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REPORT

City of Fort St. John Stormwater Masterplan

Phase 1

10808 - 100th Street, Fort St. John, BC V1J 3Z6 | T: 250.785.9697

File: 1958.0359.01

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April 29, 2013

File: 1958.0359.01

City of Fort St. John
10631 100 Street
Fort St. John, BC V1J 3Z5

Attention: **Victor Shopland, Director of Infrastructure and Capital Works**

RE: FINAL REPORT – STORMWATER MASTERPLAN – PHASE 1

Please find attached the final report analyzing the major storm issues concerning the south-central catchment within the City of Fort St. John. This report is the first phase of a complete stormwater masterplan.

We trust that the attached report fulfills the City's requirements. Please do not hesitate to contact us if you have any questions.

Sincerely,

URBAN SYSTEMS LTD.

Chad Carlstrom, EIT

Cameron Gatey, P.Eng.

/cc

Attach.

cc: Alma Medina, City of Fort St. John

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Prepared For:

City of Fort St. John

10631 100 Street

Fort St. John, BC V1J 3Z5

Attention: Victor Shopland, Director of Infrastructure and Capital Works

Prepared by:

Urban Systems

10808 100 Street

Fort St. John, BC V1J 3Z6

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March 26, 2013

Cover Photos:

1. Bouffioux Coulee stormwater outlet; Urban Systems
2. Bouffioux Coulee during July 29, 2010 rain event; EnergeticCity.ca
3. Flooding on 94 Avenue (96 – 93 St) after July 29, 2010 rain event; EnergeticCity.ca

Photos of flooding events within the report are courtesy of the Flickr user EnergeticCity

Contents

1.0 Introduction

Recognizing their current stormwater infrastructure has limitations, the City of Fort St. John is taking a proactive approach to deal with existing stormwater problems by developing a Stormwater Masterplan. The need for a comprehensive stormwater plan has been reinforced through recent rainfall events including the July 29, 2010 event which resulted in the Province approving Disaster Financial Assistance for Fort St. John.

With plans to analyze the entire City, this report acts as the first step in developing a comprehensive plan to deal with stormwater. Acting on a priority basis, the initial emphasis is on the catchments whose drainage problems present the highest risk. It is with this prioritization that the first area of focus is the South-Central catchment.

Key goals within this report include:

- Identifying specific problems in the South-Central catchment
- Identifying the return frequency and type of rainfall event that occurred on July 29, 2010
- Understanding the major system surface flow routes and determining the capacity of the existing piped storm infrastructure
- Determining approximate volumes of stormwater that results in surface flooding
- Assessing potential solutions to reduce public and private damage and calculating their corresponding Class D cost estimates
- Prioritizing actions for implementation with future Capital projects and budgets

1.1 Historical Reports

Few studies have previously analyzed the City's stormwater system with a broad perspective inclusive of major rainfall events. However, there is a 2004 Drainage Report conducted by Urban Systems for the Ministry of Transportation on the Alaska Highway No.97 – Fort St. John Corridor Improvements. This report has been used as a reference for nearby drainage systems and acknowledges that:

- Erosion at the Bouffioux Coulee is a concern and comments by geotechnical and environmental consultants indicate the channel is in severe distress
- Instability of the Bouffioux Coulee has been heightened by urbanization within the City of Fort St. John
- Storm drains at 93 Avenue (91 – 92A Street) and 100 Street (in the Alaska Highway right-of-way, immediately upstream of tie in to the 2000 mm trunk sewer) appear to be undersized for the 5-year event

The problems identified within this 2004 Ministry of Transportation report foreshadow problems that continue in the present year of 2012. As development and infill within the City progresses, pervious areas that naturally assist drainage are replaced with impervious items such as buildings, asphalt, and concrete. Continued urbanization can result in increased runoff volumes and can heighten problems such as capacity issues within the piped system and erosion at storm outlets.

Following the Ministry of Transportation report was a 2005 Drainage Report conducted by Urban Systems for the City of Fort St. John. This report created and utilized an XPSWMM computer model to analyze the minor storm system (5 year event) within the City. Based on the hydraulic analysis, improvements to the minor system were provided accompanied with a construction cost estimate. The model created for this report served as an investment by the City in the planning, upgrading, and maintenance of their drainage system. This report did not analyze the major system.

2.0South-Central Catchment

The City's drainage system is separated into various catchments and the largest is the South-Central catchment with an area of approximately 420 ha (Figure 1). This catchment is primarily composed of the downtown core, higher density housing, and service/general commercial properties. The majority of the South-Central catchment is developed and largely impervious.

The extent of the South-Central catchment captures runoff as far north as 106 Avenue along the north-south drainage divide and spans west-east from 116 Street past 86 Street. Overland flow within this catchment primarily travels in a north-south direction; consequently, streets generally act as collectors of overland flow whereas avenues typically transfer overland flow to streets. The runoff generated in the South-Central catchment discharges to the Peace River via the Bouffioux Coulee.

A unique geographical feature of Fort St. John that is also within the South-Central catchment is a low lying area referenced as the FSJ Basin (Figure 1). The FSJ Basin will be the principle area of concern within this report as the South-Central catchment's contours drain overland flow towards this basin and many historical flooding problems have occurred within it.

Overall, the South-Central catchment is selected as the focus of this report as due to its:

- Historical drainage problems
- Valuable commercial, residential, and public properties
- Large low lying area (the FSJ Basin)
- Large catchment area
- Large runoff volumes
- Existing developed areas that are highly impervious

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STORMWATER MASTERPLAN

DATE: DECEMBER 2012
CITY OF FORT ST. JOHN STORMWATER MASTERPLAN

CITY OF FORT ST. JOHN

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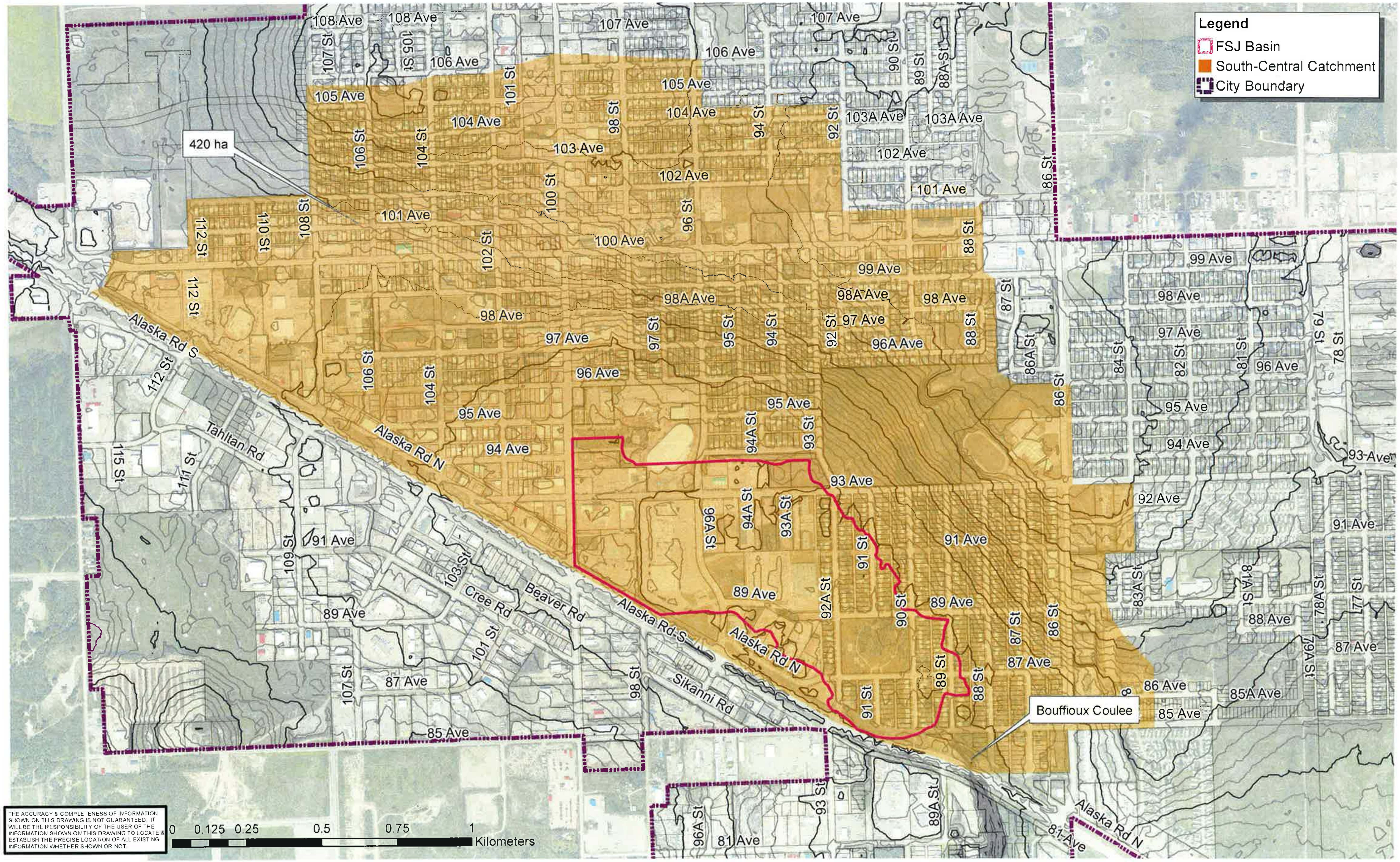


SOUTH-CENTRAL CATCHMENT

FIGURE 1

2.1 Historical Overview

Prior to the development of current businesses, the FSJ Basin area was a natural depression filled with brush surrounded by agricultural lands (Figure 2 – 1945 air photo). It is assumed that the agricultural farmers of the 1940's did not clear land within the basin because of its poor drainage qualities. The City at this time was small and concentrated at the intersection of 100 Street and 100 Avenue. Other important characteristics of the 1945 air photo include 100 Street and the Alaska Highway surrounded by agricultural lands. The Alaska Highway even appears to have shifted alignment near the Bouffioux Coulee to avoid passing through the low-lying lands.

Early construction of the Alaska Highway and 100 Street likely followed typical road construction and were built above the original ground surface. It's assumed that initially these roads did not cause any drainage problems as the surrounding lands were permeable agricultural lands and culverts could have been utilized to keep the natural drainage continuing in its south-east flow direction into the FSJ Basin.

By 1976, 31 years later, Fort St. John had expanded in all directions (Figure 2 – 1976 air photo). The Matthew's Park development can be seen encroaching into the FSJ Basin but the land within the basin largely remained untouched. At this time the City begins to have notable development characteristics and many present day streets and avenues can be identified. 93 Avenue is constructed but likely did not have the drainage issues of today as runoff could still flow south to the low-lying lands within the FSJ Basin. Similarly, other areas within the South-Central catchment likely did not have drainage problems as the undeveloped FSJ Basin, with its large area, acted to attenuate the peak flows and slowly release them for discharge into the Bouffioux Coulee. The coulee at this time is filled with vegetation growth but shows slight erosion towards the southern photo edge.

A view of present day Fort St. John (Figure 2 – 2009 air photo) resembles the 1976 air photo but has significant changes in regards to drainage in the South-Central catchment including:

- Expansion
- Increased infill in the central area
- Less grassed areas (pervious areas)
- More concrete and asphalt (impervious areas)
- The FSJ Basin has been fully developed and 92A Street is constructed through it; development within the basin significantly altered the surface drainage path for the area
- The Bouffioux Coulee has developed a well-defined scar where bare land is revealed through erosion and vegetation does not grow – this can be clearly seen in the 2009 air photo. This scar is a result of increasing urbanization and decreasing attenuation of runoff; these two factors result in increased discharge rates.

In addition, because of how development formed around the Alaska Highway and 100 Street, these original elevated roadways now act as drainage boundaries for overland flow. 100 Street, particularly between its intersection with the Alaska Highway and 96 Avenue, restricts overland flow from the west and is now a major contributor for nearby surface flooding problems.

Overall, throughout the expansion of Fort St. John, it appears that some development occurred without appropriate measures to accommodate increased runoff volumes and it appears that the major system drainage paths were not accounted for or maintained. Furthermore, adequate underground piping was not installed as compensation for the obstruction of overland flow paths caused by development.

Since the development of the large natural depression (FSJ Basin) that assisted in stormwater runoff, many areas in the South-Central catchment now rely on piped solutions to drain water to the Bouffioux Coulee outlet.

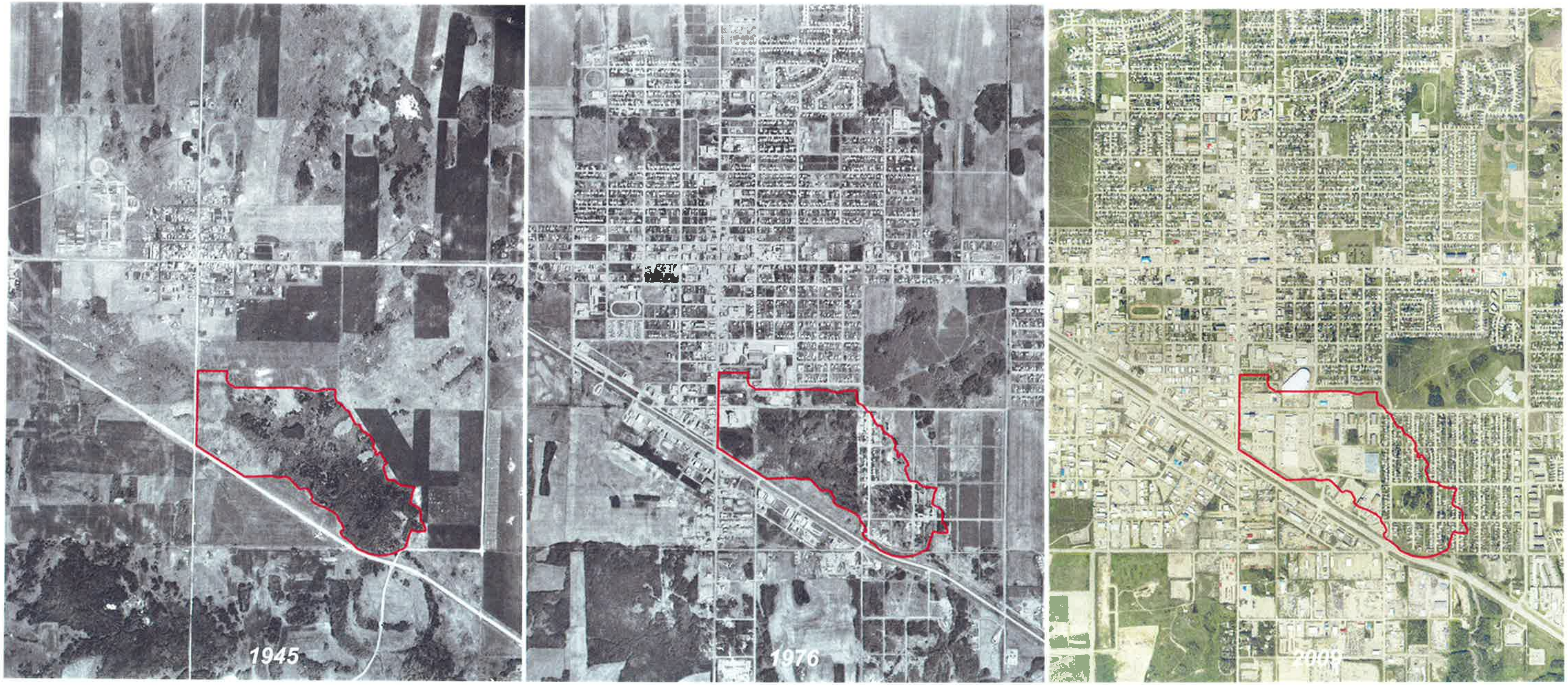


FIGURE 2. COMPARISON OF AIRPHOTOS OF THE FSJ BASIN FROM 1945, 1976, TO THE CURRENT DAY (2009 IMAGE). HISTORICALLY THE FSJ BASIN WAS A NATURAL DEPRESSION WITH BRUSH, SURROUNDED BY AGRICULTURE LAND, AND NATURALLY DRAINED BY SURFACE INTO THE BOUFFIOUX COULEE.

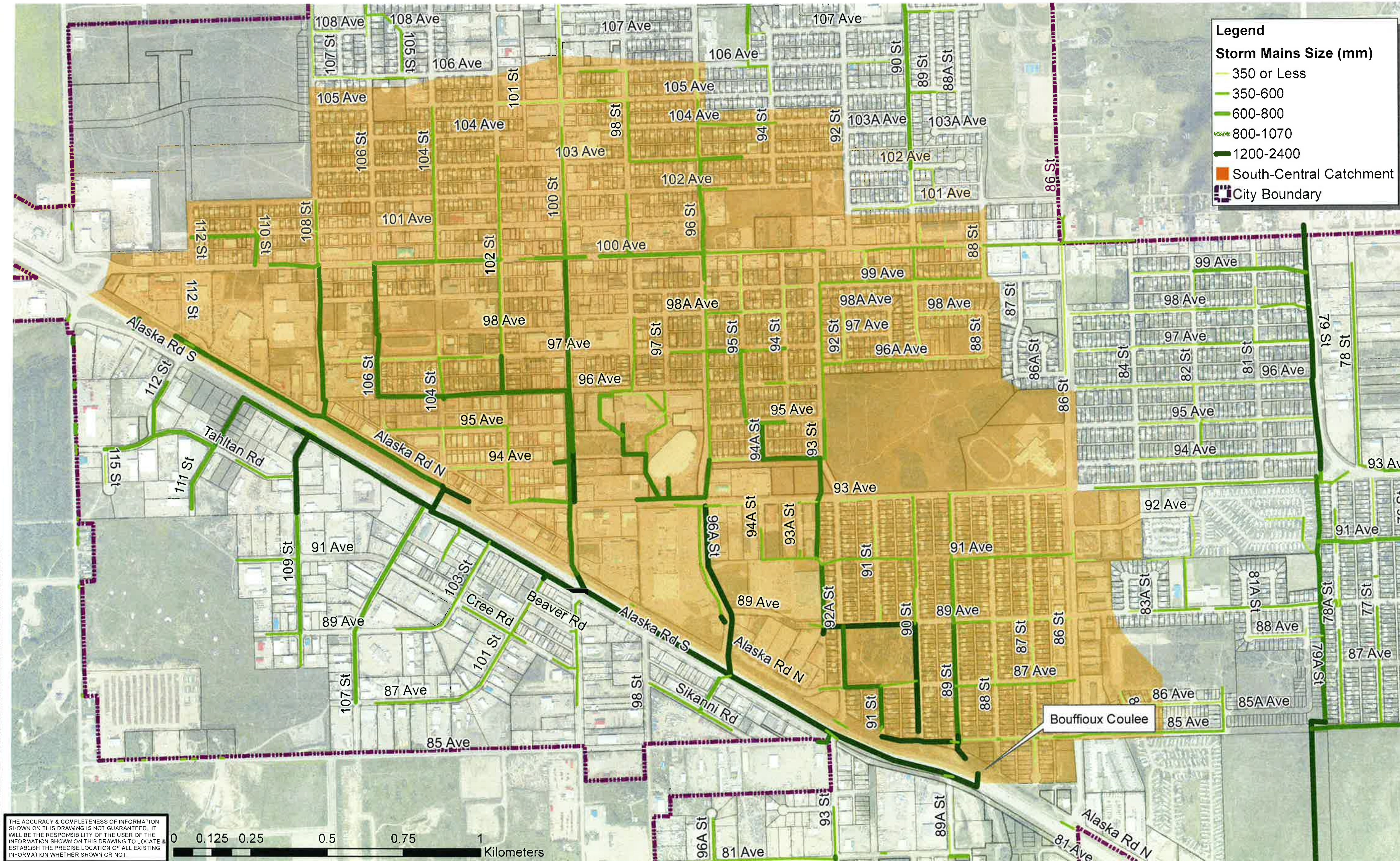
2.2 Geology

The soils around Fort St. John are generally stiff clay and offer little permeability for drainage.

2.3 Existing Drainage Infrastructure

The City has continually been expanding their storm system infrastructure as road upgrades and development occurs. Diameters of the piped storm network range between 200 mm to 2.4 m.

Figure 3 provides a graphical representation of the current piped storm network in the south-central area of the City.



CURRENT STORM INFRASTRUCTURE

FIGURE 2

2.4 July 29, 2010 Rain Event

On July 29, 2010, the City of Fort St. John experienced a major rainfall event that caused flooding and property damage throughout the City – particularly in the South-Central catchment. It further resulted in the Province approving Financial Disaster Assistance for Fort St. John.

There have been anecdotal assumptions about the return frequency of the storm; however, we were unsuccessful in locating any official rainfall summaries of the storm in Fort St. John. Knowing the return period of this rain event provides a sense of how frequent the City can expect to experience a similar storm. In addition, knowing the intensities and durations of a storm enables us to recreate the storm event for computer simulation and calibration.

At the time of the event the nearest weather monitoring station was at the Fort St. John Airport (YXJ), approximately 7 km away from the centre of Fort St. John. This weather station collects daily total precipitation values. Upon referencing historical weather data, the daily total rainfall of the July 29, 2010 event was a mere 6.8 mm as collected by the YXJ Airport. Compared to Environment Canada's Intensity-Duration-Frequency (IDF) curve for Fort St. John, this total rainfall – for a short duration storm – is a minor rain event.

An alternative publically accessible data source available is radar data collected from Environment Canada's Spirit River monitoring station. Using radar images at 10 minute intervals and estimating the rainfall intensity, a rainfall hyetograph for the July 29, 2010 event was constructed (Figure 4). This amounted to approximately 24.8 mm of rain over a one hour period.

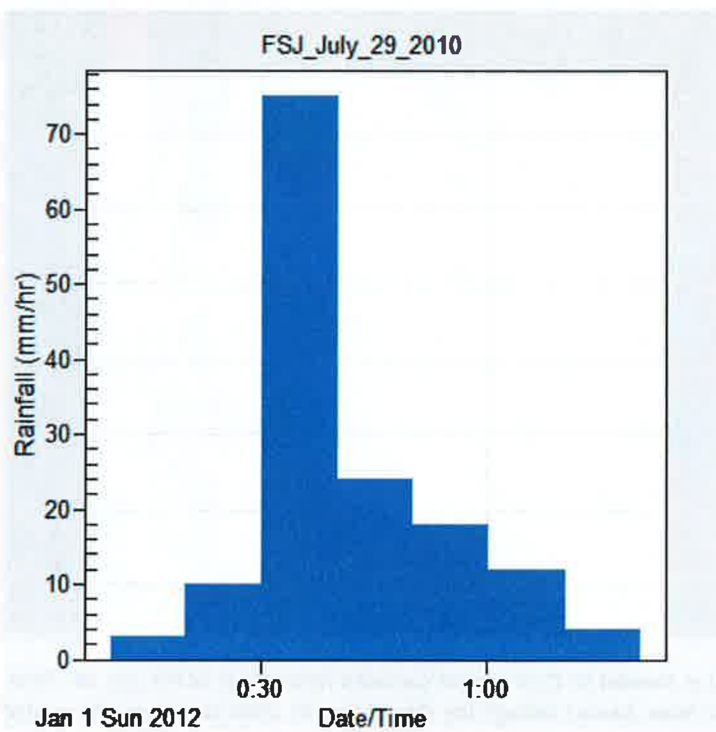


Figure 4. Rainfall hyetograph of the July 29, 2010 event constructed using radar data collected from Environment Canada's Spirit River monitoring station. This storm has a short duration and a high intensity.

The July 29, 2010 hydrograph is a typical rainfall distribution with a low intensity rainfall rate in the beginning, a peak intensity in the middle, and a gradual decrease of rainfall rates in the end. The rainfall at the start of the storm begins to saturate some areas and fill small surface voids that provide depression storage. By the time the peak intensity hits, the full effect of its high rainfall rate is experienced in areas without appropriate measures to attenuate the peak flows. The gradual ending of the rain event adds to the volume of runoff generated.

The aerial extents of high intensity storms can have very localized effects. Peak rainfalls rates within a storm event typically occur very rapidly over a concentrated area. Radar images of the July 29, 2010 event revealed that the storm skims the Fort St. John Airport while the highest intensity passes through the centre of the City (Figure 5). This confirms why the City of Fort St. John experienced high quantities of rain while the nearby airport did not.

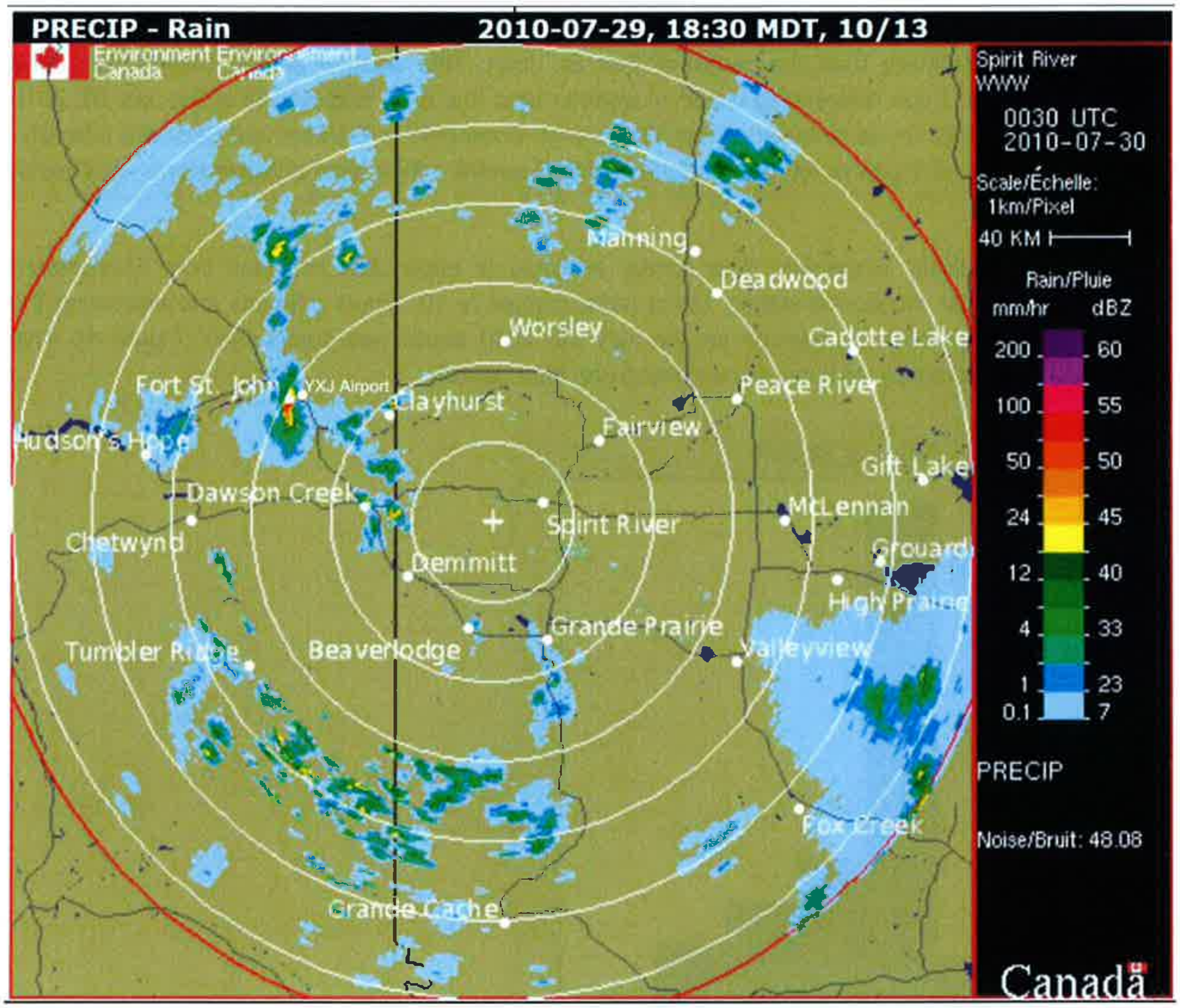


Figure 5. The Fort St. John Airport (labelled YXJ Airport) is inserted on Environment Canada's radar image of the July 29, 2010. Note the high intensity of the storm, indicated in the red hues, passes through the City of Fort St. John but misses the rainfall monitoring station at the YXJ Airport. The radar images used were collected from Environment Canada's Spirit River weather station.

With the information gathered, the peak intensities during a ten minute and one hour period are plotted on the Environment Canada IDF Curve for Fort St. John (Figure 6). Although projected with uncertainty, it appears the July 29, 2010 rain event was around a 25-year storm.

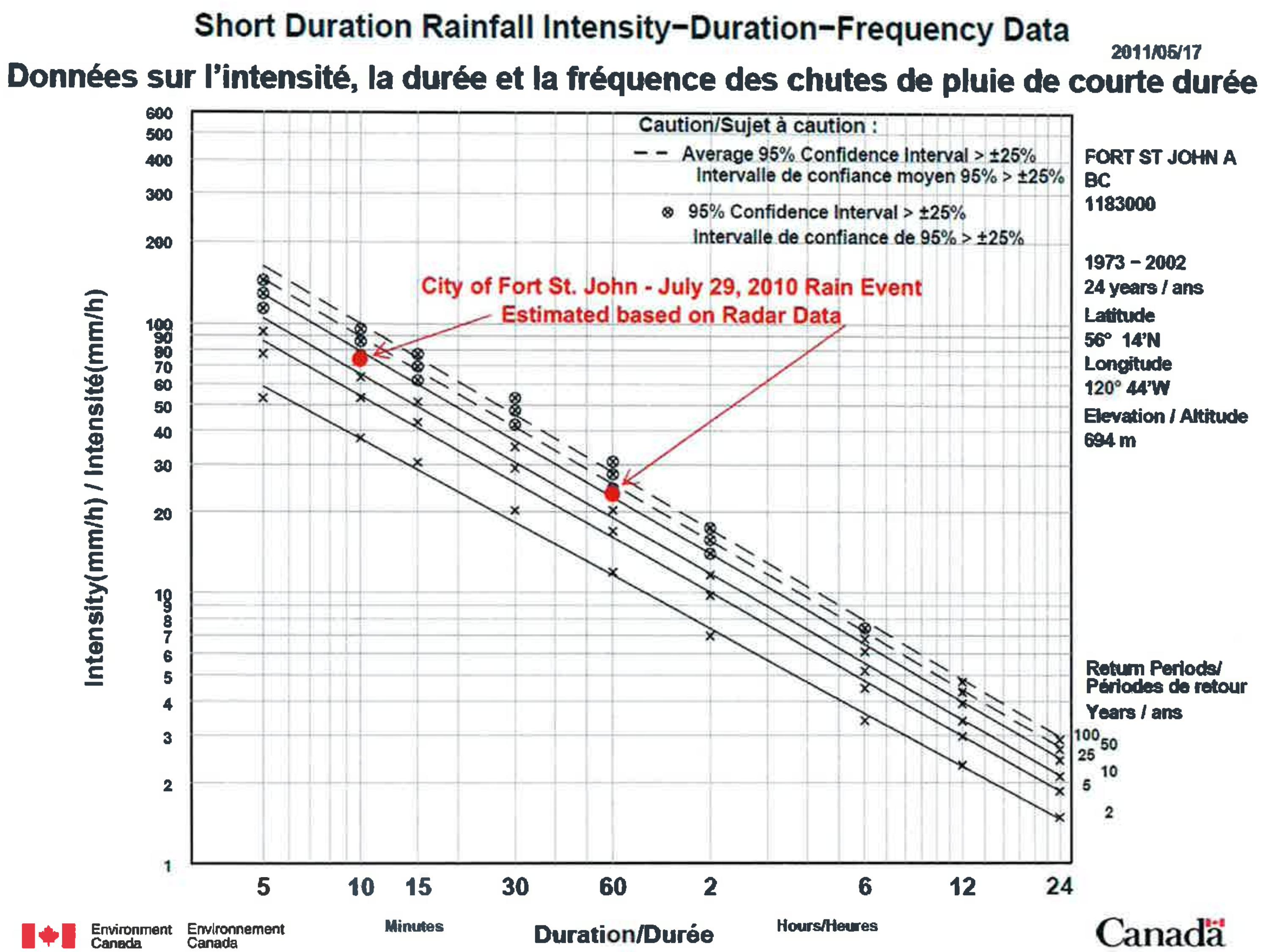


Figure 6 – IDF curve supplied for Fort St. John by Environment Canada. Two estimated plots of the July 29, 2010 rain event are plotted as solid red circles

3.0 Hydrologic and Hydraulic Modelling

3.1 Introduction

To best approximate the rainfall distribution, conveyance, runoff, and ponding, a hydraulic model was developed using a SWMM 5.0.022 engine in PCSWMM 2012 Professional software.

The benefits of using a model to obtain results include:

- Multiple rain events and scenarios can be simulated
- Quick identification of problems
- As piped or storage solutions are likely, the model can represent each feature and determine their effectiveness
- Future use for storm analysis

This model was developed with a focus on representing the south-central catchment during a major storm event.

3.2 Model Development

3.2.1 Data

The PCSWMM model was created based on existing pipe networks from the City's XPSWMM storm model. Other City data used are GIS based 1 m contours, cadastral lines, and aerial photography.

The estimated July 29, 2010 rainfall event, described in Section 2.5, was used as the primary rainfall event for analysis and acts as a benchmark.

3.2.2 Model Inputs

With the exception of the piped networks, most other model attributes from the XPSWMM model were updated to better simulate local topographic and land use conditions. The following paragraphs briefly describe some key modelling parameters and the basis for the values used in the modelling effort.

Subcatchment Delineation

New subcatchments were created for the south-central catchment area. These subcatchments account for all areas that route water to the FSJ Basin. As the focus of the model is to analyze major rain events, subcatchments were delineated in larger and coarser areas. Subcatchment boundaries were chosen based on contours, natural delineators (e.g. roads), and land use type.

Impervious Areas

Pervious and impervious ratios for each subcatchment were estimated using a combination of aerial photography within GIS and Google Earth images. Green grassed areas were assumed to be pervious; darker areas – such as roads, roofs, and driveways – were assumed to be impervious.

Catchment Widths

Within PCSWMM, catchment width is one of the most useful calibrating parameters of the software. Initially catchment widths were estimated by taking the square root of each subcatchment area. Based on model results it appeared that runoff in low-mid density residential areas were being retained for too long; widths of residential areas were therefore increased by a factor of 2 which results in a faster runoff. A faster runoff results in higher peak flows – a conservative approach for the City's storm infrastructure.

Sub-Area Routing

Although storm sewers are present throughout the primary project area, not all impervious surfaces are directly connected to a storm sewer system (e.g. a house downspout draining to a lawn); this directly affects the computation of storm hydrographs. PCSWMM allows redirection of runoff from impervious areas to pervious areas which simulates opportunities for runoff to infiltrate rather than directly enter storm sewers. A percentage of each subcatchment's impervious area is redirected to pervious surfaces to account for this based on the land use of each subcatchment. For residential areas it is assumed that 50% of the impervious runoff is routed back to pervious lands.

Rainfall Distribution

The July 29, 2010 storm – a short duration, high intensity rainfall event – was chosen as the event to be the base storm for analyzing the drainage response. Other rain events are modelled where indicated. Rainfall is distributed and applied to each subcatchment in the model.

Infiltration / Ground Conditions

The Horton Equation was used as the basis for simulating infiltration for the surface soil layers. Due to the near impervious clay soils in this area, there is a maximum amount of rainfall the pervious layers (topsoil) can hold. Once the ground surface becomes saturated, rainfall then flows across the pervious surface. A moderate rate of infiltration is attributed to grassy areas, whereas a low rate of infiltration is attributed to the clay soils.

A summary of the parameters inputted in the model are:

- Manning's N for impervious area = 0.11
- Manning's N for pervious area = 0.3
- Depth of depression storage on impervious area (mm) = 0.3
- Depth of depression storage on pervious area (mm) = 5
- Percent of impervious area with zero depression storage = 0%
- Max infiltration rate (mm/hr) = 1.3
- Min infiltration rate (mm/hr) = 0.15
- Decay constant = 3.6
- Dry time = 0

3.2.3 Data Limitations

Using local knowledge of the geography and system, best assumptions and engineering judgement were applied in choosing values for the model parameters. No soil drainage analysis was done.

This model does not incorporate surface flow routing for overland flow. Instead, when surcharging occurs, the model represents the storm water as ponded water at the surcharge location. Inlet controls were also introduced at select locations in the model to limit the amount of water that can practically enter the storm system.

3.2.4 CALIBRATION

To ensure model accuracy, the PCSWMM stormwater model is calibrated based on multimedia evidence of the July 29, 2010 rainfall event. Photos and videos of the event are easily accessible online (sources include Flickr and YouTube) and can be used to estimate surface ponding depths and extents in flooded areas. Key areas used for calibration include:

- 100 Street (96 – 93 Avenue)
- 96 Avenue (98 – 100 Street)
- 94 Avenue (92 – 96 Street)
- The Totem Mall
- Alaska Road North (near 104 Street)

3.3 Sensitivity Analysis

The existing storm system within the South-Central catchment was modelled with 4 rain events with distinctive return periods to provide a sensitivity analysis.

The four rain events used for analysis include:

- July 29, 2010 rain event (est. 25-Year, 1.3-Hour). This event is used as the benchmark event when comparing other scenarios.
    - Total Rainfall = 24.8 mm
- 50-Year, 1-Hour
    - Total Rainfall = 27.6 mm
- 100-Year, 1-Hour
    - Total Rainfall = 30.7 mm
- 25-Year, 24-Hour
    - Total Rainfall = 58.0 mm

The 50-Year 1-Hour and the 100-Year 1-Hour storm events were constructed using Environment Canada's IDF curve for Fort St. John and distributed on a hyetograph similar to the July 29, 2010 rain event (Figure 7). These hyetographs generate high peak flows which cause greater stress to the City's current infrastructure than hyetographs with low intensities and long durations.

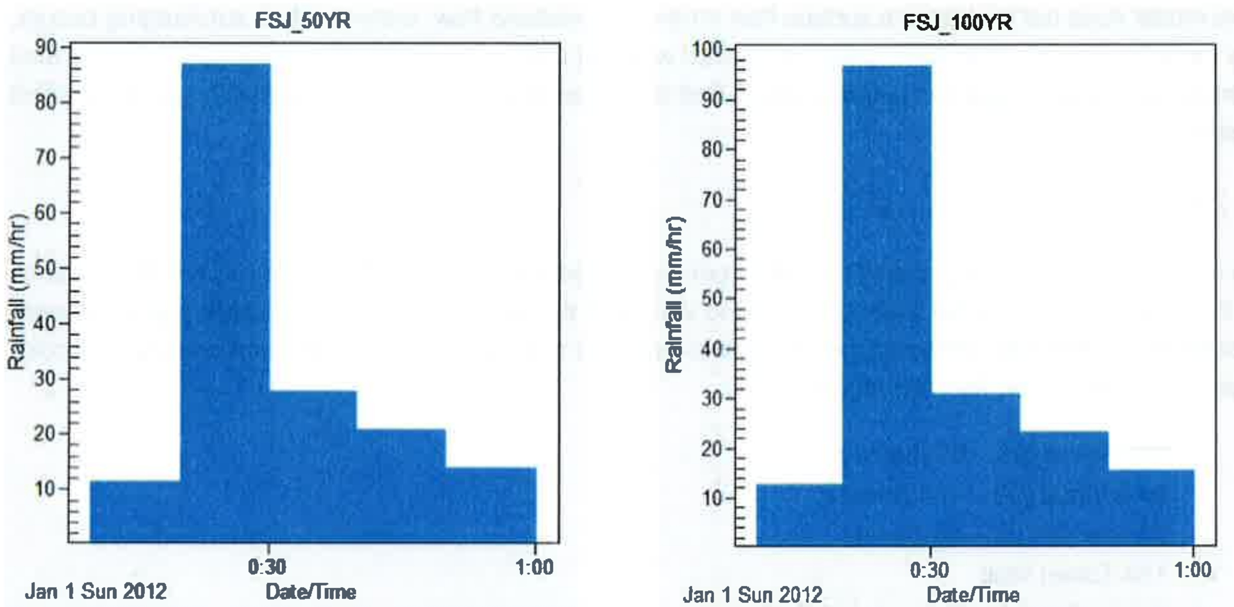


Figure 7 – Hyetographs used to analyze the 50-Year 1-Hour and 100-Year 1-Hour rain events in FSJ. Intensity variations over the 1 hour period are distributed similar to the July 29, 2010 rain event.

The 25-Year, 24-Hour storm is a SCS Type II distribution which combines a long duration storm with a high peak (Figure 8). The analysis of this distribution provides a check to how the drainage infrastructure reacts to storms with longer durations than the July 29, 2010 event while also representing high peak rainfall rates.

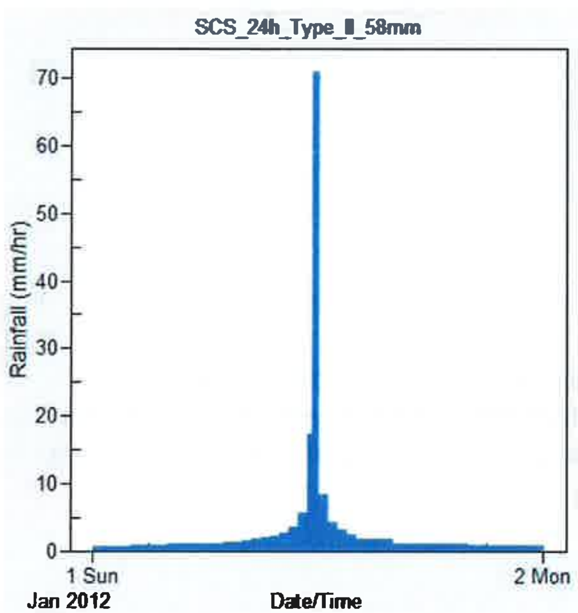


Figure 8 – SCS 24h Type II hyetograph for Fort St. John's 25 year rainfall event.

4.0Results

There are five distinct locations within the South-Central catchment that experienced significant flooding issues during the July 29, 2010 rain event. These have been the focus of the analysis in order to develop solutions aimed at reducing or relieving flooding in this area. The proposed solutions within this section are accompanied with a Class D cost estimate and represent options to accommodate a level of service that addresses peak runoff rates and volumes based on the 25-year storm event.

Figure 8 outlines the major surface flow paths of the South-Central catchment and identifies five prioritized problem areas:

1. 94 Avenue (between 93 and 96 Street)
2. The Totem Mall
3. 93 Avenue (between 96 and 102 Street) & 100 Street (between 93 and 96 Avenue)
4. 96 Avenue (between 98 and 100 Street)
5. Alaska Road North (between 104 and 106 Street)

Each of these specific areas is considered in the following sub-sections of this report.

Segments of 94 Avenue and 95 Avenue adjacent to 100 Street are identified as having drainage issues; however, because of their close connection to 100 Street, their drainage solutions are a part of 100 Street

In all cases, the simplest and most reliable approach to dealing with the surface flooding is to create a safe and reliable surface drainage route. In these locations, however, a surface route is not practical because of land ownership and topography. As a result, all solutions to the problems associated with each location focus on piped conveyance and temporary underground storage (Figure 9).

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STORMWATER MASTERPLAN

DATE: DECEMBER 2012
CITY OF FORT ST. JOHN STORMWATER MASTERPLAN

CITY OF FORT ST. JOHN

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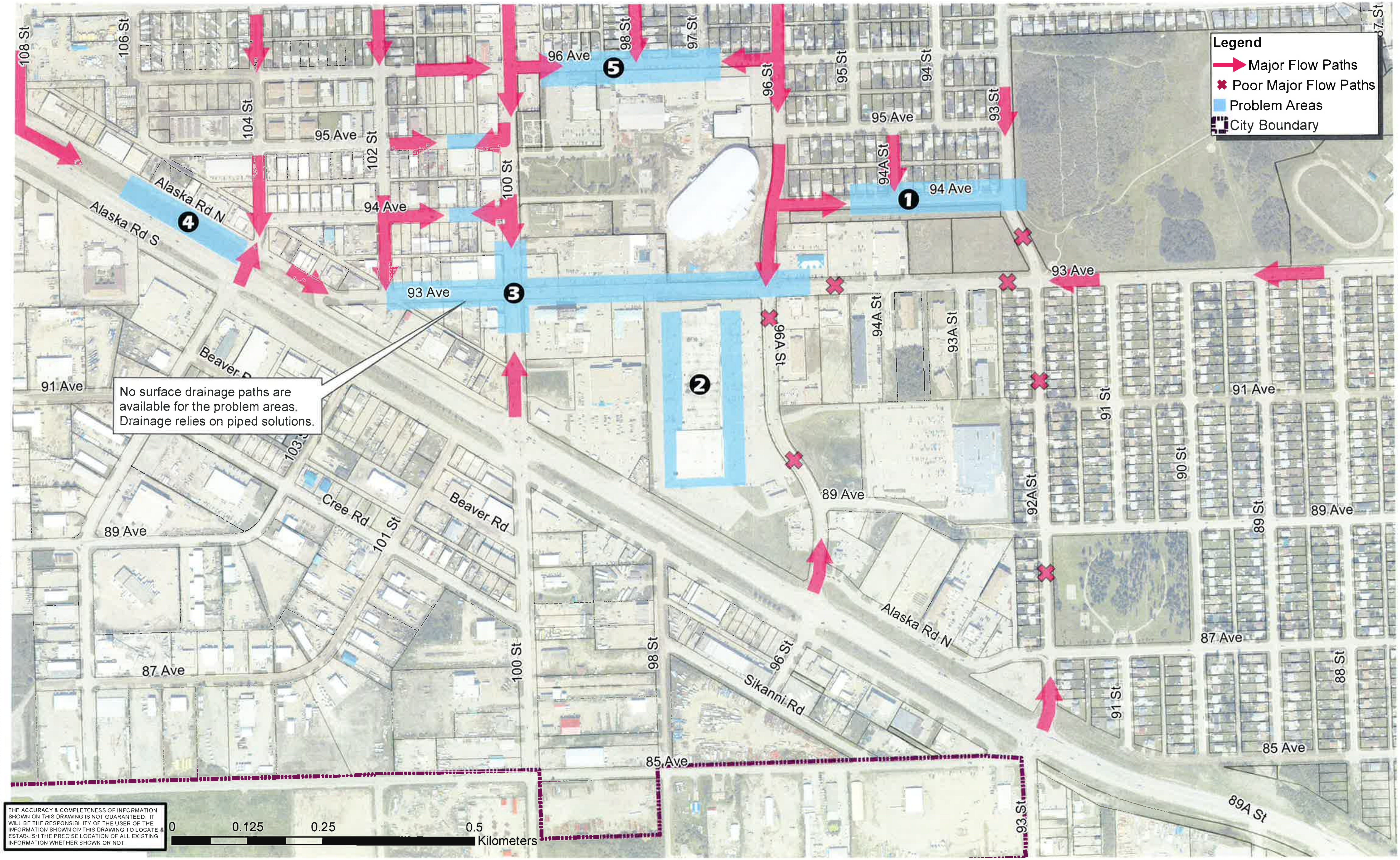

SOUTH-CENTRAL CATCHMENT DRAINAGE PROBLEMS

FIGURE

8

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STORMWATER MASTERPLAN

DATE: DECEMBER 2012
CITY OF FORT ST. JOHN STORMWATER MASTERPLAN

CITY OF FORT ST. JOHN

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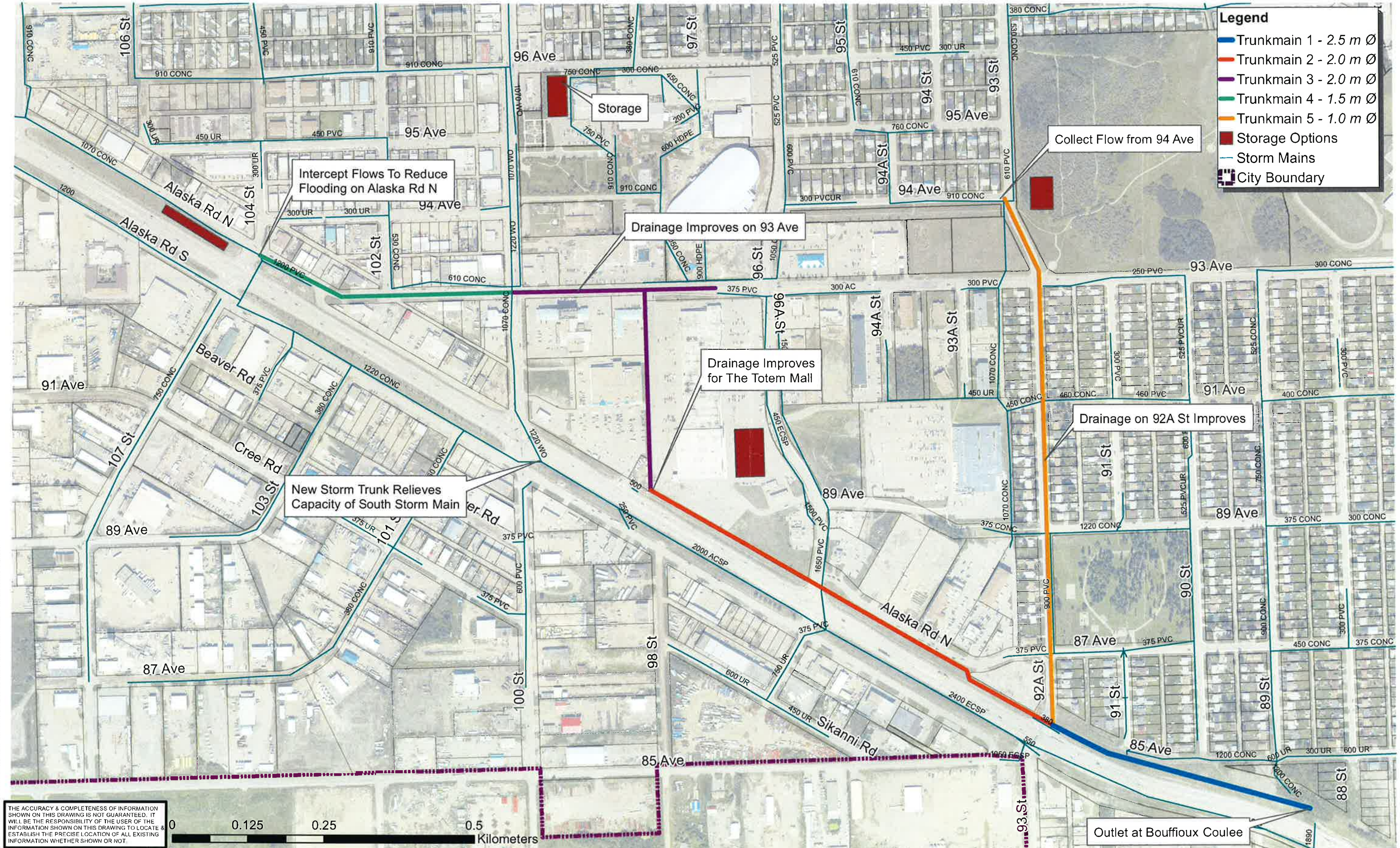


SOUTH-CENTRAL CATCHMENT DRAINAGE SOLUTIONS

FIGURE 9

4.1 94 Avenue (96 – 93 St)

4.1.1 Problems

- The road surface of 94 Avenue is depressed between 93 Street and 96 Street and does not provide an overland flow route for runoff generated by significant and severe storms.
- Stormwater runoff is discharged from the depression through an underground storm sewer that runs to the south and ultimately discharges to Bouffioux Coulee.
- The existing storm sewer inlets and pipes do not have sufficient capacity to capture and convey the runoff, which results in surface flooding during severe storm events.
- Furthermore, the storm sewer system upstream of this location collects runoff from higher elevations and generates considerable head while under full conditions. Manholes/CBs may surcharge at 94 Avenue because of this, and push the hydraulic grade line in the storm sewer to the ground surface.
- Steeper segments of 610 mm and 910 mm storm mains connect the intersection of 94 Avenue and 94A Street and flow into a flatter segment of 910 mm storm main, which results in a flow restriction at this location.

4.1.2 Model Results

Estimated volume of water flooded to surface:

Rainfall Event	Total Rainfall (mm)	Total Flooded Volume (m³)
July 29, 2010 (25 Year)	24.8	760 – 930
50 Year, 1 Hour	27.6	2,000 – 2,450
100 Year, 1 Hour	30.7	3,060 – 3,740
25 Year, 24 Hour (SCS Type II)	58.0	1,500 – 1,830

4.1.3 SOLUTIONS

There are two possible solutions to the flooding at this location. The first is to increase the capacity of both the stormwater inlets at the depression in 94 Avenue and the downstream trunk storm sewer, and the second is to modify the storm sewer system at this location in order to temporarily store the excess runoff and allow it to drain into the existing storm sewer system following the peak of the storm event.

Increasing the capacity of the storm conveyance system would require the construction of a new trunkmain from the intersection of 94 Avenue and 93 Street to the existing outfall at Bouffioux Coulee, a distance of approximately 1,500 meters.

The storage option would result in the need to construct an underground storage facility with a capacity of approximately 3,000 m^3. This facility could be located at the east end of 94 Avenue on land owned by the City of Fort St. John.

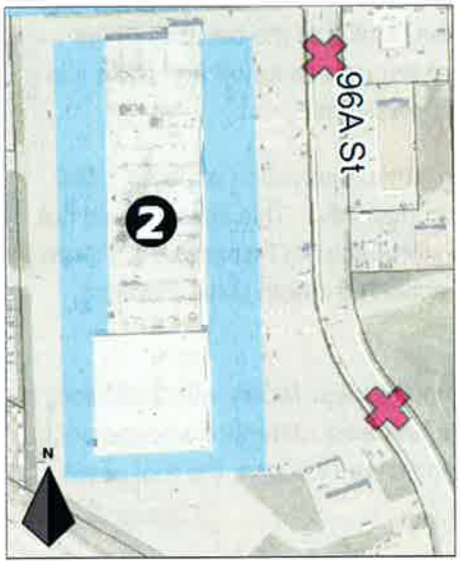
An alternative to constructing an underground storage facility would be to construct an open surface pond to detain high peak flows. Because of the large land area available in Toboggan Hill Park, adjacent to 94 Avenue, an open surface pond may be practical to construct and offers a cost saving due to its simplicity.

4.1.4 COMMENTS

The storm sewer option would result in the construction of a storm main along 92A Street, which will alleviate the drainage issues at 94 Ave as well as assist drainage at 93 Ave and along 92A St. Currently 92A Street does not have storm drainage.

When comparing the 25-year to the 50-year and 100-year events, the total flooded volumes increase significantly. This area is sensitive to slight increases of rainfall. Due to this, a solution which provides greater capacity to accommodate more extreme events may be preferable. The solutions are chosen to reflect the sensitivity analysis and are based on 3,000 m^3 of storage. The flooding photo evidence also appears to agree with the 3,000 m^3 volume.

4.2 The Totem Mall



4.2.1 Problems

- The Totem Mall was constructed in a depression within the South-Central catchment with the parking lot generally graded towards the building.
- During extreme events, runoff escapes off adjacent roads at higher elevations and drains to the Totem Mall which exacerbates the problem.
- There is no overland drainage route from the site and stormwater relies exclusively on the piped system to be discharged from the property. The existing adjacent storm main along 96A Street is unable to accommodate the Totem Mall's peak 25-year runoff without any detentions measures.

4.2.2 Model Results

Estimated volume of water flooded to surface:

Rainfall Event	Total Rainfall (mm)	Total Flooded Volume (m^3)
July 29, 2010 (25 Year)	24.8	1,300 – 1,580
50 Year, 1 Hour	27.6	1,540 – 1,890
100 Year, 1 Hour	30.7	1,790 – 2,190
25 Year, 24 Hour (SCS Type II)	58.0	930 – 1,130

Model results for the Totem Mall only account for the runoff generated on the Totem Mall property; runoff from adjacent parcels was not considered during modelling.

4.2.3 Solutions

Similar to the 94 Avenue location, there are two possible solutions to alleviate the flooding at this location. The first is to increase the capacity of the stormwater inlets at the Totem Mall and the capacity of the downstream trunk storm sewer. The second option is temporarily store the excess runoff and allow it to drain into the existing storm sewer system following the peak of the storm event.

Increasing the capacity of the storm conveyance system would require the construction of about 1,500 meters of new trunk storm sewer in the size range of 1500 to 2000 mm diameter. This sewer would run from the Totem Mall to the Bouffioux Coulee outfall. A portion of this storm sewer (Trunkmain 1, Figure 9) would also serve the 94 Avenue location, so a cost savings could be achieved if both solutions were implemented concurrently.

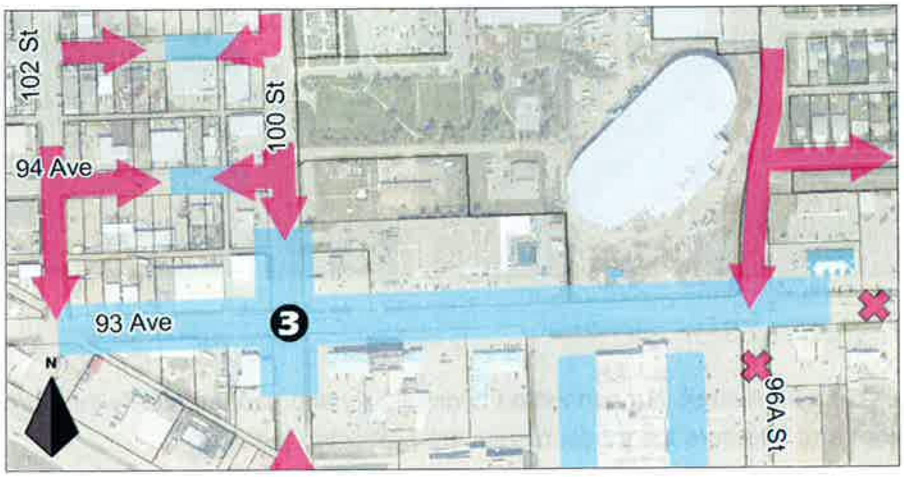
The storage option would result in the need to construct an underground storage facility with a capacity of approximately 1,500 m^3 to 2,000 m^3 of storage. As there is a large parking area, detention storage could incorporate storage on and below its asphalt. Depending on the building's construction, the roof of the mall may also be used to detain a portion of the peak runoff volumes.

4.2.4 Comments

Minor improvements such as re-grading entrances to the mall from 93 Avenue and 96A Street to redirect surface drainage paths from transporting water towards the Totem Mall will help; however, due to the volume of water generated on the Totem Mall property it will likely not be significant to improve the problems.

The Totem Mall recently videoed their on-site drainage system; their drainage system appears to be in poor condition with damaged piping and reduced inlet capacities due to accumulated debris.

4.3 93 Avenue (102 – 96A St) & 100 Street (93 – 96 Ave)



4.3.1 PROBLEMS

93 Avenue

- 93 Avenue is a 4 lane collector located within the FSJ Basin. The road has a flat grade with localized depressions along its length.
- Surface flows from 102 Street, 100 Street, and 96 Street all drain towards 93 Avenue.
- Because the storm sewer inlets and pipe capacities are limited, surface water ponding occurs at a number of locations along 93 Avenue, especially adjacent to the Totem Mall.
- The piped collection system does not extend along the entire length of the road.
- Upstream pipes collect water from higher elevations and generate head while under full conditions. Surcharging occurs and surface flow collects on 93 Avenue.
- During extreme events, when surface flooding becomes excessive, runoff can overflow from 93 Avenue to lower elevation areas such as the Totem Mall.

100 Street

- The piped system does not have capacity to collect and transfer the rainfall experienced in a major storm event – surface flooding occurs.
- The natural drainage for this area flows in a SE direction. 100 Street is elevated relative to adjacent properties so it restricts overland flow from the west of 100 Street. This has created low areas prone to ponding such as 94 Avenue and 95 Avenue.
- Surface flow travelling south on 100 Street escapes the arterial road and ponds on lower adjacent avenues

4.3.2 Model Results

As both 100 Street and 93 Avenue are connected hydraulically and geographically their problems are linked to each other and therefore the model results are presented together.

Estimated volume of water flooded to surface:

Rainfall Event	Total Rainfall (mm)	Total Flooded Volume (m³)
July 29, 2010 (25 Year)	24.8	8,230 – 10,060
50 Year, 1 Hour	27.6	10,540 – 12,880
100 Year, 1 Hour	30.7	12,850 – 15,710
25 Year, 24 Hour (SCS Type II)	58.0	3,640 – 4,450

4.3.3 Solutions

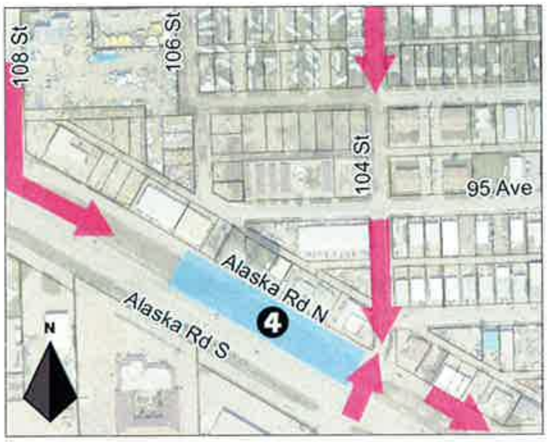
Storage options at this location are very limited due to the level of existing development and the large volume of water that is required to be stored. Utilizing Centennial Park for storage has limitations considering its limited available area without compromising existing landscaping and its higher elevation relative to the 93 Avenue. Due to this, the only practical solution is extending the trunkmain from near the Totem Mall to reach 93 Avenue and 100 Street.

4.3.4 Comments

Due to the elevation where most of this ponding occurs, and to obtain gravity drainage, the proposed solution to this problem area transfers water all the way to its outlet at the Bouffioux Coulee. Its alignment was chosen to incorporate multiple benefits including assisting the drainage for 100 Street, 93 Avenue, and the Totem Mall.

This solution assumes that cover is able to be maintained, conflicts with other utilities are avoidable, and a right-of-way is able to be established through the Totem Mall parking lot.

4.4 Alaska Road North (108 – 104 St)



4.4.1 Problems

- The existing piped system does not have capacity to collect the rainfall experienced in a major storm event therefore surface flooding is caused
- The natural surface drainage for this area flows in a SE direction. Since the Alaska Highway is elevated its approaches are also elevated; this confines overland flow between the 108 Street and 104 Street approaches (when pipe capacities are exceeded).
- Upstream pipes collect water from higher elevations and generate head while under full conditions. Surcharging occurs along Alaska Road North under high flow conditions.
- Because of surcharging, flow may spill towards 93 Avenue and further contribute to the problems there.

4.4.2 Model Results

Estimated volume of water flooded to surface:

Rainfall Event	Total Rainfall (mm)	Total Flooded Volume (m^3)
July 29, 2010 (25 Year)	24.8	1,480 – 1,180
50 Year, 1 Hour	27.6	2,310 – 2,830
100 Year, 1 Hour	30.7	3,350 – 4,090
25 Year, 24 Hour (SCS Type II)	58.0	1,250 – 1,530

4.4.3 Solutions

There are, again, two possible solutions to the flooding at this location. The first is to further extend the 93 Avenue trunk storm sewer to this location, and the second is to modify the storm sewer system at this location in order to temporarily store the excess runoff and allow it to drain into the existing storm sewer system following the peak of the storm event.

To reach this location would require the further construction of about 700 meters of new trunk storm sewer from 100 Street in the size range of 900 mm diameter.

The storage option would result in the need to construct an underground storage facility with a capacity of approximately 1,500 m^3 to 2,000 m^3 of storage. There are a limited number of locations where such a facility could be constructed, and it may be practical only to construct this storage as a linear storage facility, which will increase the unit cost per cubic meter of storage.

4.4.4 COMMENTS

Extending the storm sewer trunk to this location relieves pressure on the capacity of the storm main located along Alaska Road South.

4.5 96 Avenue (100 – 98 St)

4.5.1 Problems

- There is a localized depression along 96 Avenue
- The current piped system cannot discharge peak flows fast enough and surface flooding begins.
- Upstream pipes along 98 Street collect water from higher elevations and generate head while under full conditions. Manholes/CBs may surcharge at 96 Avenue because of this.
- Surface flow escapes from adjacent higher elevated roads (100 Street and 96 Street) and drains to 96 Avenue.
- Surface flow collected on 98 Street and 97 Street drains directly to 96 Avenue.
- The original overland drainage path, which flowed in the southern direction, is obstructed by previous development.

4.5.2 Model Results

Estimated volume of water flooded to surface:

Rainfall Event	Total Rainfall (mm)	Total Flooded Volume (m^3)
July 29, 2010 (25 Year)	24.8	950 – 1,160
50 Year, 1 Hour	27.6	1,380 – 1,670
100 Year, 1 Hour	30.7	1,900 – 2,320
25 Year, 24 Hour (SCS Type II)	58.0	1,130 – 1,340

4.5.3 Solutions

Detention storage at this area is a favourable option as the City owns the adjacent lands and a piped solution to an outlet is long. By utilizing detention, peak flows are reduced and are released to the existing storm infrastructure at a moderated rate.

Detention storage could be constructed underneath the asphalt parking lot similar to what was constructed for the Pomeroy Sport Centre (Enerplex). Alternative options for storage may be able to utilize the depressed grassed fields of Centennial Park.

4.5.4 COMMENTS

This location offers opportunities for additional rainfall collection and re-use.

4.6 Cost Summary

4.6.1 Piped Solutions

The two piped routes shown in Figure 9 were chosen to best branch out to the identified problem areas to collect runoff and discharge to the Bouffioux Coulee. Although the storms segments can be constructed incrementally, long range planning must be considered to adequately size the downstream piping. If not all problem areas are chosen to be serviced by piped solutions, there can be a cost savings as the downstream pipe segments may not have to be as large.

Table 1 summarizes the Class D construction cost estimate for each trunkmain segment assuming:

- The design frequency is the 25-year event
- All trunkmains are constructed
- No additional inlets are required
- Minimal restoration in grassed areas
- Asphalt restoration, where required, are 6 m wide segments with no curb and gutter restoration

We recognize that the some pipe alignments are positioned under existing aging roads that may require full road reconstruction. However, this cost estimate assumes that full road reconstruction may be a separate project and therefore only asphalt restoration costs are included.

Further, this cost estimate does not include any runoff control measures at the Bouffioux Coulee and assumes that a second storm highway crossing is not required.

The cost estimates are preliminary and are based on limited information. As this is a high level Class D cost estimate the values provided should not be used for budgeting purposes. A refined cost estimate is recommended if these solutions are intended to be implemented.

Segment	**Description**	**Cost**
Trunkmain 1	92A Street to outlet at Bouffioux Coulee	$ 3,400,000
Trunkmain 2	Extends from 92A Street to the Totem Mall	$ 4,500,000
Trunkmain 3	Extends from the Totem Mall to 93 Avenue & 100 Street	$ 4,200,000
Trunkmain 4	Extends from 100 Street to Alaska Road North	$ 1,600,000
Trunkmain 5	Extends from 92A Street to 94 Avenue	$ 2,300,000
Total		**$ 16,000,000**

Table 1. Cost summary of each pipe segment to construct all trunkmains as shown on Figure 9.

4.6.2 Detention Solutions

Depending on the volume of stormwater required to store, the cost to construct underground detention storage may be greater than a conveyance solution.

Detention storage is the preferred solution for 96 Avenue near the North Peace Leisure Pool.

Detention storage may also be implemented at 94 Avenue as an alternative solution to the piped system. Because of the area available near this site, an open surface detention storage pond created at Toboggan Hill Park near 94 Avenue may be a favourable alternative to below ground detention storage as its price would be significantly decreased due to the construction simplicity.

Table 2 summarizes the Class D construction cost estimate for each detention storage facility based on a design frequency of the 25-year event.

Area	Description	Storage Volume (m^3)	Cost
94 Avenue	Below ground detention storage	3000	$ 6,300,000
The Totem Mall	Below ground detention storage	2000	$ 4,200,000
Alaska Road North	Below ground detention storage	2000	$ 4,200,000
96 Avenue (NPLP)	Below ground detention storage	1000	$ 1,300,000

Table 2. Cost summary for storage solutions as shown on Figure 9.

5.0 Peace River Discharge: The Bouffioux Coulee and an Expanding Alluvial Fan

The runoff generated from the South-Central catchment discharges into the Bouffioux Coulee as previously discussed in Section 2.0. However, it is prudent to further follow the discharge along its path through the coulee to its discharge point at the Peace River.

After exiting the steep walls of the coulee runoff flows along a channelized path through the terrace shared with the Old Fort community. Runoff from the Bouffioux Coulee continues until it discharges in the Peace River (Figure 10).

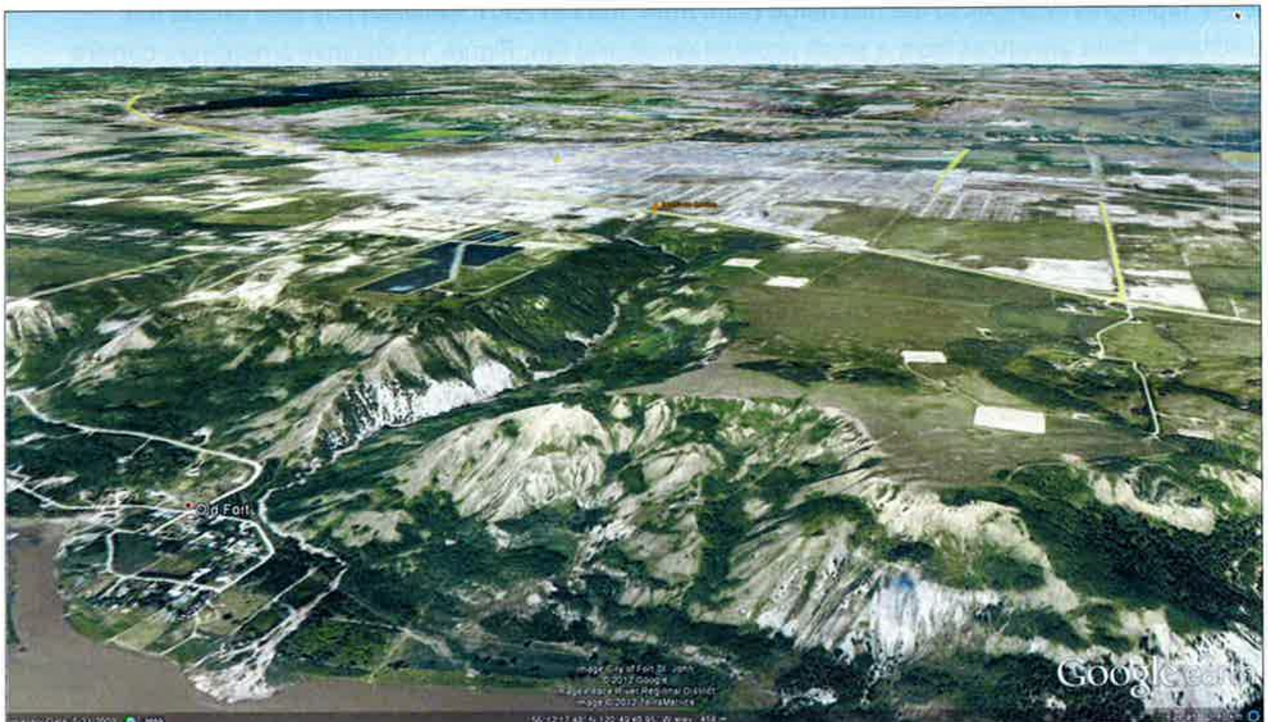


Figure 10 – Overview of the Bouffioux Coulee extents as it captures runoff from Fort St. John to its discharge point at the Peace River (Google Earth).

At the point of discharge where the Bouffioux Coulee runoff enters the Peace River an alluvial fan has been created. An alluvial fan is formed by built up sediment deposition and often occurs where stream flow emerges into a flatter plain. It is a good indicator of sediment transportation in the upstream stream flow. The current span of the alluvial fan spans approximately 200 m wide.

The size of this alluvial fan has been increasing over the years and its spread has even resulted in the relocation of the South Sewage Treatment Plant's Peace River Outfall line in 2006.

A comprehensive study was completed by UBC Professor Michael Church in 2002 about the morphology and changes in the Peace River outfall near the sewage lagoon outfall. In this report (Appendix A), Professor Church discusses extensively about the alluvial fan. He identifies two reasons for the development of the alluvial fan:

- The elimination of annual flood flows in the Peace River have been reduced or eliminated which reduces the capacity of the river to carry away gravel deposits;
- Sediment yield from the tributary has increased.

He additionally states that:

"The gully has probably yielded more sediment in the several decades since settlement activities extended into its headwaters, and it has been deposited onto a growing fan. The elimination of flood flows since the regulation has deprived the river of the ability to carry the fan gravels away, so that the fan has prograded into the river channel. By 2001 the protrusion is prominent."

The prominent protrusion of the alluvial fan is supported aerial photography in Professor Church's report which highlights changes to the discharge point from 1953 to 2001; between this time period the discharge point advances from a small outlet to an alluvial fan. Figure 11 displays a relatively current (2009) view of the alluvial fan.

Figure 11 –A 2009 view of the alluvial fan near the Old Fort community. The sediment load of the alluvial fan expands into the Peace River.

Continued erosion of the Bouffioux Coulee, sediment transportation, and sediment deposition of the alluvial fan becomes of even greater concern if piped solutions, as per Figure 9, are implemented. Piped solutions for major events will increase the flow rate seen through the coulee and heighten the current issues.

6.0Summary & Recommendations – South Central Catchment

In order to best represent the City's drainage problems the old XPSWMM storm model was upgraded to PCSWMM. Sub-catchments and parameters within the model were redefined and updated for the South-Central catchment. Using multimedia evidence, this new model was then calibrated against the July 29, 2010 rain event to ensure it adequately represented the City's problems.

Through this report, justification is provided to best estimate the July 29, 2010 rain event as having a 1/25-year probability of reoccurrence. With that discovery, the July 29, 2010 rain event served as the basis of this analysis is due to its categorization of a major system rain event, recent occurrence, and supporting multimedia evidence of the flooding problems. This rain event provides a comparison to what future major rain events of similar duration may look like.

The primary concerns to the City's storm network result when high intensity and low duration rain events occur; low intensity and long duration rain events have much less impact on the City's storm system. During major rain events with high intensities several locations in the South-Central catchment area experience flooding due to a number of similar problems including:

- Major system surface flow routes are not established or not obtainable due to localized depressions/basins
- The piped storm system network is relied upon to convey major system storm water to an outlet because surface flow routes are not available. Pipes are inherently more limited in their capacity and effectiveness than surface paths for major flows.
- Some developments were constructed without appropriate measures to deal with major system drainage
- Infill within the catchment and the reduction of pervious areas have increased the runoff volumes and peak flows

The problems identified are not new. Rather, they result from a naturally occurring area with poor drainage (FSJ basin) combined with expansion and infill of urban areas over the last 40 years without enough consideration for drainage of the area as a whole. The following recommendations should be reviewed and implemented where appropriate.

6.1 Recommendations

Based on hydraulic modelling and knowledge of the City's infrastructure, short-term and long-term drainage system recommendations have been provided. The suggested improvements are listed and ranked to prioritize each item's importance.

6.2 Short-Term Drainage System Improvements

There are a few low cost items specific to the City's current stormwater system that can be implemented in the short-term to improve the current operations of the drainage systems. Table 1 summarizes five items that are suggested for short-term implementation and indicates their importance.

Item	Description	Importance		
		Low	Med	High
1	Increase inlet capacity of catchbasins by regular cleaning of sumps – this also helps reduce gravel/debris migration into mains		X	
2	Increase conveyance capacity by flushing mains to remove any accumulated gravel/debris		X	
3	Regularly clean debris from the trash grates at the Bouffioux Coulee inlets/outlets			X
4	Replace trash racks at the Bouffioux Coulee inlets/outlets with maintenance-free grates	X		
5	Ensure the major-system flow paths defined by developers in their submitted engineered drawings are compiled in a consolidated database/map. This will ensure that future developments/roads do not interfere with pre-existing major system flow paths and that existing drainage paths are incorporated in their designs.			X
6	Continue discussions with the Totem Mall to determine appropriate solutions to the drainage problems they have been experiencing.			X

Table 1 – Recommended short-term drainage system improvements

While these suggestions may seem small, their impact on the conveyance of the system can be significant. If items 1 – 3 are not currently on the City's maintenance program, we recommend their implementation on an annual basis.

Item 5 is unique and its focus is on ensuring that continuity of the major system flow paths between various developments is maintained. Defining the major system flow paths is a requirement in the Subdivision and Development Servicing Bylaw. Designs must consider and incorporate the major flow of surrounding developments into their design even if the City does not have a Master Drainage Plan available for reference for the areas being subdivided or developed.

Often roads are used as major system flow paths so the layout and grades of future subdivision roads must be checked to ensure conveyance is maintained. This process can be similar to checking the capacity of underground piped systems. It is reminded that roads not only serve the purpose of transporting traffic; they also act to transport runoff. They act as economical replacements to large diameter pipes with the exception that they transfer storm water above surface.

6.3 Long-Term Drainage System Improvements

Unlike short-term drainage system improvements, long-term improvements require planning, design, construction, and significant costs. In return, these larger scale projects provide conveyance and control for the flooding that has been occurring. Table 2 summarizes four items that are suggested for long-term implementation and indicates their importance.

Item	Description
1	Improve the drainage of the identified problem areas, as indicated on Figure 9, by either constructing trunkmains or adding detention storage.
2	Install detention storage at 96 Ave near the North Peace Leisure Pool to capture peak flows and reduce surface flooding. Also consider options for stormwater reuse.
3	Monitor the Bouffioux Coulee for erosion and investigate protective measures for channel erosion; include protective measures for sediment transportation contributing to the expanding alluvial fan in the Peace River.

Table 2 – Recommended long-term drainage system improvements

If Item 1 is addressed using piped solutions, it has the benefit of being constructed in stages. The stages can be strategically implemented to coincide with other roadwork projects or as funding becomes available. The areas to be serviced must be determined in the initial design stage such that the downstream pipes are sized adequately.

Monitoring of the Bouffioux Coulee for erosion has been identified due to its past and current erosion concerns. While its channel banks do not impede the outlet flow, erosion will be heightened if the proposed storm mains are installed as they would increase the discharge rates to the coulee. Planning for future protection, erosion mitigation, and sedimentation reduction is important.

7.0Next Steps for Overall CFSJ Stormwater Planning

This report has initiated the first steps in stormwater planning for the City of Fort St. John by reviewing the problems and potential solutions in the catchment areas with the higher risk and history of flooding. There are additional steps for the City to consider in continuing with the development of a comprehensive Stormwater Masterplan. The end goal of the Stormwater Masterplan is to provide a clear direction and approach to stormwater management that can also be used to develop and support long term capital planning, budgeting and DCC development for stormwater projects.

7.1.1 Major System Review for Remainder of Fort St. John

Future stages of the City's Stormwater Masterplan should aim to define and establish major storm system flow routes for the entire City. Defining these paths is important to ensure that development and capital upgrades do not create new drainage problems. A consolidated plan for the entire City offers opportunities to design and construct future roads and storm infrastructure in ways that will benefit the goals of the Stormwater Masterplan, the City, and all affected members of this community. Completing a drainage plan will also aid development by clearly expressing the major system flow routes that they need to consider in their designs. Imminent projects and developments that could be reviewed in subsequent phases of the Stormwater Master plan include:

- *The Station 44 development in the SE section of the City.* Currently major stormwater runoff from higher ground flows into the grassed field approximately 160 acres in size. Upon development, the City needs to ensure that the runoff that currently flows into that land is not disrupted in such a way that will cause flooding or ponding issues to the existing development; the major system flow paths must be defined and properly accounted for in their subdivision design.

- *100 Street from 110 Avenue to the East Bypass Road (119 Avenue).* Ditches currently parallel 100 Street on either side of the road and outlet to Fish Creek. By widening the road from two-lanes to four-lanes the ditches will be removed and adequate compensation for stormwater – for both the major and minor systems – will need to be implemented.

Another possible pressing scenario to review major system storm impacts involves the expansion of the City's boundaries. If the City pursues boundary expansion, it will then be prudent to extend the Stormwater Masterplan to include the affected areas. If there are specific areas that are likely to be incorporated within the City's boundaries it is advisable that a major system analysis be done prior to development.

7.1.2 Rainfall Monitoring & LIDAR

The City of Fort St. John has invested in two weather monitoring stations located at Public Works and City Hall to track the local weather that occurs in this community. These rain stations are able to provide localized information on weather events instead of relying on the YXJ Airport weather station 7 km away. Upcoming LIDAR information with contours at 0.10 m intervals is expected to arrive in the spring of 2013.

Both of these sources of information are great assets that should be incorporated into subsequent phases of the Stormwater Masterplan and used to analyze historical weather and surface flow paths.

7.1.3 Stormwater Management & the Liquid Waste Management Plan

One of the commitments of the City's draft Liquid Waste Management Plan (LWMP) is to complete a comprehensive stormwater management plan separately from the LWMP. The LWMP is a legal document that the City must follow. It will be expected that the City follow through on this commitment. Subsequent phases of the City's Stormwater Masterplan should consider a broader perspective for stormwater management.

Appendix A

A Report on the Changes to the Channel of Peace River near Old Fort, British Columbia, 1968-2001

Michael Church, Department of Geography, The University of British Columbia

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8 January, 2002

Mr. Kevin Wiens, P.Eng.
Urban Systems, Ltd.
9807 - 100th Avenue
Fort St.John, British Columbia, V1J 1Y4

Dear Mr. Wiens

Please find enclosed a short report on the morphology and changes that have occurred in the Peace River channel near the Fort St.John sewage lagoon outfall, near Old Fort.

I have rushed the report to you as I said I would deliver it in early January. However, it is somewhat ragged (including the fact that our colour printer is not working properly, so the photo figures are an odd shade). However, I now have to go east for 7 days. I will deliver a cleaned-up copy in about 10 days. In the meantime, if you have followup questions or suggestions, please annotate this copy, and I will be able to incorporate revisions.

I hope the report is helpful

Yours sincerely

Michael Church

Michael Church
Professor

A report on changes to the channel of Peace River near Old Fort, British Columbia, 1968-2001

Michael Church
Department of Geography
The University of British Columbia
Vancouver, British Columbia, V6T 1Z2

Introduction

This report has been requested by Urban Systems, Ltd., at their Ft.St.John office, on behalf of the City of Fort St.John as part of their investigation of the position of the city's sewage lagoon outfall point in relation to the channel of Peace River. The outfall, located immediately downstream from the Old Fort settlement, discharged into a relatively deep and fast sub-channel near the left bank of the river when installed some years ago. However, gravel has subsequently aggraded on the left bank of this channel and the pipe is now buried under the channel margin, under about 2 m of gravel. Effluent emerges through the gravel onto the surface at the edge of the channel.

Studies are being conducted from UBC Geography Department of the long-term adjustment of the channel of Peace River to the regulation of flows imposed by British Columbia Hydro and Power Authority at Bennett Dam, from 1968 on. Two questions arise in relation to the sewage lagoon outfall for which the long term study may be able to provide a useful perspective:

i) Is the change in channel position at Old Fort that has isolated the City sewer outfall a part of the long term adjustment of the river to regulation?

ii) What will be the future trend of channel changes in the vicinity of Old Fort and the sewer outfall?

The UBC studies have consisted chiefly of reoccupation, approximately every 5 years, of about 35 monumented cross-sections located along the river between Hudson's Hope and the Alberta border, and planimetric mapping from air photography, at the scale 1:20 000, of the morphology of the channel and adjacent riparian zone, with a repeat mapping interval of about 10 years. The study is not fundamentally organised to detect local effects at specified places along the river, hence direct information about the outfall site that can be recovered from the study is limited. The nearest cross-section in the UBC study is cross-section "D", located about 200 m upstream from the sewer outfall, very close to the alignment of profile no.2 surveyed by Urban Systems, Ltd. personnel on 23 August, 2001. Trends in channel development at Old Fort can be inferred from the UBC information and from inspection of the historical sequence of air photographs that provide the basis for the mapping.

Site description

Figure 1 is a sketch map of the study site. At this site, a historic secondary channel that flowed behind an island at Old Fort rejoins the main channel. The main river flows on the south side of the island, and then crosses a diagonal riffle that extends downstream from the bar/island in front of Old Fort to impinge on the right bank at a major bend downstream. The major bar/island in fact continues the riffle upstream to impinge on the left bank near the confluence of a minor secondary channel that flows behind an older island. Long diagonal riffles, with superposed bars and/or islands are a common feature in gravel-bed channels like Peace River. The deep channel that collects flow below the riffle is known as a "chute". The outfall was orignally positioned in this chute.

The location of the outfall is shown precisely on drawing A-2-C01 of Urban Systems, Ltd. It is now under the left bank of the river about 150 m downstream from the projected alignment of the access road at the eastern extremity of the Old Fort subdivision. The outfall site is on the southwest corner of an active, gravel alluvial fan. The fan represents the deposits of material eroded from a major gully that drains an area extending back to the Alaska Highway. Hence, there are two factors at this site that may influence the river channel alignment and the position of the lagoon outfall in relation to the main river channel:

i) the future development of the secondary channel at Old Fort and the riffle in the main channel at the outfall site;

ii) the future development of the alluvial fan.

Development of the Peace River channel

The development of the channel in the vicinity of Old Fort can be followed on air photography over a period of 50 years (figures 2-6). Figure 2 shows the channel in 1953, before regulation. The gross appearance is not much different than we see today, although it appears that the "secondary channel" flowing behind the Old Fort bar was relatively more prominent then than it is today (in comparing the photos, the different flow levels should be recognised). A subsidiary bar in the right bank channel near the head of the island indicates that the contemporary main channel was then quite shallow.

By 1967 (immediately before the inception of flow regulation: figure 3) there is evidence of sedimentation at the confluence of the secondary channel with the minor secondary channel at the north tip of the major bar, directly in front of Old Fort, and it appears that the right bank channel of Peace River has become the dominant channel. There is also evidence of fresh sedimentation on the main riffle downstream, near the right bank and the bend. However, there are no other major changes evident. There are few further changes in the bar configuration in either 1977 (figure 4) or 1986 (figure 5). However, during this period vegetation became established on the bar and prograded down the left bank downstream from Old Fort since flows no longer overtopped these areas on a regular basis. The highest water during these years characteristically occurred as the result of frazil ice jams during winter.

The 1996 photography was taken during a major dam release flow and shows few details of the riverbed morphology. Figure 6 is a recent satellite photograph (part of Figure 17: Appendix E in the draft report of Urban Systems, Ltd. to the City of Fort St.John' taken October, 2001). Again, overall configuration has not changed significantly, although it appears as if there has been additional sedimentation in the secondary channel in front of Old Fort, so one may speculate that a higher proportion of flow is now in the right bank channel.

The general picture of stasis is not surprising. Peace River flows since regulation have not been sufficiently high to mobilise the gravel bed of the river (determined in investigations by the writer for British Columbia Hydro and Power Authority pursuant to Site C studies in 1976). The 1996 release flow was capable of mobilising channel bed gravel and it is surprising that greater changes did not occur. In fact, some change did occur in the vicinity of Old Fort. Figure 7 presents the surveys undertaken on cross-section D between 1968 and 1998. From 1968 to 1991, changes were small, except on the bar surface, which has aggraded. The observed differences could easily be the result of survey imprecision associated with line navigation or positioning on the river. However, the 1998 survey shows degradation of about 1 metre over most of the channel. The sediment mobilised from the channel was probably deposited on the riffle downstream. An enlarged area of sedimentation near the right bank downstream is visible evidence of such an outcome. A probable effect of this event would be to have redistributed the flow over the riffle.

In the years to 1991, sufficient flow passed via the secondary channel and over the upstream end of the main riffle to provide fast water in the chute immediately in front of the lagoon outfall site. Our navigation notes for the river indicate that the best boat passage (deepest water) was hard against the left bank right up to the toe of the bar/island, and then upstream just off the island. A substantial portion of the main channel flow crossed the riffle immediately below the emergent bar. In 1998, however, water was very much more slack here, implying that the main water passage had moved farther down the riffle, or become more evenly distributed along it, and probably that less water was now moving via the secondary channel. Such redistribution of discharge across diagonal riffles is an entirely normal process.

The area at the foot of the bar, in the immediate vicinity of the lagoon outfall, has been subject to local sedimentation in the past. In the 1970s, the occupants of the King property (the property immediately adjacent to the outfall site, through which access to the river is gained) had an excavated boat basin on the river edge. This basin was infilled with sediment around 1980 and efforts to re-establish it failed.

The alluvial fan

Figure 2 shows the outlet of the gully channel in 1953 cutting a substantial channel through the left-bank gravel deposits. This configuration was still present in 1967, but the stream outlet appears to have moved downstream and to be developing a small gravel fan across the inshore riverbed. (The tributary outlet may have been relocated as part of the property development in the Old Fort subdivision, and it appears as if the former channelway formed the initial boat basin at the site). By 1977, the fan was well-established and it has become more prominent since. In the 1986 photograph the fan is relatively prominent, but does not protrude into the occupied channel (the photo was taken at very low flow), whereas by 2001, the fan protruded prominently into the channel (see, in particular, figure 19 in Urban Systems, Ltd., Report to the City of Fort St.John, Appendix E).

The question arises why a fan should develop at the outlet of this small stream in recent decades. Two reasons may be adduced.

i) The elimination of annual flood flows in Peace River has reduced or eliminated the former capacity of the river to carry away gravel deposited at the mouth of the tributary;

ii) Sediment yield from the tributary has increased.

The balance of these possibilities cannot be decided in a preliminary investigation, and may not be decideable at all. The first possibility is undoubtedly real, although it should be noted that the left bank here is the site of fast water immediately below the major riffle, and the channel is unusually deep immediately downstream along this bank even today (suggesting the ability locally to carry away incoming fine gravel). The second possibility is real because land use adjacent to the gully upstream has developed extensively over the years, including the establishment of some gravel mining operations (visible in air photography). The tributary channel itself is more prominent in 1967 (figure 3) than in 1953 (figure 2), suggesting more gravel in the bottom of the gully, and has maintained a similar appearance since. There is only one very prominent sediment source along the channel itself (noted by an arrow in figures 2-5). The current surface of the fan indicates recent gravel deposition.

It is probable that a combination of these circumstances is at work. The gully has probably yielded more sediment in the several decades since settlement activities extended into its headwaters, and it has been deposited onto a growing fan. The elimination of flood flows since regulation has deprived the river of the ability to carry the fan gravels away, so that the fan has prograded into the river channel. By 2001 the protrusion is prominent.

Discussion

The evident reason for the burial of the sewage lagoon outfall is the progradation of the small alluvial fan over the end of the pipe, formerly sited in the left bank sub-channel of Peace River immediately below a major diagonal riffle. Flow regulation has likely contributed to this situation insofar as it has deprived the river of its former ability to scour sediment away from this site, in the chute below the riffle.

The 1996 flood appears to have effected minor changes to the riffle itself, which have affected the vigour of the flow in the upper end of the chute below it. This is not unusual. Considering the length of that flood, the changes are minor. There has been no systematic change in channel alignment, and there is no indication that a major change is likely to occur under the present operating regime for the river.

The outfall was installed after regulation, when the current flow regime of the river was established. The outfall site, on the toe of an active alluvial fan, was not well chosen. Extension of the pipe in its current location would leave it exposed to reburial, or to effects of sedimentation that are difficult to predict should the fan eventually grow out to approach the riffle in mid-channel. A superior alternative would be to move the outfall point downstream, away from the fan, where fast water still persists in the left-bank chute channel. In that vicinity, where the bulk of the main river flow is directed toward the left bank near the downstream end of the riffle, the channel is apt to remain stable for a long time under the current or practically foreseeable flow regimes. Since I have had no opportunity to conduct site investigations, a more detailed recommendation cannot be offered.

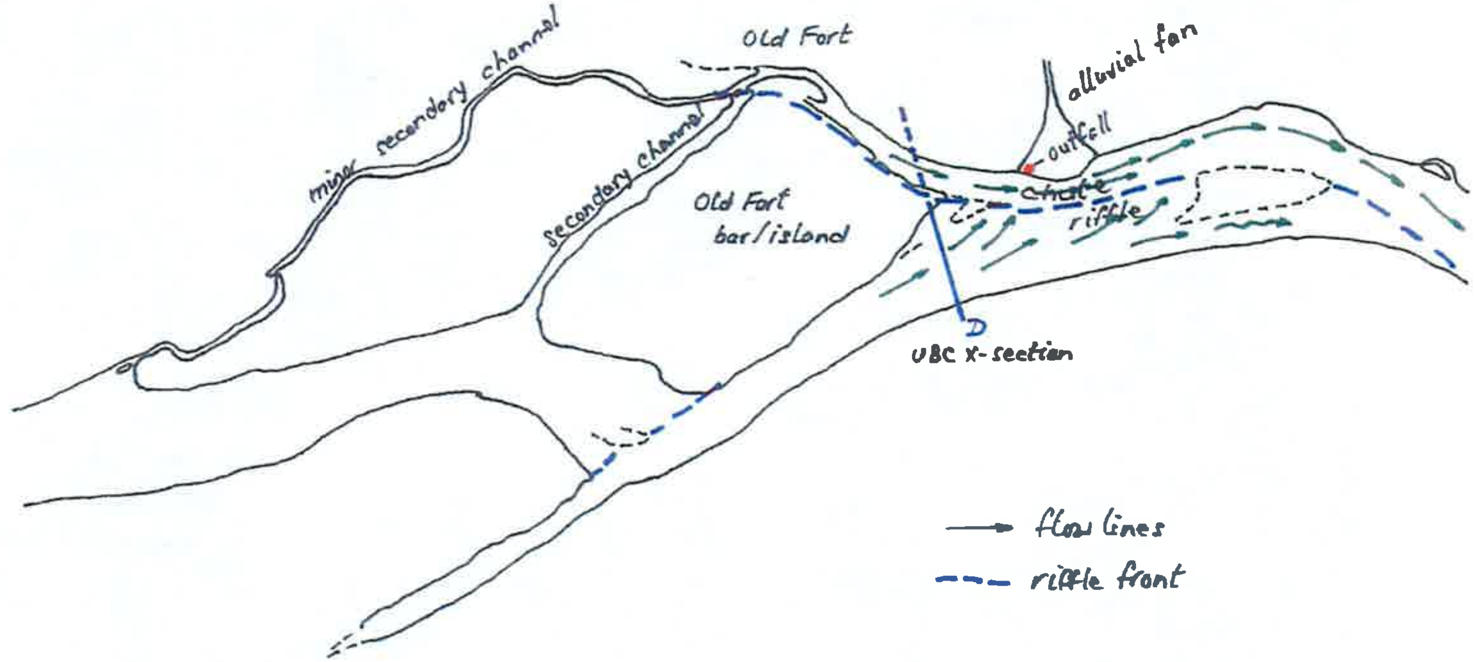


Figure 1. Sketch of the principal features of Peace River in the vicinity of Old Fort.

Figure 2. Vertical air photo of Peace River near Old Fort. Part of BC1777/48. The scales of this and the following figures (to figure 5) have been adjusted to be similar. However, they are not identical.

Figure 3. Peace River near Old Fort. Part of BC5269/00 7.

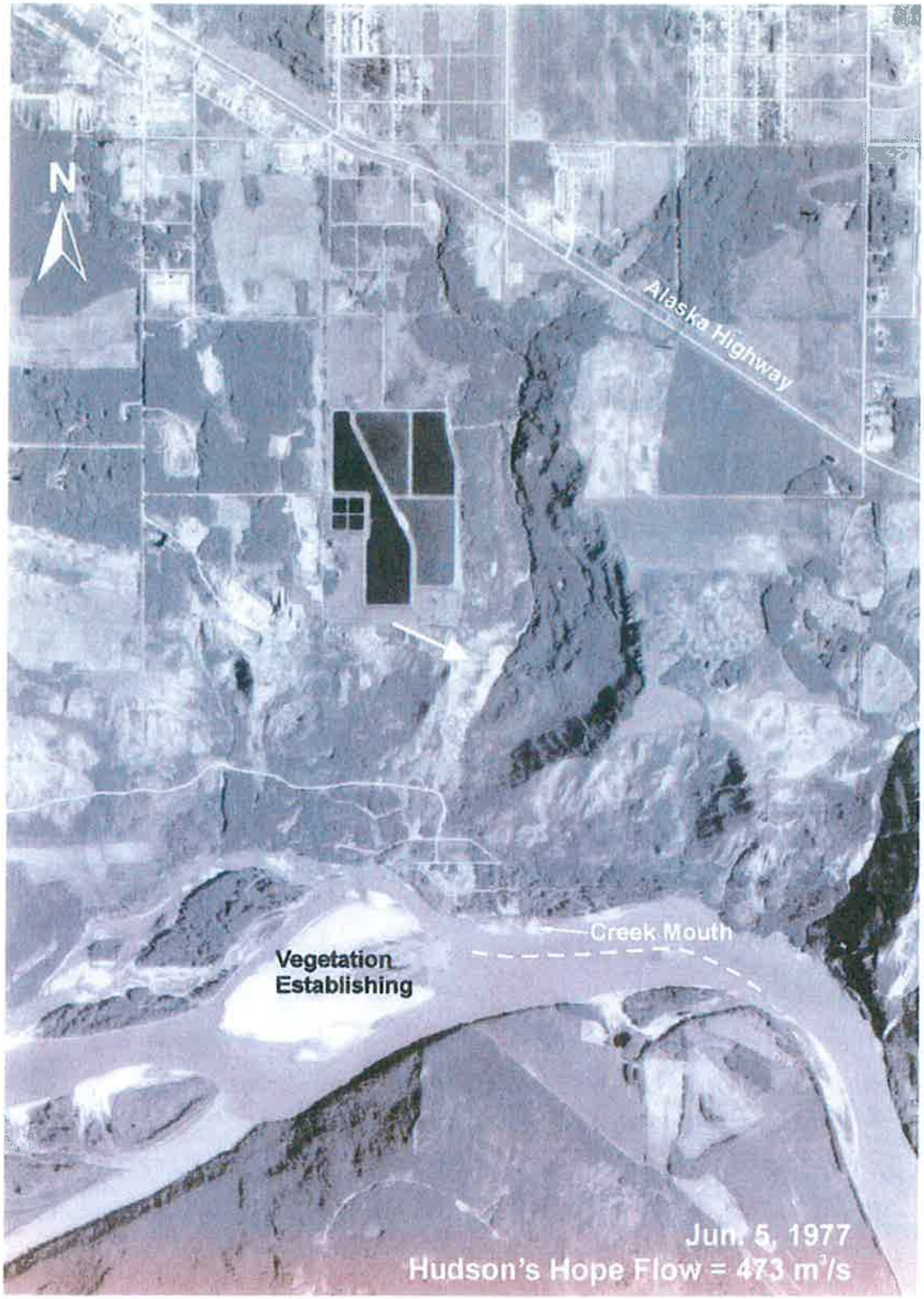


Figure 4. Peace River near Old Fort. Part of A3 7446IR/109.

Figure 5. Peace River near Old Fort. Part of BC8604 7/131.

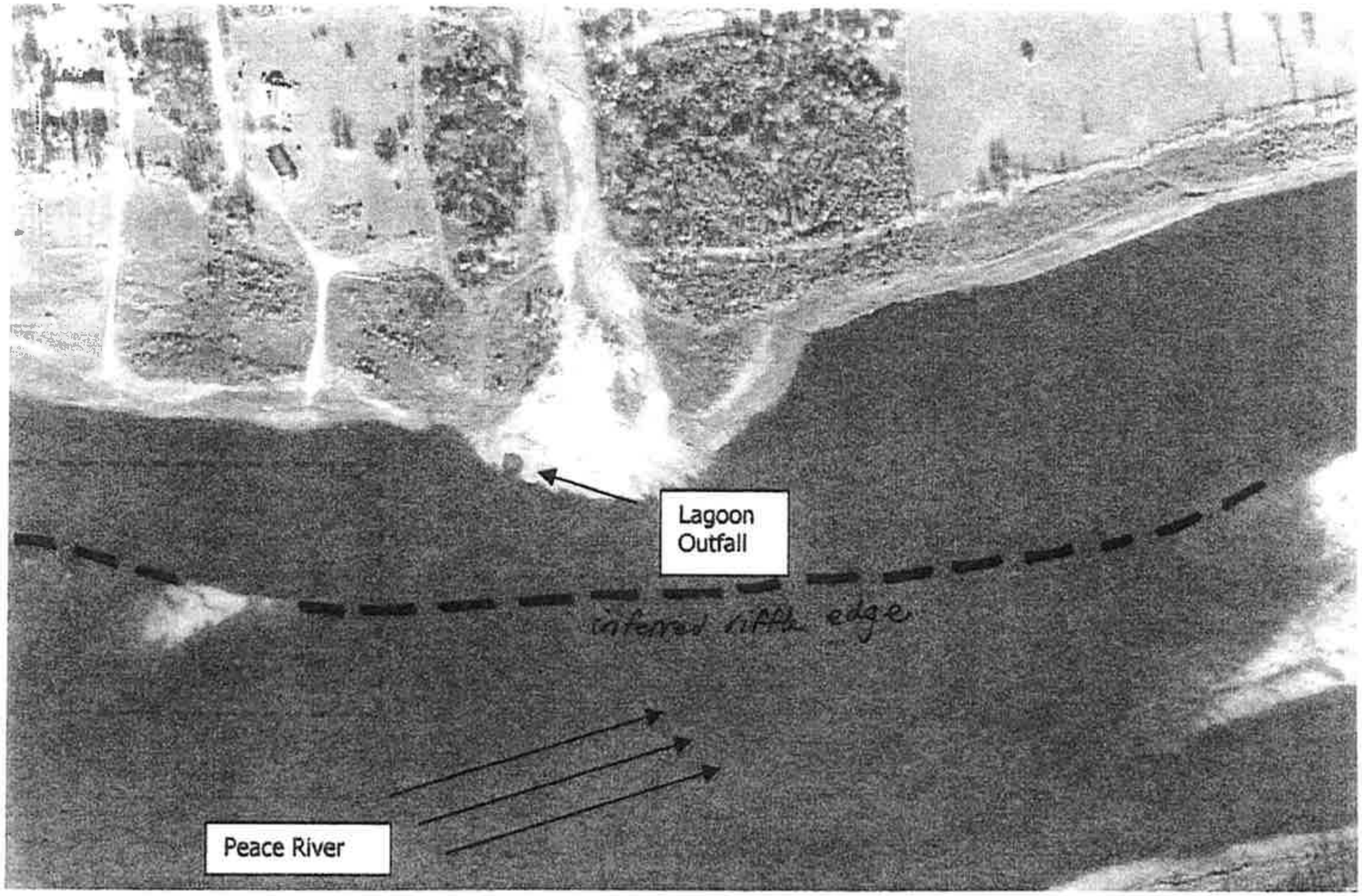
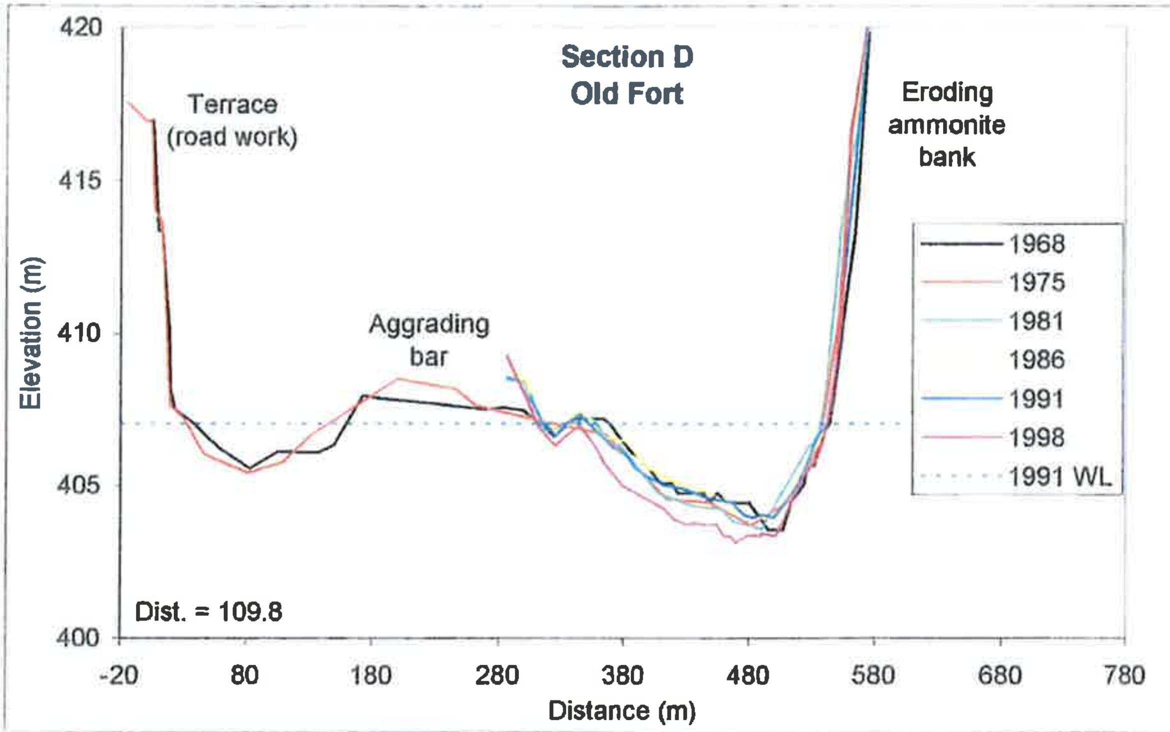


Figure 6. Left bank of Peace River immediately downstream from Old Fort. Satellite view of October, 2001 (from Urban Systems, Ltd.)



Net Gradation (m)

Pre-1996:	-0.01	Response type = Aggradation / Degradation
Post-1996:	-0.78	Response type = Degradation

Notes

- Old Fort; large bar tail DS of island before tight bend.
- Eroding ammonite cliff at RB.
- 1981: LB pin lost due to road work, so backchannel not surveyed thereafter.
- Aggrading mid-channel bar not surveyed after 75.
- 1998: GPS was off; channel survey projected to fit, but degradation is realistic.
- Sediment sources: Eroding RB, Moberly River? (sand trapping in lee of island)

Figure 7. Cross-sections at line "D" opposite Old Fort. After 1975, the survey ended on the bar/island since the control on the left bank was removed.

Appendix B

Multimedia References

YouTube Reference Videos of the July 29, 2010 Rain Event

Storm Summary by CJDC News: http://www.youtube.com/watch?v=TlcXmGULSR0
by FredericoCahis

Storm Summary: http://www.youtube.com/watch?v=Dqi9pvbDYjw
by energeticcity

General Summary: http://www.youtube.com/watch?v=xvd6aDDdy3Y
by DM2006800

100 Street and North Peace Leisure Pool: http://www.youtube.com/watch?v=xvd6aDDdy3Y
by DMD0070

100 Street and 93 Avenue: http://www.youtube.com/watch?v=D6mNnJ0AZWY

Totem Mall: http://www.youtube.com/watch?v=NrFewjNMzC0
by 787Laurie

Totem Mall Part 1: http://www.youtube.com/watch?v=UpgHjSeeOE4
Totem Mall Part 2: http://www.youtube.com/watch?v=Xbv5pabgOuI
by fullneildeal

Flickr Reference Photos of the July 29, 2010 Rain Event

Flickr: http://www.flickr.com/photos/energeticcity/sets/72157624612588830
by energeticcity