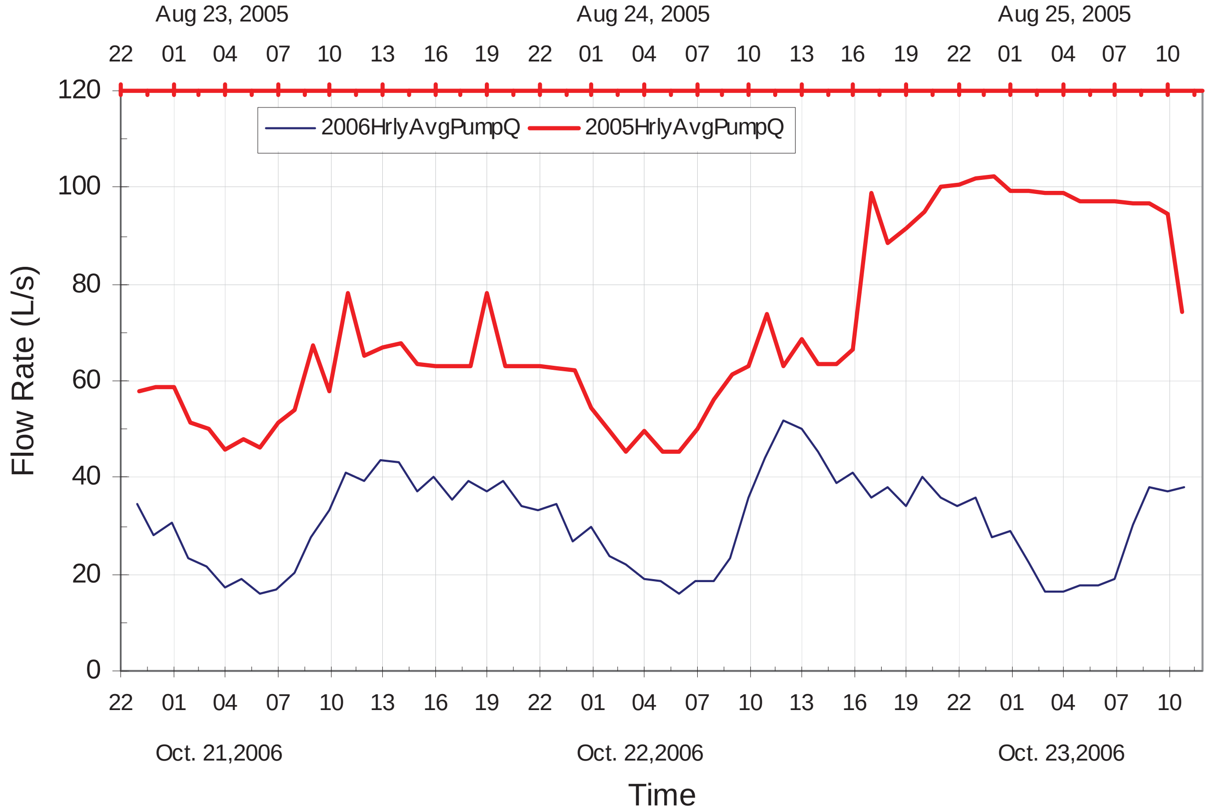


Figure 3-14: Cockburn Lift Station DWF - October 2006 and August 2005

The collection system flow monitors were re-installed for a three to four week period, being removed at the end of October 2006. Five of the collection system flow meters were installed in the same locations as in 2004, with one new location being installed on Grant Avenue, as shown in Figure 3-15. The monitoring information of particular interest is for Taylor and Rosedale, which showed a significant change from the 2004 results.

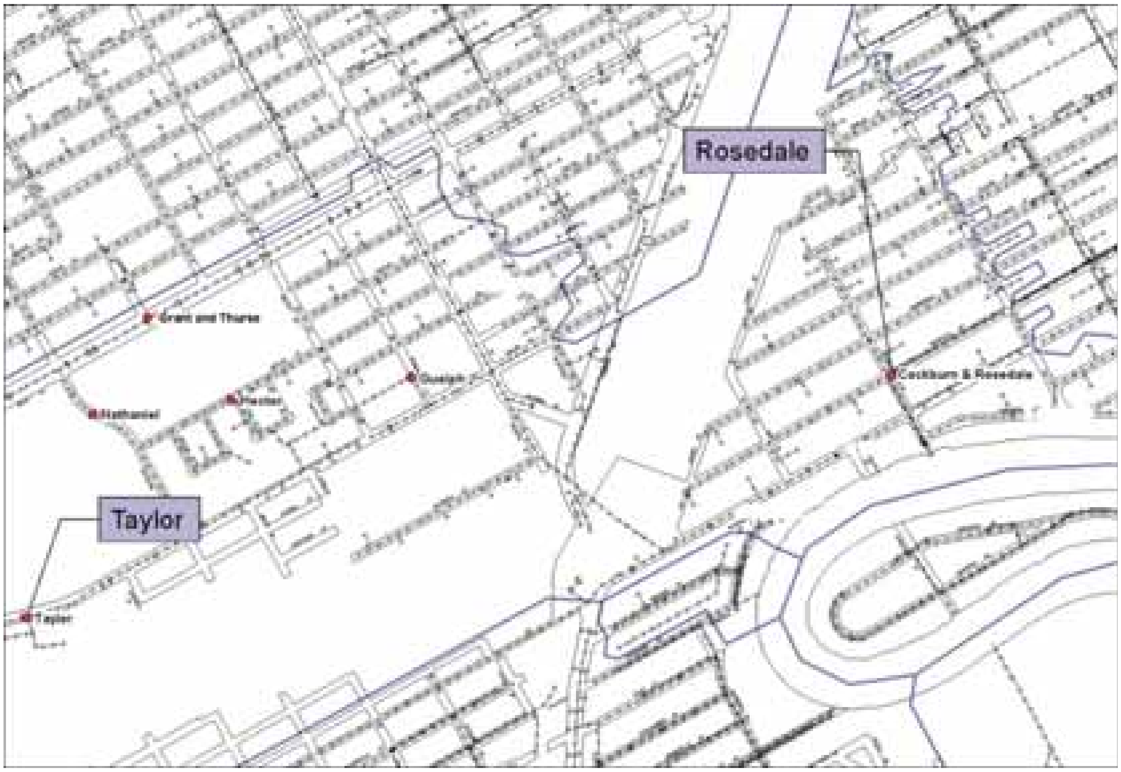


Figure 3-15 – 2006 Collection System Flow Monitoring Locations

The 2006 Taylor monitoring information is shown in Figure 3-16, along with the 2004 results. The levels are considerably less for 2006, but still higher than expected. Taylor is at the upper end of the collection system and would not be expected to have high flows. One of the potential explanations was the possible connection of the Pan Am Pool to Taylor instead of to the Ash Sewer District as indicated on the record drawings. This possibility was eliminated through consultation with pool maintenance staff and by physical inspection by the City of Winnipeg. Dye testing was used to confirm the pool was connected to the Ash Sewer District and not the Cockburn Sewer District.

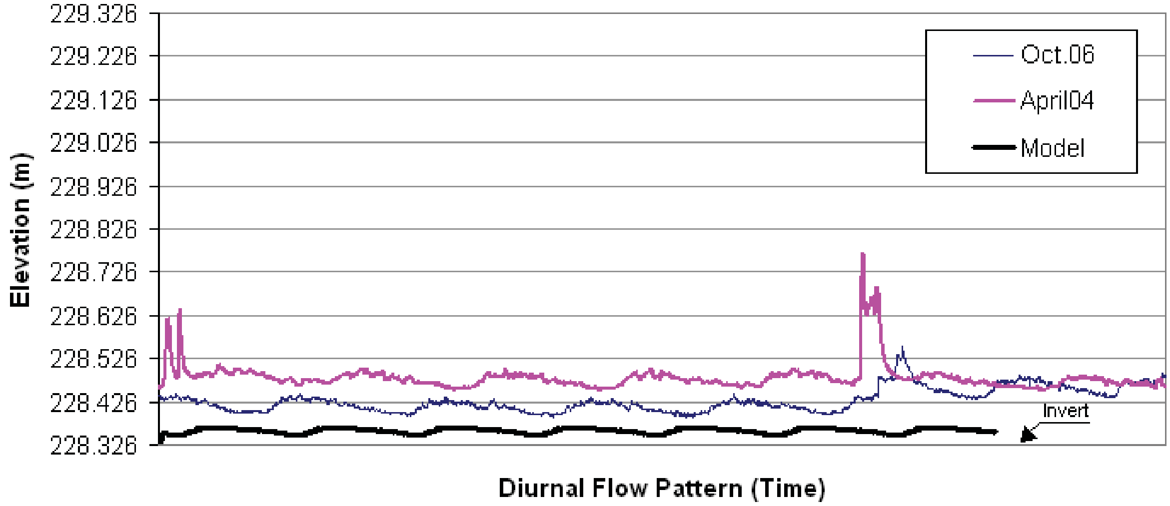


Figure 3-16: Taylor DWF – 2006 Monitoring Results

The Rosedale location, which indicated levels high enough to cause potential dry weather overflows in 2004, showed much lower depths in 2006, as shown in Figure 3-17. This change could be attributed to two factors; the groundwater cooling wells would not have been contributing flow in 2006 whereas they may have been in 2004, and the Cockburn Lift Station pumps were increased in capacity between 2004 and 2006, and would handle higher flows.

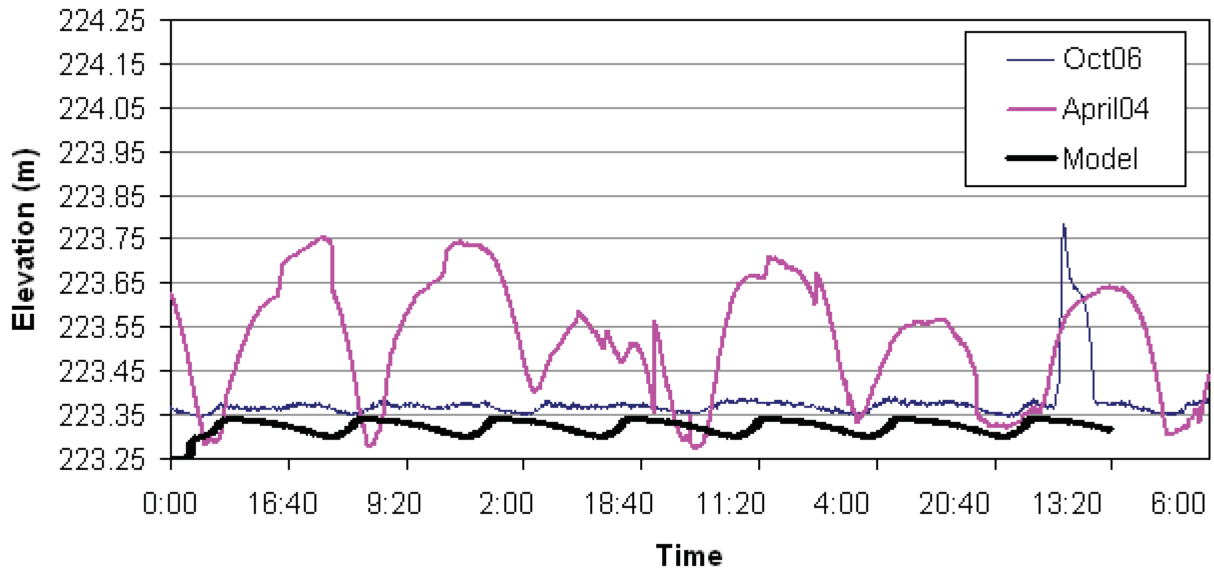


Figure 3-17: Rosedale 2006 Monitoring Results

One other potential inflow source was considered. The Cockburn weir elevation is lower than the normal summer river level, resulting in the possibility of flap gate leakage finding its way into the lift station, in reverse direction over the weir. The City has installed an area-velocity metre on the downstream side of the weir to detect such water movement. The records were reviewed for a period of time in August of 2006 and compared to simultaneous river levels to look for backflows. At the time, there was no discernable reverse flow. However, the river level was considerably higher than the weir level, which would create a positive seating pressure on the flap gate. The system was not checked for back flow under normal river levels when the seating pressure would be less.

3.3.1 2006 – Model Calibration Summary

The additional 2006 monitoring provided an indication of a significant summer increase in dry weather flow infiltration, which was not identified from the 2004 monitoring data. The presence of this additional groundwater will not have a meaningful impact on relief piping design, but would affect dry weather flow projections, wet weather overflow estimates, and sizing of wastewater separation alternatives. Its impact has been included in sewer separation alternatives as discussed in Section 8.0.

The higher than predicted flow pattern observed near the downstream (Rosedale) end of the system was not evident in the 2006 monitoring results, and it is probable that it was caused by the groundwater cooling wells which have since been removed. The cause of higher than predicted sewer levels on Taylor Avenue was not determined.

It is evident that a great deal of additional information has been identified through summer dry weather flow monitoring at the Cockburn Station. Continuous flow monitoring at the lift station should be considered for ongoing system evaluation.

4.0 WET WEATHER FLOW MODEL CALIBRATION AND VERIFICATION

4.1 GENERAL

The sewer flow was divided into 2 separate components, dry weather flow and wet weather flow. Dry weather flow is directly related to water consumption rates and is the base component of sewer flow. For this reason, flow rates are generally higher during the day and lower during the evening. Wet weather flow is described as the flow into the sewer from runoff or infiltration as a result of a rainfall event. Wet weather flow also includes flow into the sewer system as a result of snowmelt.

The XP-SWMM model for the Cockburn and Calrossie District was calibrated for both dry and wet weather flow conditions. Section 3.0 describes the calibration of the dry weather flow model. Once the calibration of the dry weather flow model was completed, various rainfall events were simulated to calibrate and verify the model for wet weather flow conditions.

4.2 RECORDED SEWER AND RAINFALL DATA USED FOR MODEL CALIBRATION

As referenced in Section 3.2.4, in 2004, the City implemented a sewer monitoring program in the Cockburn Combined Sewer District between April and November. The data gathered as part of this monitoring program was used for this study to calibrate the wet weather model.

Depth recordings from these monitors were used for the model calibration and verification process. The data was initially examined to ensure that no anomalies were found. Discrepancies identified during the review such as sudden significant increases in the depth were removed from the data set, as sudden erroneous fluctuations in the flow depth are common with sewer depth monitors.

In addition, consideration was given to the backwater from the Red River at downstream monitor locations since high river levels were experienced in 2004. The recorded water level at the James Avenue Pumping Station was used in conjunction with recorded Red River flows through the City of Winnipeg to estimate the water level at the outfall of the Cockburn Combined Sewer District. The downstream water level ranged from 223.9 m (734.58 ft) to 223.8 m (734.25 ft) for the calibration and verification events at the Cockburn outfall.

The rainfall records for the summer of 2004 included several rainfall events that would be suitable for calibration. The locations of the rainfall gauges at Harrow School and Lord Roberts School are shown in Figure 4-1, which are identified by yellow symbols on the Figure. Table 4-1 lists the storms and rainfall depths used for the calibration and verification of the XP-SWMM model.

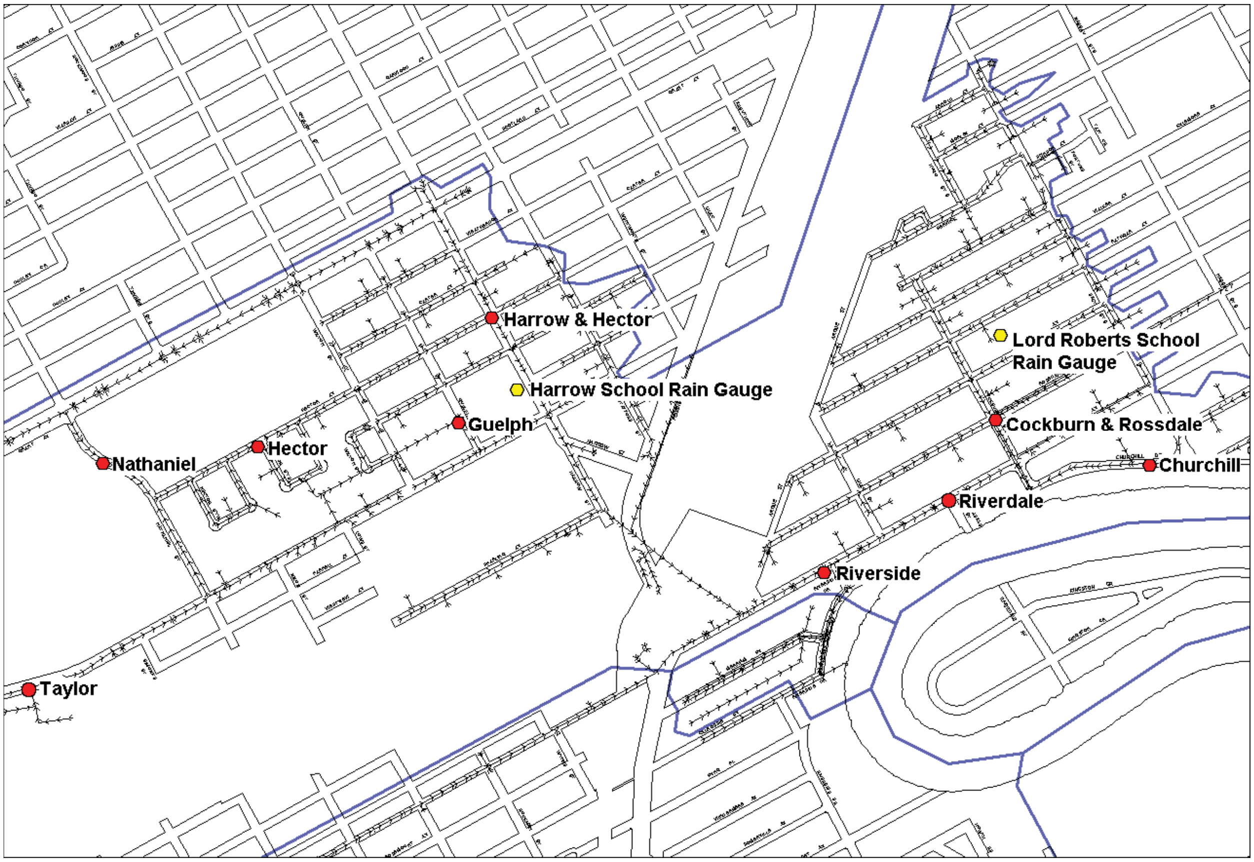


Figure 4-1: 2004 Rainfall Gauge Locations in Cockburn Combined Sewer District

Table 4-1: Recorded Rainfall Data (Summer 2004)

Rainfall Event	Total Rainfall (mm)	
	Harrow School	Lord Roberts School
July 8th to 11th	19.6	11.8
July 31st	15.2	13.2
September 20th	10.4	12.2

Recorded water levels for July 8th to July 11th from the City's 2004 sewer monitoring program were used as a basis for comparison for calibration of the XP-SWMM model. This storm was used for calibration since it was the largest recorded event during the monitoring period. The July 8th to July 11th storm is approximately equivalent to a 1.1-year summer rainfall for the City of Winnipeg based on the rainfall recorded at the Harrow School gauge. The second and third largest rainfall events during the monitoring period, July 31st and September 20th, were used for the verification of the model.

4.3 MODEL CALIBRATION PARAMETERS

The XP-SWMM model represents the response of a sewer system to a rainfall event using a combination of the hydrologic response of the basin and the hydraulics of the sewer system. Modeled depths and flows depend on the accurate representation of both the hydrologic and hydraulic systems. The hydrologic system simulates the generation of runoff from the catchment in response to the rain event.

4.3.1 Hydrologic System

The model parameters that define the hydrologic system include:

- Rainfall depth and intensity
- Basin area
- Percent imperviousness of the catchment
- Width of catchment
- Soil infiltration parameters
- Depression storage
- Surface roughness
- Slope of flow path of the catchment

Rainfall depth and the basin area are physical parameters that are recorded and measured using drainage boundary maps. The remaining six hydrologic parameters are variable. Based on previous runoff model research, the model parameters are ranked in the order of decreasing influence. Similar model parameters were used throughout the study area and are described in more detail in the following sections. Table 4-2 shows a summary of the initial and final calibration parameters for both Cockburn West (Grant/Taylor) as well as Cockburn East (Cockburn/Lord Roberts).

Table 4-2: Summary of Initial and Final Calibration Parameters

CALIBRATION PARAMETER	**Cockburn West (Grant/Taylor)**		**Cockburn East (Cockburn/Lord Roberts)**	
	Initial	**Final**	**Initial**	**Final**
Percent Imperviousness (%)	-	30.4 to 45	-	33.4 to 49.9
Soil Infiltration				
- Maximum Infiltration (mm/hr)	75	125	75	85
- Minimum Infiltration (mm/hr)	12.5	5	12.5	3
- Decay Rate (sec^{-1})	0.00115	0.00115	0.00115	0.00115
Depression Storage (mm)				
- Pervious	5	5	5	5
- Impervious	2	1.5	2	1
Surface Roughness (Manning n-value)				
- Pervious	0.015	0.015	0.015	0.015
- Impervious	0.025	0.030	0.025	0.030
Catchment Slope (%)				
- Normal Catchments	-	1.0	-	1.0
- Flat Roofs	-	0.2	-	0.2

Rainfall Depth

Rainfall depths in the hydrologic model are generally assumed to be uniform over the sewer district. While rainfall is measured at rain gauges within the district, variations in the depth can occur with distance from the gauge location, depending on the type of rainstorm and the size of the basin.

The study area can be divided into two separate areas, the areas east and west of Pembina Highway. The City used two rain gauges during the summer of 2004 to collect rainfall depths in these areas, as referenced in Table 4-1. The gauge at Harrow School is located in the Grant/Taylor area west of Pembina Highway while the Lord Roberts gauge is located east of

Pembina Highway, near Cockburn Street. Since noticeable differences were observed in the rainfall depths recorded at each gauge, the rainfall depths at both gauges were used to define the rainfall for the respective areas. Notwithstanding the use of the two gauges, it is recognized that the rainfall depth input is not absolute for a given area.

Basin Area

The basin area is a physical parameter measured based on the drainage basin boundaries. There is, however, some uncertainty in the drainage area boundaries. Sewer inlets located along street systems typically define urban drainage boundaries. Individual lot grading, however, is not precisely known. Back lane drainage generally occurs from the back of the house toward the back lane. Downspouts at the back of the house are also directed toward the back lane. Drainage area delineation therefore assumed the centre of the house as the boundary of the front to back drainage. Assumed drainage areas were not adjusted in the calibration process.

Percent Impervious

The percent imperviousness of a catchment is a primary model parameter that has an approximate linear relationship with the computed peak runoff and volume. An accurate estimation of this parameter is therefore paramount in correctly modelling the runoff process. This required an accurate discretization of the area to reflect the changes in impervious areas.

Digital ortho images were used to provide information on the percent imperviousness of each catchment. Paved streets, lanes, driveways, parking lots, sidewalks are surfaces were assumed to be impervious.

The percent imperviousness for each catchment was determined assuming percent imperviousness values ranging from 0% to 100% for house roofs. Downspout surveys showed that at least 50% of the downspouts were either directed directly onto paved surfaces or were in close proximity to these impervious surfaces to render them effectively impervious.

The impervious areas, estimated from the digital ortho images, were compared to the subcatchment areas for a total of 6 areas. Table 4-3 lists the areas considered and the corresponding percent imperviousness. The percent imperviousness for each subcatchment was defined by comparing land use and building densities to those for the test catchment areas listed in Table 4-3.

Table 4-3: Percent Imperviousness Estimates

Area	Location	Percent Imperviousness
Rosedale (Cockburn St to Daly St)	Cockburn/Lord Roberts	33.2
Back Lane (Rosedale Av and Beresford Av)	Cockburn/Lord Roberts	30.4
Arnold Av (Hugo St S to Daly St S)	Cockburn/Lord Roberts	45.0
Weatherdon Av – Ebby St	Grant/Taylor	33.4
Taylor Housing Complex	Grant/Taylor	41.9
Typical Street	Grant/Taylor	49.9

Width of Catchment

The area and overland flow width define the subcatchment surface. While the area of the subcatchment is physically defined from drainage area boundaries, the overland flow width is not necessarily the physical width of the subcatchment. The width is actually a measure of the potential for surface runoff. The subcatchment width is a calibration parameter that can be varied to some extent to assist with the model calibration. The subcatchment width can be defined as the length over which overland flow travels when draining to the inlet manhole or gutter. It is a function of the drainage density and the number of inlets. For symmetrical catchments, where the drainage area on each side of the street is equivalent, the width of the overland flow path was assumed as 2 times the length of the gutter or street that divides the area. For an asymmetrical catchment, however, the width was assumed to be equal to the length of the gutter or street. Since the majority of the catchments were irregular in shape, the width could not be defined as a physical parameter. Therefore, an approximate value was assumed and adjusted as part of the calibration process.

Soil Infiltration Parameters

The Horton Infiltration method was used in the XP-SWMM runoff model. Originally, the infiltration parameters for the model were based on values from other City of Winnipeg sewer relief studies, including the Sewer Relief and CSO Abatement Study – Strathmillan and Moorgate Combined Sewer Districts (2005). Maximum and minimum infiltration rates and the decay rate of infiltration were assumed as 75 mm/hr, 12.5 mm/hr, and 0.00115/sec, respectively. However, it was found that there was a noticeable difference in the hydrologic response of the system in the Grant/Taylor and Cockburn/Lord Roberts areas. For this reason, the infiltration parameters were adjusted to reflect the differences observed in each area, as shown in Table 4-4 below:

Table 4-4: Infiltration Parameters

Infiltration Parameter	Area	
	Grant/Taylor	Cockburn/Lord Roberts
Maximum Infiltration Rate (mm/hr)	125	85
Minimum Infiltration Rate (mm/hr)	5	3
Decay Rate (1/sec)	0.00115	0.00115

The above infiltration parameters are considered to be a reasonable estimate of the soil conditions for the City of Winnipeg. As referenced in Table 3 (pg. 17) of the Strathmillan and Moorgate Combined Sewer Districts Sewer Relief and CSO Abatement Study (UMA Engineering Ltd., 2005), the maximum and minimum infiltration rates from previous studies ranged from 25 to 100 mm/hr and from 1 to 13 mm/hr.

Depression Storage

Initial depression storage values for the XP-SWMM model were also based on previous City of Winnipeg sewer relief studies. Depression storage was assumed to be 5.0 mm for pervious areas and 2.0 mm for impervious areas. Similar to the infiltration parameters, the depression storage was adjusted to reflect the difference in the soil conditions east (Cockburn/Lord Roberts) and west of Pembina Highway (Grant/Taylor). The final depression storage values determined as part of the calibration process for the Grant/Taylor area were 5.0 mm (pervious) and 1.5 mm (impervious). In the Cockburn/Lord Roberts region, depression storage values of 5.0 mm (pervious) and 1.0 mm (impervious) were assumed. Depression storage for large flat roofs was assumed as 5 mm. This is approximately 5 times the value used for impervious catchment areas in the model.

The pervious and impervious depression storage used as XP-SWMM input parameters for past City of Winnipeg Relief Studies (UMA Engineering Ltd., 2005) ranged from 5 to 25 mm and from 1 to 13 mm, respectively. This reference also indicates that the median was used to estimate pervious and impervious depression storage values of 5 mm and 2 mm, which are consistent with the depression storage inputs used as part of the Cockburn and Calrossie / Jessie XP-SWMM model.

Surface Roughness

Surface roughness (Manning n-value) affects both the volume and peak flow. Lower Manning n-values result in more rapid runoff response from the subcatchment and hence less surface storage. Initial values were chosen based on previous City of Winnipeg Relief Studies (0.015 pervious and 0.025 impervious). Final n-values used for the calibrated XP-SWMM model were 0.015 (pervious) and 0.030 (impervious).

Catchment Slope

Steeper ground slopes result in quicker runoff response, higher peak flows and greater runoff volume. Catchment slopes were assumed as 1.0% for normal catchments and 0.2% for flat roofs. On average, a slope of 1.0% was used for normal catchments in previous City of Winnipeg Relief Studies (UMA Engineering, 2005).

4.3.2 Hydraulic System

The hydraulic system response includes the determination of sewer flow and depth in response to the surface runoff determined in the hydrologic system. Hydraulic model parameters include the physical pipe dimensions (e.g. diameter, length, slope, pipe invert elevations). Other hydraulic parameters are the Manning's n value of the pipe, expansion and contraction losses, and losses caused by the overflow weir. The Cockburn Lift Station as well as interconnections to the Cockburn Combined Sewer District were also included as part of the XP-SWMM model.

Sewer Data

Sewer dimensions were based on data retrieved from the City of Winnipeg LBIS database and were not altered as part of the model calibration. However, the as-built drawings were obtained from the City of Winnipeg for specific locations in the study area for the final sizing of the relief alternatives to confirm the sewer and manhole data from the City's LBIS database. Manning's pipe roughness coefficients were assumed as 0.015 for concrete sewers and 0.024 for corrugated steel conduits.

Outfall Rating Curve

A rating curve was computed for the outfall downstream of the Cockburn Lift Station to effectively model the entrance loss, friction loss, and gate losses (flap and positive gates) associated with the outfall for a number of discharge conditions. This is a common approach (equivalent pipe length) used in XP-SWMM modelling since it is difficult for the software to accurately simulate the complex conditions associated with the outfall. The actual outfall length of 26.7 m was replaced by the equivalent pipe length of 35 m in the XP-SWMM model to account for the losses at the outfall.

Cockburn Lift Station Diversion Weir

The elevation of the lift station diversion weir was assumed as 223.58 m, which is 0.51 m above the sewer invert level. The lift station diversion weir structure was initially modeled as a “weir” in the XP-SWMM program with the weir crest elevation and length input as part of the XP-SWMM model. However, resulting model depths were higher than experience would show for this high level of submergence. As shown in Figure 4-2, modeled losses over 1.0 m occurred under high backwater and surcharged full pipe flow conditions. The backwater effect from the 0.51 m high weir in the 2.7 m diameter pipe would be expected to be very small under these operating conditions based on sample hydraulic calculations.

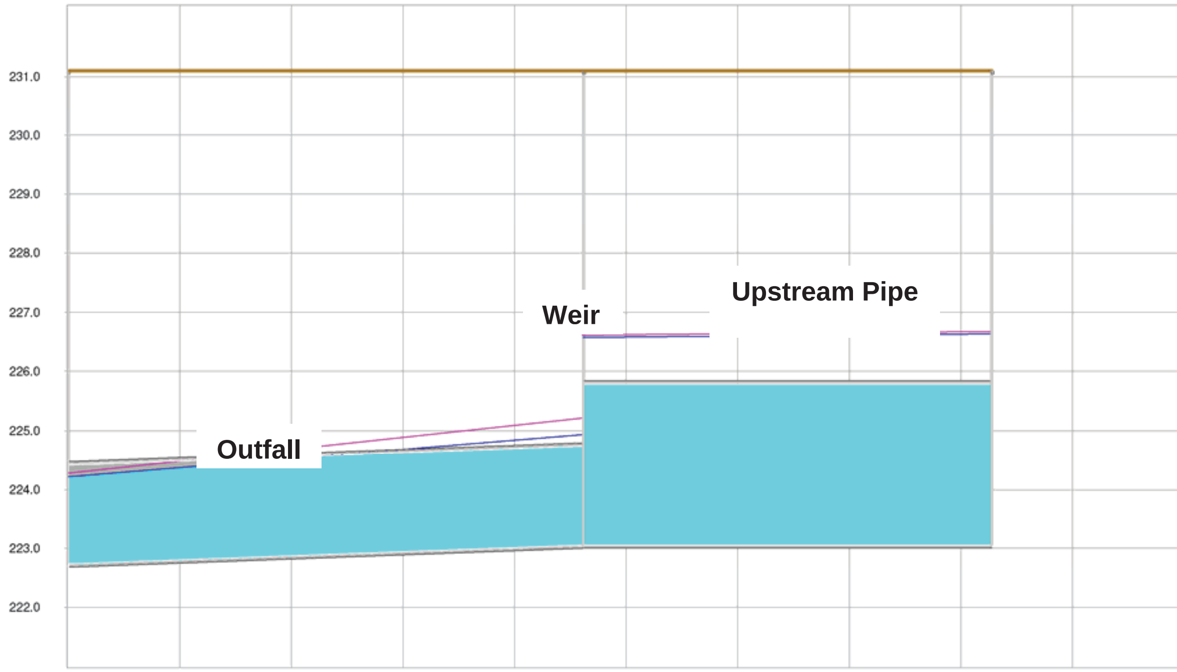


Figure 4-2: Use of XP-SWMM Weir Function

The weir function in XP-SWMM is based on the broad crested weir formula in which the upstream water level is a function of an assumed discharge coefficient and the weir crest length. Because the cross section of the egg shaped sewer at the diversion weir is highly irregular and varies with depth, the fixed length input in XP-SWMM can therefore not accurately account for varying cross section dimensions.

To compensate for the model limitations, the diversion structure was not modeled as a weir but as a conduit with the bottom of the conduit raised to simulate the height of the diversion obstruction. This assumption permits the actual sewer cross-section to be maintained from the diversion structure elevation to the elevation of the crown of the sewer conduit. The model solves for upstream water levels by normal backwater calculation. Under low downstream water levels, critical depth is assumed, based on the actual dimensions of the sewer above the obstruction. Under highly submerged downstream conditions, the upstream water level is determined in the model with consideration of expansion and contraction losses in which the actual cross section dimensions are used to determine flow areas and velocities.

Figure 4-3 shows the hydraulic losses at the diversion structure when it is defined as the actual conduit, with an appropriate allowance for the diversion structure.

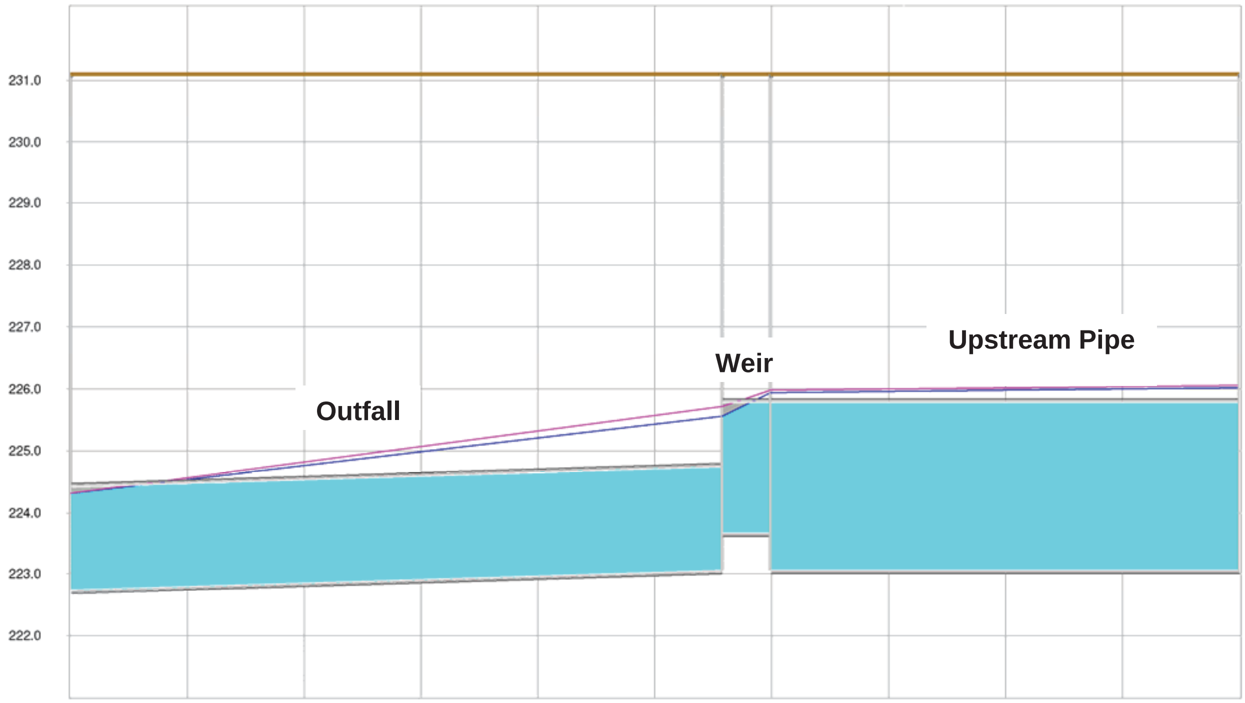


Figure 4-3: Weir Defined as Conduit with Blocked Obstruction

Cockburn Lift Station Pumping Rate

The pumping rate at the Cockburn Lift Station was also input as part of XP-SWMM model. The installed pumping capacity was upgraded during the study, as a result of the City changing pump impellors, as described in Section 11.2.1. For the calibration period, the peak pumping rate was 0.08 m^3/s, and it was subsequently upgraded to its current value of 0.105 m^3/s. However, the lift station pump capacity was reduced during the model calibration based on the measured water level drawdown following the end of the rainfall period. Drawdown of the water level in the sewer upstream from the lift station diversion weir was shown to be much more rapid in the model than that observed, if the actual pump capacity was used in the model. Since river levels at the outfall exceeded the crest elevation of the diversion weir during the observation period, river water would flow into the sewer if the flap gates were not completely seated. Due to the very low seating head (less than 0.3 m), gate leakage was therefore very likely during this monitoring period. Inflow from the river would therefore effectively reduce the flow that was evacuated by the lift station pump. An effective pump rate of 0.02 m^3/s was determined for the calibrated model by trial and error in order to replicate the measured drawdown in the sewer during the post-rainfall period.

Interconnections

A total of 6 interconnections to the Cockburn Combined Sewer District have been identified during the review of the LBIS data for input into the XP-SWMM model. These interconnections are with the Calrossie, Baltimore, and Jessie Sewer Districts and are:

- Cockburn and Calrossie Interconnection on Riverside Drive
- Cockburn-Jessie Interconnection along Ebby Avenue
- Cockburn-Jessie Interconnection along Jackson Avenue
- Cockburn-Baltimore Interconnection along McNaughton Avenue
- Cockburn-Baltimore Interconnection along Montague Avenue
- Cockburn-Baltimore Interconnection along Churchill Drive

Figure 4-4 shows the location of the interconnections with the Cockburn Combined Sewer District, which are identified by red symbols.

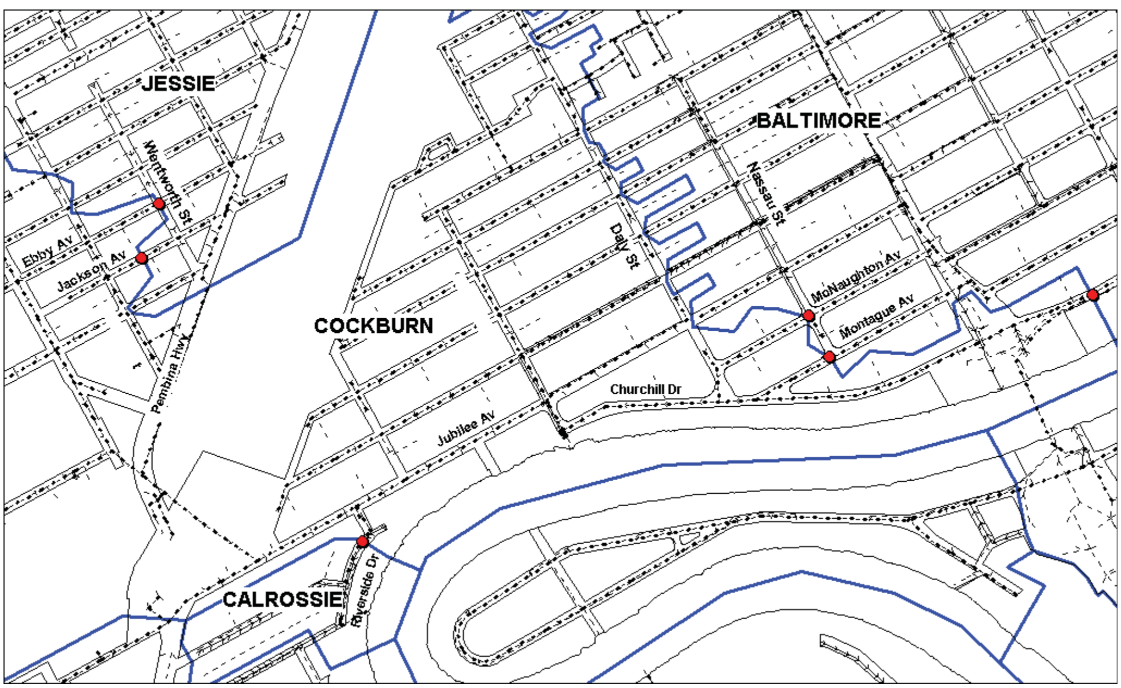


Figure 4-4: Interconnections with Cockburn District

Figure 4-5: Plan View of Cockburn and Calrossie Interconnection

The Calrossie interconnection is a WWS/CS to LDS cross-connection/overflow located east of the intersection of Calrossie Boulevard and Riverside Drive. This cross-connection/overflow relieves both the Cockburn FPS and the Riverside/Calrossie/Merriam WWS into the new 600 mm outfall (rerouted). A flap gate at the overflow protects the WWS system, while a positive gate upstream controls the flow. The Calrossie cross-connection/overflow has been incorporated as part of the model, and is shown in plan in Figure 4-5.

Figure 4-6 shows a portion of the City of Winnipeg As-Built Drawing LD-2473, which was prepared by KGS Group in 2001 as part of the Calrossie outfall repairs. This figure shows manhole interconnection details on Riverside Drive, including the locations of the positive and flap gates.

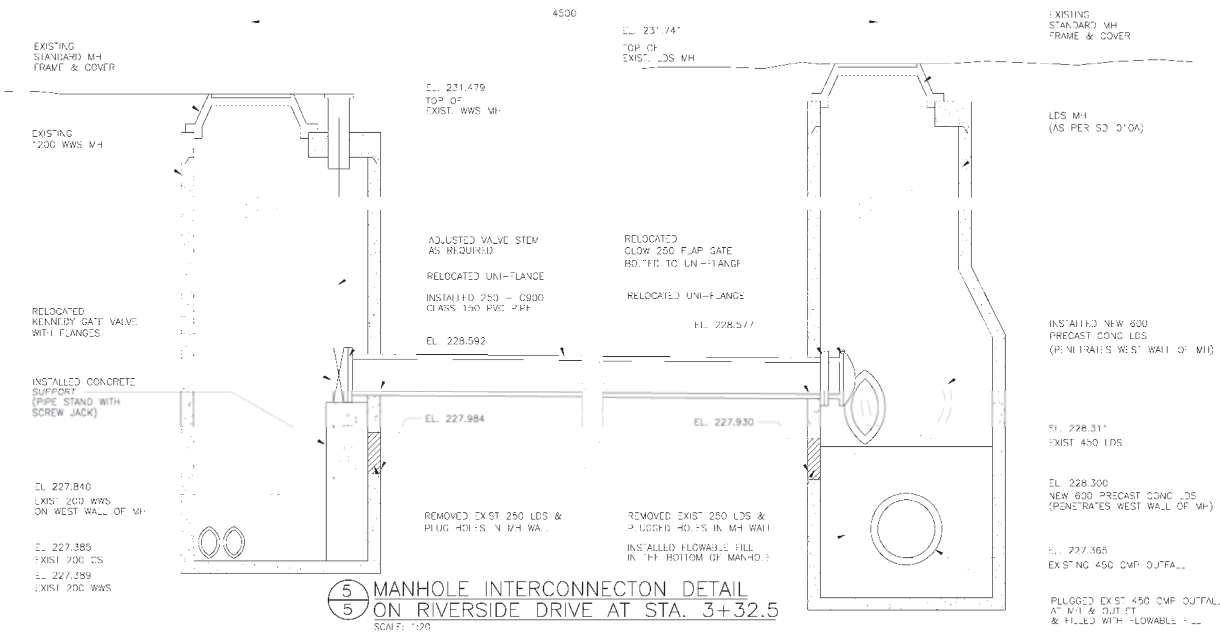


Figure 4-6: Cockburn and Calrossie Interconnection Details

The profiles along the remaining 5 interconnections are shown in Figures 4-7 to 4-11 for the July 10th, 2004 calibration storm. The peak calibration level has been shown in blue on each figure to show the potential overflow from one system to another.

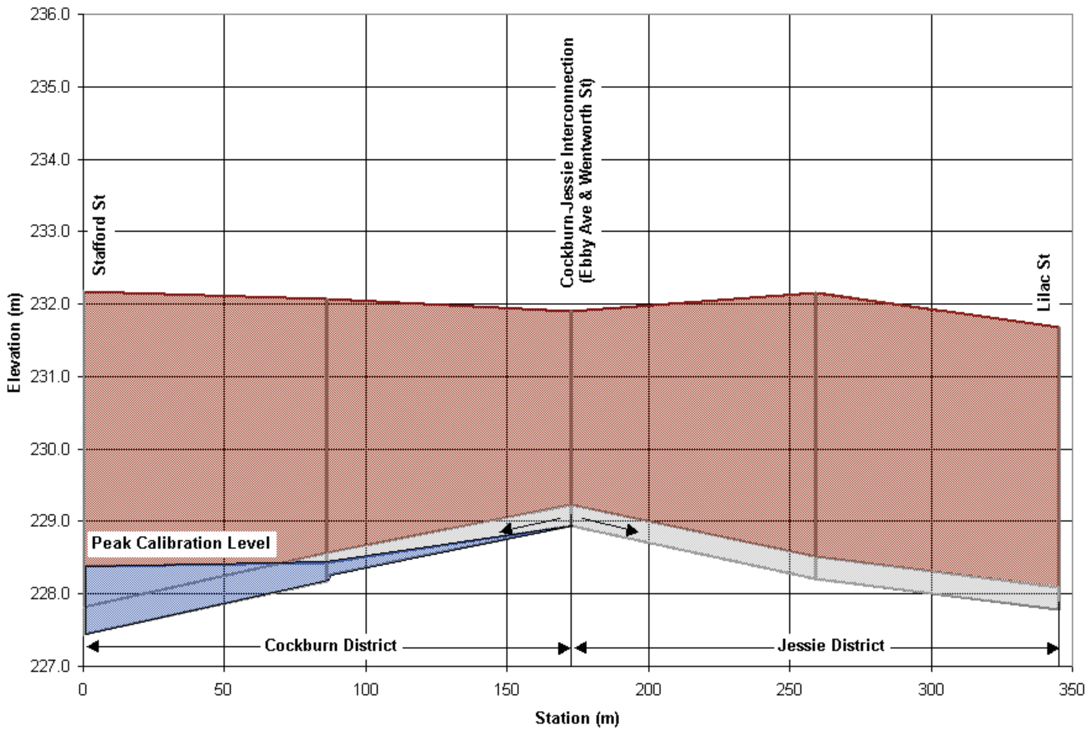


Figure 4-7: Profile of Cockburn-Jessie Interconnection along Ebby Avenue

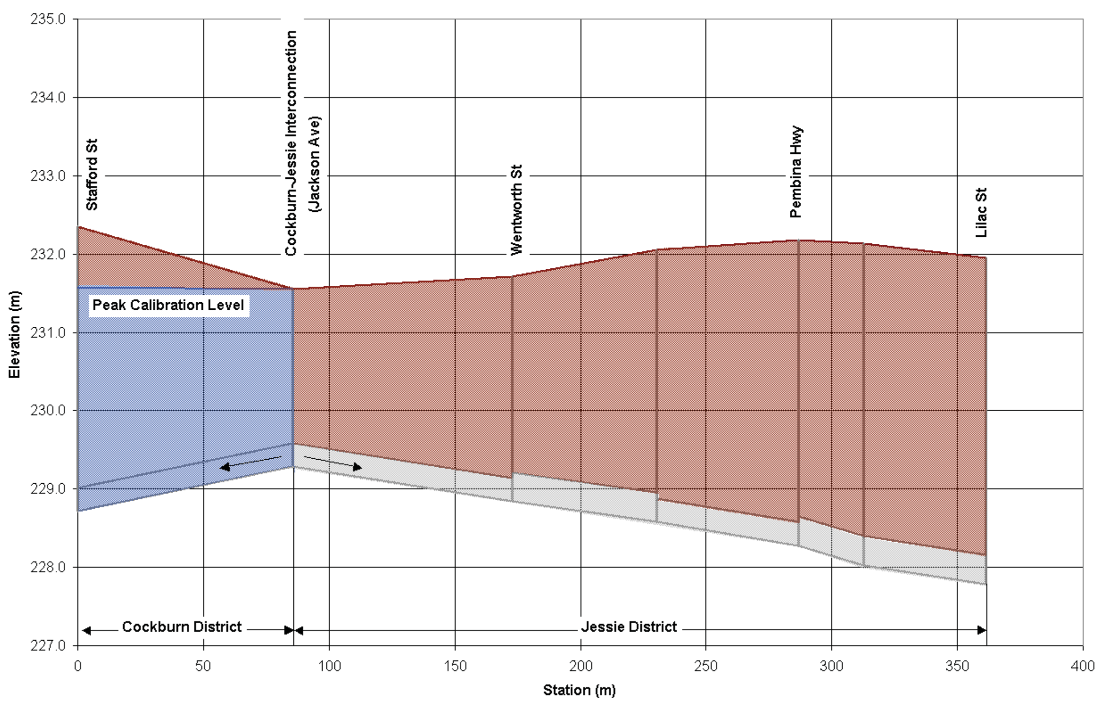


Figure 4-8: Profile of Cockburn-Jessie Interconnection along Jackson Avenue

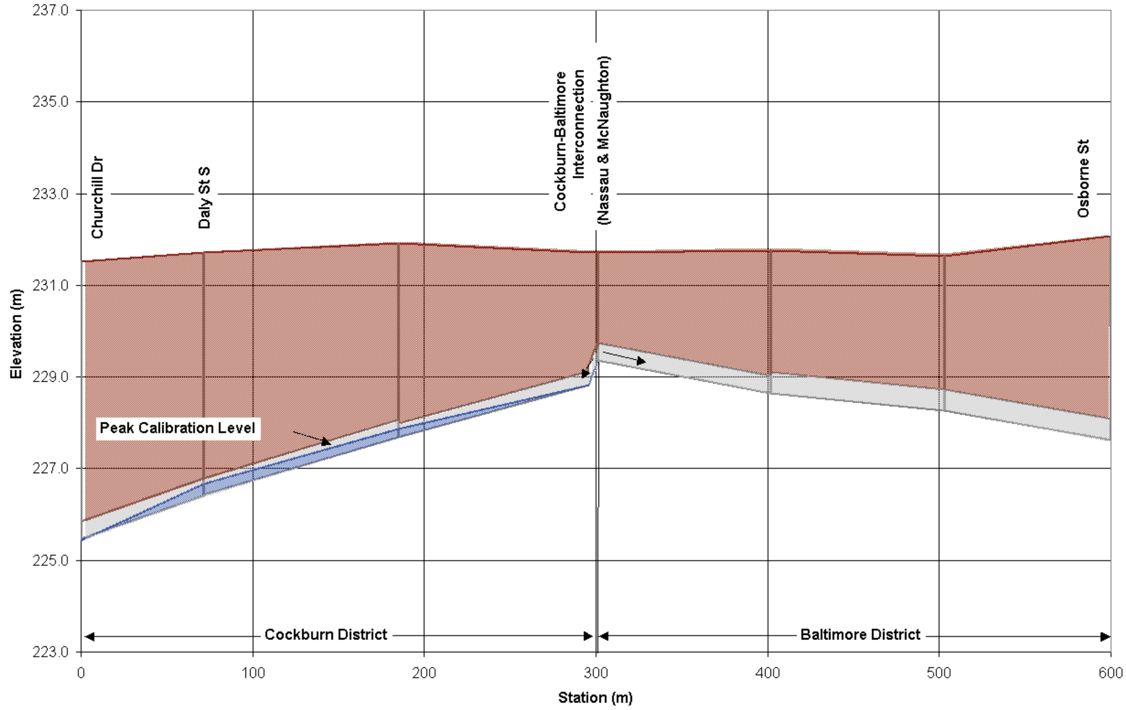


Figure 4-9: Profile of Cockburn-Baltimore Interconnection along McNaughton Avenue

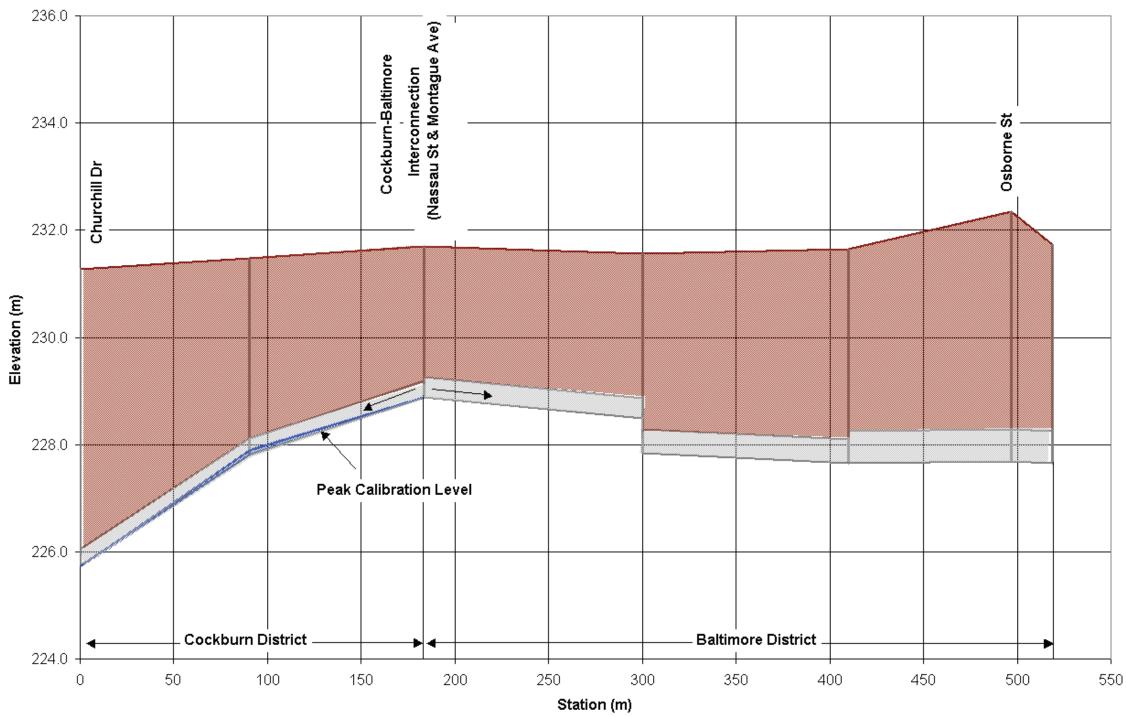


Figure 4-10: Profile of Cockburn-Baltimore Interconnection along Montague Avenue

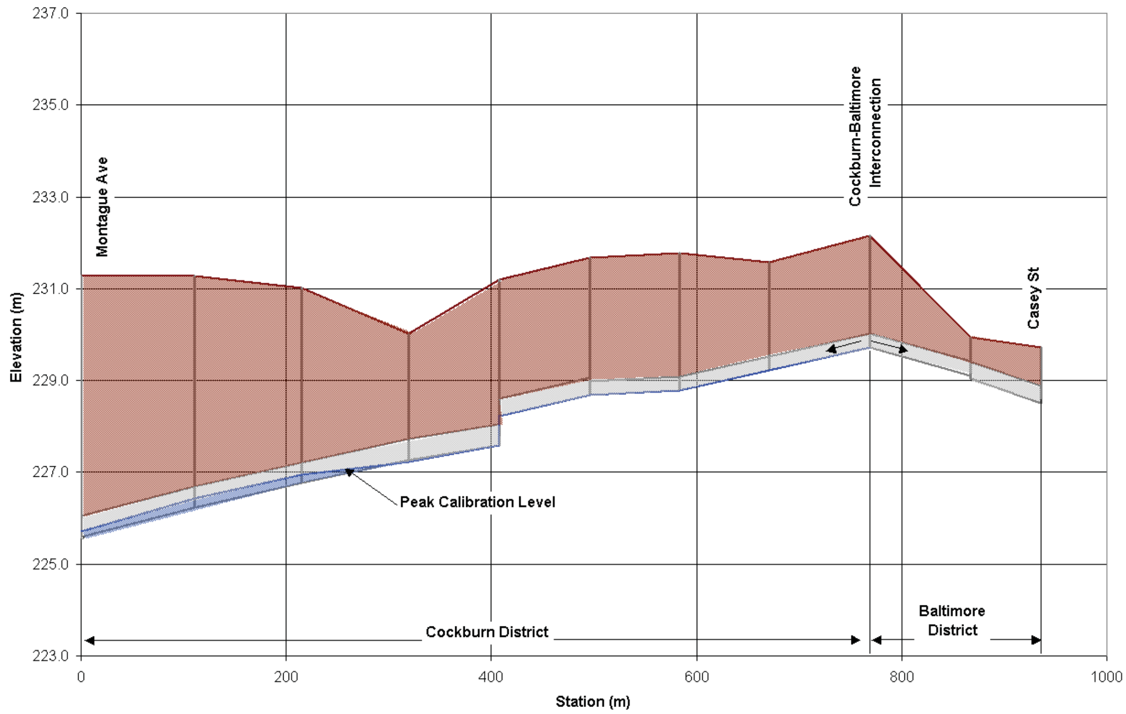


Figure 4-11: Profile of Cockburn-Baltimore Interconnection along Churchill Drive

With the exception of the interconnection shown in Figure 4-8 (Profile of Cockburn-Jessie Interconnection along Jackson Avenue), overflow from one system to the other will not occur unless flows in either system are significant due to the steep pipe gradient. The high surcharge level at the interconnection from the Cockburn District required further analysis to determine what effect outflow to the Jessie District would have on Cockburn peak water levels. The Jackson interconnection was assumed to be a free outfall from the Cockburn sewer system, which is a conservative assumption since the outflow reaches a maximum for free outfall conditions and would decrease with high surcharge levels in the Jessie system. The model results showed that there would be a negligible effect to the local hydraulic grade line if this interconnection were modeled as a free outfall with flow into the Jessie Combined Sewer District. It was concluded that the interconnections would not have to be modeled for storm events used for calibration and verification.

The effect of the interconnections was, however, considered, particularly for any separation alternatives. The interconnections were reviewed for the relief schemes and the existing level of service evaluation to confirm whether inflow hydrographs should be added at these locations to simulate the conditions of the overflow. This methodology is consistent to past studies

(Independent Review of the Colony Combined Sewer District Storm Relief, 1998). It is also clear that normal dry weather flow from the Calrossie, Baltimore, and Jessie Sewer Districts will not flow into the Cockburn Sewer District via the interconnections.

Street Storage

Street storage and inlet capacities were not considered as part of the XP-SWMM model. The effect of inadequate inlet capacity and street storage becomes significant only for storm events of a higher magnitude, usually greater than a 10-year event, and when significant street flooding occurs due to inadequate sewer capacity. The effect of minor street storage was accounted for in other model parameters including impervious depression storage and the Manning's n value. The City of Winnipeg has also advised that inlet restrictors should not be considered for this study. This is primarily because the inlet efficiency relationship currently under study by the City of Winnipeg has not been resolved. Without the use of inlet restrictions, it is unlikely that sufficient street storage would be available. Therefore, street storage was not considered in the XP-SWMM model.

4.4 CALIBRATION MODEL RESULTS

Water levels computed using observed rainfall depths, were compared to observed depths of flow at selected locations in the Cockburn Combined Sewer District. Rainfall depths were recorded at two locations; at Harrow School centered in the Grant Park area, and at Lord Roberts School in the Cockburn Street area. The two areas are separated by the CNR tracks. Water level depths were observed at nine sewer monitoring stations including Hector, Nathaniel, Harrow and Hector, Guelph, and Taylor located in the Grant Park area and Riverside, Riverdale, Cockburn and Rosedale, and Churchill located in the Lord Roberts area.

Comparisons of the recorded and observed levels are shown graphically on Figures 4-12 to 4-19 together with the rainfall intensities at the respective locations.

It should be noted that the gauge at Churchill was not used for calibration since it is located at the upstream end of the sewer district in an area with both combined and land drainage sewers. Since the flow is relatively low at this location and it was difficult to determine the drainage to each inlet, the gauge at Churchill was not considered as part of the model calibration.

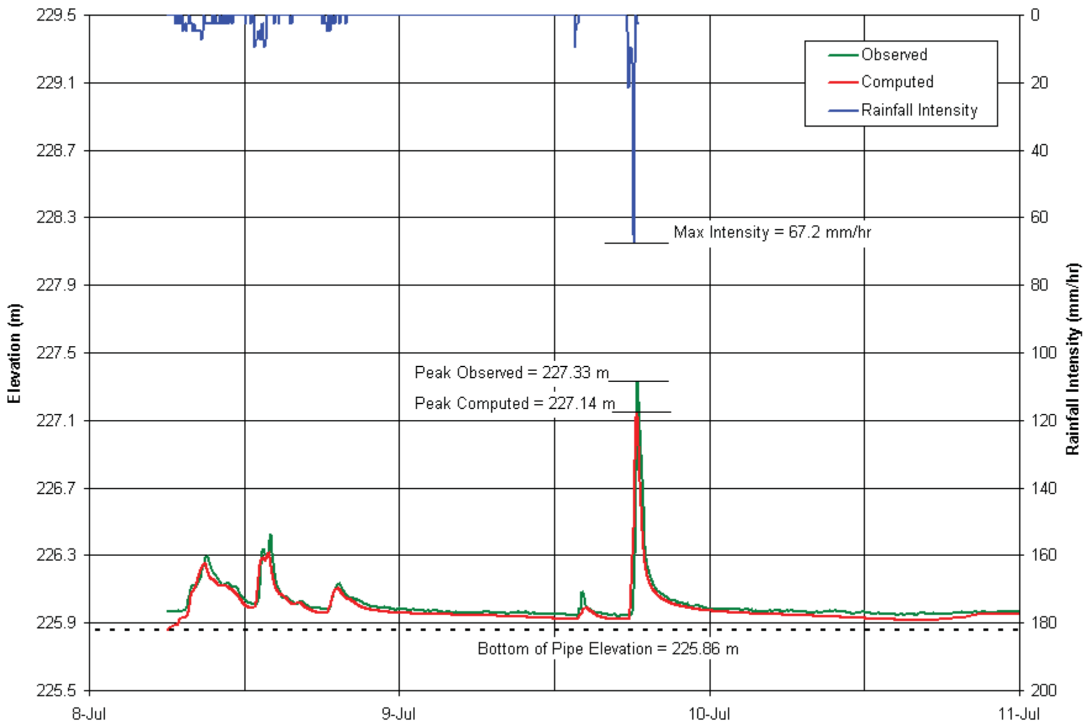


Figure 4-12: Comparison of Observed and Computed Levels at the Hector Gauge (Calibration Event)

As shown in Figure 4-12, the calibration of the XP-SWMM model was based primarily on a comparison of the peak levels during the storm and the time to peak. Although the conditions before and after the storm peak on July 10th, 2004 are comparable to the results of the XP-SWMM model, this is primarily related to the dry weather flow condition. More details on the dry weather flow model calibration are provided in Section 3.0.

The general shape of the hydrograph, including the rising and falling limb, is consistent for both the observed and computed data indicating that the model is well calibrated. Smaller rainfall events prior to the main rainfall on July 10th, 2004 are also well simulated in the XP-SWMM model. Similar results, as shown in the following figures, indicate that a good calibration has been achieved at both the upper and lower end of the sewer system.

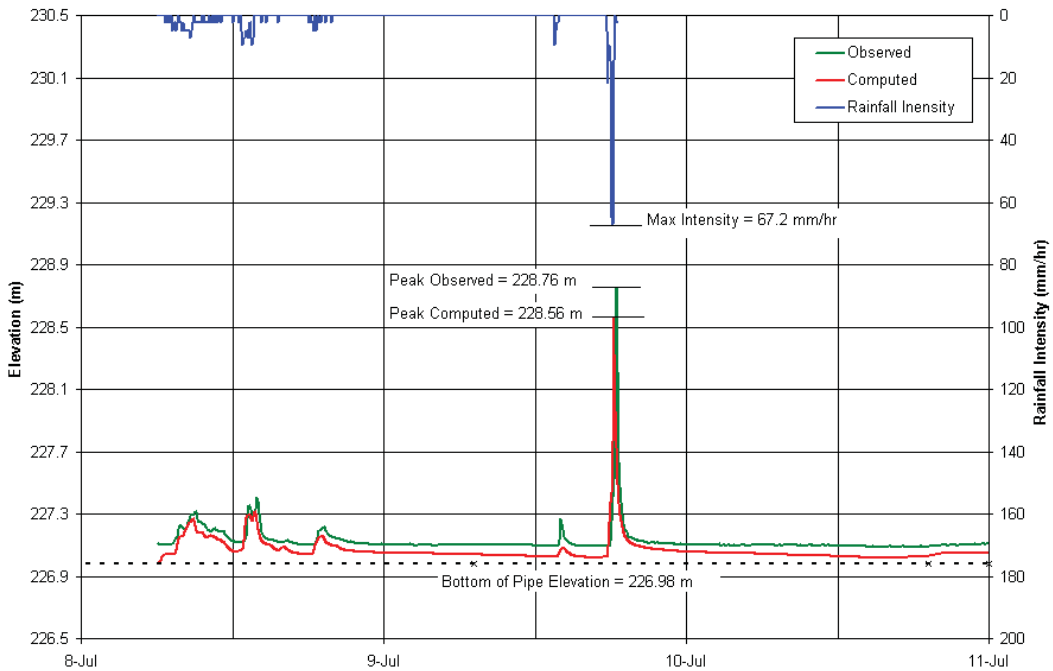


Figure 4-13: Comparison of Observed and Computed Levels at the Nathaniel Gauge (Calibration Event)

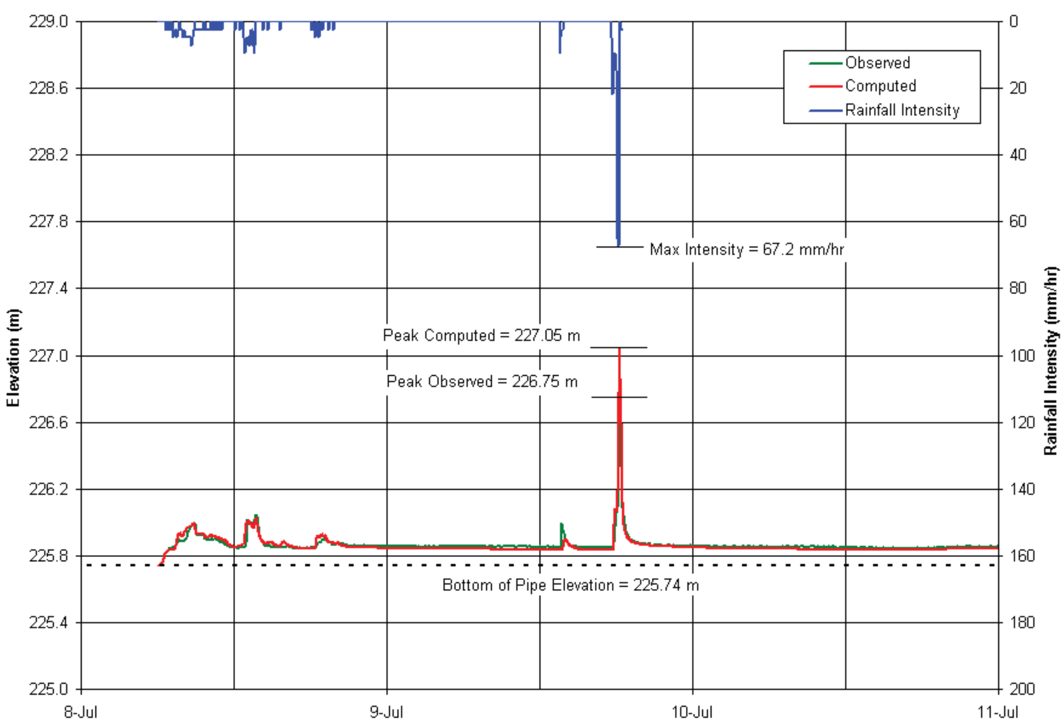


Figure 4-14: Comparison of Observed and Computed Levels at the Harrow & Hector Gauge (Calibration Event)

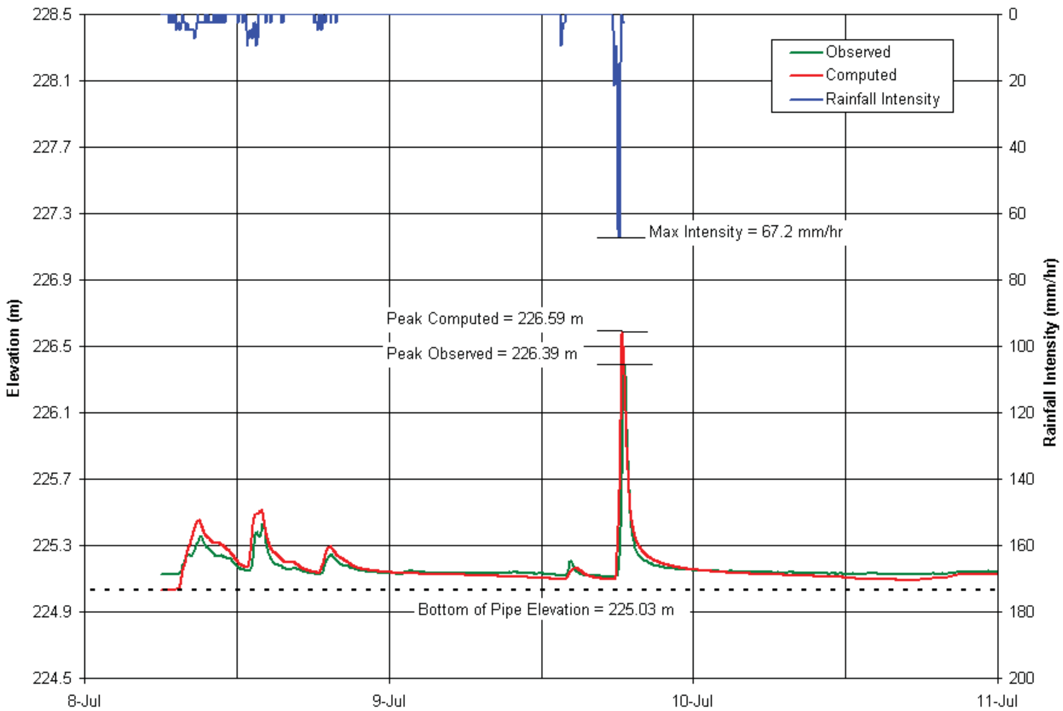


Figure 4-15: Comparison of Observed and Computed Levels at the Guelph Gauge (Calibration Event)

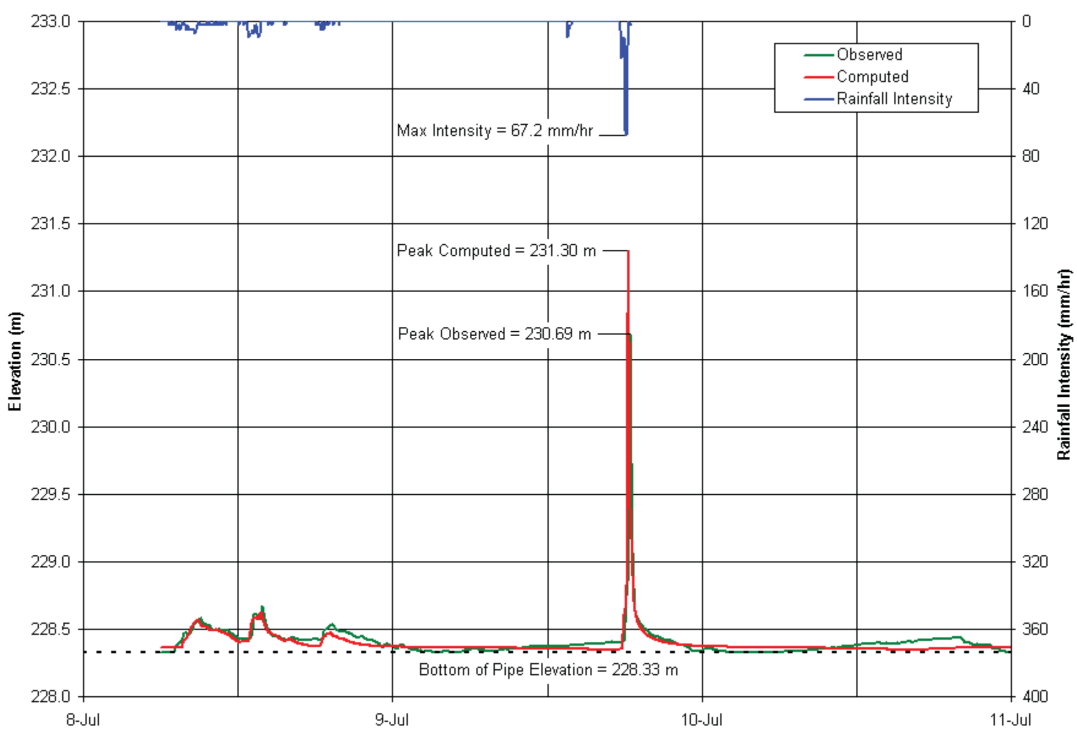


Figure 4-16: Comparison of Observed and Computed Levels at the Taylor Gauge (Calibration Event)

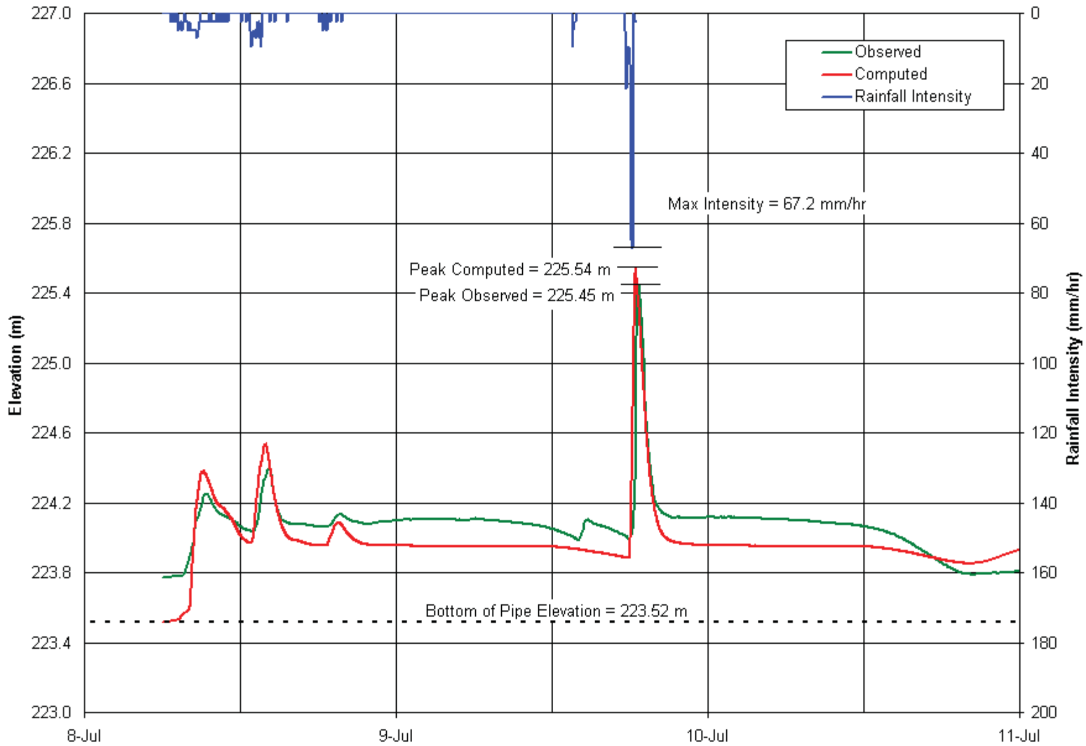


Figure 4-17: Comparison of Observed and Computed Levels at the Cockburn & Rosedale Gauge (Calibration Event)

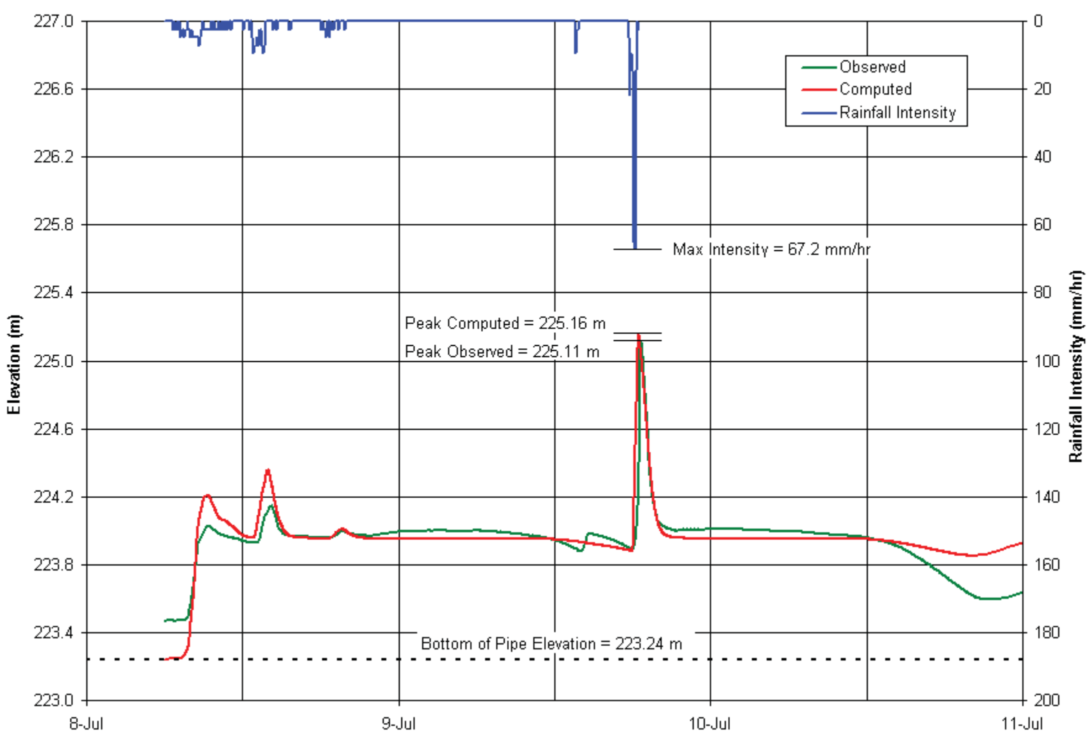


Figure 4-18: Comparison of Observed and Computed Levels at the Riverside Gauge (Calibration Event)

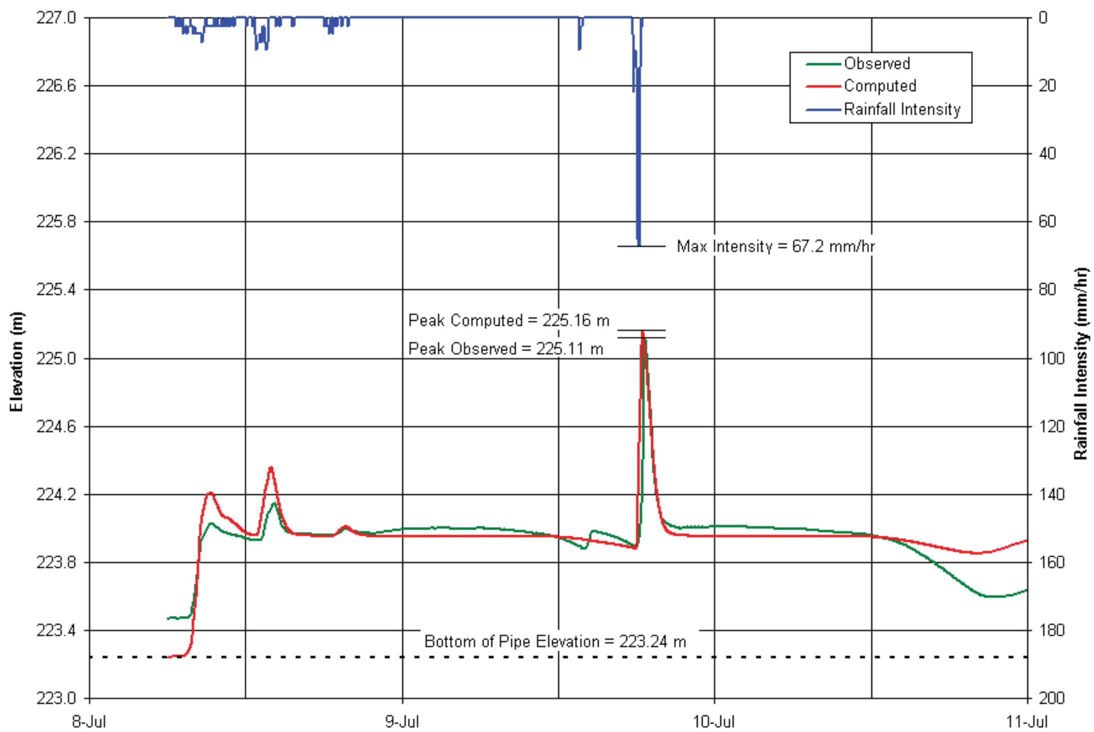


Figure 4-19: Comparison of Observed and Computed Levels at the Riverdale Gauge (Calibration Event)

In general, the figures presented indicate that a good model calibration has been achieved. Ideally, if recorded flow data at the sewer gauges was available, a volume comparison could also be made between the observed data and the results from the XP-SWMM model. However, because the differences between the hydrographs for the observed and computed levels are relatively small, the need for further model calibration is not warranted.

4.5 MODEL VERIFICATION

Following the model calibration, the model was verified using two different storm events:

- July 31st, 2004
- September 20th, 2004

The magnitude of these events is somewhat lower than the calibration event, which is equivalent to a 1-year summer event for the City of Winnipeg. These events were selected for the verification of the model since they occurred during the period of the City's 2004 sewer monitoring program and they were single rainfall events of a relatively higher magnitude. As shown previously in Table 4-1, rainfall events were selected for calibration and verification to ensure good model calibration for a range of events.

Similar to the calibration process, recorded water levels were compared to the results from the calibrated XP-SWMM model of the Cockburn and Calrossie Sewer Districts. Figures 4-20 to 4-27 show the comparison of the results for the July 31st rainfall event for the 8 gauges previously identified for the model calibration. Figures 4-28 to 4-35 provide a comparison of the results from the second verification event, September 20th, 2004.

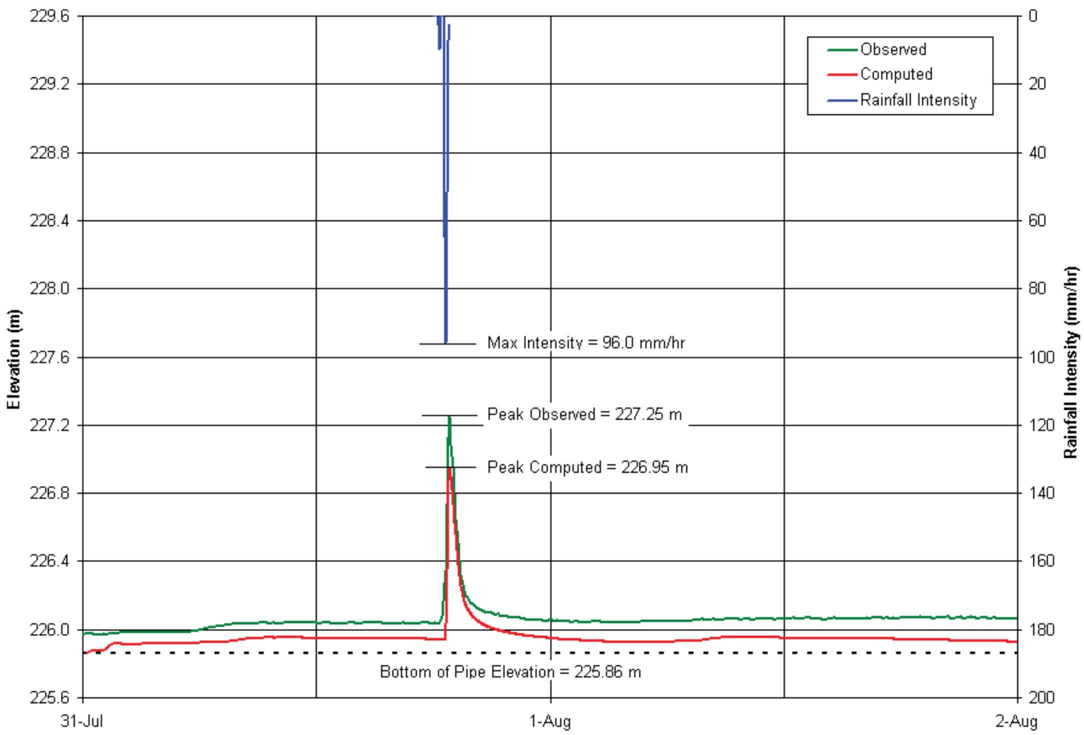


Figure 4-20: Comparison of Observed and Computed Levels at the Hector Gauge (Verification Event – July 31st, 2004)

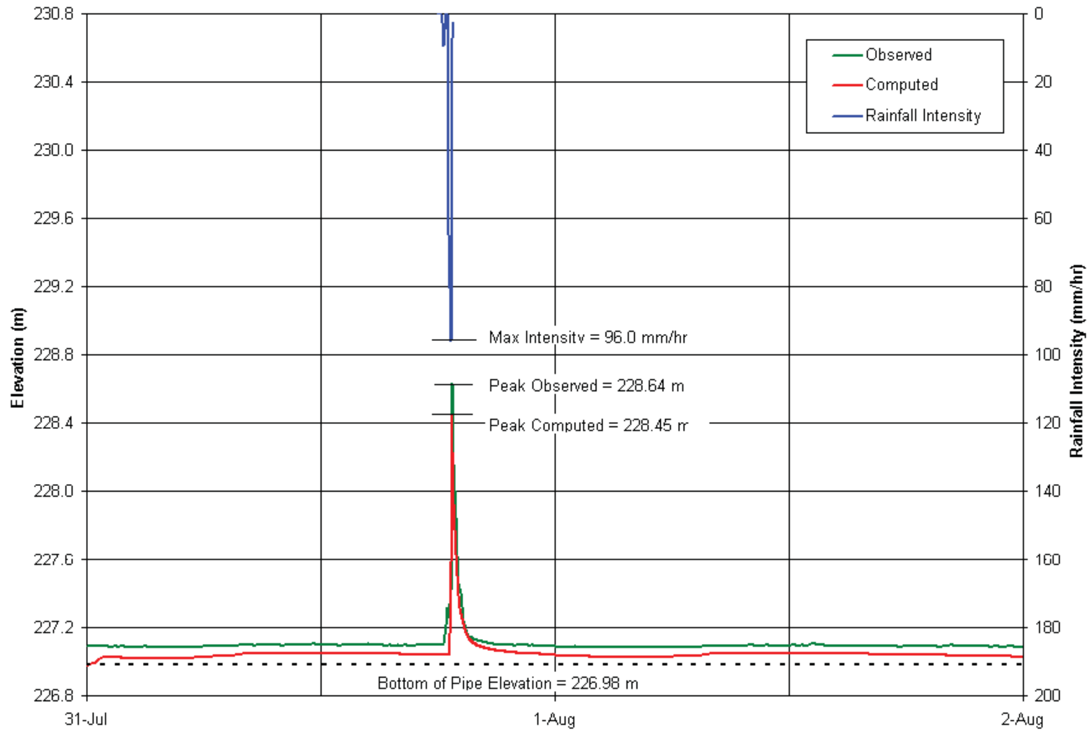


Figure 4-21: Comparison of Observed and Computed Levels at the Nathaniel Gauge (Verification Event – July 31st, 2004)

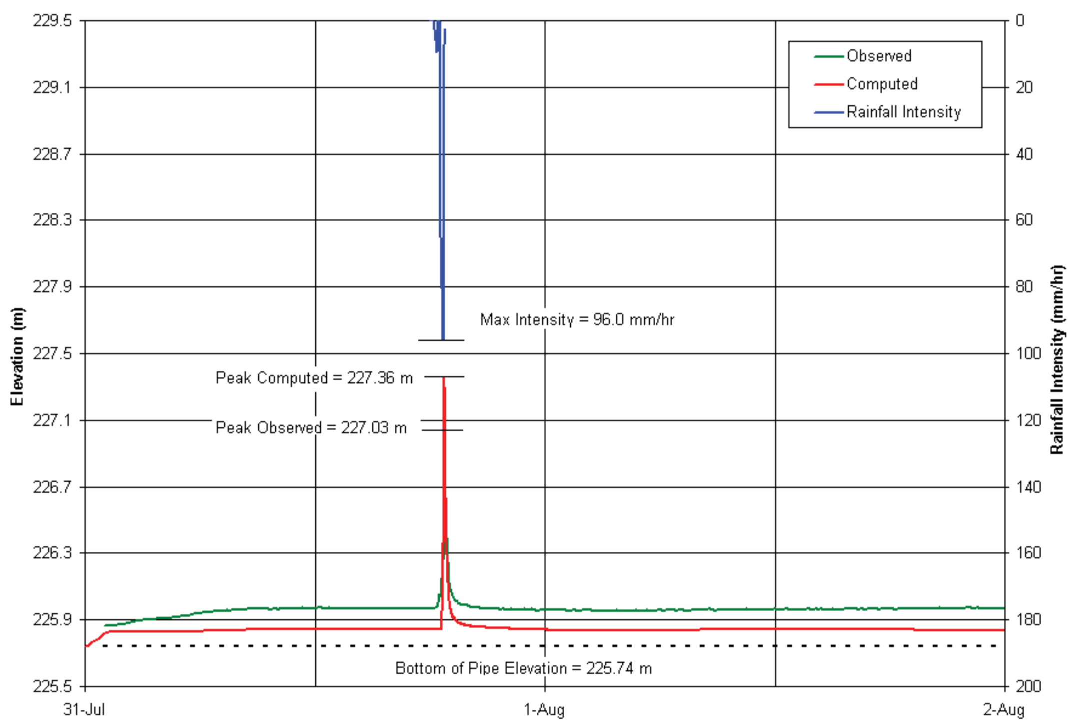


Figure 4-22: Comparison of Observed and Computed Levels at the Harrow & Hector Gauge (Verification Event – July 31st, 2004)

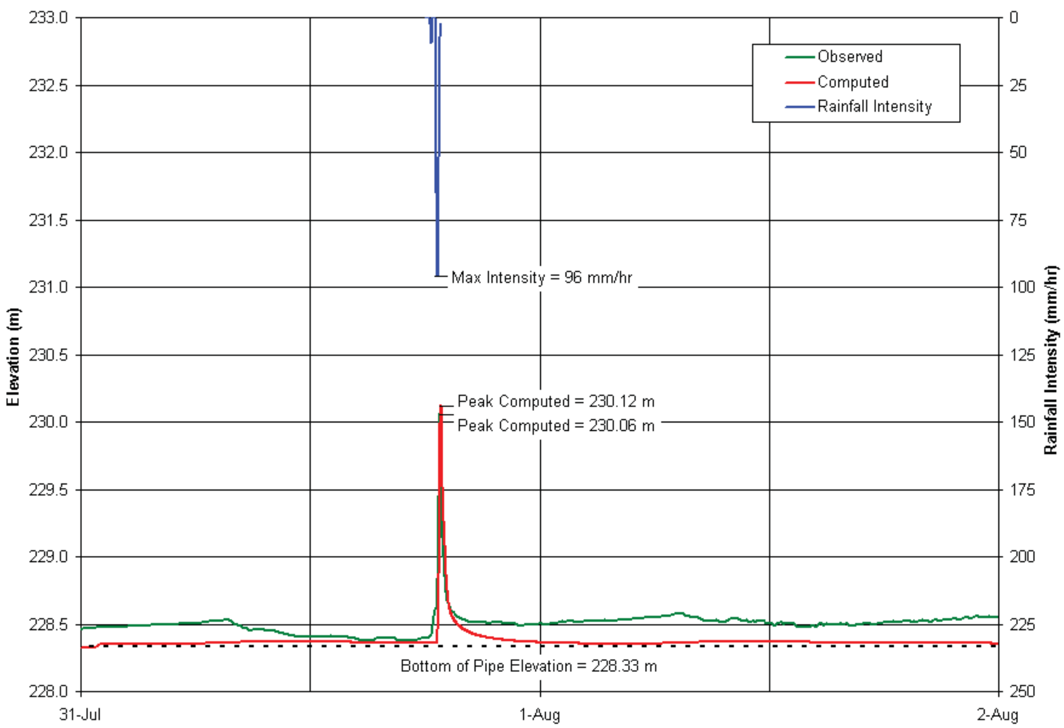


Figure 4-23: Comparison of Observed and Computed Levels at the Guelph Gauge (Verification Event – July 31st, 2004)

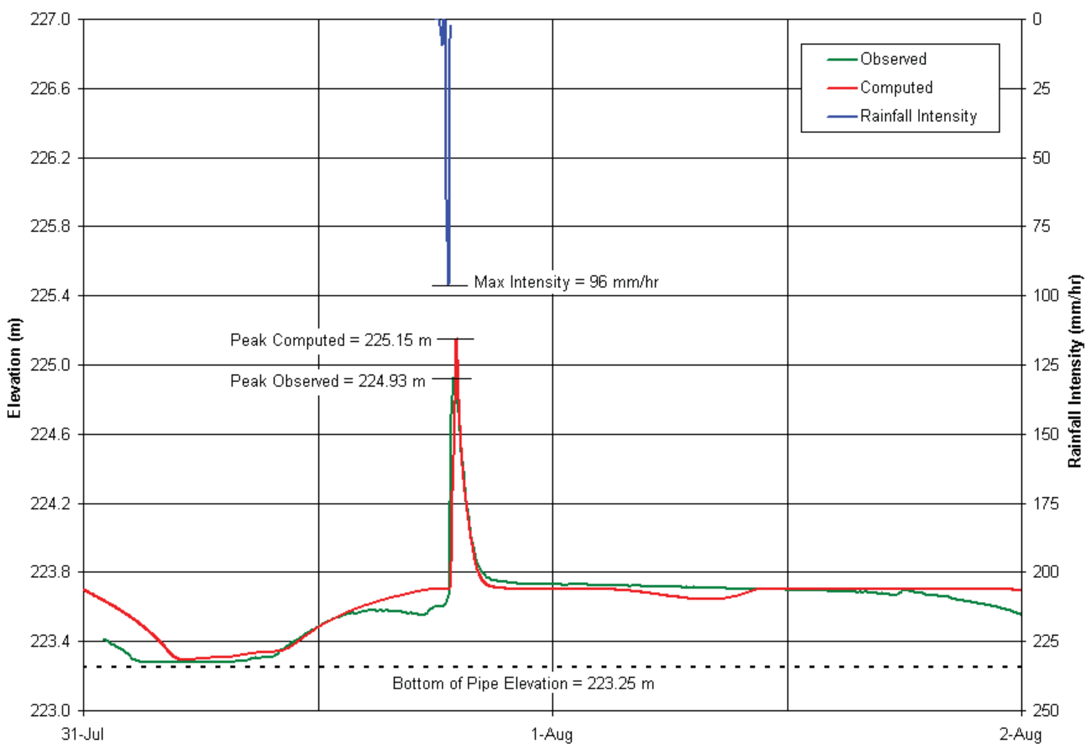


Figure 4-24: Comparison of Observed and Computed Levels at the Taylor Gauge (Verification Event – July 31st, 2004)

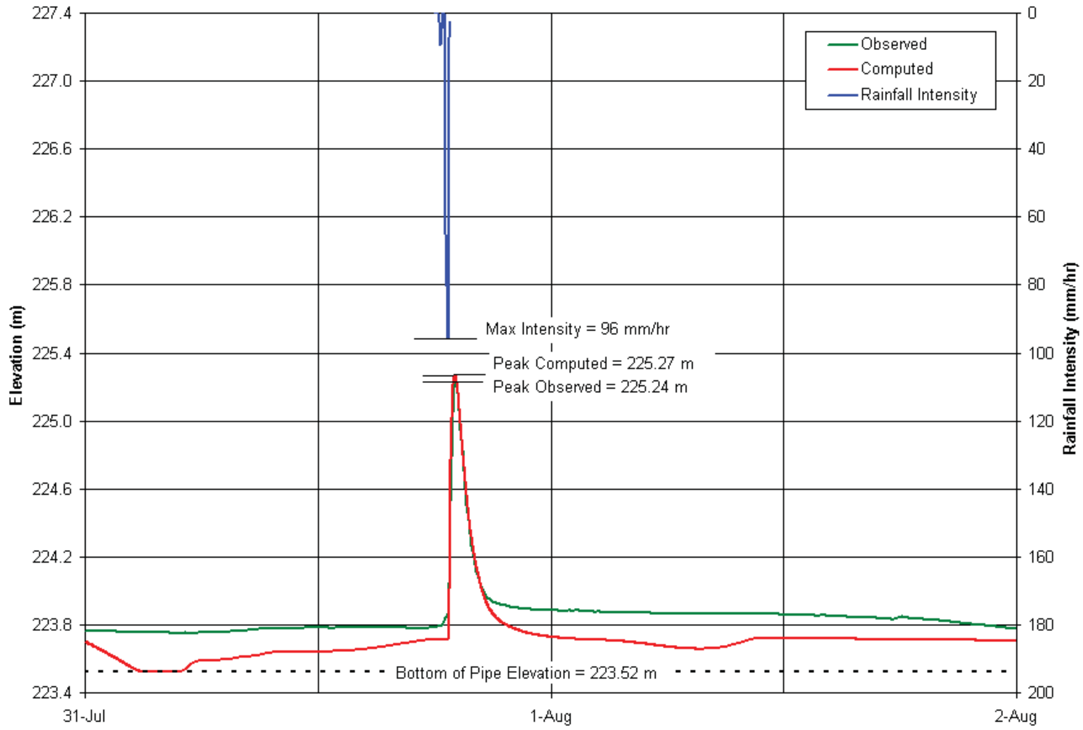


Figure 4-25: Comparison of Observed and Computed Levels at the Cockburn & Rosedale (Verification Event – July 31st, 2004)

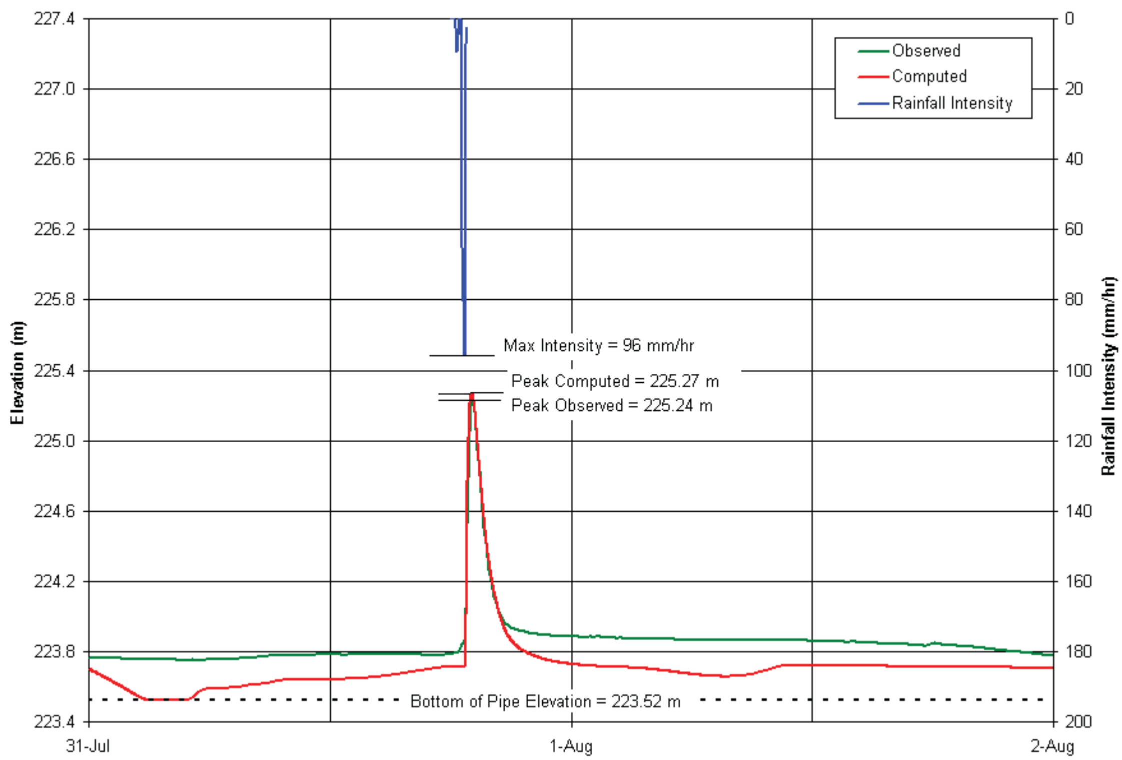


Figure 4-26: Comparison of Observed and Computed Levels at the Riverside Gauge (Verification Event – July 31st, 2004)

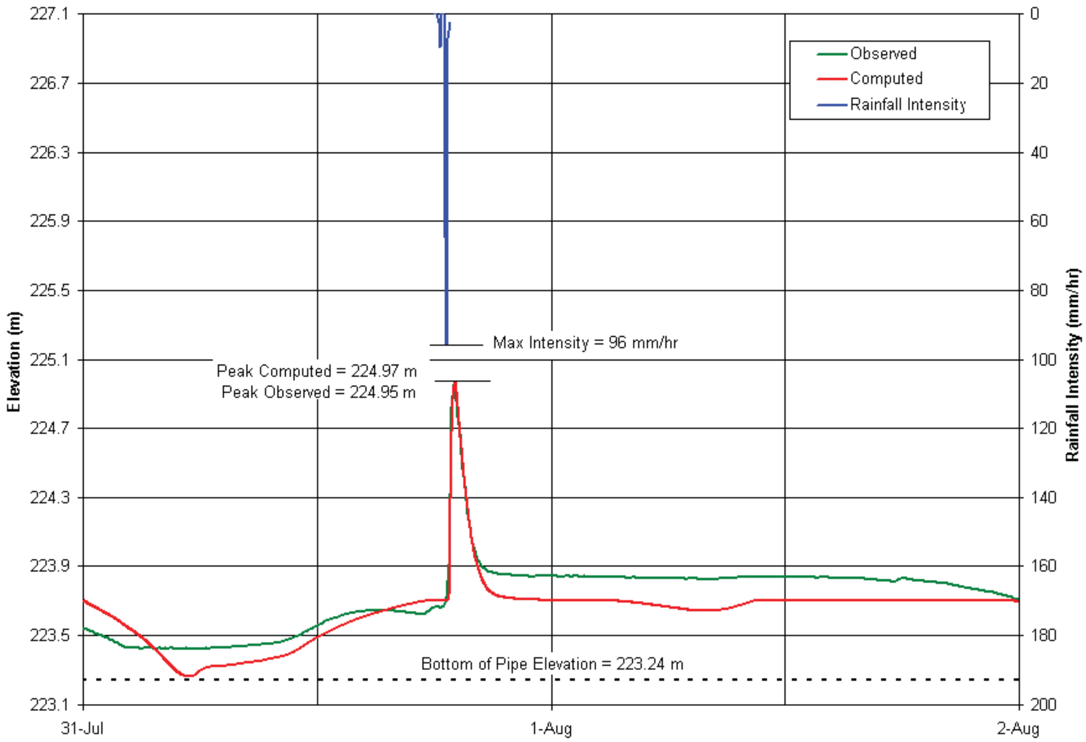


Figure 4-27: Comparison of Observed and Computed Levels at the Riverdale Gauge (Verification Event – July 31st, 2004)

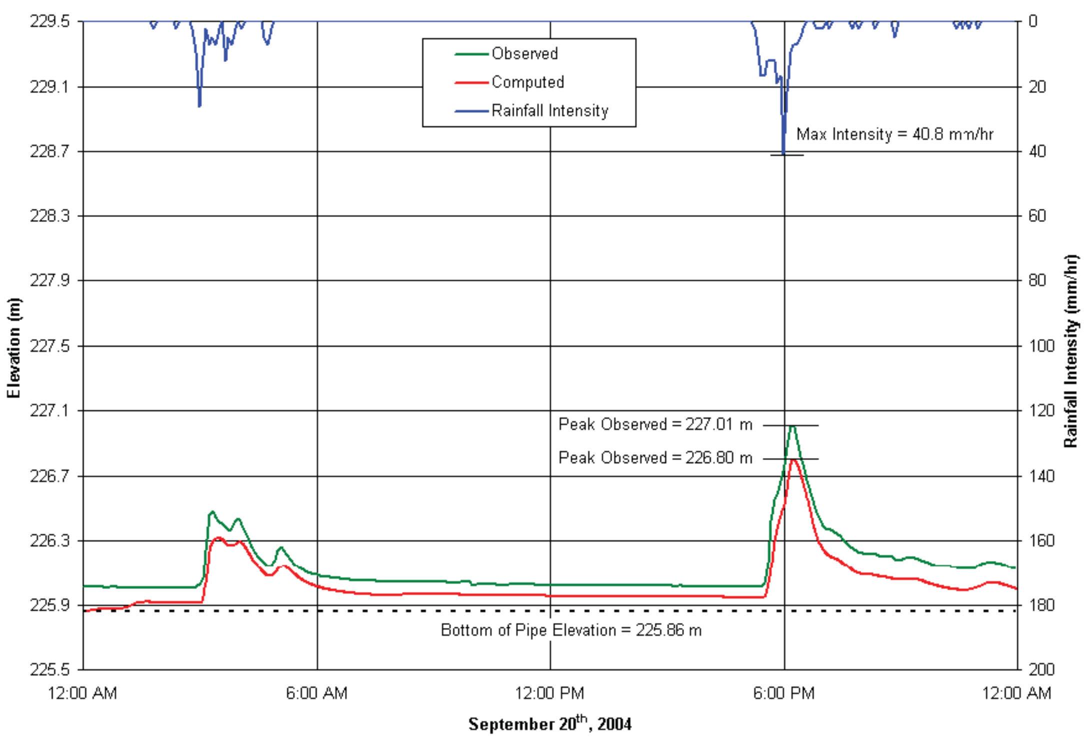


Figure 4-28: Comparison of Observed and Computed Levels at the Hector Gauge (Verification Event – September 20th, 2004)

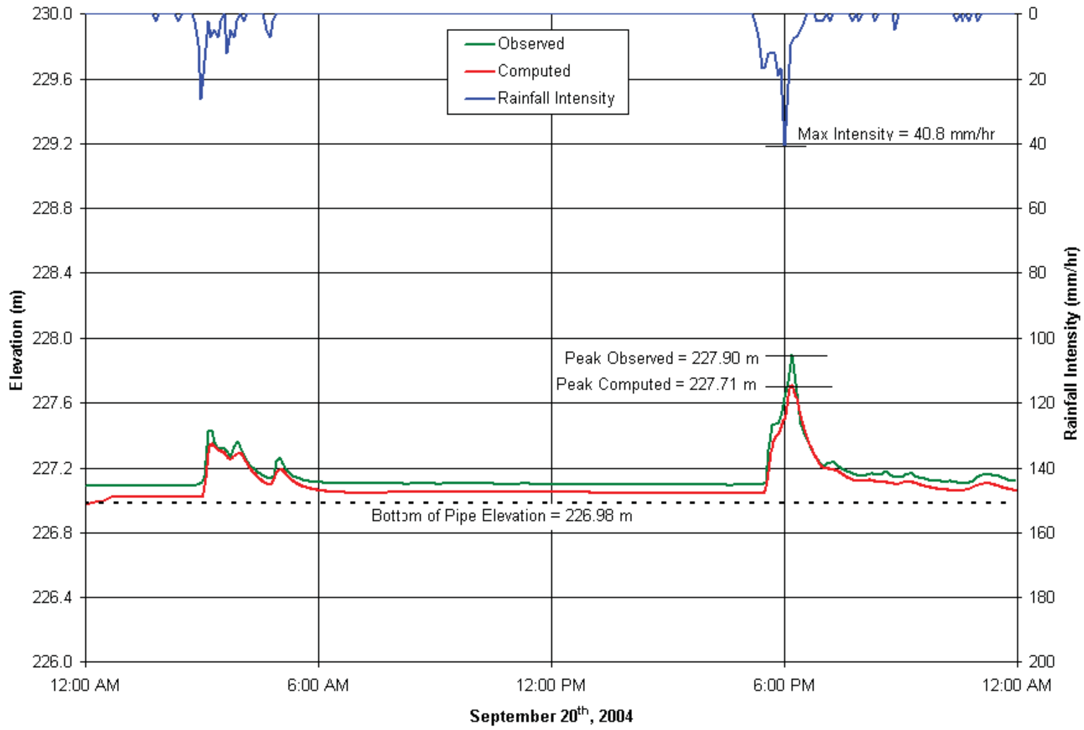


Figure 4-29: Comparison of Observed and Computed Levels at the Nathaniel Gauge (Verification Event – September 20th, 2004)

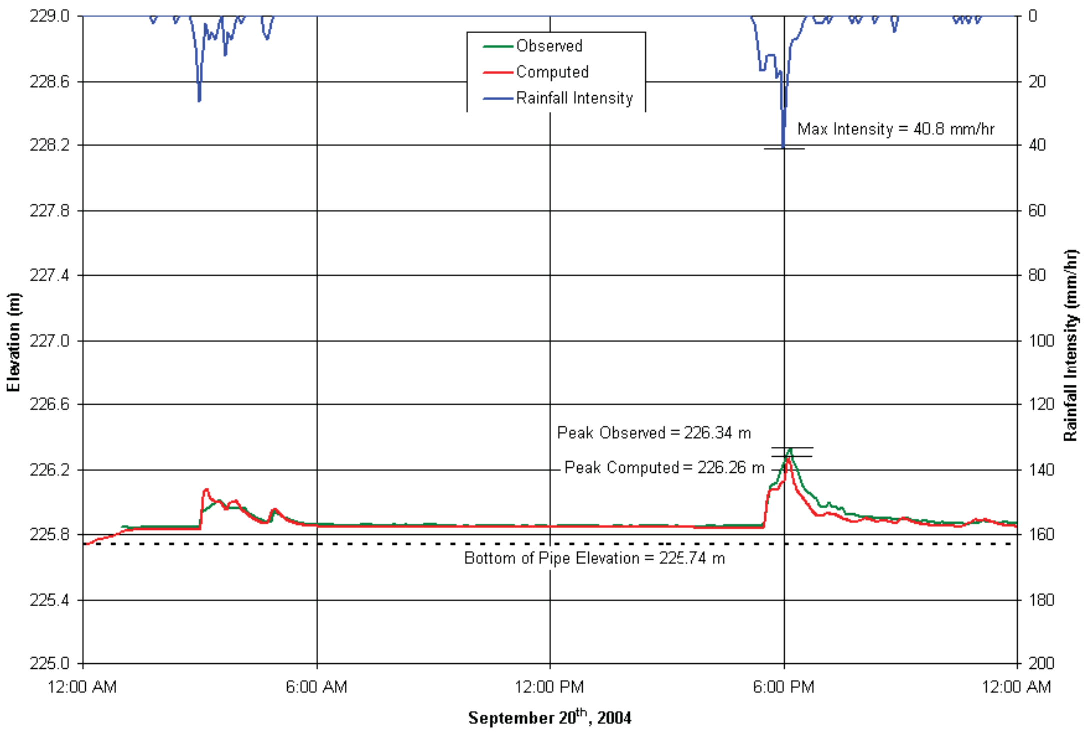


Figure 4-30: Comparison of Observed and Computed Levels at the Harrow & Hector Gauge (Verification Event – September 20th, 2004)

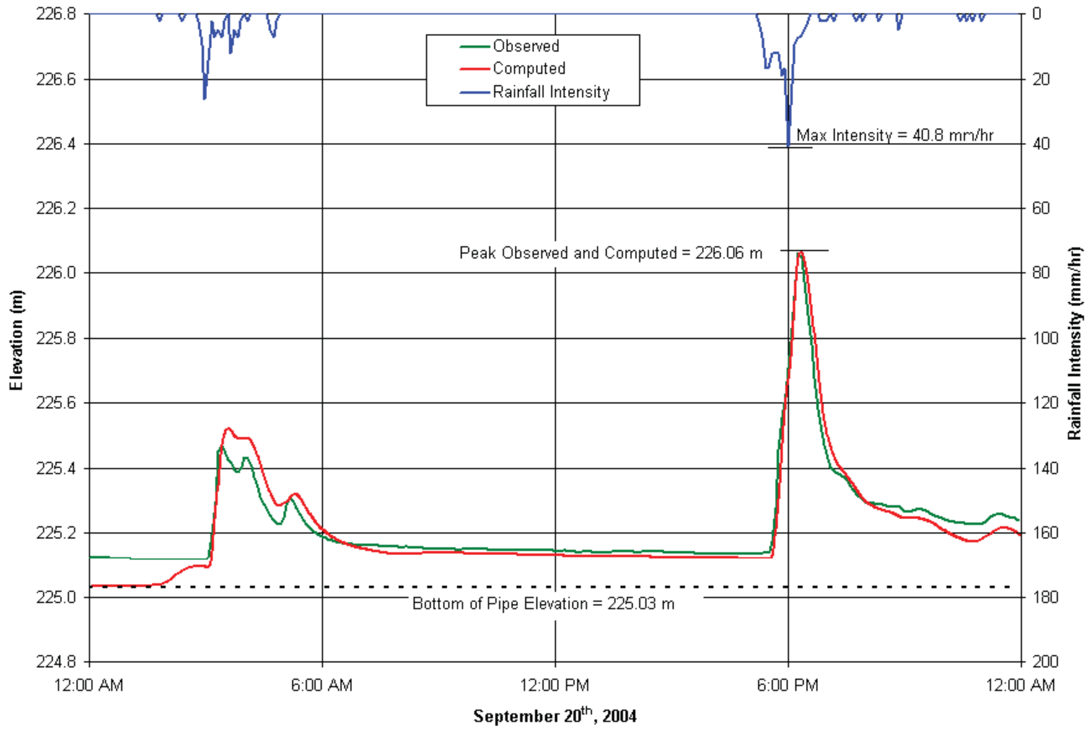


Figure 4-31: Comparison of Observed and Computed Levels at the Guelph Gauge (Verification Event – September 20th, 2004)

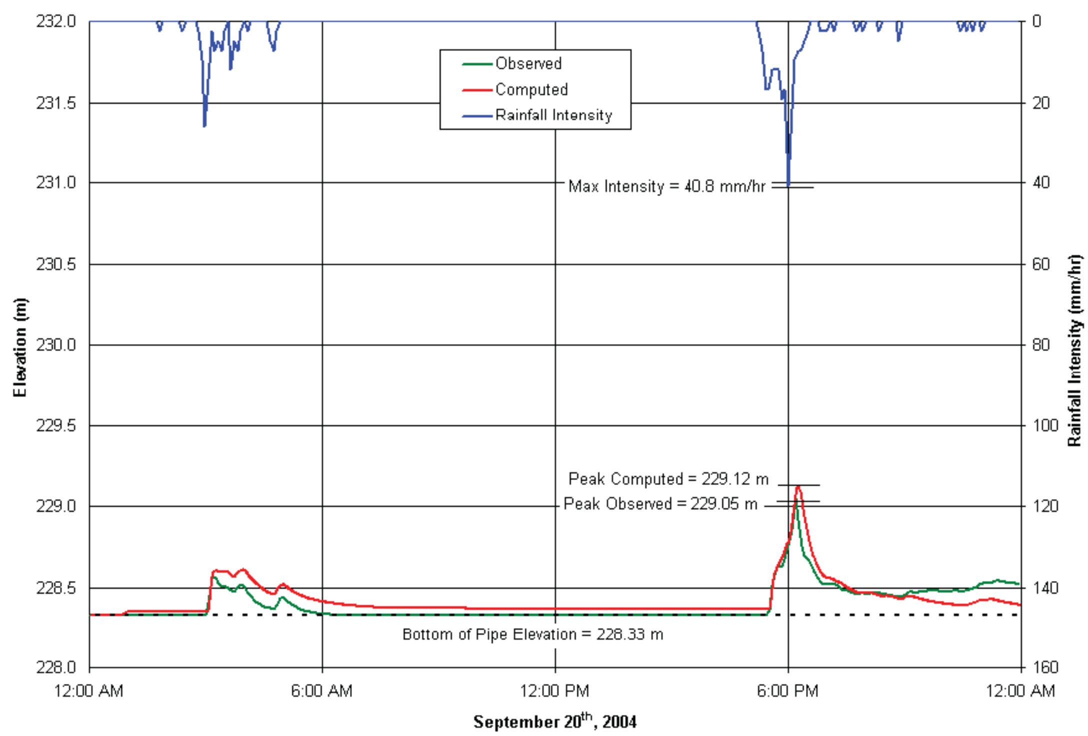


Figure 4-32: Comparison of Observed and Computed Levels at the Taylor Gauge (Verification Event – September 20th, 2004)

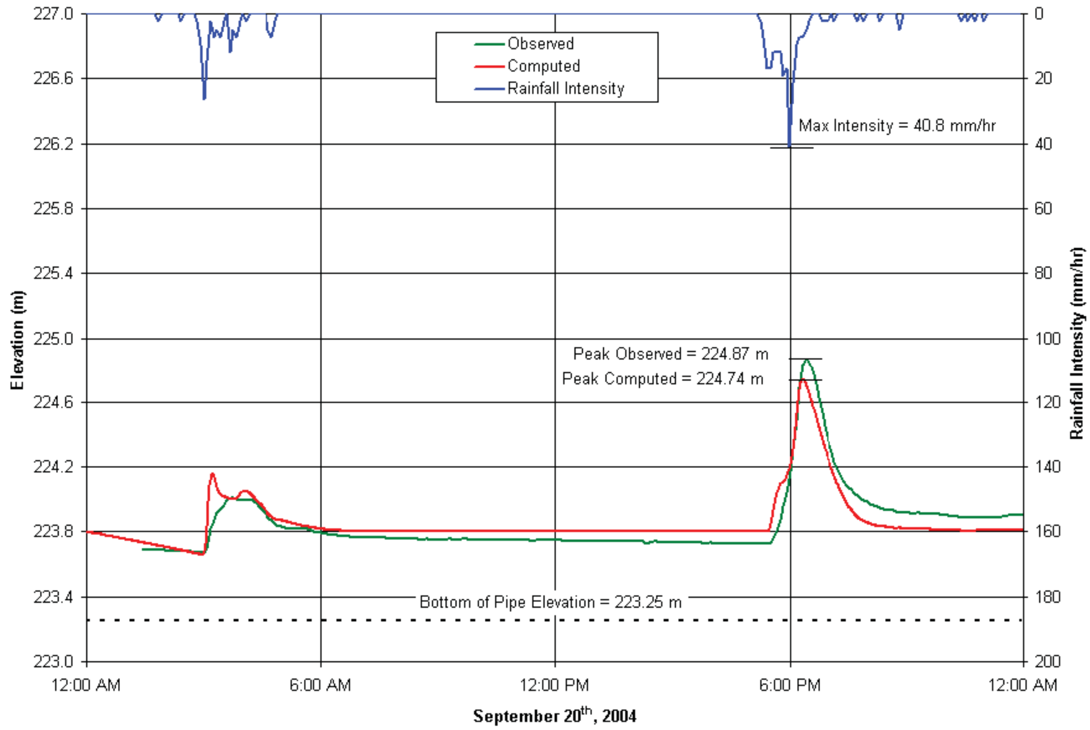


Figure 4-33: Comparison of Observed and Computed Levels at the Cockburn & Rosedale (Verification Event – September 20th, 2004)

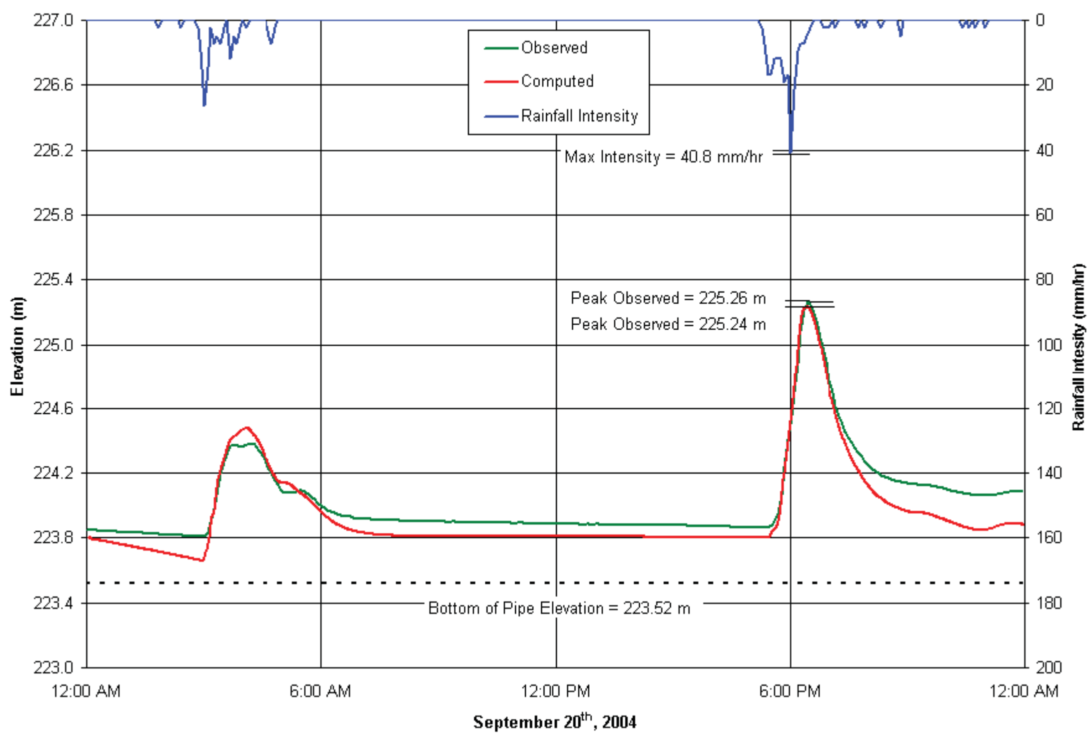


Figure 4-34: Comparison of Observed and Computed Levels at the Riverside Gauge (Verification Event – September 20th, 2004)

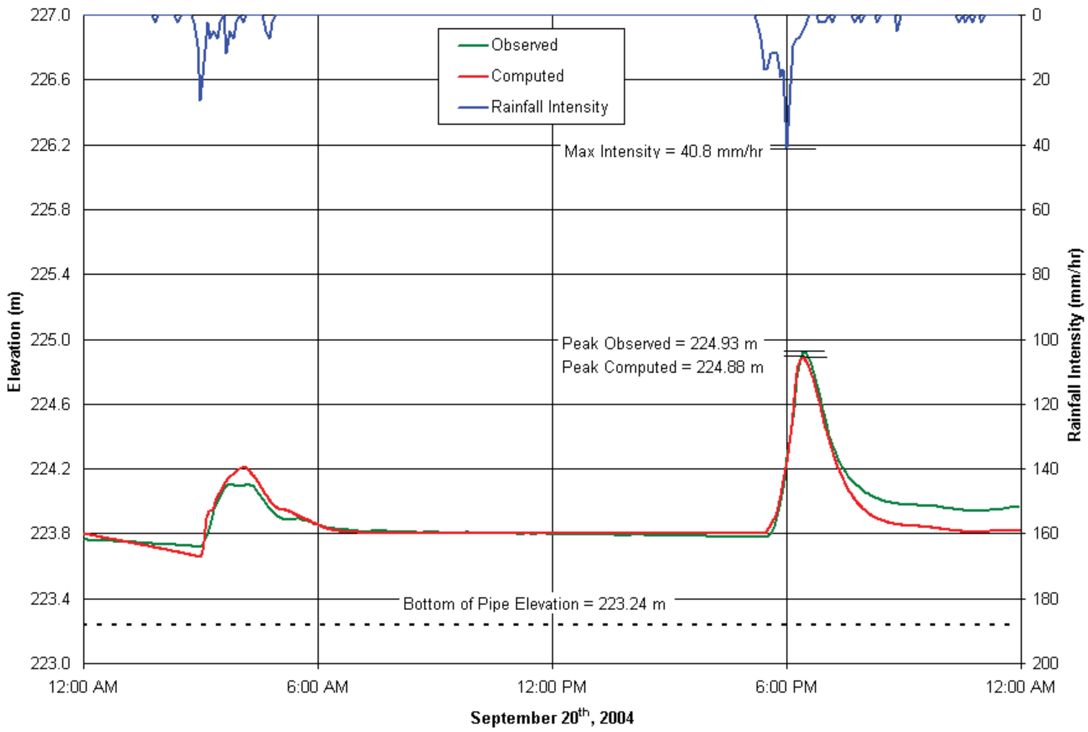


Figure 4-35: Comparison of Observed and Computed Levels at the Riverdale Gauge (Verification Event – September 20th, 2004)

Figures 4-20 to 4-35 show that a good verification of the model has been achieved using the two storm events. Similar to the calibration results, the difference in the time to peak and peak levels is minimal between the observed and computed data. In addition, the shape of the hydrograph from the XP-SWMM model is consistent with recorded observations. The model's ability to simulate the runoff and hydraulic conditions associated with a range of rainfall events is also shown since the model provides a good representation of smaller rainfall events that occurred prior to the major storm used for calibration/verification.

5.0 SOUTHEAST PART OF THE JESSIE DISTRICT

5.1 BACKGROUND

This section describes the addition of the southeast part of the Jessie Combined Sewer District to the Cockburn and Calrossie XP-SWMM model developed to determine relief/separation alternatives. This area was added to the study scope since it was not relieved as part of the Jessie Relief Project in the 1970s. The option to relieve part of the Jessie District (southeast) was originally discussed in Appendix A of the report, “Basement Flooding Relief Program Review – 1986” (City of Winnipeg).

> ***"For this study, existing combined lateral sewers on Weatherdon, Carter, Hector, Ebby and Jackson Avenues between Pembina Highway and Stafford Street were considered in detail, but were not modeled. Although they are at the upper-end of the Lilac Street collector in the Jessie Combined Sewer District System, there is a serious flooding problem in this small area. Because of their proximity to the Cockburn trunk they were not relieved with the Jessie relief project, but have been left for incorporation into the Cockburn relief project."***

No additional information regarding this issue was found in the Jessie Combined Sewer Relief Study (City of Winnipeg, 1974).

In the City of Winnipeg basement flooding relief program review study, figures related to this part of the Jessie District showed that predicted basement flooding for a 2-year storm was significant. As a result, the proposed relief piping scheme showed that the southeast part of the Jessie District would be redirected toward the Cockburn District via an extension of the sewers along Taylor Avenue, Ebby Avenue, and Carter Avenue.

This was not originally considered as part of the project scope for the Cockburn and Calrossie Combined Sewer Relief Study. However, the City has requested that the potential for relieving this part of the Jessie District toward the Cockburn District be added as part of the assessment of relief/separation alternatives.

5.2 MODEL SETUP

To facilitate this assessment, the southeast part of the Jessie District was setup in the existing model of the Cockburn and Calrossie Districts. The setup included gathering information from the LBIS data (i.e. pipe and manhole data) and inputting the data in XP-SWMM, followed by the subcatchment delineation process. Hydrologic (i.e. percent imperviousness) and infiltration parameters used in the runoff model were consistent with those used in the Cockburn and Calrossie Districts. Although no sewer monitoring data was available for the Jessie District to calibrate this part of the model, similar runoff parameters to those in the Cockburn and Calrossie model were used to ensure that the two components of the model were consistent.

The relief/separation schemes considered will prevent dry weather flow from the southeast part of the Jessie District from being directed to the Cockburn District. The impact of the increase in the dry weather flow to the Cockburn lift station was therefore not considered for the existing level of service simulations. However, for the relief/separation alternatives, the dry weather flow will be input as part of the model and routed toward the northern part of the Jessie District, which is based on the existing conditions in the Jessie District.

Presently, the storm water runoff from this area is conveyed to the Jessie Combined Sewer outfall via a 450 mm diameter combined sewer on Lilac Street at Grant Avenue. In addition, there are 2 interconnections between the Jessie and Cockburn Combined Sewer Districts located along Ebby Avenue and Jackson Avenue, referenced in Section 4.3.2. A figure of the Jessie subsystem is shown on the following page.

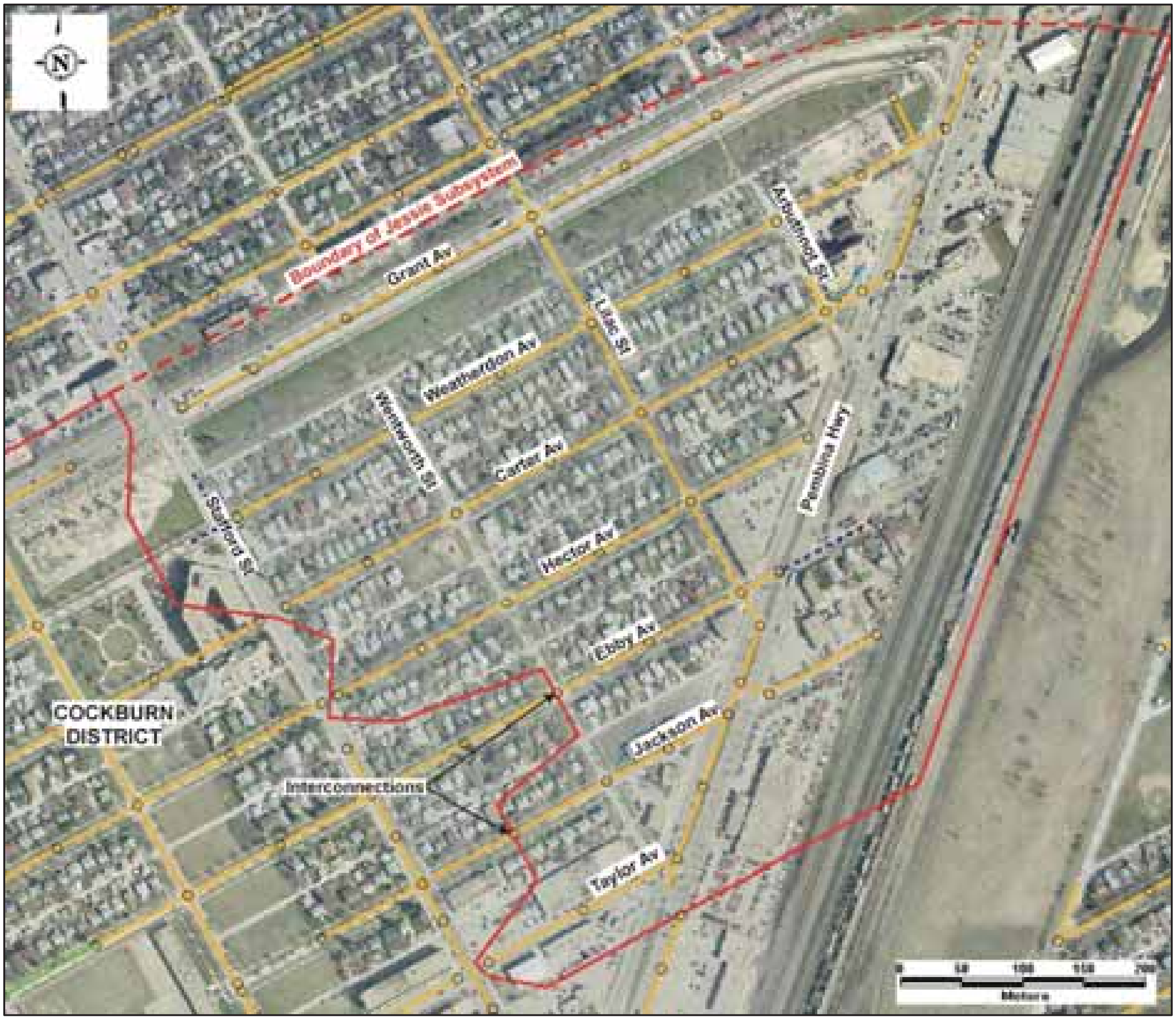


Figure 5-1: Southeast Jessie

The discharge and hydraulic grade line of the Lilac Street sewer is partly affected by the hydraulic conditions in the downstream Jessie Combined Sewer System north of Grant Avenue. To model the Lilac Street sewer in the Ebby-Wentworth part of the Jessie Combined Sewer System would require modeling of the entire Jessie Combined Sewer District. An approximate solution was, therefore, undertaken in which only the southeast part of the Jessie District up to Grant Avenue was modeled and the Lilac Street lateral at Grant Avenue was simulated as an outfall.

The Southeast Jessie boundary condition requires that the hydraulic grade line at the outfall be 2.4 m below ground elevation and that the peak discharge be limited to be approximately 0.35 m^3/s for the 5-year design discharge. The peak discharge of 0.35 m^3/s is based on normal full pipe flow conditions for the downstream conduit. The hydraulic grade line constraint is imposed since the remaining part of the Jessie Combined Sewer District has been relieved. Therefore, the 5-year design would limit the hydraulic grade line to below the basement level or 2.4 m below ground.

The water level boundary condition was modeled by adding two additional pipes downstream of the assumed outfall location at Grant Avenue and Lilac Street. A free outfall boundary condition was assumed for the downstream pipe. The length and pipe roughness were adjusted by trial and error until the computed hydraulic grade line elevation at Grant Avenue and Lilac Street reached the desired HGL elevation of 2.4 m below the ground surface for a 5-year event. The computed hydraulic grade was also verified for the 1-year, 2-year, 10-year, and 25-year event to ensure that it was within an acceptable range.

Although an XP-SWMM model of the entire Jessie District would have the potential to yield more accurate results, modelling of the southeast part only as described above was deemed to be a reasonable approach that will provide accurate results.

6.0 EXISTING LEVEL OF SERVICE EVALUATION

6.1 DEFINITION OF EXISTING LEVEL OF SERVICE

The level of protection or level of service is based on the rainfall return period for which no basement flooding occurs for the existing sewer network. Similar to past City of Winnipeg relief studies, it was assumed that basement flooding would occur if the hydraulic grade line exceeds a 2.4 m threshold below the ground surface. This was determined in the XP-SWMM model by computing the “freeboard”, defined as the depth of the hydraulic grade line below the ground surface (manhole rim elevation), at each node for a range of rainfall events. Graphical encoding was used to visually illustrate the extent of basement flooding that would occur throughout the Cockburn, Calrossie and southeast part of Jessie Sewer Districts.

Figure 6-1 illustrates the concept for determining the existing level of service for combined sewer systems. As shown on the figure, basement flooding will occur if the water level is within 2.4 m or lower of the ground surface. The value of 2.4 m is based on the average depth of the basement level (approx. 1.9 m) plus a 0.5 m allowance for house service and model safety factor.

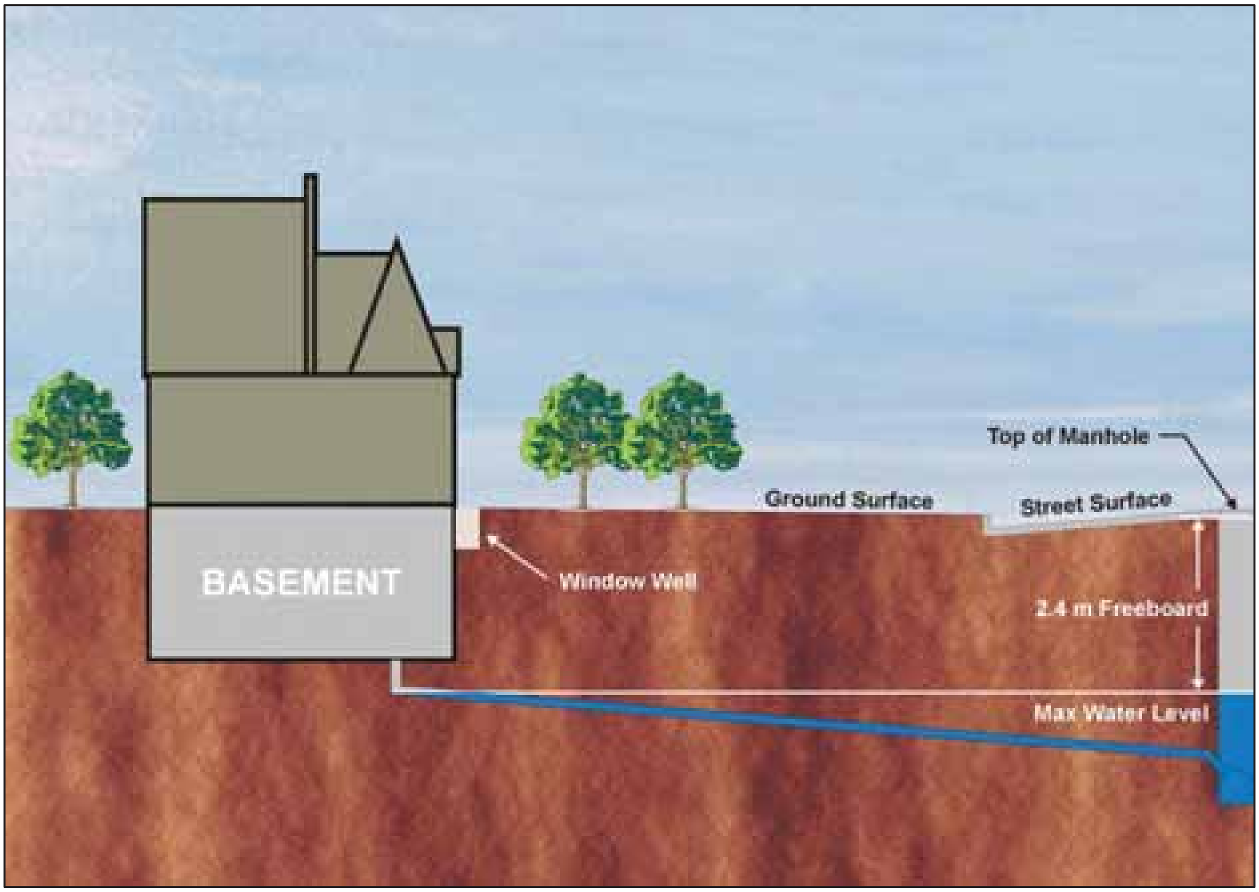


Figure 6-1: Concept of Existing Level of Service

6.2 MODEL ADJUSTMENTS

Some model adjustments were required for the existing level of service simulations because changes have occurred in the Cockburn and Calrossie Sewer Districts since the 2004 sewer monitoring program. As referenced in Section 2.1.3, there were three known apartment locations on Grant Avenue that were discharging groundwater into the sewer as part of an air conditioning system. Although the additional flow from the apartments was incorporated as part of the calibrated model, this flow was removed from the existing level of service simulations since these apartments are no longer discharging groundwater to the sewer.

The effect of the six interconnections to the Cockburn Combined Sewer District was also considered for the level of service evaluations. The model was set-up using a conservative flow toward the Cockburn District via the interconnections.

Consideration was also given to the backwater from the Red River at the Cockburn outfall. For the level of service evaluation, the normal summer water level of 223.7 m was assumed in the XP-SWMM model. This is 0.1 to 0.2 m lower than the actual water level at the outfall experienced during the 2004 events used for the model calibration and verification, but represents the long-term average level experienced at this location during the summer.

Upgrading of the Cockburn lift station pumps was also included for the prediction of the existing level of service. By 2006, the pump had been upgraded to a peak capacity of 105 l/s.

Finally, simulations for the level of service were carried out assuming that the sewers would be in the same condition as for the calibrated XP-SWMM model. The calibration of the model was based on recorded depths from sewer monitors installed after the sewers in the Cockburn Sewer District had been cleaned. Therefore, the existing level of service is based on a clean sewer system with no debris.

6.3 RAINFALL EVENTS

The rainstorm coefficients used to fit the City of Winnipeg Intensity Duration Frequency (IDF) curve were taken from the Urban Drainage Adequacy Report by Stantec Consulting Ltd. (2000). These IDF curves and the 2000 Chicago Distribution have been adopted by the City of Winnipeg to determine the design rainstorm. For design storms, the time step was increased from 5 minutes to 10 minutes and the storm advancement factor "r", representing the ratio of storm rainfall up to the time of peak rainfall intensity to the total storm rainfall, was assumed as 0.33 compared to the 1974 value of 0.31 by James F. MacLaren (1974).

6.4 SIMULATION RESULTS

The majority of the sewer system in the Cockburn, Calrossie, and Jessie Sewer Districts were installed prior to the 1970s. Although the City of Winnipeg currently uses the 5-year design storm for the level of service, results from the calibration and verification of the model for storms equivalent to a 1-year design event showed that the capacity of these sewer districts is limited, which is typical in older sewer districts.

Locations of flooding for a range of rainfall frequencies were identified based on the results of the modelling. Computed areas of flooding for the existing sewer system were used to determine areas where relief would be necessary and most effective.

Figure 6-2 shows the results from the simulation for a 1-year City of Winnipeg summer rainfall event. Computed hydraulic grade line elevation (HGL) below the ground surface was computed in the XP-SWMM model using the “freeboard” parameter, which defines the freeboard as the distance from the ground surface to the HGL. As shown in the legend, the freeboard has been divided into different categories to provide a graphical representation of the magnitude of basement flooding that occurs in the Cockburn, Calrossie, and southeast part of Jessie Sewer Districts. As shown on the figure, the severity of flooding increases from manholes coded in yellow to manholes in red. At manholes with no color-coding (black), no basement flooding occurs.

Figure 6-2: 1-Year Level of Service Simulation Results

The results shown in Figure 6-2 indicate that the majority of the Cockburn and Calrossie Combined Sewer District has a level of service equivalent to the 1-year rainfall. Areas prone to basement flooding include the Jessie subsystem, which was added to the project scope, the area near the district boundary of the Cockburn and Jessie Districts and a small area along

Taylor Avenue. The results show that the southeast part of the Jessie District has a level of service less than a 1-year event.

The Calrossie Sewer District was not considered in the existing level of service simulations since it is a separated system, where the criteria for basement flooding in combined sewers does not apply. In land drainage sewers, flooding to ground surface is generally permissible. Surcharging above the ground surface would occur at some manholes in the Calrossie Sewer District land drainage system for a 5-year rainfall. However, no surface flooding would result from a 2-year summer rainfall in the district.

Figure 6-3: 2-Year Level of Service Simulation Results

Figure 6-3 displays the results from the simulation for a 2-year rainfall event. The results from the 2-year simulation indicate that basement flooding occurs in the Cockburn and Calrossie Combined Sewer Relief District along Grant Avenue primarily near the Grant Park Shopping Centre, along Taylor Avenue and Poseidon Avenue near the Pan Am Pool, along Taylor Avenue near Manitoba Hydro. Basement flooding also occurs in the southeast part of the Jessie District.

Based on these results, the existing level of service for approximately 25 percent of the Cockburn and Calrossie Combined Sewer Relief District is equivalent to a 2-year event or smaller. Consequently, approximately 75 percent of the district has a level of service higher than a 2-year event.

Figure 6-4 shows the results from the 5-year level of service simulation. The majority of the Cockburn and Calrossie Combined Sewer Relief District as well as the southeast part of the Jessie District is prone to basement flooding for a 5-year rainfall event, with the exception of the downstream portion of the sewer system near Cockburn Street, Churchill Drive and Jubilee Avenue. Therefore, relief alternatives based on a 5-year event will focus on the regions that are most critical (i.e. 2-year level of service vs. 5-year level of service), but will essentially cover most of the district.

Figure 6-4: 5-Year Level of Service Simulation Results

Additional simulations were carried out for larger magnitude rainfall event to determine the areas with the greatest level of service. Figure 6-5 shows the results from the 10-year level of service simulation.

Figure 6-5: 10-Year Level of Service Simulation Results

The results shown in Figure 6-5 illustrate that basement flooding for the 10-year summer storm will occur for almost the entire study area, with the exception of a small area along Churchill Drive near the Cockburn Outfall.

As part of the benefit-cost analysis (Section 9.0), the manholes with a freeboard less than 2.4 m were investigated to determine the extent of basement flooding in the district for a range of rainfall events. The damages associated with the existing sewer network were determined based on the number of properties that have been identified from digital ortho photographs for each manhole, based on the contributing subcatchment boundaries.

7.0 FUTURE DEVELOPMENT

7.1 INTRODUCTION

As part of the review of the relief/separation alternatives, future development schemes for vacant lands were considered. These future development schemes were incorporated as part of the XP-SWMM models for relief/separation alternatives to assess their hydraulic impact on the sewer system. The final relief model incorporates the additional sewer pipes required to maintain the hydraulic grade line at 2.4 metres below the ground surface. It also includes the runoff from the existing subcatchments as well as runoff from areas that will likely be developed in the future.

As shown in Figure 7-1, there are a total of 4 locations with potential for future development that have been considered in the study area:

1. Fort Rouge Yards
2. Winnipeg Humane Society
3. Large Field Area North of Parker Avenue
4. Land Adjacent to Sobeys on Taylor Avenue

Figure 7-1: Potential Future Development Locations

7.2 FORT ROUGE RAIL YARDS

The Fort Rouge Rail Yards are situated between the Lord Roberts residential neighbourhood on the east and Pembina Highway on the west (see Figure 7-2). The rail yards were formerly used by the Canadian National Railway (CNR) for train marshalling and for rail tracks of the CNR Rivers (Main Line) and Letellier Subdivisions.

Figure 7-2: Fort Rouge Yards Area

The original proposal for drainage of the South West Transit Corridor in the Fort Rouge Yards (Dillon Consulting, 1983) was to slowly drain the railway lands and transit corridor (with no development) utilizing storage ponding, ditches, and discharging into the existing combined sewers of Cockburn, Baltimore, and Jessie. It was assumed that the slow discharge could be accommodated by the Cockburn (and perhaps Baltimore) systems and that the Jessie system would be able to handle the discharge, via a pumping station, for the proposed transit corridor underpass.

Since the Functional Design Study (Dillon Consulting, 1983), the residual railway lands in the Fort Rouge Yards have been sold to a private developer for the potential development of a medium to high-density urban development within these yards. This potential development required a more detailed review of the drainage for the Bus Rapid Transit (BRT) Corridor as a stand-alone project as well as the fully developed scenario of the BRT Corridor together with the private development of the Fort Rouge Yards. Since the drainage issues for these projects were inter-related, an overall drainage review of these two development scenarios was included in the original scope of work.

The objective of this drainage study was to document the background information, overall drainage area, design storm event, and drainage options considered as well as the associated costs for these drainage alternatives.

The integration of the proposed development options into the overall sewer relief plan for the area was evaluated in accordance with the original scope and is reported on in Section 15.0. Alternatives exploring on-site detention as well as outflow distribution to the existing systems surrounding the subject area were explored. Approval to proceed with the BRT corridor during the progress of the Cockburn and Calrossie project and the need for advancing the FRY development schedule resulted in the need for a more detailed study and was assigned as additional services, and is reported on separately as Appendix F. Again, the separate development of the transit corridor and the private lands was reviewed.

7.3 WINNIPEG HUMANE SOCIETY

A preliminary drawing of the site plan for the Winnipeg Humane Society, located near the corner of Hurst Way and Waverley Street, was obtained from Cochrane Engineering. This drawing showed that drainage from this development would be directed toward the Ash Combined Sewer District, which has been confirmed by the City of Winnipeg Water and Waste Department. Therefore, this development was not considered as part of the development schemes for the Cockburn and Calrossie Combined Sewer Relief Works.

7.4 PARKER AVENUE

A large field area exists north of Parker Avenue, which is located in the southwest portion of the Cockburn Combined Sewer District. The potential for future development in this region is likely, even though the relocation of some of the existing Manitoba Hydro transmission lines may be required. Although preliminary development plans for this area have been submitted to the City, none of these plans have materialized. The City of Winnipeg has, however, provided a preliminary development plan for this region that was originally submitted in 1999 as shown on Figure 7-3.

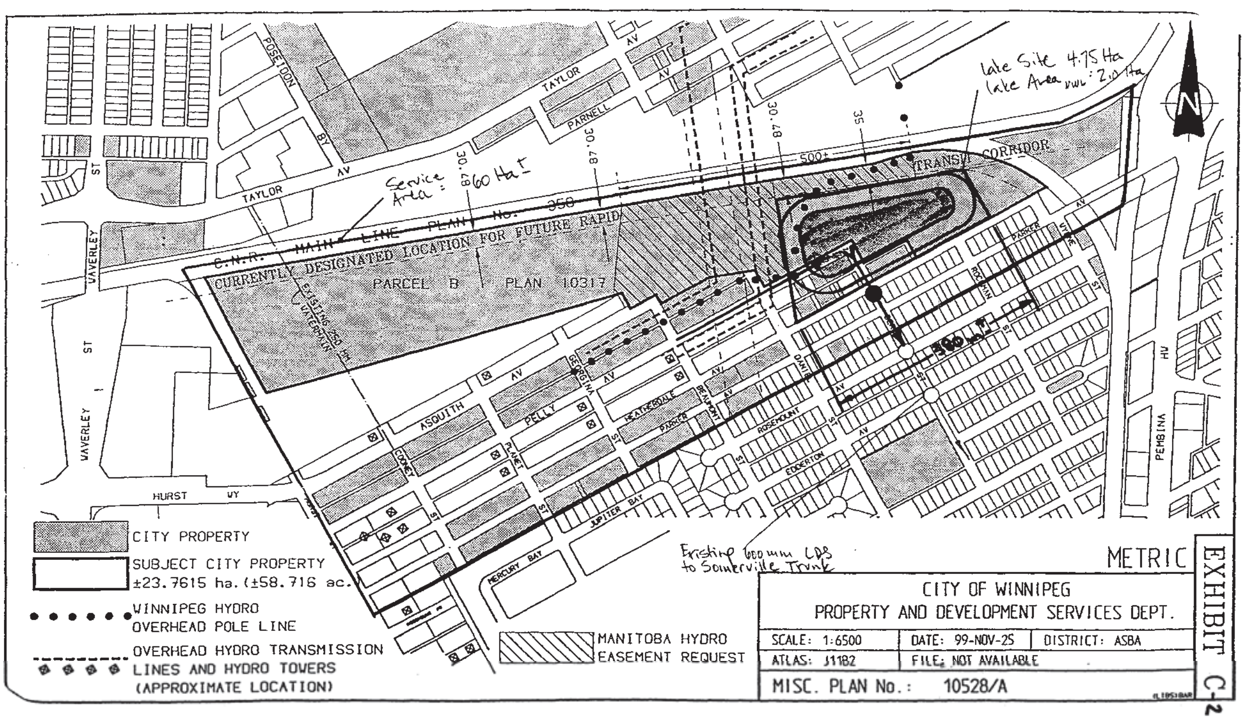


Figure 7-3: Preliminary Development Plan North of Parker Avenue

Although this plan is not proceeding at this time, it was used as a basis for a future development scheme since it is the best available information. The plan consists of a retention pond, a section of land parallel to the CN tracks designated for Bus Rapid Transit (BRT), and a residential area directly north of Parker Avenue. The location of a Storage Retention Pond (SRB) as defined by the City Property and Development Service Department is shown on Figure 7-3.

For the design of the relief/separation alternatives, the 5-year City of Winnipeg summer rainfall event was used. Under existing undeveloped conditions, it is estimated that the maximum flow for a 5-year summer event from the area would be approximately 0.5 m^3/s. This would increase to approximately 1.5 m^3/s with the area fully developed. The higher runoff would result in an increase of approximately 0.65 m in the maximum water levels in the downstream trunk sewer on Jubilee Avenue. The higher discharges and resulting water levels would result in an unacceptable reduction to the level of service in the combined sewer system based on the City of Winnipeg requirement that the peak discharge for developed lands in combined sewer areas be restricted to pre-development conditions.

To meet the City's criteria, a storm retention pond was considered as a necessary part of the development option for the area north of Parker Avenue, to limit the peak discharge to pre-development conditions. Although the pond would limit the peak discharge to existing conditions, the existing combined sewers would still experience an increase in volume due to the development flows.

For the future development scheme, the existing XP-SWMM model of the Cockburn, Calrossie and Jessie Combined Sewer Districts was modified by inputting a storm retention basin on the eastern portion of the vacant land between Parker Avenue and the CN tracks and adjusting the runoff parameters in this region to reflect the development. The location of the Storm Retention Basin (SRB) is shown on Figure 7-4. Existing subcatchment areas were retained for the computation of future runoff determination. Basin parameters used in the model included:

- Infiltration parameters for impervious areas based on calibrated runoff parameters used in the existing level of service simulations.

- Percent impervious parameters were changed to reflect those for developed catchments. The existing catchment north of Parker Avenue is undeveloped grassland with 0% imperviousness. Under future development, the percent imperviousness was increased to 32% for residential areas and 90% for commercial developments. When using the XP-SWMM runoff method in XP-SWMM and the calibrated runoff and infiltration parameters, an increase in percent imperviousness to 90% was found to be equivalent to the rational method runoff coefficient of 0.55 recommended by the City for commercial developments (Discussions with Grant Mohr, Branch Head - Land Drainage and Flood Protection, City of Winnipeg Water and Waste Department).

Runoff from the future residential developments in this area was directed east toward the pond, which was assumed to have an area of approximately 1.0 ha and a pumping capacity of 0.2 m^3/s.

The storage retention basin was designed according to the City of Winnipeg standards as documented in Table 2, Appendix A (Criteria for Stormwater Management prepared for the City – UDI Task Force Group, February 22, 2001), as outlined below:

- Runoff based on 1:25 year - 10 minute interval summer rainstorm
- Maximum design water level rise during 25-year at 1.2 m

It was assumed that outflow from the storm retention basin would be pumped to near Pembina Highway (Node 60011075) on Parker Avenue. For the 25-year event under existing conditions, the peak outflow from the Parker Area was calculated as 0.85 m^3/s. The outflow from the developed area was limited to the peak outflow under existing conditions by adjusting the physical and hydraulic parameters of the storm retention basin.

For the relief alternative, it was necessary that the runoff from the future land drainage area would be routed through the pond and then pumped into the Cockburn combined sewer under controlled flow conditions. The peak pumping rate would be restricted to be no greater than the runoff to the existing combined sewer from the undeveloped land, to satisfy City of Winnipeg land drainage regulations for new developments. The direction of the pumping flows to the combined sewer, however, would result in separated land drainage runoff being directed to the City of Winnipeg Wastewater Treatment Facility. This had been recognized as not being ideal. As an alternative, the runoff from the pond could be directed to the adjacent Somerset land drainage system to the South of Parker Avenue. Since the capacity of this system to accept flow from the Cockburn system is not known, this arrangement was not used. However, the opportunity to direct the runoff to Somerset land drainage system should be investigated in the future.

The land drainage separation alternative would be more amenable to the pond alternative. Discharge from the pond would discharge to the land drainage sewers and ultimately to the river without increasing the flow to the wastewater treatment plant.

Figure 7-4 shows the future development scheme for the vacant land north of Parker Avenue.

Figure 7-4: Parker and Taylor Future Developments

7.5 LANDS ADJACENT TO SOBEYS ON TAYLOR AVENUE

The final area for which future development is likely in the Cockburn District is located east and west of Sobeys on Taylor Avenue. It should be noted that Sobeys is not shown on the aerial image in Figure 7-4 since it was taken in 2002, before the construction of the grocery store. Similar to the area north of Parker Avenue, Manitoba Hydro has reviewed the cost of relocating the transmission lines in this region for potential developers and has indicated that some preliminary proposals for commercial developments have been submitted for this area. To date, none of these proposals have materialized.

For the purpose of this assessment, it was assumed that the likelihood for development would be relatively high, and that the development would likely be a commercial area, similar to the recent developments along this section of Taylor Avenue.

Future developments of these undeveloped lands south of Taylor Avenue will increase combined sewer flows in the Cockburn and Calrossie Combined Sewer Relief District. It is estimated that if this runoff is discharged to the Cockburn Combined Sewer System, the discharge at the downstream end of the Taylor relief sewer for a 5-year summer event would increase from approximately 2.3 m^3/s to 3.3 m^3/s. The increase in flow is based on modifications to the runoff parameters described in Section 7.4 for the area north of Parker Avenue.

The increased flows could be accommodated by increased relief sewer sizes along Taylor Avenue and downstream to the Cockburn Combined Sewer outfall. However, similar to the undeveloped area north of Parker Avenue, it was assumed that a storm retention basin would be constructed in this area to limit the peak discharges from this region to existing conditions for a 25-year event. As referenced previously, the 25-year summer event for the City of Winnipeg was used for the design of the storm retention basin based on the City of Winnipeg (2001) design standards.

The optimal location for the storm retention pond was assumed to be south of the Manitoba Hydro parking lot, north of the CN tracks. This location was selected to reduce the distance in pipe length for which an increase in volume would occur due to development flows. It was also assumed that the pond should be constructed in the area, which would best suit the development. Vacant property along Taylor Avenue was therefore assumed to be the most desirable location for future development.

To meet the City of Winnipeg criteria, a pond size of 0.62 ha was modeled for the Taylor Avenue developments, with an assumed pumping rate of 0.1 m^3/s. For the 25-year event, the peak outflow under developed conditions from the Taylor Area was restricted to 1.8 m^3/s, which is equivalent to existing conditions. Similar to the Parker Pond, the outflow from the developed area was limited to the peak outflow under existing conditions by adjusting the physical and hydraulic parameters of the storm retention basin.

Similar to the relief piping alternative for the Parker future development, runoff from the pond would be directed to the Cockburn Combined Sewer under controlled flow conditions. As with the Parker future development, land drainage flows could be directed south under the CN tracks to be combined with runoff from Parker to the Somerset land drainage system. Under such an arrangement, the Taylor pond could be eliminated with all runoff directed first to the common Parker Pond. The feasibility of this arrangement is recommended for future review.

For the land drainage separation alternative, the pond discharge would be directed to a separate land drainage sewer similar to the Parker Lake approach.

8.0 RELIEF/SEPARATION ALTERNATIVES

8.1 INTRODUCTION

Previous work conducted by the City of Winnipeg (1986) indicated that extensive flooding in the district would occur for the 2-year design storm. Similar results were calculated as part of the existing level of service evaluation for this study. As such, it is anticipated that major relief works will be necessary to achieve the City standard of at least a 5-year level of service. The design storm was simulated in the model using the 5-year design storm discretized on a 10-minute time step as defined by Stantec (2000). The results from this analysis were used to identify problem areas that required increased capacity to handle the design storm.

The development of relief alternatives was initiated based on results obtained during the calibration of the model and the existing level of service evaluations, as well as discussions during the course of the study and at progress review meetings with the Water and Waste Department.

Alternatives were developed and analyzed to provide a system capable of meeting the design criteria for the 5-year design storm. A number of design alternatives were investigated, including:

- ***Various Levels of Sewer Separation*** - Separation can be achieved through 2 approaches, either waste water separation (WWS) or land drainage separation (LDS). Wastewater separation is achieved by the construction of new wastewater pipes, with the existing combined sewer system used as the land drainage system. With the installation of wastewater separation, homes are disconnected from the storm flows and the combined sewers can surcharge to street level without causing basement flooding. Land drainage separation as opposed to WWS separation is achieved by the construction of new land drainage sewers, with the existing combined sewer system used to convey wastewater only. As a relief alternative, enough separation must be incorporated to eliminate flooding for the design level of protection. That is, in most cases, the entire area doesn't need to be separated. Complete separation would provide the highest level of service including the reduction in combined sewer overflows (CSO).

Because separation is costly, it is seldom selected as an independent method of relief, and it is more often used in combination with relief piping. Under certain circumstances, such as for areas close in proximity to the river, partial separation can provide a least cost alternative. Separate land drainage sewers are typically most efficient where flooding is located near an easily accessible outfall location.

- ***Replacement and Capacity Upgrading of Sewers*** - If hydraulic grade line backup due to high surcharge levels in the trunk and major laterals contributes to the cause of basement flooding, the provision of sewer relief pipes is likely to provide the most efficient relief.

- ***Street Storage Systems*** - Another means to reduce basement flooding in the combined sewer district is the use of above and below ground storage, in conjunction with flow restrictors on the inlet pipes. Such street storage systems often refer to temporarily storing stormwater in urban areas on the surface and, as needed, below surface close to the source. Based on comments provided by the Water and Waste Department, however, it was concluded that inlet restrictions may not be as effective as originally anticipated and street storage was therefore not considered as part of this study.

The most cost-effective approach to relief may include a combination of storm relief sewer and relief separation. All of these types of alternatives and combinations of each were considered in the assessment of relief/separation alternatives.

8.2 STORM SEWER RELIEF ALTERNATIVES

8.2.1 Method of Analysis

The storm relief sewer (SRS) alternative used the calibrated model of the existing system as the basis of the evaluation using model parameters determined in the model calibration process. The City of Winnipeg 5-year, 10-minute design summer rainstorm was substituted for the calibration rain event.

The selection of relief sewers was based on the requirement to lower the hydraulic grade line (HGL) to a minimum of 2.4 metres below the ground surface. The City of Winnipeg Sewer Management System defining the condition grade for sewers in the Cockburn and Calrossie District was considered in the final selection of the SRS.

8.2.2 Existing Sewer System Limitations

Computed hydraulic grade line (HGL) profiles for the existing sewers with the 5-year design runoff were used as an indicator of potential sewer upgrade methods. For example, if the HGL in the trunk sewer was shown to be lower than the critical 2.4 metre freeboard limit, providing increased sized lateral sewers could be effective in providing the required basement flood relief. Conversely, where the HGL in the trunk sewer was above the 2.4 metre freeboard limit, relief piping using large storm relief sewers would be required before lateral sewer upsizing could be effective.

The Cockburn and Calrossie Combined Sewer System is comprised of two distinct areas separated by the CN tracks. The Lord Roberts or Cockburn East area lies to the east of the CN tracks and Pembina Highway. The Cockburn West or Grant-Taylor area is comprised of the portion of the district to the West of the CN Fort Rouge Yards. This area is bounded by Grant Avenue to the North, and Parker Avenue to the South. The location plan showing major trunk sewers serving the district is shown on Figure 8-1. Reference numbers for the HGL profiles discussed below, are also shown on the figure.

The Cockburn East area is drained by a major trunk sewer along Cockburn Street as shown on Figure 8-1 and Figure 8-2. The Cockburn West area, including Southeast Jessie is drained by 4 major trunk sewers that connect to the Cockburn outfall via a major trunk sewer from Pembina Highway along Jubilee Avenue. The hydraulic grade line profiles along these trunk sewers are shown on Figures 8-3, 8-4 and 8-5. Figure 8-6 shows the major sewer on Lilac Street that drains the Southeast Jessie area to the Jessie combined sewer system at Lilac Street and Grant Avenue.

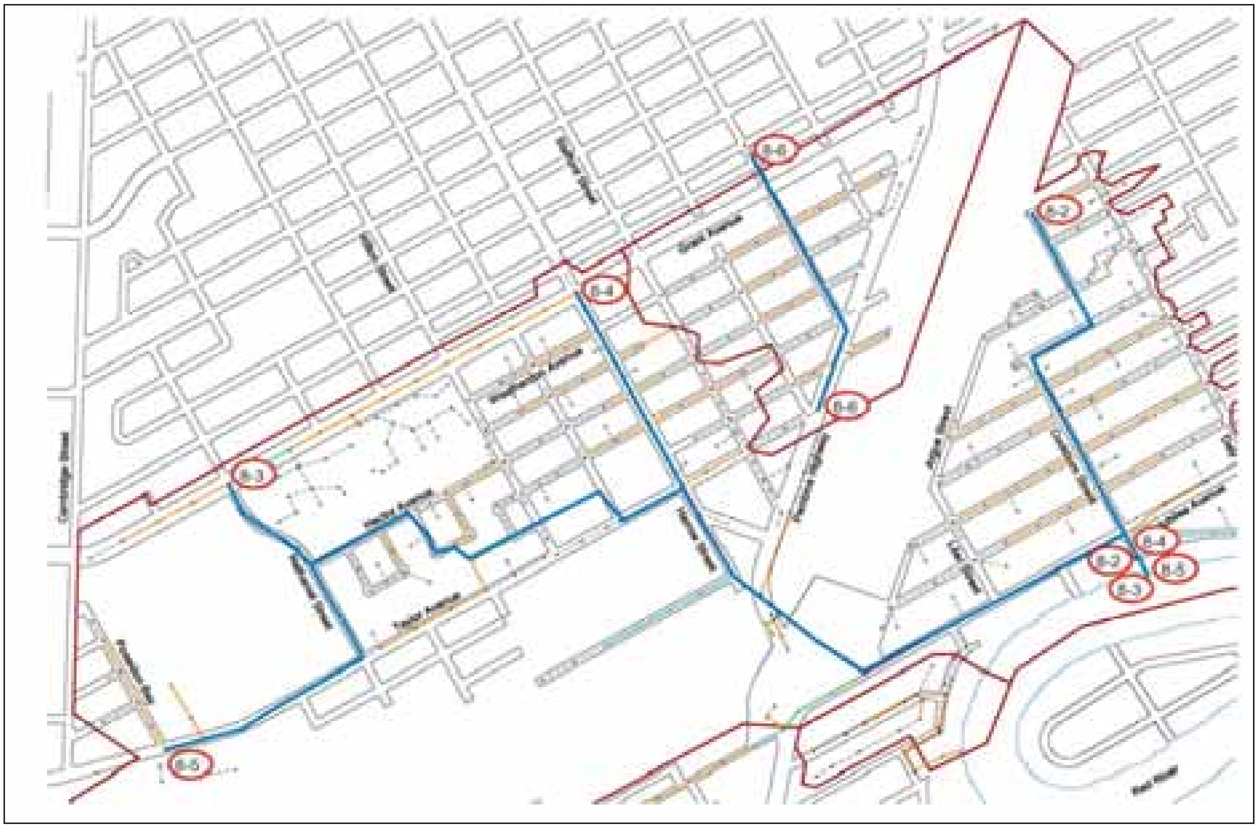


Figure 8-1: Plan View of Profiles

Cockburn East - Storm runoff from this area is conveyed to the Cockburn outfall via a 900 x 1725 mm egg-shaped sewer on Cockburn Street. This sewer runs down the centre of this area, with runoff conveyed from Daly Street to the east and Lilac Street to the west, via small lateral sewers. The lateral sewers are generally in the range from 300 to 375 mm in diameter. The sewer diameters in the Cockburn and Calrossie Combined Sewer District are shown on Drawing 1.

Hydraulic grade line profiles were used as an indicator of the need to upgrade the trunk sewers. For example, the HGL profile for the Cockburn trunk (Figure 8-2) is less than 2.4 m from the ground surface for nearly the entire length and therefore does not have sufficient capacity for the 5-year design rainstorm. Based on this conclusion, storm sewer relief for this area considered providing Storm Relief Sewers (SRS) along Cockburn Street to lower the HGL a minimum 2.4 metres below the ground surface.

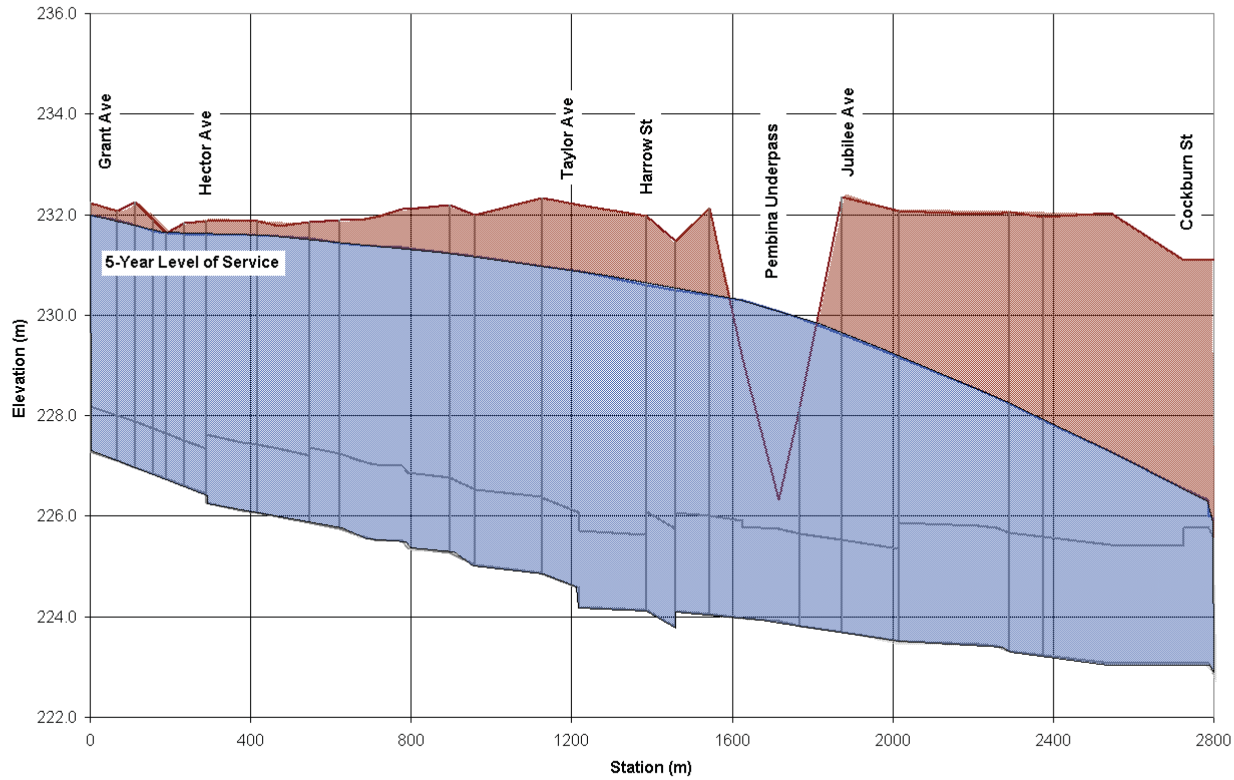


Figure 8-2: Profile along Cockburn Street and Hugo Street

Cockburn West (Grant-Taylor) - The Cockburn West area is drained at the downstream end by a 2175 x 2800 mm egg-shaped trunk sewer along Jubilee Avenue from Pembina Highway to the Cockburn outfall. Within the Cockburn West area, three major trunk sewers convey runoff to the Jubilee trunk sewer.

The HGL profile shown in Figure 8-3 is within the critical 2.4 metre freeboard limit throughout the entire Cockburn West area from the Pembina Highway underpass to Grant Avenue.

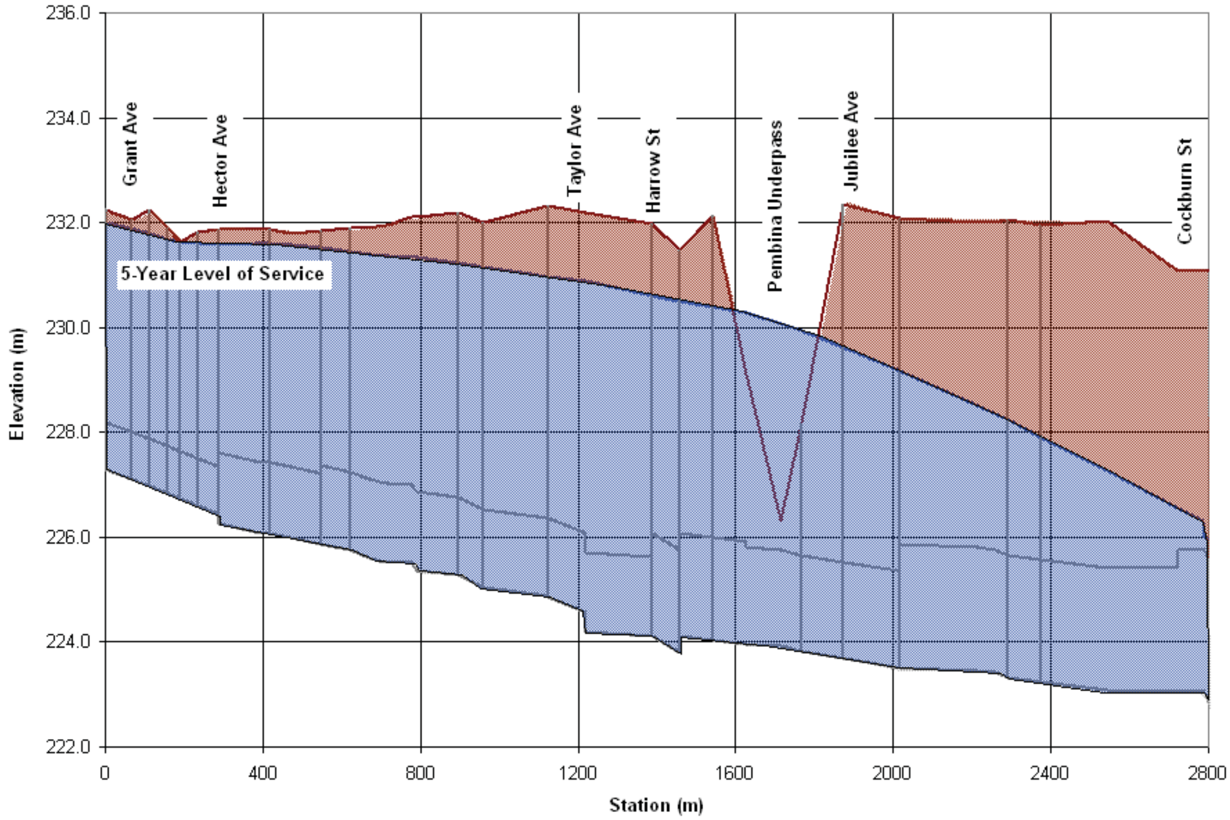


Figure 8-3: Profile from Grant Avenue along Nathaniel Street and Hector Avenue to Cockburn Outfall

The HGL profile shown on Figure 8-4 follows Harrow Street from Taylor Avenue to Grant Avenue. This profile is also within 2.4 metres of the ground surface through the entire Cockburn West district. Trunk sewer relief would therefore be required before relief of the lateral sewers would be effective.

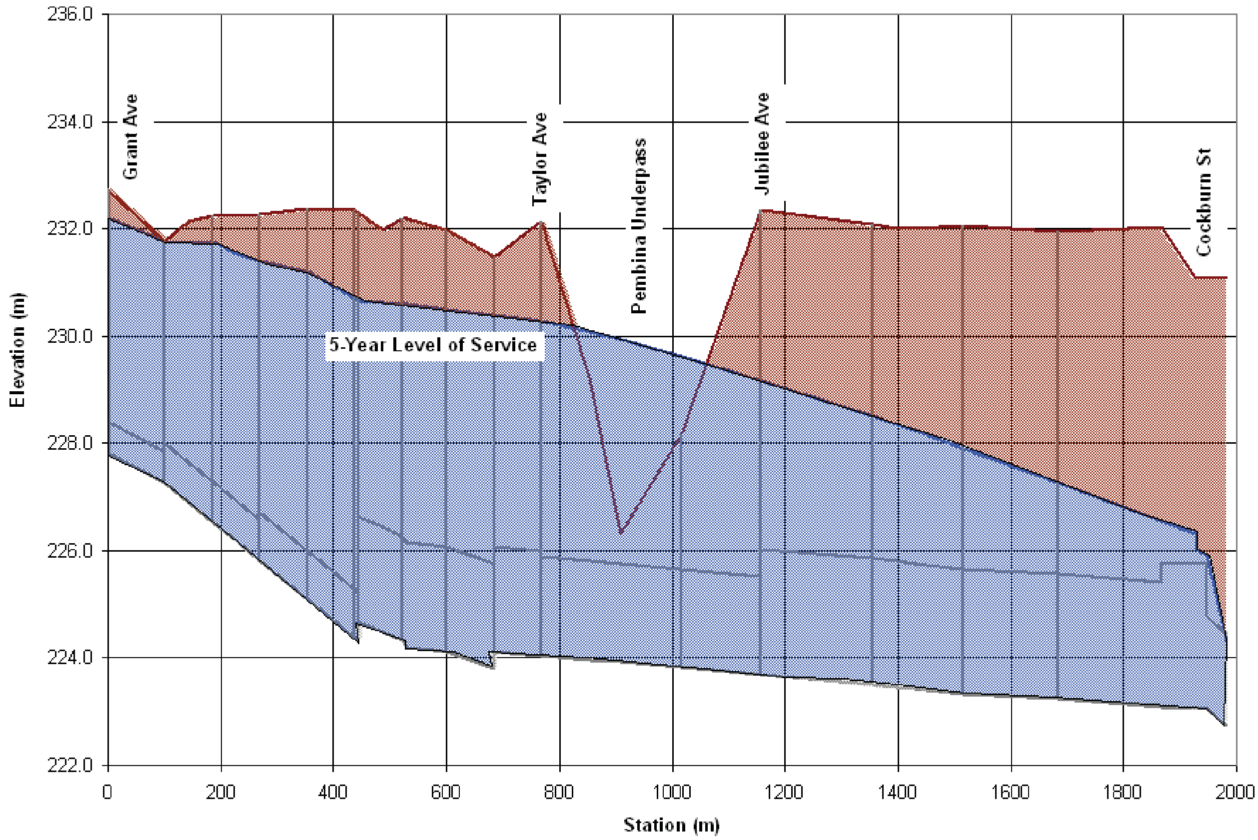


Figure 8-4: Profile from Grant Avenue along Harrow Street to Cockburn Outfall

The area west of the Grant Park Shopping Centre between Grant Avenue and Taylor Avenue is drained by a trunk sewer from Poseidon Avenue to the trunk sewer at Hector Avenue and Nathaniel Street (HGL profile 8-5). The HGL profile shown on Figure 8-5 rises within the 2.4 m basement flood level criterion for the 5-year rainfall event. Trunk sewer relief would therefore be required in order for lateral sewer relief to be effective.

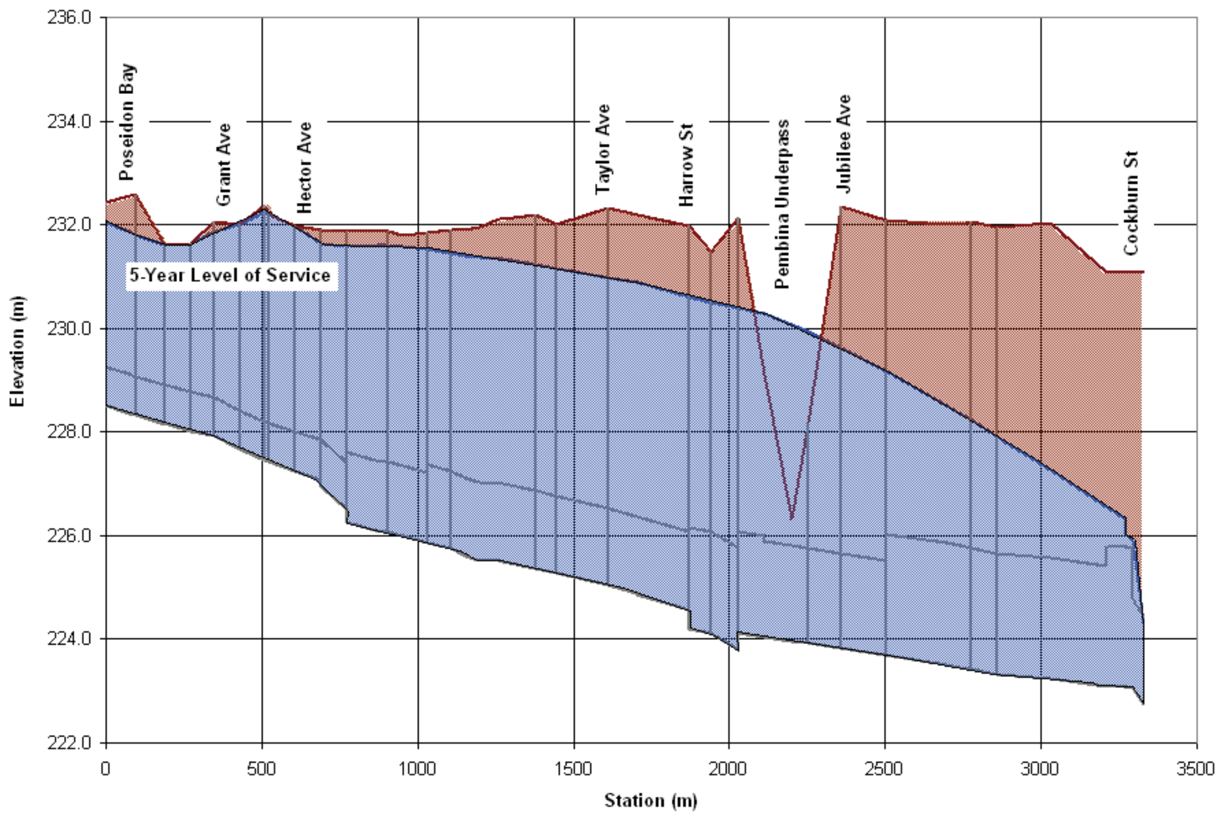


Figure 8-5: Profile from Poseidon Bay to Cockburn Outfall

Southeast Jessie - The southeast portion of the Jessie Combined Sewer District that was not relieved previously has been included in the Cockburn Sewer Relief Project. As shown on Figure 8-1, the area is located south of Grant Avenue bounded roughly by Hector Street and Pembina Highway. This area presently drains to the Jessie combined sewer by a 450 mm trunk sewer along Lilac Street (see Figures 8-1 and 8-6). The HGL profile for the 1:5 year flood, shown on Figure 8-6, rises to within the 2.4 m of the ground surface for the 1:5 year flood.

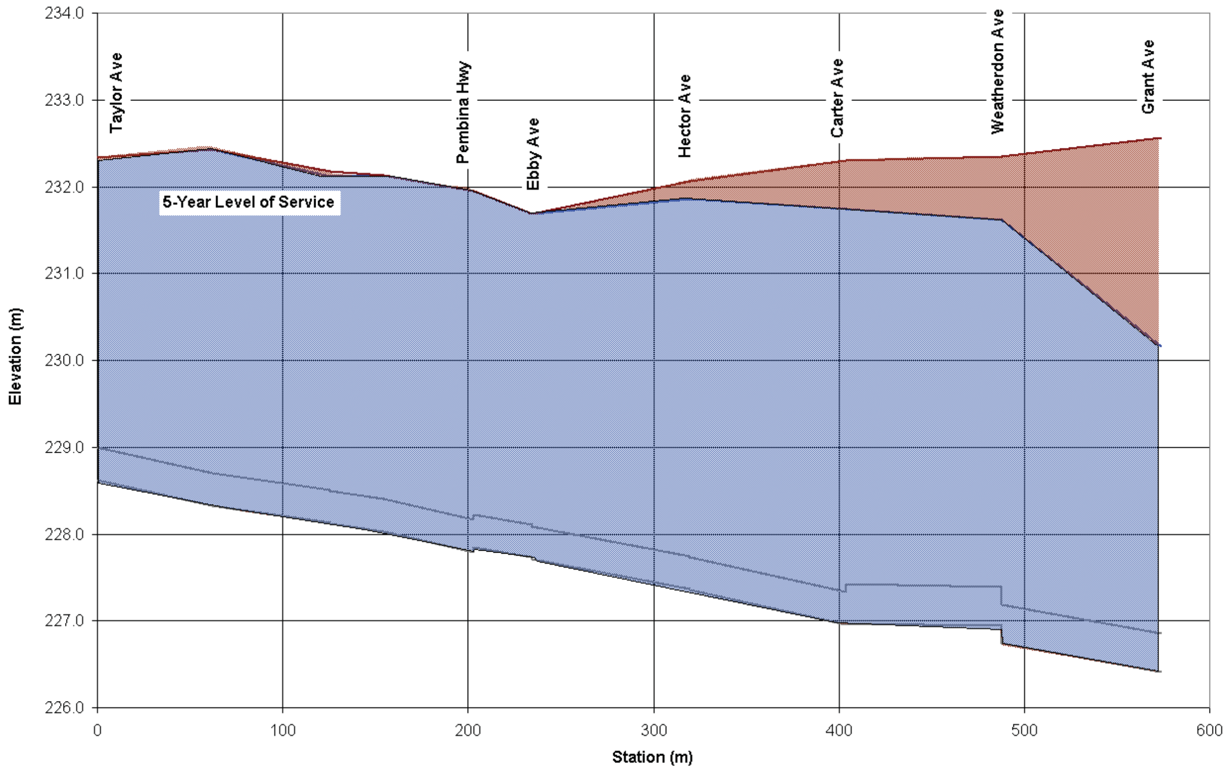


Figure 8-6: Profile along Lilac Street

8.2.3 Storm Sewer Relief Schemes

8.2.3.1 Storm Sewer Relief of Cockburn and Calrossie Districts (Without Jessie)

Cockburn East (Lord Roberts) - Hydraulic relief in the Cockburn East or Lord Roberts area considered firstly the provision of SRS pipes along Cockburn Street to lower the maximum water levels in the Cockburn trunk sewer. Initially, lateral sewers that tied into the existing and relief sewer were not increased. Provision of the SRS pipes along Cockburn by itself, however, was not sufficient to relieve flooding in the majority of the district. The small lateral sewers leading to the Cockburn storm relief sewers were generally 300 to 375 mm in diameter. Hydraulic losses in these lateral sewers required additional relief sewers on nearly all the lateral sewers to reduce the water levels below the critical basement flood levels.

As an alternative to upgrading the lateral sewers, SRS sewers along Daly Street, Lilac Street and Argue Street, in addition to the Cockburn SRS were considered. A cursory cost estimate showed that the storm relief within the trunk sewers was a more cost-effective alternative to that of lateral sewer relief. The location and diameter of the storm relief sewers are shown on Drawing No. 2.

Cockburn West (Grant-Taylor) - Hydraulic relief for Cockburn West included the 1600 mm diameter SRS pipe along Jubilee Avenue in Cockburn East and along Harrow Street in the Cockburn West. The relief sewer along Jubilee Avenue lowered the HGL at Harrow Street and Taylor Avenue by approximately 3.5 metres.

The storm sewer relief for Cockburn West, without consideration of Southeast Jessie, is shown on Drawing No. 2. Main features of the Cockburn West storm sewer relief alternative include the following:

A 1600 mm SRS along Jubilee Avenue to Harrow Street at Taylor Avenue - The provision of the 1600 mm SRS resulted in significantly lower water levels at Harrow Street and Taylor Avenue. The HGL at this location was reduced from an elevation of 230 m to an elevation of 226.3 m.

SRS along Harrow to the East side of the Grant Park Shopping Centre following Harrow Street to Weatherdon Avenue, and to Wilton Avenue. The relief sewer size varied from 1200 mm to 450 mm.

Runoff from the area to the West of the Grant Park Shopping Centre was routed to a 1200 mm SRS pipe constructed on Nathaniel Street to Taylor Avenue.

A 1600 mm SRS was provided along Taylor Avenue to 1600 mm SRS on Harrow Street - This SRS routed flow from the west side of the Grant Park Shopping Centre directly to the SRS on Harrow Street.

The 1350 mm trunk sewer on Hector Avenue at Nathaniel Street was disconnected from the 900 mm trunk sewer on Nathaniel Street. The diversion of the flow upstream of this point to the 1200 mm SRS on Nathaniel Street resulted in reduced flows on the existing 1350 mm trunk sewer on Hector Avenue. The existing sewers connected to the Hector trunk sewer from Nathaniel Street to Harrow Street were then adequate to handle runoff to these sewers. No additional relief pipes were required for this area.

A SRS along Taylor Avenue to Poseidon Bay varying in size from 750 mm at Nathaniel Street to 600 mm at Poseidon Bay.

Future development of the Parker area and along Taylor Avenue would drain to storage retention ponds with controlled outflows being pumped to the downstream Cockburn combined sewers in both cases.

The estimated cost of the Cockburn without Jessie Storm relief sewer alternative is $9.16 million (1991 Dollars). The project cost does not include the costs for the construction of the ponds or sewer cost for servicing the undeveloped lands.

8.2.3.2 Relief of Cockburn and Calrossie Districts (With Jessie)

The Cockburn and Calrossie Combined Sewer Relief Districts with Jessie included is shown on Drawings 3 and 4. These drawings represent the Jessie relief with and without relief of the commercial area along Pembina Highway as described below.

Simulations of the hydraulic conditions during the 5-year design rainfall event show the HGL above the ground surface throughout this area. With the HGL at or above the ground level, widespread basement flooding would be expected. Based on field investigation and phone enquiries to the commercial properties in the area, however, it has been concluded that nearly all the businesses have no basements. Surface flooding of the streets during large rain events would therefore be a problem for traffic safety due to street flooding and to possible flooding of the Pembina/Jubilee underpass. Relief of the Southeast Jessie District was therefore considered with and without relief along Pembina Highway.

The option to relieve flooding along Pembina Highway was also considered so that the level of service would be consistent throughout the entire district.

The option to exclude relief of Pembina Highway was undertaken in order to determine the added costs for the Pembina Highway relief. Since sewer relief at Pembina Highway would provide mainly relief of street flooding, it may be possible to cost-share the costs of Pembina Highway relief with the City of Winnipeg Streets and Transit Department.

The relief of the Jessie District with relief sewers for the commercial area along Pembina Highway is shown on Drawing 3. The high runoff from the commercial area required large diameter sewers along Pembina Highway to convey the flow. The high runoff rates also required a 1600 mm diameter SRS along Ebby Avenue connecting the Southeast Jessie combined sewer system to the Cockburn District. The additional flow from the Southeast Jessie District also required that the Harrow and Jessie SRS be increased to 2100 mm.

The estimated cost of Cockburn and Calrossie Combined Sewer Relief Districts with Jessie and Pembina Storm Relief Sewer option is $12.35 million (1991 dollars).

The relief of Jessie without improvements along Pembina Highway is shown on Drawing 4. Since the Pembina Highway sewers are of such small diameter, the flow to the downstream sewers in Southeast Jessie from Pembina Highway is very limited, with much of the runoff stored on the street. The reduced flow resulted in a smaller diameter sewer for the principal SRS along Ebby Avenue connecting the Southeast Jessie area to the Cockburn District.

The required diameter for the Ebby SRS is 1200 mm for this alternative compared to 1600 mm if larger conduits are used with the Pembina relief alternative.

The estimated cost of the storm relief sewer option for the Cockburn and Calrossie Combined Sewer Relief Districts with Jessie, but without relief of Pembina Highway is $11.331 million (1991 dollars).

8.2.3.3 Relief of East Side of Cockburn District Only

Relief of Cockburn East along the required conduit diameters for SRS pipes along Lilac, Cockburn and Daly Streets is the same size as those for relief of both Cockburn East and West. The primary difference, however, was that the 1600 mm SRS along Jubilee Avenue from Cockburn Street to Pembina Highway was not required for the relief Cockburn East only. The existing trunk sewer on Jubilee Avenue was shown to have adequate capacity with the HGL computed at the critical basement flood level. This is partly due to the lower runoff from Cockburn West if that area is not relieved.

The total estimated cost in 1991 dollars for the storm relief sewer alternative for relief of the east side of the Cockburn District only is $2.505 million.

8.3 SEPARATION ALTERNATIVES

Sewer separation was considered as a method of basement flooding relief. Sewer separation in combined sewer districts involves the construction of a second piping network within the district such that storm water runoff and sanitary sewage are collected and conveyed in separate systems. The two approaches for separation are to either construct a new land drainage piping system or a new wastewater piping system. Both approaches to separation have the advantage of reducing the amount of surface runoff collected in the wastewater system, resulting in a reduction in combined sewer overflows and the amount of wastewater to be treated.

The extent of the sewer separation alternatives depends on the objectives and may involve either complete or partial separation. For partial separation, only enough area is separated to achieve the 5-year level of basement flooding protection. Complete separation involves extending the separation alternative to the entire sewer district, which would provide a full two-pipe system similar to what has been used in new developments for the last number of years. Both partial and complete separation was considered in this study.

Method of Analysis

The sewer separation alternative evaluations were undertaken in a manner consistent with that used for relief piping alternatives. The existing system calibrated model provided the basis for the evaluation, with no changes to the calibration parameters. The future development assumptions, as described in Section 7.0, were used to design the separation alternatives, just as they were for the relief piping evaluations. The only modification for the analysis was the requirement for quantification and modeling of rainfall dependent inflow and infiltration.

With either separation approach, the land drainage sewers convey only the road drainage and not weeping tile drainage. For land drainage sewer (LDS) separation, the street inlets are connected to the new piping system. Sanitary sewage, connected downspouts and weeping tiles continue to discharge to the original combined sewers, which essentially function as wastewater sewers in the separated areas. For wastewater (WWS) sewer separation, building service connections are reconnected from the combined sewer to the new wastewater sewer. The wastewater sewers collect sanitary sewage, connected downspout flows and weeping tile drainage while the original combined sewer conveys only road drainage in the separated area.

8.3.1 Wastewater Sewer Inflow and Infiltration

The inflow and infiltration component of combined sewer flows is of more concern for separation than it is for relief piping alternatives. Sewer monitoring and computer model calibration (as discussed in Section 4.0) are based on the flows generated from all contributing sources. Since relief piping is sized for the total flow, there is no requirement to partition the flows into the various components. In contrast, separation alternatives receive flow from specific sources, which must be identified and quantified in order to analyze and design the sewer systems.

The wastewater sewers must convey base flow and rainfall dependent inflow and infiltration (RDII). The wastewater flows included in the separation analysis consisted of the following components:

- Sanitary sewage base flow
- Summer dry weather groundwater infiltration
- Rainfall dependent inflow and infiltration
- Rainfall dependent weeping tile flows (also referred to as foundation drains)

Sanitary sewage is comprised of residential, commercial and industrial discharges. The sewer separation analysis used the calibrated dry weather flow model as the basis for development of sanitary flows. Individual subcatchment flows were determined based on land use and wastewater generation rates. The model was calibrated to match the measured dry weather flow discharge. The average dry weather flow for the entire district was previously measured to be 24 L/s.

A significant increase in dry weather flow was found to occur during the summer months, which had not been quantified under the 2004 monitoring program. A second flow monitoring program was undertaken in 2006 that included measurement of lift station flows in the late summer. It showed a district wide increase between winter and summer dry weather flows of a constant 10 L/s. The increased flows were attributed to groundwater infiltration through pipe and manhole joints and cracks, and groundwater collected by weeping tiles. The additional flow was not included in the original dry weather flow model, but was added for the wastewater sewer separation flow estimates.

The rate of inflow and infiltration increases greatly during wet weather as water ponds on the surface and infiltrates into the soil. These rainfall dependent inflow and infiltration rates depend on the configuration of the system and its condition. Water ponding over manholes produces high rates of inflows, and older pipes in poor condition have high rates of infiltration. For the Cockburn and Calrossie Districts, a value of 15 L/minute/manhole was considered for manholes located where surface ponding would occur. This was assumed to encompass 50 percent of the manholes in the district. Based on 400 manholes in the service area, a flow allowance of 50 L/s would be required.

Weeping tiles collect the groundwater drainage from around the perimeter of houses and other buildings. In older parts of the City the weeping tiles discharge directly to the sanitary sewer in the building, which is connected directly to the City sewer. The amount of flow generated varies widely depending on the ability for surface water to reach the drains. In older areas such as the Cockburn and Calrossie Districts where lot grading is poor, significant runoff from rainfall is expected to drain towards the house and find its way to the weeping tiles.

An investigation of the contribution from weeping tiles was completed by Wardrop Engineering (1978). The study developed a method of predicting the quantity of flow by relating the discharge to the condition of the lot grading. Four characteristic weeping tile hydrographs were established which depend on the condition of the individual house lot grading. For the Cockburn and Calrossie Combined Sewer Relief Districts evaluation of the lot grading was assumed to be “poor”, which indicates the peak weeping tile per house would be approximately 24 litres per minute for what is equivalent to a 10-year return period. The study did not develop a relationship for the amount of flow for different return events.

The weeping tile inflow was added to the Cockburn and Calrossie Combined Sewer Relief Districts model for each house where applicable, for use in estimating wastewater sewer flows. A dampening factor, as recommended in the Wardrop (1978) report, was applied to the houses within each subcatchment, with the resulting flow input into the XP-SWMM model at each input node. Routing of the inflows was then carried out dynamically through use of the XP-SWMM model.

No allowance was added for connected downspouts. The number of connected downspouts is very low and it was assumed that complete disconnection would be made as a prerequisite for sewer separation alternatives.

The combined flows produced a discharge for the sewer district as shown in Figure 8-7. This represents the total flow collected by a wastewater sewer under the complete wastewater separation alternative. As noted the combined peak flow is approximately 700 L/s, which far exceeds the current Cockburn lift station peak capacity of 105 L/s.

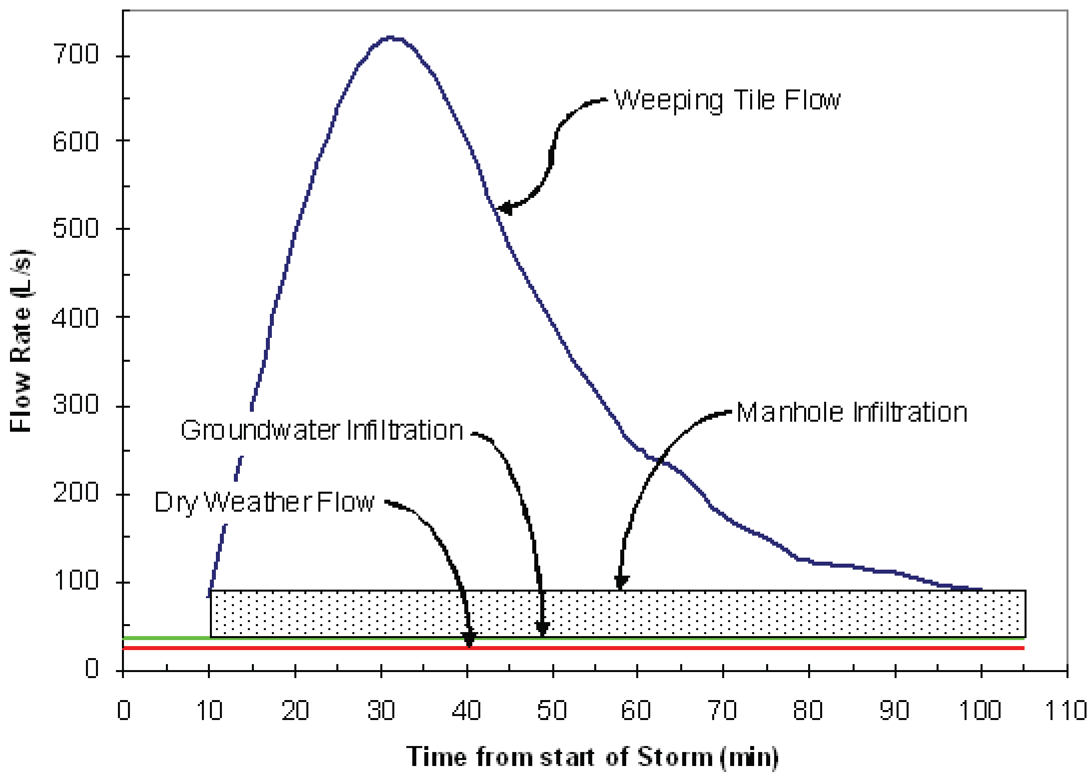


Figure 8-7: Cockburn District – Separate Wastewater Sewer Flows

The wastewater system flows were applied to the area being separated for both the LDS and WWS separation alternatives. The wastewater flows were not applied to areas that were not separated for both the LDS and WWS separation alternatives, since the flows would already be accounted for in the surface runoff and dry weather flow inputs.

One of the limitations in the analysis was the absence of a relationship between RDII flow and the frequency of occurrence. The Wardrop (1978) study provided flow information for a 10-year frequency, but there was no information available for events that are more frequent. The 10-year flows would be somewhat higher than the expected actual for the 5-year relief design, and was compensated for by eliminating the equivalent of the manhole infiltration component. The impact of not knowing the RDII flow-frequency relationship was determined to be minimal for basement flooding considerations, but significant for estimation of combined sewer overflows, as will be discussed in Section 12.0.

8.3.1 Land Drainage Separation

The LDS separation design was based on standard City of Winnipeg design criteria for new land drainage sewers:

- 5-year design storm
- surcharge permitted to a level of 0.3 metres below grade
- minimum pipe cover of 1.5 metres

The existing combined sewer system would be retained as a wastewater sewer, which depending on the level of separation may or may not also receive road drainage. Cleansing velocities in the large combined sewers are typically adequate because the egg-shaped configuration, with a reduced cross section at the lower flow range, causes an increase in velocity.

8.3.1.1 Complete Land Drainage Separation System (Without Jessie)

The complete land drainage separation alternative for Cockburn without Southeast Jessie is shown on Drawing 6.

- New land drainage sewers would be required throughout the Cockburn area to collect runoff from every existing street inlet, resulting in an extensive sewer network with large diameter pipes.

- Calrossie has already separated so it does not require additional sewers.

- Future development in the Parker area will drain to a retention pond, as discussed in Section 7.0. The pond will drain to a new LDS located on Parker Avenue.

- Future development of the Taylor area will require flow restriction to existing conditions, whether through use of a retention pond or detention storage.

- Grant Park Shopping Centre parking lot drainage will connect to the LDS on Grant Avenue.

- The system terminates at the existing Cockburn outfall, which would be converted to a land drainage outfall since because of the total separation a combined sewer outfall would not be required.

The complete land drainage separation alternative would provide a 5-year level of protection against street flooding, which is consistent with the level of service provided in separated sewer areas.

The existing combined sewer system would collect the sanitary sewage as well as the wet weather inflows and infiltration and flow to the existing Cockburn lift station. The wastewater sewer would provide a level of service, which exceeds the 5-year level because the existing combined sewer is significantly oversized as a wastewater sewer. It is evident from the wastewater sewer analysis that in excess of a 10-year level of protection would be provided.

The total estimated cost in terms of 1991 values for complete LDS separation without Jessie is $17.57 million. The cost estimates do not include the construction of the Parker Lake, Taylor area flow attenuation or servicing in the undeveloped lands.

8.3.1.2 Complete Land Drainage Separation System (With Jessie)

The complete land drainage separation alternative discussed above could readily be extended to the Southeast Jessie area. Most of the components of the complete LDS separation alternative discussed previously would be retained, with the additional construction of a land drainage system in the entire Jessie area as shown on Drawing 7. The land drainage discharge from Jessie would be routed to the Cockburn outfall. The collector and trunk sewers would have to be enlarged to handle the additional flows, as noted by the comparison between Drawings 6 and 7.

The sanitary sewage for the Southeast Jessie area would continue to be collected by the existing combined sewers, and would continue to flow to the Jessie District.

The level of service for the Cockburn and Calrossie Districts would be identical to the LDS separation alternative without Jessie discussed above.

For the Southeast Jessie area, removing the land drainage would provide a 5-year level of street flooding protection and a 5-year level of basement flooding protection. The main Jessie area to which the southeast area connects has previously been relieved to a 5-year level of protection and completion of the LDS separation would complete the relief works for the Jessie area.

The total estimated cost in terms of 1991 values for complete LDS separation with Jessie is $21.16 million. The cost estimates do not include the construction of the Parker Lake, Taylor area flow attenuation or servicing in the undeveloped lands.

8.3.1.3 Partial Land Drainage Separation (Without Jessie)

The amount of area separated under the partial separation alternative was determined by progressively removing road drainage from the combined sewer system until flooding was eliminated for the 5-year storm. The weeping tile drainage and inflow and infiltration from the separated area would remain in the combined system. A land drainage system was then designed for the separated road drainage.

The partial LDS separation alternative for the Cockburn area without Southeast Jessie is shown on Drawing 8.

- Major pipes were required throughout the area to collect the separated catchbasin flows. The existing upper end laterals were generally found to be adequate in size once the separated areas were removed.

- Calrossie has already been separated so it did not require additional sewers.

- Future development in the Parker area will drain to a retention pond, as discussed in Section 7.0. The pond will drain to the north through a new LDS located on Wilton Street, flowing to Taylor Avenue.

- Restricted flow from the Taylor area development will also flow to the Parker Lake drain, on Wilton Street.

- Localized flooding immediately east of the new Parker Lake is to be relieved by separating the area and either discharging to the retention pond or to the Wilton pond drainage pipe downstream of the lake.

- Grant Park Shopping Centre parking lot drainage will continue to flow to the combined sewer located on Grant Avenue. Although the area is relatively easy to separate, it does not produce a significant improvement in basement flooding relief. If sewer separation for pollution control is the objective, it should be considered for separation.

- The system terminates at the existing Cockburn outfall, which is to be a dual-purpose outfall for the combined sewer discharges and separate land drainage. A second outfall location was considered, but because of riverbank stability issues, routing to the existing location was the preferred approach.

With partial separation, a large portion of the area will continue to function as a traditional combined sewer system, with the remainder of the area still being connected but having road drainage removed. The system will provide a 5-year level of basement flooding protection similar to that provided by a system with sewer relief pipes. The separated area will provide a 5-year level of protection for street flooding.

The total estimated cost in terms of 1991 values for partial LDS separation without Jessie is $9.88 million. The cost estimates do not include the construction of the Parker Lake, Taylor area flow attenuation or servicing in the undeveloped lands.

8.3.1.4 Partial Land Drainage Separation (With Jessie)

Including Jessie in the partial separation alternative requires the addition of LDS sewers in the Jessie portion as well as enlarging of the collector, trunk and outfall in the Cockburn area. Nearly complete separation of the Southeast Jessie area was necessary to provide a 5-year level of basement flooding protection. With this alternative, the amount of land drainage separation for the Combined Cockburn, Calrossie and Southeast Jessie areas is 120 hectares or 36 percent of the gross district area.

The partial LDS separation is shown on Drawing 9. The land drainage discharge from Jessie would be to the Cockburn trunk sewer, which would have to be enlarged from 1500 mm to 1800 mm to handle the additional flows.

The existing Jessie combined sewers will serve primarily as a separate wastewater sewer since most of the road drainage will be removed. The wastewater will continue to flow to the Jessie pumping station.

The other design elements, including the Parker area, Taylor Avenue development and Grant Park Shopping Centre are the same as for the partial separation alternative that excludes Jessie, discussed above.

As noted for the partial LDS alternative without Jessie, the area will have a 5-year level of basement flooding protection and a 5-year level of street service in the separated areas. The level of basement flooding protection will correspond to the level of protection provided in the Jessie district, which has been assumed to be a 5-year level since it is a relieved district.

The total estimated cost in terms of 1991 values for partial LDS separation with Jessie is $11.89 million. The cost estimates do not include the construction of the Parker Lake, Taylor area flow attenuation or servicing in the undeveloped lands.

8.3.1.5 Partial Separation of the East Side of Cockburn District Only

An evaluation of partial separation for the east side of the Cockburn District was completed to compare the separation alternative to the localized relief piping alternative discussed previously in Section 8.2.3.3. The piping schemes with and without consideration for Jessie are shown on Drawings 10 and 11.

The piping schemes utilize the identical components as the district wide partial LDS separation to permit staging of implementation, rather than optimization of the east side, which could potentially compromise the design for the remainder of the district.

The outfall modification would be included to permit the east side operation in advance of the entire district relief.

The total estimated cost in terms of 1991 values for partial LDS separation of the east side of Cockburn is $4.20 million.

8.3.1.6 Phased Separation Option

The option for expanding partial separation to complete separation as a second construction phase was evaluated as an additional service at the request of the City and is reported on in Appendix G. The option would require the main piping elements to initially be oversized in comparison to the 5-year level of basement flooding protection needs, and therefore would have a higher initial cost.

The rationale for transitioning to complete separation would be for CSO control. It would produce a marginal improvement in the level of basement flooding protection, which is not likely to be defensible in terms of a benefit-cost assessment, and not in keeping with the current Basement Flooding Relief program mandate.

8.3.2 Wastewater Separation

The construction of wastewater sewers instead of land drainage sewers for separation has the advantage that they convey less flow and consequently would be smaller in diameter. The sanitary sewage, weeping tiles, connected downspouts and system inflow and infiltration would be conveyed in the new system. Service connections would be reconnected to the new wastewater system.

The existing combined sewer system would convey either all or a portion of the road drainage depending on the extent of separation. The combined sewers would now be allowed to surcharge above basement levels, and in theory up to 0.3 metres below grade in areas where basement flooding is not an issue. For complete separation, there would be no wastewater in what is currently the combined system and flooding of the streets would not be a problem. For partial WWS separation however, if the combined sewer backed up into a separated area and flooded to the street there would be potential for runoff polluted with sewage to temporarily sit on the road surface.

The wastewater sewer separation design was developed with a spreadsheet approach, and was not hydraulically modeled. The initial wastewater inputs were assumed to be similar to that of a new development and included constant rate inputs, which did not require dynamic routing. Dry weather flow rates were obtained from the calibrated dry weather flow model and uniform inflow and infiltration rates were used. District specific weeping tile flow, inflow and infiltration was not included in the initial design.

The design parameters were based on standard City of Winnipeg design criteria for wastewater sewers in new areas:

- Minimum pipe diameter of 250 mm
- Minimum pipe slope of based on cleansing velocity and pipe size
- Cleansing velocity of 0.6 m/s
- Minimum depth of 2.6 metres

Subsequent to the initial estimates, the RDII flow components, as discussed in Section 8.3.1, were developed. Being an older combined sewer area with poor lot grading, not having sump pumps, and having high system inflow and infiltration rates, the wastewater flows were found to be much higher than originally anticipated.

The wastewater design and costing included in the following sections are based on the standard design criteria, and not the Cockburn specific wet weather flow values. As will be discussed, wastewater separation as a relief alternative is not cost competitive and did not warrant updating to the new flow rates.

8.3.2.1 Complete Wastewater Separation (Without Jessie)

The WWS separation piping scheme basically parallels the entire Cockburn district piping system. The Calrossie area has already been separated and no new sewers were required. The new WWS systems was designed based on an alignment that follows the existing combined sewer system, which would provide a suitable gradient for reconstruction of the service connections to the new sewer. It would terminate at the Cockburn lift station wet well, which would be disconnected from the existing combined sewer system.

The existing combined sewer system would be retained as a land drainage system. It would be allowed to surcharge without the risk of basement flooding because the service connections would be disconnected.

The wastewater sewers were designed to the current City of Winnipeg design standards. Based on using the weeping tile criteria, the level of service would be in the order of a 10-year level of protection of service (not accounting for site-specific RDII).

The existing combined sewer system serving as a land drainage system would not provide a 5-year level of street service. Land drainage relief would have to be added to achieve the 5-year level.

The estimated cost in terms of 1991 values for complete WWS without Jessie based on standard design criteria is $13.44 million. The cost estimate does not include the construction of the Parker Lake, Taylor area flow attenuation or servicing in the undeveloped lands.

Modifications of the complete separation to a site-specific Cockburn area design would require the addition of:

- Increasing the RDII to the site-specific flows
- Including the cost of service connection reconnections
- Upgrading the combined sewer system to a 5-year level of street protection

Further in depth assessment of the WWS separation alternative was not pursued since the additional costs would clearly result in it not being cost competitive.

8.3.2.2 Complete Wastewater Separation (Jessie Only)

Complete WWS separation was considered for the Southeast Jessie area as a localized relief alternative. The wastewater sewers would be much smaller in size than the land drainage sewers, but would require that every service connection within the service area be reconnected.

- The WWS design did not include site-specific flows, similar to the case for complete WWS described above. However, this would not be expected to be an issue for the Jessie only alternative since the 250 mm diameter minimum size would govern and the sewers would generally be large enough to handle the higher flows.

- The wastewater sewers would be sized to prevent surcharging during wet weather to prevent basement flooding.

- Wastewater flow could continue to discharge to the Jessie District, or be redirected to the Cockburn District. It was assumed for the cost evaluation that a gravity discharge pipe would be routed to the Jessie District to a location with a low enough hydraulic grade line such that the backwater would not cause flooding. The Jessie District was not modeled and the hydraulic profiles are not known well enough to confirm this assumption. A more detailed evaluation would be required prior to adoption of this approach. As an alternative to the gravity discharge outlet, a lift station could be used to discharge to either the Jessie or Cockburn Districts. This option was not pursued in detail since it would add to the operating complexity of the system without providing a significant advantage.

The separated wastewater sewer would provide a 5-year level of basement flooding protection. However, since the outlet is to the Jessie Combined Sewer District, the level of protection would be governed by the level of protection provided in the Jessie District. Use of a lift station would ensure the design level of protection would be provided since it would be independent of surcharging in the Jessie Combined Sewer System.

The existing combined sewers would be allowed to surcharge since all basements would be disconnected. There is currently a very low level of service in the area and after installation of the WWS the street level of service would be less than the 5-year standard. Extensive land drainage relief pipes would be required to provide the 5-year street flooding design.

The total estimated cost in terms of 1991 values for WWS separation of the Jessie area is $2.69 million. The cost estimate does not include the cost of upgrading the combined sewer as a LDS to a 5-year level of street flooding.

8.4 HYBRID ALTERNATIVES

Hybrid alternatives refer to the combination of techniques such as relief piping along with separation to achieve an optimized solution. Often there are unique or localized areas where this technique is the most cost effective. A number of possibilities were considered, such as separation of areas adjacent to the river and use of additional outfalls.

8.4.1 Relief/Separation Hybrid

The Cockburn and Calrossie Combined Sewer Relief Districts can be divided into two distinct areas, east and west of the Fort Rouge Yards. The relief/separation alternative considers relief piping for the eastern side and partial LDS separation for the western side, as shown on Drawing 12.

The design and sizing for the east side is similar to that for the district-wide relief piping alternative, with implementation as described for relief of the East Side of Cockburn and Calrossie Combined Sewer Relief Districts, described in Section 8.2.3.3. The relief trunk along Jubilee Avenue would not be required since inflows from the west side of Cockburn would be relatively low from the existing west side sewer system without relief.

The west side of Cockburn and Calrossie Combined Sewer Relief Districts would be designed and sized similar to the district-wide partial LDS separation option in Section 8.3.1.4, with the exception that it would terminate in a new outfall. There would not be a requirement to collect the east side flows, providing the opportunity to reduce the trunk size and locate the outfall closer to the west side.

The new outfall was conceptually located at the footbridge public access location, as shown on Drawing 12.

The total estimated cost in terms of 1991 values for the relief/separation alternative, including Jessie is $12.20 million. An allowance of $300,000 was included to provide for additional construction of a gate chamber and riverbank stabilization. The cost estimates do not include the construction of the Parker Lake, Taylor area flow attenuation or servicing in the undeveloped lands.

8.4.2 Southeast Jessie Complete WWS Separation

Complete WWS separation of Southeast Jessie, as presented in Section 8.3.2 could also be used in combination with either relief piping or partial LDS separation in the Cockburn and Calrossie Combined Sewer Relief Districts.

The following combinations were considered:

- Jessie WWS separation with Cockburn relief pipes at a cost of $11.90 million (1991 dollars).
- Jessie WWS separation with partial LDS separation, at a cost of $12.20 million (1991 dollars).

The Jessie area separation and Cockburn area alternatives would be the same as previously discussed. A 5-year level of basement flooding protection would be provided for the Jessie area. However, extensive upgrading would be required to provide a 5-year level of street flooding protection.

9.0 BENEFIT-COST ANALYSIS

9.1 BENEFIT-COST METHODOLOGY

City Council adopted a policy for the Basement Flooding Relief Program which requires that project implementation be prioritized on a benefit-cost basis. The policy was based on a report prepared by the City of Winnipeg (1986) Water and Waste Department that reviewed the 34 unrelieved districts (out of the 43 total combined districts) on an individual basis and established a program approach and an implementation plan. The current Cockburn and Calrossie project is a part of that program and its prioritization for implementation is to be based on a benefit-cost approach consistent with the other areas being prioritized.

The methodology is set out in the 1986 Report, and requires quantification of benefits and costs. Benefits are calculated based on the difference in average annual damage estimates before and after implementation of relief works. Average annual damages are determined through development of flood-frequency-damage curves, by applying unit damages to flooding predictions for various design storm events. Costs for the benefit-cost analysis are based on the capital cost of the project, converted to an annual average value.

In order to provide a uniform benefit-cost comparison for the program, which extends over many years, the costs have been standardized to 1991-dollar values and the benefits to 1993-dollar values as more fully discussed in the following sections.

9.1.1 Project Costs

Project costs have been developed for each upgrading alternative presented in Section 8.0. The costs are expressed in terms of 1991-dollar values to be consistent with costs used in other relief projects, facilitating a consistent benefit-cost comparison among districts.

The unit costs in 1991 dollar values for relief piping as provided by the City for relief piping are presented in Table 9.1.

Table 9.1: Relief Piping Unit Costs - 1991-Dollars Basis

Pipe Diameter (mm)	1991 Unit Costs (per m)
250	$300
300	$360
375	$410
450	$460
525	$520
600	$565
750	$690
900	$850
1050	$1,170
1200	$1,170
1350	$1,170
1500	$1,300
1800	$1,500
2100	$1,700
2750	-

The unit costs include material and installation costs of the relief sewers, including the cost for manholes and catchbasins, connections to existing sewers, reconnection of service connections, pavement and sidewalk restoration and minor drainage appurtenances. Costs for major items such as outfalls and gate chambers are not included.

Total capital costs for each alternative were converted to annual cost for comparison with annual benefits to determine the B/C ratios. Overheads were added to the construction costs to develop a total implementation cost in terms of 1991-dollar values. The total capital cost estimates included the following:

- Construction capital costs based on unit costs
- Contingencies of 10 percent
- Engineering of 15 percent
- Burdens of 3 percent to account for in-house overhead
- Annualization of the costs based on a discount rate of 4 percent and a 50-year amortization.

The capital costs were then converted to average annual costs for use in the benefit-cost analysis.

A summary of costs for each Cockburn and Calrossie alternative is included in Table 9-2. Detailed cost estimates for each scheme are presented in Appendix C.

Table 9-2: Project Cost Summary Table – 1991-Dollar Basis

Alternative	DWG No.	1991 Const'n Cost ($1000)	Cont'y (10%)	Eng (15%)	Burden (3%)	1991 Total Capital Cost ($1000)	Average Annual Cost* ($1000)
Without Jessie							
5-Year Relief Piping	2	$7,160	$716	$1,074	$215	$9,165	$427
Partial LDS Separation	8	$7,720	$772	$1,158	$232	$9,882	$460
Complete LDS Separation	6	$13,730	$1,373	$2,060	$412	$17,574	$818
Complete WWS Separation	NA	$10,500	$1,050	$1,575	$315	$13,440	$626
With Jessie							
5-Year Relief Piping	3	$9,650	$965	$1,448	$290	$12,352	$575
Partial LDS Separation	9	$9,290	$929	$1,394	$279	$11,891	$554
Complete LDS Separation	7	$16,530	$1,653	$2,480	$496	$21,158	$985
WWS Separation	NA	$12,600	$1,260	$1,890	$378	$16,128	$751
District-Wide Hybrids with Jessie							
Separation-Relief Hybrid	12	$9,530	$953	$1,430	$286	$12,198	$568
Cockburn Relief/Jessie WWS	NA	$9,300	$930	$1,395	$279	$11,904	$554
Cockburn Parital LDS/Jessie WWS	NA	$9,500	$950	$1,425	$285	$12,160	$566
Localized Relief with Jessie							
Jessie WWS Separation	NA	$2,100	$210	$315	$63	$2,688	$125
Cockburn East Relief	NA	$1,960	$196	$294	$59	$2,509	$117
Cockburn East Partial Separation	10	$3,285	$329	$493	$99	$4,205	$196

(All Values in 1000’s of Dollars)

9.1.2 Annual Benefits

The benefits of basement flooding relief are determined by the amount of basement flooding avoided, and require estimates of damages that result from flooding events prior to and after implementation of relief. Two major flooding events caused severe flooding in Winnipeg which provided the basis for flooding damage estimates. Unit damages used in the 1986 Report were based on flooding surveys conducted after the 1984 flooding and provided the basis for the original district project prioritization. A program review report undertaken by Stantec (2000) provided updates to the flooding damages with the damages reported in 1993 values based on extensive flooding that occurred in 1993. The 1993 damage values were considerably higher as identified in Table 9-3.

Table 9-3: Unit Flooding Damages

	1986 Study (1984 Flooding)	2000 Report (1993 Flooding)
Residential	$1,000	$4,830
Commercial	$7,000	$17,340
Public	$10,000	$24,780
Multiple Unit Residential	$5,000	$12,400

Average annual benefits were determined by estimating the area-wide reduction in basement flooding damages that would occur after implementation of upgrading alternatives. The methodology was based on the City of Winnipeg (1986) Study and requires that average annual damages be developed from flood-frequency-damage curves, with the average annual benefits equaling the difference in annual damages before and after relief.

The methodology requires that damages for each storm event be estimated. The flooded area is first determined from the XP-SWMM simulations for each event, and then the damage values determined based on the number of units flooded and the average damage values. The 1993 flooding unit damages reported in 2000 were used to develop the event damages.

In developing flood damage from computed flooded areas, consideration must also be given to the fact that not all locations in the flooded area suffer damages. The concept of the damage ratio was developed in the City of Winnipeg (1986) Study to account for this fact. The damage ratio was based on examination of actual flood damage data from areas where the hydraulic grade line was above the flooded level based on a 2.4 m freeboard criteria. The damage ratio varies from a minimum of 0.10 and increases both with increasing return period and degree of district flooding. This same approach was used in the Cockburn and Calrossie Combined Sewer Relief Districts evaluation.

The combination of each flooding event is combined to produce a flood-frequency-damage curve for each alternative. The curves were estimated from the calculated individual event damages along with the complete district flooding (CDF) value. The CDF is the value of damages assuming that every basement in the district is flooded, which was assumed to occur in only the most extreme, less frequent event.

The area under the flood-frequency-damage curves represents the average annual damages. The difference in damages between the existing conditions curve and that of the relief alternative represents the reduced damages or average annual benefits resulting from the alternative.

Each of the alternatives presented in Section 8.0 may provide a different level of protection once implemented. Relief piping is designed for a 5-year level of protection and consequently basement flooding damages will occur for events exceeding the 5-year level. Only minor damages will occur for events only slightly larger than a 5-year, and they will increase as the return period increases. By comparison, alternatives such as complete LDS separation will provide greater than a 5-year level of protection against basement flooding, and the added benefit needs to be recognized in the benefit-cost analysis. This was accomplished by factoring in the added benefits in the flood-frequency-damage curves. Where there were enhanced benefits associated with the alternative, it was assumed that the level of protection would increase to a 10-year level.

The event damage values, average annual damages and average annual benefit estimates for the Cockburn and Calrossie alternatives are presented in Tables 9-4 through 9-8.

Table 9-4: Flood Damage and Benefit Estimates without Jessie

Alternative	1-year	2-year	5-year	10-year	CDF	Average Annual Damages	Average Annual Benefits
Existing w/o Jessie	$40	$150	$1,780	$3,320	$8,500	$990	$0
5-yr Relief Piping	$0	$0	$0	$2,030	$8,500	$460	$530
5-yr Partial LDS Separation	$0	$0	$0	$1,500	$8,500	$350	$640
Complete LDS Separation	$0	$0	$0	$0	$8,500	$170	$820
Complete WWS Separation	$0	$0	$0	$0	$8,500	$250	$740

(All Values in 1000's of Dollars)

Table 9-5: Flood Damage and Benefit Estimates With Jessie

Alternative	1-year	2-year	5-year	10-year	CDF	Average Annual Damages	Average Annual Benefits
Existing	$220	$400	$2,340	$4,050	$10,330	$1,390	$0
5-yr Relief Piping	$0	$0	$0	$2,720	$10,330	$560	$830
5-yr Partial LDS Separation	$0	$0	$0	$1,500	$10,330	$430	$960
Complete LDS Separation	$0	$0	$0	$0	$10,330	$200	$1,190
Complete WWS Separation	$0	$0	$0	$0	$10,330	$300	$1,090

(All Values in 1000's Dollars)

Table 9-6: Flood Damage and Benefit Estimates for Jessie Localized Relief

Alternative	1-year	2-year	5-year	10-year	CDF	Average Annual Damages	Average Annual Benefits
Jessie Existing	$180	$360	$590	$730	$1,820	$470	$0
Jessie WWS Separation	$0	$0	$0	$0	$1,820	$50	$420

(All Values in 1000's of Dollars)

Table 9-7: Flood Damage and Benefit Estimates for Cockburn East Localized Relief

Alternative	1-year	2-year	5-year	10-year	CDF	Average Annual Damages	Average Annual Benefits
Existing with Jessie	$220	$400	$2,340	$4,050	$10,330	$1,390	$0
Cockburn East 5-yr Relief	$210	$290	$1,180	$3,010	$10,330	$1,030	$360
Cockburn East Partial LDS Separation	$200	$370	$1,060	$2,700	$10,330	$1,040	$350

(All Values of 1000's Dollars)

Table 9-8: Flood Damage and Benefit Estimates for Hybrid Options

Alternative	1-year	2-year	5-year	10-year	CDF	Average Annual Damages	Average Annual Benefits
Existing	$220	$400	$2,340	$4,050	$10,330	$1,390	$0
West-Separation & East-Relief	$0	$0	$0	$1,858	$10,330	$475	$915
5-yr Relief & Jessie WWS Separation	$0	$0	$0	$2,030	$10,330	$570	$820
Partial LDS Separation & Jessie WWS Separation	$0	$0	$0	$1,500	$10,330	$400	$990

(All Values in 1000's of Dollars)

9.2 BENEFIT-COST ANALYSIS

The merits of each alternative are determined by use of the benefit-cost analyses, to make a selection from competing alternatives within each district, and also and perhaps more importantly to identify and schedule projects within the Basement Flooding Relief Program.

The benefit-cost ratio is determined by dividing the benefits by the cost of each relief alternative. The benefits and costs from the previous sections provided the inputs for the evaluation. The benefit-cost results are shown in Table 9-9 and Table 9-10:

Table 9-9: District Wide Benefit-Cost Summary

	Without Jessie					With Jessie				
Alternative	DWG No.	Average Annual Benefits	1991 Relief Project Cost ($1000)	1991 Average Annual Cost ($1000)	B/C Ratio	DWG No.	Average Annual Benefits	1991 Relief Project Cost ($1000)	1991 Average Annual Cost ($1000)	B/C Ratio
District-Wide										
5-yr Relief Piping	2	$530	$9,165	$427	1.2	3	$830	$12,352	$575	1.4
5-yr Partial LDS Separation	8	$640	$9,882	$460	1.4	9	$960	$11,891	$554	1.7
Complete LDS Separation	6	$820	$17,574	$818	-	7	$1,190	$21,158	$985	1.2
*Complete WWS Separation	NA	$740	$13,440	$626	1.2	NA	$1,090	$16,128	$751	1.5
Hybrid Alternatives										
West- Partial LDS Separation & East-Relief	-	-	-	-	-	12	$895	$12,198	$568	1.6
*Cockburn 5-yr Relief & Jessie WWS Separation	-	-	-	-	-	NA	$820	$11,904	$554	1.5
*Partial LDS Separation & Jessie WWS Separation	-	-	-	-	-	NA	$990	$12,160	$566	1.7
* WWS Separation alternatives require supplemental upgrading to provide a comparable level of service and are included for reference only										

(All Values in 1000's of Dollars)

Table 9-10: Localized Relief Benefit-Cost Summary

Localized Reliief Alternatives	DWG No.	Average Annual Benefits	1991 Relief Project Cost ($1000)	1991 Average Annual Cost ($1000)	B/C Ratio
*Jessie WWS Separation	NA	$420	$2,688	$125	3.4
Cockburn East 5-yr Relief Piping	NA	$320	$2,509	$117	2.7
Cockburn East Partial LDS Separation	10	$370	$4,205	$196	1.9
* WWS Separation alternatives require supplemental upgrading to provide a comparable level of service and are included for reference only					

(All Values in 1000's of Dollars)

9.3 DISCUSSION OF RESULTS

The benefit-cost results, as listed in Tables 9-9 and 9-10, provide the basis for project evaluation, which must be considered in the context of the overall Basement Flooding Relief Program. The following observations are made with respect to the benefit-cost analyses. The selection of a preferred alternative is discussed in Section 14.0 and includes discussion of the broader perspectives associated with integration of combined sewer overflow controls.

District Wide Alternatives

District wide alternatives are presented in Table 9-9 and are discussed as follows:

- The district-wide alternative with the highest benefit-cost ratio is partial land drainage separation, including the Southeast Jessie area. It has a benefit-cost ratio of 1.7, which indicates it will provide a positive investment and worthy of implementation based on the 1991 costs and 1993 benefit data.

- The relief/separation hybrid has a nearly identical cost, and benefit-cost ratio as the partial LDS separation alternative, but it would require installation of a second outfall. The section of riverbank west of the Cockburn Station is considered unstable and may require extensive riverbank stabilization. A cost allowance for the second outfall has been included in the separation–relief alternative but the difficulty in estimating riverbank works results in more uncertainty in the costs for that alternative.

- Conventional relief was found to have a benefit-cost ratio of 1.4, with Southeast Jessie included. The selection of a separation alternative strictly on the merits of basement flooding protection is unusual in that it has historically been found to be more costly than installation of relief piping. For the Cockburn and Calrossie Combined Sewer Relief Districts, however, the separation piping nearly mirrored the relief piping, and it consisted primarily of the larger diameter piping. The extensive upper-end sewer upgrading required in many districts was not required for Cockburn, which in comparison changed the relief needs and cost structure of the alternatives.

- The inclusion of Southeast Jessie in the LDS partial separation alternative increases the benefits of the project, increasing the benefit-cost ratio from 1.4 to 1.7. The portion of Jessie under consideration is primarily residential and has an extremely low level of service.

- The hybrid alternative using wastewater separation in Southeast Jessie and partial LDS separation in Cockburn and Calrossie Combined Sewer Relief Districts has similar costs and benefits as partial LDS separation throughout. A limitation of this alternative discussed in Section 8.0 was that supplemental upgrading and costs would be required which are not included in the estimates. The existing combined sewers would also require upgrading to provide a 5-year level of street service or the substandard level of service provided.

Localized Relief Alternatives

Localized relief is intended to provide a high level of immediate benefits, with the alternatives as shown in Table 9-10:

- The eastern portion of the Cockburn Combined Sewer Relief District is located near the outfall and on a comparative basis is less costly to relieve than the western side of Cockburn. The benefit-cost ratio for eastern Cockburn is 2.7 for relief piping, compared to the district-wide ratio of 1.7. Because of its location, the eastern works could proceed in advance and independent of the main Cockburn works.

- If the partial LDS alternative is selected as a district wide approach, partial LDS separation would be required for the eastern side of Cockburn as well. The cost for partial separation is greater than for relief and the benefit-cost ratio is reduced to 1.9 but still provides positive project benefits.

- The relief/separation hybrid alternative would be well suited to eastern side localized relief. The relief piping system, with an incremental benefit-cost ratio of 2.7, could proceed immediately and completely independently of the west side separation. Since the two sides would not connect, they could proceed independently. While the east side for this option has a higher benefit-cost ratio than the partial LDS separation alternative, the additional cost of connecting the west side separation to a new outfall increases the costs and reduces the benefit-cost ratio of the western works.

- Relief of Southeast Jessie using wastewater separation has the highest benefit-cost ratio, and could be undertaken independently of the other alternatives. The estimate is qualified as previously discussed because supplemental upgrading and costs would be required and of the under capacity of the existing combined sewers to serve as land drainage sewers.

The consideration of other associated benefits and costs that may impact the implementation recommendations and decisions are presented subsequently in Section 14.0.

10.0 SPRING LEVEL OF PROTECTION

The spring level of flood protection was determined with the storm relief sewer option for relief works. Various combinations of Red River level frequencies and storm precipitation return periods for the April-May time frame were used to determine the combined probability of incipient flooding in the district during the spring period. If the level of protection were less than the 25-year return probability, measures would be proposed to bring the level of service to the 25-year return period.

The model results for spring rainstorms showed that the runoff from the Cockburn and Calrossie Combined Sewer Districts for the storm relief sewer alternative would be stored within the existing and relief sewers for all rainstorms up to approximately the 35-year spring storm. Flood levels in the Cockburn and Calrossie Sewer Districts were therefore independent of the downstream Red River water levels during spring.

The model results also showed that basement flooding during spring would only occur with the 50-year rainstorm at a location on Grant Avenue due to limited high-end sewer capacity. However, even for the 50-year rainstorm, the sewer capacity was not affected by the downstream Red River level.

The storm sewer relief alternative design would therefore have a minimum of 50-year level of service for spring rainstorms.

10.1 REVIEW OF SPRING LEVEL OF PROTECTION FOR PREFERRED ALTERNATIVE

A similar analysis was conducted for the recommended partial land drainage separation alternative. The amount of area separated under the partial separation alternative was determined by progressively removing road drainage from the combined sewer system until flooding was eliminated for the 5-year storm. Runoff from this area was directed to the new land drainage sewers. The remainder of the runoff directed to the combined sewer was therefore considerably reduced compared to the runoff to the unrelieved combined sewer system.

During spring runoff, high Red River levels submerge the outfall and prevent normal gravity flow to the Red River. The flood pump station at the existing Cockburn outfall is then used to pump the combined sewer discharge to the Red River. Model simulations with combined runoff from rainstorms up to the 25-year spring rainstorms and 25-year Red River level showed that with the flood pumps operating, the water levels in the sewer are maintained well below the basement flood level. Figure 10-1 below illustrates the peak HGL profile for the combined 25-year spring rainstorm and the 25-year water level for the combined sewer from the Cockburn outfall to Grant Avenue.

The combined probability of the rainfall and Red River water level is much greater than the 25-year combined probability. This combination was used for demonstration purposes to show that neither the 25-year river level nor the 25-year rainstorm will result in water levels at the critical basement flood level. Similar HGL profiles occur along other combined sewers. The land drainage separation alternative therefore has a spring level of protection that is significantly greater than the 25-year spring flood event.

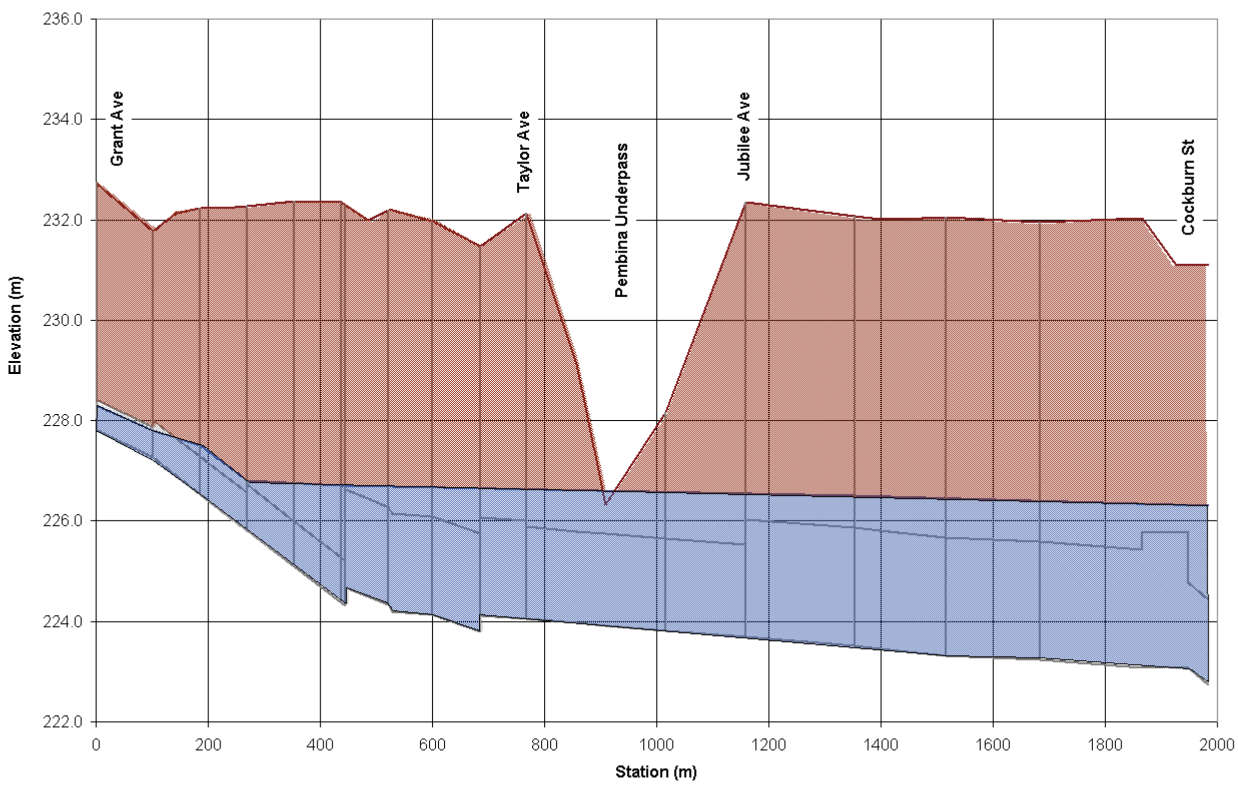


Figure 10-1: HGL Profile Cockburn Outfall to Grant Avenue

11.0 SANITARY SEWER LIFT STATION ASSESSMENT

The Cockburn and Calrossie Combined Sewer Districts both convey sanitary sewage to the Cockburn Lift Station. At one time, both Cockburn and Calrossie were combined sewer systems, but the Calrossie District has been modified to a separate sewer system. The sanitary sewage from Calrossie now combines with Cockburn flows and is conveyed to the Cockburn Lift Station while the land drainage is collected in a separate system and discharged to the river through its own outfall.

The Cockburn Lift Station is an integral component of the collection system. Although it has minimal impact during major storm events where most of the discharge flows directly to the river, it is a critical component in controlling dry weather overflows, and it is an important consideration for combined sewer overflows.

A cursory review of the Cockburn Lift Station was undertaken to identify condition and performance issues that could have a potential impact on the relief works.

11.1 PUMPING STATION CONDITION ASSESSMENT

A field visit was made to the Cockburn Pumping Station and Calrossie Sewer District on March 21st, 2006. The purpose of the visit was to undertake a cursory inspection to ensure the general site conditions and upgrading needs were known for consideration in development of combined sewer relief works recommendations. The intent was to identify major capital upgrading requirements in order to coordinate them with relief alternatives. The scope of work does not include development of minor upgrading or maintenance recommendations.

The Cockburn Pumping Station generally consists of a flood pumping station in combination with a wastewater lift station. The flood pumping station is the dominant structure on the site, consisting of a 115 square metre building built in 1954, as shown in Photo 11-1. A detailed Flood Pumping Station (FPS) Condition Assessment was carried out by KGS Group (2005). The Cockburn FPS Isometric developed as part of the City of Winnipeg Flood Activity / Emergency Manual has been included in Appendix D (Reference Drawings). The wastewater lift station was constructed as an addition to the station and consists of a covered vault with access from the pump room floor.

11.1.1 Cockburn Flood Pumping Station

The Flood Pumping Station Condition Assessment (KGS Group, 2005) included an assessment of the structural, mechanical, geotechnical and electrical components of the flood pumping station. It found the station to be in generally good condition and recommended several minor upgrades to maintain the station in good operational condition as described below.

Photo 11-1: Cockburn Flood Pumping Station

- The building was found to be in generally good condition.
- Several mechanical upgrades were recommended, including ventilation upgrading.
- Electrical and controls were found to generally be satisfactory, with the recommendation of upgrading lighting in the drywell.
- Some safety issues were identified that require upgrading.

The final recommendations for the flood pumping station were for $418,740 of upgrading in the next ten years and $352,800 (2005 present value) beyond ten years, including contingency, engineering and administration costs.

The Flood Pumping Station Condition Assessment did not specifically address the lift station components. The only major recommendation directly related to the lift station was for installation of a separate entranceway to isolate humidity and odour entering the flood pumping station.

11.1.2 Cockburn Sanitary Lift Station

The lift station was constructed after the flood pumping station was built and consists of an off-take from the combined sewer trunk, a comminutor chamber, a wet well and dry well. Flow is diverted from the combined sewer by a weir to the comminutor chamber. The comminutors have been removed but the flow still travels through the channels. A large diameter circular pipe serves as the wet well, extending the length of the flood pumping station. The dry well has been constructed as an “add-on” to the south side of the flood pumping station. Access to the lift station is from the flood pump floor through a small open doorway to the lift station pump floor. The centrifugal pumps are a vertical arrangement, with the drive shaft extending to the motor floor above.

Observations of the lift station from the March 21st, 2006 site visit are as follows:

Dry Well

The general appearance of the structure was good, with no obvious cracks and no apparent water infiltration problems.

Equipment

- The arrangement of the dry well makes it difficult to move equipment.
- The pump impellors were recently changed, the first in August 2005 and the second in March 2006.
- The motors were upgraded from 25 to 30 HP to accommodate the new impellors.
- The impellors are of the non-clog TRASH type, which have inherently poor efficiency; the City indicated there are new types of impellors they would prefer.
- Pump suction lines were replaced, with the diameters being increased from 150 mm to 300 mm.

- A sump pump is in place and normally only handles seal water.

- The City would like to install a magnetic flow meter on the discharge force main.

HVAC

There appeared to be very little air movement in the lift station. The ventilation is connected to the Flood Pumping Station and if further assessment is to be done, they would have to be reviewed together. If the two stations are to be isolated, a separate ventilation system would be required for the lift station.

Electrical

- An electrical inspection was not undertaken. However, the Water and Waste Department recently changed the motors and addressed the electrical issues at that time.

Wet Well

- The second wet well sump and suction pipe was added in the 1980's.

- Levels within the wet well are measured by a bubbler system located in the dry well.

- Grit is cleaned from the wet well whenever major maintenance is required; the last cleaning took place in the '80s. No problems have recently been evident.

Comminutor Chamber

- The comminutors have been removed and this chamber is no longer used. It serves no purpose other than to house a shut-off valve.

- The chamber is difficult to access and should be reviewed for safety concerns.

- The chamber is open to raw sewage and has poor ventilation.

Dry Weather Flow Diversion

- During the winter of 2005/2006, the City added an extension to the top of the diversion weir to capture more flows and avoid dry weather overflows. This has since been removed, and is not required in the spring and summer since river levels will maintain the flap gate in a closed position and prevent dry weather overflows.

- The City installed an area-velocity metre downstream of the weir to detect dry weather overflows.

11.1.3 Calrossie District

The Calrossie Sewer District does not have a lift station. Sanitary sewage and inflow and infiltration collected in the wastewater system flow to the Cockburn system by gravity.

11.2 LIFT STATION SYSTEM HYDRAULICS

11.2.1 Cockburn Lift Station

The Cockburn Lift Station consists of a wet well dry-well configuration. Sewage is diverted by gravity through the 500 mm off-take pipe to an abandoned comminutor station. Although the comminutors have been removed, the flow still travels through the channels. From the comminutor chamber, the sewage flows to a 16.2 m long pipe that is 1670 mm in diameter that serves as the station wet well. Two pumps with separate suction lines draw sewage from the wet well and discharge it to a 250 mm force main which flows from the station, north along Cockburn Street, to a 450 mm secondary sewer at the corner of Cockburn Street and Rosedale Avenue. The secondary sewer ultimately discharges to the Baltimore Combined Sewer District by gravity at the corner of Baltimore Road and Osborne Street.

Cockburn Pumps

The Cockburn Lift Station has two Morris 6HSD12 centrifugal vertical dry pit solids pumps. The pumps were originally equipped with 280 mm (11 inch) recessed impellors, which were replaced with 300 mm (12 inch) impellors in 2005. The motors were upgraded from 25 to 30 hp at the same time.

The original design had a single suction line from the wet well, but has since been upgraded to a dedicated suction line for each pump.

Photo 11-2: Cockburn Lift Station Pump

Pumping Capacity

The larger impellors were installed to increase the pumping capacity. Flow measurements taken in May 2004 prior to the upgrade were made using a strap-on Panametrics polysonic metre. The results indicated a typical discharge of 73 L/s for the two pumps operating in parallel, with a maximum pumping capacity recorded at 80 L/s.

In 2005, it became evident that dry weather overflows were occurring at the Cockburn Lift Station. The cause of the increased flow was attributed to the discharge of groundwater used for cooling large apartment complexes to the sewer system. A program of source control and station pumping capacity increase was undertaken to eliminate the overflows.

Flow measurements were again taken in August of 2005. At the time, only one of the impellors had been changed:

- 1-pump (original 280-mm impellor) 58 L/s
- 1-pump (upgraded 300-mm impellor) 70 L/s
- 2-pumps (1-280 mm impellor, 1-300 mm impellor) 95 L/s
- 2-pumps (2-300 mm impellors, estimated flow) 105 L/s

11.2.2 Calrossie

The Calrossie District does not have a lift station. Sanitary sewage from the Calrossie District is discharged directly into the Cockburn Combined Sewer District and is processed with the Cockburn flows.

The original combined sewer system serves as a wastewater sewer, discharging to the Cockburn Combined Sewer District, while a new land drainage sewer in the Calrossie District receives the surface drainage. A 250 mm interconnection is located on Riverside Drive, which permits flow from the wastewater system into the land drainage system. A flap gate prevents reverse flow, and a gate valve has been installed for isolation of the systems.

Pumping Station Summary

The pumping stations condition is summarized as follows:

- The flood pumping station was reported to generally be in good condition with about $500,000 in upgrading required in the short term and another $400,000 over the longer term.

- The Cockburn Lift Station does not have adequate space for access and maintenance and requires upgrading.

- The Calrossie District has a cross connection to a land drainage sewer but does not have a lift station.

In considering the relief piping and partial LDS separation alternatives, there will be either none or limited opportunity or need to integrate the pumping stations into the construction projects. With respect to the dry weather flows, the recent upgrade of the Cockburn Lift Station to a maximum capacity of 105 L/s along with elimination of the groundwater cooling wells in the Cockburn District has brought the operation to the current standards.

The combined sewer overflow alternatives, which are discussed in Sections 12.0 and 13.0, could have a major impact on both the Cockburn Lift Station and Flood Pumping Station.

12.0 CSO ANALYSIS

12.1 COMBINED SEWER MANAGEMENT STUDY

There are two issues of concern with combined sewers, the risk of basement flooding and discharge of combined sewer overflows (CSOs) to the rivers. The primary objective of the Cockburn and Calrossie Sewer Relief Works Project is to upgrade the sewer system's capacities to reduce surcharge levels and therefore, the risk of basement flooding during large rainfall events. While basement flooding is certainly a priority, the combined sewer overflows will also require extensive control works in the future. Because of the relationship between basement flooding relief works and CSO control, an added objective of the Cockburn and Calrossie Relief Works Study is to investigate modifications and additions to the relief works to reduce the frequency of CSO events.

A Combined Sewer Overflow Management Study (Wardrop, 2002), was completed by the City of Winnipeg which investigated CSO control alternatives for the entire combined sewer area in the City of Winnipeg. The Cockburn and Calrossie Districts were included in the study, although they were dealt with somewhat differently than the majority of the combined sewer districts as they are among the few districts that are not in the North End Water Pollution Control Centre (NEWPCC) service area.

The CSO Management Study was developed to the point of identifying an illustrative program, which incorporated all combined sewer districts. The illustrative program was based on a target regulation of an average of four overflows for the recreational season, extending from May 1st to September 30th of each year.

The CSO Management Study included the following control options:

- Raising diversion weirs
- Increasing interception rates
- Latent storage, that is the storage in existing relief pipes that is below river level
- Relief works modifications, including CSO controls with basement flooding relief options and sewer replacements
- In-line storage
- Off-line storage
- Tunnels

The control options were developed into a progressive implementation approach, based on undertaking the options with the least cost and highest impacts first. The results from the study are presented in Figure 12-1, which illustrates the most cost effective program.

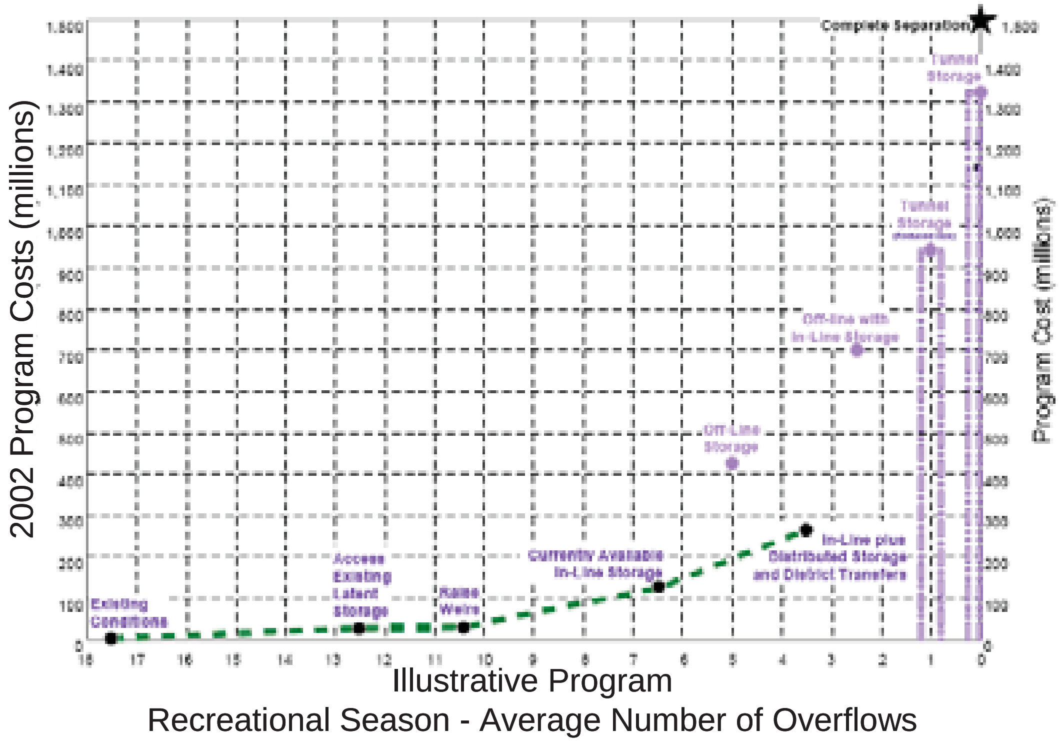


Figure 12-1: CSO Management Study Trade-Off Curve

Specific control options for each combined sewer district depend on the particular nature of each district. Each of the options was considered for Cockburn and Calrossie except for latent storage, since there are no sewers below river level, and therefore it cannot be considered as an option.

12.2 COCKBURN AND CALROSSIE CSO CONTROL

12.2.1 General

This section considers the CSO control options on an individual district basis only. Section 13.0 extends the assessment to a regional perspective with consideration for other combined sewer district south of the Assiniboine River, and the potential for diversion of wet weather flows to the NEWPCC.

The purpose of the CSO evaluation is to assess potential CSO control measures, identify if there is an opportunity or advantage to incorporate those control measures in the relief program, and provide district specific information for the future CSO capital program development.

12.2.2 Methodology

The first requirement in assessment of CSO control options is to identify the performance standards. The Cockburn and Calrossie Relief Terms of Reference requested the CSO control measures be sized to achieve a long-term CSO control target average of four overflows per recreation season. This is consistent with the performance objectives identified in the CSO Management Study for the illustrative program. This has consistently been interpreted as four overflows per year from any individual combined sewer district.

The methodology used in the CSO Management Study and replicated in subsequent basement flooding relief projects, has been to use a representative year. The long-term record has been reviewed on several occasions in these studies and the year considered to be the closest to the long-term average has been used in place of continuous simulation of the full period of record.

The second simplifying assumption typically used has been to develop a coarse model based on hourly time steps instead of 5 or 10 minute time steps. This modeling refinement has been used several times in recent basement flooding relief program CSO assessments as it reduces the computational time for continuous or long-term simulations. For the assessment carried out in this section, the coarse modeling and hourly time steps were not used, since it was determined the assessments could be carried out using the detailed Cockburn and Calrossie models with 10-minute time steps with reasonable computational times.

12.2.2.1 Rainfall Data

Rainfall data was available over the long-term from the Winnipeg International Airport, and more recent data from the City of Winnipeg's rain gauge network. The airport information had been compiled for the City on other projects, and included data checking and correction. It consisted of hourly rainfall accumulations from 1960 to 2001 for the recreation season. A second set of data including hourly rainfalls for the years 2000 to 2005 was also provided by the City but did not include the original airport rain gauge location after 2002.

The annual rainfall accumulations from the airport data were plotted to compare annual variations. As shown in Figure 12-2, there is a significant variation from year to year for rainfall accumulations. The plot suggests that the variation is random, with no increasing or decreasing trends evident over the period.

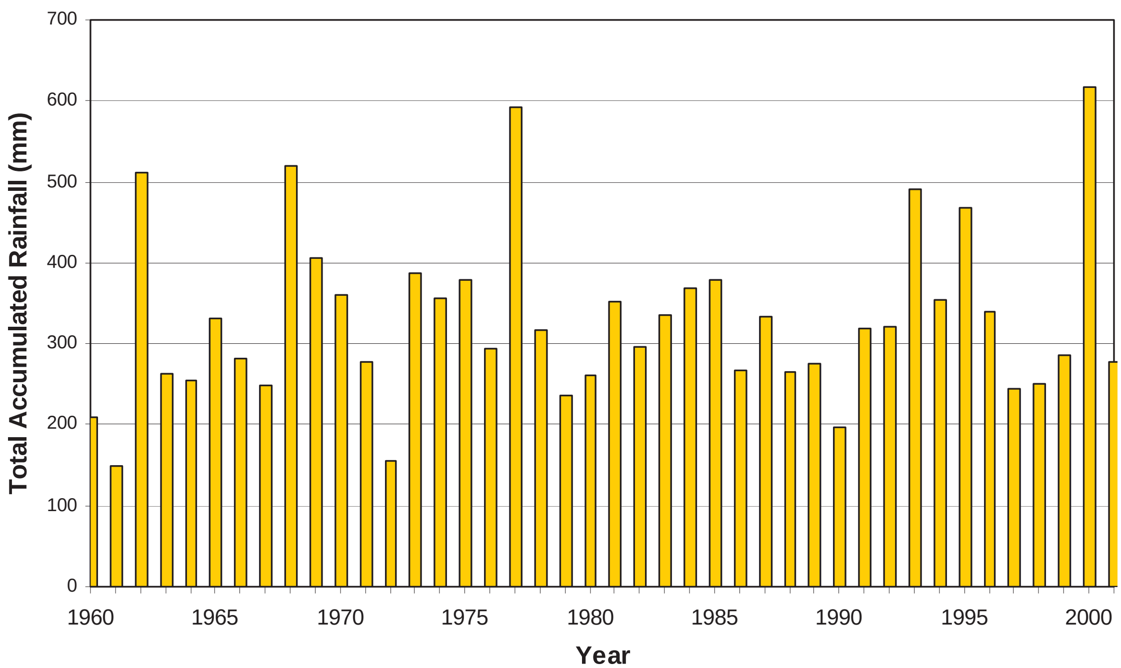


Figure 12-2: Annual City of Winnipeg Rainfall Accumulations – 1960 to 2001

12.2.2.2 Representative Year

The representative year approach was used in the CSO Management Study and previous basement flooding relief studies. It assumes that the long-term average overflows can be approximated by use of the one year that is the closest to the long-term average conditions. The representative year has been used to estimate the number of overflows, evaluate the level of improvements made by incorporation of alternative CSO controls and size the CSO control works. The advantage of using a representative year is that only one year has to be used in the evaluation rather than continuous simulation of the multi-year records.

The CSO Management Study analyzed the complete period of record from 1960 to 1995 to establish a representative year. The analysis was carried out by grouping rainfalls into size categories and comparing the frequency of rainfalls in each. On this basis, it was concluded that 1992 was the best fit for the representative year.

The CSO Management Study also recognized that although the 1992 rainfall accumulation matched the long-term average, the volume of runoff was considerably less than the long-term average.

In contrast, a representative runoff year was used in the Strathmillan and Moorgate Combined Sewer Districts Sewer Relief and CSO Abatement Study (UMA Engineering Ltd. 2005) instead of a representative rainfall year. For the evaluation, a coarse model was run using 42 years of hourly rainfall, and input into the XP-SWMM Storage/treatment block to calculate the number of overflow events and associated overflow volumes. Based on the evaluation and comparison to the long-term averages, it was recommended that 1991 be selected as the representative runoff year.

Although the two approaches used to identify representative years varied, and different years were recommended, the analysis was based on the same data set. Rather than repeat the evaluation for the Cockburn and Calrossie project, consideration was given to use of either one or the other, or consideration of both.

12.2.2.3 Comparison of 1991 and 1992 Rainfalls

Both 1991 and 1992 appear to be very similar and near the long-term average for total rainfall accumulation. They both have very close to the average annual 322 mm rainfall, but as can be seen from Figures 12-3 and 12-4, 1991 had 41 rainfalls while 1992 had 60, although 30 of them were less than 2 mm. There were 11 storms with accumulated depths between 2 and 10 mm in 1991, and 21 in 1992, in comparison to a long-term average of 18. Large rainfall accounted for more of the accumulated rainfall for 1991 than for 1992.

The Strathmillan and Moorgate Study found that 1991 produces a more representative runoff year than 1992. The runoff approach takes into account antecedent conditions, including the degree of soil saturation and its impact on infiltration, the amount of water remaining in surface storage and the amount of water held within the system. For storage options, the amount of time between rains and the dewatering rate from storage are important as back to back events will cause more overflows because of reduced storage availability.

Based on the comparative data, it would appear that the 1991 rainfall year would produce more CSO events for existing conditions. In other words, if the 1991 rainfall data were used for CSO modeling instead of the 1992 data, there would be a higher predicted number of overflows based on the existing weir height. The CSO Management Study was assessed with the 1992 representative year, however, and has generally been adopted as the existing level of performance.

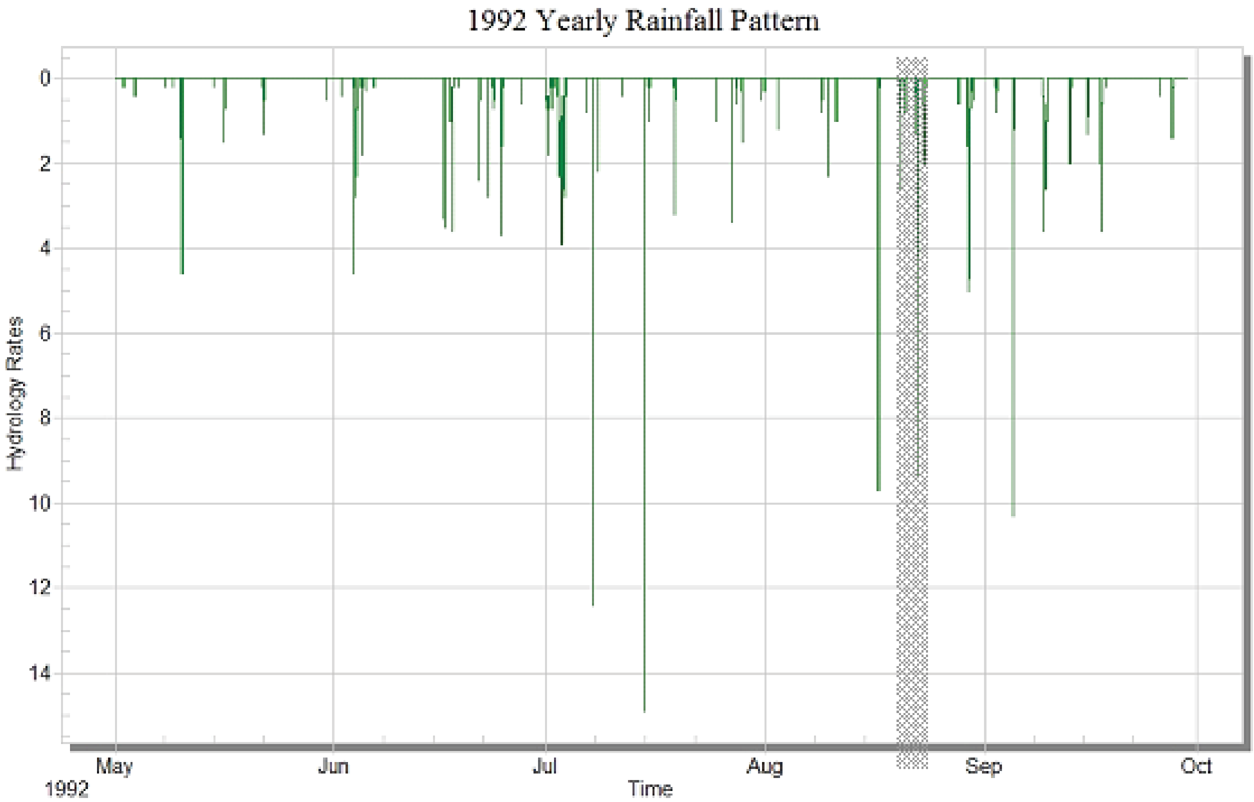


Figure 12-3: 1992 Annual Rainfall Pattern

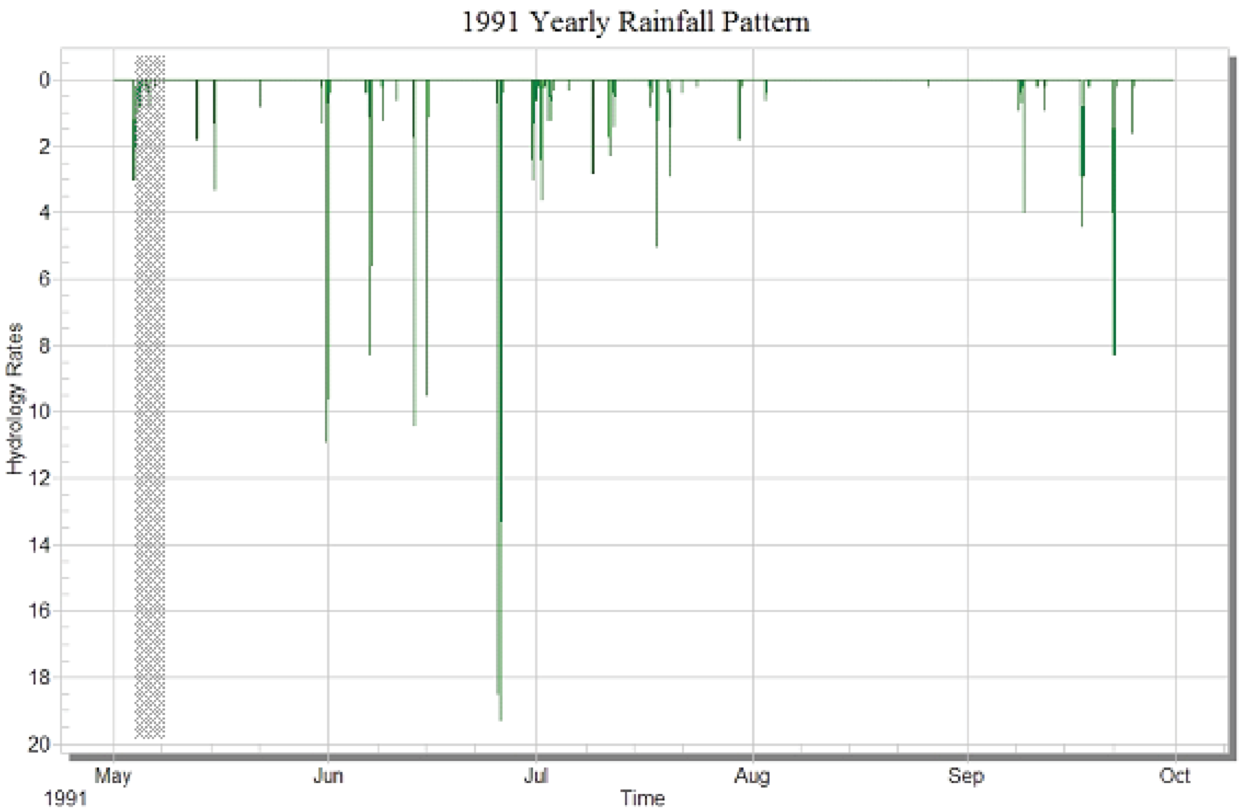


Figure 12-4: 1991 Annual Rainfall Pattern

12.2.2.4 Fifth Largest Storm

The performance objective of limiting the number of overflows to an average of four per year means that on average the fifth largest storm must be completely captured. Figure 12-5 shows a comparison of the largest, fourth largest and fifth largest storms for the full period of record. By inspection, the fourth and fifth largest storms show much less variation than the largest, and both years appear similar and in line with the long-term average.

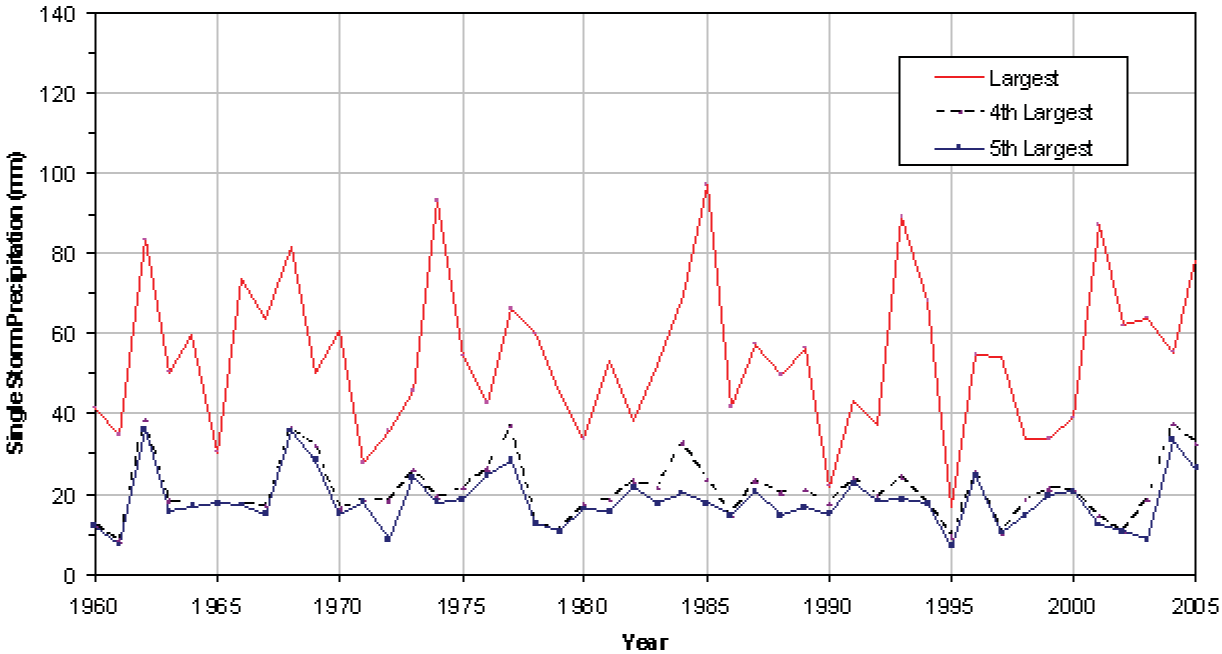


Figure 12-5: Largest, 4th Largest and 5th Largest Annual Storms

The fifth largest storm for the years 1991 and 1992 are shown on Figure 12-6. The 1992 event consists of a double peak, with a peak intensity much higher than for 1991. The 1992 storm would tend to create a higher peak rate of runoff with about the same volume of flow and in most cases would be harder to control than the 1991 storm.

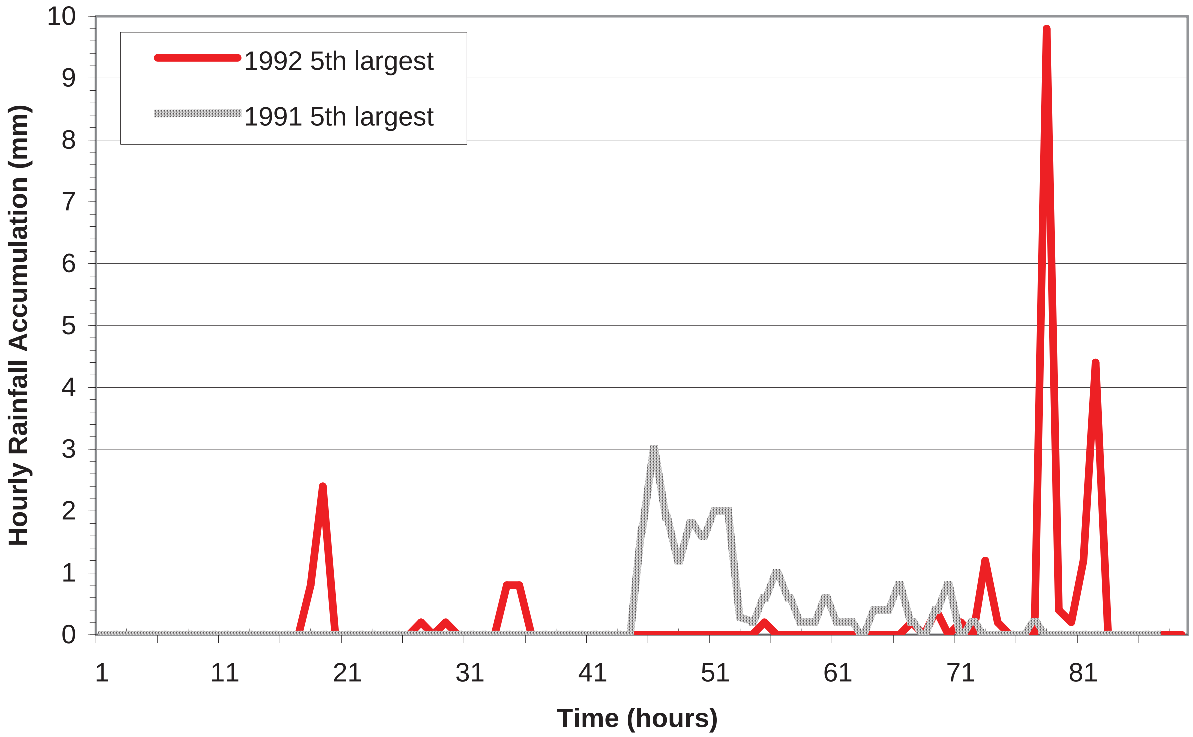


Figure 12-6: Comparison of 1991 and 1992 Fifth Largest Storms

12.2.2.5 1992 Representative Year

The 1992 rainfall year was selected for use as the representative year. While the 1991 data will predict a higher number of overflows under the existing conditions, the 1992 fifth storm is larger and more difficult to control than the 1991 fifth largest storm.

The 1992 representative year fifth largest storm was used for the evaluation of the CSO control options. The 1992 rainfalls have been sorted by rainfall intensity in Figure 12-7. The rainfalls have been defined to have at least a six hour inter-event dry period. A total of 41 rainfalls with a total of at least one millimetre occurred in 1992 (having at least five tipping-bucket tips).

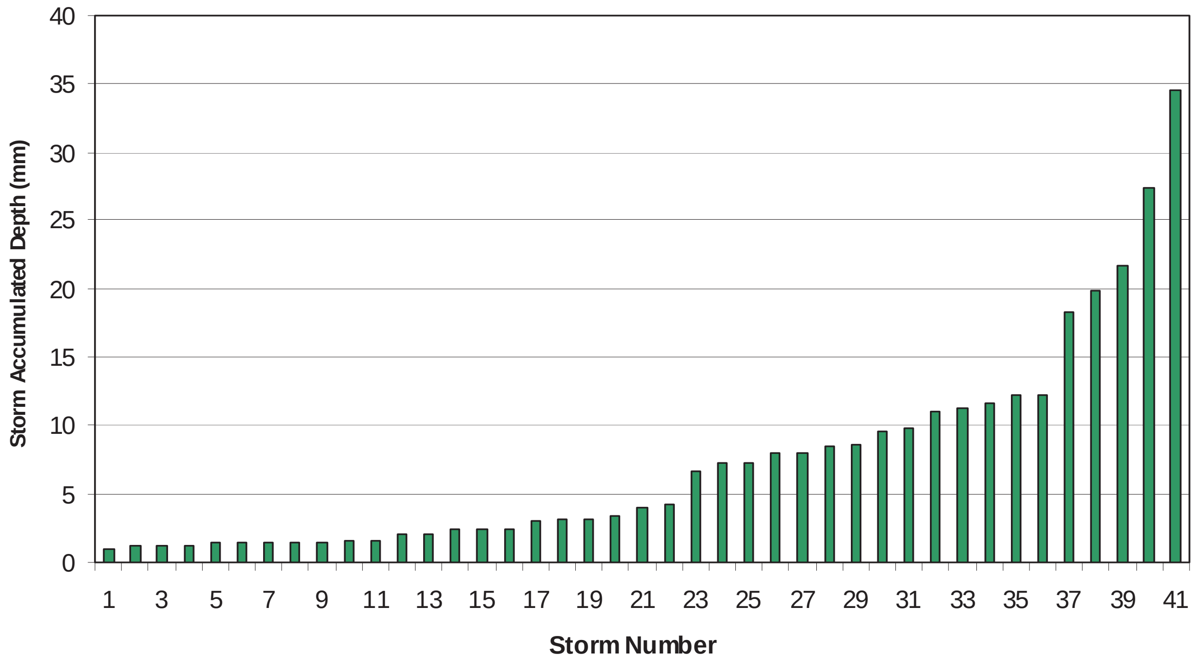


Figure 12-7: 1992 Storm Sorted By Accumulated Depth

12.2.3 Existing System Combined Sewer Overflows

The 1992 representative year was used to estimate the frequency and volume of overflows for Cockburn, and subsequently to evaluate control measures.

12.2.3.1 Frequency of Overflow

The existing CSO evaluation considered the Cockburn District, but not Calrossie. Calrossie is not of concern as it is a separated area that drains into Cockburn and other than having a land drainage sewer interconnection, does not generate its own overflows.

This Cockburn overflow situation has changed over time, with the analysis representing the currently existing conditions. For this assessment, it was assumed that extraneous flow issues resulting from the three previously identified well water-cooling systems have been eliminated (removed in 2006). The additional extraneous flow would have increased the number of overflows beyond the predicted number, and contributed to dry weather overflows. The increase in lift station pumping capacity is also included in the evaluation. The number of overflows would have been higher prior to the upgrade.

The number of overflows was estimated for the existing system by running the 1992 representative year with the calibrated model, under the following conditions:

- 10-minute rainfall time steps
- Weir height at the existing 508 mm
- Upgraded pumping capacity to 105 L/s in the existing lift station
- Dry weather flow estimated by the calibrated DWF model
- No wells, flap gate leakage or other unusual extraneous inflows

A total of 23 overflows were estimated with the overflow volumes as presented in Figure 12-8.

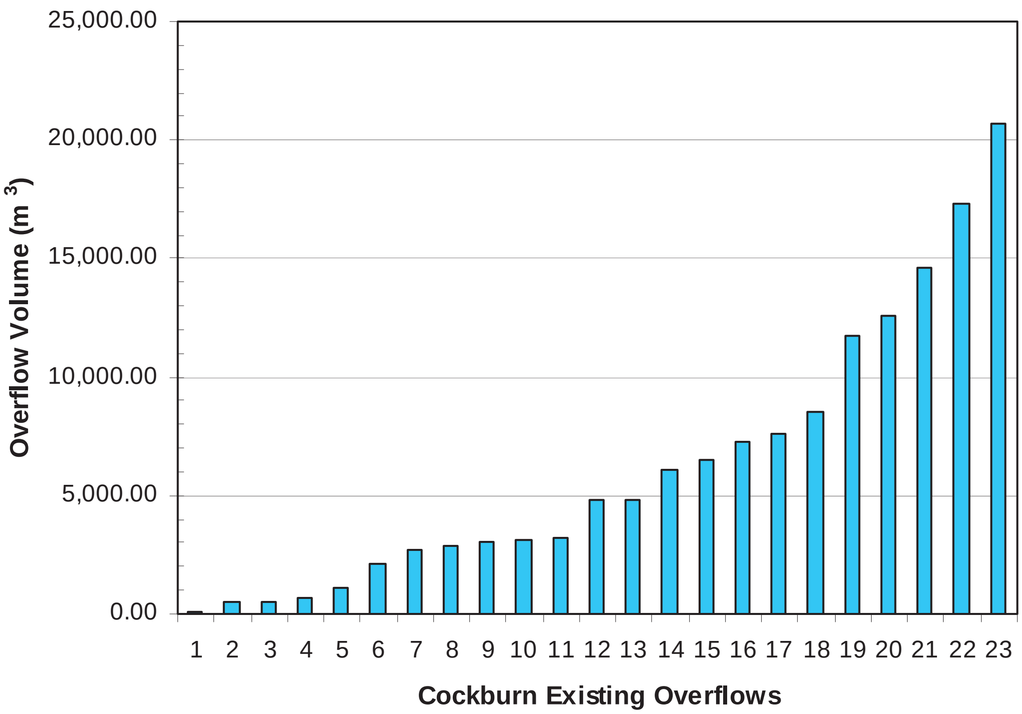


Figure 12-8: 1992 Cockburn Overflows per Recreational Season

12.2.3.2 CSO Overflow Volume

In order to limit the number of annual overflows to four, the fifth largest storm must be managed either through storage or by treatment. Based on the 1992 representative year, this storm has an overflow volume of 12,000 cubic metres.

12.2.4 CSO Abatement Alternatives

There are a number of control options that can be considered for the Cockburn District. The following section discusses the options as independent works, and subsequently considers the most appropriate combination of options.

12.2.4.1 Raising the Weir

The Cockburn Lift Station has a diversion weir and off-take pipe from the combined sewer trunk to a wastewater lift station, typical of Winnipeg's combined sewer systems. The diversion weir height has been set to intercept a nominal 2.75 times the average dry weather flow. The photograph of the Cockburn fixed weir is shown in Photo 12-1. The weir consists of a concrete lip across the invert of the trunk sewer. The weir in the photograph shows the crest increased by addition of logs.

Photo 12-1: Cockburn Fixed Weir With Stop Log Additions

With the existing weir having a height of 508 mm above invert, the storage volume behind the weir was determined to be 700 cubic metres. By raising the weir, the amount of in-line storage can be increased and the number of overflows reduced. The amount of storage available in the existing system by raising the weir is shown in Figure 12-9.

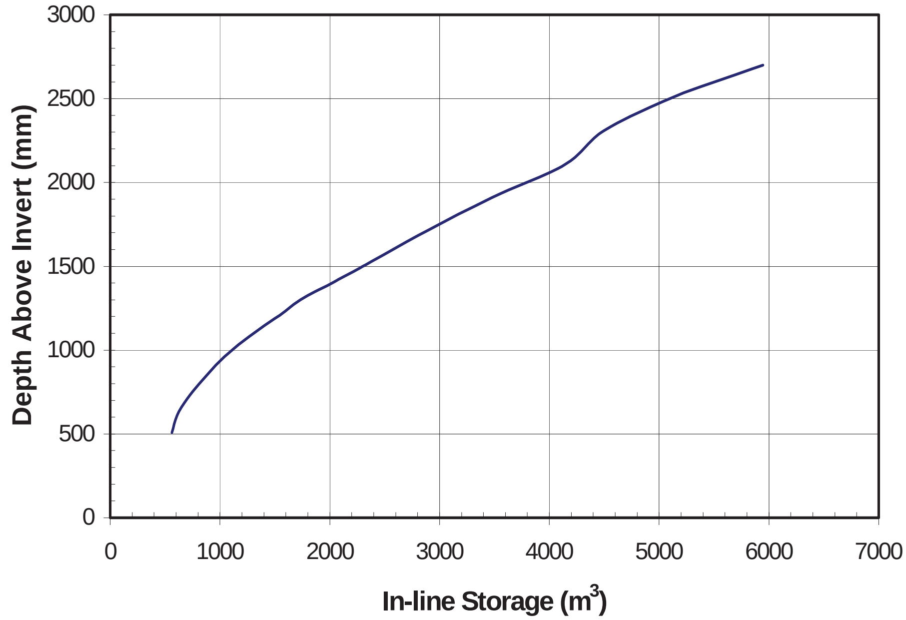


Figure 12-9: Cockburn In-Line Storage Under Existing Conditions

The problem with raising the weir is that it must be raised a significant amount to take advantage of sufficient in-line storage to make a difference, while at the same time raising it provides a hydraulic obstruction that may affect upstream water levels. An objective in raising the weir would be to avoid worsening the level of basement flooding protection under large rainfall conditions.

A detailed hydraulic assessment, which is beyond the scope of this study, would be necessary prior to implementation of a modified weir to avoid unacceptable head losses. For the Cockburn Station there may be an opportunity to locate the weir within the flood pumping station structure and construct the weir with a longer crest length. An example assessment of raising the fixed weir was carried out assuming the weir would be raised by one metre, to a height of approximately 1.5 metres. The additional storage would reduce the number of overflows for the 1992 representative year by 5, to a total annual of 18.

Other weir alternatives for consideration are finger weirs, which increase the effective weir crest length, and commercially available bending weirs. Both of these would provide a lower head loss than a similar fixed weir.

12.2.4.2 Increased Interception Rates

The current nominal interception rate of 2.75 times average dry weather flow is low relative to runoff rates generated in the combined sewers. Increasing the rate, either by itself or in combination with raising the weir or some other form of storage, was considered for its ability to reduce overflows.

The CSO Management Study evaluated the capacity of the NEWPCC interceptor and determined it could handle up to about 5 times average dry weather flow. Although the Cockburn District is in the SEWPCC service area, the maximum diversion rate can be assumed to be in the same order of magnitude, since going higher would require larger pumping and interceptor capacity, and add to the treatment requirements at the sewage treatment facility. The impact of increased pumping to a rate of 5 times on storage volume is shown in Figure 12-10.

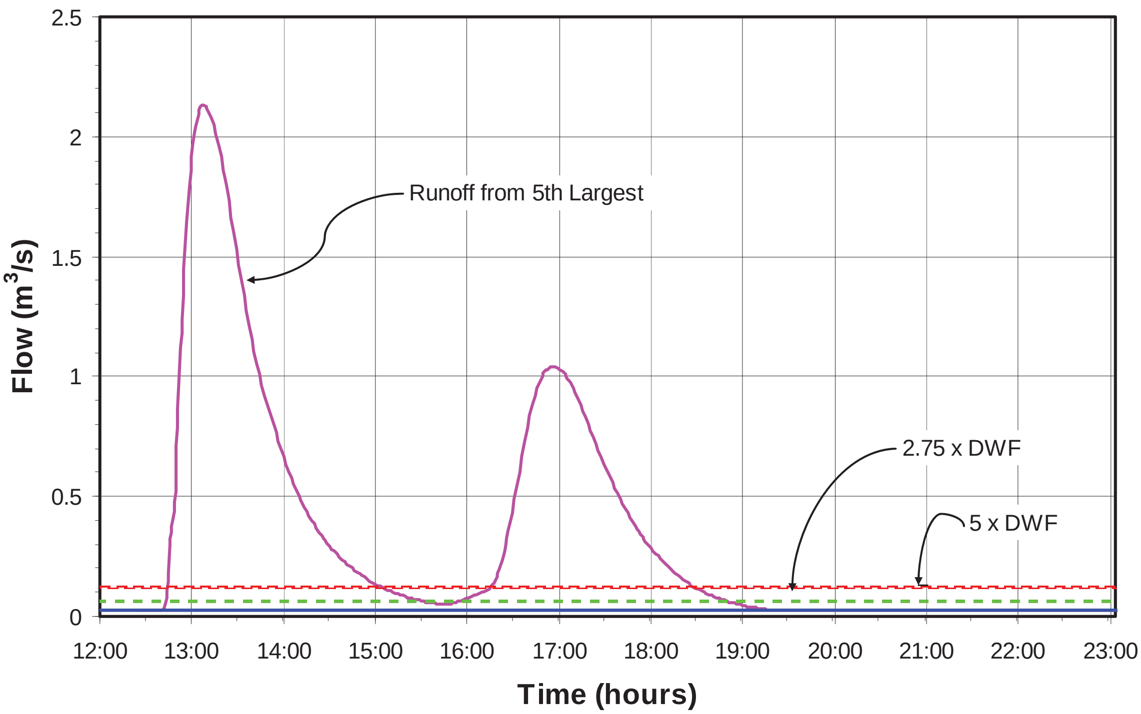


Figure 12-10: Cockburn Interception Rates

Increasing pumping to 5 times dry weather flow would reduce the required storage volume by about 1,300 cubic metres as can be seen from Table 12-1 (12,600 m^3 – 11,300 m^3). The small relative improvement results because the pumping rate increase is relatively small in comparison to the runoff rate, and it only acts on the runoff for a short period of time. In the case of the 1992 representative year, the increased pumping occurred for about two or three hours.

Table 12-1: Impact of Interception Rate on Storage Volume

Lift Station	Pumping	Storage Volume
Flow Basis	Q (L/s)	(m^3)
2.75 x dwf	66L/s	12,600
3.5 x dwf	84L/s	12,200
4.0 x dwf	96L/s	11,900
5.0 x dwf	120L/s	11,300

The Cockburn Station was recently upgraded to a pumping capacity of 105 L/s. This is near the maximum allotment that can be discharged to the interceptor without impacting conveyance capacity and other upgrades. The impact of additional upgrading on the volume of storage is relatively minor. The pumping rates from the combined sewer district to the treatment plant are more of a concern related to the length of time it takes to dewater stored sewage than for the number of overflows.

Increasing the pumping rate may be effective in eliminating the smallest of the overflows, which contribute only nominally to the quantity of overflow but count as an overflow.

12.2.4.3 In-Line Storage

An alternative to weir control is to implement some type of dynamic control at the trunk outlet to take advantage of the in-line storage. There are a number of options that can be used, those that have had serious consideration for Winnipeg include inflatable dams and mechanical gates. With either option, the device is intended to hold water back within the piping system until it is either dewatered or it receives a signal to release, such as may be required to prevent basement flooding. Real time control options provide the opportunity to enhance the in-system storage through improved prediction and operation.

A major advantage of in-line storage is that the storage volume currently exists, and it has a relatively low cost to access for CSO control. The volume accessed through in-line storage is equivalent to the value of off-line storage or the avoided cost of other CSO control measures.

A number of concerns have been raised with in-line storage, and a pilot study was recommended in the CSO Management Study to investigate them. The main issues were:

- A method of controlling the discharge is required, which has been assumed to be by inflatable dams for this assessment. At least some measure of automation is required, to sense when to inflate and deflate the dam, which adds to the complexity of the operation.

- Reliance on a mechanical method of detaining the flow adds to the risk of basement flooding. There is risk that the inflatable dam will not deflate as expected, or deflate at a lower rate than optimal, causing higher levels in the sewer system than would occur otherwise and compromise the level of basement flooding protection.

- Having sewage stored in the sewer system while another storm occurs may reduce the ability of the system to handle the storm, even if the inflatable dam operates as intended. Inlet restriction is a theoretical method of limiting inflow to the system. However, the effectiveness and applicability of inlet restrictions is under review by the City and may not prove as effective as desired.

- The impact on the long-term structural integrity of filling and drawing combined sewage from sewers that are up to a century old is not known. In the worst case, the operation may reduce the life of the sewers or require extensive internal protection.

- The operational impacts are not well known in terms of odour generation, sedimentation, floatables and final impacts to the receiving waters and water quality to the treatment plants. These concerns may require special attention to flushing systems or other add-ons that would increase costs or reduce the effectiveness of the alternative.

An increased risk of basement flooding by itself has the potential to preclude in-line storage. Inlet restriction was considered a prerequisite for in-line storage.

Limitations recently discovered in the effectiveness of inlet restriction have severely placed into question its ability to provide flow control and provide the requisite protection from sewer overloading. Testing and optimization of inlet restriction is continuing and even in the event of its limitation, in-line storage still has merits and should be considered further.

12.2.4.4 Existing System Storage

For the existing system, storage to the obvert elevation of the trunk sewer at the Cockburn Station would provide 6,000 cubic metres. This would require that approximately another 9,000 cubic metres be added by off-line storage or other means to meet four overflows. Figure 12-11 illustrates the extent of in-line storage.

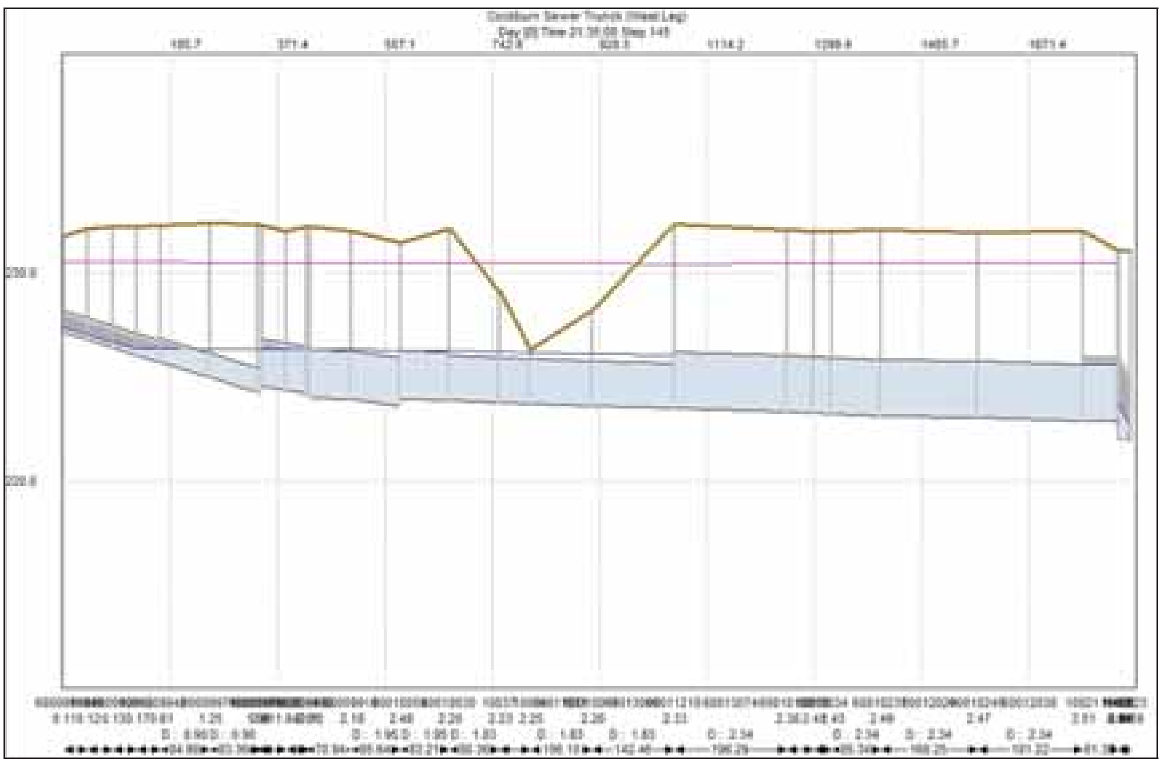


Figure 12-11: In-Line Storage Schematic With Existing System

12.2.4.5 Relief Piping

A similar comparison to that for the existing system was carried out assuming the conceptual relief piping system is installed, with the results shown in Figure 12-12. It indicates that there would be sufficient in-line storage to capture the entire 12,000 cubic metres required by the fifth largest storm, with the maximum level being below the obvert elevation.

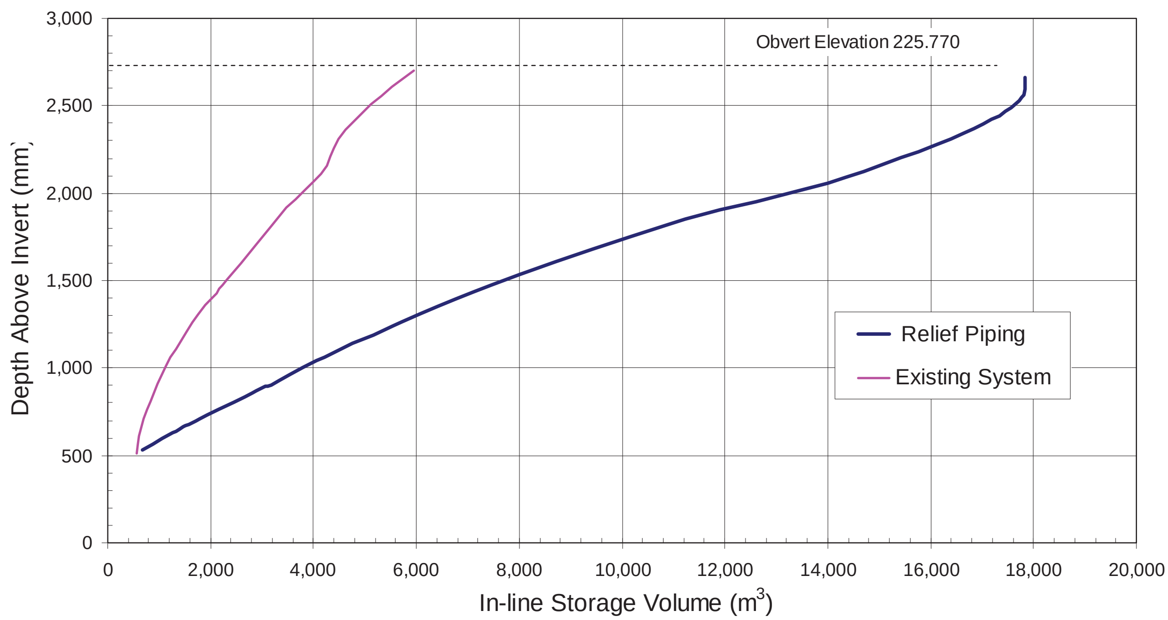


Figure 12-12: In-Line Storage With Relief Piping

The stored sewage would be dewatered using the existing lift station pumps, since the new relief sewers would be installed at approximately the same grade as the existing sewers.

Real Time Control (RTC) typically consists of a series of level sensors and controllable devices, such as an inflatable dam. RTC can be of various degrees of sophistication and complexity, but in general they operate control devices based on level sensors to optimize use of available storage. For a single district such as Cockburn, there is limited opportunity for sophistication as there would be for interconnected systems.

12.2.4.6 Off-Line Storage

Off-line storage would require construction of storage tanks in the local vicinity. Land acquisition would be an issue when using storage tanks, since there must be available land, and it must be located in near proximity to the collection system. For the Cockburn and Calrossie Combined Sewer Relief Districts, it was assumed that the storage tank could be located immediately east of the Cockburn Station in vacant land along the north shore of the river.

Off-line storage can be used with or without in-line storage. When used with in-line storage, the in-line storage, which is much less costly, offsets the sizing and cost of off-line storage. The CSO Management Study indicated a preference for near surface storage tanks rather than local tunnels as the storage tanks were considered to be more economical.

The storage tanks would consist of large near-surface buried concrete structures. The CSO Management Study assumed sewage would be pumped from the combined sewers into the tanks. For the Cockburn District, this could mean pumping the peak flow rate for the fifth largest storm of 2.1 m^3/s. If in-line storage is used, the sewer trunk would act as balancing storage and the peak pumping rate would be reduced. If, however, in-line storage is not used, the peak rate would have to be pumped. An off-take and wet-well like arrangement would be constructed adjacent to the trunk sewer. Because of the requirement to construct the wet-well below the trunk invert elevation, the existing Cockburn flood pumping station would be located at too high of an elevation to be considered for reuse, resulting in the need for costly pumping facilities.

Technology and operating practices are well established for CSO storage tanks. Dewatering of the tanks would require lift pumps at the tank. The lift pumps would be sized for the interceptor capacity (approximately 5 times average dry weather flow), being much smaller than the transfer pumps. Cleaning mechanisms would be used to remove sediment from the tanks after the storage event. The dewatering rate would be set to allow the appropriate contribution to the collection system and treatment works.

12.2.4.7 Modified Relief Piping

Implementation of the conceptual relief piping alternative would provide sufficient in-line storage to capture the entire fifth largest storm. An alternative to implementation of real time control devices would be to lower the relief piping below river level to create a natural storage basin, which would function similar to the latent storage concept described in the CSO Management Study.

Sunken Relief Alternative

A conceptual piping arrangement that includes a sunken storage-relief pipe was prepared for the Cockburn and Calrossie Districts. The sunken relief piping, without Southeast Jessie, is illustrated in Figure 12-13:

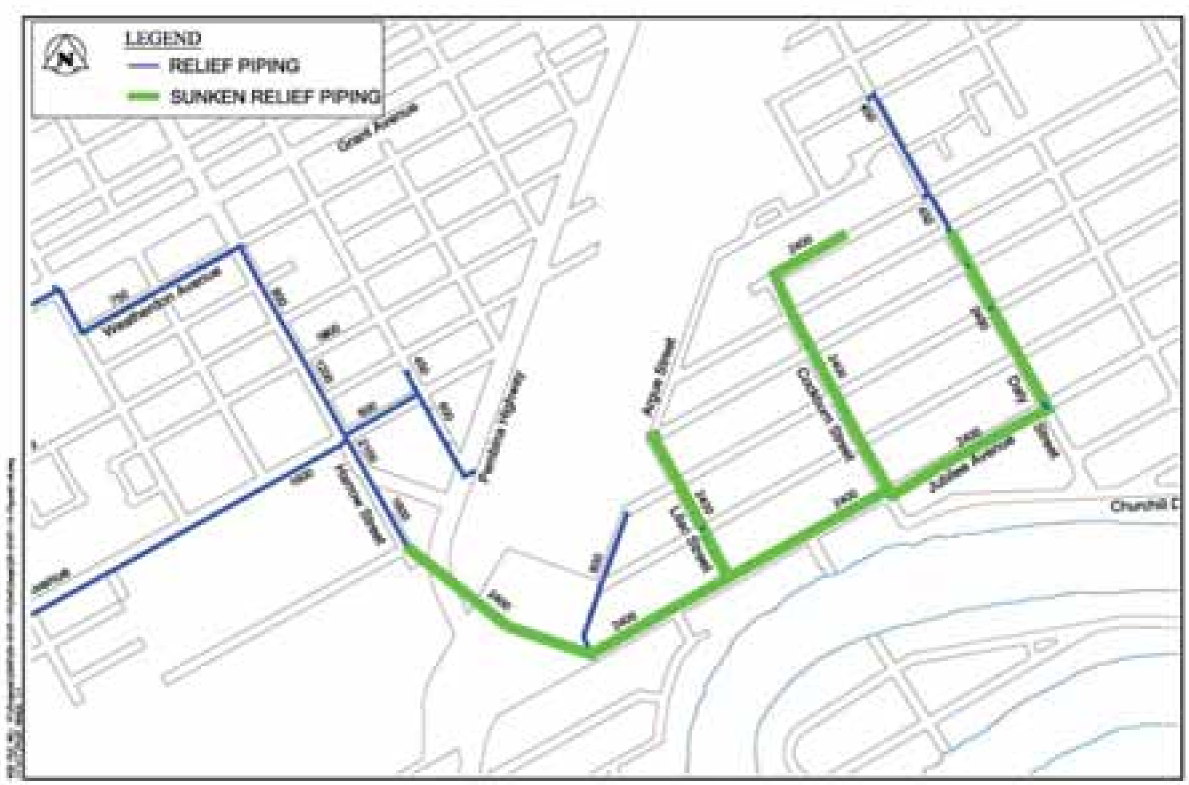


Figure 12-13: Modified Relief Piping – Sunken Relief

- The sunken relief pipe is routed on the same streets and replaces the conventional relief pipe, thereby minimizing the cost of upgrading.

- The connections between the combined sewer and the sunken relief pipe are designed to keep sanitary sewage in the original combined sewer.

- Combined sewage for the fifth largest storm for the representative year can be totally contained within the sunken relief pipes.

- The hydraulic capacity is equal or exceeds the relief piping option, even when the storage-relief pipe is full, eliminating the concern with increased risk of basement flooding as is the case with real time control, and it does not rely on inlet restriction.

- A new lift station would be required to dewater the storage-relief pipe.

This alternative requires the construction of a 3-metre tunnel with an inside diameter of 2.4 metres, which would be installed in place of the relief piping. The tunnel would be 2,700 metres in length, replacing 2,700 metres of relief piping.

The sunken relief pipe would be installed with the obvert no higher than the crest height of the diversion weir. This nominal drop in depth is required to achieve the hydraulic objectives, and would also have the advantage of avoiding conflicts with other services. Site specific geotechnical testing was not conducted. However, there are no known issues that would prohibit the construction.

The sunken relief would have the same hydraulic characteristics as relief piping, but because of its lower elevation it would not dewater by gravity and must be pumped out. A dewatering rate of 105 L/s would be used to match the existing lift station. The existing lift station could not be used because of the requirement for a lower elevation.

Relief /Separation Hybrid Alternative

The concept of implementing sunken relief could be applied to the relief/separation hybrid alternative described in Section 8.4.1 as well. The western side of the Cockburn District would be partially separated, reducing the volume of flow to be captured. Cockburn East would have relief piping, which would receive wastewater with foundation drainage from the entire district, including Southeast Jessie and store it in a sunken relief pipe.

This alternative would require the construction of 2,700 metres of a 3-metre tunnel with an inside diameter of 2.4 metres. This is the same length of tunnel as described previously for the relief alternative, but it includes the Jessie and Parker areas whereas the district-wide relief option did not. The tunnel would replace a similar amount of smaller diameter relief piping.

A dewatering station similar to that previously described for the relief piping alternative would also be required.

12.2.4.8 Separation Alternatives

Sewer separation was addressed in Section 8.0 as a method of basement flooding relief. Land drainage separation would remove road drainage from the combined sewer system and discharge it directly to the river. An alternative to land drainage separation is wastewater sewer separation that would provide new sewers for the sanitary flows.

12.2.4.9 Complete Separation

Complete separation by either LDS or WWS separation would provide CSO control by separating the storm water from the sanitary wastewater. This is often viewed as the best technical or hydraulic approach to CSO control. However, there is an increasing movement to water quality objectives that may ultimately require storm water to be managed, which would create new issues with land drainage discharges. These issues are beyond the scope of this study, but warrant further consideration if complete separation is selected as the alternative.

While sewer separation removes most of the runoff from the wastewater collection system, it was noted that a high inflow and infiltration component will remain from RDII and may require its own control measures. Future environmental licensing will define the level of control required, and it has not been determined if a completely separated area will be regulated to the four overflow limit expected for CSOs, or be subject to a sanitary sewer overflow limit (SSO) which typically would be much more stringent. For the assessment included herein, it was assumed that the four overflow criteria would govern.

12.2.4.10 Partial Separation

The cost of separation is typically higher than other alternatives for both basement flooding relief and CSO control. On a site-specific basis, however, separation of a portion of the area can be cost effective, and when the benefits of basement flooding reduction and CSO control are combined the alternative may be cost competitive.

Land drainage separation was considered as a method of controlling CSOs for the Cockburn, Calrossie and Southeast Jessie areas. The partial LDS separation alternative presented in Section 8.3.1.4 will cause the amount of combined sewer area to be reduced by 39 percent, with the separated area flowing directly to the river as land drainage discharge.

The amount of combined sewage was estimated for the fifth largest storm for the 1992 representative year, using the runoff from the combined sewer area that has not been separated, and the 10-year RDII estimate for the separated area. The volume of CSO was reduced to 5,600 m^3 discharging through the existing outfall, which is about half of what occurs under existing conditions. The estimate was based on retaining the fixed weir in the existing outfall and current rate of pumping. A CSO control method would be required to capture this overflow volume to meet the four-overflow requirement. If in-line storage were to be used, the depth in the trunk would nearly reach the obvert, and because the combined sewer system would still be used for storm drainage, the concern with an increased risk of basement flooding would still exist.

The quantity of wastewater flow is greatly influenced by the amount of RDII remaining after separation, as discussed in Section 8.3. The 10-year frequency RDII flow would tend to over estimate the amount of overflow from the fifth largest storm. However, there is very little information on the rates of inflow and infiltration from combined sewer districts after separation, and no information on what those rates would be for the fifth largest storm. This lack of information limits the accuracy of evaluating sewer separation as a CSO control option.

12.3 CSO COST EFFECTIVENESS ANALYSIS

From the foregoing discussion it is evident there are a number of options for CSO control. Some of the options will reduce the number of overflows but are not sufficient to achieve the four-overflow objective, but may be used in combination with other options.

The cost effectiveness curve as presented in Figure 12-1 provided a graphical presentation of the costs in relationship to their level of control for the entire CSO area. It included a knee of the curve analysis, which provided an indication of the relative costs in comparison to the level of control, expressed in overflows per recreational season. It also illustrated the level of control that could be achieved through minor modifications of the existing system.

The Cockburn CSO assessment assumed the level of control to be a maximum of four overflows per year for the recreational season at each outfall location as well. Some of the control alternatives could cost effectively be applied to the existing piping system to immediately improve the level of control.

12.3.1 Existing System Minor Modifications

The number of overflows for the existing Cockburn system could be reduced substantially at a relatively low cost through the use of in-line storage. It was determined that a reduction to about eight-overflows could be achieved:

- Raising the existing weir to 900 mm would immediately reduce overflows from 23 to 18.
- A bendable weir would add storage volume without compromising hydraulic capacity. The number of overflows would be somewhat improved over a fixed weir, in the range of 17 to 13.
- An inflatable dam and real time control would reduce the number of overflows to about 8 per year. To achieve this level of control, the pipe at the downstream end would be nearly full.

12.3.2 CSO Controls with Basement Flooding Relief

A cost effectiveness curve specifically for Cockburn and Calrossie is presented in Figure 12-14. The values presented are in addition to the cost of the recommended partial land drainage separation alternative.

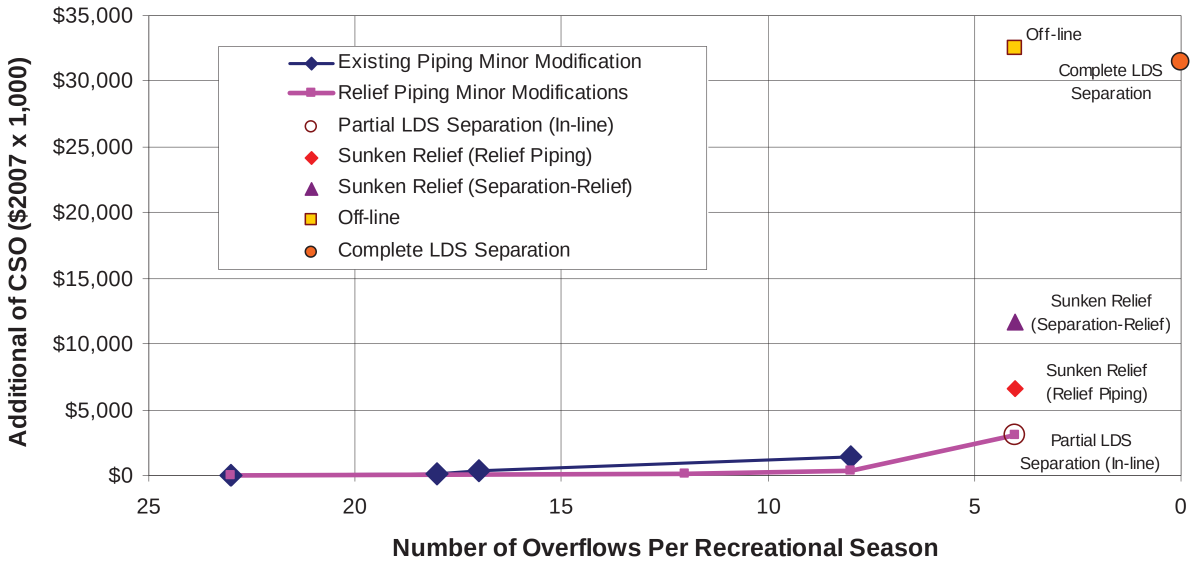


Figure 12-14: Cockburn and Calrossie CSO Cost Effectiveness Curve

12.3.3 Relief Piping Minor Modifications

If relief piping is selected for basement flooding relief, a large amount of additional in-system storage would be added and provides the opportunity to reduce overflows:

- Raising the weir or installing a bendable weir when the relief piping alternative is in place would reduce the number of overflows to as few as 8 per year.
- Installing an inflatable dam and real time control when relief piping is in place has the potential to reduce the number of overflows to the four-overflow target. In other words, in-line storage has the potential to meet the CSO target for Cockburn without supplemental controls.

12.3.4 Four-Overflow Control Options

There are a number of options for integration of CSO control into the basement flooding relief project. Table 12-2 lists the major options and identifies the incremental cost of CSO control over the cost for partial land drainage separation. A regional tunnel option cannot be considered on a district-by-district basis, but is discussed further in Section 13.0.

Table 12-2: CSO Options for Four-overflows for Cockburn and Calrossie

Relief Alternative	CSO Controls	Cost Increment ($2007)	Total Cost ($2007)
Partial LDS Separation	In-line storage	$3,000,000	$40,700,000
Relief Piping	Sunken Relief	$6,600,000	$44,300,000
Hybrid (Relief/Separation)	Sunken Relief	$11,600,000	$49,300,000
Relief Piping	Off-line Storage	$32,500,000	$70,200,000
Complete LDS Separation	In-line Storage	$31,400,000	$69,100,000

Notes:
1) Costs are in terms of 2007 dollar values and include Contingency, Engineering and Burdens
2) Cost increment is in addition to Partial Separation ($37,666,000)

The partial land drainage separation alternative was the recommended alternative for the basement flooding relief mandate, which is in conformance with current Basement Flooding Relief policy. The partial LDS alternative is used as a base cost to highlight the incremental costs of CSO control. The CSO controls presented in Table 12-2 are described as follows:

- Partial LDS Separation with in-line storage:
  The partial separation alternative reduces the runoff volume collected, but still requires a method of CSO control. An inflatable dam with real-time control is likely to be required to achieve sufficient storage within the existing combined sewer system.

  In-line storage has inherent risks, disadvantages and unknowns, whether used in conjunction with relief or separation alternatives.

- Relief Piping with Sunken Relief:
  The relief piping scheme for this option would be the same as for conventional relief piping, except for the sunken portions of pipe. The CSO storage volume required to meet the 4-overflow objective would be provided by enlarging lengths of the relief pipe and lowering it to

prevent gravity drainage. Additional costs are associated with the oversized piping and a dewatering pumping station. No gate controls would be required.

- Hybrid Option with Sunken Relief:
  With separation on the west side of Cockburn, the amount of runoff collected would be reduced, and the volume of sunken relief required on the east side of Cockburn would be reduced accordingly. A dewatering lift station would be required because of the lowered elevation of the storage pipes. No gate controls would be required.

- Relief Piping with Off-line Storage:
  Off-line requires would include the construction of large buried concrete tanks, a high rate pumping station to transfer the wastewater from the sewers to the storage tanks, and a dewatering lift station to direct it to sewage treatment facilities. Off-line could be used with either relief piping or partial separation. Where the runoff is separated out, there would be a commensurate reduction to the cost of CSO control.

- Complete LDS Separation:
  Complete separation would remove all of the road drainage from the combined system and discharge it directly to the river, leaving domestic waste, connected downspouts, foundation drainage and infiltration in the combined system. It would require a significant investment above what would be required for basement flooding relief. In addition, overflow controls may still be required because of the high inflow and infiltration, especially the foundation drainage because of the site grading and neighborhood characteristics. The total cost of separation for the Cockburn and Calrossie study area would include the cost of partial LDS separation plus the incremental cost for complete separation, for a total of about $70 million.

The cost effectiveness trade-off curve will assist in the understanding of the CSO opportunities for Cockburn and Calrossie. One of the key decisions for the CSO program will be whether to permit the use of in-line storage. The Cockburn assessment indicates that the cost of implementing in-line storage with the recommend partial LDS separation alternative is relatively low. If, however, in-line storage is not used the costs to implement CSO control along with partial LDS separation increases dramatically. If in-line storage is eliminated as a CSO control option, the most cost effective integrated CSO and BFR alternative would be sunken relief.

Further discussion on integration into the basement flooding relief project is included in Section 14.0.

12.3.5 Phased Separation Option

The City of Winnipeg assigned additional work for evaluation of expandable separation as an initial relief and ultimate CSO solution. The option consists of constructing partial land drainage separation that can be later expanded to complete LDS separation. The initially installed components would be sized for the total flows, and only those portions required to achieve the 5-year basement flooding level of protection would be installed. The remainder of the system would be installed at a later date to complete the CSO program. The additional evaluation is included as Appendix G.

13.0 NEWPCC INTERCONNECTION

The Cockburn and Calrossie Combined Sewer Relief Project includes an additional task that goes beyond what has been included in previous relief projects. Combined sewer relief projects have traditionally confined their scope to the immediate objective of reducing basement flooding. In recent years, combined sewer overflow analyses have been added in sewer relief studies in recognition of the impending requirement to reduce overflows, and potentially take advantage of cost effective alternatives that meet both objectives. For the Cockburn and Calrossie project an additional further level of analysis was included, in recognition of the opportunity to redirect south end combined sewer flows to the north. This was included in the Cockburn and Calrossie project as the NEWPCC Interconnection task.

The current state of knowledge on Winnipeg's combined sewer overflows (CSOs) is based on a multi-year Combined Sewer Overflow Management Study (Wardrop, 2002). It investigated the water quality impacts of CSOs and formulated potential CSO controls. The study referenced previously in Section 12.1 identified several alternative control options that could be implemented, and recommended a long-term implementation period with a planning level cost estimate of $270 million.

The next phase in implementation of CSO controls will be to complete a Master Plan. It will be necessary to analyze the entire wastewater infrastructure as a system, including the combined sewer districts, the wet weather treatment facilities and other inter-related programs. The master plan will define an implementation program consisting of individual projects that when considered together will result in the optimal solution for CSO control. Since the CSO Master Plan has not yet been formulated, the NEWPCC Interconnection will provide a component of the information that will ultimately be considered in the Master Plan.

13.1 COMBINED SEWER SYSTEM

There are 43 combined sewer districts within the City that cover a gross area of about 10,000 hectares with serviced land of approximately 8,700 hectares. These districts have 76 outfalls and overflow pipes that discharge directly to the Red and Assiniboine Rivers. Cockburn and Calrossie are located at the southern side of the combined sewer districts as shown on Figure 13-1.

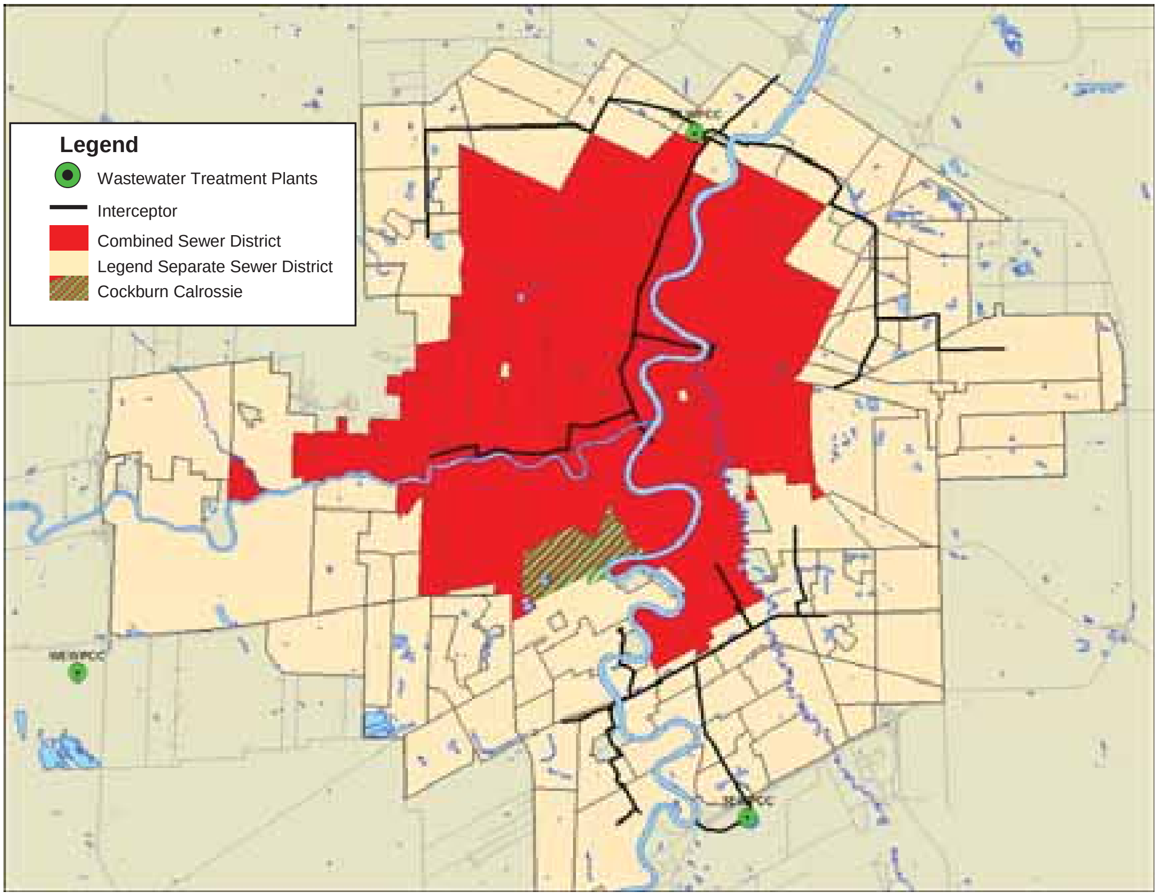


Figure 13-1: City of Winnipeg Sewer Districts and Interceptor Sewers

Wastewater from all sewer districts in the City of Winnipeg, whether combined or separate is transported to sewage treatment facilities by interceptor sewers. The interceptors terminate at one of the City's three wastewater treatment plants, the NEWPCC, SEWPCC or WEWPCC. The major interceptor sewers for the SEWPCC and NEWPCC are shown in Figure 13-1.

Of the 43 combined sewer districts, five discharge to the SEWPCC, including Cockburn and Calrossie, Baltimore, Mager and Metcalfe. The flow from these five districts is collected at Mager prior to discharge to the SEWPCC. Calrossie drains into Cockburn by gravity, which is then pumped to Baltimore. Baltimore flows are pumped to the Mager Combined Sewer District. Metcalfe Combined Sewer District dry weather flows are also pumped to Mager, and then all combined flows are pumped to the SEWPCC.

A project is currently underway for the expansions and upgrading of the SEWPCC. An environmental licence requires that nutrient removal be operational by 2012. The south end of the City is also experiencing the highest growth rate and a capacity upgrade to the entire facility has been included in the project to accommodate the growth.

Potential opportunities have been identified to reduce the amount of flow to the SEWPCC to reduce the expansion costs. An inflow and infiltration reduction program has been initiated to identify and reduce the amount of extraneous flow to the plant. In addition, consideration is being given to transferring some of the contributory districts from the SEWPCC to the NEWPCC, which has available capacity and lower growth projections. The five combined sewer districts that flow to the SEWPCC are therefore all potential candidates for redirection to the NEWPCC.

The NEWPCC is the largest of the three wastewater treatment plants. The majority of the combined sewer districts discharge to the NEWPCC. An environmental licence will also require that nutrient control be implemented at the plant by 2014.

A study of the NEWPCC upgrading requirements is currently underway to determine the issues associated and define the long-term capital upgrading program. The North End Water Pollution Control Centre Master Plan (NEMP) is considering planning issues related to the collection system, including the CSO program, wet weather treatment at the plant, and other treatment process related issues.

The NEMP is considering what the impact would be if the south end combined sewer districts were diverted to the NEWPCC. The study allowed for DWF diversions to the NEWPCC as follows:

Table 13-1: Combined Sewer District CSO Dewatering Rates

District	DWF (ML/d)	DWF (L/s)	Peak Pumping (ML/d)
Mager	6.2	71.7	45
Cockburn	2.3	26.6	9
Baltimore	2.0	23.1	19
Metcalfe	0.3	3.5	

With respect to the CSO program, the NEMP is considering the tradeoffs between CSO control options and treatment plant impacts. Combined sewer overflow options under consideration include:

- CSO storage with a dewatering rate of 825 ML/d to the NEWPCC
- CSO Storage with a dewatering rate of 600 ML/d to the NEWPCC
- CSO storage with a dewatering rate of 380 ML/d to the NEWPCC

The higher dewatering rates will require a higher rate of transport to the treatment facility and a higher rate of treatment, but a reduced requirement for CSO storage options. The rate of 825 ML/d represents a dewatering rate of approximately five times DWF from each of the combined sewer districts.

13.2 CSO CONTROL OPTIONS

13.2.1 CSO Management Study

The CSO Management Study was a comprehensive planning study that dealt with policy issues related to CSO control. It was undertaken over a period from 1994 to 2002 and encompassed all of the combined sewer districts in the City. A potential illustrative program was prepared based on selection of the most cost-effective options with a presumed control limit of four annual overflows in the recreational season. In-line storage supplemented with off-line storage was the primary control option selected.

The study considered use of both local tunnels and regional tunnels as control options but found them to be more costly than in-line and off-line storage options.

13.2.2 NEWPCC Interconnection

The NEWPCC Interconnection alternative has been proposed to address the concept of redirecting SEWPCC flows to the NEWPCC. The concept for the storage transport tunnel is as follows:

- The tunnel would provide in-system storage, to either completely store the reference year storm (described in Section 12.0), or be used in a combination with in-line storage for Cockburn and Calrossie, Baltimore, Jessie and River districts. It would eliminate the need for off-line storage in each of these districts and could optionally be used with or without in-line storage,

- Combined sewage captured in storage would be routed to the NEWPCC through the tunnel.

- Redirection of the flow to the NEWPCC would reduce the hydraulic load to the SEWPCC. It has been assumed that the dry weather flow would continue to discharge to the SEWPCC.

- A tunnel, if suitably located, would serve as a relief pipe as well as a storage element, potentially eliminating redundant piping.

- The south end storage transport tunnel would provide CSO control for all of the combined sewer districts south of the Assiniboine River, except for Mager and Metcalfe. With control of these two remaining districts, the Red River would essentially be CSO free up to the Red and Assiniboine confluence at The Forks. Progressively controlling CSOs in the direction of flow would avoid recontamination from downstream overflows.

The basic arrangement would consider a storage transport tunnel connected to the five combined sewer districts south of the Assiniboine River as shown in Figure 13-2. It would connect at the Cockburn and Calrossie Combined Sewer Relief Districts and be routed north and connect to both Jessie and River sewer districts. A second leg would connect to the Baltimore District and join the main leg south of the Jessie connection.

The tunnel could be constructed as either a deep tunnel, well below the depth of local services or as a shallow tunnel similar to those constructed in previous Winnipeg relief projects. A cursory review of the soil conditions in the area indicated a till layer from 10 to 20 metres below surface level. This would make the tunnel amenable to a shallow tunnel, with the construction process and site conditions similar to other projects undertaken by the City of Winnipeg.

Figure 13-2: NEWPCC Storage Transport Tunnel

The storage transport tunnel would be sized to store the fifth largest storm from the Cockburn and Calrossie, Baltimore, Jessie and River districts. It would replace the off-line storage options and could be designed with or without use of in-line storage.

Under normal dry weather flow all flow would continue to their respective lift stations. Runoff from flows up to and including the fifth largest storm would overflow into the storage transport tunnel without overflowing to the river. Combined sewage stored in the tunnel would drain to the Mayfair Pumping Station location near the Main Street bridge where it would be dewatered at a rate up to five times dry weather flow to the Main Street interceptor, and then flow north to the NEWPCC for wet weather treatment.

Storms larger than the fifth largest storm would fill the storage transport tunnel and then overflow to the river, which would be a permitted discharge under the four-overflow performance limit.

13.3 NEWPCC INTERCEPTOR

The NEWPCC interconnection will be required to discharge to the Main Street interceptor for ultimate treatment at the NEWPCC. It was assumed the south tunnel would terminate in the River Combined Sewer District and cross the Red River through the existing forcemain from the Mayfair Pumping Station, as shown in Figure 13-3.

Figure 13-3: Mayfair Pumping Station and River Crossing

The NEMP is investigating wet weather treatment at the NEWPCC, at the rates of 825, 600 and 380 ML/d. These flow rates represent what would be pumped by the NEWPCC raw sewage pumps and would include flows generated from the combined sewer areas, which are delivered by the Main Street interceptor, as well as flows from separate sewer areas delivered through the Northeast and Northwest interceptors.

An assessment of the Main Street interceptor was undertaken under the CSO Management Study, and was used as the basis for review of the interceptor capacity for the NEWPCC interconnection assessment. The modifications needed to upgrade the capacity of the interceptor to 825 ML/d were the addition of a 750 mm connection between the River and

Assiniboine districts, the addition of a 1350 mm pipe paralleling the interceptor between Clifton and the main interceptor, and the addition of a 600 mm pipe under Omand's Creek. The cost estimates for the 825 ML/d upgrade was $15.0 million.

The maximum flow assumed to be delivered from the south tunnel was based upon a value of five times average dry weather flow. It should be noted that the Main Street river crossing was upgraded at the time of the Main Street Norwood bridge construction project. The modifications made at that time were not reanalyzed, but are expected to satisfy the requirements for the south tunnel.

13.4 MODELING METHODOLOGY

The methodology leverages the information and techniques used in both the CSO Management Study and the Cockburn and Calrossie CSO Analysis described in Section 12.0 of this report. The Cockburn and Calrossie Combined Sewer Relief Districts portion of the analysis uses detailed modeling, while the adjacent districts were modeled on a coarse basis consistent with the CSO Management Study. A coarse model was also used for the NEWPCC Main Street interceptor evaluation.

13.4.1 Coarse Model

Coarse models were developed for the Baltimore, Jessie and River Combined Sewer Districts. The coarse models consisted of one subcatchment each, along with the piping essential for modeling of their weir and overflow. The coarse models were then integrated with the Cockburn and Calrossie detailed model into a regional tunnel model. The coarse modeling approach was tested by replicating the coarse model approach in Cockburn and comparing results to the Cockburn and Calrossie Combined Sewer Relief Districts detailed model, and was found to provide a reasonable representation.

13.5 SOUTH END DISTRICT ALTERNATIVES

The NEWPCC Interconnection alternative considered that all combined sewer districts south of the Red River be considered in this study in a comparative evaluation. Cockburn is the most southerly, and because of the logical connection to the Main Street interceptor, all of the districts in between were included. These included Baltimore, Jessie and River along with Cockburn and Calrossie.

The comparative evaluation included both non-tunnel and tunnel alternatives. The CSO Management Study developed its costs based on in-line and off-line storage without the use of tunnels. The costs of these alternatives were reproduced as a base case to compare to tunnel alternatives.

All of the alternatives considered a dewatering rate of 5 times ADWF, with a total flow of 825 ML/d to the NEWPCC.

Alternative Combinations

The alternatives for the south districts are listed in Table 13-3. Off-line storage is the main alternative to tunnel options, either with or without in-line storage. Since a decision still has to be made on Cockburn and Calrossie relief piping, the evaluation included CSO options with and without Cockburn and Calrossie relief.

It was assumed that the tunnel options would be a direct replacement for the off-line storage options. Both a 3-metre and 5-metre diameter tunnel was considered in the assessment.

Table 13-3: Off-Line Storage and Tunnel Options

	Off-line Storage Options	Storage Transport Tunnel Options	
		3-metre	5-metre
Inline without Cockburn Relief	Option 1	Option 4	Option 5
Inline with Cockburn Relief	Option 2	Option 6	Option 7
No Inline	Option 3	Option 8	Option 9

13.5.1 In-Line and Off-Line Storage

The CSO Management Study recommended that a combination of in-line and off-line storage be used for CSO control at each the south end districts, with gradual dewatering to their respective wastewater treatment facility. The off-line storage alternative could be implemented in conjunction with in-line storage or by itself.

Off-Line Storage

Potential locations for off-line storage were identified for each district, as shown in Figure 13-4.

Figure 13-4: Off-Line Storage Tank Locations

The CSO Management Study recommended near surface tanks rather than deeply buried tanks. The off-line tanks would be large concrete basins with the surface features restored to its original state to minimize impact on the community. The tanks would include a flushing system to remove settled sewage and debris after tank dewatering and odour control equipment.

Pumping would be required to transfer combined sewage from the collection system to the off-line tanks. A forcemain would be required along with the pumping. In some cases, gravity drainage to the tanks may be a viable alternative, but was not investigated for this assessment.

Dewatering pumps would be required to discharge the stored combined sewage to treatment. Both types of pumping systems were identified in the CSO Management Study, and the assumptions were considered suitable for the NEWPCC Interconnection evaluation.

In-Line Storage

The volume of in-line storage depends on the depth of storage in the sewer system, as was discussed in Section 12.0. The required and available storage volumes for the four combined sewer districts being considered are summarized in Table 13-2.

Table 13-2: In-Line Storage Volumes

	Treatment Facility	Volume of Capture Required (4-Overflows*)	Number of Overflow Points	Storage to Trunk Obvert Existing	Storage to Trunk Obvert (Includes Cockburn Relief)
Cockburn and Calrossie	SEWPCC	12,000	2	6,000	17,000
Baltimore	SEWPCC	10,000	4	2,000	2,000
Jessie	NEWPCC	12,000	2	5,000	5,000
River	NEWPCC	4,000	2	3,000	3,000
TOTAL		38,000	11	16,000	27,000

* Assumes 4 overflows per year, dewatering at 5 x ADWF

For in-line storage to be used, a method of temporarily detaining combined sewage in the piping network is required. For this assessment, it has been assumed that inflatable dams, as described in Section 12.0, will be used.

Each combined sewer district has one main trunk that will require installation of an inflatable dam. Since district pumping stations are located on the main trunks, access, space requirements and services are available at these locations. In addition to the main trunks, many of the combined sewers have been hydraulically upgraded through the addition of relief piping outfalls and overflows, which may also require controlling.

There are a total of 11 potential in-line control points in these districts as shown on Figure 13-5. Detailed investigation of each site was not undertaken. For small remote sites such as the Calrossie District, alternative methods of control may be more effective and less costly. However, there will be off-setting costs associated with providing services and potentially relocating the discharge point.

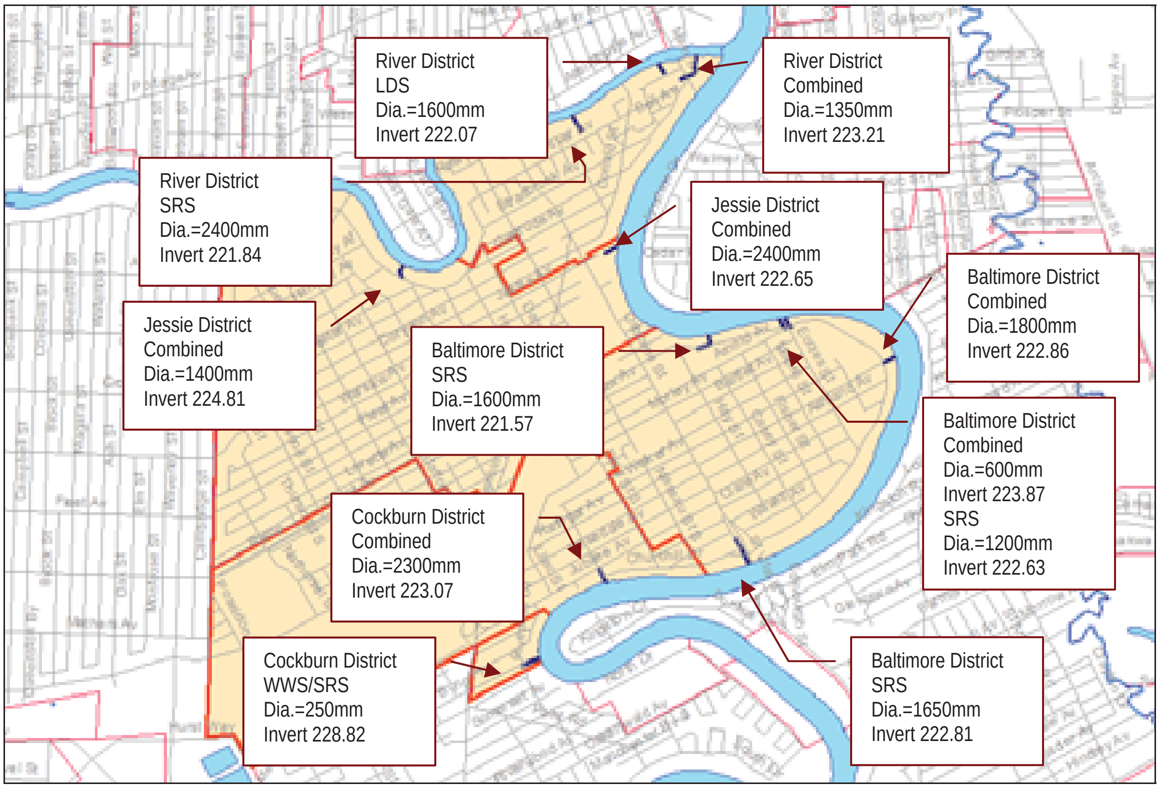


Figure 13-5: Combined Sewer Outfall Locations

The need for in-line storage control at these locations and the suitability for installation of inflatable dams would depend on specific site locations. Based on an assumed storage depth to the obvert of each outfall, 9 of the 11 locations would need control devices. A twelfth location in the River District is not of concern as it is identified on the record drawings as a separate land drainage sewer.

The stored combined sewage would be gradually dewatered to the sewage treatment facilities, either the SEWPCC or NEWPCC depending on the district. For in-line storage, the discharge point will remain at the downstream end of the trunk sewer, which is already equipped with a lift station.

13.5.1.1 Off-line Storage Options

Option 1

The first option considers in-line / off-line storage without the addition of Cockburn and Calrossie relief piping. This option is identical to the alternative proposed in the CSO Management Study illustrative program. The tanks are as located in Figure 13-4. It was assumed pumping would be required to fill the tanks, and a second pumping facility to dewater them. In-line storage would require the installation of 9 inflatable dams.

Option 2

The second option is identical to Option 1 except that the advantages of Cockburn and Calrossie relief piping are included. The addition of relief piping to a district adds to the potential in-line storage volume and demonstrates the value of conventional relief piping for CSO control. Of the south end districts being considered, they have all been upgraded with relief except for Cockburn and Calrossie. The Cockburn relief assessment as described in Section 12.0 was estimated to add approximately 11,000 cubic metres based on storage to the existing trunk obvert elevation. This results in a total of 17,000 cubic metres, which would be enough storage for combined sewer overflow control without the addition of off-line storage for Cockburn.

The Cockburn and Calrossie relief option uses the existing Cockburn outfall so the number of inflatable dams for the alternative does not change from Option 1. Since the relief piping is large enough to detain the entire representative fifth year runoff, storage tanks are not required in Cockburn and Calrossie. The transfer pumping is also eliminated for Cockburn and Calrossie, with only upgrading of the lift pumps being required.

Option 3

A third option considers off-line storage by itself, without any in-line storage. The advantage of this alternative is in the elimination of potential problems created by in-line storage. For this option all of the water must be retained in the off-line storage tanks, conventional relief piping does not add value because of the objective of not using in-line storage.

The tanks are larger in size because of the elimination of in-line storage, all the pumps are still required, but the inflatable dams are eliminated.

13.5.2 Storage Transport Tunnel

The tunnel was assumed to connect from the Cockburn and Calrossie Districts to the Main Street interceptor at the Mayfair Pumping Station located in the River District. The physical length from the Cockburn connection to the Main Street interceptor is 3,500 m, while the branch from the Baltimore District to the main leg of the tunnel is 1,900 m, for a total traversed distance of 5,400 m.

The tunnel would connect directly to the combined sewers eliminating the need for transfer pumping, and since the tunnel would drain by gravity to the Mayfair pumping location district, dewatering pumping would not be required.

It was assumed that standard size tunnels would be selected, with typical sizes for these types of tunnels being 3,000 mm or 5,000 mm outside diameter. Either size would require a 300 mm concrete wall, resulting in inside diameters of 2,400 mm and 4,400 mm, respectively.

13.5.2.1 Storage Transport Tunnel with In-Line Storage

In-line storage could be used with the tunnel in the same manner it is used with off-line storage. The volume of tunnel storage required would be reduced in direct proportion to the amount of in-line storage used.

The volume of in-line storage attainable and the number of controls are the same as discussed previously in the section on in-line storage.

Option 4

The first option with in-line storage considers a three-metre diameter storage transport tunnel with in-line storage. Considering in-line storage to the obvert of the sewers, without considering the additional volume provided by Cockburn and Calrossie relief piping, the required storage volume would be 22,000 cubic metres. The three-metre diameter tunnel has an inside area of 4.52 square metres which means the tunnel would have to be 4,900 metres in length. This is a very close match to the 5,400 metre physical distance between the combined sewer districts.

Inflatable dams would be required for this option, but transfer pumping, dewatering pumping, and supplemental storage would not be required. The tunnel would be routed through the Cockburn District and eliminate the need for parallel relief piping.

Option 5

Option 5 is similar to Option 4 but uses a five-metre tunnel. Because the tunnel is so much larger, the required tunnel length is somewhat shorter at only 1,500 metres. Pumping and forcemains from both Cockburn and Baltimore would therefore be required.

Option 6

Option 6 is the same as Option 4 but includes the benefits of Cockburn and Calrossie relief piping. When the potential additional 11,000 cubic metres of in-line storage is added from Cockburn relief piping, the required length of three-metre tunnel to provide the storage is 3,500 metres. The relief piping addition to Cockburn actually provides more in-line storage than is required for the Cockburn District by itself, but it was assumed this storage would not be available to supplement other districts.

Connection of the three-metre tunnel from Baltimore to the Mayfair station would provide the required 3,500 metre length. The Cockburn and Calrossie relief piping would have enough storage in isolation from the tunnel, and all that would be required to transport the Cockburn dewatering flow to the NEWPCC would be Cockburn dewatering pumps. This could be accomplished by new pumps and a forcemain, or in a similar manner as currently exists, with Cockburn discharging into the Baltimore District.

Option 7

Option 7 is similar to Option 6 except that it uses a five-metre tunnel. The Cockburn and Calrossie relief piping provides sufficient storage for the entire flow generated from the Cockburn and Calrossie Districts, and therefore the tunnel is reduced to 1,100 metres in length.

Pumping to the tunnel from both Cockburn and Baltimore would be required.

13.5.3 Storage Transport Tunnel without In-line Storage

Option 8

A three-metre diameter storage transport tunnel was considered as an alternative to the offline option, without the use of in-line storage. The tunnel would have an inside area of 4.52 square metres, and therefore would have a storage volume of 24,400 cubic metres over the 5,400 m physical distance between the combined sewer districts.

The tunnel would tie into the Cockburn and Calrossie system in the vicinity of the Cockburn outfall. Since the tunnel serves the same general purpose as a relief sewer, in the locations where the tunnel parallels the relief sewers, the relief sewers would be redundant and could be eliminated. Hydraulically, the tunnel would store all flow up to the fifth largest storm for the representative year and then overflow like a relief sewer to the river.

Using this tunnel without consideration for additional storage added by Cockburn and Calrossie relief for this option, an additional 13,600 cubic metres of storage would be required for the fifth largest storm for the representative year. Three options were considered to provide this additional storage:

- Add another 3,000 metres of tunnel length. This could be accomplished by running a parallel tunnel, or routing it to another location to improve drainage or basement flooding relief. This assessment did not investigate potential opportunities.

- Route the additional tunnel in locations of planned relief piping, in order to eliminate the need for the relief piping, thereby offsetting the cost of the additional tunnel. The Cockburn and Calrossie Sewer Districts are currently being considered for relief and have the approximate relief piping length to accommodate the additional tunnel length.

- Add the additional storage by constructing in-line tanks instead of additional length of tunnel. This would be advantageous where the cost of the tanks is less than the cost and benefit of additional tunnel. The height of the tanks would be limited to approximately 5 metres to accommodate the maximum storage depth. A variety in the number of tanks and configurations could be used, with in the order of three tanks being likely at approximately 4,500 cubic metres each, including a cleaning and grit removal system.

Each of these options for additional storage has its own merits and costs. The alternatives were not evaluated in detail, but included as a generic requirement.

Option 9

Since the three-metre tunnel storage volume over the physical distance between districts is insufficient to provide adequate storage for the option without in-line storage, a five-metre tunnel was considered. The five-metre tunnel would have a cross sectional area of 15.20 square metres, and to provide the required storage volume of 38,000 cubic metres, would only have to be 2,500 m in length. This is less than half of the physical distance between the combined sewer districts. If a 2,500 metre long five-metre diameter tunnel was used, the Baltimore leg could be replaced by pumping and a forcemain to reduce costs. In addition, the Cockburn and Calrossie relief piping could be re-graded to transport wet weather flow to the tunnel using the smaller size relief piping.

13.6 ALTERNATIVE COMPARISONS

The NEWPCC Interconnection assessment was prepared at a planning level to illustrate the value of a system view of CSO controls. Option comparisons can only be made on a relative basis, as the level of detail is not intended for option selection or budget estimates.

Comparative costing was prepared for each option to illustrate the relative difference in costs as presented in Table 13-4.

Table 13-4: CSO Options For South Districts - Relative Cost Comparison

Option	Off-line Tanks	Tunnel	
		3-metre	5-metre
In-line without Cockburn Relief	$86,000,000 (Option 1)	$75,000,000 (Option 4)	$74,000,000 (Option 5)
In-line with Cockburn Relief	$67,000,000 (Option 2)	$65,000,000 (Option 6)	$49,000,000 (Option 7)
No In-line	$109,000,000 (Option 3)	$84,000,000 (Option 8)	$61,000,000 (Option 9)

Notes:
1) Costs are in terms of 2007 dollar values and include Contingency, Engineering and Burdens.
2) Cost are for CSO Control only, and do not include the cost of Cockburn and Calrossie relief.

The following observations can be made from the foregoing analysis:

Baseline Cost

The illustrative implementation plan developed under the CSO Management Study was based on use of in-line and off-line storage. The control option costs presented therein were updated and grouped for Cockburn, Baltimore, Jessie and River Districts to develop a baseline cost, represented by Option 1. Basement flooding relief has been completed for all of these districts except for Cockburn and was considered accordingly under the CSO Management Study. The CSO Management Study did not make any allowances for Cockburn relief.

Cockburn Relief

A Cockburn relief project would require construction of large relief pipes or separation of a large portion of the district. The relief piping system has the potential to also provide CSO control, and result in significant program savings. Option 2 assumes that the relief program will provide adequate storage for CSO control, which means the off-line storage tanks included in Option 1 would not be required, with a cost savings of nearly $20 million.

The Baltimore, Jessie and River Districts have already been relieved. Since no further relief piping is planned, they do not have potential for a similar integration savings.

If conventional relief piping is selected for Cockburn, the CSO benefits would rely on the use of in-line storage. If at a future date in-line storage is deemed to be an inappropriate technology for CSO control, then the benefit of the dual objective project would be lost.

In-line Storage

In-line storage is a very cost effective source of storage since it already exists and only needs to be accessed. For the areas considered in the south tunnel area, in-line storage provides a cost saving of about $40 million in comparison to use of only off-line storage (Option 2 compared to Option 3). This does not include an allowance for protection or upgrading of the existing pipes to handle the additional stress of in-line storage.

In-line storage has inherent risks as described in Section 12.2.4.3 and is still the subject of uncertainty. A greater level of confidence with a number of the issues will be required before a total commitment is made to this alternative.

Off-line Storage

Off-line storage is a proven and low risk control technology. However, it does add a significant amount of infrastructure and would have a high operations and maintenance cost. Its implementation requires large storage tanks, transfer pumps and dewatering pumps. When used in combination with in-line storage, inflatable dams or other types of control gates are still required, adding to the operations and maintenance complexity.

As an independent method of CSO control, off-line storage is costly. For the four south area districts, the cost of using only off-line storage was estimated to be over $100 million (Option 3). The high rates of pumping required and site location constraints make the pumping costly. Land acquisition was not considered in the analysis herein, but it could also be a major cost and issue.

Storage-Transport Tunnels

The storage-transport tunnels were found to be cost competitive with off-line storage when considered as a regional approach. The cost per cubic metre of storage volume for a 3-metre tunnel is comparable to that of off-line storage but since the tunnel can fill by gravity, the pumping requirements are much less. In terms of dewatering, one pumping station can be used for all four of the districts when using a tunnel.

The 3-metre diameter tunnel would be of sufficient length to connect all four districts together for Options 4 and 8, but would not have sufficient length to traverse the distance from the River District to Cockburn and Calrossie for Option 6. Dewatering pumping and a forcemain from Cockburn and Calrossie to the tunnel would be required. Even with the addition of the pumping, the tunnel option would be competitive with other CSO options.

The use of a 5-metre diameter tunnel reduces the cost per cubic metre of storage and generally results in a lower capital cost. It has less flexibility in terms of length. However, even with the use of additional pumping and forcemains, it may be the most cost competitive. The assessment indicates the 5-metre tunnel could be used without in-line or off-line storage at a competitive cost (compare Option 9 to Option 2).

From the foregoing discussion, it can be concluded that tunnels provide a reasonable alternative for CSO control, when considering a regional approach. The south tunnel would effectively accomplish the secondary objective of re-routing south end flows to the NEWPCC. It also provides a pragmatic approach to CSO control by removing overflows from the upper reaches of the river first, avoiding recontamination as would happen if CSO controls were first implemented downstream of The Forks.

The tunnel option would also avoid the complexity, risks and increased operation and maintenance associated with both in-line and off-line storage options.

14.0 ALTERNATIVE SELECTION

The Cockburn and Calrossie Combined Sewer analysis described in this report provides the information required for selection of a basement flooding relief alternative. Alternatives were identified, conceptual costs were developed and combined sewer overflow impacts and opportunities were considered. The alternatives must next be evaluated in comparison to each other, and a preferred alternative selected. The Cockburn and Calrossie recommended relief alternative will then be used by the City for comparison to other similar type projects in development of a prioritized implementation plan under the Basement Flooding Relief Program.

This section considers the selection of the most appropriate relief alternative for Cockburn and Calrossie in conformance with the requirements of the Basement Flooding Relief Program, and secondly extends the evaluation to consideration of integration into a CSO program. The CSO program has taken on more prominence recently because of impending regulations and the increased awareness and sensitivity for the need to control overflows. Consideration of CSOs is particularly important for the Cockburn study because of the opportunity to redirect some of the flows to the North End Water Pollution Control Centre to lower the impact on the South End Water Pollution Control Centre, which is currently overloaded and in the process of being expanded.

14.1 SOUTHEAST JESSIE AREA

The southeast Jessie area was left out of the original Jessie relief project presumably on the basis that it would be less costly and more practicable to include it at some future date with Cockburn District relief. It would be unrealistic now to reintroduce it to the Jessie relief system, leaving the Cockburn and Calrossie project as the only reasonable opportunity to provide relief.

The relief alternatives have been developed on the basis of both including and excluding Jessie for comparative purposes. In all cases, there is a substantial premium to include Jessie, but because the area has a severe flooding problem, it also produces high benefits. If the Jessie area were relieved by itself it would be very expensive because it is isolated from a discharge point and extending a pipe to the river would be costly. Discharging it to Cockburn requires only a short connection to the Cockburn trunk and oversizing of the trunk to the outfall. Considering the Southeast Jessie addition to be a project by itself would produce a benefit-cost ratio of 2.5 or higher, and adding it to the Cockburn and Calrossie alternatives increases the overall project benefit-cost ratio by two to three points. In other words, the Jessie project would be viable on a stand-alone basis, and adds significantly to the benefit-cost ratio for the Cockburn and Calrossie alternatives.

It is therefore recommended that Southeast Jessie be included in the Cockburn and Calrossie relief project.

14.2 ALTERNATIVE SELECTION BASED ON BASEMENT FLOODING RELIEF PROGRAM

The traditional approach to selection of a basement flooding relief alternative has been to compare benefit-cost ratios for each alternative that provides a 5-year level of protection, and select the one with the highest value. The combined sewer overflow control benefits have been given some recognition in past projects, but because the program mandate has been to reduce basement flooding, the selection has not encompassed the joint consideration of a combined sewer overflow control program.

14.2.1 Benefit-Cost Based Selection

The Cockburn and Calrossie benefit-cost results were presented in Section 9.0. The costs were reported in 1991-dollar values and the benefits in terms of 1993 flooding reduction values as required by the City for project comparison purposes. Although the costs and benefits are not meaningful in terms of current values, it is essential that a common reference point be used when comparing costs of competing projects within the program. Because the benefit-cost ratio is dimensionless, the values can be considered a reasonable approximation of what it would be in terms of today’s dollars.

Only district-wide relief alternatives, with the Southeast Jessie included, are considered in the alternative selection. Selection of district-wide alternatives has been the past practice in establishing the Basement Flooding Relief Program prioritization, leaving the localized alternatives for consideration once the district-by-district decisions have been made.

A summary of the benefit-cost ratios for the Cockburn and Calrossie district-wide alternatives was presented in Table 9-9:

- The partial LDS separation alternative has the highest benefit-cost ratio of the district-wide alternatives. Its cost is essentially identical to the cost of relief piping, and it will produce somewhat higher basement flooding protection benefits.

- Relief piping presents a reasonable alternative to partial LDS separation. It has been the most commonly selected option for past relief works, but has scored somewhat lower on the benefit-cost analysis for Cockburn and Calrossie.

- The relief/separation hybrid alternative is also a competitive alternative, with a blend of the advantages and disadvantages of both LDS relief/separation piping.

- The LDS and WWS complete separation alternatives are not cost competitive when considering only basement flooding relief, as their cost is nearly double that of partial LDS or relief piping. They both provide an enhanced level of basement flooding protection, but not to the extent that they would be considered for selection. The additional cost of providing complete separation would not be justified from a Basement Flooding Relief Program perspective. These alternatives are subsequently considered from the broader perspective of CSO controls.

Each of the alternatives was also considered for combined sewer overflow impacts. The point of interest is whether there would be benefits inherent in each of the alternatives -- that is whether there would be immediate benefits without the requirement for additional capital spending. The incidental CSO benefits for each of the district-wide Cockburn and Calrossie alternatives are as follows:

- Partial LDS separation will provide a positive impact on combined sewer overflow control, but the impact will be marginal in terms of reaching the long-term objective of four overflows. Significant combined sewer overflows will remain after implementation, and meeting future requirements will still require a CSO control program.

- Conventional relief piping will have very little impact on combined sewer overflows. There will be a greater potential for in-line storage, but this is of limited value without the additional investment in control of the discharges, and use of in-line storage presents technical and risk issues.

- The relief/separation hybrid CSO benefits will fall between those for partial LDS separation and conventional relief piping, as it is a blend of the two options.

- Complete LDS separation would greatly reduce combined sewer overflows. A control program would still be required to capture overflows because of the significant RDII flow contributions from weeping tiles, and other inflows and infiltration. Retaining the combined sewer as the wastewater sewer provides significant storage volume for in-line storage. With complete separation, the systems may lose their combined sewer classification as well as the four overflow regulation, and be subject to much stricter compliance limits.

- Complete wastewater sewer separation would eliminate combined sewer overflows. Like LDS separation, the weeping tile flow collected would still be significant and the short duration high flow rates would have to be controlled to reduce the number of overflows. By converting the combined sewers to a land drainage system, infiltration would consist of clean water, which would discharge directly to the river without concern, and infiltration into the wastewater system would be reduced by construction of a new tighter sewer system.

14.2.2 Localized Relief

Often, there are opportunities to implement selected components of the relief alternative that will deliver high benefits at a relatively low cost in advance of total implementation. This concept has been called localized relief, and it was originally identified in the City of Winnipeg (1986) Report.

For Cockburn and Calrossie, the east side of Cockburn presents a viable localized relief opportunity. The eastern side experiences high flooding and is relatively easy to relieve because it is in close proximity to the Cockburn outfall.

Localized relief could be applied to the east side for several of the district-wide alternatives:

- For either the LDS partial separation or relief piping alternatives, a trunk and outfall large enough to accept flows from the entire district would first be installed along with the localized relief. Subsequent relief of the west side would then tie into the pre-constructed trunk.

- For the relief/separation hybrid alternative, the entire relief piping alternative would be constructed on the east side, totally independent of the west side because of the independent outfalls. The west side partial separation would then subsequently proceed totally independent of the east side.

14.2.3 Recommended Alternative – Basement Flooding Relief Mandate

Based on the foregoing considerations, the partial LDS separation alternative is recommended for implementation in Cockburn and Calrossie and Southeast Jessie Districts. It has the highest benefit-cost ratio, the total cost is similar to the cost of relief piping, and it offers some incidental combined sewer overflow benefits.

The costs for the recommended works in terms of 2007 dollars are presented in Table 14-1.

Table 14-1: Cost and Benefits of Recommended Relief Alternatives (2007$)

Project	2007 Construction Cost	Contingency (30%)	Eng (15%)	Burden (3%)	2007 Total Capital Cost	B/C Ratio
District-wide Partial Separation	$25,450,000	$7,635,000	$3,817,500	$763,500	$37,666,000	1.7
East Side Partial Separation	$10,480,000	$3,144,000	$1,572,000	$314,400	$15,510,400	1.9
West Side Partial Separation	$14,970,000	$4,491,000	$2,245,500	$449,100	$22,155,600	1.6

Scheduling of the Cockburn and Calrossie project will depend on how it fits into the Basement Flooding Relief Program priorities. The costs and benefit-cost ratio for the evaluation are as follows:

Burdened Cost ($1991) $11,891,000
District-wide Benefit-Cost Ratio 1.7

If the relief works are to be based on the basement flooding relief perspective alone, it is recommended that relief of the east side of Cockburn and Calrossie, with a benefit-cost ratio of 1.9 as presented in Section 8.3.1.5, be considered for localized relief. It will provide a high level of immediate benefits and can proceed independently of the western part of the district.

14.3 ALTERNATIVE SELECTION BASED ON AN INTEGRATED CSO PROGRAM

The merits of integrating basement flooding relief with combined sewer overflow works were also considered from the alternative selection perspective. It is expected that the City will be required to undertake a major long-term combined sewer overflow control program and since CSO control deals with the very same flow sources and infrastructure as basement flooding relief, decisions made on one directly impact the other. The indefinite nature of the CSO policy and the absence of program direction has to-date, however, limited the investigation and realization of joint benefits. Joint consideration and integration of both programs would provide the optimal and least cost alternatives.

All indications are that the CSO policy and program are imminent. The City has completed a multi-year CSO Management Strategy (Wardrop, 2002), the CSO issue has been dealt with by the Clean Environment Commission at public hearings held in 2003, and the Province has been adamant on proceeding with some form of licencing. It is therefore in the City's best interest to increase the emphasis on CSO control when considering basement flooding relief works. This is particularly true for Cockburn and Calrossie, where combined sewer overflows have historically been a problem and a service area interconnection to the NEWPCC is under consideration.

An evaluation of potential CSO controls for Cockburn and Calrossie and of a NEWPCC interconnection were prepared and discussed in Sections 12.0 and 13.0 of this report, respectively. The evaluation was undertaken at a planning level, with costs carried forward from existing works where available, or produced in similar cost terms where required. The evaluation provides options for considering early integration of CSO controls, and is intended to highlight the benefits of proceeding with joint considerations. The CSO controls as they relate to each of the district-wide basement flooding relief alternatives were summarized on Table 12-2.
The uncertain timing associated with CSO implementation complicates the decision process for integration approaches. For the purposes of illustration, CSO implementation was considered from three perspectives:

1. Implementation of the Cockburn and Calrossie recommended relief alternative to meet the Basement Flooding Relief mandate without consideration for CSO control, followed by a second program for CSO control at a later date.

2. Implementation of CSO control on a district-by-district basis at the same time as relief implementation, with full integration of CSO and relief projects.

3. Consideration of regional CSO control, assuming the NEWPCC Interconnection would proceed as the method of CSO control, with full integration of the CSO and relief programs.

14.3.1 Basement Flooding Relief and CSO Programs as Separate Mandates

If the relief program proceeds in advance of the CSO control program, the future CSO control will be limited to in-line storage, off-line storage, a combination of the two, or construction of additional separation. The sunken relief and tunnel storage options will be virtually eliminated because of the commitment already made to the relief approach.

- In-line storage would be the first consideration for CSO control because of its cost. An advantage of in-line storage is that it can be added at any time. A drawback is that it has a number of unknowns and risks that must be managed before it can be fully adopted. A number of operational risks have been identified, and inlet restriction has been considered as an essential component for mitigation of basement flooding risk, but it is now in doubt because of unresolved technical issues.

- Off-line storage would be the most likely control option if in-line is ineffective or insufficient. Supporting both in-line and off-line storage would be very costly and maintenance intensive and likely be impractical, with costly off-line winning out as the sole CSO control alternative.

- Expanding the area of separation after relief is in-place for CSO control is unlikely to be a cost competitive alternative. Provision for increased separation in the future by enlarging the diameters of the collectors and trunks could be provided for in the relief design, but would add to the cost of relief with no immediate basement flooding relief benefits. Subsequent CSO control would still be required.

- If either complete LDS separation or complete WWS separation were chosen as a relief option, it is likely that an overflow control program would still be required. One of the key findings from the Cockburn and Calrossie study was that even with separation there will be a large volume of RDII from weeping tiles and collection system inflow and infiltration. If the sewers were reclassified as separate sewers, a stricter sanitary sewer overflow (SSO) discharge policy would apply instead of those for CSOs.

If off-line storage, or a combination of in-line and off-line storage, is to be the ultimate CSO control method for Cockburn and Calrossie, there is little risk or lost opportunity of proceeding with the recommended partial LDS separation alternative.

The additional cost of implementing in-line storage to the Cockburn partial LDS alternative, from Table 12-2, would be in the order of $3,000,000, for a total district cost of $40,700,000. If in-line storage cannot be made to work, the high cost of adding off-line storage would be required, bringing the total cost in the range of $69,000,000 (equivalent to relief with off-line storage).

14.3.2 CSO Project Integration with Relief Project

Evaluation of CSO controls along with the relief works provides the opportunity for optimization of district based CSO control options. The in-line and off-line options, increasing the area of separation, and modifications to relief pipes are all viable options. The modification to the relief piping that is most promising is sunken relief. It provides the advantages of in-line storage, while eliminating the risks of mechanical failure and the complex operation associated with automated gates or an inflatable dam.

The sunken relief option could be implemented for either relief piping or relief/separation hybrid alternatives. For the recommended partial LDS separation alternative and the complete separation alternatives, there is no relief piping recommended, so there is no opportunity to incorporate sunken relief.

If CSO control is to be considered along with relief piping, it is recommended that sunken relief be evaluated in more detail. It has the potential to save significant costs and provide a more robust and reliable system to operate. CSO benefits would commence immediately upon its installation. Its selection would not preclude the early implementation of localized relief.

The sunken relief option cost from Table 12-2 would add $6,600,000 to the district cost, bringing the total to $44,300,000. This is a savings of approximately $25,000,000 compared to proceeding with partial LDS separation and then adding off-line CSO control.

14.3.3 CSO Regional Tunnel Integration with Relief Program

The NEWPCC interconnection concept incorporates a tunnel that would provide storage and transportation from Cockburn and Calrossie, as well as Baltimore, Jessie and River Combined Sewer Districts. It would essentially comprise the entire CSO control program for all combined sewers south of The Forks on the west side of the Red River. The assessment provided in Section 13.0 identified the compatible Cockburn alternatives and benefits of considering the connection in advance of the comprehensive CSO program.

The Cockburn and Calrossie relief piping options are the ones that are most compatible with the NEWPCC interconnection. Separation options, including complete WWS, complete LDS and partial LDS separation would preclude extension of the tunnel to Cockburn on a cost effectiveness basis. Pumping of the Cockburn flow through a forcemain would be required if redirection to the NEWPCC were to be achieved for the separation options.

The Cockburn and Calrossie relief and relief/separation hybrid alternatives, which incorporate sunken relief, are fully compatible with the NEWPCC tunnel interconnection option. The concept would be to integrate the sunken relief pipe into the proposed tunnel. In essence, a short section of the Cockburn sunken relief pipe would become a section of the future tunnel. It would serve as a relief pipe, a CSO storage element and a transportation tunnel to River District. It has the advantage of diverting the maximum amount of flow to the NEWPCC at lowest overall integrated cost.

The regional tunnel evaluation presented in Table 13-4 of Section 13.0, concluded that:

- A regional tunnel would be cost competitive with use of a blend of in-line and off-line storage for the southeast combined sewer districts (Options 6 and 7, compared to Option 2).

- If use of in-line storage is not acceptable, the cost of regional tunnel CSO control is less expensive than off-line storage for the southeast combined sewer districts, by between $25,000,000 and $49,000,000 (Options 8 and 9, compared to Option 3).

This cost comparison serves to demonstrate at a minimum that based on the current level of understanding, the tunnel costs are favourable and the tunnel eliminates the use of risky and uncertain in-line storage.

The NEWPCC interconnection would comprise one regional solution to a comprehensive CSO program. The option would complete the CSO program for the entire southwest combined sewer quadrant and would leave only the Mager and relatively minor Metcalfe District with combined sewer overflows south of The Forks. Further study would be required to evaluate whether these two districts located on the east side of the Red River should be integrated into the NEWPCC interconnection tunnel. The alternative is compatible with the North End Water Pollution Control Centre Master Plan that is currently in progress, and would not be expected to compromise integration into a citywide CSO program.

14.3.4 Recommended Alternative – Phased CSO Control

The CSO program perspectives presented in the preceding discussion creates a scheduling dilemma on proceeding with the relief works. Proceeding with Cockburn and Calrossie on the basis of strictly the basement flooding relief mandate may preclude savings of $25,000,000 or more from not integrating the CSO program, and commit the City to more complex and higher maintenance solutions for the long term. The option of waiting on the CSO program decision is reasonable from a decision perspective, but compromises the Council approved basement flooding relief mandate, and puts additional risk on residents who may be due for an upgrade to their level of protection against basement flooding.

A phased implementation approach is recommended to deal with the issue. The first phase would be to implement partial land drainage separation in Cockburn West. This is the alternative recommended for the basement flooding alone perspective, and is compatible with the three CSO perspectives. It would provide immediate basement flooding relief to all of Cockburn West as well as Southeast Jessie, which has a severe deficiency in its level of service, and a very high project benefit-cost ratio.

The second phase would be deferred until CSO master planning has proceeded to the point of a recommendation for regional CSO control. This would require a delay to implementation of relief in Cockburn East, to provide for flexibility in selection of the method of integrating basement flooding relief and CSO works. If a regional tunnel is selected for CSO control, a storage-transport tunnel component could be constructed in Cockburn East to connect to the regional tunnel. If on the other hand total separation were selected, then Cockburn East could be separated, just as Cockburn West will be. If local storage is required, the sunken relief option could be incorporated.

The alternative being recommended could result in partial separation of the entire Cockburn District, or in a hybrid partial LDS/relief alternative. Based on a partial separation concept, the estimated costs and benefits for the works are as presented in Table 14-2.

Table 14-2: Recommended Relief Alternative - Phased Implementation

Phase	Scope	Schedule	2007 Total Capital Cost	B/C Ratio
1	West Side Partial Separation	Proceed Immediately	$22,155,600	1.6
2	East Side Partial Separation	Subsequent to Regional CSO Decision	$15,510,400	1.9
Total	District-wide Partial Separation		$37,666,000	1.7

15.0 FORT ROUGE LANDS DEVELOPMENT SCENARIOS

The Cockburn and Calrossie project originally included a scope of work to assess the impact of accommodating land drainage servicing from new development in the Fort Rouge Yards through the Cockburn Combined Sewer District. During the progress of the study, a decision was made to proceed with the Bus Rapid Transit corridor, and additional services were assigned to undertake a broader and more detailed drainage study and plan for the area. The evaluation presented in Section 15.0 deals with the original scope of work (see Appendix E for details on development options), while the additional scope is reported on in Appendix F.

15.1 MODEL DEVELOPMENT

Following discussions with the project team and the City of Winnipeg, three main options were developed to simulate the combined storm system servicing the area. The Fort Rouge Yards were then modeled to assess impacts of possible development plans of the yards on the receiving combined system. The development options are described in detail in Appendix E.

The first, Option 1, considered the existing conditions for the Fort Rouge Yards. The assumption was that the existing yards would remain undeveloped and impacts in the adjacent Cockburn Combined Sewer System would not increase.

The second, Option 2 considered future development plans. Specifically, it was assumed that a large portion of the yards south of the existing railway tracks would be rezoned and utilized to construct medium to high-density residencies. This particular option was investigated following development applications submitted to the City over the past few years. Envisioning the potential development impacts on the receiving system a series of alternatives was reviewed, intended to facilitate the development of the subject property. A description of each of the alternatives, Options 2A to 2C, is provided in Table 15-1.

The third option, Option 3, examined the potential development of the BRT corridor. Specific to this same option, it was assumed that the existing yards would not be developed and left in its existing conditions. As for the second option, one of the alternatives considered, Option 3C, assumed that a pond covering approximately 1 ha of the developable land would be used to control the slow release of runoff into the receiving system reducing the impacts on the proposed upgrades. Depending on the recommendations proposed for the Cockburn system, the pond area could be adjusted to encourage the development of the site while reducing upgrade capital costs on the City. Table 15-1 provides a summary description of the different scenarios examined.

Table 15-1: Summary of Fort Rouge Yards Development Options

Land Use	Options	Description
▪ Railway Yards: Existing Conditions ▪ BRT Corridor: Existing Conditions ▪ Fort Rouge Yards: Existing Conditions	**Option 1** **(Existing Conditions)**	Existing Conditions modeled as part of the overall system by KGS Group.
▪ Railway Yards: Existing Conditions ▪ BRT Corridor: Existing Conditions ▪ Fort Rouge Yards: Proposed Development	**Option 2A**	Each catchment is assumed to drain directly into the Cockburn System along the entire Fort Rouge Yards
	Option 2B	Runoff is directed to an open channel along the BRT corridor and conveyed to Hugo Street. Discharge is uncontrolled.
	Option 2BC	Runoff is directed to a piped system along the BRT corridor and conveyed to Hugo Street. Discharge is uncontrolled.
	Option 2C	Runoff is directed to an open channel along the BRT corridor and conveyed to Hugo Street. Discharge is controlled by a 1 ha pond.
▪ Railway Yards: Existing Conditions ▪ BRT Corridor: Proposed BRT Project is Implemented ▪ Fort Rouge Yards: Existing Conditions	**Option 3A**	Each catchment is assumed to drain directly into the Cockburn System along the entire Fort Rouge Yards
	Option 3B	Runoff is directed to a large open channel along the BRT corridor and conveyed to Hugo Street. Discharge is uncontrolled.
	Option 3C	Runoff is directed to a large open channel along the BRT corridor and conveyed to Hugo Street. Discharge is controlled by a 1 ha pond.

It should be noted that these options are based on conceptual land development options (Dillon 2007). Approval from the City to proceed with such a development option was not explicitly provided and final analysis based on approved plans will be required to develop the system and meet all the City's requirements.

Ponds included in the models meet the City's recommended design requirements and have been modeled utilizing the 100-year and the 25-year storms.

As referenced in Section 2.4 (Roof Drainage), the system was modeled by separating the buildings from the catchments to model the large roof areas as separate catchments. Model parameters for the Fort Rouge Yards analysis were based on calibrated parameters (See Section 4.3) for the Cockburn East area.

Specific to the sewer contribution, it was assumed that 1,370 units would be developed on the available land and that two residents would inhabit each unit. The sewer generation rate was estimated to be 275 litres / capita / day (lcpd) the total residential area to be 13.14 ha (see Table 15-2).

Table 15-2: Sewer Rates & Parameters

Sewer Generation Rate (lcpd)	Residents per Unit	Number of units	Total Number of Residents	Total Flow (l/day)	Total Residential Area (ha)	Sewer Generation Rate (l/day/ha)
275	2	1,370	2,740	753,500	13.14	57,344

Based on the available information, the unit rate of sewer generation was estimated for each of the developed catchments.

15.2 EFFECT OF FORT ROUGE YARD DEVELOPMENT ON RELIEF ALTERNATIVES

15.2.1 Storm Sewer Relief

Development of the Fort Rouge Yards for the Storm Sewer Relief alternative would be restricted to the only the pond options (Options 2C and 3C). Development without the pond would produce runoff rates significantly higher than from the existing undeveloped land. Since the City's land drainage policy regarding runoff from new developments requires that the peak into existing combined sewer systems runoff rate not exceed pre-development flow rates, development with the use of storage is the only viable alternative.

Options 2C and 3C both consider the use of a storage retention pond to attenuate surface runoff before the runoff enters the Cockburn and Calrossie Combined Sewer System and therefore meet the City of Winnipeg runoff criterion. Option 2C considers development of the Fort Rouge Yards residential component without the development of the Bus Rapid Transit (BRT) corridor whereas Option 3C considers the development of the BRT without the development of residential component.

Outflow from the pond in the two pond options is directed into the Cockburn combined sewer system at Hugo Street and Arnold Avenue. Peak pond outflow rates are 0.014 m^3/s and 0.028 m^3/s for Options 2C and 3C, respectively. These flow rates are less than 10% of the flow rate from the existing undeveloped area draining to the inlet at Hugh Street and Arnold Avenue. In addition, there are four other locations of inflow to the Cockburn and Calrossie combined sewer each in the range of 0.1 to 0.2 m^3/s for the existing undeveloped area. The use of the ponds would therefore not require additional relief sewers to accommodate the post-development flows from Options 2C and 3C development scenarios. When the City's criteria for development is met, there will be no additional sewer relief changes.

15.2.2 Land Drainage Sewer Separation Alternatives

The impact of developing the Fort Rouge Lands was also evaluated for the partial LDS separation alternatives. The LDS separation option is most amenable to the development since the increased surface drainage can be conveyed without causing a detrimental impact to combined sewer overflows, either with or without a stormwater retention pond.

Two options for the Fort Rouge development were modeled:

- Option 2BC which includes the residential development with an internal conveyance system that discharges directly to the LDS separation sewer located at Hugo Street, with no on-site attenuation.

- Option 3B which includes development of the BRT Corridor with open channel conveyance that discharges directly to the LDS separation sewer located at Hugo Street, with no on-site attenuation.

The implementation of Option 2BC would require an increase in size of the sewer lines from the Hugo Street connection to the new LDS trunk sewer located at the intersection of Cockburn Street and Rosedale Avenue. With all the runoff from the Fort Rouge Lands being collected centrally, there would also be a reduction in runoff to other parts of the Cockburn District permitting elimination of a few upper end LDS separation sewers.

A similar result was found for Option 3B, but because the runoff rate is lower, the pipes did not have to be enlarged to the same extent. The upper end pipes were eliminated identically to Option 2BC.

The additional costs for each option were estimated as shown in Table 15-3:

Table 15-3: Estimated Incremental Cost for Addition of Fort Rouge Lands to the Partial LDS Separation Alternative

Fort Rouge Lands Option	2007 Construction Cost	Contingency (20%)	Engineering (15%)	Burden (3%)	2007 Total Capital Cost
Option 2BC	$1,261,294	$252,259	$189,194	$37,839	$1,740,585
Option 3B	$373,683	$74,737	$56,052	$11,210	$515,682

If a stormwater retention pond is constructed on-site the impact would be minimal as previously discussed for relief piping. The small potential cost of increasing the piping size would be off-set by the reduction in upper end piping.

The dry weather flow contribution would not be impacted by Option 3B since there is no additional residential development, whereas in Option 2BC the population would increase by 2,740, or an addition of about fifty percent to the sewer district. The new development would be required to separate the foundation drainage from sanitary sewage and would have minimal incremental RDII. The Cockburn average dry weather flow would increase by about 9 L/s, bringing the total to 31 L/s.

Combined sewers are sized for both wastewater and land drainage, so typically they can accommodate an increase in sanitary flow. The contribution of surface runoff to the combined sewer would be reduced by the partial LDS separation alternative, which means the Fort Rouge development sanitary flows could readily be accommodated in the existing combined sewer system with incorporation of the LDS separation alternatives.

The additional dry weather flows would have an impact on the Cockburn lift station, as well as the Baltimore and Mager lift stations, which are pumped in series. The impact to pumping rates and overflows was beyond the scope of this assessment.

Co-ordination with The City of Winnipeg Transit and Water and Waste Departments will be required at the design and implementation phases of this project.

16.0 INTEGRATION OF ON-GOING PROGRAMS AND STUDIES

There are potentially a number of other infrastructure renewal and upgrading projects undertaken by other departments or private agencies that may impact the Cockburn and Calrossie relief project. These include:

- The 5-year capital plan for sewer and street re-construction
- CSO Abatement Study
- Sewer Condition Upgrading Strategy
- Outfall Condition Assessment and Upgrades

16.1 INTEGRATION OF BASEMENT FLOODING RELIEF WITH STREETS CAPITAL PROGRAM

The City of Winnipeg Capital Plan sets out planned expenditures on various capital works programs for the year. The review of the Capital Plan for the current year would identify locations in the combined sewer district where potential sewer replacement and road construction works are planned. The co-ordination of this program with the sewer relief works recommended by the Cockburn and Calrossie Combined Sewer Relief Study could involve the relief sewers to be used in place of existing sewers as part of the current Capital Program. A review of the plans was undertaken and no immediate synergies were identified. This should be reassessed again at the final design stage when capital budgets are committed.

16.2 SEWER CONDITION UPGRADING PROGRAM

The sewers in the Cockburn and Calrossie and Southeast Jessie Combined Sewer Districts were inspected in 2003 under the City's Sewer Condition Upgrading Program. This program identifies and prioritizes the annual requirements for rehabilitation on the basis of repair cost factors and overall cost factors. Repair cost factors relate the direct costs of repairing the sewer to optimum point in the deterioration of sewer and the costs required after a complete collapse of the sewer. Overall cost factors are determined in a similar manner but also consider indirect cost factors such as traffic disruption and impact on other infrastructure.

The Sewer Condition Assessment Program has classified all sewers in the Cockburn and Calrossie and Southeast Jessie Combined Sewer Districts in terms of the Structural Performance Grade (SPG). This rating is a 5 point rating system with sewers with an SPG rating of 1 corresponding to sewers having acceptable structural conditions, and 5 corresponding to sewers where collapse has occurred or is imminent. The sewers are also categorized into an A, B and C classification with categories A and B having the highest repair and overall cost factors. Figure B1 in Appendix B – illustrates the SPG rating of the sewers in the Cockburn and Calrossie Sewer Districts with each sewer colour coded according to the SPG rating.

Table 16-1 below summarizes the SPG rating for the Cockburn and Calrossie Sewer Districts for the 3 categories.

Table 16-1: Cockburn and Calrossie Sewer Condition Summary

SPG	Category							
	A		B		C		Total	
	Length	% by Length	Length	% by Length	Length	% by Length	Length	% by Length
5	248	2.2	976	16.1	305	8.1	1529	7.2
4	1463	12.8	2364	39.0	1147	30.3	4974	23.4
3	4177	36.6	1330	21.9	1617	42.7	7124	33.5
2	3344	29.3	668	11.0	468	12.4	4480	21.1
1	2174	19.1	731	12.0	246	6.5	3151	14.8
Average SPG	2.50		3.36		3.21		2.87	

The overall SPG rating for the Cockburn and Calrossie Districts is 2.87 with approximately 64 percent of all sewers having an SPG rating of 3 to 5.

The objective of the Sewer Condition Assessment Program is to rehabilitate all sewers in Category A if the SPG rating is 3 or higher, and to rehabilitate sewers in Category B when they are in the 3 to 4 range (or higher). Category C sewers are typically rehabilitated when the SPG rating is 4 to 5.

As shown in Table 16-1, approximately 64 percent of the sewers in the district rated in the range of 3 to 5 for which rehabilitation is required. Therefore, there exists opportunities to integrate the repair works under the Sewer Condition Upgrading Works with the recommendations of the Basement Flood Relief program provided by this study. The storm sewer relief alternative for basement flood relief comprised of a number of new SRS pipes to be provided in addition to the existing sewers. Consequently, none of the rehabilitation requirements under the sewer condition assessment program impact the storm sewer relief alternative under the basement flood relief program.

The recommended partial LDS separation alternative will require there to be both land drainage and wastewater sewers wherever the new LDS sewers are added. Since the original combined sewers will be converted to the wastewater sewers, they will be oversized for the purpose and there will be an opportunity to downsize them when they are scheduled for rehabilitation or replacement. Replacement or relining with a smaller diameter has the potential to reduce the future costs. The uncertainty in timing and the decision on whether to rehabilitate or replace the combined sewers precludes development of an integration plan and cost savings estimate at this time.

16.3 CSO ABATEMENT PROGRAM

The CSO objective of reducing CSO overflows to a maximum of 4 per year could be achieved by the use of in-line storage in conjunction with RTC measures. In general, in-line storage should only be considered with sewers having a rating of 1 or 2. Integration of the CSO abatement and basement flood relief programs would involve upgrading all sewers to at least a SPG rating of 2 before implementing in-line storage. Opportunities for integration with the CSO program with relief options in place and for relief integration with CSO control are discussed in Section 14.3.

16.4 OUTFALL CONDITION UPGRADING PROGRAM

The Cockburn outfall was inspected under the City's Outfall Condition Assessment Program, and no structural problems or other issues were identified that would require attention in the short term. The requirement to upgrade the gravity sewer outfall pipe would therefore be included only under the basement flood relief program. If the storm relief sewer alternative is accepted, the Cockburn outfall will have to be replaced to provide increased discharge capacity. This work would, however, be conducted as part of the basement flood relief work, independent of the Outfall Condition Assessment Program.

17.0 CONCLUSIONS AND RECOMMENDATIONS

17.1 CONCLUSIONS

Basement Flooding Relief

- The study boundary includes the Cockburn, Calrossie and southeast part of the Jessie Sewer Districts. The southeast part of the Jessie Combined Sewer District was added to the project scope as it was not relieved as part of the Jessie Relief Project in the 1970s.

- The hydrologic and hydraulic model was calibrated and verified using independent data collected by the City monitoring program. The model accurately simulates the rainfall runoff response as depicted by the comparison of modeled and recorded water levels at monitoring gauges located at a number of locations within the district.

- The majority of downspouts in the Cockburn and Calrossie areas have been disconnected from the sewer system.

- The existing level of service for the majority of the Cockburn and Calrossie and Southeast Jessie District is less than a 2-year based on the City's summer design rainstorm.

- The Cockburn lift station is in need of upgrading from a building code and health and safety perspective but there is limited opportunity to achieve benefits from integration with the basement flooding relief program. The future CSO may dictate the requirements for major changes to the lift station requirements.

- A previous study identified about $500,000 in immediate upgrades being required for the flood pumping station, and another $400,000 over the longer term. There is limited opportunity to achieve integration benefits with the basement flooding relief program. The future CSO may dictate the requirements for major changes to the lift station requirements.

- Ten alternatives for complete district-wide relief and localized relief were developed to provide a 5-year level of service. The most cost-effective alternative consists of a partial land drainage alternative. This alternative would be comprised of major land drainage sewers throughout the district to collect catch basin flows. Nearly complete land drainage separation would be required for the Southeast Jessie area. The estimated cost for partial LDS separation was estimated at $37.7 million ($2007).

- The former concept of planning for upgrading of the 5-year relief design to a 10-year level through the use of inlet restriction was not included. Unresolved technical issues with inlet restriction may preclude its use entirely.

- The benefit-cost approach utilized in the 1986 Study provides an appropriate and consistent method of evaluating relief options and prioritizing projects for the Basement Flooding Relief Program. The comparative values as used in the program prioritization for Cockburn and Calrossie are:

    - 1991 Burdened Cost = $11,891,000
    - District Wide Benefit-Cost Ratio = 1.7

- The existing Cockburn and Calrossie Combined Sewer System do not have capacity for the 25-year return spring storm regardless of the Red River water level. With relief piping in place, the level of service for the combined probability of spring rainfall and Red River water levels is greater than 1 in 35 years.

- The Cockburn and Calrossie Districts have a number of sewers in need of upgrading. With the recommended partial land drainage alternative, there may be an opportunity to replace the combined sewer with smaller diameter sewers if sewer replacement is required in the future.

Evaluation of Fort Rouge Yards servicing was completed as additional services to accommodate the Bus Rapid Transit corridor development. It was recommended (Appendix F) that land drainage servicing for the entire area be routed through the Glasgow outfall, which is completely independent of the Cockburn and Calrossie areas, and as such the projects will not impact each other.

- The future Fort Rouge Lands high-density residential development will increase the Cockburn lift station flow by nearly fifty percent. The increased flow would have minimal impact on the sewer level of service, but would be significant to lift station pumping, as well as downstream pumping at Baltimore and Mager lift stations.

CSO Control

- Based on use of the 1992 representative year, the existing Cockburn system has an average of 23 overflows per year, after removal of the cooling water wells that were once contributing to the collection system. The fifth largest storm in 1992 would produce an overflow volume of 12,000 cubic metres at the Cockburn outfall.

- Raising of the existing weir, or installation of a bendable weir would provide immediate CSO control benefits. If the concept is extended to include real time control, the number of overflows with the existing system could be reduced as low as eight overflows.

- The uncertainty associated with in-line storage prevents informed decisions being made with respect to BFR and CSO alternative selection and system optimization.

- Combined sewer overflow control and basement flooding relief are closely linked, and there are tangible benefits to integrate the programs. There are additional potential benefits to consider integration of adjacent combined sewer districts within a regional CSO plan.

- Integration of CSO control with basement flooding relief results is the lowest overall cost for the district works. A sunken relief option could be implemented at an additional cost of $6,600,000 and provide the district with overflow controls to the four-overflow level without the need for automated gate controls.

- A tunnel connection from the Cockburn to the River District is a feasible alternative to in-line and off-line storage alternatives if Cockburn, Baltimore, Jessie and River are included in the evaluation.

17.2 RECOMMENDATIONS

Basement Flooding Relief

- The Cockburn and Calrossie project should be prioritized in the Basement Flooding Relief Program based on a 1991 cost of $11,900,000 and a benefit-cost ratio of 1.7.

- District-wide partial LDS separation should be implemented in the Cockburn District. For the district as a whole, it will provide basement flooding relief protection to a 5-year level at a 2007 based cost of $37.7 million.

- Partial separation should be phased in with implementation in Cockburn West and Southeast Jessie proceeding first, and Cockburn East being phased in at a later time. The two phases will function independently and will accommodate future decisions made under the CSO program. The first phase is estimated to cost $22.0 million ($2007), with a Benefit-Cost ratio of 1.6.

CSO Control

- Monitoring of the Calrossie area should be undertaken to provide an accurate estimate of the amount of inflow and infiltration associated with LDS separation options. The amount of RDII that is generated in older combined sewers after separation is unknown and will have an impact on the extent of separation and subsequent CSO control program. Because the Calrossie District has been separated (originally combined sewer system) and would likely exhibit similar characteristics to the Cockburn District due to its proximity, monitoring should take place to determine the amount of RDII in this district.

- Continuous monitoring of the Cockburn lift station pumps should be implemented. The monitoring that was carried out suggested there is a high summer dry weather and RDII component and additional monitoring is required to confirm the flows and identify future program needs.

- Prior to proceeding with the second phase of the Cockburn and Calrossie project (Cockburn East), the merits of CSO program integration should be considered. The evaluation presented herein demonstrates that without in-line storage, a cost savings of $25,000,000 may be realized by early consideration of CSO program integration.

- A conclusion should be reached on the use of inlet restriction. The CSO alternatives that incorporate in-line storage, and the second stage upgrading of basement flooding protection to a 10-year depend on incorporation of inlet restriction. Informed decisions cannot be made until this issue is resolved.

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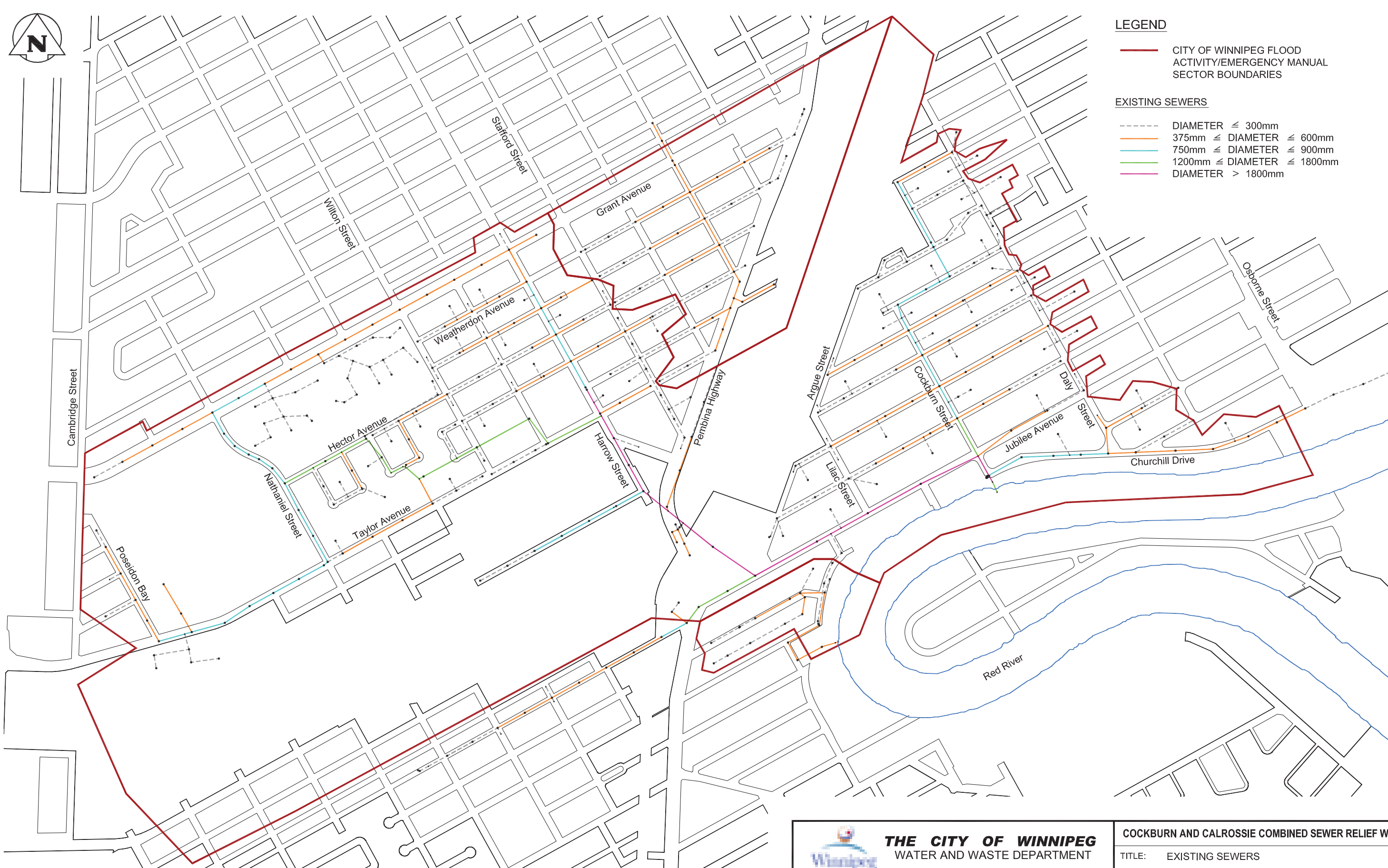
DRAWINGS



THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

KGS GROUP

CH2MHILL

DILLON CONSULTING

COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS

TITLE: EXISTING SEWERS

JOB NO.: 05-107-14	DATE: MAY 2010
SCALE : AS NOTED	DWG NO.: 1
CHECKED:	

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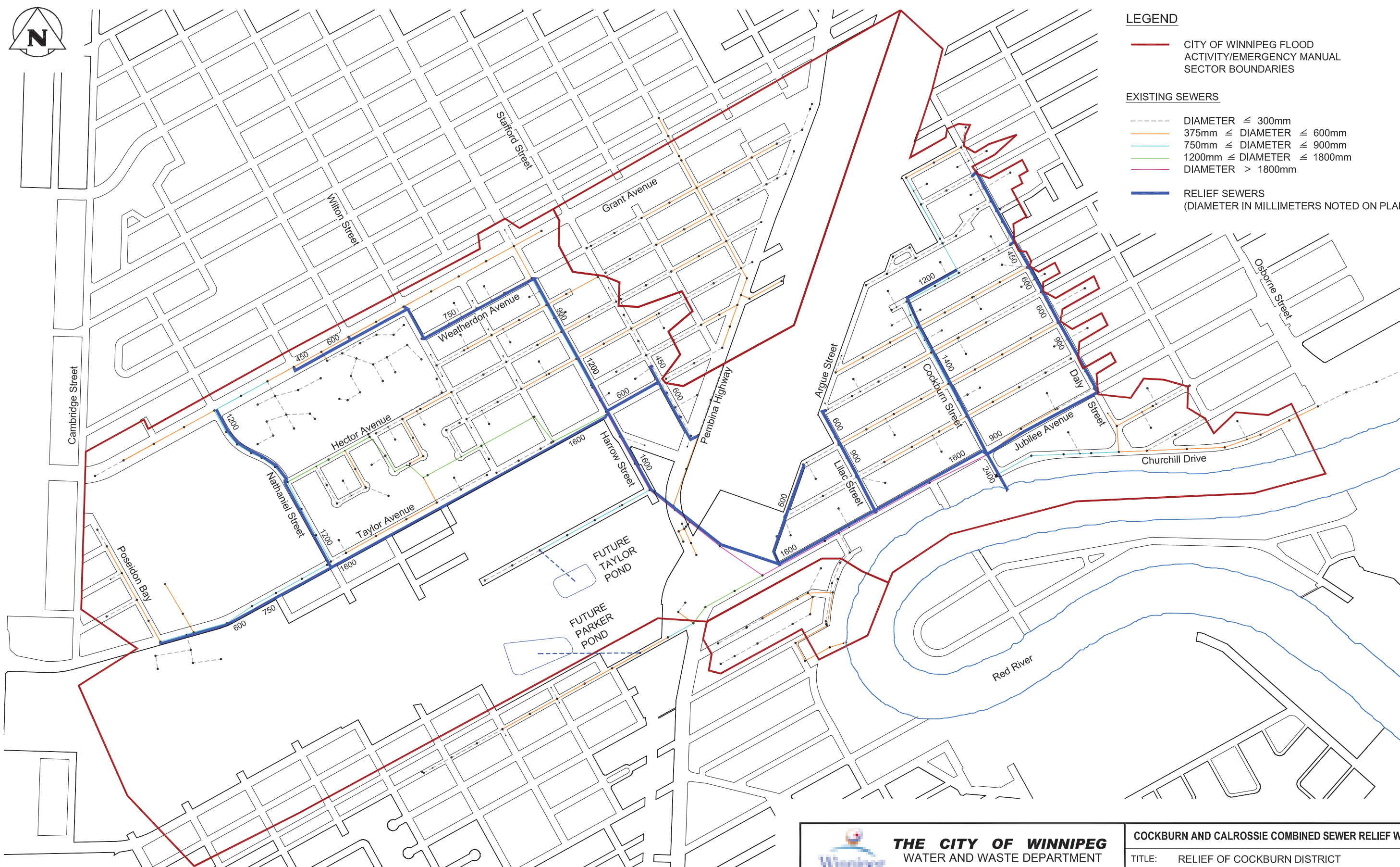

LEGEND

CITY OF WINNIPEG FLOOD ACTIVITY/EMERGENCY MANUAL SECTOR BOUNDARIES

EXISTING SEWERS

- DIAMETER ≤ 300mm
- 375mm ≤ DIAMETER ≤ 600mm
- 750mm ≤ DIAMETER ≤ 900mm
- 1200mm ≤ DIAMETER ≤ 1800mm
- DIAMETER > 1800mm

RELIEF SEWERS (DIAMETER IN MILLIMETERS NOTED ON PLAN)

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

KGS GROUP · CH2MHILL · DILLON CONSULTING

COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS

TITLE:	RELIEF OF COCKBURN DISTRICT WITHOUT JESSIE		
JOB NO.:	05-107-14	DATE:	MAY 2010
SCALE :	AS NOTED	DWG NO.:	2
CHECKED:			

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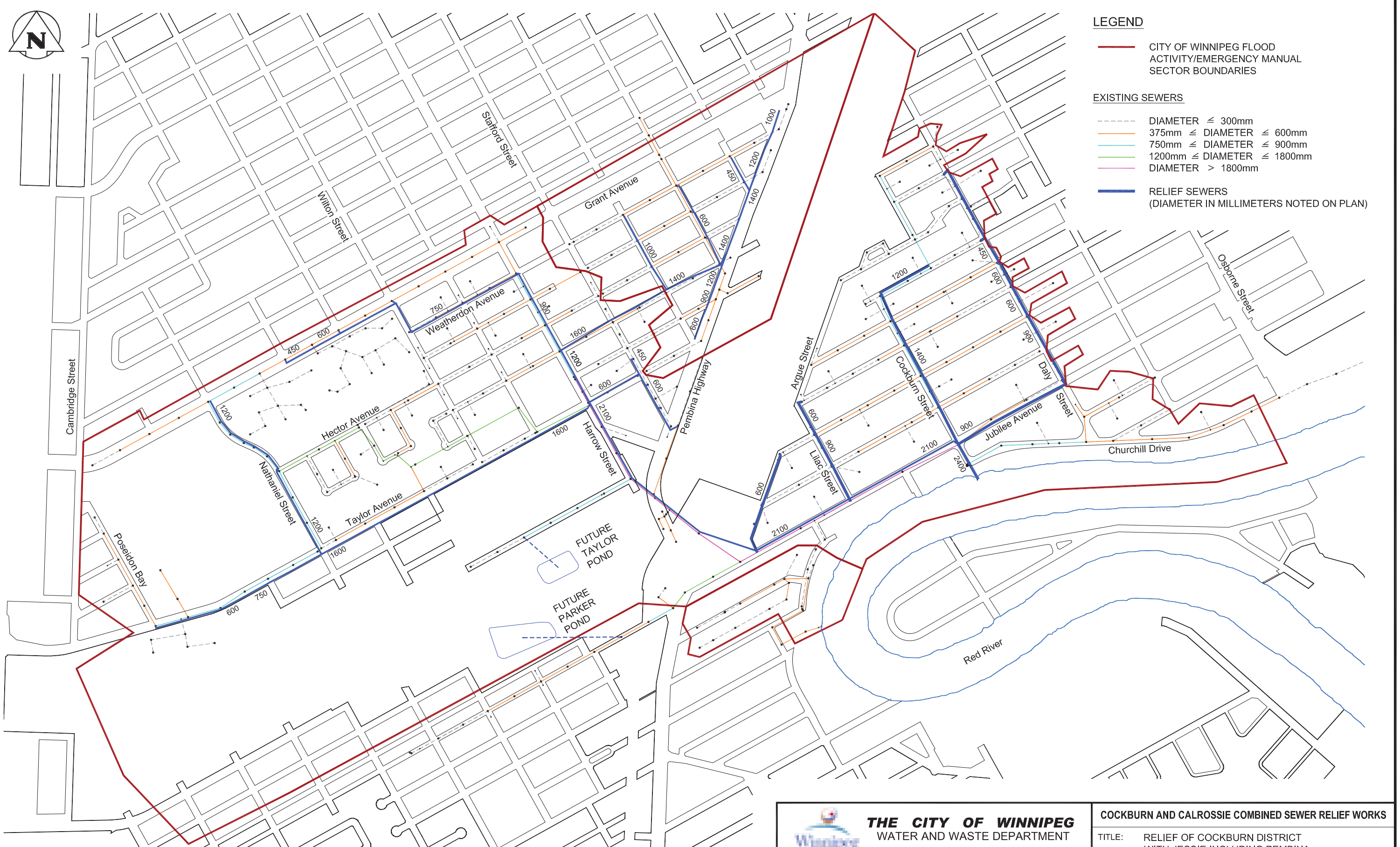

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

KGS GROUP

COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS

TITLE: RELIEF OF COCKBURN DISTRICT WITH JESSIE INCLUDING PEMBINA

JOB NO.: 05-107-14

DATE: MAY 2010

SCALE : AS NOTED

DWG NO.: 3

CHECKED:

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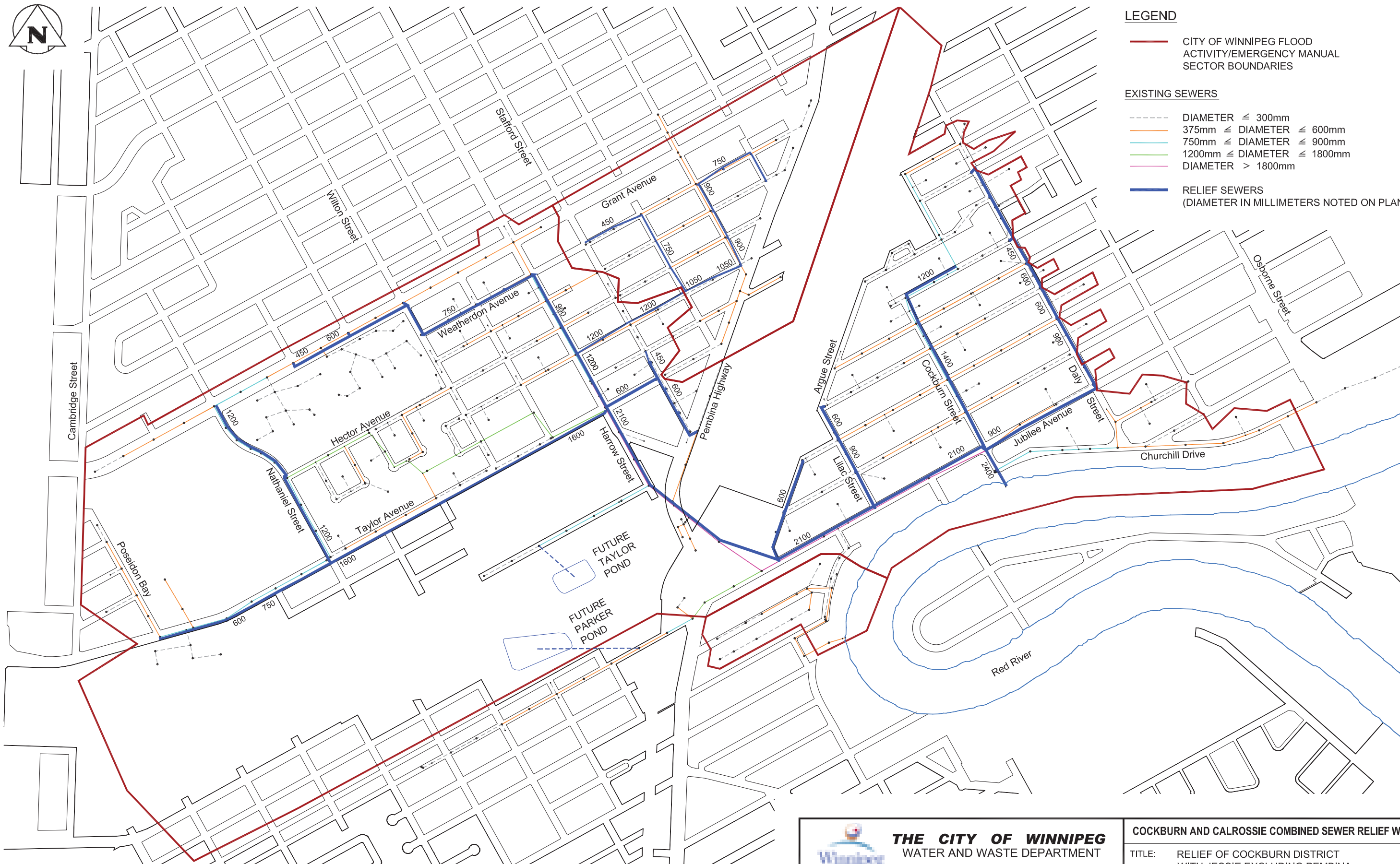

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

KGS GROUP

CH2MHILL

DILLON CONSULTING

COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS

TITLE:	RELIEF OF COCKBURN DISTRICT WITH JESSIE EXCLUDING PEMBINA
JOB NO.: 05-107-14	DATE: MAY 2010
SCALE : AS NOTED	DWG NO.: 4
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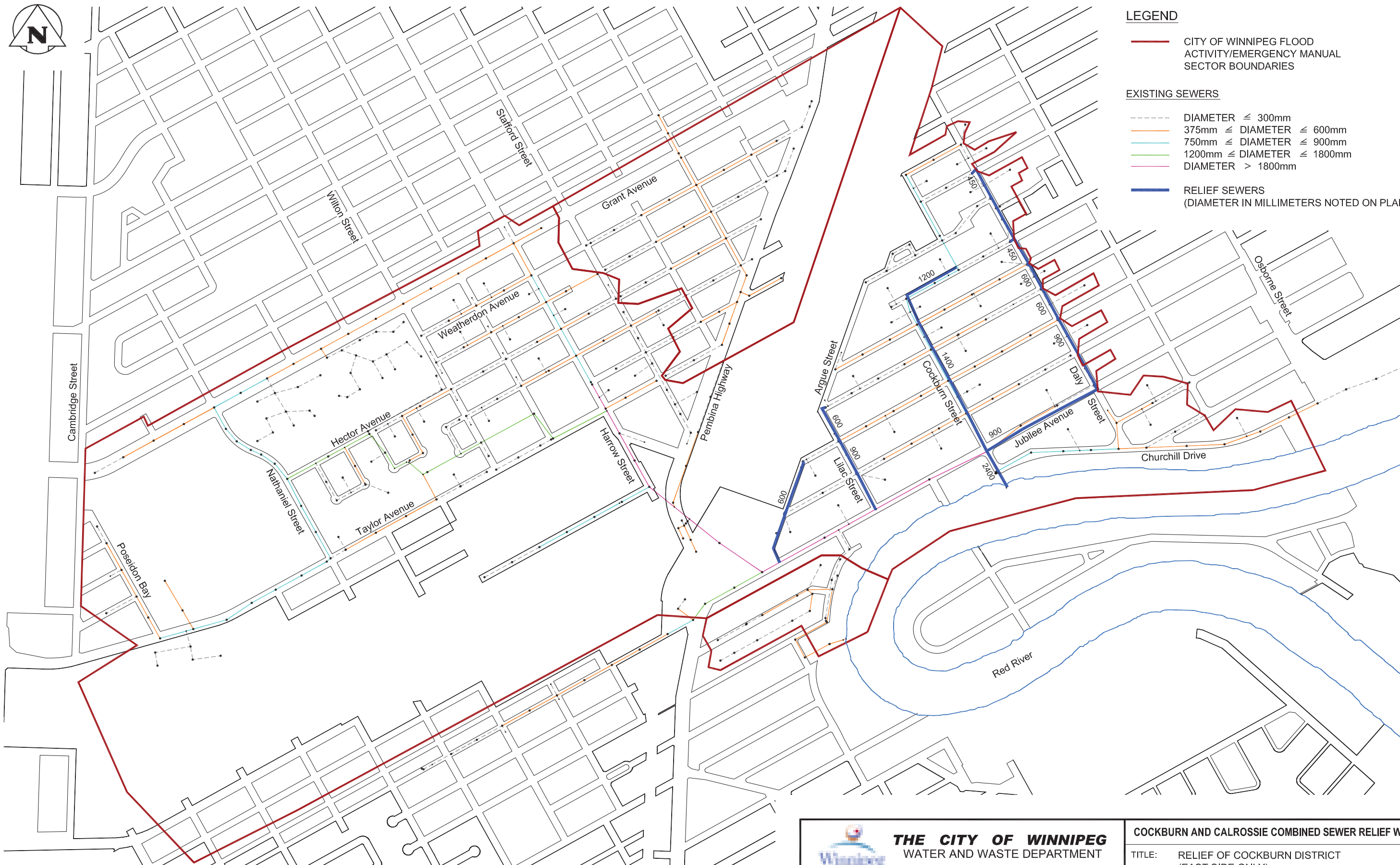

THE CITY OF WINNIPEG WATER AND WASTE DEPARTMENT	COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS	
KGS GROUP · CH2MHILL · DILLON CONSULTING	TITLE: RELIEF OF COCKBURN DISTRICT (EAST SIDE ONLY)	
	JOB NO.: 05-107-14	DATE: MAY 2010
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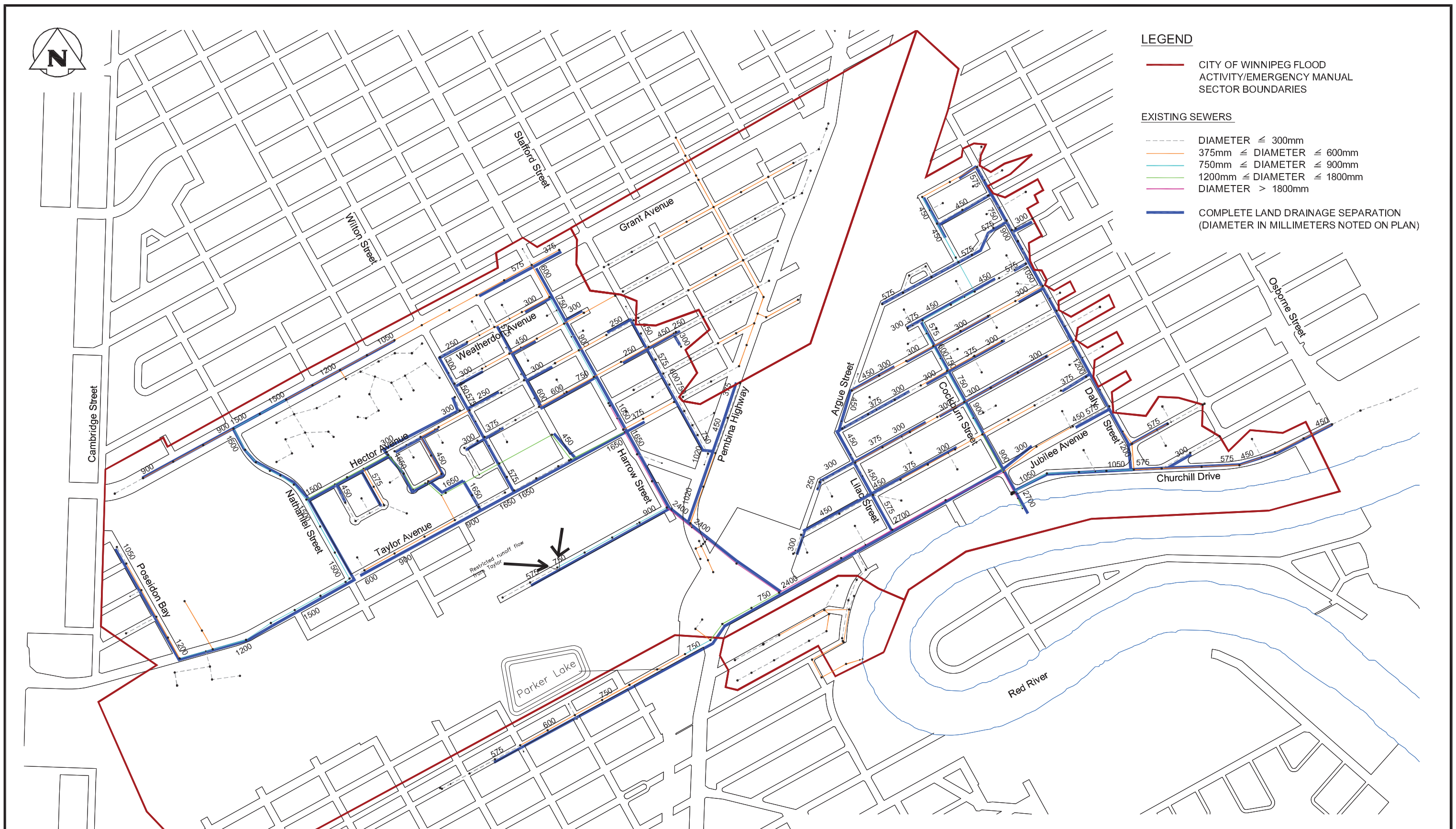

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

KGS GROUP | CH2MHILL | DILLON CONSULTING

COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS	
TITLE: COMPLETE LAND DRAINAGE SEPARATION OF COCKBURN DISTRICT WITHOUT JESSIE	
JOB NO.: 05-107-14	DATE: MAY 2010
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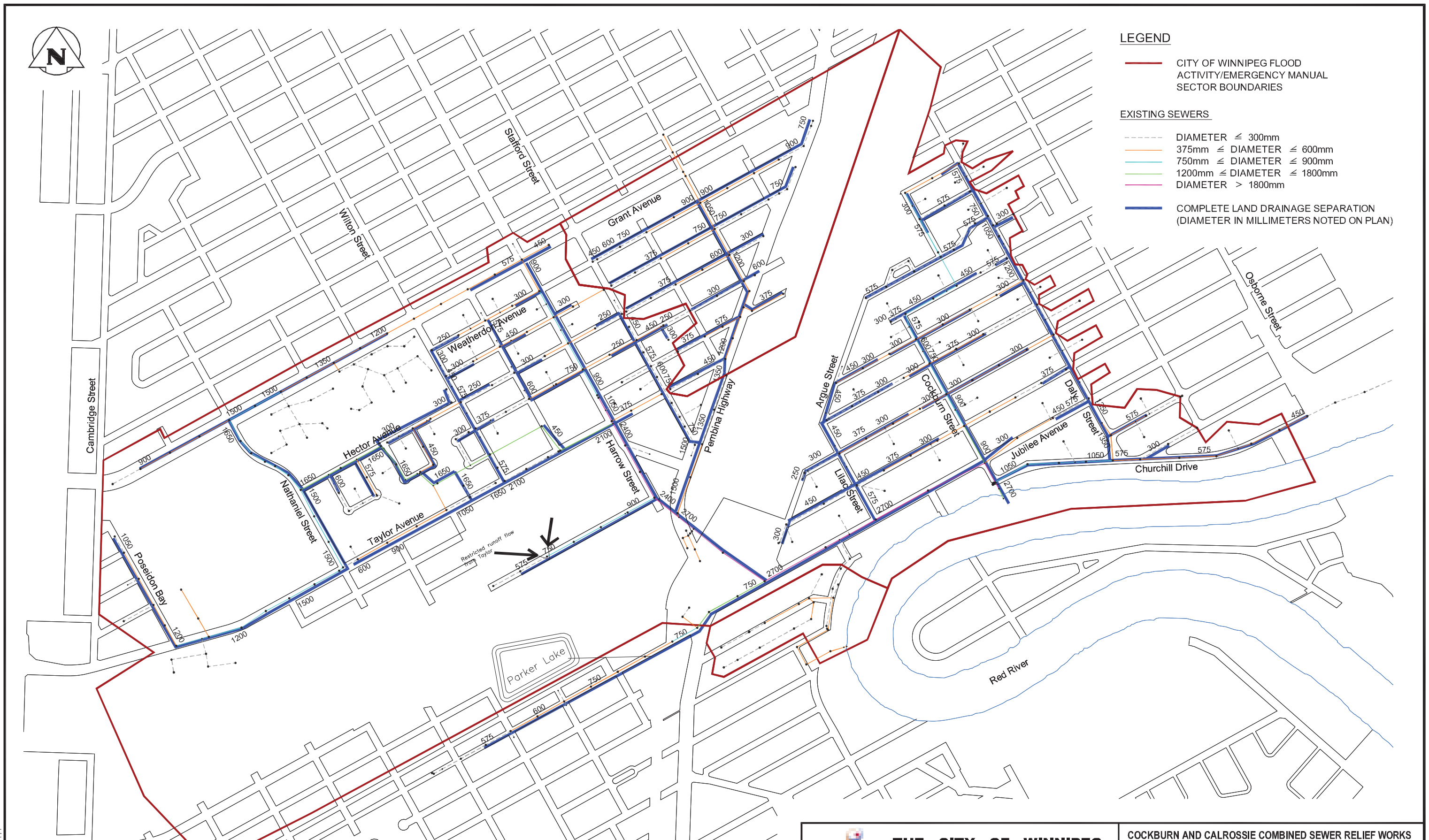

THE CITY OF WINNIPEG WATER AND WASTE DEPARTMENT KGS GROUP · CH2MHILL · DILLON	COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS	
	TITLE: COMPLETE LAND DRAINAGE SEPARATION OF COCKBURN DISTRICT WITH JESSIE	
	JOB NO.: 05-107-14	DATE: MAY 2010
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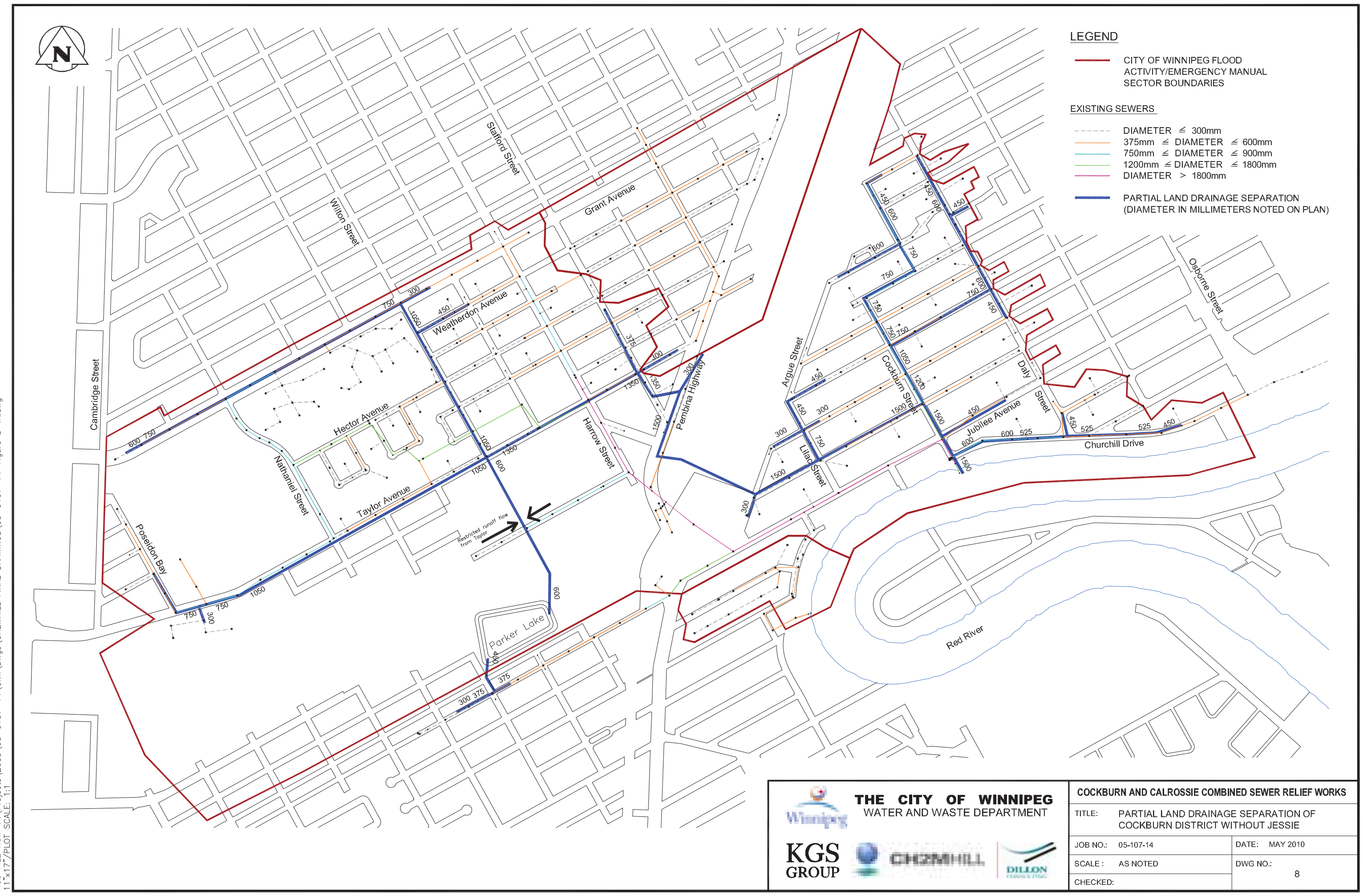

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

KGS GROUP

CH2MHILL

DILLON

COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS

TITLE: PARTIAL LAND DRAINAGE SEPARATION OF COCKBURN DISTRICT WITHOUT JESSIE

JOB NO.: 05-107-14	DATE: MAY 2010
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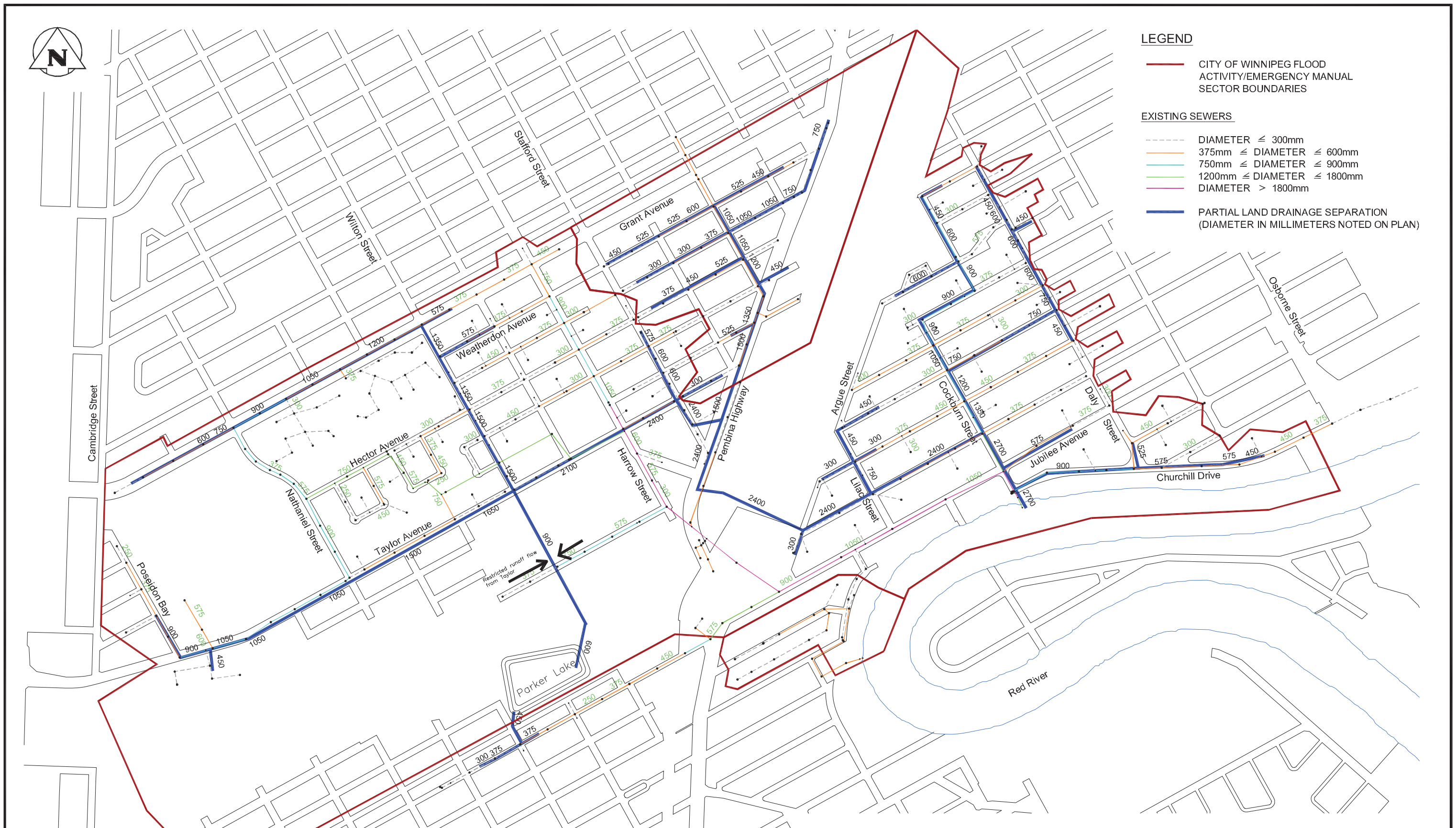

COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

Winnipeg

KGS GROUP

CH2MHILL

DILLON

TITLE: PARTIAL LAND DRAINAGE SEPARATION OF COCKBURN DISTRICT WITH JESSIE

JOB NO.: 05-107-14	DATE: MAY 2010
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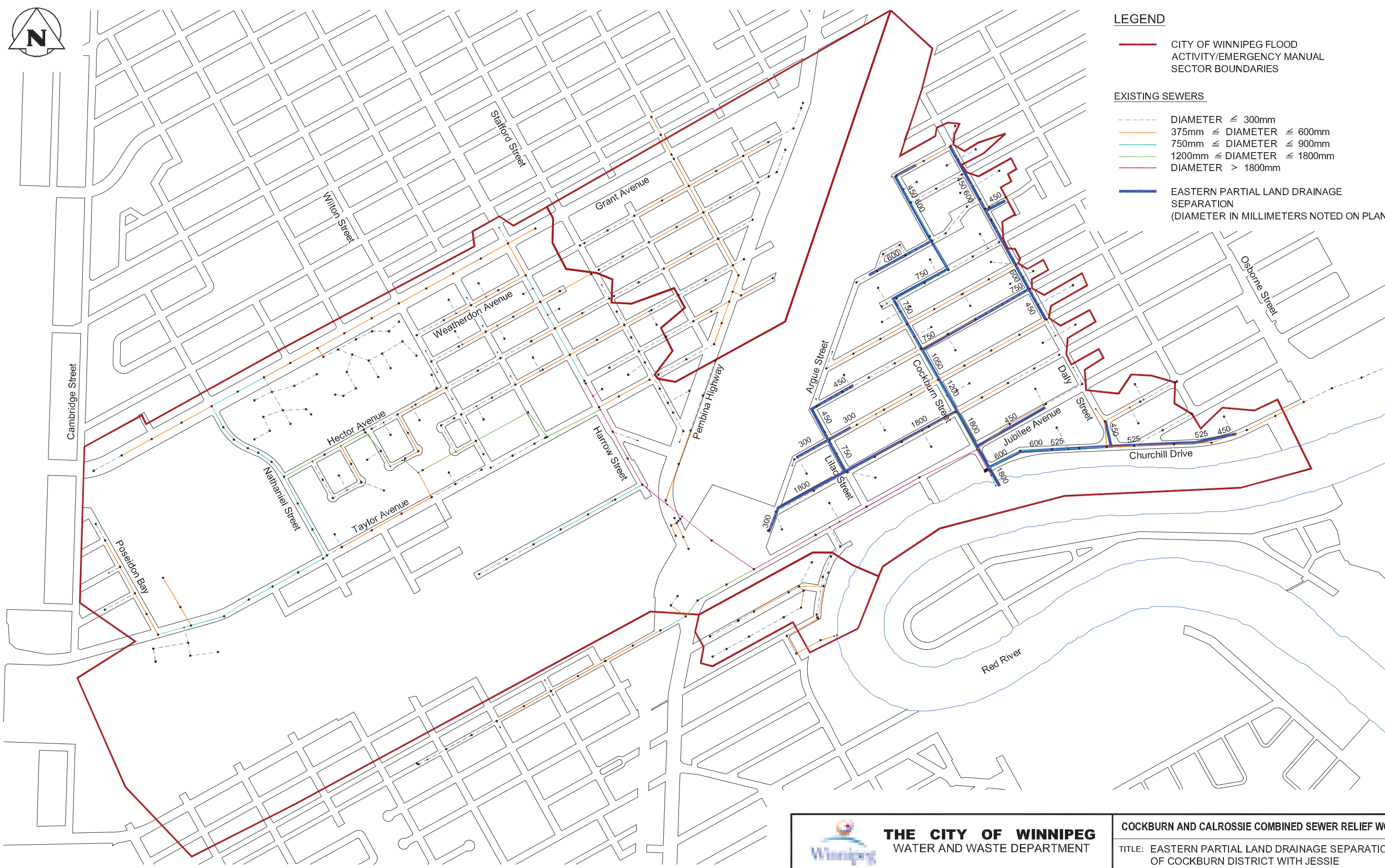

LEGEND

CITY OF WINNIPEG FLOOD ACTIVITY/EMERGENCY MANUAL SECTOR BOUNDARIES

EXISTING SEWERS

- DIAMETER ≤ 300mm
- 375mm ≤ DIAMETER ≤ 600mm
- 750mm ≤ DIAMETER ≤ 900mm
- 1200mm ≤ DIAMETER ≤ 1800mm
- DIAMETER > 1800mm

EASTERN PARTIAL LAND DRAINAGE SEPARATION (DIAMETER IN MILLIMETERS NOTED ON PLAN)

NOTE: PROPOSED PARTIAL LAND DRAINAGE SEPARATION SEWERS HAVE BEEN DESIGNED TO HANDLE ADDITIONAL FLOW FROM COCKBURN WEST (INCLUDING SOUTHEAST JESSIE).

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

KGS GROUP

CH2MHILL

DILLON

COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS

TITLE: EASTERN PARTIAL LAND DRAINAGE SEPARATION OF COCKBURN DISTRICT WITH JESSIE

JOB NO.: 05-107-14	DATE: MAY 2010
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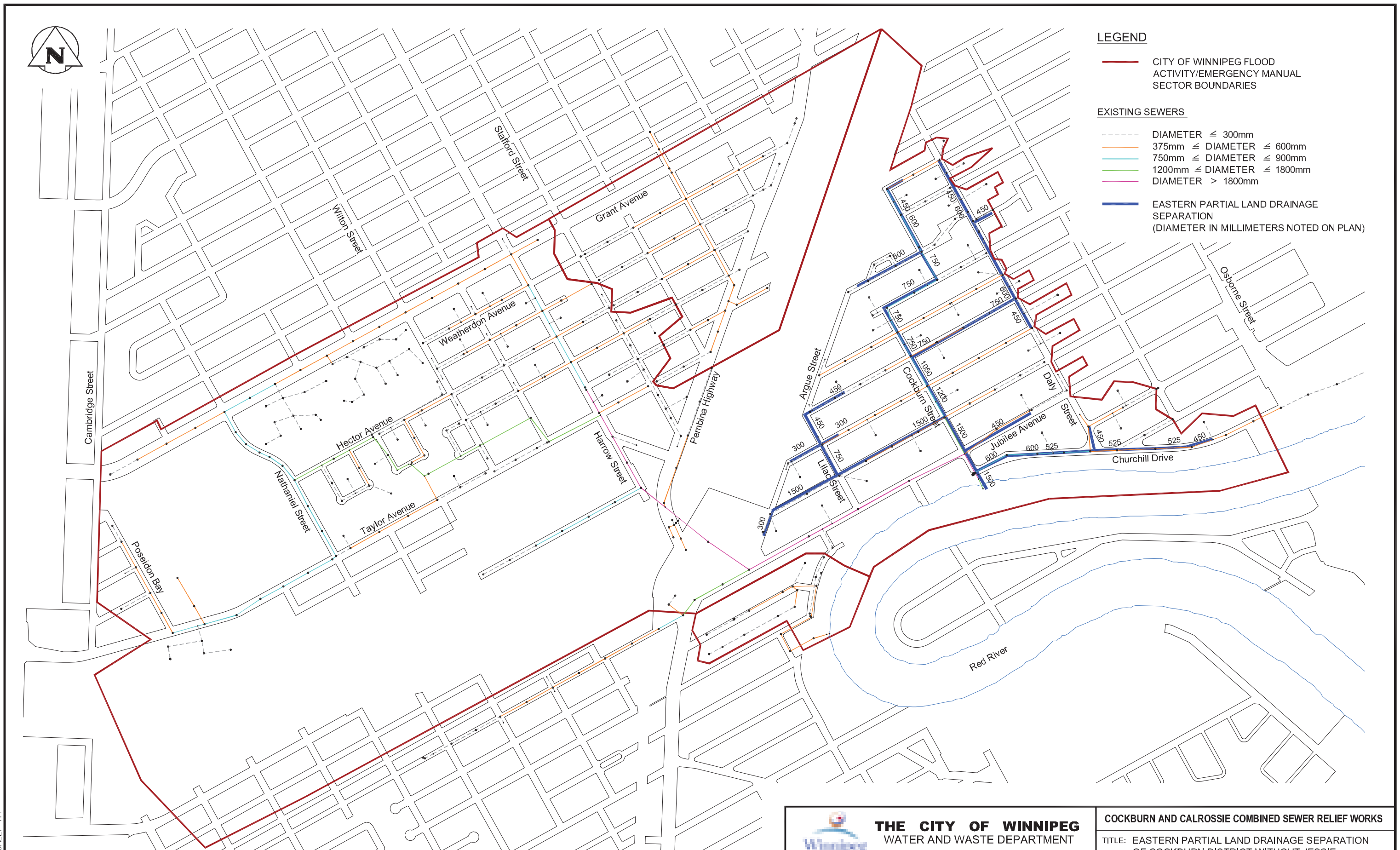

NOTE: PROPOSED PARTIAL LAND DRAINAGE SEPARATION SEWERS HAVE BEEN DESIGNED TO HANDLE ADDITIONAL FLOW FROM COCKBURN WEST (WITHOUT SOUTHEAST JESSIE).

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

KGS GROUP

COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS

TITLE: EASTERN PARTIAL LAND DRAINAGE SEPARATION OF COCKBURN DISTRICT WITHOUT JESSIE	
JOB NO.: 05-107-14	DATE: MAY 2010
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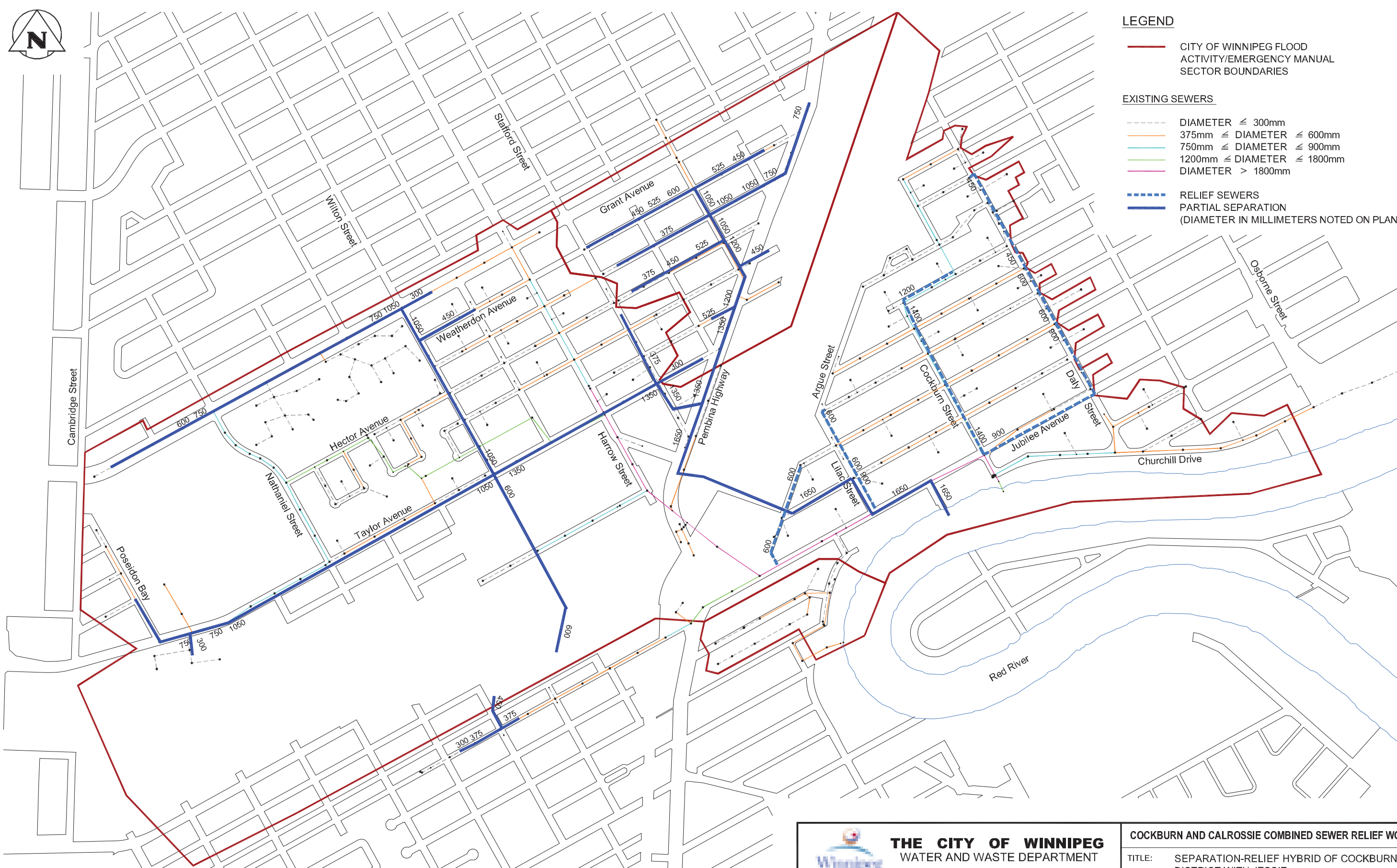

THE CITY OF WINNIPEG WATER AND WASTE DEPARTMENT	COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS	
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APPENDIX A

COCKBURN FPS OUTFALL CONDITION SURVEY

APPENDIX A

Cockburn Outfall Condition Assessment

There are two outfalls present at the Cockburn pumping station. A structural condition assessment of these outfalls was carried out on March 22, 2006.

RR-39

26.6 m of 1800 mm CMP pipe starting at the positive gate and heading out to the river
Pipe in good condition:

- Slight rusting of pipe at SWL (@ 2 & 10)
- No obvious deflections
- Invert covered by ice: could not assess the invert condition

RR-38

33 m of 1500 mm CMP pipe c/w dampeners starting in the pump station and heading out to the river.

Pipe in good condition:

- No pipe deflections.

- Pipe line deviates downwards and has four linear metal brackets at joints holding the pipe sections together. At the first joint (9m downstream of chamber, all four of these brackets are cracked and no longer holding the pipe sections together. Pipe has separated slightly at top of pipe. These brackets can be repaired from inside of the pipe.

- Invert is slight rusted beginning at 19m downstream of chamber and continuing to end of outfall.

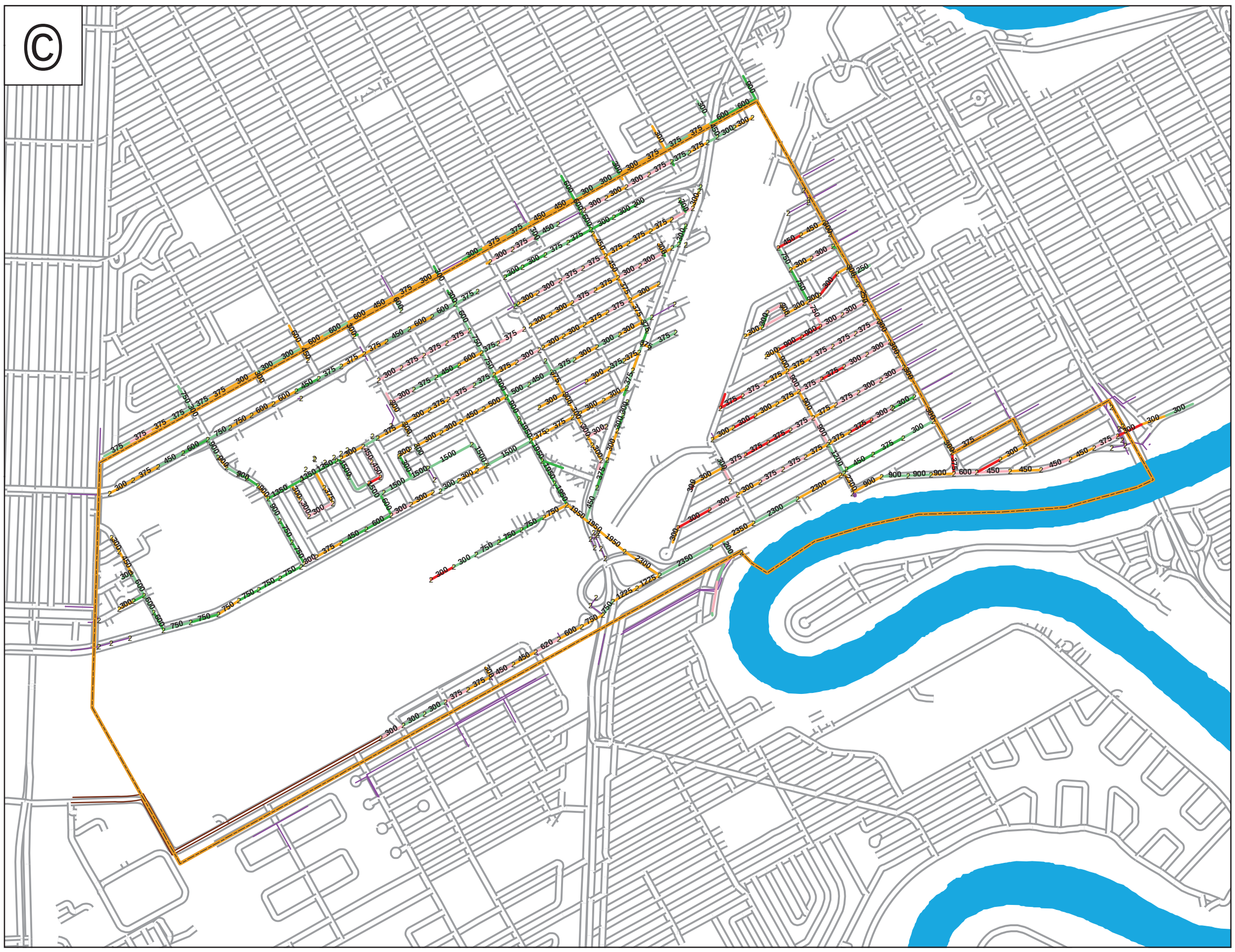
- End section of the outfall was below the ice level and could not be assessed.

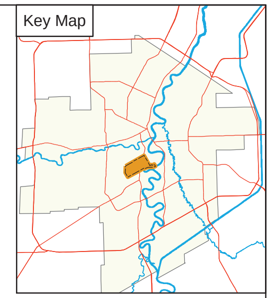
Geotechnical and hydraulic concerns:

- 1997 KGS inspection on the outfall rated the geotechnical Condition as 1 (Low Risk of Failure); and hydraulic condition as 1 (minor erosion – between 20 and 30 m from the outfall).

APPENDIX B

SEWER MANAGEMENT SYSTEM PIPE CONDITION DRAWING





Legend

Study Area

2 Manholes

Standard Performance Grade

- SPG-1
- SPG-2
- SPG-3
- SPG-4
- SPG-5

Sewer Main

- Ditch
- Sewer Main

1:12,500

0 100 200 300 400 500

Meters

KGS GROUP - CH2MHILL - DILLON

CALROSSIE/COCKBURN

Sewer Management Condition Survey
Standard Performance Grade Results

APRIL 2007	FIGURE B1	REV: A

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APPENDIX C

DETAILED COST ESTIMATES

APPENDIX C
DETAILED COST ESTIMATE

Table C-1

Storm Sewer Relief Piping Alternative
Without Jessie and Without Future Developments

Name	Diameter (m)	Diameter (mm)	Length (m)	1991 $/m	1991 $	2007 $/m	2007 $
L580	0.3	300	55.950	360	$20,142	770	$43,082
L579	0.3	300	50.610	360	$18,220	770	$38,970
L578	0.375	375	10.000	410	$4,100	930	$9,300
L564	0.375	375	10.000	410	$4,100	930	$9,300
L577	0.45	450	10.000	460	$4,600	1055	$10,550
L576	0.45	450	10.000	460	$4,600	1055	$10,550
L575	0.45	450	10.814	460	$4,974	1055	$11,409
L567	0.45	450	95.398	460	$43,883	1055	$100,645
L566	0.45	450	8.000	460	$3,680	1055	$8,440
L565	0.45	450	8.240	460	$3,790	1055	$8,693
L559	0.45	450	10.000	460	$4,600	1055	$10,550
L558	0.45	450	10.000	460	$4,600	1055	$10,550
L557	0.45	450	10.000	460	$4,600	1055	$10,550
L553	0.45	450	23.942	460	$11,013	1055	$25,259
L551	0.45	450	47.255	460	$21,737	1055	$49,854
L550	0.45	450	10.000	460	$4,600	1055	$10,550
L548	0.45	450	10.000	460	$4,600	1055	$10,550
L547	0.45	450	10.000	460	$4,600	1055	$10,550
L543	0.45	450	10.000	460	$4,600	1055	$10,550
L542	0.45	450	10.000	460	$4,600	1055	$10,550
L541	0.45	450	10.000	460	$4,600	1055	$10,550
L537	0.45	450	10.000	460	$4,600	1055	$10,550
L536	0.45	450	10.000	460	$4,600	1055	$10,550
L535	0.45	450	10.000	460	$4,600	1055	$10,550
L534	0.45	450	10.000	460	$4,600	1055	$10,550
L533	0.45	450	10.000	460	$4,600	1055	$10,550
L532	0.45	450	10.000	460	$4,600	1055	$10,550
L531	0.45	450	10.000	460	$4,600	1055	$10,550
L522	0.45	450	84.910	460	$39,059	1055	$89,580
L521	0.45	450	45.504	460	$20,932	1055	$48,007
L520	0.45	450	87.536	460	$40,267	1055	$92,350
L519	0.45	450	84.521	460	$38,880	1055	$89,170
L572	0.6	600	82.811	565	$46,788	1200	$99,373
L571	0.6	600	93.616	565	$52,893	1200	$112,339
L570	0.6	600	92.585	565	$52,311	1200	$111,102
L569	0.6	600	87.234	565	$49,287	1200	$104,681
L568	0.6	600	77.938	565	$44,035	1200	$93,526
L556	0.6	600	36.976	565	$20,891	1200	$44,371
L555	0.6	600	73.300	565	$41,415	1200	$87,960
L554	0.6	600	71.214	565	$40,236	1200	$85,457
L552	0.6	600	161.896	565	$91,471	1200	$194,275
L549	0.6	600	36.965	565	$20,885	1200	$44,358
L546	0.6	600	37.695	565	$21,298	1200	$45,234
L545	0.6	600	71.603	565	$40,456	1200	$85,924
L544	0.6	600	140.392	565	$79,321	1200	$168,470
L538	0.6	600	96.659	565	$54,612	1200	$115,991
L524	0.6	600	93.146	565	$52,627	1200	$111,775

Table C-1

Storm Sewer Relief Piping Alternative
Without Jessie and Without Future Developments

L523	0.6	600	69.033	565	$39,004	1200	$82,840
L507	0.6	600	10.000	565	$5,650	1200	$12,000
L503	0.6	600	84.781	565	$47,901	1200	$101,737
L502	0.6	600	116.361	565	$65,744	1200	$139,633
L501	0.6	600	73.774	565	$41,682	1200	$88,529
L500	0.6	600	10.000	565	$5,650	1200	$12,000
L573	0.75	750	87.624	690	$60,461	1980	$173,496
L562	0.75	750	84.076	690	$58,012	1980	$166,470
L561	0.75	750	90.797	690	$62,650	1980	$179,778
L506	0.75	750	86.400	690	$59,616	1980	$171,072
L505	0.75	750	81.900	690	$56,511	1980	$162,162
L504	0.75	750	73.543	690	$50,745	1980	$145,615
L468	0.75	750	185.190	690	$127,781	1980	$366,676
L540	0.9	900	118.498	850	$100,723	2410	$285,580
L539	0.9	900	101.092	850	$85,928	2410	$243,632
L529	0.9	900	134.258	850	$114,119	2410	$323,562
L528	0.9	900	114.587	850	$97,399	2410	$276,155
L527	0.9	900	120.332	850	$102,282	2410	$290,000
L526	0.9	900	112.987	850	$96,039	2410	$272,299
L525	0.9	900	113.527	850	$96,498	2410	$273,600
L483	0.9	900	10.000	850	$8,500	2410	$24,100
L469	0.9	900	169.384	850	$143,976	2410	$408,215
L518	1.2	1200	11.682	1170	$13,668	3175	$37,090
L517	1.2	1200	48.869	1170	$57,177	3175	$155,159
L516	1.2	1200	45.846	1170	$53,640	3175	$145,561
L515	1.2	1200	31.655	1170	$37,036	3175	$100,505
L514	1.2	1200	43.804	1170	$51,251	3175	$139,078
L513	1.2	1200	43.554	1170	$50,958	3175	$138,284
L512	1.2	1200	66.930	1170	$78,308	3175	$212,503
L499	1.2	1200	10.382	1170	$12,147	3175	$32,963
L491	1.2	1200	97.885	1170	$114,525	3175	$310,785
L489	1.2	1200	83.087	1170	$97,212	3175	$263,801
L488	1.2	1200	84.211	1170	$98,527	3175	$267,370
L484	1.2	1200	10.000	1170	$11,700	3175	$31,750
L470	1.2	1200	166.820	1170	$195,179	3175	$529,654
L455	1.2	1200	164.194	1170	$192,107	3175	$521,316
L485	1.4	1400	10.000	1213	$12,133	3716	$37,165
L460	1.4	1400	119.783	1213	$145,337	3716	$445,168
L459	1.4	1400	102.443	1213	$124,298	3716	$380,724
L458	1.4	1400	98.145	1213	$119,083	3716	$364,751
L457	1.4	1400	10.000	1213	$12,133	3716	$37,165
L456	1.4	1400	81.063	1213	$98,356	3716	$301,267
L498	1.6	1600	8.426	1367	$11,516	4291	$36,154
L497	1.6	1600	163.005	1367	$222,774	4291	$699,424
L496	1.6	1600	104.776	1367	$143,194	4291	$449,574
L495	1.6	1600	177.951	1367	$243,200	4291	$763,554
L494	1.6	1600	170.487	1367	$232,999	4291	$731,527
L493	1.6	1600	96.147	1367	$131,401	4291	$412,549
L492	1.6	1600	148.893	1367	$203,487	4291	$638,872

Table C-1

Storm Sewer Relief Piping Alternative
Without Jessie and Without Future Developments

L487	1.6	1600	247.107	1367	$337,713	4291	$1,060,289
L481	1.6	1600	15.720	1367	$21,484	4291	$67,452
L476	1.6	1600	169.007	1367	$230,976	4291	$725,177
L475	1.6	1600	285.434	1367	$390,093	4291	$1,224,743
L474	1.6	1600	186.243	1367	$254,532	4291	$799,133
L473	1.6	1600	167.512	1367	$228,933	4291	$718,762
L472	1.6	1600	245.614	1367	$335,672	4291	$1,053,883
					$7,155,724		***$20,351,095***

Average Annual Cost Estimate (1991 Dollars)		
Total Construction Cost	$	7,155,700
Contingencies 10%	$	715,600
Engineering 15%	$	1,073,400
Burden Net GST 3%	$	214,700
1991 Total Capital Cost	$	9,159,400
Average Annual Cost (50 yr, 4%)		**$426,400**

Table C-2

Storm Sewer Relief Piping Alternative
With Jessie and Pembina Highway Relief

Name	Diameter (m)	Diameter (mm)	Length (m)	1991 $/m	1991 $	2007 $/m	2007 $
L579	0.3	300	50.610	360	$18,220	770	$38,970
L580	0.3	300	55.950	360	$20,142	770	$43,082
L629	0.3	300	6.400	360	$2,304	770	$4,928
L630	0.3	300	6.710	360	$2,416	770	$5,167
L631	0.3	300	5.000	360	$1,800	770	$3,850
L564	0.375	375	10.000	410	$4,100	930	$9,300
L578	0.375	375	10.000	410	$4,100	930	$9,300
L450	0.381	381	5.000	414	$2,070	960	$4,800
L519	0.45	450	84.521	460	$38,880	1055	$89,170
L520	0.45	450	87.536	460	$40,267	1055	$92,350
L521	0.45	450	45.504	460	$20,932	1055	$48,007
L522	0.45	450	84.910	460	$39,059	1055	$89,580
L531	0.45	450	10.000	460	$4,600	1055	$10,550
L532	0.45	450	10.000	460	$4,600	1055	$10,550
L533	0.45	450	10.000	460	$4,600	1055	$10,550
L534	0.45	450	10.000	460	$4,600	1055	$10,550
L535	0.45	450	10.000	460	$4,600	1055	$10,550
L536	0.45	450	10.000	460	$4,600	1055	$10,550
L537	0.45	450	10.000	460	$4,600	1055	$10,550
L541	0.45	450	10.000	460	$4,600	1055	$10,550
L542	0.45	450	10.000	460	$4,600	1055	$10,550
L543	0.45	450	10.000	460	$4,600	1055	$10,550
L547	0.45	450	10.000	460	$4,600	1055	$10,550
L548	0.45	450	10.000	460	$4,600	1055	$10,550
L550	0.45	450	10.000	460	$4,600	1055	$10,550
L551	0.45	450	47.255	460	$21,737	1055	$49,854
L553	0.45	450	23.942	460	$11,013	1055	$25,259
L557	0.45	450	10.000	460	$4,600	1055	$10,550
L558	0.45	450	10.000	460	$4,600	1055	$10,550
L559	0.45	450	10.000	460	$4,600	1055	$10,550
L565	0.45	450	8.240	460	$3,790	1055	$8,693
L566	0.45	450	8.000	460	$3,680	1055	$8,440
L567	0.45	450	95.398	460	$43,883	1055	$100,645
L575	0.45	450	10.814	460	$4,974	1055	$11,409
L576	0.45	450	10.000	460	$4,600	1055	$10,550
L577	0.45	450	10.000	460	$4,600	1055	$10,550
L633	0.45	450	83.730	460	$38,516	1055	$88,335
L634	0.45	450	23.320	460	$10,727	1055	$24,603
L449	0.508	508	5.000	506	$2,532	1105	$5,526
L500	0.6	600	10.000	565	$5,650	1200	$12,000
L501	0.6	600	73.774	565	$41,682	1200	$88,529
L502	0.6	600	116.361	565	$65,744	1200	$139,633
L503	0.6	600	84.781	565	$47,901	1200	$101,737
L507	0.6	600	10.000	565	$5,650	1200	$12,000
L523	0.6	600	69.033	565	$39,004	1200	$82,840

Table C-2

Storm Sewer Relief Piping Alternative
With Jessie and Pembina Highway Relief

L524	0.6	600	93.146	565	$52,627	1200	$111,775
L538	0.6	600	96.659	565	$54,612	1200	$115,991
L544	0.6	600	140.392	565	$79,321	1200	$168,470
L545	0.6	600	71.603	565	$40,456	1200	$85,924
L546	0.6	600	37.695	565	$21,298	1200	$45,234
L549	0.6	600	36.965	565	$20,885	1200	$44,358
L552	0.6	600	161.896	565	$91,471	1200	$194,275
L554	0.6	600	71.214	565	$40,236	1200	$85,457
L555	0.6	600	73.300	565	$41,415	1200	$87,960
L556	0.6	600	36.976	565	$20,891	1200	$44,371
L568	0.6	600	77.938	565	$44,035	1200	$93,526
L569	0.6	600	87.234	565	$49,287	1200	$104,681
L570	0.6	600	92.585	565	$52,311	1200	$111,102
L571	0.6	600	93.616	565	$52,893	1200	$112,339
L572	0.6	600	82.811	565	$46,788	1200	$99,373
L621	0.6	600	60.410	565	$34,132	1200	$72,492
L626	0.6	600	85.960	565	$48,567	1200	$103,152
L627	0.6	600	82.760	565	$46,759	1200	$99,312
L628	0.6	600	85.430	565	$48,268	1200	$102,516
L468	0.75	750	185.190	690	$127,781	1980	$366,676
L504	0.75	750	73.543	690	$50,745	1980	$145,615
L505	0.75	750	81.900	690	$56,511	1980	$162,162
L506	0.75	750	86.400	690	$59,616	1980	$171,072
L561	0.75	750	90.797	690	$62,650	1980	$179,778
L562	0.75	750	84.076	690	$58,012	1980	$166,470
L573	0.75	750	87.624	690	$60,461	1980	$173,496
L469	0.9	900	169.384	850	$143,976	2410	$408,215
L483	0.9	900	10.000	850	$8,500	2410	$24,100
L525	0.9	900	113.527	850	$96,498	2410	$273,600
L526	0.9	900	112.987	850	$96,039	2410	$272,299
L527	0.9	900	120.332	850	$102,282	2410	$290,000
L528	0.9	900	114.587	850	$97,399	2410	$276,155
L529	0.9	900	134.258	850	$114,119	2410	$323,562
L539	0.9	900	101.092	850	$85,928	2410	$243,632
L540	0.9	900	118.498	850	$100,723	2410	$285,580
L622	0.9	900	57.790	850	$49,122	2410	$139,274
L622.1	0.9	900	41.000	850	$34,850	2410	$98,810
L613	1	1000	84.120	1063	$89,448	2920	$245,630
L614	1	1000	83.730	1063	$89,033	2920	$244,492
L615	1	1000	72.950	1063	$77,570	2920	$213,014
L617	1	1000	63.890	1063	$67,936	2920	$186,559
L618	1	1000	58.600	1063	$62,311	2920	$171,112
L455	1.2	1200	164.194	1170	$192,107	3175	$521,316
L470	1.2	1200	166.820	1170	$195,179	3175	$529,654
L484	1.2	1200	10.000	1170	$11,700	3175	$31,750
L488	1.2	1200	84.211	1170	$98,527	3175	$267,370
L489	1.2	1200	83.087	1170	$97,212	3175	$263,801

Table C-2

Storm Sewer Relief Piping Alternative
With Jessie and Pembina Highway Relief

L491	1.2	1200	97.885	1170	$114,525	3175	$310,785
L499	1.2	1200	10.382	1170	$12,147	3175	$32,963
L512	1.2	1200	66.930	1170	$78,308	3175	$212,503
L513	1.2	1200	43.554	1170	$50,958	3175	$138,284
L514	1.2	1200	43.804	1170	$51,251	3175	$139,078
L515	1.2	1200	31.655	1170	$37,036	3175	$100,505
L516	1.2	1200	45.846	1170	$53,640	3175	$145,561
L517	1.2	1200	48.869	1170	$57,177	3175	$155,159
L518	1.2	1200	11.682	1170	$13,668	3175	$37,090
L534.1	1.2	1200	92.780	1170	$108,553	3175	$294,577
L619	1.2	1200	78.770	1170	$92,161	3175	$250,095
L623	1.2	1200	105.340	1170	$123,248	3175	$334,455
L456	1.4	1400	81.063	1213	$98,356	3716	$301,267
L457	1.4	1400	10.000	1213	$12,133	3716	$37,165
L458	1.4	1400	98.145	1213	$119,083	3716	$364,751
L459	1.4	1400	102.443	1213	$124,298	3716	$380,724
L460	1.4	1400	119.783	1213	$145,337	3716	$445,168
L485	1.4	1400	10.000	1213	$12,133	3716	$37,165
L607	1.4	1400	87.830	1213	$106,567	3716	$326,416
L608	1.4	1400	80.190	1213	$97,297	3716	$298,022
L620	1.4	1400	41.440	1213	$50,281	3716	$154,010
L620.1	1.4	1400	66.730	1213	$80,966	3716	$247,999
L624	1.4	1400	119.620	1213	$145,139	3716	$444,562
L625	1.4	1400	40.250	1213	$48,837	3716	$149,587
L481	1.6	1600	15.720	1367	$21,484	4291	$67,452
L492	1.6	1600	148.893	1367	$203,487	4291	$638,872
L493	1.6	1600	96.147	1367	$131,401	4291	$412,549
L494	1.6	1600	170.487	1367	$232,999	4291	$731,527
L495	1.6	1600	177.951	1367	$243,200	4291	$763,554
L496	1.6	1600	104.776	1367	$143,194	4291	$449,574
L497	1.6	1600	163.005	1367	$222,774	4291	$699,424
L498	1.6	1600	8.426	1367	$11,516	4291	$36,154
L609	1.6	1600	102.500	1367	$140,083	4291	$439,808
L610	1.6	1600	80.520	1367	$110,044	4291	$345,496
L611	1.6	1600	85.630	1367	$117,028	4291	$367,422
L612	1.6	1600	77.910	1367	$106,477	4291	$334,297
L451	1.676	1676	16.154	1417	$22,896	4511	$72,863
L472	2.1	2100	245.614	1700	$417,544	5750	$1,412,183
L473	2.1	2100	167.512	1700	$284,770	5750	$963,127
L474	2.1	2100	186.243	1700	$316,613	5750	$1,070,823
L475	2.1	2100	285.434	1700	$485,238	5750	$1,641,132
L476	2.1	2100	169.007	1700	$287,312	5750	$971,723
L487	2.1	2100	247.107	1700	$420,082	5750	$1,420,767
					$9,647,299	***TOTAL***	***$28,122,043***

Table C-2

Storm Sewer Relief Piping Alternative
With Jessie and Pembina Highway Relief

Average Annual Cost Estimate (1991 Dollars)	
Total Construction Cost	$ 9,647,300
Contingencies 10%	$ 964,700
Engineering 15%	$ 1,447,100
Burden Net GST 3%	$ 289,400
1991 Total Capital Cost	$ 12,348,500
Average Annual Cost (50 yr, 4%)	**$ 574,800**

Table C-3

Combined Storm Relief Sewer (SRS) Alternative
With Jessie Without Pembina Highway Relief

Name	Diameter (m)	Diameter (mm)	Length (m)	1991 $/m	1991 $	2007 $/m[1]	2007 $
L449	0.508	508	5.0	506	$2,532	1105	$5,526
L450	0.381	381	5.0	414	$2,070	960	$4,800
L451	1.676	1676	16.2	1417	$22,896	4511	$72,863
L455	1.2	1200	164.2	1170	$192,107	3175	$521,316
L456	1.4	1400	81.1	1213	$98,356	3716	$301,267
L457	1.4	1400	10.0	1213	$12,133	3716	$37,165
L458	1.4	1400	98.1	1213	$119,083	3716	$364,751
L459	1.4	1400	102.4	1213	$124,298	3716	$380,724
L460	1.4	1400	119.8	1213	$145,337	3716	$445,168
L468	0.75	750	185.2	690	$127,781	1980	$366,676
L469	0.9	900	169.4	850	$143,976	2410	$408,215
L470	1.2	1200	166.8	1170	$195,179	3175	$529,654
L472	2.1	2100	245.6	1700	$417,544	5750	$1,412,183
L473	2.1	2100	167.5	1700	$284,770	5750	$963,127
L474	2.1	2100	186.2	1700	$316,613	5750	$1,070,823
L475	2.1	2100	285.4	1700	$485,238	5750	$1,641,132
L476	2.1	2100	169.0	1700	$287,312	5750	$971,723
L481	1.6	1600	15.7	1367	$21,484	4291	$67,452
L483	0.9	900	10.0	850	$8,500	2410	$24,100
L484	1.2	1200	10.0	1170	$11,700	3175	$31,750
L485	1.4	1400	10.0	1213	$12,133	3716	$37,165
L487	2.1	2100	247.1	1700	$420,082	5750	$1,420,767
L488	1.2	1200	84.2	1170	$98,527	3175	$267,370
L489	1.2	1200	83.1	1170	$97,212	3175	$263,801
L491	1.2	1200	97.9	1170	$114,525	3175	$310,785
L492	1.6	1600	148.9	1367	$203,487	4291	$638,872
L493	1.6	1600	96.1	1367	$131,401	4291	$412,549
L494	1.6	1600	170.5	1367	$232,999	4291	$731,527
L495	1.6	1600	178.0	1367	$243,200	4291	$763,554
L496	1.6	1600	104.8	1367	$143,194	4291	$449,574
L497	1.6	1600	163.0	1367	$222,774	4291	$699,424
L498	1.6	1600	8.4	1367	$11,516	4291	$36,154
L499	1.2	1200	10.4	1170	$12,147	3175	$32,963
L500	0.6	600	10.0	565	$5,650	1200	$12,000
L501	0.6	600	73.8	565	$41,682	1200	$88,529
L502	0.6	600	116.4	565	$65,744	1200	$139,633
L503	0.6	600	84.8	565	$47,901	1200	$101,737
L504	0.75	750	73.5	690	$50,745	1980	$145,615
L505	0.75	750	81.9	690	$56,511	1980	$162,162
L506	0.75	750	86.4	690	$59,616	1980	$171,072
L507	0.6	600	10.0	565	$5,650	1200	$12,000
L512	1.2	1200	66.9	1170	$78,308	3175	$212,503
L513	1.2	1200	43.6	1170	$50,958	3175	$138,284
L514	1.2	1200	43.8	1170	$51,251	3175	$139,078
L515	1.2	1200	31.7	1170	$37,036	3175	$100,505
L516	1.2	1200	45.8	1170	$53,640	3175	$145,561

Table C-3

Combined Storm Relief Sewer (SRS) Alternative
With Jessie Without Pembina Highway Relief

L517	1.2	1200	48.9	1170	$57,177	3175	$155,159
L518	1.2	1200	11.7	1170	$13,668	3175	$37,090
L519	0.45	450	84.5	460	$38,880	1055	$89,170
L520	0.45	450	87.5	460	$40,267	1055	$92,350
L521	0.45	450	45.5	460	$20,932	1055	$48,007
L522	0.45	450	84.9	460	$39,059	1055	$89,580
L523	0.6	600	69.0	565	$39,004	1200	$82,840
L524	0.6	600	93.1	565	$52,627	1200	$111,775
L525	0.9	900	113.5	850	$96,498	2410	$273,600
L526	0.9	900	113.0	850	$96,039	2410	$272,299
L527	0.9	900	120.3	850	$102,282	2410	$290,000
L528	0.9	900	114.6	850	$97,399	2410	$276,155
L529	0.9	900	134.3	850	$114,119	2410	$323,562
L531	0.45	450	10.0	460	$4,600	1055	$10,550
L532	0.45	450	10.0	460	$4,600	1055	$10,550
L533	0.45	450	10.0	460	$4,600	1055	$10,550
L534	0.45	450	10.0	460	$4,600	1055	$10,550
L534.1	1.2	1200	92.8	1170	$108,553	3175	$294,577
L535	0.45	450	10.0	460	$4,600	1055	$10,550
L536	0.45	450	10.0	460	$4,600	1055	$10,550
L537	0.45	450	10.0	460	$4,600	1055	$10,550
L538	0.6	600	96.7	565	$54,612	1200	$115,991
L539	0.9	900	101.1	850	$85,928	2410	$243,632
L540	0.9	900	118.5	850	$100,723	2410	$285,580
L541	0.45	450	10.0	460	$4,600	1055	$10,550
L542	0.45	450	10.0	460	$4,600	1055	$10,550
L543	0.45	450	10.0	460	$4,600	1055	$10,550
L544	0.6	600	140.4	565	$79,321	1200	$168,470
L545	0.6	600	71.6	565	$40,456	1200	$85,924
L546	0.6	600	37.7	565	$21,298	1200	$45,234
L547	0.45	450	10.0	460	$4,600	1055	$10,550
L548	0.45	450	10.0	460	$4,600	1055	$10,550
L549	0.6	600	37.0	565	$20,885	1200	$44,358
L550	0.45	450	10.0	460	$4,600	1055	$10,550
L551	0.45	450	47.3	460	$21,737	1055	$49,854
L552	0.6	600	161.9	565	$91,471	1200	$194,275
L557	0.45	450	10.0	460	$4,600	1055	$10,550
L561	0.75	750	90.8	690	$62,650	1980	$179,778
L562	0.75	750	84.1	690	$58,012	1980	$166,470
L564	0.375	375	10.0	410	$4,100	930	$9,300
L565	0.45	450	8.2	460	$3,790	1055	$8,693
L566	0.45	450	8.0	460	$3,680	1055	$8,440
L567	0.45	450	95.4	460	$43,883	1055	$100,645
L568	0.6	600	77.9	565	$44,035	1200	$93,526
L569	0.6	600	87.2	565	$49,287	1200	$104,681
L570	0.6	600	92.6	565	$52,311	1200	$111,102
L571	0.6	600	93.6	565	$52,893	1200	$112,339
L572	0.6	600	82.8	565	$46,788	1200	$99,373

Table C-3

Combined Storm Relief Sewer (SRS) Alternative
With Jessie Without Pembina Highway Relief

L573	0.75	750	87.6	690	$60,461	1980	$173,496
L575	0.45	450	10.8	460	$4,974	1055	$11,409
L576	0.45	450	10.0	460	$4,600	1055	$10,550
L577	0.45	450	10.0	460	$4,600	1055	$10,550
L578	0.375	375	10.0	410	$4,100	930	$9,300
L579	0.3	300	50.6	360	$18,220	770	$38,970
L580	0.3	300	56.0	360	$20,142	770	$43,082
L607	1.05	1050	87.8	1170	$102,761	3175	$278,860
L608	1.05	1050	80.2	1170	$93,822	3175	$254,603
L609	1.2	1200	102.5	1170	$119,925	3175	$325,438
L610	1.2	1200	80.5	1170	$94,208	3175	$255,651
L611	1.2	1200	85.6	1170	$100,187	3175	$271,875
L612	1.2	1200	77.9	1170	$91,155	3175	$247,364
L613	0.75	750	84.1	690	$58,043	1980	$166,558
L614	0.75	750	83.7	690	$57,774	1980	$165,785
L615	0.75	750	73.0	690	$50,336	1980	$144,441
L626	0.9	900	86.0	850	$73,066	2410	$207,164
L627	0.9	900	82.8	850	$70,346	2410	$199,452
L628	0.9	900	85.4	850	$72,616	2410	$205,886
L629	0.3	300	6.4	360	$2,304	770	$4,928
L630	0.3	300	6.7	360	$2,416	770	$5,167
L631	0.3	300	5.0	360	$1,800	770	$3,850
L633	0.45	450	83.7	460	$38,516	1055	$88,335
L638	0.75	750	86.8	690	$59,913	1980	$171,923
L639	0.75	750	79.9	690	$55,117	1980	$158,162
L640	0.45	450	9.4	460	$4,338	1055	$9,949
L641	0.45	450	8.6	460	$3,956	1055	$9,073
L642	0.45	450	89.1	460	$40,972	1055	$93,969
L643	0.45	450	85.6	460	$39,385	1055	$90,329
L644	0.45	450	35.4	460	$16,302	1055	$37,389
					$8,851,915	***TOTAL***	***$25,758,634***

Average Annual Cost Estimate (1991 Dollars)	
Total Construction Cost	$ 8,851,900
Contingencies 10%	$ 885,200
Engineering 15%	$ 1,327,800
Burden Net GST 3%	$ 265,600
1991 Total Capital Cost	$ 11,330,500
Average Annual Cost (50 yr, 4%)	**$ 527,400**

Table C-4

Storm Sewer Relief Piping Alternative
Localized Relief Cockburn East

Conduit Name	Diameter (m)	Diameter (mm)	Length (m)	1991 $/m	1991 $	2007 $/m[1]	2007 $
L579	0.3	300	50.610	360	$18,220	770	$38,970
L580	0.3	300	55.950	360	$20,142	770	$43,082
L450	0.381	381	5.000	414	$2,070	908	$4,538
L519	0.45	450	84.521	460	$38,880	1055	$89,170
L520	0.45	450	87.536	460	$40,267	1055	$92,350
L521	0.45	450	45.504	460	$20,932	1055	$48,007
L522	0.45	450	84.910	460	$39,059	1055	$89,580
L531	0.45	450	10.000	460	$4,600	1055	$10,550
L532	0.45	450	10.000	460	$4,600	1055	$10,550
L533	0.45	450	10.000	460	$4,600	1055	$10,550
L534	0.45	450	10.000	460	$4,600	1055	$10,550
L535	0.45	450	10.000	460	$4,600	1055	$10,550
L536	0.45	450	10.000	460	$4,600	1055	$10,550
L537	0.45	450	10.000	460	$4,600	1055	$10,550
L541	0.45	450	10.000	460	$4,600	1055	$10,550
L542	0.45	450	10.000	460	$4,600	1055	$10,550
L543	0.45	450	10.000	460	$4,600	1055	$10,550
L547	0.45	450	10.000	460	$4,600	1055	$10,550
L548	0.45	450	10.000	460	$4,600	1055	$10,550
L550	0.45	450	10.000	460	$4,600	1055	$10,550
L449	0.508	508	5.000	506	$2,532	1105	$5,526
L523	0.6	600	69.033	565	$39,004	1200	$82,840
L524	0.6	600	93.146	565	$52,627	1200	$111,775
L538	0.6	600	96.659	565	$54,612	1200	$115,991
L544	0.6	600	140.392	565	$79,321	1200	$168,470
L545	0.6	600	71.603	565	$40,456	1200	$85,924
L546	0.6	600	37.695	565	$21,298	1200	$45,234
L549	0.6	600	36.965	565	$20,885	1200	$44,358
L525	0.9	900	113.527	850	$96,498	2410	$273,600
L526	0.9	900	112.987	850	$96,039	2410	$272,299
L527	0.9	900	120.332	850	$102,282	2410	$290,000
L528	0.9	900	114.587	850	$97,399	2410	$276,155
L529	0.9	900	134.258	850	$114,119	2410	$323,562
L539	0.9	900	101.092	850	$85,928	2410	$243,632
L540	0.9	900	118.498	850	$100,723	2410	$285,580
L455	1.2	1200	164.194	1170	$192,107	3175	$521,316
L456	1.4	1400	81.063	1213	$98,356	3716	$301,267
L457	1.4	1400	10.000	1213	$12,133	3716	$37,165
L458	1.4	1400	98.145	1213	$119,083	3716	$364,751
L459	1.4	1400	102.443	1213	$124,298	3716	$380,724
L460	1.4	1400	119.783	1213	$145,337	3716	$445,168
L451	1.676	1676	16.154	1417	$22,896	4511	$72,863
					$1,957,302	***TOTAL***	***$5,291,045***

Average Annual Cost Estimate (1991 Dollars)	
Total Construction Cost	$ 1,957,300
Contingencies 10%	$ 195,700
Engineering 15%	$ 293,600
Burden Net GST 3%	$ 58,700
1991 Total Capital Cost	$ 2,505,300
Average Annual Cost (50 yr, 4%)	**$116,600**

Table C-5

Complete LDS Separation (Without Jessie)
Report Reference Section 8.3.1.1

Location	Name	Diameter (m)	Length
West	60011867	0.25	7.015
West	L491	0.25	43
West	L494	0.25	52
West	L496	0.25	42
West	L499	0.25	43
West	60011427	0.3	4.013
West	60011438	0.3	37.137
West	60011560	0.3	41.759
West	60011566	0.3	33.528
West	60011692	0.3	62.486
West	60011866	0.3	42.082
West	80011438	0.3	45.163
West	80011554	0.3	45.157
West	L481	0.3	52
West	L485	0.3	52
West	L489	0.3	51
West	L492	0.3	51
West	L510	0.3	22
West	LGP29_30	0.3	40.48
West	LGP30_31	0.3	220.9
West	60011674	0.375	62.486
West	60011724	0.375	86.563
West	60011883	0.375	102.788
West	60011617	0.4	48.162
West	60011428	0.45	58.802
West	60011528	0.45	58.488
West	60011535	0.45	5.779
West	60011536	0.45	41.76
West	60011555	0.45	58.829
West	60011563	0.45	33.528
West	60011646	0.45	35.97
West	60011761	0.45	42.866
West	60011877	0.45	102.788
West	60021705	0.45	92.714
West	80011427	0.45	54.864
West	80011867	0.45	79.249
West	L448	0.45	27
West	L470	0.45	47
West	L487	0.45	8
West	60011424	0.575	58.425
West	60011534	0.575	42.39
West	60011549	0.575	35.052
West	60011573	0.575	86.563
West	60011618	0.575	27.432
West	60011645	0.575	18.898
West	60011650	0.575	18.898

Location	Name	Diameter (Height)	Length
East	60012017	0.25	17.678
East	60009032	0.3	42.113
East	60009048	0.3	2.438
East	60011981	0.3	4.819
East	60011982	0.3	52.73
East	60012018	0.3	101.194
East	60012047	0.3	64.923
East	60012063	0.3	15.85
East	60012071	0.3	85.458
East	60012079	0.3	82.906
East	60012103	0.3	86.534
East	60012109	0.3	85.771
East	60012116	0.3	86.258
East	60012117	0.3	86.258
East	60012122	0.3	86.258
East	60012147	0.3	115.998
East	60012180	0.3	85.954
East	60012193	0.3	86.219
East	60012196	0.3	86.258
East	60012209	0.3	11.649
East	60012211	0.3	53.679
East	60012317	0.3	90.526
East	80012018	0.3	11.133
East	80012047	0.3	21.336
East	80012058	0.3	25.907
East	80012203	0.3	5.486
East	L461	0.3	44
East	L463	0.3	31
East	L465	0.3	42
East	60011998	0.375	26.213
East	60012003	0.375	74.219
East	60012009	0.375	86.868
East	60012052	0.375	86.563
East	60012058	0.375	86.258
East	60012096	0.375	4.249
East	60012248	0.375	79.553
East	80000826	0.375	10.973
East	80011998	0.375	57.303
East	80012063	0.375	31.051
East	80012096	0.375	82.009
East	L502	0.375	40
East	60011986	0.45	121.289
East	60011989	0.45	106.68
East	60011996	0.45	85.649
East	60012002	0.45	18.898
East	60012004	0.45	7.468

Table C-5

Complete LDS Separation (Without Jessie)
Report Reference Section 8.3.1.1

West	60011655	0.575	86.9
West	60011841	0.575	44.59
West	60011844	0.575	39.624
West	60012777	0.575	79.858
West	60012782	0.575	86.563
West	60012784	0.575	85.954
West	L477	0.575	66
West	L478	0.575	67
West	L479	0.575	58
West	L482	0.575	50
West	L483	0.575	41
West	L500	0.575	43
West	L501	0.575	57
West	60011194	0.6	95.102
West	60011200	0.6	95.102
West	60011295	0.6	95.098
West	60011300	0.6	95.052
West	60011707	0.6	78.642
West	60011708	0.6	27.738
West	60011727	0.6	101.315
West	60011838	0.6	35.038
West	60012859	0.6	86.134
West	60012864	0.6	86.258
West	80011707	0.6	7.924
West	LGP31	0.6	14.38
West	60011506	0.75	86.26
West	60011507	0.75	86.565
West	60011512	0.75	76.354
West	60011522	0.75	7.315
West	60011693	0.75	42.039
West	60011713	0.75	42.031
West	60011837	0.75	83.531
West	60011873	0.75	45.415
West	60011876	0.75	30.48
West	60011878	0.75	59.371
West	60012909	0.75	86.563
West	60012913	0.75	87.478
West	60012962	0.75	91.745
West	60012967	0.75	55.474
West	60012970	0.75	80.203
West	60013004	0.75	87.782
West	60021814	0.75	81.987
West	80011693	0.75	42.076
West	L490	0.75	43
West	L513	0.75	43
West	L514	0.75	20
West	60011205	0.9	95.102
West	60011515	0.9	95.441
West	60011524	0.9	86.26
West	60011525	0.9	75.35
West	60011698	0.9	84.903
West	60011746	0.9	83.365
West	80011713	0.9	42.086

East	60012010	0.45	24.384
East	60012014	0.45	42.672
East	60012040	0.45	86.563
East	60012083	0.45	89.345
East	60012138	0.45	31.755
East	60012141	0.45	79.858
East	60012174	0.45	6.4
East	60012320	0.45	39.624
East	60012433	0.45	88.087
East	70012354	0.45	78.708
East	80009032	0.45	42.092
East	80012138	0.45	43.094
East	80012320	0.45	64.922
East	L451	0.45	46
East	L462	0.45	89
East	L464	0.45	78
East	L466	0.45	51
East	L506	0.45	49
East	60009241	0.575	42.382
East	60012070	0.575	41.664
East	60012084	0.575	65.227
East	60012087	0.575	90.011
East	60012128	0.575	95.066
East	60012131	0.575	42.386
East	60012132	0.575	84.734
East	60012187	0.575	35.662
East	60012210	0.575	42.348
East	60012241	0.575	115.824
East	60012315	0.575	110.642
East	60012316	0.575	104.546
East	60012318	0.575	76.775
East	60012329	0.575	33.528
East	80012070	0.575	39.399
East	80012329	0.575	79.653
East	L504	0.575	43
East	L505	0.575	8.5
East	L512	0.575	112
East	60012097	0.6	39.418
East	60009033	0.75	50.068
East	60012104	0.75	98.145
East	80012097	0.75	39.405
East	L452	0.75	40
East	60012045	0.9	51.221
East	60012183	0.9	41.403
East	60012204	0.9	35.052
East	60012208	0.9	29.87
East	60013636	0.9	119.783
East	80012045	0.9	51.222
East	L453	0.9	20
East	60012154	1.05	76.2
East	60012155	1.05	30.729
East	60012156	1.05	88.697
East	60012236	1.05	39.403

Table C-5

Complete LDS Separation (Without Jessie)
Report Reference Section 8.3.1.1

West	60011801	1.02	98.823
West	60011827	1.02	12.192
West	60011829	1.02	107.449
West	60011100	1.05	52.733
West	60011454	1.05	85.652
West	60011482	1.05	86.262
West	60011675	1.05	40.845
West	60011747	1.05	7.315
West	60012635	1.05	84.434
West	60012647	1.05	65.837
West	60012669	1.05	84.434
West	60023852	1.05	7.002
West	80011675	1.05	35.357
West	60011388	1.2	82.909
West	60011393	1.2	86.567
West	60012651	1.2	95.402
West	60012655	1.2	74.739
West	60012656	1.2	66.067
West	80012655	1.2	20.422
West	60011294	1.5	82.906
West	60011301	1.5	82.601
West	60011304	1.5	84.758
West	60011313	1.5	45.509
West	60011315	1.5	31.346
West	60011319	1.5	54.807
West	60011323	1.5	89.76
West	60011324	1.5	44.884
West	60011325	1.5	67.682
West	60011328	1.5	44.885
West	60011334	1.5	82.906
West	60011336	1.5	83.455
West	60011421	1.5	51.396
West	60011423	1.5	38.909
West	60011434	1.5	77.839
West	60012639	1.5	75.286
West	60012649	1.5	83.21
West	60012659	1.5	81.266
West	60012700	1.5	79.248
West	60012702	1.5	14.021
West	60011419	1.65	74.676
West	60011499	1.65	37.219
West	60011500	1.65	82.605
West	60011537	1.65	50.685
West	60011538	1.65	69.494
West	60011539	1.65	60
West	60011540	1.65	13.716
West	60011541	1.65	61.859
West	60011677	1.65	68.885
West	60011678	1.65	85.639
West	60011680	1.65	34.03
West	60011684	1.65	168.661

East	70007653	1.05	104.036
East	80012155	1.05	45.472
East	80012269	1.05	48.403
East	L454	1.05	38
East	L455	1.05	10
East	L509	1.05	78
East	60012242	1.2	42.672
East	60012245	1.2	52.426
East	60012274	1.2	51.188
East	L457	1.2	54
East	L458	1.2	55
East	L459	1.2	80
East	60012151	1.35	71.628
East	60011974	2.4	44.583
East	60013074	2.4	196.291
East	60013635	2.4	32.022
East	80013635	2.4	85.344
East	60012029	2.7	168.25
East	60012037	2.7	35
East	60012038	2.7	181.221
East	70007664	2.7	61.382
East	80007664	2.7	21.218
		Total	7318.179

Table C-5

Complete LDS Separation (Without Jessie)
Report Reference Section 8.3.1.1

West	60011685	1.65	5.889
West	60011804	1.65	83.212
West	60023853	1.65	70.943
West	80011537	1.65	37.242
West	80021537	1.65	5.407
West	L449	1.65	42
West	L450	1.65	27
West	60011811	2.4	106.102
West	60011825	2.4	53.019
West	60011828	2.4	88.36
West	60013006	2.4	142.464
		Total	9747.684

Summary	Total Length	2007 Price	1991 Price
0.3	987.72	$760,544.40	$355,579.20
0.375	251.837	$234,208.41	$103,253.17
0.45	795.799	$839,567.95	$366,067.54
0.525	1093.147	$1,224,324.64	$568,436.44
0.6	817.783	$981,339.60	$462,047.40
0.75	1278.669	$2,531,764.62	$882,281.61
0.9	562.507	$1,355,641.87	$478,130.95
1.05	768.335	$2,439,463.63	$898,951.95
1.2	426.106	$1,352,886.55	$498,544.02
1.35			
1.5	1296.674	$5,191,882.70	$1,685,676.20
1.65	1079.162	$4,786,083.47	$1,618,743.00
1.8			
2.1			
2.4	389.945	$2,586,505.19	$662,906.50
2.7			
Total	9747.684	**$24,284,213**	**$8,580,618**

Summary	Total Length	2007 Price	1991 Price
0.3	1612.333	$1,241,496.41	$580,439.88
0.375	665.259	$618,690.87	$272,756.19
0.45	1370.488	$1,445,864.84	$630,424.48
0.525	1263.347	$1,414,948.64	$656,940.44
0.6	39.418	$47,301.60	$22,271.17
0.75	227.618	$450,683.64	$157,056.42
0.9	348.551	$840,007.91	$296,268.35
1.05	558.94	$1,774,634.50	$653,959.80
1.2	335.286	$1,064,533.05	$392,284.62
1.35	71.628	$244,251.48	$83,804.76
1.5			
1.65			
1.8			
2.1			
2.4	358.24	$2,376,205.92	$609,008.00
2.7	467.071	$3,586,171.14	$794,020.70
Total	7318.179	**$15,104,790**	**$5,149,235**

Project and Average Annual Cost Estimate (1991 $)	
ITEM	**Cost (1991 $)**
Total construction cost	$13,729,853
Contingencies (10%)	$1,372,985
Engineering (15%)	$2,059,478
Burden (3%)	$411,896
Total Project Cost	**$17,574,212**
Average Annual Cost (4%,50 years)	**$818,080**

Total Construction Cost		
	2007 Cost	**1991 Cost**
West	$24,284,213	$8,580,618
East	$15,104,790	$5,149,235
TOTAL	**$39,389,003**	**$13,729,853**

Table C-6

Complete LDS Separation (With Jessie)
Report Reference Section 8.3.1.2

Location	Name	Diameter (m)	Length
West	L491	0.25	43
West	L494	0.25	52
West	60011427	0.3	4.013
West	60011438	0.3	37.137
West	60011560	0.3	41.759
West	60011566	0.3	33.528
West	60011692	0.3	62.486
West	80011438	0.3	45.163
West	80011554	0.3	45.157
West	L481	0.3	52
West	L485	0.3	52
West	L489	0.3	51
West	L492	0.3	51
West	L510	0.3	22
West	LGP29_30	0.3	40.48
West	LGP30_31	0.3	220.9
West	60011617	0.375	48.162
West	60011674	0.375	62.486
West	60011528	0.45	58.488
West	60011535	0.45	5.779
West	60011536	0.45	41.76
West	60011555	0.45	58.829
West	60011563	0.45	33.528
West	60011646	0.45	35.97
West	60011724	0.45	86.563
West	60021705	0.45	92.714
West	80011427	0.45	54.864
West	L487	0.45	8
West	60011424	0.575	58.425
West	60011534	0.575	42.39
West	60011549	0.575	35.052
West	60011573	0.575	86.563
West	60011618	0.575	27.432
West	60011645	0.575	18.898
West	60011650	0.575	18.898
West	60011655	0.575	86.9
West	60012777	0.575	79.858
West	60012782	0.575	86.563
West	60012784	0.575	85.954
West	L477	0.575	66
West	L478	0.575	67
West	L479	0.575	58
West	L482	0.575	50
West	L483	0.575	41
West	L500	0.575	43
West	L501	0.575	57

Location	Name	Diameter (Height)	Length
East	60012017	0.25	17.678
East	60009048	0.3	2.438
East	60011981	0.3	4.819
East	60009032	0.3	42.113
East	60011982	0.3	52.73
East	60012018	0.3	101.194
East	60012047	0.3	64.923
East	60012063	0.3	15.85
East	60012071	0.3	85.458
East	60012079	0.3	82.906
East	60012103	0.3	86.534
East	60012109	0.3	85.771
East	60012116	0.3	86.258
East	60012117	0.3	86.258
East	60012122	0.3	86.258
East	60012147	0.3	115.998
East	60012180	0.3	85.954
East	60012193	0.3	86.219
East	60012196	0.3	86.258
East	60012209	0.3	11.649
East	60012211	0.3	53.679
East	60012317	0.3	90.526
East	80009032	0.3	42.092
East	80012018	0.3	11.133
East	80012047	0.3	21.336
East	80012058	0.3	25.907
East	80012203	0.3	5.486
East	L461	0.3	44
East	L463	0.3	31
East	L465	0.3	42
East	60011998	0.375	26.213
East	60012003	0.375	74.219
East	60012009	0.375	86.868
East	60012052	0.375	86.563
East	60012058	0.375	86.258
East	60012096	0.375	4.249
East	60012248	0.375	79.553
East	80000826	0.375	10.973
East	80011998	0.375	57.303
East	80012063	0.375	31.051
East	80012096	0.375	82.009
East	60011986	0.45	121.289
East	60011989	0.45	106.68
East	60011996	0.45	85.649
East	60012002	0.45	18.898
East	60012004	0.45	7.468

Table C-6

Complete LDS Separation (With Jessie)
Report Reference Section 8.3.1.2

West	60011428	0.6	58.802	East	60012010	0.45	24.384
West	60011707	0.6	78.642	East	60012014	0.45	42.672
West	60011708	0.6	27.738	East	60012040	0.45	86.563
West	60012859	0.6	86.134	East	60012083	0.45	89.345
West	60012864	0.6	86.258	East	60012138	0.45	31.755
West	80011707	0.6	7.924	East	60012174	0.45	6.4
West	L448	0.6	27	East	60012320	0.45	39.624
West	LGP31	0.6	14.38	East	60012433	0.45	88.087
West	60011506	0.75	86.26	East	80012138	0.45	43.094
West	60011507	0.75	86.565	East	80012320	0.45	64.922
West	60011512	0.75	76.354	East	L462	0.45	89
West	60011522	0.75	7.315	East	L464	0.45	78
West	60012909	0.75	86.563	East	L466	0.45	51
West	60012913	0.75	87.478	East	L506	0.45	49
West	60012962	0.75	91.745	East	60009241	0.575	42.382
West	60012967	0.75	55.474	East	60012070	0.575	41.664
West	60012970	0.75	80.203	East	60012084	0.575	65.227
West	60013004	0.75	87.782	East	60012087	0.575	90.011
West	60021814	0.75	81.987	East	60012128	0.575	95.066
West	L490	0.75	43	East	60012131	0.575	42.386
West	L513	0.75	43	East	60012132	0.575	84.734
West	60011194	0.9	95.102	East	60012141	0.575	79.858
West	60011200	0.9	95.102	East	60012187	0.575	35.662
West	60011205	0.9	95.102	East	60012210	0.575	42.348
West	60011295	0.9	95.098	East	60012241	0.575	115.824
West	60011524	0.9	86.26	East	60012315	0.575	110.642
West	60011693	0.9	42.039	East	60012316	0.575	104.546
West	60011698	0.9	84.903	East	60012318	0.575	76.775
West	60011713	0.9	42.031	East	60012329	0.575	33.528
West	60011727	0.9	101.315	East	70012354	0.575	78.708
West	60011746	0.9	83.365	East	80012070	0.575	39.399
West	80011693	0.9	42.076	East	80012329	0.575	79.653
West	80011713	0.9	42.086	East	L451	0.575	46
West	60011100	1.05	52.733	East	L502	0.575	40
West	60011300	1.05	95.052	East	L504	0.575	43
West	60011515	1.05	95.441	East	L505	0.575	8.5
West	60011525	1.05	75.35	East	L512	0.575	112
West	60011675	1.05	40.845	East	60012097	0.6	39.418
West	60011747	1.05	7.315	East	60009033	0.75	50.068
West	60012635	1.05	84.434	East	60012104	0.75	98.145
West	60012647	1.05	65.837	East	80012097	0.75	39.405
West	60012669	1.05	84.434	East	L452	0.75	40
West	60023852	1.05	7.002	East	60012045	0.9	51.221
West	80011675	1.05	35.357	East	60013636	0.9	119.783
West	60011454	1.2	85.652	East	80012045	0.9	51.222
West	60011482	1.2	86.262	East	60012154	1.05	76.2
West	60012639	1.2	75.286	East	60012155	1.05	30.729
West	60012649	1.2	83.21	East	60012156	1.05	88.697
West	60012651	1.2	95.402	East	60012183	1.05	41.403
West	60012655	1.2	74.739	East	60012204	1.05	35.052
West	60012656	1.2	66.067	East	60012208	1.05	29.87
West	80012655	1.2	20.422	East	70007653	1.05	104.036
West	60011388	1.35	82.909	East	80012155	1.05	45.472
West	60011393	1.35	86.567	East	L453	1.05	20
West	60011294	1.5	82.906	East	60012236	1.2	39.403
West	60011301	1.5	82.601	East	60012245	1.2	52.426
West	60011304	1.5	84.758	East	60012274	1.2	51.188

Table C-6

Complete LDS Separation (With Jessie)
Report Reference Section 8.3.1.2

West	60011334	1.5	82.906
West	60011336	1.5	83.455
West	60012659	1.5	81.266
West	60012700	1.5	79.248
West	60012702	1.5	14.021
West	60011313	1.65	45.509
West	60011315	1.65	31.346
West	60011319	1.65	54.807
West	60011323	1.65	89.76
West	60011324	1.65	44.884
West	60011325	1.65	67.682
West	60011328	1.65	44.885
West	60011419	1.65	74.676
West	60011421	1.65	51.396
West	60011423	1.65	38.909
West	60011434	1.65	77.839
West	60011499	1.65	37.219
West	60011500	1.65	82.605
West	60011537	1.65	50.685
West	60011539	1.65	60
West	60011540	1.65	13.716
West	60011541	1.65	61.859
West	80011537	1.65	37.242
West	80021537	1.65	5.407
West	L449	1.65	42
West	L450	1.65	27
West	60011538	2.1	69.494
West	60011677	2.1	68.885
West	60011680	2.1	34.03
West	60011684	2.1	168.661
West	60011685	2.1	5.889
West	60011678	2.4	85.639
West	60011804	2.4	83.212
West	60011828	2.4	88.36
West	60023853	2.4	70.943
West	60011811	2.7	106.102
West	60011825	2.7	53.019
West	60013006	2.7	142.464
		Total	8662.383

East	80012269	1.2	48.403
East	L454	1.2	38
East	L455	1.2	10
East	L457	1.2	54
East	L458	1.2	55
East	L509	1.2	78
East	60012151	1.35	71.628
East	60012242	1.35	42.672
East	L459	1.35	80
East	60011974	2.7	44.583
East	60012029	2.7	168.25
East	60012037	2.7	35
East	60012038	2.7	181.221
East	60013074	2.7	196.291
East	60013635	2.7	32.022
East	70007664	2.7	61.382
East	80007664	2.7	21.218
East	80013635	2.7	85.344
		Total	7318.179

Table C-6

Complete LDS Separation (With Jessie)
Report Reference Section 8.3.1.2

Summary	Total Length	2007 Price	1991 Price
0.3	853.623	$657,289.71	$307,304.28
0.375	110.648	$102,902.64	$45,365.68
0.45	476.495	$502,702.23	$219,187.70
0.525	1008.933	$1,130,004.96	$524,645.16
0.6	386.878	$464,253.60	$218,586.07
0.75	913.726	$1,809,177.48	$630,470.94
0.9	904.479	$2,179,794.39	$768,807.15
1.05	643.8	$2,044,065.00	$753,246.00
1.2	587.04	$1,863,852.00	$686,836.80
1.35	169.476	$577,913.16	$198,286.92
1.5	591.161	$2,367,008.64	$768,509.30
1.65	1039.426	$4,609,854.31	$1,559,139.00
1.8			
2.1	346.959	$1,993,973.37	$589,830.30
2.4	328.154	$2,176,645.48	$557,861.80
2.7	301.585	$2,315,569.63	$512,694.50
Total	8662.383	**$24,795,007**	**$8,340,772**

Summary	Total Length	2007 Price	1991 Price
0.3	1654.425	$1,273,907.25	$595,593.00
0.375	625.259	$581,490.87	$256,356.19
0.45	1123.83	$1,185,640.65	$516,961.80
0.525	1507.913	$1,688,862.56	$784,114.76
0.6	39.418	$47,301.60	$22,271.17
0.75	227.618	$450,683.64	$157,056.42
0.9	222.226	$535,564.66	$188,892.10
1.05	471.459	$1,496,882.33	$551,607.03
1.2	426.42	$1,353,883.50	$498,911.40
1.35	194.3	$662,563.00	$227,331.00
1.5			
1.65			
1.8			
2.1			
2.4			
2.7	825.311	$6,336,737.86	$1,403,028.70
Total	7318.179	**$15,613,518**	**$5,202,124**

Summary	Total Length	2007 Price	1991 Price
0.3	416.478	$320,688.06	$149,932.08
0.375	530.665	$493,518.45	$217,572.65
0.45	359.944	$379,740.92	$165,574.24
0.525	198.213	$221,998.56	$103,070.76
0.6	316.673	$380,007.60	$178,920.25
0.75	959.221	$1,899,257.58	$661,862.49
0.9	417.271	$1,005,623.11	$354,680.35
1.05	168.262	$534,231.85	$196,866.54
1.2	319.584	$1,014,679.20	$373,913.28
1.35	255.576	$871,514.16	$299,023.92
1.5	218.464	$874,729.86	$284,003.20
1.65			
1.8			
2.1			
2.4			
2.7			
Total	4160.351	**$7,995,989**	**$2,985,420**

Project and Average Annual Cost Estimate (1991 $)	
ITEM	**Cost (1991 $)**
Total construction cost	$16,528,315
Contingencies (10%)	$1,652,831
Engineering (15%)	$2,479,247
Burden (3%)	$495,849
Total Project Cost	**$21,156,243**
Average Annual Cost (4%,50 years)	**$984,823**

Total Construction Cost		
	2007 Cost	**1991 Cost**
West	$24,795,007	$8,340,772
East	$15,613,518	$5,202,124
Jessie	$7,995,989	$2,985,420
TOTAL	**$48,404,514**	**$16,528,315**

Table C-7

Partial LDS Separation (Without Jessie)
Report Reference Section 8.3.1.3

Location	Name	Diameter (m)	Length
West	70018936	0.3	44.196
West	L667	0.3	80
West	L690	0.3	144
West	L735	0.3	102.788
West	L901	0.3	40
West	L660	0.375	43
West	L661	0.375	40
West	L662	0.375	45
West	L663	0.375	84
West	L902	0.375	79.858
West	L903	0.375	60
West	L668	0.45	86
West	L687	0.45	86
West	L904	0.45	100
West	60011127.1	0.6	20
West	L737	0.6	350
West	L739	0.6	200
West	60011194.1	0.75	95
West	60011200.1	0.75	95
West	60011205.1	0.75	95
West	60011334.1	0.75	83
West	60011336.1	0.75	83.5
West	60011388.1	0.75	83
West	60011393.1	0.75	87
West	60011454.1	0.75	86
West	L536	0.75	90
West	L537	0.75	95
West	L567	0.75	200
West	L665	0.75	66
West	L666	0.75	75
West	L669	0.75	66
West	L538	1.05	100
West	L539	1.05	85
West	L540	1.05	85
West	L541	1.05	86
West	L542	1.05	84
West	L543	1.05	85
West	L545	1.05	121
West	L552	1.05	75
West	L564	1.05	64
West	L565	1.05	95
West	L566	1.05	79
West	L568	1.05	152
West	L729	1.05	95
West	L730	1.05	95
West	L557	1.35	72
West	L558	1.35	112
West	L559	1.35	95
West	L560	1.35	149
West	L562	1.35	51
West	L563	1.35	69
West	L628	1.35	70
West	L658	1.35	56

Location	Name	Diameter (Height)	Length
East	L519	0.3	101
East	L532	0.3	52.73
East	L692	0.3	50
East	L497	0.45	42
East	L498	0.45	42
East	L511	0.45	89
East	L512	0.45	98
East	L522	0.45	42
East	L524	0.45	53.679
East	L670	0.45	92.113
East	L671	0.45	42.092
East	L686	0.45	26.213
East	L693	0.45	116
East	L695	0.45	114
East	L698	0.45	98
East	L700	0.45	72
East	L738	0.45	64.922
East	L697	0.525	75
East	L699	0.525	76
East	L736	0.525	291.97
East	60012084.1	0.6	25
East	L499	0.6	30
East	L500	0.6	78
East	L501	0.6	39
East	L523	0.6	41
East	L526	0.6	50
East	L527	0.6	45
East	L529	0.6	39
East	L569	0.6	85
East	L659	0.6	90
East	L672	0.6	107.594
East	L673	0.6	14.524
East	L694	0.6	104
East	L696	0.6	89
East	L502	0.75	86
East	L503	0.75	86
East	L504	0.75	86
East	L505	0.75	86
East	L513	0.75	102
East	L674	0.75	92.957
East	L675	0.75	31.755
East	L676	0.75	43.094
East	L677	0.75	89.345
East	L678	0.75	41.664
East	L679	0.75	39.399
East	L680	0.75	39.418
East	L681	0.75	39.405
East	L506	1.05	98
East	L507	1.2	51
East	L528	1.2	51
East	L508	1.5	120
East	L509	1.5	61
East	L510	1.5	54

Table C-7

Partial LDS Separation (Without Jessie)
Report Reference Section 8.3.1.3

West	L555	1.5	103
West	L625	1.5	99
		Total	5081.342

East	L514	1.5	87
East	L515	1.5	87
East	L517	1.5	121
East	L518	1.5	107
East	L520	1.5	86
East	L521	1.5	92
East	L621	1.5	75
East	L622	1.5	75
East	L623	1.5	75
East	L624	1.5	75
		Total	4653.874

Summary	Total Length	**2007 Price**	**1991 Price**
0.3	410.984	$316,457.68	$147,954.24
0.375	351.858	$327,227.94	$144,261.78
0.45	272	$286,960.00	$125,120.00
0.525		$0.00	$0.00
0.6	570	$684,000.00	$322,050.00
0.75	1299.5	$2,573,010.00	$896,655.00
0.9		$0.00	$0.00
1.05	1301	$4,130,675.00	$1,522,170.00
1.2	0	$0.00	$0.00
1.35	674	$2,298,340.00	$788,580.00
1.5	202	$688,820.00	$262,600.00
1.65		$0.00	$0.00
1.8		$0.00	$0.00
2.1		$0.00	$0.00
2.4		$0.00	$0.00
2.7			
Total	5081.342	**$11,305,491**	**$4,209,391**

Summary	Total Length	**2007 Price**	**1991 Price**
0.3	203.73	$156,872.10	$73,342.80
0.375			$0.00
0.45	992.019	$1,046,580.05	$456,328.74
0.575	442.97	$496,126.40	$230,344.40
0.6	837.118	$1,004,541.60	$472,971.67
0.75	863.037	$1,708,813.26	$595,495.53
0.9			$0.00
1.05	98	$311,150.00	$114,660.00
1.2	102	$323,850.00	$119,340.00
1.35			$0.00
1.5	1115	$4,464,460.00	$1,449,500.00
1.65			$0.00
1.8			$0.00
2.1			$0.00
2.4			$0.00
2.7			
Total	4653.874	**$9,512,393**	**$3,511,983**

Project and Average Annual Cost Estimate (1991 $)	
ITEM	**Cost (1991 $)**
Total construction cost	$7,721,374
Contingencies (10%)	$772,137
Engineering (15%)	$1,158,206
Burden (3%)	$231,641
Total Project Cost	**$9,883,359**
Average Annual Cost (4%,50 years)	**$460,070**

Total Construction Cost		
	2007 Cost	**1991 Cost**
West	$11,305,491	$4,209,391
East	$9,512,393	$3,511,983
TOTAL	**$20,817,884**	**$7,721,374**

Table C-8

Partial Land Drainage Separation (With Jessie)

Recommended Relief Option

Report Section Reference 8.3.1.4

Location	Conduit Name	Diameter (m)	Diameter (mm)	Length (m)	1991 $/m	1991 $	2007 $/m	2007 $
East	L519	0.3	300	101	$360	$36,360	$770	$77,770
East	L532	0.3	300	52.73	$360	$18,983	$770	$40,602
East	L692	0.3	300	50	$360	$18,000	$770	$38,500
East	L497	0.45	450	42	$460	$19,320	$1,055	$44,310
East	L498	0.45	450	42	$460	$19,320	$1,055	$44,310
East	L511	0.45	450	89	$460	$40,940	$1,055	$93,895
East	L512	0.45	450	98	$460	$45,080	$1,055	$103,390
East	L522	0.45	450	42	$460	$19,320	$1,055	$44,310
East	L524	0.45	450	53.679	$460	$24,692	$1,055	$56,631
East	L670	0.45	450	92.113	$460	$42,372	$1,055	$97,179
East	L671	0.45	450	42.092	$460	$19,362	$1,055	$44,407
East	L686	0.45	450	26.213	$460	$12,058	$1,055	$27,655
East	L693	0.45	450	116	$460	$53,360	$1,055	$122,380
East	L695	0.45	450	114	$460	$52,440	$1,055	$120,270
East	L698	0.45	450	98	$460	$45,080	$1,055	$103,390
East	L700	0.45	450	72	$460	$33,120	$1,055	$75,960
East	L738	0.45	450	64.922	$460	$29,864	$1,055	$68,493
East	L697	0.525	525	75	$520	$39,000	$1,120	$84,000
East	L699	0.525	525	76	$520	$39,520	$1,120	$85,120
East	L736	0.525	525	291.97	$520	$151,824	$1,120	$327,006
East	60012084.1	0.6	600	25	$565	$14,125	$1,200	$30,000
East	L499	0.6	600	30	$565	$16,950	$1,200	$36,000
East	L500	0.6	600	78	$565	$44,070	$1,200	$93,600
East	L501	0.6	600	39	$565	$22,035	$1,200	$46,800
East	L523	0.6	600	41	$565	$23,165	$1,200	$49,200
East	L526	0.6	600	50	$565	$28,250	$1,200	$60,000
East	L527	0.6	600	45	$565	$25,425	$1,200	$54,000
East	L529	0.6	600	39	$565	$22,035	$1,200	$46,800
East	L569	0.6	600	85	$565	$48,025	$1,200	$102,000
East	L659	0.6	600	90	$565	$50,850	$1,200	$108,000
East	L672	0.6	600	107.594	$565	$60,791	$1,200	$129,113
East	L673	0.6	600	14.524	$565	$8,206	$1,200	$17,429
East	L694	0.6	600	104	$565	$58,760	$1,200	$124,800
East	L696	0.6	600	89	$565	$50,285	$1,200	$106,800
East	L502	0.75	750	86	$690	$59,340	$1,980	$170,280
East	L503	0.75	750	86	$690	$59,340	$1,980	$170,280
East	L504	0.75	750	86	$690	$59,340	$1,980	$170,280
East	L505	0.75	750	86	$690	$59,340	$1,980	$170,280
East	L513	0.75	750	102	$690	$70,380	$1,980	$201,960
East	L674	0.75	750	92.957	$690	$64,140	$1,980	$184,055
East	L675	0.75	750	31.755	$690	$21,911	$1,980	$62,875
East	L676	0.75	750	43.094	$690	$29,735	$1,980	$85,326
East	L677	0.75	750	89.345	$690	$61,648	$1,980	$176,903
East	L678	0.75	750	41.664	$690	$28,748	$1,980	$82,495
East	L679	0.75	750	39.399	$690	$27,185	$1,980	$78,010
East	L680	0.75	750	39.418	$690	$27,198	$1,980	$78,048
East	L681	0.75	750	39.405	$690	$27,189	$1,980	$78,022
East	L506	1.05	1050	98	$1,170	$114,660	$3,175	$311,150
East	L507	1.2	1200	51	$1,170	$59,670	$3,175	$161,925

Location	Conduit Name	Diameter (m)	Diameter (mm)	Length (m)	1991 $/m	1991 $	2007 $/m	2007 $
East	L528	1.2	1200	51	$1,170	$59,670	$3,175	$161,925
East	L508	1.8	1800	120	$1,500	$180,000	$4,200	$504,000
East	L509	1.8	1800	61	$1,500	$91,500	$4,200	$256,200
East	L510	1.8	1800	54	$1,500	$81,000	$4,200	$226,800
East	L514	1.8	1800	87	$1,500	$130,500	$4,200	$365,400
East	L515	1.8	1800	87	$1,500	$130,500	$4,200	$365,400
East	L517	1.8	1800	121	$1,500	$181,500	$4,200	$508,200
East	L518	1.8	1800	107	$1,500	$160,500	$4,200	$449,400
East	L520	1.8	1800	86	$1,500	$129,000	$4,200	$361,200
East	L521	1.8	1800	92	$1,500	$138,000	$4,200	$386,400
East	L621	1.8	1800	75	$1,500	$112,500	$4,200	$315,000
East	L622	1.8	1800	75	$1,500	$112,500	$4,200	$315,000
East	L623	1.8	1800	75	$1,500	$112,500	$4,200	$315,000
East	L624	1.8	1800	75	$1,500	$112,500	$4,200	$315,000
West	70018936	0.3	300	44.196	$360	$15,911	$770	$34,031
West	L667	0.3	300	80	$360	$28,800	$770	$61,600
West	L690	0.3	300	144	$360	$51,840	$770	$110,880
West	L911	0.3	300	40	$360	$14,400	$770	$30,800
West	L639	0.375	375	87	$410	$35,670	$930	$80,910
West	L640	0.375	375	85	$410	$34,850	$930	$79,050
West	L641	0.375	375	124	$410	$50,840	$930	$115,320
West	L650	0.375	375	127	$410	$52,070	$930	$118,110
West	L660	0.375	375	43	$410	$17,630	$930	$39,990
West	L661	0.375	375	40	$410	$16,400	$930	$37,200
West	L662	0.375	375	45	$410	$18,450	$930	$41,850
West	L663	0.375	375	84	$410	$34,440	$930	$78,120
West	L912	0.375	375	79.858	$410	$32,742	$930	$74,268
West	L913	0.375	375	60	$410	$24,600	$930	$55,800
West	L642	0.45	450	87	$460	$40,020	$1,055	$91,785
West	L654	0.45	450	117	$460	$53,820	$1,055	$123,435
West	L668	0.45	450	86	$460	$39,560	$1,055	$90,730
West	L687	0.45	450	86	$460	$39,560	$1,055	$90,730
West	L689	0.45	450	85.649	$460	$39,399	$1,055	$90,360
West	L747	0.45	450	100	$460	$46,000	$1,055	$105,500
West	L902	0.45	450	87.502	$460	$40,251	$1,055	$92,315
West	L903	0.45	450	35.357	$460	$16,264	$1,055	$37,302
West	L630	0.525	525	87	$520	$45,240	$1,120	$97,440
West	L643	0.525	525	86	$520	$44,720	$1,120	$96,320
West	L649	0.525	525	87	$520	$45,240	$1,120	$97,440
West	L653	0.525	525	159	$520	$82,680	$1,120	$178,080
West	60011127.1	0.6	600	20	$565	$11,300	$1,200	$24,000
West	60011194.1	0.6	600	95	$565	$53,675	$1,200	$114,000
West	60011200.1	0.6	600	95	$565	$53,675	$1,200	$114,000
West	L631	0.6	600	85	$565	$48,025	$1,200	$102,000
West	L737	0.6	600	350	$565	$197,750	$1,200	$420,000
West	L739	0.6	600	200	$565	$113,000	$1,200	$240,000
West	60011205.1	0.75	750	95	$690	$65,550	$1,980	$188,100
West	60011334.1	0.75	750	83	$690	$57,270	$1,980	$164,340
West	60011336.1	0.75	750	83.5	$690	$57,615	$1,980	$165,330
West	60011388.1	0.75	750	83	$690	$57,270	$1,980	$164,340
West	60011393.1	0.75	750	87	$690	$60,030	$1,980	$172,260
West	60011454.1	0.75	750	86	$690	$59,340	$1,980	$170,280
West	L536	0.75	750	90	$690	$62,100	$1,980	$178,200
West	L567	0.75	750	200	$690	$138,000	$1,980	$396,000
West	L634	0.75	750	68	$690	$46,920	$1,980	$134,640
West	L635	0.75	750	66	$690	$45,540	$1,980	$130,680

Location	Conduit Name	Diameter (m)	Diameter (mm)	Length (m)	1991 $/m	1991 $	2007 $/m	2007 $
West	L651	0.75	750	34	$690	$23,460	$1,980	$67,320
West	L652	0.75	750	26	$690	$17,940	$1,980	$51,480
West	L665	0.75	750	66	$690	$45,540	$1,980	$130,680
West	L666	0.75	750	75	$690	$51,750	$1,980	$148,500
West	L669	0.75	750	66	$690	$45,540	$1,980	$130,680
West	L688	0.75	750	60	$690	$41,400	$1,980	$118,800
West	L537	1.05	1050	95	$1,170	$111,150	$3,175	$301,625
West	L538	1.05	1050	100	$1,170	$117,000	$3,175	$317,500
West	L539	1.05	1050	85	$1,170	$99,450	$3,175	$269,875
West	L540	1.05	1050	85	$1,170	$99,450	$3,175	$269,875
West	L541	1.05	1050	86	$1,170	$100,620	$3,175	$273,050
West	L542	1.05	1050	84	$1,170	$98,280	$3,175	$266,700
West	L543	1.05	1050	85	$1,170	$99,450	$3,175	$269,875
West	L545	1.05	1050	121	$1,170	$141,570	$3,175	$384,175
West	L552	1.05	1050	75	$1,170	$87,750	$3,175	$238,125
West	L564	1.05	1050	64	$1,170	$74,880	$3,175	$203,200
West	L565	1.05	1050	95	$1,170	$111,150	$3,175	$301,625
West	L566	1.05	1050	79	$1,170	$92,430	$3,175	$250,825
West	L568	1.05	1050	152	$1,170	$177,840	$3,175	$482,600
West	L632	1.05	1050	32	$1,170	$37,440	$3,175	$101,600
West	L633	1.05	1050	85	$1,170	$99,450	$3,175	$269,875
West	L637	1.05	1050	88	$1,170	$102,960	$3,175	$279,400
West	L638	1.05	1050	85	$1,170	$99,450	$3,175	$269,875
West	L729	1.05	1050	95	$1,170	$111,150	$3,175	$301,625
West	L730	1.05	1050	95	$1,170	$111,150	$3,175	$301,625
West	L645	1.2	1200	84	$1,170	$98,280	$3,175	$266,700
West	L646	1.2	1200	40	$1,170	$46,800	$3,175	$127,000
West	L647	1.2	1200	27	$1,170	$31,590	$3,175	$85,725
West	L557	1.35	1350	72	$1,170	$84,240	$3,410	$245,520
West	L558	1.35	1350	112	$1,170	$131,040	$3,410	$381,920
West	L559	1.35	1350	95	$1,170	$111,150	$3,410	$323,950
West	L560	1.35	1350	149	$1,170	$174,330	$3,410	$508,090
West	L562	1.35	1350	51	$1,170	$59,670	$3,410	$173,910
West	L563	1.35	1350	69	$1,170	$80,730	$3,410	$235,290
West	L628	1.35	1350	70	$1,170	$81,900	$3,410	$238,700
West	L658	1.35	1350	56	$1,170	$65,520	$3,410	$190,960
West	L555	1.8	1800	103	$1,500	$154,500	$4,200	$432,600
West	L625	1.8	1800	99	$1,500	$148,500	$4,200	$415,800
						$9,289,939		$24,385,143

Average Annual Cost Estimate (1991)	
Total Construction cost	$9,289,939
Contingencies (10%)	$928,994
Engineering (15%)	$1,393,491
Burden (3%)	$278,698
Total Capital Cost	**$11,891,122**
Average Annual Cost (4%,50 years)	**$553,532**

Table C-9

Cocburn East Partial Separation (With Jessie)
Report Reference Section 8.3.1.5

Name	Diameter (m)	Length
L692	0.3	50
L519	0.3	101
L532	0.3	52.73
L698	0.45	98
L497	0.45	42
L524	0.45	53.679
L670	0.45	92.113
L671	0.45	42.092
L686	0.45	26.213
L511	0.45	89
L512	0.45	98
L695	0.45	114
L693	0.45	116
L738	0.45	64.922
L700	0.45	72
L522	0.45	42
L498	0.45	42
L736	0.525	291.97
L699	0.525	76
L697	0.525	75
60012084	0.6	25
L659	0.6	90
L569	0.6	85
L672	0.6	107.594
L673	0.6	14.524
L696	0.6	89
L694	0.6	104
L523	0.6	41
L499	0.6	30
L526	0.6	50
L527	0.6	45
L500	0.6	78
L501	0.6	39
L529	0.6	39
L674	0.75	92.957
L675	0.75	31.755
L676	0.75	43.094
L677	0.75	89.345
L678	0.75	41.664
L679	0.75	39.399
L680	0.75	39.418

Name	Diameter (m)	Length
L681	0.75	39.405
L503	0.75	86
L504	0.75	86
L505	0.75	86
L513	0.75	102
L502	0.75	86
L506	1.05	98
L507	1.2	51
L528	1.2	51
L509	1.8	61
L510	1.8	54
L517	1.8	121
L518	1.8	107
L514	1.8	87
L515	1.8	87
L520	1.8	86
L521	1.8	92
L508	1.8	120
	Total	4353.874

Summary	Total Length	**2007 Price**	**1991 Price**
0.3	203.73	$156,872.10	$73,342.80
0.375			$0.00
0.45	992.019	$1,046,580.05	$456,328.74
0.525	442.97	$496,126.40	$230,344.40
0.6	837.118	$1,004,541.60	$472,971.67
0.75	863.037	$1,708,813.26	$595,495.53
0.9			$0.00
1.05	98	$311,150.00	$114,660.00
1.2	102	$323,850.00	$119,340.00
1.35			$0.00
1.5			$0.00
1.6 and 1.65			$0.00
1.8	815	$3,969,050.00	$1,222,500.00
2.1			$0.00
2.4			$0.00
Total	4353.874	**$9,016,983**	**$3,284,983**

Table C-9

Cocburn East Partial Separation (With Jessie)
Report Reference Section 8.3.1.5

Project and Average Annual Cost Estimate (1991 $)	
ITEM	**Cost (1991 $)**
Total construction cost	$3,284,983
Contingencies (10%)	$328,498
Engineering (15%)	$492,747
Burden (3%)	$98,549
Total Project Cost	**$4,204,778**
Average Annual Cost (4%,50 years)	**$195,732**

Table C-10

Complete WWS Separation (Without Jessie)
Report Reference Section 8.3.2.1

Summary	Total Length	**2007 Price**	**1991 Price**
0.25	15700	$12,089,000	$4,710,000
0.3	540	$415,800	$194,400
0.375	1120	$1,041,600	$459,200
0.45	1100	$1,160,500	$506,000
0.525	200	$224,000	$104,000
0.6	65	$78,000	$36,725
0.75	65	$128,700	$44,850
Sub-Total	18790	$15,137,600	$6,055,175
Service Connection		$9,718,000	$4,458,000
Total		**$24,855,600**	**$10,513,175**

Project and Average Annual Cost Estimate (1991 $)	
ITEM	**Cost (1991 $)**
Total construction cost	$10,513,175
Contingencies (10%)	$1,051,318
Engineering (15%)	$1,576,976
Burden (3%)	$315,395
Total Project Cost	**$13,456,864**
Average Annual Cost (4%,50 years)	**$626,417**

Table C-11

Jessie WWS Separation
Report Reference Section 8.3.2.2

Jessie WWS Cost Table

Pipe Dia.	1991 Unit Cost	Pipe Length	Total
m	**$/m**	**m**	**1991$**
250	$300	3111	$933,300
Service connections	$3000/each	287	$861,000
Lift STN	$300,000	1	$300,000
		Total	**$2,094,300**

Project and Average Annual Cost Estimate (1991 $)	
ITEM	**Cost (1991 $)**
Total construction cost	$2,094,300
Contingencies (10%)	$209,430
Engineering (15%)	$314,145
Burden (3%)	$62,829
Total Project Cost	**$2,680,704**
Average Annual Cost (4%,50 years)	**$124,787**

Table C-12

Separation-Relief Hybrid (With Jessie)
Report Reference Section 8.4.1

Location	Name	Diameter (m)	Length
West	L667	0.3	80
West	L690	0.3	144
West	L911	0.3	40
West	L639	0.375	87
West	L640	0.375	85
West	L641	0.375	124
West	L650	0.375	127
West	L660	0.375	43
West	L661	0.375	40
West	L662	0.375	45
West	L663	0.375	84
West	L912	0.375	79.858
West	L913	0.375	60
West	L642	0.45	87
West	L654	0.45	117
West	L668	0.45	86
West	L687	0.45	86
West	L689	0.45	85.649
West	L747	0.45	100
West	L902	0.45	87.502
West	L903	0.45	35.357
West	L630	0.525	87
West	L643	0.525	86
West	L649	0.525	87
West	L653	0.525	159
West	60011127.1	0.6	20
West	60011194.1	0.6	95
West	60011200.1	0.6	95
West	L631	0.6	85
West	L737	0.6	350
West	L739	0.6	200
West	60011205.1	0.75	95
West	60011334.1	0.75	83
West	60011336.1	0.75	83.5
West	60011388.1	0.75	83
West	60011393.1	0.75	87
West	60011454.1	0.75	86
West	L536	0.75	90
West	L567	0.75	200
West	L634	0.75	68
West	L635	0.75	66
West	L651	0.75	34
West	L652	0.75	26
West	L665	0.75	66
West	L666	0.75	75
West	L669	0.75	66

Location	Name	Diameter (Height)	Length
East	L1088	0.45	10
East	L1092	0.45	10
East	L1093	0.45	10
East	L1094	0.45	10
East	L1095	0.45	10
East	L519	0.45	84.521
East	L520	0.45	87.536
East	L521	0.45	45.504
East	L522	0.45	84.91
East	L531	0.45	10
East	L532	0.45	10
East	L533	0.45	10
East	L534	0.45	10
East	L535	0.45	10
East	L547	0.45	10
East	L548	0.45	10
East	L550	0.45	10
East	L1089	0.6	96.659
East	L523	0.6	69.033
East	L524	0.6	93.146
East	L544	0.6	140.392
East	L545	0.6	71.603
East	L546	0.6	37.695
East	L549	0.6	36.965
East	L1090	0.9	101.092
East	L1091	0.9	118.498
East	L525	0.9	113.527
East	L526	0.9	112.987
East	L527	0.9	120.332
East	L528	0.9	114.587
East	L529	0.9	134.258
East	L455	1.2	164.194
East	L456	1.4	81.063
East	L457	1.4	10
East	L458	1.4	98.145
East	L459	1.4	102.443
East	L460	1.4	119.783
		Total.	2368.873

Table C-12

Separation-Relief Hybrid (With Jessie)
Report Reference Section 8.4.1

West	L688	0.75	60
West	L537	1.05	95
West	L538	1.05	100
West	L539	1.05	85
West	L540	1.05	85
West	L541	1.05	86
West	L542	1.05	84
West	L543	1.05	85
West	L545-1	1.05	121
West	L552	1.05	75
West	L564	1.05	64
West	L565	1.05	95
West	L566	1.05	79
West	L568	1.05	152
West	L632	1.05	32
West	L633	1.05	85
West	L637	1.05	88
West	L638	1.05	85
West	L729	1.05	95
West	L730	1.05	95
West	L644	1.2	84
West	L645	1.2	84
West	L646	1.2	40
West	L647	1.2	27
West	L557	1.35	72
West	L558	1.35	112
West	L559	1.35	95
West	L560	1.35	149
West	L562	1.35	51
West	L563	1.35	69
West	L626	1.35	103
West	L627	1.35	55.111
West	L628	1.35	70
West	L629	1.35	62
West	L648	1.35	56
West	L658	1.35	56
West	L4001	1.65	168.25
West	L4002	1.65	115
West	L514	1.65	119.783
West	L517	1.65	121
West	L518	1.65	107
West	L555	1.65	103
West	L621	1.65	75
West	L622	1.65	75
West	L623	1.65	75
West	L624	1.65	75
West	L625	1.65	99
		Total	8260.01

Table C-12

Separation-Relief Hybrid (With Jessie)
Report Reference Section 8.4.1

Summary	Total Length	2007 Price	1991 Price
0.3	264	$203,280.00	$95,040.00
0.375	774.858	$720,617.94	$317,691.78
0.45	684.508	$722,155.94	$314,873.68
0.525	419	$469,280.00	$217,880.00
0.6	845	$1,014,000.00	$477,425.00
0.75	1268.5	$2,511,630.00	$875,265.00
0.9			
1.05	1686	$5,353,050.00	$1,972,620.00
1.2	235	$746,125.00	$274,950.00
1.35	950.111	$3,239,878.51	$1,111,629.87
1.5			
1.65	1133.033	$0.00	$1,699,549.50
1.8			
2.1			
2.4			
2.7			
Sub-Total	8260.01	$14,980,017	$7,356,925
New Outfall		$654,000	$300,000
Total		**$15,634,017**	**$7,656,925**

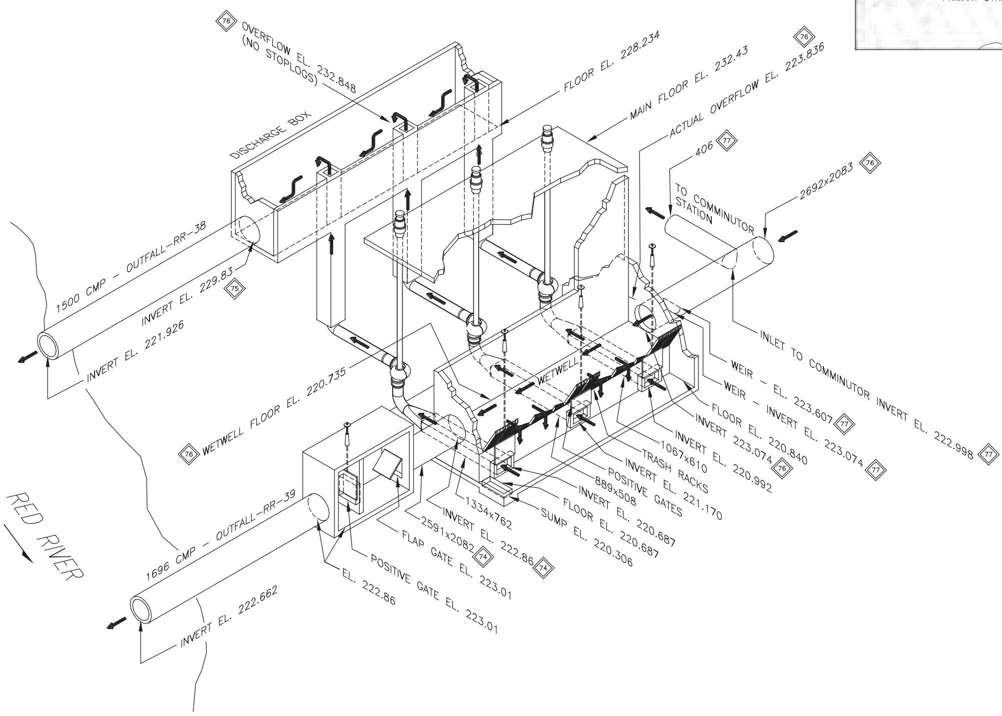
Summary	Total Length	2007 Price	1991 Price
0.45	432.471	$456,256.91	$198,936.66
0.6	545.493	$654,591.60	$308,203.55
0.9	815.281	$1,964,827.21	$692,988.85
1.2	164.194	$521,315.95	$192,106.98
1.35	411.434	$1,402,989.94	$481,377.78
Total	2368.873	**$4,999,982**	**$1,873,614**

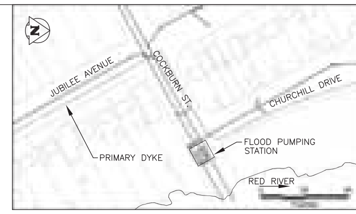
Project and Average Annual Cost Estimate (1991 $)	
ITEM	**Cost (1991 $)**
Total construction cost	$9,530,539
Contingencies (10%)	$953,054
Engineering (15%)	$1,429,581
Burden (3%)	$285,916
Total Project Cost	**$12,199,089**
Average Annual Cost (4%,50 years)	**$567,868**

Total Construction Cost		
	2007 Cost	**1991 Cost**
West	$15,634,017	$7,656,925
East	$4,999,982	$1,873,614
TOTAL	**$20,633,999**	**$9,530,539**

APPENDIX D

REFERENCE DRAWING





SITE PLAN

LOCATION

- AREA SOUTH
- SECTOR 15
- ADDRESS ______________

KEY ELEVATIONS

- JAMES ST. 25.8 FT = 7.864m
- LOW BASEMENT 229.73
- MAXIMUM ACTIVATION 229.12
- ACTUAL ACTIVATION
  - JAMES 4.27
  - SITE RIVER 226.88
- PUMP START/STOP 1 . . . . 224.89/224.28
  - 2 . . . . 225.05/224.44
  - 3 . . . . 225.20/224.59
- HIGH ALARM . . . . ______

NOTES

1. SOURCE OF DATA SHOWN CAN BE TRACED BY REFERRING TO THE BASELINE DATA SPREADSHEETS. FOR SPECIFIC CROSS REFERENCES ON THE DRAWING (IE. 73), REFER TO THE FPS BASELINE DATA SPREADSHEET-SUPERSCRIPT CROSS-REFERENCE SHEET.
2. DEWATERING PUMP PRESENT AT THIS STATION.

PUMP INFORMATION

PUMP REF No.	HP	CAPACITY (CMS)
1-111	200	
2-110	150	
3-109	250	
TOTAL		2.38

NO.	D / M / Y	DESCRIPTION	BY
2	15/12/08	UPDATED	CMS
1	10/03/05	UPDATED	RED

REVISIONS / ISSUE

THE CITY OF WINNIPEG
Winnipeg WATER AND WASTE DEPARTMENT
uma KGS GROUP

FLOOD ACTIVITY / EMERGENCY MANUAL

TITLE: COCKBURN FPS ISOMETRIC	
JOB No. 020-08-09-09-00	DATE: MAR. 19, 2003
SCALE: N.T.S.	DWG. No. 00-107-10-M8
CHECKED: HSW/RED/CMS	

FILE No.: P/PROJECTS/2008/08-0107-22/DWG/STRUCT/Cockburn-M008-Rev.2.dwg

APPENDIX E

FORT ROUGE YARDS MEMORANDUM - DILLON

MEMO

DILLON CONSULTING

ORGANIZATION: KGS Group

cc:

FROM: John Ewing

DATE: January 26, 2007

SUBJECT: Fort Rouge Yards Drainage Study

OUR FILE: 06-5893 **TOTAL PAGES:** 29

As requested, we have re-modeled the Fort Rouge Yards to assess impacts of possible development plans of the yards on the receiving combined system. Specifically, three options were explored. The first, Option 1, was developed by KGS and looked at the existing conditions. The second, Option 2, was developed by Dillon Consulting Limited (Dillon) and looked at future development plans. Specifically, it was assumed that a large portion of the existing yards south of the existing railway tracks would be rezoned and utilized to construct medium to high density residencies. The third and final option, Option 3, looked at the potential development of the BRT corridor. Specific to this same option, it was assumed the existing yards would not be developed and left in its existing conditions. Table 1 provides a summary description of the different scenarios Dillon has explored.

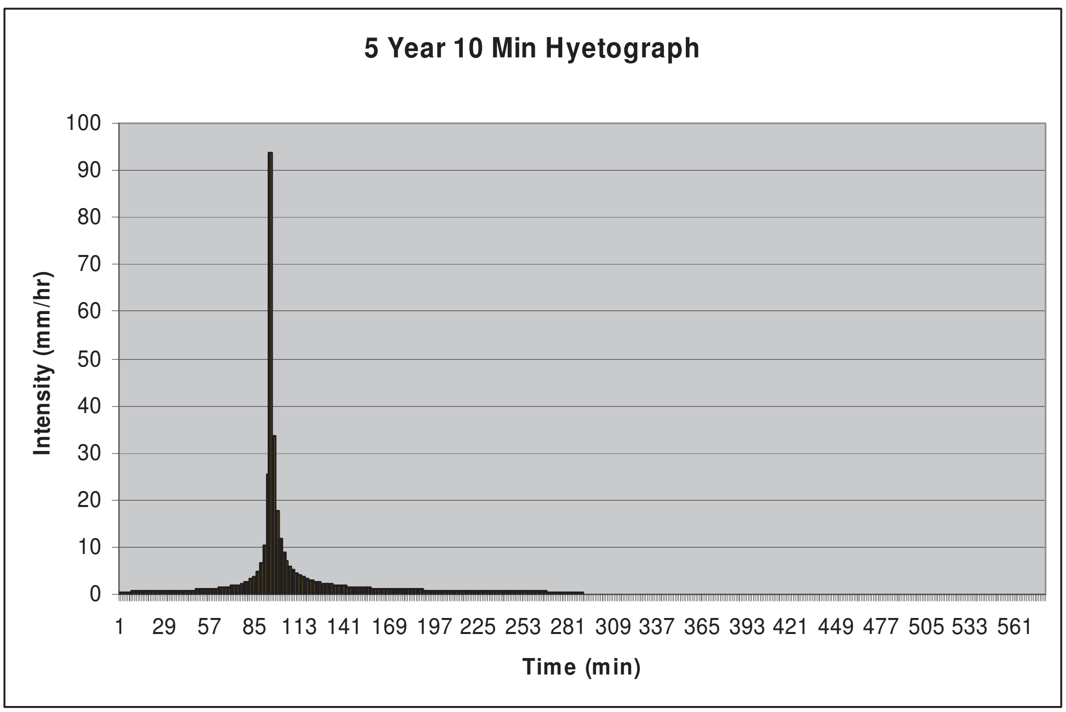
Table 1 – Options Summary

Land Use	Options	Description	Model
• Railway Yards: Existing Conditions • BRT Corridor: Existing Conditions • Fort Rouge Yards: Existing Conditions	Option 1	Modeled as part of the overall system by KGS	N/A
• Railway Yards: Existing Conditions • BRT Corridor: Existing Conditions • **Fort Rouge Yards: Proposed Development**	Option 2A	Each catchment is assumed to drain directly into the Cockburn System along the entire Fort Rouge Yards	Option2AKGS.xp
	Option 2B	Runoff is directed to a large open channel along the BRT corridor and conveyed to Hugo Street. Discharge is uncontrolled.	Option2BKGS.xp
	Option 2BC	Runoff is directed to a piped system along the BRT corridor and conveyed to Hugo Street. Discharge is uncontrolled.	Option2BCKGS.xp
	Option 2C	Runoff is directed to a large open channel along the BRT corridor and conveyed to Hugo Street. Discharge is controlled by a 1ha pond.	Option2CKGS.xp

Land Use	Options	Description	Model
• Railway Yards: Existing Conditions • **BRT Corridor: Proposed BRT Project is Implemented** • Fort Rouge Yards: Existing Conditions	Option 3A	Each catchment is assumed to drain directly into the Cockburn System along the entire Fort Rouge Yards	Option3AKGS.xp
	Option 3B	Runoff is directed to a large open channel along the BRT corridor and conveyed to Hugo Street. Discharge is uncontrolled.	Option3BKGS.xp
	Option 3C	Runoff is directed to a large open channel along the BRT corridor and conveyed to Hugo Street. Discharge is controlled by a 1ha pond.	Option3CKGS.xp

As detailed in Figure 1, we have utilized the 5-year 10 min storm to model the system.

Figure 1



The following is a detailed description of each of the options Dillon has explored. It should be noted that these options are based on conceptual land development options previously explored by Dillon. Approval from the City of Winnipeg (City) to precede with such development options was not provided and final analysis based on actual approved plans will have to be completed to optimize the system and meet all the City requirements. Although there are maintenance costs related to open ditches we have included ditches in one of the options for all scenarios for outflow comparisons to the City system. Once again, these scenarios are conceptual and would have to pass City approvals.

Ponds included in the models meet the City's recommended **design** requirements and have been modeled utilizing the 100-year and the 25-year storms provided by KGS.

1. OPTION 2A

As detailed in the Option 2A schematic (refer to attached "Schematic PDF) we have assumed that a large portion of the Fort Rouge Yards would get developed. As detailed in the report prepared by the KGS Group, "Calibration and Verification of SWMM Model for Cockburn and Calrossie Combined Sewer Districts", we have modeled the system by separating the buildings from the catchments to model the large roof areas as separate catchments. Table 2 and 3 details the parameters used in the model.

Table 2 – Hydrologic / Infiltration Parameters (KGS Aug. '06)

Infiltration Parameter		**Cockburn**
Maximum Infiltration Rate (mm/hr)		85
Minimum Infiltration Rate (mm/hr)		3
Decay Rate (1/sec)		0.00115
Description		**Values**
Surface Roughness	Impervious	0.015
	Pervious	0.030
Depression Storage	Impervious	1.5mm
	Pervious	5mm

Table 3 – Hydrologic Parameters (Roof Areas) (KGS Aug. '06)

Description		**Values**
Surface Roughness	Impervious	0.25
	Pervious	0.030
Depression Storage	Impervious	5mm
	Pervious	5mm

As detailed in the Option 2A schematic (refer to attached "Schematic PDF") it was assumed that each of the catchments would drain at separate locations along the Fort Rouge corridor. As detailed in the same figure, all other catchments were assumed to drain through the exiting system towards the Jessie System.

The enclosed hydrographs detail runoff estimates for each of the aforementioned areas. Option 2A is intended to simulate the possible development of the Fort Rouge yards and distribute the resulting runoff along the system servicing the Cockburn area.

Figure 2

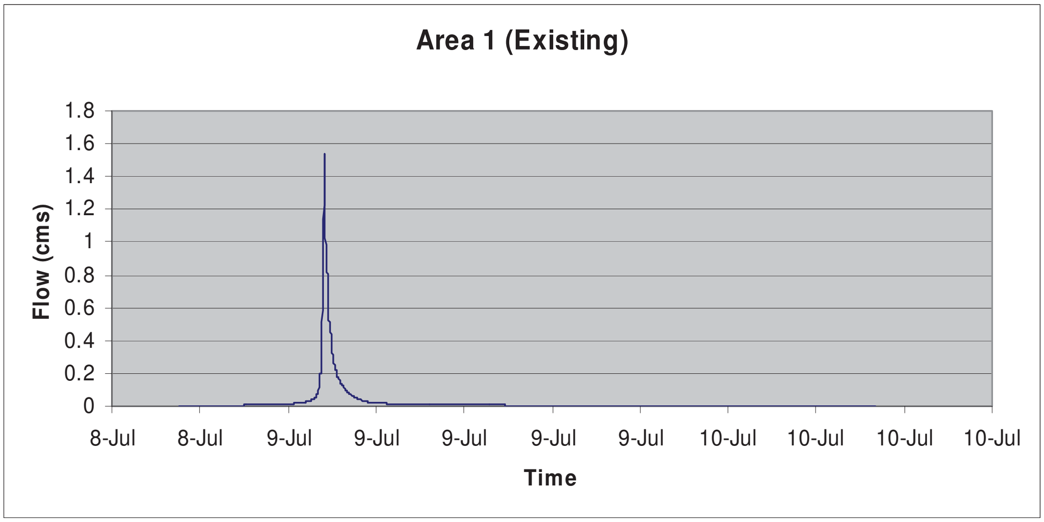


Figure 3

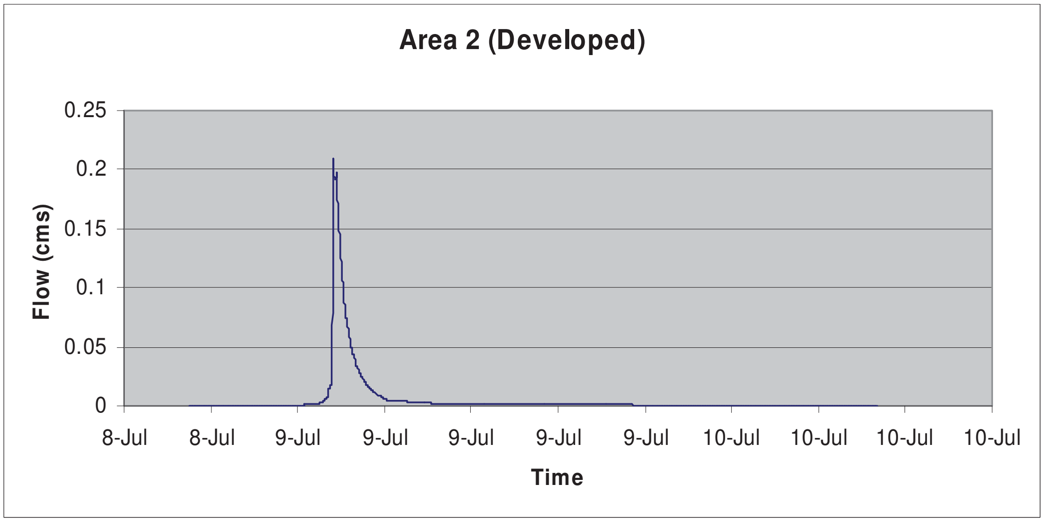


Figure 4

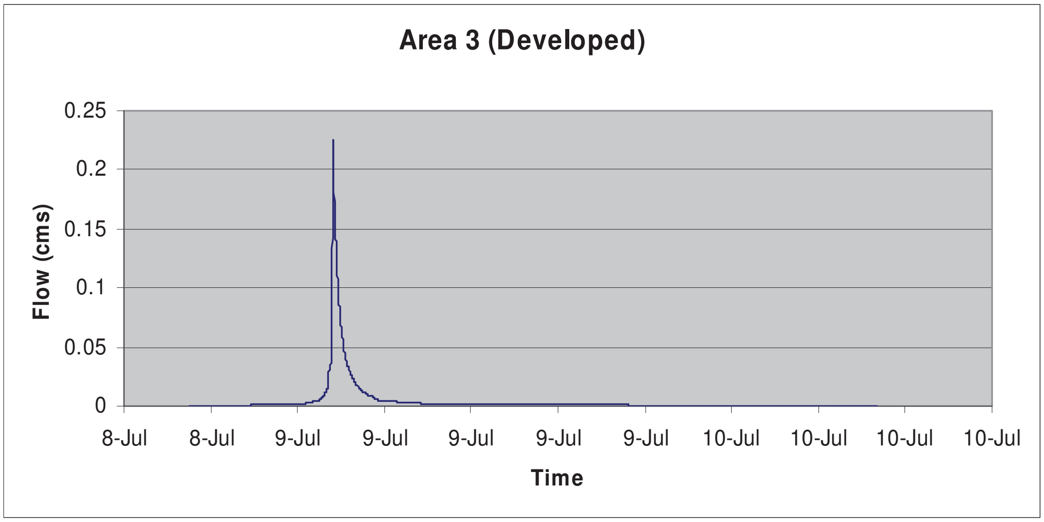


Figure 5

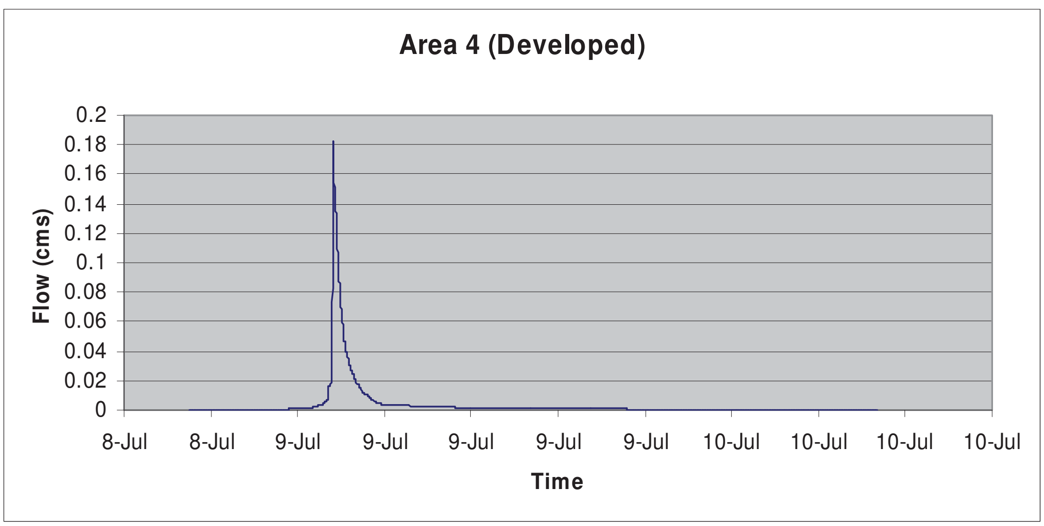


Figure 6

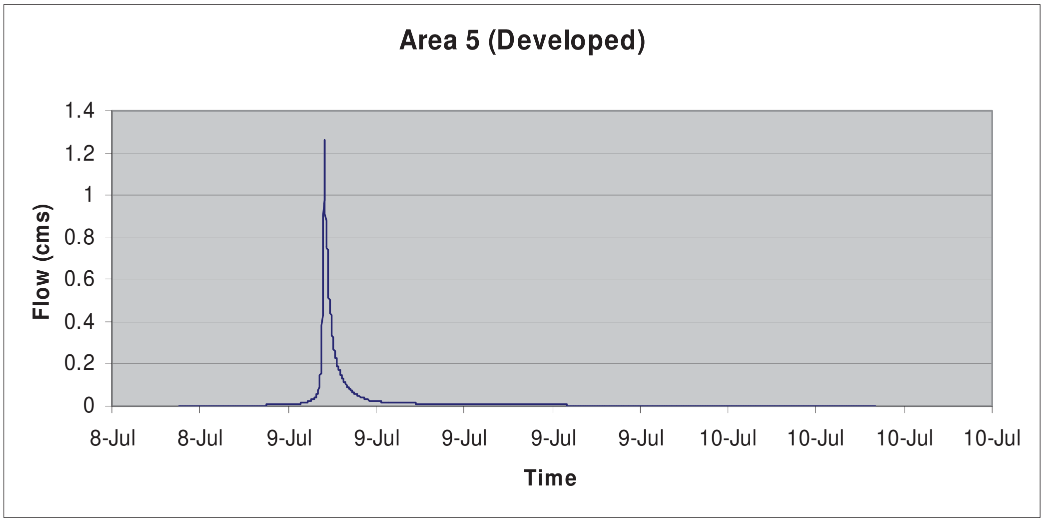
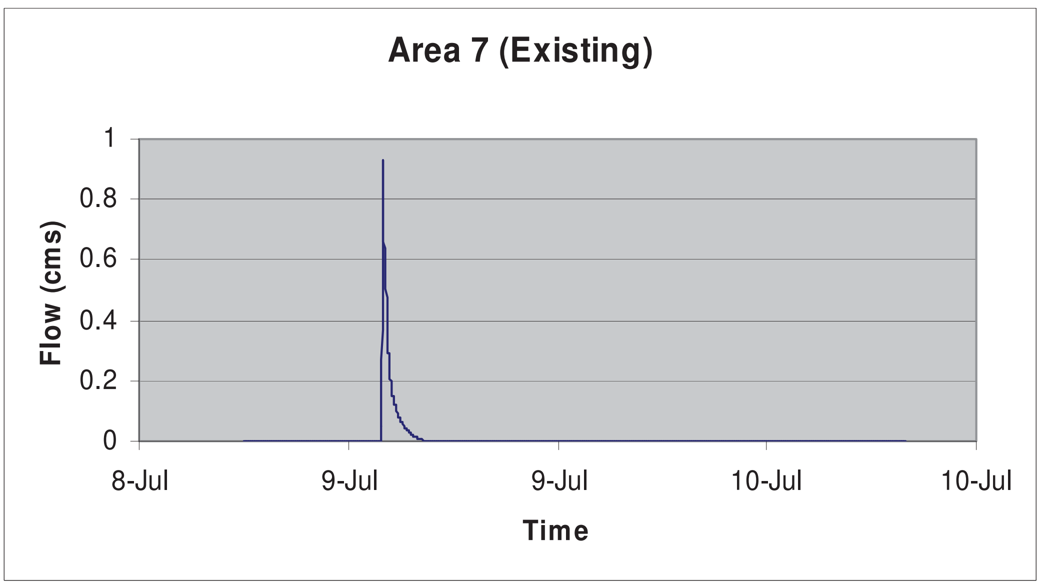


Figure 7



Specific to the sewer contribution, it was assumed that 1,370 units would be developed on the available land and that two residents would inhabit each unit. The sewer generation rate was estimated to be 275 l/c/day and the total residential area to be 13.14ha (see Table 4).

Table 4 – Sewer Rates & Parameters

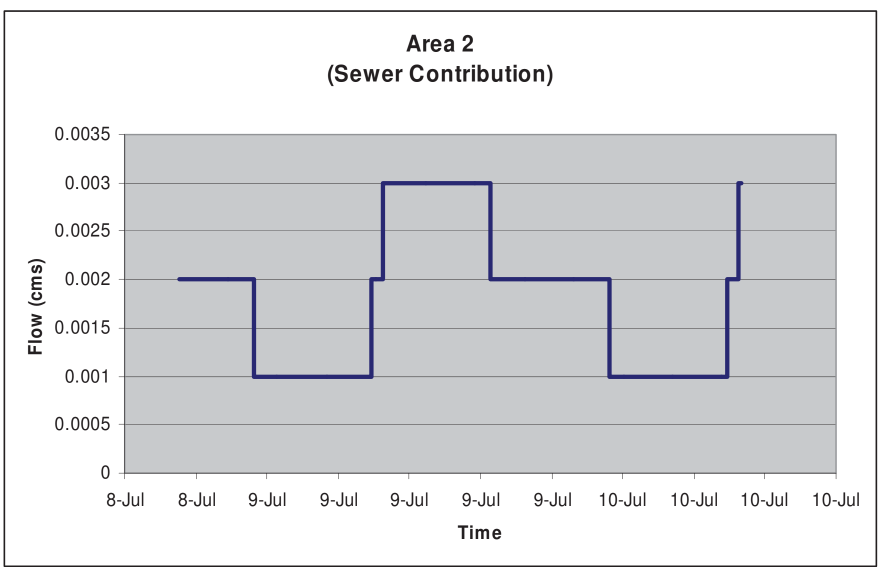
Sewer Generation Rate (l/c/day)	Residents per Unit	Number of units	Total Number of Residents	Total Flow (l/day)	Total Residential Area (ha)	Sewer Generation Rate (l/day/ha)
275	2	1,370	2,740	753,500	13.14	57,344

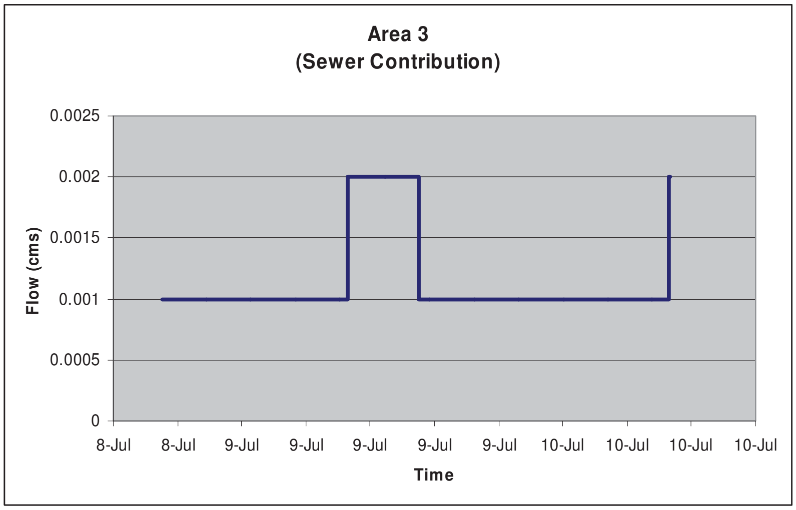
Based on the available information the unit rate of sewer generation was estimated for each of the catchments. The following table details the distribution of sewer rates over the areas identified as developable.

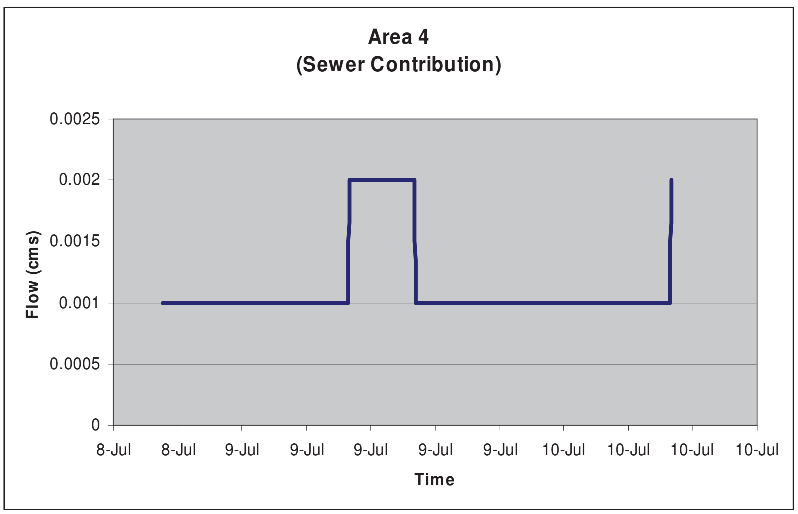
Table 5 – Sewer Rates over Developable Area

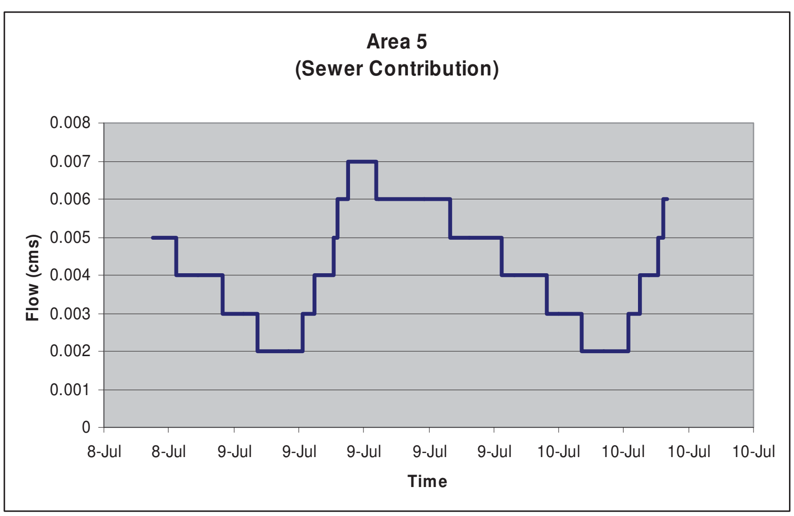
Area	Catchment Area	Total Sewer Generation Rate (l/day)
Area2	2.91	166,871
Area3	1.69	96,911
Area4	1.67	95,764
Area5	6.87	393,953
Total	**13.14**	**753,500**

The enclosed diagrams detail the sewer contributions for each of the residential areas. (Temporal variation distribution used in the model was based on the model developed by KGS).




Area 3
(Sewer Contribution)
0.0025
0.002
0.0015
0.001
0.0005
0
Flow (cms)
8-Jul
8-Jul
9-Jul
9-Jul
9-Jul
9-Jul
9-Jul
10-Jul
10-Jul
10-Jul
10-Jul
Time


Area 4
(Sewer Contribution)
0.0025
0.002
0.0015
0.001
0.0005
0
Flow (cms)
8-Jul
8-Jul
9-Jul
9-Jul
9-Jul
9-Jul
9-Jul
10-Jul
10-Jul
10-Jul
10-Jul
Time


Area 5
(Sewer Contribution)
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Flow (cms)
8-Jul
8-Jul
9-Jul
9-Jul
9-Jul
9-Jul
9-Jul
10-Jul
10-Jul
10-Jul
10-Jul
Time

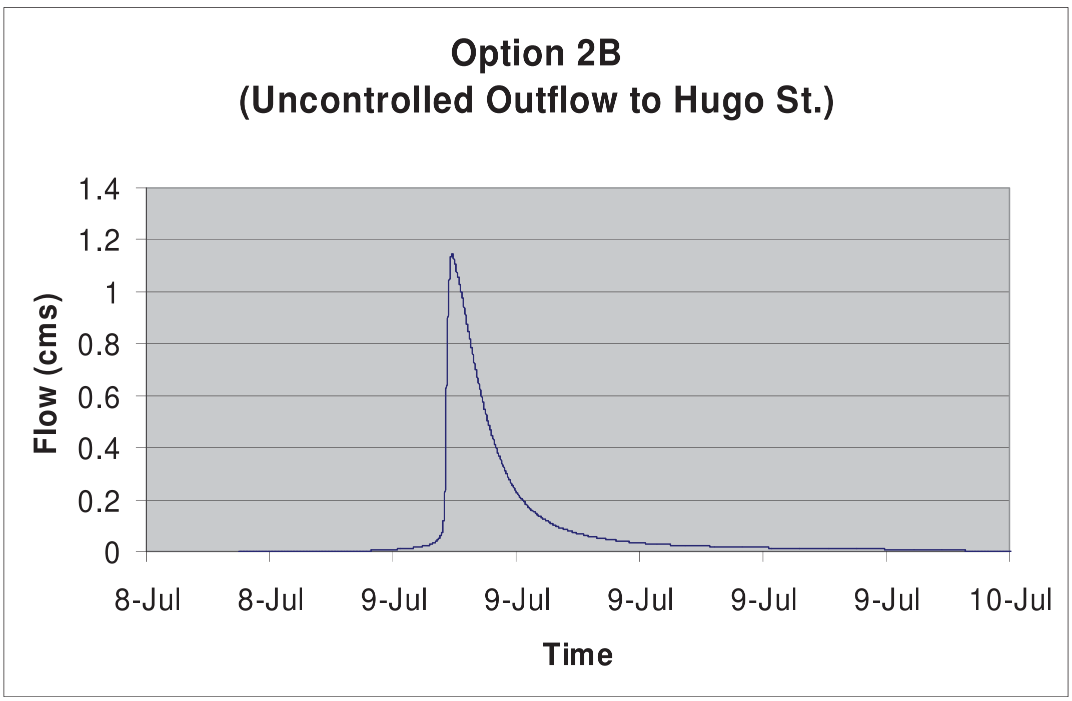
2. OPTION 2B

As shown in the Option 2B schematic (refer to attached "Schematic PDF) it was assumed that all the Fort Rouge area would drain toward an open ditch draining east towards Hugo Street. No storage or flow control facility was included. All runoff was assumed to drain towards the existing system along Hugo Street.

The open ditch alternative was proposed due to the high cost associated with the construction of a closed pipe system. The proximity to the railway yard allows the inclusion of such a system without impacting the general use of the adjacent lands.

The enclosed hydrograph (Figure 8) reflects the total runoff exiting the entire Fort Rouge yards. Sewer contribution was not included in this option.

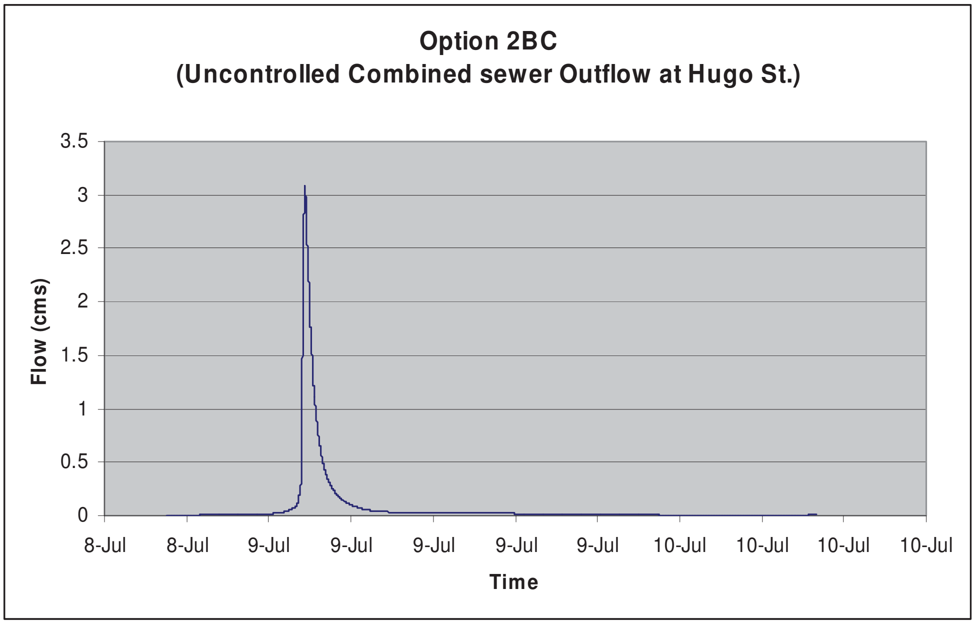
Figure 8



3. OPTION 2BC

As for option 2B, it was assumed that a collection system would convey runoff to Hugo Street. Option 2BC was developed to explore runoff values should the City wish to construct a pipes system to drain the area. The intent was also to develop a closed system able to convey both storm runoff and sewer outflow. The enclosed hydrograph (Figure 9) represents the total flow estimated for the specified project area.

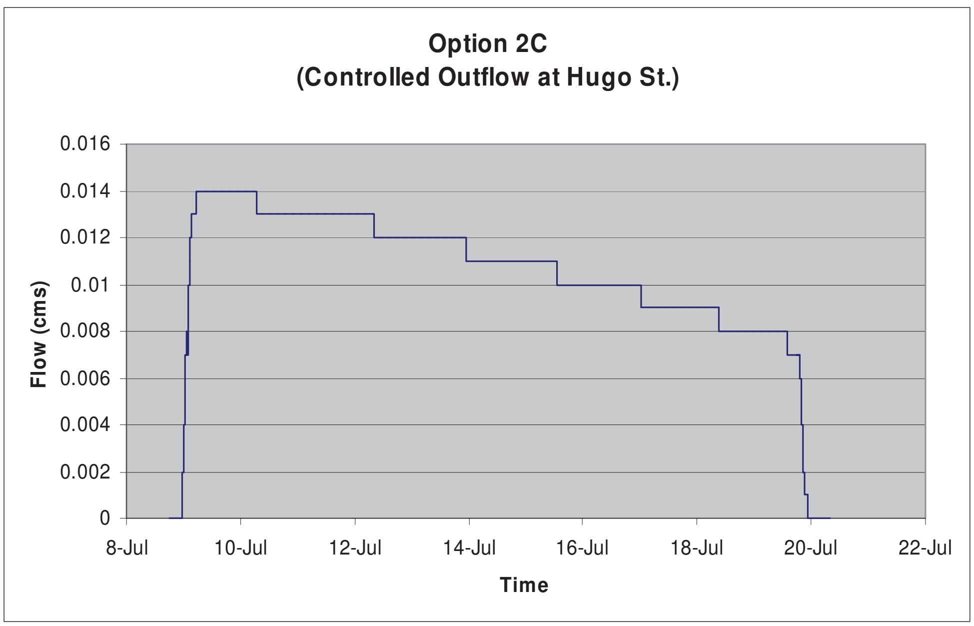
Figure 9



4. OPTION 2C

Similarly to Option 2B it was assumed that a ditch along the BRT ROW would collect runoff from the Fort Rouge Area and convey this to a detention pond designed to release runoff to the Hugo Street system at a rate which may be comparable to or lower than the existing conditions. Drawing Option 2C (refer to the attached "Schematic PDF) summarizes the possible location of a 1ha pond which may be used to control the runoff from the site. Figure 10 reflects the controlled release of runoff into the Cockburn system. As shown, the proposed pond would reduce the peak flow (see Option 2B for comparison) from 1.14 m^3/sec to 0.014 m^3/sec and distribute the outflow over a longer period of time.

Figure 10



5. OPTION 3

Differently from Option 2 it was assumed that no development would take place throughout the Fort Rouge Yards and that the sole changes to the system would come from the construction of the BRT corridor.

6. OPTION 3A

As Option 2A it was assumed that the existing lands would drain along the Cockburn system and it was also assumed that the runoff from the BRT line would enter the combined system at Hugo St. The Option 3A schematic (refer to attached "Schematic PDF") details the characteristics of this option.

The enclosed hydrographs reflect runoff from each of the areas identified in Option 3A.

Figure 11

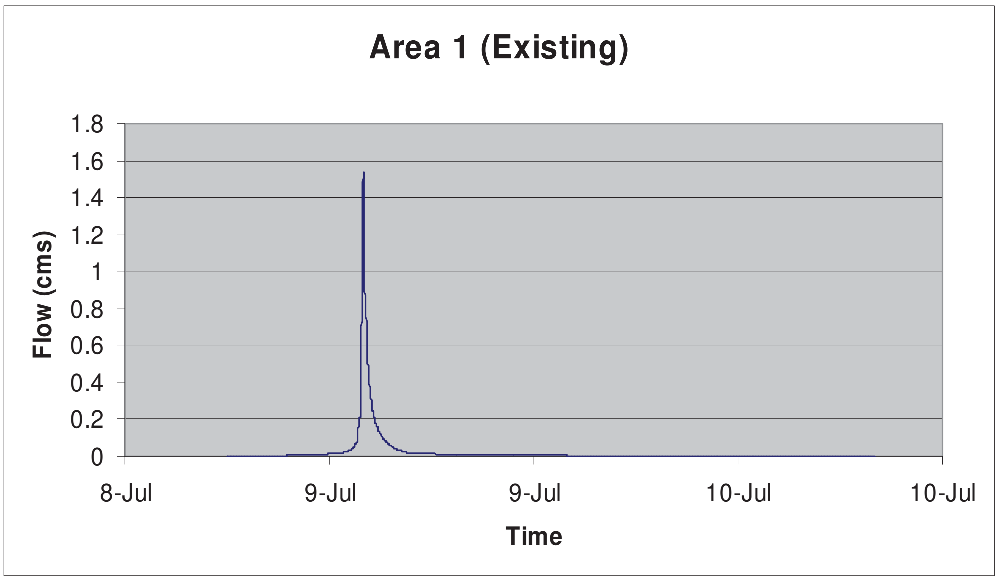


Figure 12

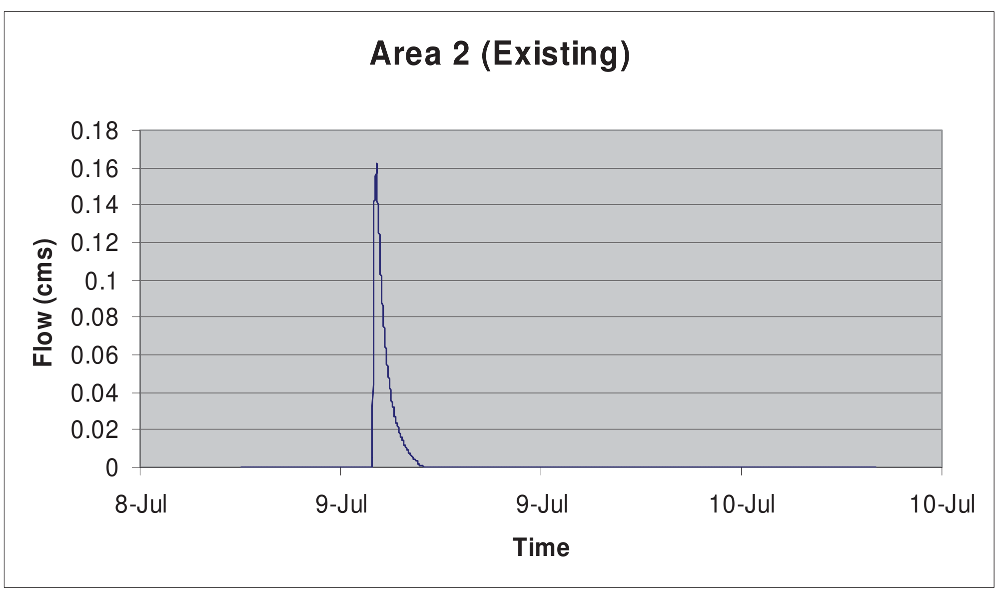


Figure 13

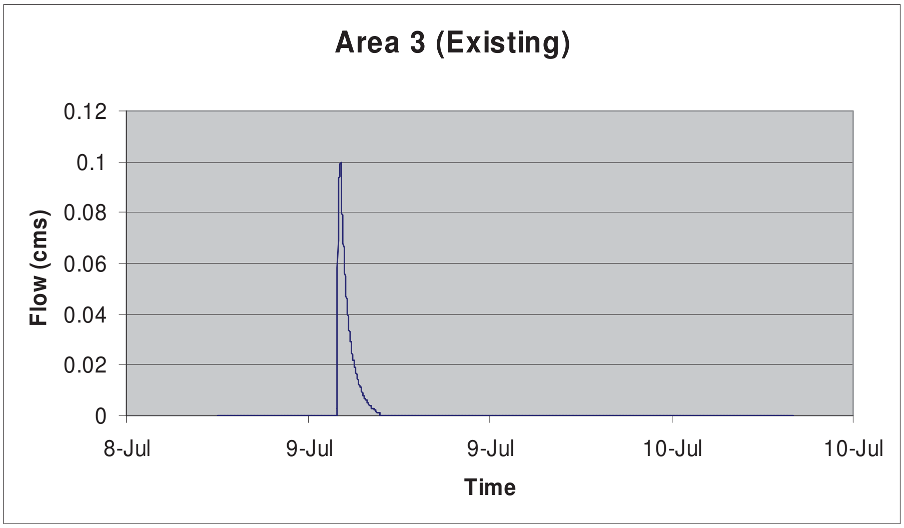


Figure 14

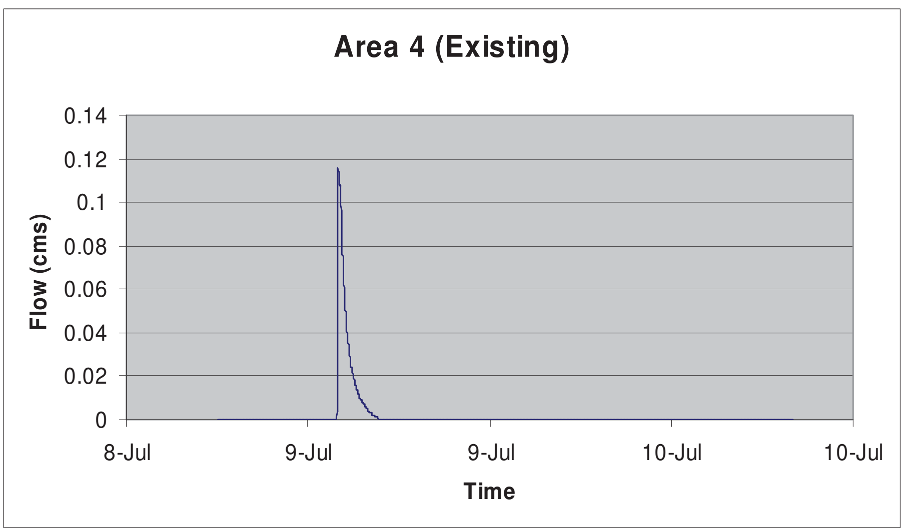


Figure 15

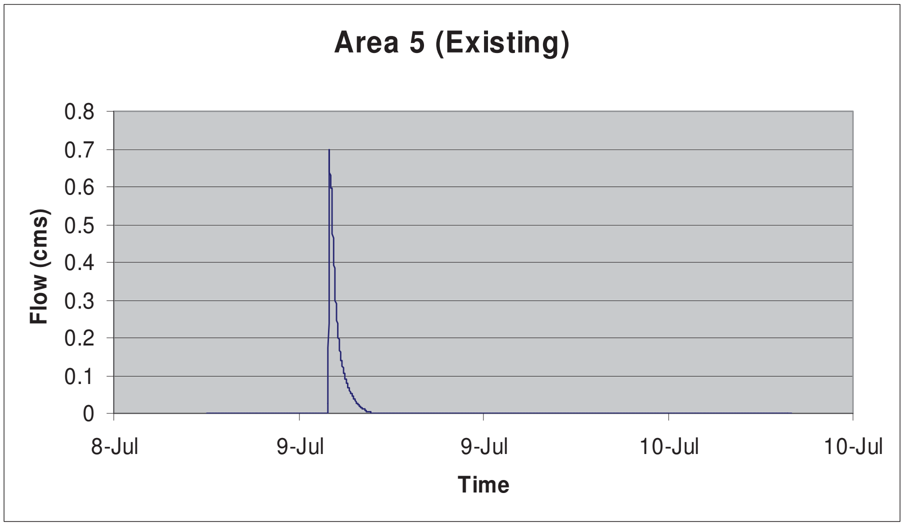
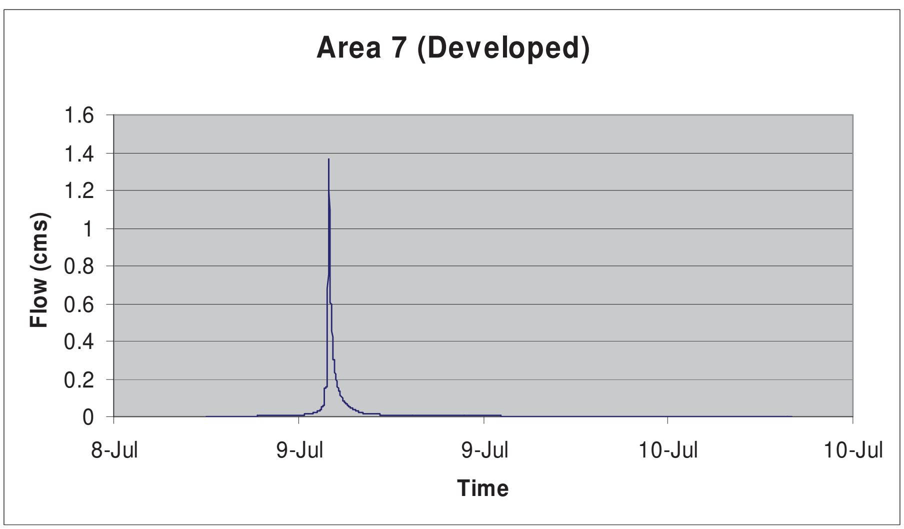


Figure 16

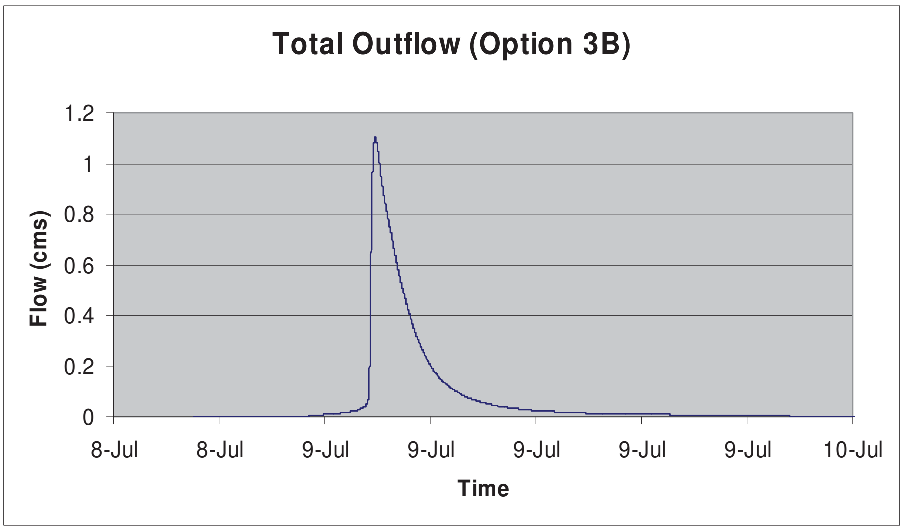


7. OPTION 3B

Like Option 2B it was assumed that an open ditch would convey runoff from the Fort Rouge Yards to Hugo St. and be released without control into the receiving Cockburn system. The schematic for Option 3B (refer to the attached "Schematic PDF) provides details specific to the proposed system.

Figure 17 details the total runoff estimated following the construction of the BRT line.

Figure 17

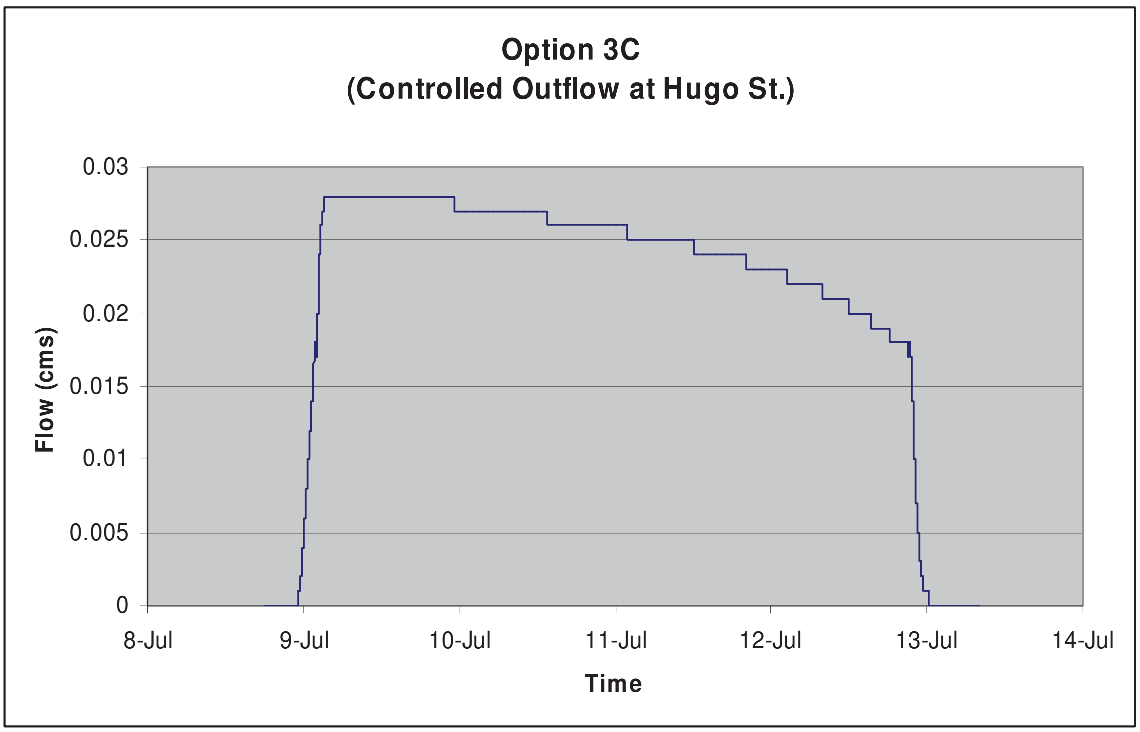


8. OPTION 3C

The controlled release of runoff into the Cockburn system was also modeled to offset possible development of the BRT corridor. The schematic for Option 3C (refer to attached "Schematic PDF") details the location of a pond which may be used to release excess runoff at Hugo St.

Figure 18 summarizes the expected runoff utilizing a detention pond upstream of the Cockburn system. As shown, the proposed pond would reduce the peak flow (see Option 3B for comparison) from 1.11 m^3/sec to 0.028 m^3/sec and distribute the outflow over a longer period of time. Depending on the ultimate design of the pond, the total outflow may be reduced depending on the ultimate development plans for the Fort Rouge Area.

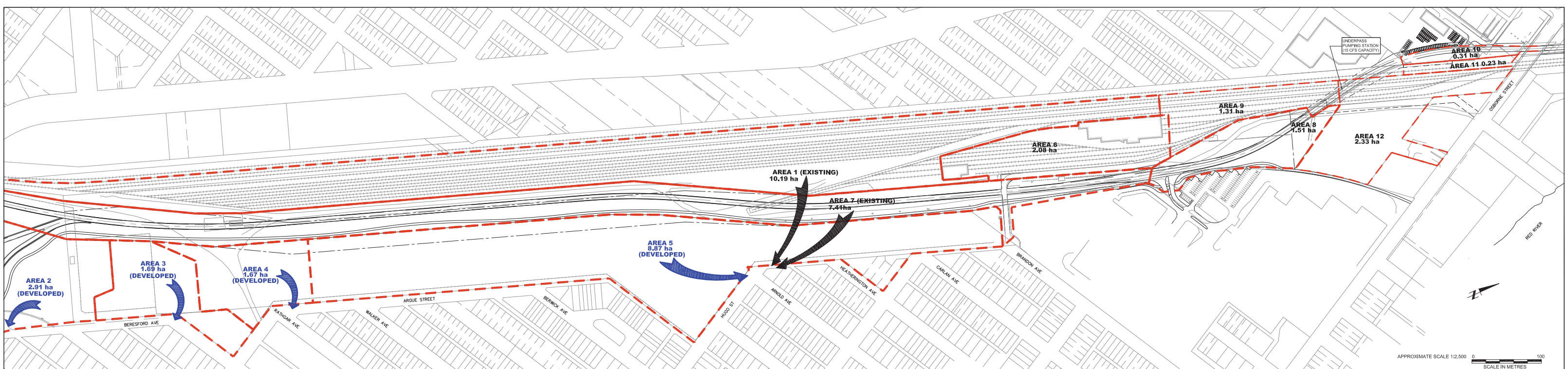
Figure 18



Fort Rouge Yards

Proposed Site Development

Figure 2

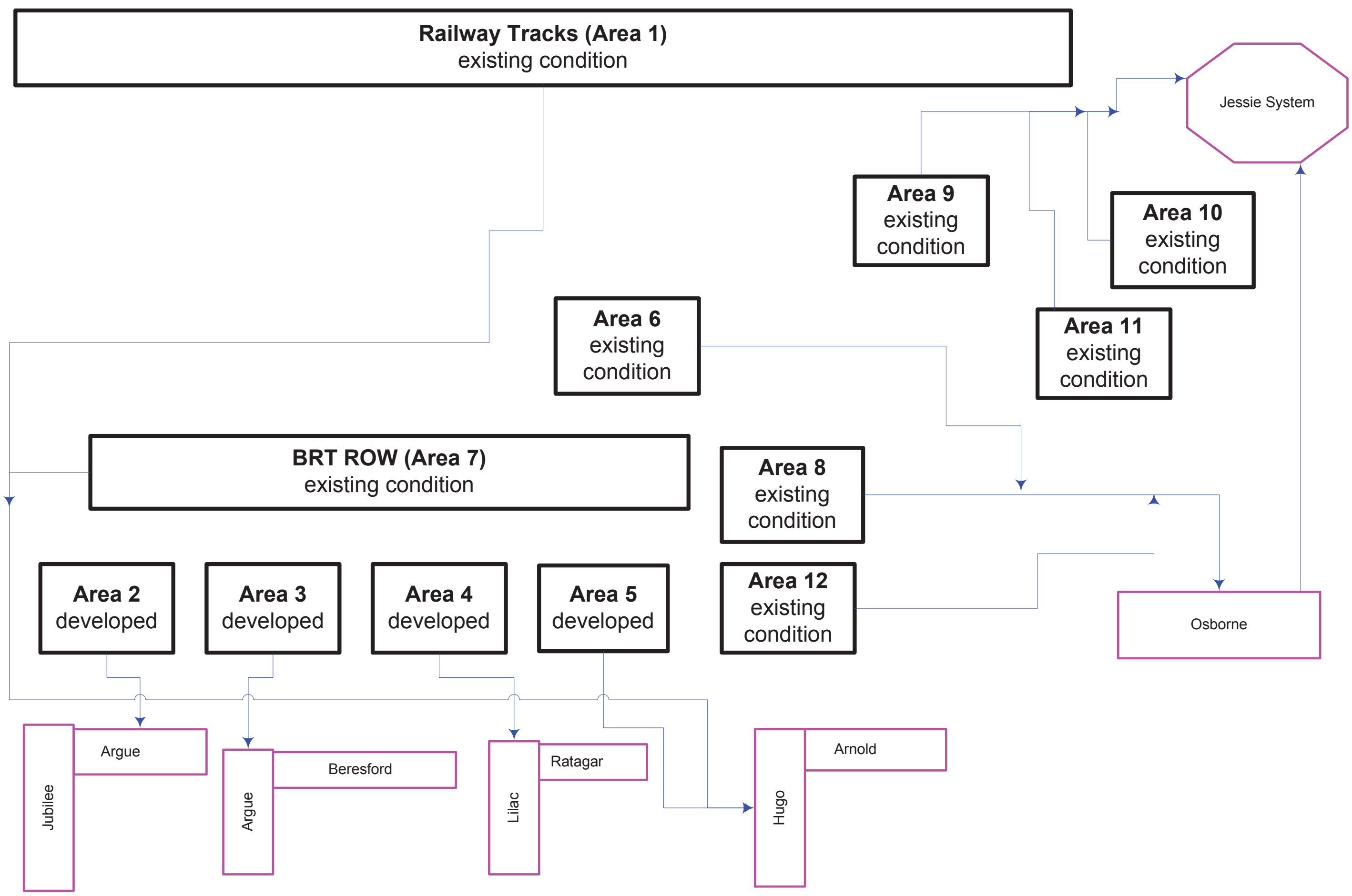


DILLON CONSULTING

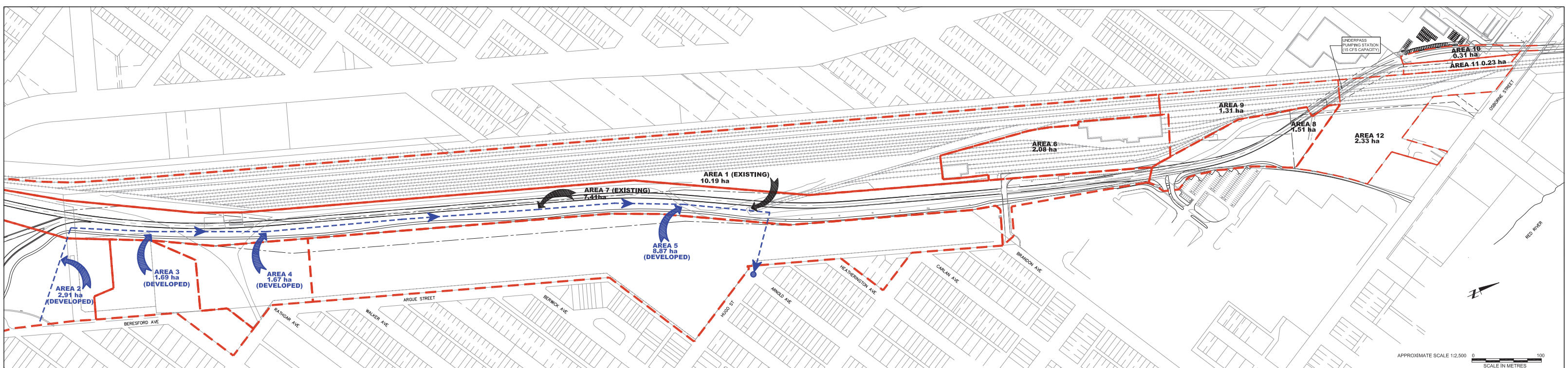
FORT ROUGE YARDS DRAINAGE STUDY
DRAINAGE OPTION 2A

PROJECT NO. **06-5893**
FIGURE NO. **FRYD-10**
DATE **NOVEMBER 2006**

OPTION 2A



Railway Tracks (Area 1)
existing condition
Jessie System
Area 9
existing condition
Area 10
existing condition
Area 6
existing condition
Area 11
existing condition
BRT ROW (Area 7)
existing condition
Area 8
existing condition
Area 2
developed
Area 3
developed
Area 4
developed
Area 5
developed
Area 12
existing condition
Osborne
Argue
Jubilee
Beresford
Argue
Ratagar
Lilac
Arnold
Hugo

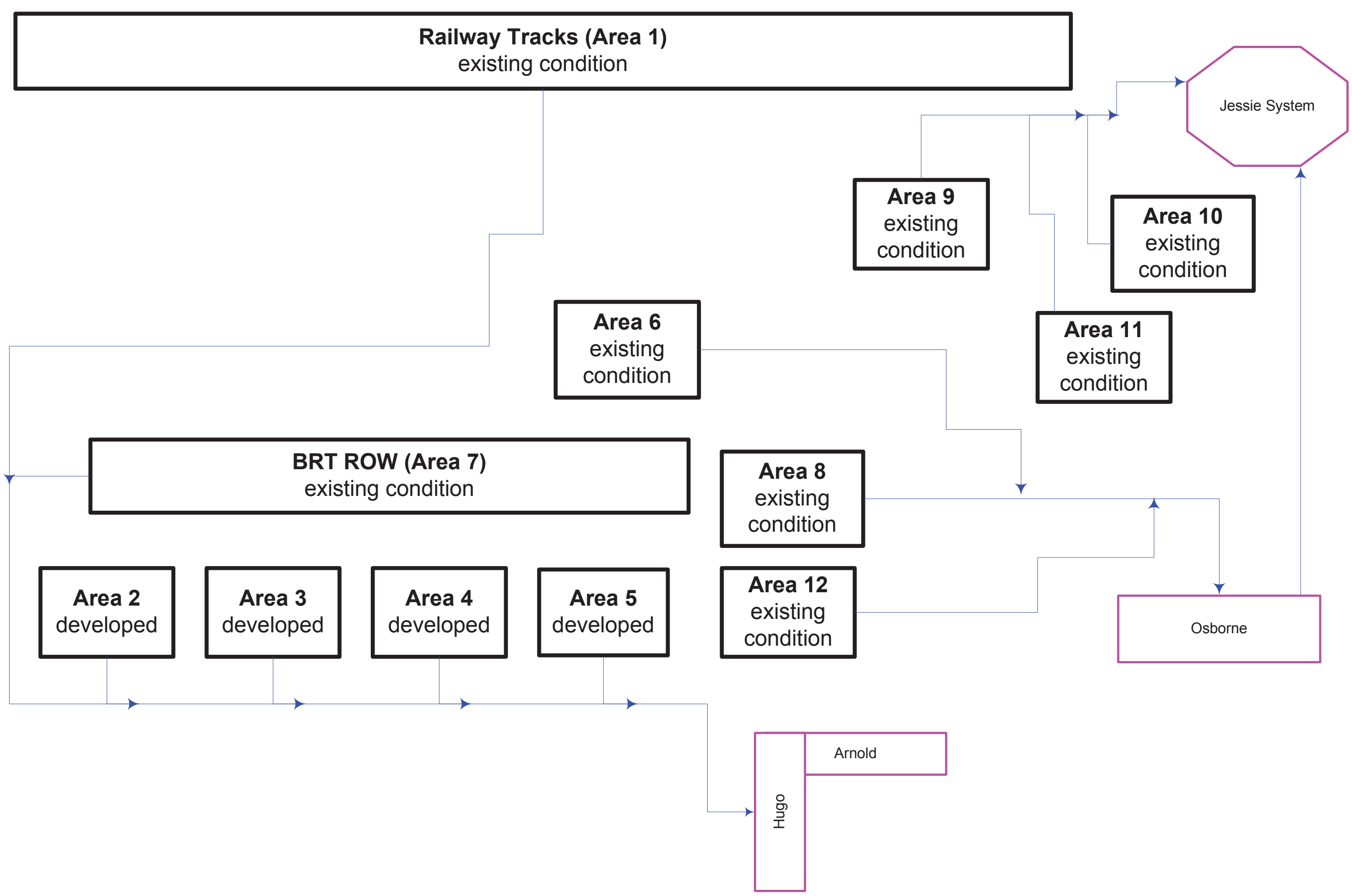


DILLON CONSULTING

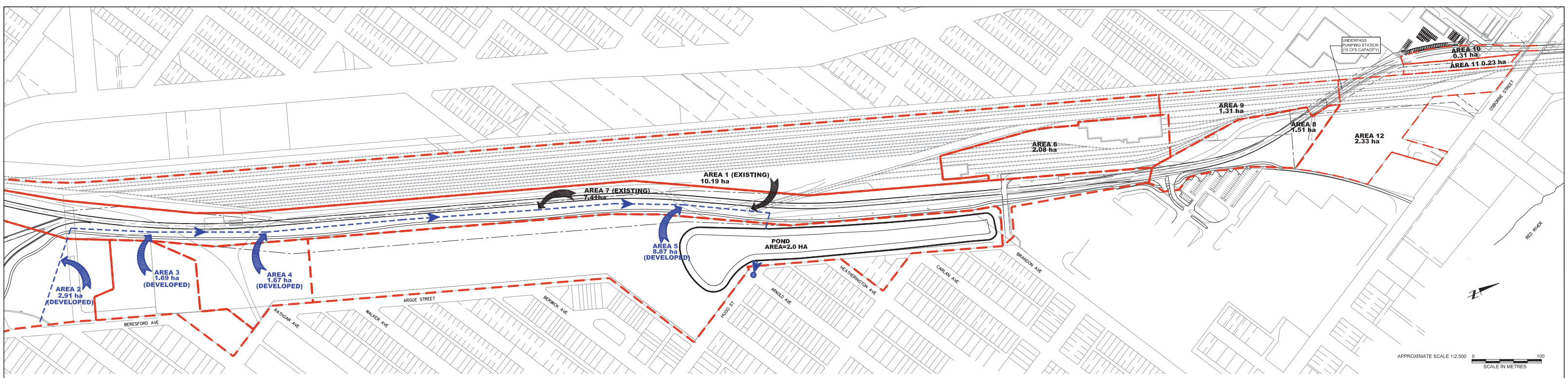
FORT ROUGE YARDS DRAINAGE STUDY
DRAINAGE OPTION 2B

PROJECT NO. **06-5893**
FIGURE NO. **FRYD-10**
DATE **NOVEMBER 2006**

OPTION 2B



Railway Tracks (Area 1)
existing condition
Jessie System
Area 9
existing
condition
Area 10
existing
condition
Area 6
existing
condition
Area 11
existing
condition
BRT ROW (Area 7)
existing condition
Area 8
existing
condition
Area 2
developed
Area 3
developed
Area 4
developed
Area 5
developed
Area 12
existing
condition
Osborne
Arnold
Hugo

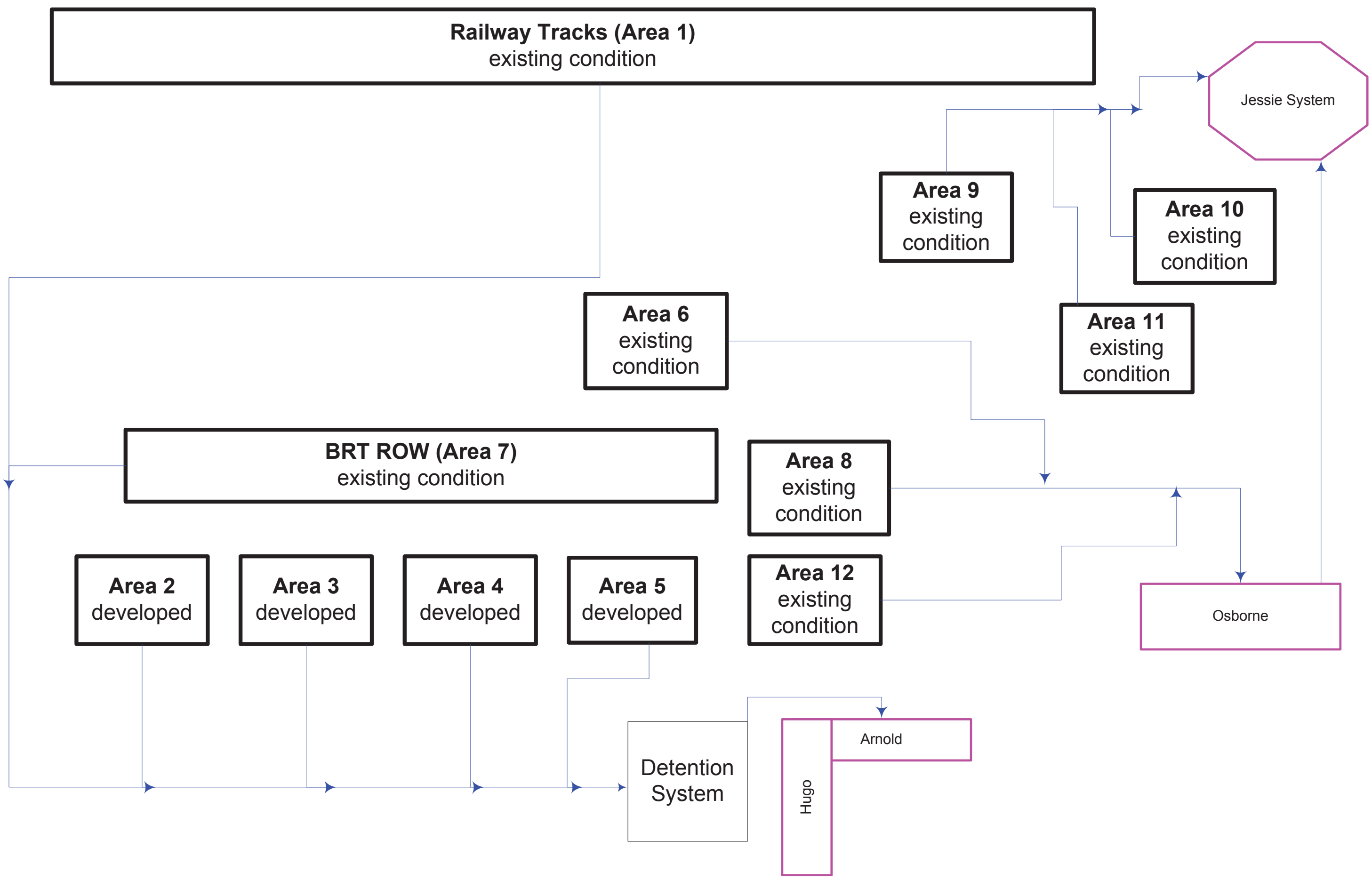


DILLON CONSULTING

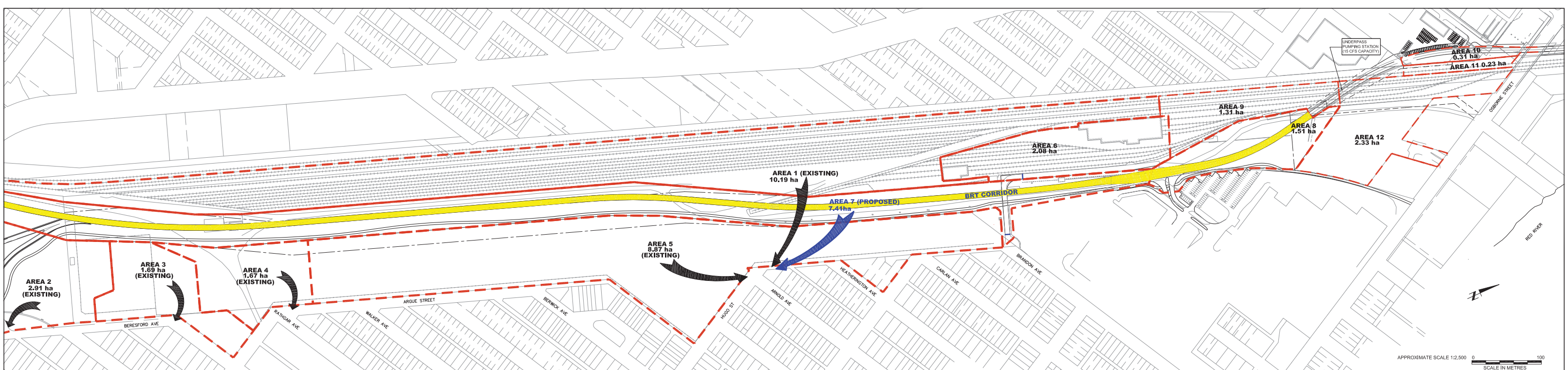
FORT ROUGE YARDS DRAINAGE STUDY
DRAINAGE OPTION 2C

PROJECT NO. **06-5893**
FIGURE NO. **FRYD-10**
DATE **NOVEMBER 2006**

OPTION 2C



Railway Tracks (Area 1)
existing condition
Jessie System
Area 9
existing
condition
Area 10
existing
condition
Area 11
existing
condition
Area 6
existing
condition
BRT ROW (Area 7)
existing condition
Area 8
existing
condition
Area 2
developed
Area 3
developed
Area 4
developed
Area 5
developed
Area 12
existing
condition
Osborne
Detention
System
Arnold
Hugo

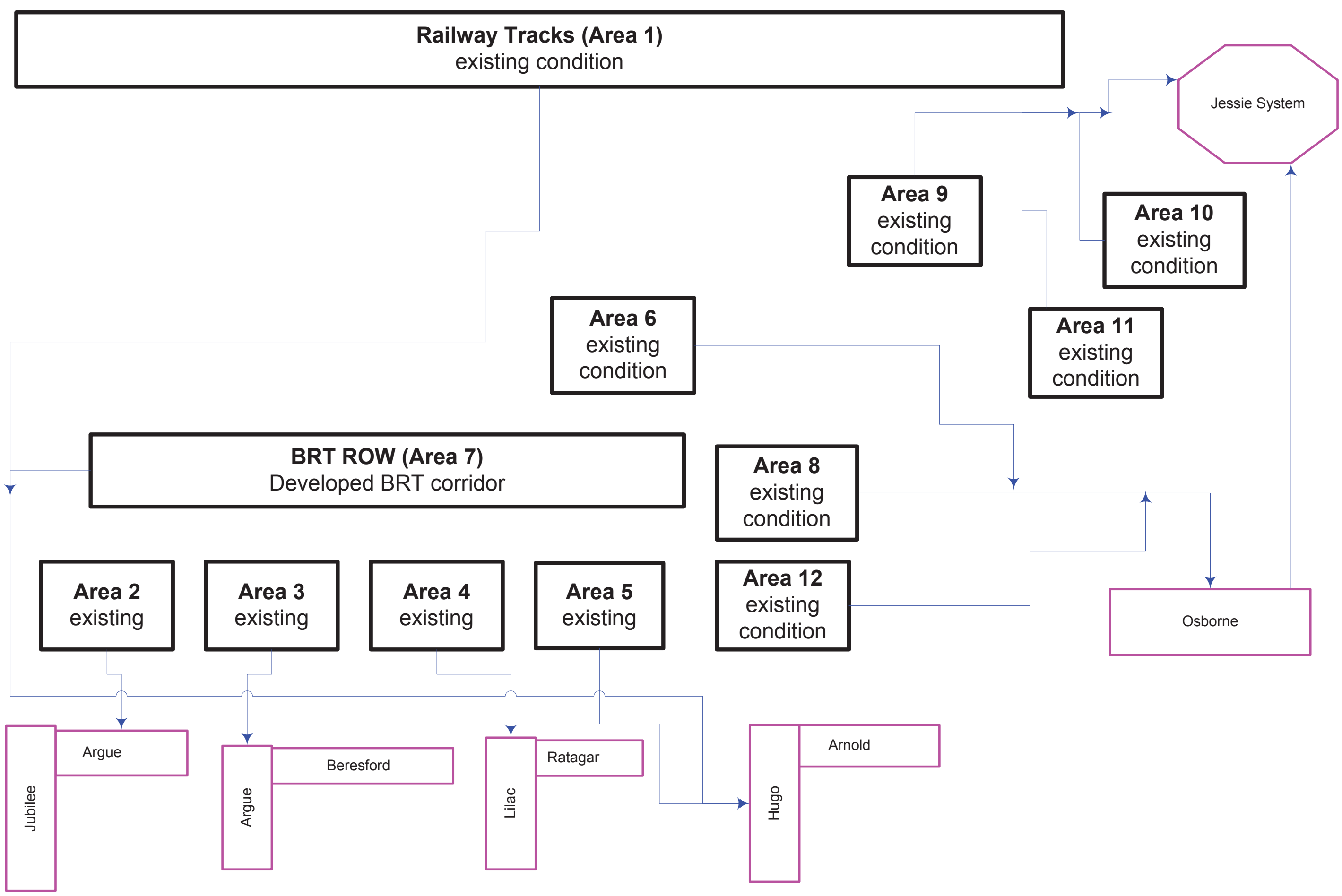


DILLON CONSULTING

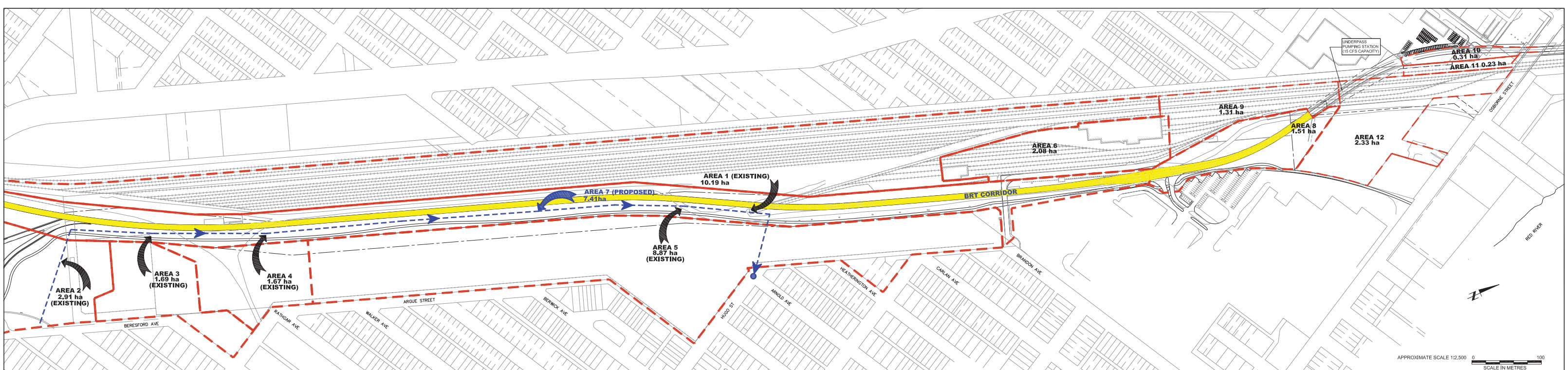
FORT ROUGE YARDS DRAINAGE STUDY
DRAINAGE OPTION 3A

PROJECT NO.	06-5893
FIGURE NO.	FRYD-10
DATE	NOVEMBER 2006

OPTION 3A



Railway Tracks (Area 1)
existing condition
Jessie System
Area 9
existing
condition
Area 10
existing
condition
Area 11
existing
condition
Area 6
existing
condition
BRT ROW (Area 7)
Developed BRT corridor
Area 8
existing
condition
Area 12
existing
condition
Osborne
Area 2
existing
Area 3
existing
Area 4
existing
Area 5
existing
Jubilee
Argue
Argue
Beresford
Lilac
Ratagar
Hugo
Arnold

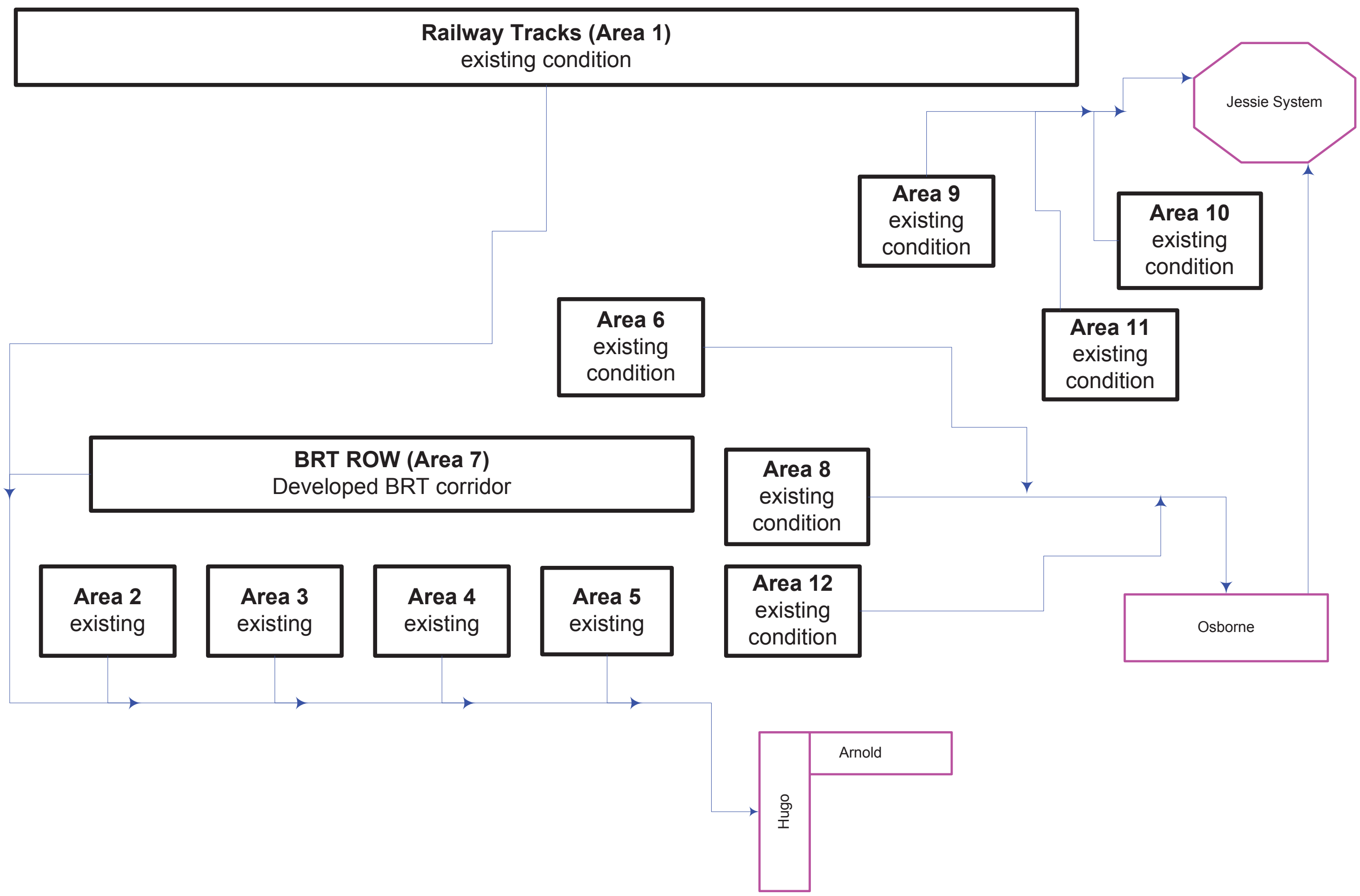


DILLON CONSULTING

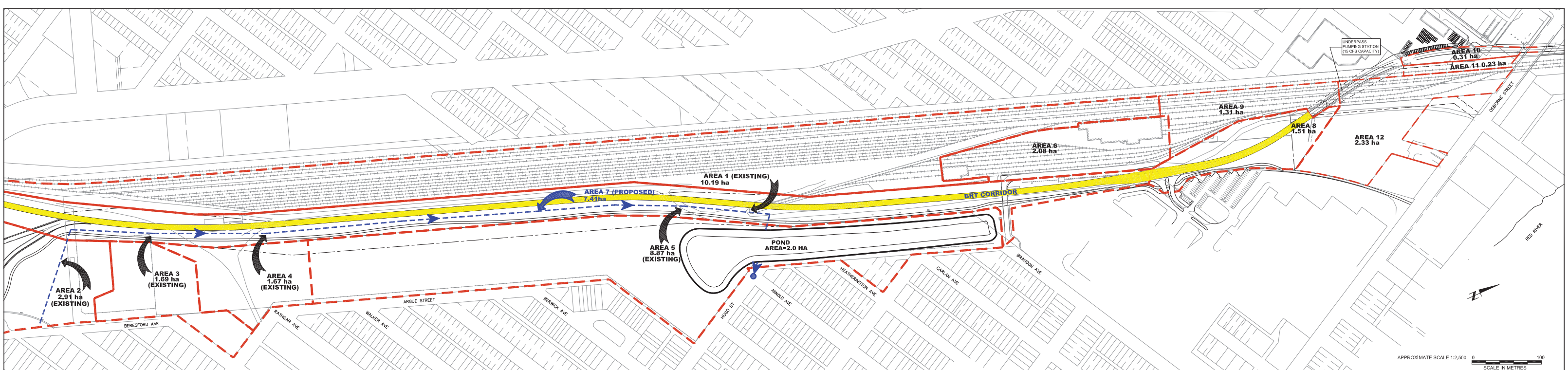
FORT ROUGE YARDS DRAINAGE STUDY
DRAINAGE OPTION 3B

PROJECT NO.	06-5893
FIGURE NO.	FRYD-10
DATE	NOVEMBER 2006

OPTION 3B



Railway Tracks (Area 1)
existing condition
Jessie System
Area 9
existing
condition
Area 10
existing
condition
Area 6
existing
condition
Area 11
existing
condition
BRT ROW (Area 7)
Developed BRT corridor
Area 8
existing
condition
Area 2
existing
Area 3
existing
Area 4
existing
Area 5
existing
Area 12
existing
condition
Osborne
Arnold
Hugo

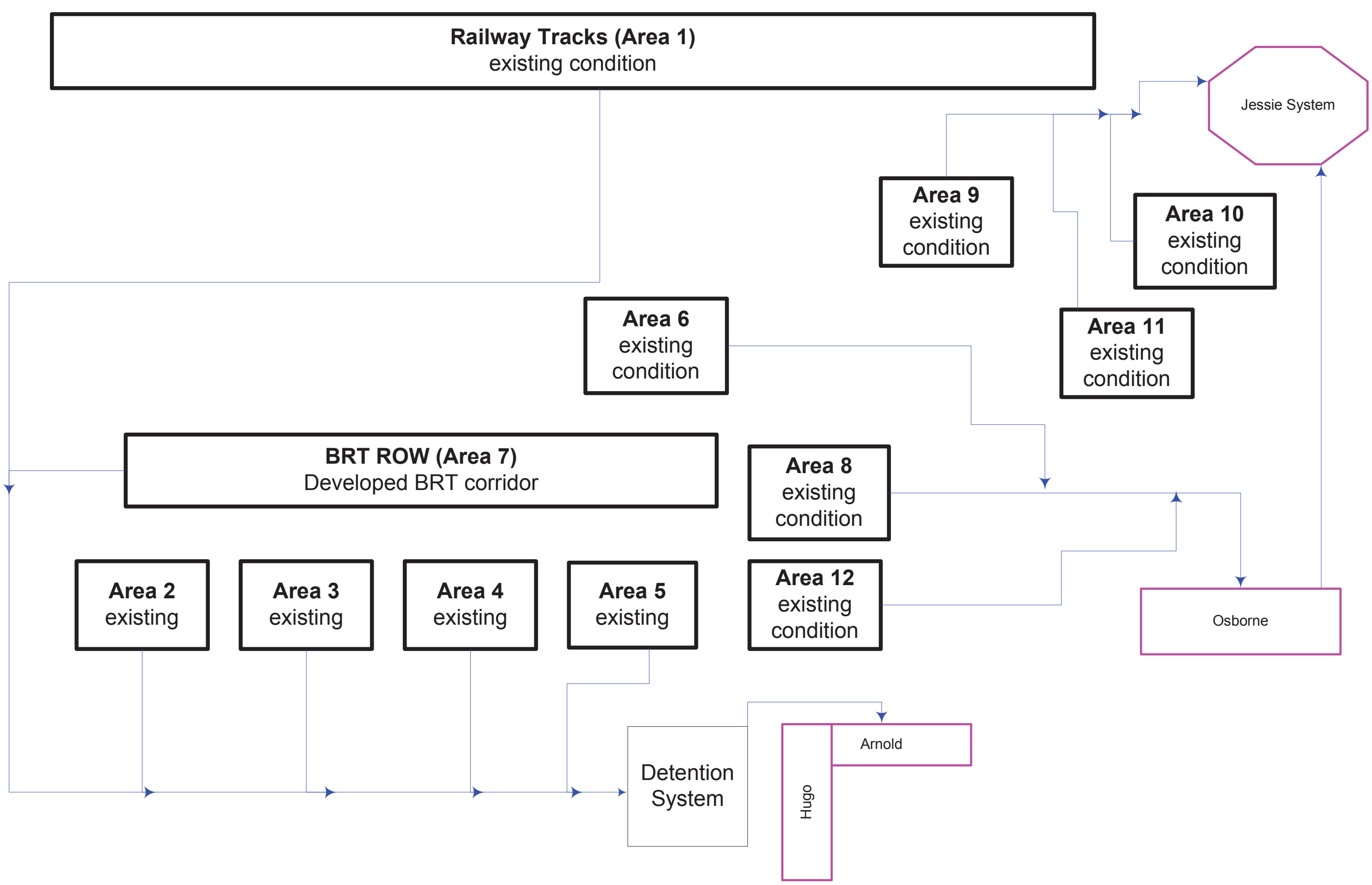


DILLON CONSULTING

FORT ROUGE YARDS DRAINAGE STUDY
DRAINAGE OPTION 3C

PROJECT NO.	06-5893
FIGURE NO.	FRYD-10
DATE	NOVEMBER 2006

OPTION 3C



Railway Tracks (Area 1)
existing condition
Jessie System
Area 9
existing
condition
Area 10
existing
condition
Area 6
existing
condition
Area 11
existing
condition
BRT ROW (Area 7)
Developed BRT corridor
Area 8
existing
condition
Area 2
existing
Area 3
existing
Area 4
existing
Area 5
existing
Area 12
existing
condition
Osborne
Arnold
Detention
System
Hugo

APPENDIX F

FORT ROUGE YARDS ADDITION – CONCEPTUAL DESIGN REPORT

THE CITY OF WINNIPEG
WATER & WASTE DEPARTMENT

COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS
FORT ROUGE YARDS ADDITION
FINAL TECHNICAL MEMORANDUM

FINAL
MAY, 2010

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KGS GROUP
CONSULTING ENGINEERS

COCKBURN / CALROSSIE COMBINED SEWER RELIEF WORKS FORT ROUGE YARDS ADDITION

FINAL TECHNICAL MEMORANDUM

PREPARED FOR:
CITY OF WINNIPEG WATER AND WASTE DEPARTMENT

KGS FILE 08-107-14

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EXECUTIVE SUMMARY

Additional engineering services have been undertaken by the Cockburn and Calrossie study team to investigate land drainage servicing options for Fort Rouge Yards (FRY). Development is planned for FRY, with the immediate priority being a bus rapid transit corridor, which will require collection and discharge of land drainage from both a proposed bus underpass and the main site area. The development is adjacent to the Cockburn District, which has been the subject of an ongoing drainage study, and may provide the opportunity for project integration. The integration could potentially reduce the total cost of the drainage works while avoiding an increase in combined sewer flows.

The scope of the additional services involved investigation of three drainage alternatives for the underpass and identification and evaluation of options for routing the main site area to Cockburn District. The evaluation included consideration and comparison of direct drainage options for FRY and opportunities for combining the drainage with Cockburn relief works. The evaluation considered only land drainage servicing, sanitary servicing was not included.

Cockburn drainage was considered from several perspectives in the draft Cockburn and Calrossie relief study. Partial land drainage separation was recommended if the objective is to be basement flooding relief only, with sunken relief piping being recommended if CSO control is to be included in the objective. Since the FRY decision is required before the CSO issues will be dealt with, part of the additional effort in this study includes identifying options that preserve the long-term CSO options while at the same time permitting the FRY to proceed.

A hybrid option, which was identified in the Cockburn and Calrossie report but not recommended, was considered to be the most amenable for the FRY addition. It uses partial separation in Cockburn West and relief piping in Cockburn East and could be staged to avoid compromising future Cockburn long-term CSO strategies. It includes the construction of a new outfall in close proximity to FRY, which would facilitate staging of FRY construction.

The Glasgow outfall was identified as a potential location for direct discharge of the underpass and potentially some of the main FRY drainage. The outfall was constructed at the time the Transit garage complex was built and currently serves only the Transit properties. Its location is well situated for servicing of the FRY development.

It was determined that the capacity of the Glasgow outfall is far more than originally anticipated and is a good option for servicing of the FRY area. The entire South West Bus Rapid Transit (SWBRT) could be serviced through the Glasgow outfall. It would also provide for a scheduling advantage in that it could be implemented without first constructing any of the relief works for the Cockburn Combined Sewer District.

Since the Glasgow option was found to have excess capacity, new options for rerouting runoff from the proposed FRY residential development as well as the Southeast Jessie District were considered, as outlined in the following table:

Option	Discharge Location			Cockburn Relief Option
	SWBRT (Areas 1, 2 & 3)	FRY Residential	Southeast Jessie	
1	Glasgow	Cockburn	Cockburn	Hybrid
2	Glasgow	Glasgow	Cockburn	Partial LDS
3	Glasgow	Cockburn	Glasgow	Hybrid
4	Glasgow	Glasgow	Glasgow	Partial LDS

Costs for the options were based the combined Cockburn and Fort Rouge Yards works, regardless of them being owned by the Water and Waste Department or Transit Department. The evaluation used costs in 2008 values, including allowances for engineering, burdens and a contingency allowance.

- Option 1 assumed the FRY drainage would be mostly serviced internally, with only the residential development being directed to the Cockburn District. For this option, the hybrid alternative would be implemented in Cockburn, with partial land drainage separation in Cockburn West and relief piping in Cockburn East. The hybrid option permits the FRY drainage to connect to the new Cockburn partial land drainage separation system, while preserving the option in Cockburn East for future CSO options. Use of the hybrid option substantially increases the total investment cost, resulting in a combined project cost of $58,832,000.

- Option 2 assumed FRY internal drainage would all be discharged to the Glasgow outfall, and therefore is totally independent of the Cockburn relief project. Partial LDS separation was assumed as the relief option for Cockburn, which is essentially the same approach as recommended in the Cockburn conceptual design when the decision perspective was for basement flooding relief alone, without consideration for integration of the CSO program. Although this option had the lowest combined cost at $51,748,000, it does not consider future integration of the CSO Program.

- Option 3 was similar to Option 1, with the exception that Southeast Jessie would be diverted to the FRY area. The proposed FRY land drainage trunk would be oversized and flow to an upgraded Glasgow outfall. This option also requires use of the hybrid option for the Cockburn District and substantially increases the total investment cost, resulting in a combined project cost of $60,202,000. It does consider future integration of the CSO Program.

- Option 4 was similar to Option 2, with the exception that Southeast Jessie would be diverted to the FRY area. The internal FRY area would all be directed to the upgraded Glasgow outfall and therefore be totally independent of the Cockburn project. Partial LDS separation would be implemented throughout Cockburn, which is a less expensive option than the hybrid. However, routing of Jessie to the FRY would cost an additional $1,300,000. The total investment cost for this option was $52,970,000.

The options were evaluated on a total investment basis, as well as for their effect on the Cockburn basement flooding relief project benefit-costs and their impacts on the potential future CSO program.

Total investment evaluation conclusions are as follows:

- From a total investment perspective, the lowest cost is for Option 2, which is to proceed with the SWBRT services independently. The Transit piping system and Glasgow outfall have capacity for the FRY flows and there was no cost advantage found to route the drainage to Cockburn.

- There is no advantage to route the FRY residential area to Cockburn (comparing options 1 and 2). Including the residential area with the FRY development removes its reliance on implementation of the Cockburn relief project to proceed.

- There is a $1,300,000 premium to route Southeast Jessie to FRY, which requires the crossing of multiple rail lines. It has the advantage of providing earlier implementation of basement flooding relief in the Southeast Jessie area which currently has a low level of service.

Assessment of the four options on the Cockburn relief project benefit-cost analysis indicated that all of the options had a B/C ratio greater than one, and would be justifiable projects on their own merits.
Project benefit-cost evaluation conclusions are as follows:

- Option 2 is similar to the alternative recommended in the Cockburn and Calrossie report, with a B/C ratio for partial LDS separation of 1.7. The B/C ratio was virtually the same whether or not Southeast Jessie was routed to Cockburn or FRY, since the relative cost difference is minor in relation to the total cost of relief.

- Selection of the hybrid reduced the B/C ratio because of its higher inherent cost. The hybrid option, however, offers additional advantages from the CSO perspective, which was not included in the FRY servicing assessment, but needs to be considered in the Cockburn relief and CSO decision process.

- The B/C ratio for Southeast Jessie alone was 3.4 in the case where Jessie was routed to Cockburn, decreasing to 2.8 for Jessie being routed to FRY. This very high B/C results from a severe problem with the level of service in the subarea. This was found in spite of the fact that the cost of servicing the area is high because it is essentially a land locked parcel of land with no convenient outlet. The Cockburn and FRY provide the only reasonable options for its upgrading.

The FRY servicing assessment included a review of the potential impacts on future Cockburn and Calrossie combined sewer overflow control works. The CSO evaluation was intended to identify risks and lost opportunity from proceeding with a FRY servicing option in advance of CSO decisions.
It was determined that FRY servicing integration with Cockburn could proceed without impacting the CSO options through use of the hybrid alternative for Cockburn. The hybrid would use partial LDS separation in Cockburn West, which would allow for early relief of Southeast Jessie as well as connection to FRY. Cockburn East could be delayed until the CSO decisions are made. At that time, sunken relief, extension of partial separation, or a CSO tunnel could be implemented.

The CSO impact conclusions are as follows:

- The hybrid alternative (Options 1 or 3) would preserve future CSO options. Relief piping would not be amenable to FRY servicing and partial LDS separation would prematurely commit the City to a CSO approach.

- If internal servicing alternatives (Options 2 or 4) are selected for FRY, there would be no impact on the Cockburn CSO program.

The hybrid alternative for Cockburn, before being modified for FRY development, had a cost premium of $4,209,000 in comparison to partial land drainage separation. An update to the hybrid alternative would be required for the FRY addition, bringing the premium for the hybrid to $6,633,000.

In reality, the full additional cost for the hybrid should not be attributed to the FRY development, since the primary advantages relate to CSO program savings. However, reassignment of the hybrid premium to the CSO program would still result in internal FRY servicing being the least costly.

The hybrid option allows for complete and independent servicing of Cockburn West because of the addition of a new LDS outfall. The outfall could be located at several alternative locations along the Red River, with the most probable locations being the Elm Park Foot Bridge or the existing Cockburn outfall location. This decision will be required if the hybrid option is selected.

Proceeding with partial land drainage separation of Cockburn West accommodates, but does not necessarily require use of the hybrid. The western partial separation can proceed without making any final decisions on relief of Cockburn East. The Cockburn East decision could as easily be through extension of partial land drainage separation, in which case partial land drainage separation would extend over the entire district, and be consistent with the recommendation for the basement flooding relief mandate perspective, and have no cost premium over the least cost recommendation.

In summary there are no advantages from integrating the Cockburn relief and FRY development projects, and it is recommended that all of the FRY areas proceed independently:

- The lowest cost from a total investment perspective is to proceed with FRY independently.

- Routing Southeast Jessie to FRY may provide a scheduling advantage, but is not recommended as it would cost more and require routing of pipes through a major railway yard.

- Proceeding independently has a major coordination advantage for FRY in that the projects can proceed without scheduling implications from one to the other.

Note: Consideration for providing a partial land drainage separation option that would provide for subsequent upgrading to complete separation was completed under the additional scope of work, but is reported on under a separate document.

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1.0 INTRODUCTION

1.1 BACKGROUND

The Cockburn and Calrossie Combined Sewer Relief Works project was assigned to KGS Group, Dillon Consulting and CH2M HILL in December 2005. The main tasks included in the scope of work were:

- Basement Flooding Relief (BFR) Assessment and Conceptual Design
- Combined Sewer Overflow (CSO) Evaluation
- North End Water Pollution Control Centre (NEWPCC) Interconnection
- Fort Rouge Yards (FRY) Evaluation

The evaluations were based on upgrading the level of basement flooding protection to a 5-year level, with additional consideration for combined sewer overflow control and a regional combined sewer overflow program, which involved transferring district wet weather flows from the south end combined sewer collection area to the north end, referred to as the NEWPCC Interconnection.

As part of the project, a preliminary assessment of land drainage options from the Fort Rouge Yards was carried out. The Fort Rouge Yards (FRY) is defined as the area bounded by the Lord Roberts residential area to the east and Pembina Highway to the west, as highlighted in red in Figure 1-1. Land use within the area includes the proposed bus rapid transit corridor (BRT), the CNR tracks and vacant land proposed to be developed into multifamily residential.

The Cockburn study demonstrated that the Cockburn Combined Sewer District partial land drainage separation alternative could accommodate runoff from the future South West Bus Rapid Transit (SWBRT). The partial land drainage separation option was considered to be the most amenable to the FRY development since the increased surface runoff could be conveyed without causing detrimental CSO impacts. A hybrid option consisting of partial land drainage separation in Cockburn West and relief piping in Cockburn East was also found to be cost competitive to the partial separation option, with only marginally higher costs, but required the construction of a new outfall.

Figure 1-1: Study Area

1.2 SCOPE OF WORK

Subsequent to the submission of the Cockburn Draft Conceptual Report, additional information and interest was raised with respect to the potential development of the SWBRT corridor as well as the vacant lands within the FRY. As an extension to the original Cockburn study, a scope change was authorized to evaluate and present recommendations on land drainage options for the servicing of FRY while giving consideration to both basement flooding relief of the Cockburn Sewer District, as well as district and regional CSO control. Based on these new design objectives, the separation/relief hybrid alternative was deemed to be the most appropriate option rather than the partial land separation option since it would be less likely to preclude CSO control or NEWPCC interconnection options.

The additional scope of work for the Cockburn project also included:

- A review of plans for the FRY development and confirmation or updating of internal drainage and storm water collection plans. Dillon Consulting, acting on behalf of the Winnipeg Transit Department, has provided details of the development. Servicing plans related to the land drainage collection within the development were consistent with conventional drainage standards and best practices.
- Assessment of SWBRT land drainage options that include routing to the river, or to the adjacent sewer districts, which include Cockburn, Baltimore and Jessie.
- Updating of the Cockburn study hybrid option, along with its modification and optimization to accommodate FRY development.
- WWD requested that provisions for complete separation be considered for the partial land drainage separation option as a CSO control measure.
- Evaluation of options with consideration to costs and impacts on adjacent combined sewer districts, including basement flooding protection and CSOs.
- Assessment of the compatibility of the development to the long-term CSO options identified in the original Cockburn Study.
- Recommendations based on cost-effectiveness, considering the three perspectives in the Cockburn study, being basement flooding relief alone, basement flooding relief plus district CSO control, and basement flooding relief plus a regional CSO program.

2.0 COCKBURN AND CALROSSIE RELIEF WORKS PROJECT

2.1 BASEMENT FLOODING RELIEF

In keeping with the original basement flooding relief program mandate, a number of options were considered to provide basement flooding relief, independent of combined sewer overflow control. The option with the highest benefit-cost ratio was found to be partial land drainage separation. With this option, land drainage pipes would be installed to collect enough storm water to eliminate basement flooding to the 5-year level of protection.

A second hybrid option consisting of partial land drainage separation in Cockburn West and relief piping in Cockburn East was found to be competitive, with only marginally higher costs, but requiring the construction of a new outfall. The partial land drainage alternative was recommended as it had the highest benefit-cost ratio, and did not require a new outfall. A cost estimate for a new outfall has been provided in Section 6.3. However, depending on the location, there may be a number of uncertainties associated with riverbank stabilization works, the acquisition of environmental regulatory approvals and potential issues with adjacent landowners.

The Cockburn and Calrossie Combined Sewer Relief Works report recommended an alternative based on the current basement flooding relief mandate. The report recommendations also considered the integration of combined sewer overflow control with basement flooding relief (BFR) works and the feasibility of extending the integration to a regional basis through interconnection to the NEWPCC using a storage/transport tunnel.

The main report findings were as presented in Table 2-1.

TABLE 2-1: REPORT FINDINGS

Decision Perspective	Preferred Option	Comments
BFR alone	Partial Separation for the entire district	Highest benefit-cost considering only BFR
BFR with CSO	Relief Piping with Sunken Relief	Lowest cost considering both BFR and CSO control on a district basis
BFR/CSO Program	Relief Piping with a Storage/Transport Tunnel Interconnection to NEWPCC	Tunnel was found to be feasible, with potential to provide significant CSO program savings

2.2 BASEMENT FLOODING RELIEF WITH COMBINED SEWER OVERFLOW CONTROL

The second perspective considered basement flooding relief along with combined sewer overflow (CSO) control. A CSO program appears to be imminent, and because of the relationship and common elements between it and the basement flooding relief program, it was considered prudent to consider them together. A full spectrum of CSO control alternatives was considered and evaluated jointly with BFR implementation.

The CSO analysis indicated that in-line storage would be very cost effective. The district requires large pipes for basement flooding relief and has adequate in system storage to provide CSO control to four overflows per year.

While in-line storage is clearly the least costly of the options, its use is in doubt because of inherent risks and uncertainties:

- Mechanical control devices increase the risk of failure and may result in basement flooding
- There were a number of operational concerns raised in the CSO Management Study, which have not been resolved
- Inlet restriction, which was considered to be a prerequisite for in-line storage, may not provide the required certainty in flow control
- The amount of inflow and infiltration from a separated combined sewer district is unknown and may be of sufficient volume to cause the volume of in-line storage available in existing systems to be exceeded.

If in-line storage were ruled out for CSO control, there would be a dramatic increase in costs. If off-line storage were required to supplement or replace in-line storage, the cost would increase dramatically.

If in-line storage is eliminated, the next most cost-effective option for CSO control of the Cockburn District was found to be through modification of the relief piping scheme. CSO control would be provided by constructing sunken relief -- that is by enlarging sections of the relief piping to sufficiently provide CSO storage and installing it at a lower depth to retain the hydraulic capacity while at the same time eliminating the need for mechanical discharge controls.

The sunken relief option was the preferred alternative if the selection was to be based on providing basement flooding relief along with CSO control on a single district basis for Cockburn.

2.3 NEWPCC INTERCONNECTION

The third perspective in the assessment involved consideration of a regional CSO program. A tunnel sewer interconnection to the North End Water Pollution Control Centre (NEWPCC) was considered at a feasibility level. The tunnel has the following advantages:

- Eliminates complex CSO controls needed for both in-line and off-line storage
- Reduces the risk of equipment failure and basement flooding
- Provides cost optimization through economies of scale in building CSO storage volume
- Diverts flows from several districts from the south to the north, reducing pressure on the SEWPCC (South End Water Pollution Control Centre) wet weather loading and transferring it to the NEWPCC where wet weather treatment will be available

The area under consideration extended from the Cockburn District to the south and the River District to the north, with the Baltimore and Jessie districts in between. The tunnel would be connected to the Cockburn Trunk sewer and would be sized to capture the fifth largest storm from each district. Flow exceeding the fifth largest storm would be permitted to overflow, which is consistent with the presumed four-overflow control regulation.

The evaluation concluded that the storage transportation tunnel is a competitive alternative to in-line and off-line CSO control options for these combined south end districts and in fact provides a number of inherent advantages. It was recommended that based on the feasibility of the option, it should be considered further as a regional CSO control option.

2.4 FORT ROUGE YARDS DEVELOPMENT

The Cockburn study terms of reference required that a cursory assessment of the Fort Rouge Yards development be included. Development criteria were provided by Dillon Consulting, and included flow rates for specified locations.

The Fort Rouge Yards development was considered from the three decision perspectives (presented in Table 2-1), with the results as indicated in Table 2-2.

TABLE 2-2: FORT ROUGE YARDS OPTION COMPATIBILITY

Decision Perspective	Fort Rouge Yards Addition
BFR alone	Fully Compatible
BFR with CSO	Not Compatible
BFR/CSO Program	Not Compatible

The FRY development was found to be fully compatible with the partial land drainage separation alternative, which was recommended for the BFR alone perspective. The land drainage from FRY would be accommodated by over sizing the proposed Cockburn land drainage pipes, with the separated water draining into the river. Combined sewer overflows would not be impacted because the FRY flows would be drained strictly to a land drainage sewer.

The addition of FRY land drainage was not viewed as compatible when considering the recommended option for BFR along with CSO control. The option involved construction of sunken relief, which has an inherent built in CSO storage volume. The addition of FRY land drainage would add to the CSO capture requirements, increasing the cost of CSO control and sewage treatment.

The FRY land drainage addition was also not considered compatible with the third perspective of a BFR/CSO regional program. As with sunken relief, the addition of land drainage flow would add to the volume of tunnel storage required and also to the volume of flow to be treated.

2.5 RE-EVALUATION OF FORT ROUGE YARDS DEVELOPMENT

Because of the proximity of the Fort Rouge Yards to the Cockburn Combined Sewer District, the timing of the two projects and the potential for savings, the Water and Waste and Transit Departments agreed that there was merit in further investigating opportunities to integrate the projects. Accordingly, the Water and Waste Department requested that our study team further consider alternative methods of accommodating the FRY development without compromising the level of basement flooding protection, the current CSO situation or the long-term CSO program.

In response to the request from the Water and Waste Department, our team has reassessed the newly defined objectives and available options and has identified that the separation/relief hybrid alternative appears to be the most appropriate alternative to meet the combined objectives for the two projects:

- The separation/relief hybrid consists of land drainage separation for Cockburn West and relief of Cockburn East
- The option is somewhat more costly than partial land drainage separation for the entire district, but not by a large amount
- A new outfall at the Elm Park Footbridge (adjacent to the Bridge Drive Inn) or an upsized existing Cockburn outfall would be ideally situated for collection of storm water discharge from Fort Rouge Yards
- The outfall location would allow optimization and joint use of land drainage separation piping from Fort Rouge Yards through the Cockburn drainage area
- The sunken relief piping option could readily be adapted to the Cockburn East relief piping to provide district CSO control. Flows from Cockburn West would be reduced because of the partial separation and would require less sunken relief storage volume
- Having the sunken relief in Cockburn East would continue to support the concept of a storage-transport tunnel connection to the NEWPCC

In summary, the alternative is well suited to the development since it consists of relief piping in Cockburn East and LDS separation in Cockburn West. By routing the development flows from the Fort Rouge Yards addition to Cockburn West where partial LDS separation would be implemented under this hybrid alternative, there would be no concern regarding additional flows to the combined sewer system.

It was therefore recommended that the Cockburn hybrid alternative be considered jointly with the FRY development.

3.0 EVALUATION OF SWBRT DRAINAGE OPTIONS

3.1 OPTIONS CONSIDERED

The SWBRT runoff consists of drainage from a new bus underpass, which must be collected and then pumped and surface drainage from the main area, which can flow by gravity to a river outfall location. It was originally assumed that the main drainage from the SWBRT would be routed to the Cockburn District. The main drainage would be connected to a LDS separation system, where it would flow by gravity to the Red River without any CSO implications.

The additional work included evaluation of three options for the underpass drainage. A pumping station would discharge the underpass drainage to either the Jessie Combined Sewer District (see Figure 3-1) or the adjacent Baltimore Combined Sewer District.

These options are listed below:

1. ***SWBRT Underpass to the Jessie Trunk***

   This option would involve routing the flows from the SWBRT Underpass to the Jessie Trunk, while the remaining drainage from the SWBRT would be routed toward the Cockburn Combined Sewer District. Routing flows from the SWBRT to the Jessie Trunk will have consequences on basement flooding protection (BFR), CSOs and sewage treatment.

2. ***SWBRT Underpass to the Jessie Outfall***

   This option would involve routing the flows from the SWBRT Underpass to a point downstream of the Jessie diversion weir, while the remaining drainage from the SWBRT would be routed toward the Cockburn Combined Sewer District. This option is a variation of Option 1 that is advantageous because the CSO and increased sewage volume problems would be avoided.

3. ***SWBRT Underpass to Baltimore Combined Sewer District***

   This option would involve routing the flows from the SWBRT Underpass to the Baltimore Combined Sewer District, while the remaining drainage from the SWBRT would be routed toward the Cockburn Combined Sewer District. The Baltimore combined sewer relief system has partial land drainage separation.

Figure 3-1: Jessie and Baltimore Land Drainage Options

The Glasgow outfall option, which is discussed subsequently in this technical memorandum, is a variation of the third option considered, “SWBRT Underpass to Baltimore Combined Sewer District”.

The additional work included determining the feasibility of these options, including the assessment of the impacts of the additional flow on the capacity of the systems and the costs to provide for any new sewers required for the diversion of the SWBRT flows. As a result of this assessment, it was concluded that the option to route runoff from the SWBRT to the existing Glasgow LDS outfall was the preferred option as the system was found to have excess capacity. It is also an advantageous option because runoff would be routed to a separated LDS system instead of a combined sewer system. For this reason, the project team was asked to investigate the Glasgow option (variation of Option 3 to Baltimore Combined Sewer District), which would accommodate runoff from both the northern and southern areas of the SWBRT, not only the underpass drainage as referenced above.

3.2 SOUTHWEST BUS RAPID TRANSIT STUDY AREA

Dillon Consulting Limited is conducting the assessment study of the SWBRT corridor through the Fort Rouge Yards on behalf of the City of Winnipeg Transit Department. The proposed SWBRT system extends from Main Street to Jubilee Avenue and Pembina Highway and crosses the Fort Rouge Yards (FRY) in the Cockburn Combined Sewer District. Dillon prepared a memorandum titled “Southwestern Bus Rapid Transit Corridor Stage 1 – Land Drainage Sewer Options for the Transit Corridor between Jubilee and Osborne, including the CN Underpass” (February, 2009) – See Appendix A. The memorandum presents the preliminary drainage design for the area shown on Figure 3-2.

The Fort Rouge Yards has been separated into 3 study areas, including Study Area 1, comprising the land draining to the SWBRT underpass, Study Area 2, comprising the remainder of the SWBRT and CNR track right-of-way, and Study Area 3, comprising a portion of the FRY from Mulvey Avenue to Brandon Avenue for the future Transit garage. It is proposed that runoff from Areas 2 and 3 would be collected in a closed gravity sewer system. A lift station would be used to pump the runoff from the underpass (Study Area 1) to the downstream receiving sewer system. The drainage area for Study Area 1 is 3.6 Ha. Study Area 2, which includes the remainder of the CNR tracks and the SWBRT, has a drainage area of 20.9 Ha, and Study Area 3 has a drainage area of 4.8 ha.

Dillon Consulting assumed that runoff from Area 2 would be discharged by a closed piped system to the land drainage sewers in the proposed separation/relief hybrid option proposed in the original Cockburn Study.

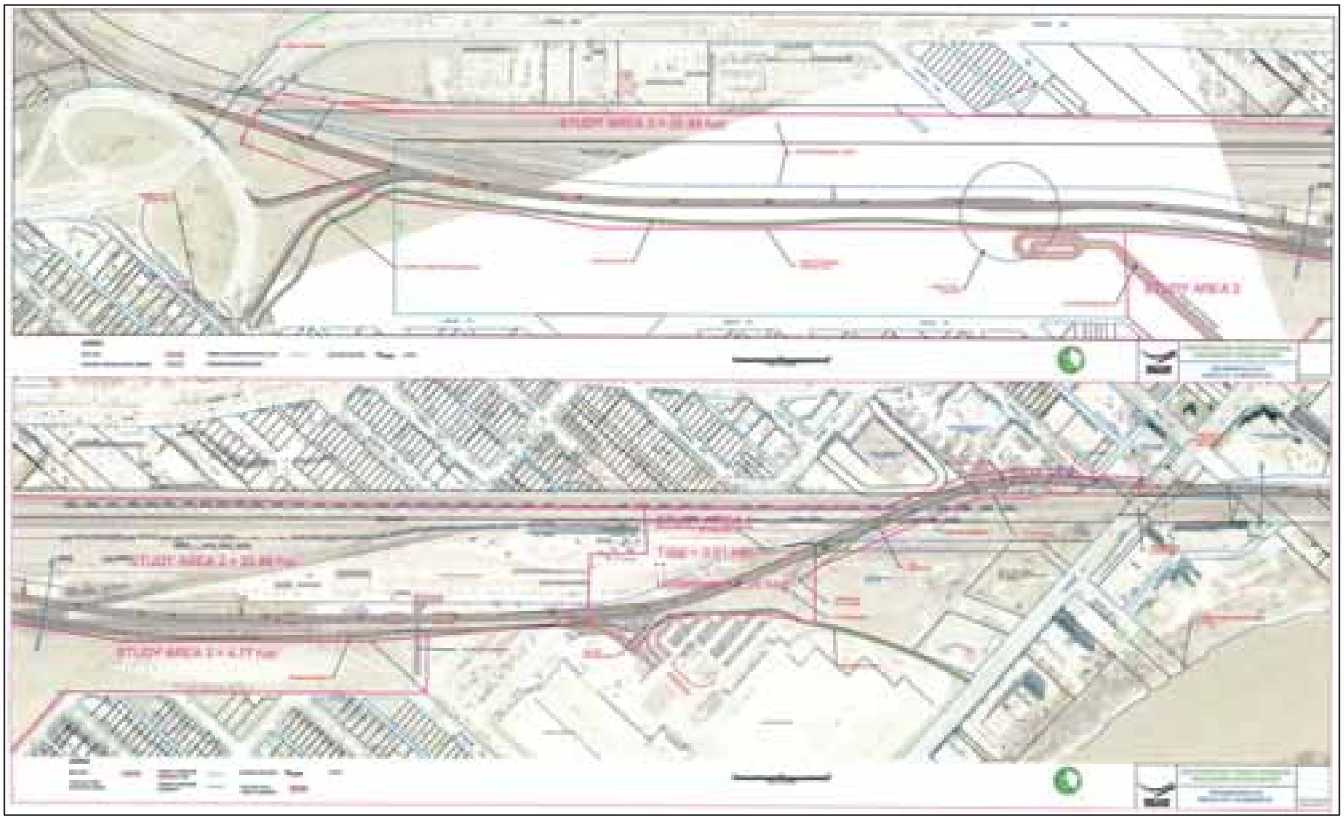


Figure 3-2: SWBRT Closed Drainage Option (Jubilee Street to Osborne Street)

The proposed FRY residential development was not considered as part of Dillon's analysis since it was not related to the SWBRT. However, Dillon did consider this area as part of their original scope of work related to the Cockburn Draft Conceptual Report (July 2007). Because B & M Lands, the developer for this area, have not yet finalized their plans for a medium to high-density residential development at this location, assumptions were made by KGS Group to incorporate the development as part of this study. These assumptions were consistent with the original Cockburn Study and were based on the calibrated parameters in Cockburn East. These modeling assumptions are described in more detail in a memorandum prepared by KGS Group, referenced as Appendix A within the Dillon Report – "Final Fort Rouge Yards Drainage Option (Option 2)" in Appendix A of this technical memorandum ("Southwestern Bus Rapid Transit Corridor Stage 1 – Land Drainage Sewer Options for the Transit Corridor between Jubilee and Osborne, including the CN Underpass" February, 2009 – Dillon Consulting).

3.3 SWBRT RUNOFF ASSESSMENT

The delineation of drainage area boundaries as it pertains to the Cockburn Combined Sewer District and the assessment of the runoff from the BRT site has been defined in the Dillon report "Southwestern Bus Rapid Transit Corridor Stage 1 - Land Drainage Sewer Options between Jubilee and Osborne, including the CN Underpass". As part of the assessment, the runoff and discharge hydrographs for each study area were determined by developing an XP-SWMM model. Model parameters are summarized below.

3.3.1 Design Rainfall

The design rainfall used for the runoff assessment of the SWBRT was consistent with the design rainfall used in the original Cockburn Study. Based on recommendations from Grant Mohr, Branch Head - Land Drainage and Flood Protection, City of Winnipeg Water and Waste Department, the design rainfall should be based on the rainstorm coefficients used to fit the City of Winnipeg intensity duration frequency (IDF) curve from the 2000 Stantec Report, "An Urban Drainage Adequacy Review for the City of Winnipeg Rainfall and Runoff". This recommendation was made to be consistent with other basement flood relief studies for the City of Winnipeg.

For design storms, the time step was increased from 5 to 10 minutes and the storm advancement factor "r", representing the ratio of storm rainfall up to the time of peak rainfall intensity to the total storm rainfall, was assumed as 0.33 compared to the 1974 value (Drainage Criteria Manual for the City of Winnipeg, MacLaren) of 0.31.

The assessment of the runoff from the SWBRT site considered a combined 1:5-year rainfall event for Areas 2 and 3, and the 1:25-year rainfall event for the SWBRT underpass (Area 1). While the use of dual probabilities for assessing the runoff from a common system is not normally used, in the case of the SWBRT runoff, it has been reasoned by the WWD and Dillon Consulting that during the 25-year storm event, the SWBRT underpass would be pumped with a lift station having a 1:25-year runoff capacity but the runoff rates from Area 2 would be limited by the closed piped drainage system that would be designed to handle runoff from the 5-year event. Runoff from larger rainstorms would be prevented from entering the sewer system since the hydraulic grade line (HGL) would be at ground surface for the 5-year level of flow with the excess water stored on the streets. While it is unlikely that the entire 25-year runoff could be discharged, the flow would be somewhere between the 5-year and 25-year unrestricted flow for a 25-year event.

3.3.2 Water Level Assumptions at Glasgow Outfall

The water level assumed at the Glasgow outfall for the hydraulic analysis was the 1:10-year June water level of 225.55 m (JAPSD 11.5 ft), based on recommendations from Grant Mohr (Branch Head – Land Drainage and Flood Protection, City of Winnipeg Water and Waste Department). For any recent land drainage systems that have been constructed with the City (i.e. River Ridge Subdivision, Van Hull), it has been recommended that this more stringent criteria be used for design instead of the normal summer water level, which is approximately 223.70 m (JAPSD 6.5 ft) at the Glasgow outfall. The criteria for design has been revised on the basis that since 1998, there have only been 2 years where the June water level was roughly equivalent to the normal water level. This design is not applied to combined sewer systems, since these systems typically have flood pump stations to deal with high river levels but it is considered applicable for land drainage systems.

3.3.3 Runoff Parameters

The Horton Infiltration Method was used in the runoff model for the SWBRT and CNR rail yards. The Horton infiltration parameters used for the runoff assessment were equivalent to the calibrated parameters from the original Cockburn study. Maximum and minimum infiltration rates and the decay rate of infiltration were assumed as 85 mm/hr, 3 mm/hr, and 0.00115/sec, respectively.

Depression storage was assumed as 1.0 mm for impervious surfaces for both the SWBRT and CNR runoff catchments. The SWBRT and CNR yards were assumed to be 40% and 5% impervious, respectively. The depression storage for the SWBRT pervious area was assumed as 5 mm, but the depression storage was increased to 10 mm for the CNR yards to reflect the increased storage of the ballast used in the track bed. The assumptions made for depression storage and for the percent imperviousness are consistent with the Dillon memorandum referenced herein.

3.3.4 SWBRT Hydraulic Model

A closed piped hydraulic system has been assumed to convey runoff from the BRT right-of-way. While the runoff from the CNR yards would be collected in an open ditch system, it would be routed to the SWBRT closed pipe system at a number of design low points. Concrete pipe with a Manning's roughness coefficient of 0.013 was assumed for the SWBRT sewer. The diameter of the sewer was sized to discharge the design flow with the hydraulic grade line at 0.3 m below the ground surface.

3.4 ALTERNATIVE ROUTING OPTIONS FOR SWBRT DRAINAGE

Dillon Consulting developed runoff hydrographs, either separately or in combination, from each of the SWBRT study areas described in Section 3.2. Three alternatives were considered for the diversion of BRT flows to the Transit LDS system.

- Alternative 1 - Discharge of Area 1 to the Transit LDS system leading to the Glasgow outfall (25-year runoff). Runoff from Areas 2 and 3 would be discharged to the Cockburn partial land drainage sewer relief system.
- Alternative 1A – Discharge of Area 1 (25-year runoff) and Area 3 (5-year runoff), to the Transit LDS system leading to the Glasgow outfall. Runoff from Area 2 would be discharged to the Cockburn partial LDS relief system.
- Alternative 2 – Discharge of the combined runoff from Area 1 (25-year runoff) and Areas 2 and 3 (5-year runoff) to the Transit LDS system leading to the Glasgow outfall.

Since Winnipeg Transit has showed a preference in routing all 3 areas to the Transit LDS system, all three alternatives are being considered.

Although a flow optimization exercise could be carried out to determine the least cost option for the location for the drainage from Area 2, because of the immediate priority for development of the SWBRT, this was not considered to be a feasible alternative due to the potential delays that could result. However, as discussed in subsequent sections of this Technical Memorandum, possibilities to divert flow from the southeast part of the Jessie District and/or the proposed FRY residential development to the Glasgow outfall were considered.

The computed runoff hydrographs for each of the above 3 alternatives are shown on Figures 3-3, 3-4 and 3-5, respectively.

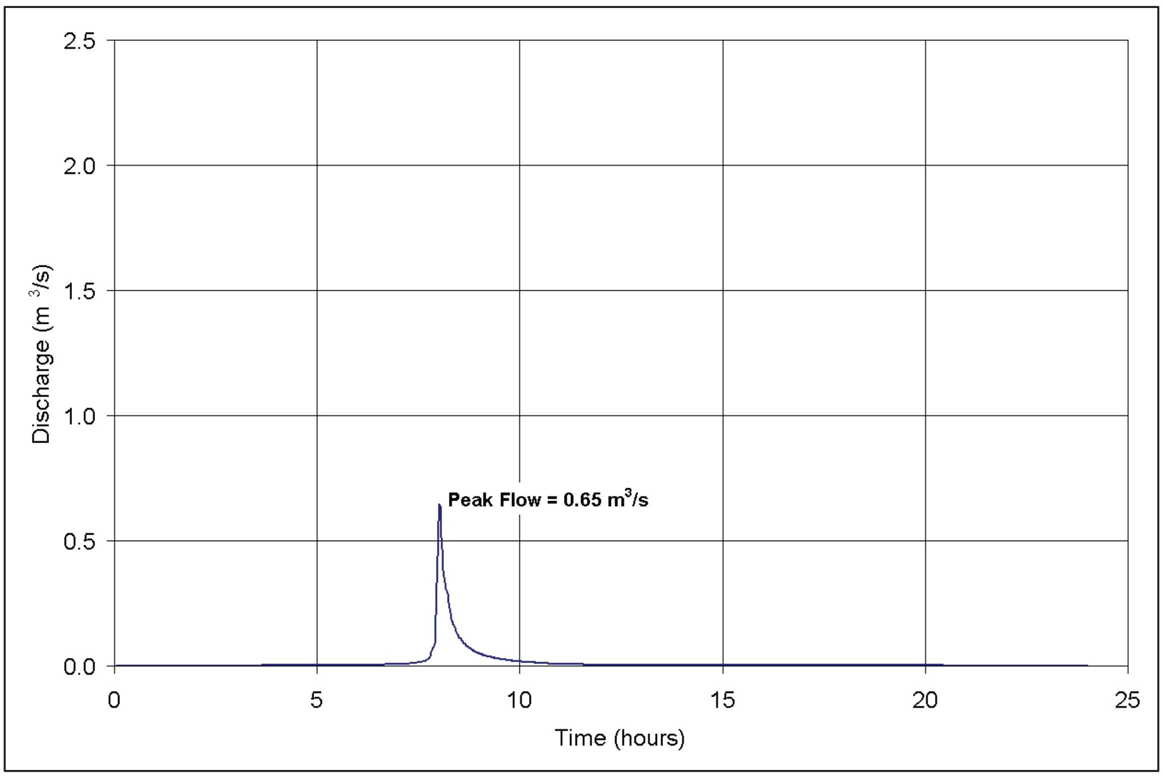


Figure 3-3: Alternative 1 Discharge Hydrograph (Area 1)

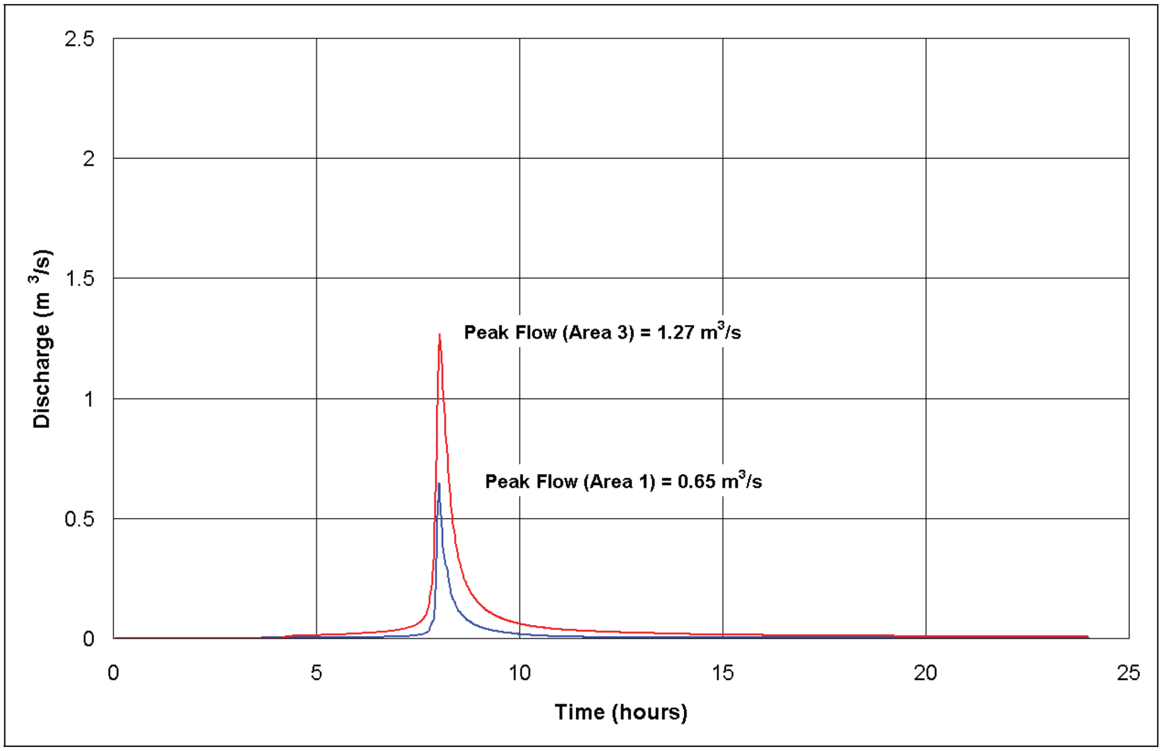


Figure 3-4: Alternative 1A Discharge Hydrographs (Areas 1 and 3)

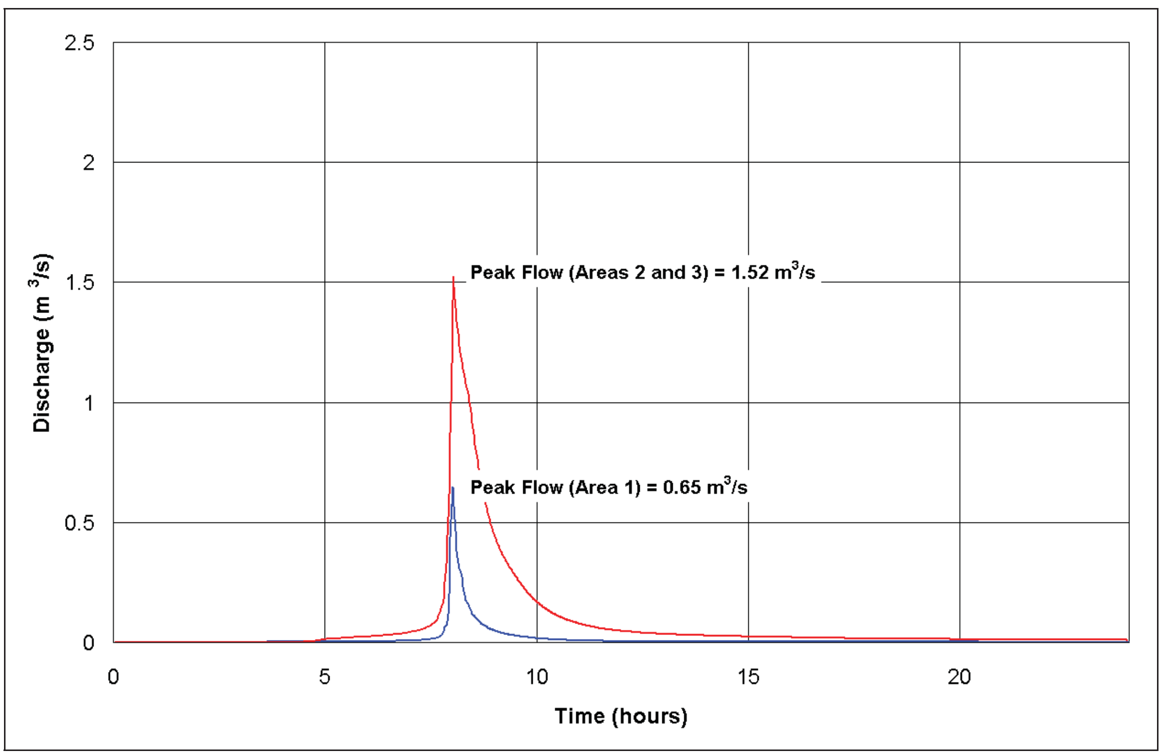


Figure 3-5: Alternative 2 Discharge Hydrographs (Areas 1, 2 and 3)

The discharges from the SWBRT and CNR Fort Rouge Yards shown in the above hydrographs were routed to the Transit LDS system leading to the Glasgow outfall, as described in the following section.

3.5 TRANSIT LAND DRAINAGE SEWER SYSTEM

3.5.1 Description of Transit LDS Site

During the course of this study, it was noted that the land drainage sewer servicing the Transit complex was located in the proximity to the FRY, and that this system had excess drainage capacity. The sewer system was constructed to provide drainage to the transit buildings and extends directly to the outfall on the Red River on Glasgow Avenue.

Upon further evaluation and after discussions with the City of Winnipeg Water and Waste and Transit Departments, the option to route the SWBRT flow to the existing 1200 mm Glasgow land drainage sewer (LDS) outfall was selected as the preferred option. Because of the proximity to the SWBRT to the Glasgow outfall, it also appeared to be the least costly option in terms of the additional piping required to divert the flow from the SWBRT.

The Winnipeg Transit Garage is located at the intersection of Osborne Street and Glasgow Avenue. The site lies adjacent to the CNR tracks and the proposed BRT underpass. The development of the Transit site in the mid to late 1960s included a land drainage sewer system with an outfall to the Red River at Glasgow Street. The existing drainage area associated with the Glasgow outfall is 9.5 ha in size. This area includes the Transit Garage and the Overhaul and Repair Shop. Attached to the Overhaul Repair Shop is the Ways and Streets Facilities Building.

The sewer system was constructed with a number of lateral sewers to drain the Transit site. As shown on Figure 3-6, the site is comprised of paved access roads, parking lots and large buildings housing bus storage and repair facilities and administration offices. The buildings are comprised of flat roofs with relatively flat drainage slopes. Runoff from the roofs is directed to the underlying LDS sewer via vertical standpipes located in the building. The surrounding parking lots are paved with relatively steep drainage slopes. The slopes were estimated at 1% grade based on site observations conducted during the course of this study.

Figure 3-6: Transit LDS System

Information used to define the pipe locations, diameters and invert elevations was taken from several sources including:

- City of Winnipeg records from the LBIS data system
- City of Winnipeg Transit Storage and Shop Facilities Site Services Storm and Sanitary Sewer Drawing No. 2185-102
- Construction drawings for the Glasgow Avenue outfall, gate chamber and concrete storm sewer from Osborne Street to the Red River

Figure 3-6 also shows the location of the LDS sewers and manholes, as defined from the above information sources. The contributing drainage area to each manhole was based on the locations of the manholes and the surrounding area, and partly from field observations. Figure 3-7 illustrates the drainage manholes and the subcatchment boundaries.

Figure 3-7: Catchment Areas in Transit LDS System

The naming convention used for the catchment areas was based on the sewer manhole to which the catchment drains. For example, catchment SC6 and SC6R (portion of garage roof area) both drain to sewer Manhole S6. The sewer manhole names were taken from the Site Services Storm and Sanitary Drawing referenced previously.

Figure 3-8 shows a profile of the land drainage sewer from the Glasgow outfall to Manhole S17 located near the west end of the transit garage. The profile illustrates the sewer invert levels and diameters of the sewers pipes. The gate chamber for the Transit LDS system is located at Manhole S21. A significant drainage feature that is shown on Figure 3-8 is the drop in the invert level of the sewer at Osborne Street between Manholes S19 and S20. The importance of this feature as it relates to the SWBRT drainage system is discussed in Section 3.5.3.

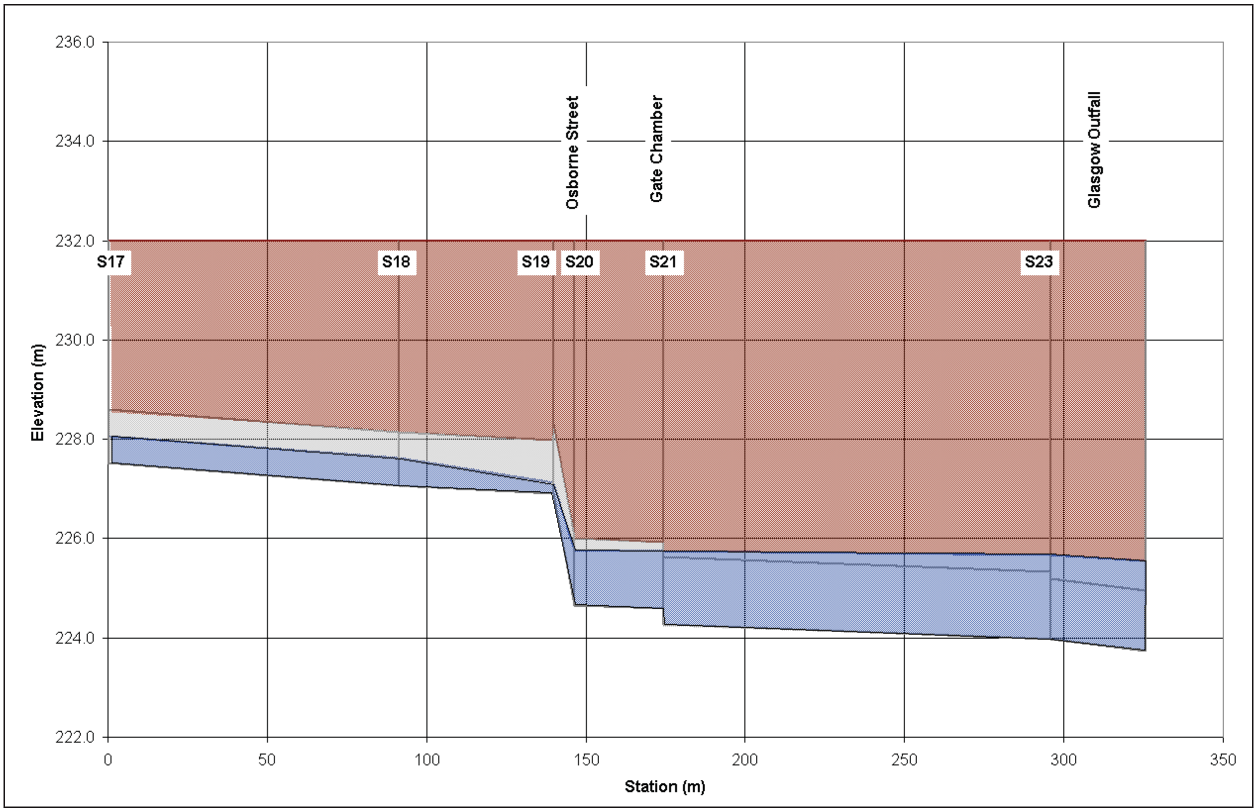


Figure 3-8: Profile of LDS from Glasgow Outfall to West End of Transit Garage (Existing Conditions – 5-Year Design Rainfall)

The XP-SWMM model for the transit site was setup based on the same parameters of the calibrated SWMM model used for the original Cockburn Study. This assumption is considered to be reasonable since the site lies at the boundary of the Cockburn and Baltimore Combined Sewer Districts. Similar to the Cockburn model, the roof drainage was modelled as separate subcatchments to adequately represent the restriction of runoff into the sewer.

3.5.2 Existing LDS Capacity

Table 3-1 lists the computed hydraulic grade line (HGL) elevation for the 1:5-year design storm at each manhole in the Transit LDS system. As noted in Table 3-1, the HGL elevation is below the ground surface elevation at every location.

Manholes S13, S6, S1, S12 and S22 are high-end sewer manholes corresponding to each lateral in the Transit LDS system. Manhole S1 has the highest HGL elevation and also the minimum freeboard in the system (1.12 m). The system therefore has significant reserve capacity to accept additional runoff from the SWBRT.

The hydraulic grade line profile from the outfall to Node S17 is also illustrated on Figure 3-8. Node S17 and S20 are significant in that these are two potential locations for inputting flow from the FRY and the SWBRT. If the point of diversion were Manhole S20, the drop in sewer invert level between Manholes S20 and S21 would provide additional capacity for diverting water to the system.

Table 3-2 lists the corresponding discharges for the 1:5 year rainfall event. The maximum flow at the Glasgow outfall for the 5-year design storm is 1.37 m^3/s.

Table 3-1: HGL Elevations and Freeboard for Existing LDS System (1:5-Year Runoff)

Manhole	HGL Elevation (m)	Depth Below Ground (m)
Outfall to Manhole S17		
Outfall	225.550	6.45
S23	225.664	6.34
S21	225.741	6.26
S20	225.756	6.24
S19	227.124	4.88
S18	227.615	4.39
S17	228.063	3.94
Manhole S17 to Manhole S13 (South Side Overhaul & Repair Building)		
S17	228.063	3.94
S16	228.896	3.10
S15	229.270	2.73
S14	230.243	1.76
S13	230.628	1.37
Manhole S17 to Manhole S6 (West Side Transit Storage Building)		
S17	228.063	3.94
S8	228.370	3.63
S7	228.613	3.39
S6	230.367	1.63
Manhole S19 to Manhole S1 (North Side Transit Storage Building)		
S19	227.124	4.88
S5	229.110	2.89
S4	229.545	2.46
S3	229.955	2.04
S2	230.537	1.46
S1	230.878	1.12
Manhole S8 to Manhole S12 (West Side Overhaul & Repair Shop)		
S17	228.063	3.94
S8	228.370	3.63
S9	229.470	2.53
S10	229.971	2.03
S11	230.285	1.72
S12	230.577	1.42
Manhole S17 to Manhole S22		
S17	228.063	3.94
S8	228.370	3.63
S22	230.510	1.49

Table 3-2: Peak Discharges for Existing LDS System (1:5-Year Runoff)

Sewer Segment	Peak Flow (m^3/s)
Outfall to Manhole S17	
L23Outfall	1.37
L2123	1.37
L2021	1.36
L1920	1.36
L1819	1.06
L1718	1.01
Manhole S17 to Manhole S13 (South Side Overhaul& Repair Building)	
L1617	0.24
L1516	0.16
L1415	0.07
L1314	0.04
Manhole S8 to Manhole S12 (West Side Overhaul & Repair Shop)	
L0908	0.31
L1009	0.26
L1110	0.22
L1211	0.17
Manhole S8 to Manhole S6 (West Side Transit Storage Building)	
L0708	0.27
L0607	0.11
Manhole S19 to Manhole S1 (North Side Transit Storage Building)	
L0519	0.25
L0405	0.25
L0304	0.21
L0203	0.18
L0102	0.11
Manhole S8 to Manhole S22	
L2208	0.06

3.5.3 Effect of SWBRT and CNR Runoff

The three alternatives (Alternatives 1, 1A and 2) for diversion of SWBRT flows to the Transit LDS system in the Baltimore Sewer District were modelled by inputting the time-discharge hydrograph from each study area at Manhole S20 in the SWMM model of the Transit LDS system.

The assumed original input location for SWBRT and CNR runoff was at Manhole S17 because it is located at the upstream end of the main trunk of the Transit LDS system. It is desirable to connect to the main trunk since it has a significantly greater capacity than the high-end lateral sewers. Also, by connecting to the upstream end of the main trunk, the cost to add piping to connect the SWBRT lift station to the Transit LDS is kept to a minimum.

However, input at Manhole S20, which is approximately 175 m downstream of Manhole S17, is better hydraulically. Because there is a significant drop in the sewer elevation between Manholes S19 and S20 (across Osborne Street), there is an opportunity to provide additional capacity for diverting water to the system. Based on Dillon's review of the SWBRT internal land drainage piping design, it was found that the connection point would need to be at Manhole S20 regardless, primarily due to limitations in the elevations of the piping caused by a low ground elevation at the high end of the SWBRT system. For this reason, Manhole S20 was selected as the input location for the majority of SWBRT and CNR runoff (SWBRT Areas 2 and 3).

During Dillon's review, it was also noted that the layout of the SWBRT land drainage system had been modified to be more cost-effective by routing drainage from SWBRT Area 1 (Underpass) to Manhole S7, located on the northern sewer lateral of the Glasgow LDS system. KGS Group has verified that the freeboard requirements for LDS systems (0.3 m minimum freeboard) would be satisfied for this scenario.

As described in Section 3.4, the hydrograph for Area 1 (SWBRT underpass) was computed for the 1:25-year rainfall event while the 5-year rainfall event was used to compute the hydrographs from Area 2 and Area 3. The HGL elevations computed at each node for the three alternatives are listed in Table 3-3. The available freeboard at each manhole is listed in Table 3-4, while the peak flows associated with the existing LDS system and Options 1 to 3 for the 5-year rainfall event are shown in Table 3-5.

Modelling for Alternatives 1 to 3 was carried out in sequence. Once it was concluded that Alternative 1 resulted in acceptable flow and hydraulic grade line conditions in the existing Transit LDS system, modelling was carried out for Alternative 1A, and finally Alternative 2. The capacity of the system is exceeded when the HGL reaches 0.3 m below the ground surface.

As mentioned briefly in previous sections, the original intent was to consider routing runoff from Area 2 south toward a relieved portion of the Cockburn District. This option will be considered as part of the next step of this study, the flow split optimization. For the flow split optimization, various options will be considered to ensure that the proposed land drainage option for the FRYs is the most cost-effective, with consideration of the Cockburn District BFR, district and regional CSO control.

Table 3-3: Peak HGL Elevation - Existing Transit LDS System and Alternatives 1, 1A and 2

Manhole	Existing LDS	Alternative 1 (Area A1)	Alternative 1A (Areas A1+ A3)	Alternative 2 (Areas A1+ A2 + A3)
Outfall to Manhole S17				
Outfall	225.550	225.550	225.550	225.550
S23	225.664	225.781	226.163	226.279
S21	225.741	225.946	226.598	226.791
S20	225.756	225.983	226.699	226.911
S19	227.124	227.164	227.194	227.240
S18	227.615	227.752	227.754	227.758
S17	228.063	228.249	228.249	228.249
Manhole S17 to Manhole S13 (South Side Overhaul & Repair Building)				
S17	228.063	228.249	228.249	228.249
S16	228.896	228.896	228.896	228.896
S15	229.270	229.270	229.270	229.270
S14	230.243	230.243	230.243	230.243
S13	230.628	230.628	230.628	230.628
Manhole S17 to Manhole S6 (West Side Transit Storage Building)				
S17	228.063	228.249	228.249	228.249
S8	228.370	228.937	228.938	228.938
S7	228.613	231.158	231.159	231.159
S6	230.367	231.259	231.260	231.260
Manhole S19 to Manhole S1 (North Side Transit Storage Building)				
S19	227.124	227.164	227.194	227.240
S5	229.110	229.110	229.110	229.110
S4	229.545	229.545	229.545	229.545
S3	229.955	229.955	229.955	229.955
S2	230.537	230.537	230.537	230.537
S1	230.878	230.878	230.878	230.878
Manhole S8 to Manhole S12 (West Side Overhaul & Repair Shop)				
S17	228.063	228.249	228.249	228.249
S8	228.370	228.937	228.938	228.938
S9	229.470	229.469	229.470	229.470
S10	229.971	229.971	229.971	229.971
S11	230.285	230.285	230.285	230.285
S12	230.577	230.577	230.577	230.577
Manhole S17 to Manhole S22				
S17	228.063	228.249	228.249	228.249
S8	228.370	228.937	228.938	228.938
S22	230.510	230.510	230.510	230.510

As shown in Table 3-3, the peak water levels along the high-end sewer laterals (i.e. S15, S14, S13, S6, S5, S4, S3, S2, S1, S10, S11, S12 and S22) are not increased over those levels that would occur under existing drainage conditions.

Table 3-4: Freeboard Associated with Existing Transit LDS System and Alternatives 1, 1A and 2

Manhole	Existing LDS	Alternative 1 (Area A1)	Alternative 1A (Areas A1+ A3)	Alternative 2 (Areas A1+ A2 + A3)
Outfall to Manhole S17				
Outfall	6.45	6.45	6.45	6.45
S23	6.34	6.22	5.84	5.72
S21	6.26	6.05	5.40	5.21
S20	6.24	6.02	5.30	5.09
S19	4.88	4.84	4.81	4.76
S18	4.39	4.25	4.25	4.24
S17	3.94	3.75	3.75	3.75
Manhole S17 to Manhole S13 (South Side Overhaul & Repair Building)				
S17	3.94	3.75	3.75	3.75
S16	3.10	3.10	3.10	3.10
S15	2.73	2.73	2.73	2.73
S14	1.76	1.76	1.76	1.76
S13	1.37	1.37	1.37	1.37
Manhole S17 to Manhole S6 (West Side Transit Storage Building)				
S17	3.94	3.75	3.75	3.75
S8	3.63	3.06	3.06	3.06
S7	3.39	0.84	0.84	0.84
S6	1.63	0.74	0.74	0.74
Manhole S19 to Manhole S1 (North Side Transit Storage Building)				
S19	4.88	4.84	4.81	4.76
S5	2.89	2.89	2.89	2.89
S4	2.46	2.46	2.46	2.46
S3	2.04	2.04	2.04	2.04
S2	1.46	1.46	1.46	1.46
S1	1.12	1.12	1.12	1.12
Manhole S8 to Manhole S12 (West Side Overhaul & Repair Shop)				
S17	3.94	3.75	3.75	3.75
S8	3.63	3.06	3.06	3.06
S9	2.53	2.53	2.53	2.53
S10	2.03	2.03	2.03	2.03
S11	1.71	1.72	1.72	1.72
S12	1.42	1.42	1.42	1.42
Manhole S17 to Manhole S22				
S17	3.94	3.75	3.75	3.75
S8	3.63	3.06	3.06	3.06
S22	1.49	1.49	1.49	1.49

Table 3-5: Peak Flows Associated with Existing Transit LDS System and Alternatives 1, 1A and 2

Sewer Segment	Existing LDS	Alternative 1 (Area A1)	Alternative 1A (Areas A1+ A3)	Alternative 2 (Areas A1+ A2 + A3)
Outfall to Manhole S17				
L23Outfall	1.37	1.94	3.17	3.45
L2123	1.37	1.94	3.17	3.45
L2021	1.36	1.94	3.16	3.45
L1920	1.36	1.94	1.94	1.94
L1819	1.06	1.65	1.65	1.65
L1718	1.01	1.60	1.60	1.60
Manhole S17 to Manhole S13 (South Side Overhaul& Repair Building)				
L1617	0.24	0.24	0.24	0.24
L1516	0.16	0.16	0.16	0.16
L1415	0.07	0.07	0.07	0.07
L1314	0.04	0.04	0.04	0.04
Manhole S17 to Manhole S12 (West Side Overhaul & Repair Shop)				
L0817	0.70	1.31	1.31	1.31
L0908	0.31	0.31	0.31	0.31
L1009	0.26	0.26	0.26	0.26
L1110	0.22	0.22	0.22	0.22
L1211	0.17	0.17	0.17	0.17
Manhole S8 to Manhole S6 (West Side Transit Storage Building)				
L0817	0.70	1.31	1.31	1.31
L0708	0.27	0.89	0.89	0.89
L0607	0.11	0.11	0.11	0.11
Manhole S19 to Manhole S1 (North Side Transit Storage Building)				
L0519	0.25	0.25	0.25	0.25
L0405	0.25	0.25	0.25	0.25
L0304	0.21	0.21	0.21	0.21
L0203	0.18	0.18	0.18	0.18
L0102	0.11	0.11	0.11	0.11
Manhole S8 to Manhole S22				
L2208	0.06	0.06	0.06	0.06

Figure 3-9 shows the HGL profile associated with Alternative 2, which considers Areas 1, 2 and 3 to be routed to the Transit LDS system. Discharge from the SWBRT Underpass was routed to Manhole S7 and discharge from Areas 2 and 3 were routed to Manhole S20. Manhole S17 was selected as the starting point of the profile because it is the upper end of the main trunk sewer. Although the profile was not extended to some of the high-end lateral sewers in the system, the results in Table 3-4 confirm that there are no points in the system where the HGL reaches 0.3 m below the ground surface. As shown in the figure, there is sufficient capacity in the system to handle the combined flows from the SWBRT and CNR for the design condition.

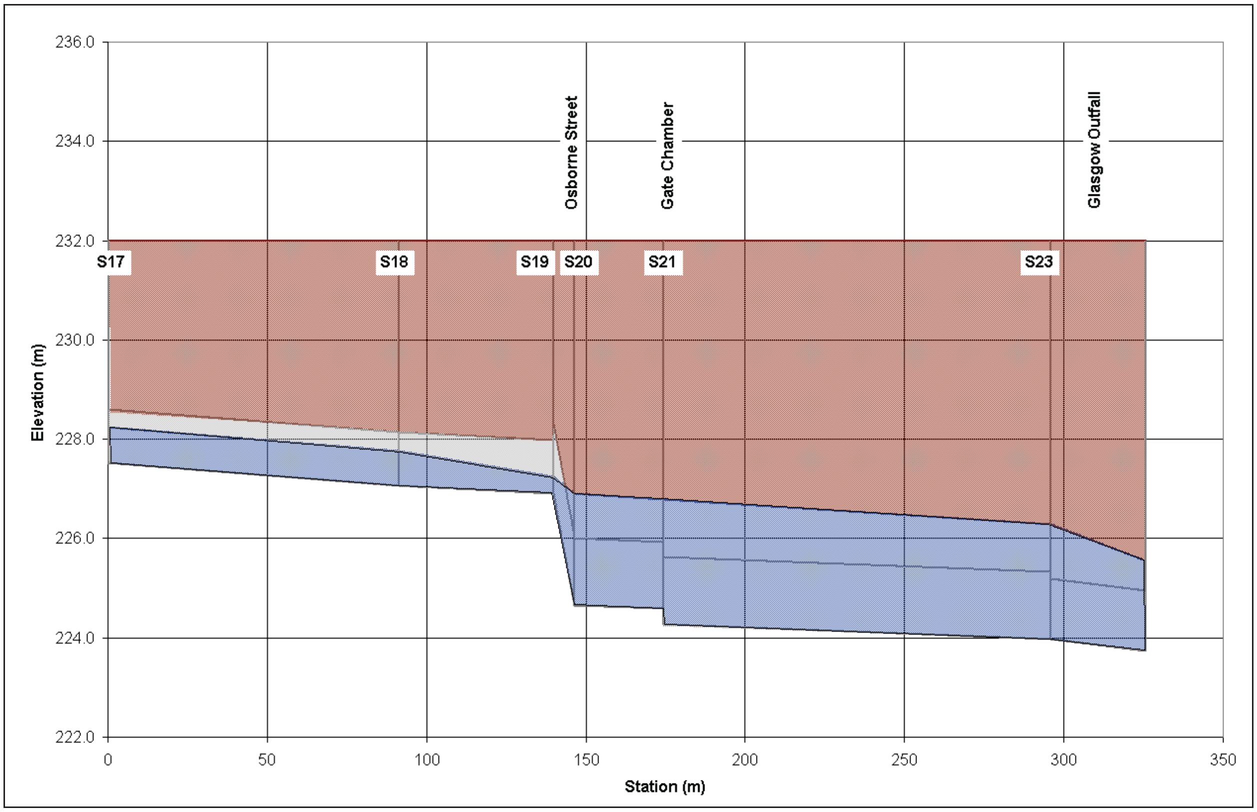


Figure 3-9: Profile of LDS from Glasgow Outfall to West End of Transit Garage (Option 2 – Combined Areas 1, 2 and 3 with Existing Runoff from Transit Site)

The option of directing the runoff to the Glasgow LDS outfall has been determined to be a viable alternative, and because of its excess capacity may have potential to service the entire FRY area.

3.5.4 Glasgow Outfall

In 2001, KGS Group carried out a riverbank stability assessment for the Churchill Drive Pathway between Woodward and Togo Avenues. This assessment included an evaluation of the slope stability of the riverbank relative to the proposed extension of the Churchill Drive Pathway as well as an update of the structural condition of the Glasgow Avenue outfall pipe.

The Glasgow Land Drainage Sewer (LDS) outfall was installed in 1968 and is located on the west bank of the Red River, on a sharp outside bend, approximately 2 km upstream of the Norwood Bridge. Based on the available background information at the time of the KGS Group 2001 study (previously issued Waterways Permits, historical site photos, and air photos), the riverbank between Togo and Woodward Avenues experienced significant overall slope movements prior to 1955 and continued until 1986. Regrading of the bank, riprap placement and the reconstruction of the Glasgow outfall were completed in 1987, following the significant bank movements in 1986. Since 1987, however, there have been no signs of major deep-seated bank movement around the outfall pipe. As part of the KGS Group 2001 study, it was concluded that the riverbank in the area of the Glasgow outfall was quasi-stable, but may continue to experience loss of bank and slope movements in the future.

An internal inspection of the Glasgow outfall was also carried out by KGS Group in November 1996 as part of KGS Group's 1998 report, "Outfall Condition and Maintenance Study Final Report", which was submitted to the City of Winnipeg Water and Waste Department. KGS Group re-inspected the outfall for the 2001 geotechnical study referenced above.

The Glasgow outfall consists of 122 m of 1350 mm diameter pre-cast concrete pipe extending from the gate chamber located on the northeast corner of Glasgow Avenue and Osborne Street to the Red River. The last section of outfall pipe then changes from pre-cast concrete to a 1200 mm diameter by 30 m long corrugated metal pipe (CMP) down to its outlet at the Red River. The results from the 2001 inspection showed that the pre-cast concrete pipe was in very good condition with only a few seeping joints over its entire length. During the 1996 inspection, the CMP portion of the pipe was found to be in good condition. Similar observations were made for the CMP portion of the pipe as part of the 2001 inspection.

As noted in the previous section, it has been recommended that all SWBRT areas (1, 2 and 3) be routed north toward the Glasgow outfall, as a base case scenario. Although the most recent outfall inspections have indicated that this outfall is in good condition, it is recommended that a complete outfall inspection (both pre-cast concrete pipe and CMP sections) be carried out during the winter of 2009 to confirm its present state. If the structural condition of the outfall has worsened, it is possible that replacement of the outfall pipe may be required and would therefore be a good candidate for replacement as part of WWD's outfall renewal program.

4.0 DIVERSION OF RUNOFF FROM SOUTHEAST JESSIE OR FRY DEVELOPMENT

The analysis described herein was carried out as an extension of the original Cockburn Study, to incorporate the Fort Rouge Yards drainage as part of a relief alternative that would consider basement flooding relief and CSO control. As such, it was recommended that a more detailed analysis be carried out of the separation/relief hybrid presented in the original Cockburn Study.

In the original Cockburn study, it was proposed that the southeast part of the Jessie District be relieved as part of the Cockburn District relief works, since this area was not relieved along with the majority of the Jessie District in the 1970s. However, because the southeast part of the Jessie District is closer to the Transit LDS system, it may be more cost-effective to divert flows to this area instead of routing flows through Cockburn West, across Pembina Highway, and to the Cockburn outfall.

Results from the analysis described in Section 3.5 show that there is enough capacity in the Transit LDS system to handle runoff from the three study areas (Study Area 1 - SWBRT underpass, Study Area 2 - remainder of the SWBRT and CNR track right-of-way, Study Area 3 - future Transit garage). Because the Transit LDS system has the capacity required to handle the runoff from both the SWBRT and CNR tracks, there may also be a possibility of diverting flow from the proposed residential FRY development or Southeast Jessie to the Transit LDS system rather than to the Cockburn Combined Sewer District. This would be beneficial, as it would result in a reduction in flows to be treated in a combined sewer system.

The design of the SWBRT is an immediate priority as construction is tentatively scheduled for Spring 2009. However, WWD wanted to ensure that no short-term decisions were made regarding the SWBRT that would affect the Basement Flooding Relief (BFR) of the Cockburn and Jessie Districts or Combined Sewer Overflow (CSO) control. In particular, opportunities to tie-in Southeast Jessie and/or the proposed Fort Rouge Yards (FRY) residential development to the land drainage system to be constructed for the BRT have been assessed. Because the results from the Glasgow LDS system review showed that the system had excess capacity, as a base case scenario, it was assumed that all land drainage flow from the SWBRT (Areas 1, 2, and 3) would be routed to the Glasgow LDS system. Therefore, the design of the BRT LDS system would not be contingent on the relief of Cockburn and Winnipeg Transit could proceed based on its tight schedule. Variations of the options considered are described in the following subsections.

XP-SWMM models of each of the options were developed to determine the hydraulic impact on the existing Transit LDS system, including the Glasgow LDS outfall. Because Dillon Consulting was responsible for the design of the internal FRY LDS system designed specifically for the SWBRT, at WWD's request, KGS Group/CH2M HILL worked with Dillon Consulting to determine the FRY internal pipe upsizing required to account for the proposed FRY residential development and/or the Southeast Jessie District. The FRY internal pipe upsizing costs referenced in the following subsections were determined based on the results from this hydraulic assessment.

4.1 OPTION 1 – BASE CASE

The following assumptions were made for the base case scenario (Option 1), where all 3 SWBRT Areas were routed to the Glasgow outfall.

a) Route SWBRT Area 1 (Underpass) to Manhole S7 (Transit LDS System – Glasgow Outfall).

b) Route SWBRT Areas 2 and 3 to Manhole S20 (Transit LDS System – Glasgow Outfall).

c) Route land drainage from Southeast Jessie to the Cockburn District, as part of the Cockburn Relief Works.

d) Route land drainage from FRY residential development to the Cockburn District, as part of the Cockburn Relief Works.

As noted above, it was assumed that all SWBRT areas would be routed to the Glasgow outfall because it was found that the Transit LDS system had enough capacity to handle the additional flows from the SWBRT. This will also allow Winnipeg Transit to proceed with their LDS design for the SWBRT without being contingent on the implementation of Cockburn Relief Works.

Figure 4-1 shows each of the areas outlined above (SWBRT Areas 1, 2 and 3 – highlighted in red, Proposed FRY Residential Development – highlighted in blue, and Southeast Jessie – highlighted in yellow). The dashed lines in the figure represents the direction to which runoff from these areas is being routed for Option 1.

The total cost for Option 1, in 2008 dollars, is approximately $11.0 Million. This cost is considered to be a conceptual engineering level estimate and includes the cost of the SWBRT Lift Station for the

Underpass, as well as contingencies (30%), engineering (15%), and burden (3%). Contingencies, engineering and burden were consistent with assumptions made for the 2007 cost estimates determined as part of the original Cockburn study.

Figure 4-1 – Option 1 (Base Case)

Drawings provided by Dillon Consulting of the internal FRY land drainage piping for Option 1 have been included in Appendix B of this Technical Memorandum. The pipe diameters and layout shown in the drawings are considered preliminary and will be confirmed by Dillon Consulting at the final design stage.

4.2 OPTION 2 – BASE CASE WITH CONSIDERATION OF FRY RESIDENTIAL DEVELOPMENT

For Options 2 to 4, it is also assumed that SWBRT Areas 1, 2 and 3 would be routed to the Transit LDS System – Glasgow Outfall. For Option 2, however, instead of routing the proposed FRY residential development to the Cockburn District, runoff from the development would be routed north to the Transit LDS System – Glasgow Outfall. The following assumptions were made for Option 2:

a) Route SWBRT Area 1 (Underpass) to Manhole S7 (Transit LDS System – Glasgow Outfall)

b) Route SWBRT Areas 2 and 3 to Manhole S20 (Transit LDS System – Glasgow Outfall)

c) Route land drainage from FRY residential development to Transit LDS System – Glasgow Outfall

d) Route land drainage from SE Jessie to the Cockburn District, as part of the Cockburn Relief Works

Figure 4-2 shows a schematic of the areas considered and where they are to be diverted for Option 2. The total cost for Option 2, in 2008 dollars, is approximately $13.2 Million (Incremental Cost = $2.2 Million). This includes the cost of the SWBRT Lift Station for the Underpass, as well as contingencies (30%), engineering (15%), and burden (3%). Also included was the FRY internal pipe upsizing required to accommodate the runoff from the FRY proposed residential development. The incremental cost of $2.2 Million represents the additional cost above the base cost of Option 1 ($11 Million) to route the proposed FRY residential development to the Transit LDS System – Glasgow Outfall.

Drawings provided by Dillon Consulting of the FRY land drainage piping for Option 2 have been included in Appendix B of this Technical Memorandum. The pipe diameters and layout shown in the drawings are considered preliminary and will be confirmed by Dillon Consulting at the final design stage.

Figure 4-2 – Option 2 (Base Case with Consideration of FRY Residential Development)

4.3 OPTION 3 – BASE CASE WITH CONSIDERATION OF SOUTHEAST JESSIE

For Option 3, as referenced previously, it is assumed that SWBRT Areas 1, 2 and 3 would be routed to the Transit LDS System – Glasgow Outfall (Option 1 – Base Case). For Option 3, however, instead of routing the runoff from Southeast Jessie to the Cockburn District, it would be routed to the Transit LDS System – Glasgow Outfall. The following assumptions were made for Option 3:

a) Route SWBRT Area 1 (Underpass) to Manhole S7 (Transit LDS System – Glasgow Outfall)

b) Route SWBRT Areas 2 and 3 to Manhole S20 (Transit LDS System – Glasgow Outfall)

c) Route land drainage from SE Jessie to Transit LDS System – Glasgow Outfall

d) Route land drainage from FRY residential development to the Cockburn District, as part of the Cockburn Relief Works

Figure 4-3 shows a schematic of the areas considered and where they are to be diverted for Option 3. The total cost for Option 3, in 2008 dollars, is approximately $13.8 Million (Incremental Cost = $2.8 Million). This includes the cost of the SWBRT Lift Station for the Underpass, as well as contingencies (30%), engineering (15%), and burden (3%). The incremental cost of $2.8 Million represents the additional cost above the base cost of Option 1 ($11 Million) to route runoff from the Southeast Jessie District to the Transit LDS System – Glasgow Outfall.

Drawings provided by Dillon Consulting of the FRY land drainage piping for Option 3 have been included in Appendix B of this Technical Memorandum. The pipe diameters and layout shown in the drawings are considered preliminary and will be confirmed by Dillon Consulting at the final design stage.

Also included in the cost was the FRY internal pipe upsizing required to accommodate the runoff from SE Jessie as well as the cost to upsize the CMP section of the Glasgow outfall ($320,000), which would be required as part of this option. The piping cost (across the CN tracks) to connect Southeast Jessie to the Glasgow LDS system was not considered as part of this cost estimate.

Based on a cursory hydraulic assessment, upsizing of the CMP section of the Glasgow outfall would be required for this option so that the Transit LDS system would have enough capacity to handle both the runoff from the SWBRT as well as runoff from Southeast Jessie. As noted above, if the CMP section of the outfall were replaced, the estimated cost would be approximately $320,000 (2008 dollars). This cost includes the pipe replacement itself ($200,000 including contingency, engineering and burden costs), the connection cost ($20,000), as well as cost for shoring of the excavation ($100,000). This does not include any bank stabilization works as it was assumed that if any bank failure would occur at this outfall, that bank stabilization would be required regardless of whether the CMP section of the outfall were upsized. However, cursory estimates of the bank stabilization works that would be recommended for this section of riverbank due to its history of previous movements would be in the order of $125,000 in 2008 dollars. This cost includes $25,000 for site access and restoration, $75,000 for a 50-metre long riprap blanket, $15,000 for final design (15%) and $10,000 for the contingency (10%). The cost of the riverbank stabilization works have not been included as part of the total cost for Option 3 ($13.8 Million) since stabilization of the bank would not be required as part of any upgrade to the CMP section of the outfall.

Figure 4-3 – Option 3 (Base Case with Consideration of Southeast Jessie)

4.4 OPTION 4 – BASE CASE WITH CONSIDERATION OF FRY RESIDENTIAL DEVELOPMENT AND SE JESSIE

For Option 4, it is assumed that SWBRT Areas 1, 2 and 3 would be routed to the Transit LDS System – Glasgow Outfall (Option 1 – Base Case). However, instead of routing the runoff from Southeast Jessie and the proposed FRY residential development to the Cockburn District, it would be routed to the Transit LDS System – Glasgow Outfall. The following assumptions were made for Option 4:

a) Route SWBRT Area 1 (Underpass) to Manhole S7 (Transit LDS System – Glasgow Outfall)

b) Route SWBRT Areas 2 and 3 to Manhole S20 (Transit LDS System – Glasgow Outfall)

c) Route land drainage from SE Jessie to Transit LDS System – Glasgow Outfall

d) Route land drainage from FRY residential development to Transit LDS System – Glasgow Outfall

Figure 4-4 shows a schematic of the areas considered and where they are to be diverted for Option 4. The total cost for Option 4 in 2008 dollars, is approximately $15.9 Million (Incremental Cost = $4.9 Million). This includes the cost of the SWBRT Lift Station for the Underpass, as well as contingencies (30%), engineering (15%), and burden (3%). The incremental cost of $4.9 Million represents the additional cost above the base cost of Option 1 ($11 Million) to route runoff from the Southeast Jessie District and the proposed FRY residential development to the Transit LDS System – Glasgow Outfall.

Also included was the FRY internal pipe upsizing required to accommodate the runoff from SE Jessie and the proposed FRY residential development, as well as the cost to upsize the CMP section of the Glasgow outfall ($320,000), as described in Section 3.5.4, which would be required as part of this option. The piping cost (across the CN tracks) to connect Southeast Jessie to the Glasgow LDS system was not considered as part of this cost estimate.

Drawings provided by Dillon Consulting of the FRY land drainage piping for Option 4 have been included in Appendix B of this Technical Memorandum. The pipe diameters and layout shown in the drawings are considered preliminary and will be confirmed by Dillon Consulting at the final design stage.

Figure 4-4 – Option 4 (Base Case with Consideration of FRY Residential Development and SE Jessie)

4.5 SUMMARY OF OPTIONS

Table 4-1 compares the total costs of Options 1 to 4, and also shows the incremental cost of considering each area (SE Jessie and Proposed FRY Residential Development) separately and combined. The incremental cost is the additional cost required on top of the base case scenario (Option 1) to pursue the other options. As shown in the table, there only appears to be a small incremental benefit (approx. $100,000) from considering both the proposed FRY residential development and Southeast Jessie (Option 4).

Table 4-1 – Summary of Options

Options	Total Cost (2008 dollars)	Incremental Cost (2008 dollars)
Option 1 – Base Case	$11.0 Million	-
Option 2 – Base Case & FRY Residential Development	$13.2 Million	$2.2 Million
Option 3 – Base Case & SE Jessie	$13.8 Million	$2.8 Million
Option 4 – Base Case, FRY Residential Development & SE Jessie	$15.9 Million	$4.9 Million

Although the costs listed in Table 4-1 provide a good comparison of each option, it is critical that these options be considered with integration of Cockburn Relief. The consideration of Cockburn Relief is necessary so that no short-term decisions are made that would impact basement flooding relief of the Cockburn and Southeast Jessie Combined Sewer Districts. District and/or regional CSO issues should also be addressed. A total investment analysis was carried out as part of this evaluation and is discussed in more detail in Section 6.0.

5.0 FRY INTEGRATION WITH COCKBURN RELIEF

Development of the Fort Rouge Yards will require the provision of municipal services, with the type and extent of services depending on the development. The bus rapid transit corridor will require portions of the existing Fort Rouge Yards to be paved and the grading improved which will increase the rate of runoff and necessitate land drainage servicing. The residential development will require land drainage servicing as well as wastewater sewer servicing. The discharge location for the servicing is a key consideration in its design and operation and greatly influences its cost.

The FRY area is bounded by a number of combined sewer districts. The southern portion intersects the Cockburn Combined Sewer District, while the northern portion abuts the Baltimore and Jessie Combined Sewer Districts. Being adjacent to combined sewer districts limits the opportunities for land drainage servicing. The City imposes development controls in combined sewer districts, prohibiting increases to the rate of outflow as a method of controlling combined sewer overflows.

The Cockburn Sewer Relief study provides an opportunity for integration of the FRY development into the Cockburn Relief works. The opportunities include routing of land drainage from the combined sewer districts into the FRY area, or routing land drainage out of the FRY area to new separated sewers in the combined sewer districts. The scope of this study considers only the land drainage aspect, and not wastewater servicing.

5.1 COCKBURN HYBRID

Routing of FRY land drainage to an adjacent combined sewer district would only be permitted if the receiving sewer were a separate land drainage sewer. The Cockburn District currently does not have separate land drainage sewers, but they are being considered for future implementation under the basement flooding relief study.

Partial land drainage separation for the Cockburn District was recommended in the Cockburn conceptual design report, based on the mandate for basement flooding relief without consideration for CSO control. Partial land drainage separation provides an ideal situation for the FRY connections since the land drainage sewers could be connected directly to the new separate sewers, without any impact on the sanitary component. The drawback in proceeding with this approach is that it is unclear if the Cockburn decision will be made based on this perspective, or whether a broader view on the basement flooding program will be taken with potential for integration of combined sewer overflow control.

If the Cockburn basement flooding relief decision perspective considers integration of CSO control without a regional CSO perspective, the recommended alternative is to install relief sewers, using the sunken relief concept. Connection of FRY land drainage would be counter productive since it would be blended with combined sewage, temporarily stored in the sunken relief, and then routed to a wastewater treatment plant for processing. This would require enlarging of the sunken relief piping and an increase in operational and maintenance costs to handle the additional pumping and treatment.

The third perspective involves considering regional combined sewer overflow control. It would use a storage transport tunnel and function conceptually much like sunken relief, with the exception being it would connect several districts together. The drawback to connecting the FRY would be the same as for the sunken relief option.

In reviewing the FRY servicing needs with respect to the three decision perspectives, it became apparent that the hybrid alternative would be the most flexible in meeting the FRY objectives, and could potentially be implemented without compromising future decisions made under each perspective. The hybrid option was included in the Cockburn conceptual design report, and uses partial separation in Cockburn West and relief piping in Cockburn East, as shown in Drawing 1. The partial LDS piping would be adjacent to the southern point of FRY and a relatively short distance for connection of the piping systems.

The hybrid has two main advantages when considering the FRY development:

- The hybrid includes a new land drainage outfall which would permit FRY flows to drain directly to the river. The outfall is located in close proximity to FRY, and the outfall and connecting pipes could readily be staged as part of the Cockburn project to accommodate the development.

- The hybrid option would preserve flexibility for future CSO options. The western partial separation can proceed without making any final decisions on the relief of Cockburn East. If the ultimate decision on the east is also land drainage separation, it can be carried out consistent with the west. If the CSO program drives the decision to cost effectively store combined sewage, the relief piping alternative can be installed in the east with sunken relief. The sunken relief would be similar in concept to the district-wide relief piping option, but less of it would be required. The regional tunnel would, in concept, be similar to the sunken relief option, but because of the reduced scale may not have the same economic advantage.

The FRY addition provided a new option for the Southeast Jessie area. Instead of routing the discharge from Southeast Jessie to the Cockburn outfall, it could be routed to the proposed FRY Trunk. This would mean that Southeast Jessie would not be included in the hybrid alternative, and has the potential for reduced cost and an advanced schedule for Southeast Jessie relief.

5.1.1 Hybrid Model

The Cockburn hybrid, as presented in the conceptual report, was updated for inclusion of the FRY area. The area was modeled with a number of independent XP-SWMM models:

- A partial LDS separation model was used for Cockburn West, with the inflows being from the surface drainage in the separated area.
- The existing combined sewer area in Cockburn West collects the un-separated surface drainage. It also collects all of the foundation drainage from the separated and un-separated areas. A methodology for estimating and modeling the foundation drainage from separated areas is included in the Cockburn conceptual report.
- A conventional model of the existing system was used for Cockburn East to model relief piping.

5.1.2 Cockburn Hybrid Model Update

For the FRY addition to the hybrid option, the partial separation of Cockburn West would remain the same, with potential modifications to Cockburn East and the outfall location. The conceptual report identified a premium of $4,209,000 or about a 10 percent premium for selection of the hybrid option over partial separation. The option was reassessed and updated for the FRY addition scope change with respect to it being the recommended option with the FRY drainage included. In total, the premium for selection of the hybrid over partial separation was determined to be $6,633,000 in terms of 2008 values, with all markups included.

The following updates were made:

- Additional consideration of the outfall location indicated that more extensive riverbank stabilization would be required than had previously been allowed for in the Cockburn conceptual report. A premium of $1,400,000, which includes all markups was included. Further outfall discussion is included in Section 6.3.

- Connection of the FRY residential area would require that partial LDS separation be extended into Cockburn East, as shown in Figure 5-1 for options 1 and 3. New piping would be required along Argue Street, and the originally planned connecting pipe increased in diameter to accommodate the higher flows. The increment for connection of the FRY to the hybrid option was estimated at $2,451,000 in terms of 2008 values including all markups.

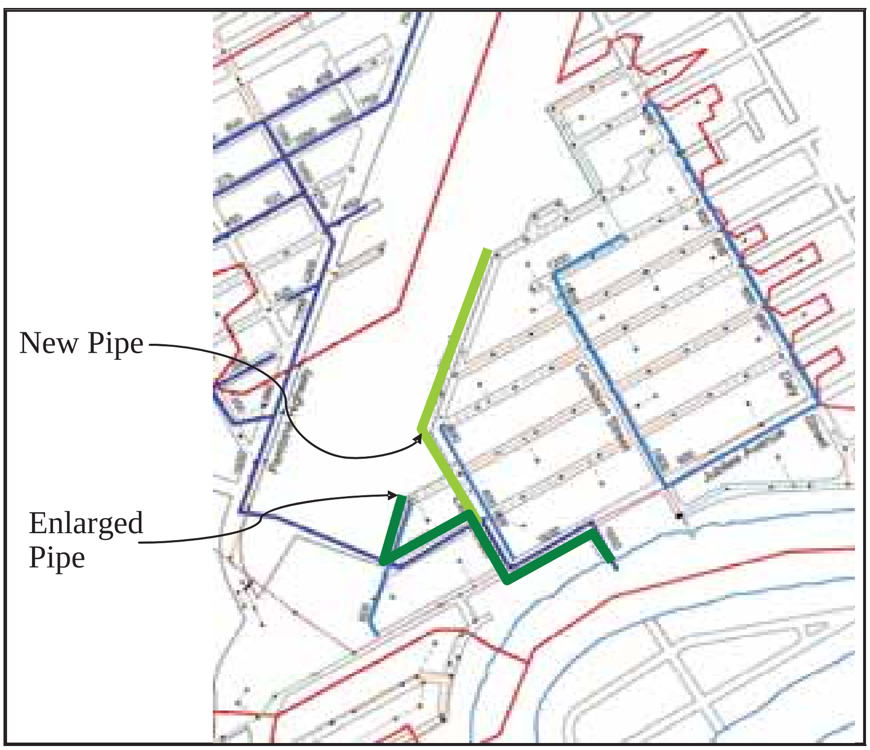


Figure 5-1 – FRY Land Drainage Connection to Cockburn Hybrid (With the Elm Park Bridge Outfall Option)

- The hybrid models were also rerun with the FRY residential area included to evaluate upstream impacts. Two areas were identified where the hydraulic grade line was marginal with respect to the design criteria, and piping revisions were made to improve the level of protection, at a cost increase of $1,000,000.

The hybrid evaluated in the conceptual report included a new outfall at the Elm Park Bridge location, adjacent to the Bridge Drive Inn. In reviewing the hybrid layout, the City expressed concern with the new outfall location, and requested the option of utilizing the existing Cockburn outfall location for the partial separation discharge. This would involve retaining the Cockburn East discharge point there as well. In this way, there would only be one outfall location, and issues such as riverbank stability and public perception would be easier to manage.

Realignment of the hybrid outfall to the existing Cockburn outfall location would be a viable option and is discussed in more detail in Section 6.3. In general, it would require an additional length of large diameter pipe between the Elm Park Bridge site and Cockburn Street. Since the existing combined sewer trunk would still be required on Cockburn for Cockburn East combined sewage flow, a parallel piping arrangement would be required, making for tight site conditions.

The FRY integration and initial total investment analysis assumes the hybrid outfall will be located at the Elm Park Bridge. Alternative outfall locations are discussed subsequently in Section 6.3.

5.2 SOUTHEAST JESSIE

Southeast Jessie is a part of the Jessie Combined Sewer District, and is only the portion of the Jessie District south of Grant Avenue. When relief piping was installed in the 1970s, Southeast Jessie was excluded, presumably because the thinking at the time was that it could be more cost effectively relieved if included with the Cockburn District relief. The subarea is now essentially land-locked, in that it is at the upper end of two sewer districts without a convenient or cost effective discharge location.

The Cockburn study assessed the level of service in Southeast Jessie and found it to be a very flood prone area, with hydraulic results predicting significant basement flooding for even a 1-year storm. This exceptionally low level of service would mean frequent and extensive basement flooding could be occurring, or alternatively, if local residents have protected themselves through use of backflow prevention devices, the problem would present itself as a low level of protection against street flooding, since it is severely limited in hydraulic capacity. The Basement Flooding Relief Program Review – 1986 document, which established the basis for the council approved policy, recognized the need for addressing such circumstances through a targeted localized relief approach, for which Southeast Jessie would be an ideal candidate. Relief of the subarea should be considered not only because of its high benefit-cost ratio, but to eliminate a severely under serviced area relative to current standards and in comparison to other areas of the city.

The Cockburn study options considered adding Jessie to the relief piping networks, with routing the outflows south to the Cockburn outfall. The Cockburn piping would be enlarged to accommodate the increased flows.

The FRY development provides a new option for Jessie basement flooding relief upgrading. Partial land drainage separation from Jessie could be discharged to the new FRY land drainage sewer. The service would be fully compatible since both would collect and discharge only storm water, and the option would have a positive effect on combined sewer overflows since storm water would be taken out of the Jessie District, thereby reducing the CSO volume.

5.2.1 Southeast Jessie Servicing

Southeast Jessie is adjacent to Cockburn West and like Cockburn West was planned to be relieved by installation of partial land drainage separation under the hybrid option. As shown in Drawing 1, the partial separation piping would cover a large portion of the area. Based on estimates prepared for the conceptual report, the cost of partial land drainage sewer separation for Southeast Jessie, excluding routing of the flows to the Cockburn District would be $3,387,000 in 2008 dollars, including contingencies, engineering and burden costs.

Southeast Jessie flows for the hybrid option would be routed through future Cockburn Trunk sewers to the Cockburn outfall. The discharge point from Jessie would be located on the southern part of the area, which is in the relative vicinity of the Cockburn Trunk. No new additional sewers are required in the Cockburn District to route the Jessie flows, but they would have to be oversized for a considerable length. Based on information in the Cockburn conceptual report, it was estimated that the connection to Cockburn and the oversizing would cost $3,165,000 in 2008 dollars, including contingencies, engineering and burden costs.

Rerouting Southeast Jessie to FRY would require realignment of the Jessie partial separation piping and a trunk sewer connection to the FRY Trunk. The partial land drainage realignment assumed the discharge point would be at Pembina Highway and Carter Avenue, with the discharge trunk routed to the east at right angles to the railway track crossings, as shown in Figure 5-2.

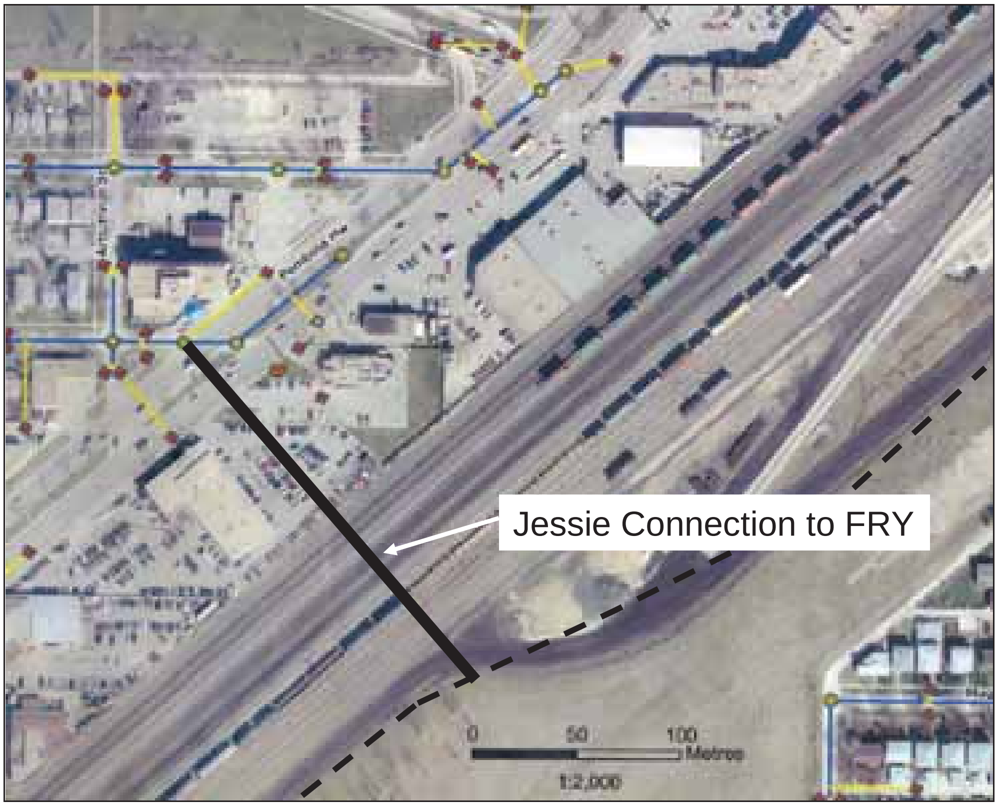


Figure 5-2 – Rerouting Southeast Jessie to FRY

The railway crossing would require special considerations. It would cross underneath multiple tracks, and need to meet the standards for railway crossings. As part of a preliminary assessment of this option, the document, “Railway Association of Canada Standards Respecting Pipeline Crossings under Railways” TC number E-10, was reviewed. It was found that there were no references in the document that would prohibit the crossing, and no practical considerations such as depth of bury that would have a significant adverse impact on the installation. The local railroad authority was not contacted about the approval process.

The pipeline would have to be designed for the appropriate railway loading, which in this case would extend for approximately 100 m because of the multi-track crossing. The typical installation is to encase the carrier pipe in a larger casing pipe, but this requirement can be waived if the carrier pipe is suitably designed.

The cost of providing the pipeline from the Southeast Jessie location to the FRY Trunk was estimated at $1,698,000 in 2008 dollars, including contingencies, engineering and burden costs.

6.0 TOTAL INVESTMENT ANALYSIS

A total investment analysis was used to evaluate the economics of the combined FRY and Cockburn relief project drainage options. The analysis considers the combined total capital costs of all works within the study area, regardless of purpose, ownership or authority, and assumes that all of the work will be completed.

The options presented in Section 4.0 included the costs for all servicing within the Fort Rouge Yards area but not those connecting to or within the Cockburn District. The total investment analysis presented in this section combines the internal FRY and Cockburn costs to present the total of all values. A summary of the options considered is shown in Table 6-1.

Table 6-1 – Total Investment Evaluation Options

Option	Discharge Location			Cockburn Relief Option
	SWBRT (Areas 1, 2 & 3)	FRY Residential	Southeast Jessie	
1	Glasgow	Cockburn	Cockburn	Hybrid
2	Glasgow	Glasgow	Cockburn	Partial LDS
3	Glasgow	Cockburn	Glasgow	Hybrid
4	Glasgow	Glasgow	Glasgow	Partial LDS

All costs are compared in terms of 2008-dollar values. Many of the costs were derived from the Cockburn Conceptual Design, which utilized both 1991 and 2007 cost bases. The 1991 base was used for relief project prioritization under the basement flooding relief program. The costs are not relevant in today's terms, but they provide a common basis for comparison among districts. Cockburn project costs were reported in 2007-dollar values for budget estimates, which was the year in which the draft report was completed. The increase from 2007 to 2008 values was made by adding a three percent inflation factor.

The project costs are fully marked up, as follows:

- 15% Engineering
- 3% Burdens
- 30% Contingency

The mark-up factors were applied uniformly to the construction cost estimates for both the Cockburn and FRY projects, and are consistent with those used in the Cockburn report. It should be noted that project specific mark-ups reported elsewhere for the SWBRT project may be different since the project is proceeding beyond the conceptual stage and mark-up refinements are normally made as projects evolve.

The total investment analysis results are presented in Table 6-2.

Table 6-2 – Total Investment Analysis

Option	Jessie with Cockburn Partial Separation	Jessie with Cockburn Hybrid[2]	Cockburn Alone Partial Separation	Jessie Alone Partial Separation	Jessie Connection to FRY	Refer to Table 4-1		Residential Development to Cockburn	Total Investment ($2008)
						SWBRT[3,4] (Areas 1,2 & 3) to Glasgow	Glasgow Outfall Upgrade		
1 (Base)	$38,796	$6,633	-	-	-	$10,952	-	$2,451	$58,832
2	$38,576	-	-	-	-	$13,172	-	-	$51,748
3	-	$6,633	$32,245	$3,387	$1,698	$13,468	$320	$2,451	$60,202
4	-	-	$32,025	$3,387	$1,698	$15,540	$320	-	$52,970

Notes: 1) Costs are in 2008 dollars (x1,000).

2) Cost includes $1.4 million riverbank stabilzation for new outfall at Elm Park Bridge.

3) Costs for SWBRT were updated by Dillon subsequent to September 30, 2008 meeting.

4) Underpass cost is included with markups.

6.1 TOTAL INVESTMENT OPTION DESCRIPTIONS

The investment analysis is presented for the four options described in Table 6-1.

6.1.1 Option 1 – Base Case

This option was referred to as the base case since it was originally thought to be the most likely option for project integration. It assumes the FRY area will be serviced internally except for the residential development, which would be routed to the Cockburn District.

- The hybrid option would be selected as the method of relief for the Cockburn District. Partial LDS separation would be constructed in Cockburn West with a new outfall constructed at the Elm Park Bridge (BDI site). The cost increment to switch from the Cockburn partial LDS separation option to the hybrid option would be $6,633,000, which includes riverbank stabilization and protection for the new outfall.

- Southeast Jessie would be routed to the Cockburn District.

- SWBRT areas 1, 2 and 3 would be serviced internally and discharged to the existing Glasgow outfall. There would be no need to upgrade the Glasgow outfall.

- The FRY residential area would discharge to the Cockburn hybrid system. Partial land drainage separation would be extended northward from the new separate LDS sewer to the boundary of FRY to service the FRY future development.

The total cost for this option is $58,832,000.

6.1.2 Option 2 – Totally Independent Projects

Option 2 is for totally independent projects, as would be the case if the projects were owned and undertaken by different entities. There would be no need to implement the Cockburn hybrid to accommodate the FRY development:

- It was assumed the partial separation option would be selected for the Cockburn District. This option was discussed previously as the recommended option if the Cockburn basement flooding relief alternative selection is to be based on a mandate of basement flooding relief alone, without consideration for combined sewer overflow control.

- Southeast Jessie would be included in the Cockburn relief project.

- Servicing of the FRY undeveloped land to Cockburn, as is currently included in the Cockburn conceptual design report, would not be required, resulting in a $220,000 cost reduction.

- SWBRT areas 1, 2 and 3 would be serviced internally and discharge to the existing Glasgow outfall.

- The FRY residential area would be serviced internally and discharge to the Glasgow outfall.

- There would be no need to upgrade the Glasgow outfall.

The total cost for this option is $51,748,000.

6.1.3 Option 3

Option 3 is the same as Option 1 except that Southeast Jessie would be routed to FRY.

- The hybrid option would be selected as the method of relief for the Cockburn District. Partial LDS separation would be constructed in Cockburn West with a new outfall constructed at the Elm Park Bridge (BDI site). The cost increment to switch from the Cockburn partial LDS separation option to the hybrid option would be $6,633,000, which includes riverbank stabilization and protection for the new outfall.

- Removal of Southeast Jessie from Cockburn relief would save $6,551,000 ($38,796,000 minus $32,245,000). This includes elimination of the local collection piping and the oversizing of the trunk sewers from Cockburn West to the outfall, which would no longer carry the flow from Jessie.

- Jessie relief would then be directed to the future FRY Trunk. The partial LDS separation within Jessie would cost $3,387,000 and would require a new discharge connection to FRY.

- The connection from Jessie to FRY is a fairly short connection but, but would run underneath a major railway yard with multiple tracks. The connection to FRY was estimated at $1,696,000.

- SWBRT areas 1, 2 and 3 would be serviced internally and discharged to the existing Glasgow outfall.

- The FRY Trunk would be oversized for the Jessie connection. The oversizing of the trunk is included in Option 3 as discussed in Section 4.3. The FRY cost increment assumes oversizing for the Jessie flows but not for the pipe connecting from the FRY Trunk to the Jessie District. A pipe stub would be provided to facilitate installation at a later date.

- The FRY flows would increase significantly because of the Jessie addition and all be routed to the Glasgow outfall. An upgrade to the outfall would be required to improve its hydraulics.

- The FRY residential area would discharge to the Cockburn hybrid system. Partial land drainage separation would be extended northward from the new separate LDS sewer to the boundary of FRY to service the FRY future development.

The total cost for this option is $60,202,000.

6.1.4 Option 4

With Option 4, the projects are fully independent as they are in Option 2, except that Southeast Jessie would be routed to FRY.

- It was assumed the partial separation option would be selected for the Cockburn District. This option was discussed previously as the recommended option if the Cockburn basement flooding relief alternative selection is based on a mandate of basement flooding relief alone without consideration for combined sewer overflow control.

- Removing Southeast Jessie from Cockburn relief would save $6,551,000 ($38,796,000 minus $32,245,000). This includes elimination of the local collection piping and the oversizing of the trunk sewers from Cockburn West to the outfall, which would no longer carry the Jessie flows.

- Servicing of the FRY undeveloped land to Cockburn, as is currently included in the Cockburn conceptual design report, would not be required, resulting in a $220,000 cost reduction.

- Jessie relief would then be directed to the future FRY Trunk. The partial LDS separation within Jessie would cost $3,387,000 and would require a new discharge connection to FRY.

- The connection from Jessie to FRY is a fairly short connection but would run underneath a major railway yard with multiple tracks. The connection to FRY was estimated at $1,696,000.

- FRY areas 1, 2 and 3 would be serviced internally and discharged to the existing Glasgow outfall.

- The FRY residential area would be serviced internally and discharge to the Glasgow outfall.

- The FRY Trunk would be oversized to accommodate the Jessie connection and the FRY residential area. The FRY cost increment assumes oversizing for the Jessie flows but not for the pipe connecting from the FRY Trunk to the Jessie District. Provision for the connection would be provided to facilitate installation at a later date.

- The FRY flows would increase significantly because of the Jessie addition and all be routed to the Glasgow outfall. An upgrade to the outfall would be required to improve its hydraulics.

The total cost for this option is $52,970,000.

6.2 DISCUSSION OF COST RESULTS

The results indicate that from a total investment basis, the lowest cost is for Option 2, which is to proceed with the projects independently.

The evaluation indicates there would be about a $1,300,000 premium to route Southeast Jessie through the FRY as compared to routing it to Cockburn (Option 1 versus 3, or 2 versus 4). While there is a significant saving in not having to upsize the Cockburn Trunk for Jessie flows, the costs to reroute it to the FRY, oversize the FRY Trunk and upgrade the Glasgow outfall is more than what would be saved.

There was no cost advantages found for routing internal FRY drainage to the Cockburn District. It had been predetermined that FRY areas 1, 2 and 3 would be discharged to the Glasgow outfall, and the evaluation suggests there is an advantage to route the residential development to the Glasgow outfall as well. The analysis presented in Table 6-1 assumed that routing of land drainage flows would require implementation of the hybrid option in Cockburn, which would necessitate selection of a $6,633,000 more expensive relief option for the Cockburn District. This would not nearly be offset by the benefit of removing the residential area from FRY.

In actuality, the selection of the hybrid option would be made for combined sewer overflow control reasons and not just to accommodate the residential development, and therefore attributing the cost to FRY servicing for the evaluation may not be appropriate. As a result, a second review of the residential area servicing was made based on use of the partial LDS separation option, which was recommended if the perspective for Cockburn relief was for basement flooding alone, and not combined sewer overflow control.

The second evaluation using the partial LDS separation option for the entire Cockburn District determined that the connection from the FRY residential area could be made for $1,792,000 instead of $2,451,000 as determined for the hybrid. The resulting cost for Option 1 would be reduced to $51,540,000, which is very close to Option 2 at $51,748,000. The disadvantages with proceeding with the partial separation option are that the decision regarding Cockburn relief has not been made and there is no certainty to timing.

It can be concluded from the foregoing that on a total investment basis, there is no advantage or lost opportunities in proceeding with the FRY developments and Cockburn District relief works independently. There may in fact be more advantage in proceeding with them independently because of potential scheduling conflicts.

6.3 ALTERNATIVE OUTFALL LOCATIONS

The outfall for the hybrid option was located at the Elm Park Foot Bridge (Bridge Drive Inn) in the Cockburn conceptual design report, and this location was considered in the preceding FRY integration evaluations. However, based on discussions with WWD regarding concerns over the BDI outfall location, it was recommended that the alternative Cockburn and Calrossie outfall locations be considered.

As discussed previously, for the Cockburn hybrid option, it is necessary to construct a new LDS outfall for partial separation of Cockburn West. A total of 3 potential outfall locations have been identified:

1. Existing Cockburn Flood Pump Station (FPS)
2. Elm Park Foot Bridge (Bridge Drive Inn) – Riverdale Street and Jubilee Avenue
3. Existing Calrossie LDS Outfall (Toilers Park)

The proposed outfall locations are shown in Drawing 2.

For the Cockburn FPS and the Calrossie outfall locations, it is assumed that the existing outfalls would be either upsized or paralleled, whereas a new outfall would need to be constructed for the Elm Park Foot Bridge (Bridge Drive Inn) location. A description of the riverbank condition at these locations is included in the following subsections.

6.3.1 Existing Cockburn Flood Pump Station

The Cockburn Flood Pumping Station was constructed in the mid 1950's and is a combination flood and wastewater pumping station located on the north bank of the Red River approximately 200 m downstream of the Elm Park Foot Bridge. Discharge from the 1830 mm diameter outfall resulted in extensive scour and erosion, creating localized oversteepening of the riverbank. As a result, significant remedial works were constructed in 1989, which included:

- Replacement of the 1830 mm diameter high level outfall;
- Extension of the existing 2675 mm diameter low level outfall;

- Construction of a rockfill toe berm to increase riverbank stability and arrest shoreline erosion;
- Installation of a grout apron around the outfall pipe outlets; and
- Regrading of riverbank.

A preliminary review of stereo aerial photographs taken after construction of the remedial works indicate that there is no evidence of subsequent riverbank movement or shoreline erosion within the limits of the works. A site visit on July 9, 2008 did not reveal any evidence of recent riverbank movement at the Cockburn Flood Pumping Station site as shown on Photos 1 to 3 included in Appendix C.

Based on this preliminary review and the site inspection completed in July 2008, it is unlikely that any additional riverbank stability improvement works are required at the existing Cockburn Flood Pump Station. No evidence of riverbank instability has been noted at the site since the construction of the remedial works completed in 1989.

6.3.2 Elm Park Foot Bridge (Bridge Drive Inn)

The proposed outfall would be located on the north bank of the Red River along a relatively sharp outside bend immediately downstream of the Elm Park Foot Bridge as shown in Drawing 2.

The riverbank along this outside bend is subject to ongoing shoreline erosion, slumping and ultimately bank loss as shown in Photos 4 and 7 in Appendix C. Bank loss is also evident along the shoreline of the two properties located immediately upstream of the bridge. At the proposed site, the riverbank is hummocky and irregular with evidence of historic bank movement and shoreline erosion. Cracking of the grouted apron adjacent to the west abutment of the Elm Park Foot Bridge was also noted during a site visit on July 9, 2008 (See Photo 8).

Based on the site inspection and a preliminary review of aerial photographs, this proposed location for a new outfall would require significant riverbank stability improvement works in order to improve existing riverbank stability and minimize the risk of riverbank movement impacting the proposed outfall pipe. The riverbank stability improvement works recommended would include a rockfill rock column shear key, a rockfill riprap blanket, and some minor bank regrading.

The estimated cost for the required riverbank stability improvement works at the Elm Park Foot Bridge location is $1,424,000 (2008 dollars) and includes the following:

▪ Site access and restoration (including bank regrading)	$75,000
▪ 70 lineal metres of shear key constructed from rockfill columns	$560,000
▪ 70 metre long rockfill riprap blanket	$105,000
▪ Sheet piling to protect existing bridge abutment and to allow for equipment access to lower bank area	$400,000
▪ Final Design (±15%)	$170,000
▪ Contingency (±10%)	$114,000
Total Estimated Cost for Riverbank Stability Improvement Works	***$1,424,000***

6.3.3 Existing Calrossie LDS Outfall (Toilers Park)

In 2003, an 80 m length of the existing 450 mm diameter Calrossie Boulevard outfall was re-routed through Toilers Park and upgraded to a 600 mm diameter concrete trunk and 600 mm diameter CMP outfall. In addition to the re-routing of the new outfall, a 6.0 m long by 10 m wide by 0.75 m thick rockfill riprap splash pad was constructed at the outlet.

A review of background information showed that ongoing shoreline erosion and retrogressive bank slippage was occurring downstream of Toilers Park. While upstream shoreline erosion was evident, retrogressive bank slippage was not occurring. Along this upstream section of river, the banks are lower with steeper nearly vertical side slopes. At Toilers Park, shoreline erosion was occurring but there was no direct evidence of deep-seated overall bank failures. Based on these observations and a detailed site investigation, no riverbank stability improvement works were constructed as part of the Calrossie Boulevard outfall replacement.

Although no riverbank stability improvement works would be required at this location, it is recommended that a rockfill riprap blanket be installed as erosion protection to arrest shoreline erosion should this site be chosen for the Cockburn Relief – LDS Separation outfall.

The estimated cost for the required erosion protection works at the existing Calrossie LDS Outfall (Toilers Park) site is $81,000 (2008 dollars) and includes the following:

▪ Site access and restoration	$20,000
▪ 30 metre long rockfill riprap blanket	$45,000
▪ Final Design (±15%)	$9,500
▪ Contingency (±10%)	$6,500

Total Estimated Cost for Erosion Protection Works ***$81,000***

6.3.4 Evaluation of Outfall Locations

Although the costs of any riverbank stabilization works required for the outfall locations have been summarized in the previous subsections, consideration of the piping cost associated with each location is critical, particularly since the piping costs are generally significantly higher than the costs of the recommended riverbank stabilizations works.

The costs were summarized for each location by tabulating the riverbank stabilization costs along with the cost of piping from the intersection of Lilac Street and Jubilee Avenue, which is a common point on the route to each outfall location. The outfall upgrades were not considered in detail, broad assumptions were made for pipe alignments, gate chamber arrangements and modifications to the Cockburn Lift Station.

Table 6-3 provides a summary of piping and stabilization costs for each alternative.

Table 6-3 – Cost Summary of Cockburn Relief Outfall Alternatives

	Pipe Length (m)[1]	Piping Cost ($2008)[2]	Bank Stabilization ($2008)[3]	Total Cost ($2008)
Existing Cockburn Flood Pump Station	575	$3,945,000	$0	$3,945,000
Elm Park Bridge (Bridge Drive Inn)	245	$1,680,000	$1,424,000	$3,104,000
Adjacent to Existing Calrossie LDS Outfall[4]	685	$4,700,000	$81,000	$4,781,000

Note:
1. Length required to extend the pipe from the intersection of Lilac Street and Jubilee Avenue (common point for all options) to the proposed outfall locations.
2. The piping cost includes contingencies (30%), engineering (15%), and burden (3%), which is consistent with cost estimates prepared as part of the original Cockburn report as well as the additional cost estimates provided in this Technical Memorandum. Piping cost is based on 1650 mm diameter pipe.
3. Contingencies for bank stabilization works differ from those assumed for piping costs (10%).
4. The piping cost associated with the existing Calrossie LDS outfall assumes that a 1650 mm diameter outfall would be used. However, if the Calrossie Land Drainage District were tied into the Cockburn Relief – Partial LDS Separation outfall, the size of the outfall would likely have to be increased marginally.

The evaluation indicates that the cost of a new outfall at the Elm Park Bridge would be the lowest, and that a premium of approximately $840,000 would be required to route the new partial LDS to Cockburn Flood Pump Station instead of the Elm Park Bridge.

Although it would have the lowest cost, locating a new outfall at the Elm Park Bridge would have a number of disadvantages:

- The outfall would be located in a high pedestrian traffic area and would require special attention to access and aesthetic issues.
- It would add another outfall which adds additional operations and maintenance responsibilities.
- There are more risks of unknowns associated with constructing an outfall in comparison to reusing an existing outfall location.
- Regulatory environmental approvals from agencies such as the Department of Fisheries and Oceans would be much more difficult to obtain for a new outfall location in comparison to reuse of an existing outfall.
- The new outfall may have issues with adjacent land owners (such as Bridge Drive Inn).

The Toiler Park location in the Calrossie District is also a favorable location in terms of riverbank stability but is about $900,000 more than the Cockburn outfall location without any additional advantages, and is therefore not recommended.

In conclusion, selection of an outfall location does not have an impact on the decisions for integration of FRY with the Cockburn relief works. If the hybrid option is selected for Cockburn relief, the premium to relocate the outfall to the existing Cockburn outfall location will require an additional cost of $840,000 and must be dealt with as part of the basement flooding relief program decisions.

7.0 BASEMENT FLOODING RELIEF BENEFIT-COST EVALUATION

The Cockburn conceptual report included a comprehensive benefit cost evaluation. The evaluation was produced to compare projects within the Cockburn area and also to compare projects under the citywide basement flooding relief program.

The benefit-cost assessment included herein is specifically for the Cockburn District. The benefits associated with servicing the Fort Rouge Yards are not considered to have an impact on the Cockburn District benefit-cost assessment. Its servicing will be for development and not to address an existing basement flooding problem.

A summary of the benefit-cost assessment for the Cockburn District based on alternative options as described in the total investment analysis (Section 6.0) is shown in Table 7-1.

Table 7-1 – Benefit-Cost Assessment

Option	Cockburn and Jessie Combined Results		Cockburn Alone	Jessie[1] Alone
	Jessie to Cockburn	Jessie to FRY		
1 (Hybrid)	1.5	-	1.2	3.4
2 (Partial Separation)	1.7	-	1.4	3.4
3 (Hybrid)	-	1.4	1.2	2.8
4 (Partial Separation)	-	1.7	1.4	2.8

Note: 1. Includes cost of upsizing of Cockburn and/or FRY Trunks

The following observations can be made from the analysis:

- Options 1 and 3 include the cost for selection of the hybrid model whereas Options 2 and 4 are for partial LDS separation of the entire Cockburn area. The assessment suggests there is a financial advantage in selection of partial separation over the hybrid option. However, the hybrid option has potential CSO control advantages, which are not accounted for in the assessment.

- Options 1 and 2 include routing of Southeast Jessie to Cockburn while for Options 3 and 4 Southeast Jessie is routed to FRY. The combined B/C ratio for either set of options is similar, which means there is no financial advantage in selection of one over the other.

- The evaluation for Southeast Jessie alone, which included the cost of upsizing the discharge piping through either Cockburn or FRY, indicates a higher B/C ratio for routing to Cockburn.

- Basement flooding relief for Southeast Jessie, whether routed to Cockburn or to FRY, has a very high B/C ratio. This high ratio is in spite of the fact that a large cost component is for upsizing the pipe from the outlet of the area to the outfall. This subarea would be expected to rank high on a localized relief project prioritization.

In conclusion, the assessment indicates that all of the benefit-cost ratios exceed one, which suggests that all of the options have merit and are viable projects. The hybrid option has a lower B/C ratio than partial separation, but the value of the option on CSO control has not been quantified or included in the analysis. There is no clear advantage for routing of Southeast Jessie to Cockburn or FRY.

8.0 CSO PROGRAM IMPACTS

An objective of the FRY scope change was to identify opportunities for integration of FRY into the adjacent combined sewer districts. A key consideration of the Cockburn relief integration was the impact on future CSO programs. The FRY evaluation considered use of the Cockburn hybrid option, which was thought to preserve CSO control options while permitting immediate implementation of part of the Cockburn works to accommodate FRY development.

It became evident very early in the analysis that all of the FRY development could readily and economically be routed to the Glasgow outfall. An advantage of the Glasgow option was that it served a separate land drainage system and, therefore, would not be impacted by combined sewer overflow decisions. By being independent from the adjacent combined sewer districts, the Glasgow option also had a programming and scheduling advantage, since works could proceed independent of the Cockburn project.

In recognition of the potential for the Glasgow outfall, the City also requested that consideration be given to routing partial LDS separation from Southeast Jessie to the outfall. The Jessie evaluation was not included in the original scope of work but was considered prudent to be added by the City because of the potential to advance the schedule for basement flooding relief of the Southeast Jessie area.

While the FRY recommended options do not require that the hybrid option be implemented in Cockburn, the analysis is still of interest to the Cockburn relief project for consideration of an approach in which basement flooding relief could proceed without waiting on the CSO decision perspective to be resolved.

8.1 HYBRID SUNKEN RELIEF OPTION

The Cockburn hybrid option would include installation of partial LDS separation in Cockburn West and Southeast Jessie, with the Cockburn LDS trunk sewer oversized to carry the additional flow from Jessie. The new LDS would collect only road drainage and discharge to a new outfall either at the Elm Park Bridge (BDI location) or a separated outfall at the existing Cockburn outfall location.

The existing combined sewers in Cockburn West would collect sanitary sewage, foundation drainage and other inflow and infiltration that enter the system. The Southeast Jessie combined sewers would collect flow from the same sources but would continue to discharge to the Jessie Combined Sewer District. The Southeast Jessie separation would reduce the wet weather loading to the Jessie District, but the benefits of this change were not accounted for in the benefit assessments.

Under the hybrid option, it has been assumed relief piping would be installed in Cockburn East and discharge to the Cockburn Lift Station, much like the existing operation. The sunken relief component would involve enlarging a section of relief pipe to serve as CSO storage. The sunken relief would receive combined sewage from Cockburn East, as well as flow from the original Cockburn West combined sewers that would now include both separated and un-separated areas. The sunken relief would be sized to contain the fifth largest storm, requiring a volume of 11,700 cubic meters, to meet the objective of a maximum of four overflows per year. The sunken relief pipeline would have a continuous diameter of 2,400 mm and would extend for a distance of 2,400 metres, as shown in Figure 8-1. This pipe would also serve as the relief sewer pipe, which effectively reduces the cost by integrating relief and CSO storage.

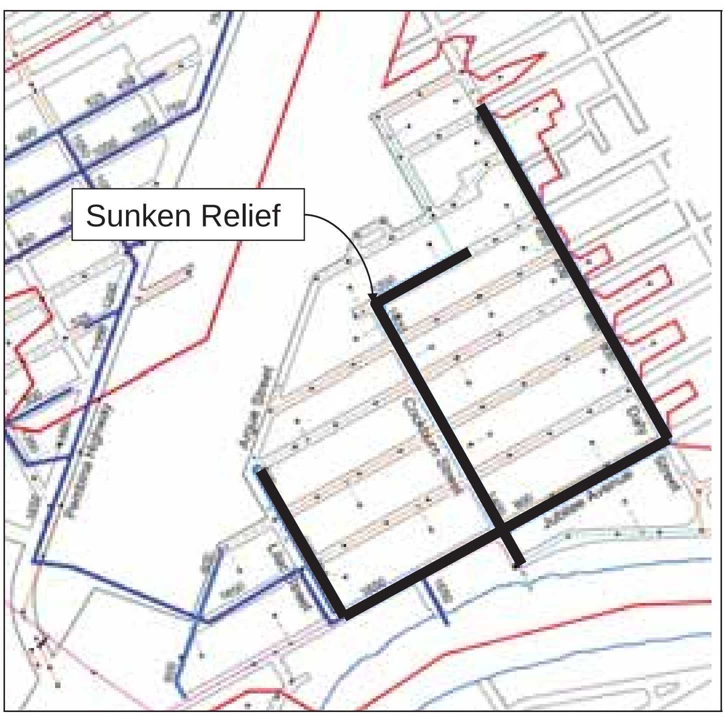


Figure 8-1: Sunken Relief for Cockburn Hybrid Option

The sunken relief pipes would be “sunken”. They would be installed at a lower level than the existing overflow weir, thereby containing the stored sewage within the system without gravity discharge. A lift station would be required to dewater the sunken relief pipes. A key advantage of the sunken relief concept is that it will fill by gravity, and not adversely affect discharge hydraulics or the level of basement flooding protection. It will not require use of inflatable dams or mechanical control gates, which because they have moving parts increase the risk of failure. Sunken relief would be sized to discharge design storms through the system without an increased risk of basement flooding, and since the sewer diameter is enlarged, may even have improved storm water carrying capacity.

The use of sunken relief with the hybrid option has advantages over the use of sunken relief with the district-wide relief option. Partial separation would remove a portion of the flow what would have been discharged to sunken relief, and thereby reduce the amount of sunken relief required and the amount of sewage pumped to and treated by the wastewater treatment plant. Even complete separation would require the use of another method of CSO storage; and with total separation, the sanitary flows mixed with foundation drainage and other rainfall dependent inflow and infiltration (RDII) would require temporary storage either in the existing combined sewer system or with off-line storage, which is more difficult and more risky than with sunken relief.

The hybrid evaluation demonstrates that it is reasonable to proceed with basement flooding relief using partial separation in Cockburn West. Since Southeast Jessie is not recommended to be included in the FRY project, the Cockburn West project would bring the earliest relief to this area of extremely low basement flooding protection.

8.2 NEWPCC INTERCONNECTION

The Cockburn study included consideration of a regional combined sewer overflow control approach. The concept was to connect a number south end combined sewer districts and route them to the north, for subsequent pumping to the NEWPCC where wet weather flow treatment will be required because of the large number of combined sewer districts in its service area. By removing the south end combined sewer flows from the SEWPCC, most of the remaining area would be separate sewer areas, which would provide an advantage to the size and operation of the new SEWPCC facility.

The Cockburn regional CSO evaluation was completed at a feasibility level. The study found significant potential for proceeding on an integrated basis rather than independently, district-by-district and with un-integrated basement flooding relief and CSO programs. A regional tunnel would be cost competitive with the in-line storage concept. If in-line storage were not selected, the tunnel would be in the range of $40 million less expensive than off-line storage and much less complex to operate and maintain.

An interconnecting tunnel was found to be a viable regional CSO solution for Cockburn, Baltimore, Jessie and River Combined Sewer Districts. The tunnel would work like the sunken relief option discussed previously. The tunnel would be sized to store the fifth largest storm for each of the districts, and would be discharged by lift pumps at the River station to the NEWPCC.

Use of the hybrid option for Cockburn along with the regional tunnel option was considered conceptually but not evaluated quantitatively in this scope change. It is evident from the way it is intended to function that there would be little impact from selection of the hybrid on the tunnel's design or operation. With the hybrid, combined sewage from Cockburn West would flow in the existing combined sewer to the tunnel connection (as opposed to the sunken relief discussed previously). The volume collected in the tunnel would be somewhat less for use of the hybrid option than it would be for complete relief piping. However, the impact would be to reduce the diameter or length of the tunnel and not to eliminate the concept.

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 CONCLUSIONS

- A review of various drainage options for the SWBRT showed that the Transit LDS system (Glasgow outfall) had excess capacity and was the preferable option to accommodate the runoff from this area. It also has a scheduling advantage in that it could be implemented without the construction of any relief works for the Cockburn Combined Sewer District.

- Diverting of runoff from the SWBRT and CNR tracks will increase the flow at the Glasgow LDS outfall from 1.37 m^3/s under existing conditions to 3.45 m^3/s, if all runoff from the SWBRT and CNR tracks in the FRY is considered. Under these conditions, the Transit LDS system has sufficient capacity to handle the increase in flow.

- Routing of FRY flows to the Glasgow outfall will not have adverse impacts on the Cockburn basement flooding relief or CSO options. In fact, removal of the existing FRY drainage will have a positive, although minor, beneficial impact on the Cockburn District.

- The selection of either partial separation or the hybrid option using partial separation in Cockburn West would be required if routing of flows from FRY to the Cockburn District is to be considered, since storm water from the development would not be permitted in combined sewers. The hybrid option provides the most flexibility for future combined sewer overflow options in the Cockburn District, but would have a total investment cost increase of $6,633,000 over the separation option.

- The total cost of a new Cockburn LDS outfall at the Elm Park Bridge would be the lowest of all outfall alternatives considered (Elm Park Bridge (BDI), Cockburn FPS, and Calrossie). Although the Elm Park Bridge has the lowest cost, there are many disadvantages associated with this location (i.e. aesthetics, operations, regulatory approvals, potential issues with adjacent land owners). The City would need to pay a premium of approximately $840,000 to upsize the existing outfall at the Cockburn Flood Pump Station as an alternative.

- On a total investment basis, the cost of routing the FRY residential development to Cockburn or to the Glasgow outfall is virtually the same. However, routing to the Cockburn District would require selection of a partial land drainage separation option and the development could not proceed until the Cockburn upgrading is in place.

- On a total investment basis, there is about a $1.3 million premium to discharge Southeast Jessie to the planned FRY Trunk in comparison to routing it to the Cockburn District. Servicing Southeast Jessie through the FRY would also require crossing a large railway yard and enlarging the size of the FRY Trunk to accommodate the flows. The division of responsibilities, complexity of construction and future operational concerns are detrimental to the option.

- Selection of the hybrid option, using partial LDS separation in Cockburn West provides an approach in which relief could proceed immediately, without adversely impacting future CSO program options. Implementation of partial separation in Cockburn West would permit early relief to the Southeast Jessie area, which currently has a severely substandard level of basement flooding protection.

- Selection of the hybrid would allow future selection of partial LDS separation, sunken relief or a regional tunnel option for Cockburn East, which encompasses the entire range of options for decisions with and without integrated basement flooding relief and CSO control.

- On a total investment basis, there is no cost advantage to integrate the Cockburn relief and FRY servicing projects. The lowest cost is for Option 2, which is to proceed with the projects independently.

9.2 RECOMMENDATIONS

- The entire FRY internal drainage, including the future residential development, should be routed to the Glasgow outfall and not to the Cockburn District.

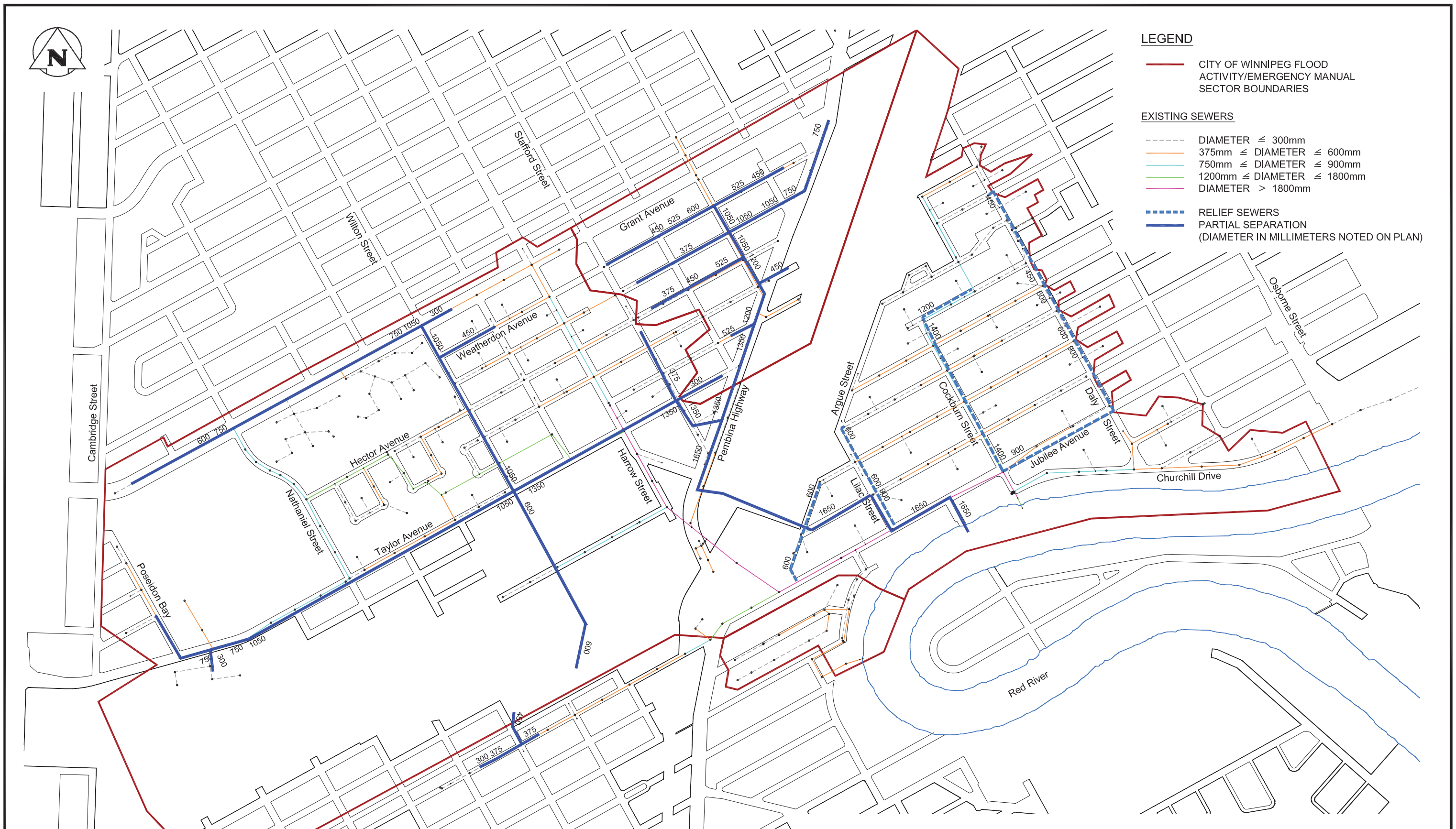
- Although the most recent outfall inspections have indicated that the Glasgow outfall is in good condition, it is recommended that a complete outfall inspection (both pre-cast concrete pipe and CMP sections) be carried out during the winter of 2009 to confirm its present state.

- Basement flooding relief for the Southeast Jessie District should be included with the Cockburn project, and not be routed to the future FRY Trunk.

- Cockburn West partial LDS separation of the hybrid option should be considered for immediate implementation in the basement flooding relief program, with subsequent decision on Cockburn East delayed until a decision is made on the combined sewer overflow approach, thereby permitting advanced relief of the flood prone Southeast Jessie area.

- Additional evaluation should be carried out to finalize the Cockburn LDS outfall location.

DRAWINGS



THE CITY OF WINNIPEG WATER AND WASTE DEPARTMENT KGS GROUP · CH2MHILL · DILLON CONSULTING	**COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS**
TITLE:	SEPARATION-RELIEF HYBRID OF COCKBURN DISTRICT WITH JESSIE
JOB NO.: 08-107-14	DATE: MAY 2010
SCALE : AS NOTED	DWG NO.: 1
CHECKED:	

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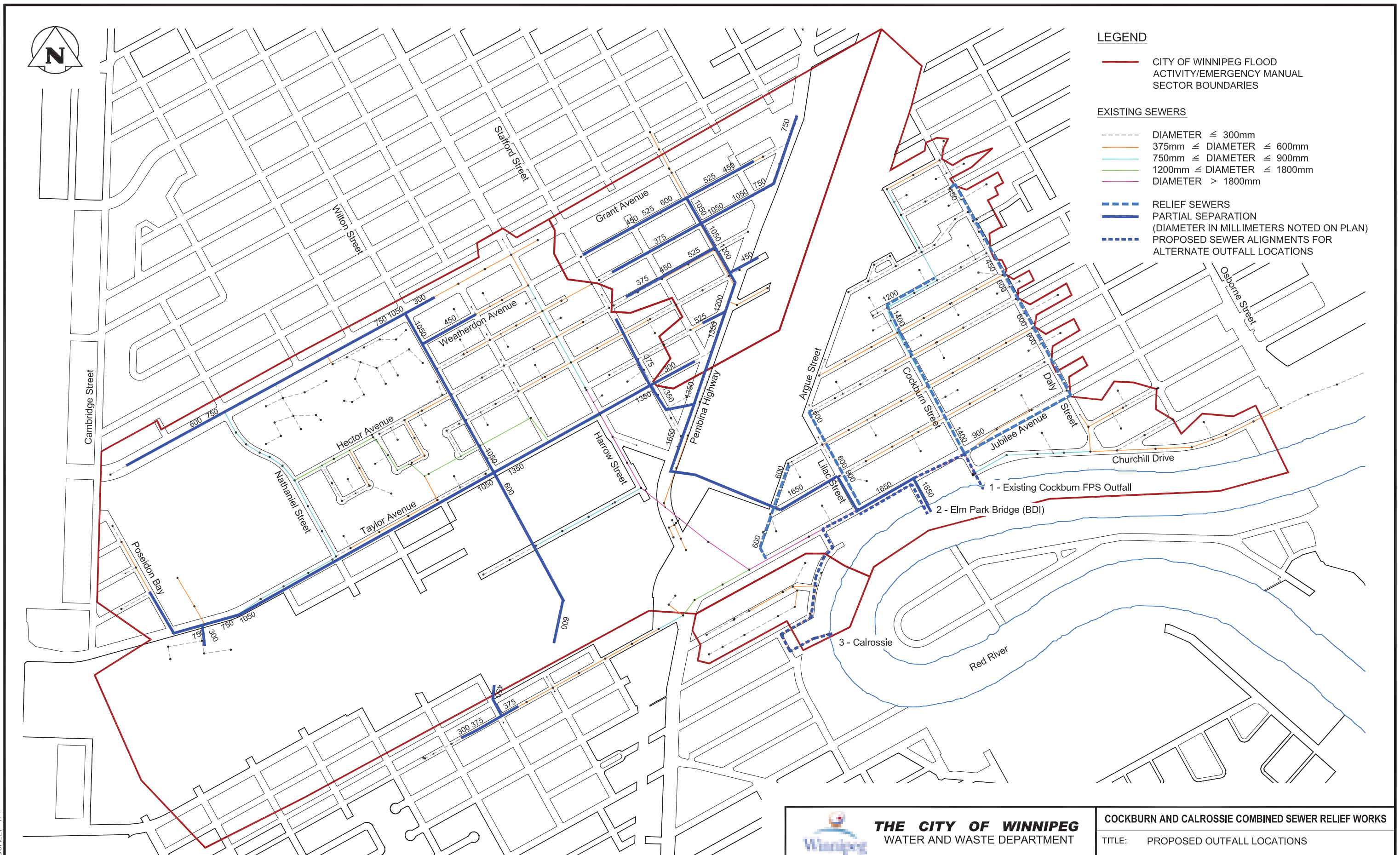

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

KGS GROUP
CH2MHILL
DILLON CONSULTING

COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS

TITLE: PROPOSED OUTFALL LOCATIONS	
JOB NO.: 08-107-14	DATE: MAY 2010
SCALE : AS NOTED	DWG NO.: 2
CHECKED:	

KGS FILE NO.: P:\Projects\2005\05-0107-14\Civil\Dwgs\Working\05-0107-14-02-r0.dwg
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APPENDIX A

DILLON MEMORANDUM – SWBRT LDS OPTIONS

Southwest Rapid Transit Corridor Stage 1 - Land Drainage Design for the Transit Corridor Between Jubilee Avenue and Osborne Street, Including the CN Underpass

Final Report

February 2009

PROVINCE OF MANITOBA
02/26/09
D. P.
KRAHN
Member
12926
REGISTERED PROFESSIONAL ENGINEER

APEGM
Certificate of Authorization
Dillon Consulting Limited (MB)
No. 1789 Date: Feb 26/09

Southwest Rapid Transit Corridor Stage 1 - Land Drainage Design for the Transit Corridor Between Jubilee Avenue and Osborne Street, Including the CN Underpass

City of Winnipeg

08-8813

Dave P. Krahn, P.Eng. - Project Manager

Submitted by

Dillon Consulting Limited

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(In reply, please refer to)
Our File: 08-8813

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February 26, 2009

City of Winnipeg
Water and Waste Department
110-1199 Pacific Avenue
Winnipeg MB, R3E 3S8

Attention: Mr. Grant Mohr, P.Eng.
Branch Head - Land Drainage and Flood Protection

Southwest Transit Rapid Transit Corridor – Stage 1
Drainage Design for the Transit Corridor Between Jubilee Avenue and Osborne Street, Including the CN Underpass

Dear Mr. Mohr:

Attached for your information, please find three (3) copies of the above-mentioned report. This report summarizes the work that was undertaken in conjunction with KGS Group in determining the best drainage alternative for the Transit lands within the Fort Rouge Area. The recommended drainage alternative includes a new drainage piping system within the Transitway lands that accommodates both the Transitway as well as the future development of the B&M lands with discharge of the existing Glasgow outfall at Osborne Street.

If you have any questions regarding this report, please do not hesitate to give me a call.

Yours sincerely,

DILLON CONSULTING LIMITED

David Krahn, P.Eng.
Project Manager

DPK/ers

Encl.

cc:	*Bill Menzies*	*City Transit Department*
	Randy Fingas	*City Transit Department*
	Andree Kirouac Huth	*KGS Group*

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1 INTRODUCTION

The City of Winnipeg Transit Department (Transit) has retained Dillon Consulting Limited (Dillon) to provide planning and design services for the Southwest Rapid Transit Corridor – Stage 1. The fundamental objective of this project is to provide planning and design services for the completion of the preliminary design and the development of the final design for Stage 1 of the Transit Corridor (Queen Elizabeth Way to Jubilee Avenue).

The goals of the Bus Rapid Transit System are to: encourage a modal shift to transit; reduce emissions in heavily travelled Corridors; provide opportunities for "smart growth" development; support the revitalization of downtown; and to reduce the requirements for parking. Stage 1 work for the Transit Corridor consists of the area from Queen Elizabeth Way (QEW) and Stradbrook Avenue to Pembina Highway and Jubilee Avenue, which will accommodate transit buses on an exclusive right-of-way, and thereby significantly reduce travel time for transit users.

Land drainage is vital to the safe and successful operation of any mode of transportation system and economizing the life cycle costs of the system. Stage 1 of the Transit Corridor lines straddles a number of combined sewer districts including River on the eastern portion of the line, to Baltimore/Jessie in the centre, to Cockburn on the western side of the line. KGS Group has developed storm relief plans, in a separate study, for the Cockburn Sewer District located just to the east of the Transitway lands. A number of drainage options were analyzed by KGS through this Cockburn study and are included in Appendix A. This report provides the land drainage design of the preferred option, which drains the Transit Corridor lands as well the future B&M lands to the existing Glasgow outfall at Osborne Street. This report assesses the land drainage impacts of the section of Transit Corridor from Jubilee Avenue to Osborne Street.

A separate report will be submitted by Dillon to assess drainage impacts on the River Sewer District for the section of the Transit Corridor from Queen Elizabeth Way (Main Street) to Osborne Street.

2 STUDY AREA

The overall study area for Stage 1 extends from Jubilee Avenue to Queen Elizabeth Way. The focus of this report encompasses the Transit Corridor study area from Jubilee Avenue to Osborne Street. The study area from Jubilee Avenue to Osborne Street has been divided into three sub areas: Area 1, Area 2, and Area 3, as shown in Figure 1.

Area 1 consists of the area from approximately Brandon Avenue behind the Transit Garage to Osborne Street and includes the Transit Corridor underpass of the existing CN tracks. The total area of Area 1 is 3.61 ha, with 1.35 ha of this area draining to the existing system, not through the underpass pump station, and the remaining 2.26 ha draining to the underpass pump station. The runoff hydrograph from Area 1 is for the underpass section only.

Area 2 extends from the Transit Garage south to Jubilee Avenue. This area consists of the Transit Corridor right-of-way and a portion of the CN Yards in the vicinity to the west of the proposed Transit Corridor. The total area of this land is 20.88 ha, with 7.38 ha being new Transit Corridor lands and the remaining 13.5 ha being rail yards.

Area 3 includes part of the Fort Rouge Yards (FRY) area west of the Transit Corridor right-of-way, from Brandon Avenue (south of Transit Garage) to back lane of Berwick Place (south of Morley Avenue extension). This area is 4.77 ha. This area is being included for the new proposed Transit Garage.

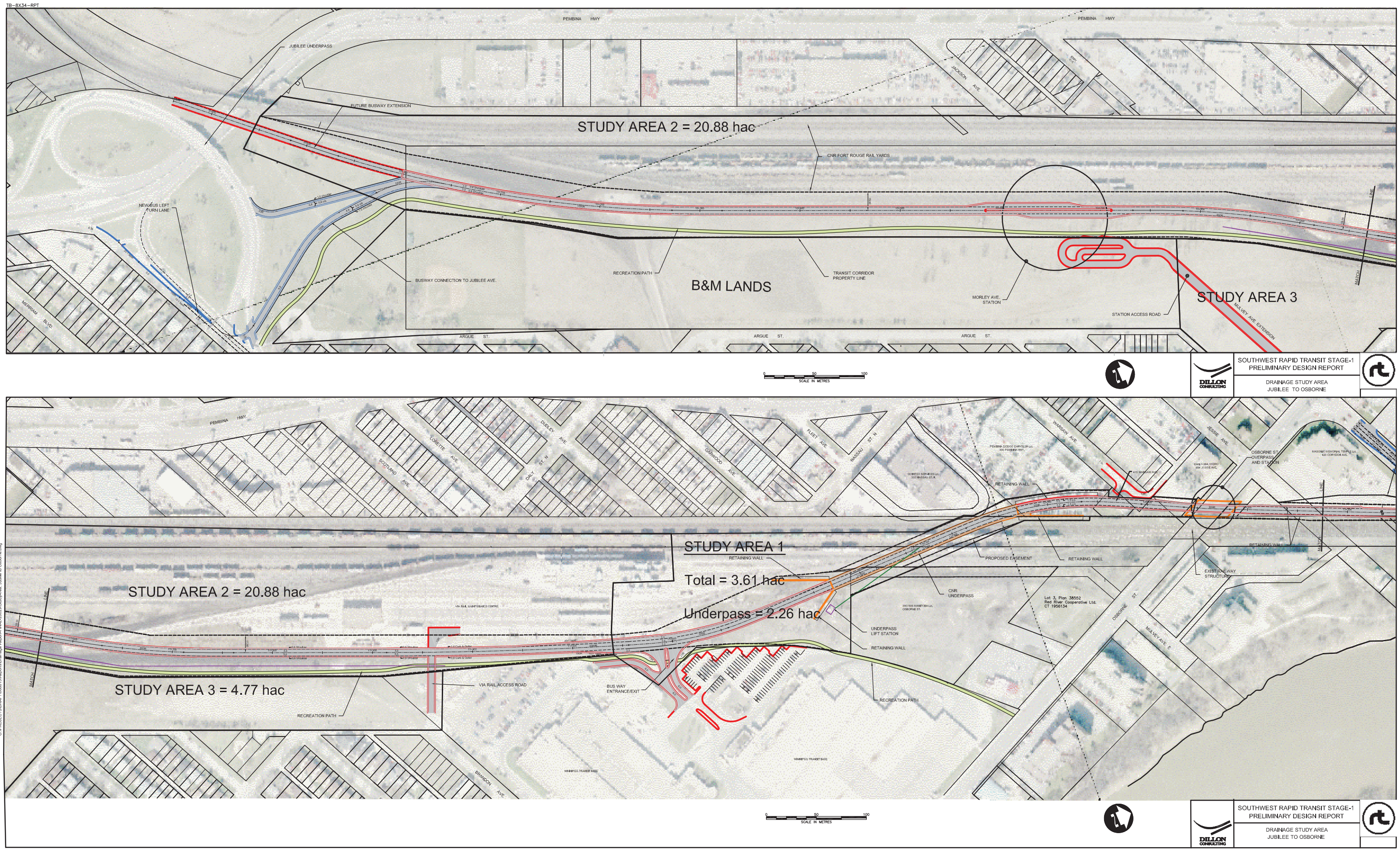


FIGURE 1 - SOUTHWEST RAPID TRANSIT STAGE 1 - DRAINAGE, STUDY AREA, JUBILEE TO OSBORNE AND UNDERPASS

3 LAND DRAINAGE DESIGN PARAMETERS

3.1 Design Storm

For design purposes, Area 1, which contains the underpass, has been designed to the 25-year storm. Transit has indicated that this is an adequate design level for their underpass and that bus service can be shutdown temporarily if a larger storm event did occur. For the remaining area, i.e. Area 2 and 3, the 5-year design storm has been used, which is the City's Water and Waste Department standard practice. Both design storms come from "Stantec, 2000." The following figures, Figure 2 and Figure 3, show the design hyetographs for 5-year and 25-year design storms, respectively.

Figure 2: Design Hyetograph for 5-Year Design Storm

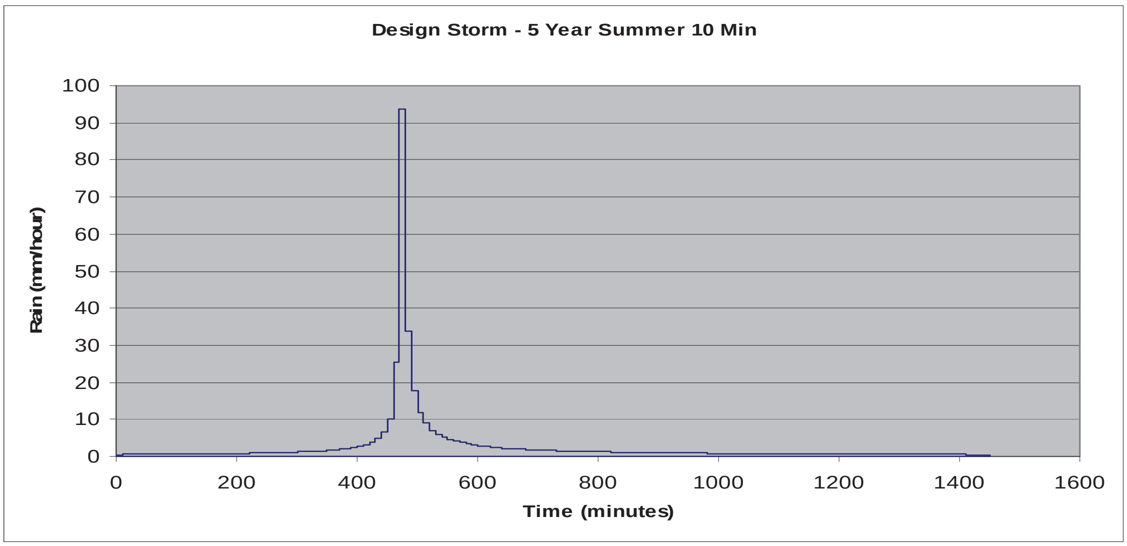
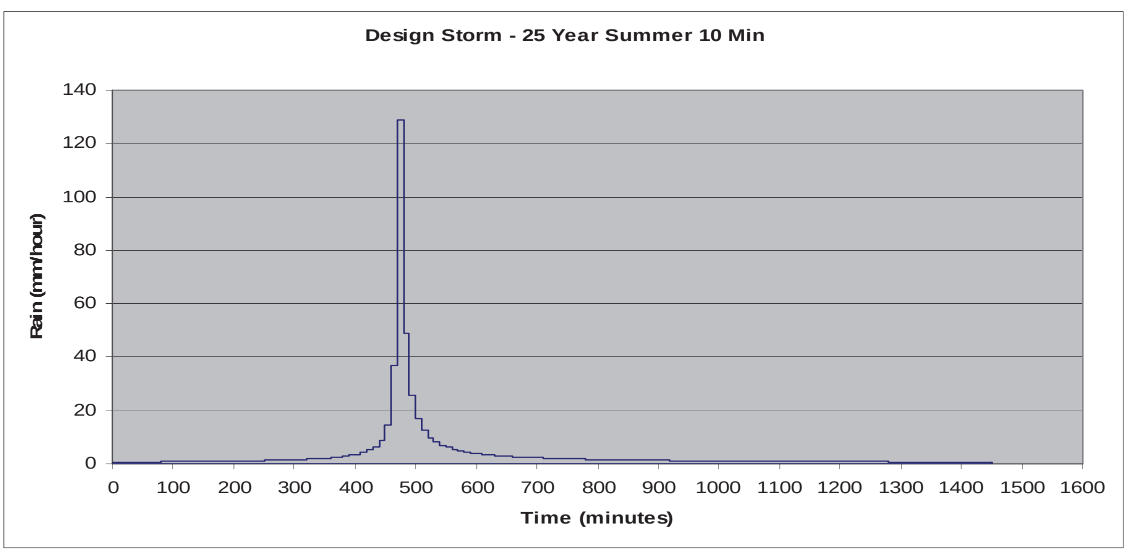


Figure 3: Design Hyetographs for 25-Year Design Storm



3.2 Hydrologic/Infiltration Parameters

The following Table 1 summarizes the hydrologic/infiltration parameters used for modeling the runoff from the Rapid Transit Corridor right-of-way.

Table 1: Hydrologic/Infiltration Parameters – Transit Corridor Right-of-Way

Infiltration Parameter		**Value**
Maximum Infiltration Rate (mm/hr)		85
Minimum Infiltration Rate (mm/hr)		3
Decay Rate (1/sec)		0.00115
Description		**Value**
Surface Roughness	Impervious	0.015
	Pervious	0.030
Depression Storage	Impervious	1.5 mm
	Pervious	5 mm

The Transit Corridor right-of-way was assumed to be 40% impervious and 60% pervious with a slope of 0.01. Other hydrologic parameters used in the SWMM model are as in the above table (Table 1). These parameters match those of the calibrated model for the Cockburn Sewer District (KGS 2007).

The following Table 2 summarizes the hydrologic/infiltration parameters used for modeling the runoff from the CN Yards.

Table 2: Hydrologic/Infiltration Parameters – CN Yards

Infiltration Parameter		**Value**
Maximum Infiltration Rate (mm/hr)		85
Minimum Infiltration Rate (mm/hr)		3
Decay Rate (1/sec)		0.00115
Description		**Value**
Surface Roughness	Impervious	0.015
	Pervious	0.030
Depression Storage	Impervious	1.5 mm
	Pervious	10 mm

The CN Yards were assumed to be 5% impervious and 95% pervious, and have a slope of 0.002, taking into consideration the ballast tracks in this area. Other hydrologic parameters used in the SWMM model are as in the above table (Table 2). These parameters matches those of the calibrated model for the Cockburn Sewer District (KGS 2007)

Area 3 (after development) is assumed 100% impervious. The surface roughness for this area is assumed as 0.015 and the depression storage is assumed as 1.5 mm.

3.3 Hydraulic Parameters

The runoff from the Transit Corridor right-of-way is conveyed to the tie-in location by means of a piped system of sewers, while the runoff collected from the CN Yards is assumed to drain to a ditch along the west side of the Transit Corridor. The flow from the ditch is connected to the Transit Corridor sewer at the low points by placing inlets in the ditch at low points.

Assuming concrete piping for the Transit Corridor sewer, a Manning's roughness coefficient "n" of 0.013 and City of Winnipeg slope standards for maintaining minimum velocity of 3 fps were used in the hydraulic model. Manning's "n" for the ditch is assumed as 0.070, assuming grassed ditch with the slope in the ditch system varying from 0.15% to 0.35%. The flow in the west CN ditch is drained to the Transit Corridor sewer at low points corresponding to the roadway low points.

4 PREFERRED DRAINAGE OPTIONS

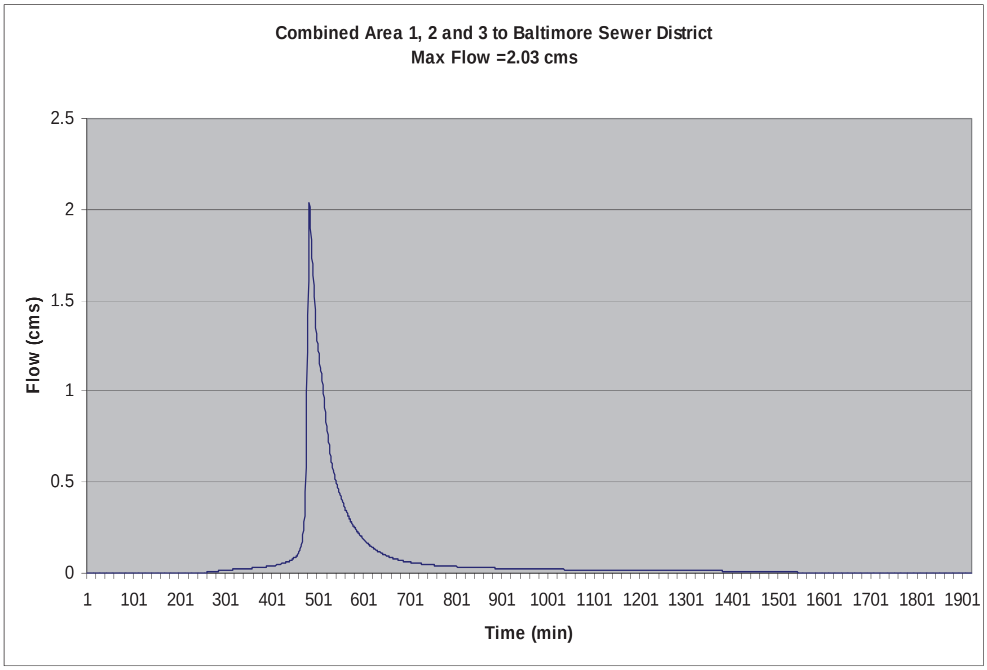
A number of potential preliminary drainage options were analyzed collaboratively with KGS/CH2M Hill as part of their Cockburn Storm Relief Study (see Appendix A). The preferred option, which meets Transit's development schedule and allows the orderly development of the B&M lands concurrently with the Transit Corridor, is to collect the runoff from Area 1, Area 2 and Area 3, and convey it by a piped system to the proposed Glasgow tie-in location in the Baltimore Sewer District. In meetings with the Water and Waste Department in the fall of 2008, they agree with this preferred option.

For the final design of the Transit Corridor sewer system, Dillon was responsible for the analysis of surface runoff and the final determination of the discharge hydrographs with input from KGS on the hydraulic parameters for the Baltimore Sewer System. Since the hydraulic grade line elevation in the existing Transit drainage system was dependent on the discharge from the Transit Corridor sewer system, which in turn also affected the design of the Transit Corridor sewer, the final discharge hydrograph was determined by an iterative procedure in which the Transit Corridor hydrograph for a particular sewer design was used in the Transit model to produce a new water level hydrograph for the Transit Corridor sewer model. (See attached KGS memo in Appendix A on the evaluation that they carried out). Another report has been prepared by KGS that documents all the background information, costs and evaluations.

5 RUNOFF/DISCHARGE HYDROGRAPHS

The runoff/discharge hydrographs at the corresponding tie-in location to the City's sewer system is as documented below in Figure 4. This hydrograph has been generated from XP-SWMM simulation.

Figure 4: Alternative 2, Discharge of Area 1 (25-Year Storm), Area 2 and 3 (5- Year Storm), to Baltimore Sewer District



6 RESULTS FOR HYDRAULIC ANALYSIS OF PROPOSED TRANSIT CORRIDOR SYSTEM

The following information is provided for the recommended drainage option (Transit Corridor lands plus developable B&M lands) that will discharge into the existing Glasgow Outfall at Osborne Street.

- Table 3: Tabulation of Critical Elevations and Flows for Recommended Drainage Option
- Figure 5: Jubilee to Osborne
- Figure 6: Hydraulic Grade Line for Recommended Drainage Option

The following should be noted regarding this evaluation:

- The evaluations were carried out as an iterative process using information prepared by both KGS and Dillon.
- As the recommended drainage option includes the proposed developable B&M lands, the City will need to enter into an agreement with B&M lands regarding cost sharing for the upsizing of the land drainage from the base case.
- The lowest ground/catchbasin elevation is at a catchbasin at the south upstream end of the Transit Corridor, which is about 231.8 m giving a cover/freeboard of about 0.86 m.
- The hydraulic grade line and pipe sizing for the recommended drainage option takes into consideration the expected installation of a private land drainage sewer system within the B&M lands.
- The full documentation of the land drainage options, as carried out by KGS, is documented in a separate report.
- The total discharge at MH 21 includes runoff from the Transit Corridor lands from Jubilee Avenue to Brandon Avenue, the proposed B&M lands to the east of the Transit Corridor, the Transit Corridor Underpass of the CN tracks, and runoff from the existing Transit facilities located at 421 Osborne Street.

Table 3: Tabulation of Critical Elevations and Flows for Recommended Drainage Option

Manhole	HGL Elevation (m)	Ground Elevation (m)	Freeboard (m)	Peak Flow (cms)	Comments
MH 1	229.700	232.740	3.040	0.302	MH 1 to MH 2
MH 2	229.680	232.668	2.985	0.600	B&M @ MH 2 = 0.356
MH 3	229.595	232.630	3.035	0.535	MH 3 to MH 4
MH 4	229.580	233.365	3.790	0.989	B&M @ MH 4 = 0.261
MH 5	229.395	233.215	3.820	0.864	MH 5 to MH 6
MH 6	229.260	233.030	3.770	1.045	B&M @ MH 6 = 0.285
MH 7	229.185	232.740	3.555	1.139	MH 7 to MH 8
MH 8	229.065	232.880	3.815	1.290	B&M @ MH 8 = 0.212
MH 9	228.890	233.025	4.140	1.631	MH 9 MH 10
MH 10	228.590	232.425	3.835	1.861	MH 10 MH 11
MH 11	228.410	232.275	3.865	2.192	MH 11 MH 12
MH 12	228.195	232.160	3.960	2.116	MH 12 MH 13
MH 13	227.990	232.195	4.210	2.172	MH 13 MH 14
MH 14	227.860	232.095	4.230	2.113	MH 14 MH 15
MH 15	227.705	232.565	4.860	2.114	MH 15 MH 17
MH 17	227.570	232.555	4.985	2.162	Underpass @ MH 21 = 0.68
MH 21	227.420	232.590	5.165	2.494	MH 21 MH 22
MH 22	227.365	232.395	5.030	2.496	MH 22 MH 23
MH 23	227.185	232.665	5.485	2.492	MH 23 MH 24
MH 24	227.010	232.130	5.120	2.479	MH 24 MH 25 *****
MH 25 *****	226.940	231.940	5.000		

***** Dillon's manhole MH 25 corresponds to KGS MH S21 – HGL Elevations of 226.940 are the same for both.

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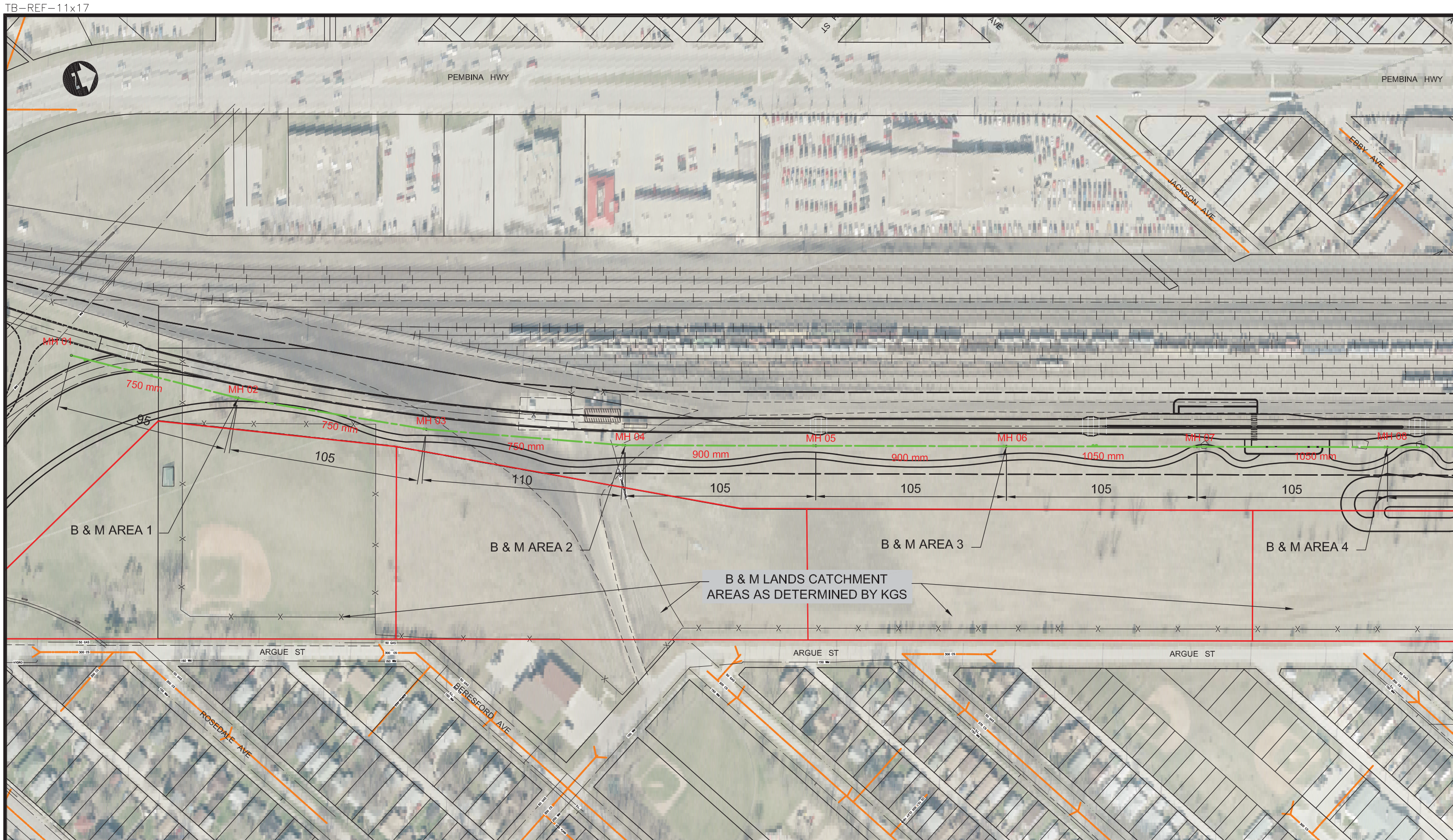

PROPOSED LAND DRAINAGE SEWER

EXISTING LAND DRAINAGE SEWER

EXISTING WASTE WATER SEWER

DILLON CONSULTING

SCALE 1:2000

SOUTHWEST RAPID TRANSIT CORRIDOR - STAGE 1
RECOMMENDED DRAINAGE OPTION

FIGURE 5
SEWER ALIGNMENT AND SIZES

REF-T50 (1 OF 3)

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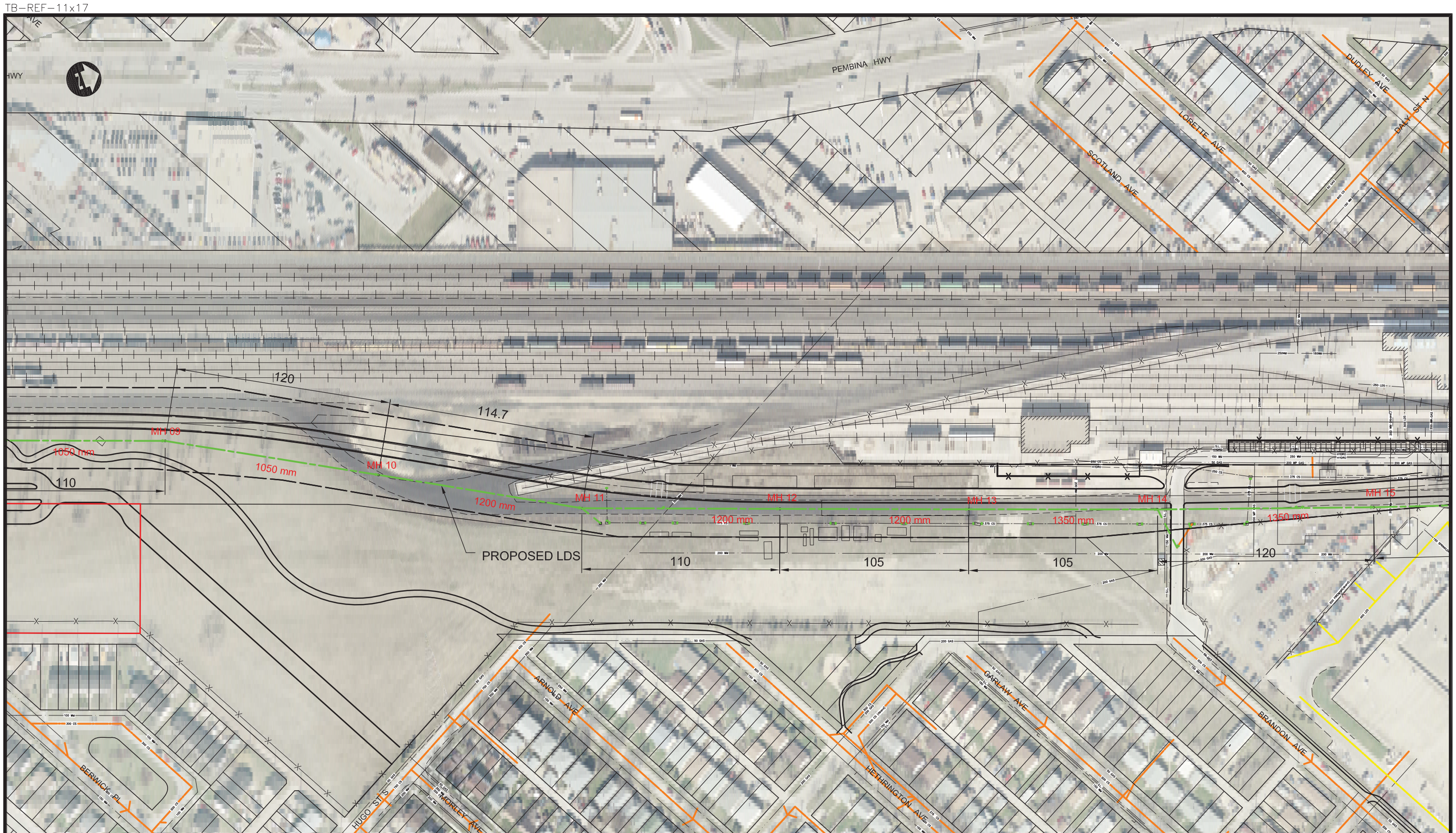

PROPOSED LAND DRAINAGE SEWER

EXISTING LAND DRAINAGE SEWER

EXISTING WASTE WATER SEWER

DILLON CONSULTING

SCALE 1:2000

SOUTHWEST RAPID TRANSIT CORRIDOR - STAGE 1
RECOMMENDED DRAINAGE OPTION

FIGURE 5
SEWER ALIGNMENT AND SIZES

REF-T50 (2 OF 3)

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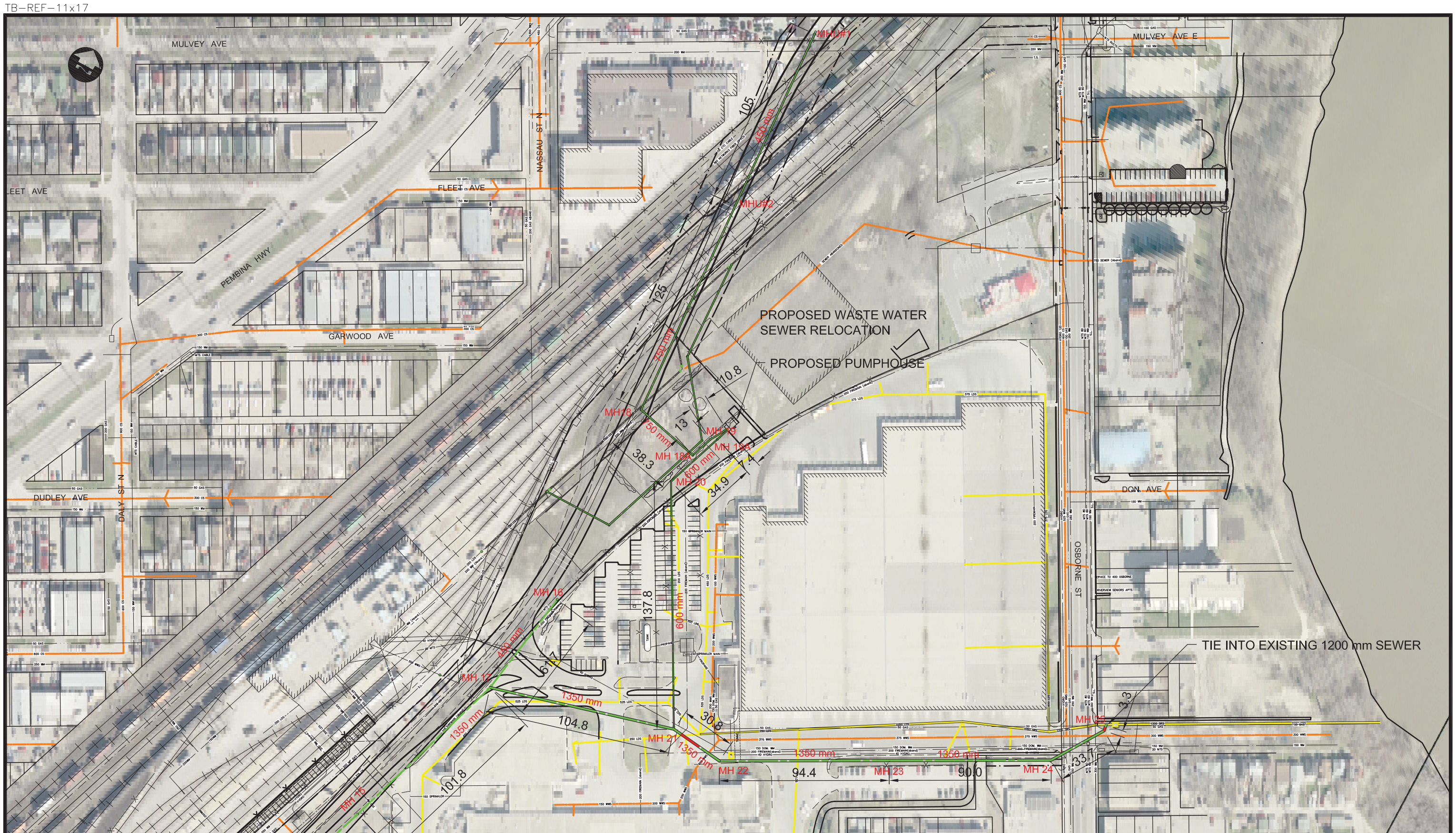

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PROPOSED LAND DRAINAGE SEWER

EXISTING LAND DRAINAGE SEWER

EXISTING WASTE WATER SEWER

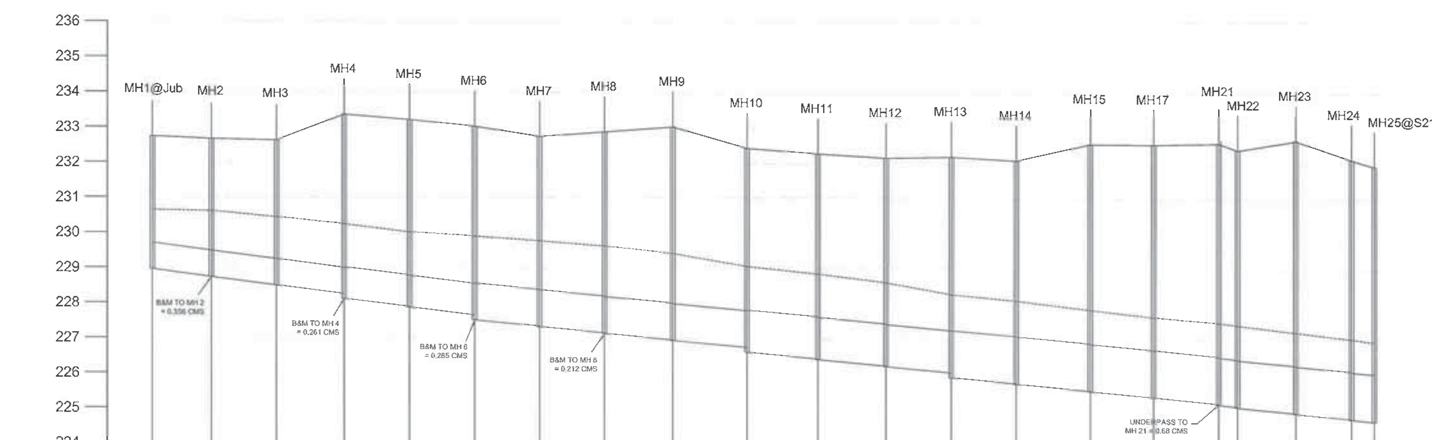
DILLON CONSULTING

SCALE 1:2000

SOUTHWEST RAPID TRANSIT CORRIDOR - STAGE 1
RECOMMENDED DRAINAGE OPTION

FIGURE 5
SEWER ALIGNMENT AND SIZES

REF-T50 (3 OF 3)



Maximum Flow (CMS)	Diameter (m)	Maximum HGL Elevation (m)	Invert Elevation (m)	Ground Elevation (m)	Station (m)
0.295	0.750	230.645 / 230.620	228.940 / 228.750	232.740 / 232.670	1973 / 1878
0.587	0.750	230.620 / 230.440	228.720 / 228.510	232.630	1773
0.510	0.750	230.440 / 230.245	228.480 / 228.260	233.365	1663
0.958	0.900	230.245 / 230.020	228.110 / 227.900	233.215	1558
0.815	0.900	230.020 / 229.910	227.870 / 227.660	233.030	1453
1.026	1.050	229.910 / 229.780	227.510 / 227.350	232.740	1348
1.146	1.050	229.780 / 229.635	227.320 / 227.165	232.880	1243
1.302	1.050	229.635 / 229.430	227.135 / 226.970	233.025	1133
1.669	1.050	229.430 / 229.065	226.940 / 226.760	232.425	1013
1.917	1.200	229.065 / 228.855	226.610 / 226.440	232.275	898
2.196	1.200	228.855 / 228.615	226.410 / 226.245	232.160	788
2.144	1.200	228.615 / 228.280	226.215 / 226.055	232.195	683
2.277	1.350	228.280 / 228.100	225.905 / 225.750	232.095	578
2.386	1.350	228.100 / 227.845	225.720 / 225.540	232.565	458
2.393	1.350	227.845 / 227.640	225.510 / 225.355	232.555	357
2.440	1.350	227.640 / 227.475	225.325 / 225.170	232.590	252
2.800	1.350	227.475 / 227.410	225.140 / 225.090	232.395	221
2.819	1.350	227.410 / 227.210	225.060 / 224.920	232.665	127
2.829	1.350	227.210 / 227.020	224.890 / 224.755	232.130	37
2.832	1.350	227.020 / 226.940	224.725 / 224.670	231.940	0

Datum RL 221.000 (m)

FIGURE 6 - HYDRAULIC GRADE LINE FOR RECOMMENDED SOUTHWEST RAPID TRANSIT STAGE - 1 DRAINAGE OPTION (JUBILEE TO OSBORNE)

APPENDIX A

FINAL FORT ROUGE YARDS DRAINAGE OPTION (OPTION 2) FROM KGS

KGS GROUP

MEMORANDUM

TO: **Dave Krahn, P. Eng.**

FROM: **Andrée Kirouac Huth, P. Eng.**

DATE: **December 11, 2008**

PROJECT NO: **08-0107-14**

RE: **Final Fort Rouge Yards Drainage Option (Option 2)**

1.0 SUMMARY OF FINAL FORT ROUGE YARDS DRAINAGE OPTION

Because the results from the Transit LDS System – Glasgow Outfall review showed that the system had excess capacity, as a base case scenario, it was assumed that all land drainage flow from the SWBRT (Southwestern Bus Rapid Transit) Corridor would be routed to the Glasgow system. Therefore, the design of the BRT LDS system would not be contingent on the relief of Cockburn and Winnipeg Transit could proceed based on their tight schedule. Variations of the options considered include:

- Option 1 – Base Case (SWBRT Areas 1, 2 and 3 to Glasgow Outfall)
- Option 2 – SWBRT Areas (1, 2 and 3) and Proposed B & M Lands Residential Development to Glasgow Outfall
- Option 3 – SWBRT Areas (1, 2 and 3) and Southeast Jessie to Glasgow Outfall
- Option 4 – SWBRT Areas (1, 2 and 3), Proposed B & M Lands Residential Development and Southeast Jessie to Glasgow Outfall

These options will be summarized in more detail in the KGS Group/CH2M HILL Technical Memorandum, "Cockburn / Calrossie Combined Sewer Relief Works Fort Rouge Yards Addition", which will tentatively be submitted to the City of Winnipeg Water and Waste Department (WWD) in December 2008. As part of this work, a total investment analysis was carried out by KGS Group and CH2M HILL to determine the preferred drainage option for the Fort Rouge Yards (FRY), which is described briefly in the following subsection. More details on the analysis will also be included in the Technical Memorandum referenced above. A detailed hydraulic summary of the final drainage option has also been provided by KGS Group (see Section 1.2).

1.1 TOTAL INVESTMENT ANALYSIS

The total investment analysis was used to evaluate the economics of the FRY addition to the Cockburn relief project. The analysis considered the combined total capital costs of all works within the study area, regardless of purpose, ownership or authority, and assumed that all of the work would be completed.

Results from the investment analysis showed that Option 2 was the preferred option in terms of least overall cost, with consideration of Cockburn Relief. For Option 2, SWBRT Areas 1, 2 and 3 as well as the proposed FRY residential development would be routed north to the Transit LDS System – Glasgow outfall, while land drainage from the Southeast Jessie District would be routed to the Cockburn District, as part of the Cockburn Relief Works. The following assumptions were made for Option 2:

a) Route SWBRT Area 1 (Underpass) to Manhole S7 (Transit LDS System – Glasgow Outfall).

b) Route SWBRT Areas 2 and 3 to Manhole S20 (Transit LDS System – Glasgow Outfall)

c) Route land drainage from FRY residential development to Transit LDS System – Glasgow Outfall.

d) Route land drainage from SE Jessie to the Cockburn District, as part of the Cockburn Relief Works.

Figure 1 shows a schematic of the areas considered and where they are to be diverted for Option 2.

Figure 1 – Option 2 Drainage Schematic

1.2 HYDRAULIC SUMMARY OF PREFERRED OPTION

XP-SWMM models of each of the options were developed to determine the hydraulic impact on the existing Transit LDS system, including the Glasgow Land Drainage Sewer (LDS) outfall. Since Dillon Consulting was responsible for the design of the internal FRY LDS system designed specifically for the SWBRT Corridor, at WWD's request, KGS Group/CH2M HILL worked with Dillon Consulting to determine the FRY internal pipe upsizing required to account for the proposed FRY residential development and/or the Southeast Jessie District. To facilitate this process, two separate XP-SWMM models were used.

1. Transit LDS System – Glasgow Outfall (developed by KGS Group/CH2M HILL as part of the Cockburn / Calrossie Combined Sewer Relief Works Fort Rouge Yards Addition for WWD)

2. SWBRT FRY Internal LDS System (developed by Dillon Consulting as part of SWBRT final design for Winnipeg Transit).

Manhole S20 was selected as the input location for SWBRT Areas 2 and 3 while SWBRT Area 1 (Underpass) was routed to Manhole S7, located on the northern sewer lateral of the Glasgow LDS system. Hydraulic grade line (HGL) assumptions were made at MH S20, located just upstream of gate chamber on Osborne Street and an iterative process developed for running both models for the various options so that each model would have the same boundary condition at the downstream end (HGL) for the final simulation. Table 1 lists the computed HGL elevation for Option 2 (preferred option) for the 1:5-year design storm at each manhole in the Transit LDS system. As shown in Table 1, the freeboard requirements for LDS systems (0.3 m minimum freeboard) is satisfied for the preferred option since the minimum freeboard is 0.78 m.

Table 1: HGL Elevations and Freeboard for Option 2 (Preferred Option)

Manhole	HGL Elevation (m)	Depth Below Ground (m)
Outfall to Manhole S17		
Outfall	225.550	6.45
S23	226.359	5.64
S21	226.941	5.06
S20	227.060	4.94
S19	227.256	4.74
S18	227.742	4.26
S17	228.230	3.77
Manhole S17 to Manhole S13 (South Side Overhaul & Repair Building)		
S17	228.230	3.77
S16	228.896	3.10
S15	229.270	2.73
S14	230.243	1.76
S13	230.628	1.37
Manhole S17 to Manhole S6 (West Side Transit Storage Building)		
S17	228.230	3.77
S8	228.924	3.08
S7	231.152	0.85
S6	231.221	0.78
Manhole S19 to Manhole S1 (North Side Transit Storage Building)		
S19	227.256	4.74
S5	229.110	2.89
S4	229.545	2.46
S3	229.955	2.04
S2	230.537	1.46
S1	230.878	1.12
Manhole S8 to Manhole S12 (West Side Overhaul & Repair Shop)		
S17	228.230	3.77
S8	228.924	3.08
S9	229.470	2.53
S10	229.971	2.03
S11	230.285	1.72
S12	230.577	1.42
Manhole S17 to Manhole S22		
S17	228.230	3.77
S8	228.924	3.08
S22	230.510	1.49

The HGL profile from the outfall to Node S17 is also illustrated in Figure 2.

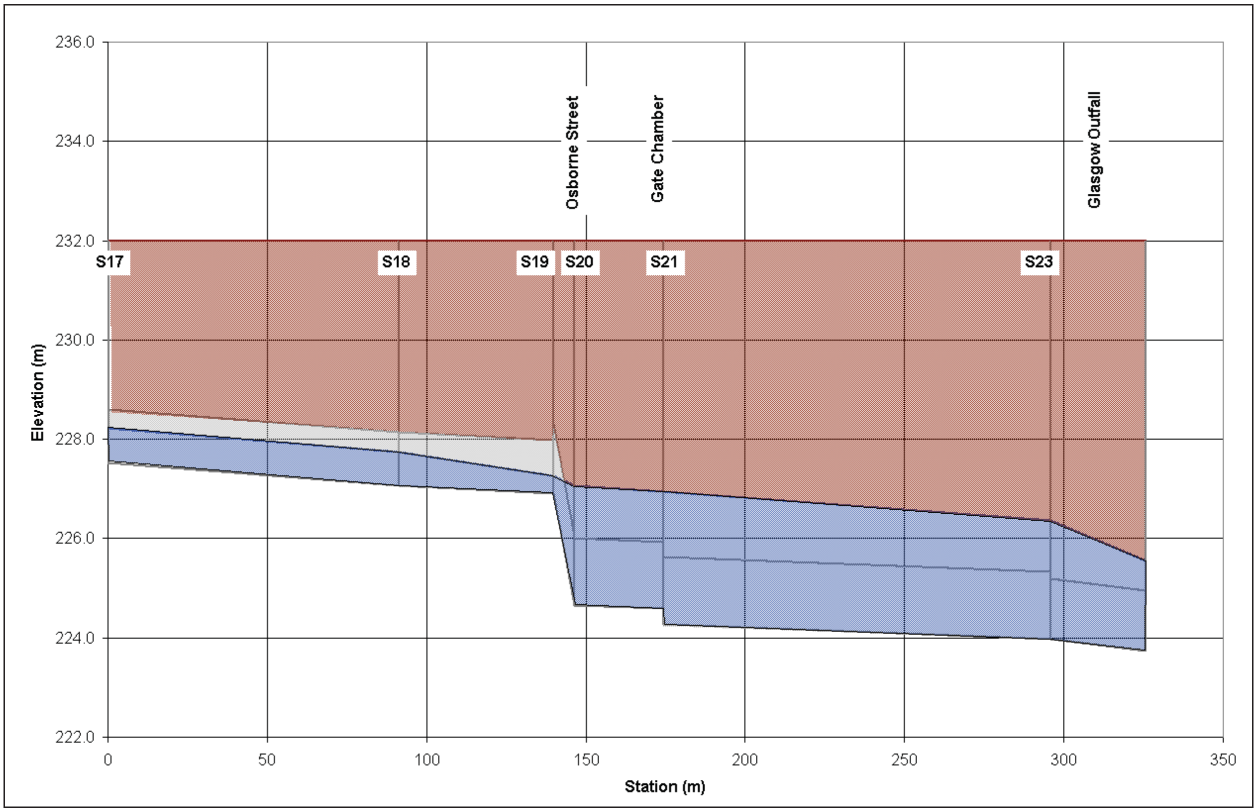


Figure 2: Profile of LDS from Glasgow Outfall to West End of Transit Garage (Option 2 – 5-Year Design Rainfall)

1.3 B & M LANDS RESIDENTIAL DEVELOPMENT

For Option 2, it was assumed that the proposed FRY residential development would be routed north to the Glasgow LDS outfall. Because B & M Lands, the developer of this area, have not yet finalized their plans for a medium to high-density residential development at this location, assumptions were made to incorporate this development as part of the SWMM model. These modelling assumptions were consistent with the original Cockburn Study and were based on the calibrated parameters for Cockburn East. The model parameters are listed in Table 2.

Table 2: Summary of Model Parameters

Calibration Parameter	FRY Residential Development
Percent Imperviousness (%)	~ 35
Soil Infiltration	
- Maximum Infiltration (mm/hr)	85
- Minimum Infiltration (mm/hr)	3
- Decay Rate (sec^{-1})	0.00115
Depression Storage (mm)	
- Pervious	5
- Impervious	1.5
Surface Roughness (Manning n-value)	
- Pervious	0.015
- Impervious	0.030
Catchment Slope (%)	
- Normal Catchments	1.0
- Flat Roofs	0.2

The FRY residential area was divided into four subcatchments for purposes of development of runoff hydrographs to the land drainage sewer servicing the SWBRT. These subcatchments are shown in Figure 3, and are labelled as R1, R2, R3 and R4. Since there is no internal storm water drainage plans for the proposed development, runoff from each of the four areas was analyzed using a lumped sewer system approach.

Figure 3: FRY Residential Development - Subcatchments

Figures 4 to 7 show the runoff hydrographs associated with each of the 4 subcatchments displayed above. Because the areas differed slightly from those originally assumed by Dillon Consulting as part of the original Cockburn Study, a comparison was made between the hydrographs shown in Figures 4 to 7 and the runoff hydrographs produced by Dillon Consulting for the original study. The comparison showed that the hydrograph peaks were similar. An exact match was not anticipated, as the areas used for both analyses were not the same. One of the reasons for which the developable area was not the same as the original Cockburn Study was because part of the area has been sold to Winnipeg Transit for the future construction of a Transit Garage.

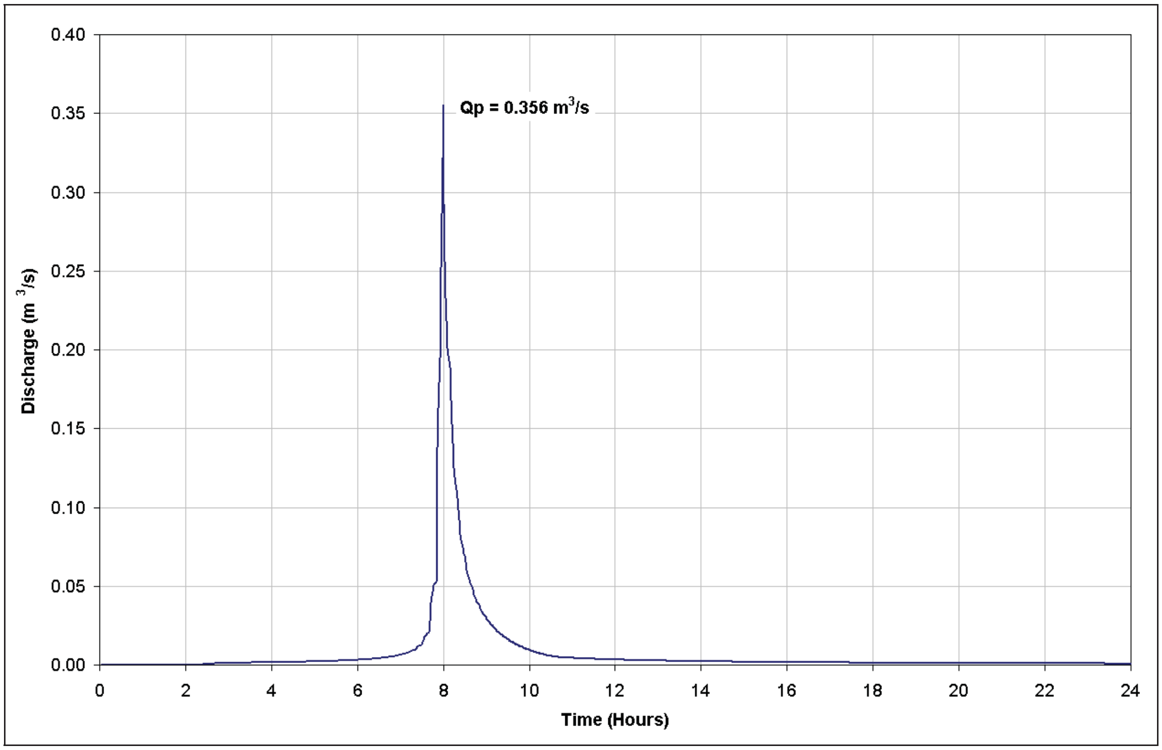


Figure 4 – Runoff Hydrograph (Area R1 – FRY Residential Development)

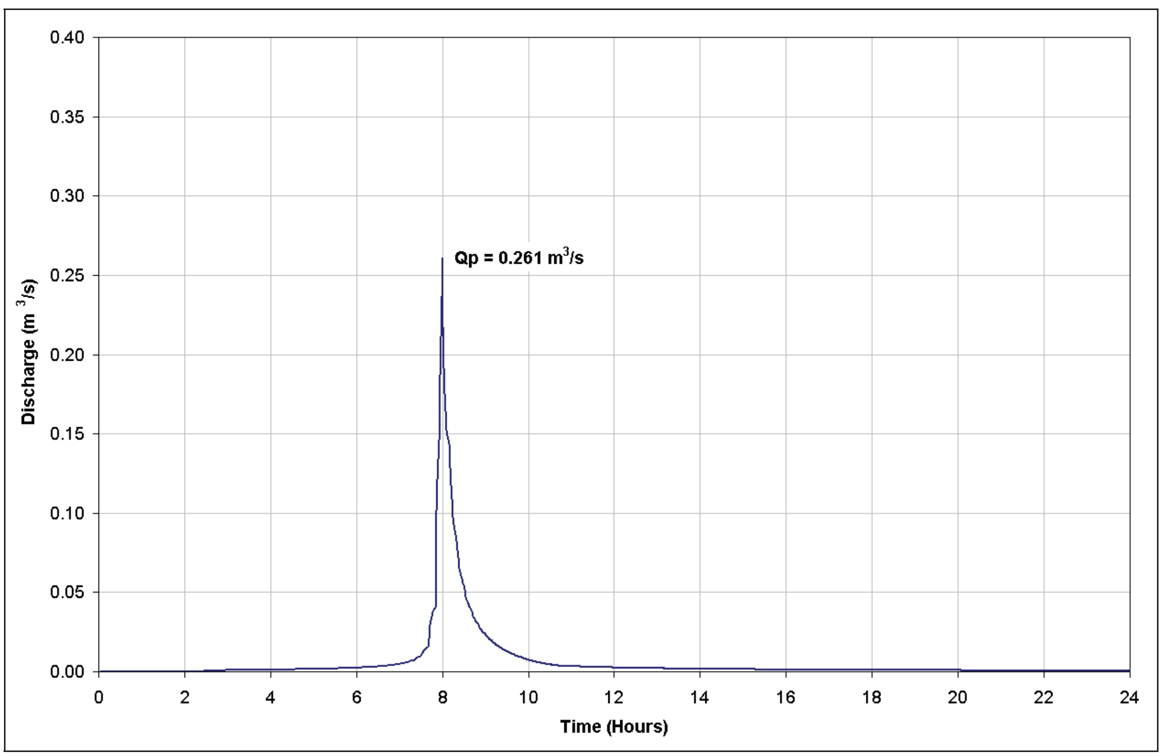


Figure 5 – Runoff Hydrograph (Area R2 – FRY Residential Development)

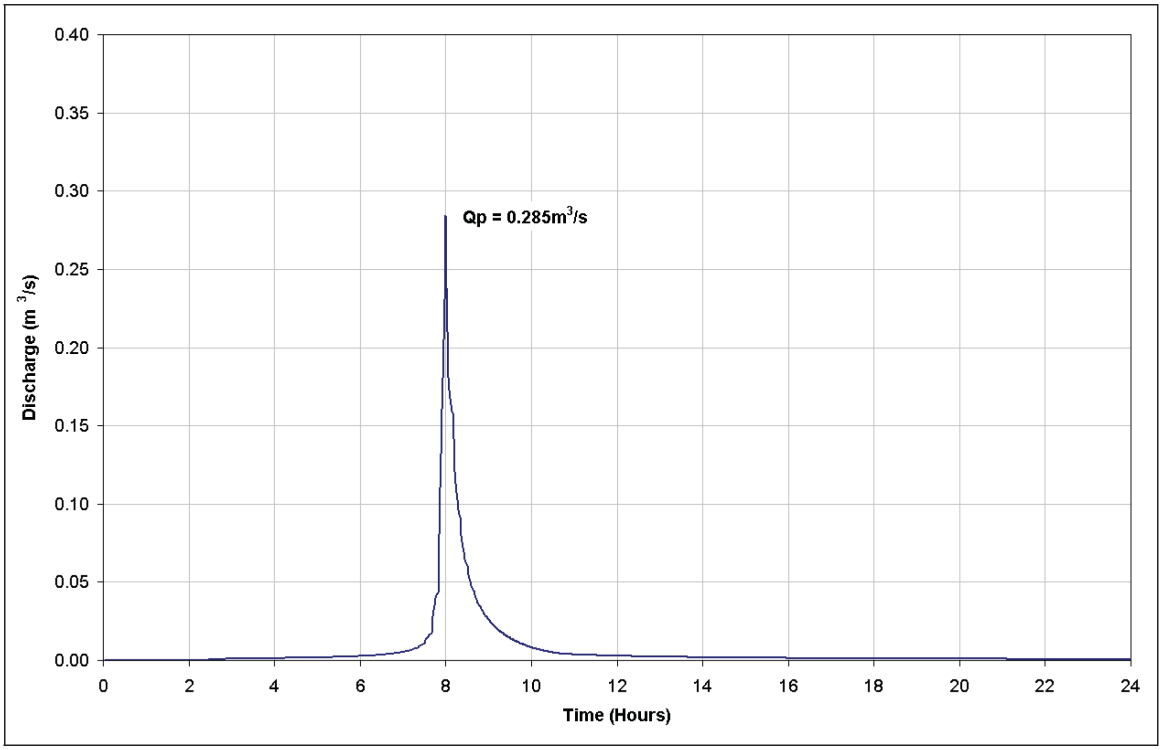


Figure 6 – Runoff Hydrograph (Area R3 – FRY Residential Development)

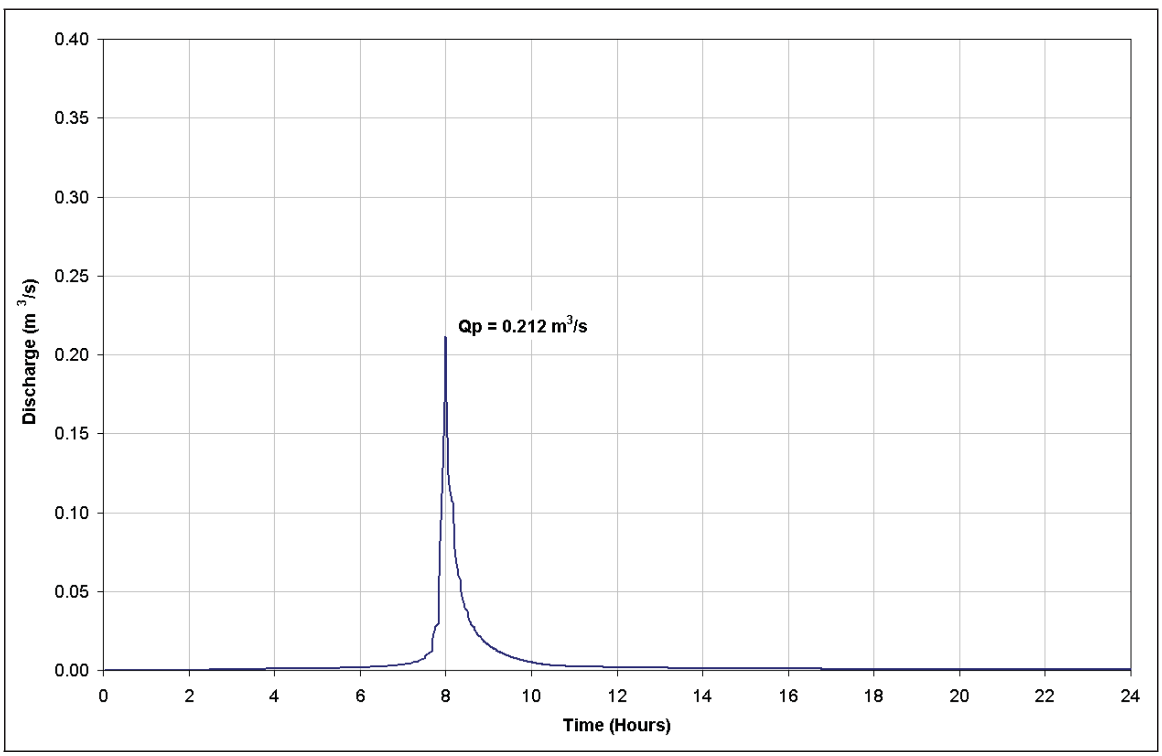


Figure 7 – Runoff Hydrograph (Area R4 – FRY Residential Development)

APPENDIX B

DILLON DRAWINGS – FORT ROUGE YARDS LDS PIPING

SOUTHWESTERN TRANSIT CORRIDOR

LAND DRAINAGE SEWER
OPTION 1 - BASE CASE TO SERVICE BRT ONLY

DILLON CONSULTING

SCALE 1:2000

REF-T50 (1 OF 3)

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DILLON CONSULTING

SCALE 1:2000

SOUTHWESTERN TRANSIT CORRIDOR

LAND DRAINAGE SEWER

OPTION 1 - BASE CASE TO SERVICE BRT ONLY

REF-T50 2 OF 3

SOUTHWESTERN TRANSIT CORRIDOR

LAND DRAINAGE SEWER
OPTION 1 - BASE CASE TO SERVICE BRT ONLY

SCALE 1:2000

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-REF-11x17

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DILLON CONSULTING

SCALE 1:2000

SOUTHWESTERN TRANSIT CORRIDOR

LAND DRAINAGE SEWER

OPTION 2 TO SERVICE BRT AND B&M LANDS

REF-T50 (1 OF 3)

DILLON CONSULTING

SCALE 1:2000

SOUTHWESTERN TRANSIT CORRIDOR

LAND DRAINAGE SEWER
OPTION 2 TO SERVICE BRT AND B&M LANDS

REF-750 (2 OF 2)

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DILLON CONSULTING

SCALE 1:2000

SOUTHWESTERN TRANSIT CORRIDOR

LAND DRAINAGE SEWER
OPTION 2 TO SERVICE BRT AND B&M LANDS

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DILLON CONSULTING

SCALE 1:2000

SOUTHWESTERN TRANSIT CORRIDOR

LAND DRAINAGE SEWER
OPTION 3 TO SERVICE BRT AND SE JESSIE

IB-REF-11x17

DILLON CONSULTING	SOUTHWESTERN TRANSIT CORRIDOR	
SCALE 1:2000	LAND DRAINAGE SEWER OPTION 3 TO SERVICE BRT AND SE JESSIE	REF-T50 (2 OF 3)

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SOUTHWESTERN TRANSIT CORRIDOR

LAND DRAINAGE SEWER
OPTION 3 TO SERVICE BRT AND SE JESSIE

SCALE 1:2000

DILLON CONSULTING

TB-REF-11x17

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DILLON CONSULTING

SCALE 1:2000

SOUTHWESTERN TRANSIT CORRIDOR

LAND DRAINAGE SEWER
OPTION 4 TO SERVICE BRT, B&M AND SE JESSIE

REF-T50 (1 OF 3)

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DILLON CONSULTING

SCALE 1:2000

SOUTHWESTERN TRANSIT CORRIDOR

LAND DRAINAGE SEWER

OPTION 4 TO SERVICE BRT, B&M AND SE JESSIE

REF-T50 (2 OF 3)

SOUTHWESTERN TRANSIT CORRIDOR

LAND DRAINAGE SEWER
OPTION 4 TO SERVICE BRT, BMM AND SE JESSIE

DILLON CONSULTING

SCALE 1:2000

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APPENDIX C

PHOTOS OF RIVERBANK CONDITIONS AT POTENTIAL OUTFALL LOCATIONS

Photo 1 – Looking from top of bank at existing Cockburn Flood Pump Station.

Photo 2 – Looking downstream at shoreline from Cockburn FPS outfall. Note: Existing rockfill from remedial works completed in 1989.

Photo 3 – Outlet of existing high level outfall at Cockburn.

Photo 4 – Looking upstream from Elm Park Foot Bridge at ongoing riverbank instability.

Photo 5 – Riverbank instability at property located immediately upstream of Elm Park Foot Bridge (BDI Location).

Photo 6 – Top of bank area of proposed BDI outfall location. Note: Evidence of historic bank movement near top of bank.

Photo 7 – Looking upstream at shoreline from proposed BDI location.

Photo 8 – Cracked grout apron at Elm Park Foot Bridge.

APPENDIX G

PHASED SEPARATION OPTION – TECHNICAL MEMORANDUM

COCKBURN / CALROSSIE COMBINED SEWER RELIEF
PHASED SEPARATION OPTION

FINAL TECHNICAL MEMORANDUM

PREPARED FOR:
CITY OF WINNIPEG WATER AND WASTE DEPARTMENT

KGS FILE 08-107-14

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CH2MHILL
Responsible Solutions for a Sustainable Future

KGS GROUP
CONSULTING ENGINEERS

EXECUTIVE SUMMARY

This report presents the results of a supplemental investigation into the Cockburn and Calrossie Relief project of a phased land drainage sewer (LDS) separation option. The Cockburn study included a partial LDS separation alternative sized to provide a 5-year level of basement flooding protection, and a complete LDS separation alternative that would not only provide basement flooding protection but also combined sewer overflow (CSO) control; but it did not consider an incremental or phased approach involving the two.

The basement flooding relief program has a mandate to upgrade the level of basement flooding protection, and while it has considered CSO issues in the past, only limited program integration has been practiced. Recent regulatory direction suggests that a CSO program is imminent, and the Water and Waste Department has been increasing their focus and pursuit of options that include CSO integration with basement flooding relief. The Cockburn and Calrossie study dedicated a significant effort to CSO issues, and in fact developed options from three decision perspectives, firstly considering only basement flooding relief (in other words without consideration of CSO controls), secondly considering integration of CSO on a Cockburn and Calrossie district perspective, and finally considering regional CSO control, which included control of the combined sewer districts from the south end of the city extending as far north as The Forks.

The new option included in this investigation involves a 2-phase (optional) “partial to complete separation” approach. The concept is to design a complete LDS separation scheme, but only install enough of the piping to meet the 5-year level of basement flooding protection. The installed piping would be initially oversized for the area served, but would be in-place and adequately sized for the second phase, which would add connecting piping to the remainder of the unconnected district. The advantage of the alternative is that the initial costs would be limited to meeting the basement flooding objective, and it does not preclude moving to the complete LDS separation alternative at a later date. The second phase would depend on the CSO program decisions, and would only proceed to construction after CSO program budget allocations are in place. The main disadvantage is that if complete separation is never implemented then the investment in the larger pipes will never return any benefits.

The approach included the conceptual design of a new complete LDS separation scheme for the Cockburn and Calrossie districts, including Southeast Jessie. The first phase was developed from the complete separation scheme by removing piping from drainage area not necessary to achieve a 5-year level of basement flooding protection. The unconnected area of the first phase would remain connected to the combined sewers and would be a source of combined sewer overflows.

The cost of the first separation phase was determined to be $49.1 million in terms of 2007 dollar values. This compares to the basement flooding relief partial LDS scheme, which is not oversized, of $37.6 million, or in other words it has an $11.5 million premium.

The second phase of the partial to complete separation option would be to extend the separation to the full district. The cost for the second phase was estimated at $11.0 million. Therefore, the total cost of the complete separation for the district would be $60.1 million.

From a benefit-cost perspective, the first phase of the partial LDS separation option in comparison to the non-phased separation alternative results in a drop from 1.7 to 1.4. The drop would lower the relative raking of the district in the basement flooding relief program, and the extra expenditure would not add basement flooding relief benefits. The alternative would clearly not be selected if only considering the basement flooding relief mandate.

The second decision perspective considers the value of integrating CSO controls with basement flooding relief. Both phases of the phased LDS separation option were compared to other alternatives on a CSO trade-off curve; and it was concluded there are other more cost effective alternatives, which are likely to be selected before the phased approach. Justification for use of the alternative would have to come from additional considerations, such as conformance to regional planning, changed conditions or identification of additional values.

Finally, the phased LDS separation was not considered compatible with the regional CSO perspective. The NEWPCC tunnel interconnection relies on multiple district contributions, and elimination of Cockburn would compromise the option, not only for Cockburn, but potentially for the other districts identified as potential interconnection candidates.

In summary, based on a broad range of decision perspectives and the basement flooding relief and CSO program objectives as they are known at the present time, the phased approach to complete LDS separation would be very expensive and unlikely to be selected. However, it is impossible to undertake a complete evaluation or make recommendations without consideration of the CSO program on a broader scale, which is beyond the scope of this additional evaluation. The findings of this evaluation are included and further considered in the Executive Summary of the Cockburn and Calrossie Basement Flooding Relief report.

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1.0 INTRODUCTION

The Cockburn and Calrossie Combined Sewer Relief project was assigned to the team of KGS Group, CH2M HILL and Dillon Consulting on December 15th, 2005. The major elements of the original scope of work included conceptual design of basement flooding relief, combined sewer overflow (CSO) evaluation, analysis of a potential NEWPCC Interconnection, and integration of the Fort Rouge Yards development. The analysis was summarized in a draft report submitted on July 6th, 2007.

Subsequent to submission of the report, further analysis was requested by the Water and Waste Department. The two major additional items included evaluation of integration opportunities for the portion of the proposed Bus Rapid Transit (BRT) corridor development extending through the Fort Rouge Yards (FRY) and providing for expandability of the partial LDS separation alternative to complete separation. The FRY drainage evaluation is included in a separate document, titled "Cockburn and Calrossie Combined Sewer Relief Works Fort Rouge Yards Addition." The phased separation evaluation was assigned along with the FRY evaluation and is discussed in this report.

The phased separation concept would address the immediate need for basement flooding relief and at the same time provide provision for future complete separation. The transition would be made from the existing non-separated system to a completely separated system in two phases. The first phase would involve partially separating the system to meet the basement flooding protection objective. The second and final phase would involve complete separation of the system by adding new land drainage sewers to collect all surface runoff throughout the district. The land drainage sewers installed in the first phase of the partially separated system would be oversized to accommodate the future expansion to complete separation.

The Cockburn and Calrossie report included a complete range of CSO integration options. It included partial LDS separation and complete LDS separation, but did not include the option involving the provision to transition from partial to complete. An apparent advantage of the partial to complete option is that it keeps the options open if a decision cannot be made on CSO controls. It could be constructed immediately as a basement flooding relief option, without the commitment to full separation. If full separation is subsequently selected, it could readily be upgraded, which is not the case with other options. If complete separation is not selected, the second phase upgrading cost would not be required.

This report presents the results of the phased option, including the initial over-sizing costs and impact on the benefit-cost evaluation in comparison to other basement flooding relief alternatives. The ultimate transition to complete separation is also presented and considered in relation to other CSO alternatives.

2.0 PARTIAL SEPARATION

The approach used for partially separating the system as a basement flooding relief alternative, is discussed in Section 8.3 “Separation Alternatives” of the Cockburn and Calrossie report. The piping schematic for the partial separation option, with Southeast Jessie included, is presented as Drawing No. 9 in the report. The new land drainage sewers would require an outfall separate from the combined system, which was assumed to be co-located at the existing Cockburn outfall location.

The extent of area separated was determined by progressively removing road drainage from the combined sewer system until basement flooding was eliminated for the 5-year storm. A partial land drainage system was then designed for the separated area. Weeping tile drainage, inflow and infiltration in the piping system, and dry weather flow from the separated area were retained in the combined system using the methodology developed and reported on in the report.

3.0 "PARTIAL TO COMPLETE" PHASED SEPARATION DESIGN

The partial to complete phased separation option required that a complete LDS separation alternative be developed, with the sewers not required to meet the basement flooding 5-year level of protection relief objective subsequently removed.

For complete separation, all of the existing catch basins (road drainage) were assumed to be reconnected to the new LDS piping system, which essentially required new pipes to be routed down every street. The City of Winnipeg's Sewer Management System (SMS) was used to find existing catch basin locations. The weeping tiles, inflow and infiltration and dry weather flow was retained in the combined system. Roof drainage, including flat roofs, was assumed to be disconnected from the combined sewers and directed to the land drainage sewers, primarily by overland routing. Rerouting the flows to the new LDS separation system eliminated the majority of the flow in the combined sewer system and provided in excess of the 5-year level of basement flooding protection objective.

Only the LDS sewers required to achieve a 5-year level of basement flooding protection would be constructed under the basement flooding relief program. These sewers were identified by ensuring the flow remaining in the combined system would not cause basement flooding, which was assumed to be a surcharge level exceeding 2.4 metres below grade. The amount of separation was determined by re-introducing upper end flows to the combined sewer system until the combined system was at incipient flooding for a 5-year event. The area that was not added back was then the area required to be separated, and the pipe sizing for those areas assumed to be left at the same size as required for complete separation. The remaining LDS sewers would be oversized for the amount of area they serve and would only be at design capacity if and when the area becomes fully separated in the future.

The analysis was done for the Cockburn and Calrossie service area and included Southeast Jessie. Grant Park Mall parking lot drainage was connected to the land drainage system on Grant Avenue, and Parker Lake and Taylor Pond were included in the model without being modified.

The City of Winnipeg's criteria for land drainage sewer design was used for the LDS sewer sizing, as described in the Cockburn and Calrossie report:

- Surcharge permitted to a maximum height of 0.3 metres below surface
- Minimum pipe cover of 1.5 metres

In the design, slopes of between 0.5% and 1% were typically assigned to the new land drainage sewers. On occasions, flatter slopes were assigned to meet the minimum cover criteria of 1.5 m. In some cases, slopes greater than 1% were used to meet the minimum velocity requirement of 0.94 m/s (3 fps) as per City of Winnipeg criteria.

4.0 "PARTIAL TO COMPLETE" PHASED SEPARATION RESULTS

The complete separation piping scheme designed for a 5-year storm event is shown in Figure 1.

A new LDS outfall is co-located with the existing Cockburn combined sewer trunk and outfall.

Surface runoff in Cockburn East is primarily directed to Cockburn Street.

For Cockburn West, a new land drainage system is located on Harrow Street that will connect to the Taylor Avenue LDS. Drainage on Carter Avenue, Hector Avenue, and Ebby Avenue is assumed to be spilt between the Harrow and Wilton Street LDS. A new LDS will collect surface drainage from Nathaniel and connect to the Taylor Avenue LDS. The Nathaniel LDS will also accept surface drainage from the subdivision south of Grant Park Mall. Drainage from part of this subdivision will also flow directly to Taylor Avenue. A new LDS will collect runoff from Parker Street and direct it to the Cockburn LDS.

The land drainage sewers in Southeast Jessie were sized to accept all surface runoff. In the previous analysis summarized in the Cocbkurn report, not all of the area had to be separated to meet the basement flooding relief objective.

It was not possible to connect the catch basins north of the Pembina underpass to the proposed LDS. The proposed LDS on Parker, Pembina or Harrow would have to be lowered considerably and slopes would need to be much flatter. This would, therefore, increase the size of the required LDS and decrease the velocities. This small area was, therefore, assumed to remain connected to the combined system.

With this proposed separation scheme, the 0.3 m freeboard requirement in the LDS is achieved except in some localized areas:

- Parking lots (Grant Park Mall Parking and parking lot south of Taylor, close to Poseidon)
- Subdivisions west of Parker Lake (future development)
- Areas in Calrossie

Surface ponding is acceptable in the parking lots and no further design changes will be required in these areas. Surcharge occurs in Calrossie, which is an already separated area and because it is a street flooding issue is not likely to be of concern. The Parker Lake area would be considered with the lake development.

In the combined sewer system, now only accepting dry weather, weeping tile flows and inflow and infiltration, the hydraulic grade line will be at least 2.4 m below grade and, therefore, provides in excess of the required 5-year level of basement flooding protection.

Figure 2 shows the revised partial separation model with oversized land drainage sewers capable of accepting runoff volumes from complete separation. Both the 0.3 m freeboard for the LDS and the 2.43 m freeboard for basement flooding protection requirements will be achieved for the 5-year storm event with this configuration. This represents the first phase of the phased LDS separation option.

5.0 BENEFIT-COST ANALYSIS

5.1 PROJECT COSTS

Construction costs, including Southeast Jessie, for the partial and complete separation alternatives are summarized in Table 1. The costs are expressed in terms of 1991 and 2007 dollar values to be consistent with costs used in other relief projects and in the Cockburn report. The costs were based on the same unit costs as detailed in the Cockburn study.

Table 1: Construction Cost Summary (including Southeast Jessie)

Alternative	1991 Cost	2007 Cost
Partial LDS Separation (first phase)	$11,220,000	$33,216,000
Complete LDS Separation (second phase)	$15,850,000	$40,658,000

The total project costs include overhead and burdens in addition to the construction costs, as follows:

- Contingencies of 10 percent
- Engineering of 15 percent
- Burdens of 3 percent for internal City administration and financing

Total capital costs for each alternative were converted to annual costs for comparison with annual benefits using the same methodology as presented in the Cockburn report. The annual calculation was based on a discount rate of 4 percent and a 50 year amortization. Costs and benefits for the benefit-cost evaluation and comparisons to competing districts for the basement flooding relief program prioritization process are required to be in terms of 1991 values. A summary of costs in 1991 dollars is included in Table 2:

Table 2: Separation Alternatives Cost Summary (1991 Cost Basis x $1000 including Southeast Jessie)

Alternative	1991 Construction Cost	Contingency (10%)	Eng (15%)	Burden (3%)	1991 Total	Average Annual Cost
Partial LDS Separation (first phase)	$11,220	$1,220	$1,683	$337	$14,460	$670
Complete LDS Separation (second phase)	$15,850	$1,585	$2,378	$476	$20,289	$945

While the 1991 costs are of interest for the basement flooding relief program considerations, budgets are required in terms of current costs. The Cockburn report used a 2007 base year, which is presented in Table 3. A contingency of 30 percent was used for budgeting purposes.

Table 3: Separation Alternatives Cost Summary (2007 Cost Basis including Southeast Jessie)

Alternative	2007 Construction Cost	Contingency (30%)	Eng (15%)	Burden (3%)	Total 2007 Capital Cost
Partial LDS Separation (Cockburn report)	$25,450	$7,635	$3,818	$764	$37,666
Partial LDS Separation (first phase)	$33,216	$9,965	$4,982	$996	$49,160
First Phase Premium					$11,494
Complete LDS Separation (second phase)	$40,657	$12,197	$6,099	$1,220	$60,172
Second Phase Premium					$11,013

5.2 ANNUAL BENEFITS

Average annual benefits were determined by estimating the area-wide reduction in basement flooding that would occur after implementation of upgrading alternatives. Average annual damages are developed from flood-frequency-damage curves, with the average annual benefits equaling the difference in annual damages before and after relief implementation. The methodology used for estimating damages is consistent with the Basement Flooding Relief program approach and was summarized in the Cockburn report.

The event damage values, average annual damages and average annual benefit estimates are presented in Table 4. There would be no flooding damages for the 5-year event for any of the upgrading options since the design is based on a 5-year level of protection. Flooding damages would occur for the 10-year event for the first phase partial separation alternative, but not for complete separation. Complete district flooding is the result of an extreme event and is so extreme the damages would be identical regardless of the upgrading alternative.

Table 4: Average Annual Damages and Benefits (1991 x $1000 including Southeast Jessie)

Alternative	1-year	2-year	5-year	10-year	Complete Flooding	Average Annual Damages	Average Annual Benefits
Existing	$220	$400	$2,340	$4,050	$10,330	$1,390	$0
Partial LDS Separation (first phase)	$0	$0	$0	$1,500	$10,330	$430	$960
Complete LDS Separation (second phase)	$0	$0	$0	$0	$10,330	$200	$1,190

The first phase LDS separation and remaining combined sewer system were analyzed for the 10-year event, with the findings as follows:

- Partial LDS (first phase): The 0.3 m freeboard requirement was met, except in parts of Southeast Jessie and along Daly Street. Although the level of street flooding protection is greater with the LDS sewer over-sizing where the pipe is installed, it does not have an advantage in terms of flooding benefits since it does not affect the flows in the combined system.
- Combined Sewer System: The 2.43 m freeboard requirement for basement flooding protection was not met in several areas of the study area for the 10-year storm event. This is expected because the oversized LDS separation sewers are on the land drainage system, and they provide no direct improvement to basement flooding protection.

The benefits for complete separation, with separation of the entire area in place, would be similar to the complete separation described in the Cockburn report. It would have a higher level of protection, and no flooding would be expected for the 10-year storm.

5.3 BENEFIT-COST RATIO

The benefit-cost ratio is determined by dividing the average annual benefits (Table 4) by the average annual cost (Table 2). The benefit-cost results for the original Cockburn report partial land drainage separation alternative, the first phase of the phased LDS alternative, and the final complete separation alternative are presented in Table 5.

Table 5: Benefit-Cost Comparison with Southeast Jessie

Alternative	Benefit/Cost
Partial LDS Separation (Cockburn report)	1.7
Partial LDS Separation (first phase)	1.4
Total LDS Separation	1.3

The phased partial LDS separation alternative has a benefit-cost ratio of 1.4, while the basement flooding relief alternative partial separation presented in the Cockburn report has a benefit cost ratio of 1.7. The reduced B/C ratio results from the additional investment in potential CSO control and should not necessarily be used for scheduling of projects in the basement flooding relief program. The complete separation B/C ratio does not change, other than for refinements to the alternative cost estimate.

6.0 COMBINED SEWER OVERFLOW CONSIDERATIONS

The Cockburn and Calrossie report considered options for integration of combined sewer overflow controls with basement flooding relief. It considered three perspectives, with the first being basement flooding relief alone, the second including integration of CSO control into basement flooding relief on a district specific basis and the third considering the integration of basement flooding relief into a regional CSO solution. The phased separation alternative was evaluated in terms of how it would fit into each perspective.

In terms of the first perspective, the phased separation option would not be selected. The perspective considers only the basement flooding relief mandate and not additional value added by CSO control. A premium of $11.5 million would be required for the first phase of partial separation and would not provide additional basement flooding benefits. The comparative options for a district specific solution as discussed in Section 13 of the Cockburn report clearly demonstrate that there are other alternatives that are more cost effective. The second phase of complete separation would add another $11.0 million and would clearly not be justified in terms of strictly basement flooding benefits. It is evident that combined sewer overflow benefits would be required to justify the phased separation option.

Phased separation specifically addresses the second perspective, since it provides the combined benefits of basement flooding relief along with district specific CSO control. Storm water that is removed from the combined system with separation reduces the combined sewage volume making it easier to store and pump to the wastewater treatment plant. The removed land drainage component would not contain domestic sewage and in accordance with current regulations could be discharged without further treatment to the river.

The district specific CSO option trade-off curve was presented in the Cockburn report and has been reproduced in Figure 3. The costs presented in the figure represent the premium for CSO control over and above the $36.0 million cost of the recommended partial separation relief alternative (in terms of 2007 dollars, without the phased option), which was established as a base cost. The phased separation approach has been added to the figure, with the first phase being installation of the enlarged partial LDS separation piping (point 1) and the second phase being extending separation to the entire district (point 2).

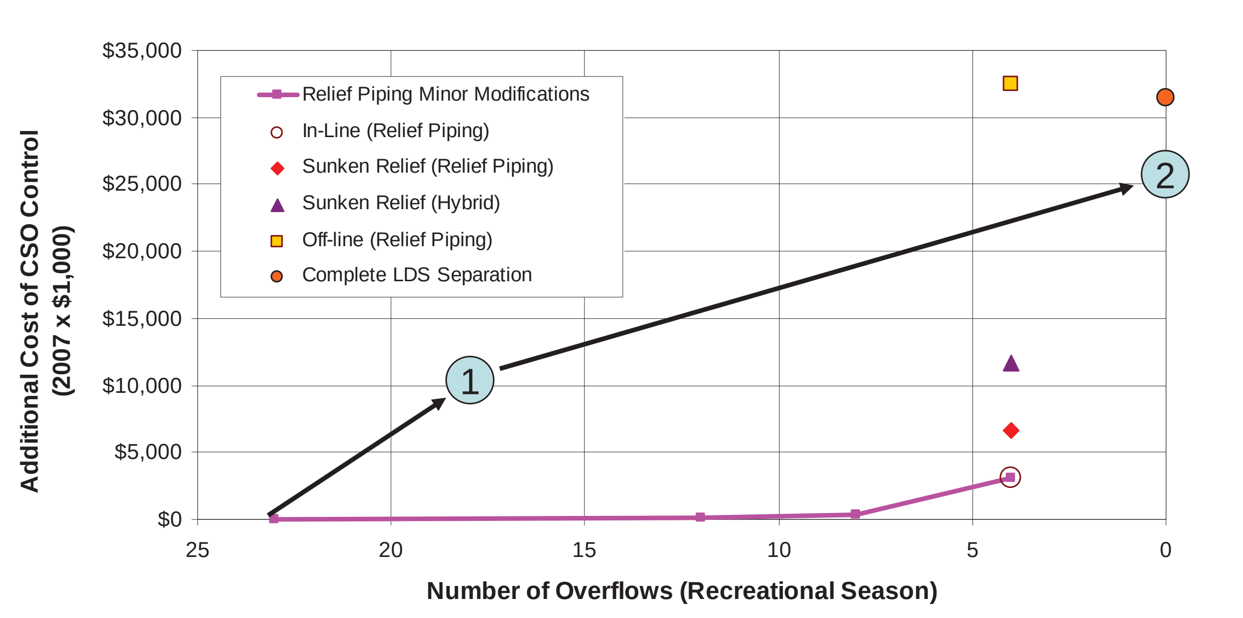


Figure 3: Cockburn CSO Trade-Off Curve

Partial separation without supplemental CSO control (point 1) would provide only a nominal reduction in combined sewer overflows. Lower volumes of runoff would enter the combined sewer and the weir would be exceeded less often. The $11.5 million premium to achieve the additional overflow control would not by itself be cost competitive with other minor modifications as shown in the figure, such as raising weirs.

After construction of the first phase (point 1), the option of choosing CSO storage options or continuing with complete separation is available. Partial separation reduces the volume of combined sewage to be managed, but achieving the four overflow objective would require a significant investment. With partial LDS separation, a large volume of wet weather flow would still be collected in the combined sewer system; and because it would exceed the rate of pumping provided by the lift station, would require temporary storage. It is quite likely the excess volume of the combined sewers could be used for in-line storage, but would require gate controls and would be subject to most of the previously identified in-line storage concerns, such as sedimentation, cleaning, and odour control.

The second phase (point 2), which involves separation of the rest of the district, would result in complete separation at an additional cost of $11.0 million. It would function identically to the complete separation alternative discussed in the Cockburn report. With complete separation, it has been assumed that the virtual elimination of overflows would be achievable, which is an advantage over other alternatives, but based on the anticipated regulatory limits may not have a tangible value.

Complete separation would eliminate all street runoff to the combined sewers; but they would still receive flow from foundation drains, manhole and pipeline inflow and infiltration, and dry weather flows. The amount of flow has not been field verified, but based on indications from the Cockburn and Calrossie study, it would greatly exceed the capacity of the lift station and in-line storage would be required. Sedimentation may become a problem because of the reduced flushing action of the lower inflows and require cleaning provisions to be built, or a cleaning program to be implemented. An additional cost in the order of $3.0 million would have to be added to the $11.0 million second phase cost for controls and flushing.

Based on a comparison of alternatives from Figure 3, there are more cost effective alternatives to meet the district specific perspective of combining CSO control with basement flooding relief. Justification of complete separation would have to include additional considerations such as conformance to a regional plan, changed conditions or identification of additional values and evaluation criteria.

The phased LDS separation option would not be consistent with the regional CSO perspective proposed in the Cockburn study. A tunnel connection from Cockburn District to the River District near The Forks was considered viable for this third perspective. The tunnel would serve as a storage and transport element for all of the combined sewer districts in the southwest quadrant of the city, including Cockburn. Although the evaluation was completed at a planning level, it concluded the tunnel connection was competitive to a combination of in-line and off-line CSO options, and more competitive than CSO options exclusively using off-line storage.

The cost of an incremental CSO tunnel for the NEWPCC interconnection option would be less than the cost of the phased Cockburn LDS separation option. Not including Cockburn in the tunnel option would reduce the cost effectiveness of the entire regional tunnel option, and could result in the combination of in-line and off-line options, or the more costly off-line alone option to be implemented. If a regional tunnel is to be used, it would extend to as many districts as practicable, which is inconsistent with the separation options.

7.0 PHASED SEPARATION EVALUATION

A summary of the pros and cons for phased LDS separation option is as follows:

Pros

- Implementation of the first phase of the phased LDS separation option would preserve the complete separation option. If partial separation is implemented without oversizing the pipes for future complete separation, the opportunity would be lost if it were ultimately determined complete separation was desired.

- The CSO program is likely to include a mixture of control options, and if there is a requirement for separation to be implemented then Cockburn would be one of the least costly because of the opportunity to integrate it with basement flooding relief.

- Complete separation would provide an increase to the level of basement flooding protection.

- Complete separation would provide a viable option if the ultimate objective is to eliminate overflows.

Cons

- Including the phased option is costly. A premium of $11.5 million is required for the first phase and adds little to the basement flooding relief benefits. The second phase would add another $11.0 million and would require CSO controls in addition to the separation costs.

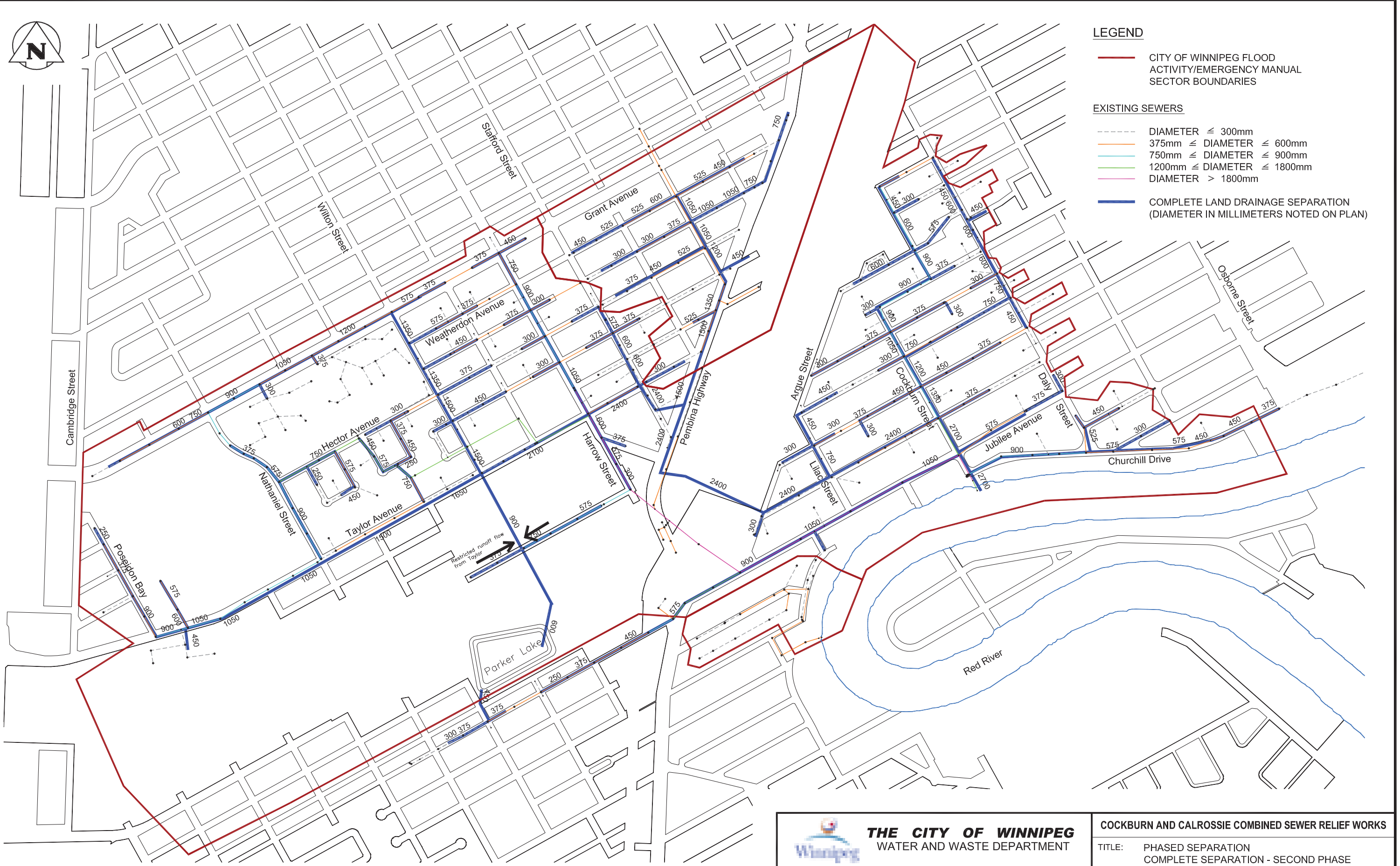
- Complete separation may cause the system to be reclassified as a separate sewer system and be subject to a more stringent Sanitary Sewer Overflow (SSO) standard, instead of a presumed CSO regulation of four overflows per year.

- Proceeding with the alternative may pre-determine the regional CSO solution, by an early commitment to separation.

- Complete separation requires construction on each and every street and is disruptive.

- Complete separation adds infrastructure which must be maintained over the long term and does not address the need for existing combined sewer rehabilitation.

FIGURES



COCKBURN AND CALROSSIE COMBINED SEWER RELIEF WORKS

THE CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

KGS GROUP
CH2MHILL
DILLON CONSULTING

TITLE:	PHASED SEPARATION COMPLETE SEPARATION - SECOND PHASE		
JOB NO.:	05-107-14	DATE:	MAY 2010
SCALE :	AS NOTED	FIGURE :	1
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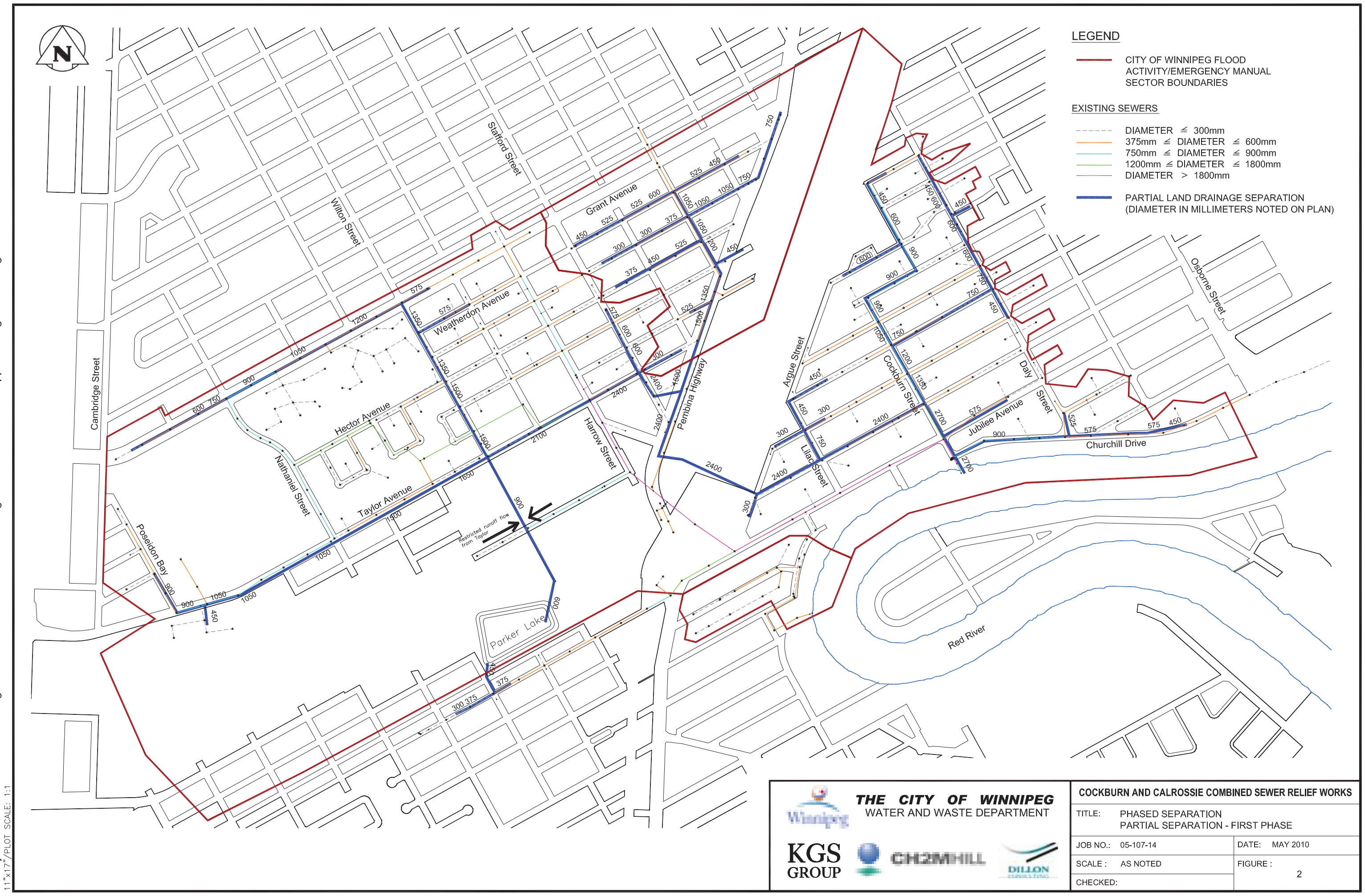

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