Final Report for:

LETHBRIDGE COUNTY

TIFFIN DRAIN – MASTER DRAINAGE PLAN

Date: March 2021

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March 12, 2021
File: N:\1755\072\R01

Attention: **Mr. Devon Thiele. C.E.T.**
Technical Services Supervisor

Dear Mr. Thiele:

Re: **Six Mile Coulee / Tiffin Drain**
Master Drainage Plan

We are pleased to submit the Final Tiffin Drain Master Drainage Plan. This report provides an overview of the stormwater issues, recommended upgrades and design criteria for this drainage basin.

We look forward to your comments for inclusion in the Final Report. Should you have any questions, please call me at (403) 317-3634.

Yours truly,

MPE ENGINEERING LTD.

Jeffrey Hust, P.Eng.
Project Manager

PM/pm
Enclosure

CORPORATE AUTHORIZATION

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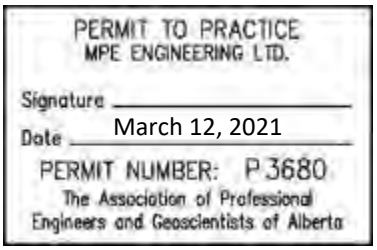

EXECUTIVE SUMMARY

The area known as the Tiffin Drainage Basin is one of the southern-most drainage basins within Lethbridge County and is located southeast of the City of Lethbridge. This drainage basin covers approximately 16,000 ha consisting of primarily agricultural land, with a significant amount of country residential development near the City of Lethbridge. The original study boundary outlined in the Lethbridge County Stormwater Management Plant (SWMP) (MPE, 2015) excluded an area of 1840 ha on the east edge of the basin that has now been included. This study also includes the St. Mary River Irrigation District (SMRID) Main Canal South Basin as identified in the SWMP which is a 1300 ha sub-basin located south of the Tiffin Drain area that drains directly into the SMRID main canal. These areas can be seen on ***Map 2.1***.

The general drainage direction of this area is northwest, water is conveyed overland towards two major drainage ditches; Tiffin Drain and Crombrez Drain. These two drains merge together and drain into Six Mile Coulee, which then travels through the City of Lethbridge to the Old Man River. A portion of the Tiffin Drainage Basin is intercepted by the SMRID Main Canal and does not drain into Six Mile Coulee.

<u>Existing Conditions</u>

- Using LIDAR data from the County a model of the drainage basin was set up in PCSWMM modelling software to analysis the existing conditions in the basin,
- Survey data was collected on the drainage channels and culverts and incorporated into the model.
- The LIDAR data shows that the SMRID Main Canal effectively restricts drainage from the east half of the basin, essentially splitting the basin into east and west halves,
- There is an underdrain on the SMRID main canal which permits drainage to pass from the east half, however the capacity of the underdrain is small relative to the contributing area (maximum capacity = 1.6 m^3/s or 0.22 l/s/ha),
- The SMRID Main Canal underdrain is typically closed to prevent complaints from downstream landowners,
- The effects of the SMRID Main Canal underdrain were modelled in the existing system to determine if in fact the underdrain makes flooding worse on the west half of the basin. The modelling shows that the flows at the downstream end of the system are increased by

approximately 0.5% (31.5 m^3/s vs 31.65 m^3/s). Opening the underdrain significantly reduces flooding on the east half of the basin. The benefits gained by opening the underdrain potentially outweigh the negative downstream effects, which are mitigated as part of the proposed drainage improvements. It is recommended that the SMRID main canal underdrain be fully opened during storm events after the system upgrades are completed,

- In general the capacity of the Tiffin Drain and Crombrez Drain is adequate when the 1:100 year 24 hour rainfall is applied to the basin. The lack of culvert capacity is the limiting factor in effective drainage,
- There is significant overland flooding caused by a 24 hour 1:100 year storm. The volume of water stored in the natural low areas is approximately 1,400,000 m^3, which helps to attenuate storm events,
- The culverts on the Tiffin Drain and Crombrez Drain appear to be the primary restrictions within the system and the main cause of overland flooding within the basin,
- The hotspots identified by the interviews with County personnel and the Lethbridge County Stormwater Master Plan (MPE, 2015) were confirmed by the modelling.

<u>Improvement Scenarios</u>

- To determine the improvements required throughout the basin a variety of modelling scenarios were run, with the SMRID Main Canal splitting the basin in half. Since the effects of operating the SMRID main canal underdrain can be mitigated in the west half of the basin the SMRID main canal underdrain was modelled fully opened in all scenarios. The scenarios selected were based on providing different minimum unit area capacities to the system and are summarized below:
    - Scenario 1: This scenario will maintain the existing infrastructure and construct additional storage to avoid upgrading the channels or culverts. Trapped lows being drained would store all runoff until after the event. The proposed storage areas in the west half of the basin has been sized to account for flows from the SMRID Main Canal underdrain,
    - Scenario 2: This scenario represents improving the infrastructure to a minimum capacity of 0.22 l/s/ha on the east half of the basin and 0.5 l/s/ha on the west half of the basin, additional storage capacity is included in the west half of the basin to accommodate the flows contributed from the SMRID underdrain,

- Scenario 3: This scenario represents improving the infrastructure to a minimum capacity of 0.22 l/s/ha on the east half of the basin and 2.0 l/s/ha on the west half of the basin, additional storage capacity is included in the west half of the basin to accommodate the flows contributed from the SMRID underdrain,
- Scenario 4: This scenario represents improving the infrastructure to a minimum capacity of 0.22 l/s/ha on the east half of the basin and 5.0 l/s/ha on the west half of the basin, additional storage capacity is included in the west half of the basin to accommodate the flows contributed from the SMRID underdrain,
- Scenario 5: This scenario would improve the infrastructure to minimum capacity of 0.22 l/s/ha on the east half of the basin and 2.0 l/s/ha on the west half of the basin, additional storage capacity is included in the west half of the basin to accommodate the flows contributed from the SMRID underdrain. This scenario relies on the existing overland flood areas to store water, with some road improvements and berm construction to enable an additional 443,000 m^3 of storage in the basin,

- Releases from a storage pond or overflow area were set to match the capacity of the downstream infrastructure,
- The improvements also include the addition of drains to connect three hotspots which are isolated from the main system: Kaminsky, Morden, and Highway 508,
- No upgrades of the channels in the Tiffin Drain and Crombrez Drain are required for the recommended alternative, Scenario 5,
- New developments should have a maximum release rate of 2.0 l/s/ha on the west half of the basin and 0.22 l/s/ha on the east half to avoid overwhelming the infrastructure improvements.

<u>Recommended Alternative</u>

- The recommended alternative is Scenario 5, which includes upgrading the east half of the basin to a capacity of 0.22 L/s/ha and upgrading the west half of the basin to a capacity of 2 L/s/ha. This scenario is the lowest cost scenario, Scenario 5 is the preferred alternative for the following reasons:
  - The 2.0 l/s/ha minimum capacity is consistent with the County Stormwater Master Plan (MPE, 2015) and the Malloy Drain Master Drainage Plan (MPE, 2011),

- The 2.0 l/s/ha minimum capacity significantly reduces the existing peak flow discharge into Six Mile Coulee from 34.65 m^3/s to 16.44 m^3/s which will reduce potential erosion in the City of Lethbridge,
- The SMRID underdrain does not require upgrading rather it will be utilized to its existing design capacity. Upgrading the underdrain would have created a situation where downstream landowners are potentially exposed to additional stormwater,
- The higher release rates require significant culvert upgrading, requiring open cutting roads and disturbing traffic.

Implementation

- Implementation of the proposed improvements is an important component of project planning and preliminary phasing has been included which focuses on remedying high priority hotspots and restrictions first. Phases will be in the 0.7 to 4.5 million dollar range but can be increased or decreased depending on funding.
- The proposed project phasing is described below:
  - Phase One: System upgrades along the Tiffin Drain and drainage improvements around the Kaminsky hotspot,
  - Phase Two: Construction of temporary storage areas and drainage improvements around the Buckman hotspot,
  - Long term Improvements: drainage improvements around the Morden hotspot,
- The estimated total cost of the implementation plan is $ 6,180,000, including contingencies (20 %), Engineering (15%), GST (5%), and is estimated based on 2016 construction costs.
- It is recommended that the improvements proposed in this drainage plan be implemented as funding permits.
- Agreements may be required to use trap low areas as storage facilities, and landowner consultation should be undertaken prior to plan implementation.

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1.0 INTRODUCTION

This report serves to provide an assessment of the overall drainage within the Tiffin Drainage Basin within Lethbridge County. As a result of the work completed in the *Lethbridge County Stormwater Master Plan, (MPE 2015)* (SWMP), there were several basins that were recommended to have Master Drainage Plans developed. Lethbridge County wishes to develop a high level master drainage plan for the Tiffin Drainage Basin to further their knowledge on the options available to solve the drainage issues present within the basin.

1.1 Study Scope

The following points summarize the overall scope of work for this study:

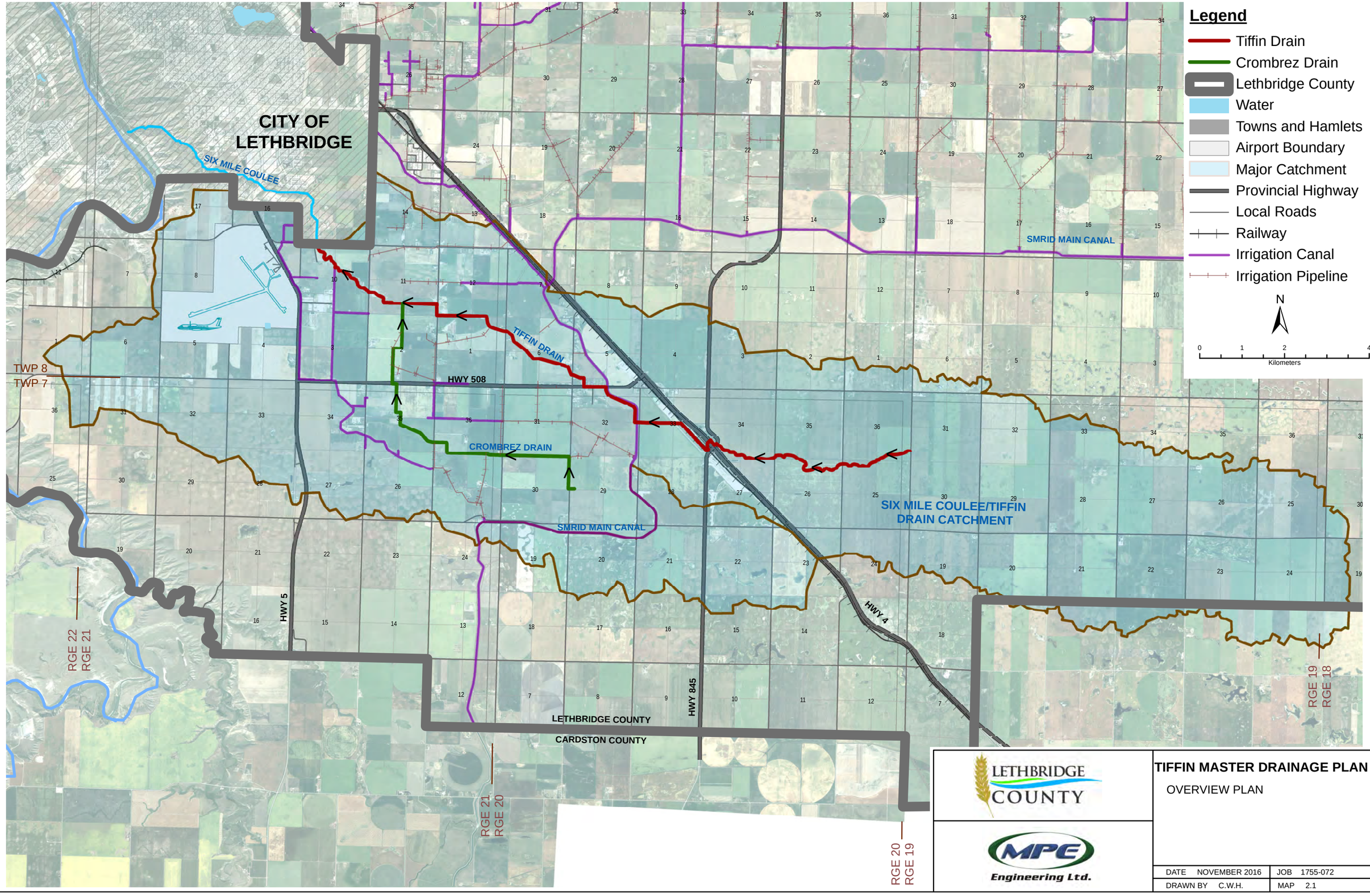
- Review existing background information,
- Conduct field reconnaissance of drainage conveyance infrastructure,
- Delineate sub-catchments within and upstream of the study area,
- Review performance of existing conveyance systems (culverts and drainage ditches) to identify and recommend remedial measures and associated costs,
- Hydraulic modelling to assess current infrastructure capacities, constraints and issues related to further development,
- Identify options for long-term remediation,
- Prepare probable cost estimates (Class D) for proposed improvements to existing drainage systems.

2.0 BACKGROUND INFORMATION

2.1 Study Area

The area known as the Tiffin Drainage Basin is one of the southern-most drainage basins within Lethbridge County and is located southeast of the City of Lethbridge. This drainage basin covers approximately 16,000 ha consisting of primarily agricultural land, with a significant amount of country residential development near the City of Lethbridge. The original study boundary outlined in the Lethbridge County Stormwater Management Plant (SWMP) (MPE, 2015) excluded an area of 1840 ha on the east edge of the basin that has now been included. This study also includes the St. Mary River Irrigation District (SMRID) Main Canal South Basin as identified in the SWMP which is a 1300 ha sub-basin located south of the Tiffin Drain area that drains directly into the SMRID main canal. These areas can be seen on ***Map 2.1***.

The general drainage direction of this area is northwest, water is conveyed overland towards two major drainage ditches; Tiffin Drain and Crombrez Drain. These two drains merge together and drain into Six Mile Coulee, which then travels through the City of Lethbridge into the Old Man River. A portion of the Tiffin Drainage Basin is intercepted by the SMRID Main Canal and does not drain into Six Mile Coulee.



LETHBRIDGE COUNTY

MPE Engineering Ltd.

TIFFIN MASTER DRAINAGE PLAN

OVERVIEW PLAN

DATE NOVEMBER 2016	JOB 1755-072
DRAWN BY C.W.H.	MAP 2.1

2.2 Stakeholders

Several agencies and landowners are directly impacted by the drainage concerns in this area. The needs and interests of these stakeholders must be considered when deciding upon future upgrades and alterations to the current infrastructure. The following stakeholders are impacted differently and must be analyzed accordingly.

Alberta Environment and Parks

Alberta Environment and Parks (AEP) is the regulatory authority for stormwater management in the Province of Alberta and is responsible for the development and enforcement of the *Environmental Protection and Enhancement Act* and the *Water Act*.

Alberta Transportation

Alberta Transportation (AT) is responsible for highways and associated bridge infrastructure in the study area.

Lethbridge County

Lethbridge County has a strong interest in finding solutions to the drainage problems in this drainage basin. Its primary interests focus on responding to property owner concerns with a consistent and responsible stormwater plan to eliminate or alleviate overland flooding, and fully understand the operational issues with regard to the basin and how it effects existing infrastructure. The Tiffin Drainage Basin has high development potential due to its proximity to the City of Lethbridge. Previous flooding of the Tiffin Drainage Basin the has occurred in June of 2010 and 2014 will have an effect on future development.

St. Mary River Irrigation District

The St. Mary River Irrigation District is the raw water supplier for agriculture, commercial, municipal and domestic use throughout the study area. The irrigation canals are not designed to convey stormwater, cooperation between the SMIRD and the County has occurred in the past to allow for acceptance of stormwater when their system has capacity. The Tiffin and Crombrez drains are owned and operated by SMRID.

City of Lethbridge

The City of Lethbridge is located on the downstream end of the system and receives drainage water via Six Mile Coulee. Six Mile Coulee is a largely undeveloped coulee with one major fill at Mayor Magrath Drive, residential and commercial development is located on either side of the coulee within the City limits. The residential development is well above the coulee bottom and is not at risk of flooding. Currently there are no major concerns with the downstream flows coming from the study area. Any changes made to the upstream infrastructure may have an impact downstream. The City is typically concerned with excess erosion within the channel leading to coulee instability. Sloughing of Six Mile Coulee is already occurring adjacent to residential areas.

Landowners

Landowners located near any of the drainage infrastructure rely on the functionality of this infrastructure to assure their property is not negatively impacted. There is a history of farmland being inundated after large storm events, especially in June 2010 and 2014. The landowners would like their property to drain as quickly as possible to avoid impacting their crop production and land values.

2.3 Existing Infrastructure

The majority of the existing infrastructure in the Tiffin Drainage Basin consists of transportation networks (Provincial highways and local roads), water conveyance infrastructure such as: canals, pipelines, and drains, and the Lethbridge County Airport. The drainage conveyance network is the main concern of this study, and the overall condition of the drainage network was assessed by visual inspection. Overall, the drainage ditches are well maintained, have few obstructions, and have well defined side slopes with very few signs of erosion. Some of the ditches have very flat grades causing standing water which promotes plant growth (cattails) which can reduce the capacity of the drain. In addition some of the culverts have collapsed inlets and outlets which decreases the overall culvert capacity. Overall the condition of the drains appears adequate and is not significantly impacting or reducing the system capacity.

Tiffin Drain - Good Condition, North of Highway 508

Collapsed Culverts- Upstream Tiffin Drain

2.3.1 Alberta Transportation

Alberta Transportation infrastructure within the Tiffin drainage basin includes: Highway 4, Highway 5 and Highway 508. The drainage from these highways is integrated into the surrounding conveyance systems using the roadside ditches. Culverts underneath the provincial highways are key pieces of the storm water management infrastructure. Culverts within the Alberta Transportation Infrastructure were generally found to be in fair condition.

2.3.2 Lethbridge County

Lethbridge County owns the network of paved and gravel Township and Range Roads throughout the Tiffin drainage basin and their associated drainage systems. These small drainage systems generally convey runoff to either the Tiffin Drain or the Crombrez Drain. The roadside ditches are sometimes referred to as 'borrow pits' and were not designed for the conveyance of significant stormwater runoff events.

The Tiffin drainage basin does not currently contain any constructed storm water ponds, or other engineered storm water management structures. Tiffin Drain and Crombrez Drain were originally constructed as irrigation delivery tailout systems, not for the conveyance of stormwater runoff events.

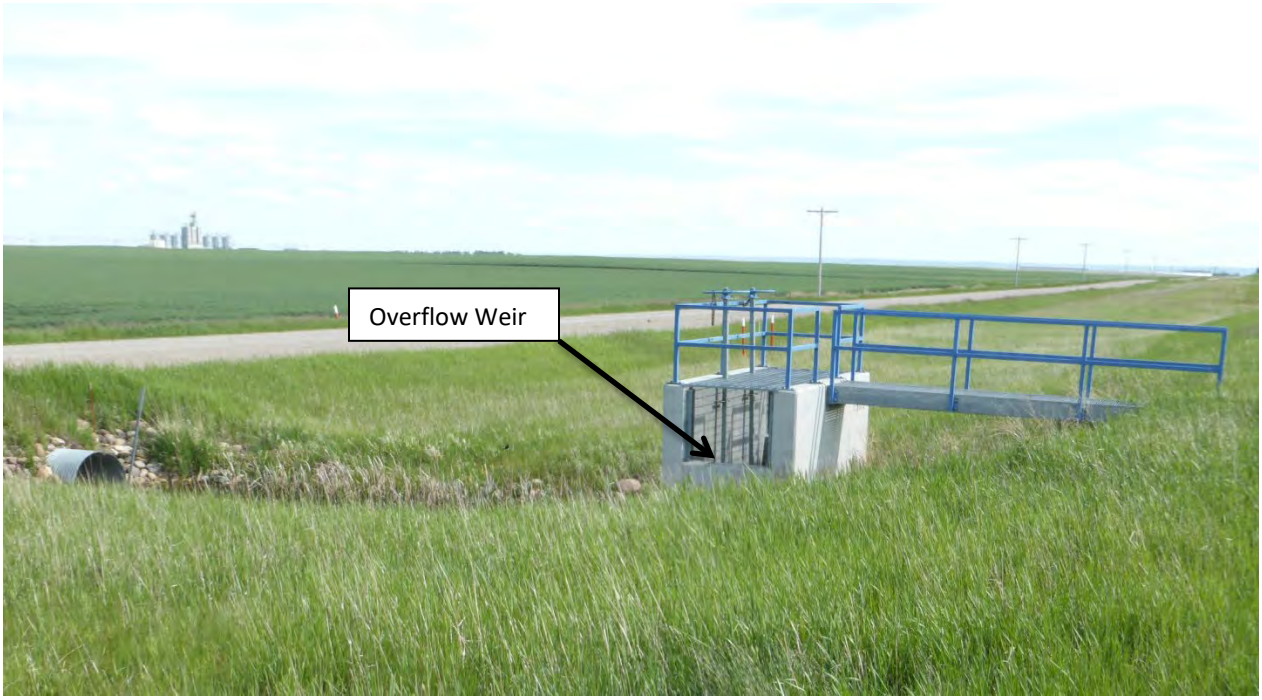
2.3.3 St. Mary River Irrigation District

SMRID owns and operates the irrigation and drainage conveyance infrastructure within the Tiffin Drainage Basin. Their infrastructure includes the SMRID Main Canal, Tiffin Drain, Crombrez Drain, as well as other small irrigation canals and buried pipelines. SMRID controls the timing and acceptance of stormwater inflows to their system.

<u>SMRID Main Canal</u>

The SMRID Main Canal bisects the drainage area into east and west segments. An 800 mm diameter underdrain allows runoff to pass underneath the canal. The underdrain is placed along the natural drainage route within the basin, which was installed to allow drainage from the east half of the basin to cross over to the west half of the basin. The underdrain is gated and is typically closed. There is also a drain inlet adjacent to the underdrain which cannot be used during the operating season due to high water levels in the SMRID Main Canal. Water can enter the canal if water levels on the outside of the

canal exceed FSL and can pass over the drain inlet side weirs. See photo below of the Drain inlet located west of the LA Grain Site. The drain inlets are typically opened in the off season to allow snowmelt to enter the canal.



SMRID Main Canal Drain Inlet

Tiffin Drain

The Tiffin Drain begins east of Highway 4 flowing west, underneath multiple County Roads via culverts and over relatively flat terrain. The portion of the drain east of Highway 4 is more natural, not well defined, and not heavily developed. Tiffin Drain turns into a constructed drain on the east side of the Highway 4 and Highway 845 intersection, Tiffin Drain crosses Highway #4 near the LA Grain site through multiple culverts and swales.

Constructed drains convey water to the SMRID Main Canal. Stormwater can pass underneath the SMRID Main Canal via the gated 800 mm diameter underdrain. The underdrain gate is typically closed letting no runoff through. This is done to avoid issues with downstream infrastructure and landowners who see the underdrain as the source of the flooding.

Downstream of the SMRID Main Canal Tiffin Drain becomes quite well defined and the flow capacity increases as the drain proceeds downstream. A major capacity restriction of Tiffin Drain is created by a 300 m long, 1500 mm diameter that CSP carries Tiffin Drain directly underneath Tiffin Dairy and Range Road 212, this culvert discharges into the start of Six Mile Coulee.

Crombrez Drain

Crombrez Drain begins west of the SMRID Main Canal near the south end of the Tiffin Drainage Basin in a large trapped low area. Crombrez Drain conveys stormwater that collects in this trapped low northeast through a well-defined channel. Crombrez Drain merges with the Tiffin Drain a ½ mile upstream of the Tiffin Dairy before emptying into Six Mile Coulee.

2.4 Previous Studies

The following section provides an overview of the existing reports and documents used to guide the development of the Tiffin Drain MDP.

2.4.1 Lethbridge County Stormwater Master Plan, MPE 2015

The Lethbridge County Stormwater Master Plan (SWMP) (MPE, 2015) was developed to assist Lethbridge County in its future development plans with regards to stormwater drainage throughout its multiple drainage basins. Various "hotspots" were identified using background information and culvert capacity calculations. General remediation techniques were recommended as well as further analysis for certain areas, and developing basin specific Master Drainage Plans (MDP). The Tiffin Drainage Basin is identified in the SWMP as one of the basins that should be analyzed further.

There were twelve hotspots identified within this drainage basin, three of which are considered to have now been addressed. These hot spots with a brief description are found in ***Table 2.1***. The number one priority hotspot is known as the LA Grain site, which is a grain handling and storage site located adjacent to the Highway 4 and 845 intersection and the CPR mainline. This hot spot was determined to be the highest priority due to frequent flooding during large storm events. Multiple options were explored to improve the drainage around the LA Grain Site such as increasing culvert size, or implementing berms to protect current infrastructure.

Table 2.1 2015 SWMP Hot Spot Summary

Number	Priority	Location	Problem
73	1	SE 33-7-20-W4	LA Grain Site- Low culvert capacities causing flooding near highway and structures
90	2	SW 10-8-21-W4	Duncan Subdivision- Low lying area flooding, no storm pond and small gated culverts – ADDRESSED
72	2	NW 32-7-20-W4	Prairie Acres- water collecting at front of lots
79	3	SW 5-8-21-W4	Morden- Standing water at intersection, no culverts
78	3	SE 16-8-21-W4	Ditches need to be maintained – will be addressed during highway upgrades
77	3	NE 10-8-21-W4	Intersection floods, must pump water to Tiffin Drain
76	3	SW 12-8-21 W4	Carlson- Low spot with flooding issues
92	3	SE 10-8-21-W4	Tiffin Dairy Farm- large pipe under farm cannot handle large flows
113	3	SW 14-8-21-W4	Kaminski- Culvert cannot handle flow, water must be pumped during large rain events
91	4	N 5-8-21-W4	Airport- Birds nesting in wetland near runway – ADDRESSED
88	4	N 11-8-21-W4	Coupland/ Kenica- Issues with drainage since canal converted to pipeline, large trapped low in area
75	4	NE 30-7-20-W4	Drain backs up into field, ditches fill with snow and prevent effective drainage, large trapped low area

The Tiffin Drain MDP is focused on improving the hotspots with a 3 or higher priority. The priority 4 hotspots in general only affect agricultural lands with no threat to infrastructure or public safety.

2.4.2 County of Lethbridge Drainage Assessment Report

The C*ounty of Lethbridge Drainage Assessment Report* (EXH, 2008), was prepared to assess the drainage around the intersection around Range Road 212 and Township Road 82, and to develop a conceptual design alternative to alleviate ponding of stormwater. The area studied is also referred to as the Kaminsky hotspot in the 2015 SWMP. The Drainage Assessment report looked at three pipeline options, creation of a storage pond, and regrading of road ditches as options to alleviate the flooding around the intersection. The recommended solution was to construct a drain capable of handling the 1:100 year storm event on the south side of Township Road 82 that would carry stormwater west into Six Mile Coulee. The improvements recommended in this report have not been implemented.

2.4.3 County of Lethbridge Airport Overland Drainage Assessment

The C*ounty of Lethbridge Airport Overland Drainage Assessment Report* (Genivar, 2012), was prepared to assess the drainage around the west side of the Airport and the area around the Morden Homestead (Range Road 215 and Township Road 80), and to develop a conceptual design alternative to alleviate ponding of stormwater. The area studied is also referred to as the Morden hotspot in the 2015 SWMP. The Drainage Assessment report looked at several options to convey stormwater from the Morden Ponding location to the Oldman River, either via a Coulee located a mile north of the Morden site or around the Airport and into Six Mile Coulee. The recommended solution was to construct a drain on the west side of Range Road 215 that would convey stormwater west into a Coulee west of the Airport and the creation of a dry stormwater pond before the Coulee to control releases. The improvements recommended in this report have not been implemented.

2.5 Drainage Concerns

From discussions with the County six primary areas of concern have been identified within the Tiffin Drainage basin. The flooding associated with these hotspots often causes disruption of business and can threaten nearby homes, although there is no record of homes being damaged in the Tiffin Drain area from overland flooding. The hotspot areas are shown on ***Map 2.2***. The following sections detail the specific concerns and provide a brief history of each hotspot.

CITY OF LETHBRIDGE

SIX MILE COULEE

Kaminski

Tiffin Dairy

Buckman Riding Arena

TIFFIN DRAIN

Morden

TWP 8

TWP 7

Highway 508/McNally Road

HWY 508

LA Grain

CROMBREZ DRAIN

SMRID MAIN CANAL

SMRID MAIN CANAL

SIX MILE COULEE/TIFFIN DRAIN CATCHMENT

HWY 5

HWY 4

HWY 845

LETHBRIDGE COUNTY

CARDSTON COUNTY

RGE 22

RGE 21

RGE 21

RGE 20

RGE 20

RGE 19

RGE 19

RGE 18

Legend

- Tiffin Drain
- Crombrez Drain
- Drainage Direction
- Lethbridge County
- Water
- Towns and Hamlets
- Airport Boundary
- Major Catchment
- Provincial Highways
- Local Roads
- Railway
- Irrigation Canal
- Irrigation Pipeline
- Under Drains
- Bridges

Drainage Hotspots (MPE, 2015)

- 1 - Public Health & Safety / Multiple Homes
- 3 - Flooding of Farms & Out Buildings
- 4 - Flooding of Local Roads

N

0 1 2 4

Kilometers

LETHBRIDGE COUNTY

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TIFFIN MASTER DRAINAGE PLAN

DRAINAGE HOTSPOTS

DATE NOVEMBER 2016	JOB 1755-072
DRAWN BY C.W.H.	MAP 2.2

2.5.1 LA Grain Site

LA Grain as described above is a large grain elevator site located directly west of the Highway 4 and Highway 845 intersection. In general, runoff water from the catchments east of Highway 4 drains towards this area affecting the site. There are several barriers to stormwater flow from east to west in the area such as: Highway 4, site access roads, and the CPR Railway. Runoff water must pass through a serious of inconsistently sized culverts under these transportation facilities. There are also culverts directly underneath the site which convey the runoff from an area northeast of the site into Tiffin Drain (Sub catchment E12). Many of these culverts are undersized and flooding occurs as a result. In June 2014, during a particularly heavy rainfall event, flooding occurred causing both the highway and the site to be under water. The photo below shows the general extent of the flooding, note the LA Grain site is flooded at the top of the picture and the Wilson Siding elevator near the bottom of the photo is largely unaffected.

LA Grain Site Flooding June 19, 2014

2.5.2 Tiffin Dairy Farm

Tiffin Dairy Farm is located near the terminus of Tiffin Drain and the border of the City of Lethbridge, on the east side of Range Road 212 (start of Six Mile Coulee). Tiffin drain runs directly underneath the

farmyard using a 1500mm diameter CSP which is approximately 300 m long. This buried CSP is inadequately sized which causes flooding at the upstream end of the culvert which then overflows and floods the dairy farmyard. There is also a CSP catchbasin located in the center of Tiffin Dairy which normally allows runoff within the farm to be conveyed into Six Mile Coulee downstream of Range Road 212. Since this site is near the downstream end of Tiffin drain the contributing area is very large (approx. 3700 ha). The dairy farm is also built on an existing low spot, which naturally collects stormwater. The photo below shows the flooding in the farmyard during the 2010 storm event which inundated a few outbuildings on the property.

Tiffin Dairy Farmyard Flooding June 2010

2.5.3 Buckman Riding Arena

The Buckman Riding Arena is located east of Range Road 211 approximately one mile north of Highway 508. This site is directly north of the Tiffin Drain and is built within an existing low area; this area is prone to overland flooding during runoff events. The culvert on Tiffin Drain that crosses Range Road 211 could be the cause of the backup as it is a single 1200 mm culvert with a large contributing area. There is no photograph of this area but the County has confirmed that the riding arena flooded in the 2010 storm event.

2.5.4 Kaminski Homestead

A trapped low on the NE corner of the Intersection of 58th Street S (Range Road 212) and 60th Ave S. (Township Road 82) can potentially impact the Kaminsky homestead during large storm events. There are no culverts underneath 58th Street (Range Road 212) that convey water west to Six Mile Coulee, and the landowner has to pump the trapped low. There is a culvert that conveys water to the south under Township Road 82 approximately 200 m east of this low spot. The majority of the runoff bypasses this culvert due to the local topography. EXH Engineering prepared a report in 2008 called the '*County of Lethbridge Drainage Assessment Report'* (EXH, 2008) which outlined drainage improvement options for this hotspot as previously discussed in Section 2.4.2.

2.5.5 Morden Homestead

This site is located on the south side of Highway 508 near the western boundary of this drainage basin. The contributing area to this hotspot is approximately 360 ha. However, the runoff from the catchment is retained by the intersection of Range Road 215 and Township Road 80 which blocks the natural drainage path to a coulee approximately one mile to the north. The residences in the area are significantly higher than the road grades and, therefore, water will overtop the roads and continue northwards before homesteads are inundated. The frequency of flooding in recent years has been particularly concerning to the County and residents. The photo below shows the overland flooding around the Morden homestead in the 2014 flood, it can be seen that flood waters completely encircle the homestead. This area was studied previously as part of the *'Airport Overland Drainage Assessment'* (Genivar, 2012).

Morden Homestead Flooding June 20, 2014

2.5.6 Highway 508

This area is located at the intersection of Highway 508 and Range Road 211 south of the Tiffin Drain. The sub-catchment to this hot spot is approximately 140 ha and flows from south to north towards Highway 508. At the intersection of Highway 508 and Range Road 211 there are no culverts pass underneath Highway 508 to convey the stormwater northwards towards Tiffin Drain. According to a discussion with Alberta Transportation the stormwater flows east in the Highway 508 ditch 350 m to the east where a culvert conveys water to the north ditch of Highway 508. This culvert also creates some flooding in the adjacent field. A diagonal culvert that passes underneath a berm and power pole east of Range Road 211 further constricts stormwater flowing in the north ditch. This convoluted drainage path with culvert restrictions essentially dams the stormwater and causes overland flooding in the existing trapped lows. There is no history of overland flooding damaging homes in the area, however the flooding is a concern to the County and should be addressed.

3.0 HYDRAULIC PCSWMM COMPUTER MODELLING

Hydraulic modelling was used to analyze the current drainage systems during the 1:100 year storm as determined in the SWMP (MPE, 2015). Areas with drainage concerns were identified in the PCSWMM model and various options were explored to determine the optimal infrastructure enhancements required.

3.1 Model Assumptions

Assumptions about the Tiffin Drain system were made when modelling the existing and future conditions within the drainage basin. RTK GPS survey was completed on major culvert crossings of both the Tiffin Drain and the Crombrez Drain to determine culvert size and grades. Cross sectional surveys of the Tiffin and Crombrez Drain were also completed to input into the model.

Sub-catchments in the Tiffin Basin were delineated using Lidar 15 contours and the Arc GIS mapping program. These sub-catchments were then analyzed and refined by hand using the contour data as well as known information from Lethbridge County about the drains and canals in the area. Natural trap-lows were modelled as storage pond using approximate volumes from Lidar 15 contours; the water was allowed to spill to the subsequent drain at the top of the trap-low.

Based on the aerial photographs and the Lidar data there appears to be a large quantity of small sloughs and ponding areas on the east side of the basin that would have a significant amount of storage. Since it is difficult to model small storage areas in PCSWMM these slough areas were not incorporated into the model. This may produce a higher runoff than real world conditions making the model more conservative.

3.2 Model Parameters

PCSWMM (Version 6.2, 2015) stormwater modelling software was used to analyze the hydraulics of Six Mile Coulee, Crombrez Drain, and Tiffin Drain systems, as well as the surrounding sub-catchments. ***Table 3.1*** shows the parameters used in the PCSWMM model which are based on data within the *City of Lethbridge Design Standards (2011)* as well as the *City of Calgary Stormwater Management and Design Manual (2011).* These documents were recommended as part of the 2015 SWMP to guide future development of stormwater management plans.

Table 3.1 PCSWMM Modelling Parameters

Manning's "n"	
Pervious Area Overland Flow	0.15
Impervious Area Overland Flow	0.013
Culverts - CSP	0.024
Ditch	0.030
Depression Storage	
Impervious Areas	1.6mm
Pervious Areas	7.5mm
Green-Ampt Parameters	
Suction Head	270 mm
Conductivity	1.0 mm/hr
Initial Deficit	0.277

3.2.1 Design Storms

The development of applicable stormwater rainfall events was completed in the SWMP by using a regional rainfall analysis. The SWMP has prepared the 1:100 year rainfall distributions for the three storm events over different time periods, these rainfall distributions can be seen in ***Table 3.2***, ***Table 3.3*** and ***Table 3.4.***

Table 3.2 Rainfall Distribution 1:100 Year 24 Hour Event

Hour	Depth(mm)	Hour	Depth (mm)	Hour	Depth (mm)
1	0.1	9	6.2	17	2.8
2	0.2	10	37.0	18	1.7
3	0.3	11	21.8	19	0
4	0.4	12	15.7	20	0
5	0.6	13	9.0	21	0
6	0.8	14	5.6	22	0
7	0.9	15	4.5	23	0
8	1.1	16	3.4	24	0
				Total Depth	**112.1**

Table 3.3 Rainfall Distribution 1:100 Year 2-Day Event

Hour	Depth(mm)	Hour	Depth (mm)	Hour	Depth (mm)
1	0.1	17	5.3	33	1.6
2	0.1	18	5.6	34	1.3
3	0.1	19	5.9	35	0.6
4	0.1	20	6.3	36	0.6
5	0.4	21	7.5	37	0.5
6	0.9	22	17.3	38	0.5
7	1.0	23	7.7	39	0.5
8	1.1	24	5.0	40	0.4
9	1.3	25	4.7	41	0.3
10	1.9	26	4.4	42	0.2
11	2.5	27	3.8	43	0.1
12	3.1	28	3.4	44	0.1
13	4.4	29	3.1	45	0.0
14	4.7	30	2.5	46	0.0
15	5.0	31	2.2	47	0.0
16	5.2	32	1.9	48	0.0
				Total Depth	**124.7**

Table 3.4 Rainfall Distribution 1:100 Year 3-Day Event

Hour	Depth(mm)	Hour	Depth (mm)	Hour	Depth (mm)
1	0.7	25	1.7	49	2.4
2	1.0	26	1.7	50	2.4
3	1.4	27	1.7	51	2.5
4	1.7	28	1.8	52	2.5
5	2.0	29	1.8	53	2.2
6	2.4	30	1.8	54	1.9
7	2.7	31	1.9	55	1.7
8	3.1	32	1.9	56	1.4
9	3.4	33	1.9	57	1.1
10	3.7	34	2.0	58	0.9
11	4.1	35	2.1	59	0.8
12	4.1	36	2.2	60	0.7
13	5.3	37	2.2	61	0.7
14	4.1	38	2.3	62	0.6
15	3.4	39	2.3	63	0.6
16	2.7	40	2.3	64	0.5
17	2.0	41	2.3	65	0.5
18	2.0	42	2.4	66	0.5
19	1.9	43	2.4	67	0.5
20	1.8	44	2.4	68	0.4
21	1.8	45	2.4	69	0.4
22	1.7	46	2.4	70	0.2
23	1.6	47	2.4	71	0.1
24	1.7	48	2.4	72	0.0
				Total Depth	**136.2**

The 1:100 year 24 hour event was used for the analysis due to the resulting runoff depth being most reflective of an actual event in this region.

3.3 Existing Scenario Analysis

The existing scenario analysis includes a relatively detailed representation of the Tiffin and Crombrez Drain, accurate culvert sizing and details using recent RTK GPS survey data. Existing minor ditches throughout the drainage basin were not modeled, and delineated sub-catchments are directed towards a section of ditch or a trapped low. The basin is roughly divided in half by the SMRID Main Canal, with

8900 ha of the basin lying to the east of the canal and 7400 ha west of the canal. The SMRID Main canal physically divides the Tiffin Drainage Basin and prevents stormwater from the east from impacting basins to the west and in essence provides protection to areas downslope (west) of the canal. The SMRID main canal has an 800 mm diameter underdrain which can transport stormwater underneath the canal into the west portion of the basin. The SMRID main canal underdrain is typically closed due to complaints from residents downstream of the canal. The SMRID Main Canal underdrain has been closed when modelling the existing conditions.

3.3.1 Sub-catchments

Approximately 12,400 ha of the total 16,300 ha study area drains into the Tiffin and Crombrez Drains and eventually into Six Mile Coulee to discharge into the Oldman River. The runoff from the remaining 3900 ha within the basin is directed either into an SMRID canal, stored within the sub-catchment (dead basin), or discharged northwest into another coulee west of the Lethbridge County Airport. The areas collected by the Tiffin and Crombrez drains enter the drains somewhat sporadically typically using road ditches or shallow swales to enter the drain near road crossings or in the agricultural fields. For modelling purposes each sub-catchment has been assumed to drain entirely towards the upstream node of a drain segment unless a clear drain is defined in the contour data.

All sub-catchments in this drainage basin are mainly comprised of agricultural and country residential land, resulting in a very low runoff coefficient. The relatively flat terrain also includes many potholes and sloughs which creates natural storage, these trapped lows make it difficult to assume the timing of the peak runoff; assumptions on overland storage have been made to model the basin. Large trapped lows have been fully modelled based on the Lidar data and their storage has been incorporated. ***Map 3.1*** and ***Table 3.5*** present the data collecting from the existing PCSWMM model from the sub-catchments.

CITY OF LETHBRIDGE

SIX MILE COULEE

TIFFIN DRAIN

CROMBREZ DRAIN

SMRID MAIN CANAL

SMRID MAIN CANAL

NW14 NW11 NW8 NW15 NW12 NW10 NW7 NW18 NW17 NW16 NW13 NW9 NW6 NW4 NW2 NW1 NW19 NW5 NW3

E13, E14, E15, E16, AND E17

E11 E18 E12 E9 E19 E7 E5 E3 E1 E20 E21 E10 E8 E6 E4 E2

SW13 SW9 SW6 SW4 SW12 SW10 SW7 SW3 SW1 SW11 SW5 SW2 SW8 E22

SIX MILE COULEE/TIFFIN DRAIN CATCHMENT

TWP 8
TWP 7

HWY 508

HWY 5

HWY 4

HWY 845

LETHBRIDGE COUNTY

CARDSTON COUNTY

RGE 22
RGE 21

RGE 21
RGE 20

RGE 20
RGE 19

RGE 19
RGE 18

Legend

- Tiffin Drain
- Crombrez Drain
- Subcatchment
- Drainage Direction
- Lethbridge County
- Water
- Towns and Hamlets
- Airport Boundary
- Provincial Highways
- Local Roads
- Railway
- Irrigation Canal
- Irrigation Pipeline
- Under Drains
- Bridges

N

0 1 2 4
Kilometers

LETHBRIDGE COUNTY

MPE Engineering Ltd.

TIFFIN MASTER DRAINAGE PLAN

MAJOR SUBCATCHMENTS

DATE NOVEMBER 2016	JOB 1755-072
DRAWN BY C.W.H.	MAP 3.1

Table 3.5 Sub-catchment Summary

EAST OF SMRID MAIN CANAL			
Name	**Area (ha)**	**Outlet**	**Peak Runoff (m^3/s)**
E1	973	Tiffin Trap Low N	3.29
E2	1,851	Tiffin Trap Low S	5.86
E3	771	Tiffin Drain	5.32
E4	851	Tiffin Trap Low S	7.61
E5	370	Tiffin Drain	3.23
E6	375	Tiffin Drain	4.16
E7	209	Tiffin Drain	1.90
E8	124	Tiffin Drain	2.41
E9	611	Tiffin Drain	5.21
E10	283	Tiffin Drain	4.25
E11	341	SMRID Main Canal	3.33
E12	224	LA Grain Culverts	2.58
E13	5	Highway 4 Culverts	0.25
E14	3	Highway 4 Culverts	0.12
E15	3	Highway 4 Culverts	0.13
E16	5	Highway 4 Culverts	0.27
E17	14	Tiffin Drain	0.38
E18	165	SMRID Main Canal	5.43
E19	83	Tiffin Drain	2.04
E20	238	Tiffin Drain	2.90
E21	101	Tiffin Drain	1.38
E22	1,332	SMRID Main Canal	9.23
SUBTOTAL (East)	**8938**		

WEST OF SMRID MAIN CANAL			
Name	**Area (ha)**	**Outlet**	**Peak Runoff (m^3/s)**
NW1	52	Tiffin Drain	1.08
NW2	35	Tiffin Drain	0.76
NW3	80	Tiffin Drain	1.76
NW4	179	Tiffin Drain	2.63
NW5	158	Tiffin Drain	3.06
NW6	261	Tiffin Drain	4.31
NW7	152	Tiffin Drain	2.31
NW8	315	Six Mile Trap Low	4.07
NW9	146	Tiffin Drain	0.93
NW10	79	Six Mile Drain	1.72
NW11	104	Six Mile Trap Low	1.10
NW11-1	24	Tiffin Dairy Catchbasin	0.34
NW12	42	Tiffin Drain	0.45
NW13	142	Tiffin Drain	2.44
NW14	201	Kaminski Trap	2.13
NW15	59	Tiffin Drain	0.62
NW16	190	Tiffin Drain	2.93
NW17	294	Six Mile Coulee	3.69
NW18	1,329	Six Mile Coulee	18.71
NW19	382	North Outlet	5.51
SW1	217	Tiffin Drain	4.11
SW2	591	Crombrez Trap Low	3.69
SW3	129	Crombrez Drain	0.81
SW4	140	Hwy 508 Trap Low	3.57
SW5	363	Crombrez Drain	6.70
SW6	72	Crombrez Drain	1.34
SW7	85	Crombrez Drain	2.73
SW8	260	SMRID Sub Canal	4.57
SW9	79	Crombrez Drain	1.82
SW10	102	Crombrez Drain	2.32
SW11	268	SMRID Sub Canal	4.22
SW12	514	SMRID Sub Canal	6.05
SW13	360	Morden Trap Low	7.79
SUBTOTAL (West)	**7,404**		
TOTAL	**16,342**		

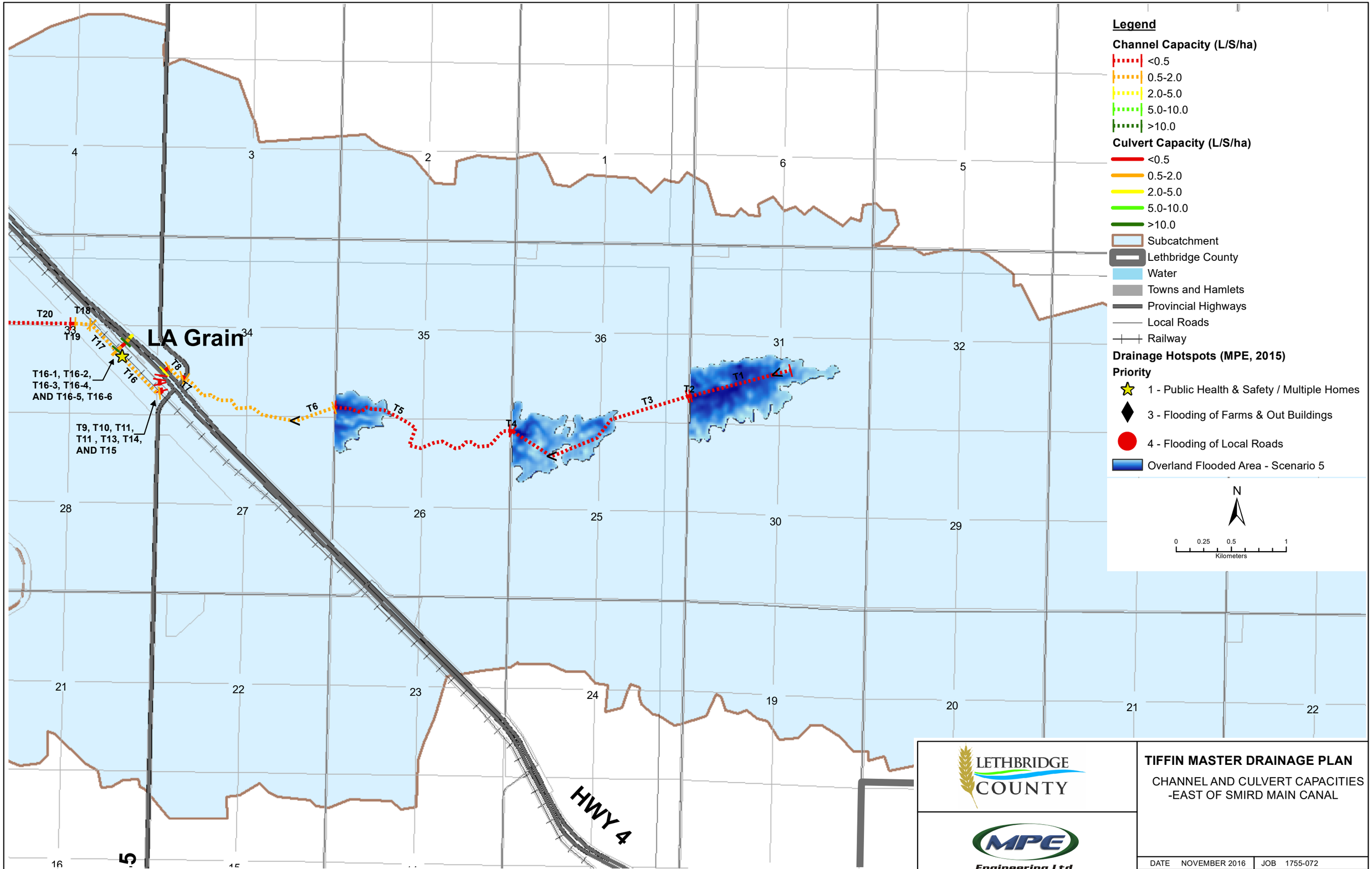
3.3.2 Ditches and Culverts

Field analysis and RTK GPS surveys were completed to determine the size and grades of the major culverts within the Tiffin and Crombrez drains. Culverts within the drains as well as ditch cross sections upstream and downstream of culverts were surveyed to determine parameters for the PCSWMM model and capacity analysis. The drains were then assumed to have a consistent cross section throughout the reach.

The drains and culverts were analyzed to compute the maximum capacity available in each. Ditch flow data was taken from the PCSWMM model, and culvert maximum flows were calculated using Culvert Master. Maximum flows have been combined with contributing area for each capacity. ***Map 3.2*** and ***Map 3.3*** show the analyzed sections ranked according to capacity (L/s/ha) the reaches have been colour coded for capacity. The legend for the capacity colour coding is found on ***Table 3.6***; ***Table 3.7*** and ***Table 3.8*** show the design parameters of each reach of drain and culvert.

The following assumptions were made when determining head and tail water depths for the culvert analysis: The headwater depth used was the top of the upstream ditch (i.e. natural ground), this corresponds with the elevation the water would be at before spilling onto adjacent lands. Many culverts have low lying areas near the ditches which hold water and would cause for a higher headwater elevation, but this was not taken into account for capacity calculations. Tailwater depths were assumed to be at the top of the downstream end of the culvert. In cases where the headwater of a culvert was not at the top of the culvert a tailwater elevation 0.1m lower than the headwater elevation was assumed. The capacity for the SMRID Main Canal underdrain (T22) was calculated assuming the gate was fully open.

Total contributing area was summed up and used for these capacity calculations. The total contributing area for infrastructure west of the SMRID main canal did not include the areas contributing to the SMRID main canal underdrain of 7100 ha.



LETHBRIDGE COUNTY

MPE Engineering Ltd.

TIFFIN MASTER DRAINAGE PLAN

CHANNEL AND CULVERT CAPACITIES
-EAST OF SMIRD MAIN CANAL

DATE NOVEMBER 2016	JOB 1755-072
DRAWN BY C.W.H.	MAP 3.2

PROPOSED DRAIN

Kaminski

SM2

SM1

Tiffin Dairy

T38-1 T38 T37

T36 T34

Buckman Riding Area

T35

C9

PROPOSED DRAIN

T33

TIFFIN DRAIN

T32 T31 T30 T29 T28 T27 T24

T26 T25 T23-5 T23-4 T23-3 T23-2 T23-1 T22 T21

HWY 4

PROPOSED DRAIN

Morden

Highway 508/McNally Road

HWY 508

C8 C7 C6 C5 C4 C3 C2 C1

CROMBREZ DRAIN

T20 T18 T19 T17

LA Grain

T16-1, T16-2, T16-3, T16-4, AND T16-5, T16-6

T16 T8 T7

T9, T10, T11, T11 , T13, T14, AND T15

T6 T5

SMRID MAIN CANAL

HWY 5

Legend

Channel Capacity (L/S/ha)
- <0.5
- 0.5-2.0
- 2.0-5.0
- 5.0-10.0
- >10.0

Culvert Capacity (L/S/ha)
- <0.5
- 0.5-2.0
- 2.0-5.0
- 5.0-10.0
- >10.0
- Proposed Drain
- Subcatchment
- Lethbridge County
- Water
- Towns and Hamlets
- Airport Boundary
- Provincial Highways
- Local Roads
- Railway
- Irrigation Canals

Drainage Hotspots (MPE, 2015)

Priority
- 1 - Public Health & Safety / Multiple Homes
- 3 - Flooding of Farms & Out Buildings
- 4 - Flooding of Local Roads

N

1:40,000

0 0.5 1 2

Kilometers

LETHBRIDGE COUNTY

MPE Engineering Ltd.

TIFFIN MASTER DRAINAGE PLAN

CHANNEL AND CULVERT CAPACITIES -WEST OF SMIRD MAIN CANAL

DATE SEPTEMBER 2018	JOB 1755-072
DRAWN BY C.W.H.	MAP 3.3

Table 3.6 Capacity Legend

Capacity (L/s/ha)	Colour Code
< 0.5	
0.5 – 2.0	
2.0 – 5.0	
5.0 – 10.0	

Table 3.7 Existing Culvert Design Capacities

Name	Description	Size (m)	Slope (%)	Contributing Area* (ha)	Unit Area Capacity (L/s/ha)
Tiffin Drain					
T2	Rang Road 200	0.3	-0.63	4447	**0.01**
T4	Range Road 201	Dual 0.3	-0.57	5192	**0.01**
T7	Highway 845	1.2	0.40	6419	**0.05**
T9	Highway 4 Northbound Lanes	2.4	0.44	6424	**0.23**
T11	Highway 4 Southbound Lanes	1.2x1.8 (arch)	0.35	6426	**0.14**
T13	LA Grain Access Road	0.8	0.77	6430	**0.05**
T15	CPR Railway	Dual 1.2	0.35	6434	**0.16**
T16-1	Highway 4 Northbound Lanes	Dual 0.9	0.43	224	**3.62**
T16-3	Highway 4 Southbound Lanes	0.6	0.25	224	**0.67**
T16-5	CSP under LA Grain	0.6	0.50	224	**0.43**
T19	Wilson Siding Access Road	Dual 1.2	0.07	6773	**0.46**
T21	Range Road 204	0.8	5.76	7094	**0.01**
T22	SMRID Main Canal Underdrain	0.8	0.27	7094	**0.22**
T23-2	Farm Crossing	0.6	0.09	217	**3.04**
T23-4	Culvert Underneath Dugout	0.5	0.07	217	**1.27**
T24	Residential Access Road	0.9	0.11	217	**8.80**
T26	Highway 508	0.9	0.28	217	**9.08**
T28	Farm Access	0.8	0.40	269	**5.44**
T30	Range Road 205	1.05	0.40	269	**12.14**
T33	Range Road 210	1.2	0.39	720	**4.85**
T35	Range Road 211	1.2	0.08	1133	**2.10**
T38	Tiffin Dairy and Range Road 212	1.5	0.60	2964	**1.28**
T38-1	Tiffin Dairy Catch Basin	1.2	1.55	444	**11.99**
Crombrez Drain					
C2	Range Road 210	1.05	0.30	720	**3.59**
C4	Range Road 211	1.05	0.23	1083	**2.11**
C6	Farm Crossing	1.05	0.42	1270	**2.03**
C8	Highway 508	1.2	0.93	1421	**1.51**

*Contributing area resets to zero west of the SMRID Main Canal at T23-2

Table 3.8 Existing Channel Design Capacities

Name	Height (m)	Bottom Width (m)	Length (m)	Side Slopes (m/m)	Slope (%)	Contributing Area*(ha)	Unit Area Capacity (L/s/ha)
Tiffin Drain							
T1	0.5	10	952	100	0.12	1744	**8.45**
T3	0.3	20	1815	55	0.11	5192	**0.83**
T5	0.4	10	2014	20	0.16	5524	**0.73**
T6	0.5	5	1524	30	0.23	6419	**1.08**
T8	1	4	187	7	0.22	6419	**1.91**
T10	0.5	3	20	30	-2.49	6426	**3.07**
T12	0.6	3	53	2.5	-0.19	6430	**0.35**
T14	0.75	2.5	80	3.8	-0.08	6434	**0.35**
T16	1.4	3	564	3.6	0.09	6535	**1.53**
T16-2	1.93	1	9	3	0.33	224	**114.67**
T16-4	0.94	1	25	3	0.57	224	**25.84**
T16-6	1.4	3	20	3	3.28	224	**241.28**
T17	1.4	3	334	3.1	0.12	6773	**1.59**
T18	1.5	2.7	149	2.25	0.17	6773	**1.72**
T20	1.1	2.3	1069	2.7	0.05	7011	**0.49**
T23	2.65	2.5	1326	1.7	0.09	217	**103.14**
T25	2.52	2.8	201	1.5	0.07	217	**87.33**
T27	2.9	2.5	217	1.3	0.29	269	**170.66**
T29	3.26	1.7	209	2	0.36	269	**255.99**
T31	3.03	1.5	1273	2.2	0.16	384	**116.71**
T32	3.5	1.01	727	2	0.26	720	**96.40**
T34	1.87	4	1775	1.6	0.15	1133	**16.61**
T36	2	1.8	803	1.57	0.18	1279	**11.39**
T37	2.8	2.3	974	2.2	0.23	2922	**17.17**
Crombrez Drain							
C1	3.1	2.5	1562	2.26	0.05	720	**53.36**
C3	2.54	1.5	1809	1.8	0.05	720	**19.13**
C5	2.32	1.5	1259	2.15	0.06	1168	**12.17**
C7	1.5	3	747	2	0.04	1270	**4.37**
C9	2.84	1.3	1796	1.4	0.37	1421	**26.52**
Six Mile Coulee							
SM1	2.39	1.08	1904	2.5	0.42	3656	**11.33**
SM2	3	1.08	125	2.5	0.40	5278	**16.84**

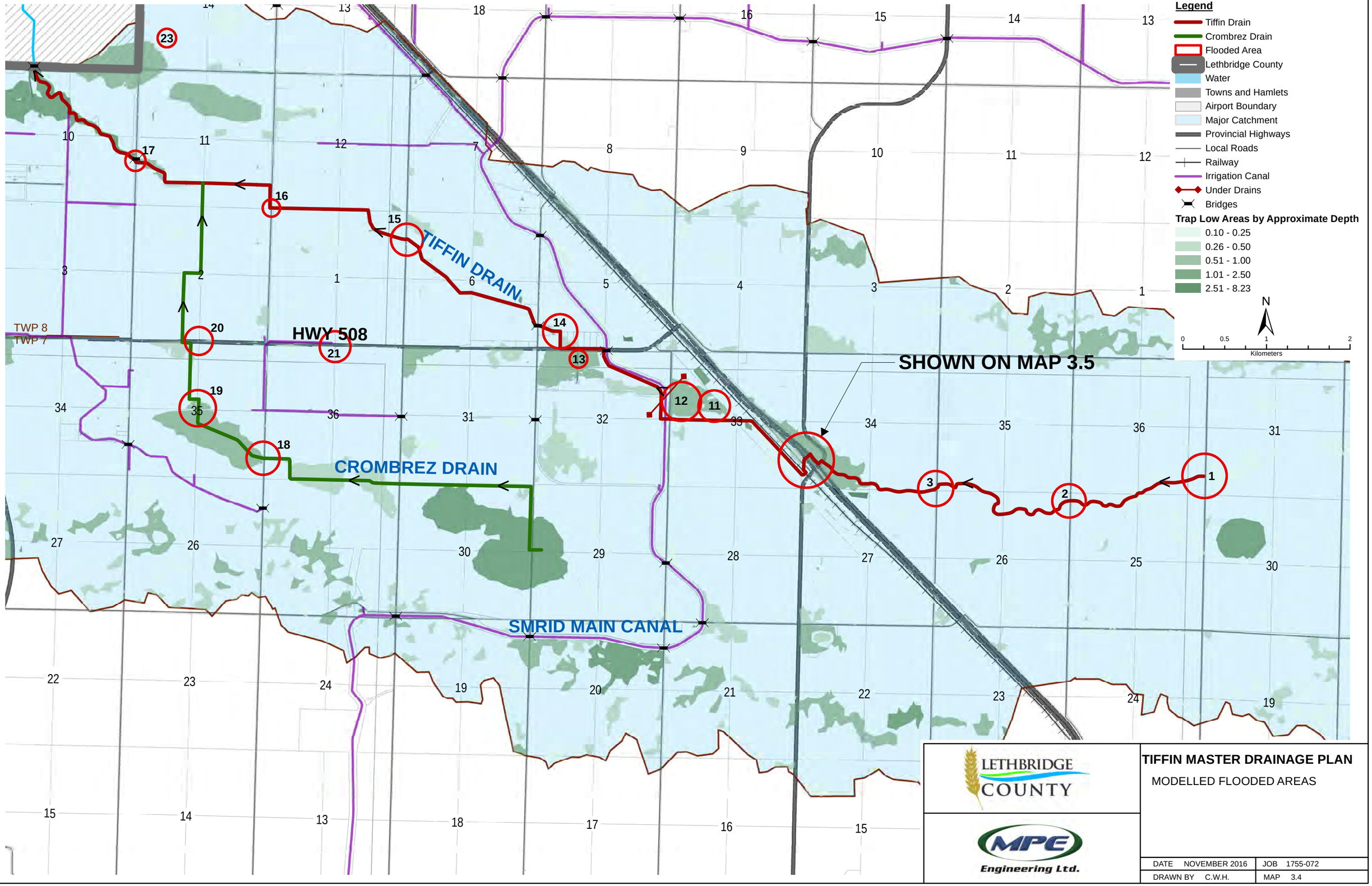
*Contributing area resets to zero west of the SMRID Main Canal at T23

As seen in Tables above, there are many components of the system with low unit area capacities (i.e. L/s/ha). The results show that in general the culverts have a lower unit area capacity than the drainage channels. Some of the problems noted with the culverts were related to size and lack of adequate culvert headwater. A shallow drain section upstream of a culvert creates less headwater than required to maximize the culvert efficiency.

In general the west side of the basin has a higher capacity than the east side of the basin. The major culvert restrictions within the system are, starting from the downstream end: T38, T35, T23-4, T21, T19, T15, T13, T11, T9, T16-5, and T16-3. Most of these culverts are located in the area of the LA Grain hotspot. T38 and T35 correspond with the Tiffin Dairy and Buckman Riding Arena hotspots. Major drain channel restrictions include: T20, T18, T17, T16, T14, and T12; these are all located east of the SMRID Main Canal and are located around the LA Grain hotspot.

3.3.3 Drainage Concerns

The primary hotspots identified by the Lethbridge County SWMP and conversations with Lethbridge County operations staff, in general have been confirmed by the modelling. The model also identified new potential problem areas which may need to be addressed. These problem areas are either an area in which the model shows that there is flooding from a ditch or culvert section, or where the water is reaching a level where it could potentially over top the road. ***Map 3.4 and Map 3.5*** shows the location of the areas that are prone to flooding as determined by the PCSWMM modelling. The number and sizes of the culverts on Map 3.5 are intended to show the current in-place culverts not the upgraded scenario.



LETHBRIDGE COUNTY

MPE Engineering Ltd.

TIFFIN MASTER DRAINAGE PLAN

MODELLED FLOODED AREAS

DATE NOVEMBER 2016	JOB 1755-072
DRAWN BY C.W.H.	MAP 3.4

Limited Culvert Capacity of T16-5 causes significant overland flooding around the LA Grain Site

Limited Culvert Capacity at T13 causes water to flood median and flow to the North

2 - 1200 CSP
T19
10
T18
9
T17
2 - 900 CSP
T16-1
600 CSP
T16-2
T16-3
T16-4
600 CSP
T16-5
T16-6
HWY 845
7
HWY 4
6
HWY 4
8
T16
2400 CSP
T9
5
1800x1200 CSP
T10
T11
T8
1200 CSP
T7
T12
800 CSP
T13
4
T14
T15
2 - 1200 CSP
HWY 845

Legend

Channel Capacity (L/S/ha)

- <0.5
- 0.5-2.0
- 2.0-5.0
- 5.0-10.0
- >10.0

Culvert Capacity (L/S/ha)

- <0.5
- 0.5-2.0
- 2.0-5.0
- 5.0-10.0
- >10.0

N

0 25 50 100
Meters

LETHBRIDGE COUNTY

MPE Engineering Ltd.

TIFFIN MASTER DRAINAGE PLAN

MODELLED FLOODED AREAS
- LA GRAIN SITE

DATE NOVEMBER 2016	JOB 1755-072
DRAWN BY C.W.H.	MAP 3.5

3.4 SMRID Main Canal Underdrain

Since the underdrain is typically closed to avoid landowner complaints, as part of the analysis the true effects of underdrain operation were investigated. Modelling of the existing system with the underdrain almost entirely closed and the underdrain fully open was undertaken. Data was compared to determine the impact of the underdrain on the entire system.

Table 3.9 Underdrain Effects Data Comparison

Parameter	Existing Peak Flows	Peak Flows when Underdrain Fully Open
Flow through underdrain (T22)	0.005 m^3/s	1.60 m^3/s
Flow through ditch upstream of underdrain (T20)	2.83 m^3/s	2.95 m^3/s
Flow in ditch where Crombrez and Tiffin merge (T37)	25.6 m^3/s	25.8 m^3/s
Flow in coulee entering City of Lethbridge (SM1)	31.5 m^3/s	31.65 m^3/s

As seen in the ***Table 3.9*** above, opening the SMRID main canal underdrain does increase the peak flows on the Tiffin Drain, but the impact becomes less significant the further downstream the location is from the underdrain. The underdrain is a relatively small diameter pipe (800 mm), so is it still restricts the discharge from the east side of the SMRID main canal. The flow entering the City of Lethbridge through the Six Mile Coulee only increases by 0.15 m^3/s which is equivalent to 0.5% of its original flow.

4.0 DRAINAGE IMPROVEMENTS

Table 4.1 provides an overview of the scenarios that were modelled as part of this study. The modelled scenarios were based on previous stormwater studies performed in Lethbridge County, particularly the Malloy Drain MDP (MPE, 2010). Based on the results of the Malloy Drain MDP a scenario with no storage is not realistic to construct and operate due to the large channel capacity required and was not investigated as a part of this study.

Table 4.1 Improvement Scenarios

Scenario	Scenario Detail (Minimum Conveyance Capacity)
1	No culvert or drain upgrades
2	Main Canal Underdrain fully opened, minimum conveyance capacity of 0.22 l/s/ha east of the Main Canal, 0.5 l/s/ha west of the Main Canal
3	Main Canal Underdrain fully opened, minimum conveyance capacity of 0.22 l/s/ha east of the Main Canal, 2.0 l/s/ha west of the Main Canal
4	Main Canal Underdrain fully opened, minimum conveyance capacity of 0.22 l/s/ha east of the Main Canal, 5.0 l/s/ha west of the Main Canal
5	Main Canal Underdrain fully opened, minimum conveyance capacity of 0.22 l/s/ha east of the Main Canal, 2.0 l/s/ha west of the Main Canal, utilization of existing trap low areas for storage

PCSWMM was used to model the alterations to the Tiffin Drain system so that no flooding occurs when the restrictions within the system have been upgraded to the minimum required scenario capacity. The PCSWMM model has not restricted culverts or drain reaches with capacities higher than the minimum unit area capacity, therefore, drains may flow at a rate higher than the minimum required capacity.

Upgrade options to control flooding within the basin are comprised primarily of constructed storage ponds upstream of flooded areas. These storage ponds were modelled as having a High Water Level (HWL) 0.3 meters lower than the existing road elevations and were sized to ensure the water will not flow over top of the roads in the 1:100 year storm event. Another option rather than constructing storage ponds may be to increase the road elevations to limit flooding over the roads, this can be explored further in detailed design.

Calculations for capacity upgrades are performed using PCSWMM and Culvert Master. Culvert capacity can be increased in a variety of ways such as: increasing the diameter or number of conduits, increasing the grade, decreasing the length, increasing headwater depth or decreasing tailwater depth. The modelling in this study increased the culvert capacity primarily by increasing the headwater elevation, increasing the size of the culvert, or adding an additional culvert. The upgrades avoided modifying culvert inverts and roads crests. Drain slopes were also maintained, as capacity upgrades to the drains were achieved by increasing depth and width of the channel.

Capacity improvements for the smaller culverts upstream of Highway 845 (directly east of Highway 4) were not considered as overtopping these roads is frequent and does not cause significant damage.

Surveys were not undertaken at the three offline drainage hotspot areas (Morden, Kaminsky, and Highway 508). To assess the culvert capacity required, road elevations and ditch depths were assumed in order to size these components.

4.1.1 Utilization of SMRID Main Canal Underdrain

Opening the SMIRD main canal underdrain has minimal impact on Tiffin Drain downstream as shown in Section 3.4. Therefore, all the scenarios have assumed to f have the underdrain fully open during a storm event. The capacity of the underdrain (T22) is currently 0.22 L/s/ha (1.57 m^3/s total). Storage ponds upstream can be sized to avoid upgrades to the underdrain. If the capacity of the SMRID Main Canal underdrain was doubled it would only reduce storage requirements east of the SMRID Main Canal by about 40,000 m^3/s. Increasing the underdrain capacity would also require additional culvert upgrades downstream, where there are currently minimal upgrades required. The report determined that it would be more cost effective to create additional storage upstream of the underdrain.

4.1.2 LA Grain Site Improvements

The area around the LA Grain Site is prone to flooding even in smaller events. The root cause of the flooding is a culvert restriction underneath the LA Grain Access Road (T13). This culvert is a single 800 mm diameter and in larger event restrictions at the culvert forces water into the median and ditch of Highway 4 where it eventually flows north back underneath Highway 4 and floods around the LA Grain Site. To

improve drainage in the area the culvert under the LA Grain Access Road should be upgraded from a single 800 mm CSP to a dual 1050 mm CSP. Building a berm in the ditch and median of Highway 4 should also be considered to prevent routing of water northwards to the LA Grain Site.

4.2 Scenario 1 - No Culvert or Drain Upgrades

Scenario 1 assumed that no culvert or drain upgrades would be completed and storage ponds would be constructed to avoid flooding any drains or culverts. The only infrastructure that would be constructed in Scenario 1 is storage ponds.

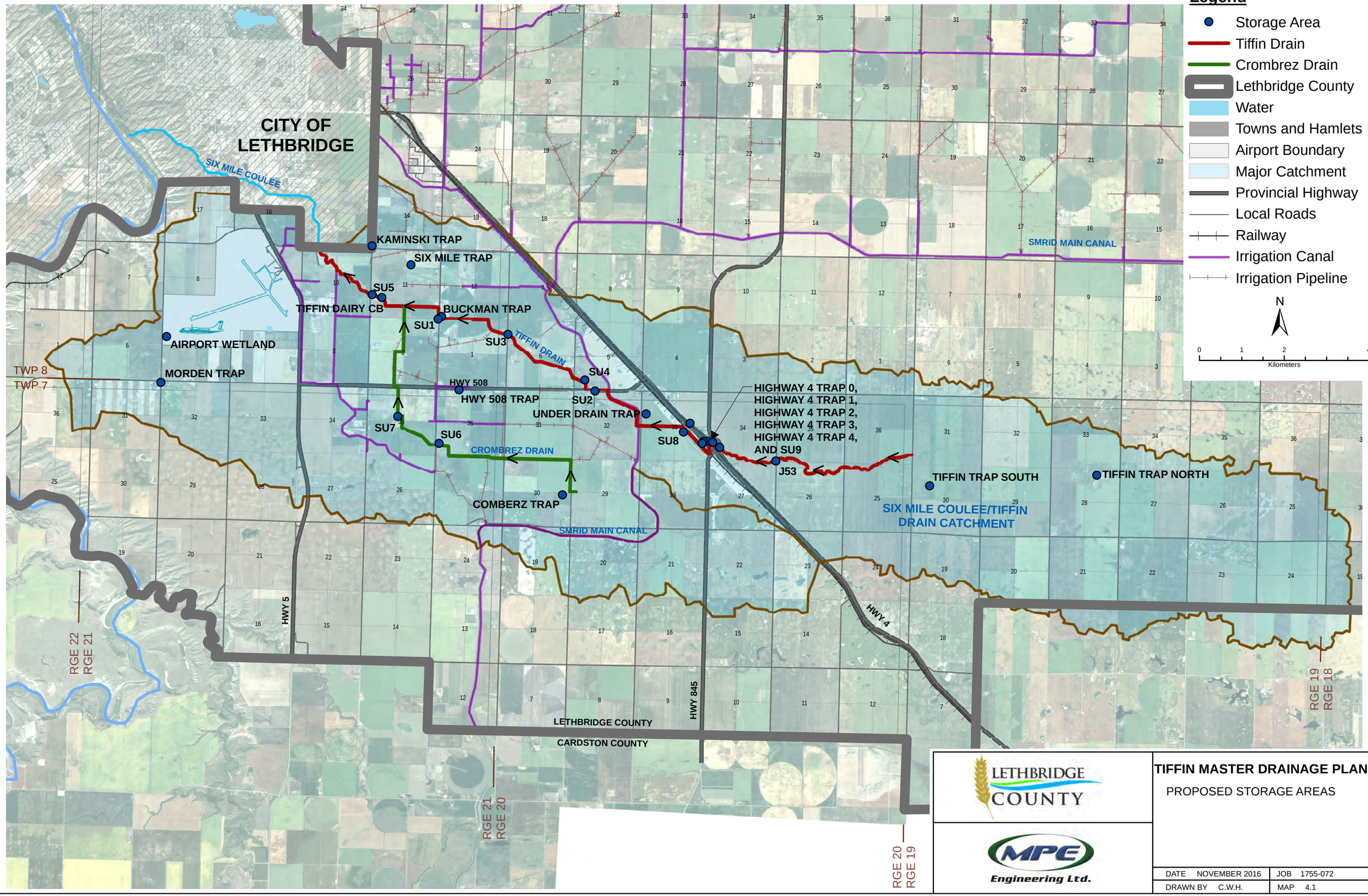
Hydraulic modelling determined that the LA grain site has such poor drainage that construction of storage ponds alone would not help alleviate flooding at the site. Minor upgrades to the drain ditches and culverts in the vicinity were included to allow runoff to enter the proposed storage ponds.

Volumes for the proposed storage ponds from PCSWMM, can be seen in ***Table 4.2***. The location of the proposed storage pond can be seen on **Map 4.1** and **Map 4.2.** these storage ponds remain in the same location for all the improvement scenarios.

Table 4.2 Storage Pond Requirements No Upgrades

Label	Description	Storage Required (m^3)
EAST		
Tiffin Trap North	Culvert crossing flooding under Range Road 200	175,000
Tiffin Trap South	Culvert crossing flooding under Range Road 201	75,000
J53	Junction ½ mile upstream of Highway 845	190,000
Highway4Trap4	Storage upstream of Hwy 845 Culvert	74,000
Highway4Trap0	Storage upstream of Hwy 4 Culverts	150,000
SU9	Storage upstream of LA Grain Culverts	84,000
Underdrain Trap	Storage upstream of SMRID Main Canal underdrain	148,000
	East Storage	**896,000**
WEST		
SU2	Storage upstream of Township Rd 80	106,000
SU3	Storage upstream of Range Road 210	43,000
BuckmanTrap	Storage upstream of Buckman Riding Arena (Range Road 211)	248,000
SU5	Storage upstream of Tiffin Dairy Farm (Range Road 212)	286,000
SU6	Storage upstream of Range Road 211 (Crombrez Drain)	79,000
SU7	Storage upstream culvert crossing under driveway south of Hwy 508 (Crombrez Drain)	113,000
Hwy508Trap	Hwy 508 trapped low storage	78,000
MordenTrap	Morden trapped low storage	186,000
KaminskiTrap	Kaminski trapped low storage	69,000
	West Storage	**1,208,000**
	Total Storage	**2,104,000**

The storage required for this scenario corresponds with a unit area storage of 399 m^3/ha. The three offline areas (Morden, Kaminsky, and Highway 508) have had drains and culverts included in the modelling to allow for gravity drainage after a storm event.



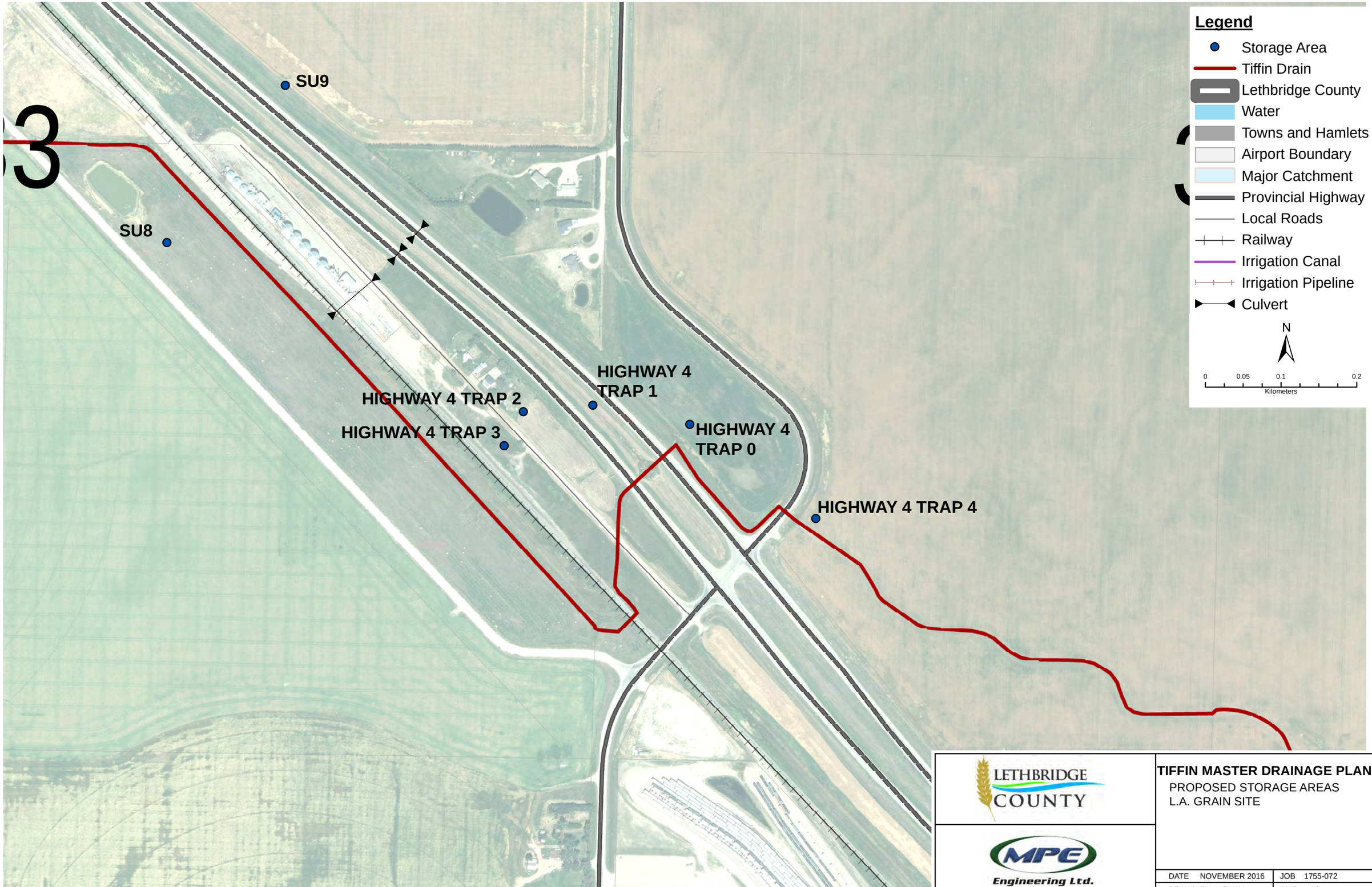
LETHBRIDGE COUNTY

MPE Engineering Ltd.

TIFFIN MASTER DRAINAGE PLAN

PROPOSED STORAGE AREAS

DATE NOVEMBER 2016	JOB 1755-072
DRAWN BY C.W.H.	MAP 4.1



LETHBRIDGE COUNTY

MPE Engineering Ltd.

TIFFIN MASTER DRAINAGE PLAN

PROPOSED STORAGE AREAS
L.A. GRAIN SITE

DATE NOVEMBER 2016	JOB 1755-072
DRAWN BY C.W.H.	MAP 4.2

4.3 Scenario 2 - 0.22 l/s/ha East, 0.5 l/s/ha West Capacity

Scenario 2 involves culvert replacements, and modification to drains to convey the release rate of 0.22 l/s/ha to the SMRID Main Canal underdrain on the east half of the basin. The west half of the basin will be upgraded to a minimum unit area capacity of 0.5 l/s/ha, plus additional capacity to account for the flows contributed by the SMRID Main Canal underdrain. The key component of the improvements is the creation of storage ponds throughout the Tiffin Drainage Basin, particularly east of Highway 4 to avoid flooding around the LA Grain site and the SMRID Main Canal underdrain. Storage ponds will also be developed in the west half of the basin to avoid flooding the Tiffin Dairy and the Buckman Riding Arena. Storage volumes needed for the Scenario 2 upgrades can be found in ***Table 4.3***.

A summary of the improvements required in Scenario 2 is presented below:

- Culvert Upgrades needed for Scenario 2 include:
    - T7, increase size from single 1200 mm to dual 1200 mm, and improve headwater and tailwater conditions,
    - T11, improve headwater and tailwater conditions,
    - T13, increase size from a single 800 mm to a dual 1050 mm and improve headwater and tailwater conditions,
    - T15, improve headwater and tailwater conditions,
    - T21, increase size from a single 800 mm to a dual 800 mm, and improve headwater conditions.
- Addition of three culverts and drains to allow drainage of the Morden, Kaminsky, and Highway 508 trapped lows. These are culverts P1, P3, and P5; and drains P2, P4, and P6.

Table 4.3 Storage Data (0.22 l/s/ha East, 0.5 l/s/ha West)

Label	Description	Storage Required (m^3)
EAST		
Tiffin Trap North	Culvert crossing flooding under Range Road 200	175,000
Tiffin Trap South	Culvert crossing flooding under Range Road 201	71,000
J53	Junction ½ mile upstream of Highway 845	0
Highway4Trap4	Storage upstream of Hwy 845 Culvert	118,000
Highway4Trap0	Storage upstream of Hwy 4 Culverts	179,000
SU9	Storage upstream of LA Grain Culverts	84,000
Underdrain Trap	Storage upstream of SMRID Main Canal underdrain	240,000
	East Storage	**867,000**
WEST		
SU2	Storage upstream of Township Rd 80	112,000
SU3	Storage upstream of Range Road 210	44,000
BuckmanTrap	Storage upstream of Buckman Riding Arena (Range Road 211)	250,000
SU5	Storage upstream of Tiffin Dairy Farm (Range Road 212)	285,000
SU6	Storage upstream of Range Road 211 (Crombrez Drain)	79,000
SU7	Storage upstream culvert crossing under driveway south of Hwy 508 (Crombrez Drain)	113,000
Hwy508Trap	Hwy 508 trapped low storage	74,000
MordenTrap	Morden trapped low storage	180,000
KaminskiTrap	Kaminski trapped low storage	65,000
	West Storage	**1,202,000**
	Total Storage (m^3)	**2,069,000**

The storage requirement for a release rate of 0.5 l/s/ha is 392 m^3/ha. The 0.5 l/s/ha west upgrade scenario has very little change in overall storage volume compared to the no upgrade scenario. The change in storage volumes primarily comes from allowing drainage during storm events from the Morden,

Kaminsky, and Highway 508 hotspots. Most of the culverts in the west part of the basin have capacity higher than 0.5 L/s/ha.

4.4 Scenario 3 - 0.22 l/s/ha East, 2.0 l/s/ha West Capacity

Scenario 3 involves culvert replacements, and modification to drains to convey the release rate of 0.22 l/s/ha to the SMRID Main Canal underdrain on the east side of the basin. The west side of the basin will be upgraded to a minimum unit area capacity of 2.0 l/s/ha, plus additional capacity to account for the flows contributed by the SMRID Main Canal underdrain. The key component of the improvements is the creation of storage ponds throughout the Tiffin Drainage Basin, particularly east of Highway 4 to alleviate flooding around the LA Grain site and the SMRID Main Canal underdrain. Storage ponds will also be developed on the west half of the basin to avoid flooding the Tiffin Dairy and the Buckman Riding Arena. The storage volumes needed for the Scenario 3 upgrades are found in ***Table 4.4.***

A summary of the improvements completed in Scenario 3 is presented below:

- Culvert Upgrades needed for Scenario 3 include:
    - T7, increase size from single 1200 mm to dual 1200 mm, and improve headwater and tailwater conditions,
    - T11, improve headwater and tailwater conditions,
    - T13, increase size from a single 800 mm to a dual 1050 mm and improve headwater and tailwater conditions,
    - T15, improve headwater and tailwater conditions,
    - T21, increase size from a single 800 mm to a dual 800 mm, and improve headwater conditions,
    - T23-4, remove culvert underneath dugout and convert to an open channel,
    - T35, increase size from a single 1200 mm to a dual 1200mm,
    - T38 (under Tiffin Dairy), increase size from a single 1500 mm to a dual 1500 mm,
    - C8, improve headwater conditions,
- Addition of three culverts and drains to allow drainage of the Morden, Kaminsky, and Highway 508 trapped lows. These are culverts P1, P3, and P5; and drains P2, P4, and P6.

Table 4.4 Storage Data (0.22 l/s/ha East, 2.0 l/s/ha West)

Label	Description	Storage Required (m^3)
EAST		
Tiffin Trap North	Culvert crossing flooding under Range Road 200	175,000
Tiffin Trap South	Culvert crossing flooding under Range Road 201	71,000
J53	Junction ½ mile upstream of Highway 845	0
Highway4Trap4	Storage upstream of Hwy 845 Culvert	118,000
Highway4Trap0	Storage upstream of Hwy 4 Culverts	179,000
SU9	Storage upstream of LA Grain Culverts	84,000
Underdrain Trap	Storage upstream of SMRID Main Canal underdrain	240,000
	East Storage	**867,000**
WEST		
SU2	Storage upstream of Township Rd 80	112,000
SU3	Storage upstream of Range Road 210	44,000
BuckmanTrap	Storage upstream of Buckman Riding Arena (Range Road 211)	188,000
SU5	Storage upstream of Tiffin Dairy Farm (Range Road 212)	205,000
SU6	Storage upstream of Range Road 211 (Crombrez Drain)	79,000
SU7	Storage upstream culvert crossing under driveway south of Hwy 508 (Crombrez Drain)	113,000
Hwy508Trap	Hwy 508 trapped low storage	66,000
MordenTrap	Morden trapped low storage	158,000
KaminskiTrap	Kaminski trapped low storage	51,000
	West Storage	**1,016,000**
	Total Storage	**1,883,000**

The storage requirement for a release rate of 2.0 l/s/ha is 357 m^3/ha. The total storage required for this scenario is 1,883,000 m^3 a decrease of 131,000 m^3 (6.5%) in comparison to the storage required for Scenario 1.

4.5 Scenario 4 - 0.22 l/s/ha East, 5.0 l/s/ha West Capacity

Scenario 4 involves culvert replacements, and modification to drains to convey the release rate of 0.22 l/s/ha to the SMRID Main Canal underdrain on the east side of the basin. The west side of the basin will be upgraded to a minimum unit area capacity of 5.0 l/s/ha, plus additional capacity to account for the flows contributed by the SMRID Main Canal underdrain. The key component of the improvements is the creation of storage ponds throughout the Tiffin Drainage Basin, particularly east of Highway 4 to alleviate flooding around the LA Grain site and near the SMRID Main Canal underdrain. Storage ponds will also be developed on the west half of the basin to avoid flooding the Tiffin Dairy and the Buckman Riding Arena. The storage volumes needed for the Scenario 2 upgrades are found in ***Table 4.5***.

A summary of the improvements completed in Scenario 4 is presented below:

- No drain capacity upgrades necessary,
- Culvert Upgrades needed for Scenario 4 include:
    - T7, increase size from single 1200 mm to dual 1200 mm, and improve headwater and tailwater conditions,
    - T11, improve headwater and tailwater conditions,
    - T13, increase size from a single 800 mm to a dual 1050 mm and improve headwater and tailwater conditions,
    - T15, improve headwater and tailwater conditions,
    - T21, increase size from a single 800 mm to a dual 800 mm, and improve headwater conditions,
    - T23-2, increase size from a single 600 mm to a single 800 mm,
    - T23-4, remove culvert underneath dugout and convert to an open channel,
    - T33, increase size from 1200 mm to 1400 mm, and improve headwater conditions,
    - T35, increase size from a single 1200 mm to a dual 1500 mm, and improve headwater conditions,
    - T38, increase size from a single 1500 mm to a quad 1500 mm,
    - C2, increase size from a 1050 mm to a 1200 mm, and improve headwater conditions,
    - C4, increase size from a single 1050 mm to a dual 1200 mm,
    - C6, increase size from a single 1050 mm to a dual 1200 mm, and improve headwater conditions,

- C8, increase size from a single 1050 mm to a dual 1200 mm, and improve headwater conditions.

- Addition of three culverts and drains to allow drainage of the Morden, Kaminsky, and Highway 508 trapped lows. These are culverts P1, P3, and P5; and drains P2, P4, and P6.

Table 4.5 Storage Data (0.22 l/s/ha East, 5.0 l/s/ha West)

Label	Description	Storage Required (m^3)
EAST		
Tiffin Trap North	Culvert crossing flooding under Range Road 200	175,000
Tiffin Trap South	Culvert crossing flooding under Range Road 201	71,000
J53	Junction ½ mile upstream of Highway 845	0
Highway4Trap4	Storage upstream of Hwy 845 Culvert	118,000
Highway4Trap0	Storage upstream of Hwy 4 Culverts	179,000
SU9	Storage upstream of LA Grain Culverts	84,000
Underdrain Trap	Storage upstream of SMRID Main Canal underdrain	240,000
	East Storage	**867,000**
WEST		
SU2	Storage upstream of Township Rd 80	112,000
SU3	Storage upstream of Range Road 210	19,000
BuckmanTrap	Storage upstream of Buckman Riding Arena (Range Road 211)	184,000
SU5	Storage upstream of Tiffin Dairy Farm (Range Road 212)	115,000
SU6	Storage upstream of Range Road 211 (Crombrez Drain)	17,000
SU7	Storage upstream culvert crossing under driveway south Hwy 508 (Crombrez Drain)	96,000
Hwy508Trap	Hwy 508 trapped low storage	51,000
MordenTrap	Morden trapped low storage	147,000
KaminskiTrap	Kaminski trapped low storage	38,000
	West Storage	**779,000**
	Total Storage	**1,646,000**

The storage requirement for a release rate of 5.0 l/s/ha is 312 m^3/ha under the current land use and development. The total storage required for this scenario is 1,646,000 m^3 a decrease of 368,000 m^3 (18.3%) decrease in comparison to the storage required in Scenario 1.

4.6 Scenario 5 - Utilization of Existing Trap Low Areas

Scenarios 1-4, provides for the required stormwater storage within the basin by using constructed stormwater ponds. The construction of these ponds requires earthmoving, land negotiation, and control structures, which increases the overall project costs significantly. Generally having the stormwater storage in a dedicated faculty is desirable in an urban environment, however due to the rural nature of the basin and the relatively infrequency of events and the high agricultural value of land in the area a constructed stormwater management facility is not the most cost effective alternative.

An option for storing stormwater is to use the existing trap lows and overland storage areas rather than creating new stormwater ponds. The road network already ponds some of the water and there are large natural storage areas in the basin as identified on Map 3.4. Some modifications to road, irrigation infrastructure, and possibly farm outbuildings and homes may be required to gain the amount of storage required, which is not detailed as part of this report.

Based on the modelling there is approximately 1,400,000 m^3 of storage within the existing trap low areas within the basin, modelling shows that the volume of storage required for a 1:100 year storm is approximately 1,883,000 m^3. Therefore, 443,000 m^3 of additional storage will be required; this will be assumed to be achieved via road modifications and small containment berms. These berms are proposed upstream of Highway 845 on non-irrigated land the flooded land area is shown on Map 3.2.

Scenario 5 will be designed to the same unit runoff capacity as Scenario 3, 0.22 l/s/ha on the east side of the basin, and 2.0 l/s/ha on the west side of the basin. The drainage infrastructure such as culverts and channels will be upgraded to the required minimum unit area capacities, plus additional capacity on the west half of the basin to account for the flows contributed by the SMRID Main Canal underdrain.

A summary of the improvements completed in Scenario 5 is presented below:

- Culvert Upgrades needed for Scenario 5 include:
    - T7, increase size from single 1200 mm to dual 1200 mm, and improve headwater and tailwater conditions,
    - T11, improve headwater and tailwater conditions,
    - T13, increase size from a single 800 mm to a dual 1050 mm and improve headwater and tailwater conditions,
    - T15, improve headwater and tailwater conditions,
    - T21, increase size from a single 800 mm to a dual 800 mm, and improve headwater conditions,
    - T23-4, remove culvert underneath dugout and convert to an open channel,
    - T35, increase size from a single 1200 mm to a dual 1200mm,
    - T38 (under Tiffin Dairy), increase size from a single 1500 mm to a dual 1500 mm,
    - C8, improve headwater conditions,
- Addition of three culverts and drains to allow drainage of the Morden, Kaminsky, and Highway 508 trapped lows. These are culverts P1, P3, and P5; and drains P2, P4, and P6.

4.7 Storage Volume Comparison

When comparing storage volumes for the storage ponds across the different scenarios the some of the volumes do not change significantly or at all. The system is designed to have a minimum discharge capacity and some of the existing channels and culverts have a capacity higher than the minimum. For example SU3 has the same storage volume of 44,000 m^3 in Scenarios 1-3, and in Scenario 4 the volume drops to 19,000 m^3. The reason the storage stays the same until Scenario 4 is that the culvert downstream of SU3 has an existing unit area capacity of 4.85 l/s/ha, so the pond is releasing at 4.85 l/s/ha in Scenarios 1-3 until the culvert is upgraded to a larger size in Scenario 4. When storage volumes remain constant between scenarios the PCSWMM model is maximizing the existing in place infrastructure. It is important to consider the reduction in overall system wide storage rather than the reduction of a single pond since reducing the volume of one pond may move storage into the pond downstream.

The Tiffin basin is controlled by the furthest downstream culvert, located at Tiffin Dairy (T38). This culvert has the lowest unit area capacity in the west half of the basin. Therefore this culvert controls the overall minimum capacity within the west half of the basin, similar to how the SMRID main canal underdrain controls the east half of the basin. The Tiffin Dairy culvert requires upgrading in Scenarios 3 and 4, therefore, the storage pond upstream of this site (SU5) decreases in size in every scenario.

4.8 Cost Estimates

Cost estimates have been prepared for the different upgrade scenarios presented in Section 4.0. Costs were divided into: channel costs, culvert costs, and storage costs. Cost estimates are based on data obtained from similar construction projects completed in 2016. Final cost estimates include project contingencies of 20%, engineering fees of 15%, and GST of 5%. Storage pond costs have assumed a pond depth of 3 m, length to width of 2:1, 15 m of right of way around the pond, and land acquisition costs of $12,000 /ac. No land acquisition costs were included for channel construction as it was assumed that drain construction would remain within existing road or drain right of ways.

4.8.1 Channels

Table 4.6 shows the channel upgrades required. In general the channel capacity is adequate and only the new offsite drainage areas require any drain modifications. The cost estimates do not vary between the improvement scenarios since drain construction would create a ditch that is adequate for all proposed release rates.

Table 4.6: Channel Capacity Increase Cost Estimates

Channel ID	Scenario				
	1	2	3	4	5
Offsite Areas (Morden, Buckman, Highway 508)					
P2	$ 475,000	$ 475,000	$ 475,000	$ 475,000	$ 475,000
P4	$ 380,000	$ 380,000	$ 380,000	$ 380,000	$ 380,000
P6	$ 310,000	$ 310,000	$ 310,000	$ 310,000	$ 310,000
Total	**$ 1,165,000**	**$ 1,165,000**	**$ 1,165,000**	**$ 1,165,000**	**$ 1,165,000**

4.8.2 Culvert Costs

Table 4.7 lists the upgrade costs for the required culvert upgrades. The costs for linear CSP installation are from the Alberta Transportation Unit Price averages data from 2015. Where a headwater or tailwater improvement is required a unit cost of $4,000 was assumed for each improvement. The headwater and tailwater improvements are generally minor earthworks to raise adjacent banks or installing an improved CSP inlet such as a flared end to enable more culvert capacity.

Table 4.7 Culvert Upgrade Costs

Culvert ID	Scenario				
	1	2W	3W	4W	5
East of SMRID Main Canal					
T2	-	-	-	-	-
T4	-	-	-	-	-
T7	-	$ 83,000	$ 83,000	$ 83,000	$ 83,000
T9	-	-	-	-	-
T11	-	$ 8,000	$ 8,000	$ 8,000	$ 8,000
T13	-	$ 31,400	$ 31,400	$ 31,400	$ 31,400
T15	-	$ 8,000	$ 8,000	$ 8,000	$ 8,000
T16-1	-	-	-	-	-
T16-3	-	-	-	-	-
T16-5	-	-	-	-	-
T19	-	-	-	-	-
T21	-	$ 13,625	$ 13,625	$ 13,625	$ 13,625
T22	-	-	-	-	-
West of SMRID Main Canal					
T23-2	-	-	-	$ 6,875	-
T23-4	-	-	$ 25,000	$ 25,000	$ 25,000
T24	-	-	-	-	-
T26	-	-	-	-	-
T28	-	-	-	-	-
T30	-	-	-	-	-
T33	-	-	-	$ 35,250	-
T35	-	-	$ 13,750	$ 66,500	$ 13,750
T38	-	-	$ 368,750	$ 1,106,250	$ 368,750
T38-1	-	-	-	-	-
C2	-	-	-	$ 31,500	-
C4	-	-	-	$ 49,500	-
C6	-	-	-	$ 31,500	-

C8	-	-	$ 4,000	$ 23,250	$ 4,000
Offsite Areas (Morden, Buckman, Highway 508)					
P1	-	$ 7,050	$ 15,300	$ 23,400	$ 15,300
P3	-	$ 7,650	$ 15,600	$ 33,000	$ 15,600
P5	-	$ 7,050	$ 15,300	$ 24,750	$ 15,300
Total	**$ 0**	**$ 165,775**	**$ 601,725**	**$ 1,600,800**	**$ 601,725**

4.8.3 Storage Costs

Table 4.8 lists the costs associated with constructing the proposed storage ponds for scenarios 1-4, the costs for scenario 5 are to improve the local roads and other infrastructure to gain the additional storage required over what the existing trap lows can provide. Storage pond costs have assumed a pond depth of 3 m, length to width of 2:1, 15 m of right of way around the pond, and land acquisition costs of $12,000 /ac.

Table 4.8 Estimated Storage Ponds Construction Costs

Pond Site	Scenario				
	1	2	3	4	5
East of SMRID Main Canal					
Tiffin Trap N	175,000 m^3	175,000 m^3	175,000 m^3	175,000 m^3	-
$	$ 1,058,000	$ 1,058,000	$ 1,058,000	$ 1,058,000	-
Tiffin Trap S	75,000 m^3	71,000 m^3	71,000 m^3	71,000 m^3	-
$	$ 568,000	$ 548,000	$ 548,000	$ 548,000	-
J 53	190,000 m^3	-	-	-	-
$	$ 1,131,000	-	-	-	-
Highway4 Trap4	74,000 m^3	118,000 m^3	118,000 m^3	118,000 m^3	-
$	$ 563,000	$ 778,000	$ 778,000	$ 778,000	-
Highway4Trap0	150,000 m^3	179,000 m^3	179,000 m^3	179,000 m^3	-
$	$ 935,000	$ 1,077,000	$ 1,077,000	$ 1,077,000	-
SU9	84,000	84,000	84,000	84,000	-
$	$ 612,000	$ 612,000	$ 612,000	$ 612,000	-
Underdrain Trap	200,000 m^3	240,000 m^3	240,000 m^3	240,000 m^3	-
$	$ 1,180,000	$ 1,376,000	$ 1,376,000	$ 1,376,000	-
Subtotal East	**948,000 m^3**	**867,000 m^3**	**867,000 m^3**	**867,000 m^3**	**-**
Subtotal Cost East	**$ 6,047,000**	**$ 5,450,000**	**$ 5,450,000**	**$ 5,450,000**	**-**

* Cost Estimates have assumed land to cost $12,000 /ac

** Cost Estimate for Scenario 5 assumed no land purchase would be required; storage costs estimated using same methodology as scenarios 1-4

West of SMRID Main Canal					
SU2	60,000 m^3	112,000 m^3	112,000 m^3	112,000 m^3	-
$	$ 514,000	$ 749,000	$ 749,000	$ 749,000	-
SU3	43,000 m^3	44,000 m^3	44,000 m^3	19,000 m^3	-
$	$ 411,000	$ 416,000	$ 416,000	$ 293,000	-
Buckman Trap	248,000 m^3	250,000 m^3	188,000 m^3	184,000 m^3	-
$	$ 1,415,000	$ 1,425,000	$ 1,121,000	$ 1,102,000	-
SU5	286,000 m^3	285,000 m^3	205,000 m^3	115,000 m^3	-
$	$ 1,602,000	$ 1,597,000	$ 1,205,000	$ 1,102,000	-
SU6	79,000 m^3	79,000 m^3	79,000 m^3	17,000 m^3	-
$	$ 587,000	$ 587,000	$ 587,000	$ 283,000	-
SU7	113,000 m^3	113,000 m^3	113,000 m^3	96,000 m^3	-
$	$ 754,000	$ 754,000	$ 754,000	$ 671,000	-
Hwy508Trap	78,000 m^3	74,000 m^3	66,000 m^3	51,000 m^3	-
$	$ 582,000	$ 563,000	$ 524,000	$ 450,000	-
Morden Trap	186,000 m^3	180,000 m^3	158,000 m^3	147,000 m^3	-
$	$ 1,112,000	$ 1,082,000	$ 974,000	$ 921,000	-
Kaminsky Trap	69,000 m^3	65,000 m^3	51,000 m^3	38,000 m^3	-
$	$ 538,000	$ 519,000	$ 450,000	$ 386,000	-
Subtotal West	**1,162,000 m^3**	**1,202,000 m^3**	**1,016,000 m^3**	**779,000 m^3**	**-**
Subtotal Cost West	**$ 7,516,000**	**$ 7,692,000**	**$ 6,780,000**	**$ 5,619,000**	**-**
Total Storage	**2,104,000 m^3**	**2,069,000 m^3**	**1,883,000 m^3**	**1,646,000 m^3**	**443,000 m^3**
Grand Total	**$ 13,562,000**	**$ 13,141,000**	**$ 12,230,000**	**$ 11,068,000**	**$ 2,495,000**

* Cost Estimates have assumed land to cost $12,000 /ac

** Cost Estimate for Scenario 5 assumed no land purchase would be required; storage costs estimated using same methodology as scenarios 1-4

4.8.4 Combined Costs

The costs for the different improvement components, channels, culverts, and storage are compiled and summarized in ***Table 4.9***.

Table 4.9: Scenario Cost Estimate Summary

Component	Scenario				
	1	2	3	4	5
Channels	$ 1,165,000	$ 1,165,000	$ 1,165,000	$ 1,165,000	$ 1,165,000
Culverts	$ 0	$ 166,000	$ 602,000	$ 1,601,000	$ 602,000
Storage	$ 13,562,000	$ 13,141,000	$ 12,230,000	$ 11,068,000	$ 2,495,000
Sub-Total*	**$ 14,727,000**	**$ 14,471,000**	**$ 13,936,000**	**$ 13,834,000**	**$ 4,262,000**
Contingency (20%)	**$ 2,945,000**	**$ 2,894,000**	**$ 2,799,000**	**$ 2,767,000**	**$ 852,000**
Engineering (15%)	**$ 2,651,000**	**$ 2,605,000**	**$ 2,519,000**	**$ 2,490,000**	**$ 767,000**
GST (5%)	**$ 1,016,000**	**$ 999,000**	**$ 966,000**	**$ 955,000**	**$ 294,000**
Grand Total*	***$ 21,339,000***	***$ 20,970,000***	***$ 20,280,000***	***$ 20,046,000***	***$ 6,175,000***

*Grand Total includes Contingency, Engineering, and GST

4.9 Recommended Alternative

The recommended alternative is Scenario 5, which includes upgrading the east half of the basin to a capacity of 0.22 L/s/ha and upgrading the west half of the basin to a capacity of 2 L/s/ha. This scenario is the lowest cost scenario, Scenario 5 is the preferred alternative for the following reasons:

- The 2.0 l/s/ha minimum capacity is consistent with the County Stormwater Master Plan (MPE, 2015) and the Malloy Drain Master Drainage Plan (MPE, 2011),
- The 2.0 l/s/ha minimum capacity significantly reduces the existing peak flow discharge into Six Mile Coulee from 34.65 m^3/s to 16.44 m^3/s which will reduce potential erosion in the City of Lethbridge,
- The SMRID underdrain does not require upgrading rather it will be utilized to its existing design capacity. Upgrading the underdrain would have created a situation where downstream landowners are potentially exposed to additional stormwater,
- The higher release rates require significant culvert upgrading, requiring open cutting roads and disturbing traffic.

The upgrades on the east half of the Tiffin Drain Basin includes opening the SMRID main canal underdrain to utilize its full design capacity. Since the existing capacity of that underdrain is 0.22 L/s/ha, it is recommended that the drainage system upstream of the underdrain be sized to be the same. The storage volume required on the east half of the basin for a release rate of 0.22 l/s/ha is 867,000 m^3.

The west half of the basin the system has been designed with a capacity slightly higher than the 2 L/s/ha to account for the additional 1.60 m^3/s contributed from the SMRID main canal underdrain. The total storage that will be needed with this additional flow will be 1,016,000 m^3 or 191 m^3/ha; this equates to an additional 47,000 m^3 of storage in the west half of the basin compared to when the underdrain is closed. Opening the underdrain reduces the storage on the east half by 81,000 m^3 for a net reduction in storage required within the entire system of 34,000 m^3. The total storage needed for the recommended scenario will be 1,883,000m^3, or 151 m^3/ha.

By using the existing trap low areas as overflow areas the construction costs are significantly reduced. This will require a larger by-in from the landowners and understanding that the drainage system is intended to flood, although with drain improvements the frequency and duration of overland flooding will be reduced. Overall the additional storage is proposed primarily to the East of Highway 845 on non-irrigated land.

New developments within the Tiffin Drainage Basin should not be allowed to discharge at rates higher than the minimum system capacity (0.22 l/s/ha east, 2.0 l/s/ha west).

5.0 PROJECT IMPLEMENTATION

This section provides a plan for implementation of the proposed drainage works and identifies proposed construction projects with a construction cost of approximately $ 700,000 to $4,500,000 for each phase. The overall cost of the plan means that the improvements can be completed in two phases, with some long term improvements that could be addressed later. Phase one comprises of the highest priority areas including improving culverts along the Tiffin Drain and constructing the drain around the Kaminsky hotspot. Phase two includes the improvements to overland storage areas, construction of the drain from Highway 508, and a few additional culvert upgrades. The construction of the drain at the Morden hotspot is a long term improvement, with no timeline for implementation.

5.1 Phase One to Phase Three Implementation

5.1.1 Phase One

Phase One would involve the improvements of culverts along the Tiffin Drain and drain construction around the Kaminsky hotspot:

- Improve the headwater and tailwater conditions for and T11 underneath the southbound lanes of Highway 4,
- Increase the size of T13 underneath the LA Grain access road from a single 800 mm to a dual 1050 mm, and improve headwater and tailwater conditions,
- Improve the headwater and tailwater conditions for and T15 underneath the CPR Railway,
- Increase the size of T21 from a single 800 mm to a dual 800 mm and improve the headwater conditions,
- Increase the size of T35 (Range Road 211) from a single 1200 mm to a dual 1200 mm, and improve the headwater and tailwater conditions,
- Increase the size of T38 underneath the Tiffin Dairy from a single 1500 mm to a dual 1500 mm,
- Install a new culvert underneath Range Road 212 and construct 1240 m of new drain from the Kaminsky residence to Six Mile Coulee to enable drainage around the Kaminsky hotspot.

Phase One Estimated Cost = $ 1,216,000

5.1.2 Phase Two

Phase Two will involve the construction of all storage areas, upgrades to culverts along the Tiffin Drain and Crombrez Drain, and drain construction around the Buckman hotspot. Upgrades would include:

- Increase the size of T7 underneath Highway 845 from a single 1200 mm to a dual 1200 mm and improve the headwater and tailwater conditions,
- Remove the culvert T23-4 underneath the dugout and convert to an open channel,
- Improve headwater and tailwater conditions at C8 (Highway 508),
- Enhancement of the existing overland storage areas upstream of Highway 4 and 845.
- Construction of a new culvert underneath Highway 508 on the east side of Range Road 211 to enable drainage to pass northwards underneath Highway 508, and construction/ improvement of

a roadside drain on the east side of Range Road 211 from Highway 508 to Tiffin Drain near the Buckman Riding Arena to better drain the Highway 508 area.

Phase Two Estimated Cost = $4,249,000

5.1.3 Long term Improvements

Long term improvements include:

- Install a new culvert underneath Township Road 8-0 and construct 1520 m of new drain north to a coulee west of the Airport to enable drainage of the area around the Morden hotspot.

Long Term Estimated Cost = $ 711,000

5.2 Implementation Cost Summary

The costs for each improvement phase have been summarized below in ***Table 5.1***.

Table 5.1: Implementation Cost Summary

Project	Cost
Phase One Rehabilitation	$ 1,216,000
Phase Two Rehabilitation	$ 4,249,000
Long Term	$ 711,000
Total Estimated Rehabilitation Costs Phases One through Three *	**$ 6,176,000**

* Costs are based on 2016 Construction costs with no allowances for inflation.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Existing Conditions

- Using LIDAR data from the County a model of the drainage basin was set up in PCSWMM modelling software to analysis the existing conditions in the basin,
- Survey data was collected on the drainage channels and culverts and incorporated into the model.
- The LIDAR data shows that the SMRID Main Canal effectively restricts drainage from the east half of the basin, essentially splitting the basin into east and west halves,
- There is an underdrain on the SMRID main canal which permits drainage to pass from the east half, however the capacity of the underdrain is small relative to the contributing area (maximum capacity = 1.6 m^3/s or 0.22 l/s/ha),
- The SMRID Main Canal underdrain is typically closed to prevent complaints from downstream landowners,
- The effects of the SMRID Main Canal underdrain were modelled in the existing system to determine if in fact the underdrain makes flooding worse on the west half of the basin. The modelling shows that the flows at the downstream end of the system are increased by approximately 0.5% (31.5 m^3/s vs 31.65 m^3/s). Opening the underdrain significantly reduces

flooding on the east half of the basin. The benefits gained by opening the underdrain potentially outweigh the negative downstream effects, which can be mitigated as part of the proposed drainage improvements. It is recommended that the SMRID main canal underdrain be fully opened during storm events as originally designed,

- In general the capacity of the Tiffin Drain and Crombrez Drain is adequate when the 1:100 year 24 hour rainfall is applied to the basin. The lack of culvert capacity is the limiting factor in effective drainage,
- There is significant overland flooding caused by a 24 hour 1:100 year storm. The volume of water stored in the natural low areas is approximately 1,400,000 m^3, which helps to attenuate storm events,
- The culverts on the Tiffin Drain and Crombrez Drain appear to be the primary restrictions within the system and the main cause of overland flooding within the basin,
- The hotspots identified by the interviews with County personnel and the Lethbridge County Stormwater Master Plan (MPE, 2015) were confirmed by the modelling.

<u>Improvement Scenarios</u>

- To determine the improvements required throughout the basin a variety of modelling scenarios were run, with the SMRID Main Canal splitting the basin in half. Since the effects of operating the SMRID main canal underdrain can be mitigated in the west half of the basin the SMRID main canal underdrain was modelled fully opened in all scenarios. The scenarios selected were based on providing different minimum unit area capacities to the system and are summarized below:
    - Scenario 1: This scenario will maintain the existing infrastructure and construct additional storage to avoid upgrading the channels or culverts. Trapped lows being drained would store all runoff until after the event. The proposed storage areas in the west half of the basin has been sized to account for flows from the SMRID Main Canal underdrain,
    - Scenario 2: This scenario represents improving the infrastructure to a minimum capacity of 0.22 l/s/ha on the east half of the basin and 0.5 l/s/ha on the west half of the basin, additional storage capacity is included in the west half of the basin to accommodate the flows contributed from the SMRID underdrain,

- Scenario 3: This scenario represents improving the infrastructure to a minimum capacity of 0.22 l/s/ha on the east half of the basin and 2.0 l/s/ha on the west half of the basin, additional storage capacity is included in the west half of the basin to accommodate the flows contributed from the SMRID underdrain,
- Scenario 4: This scenario represents improving the infrastructure to a minimum capacity of 0.22 l/s/ha on the east half of the basin and 5.0 l/s/ha on the west half of the basin, additional storage capacity is included in the west half of the basin to accommodate the flows contributed from the SMRID underdrain,
- Scenario 5: This scenario would improve the infrastructure to minimum capacity of 0.22 l/s/ha on the east half of the basin and 2.0 l/s/ha on the west half of the basin, additional storage capacity is included in the west half of the basin to accommodate the flows contributed from the SMRID underdrain. This scenario relies on the existing overland flood areas to store water, with some road improvements and berm construction to enable an additional 443,000 m^3 of storage in the basin,

- Releases from a storage pond or overflow area were set to match the capacity of the downstream infrastructure,
- The improvements also include the addition of drains to connect three hotspots which are isolated from the main system: Kaminsky, Morden, and Highway 508,
- No upgrades to the channels in the Tiffin Drain and Crombrez Drain are required for the improvements required in Scenario 5,
- New developments should have a maximum release rate of 2.0 l/s/ha on the west half of the basin and 0.22 l/s/ha on the east half to avoid overwhelming the infrastructure improvements.

<u>Recommended Alternative</u>

- The recommended alternative is Scenario 5, which includes upgrading the east half of the basin to a capacity of 0.22 L/s/ha and upgrading the west half of the basin to a capacity of 2 L/s/ha. This scenario is the lowest cost scenario, Scenario 5 is the preferred alternative for the following reasons:
  - The 2.0 l/s/ha minimum capacity is consistent with the County Stormwater Master Plan (MPE, 2015) and the Malloy Drain Master Drainage Plan (MPE, 2011),

- The 2.0 l/s/ha minimum capacity significantly reduces the existing peak flow discharge into Six Mile Coulee from 34.65 m^3/s to 16.44 m^3/s which will reduce potential erosion in the City of Lethbridge,
- The SMRID underdrain does not require upgrading rather it will be utilized to its existing design capacity. Upgrading the underdrain would have created a situation where downstream landowners are potentially exposed to additional stormwater,
- The higher release rates require significant culvert upgrading, requiring open cutting roads and disturbing traffic.
- Agreements may be required to use trap low areas as storage facilities, and landowner consultation should be undertaken prior to plan implementation.

Implementation

- Implementation of the proposed improvements is an important component of project planning and preliminary phasing has been included which focuses on remedying high priority hotspots and restrictions first. Phases will be in the 0.7 to 4.5 million dollar range but can be increased or decreased depending on funding.
- The proposed project phasing is described below:
    - Phase One: System upgrades along the Tiffin Drain and drainage improvements around the Kaminsky hotspot,
    - Phase Two: Construction of storage areas and drainage improvements around the Buckman hotspot,
    - Long term Improvements: Drainage improvements around the Morden hotspot.
- The estimated total cost of the implementation plan is $ 6,176,000, including contingencies (20 %), Engineering (15%), GST (5%), and is estimated based on 2016 construction costs.
- It is recommended that the improvements proposed in this drainage plan be implemented as funding permits.
- Agreements may be required to use trap low areas as storage facilities, and landowner consultation should be undertaken prior to plan implementation.

7.0 REFERENCES

1. City of Lethbridge, 2011. *City of Lethbridge Design Standards.*
2. EXH Engineering Services (Genivar), 2008. *County of Lethbridge Drainage Assessment Report.*
3. Genivar, 2012. *Airport Overland Drainage Assessment.*
4. Lethbridge County, 2009. *Lethbridge County Engineering Guidelines.*
5. MPE Engineering Ltd, 2010*. Malloy Drain Master Drainage Plan.*
6. MPE Engineering Ltd, 2015. *Lethbridge County Stormwater Master Plan FINAL DRAFT.*

APPENDIX A

Recommended Alternative PCSWMM Model Output

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.010)
--------------------------------------------------------------

WARNING 10: crest elevation is below downstream invert for regulator Link W48
WARNING 02: maximum depth increased for Node J11
WARNING 02: maximum depth increased for Node J12
WARNING 02: maximum depth increased for Node J13
WARNING 02: maximum depth increased for Node J19
WARNING 02: maximum depth increased for Node J21
WARNING 02: maximum depth increased for Node J23
WARNING 02: maximum depth increased for Node J25
WARNING 02: maximum depth increased for Node J27
WARNING 02: maximum depth increased for Node J29
WARNING 02: maximum depth increased for Node J30
WARNING 02: maximum depth increased for Node J33
WARNING 02: maximum depth increased for Node J36
WARNING 02: maximum depth increased for Node J38
WARNING 02: maximum depth increased for Node J40
WARNING 02: maximum depth increased for Node J44
WARNING 02: maximum depth increased for Node J48
WARNING 02: maximum depth increased for Node J49
WARNING 02: maximum depth increased for Node J52
WARNING 02: maximum depth increased for Node J53
WARNING 02: maximum depth increased for Node J55
WARNING 02: maximum depth increased for Node J9

*************
Element Count
*************
Number of rain gages ...... 3
Number of subcatchments ... 55
Number of nodes ........... 98
Number of links ........... 115
Number of pollutants ...... 0
Number of land uses ....... 0


****************
Raingage Summary
****************
                                                  Data       Recording
Name                 Data Source                  Type       Interval
----------------------------------------------------------------------
1:100year24hr        1:100year24hourRain          INTENSITY   60 min.
1:100year2day        1:100year2dayRain            INTENSITY   60 min.
```

1:100year3day 1:100year3dayRain INTENSITY 60 min.

****
Subcatchment Summary
****

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
E1	972.88	1450.33	2.00	0.1000	1:100year24hr	TiffinTrapN
E10	283.45	1090.19	7.00	0.5000	1:100year24hr	J53
E11	341.35	1145.48	1.00	0.3000	1:100year24hr	MainCanal3
E12	224.47	863.00	5.00	0.2700	1:100year24hr	SU9
E13	5.00	184.59	10.00	1.3000	1:100year24hr	Highway4Trap0
E14	2.83	83.36	20.00	0.3000	1:100year24hr	J2
E15	3.25	95.46	20.00	0.2200	1:100year24hr	J4
E16	4.82	99.48	40.00	0.3700	1:100year24hr	J6
E17	13.51	239.15	10.00	0.1800	1:100year24hr	J17
E18	165.22	3003.93	7.00	0.4500	1:100year24hr	MainCanal2
E19	82.79	902.87	7.00	0.3300	1:100year24hr	J44
E2	1851.41	2373.60	1.00	0.1300	1:100year24hr	E4
E20	237.67	1182.43	1.00	0.2500	1:100year24hr	J10
E21	100.99	388.42	10.00	0.2700	1:100year24hr	J8
E22	1331.86	3256.39	2.00	0.2200	1:100year24hr	MainCanal1
E3	770.85	2227.88	1.00	0.1700	1:100year24hr	J57
E4	851.45	2139.32	2.00	0.2200	1:100year24hr	TiffinTrapS
E5	370.44	1470.01	1.00	0.1600	1:100year24hr	J56
E6	374.52	1361.88	1.00	0.3600	1:100year24hr	J56
E7	209.12	804.29	1.00	0.1900	1:100year24hr	J51
E8	123.70	787.92	1.00	0.6100	1:100year24hr	J51
E9	610.77	1785.89	1.00	0.2800	1:100year24hr	J53
NW1	51.61	491.55	4.00	0.2900	1:100year24hr	J22
NW10	79.46	690.98	2.00	0.4300	1:100year24hr	J29
NW11	104.18	418.40	1.00	0.2600	1:100year24hr	SixMileTrap
NW11-1	24.30	97.61	10.00	0.2600	1:100year24hr	TiffinDairyCB
NW12	42.36	170.13	1.00	0.2600	1:100year24hr	J30
NW13	142.04	850.56	1.00	0.4800	1:100year24hr	J29
NW14	201.23	808.14	1.00	0.2600	1:100year24hr	KaminskiTrap
NW15	58.55	235.13	1.00	0.2600	1:100year24hr	J31
NW16	189.67	903.17	1.00	0.5500	1:100year24hr	J31
NW17	293.62	956.41	5.00	0.4900	1:100year24hr	J54
NW18	1328.66	4399.55	5.00	0.6600	1:100year24hr	SixMileCoulee1
NW19	381.53	1589.72	1.00	0.5800	1:100year24hr	AirportWetland
NW2	34.64	364.60	5.00	0.2600	1:100year24hr	J24
NW3	80.34	692.59	3.00	0.4300	1:100year24hr	J24
NW4	179.05	1147.76	1.00	0.2600	1:100year24hr	J50
NW5	157.59	1023.32	2.00	0.5500	1:100year24hr	J50

NW6	261.03	1631.44	2.00	0.3700	1:100year24hr	J26
NW7	152.24	939.78	1.00	0.3100	1:100year24hr	J26
NW8	315.20	1260.81	2.00	0.4300	1:100year24hr	SixMileTrap
NW9	145.98	335.56	1.00	0.2200	1:100year24hr	J28
SW1	216.95	1607.04	3.00	0.3700	1:100year24hr	J43
SW10	101.84	893.32	3.00	0.4800	1:100year24hr	J35
SW11	268.17	1327.60	1.00	0.5400	1:100year24hr	SubCanal2
SW12	514.21	1714.02	1.00	0.5000	1:100year24hr	SubCanal3
SW13	360.39	2772.21	1.00	0.5800	1:100year24hr	MordenTrap
SW2	590.51	1549.90	1.00	0.1600	1:100year24hr	CombrezTrap
SW3	129.13	338.92	1.00	0.1600	1:100year24hr	J58
SW4	140.39	1743.97	2.00	0.3700	1:100year24hr	Hwy508Trap
SW5	363.08	2521.41	1.00	0.4400	1:100year24hr	J36
SW6	72.17	611.57	1.00	0.3000	1:100year24hr	J32
SW7	85.44	1162.43	1.00	0.8800	1:100year24hr	J37
SW8	259.77	1593.70	1.00	0.4900	1:100year24hr	SubCanal1
SW9	78.58	714.38	2.00	0.5000	1:100year24hr	J32

****
Node Summary
****

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
J1	JUNCTION	925.95	3.95	6000.0	
J10	JUNCTION	924.93	1.97	500.0	
J11	JUNCTION	926.66	1.24	500.0	
J12	JUNCTION	926.25	1.40	500.0	
J13	JUNCTION	926.87	2.13	500.0	
J14	JUNCTION	926.80	1.80	500.0	
J15	JUNCTION	927.04	2.66	500.0	
J16	JUNCTION	926.90	2.80	500.0	
J17	JUNCTION	925.60	2.00	500.0	
J18	JUNCTION	925.20	2.30	10000.0	
J19	JUNCTION	921.06	3.15	1000.0	
J2	JUNCTION	925.79	3.57	500.0	
J20	JUNCTION	921.03	3.47	500.0	
J21	JUNCTION	920.89	3.61	500.0	
J22	JUNCTION	920.83	3.53	500.0	
J23	JUNCTION	919.26	4.22	500.0	
J24	JUNCTION	919.17	3.53	500.0	
J25	JUNCTION	915.18	4.02	500.0	
J26	JUNCTION	915.10	3.40	500.0	
J27	JUNCTION	912.46	2.74	500.0	
J28	JUNCTION	912.44	2.56	500.0	

J29	JUNCTION	911.00	2.84	500.0
J3	JUNCTION	926.30	2.52	500.0
J30	JUNCTION	908.73	3.27	500.0
J31	JUNCTION	906.96	5.04	500.0
J32	JUNCTION	917.90	3.20	500.0
J33	JUNCTION	917.58	2.84	500.0
J34	JUNCTION	918.18	3.00	500.0
J35	JUNCTION	918.20	3.00	500.0
J36	JUNCTION	919.10	3.47	500.0
J37	JUNCTION	919.00	3.14	500.0
J38	JUNCTION	920.20	4.03	500.0
J39	JUNCTION	920.05	3.55	500.0
J4	JUNCTION	926.19	2.41	500.0
J40	JUNCTION	926.46	2.84	0.0
J41	JUNCTION	926.36	2.44	6000.0
J42	JUNCTION	922.40	4.55	10000.0
J43	JUNCTION	922.19	3.51	500.0
J44	JUNCTION	924.36	2.71	500.0
J45	JUNCTION	919.80	1.00	0.0
J46	JUNCTION	933.40	1.00	0.0
J47	JUNCTION	909.90	1.00	0.0
J48	JUNCTION	920.00	3.26	500.0
J49	JUNCTION	920.20	3.40	5000.0
J5	JUNCTION	926.29	1.71	500.0
J50	JUNCTION	917.10	3.50	500.0
J51	JUNCTION	933.10	0.94	300000.0
J52	JUNCTION	933.36	1.28	300000.0
J53	JUNCTION	929.96	1.20	500000.0
J54	JUNCTION	899.00	11.00	500.0
J55	JUNCTION	935.33	1.06	200000.0
J56	JUNCTION	935.43	0.66	300000.0
J57	JUNCTION	936.50	0.50	160000.0
J58	JUNCTION	921.04	3.26	500.0
J59	JUNCTION	921.53	3.00	50000.0
J6	JUNCTION	926.09	2.21	500.0
J60	JUNCTION	921.51	2.99	0.0
J61	JUNCTION	921.37	2.88	0.0
J62	JUNCTION	921.29	2.83	0.0
J7	JUNCTION	926.15	1.65	7000.0
J8	JUNCTION	926.10	1.94	500.0
J9	JUNCTION	924.95	2.44	500.0
MainCanal1	OUTFALL	0.00	0.00	0.0
MainCanal2	OUTFALL	0.00	0.00	0.0
MainCanal3	OUTFALL	0.00	0.00	0.0
OF1	OUTFALL	928.00	1.00	0.0
SixMileCoulee1	OUTFALL	898.50	3.00	0.0

SixMileCoulee2	OUTFALL	898.50	1.00	0.0
SubCanal1	OUTFALL	927.00	0.00	0.0
SubCanal2	OUTFALL	926.00	0.00	0.0
SubCanal3	OUTFALL	925.00	0.00	0.0
WestOutlet	OUTFALL	928.00	0.00	0.0
AirportWetland	STORAGE	928.50	1.00	0.0
BuckmanTrap	STORAGE	912.46	1.94	0.0
CombrezTrap	STORAGE	922.50	1.50	0.0
Highway4Trap0	STORAGE	925.95	3.20	0.0
Highway4Trap1	STORAGE	927.00	1.80	0.0
Highway4Trap2	STORAGE	926.70	1.30	0.0
Highway4Trap3	STORAGE	927.00	1.00	0.0
Highway4Trap4	STORAGE	927.00	1.50	0.0
Hwy508Trap	STORAGE	920.00	1.00	0.0
KaminskiTrap	STORAGE	910.00	1.00	0.0
MordenTrap	STORAGE	933.70	1.00	0.0
SixMileTrap	STORAGE	912.00	2.00	0.0
SU1	STORAGE	914.60	0.50	0.0
SU10	STORAGE	923.95	0.30	0.0
SU2	STORAGE	921.06	2.35	0.0
SU3	STORAGE	915.18	3.22	0.0
SU4	STORAGE	923.10	0.50	0.0
SU5	STORAGE	908.73	2.50	0.0
SU6	STORAGE	919.10	2.67	0.0
SU7	STORAGE	918.20	2.20	0.0
SU8	STORAGE	925.20	1.39	0.0
SU9	STORAGE	927.04	2.36	0.0
TiffinDairyCB	STORAGE	908.48	3.52	0.0
TiffinTrapN	STORAGE	937.50	1.00	0.0
TiffinTrapS	STORAGE	935.50	2.00	0.0
UnderDrainTrap	STORAGE	924.36	1.84	0.0

****
Link Summary
****

Name	From Node	To Node	Type	Length	%Slope	Roughness
C1	J58	J38	CONDUIT	1562.5	0.0538	0.0240
C2	J38	J39	CONDUIT	50.0	0.3003	0.0240
C3	J39	J36	CONDUIT	1809.3	0.0525	0.0300
C4	J36	J37	CONDUIT	44.2	0.2262	0.0240
C5	J37	J35	CONDUIT	1259.4	0.0635	0.0300
C6	J35	J34	CONDUIT	23.7	0.0844	0.0240
C7	J34	J32	CONDUIT	747.0	0.0375	0.0300
C8	J32	J33	CONDUIT	34.4	0.9311	0.0240

C9	J33	J29	CONDUIT	1795.6	0.3664	0.0300
P1	Hwy508Trap	J45	CONDUIT	55.1	0.3630	0.0240
P2	J45	J26	CONDUIT	1904.4	0.2468	0.0300
P3	MordenTrap	J46	CONDUIT	38.5	0.7801	0.0240
P4	J46	OF1	CONDUIT	1518.1	0.3557	0.0300
P5	KaminskiTrap	J47	CONDUIT	29.4	0.3398	0.0240
P6	J47	SixMileCoulee2	CONDUIT	1235.9	0.9224	0.0300
SM1	J31	J54	CONDUIT	1904.1	0.4180	0.0300
SM2	J54	SixMileCoulee1	CONDUIT	125.4	0.3986	0.0240
T1	J57	J55	CONDUIT	951.7	0.1229	0.0300
T10	J2	J3	CONDUIT	20.5	-2.4922	0.0300
T11	J3	J4	CONDUIT	31.9	0.3454	0.0240
T12	J4	J5	CONDUIT	52.8	-0.1895	0.0300
T13	J5	J6	CONDUIT	26.1	0.7660	0.0240
T14	J6	J7	CONDUIT	79.5	-0.0755	0.0300
T15	J7	J8	CONDUIT	14.2	0.3519	0.0240
T16	J8	J17	CONDUIT	563.9	0.0887	0.0300
T16-1	J15	J16	CONDUIT	32.9	0.4258	0.0240
T16-2	J16	J13	CONDUIT	9.2	0.3250	0.0300
T16-3	J13	J14	CONDUIT	28.6	0.2452	0.0240
T16-4	J14	J11	CONDUIT	24.8	0.5657	0.0300
T16-5	J11	J12	CONDUIT	82.6	0.4964	0.0240
T16-6	J12	J17	CONDUIT	19.8	3.2813	0.0300
T17	J17	J18	CONDUIT	333.9	0.1198	0.0300
T18	J18	J9	CONDUIT	148.6	0.1683	0.0300
T19	J9	J10	CONDUIT	30.2	0.0662	0.0240
T2	J55	J56	CONDUIT	15.9	-0.6285	0.0240
T20	J10	J44	CONDUIT	1068.7	0.0533	0.0300
T21	J44	J42	CONDUIT	34.0	0.1764	0.0240
T22	J42	J43	CONDUIT	77.4	0.3876	0.0240
T23_1	J43	J59	CONDUIT	776.5	0.0855	0.0300
T23_2	J59	J60	CONDUIT	17.7	0.0905	0.0300
T23_3	J60	J61	CONDUIT	174.0	0.0828	0.0300
T23_4	J61	J62	CONDUIT	110.0	0.0673	0.0220
T23_5	J62	J19	CONDUIT	269.7	0.0860	0.0300
T24	J19	J20	CONDUIT	27.8	0.1080	0.0240
T25	J20	J21	CONDUIT	201.1	0.0696	0.0300
T26	J21	J22	CONDUIT	21.5	0.2788	0.0240
T27	J22	J49	CONDUIT	217.3	0.2900	0.0300
T28	J49	J48	CONDUIT	49.7	0.4026	0.0240
T29	J48	J23	CONDUIT	208.5	0.3549	0.0300
T3	J56	J52	CONDUIT	1814.8	0.1141	0.0300
T30	J23	J24	CONDUIT	22.6	0.3984	0.0240
T31	J24	J50	CONDUIT	1273.1	0.1626	0.0300
T32	J50	J25	CONDUIT	726.8	0.2642	0.0300
T33	J25	J26	CONDUIT	20.3	0.3943	0.0240

T34	J26	J27	CONDUIT	1775.0	0.1487	0.0300
T35	J27	J28	CONDUIT	24.6	0.0812	0.0240
T36	J28	J29	CONDUIT	803.4	0.1792	0.0300
T37	J29	J30	CONDUIT	974.5	0.2329	0.0300
T38	J30	J31	CONDUIT	293.5	0.6035	0.0240
T38-1	TiffinDairyCB	J31	CONDUIT	65.4	1.5542	0.0240
T4	J52	J51	CONDUIT	12.3	2.1074	0.0240
T5	J51	J53	CONDUIT	2013.9	0.1559	0.0300
T6	J53	J40	CONDUIT	1524.1	0.2296	0.0300
T7	J40	J41	CONDUIT	25.2	0.3965	0.0240
T8	J41	J1	CONDUIT	186.9	0.2193	0.0300
T9	J1	J2	CONDUIT	36.6	0.4369	0.0240
W1	TiffinTrapN	J57	WEIR			
W10	J5	Highway4Trap2	WEIR			
W11	J11	J12	WEIR			
W12	J11	Highway4Trap3	WEIR			
W13	J7	Highway4Trap3	WEIR			
W14	J9	J10	WEIR			
W15	J44	UnderDrainTrap	WEIR			
W16	J44	J42	WEIR			
W17	J19	J20	WEIR			
W18	J21	J22	WEIR			
W19	J49	J48	WEIR			
W2	TiffinTrapS	J55	WEIR			
W20	J23	J24	WEIR			
W21	J25	J26	WEIR			
W22	BuckmanTrap	J27	WEIR			
W23	J27	J28	WEIR			
W24	J30	TiffinDairyCB	WEIR			
W25	SixMileTrap	TiffinDairyCB	WEIR			
W26	J59	J60	WEIR			
W27	J32	J33	WEIR			
W28	J35	J34	WEIR			
W29	J36	J37	WEIR			
W3	J55	J56	WEIR			
W30	J38	J39	WEIR			
W31	CombrezTrap	J58	WEIR			
W32	AirportWetland	WestOutlet	WEIR			
W33	J1	Highway4Trap0	WEIR			
W34	J40	Highway4Trap4	WEIR			
W35	Highway4Trap2	Highway4Trap3	WEIR			
W36	SU2	J19	WEIR			
W37	SU3	J25	WEIR			
W38	SU4	J49	WEIR			
W39	SU5	J30	WEIR			
W4	J52	J51	WEIR			

W40	TiffinDairyCB	J31	WEIR
W41	SU6	J36	WEIR
W42	SU7	J35	WEIR
W43	J9	SU8	WEIR
W44	J18	SU8	WEIR
W45	J10	UnderDrainTrap	WEIR
W46	SU1	J28	WEIR
W47	SU9	J15	WEIR
W48	J61	SU10	WEIR
W49	SU10	J62	WEIR
W5	J40	J41	WEIR
W6	J3	Highway4Trap1	WEIR
W7	J13	Highway4Trap1	WEIR
W8	J13	J14	WEIR
W9	J11	Highway4Trap2	WEIR

****
Cross Section Summary
****

Conduit	Shape	Full Depth	Full Area	Hyd. Rad.	Max. Width	No. of Barrels	Full Flow
C1	TRAPEZOIDAL	3.10	29.47	1.65	16.51	1	39.82
C2	CIRCULAR	1.05	0.87	0.26	1.05	1	0.81
C3	TRAPEZOIDAL	2.54	15.42	1.29	10.64	1	13.96
C4	CIRCULAR	1.05	0.87	0.26	1.05	1	0.70
C5	TRAPEZOIDAL	2.32	15.05	1.20	11.48	1	14.31
C6	CIRCULAR	1.05	0.87	0.26	1.05	1	0.43
C7	TRAPEZOIDAL	2.10	15.12	1.22	11.40	1	11.14
C8	CIRCULAR	1.20	1.13	0.30	1.20	1	2.04
C9	TRAPEZOIDAL	2.84	14.98	1.35	9.25	1	37.00
P1	CIRCULAR	0.45	0.16	0.11	0.45	2	0.09
P2	TRAPEZOIDAL	1.00	4.00	0.55	7.00	1	4.43
P3	CIRCULAR	0.60	0.28	0.15	0.60	2	0.29
P4	TRAPEZOIDAL	1.00	4.00	0.55	7.00	1	5.31
P5	CIRCULAR	0.53	0.22	0.13	0.53	2	0.14
P6	TRAPEZOIDAL	1.00	4.00	0.55	7.00	1	8.56
SM1	TRAPEZOIDAL	2.39	16.86	1.21	13.03	1	41.24
SM2	TRAPEZOIDAL	3.00	25.74	1.49	16.08	1	88.49
T1	TRAPEZOIDAL	0.50	30.00	0.27	110.00	1	14.75
T10	TRAPEZOIDAL	1.20	46.80	0.62	75.00	1	179.80
T11	RECT_CLOSED	1.20	2.16	0.36	1.80	1	2.68
T12	TRAPEZOIDAL	1.40	9.10	0.86	10.00	1	11.97
T13	CIRCULAR	1.05	0.87	0.26	1.05	2	1.29
T14	TRAPEZOIDAL	1.25	9.06	0.74	12.00	1	6.76

T15	CIRCULAR	1.20	1.13	0.30	1.20	2	1.25
T16	TRAPEZOIDAL	1.40	11.26	0.84	13.08	1	9.92
T16-1	CIRCULAR	0.90	0.64	0.23	0.90	2	0.64
T16-2	TRAPEZOIDAL	0.75	2.44	0.42	5.50	1	2.62
T16-3	CIRCULAR	0.60	0.28	0.15	0.60	1	0.16
T16-4	TRAPEZOIDAL	0.75	2.44	0.42	5.50	1	3.45
T16-5	CIRCULAR	0.60	0.28	0.15	0.60	1	0.23
T16-6	TRAPEZOIDAL	1.40	10.08	0.85	11.40	1	54.64
T17	TRAPEZOIDAL	1.40	10.28	0.85	11.68	1	10.62
T18	TRAPEZOIDAL	1.50	9.11	0.90	9.45	1	11.65
T19	CIRCULAR	1.20	1.13	0.30	1.20	2	0.54
T2	CIRCULAR	0.30	0.07	0.07	0.30	1	0.04
T20	TRAPEZOIDAL	1.34	7.93	0.79	9.54	1	5.23
T21	CIRCULAR	0.82	0.53	0.21	0.82	2	0.33
T22	CIRCULAR	0.80	0.50	0.20	0.80	1	0.45
T23_1	TRAPEZOIDAL	2.65	18.56	1.43	11.51	1	23.00
T23_2	CIRCULAR	0.60	0.28	0.15	0.60	1	0.08
T23_3	TRAPEZOIDAL	2.65	18.56	1.43	11.51	1	22.63
T23_4	CIRCULAR	0.68	0.36	0.17	0.68	1	0.13
T23_5	TRAPEZOIDAL	2.65	18.56	1.43	11.51	1	23.07
T24	CIRCULAR	0.90	0.64	0.23	0.90	1	0.32
T25	TRAPEZOIDAL	2.52	16.58	1.40	10.36	1	18.21
T26	CIRCULAR	0.90	0.64	0.23	0.90	1	0.52
T27	TRAPEZOIDAL	2.90	18.18	1.51	10.04	1	43.03
T28	CIRCULAR	0.80	0.50	0.20	0.80	1	0.45
T29	TRAPEZOIDAL	3.26	26.80	1.65	14.74	1	74.20
T3	TRAPEZOIDAL	0.30	10.95	0.21	53.00	1	4.31
T30	CIRCULAR	1.05	0.87	0.26	1.05	1	0.93
T31	TRAPEZOIDAL	3.03	24.74	1.53	14.83	1	44.22
T32	TRAPEZOIDAL	3.50	28.03	1.68	15.01	1	67.96
T33	CIRCULAR	1.20	1.13	0.30	1.20	1	1.33
T34	TRAPEZOIDAL	1.87	13.08	1.18	9.98	1	18.80
T35	CIRCULAR	1.20	1.13	0.30	1.20	2	0.60
T36	TRAPEZOIDAL	2.00	9.88	1.07	8.08	1	14.58
T37	TRAPEZOIDAL	2.80	23.69	1.50	14.62	1	49.86
T38	CIRCULAR	1.50	1.77	0.38	1.50	2	2.97
T38-1	CIRCULAR	1.20	1.13	0.30	1.20	1	2.63
T4	CIRCULAR	0.30	0.07	0.07	0.30	2	0.08
T5	TRAPEZOIDAL	0.40	7.20	0.28	26.00	1	4.02
T6	TRAPEZOIDAL	1.20	49.20	0.64	77.00	1	58.29
T7	CIRCULAR	1.20	1.13	0.30	1.20	2	1.33
T8	TRAPEZOIDAL	1.00	11.00	0.61	18.00	1	12.30
T9	CIRCULAR	2.40	4.52	0.60	2.40	1	8.86

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*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

***************
Analysis Options
***************
Flow Units ............... CMS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ YES
  Water Quality .......... NO
Infiltration Method ...... GREEN_AMPT
Flow Routing Method ...... DYNWAVE
Starting Date ............ JUN-02-2016 00:00:00
Ending Date .............. JUN-03-2016 00:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 00:01:00
Wet Time Step ............ 00:05:00
Dry Time Step ............ 00:05:00
Routing Time Step ........ 5.00 sec
Variable Time Step ....... YES
Maximum Trials ........... 8
Number of Threads ........ 4
Head Tolerance ........... 0.001500 m


**************************        Volume         Depth
Runoff Quantity Continuity     hectare-m            mm
**************************     ---------       -------
Total Precipitation ......      1831.297       112.100
Evaporation Loss .........         0.000         0.000
Infiltration Loss ........       739.032        45.239
Surface Runoff ...........       527.372        32.282
Final Storage ............       565.453        34.613
Continuity Error (%) .....        -0.031


**************************        Volume        Volume
Flow Routing Continuity        hectare-m      10^6 ltr
```

**************************	---------	---------
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	526.793	5267.983
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	228.491	2284.935
Flooding Loss	0.000	0.000
Evaporation Loss	0.000	0.000
Exfiltration Loss	0.000	0.000
Initial Stored Volume	0.000	0.004
Final Stored Volume	286.802	2868.049
Continuity Error (%)	2.183	

****
Highest Continuity Errors
****
Node J52 (21.30%)
Node J55 (21.11%)
Node J39 (18.22%)
Node J38 (16.96%)
Node J40 (13.01%)

****
Time-Step Critical Elements
****
Link T13 (22.90%)
Link T33 (15.34%)
Link T19 (13.80%)
Link T30 (9.98%)
Link T15 (7.00%)

****
Highest Flow Instability Indexes
****
Link W37 (3)
Link T16-6 (1)
Link W41 (1)
Link W42 (1)

****
Routing Time Step Summary

****
Minimum Time Step   :   0.50 sec
Average Time Step   :   2.33 sec
Maximum Time Step   :   5.00 sec
Percent in Steady State   :   0.00
Average Iterations per Step :   2.00
Percent Not Converging   :   0.00

****
Subcatchment Runoff Summary
****

Subcatchment	Total Precip mm	Total Runon mm	Total Evap mm	Total Infil mm	Total Runoff mm	Total Runoff 10^6 ltr	Peak Runoff CMS	Runoff Coeff
E1	112.10	0.00	0.00	45.73	14.07	136.92	3.29	0.126
E10	112.10	0.00	0.00	42.76	44.94	127.39	4.25	0.401
E11	112.10	0.00	0.00	45.75	32.63	111.37	3.33	0.291
E12	112.10	0.00	0.00	43.85	37.91	85.10	2.58	0.338
E13	112.10	0.00	0.00	40.18	70.75	3.54	0.25	0.631
E14	112.10	0.00	0.00	35.95	72.17	2.05	0.12	0.644
E15	112.10	0.00	0.00	36.01	71.38	2.32	0.13	0.637
E16	112.10	0.00	0.00	26.96	81.95	3.95	0.27	0.731
E17	112.10	0.00	0.00	40.84	60.87	8.22	0.38	0.543
E18	112.10	0.00	0.00	41.98	63.10	104.25	5.43	0.563
E19	112.10	0.00	0.00	42.31	56.88	47.09	2.04	0.507
E2	112.10	0.00	0.00	46.20	12.79	236.83	5.86	0.114
E20	112.10	0.00	0.00	45.60	38.02	90.36	2.90	0.339
E21	112.10	0.00	0.00	41.51	42.62	43.04	1.38	0.380
E22	112.10	0.00	0.00	45.48	25.64	341.48	9.23	0.229
E3	112.10	0.00	0.00	45.94	25.22	194.44	5.32	0.225
E4	112.10	27.70	0.00	45.75	36.17	307.97	7.61	0.259
E5	112.10	0.00	0.00	45.82	30.05	111.31	3.23	0.268
E6	112.10	0.00	0.00	45.67	35.68	133.63	4.16	0.318
E7	112.10	0.00	0.00	45.80	31.00	64.83	1.90	0.277
E8	112.10	0.00	0.00	45.21	49.45	61.17	2.41	0.441
E9	112.10	0.00	0.00	45.83	29.60	180.82	5.21	0.264
NW1	112.10	0.00	0.00	43.81	52.16	26.92	1.08	0.465
NW10	112.10	0.00	0.00	44.67	52.10	41.40	1.72	0.465
NW11	112.10	0.00	0.00	45.70	34.55	35.99	1.10	0.308
NW11-1	112.10	0.00	0.00	41.50	43.02	10.45	0.34	0.384
NW12	112.10	0.00	0.00	45.70	34.55	14.64	0.45	0.308
NW13	112.10	0.00	0.00	45.32	46.69	66.32	2.44	0.417

NW14	112.10	0.00	0.00	45.70	34.55	69.52	2.13	0.308
NW15	112.10	0.00	0.00	45.70	34.55	20.23	0.62	0.308
NW16	112.10	0.00	0.00	45.41	44.08	83.61	2.93	0.393
NW17	112.10	0.00	0.00	43.78	40.18	117.98	3.69	0.358
NW18	112.10	0.00	0.00	43.70	42.99	571.16	18.71	0.383
NW19	112.10	0.00	0.00	45.47	42.28	161.30	5.51	0.377
NW2	112.10	0.00	0.00	43.32	53.52	18.54	0.76	0.477
NW3	112.10	0.00	0.00	44.22	52.72	42.36	1.76	0.470
NW4	112.10	0.00	0.00	45.45	42.78	76.60	2.63	0.382
NW5	112.10	0.00	0.00	44.77	49.74	78.39	3.06	0.444
NW6	112.10	0.00	0.00	44.91	46.12	120.39	4.31	0.411
NW7	112.10	0.00	0.00	45.43	43.63	66.42	2.31	0.389
NW8	112.10	0.00	0.00	45.11	39.86	125.65	4.07	0.356
NW9	112.10	0.00	0.00	45.97	23.63	34.50	0.93	0.211
SW1	112.10	0.00	0.00	44.35	49.55	107.49	4.11	0.442
SW10	112.10	0.00	0.00	44.18	53.66	54.65	2.32	0.479
SW11	112.10	0.00	0.00	45.39	44.57	119.53	4.22	0.398
SW12	112.10	0.00	0.00	45.63	37.06	190.57	6.05	0.331
SW13	112.10	0.00	0.00	45.12	51.73	186.42	7.79	0.461
SW2	112.10	0.00	0.00	45.98	23.22	137.11	3.69	0.207
SW3	112.10	0.00	0.00	45.98	23.22	29.98	0.81	0.207
SW4	112.10	0.00	0.00	44.51	55.56	78.00	3.57	0.496
SW5	112.10	0.00	0.00	45.26	48.31	175.39	6.70	0.431
SW6	112.10	0.00	0.00	45.25	48.42	34.94	1.34	0.432
SW7	112.10	0.00	0.00	44.69	59.87	51.16	2.73	0.534
SW8	112.10	0.00	0.00	45.30	47.23	122.70	4.57	0.421
SW9	112.10	0.00	0.00	44.60	53.65	42.16	1.82	0.479

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Node Depth Summary
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Node	Type	Average Depth Meters	Maximum Depth Meters	Maximum HGL Meters	Time of Max Occurrence days hr:min	Reported Max Depth Meters
J1	JUNCTION	1.13	1.55	927.50	0 16:13	0.47
J10	JUNCTION	0.94	1.24	926.17	0 14:14	0.38
J11	JUNCTION	0.02	0.58	927.24	0 23:59	0.18
J12	JUNCTION	0.22	0.39	926.64	0 14:26	0.12
J13	JUNCTION	0.03	0.58	927.45	1 00:00	0.18
J14	JUNCTION	0.02	0.45	927.25	0 23:59	0.14
J15	JUNCTION	0.02	0.42	927.46	1 00:00	0.13
J16	JUNCTION	0.02	0.55	927.45	1 00:00	0.17

J17	JUNCTION	0.74	1.04	926.64	0	14:26	0.32
J18	JUNCTION	0.94	1.32	926.52	0	14:28	0.40
J19	JUNCTION	1.49	2.11	923.17	0	14:03	0.64
J2	JUNCTION	1.26	1.69	927.48	0	16:11	0.51
J20	JUNCTION	1.33	2.06	923.09	0	14:07	0.63
J21	JUNCTION	1.43	2.20	923.09	0	14:07	0.67
J22	JUNCTION	1.35	2.19	923.02	0	14:03	0.67
J23	JUNCTION	0.78	1.20	920.46	0	13:49	0.36
J24	JUNCTION	0.69	1.05	920.22	0	13:21	0.32
J25	JUNCTION	1.95	3.16	918.34	0	17:30	0.96
J26	JUNCTION	1.01	1.52	916.62	0	14:02	0.46
J27	JUNCTION	1.29	1.79	914.25	0	14:06	0.55
J28	JUNCTION	1.02	1.37	913.81	0	14:04	0.42
J29	JUNCTION	1.14	1.63	912.63	0	14:01	0.50
J3	JUNCTION	0.84	1.18	927.48	0	16:11	0.36
J30	JUNCTION	1.72	2.38	911.11	0	14:05	0.73
J31	JUNCTION	1.13	1.49	908.45	0	16:01	0.45
J32	JUNCTION	1.33	2.13	920.03	0	13:56	0.65
J33	JUNCTION	0.76	1.06	918.64	0	14:03	0.32
J34	JUNCTION	1.14	1.85	920.03	0	13:56	0.56
J35	JUNCTION	1.48	2.01	920.21	0	13:14	0.61
J36	JUNCTION	1.85	2.47	921.57	0	20:19	0.75
J37	JUNCTION	1.04	1.52	920.52	0	13:05	0.46
J38	JUNCTION	1.02	1.47	921.67	0	15:27	0.45
J39	JUNCTION	1.08	1.53	921.58	0	20:21	0.47
J4	JUNCTION	0.87	1.19	927.38	0	15:53	0.36
J40	JUNCTION	1.31	1.98	928.44	0	16:27	0.60
J41	JUNCTION	0.90	1.29	927.65	0	16:19	0.39
J42	JUNCTION	2.63	3.34	925.74	0	13:01	1.02
J43	JUNCTION	1.70	2.25	924.44	0	13:01	0.69
J44	JUNCTION	1.17	1.51	925.87	0	13:01	0.46
J45	JUNCTION	0.21	0.31	920.11	0	22:11	0.10
J46	JUNCTION	0.35	0.56	933.96	0	22:36	0.17
J47	JUNCTION	0.18	0.30	910.20	1	00:00	0.09
J48	JUNCTION	0.40	0.54	920.54	0	14:05	0.16
J49	JUNCTION	1.85	2.82	923.02	0	14:04	0.86
J5	JUNCTION	0.77	1.07	927.36	0	15:47	0.33
J50	JUNCTION	0.99	1.55	918.65	0	13:46	0.47
J51	JUNCTION	0.67	1.16	934.26	1	00:00	0.35
J52	JUNCTION	0.62	0.94	934.30	1	00:00	0.29
J53	JUNCTION	0.47	0.65	930.61	0	15:02	0.20
J54	JUNCTION	1.09	1.48	900.48	0	14:04	0.45
J55	JUNCTION	0.74	1.18	936.51	1	00:00	0.36
J56	JUNCTION	0.66	1.08	936.51	1	00:00	0.33
J57	JUNCTION	0.23	0.33	936.83	0	15:06	0.10
J58	JUNCTION	0.45	0.66	921.70	0	15:33	0.20

J59	JUNCTION	2.21	2.87	924.40	0	13:04	0.88
J6	JUNCTION	0.79	1.04	927.13	0	15:00	0.32
J60	JUNCTION	1.97	2.67	924.18	0	13:04	0.81
J61	JUNCTION	2.09	2.80	924.17	0	13:05	0.85
J62	JUNCTION	1.33	1.91	923.20	0	14:02	0.58
J7	JUNCTION	0.71	0.95	927.10	0	14:56	0.29
J8	JUNCTION	0.68	0.92	927.02	0	14:05	0.28
J9	JUNCTION	1.11	1.53	926.48	0	14:28	0.47
MainCanal1	OUTFALL	0.00	0.00	0.00	0	00:00	0.00
MainCanal2	OUTFALL	0.00	0.00	0.00	0	00:00	0.00
MainCanal3	OUTFALL	0.00	0.00	0.00	0	00:00	0.00
OF1	OUTFALL	0.19	0.31	928.31	0	22:36	0.09
SixMileCoulee1	OUTFALL	0.99	1.35	899.85	0	14:04	0.41
SixMileCoulee2	OUTFALL	0.14	0.25	898.75	1	00:00	0.08
SubCanal1	OUTFALL	0.00	0.00	927.00	0	00:00	0.00
SubCanal2	OUTFALL	0.00	0.00	926.00	0	00:00	0.00
SubCanal3	OUTFALL	0.00	0.00	925.00	0	00:00	0.00
WestOutlet	OUTFALL	0.00	0.00	928.00	0	00:00	0.00
AirportWetland	STORAGE	0.53	0.96	929.46	0	23:33	0.29
BuckmanTrap	STORAGE	0.67	1.40	913.86	0	23:16	0.43
CombrezTrap	STORAGE	0.08	0.20	922.70	1	00:00	0.06
Highway4Trap0	STORAGE	0.45	1.23	927.18	1	00:00	0.37
Highway4Trap1	STORAGE	0.00	0.00	927.00	0	00:00	0.00
Highway4Trap2	STORAGE	0.00	0.00	926.70	0	00:00	0.00
Highway4Trap3	STORAGE	0.00	0.00	927.00	0	00:00	0.00
Highway4Trap4	STORAGE	0.29	0.87	927.87	1	00:00	0.27
Hwy508Trap	STORAGE	0.52	0.82	920.82	0	21:38	0.25
KaminskiTrap	STORAGE	0.39	0.75	910.75	1	00:00	0.23
MordenTrap	STORAGE	0.46	0.84	934.54	0	22:25	0.26
SixMileTrap	STORAGE	0.36	0.57	912.57	0	19:53	0.17
SU1	STORAGE	0.00	0.00	914.60	0	00:00	0.00
SU10	STORAGE	0.08	0.17	924.12	0	13:05	0.05
SU2	STORAGE	0.94	1.90	922.96	1	00:00	0.58
SU3	STORAGE	1.74	3.16	918.34	0	17:31	0.96
SU4	STORAGE	0.00	0.00	923.10	0	00:00	0.00
SU5	STORAGE	0.93	1.91	910.64	1	00:00	0.58
SU6	STORAGE	1.35	2.47	921.57	0	20:19	0.75
SU7	STORAGE	1.01	1.85	920.05	0	23:47	0.56
SU8	STORAGE	0.00	0.00	925.20	0	00:00	0.00
SU9	STORAGE	0.90	1.74	928.78	1	00:00	0.53
TiffinDairyCB	STORAGE	0.69	1.06	909.53	0	19:02	0.32
TiffinTrapN	STORAGE	0.28	0.50	938.00	1	00:00	0.15
TiffinTrapS	STORAGE	0.75	1.67	937.17	1	00:00	0.51
UnderDrainTrap	STORAGE	0.64	1.26	925.62	1	00:00	0.38

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Node Inflow Summary
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Node	Type	Maximum Lateral Inflow CMS	Maximum Total Inflow CMS	Time of Max Occurrence days	Time of Max Occurrence hr:min	Lateral Inflow Volume 10^6 ltr	Total Inflow Volume 10^6 ltr	Flow Balance Error Percent
J1	JUNCTION	0.000	7.510	0	16:35	0	296	0.622
J10	JUNCTION	2.904	7.116	0	14:16	90.3	261	1.388
J11	JUNCTION	0.000	0.315	1	00:00	0	0.583	5.761
J12	JUNCTION	0.000	1.039	0	23:59	0	0.645	3.165
J13	JUNCTION	0.000	0.273	0	23:59	0	0.612	1.965
J14	JUNCTION	0.000	0.271	0	23:59	0	0.601	2.993
J15	JUNCTION	0.000	0.280	1	00:00	0	0.643	1.605
J16	JUNCTION	0.000	0.278	1	00:00	0	0.633	3.349
J17	JUNCTION	0.377	4.549	0	23:59	8.22	175	1.427
J18	JUNCTION	0.000	4.288	0	14:17	0	173	0.964
J19	JUNCTION	0.000	5.002	0	13:06	0	137	1.079
J2	JUNCTION	0.120	3.009	1	00:00	2.05	122	0.659
J20	JUNCTION	0.000	1.711	0	12:12	0	40.4	2.071
J21	JUNCTION	0.000	1.345	0	12:13	0	39.6	2.321
J22	JUNCTION	1.082	1.906	0	12:20	26.9	65.6	1.141
J23	JUNCTION	0.000	1.515	0	14:05	0	63.6	0.438
J24	JUNCTION	2.514	3.929	0	13:00	60.9	124	1.036
J25	JUNCTION	0.000	9.429	0	13:46	0	284	0.445
J26	JUNCTION	6.595	12.585	0	14:00	187	439	1.212
J27	JUNCTION	0.000	12.542	0	14:02	0	433	1.729
J28	JUNCTION	0.931	6.547	0	14:00	34.4	274	0.636
J29	JUNCTION	4.156	14.811	0	14:00	108	545	1.437
J3	JUNCTION	0.000	3.008	1	00:00	0	121	0.451
J30	JUNCTION	0.449	15.243	0	14:00	14.6	551	1.386
J31	JUNCTION	3.551	12.926	0	15:00	104	550	1.261
J32	JUNCTION	3.164	4.421	0	13:00	77.1	170	1.532
J33	JUNCTION	0.000	4.247	0	13:56	0	167	1.256
J34	JUNCTION	0.000	2.606	1	00:00	0	94.8	2.494
J35	JUNCTION	2.323	7.173	0	13:00	54.6	214	2.981
J36	JUNCTION	6.705	7.117	0	14:00	175	209	5.145
J37	JUNCTION	2.731	4.932	0	13:00	51.2	162	2.009
J38	JUNCTION	0.000	1.262	0	12:24	0	30.8	20.417
J39	JUNCTION	0.000	2.215	0	12:19	0	34.7	22.274
J4	JUNCTION	0.130	3.006	1	00:00	2.32	123	0.173
J40	JUNCTION	0.000	12.973	0	15:02	0	478	14.950
J41	JUNCTION	0.000	7.508	0	16:32	0	297	0.517

J42	JUNCTION	0.000	1.128	0	10:48	0	47.2	0.114	
J43	JUNCTION	4.112	5.042	0	13:00	107	155	3.541	
J44	JUNCTION	2.037	5.437	0	13:00	47.1	204	2.305	
J45	JUNCTION	0.000	0.346	0	21:41	0	13.7	7.460	
J46	JUNCTION	0.000	0.861	0	22:22	0	29.8	3.721	
J47	JUNCTION	0.000	0.571	1	00:00	0	18	2.008	
J48	JUNCTION	0.000	1.515	0	14:04	0	63.7	0.247	
J49	JUNCTION	0.000	1.614	0	12:38	0	64.8	1.768	
J5	JUNCTION	0.000	3.006	1	00:00	0	122	0.149	
J50	JUNCTION	5.642	9.461	0	13:00	155	278	0.801	
J51	JUNCTION	4.226	7.947	0	15:00	126	279	8.524	
J52	JUNCTION	0.000	4.451	0	22:53	0	195	27.065	
J53	JUNCTION	9.261	13.172	0	14:00	308	494	3.459	
J54	JUNCTION	3.693	16.471	0	14:00	118	661	0.806	
J55	JUNCTION	0.000	5.303	0	15:06	0	192	26.751	
J56	JUNCTION	7.388	11.639	0	14:19	245	366	7.720	
J57	JUNCTION	5.323	5.323	0	15:00	194	194	1.700	
J58	JUNCTION	0.807	0.807	0	15:00	29.9	29.9	4.903	
J59	JUNCTION	0.000	5.026	0	13:02	0	149	5.178	
J6	JUNCTION	0.270	3.005	1	00:00	3.95	126	0.213	
J60	JUNCTION	0.000	5.017	0	13:04	0	142	1.078	
J61	JUNCTION	0.000	5.016	0	13:04	0	140	1.198	
J62	JUNCTION	0.000	5.013	0	13:05	0	139	0.920	
J7	JUNCTION	0.000	3.005	1	00:00	0	125	0.183	
J8	JUNCTION	1.377	4.042	0	14:00	43	168	0.842	
J9	JUNCTION	0.000	4.286	0	14:50	0	171	0.341	
MainCanal1	OUTFALL	9.230	9.230	0	14:00	341	341	0.000	
MainCanal2	OUTFALL	5.430	5.430	0	13:00	104	104	0.000	
MainCanal3	OUTFALL	3.333	3.333	0	14:00	111	111	0.000	
OF1	OUTFALL	0.000	0.861	0	22:36	0	28.7	0.000	
SixMileCoulee1	OUTFALL	18.705	34.697	0	14:00	571	1.23e+003	0.000	
SixMileCoulee2	OUTFALL	0.000	0.571	1	00:00	0	17.6	0.000	
SubCanal1	OUTFALL	4.570	4.570	0	13:00	123	123	0.000	
SubCanal2	OUTFALL	4.220	4.220	0	14:00	119	119	0.000	
SubCanal3	OUTFALL	6.046	6.046	0	14:00	190	190	0.000	
WestOutlet	OUTFALL	0.000	1.032	0	23:33	0	23.9	0.000	
AirportWetland	STORAGE	5.505	5.505	0	14:00	161	161	0.009	
BuckmanTrap	STORAGE	0.000	6.915	0	14:06	0	187	0.011	
CombrezTrap	STORAGE	3.688	3.688	0	15:00	137	137	0.011	
Highway4Trap0	STORAGE	0.255	4.775	0	16:06	3.54	179	-49.997	
Highway4Trap1	STORAGE	0.000	0.000	0	00:00	0	0	0.000	ltr
Highway4Trap2	STORAGE	0.000	0.000	0	00:00	0	0	0.000	ltr
Highway4Trap3	STORAGE	0.000	0.000	0	00:00	0	0	0.000	ltr
Highway4Trap4	STORAGE	0.000	4.940	0	16:27	0	118	-49.997	
Hwy508Trap	STORAGE	3.568	3.568	0	13:00	78	78	0.027	
KaminskiTrap	STORAGE	2.133	2.133	0	14:00	69.4	69.4	0.021	

MordenTrap	STORAGE	7.788	7.788	0	13:00	186	186	0.016	
SixMileTrap	STORAGE	5.170	5.170	0	14:00	161	161	0.004	
SU1	STORAGE	0.000	0.000	0	00:00	0	0	0.000	ltr
SU10	STORAGE	0.000	4.546	0	13:05	0	116	0.000	
SU2	STORAGE	0.000	4.344	0	14:03	0	95.5	0.011	
SU3	STORAGE	0.000	3.658	0	14:00	0	43.1	0.082	
SU4	STORAGE	0.000	0.000	0	00:00	0	0	0.000	ltr
SU5	STORAGE	0.000	7.762	0	14:05	0	205	0.011	
SU6	STORAGE	0.000	4.818	0	14:00	0	78.7	0.015	
SU7	STORAGE	0.000	5.675	0	13:14	0	113	0.013	
SU8	STORAGE	0.000	0.000	0	00:00	0	0	0.000	ltr
SU9	STORAGE	2.578	2.578	0	13:00	85	85	0.011	
TiffinDairyCB	STORAGE	0.336	2.809	0	19:00	10.4	107	0.037	
TiffinTrapN	STORAGE	3.294	3.294	0	14:00	137	137	0.011	
TiffinTrapS	STORAGE	7.605	7.605	0	17:00	307	307	0.011	
UnderDrainTrap	STORAGE	0.000	7.948	0	14:01	0	253	-49.997	

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Node Surcharge Summary
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Surcharging occurs when water rises above the top of the highest conduit.

Node	Type	Hours Surcharged	Max. Height Above Crown Meters	Min. Depth Below Rim Meters
J42	JUNCTION	13.02	0.619	1.206
J56	JUNCTION	2.52	0.017	0.000
Hwy508Trap	STORAGE	10.96	0.366	0.184
KaminskiTrap	STORAGE	7.57	0.224	0.251
MordenTrap	STORAGE	8.07	0.238	0.162
SixMileTrap	STORAGE	7.77	0.066	1.434

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Node Flooding Summary
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Flooding refers to all water that overflows a node, whether it ponds or not.

Node	Hours Flooded	Maximum Rate CMS	Time of Max Occurrence days hr:min	Total Flood Volume 10^6 ltr	Maximum Ponded Depth Meters

J51	8.97	3.739	0	15:01	71.115	0.218
J55	6.37	2.624	0	17:54	29.540	0.119
J56	10.56	7.489	0	14:19	145.043	0.417

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Storage Volume Summary
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Storage Unit	Average Volume 1000 m3	Avg Pcnt Full	Evap Pcnt Loss	Exfil Pcnt Loss	Maximum Volume 1000 m3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CMS
AirportWetland	70.331	48	0	0	137.379	94	0 23:33	1.032
BuckmanTrap	83.705	29	0	0	186.833	65	0 23:16	0.000
CombrezTrap	56.795	4	0	0	136.864	9	1 00:00	0.000
Highway4Trap0	62.401	11	0	0	178.645	30	1 00:00	0.000
Highway4Trap1	0.000	0	0	0	0.000	0	0 00:00	0.000
Highway4Trap2	0.000	0	0	0	0.000	0	0 00:00	0.000
Highway4Trap3	0.000	0	0	0	0.000	0	0 00:00	0.000
Highway4Trap4	39.056	18	0	0	118.209	55	1 00:00	0.000
Hwy508Trap	37.370	38	0	0	65.486	66	0 21:38	0.346
KaminskiTrap	25.708	34	0	0	51.441	69	1 00:00	0.571
MordenTrap	86.779	46	0	0	157.818	83	0 22:25	0.861
SixMileTrap	43.775	7	0	0	76.533	13	0 19:53	2.648
SU1	0.000	0	0	0	0.000	0	0 00:00	0.000
SU10	0.127	28	0	0	0.250	56	0 13:05	4.545
SU2	44.018	35	0	0	95.531	76	1 00:00	0.000
SU3	22.382	50	0	0	43.144	97	0 17:31	1.220
SU4	0.000	0	0	0	0.000	0	0 00:00	0.000
SU5	88.978	28	0	0	204.916	66	1 00:00	0.000
SU6	39.271	44	0	0	78.686	87	0 20:19	0.932
SU7	57.017	39	0	0	112.613	77	0 23:47	0.054
SU8	0.000	0	0	0	0.000	0	0 00:00	0.000
SU9	39.999	31	0	0	84.362	65	1 00:00	0.280
TiffinDairyCB	0.011	0	0	0	0.037	0	0 19:02	2.809
TiffinTrapN	58.345	11	0	0	136.639	25	1 00:00	0.006
TiffinTrapS	120.108	30	0	0	306.335	77	1 00:00	0.242
UnderDrainTrap	104.689	19	0	0	252.527	46	1 00:00	0.000

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CMS	Max Flow CMS	Total Volume 10^6 ltr
MainCanal1	97.75	5.759	9.230	340.905
MainCanal2	97.80	1.780	5.430	104.244
MainCanal3	97.52	1.911	3.333	111.214
OF1	77.26	0.608	0.861	28.715
SixMileCoulee1	97.88	20.843	34.697	1225.941
SixMileCoulee2	76.89	0.373	0.571	17.630
SubCanal1	97.67	2.134	4.570	122.621
SubCanal2	97.64	2.074	4.220	119.442
SubCanal3	97.70	3.278	6.046	190.347
WestOutlet	55.31	0.689	1.032	23.866
System	89.34	39.450	66.858	2284.925

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CMS	Time of Max Occurrence days	hr:min	Maximum |Veloc| m/sec	Max/ Full Flow	Max/ Full Depth
C1	CONDUIT	0.809	0	16:06	0.40	0.02	0.34
C2	CONDUIT	0.851	0	17:00	0.98	1.05	1.00
C3	CONDUIT	2.215	0	12:19	0.33	0.16	0.79
C4	CONDUIT	2.579	0	20:45	2.98	3.67	1.00
C5	CONDUIT	4.867	0	13:05	0.54	0.34	0.76
C6	CONDUIT	2.606	1	00:00	3.01	6.06	1.00
C7	CONDUIT	2.620	1	00:00	0.41	0.24	0.94
C8	CONDUIT	4.247	0	13:56	3.84	2.08	0.94
C9	CONDUIT	4.245	0	14:03	0.99	0.11	0.47
P1	CONDUIT	0.346	0	21:41	1.20	1.86	0.85
P2	CONDUIT	0.346	0	22:11	0.24	0.08	0.66
P3	CONDUIT	0.861	0	22:22	1.54	1.46	0.97
P4	CONDUIT	0.861	0	22:36	0.85	0.16	0.44
P5	CONDUIT	0.571	1	00:00	1.56	2.10	0.79
P6	CONDUIT	0.571	1	00:00	1.13	0.07	0.28
SM1	CONDUIT	12.912	0	15:02	1.83	0.31	0.62
SM2	CONDUIT	16.440	0	14:04	2.53	0.19	0.47

T1	CONDUIT	5.303	0	15:06	0.30	0.36	0.83
T10	CONDUIT	3.008	1	00:00	0.07	0.02	0.99
T11	CONDUIT	3.006	1	00:00	1.45	1.12	0.99
T12	CONDUIT	3.006	1	00:00	0.47	0.25	0.81
T13	CONDUIT	3.005	1	00:00	1.75	1.16	1.00
T14	CONDUIT	3.005	1	00:00	0.52	0.44	0.80
T15	CONDUIT	3.005	1	00:00	1.73	1.20	0.78
T16	CONDUIT	4.028	0	14:05	0.64	0.41	0.70
T16-1	CONDUIT	0.278	1	00:00	0.44	0.22	0.54
T16-2	CONDUIT	0.273	0	23:59	0.20	0.10	0.75
T16-3	CONDUIT	0.271	0	23:59	1.10	1.64	0.85
T16-4	CONDUIT	0.315	1	00:00	0.31	0.09	0.68
T16-5	CONDUIT	0.272	0	23:59	1.44	1.16	0.75
T16-6	CONDUIT	1.274	0	23:59	0.49	0.02	0.51
T17	CONDUIT	4.288	0	14:17	0.58	0.40	0.84
T18	CONDUIT	4.286	0	14:50	0.52	0.37	0.94
T19	CONDUIT	4.286	0	14:52	1.89	3.94	1.00
T2	CONDUIT	0.042	0	11:25	0.70	1.02	1.00
T20	CONDUIT	3.580	0	15:01	0.48	0.69	0.96
T21	CONDUIT	1.128	0	10:48	1.41	1.73	1.00
T22	CONDUIT	1.122	0	11:15	2.23	2.51	1.00
T23_1	CONDUIT	5.026	0	13:02	0.47	0.22	0.92
T23_2	CONDUIT	0.733	0	11:42	2.59	9.15	1.00
T23_3	CONDUIT	5.016	0	13:04	0.27	0.22	1.00
T23_4	CONDUIT	0.739	0	11:58	2.11	5.73	1.00
T23_5	CONDUIT	5.002	0	13:06	0.68	0.22	0.76
T24	CONDUIT	1.711	0	12:12	2.69	5.31	1.00
T25	CONDUIT	1.345	0	12:13	0.31	0.07	0.84
T26	CONDUIT	1.170	1	00:00	1.84	2.26	1.00
T27	CONDUIT	1.614	0	12:38	0.47	0.04	0.87
T28	CONDUIT	1.515	0	14:04	3.37	3.33	0.84
T29	CONDUIT	1.515	0	14:05	0.64	0.02	0.27
T3	CONDUIT	4.451	0	22:53	0.41	1.03	1.00
T30	CONDUIT	1.525	0	14:16	1.94	1.63	1.00
T31	CONDUIT	3.881	0	13:21	0.69	0.09	0.43
T32	CONDUIT	9.429	0	13:46	1.06	0.14	0.64
T33	CONDUIT	6.328	0	17:53	5.59	4.77	1.00
T34	CONDUIT	12.542	0	14:02	1.14	0.67	0.88
T35	CONDUIT	5.623	0	13:34	2.49	4.67	1.00
T36	CONDUIT	6.543	0	14:04	1.12	0.45	0.75
T37	CONDUIT	14.795	0	14:01	1.30	0.30	0.72
T38	CONDUIT	7.714	0	12:26	2.20	1.30	1.00
T38-1	CONDUIT	2.809	0	19:03	2.76	1.07	0.84
T4	CONDUIT	0.233	0	13:59	1.65	1.53	1.00
T5	CONDUIT	4.423	1	00:00	0.61	1.10	1.00
T6	CONDUIT	12.973	0	15:02	0.62	0.22	0.77

T7	CONDUIT	7.508	0	16:32	3.32	2.82	1.00
T8	CONDUIT	7.510	0	16:35	0.68	0.61	1.00
T9	CONDUIT	3.009	1	00:00	0.95	0.34	0.67
W1	WEIR	0.006	1	00:00			0.03
W10	WEIR	0.000	0	00:00			0.00
W11	WEIR	0.000	0	00:00			0.00
W12	WEIR	0.000	0	00:00			0.00
W13	WEIR	0.000	0	00:00			0.00
W14	WEIR	0.000	0	00:00			0.00
W15	WEIR	4.493	0	13:01			0.33
W16	WEIR	0.000	0	00:00			0.00
W17	WEIR	0.000	0	00:00			0.00
W18	WEIR	0.000	0	00:00			0.00
W19	WEIR	0.000	0	00:00			0.00
W2	WEIR	0.242	1	00:00			0.35
W20	WEIR	0.000	0	00:00			0.00
W21	WEIR	0.000	0	00:00			0.00
W22	WEIR	6.915	0	14:06			0.70
W23	WEIR	0.000	0	00:00			0.00
W24	WEIR	0.000	0	00:00			0.00
W25	WEIR	2.648	0	19:53			1.00
W26	WEIR	4.721	0	13:04			0.57
W27	WEIR	0.000	0	00:00			0.00
W28	WEIR	0.000	0	00:00			0.00
W29	WEIR	0.000	0	00:00			0.00
W3	WEIR	4.376	0	15:09			1.00
W30	WEIR	0.000	0	00:00			0.00
W31	WEIR	0.000	0	00:00			0.00
W32	WEIR	1.032	0	23:33			0.92
W33	WEIR	4.729	0	16:13			0.99
W34	WEIR	4.940	0	16:27			0.89
W35	WEIR	0.000	0	00:00			0.00
W36	WEIR	4.344	0	14:03			0.51
W37	WEIR	3.658	0	14:00			0.87
W38	WEIR	0.000	0	00:00			0.00
W39	WEIR	7.762	0	14:05			0.76
W4	WEIR	4.324	1	00:00			0.32
W40	WEIR	0.000	0	00:00			0.00
W41	WEIR	4.818	0	14:00			0.60
W42	WEIR	5.675	0	13:14			0.61
W43	WEIR	0.000	0	00:00			0.00
W44	WEIR	0.000	0	00:00			0.00
W45	WEIR	3.548	0	14:14			0.16
W46	WEIR	0.000	0	00:00			0.00
W47	WEIR	0.280	1	00:00			0.08
W48	WEIR	4.546	0	13:05			0.73

W49	WEIR	4.545	0	13:05	0.56
W5	WEIR	0.000	0	00:00	0.00
W6	WEIR	0.000	0	00:00	0.00
W7	WEIR	0.000	0	00:00	0.00
W8	WEIR	0.000	0	00:00	0.00
W9	WEIR	0.000	0	00:00	0.00

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Flow Classification Summary
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	Adjusted	Fraction of Time in Flow Class								
Conduit	/Actual Length	Dry	Up Dry	Down Dry	Sub Crit	Sup Crit	Up Crit	Down Crit	Norm Ltd	Inlet Ctrl
C1	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.04	0.00
C2	1.00	0.11	0.00	0.00	0.89	0.00	0.00	0.00	0.01	0.00
C3	1.00	0.02	0.17	0.00	0.81	0.00	0.00	0.00	0.05	0.00
C4	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.00	0.00
C5	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.40	0.00
C6	1.00	0.02	0.00	0.00	0.94	0.04	0.00	0.00	0.00	0.00
C7	1.00	0.02	0.07	0.00	0.91	0.00	0.00	0.00	0.26	0.00
C8	1.00	0.02	0.00	0.00	0.88	0.10	0.00	0.00	0.00	0.00
C9	1.00	0.02	0.05	0.00	0.93	0.00	0.00	0.00	0.85	0.00
P1	1.00	0.05	0.00	0.00	0.90	0.05	0.00	0.00	0.00	0.00
P2	1.00	0.02	0.14	0.00	0.84	0.00	0.00	0.00	0.65	0.00
P3	1.00	0.08	0.00	0.00	0.84	0.07	0.00	0.00	0.00	0.00
P4	1.00	0.14	0.00	0.00	0.86	0.00	0.00	0.00	0.14	0.00
P5	1.00	0.07	0.00	0.00	0.90	0.03	0.00	0.00	0.00	0.00
P6	1.00	0.13	0.00	0.00	0.87	0.00	0.00	0.00	0.15	0.00
SM1	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.43	0.00
SM2	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.03	0.00
T1	1.00	0.02	0.01	0.00	0.97	0.00	0.00	0.00	0.54	0.00
T10	1.00	0.02	0.15	0.00	0.83	0.00	0.00	0.00	0.08	0.00
T11	1.00	0.02	0.15	0.00	0.83	0.00	0.00	0.00	0.00	0.00
T12	1.00	0.02	0.14	0.00	0.84	0.00	0.00	0.00	0.00	0.00
T13	1.00	0.02	0.14	0.00	0.84	0.00	0.00	0.00	0.08	0.00
T14	1.00	0.02	0.11	0.00	0.87	0.00	0.00	0.00	0.00	0.00
T15	1.00	0.02	0.11	0.00	0.87	0.00	0.00	0.00	0.11	0.00
T16	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.52	0.00
T16-1	1.00	0.92	0.00	0.00	0.08	0.00	0.00	0.00	0.02	0.00
T16-2	1.00	0.92	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
T16-3	1.00	0.92	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
T16-4	1.00	0.92	0.00	0.00	0.08	0.00	0.00	0.00	0.01	0.00

T16-5	1.00	0.25	0.67	0.00	0.08	0.00	0.00	0.00	0.01	0.00
T16-6	1.00	0.03	0.22	0.00	0.75	0.00	0.00	0.00	0.00	0.00
T17	1.00	0.03	0.00	0.00	0.97	0.00	0.00	0.00	0.02	0.00
T18	1.00	0.07	0.00	0.00	0.93	0.00	0.00	0.00	0.11	0.00
T19	1.00	0.02	0.09	0.00	0.89	0.00	0.00	0.00	0.10	0.00
T2	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.04	0.00
T20	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.39	0.00
T21	1.00	0.02	0.00	0.00	0.79	0.00	0.00	0.19	0.00	0.00
T22	1.00	0.02	0.07	0.00	0.91	0.00	0.00	0.00	0.13	0.00
T23_1	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.12	0.00
T23_2	1.00	0.05	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00
T23_3	1.00	0.07	0.00	0.00	0.93	0.00	0.00	0.00	0.03	0.00
T23_4	1.00	0.14	0.00	0.00	0.86	0.00	0.00	0.00	0.00	0.00
T23_5	1.00	0.16	0.00	0.00	0.84	0.00	0.00	0.00	0.02	0.00
T24	1.00	0.18	0.00	0.00	0.81	0.01	0.00	0.00	0.00	0.00
T25	1.00	0.19	0.00	0.00	0.81	0.00	0.00	0.00	0.03	0.00
T26	1.00	0.02	0.17	0.00	0.81	0.00	0.00	0.00	0.00	0.00
T27	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.29	0.00
T28	1.00	0.04	0.00	0.00	0.20	0.76	0.00	0.00	0.00	0.00
T29	1.00	0.05	0.00	0.00	0.95	0.00	0.00	0.00	0.68	0.00
T3	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.00	0.00
T30	1.00	0.02	0.06	0.00	0.91	0.00	0.00	0.00	0.20	0.00
T31	1.00	0.02	0.01	0.00	0.98	0.00	0.00	0.00	0.95	0.00
T32	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.56	0.00
T33	1.00	0.02	0.03	0.00	0.93	0.02	0.00	0.00	0.13	0.00
T34	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.53	0.00
T35	1.00	0.03	0.05	0.00	0.92	0.00	0.00	0.00	0.22	0.00
T36	1.00	0.02	0.01	0.00	0.97	0.00	0.00	0.00	0.72	0.00
T37	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.56	0.00
T38	1.00	0.02	0.02	0.00	0.96	0.00	0.00	0.00	0.40	0.00
T38-1	1.00	0.02	0.00	0.00	0.76	0.00	0.00	0.21	0.18	0.00
T4	1.00	0.03	0.07	0.00	0.90	0.00	0.00	0.00	0.29	0.00
T5	1.00	0.02	0.01	0.00	0.97	0.00	0.00	0.00	0.48	0.00
T6	1.00	0.02	0.00	0.00	0.98	0.00	0.00	0.00	0.53	0.00
T7	1.00	0.07	0.00	0.00	0.92	0.01	0.00	0.00	0.00	0.00
T8	1.00	0.10	0.00	0.00	0.90	0.00	0.00	0.00	0.07	0.00
T9	1.00	0.02	0.14	0.00	0.84	0.00	0.00	0.00	0.02	0.00

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Conduit Surcharge Summary
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	Hours Full			Hours Above Full	Hours Capacity
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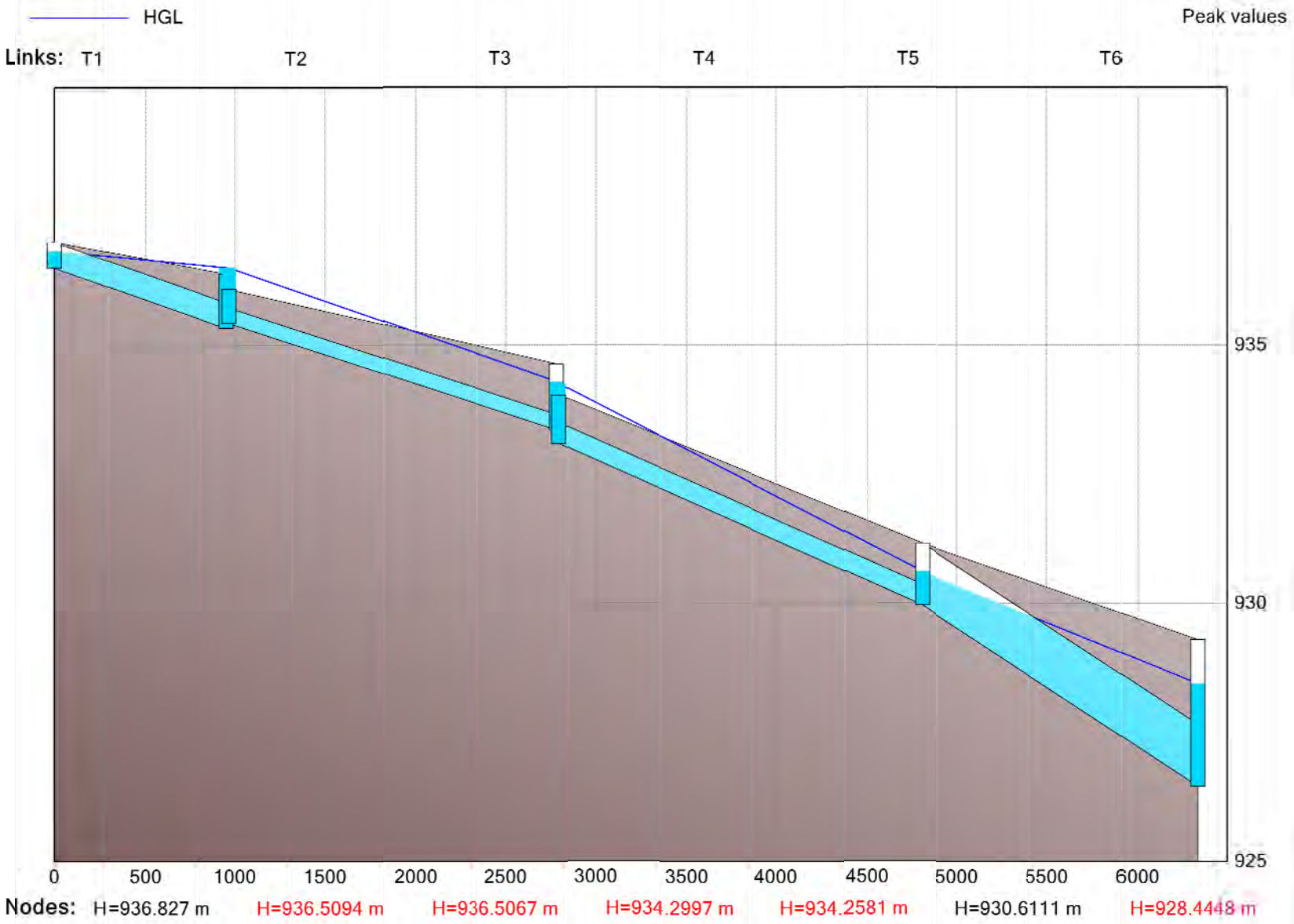
Conduit	Both Ends	Upstream	Dnstream	Normal Flow	Limited
C2	11.45	11.45	11.74	1.99	1.99
C4	12.77	12.97	12.77	13.20	12.77
C6	12.45	12.88	12.45	13.43	12.45
C7	0.01	0.01	1.17	0.01	0.01
C8	0.01	12.49	0.01	12.86	0.01
P1	0.01	10.96	0.01	12.29	0.01
P2	0.01	0.01	10.31	0.01	0.01
P3	0.01	8.07	0.01	10.66	0.01
P5	0.01	7.57	0.01	10.52	0.01
T1	0.01	0.01	11.69	0.01	0.01
T10	0.01	0.01	12.02	0.01	0.01
T11	0.01	0.01	0.01	9.53	0.01
T13	0.01	5.26	0.01	11.94	0.01
T15	0.01	0.01	0.01	12.16	0.01
T16-3	0.01	0.01	0.01	0.50	0.01
T16-5	0.01	0.01	0.01	0.11	0.01
T18	0.01	0.01	2.69	0.01	0.01
T19	6.84	12.22	6.84	13.40	6.84
T2	12.31	12.31	12.45	0.16	0.01
T20	0.01	0.01	12.76	0.01	0.01
T21	13.02	13.11	13.02	13.74	13.02
T22	13.24	13.54	13.24	13.64	13.24
T23_1	0.01	0.01	12.35	0.01	0.01
T23_2	13.32	13.62	13.32	14.05	13.32
T23_3	2.23	2.23	12.05	0.01	0.01
T23_4	12.02	13.39	12.02	13.59	12.02
T24	11.89	11.99	11.89	12.82	11.89
T26	11.91	11.93	11.91	11.96	11.91
T28	0.01	12.86	0.01	13.16	0.01
T3	11.74	12.31	11.74	7.63	7.61
T30	0.77	4.15	0.77	12.07	0.77
T33	8.77	11.65	8.77	13.16	8.77
T35	11.32	12.48	11.32	13.07	11.32
T38	0.01	12.25	0.01	12.70	0.01
T38-1	0.01	0.01	0.01	6.00	0.01
T4	11.74	11.74	12.06	8.84	2.51
T5	10.93	10.93	12.86	9.53	9.53
T6	0.01	0.01	11.09	0.01	0.01
T7	9.73	11.09	9.73	12.45	9.73
T8	10.84	10.84	12.17	0.01	0.01

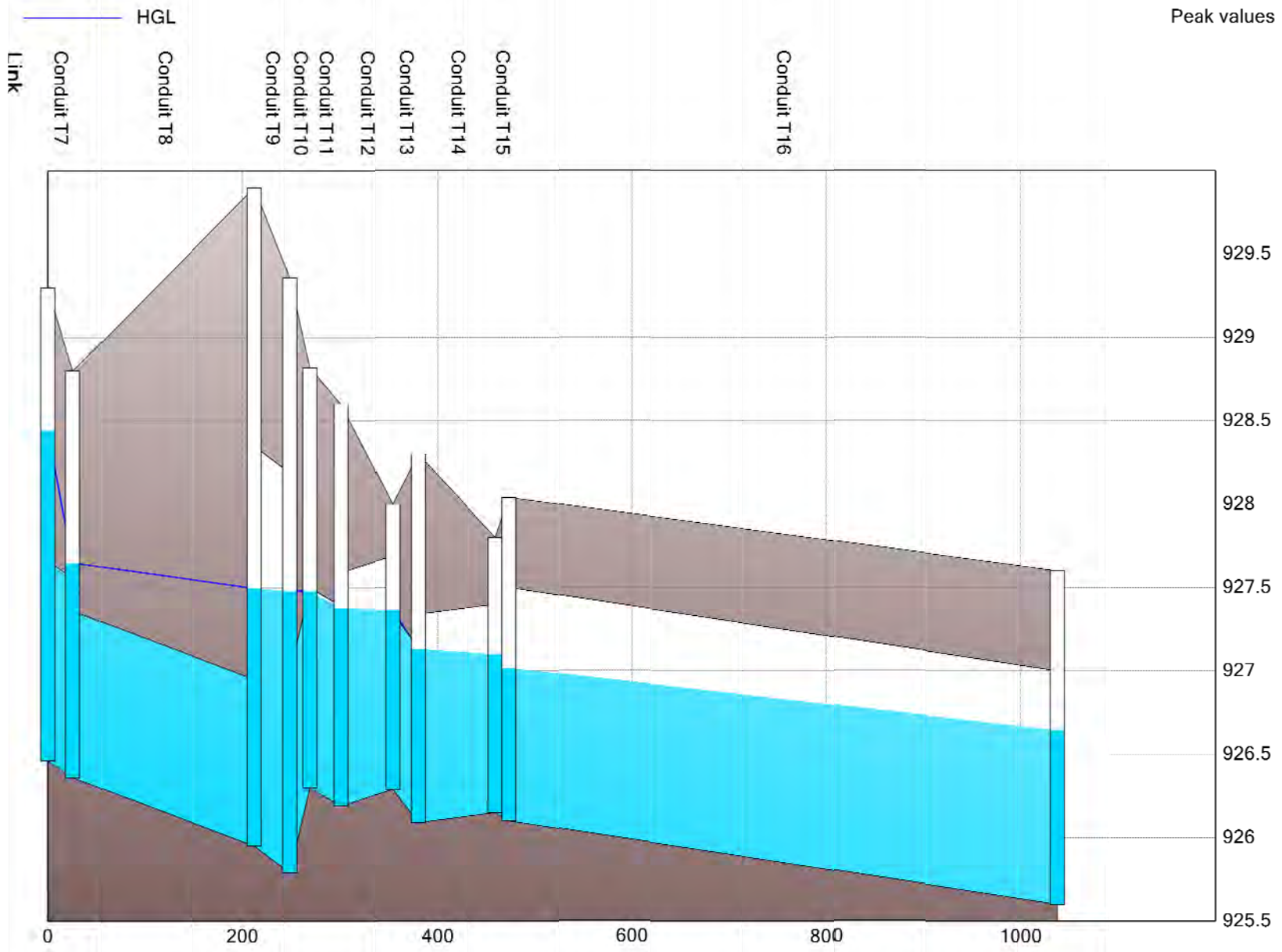
Analysis begun on: Thu Sep 13 11:18:19 2018
Analysis ended on: Thu Sep 13 11:18:25 2018

Total elapsed time: 00:00:06

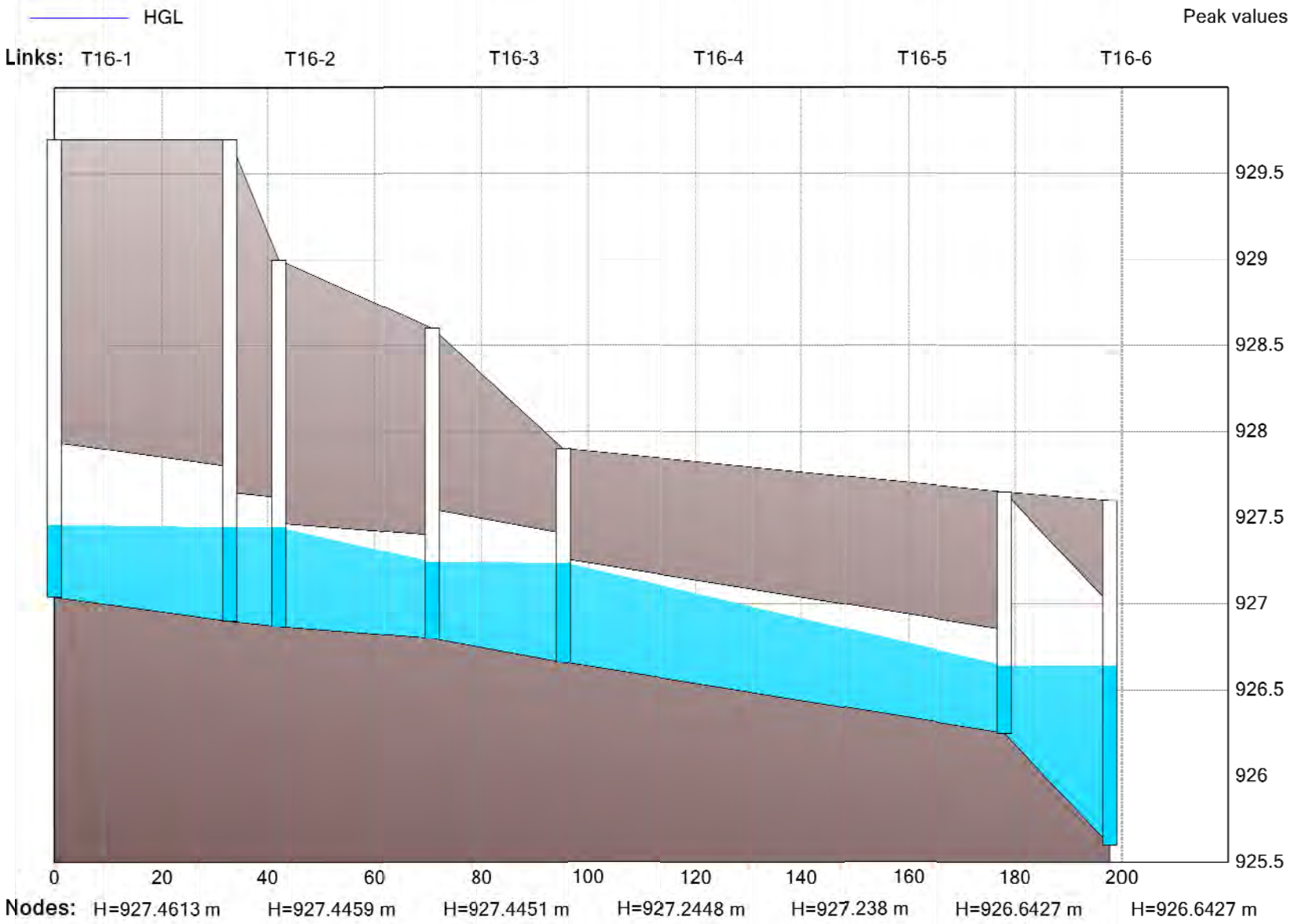
APPENDIX B

Recommended Alternative Drain Profiles from PCSWMM

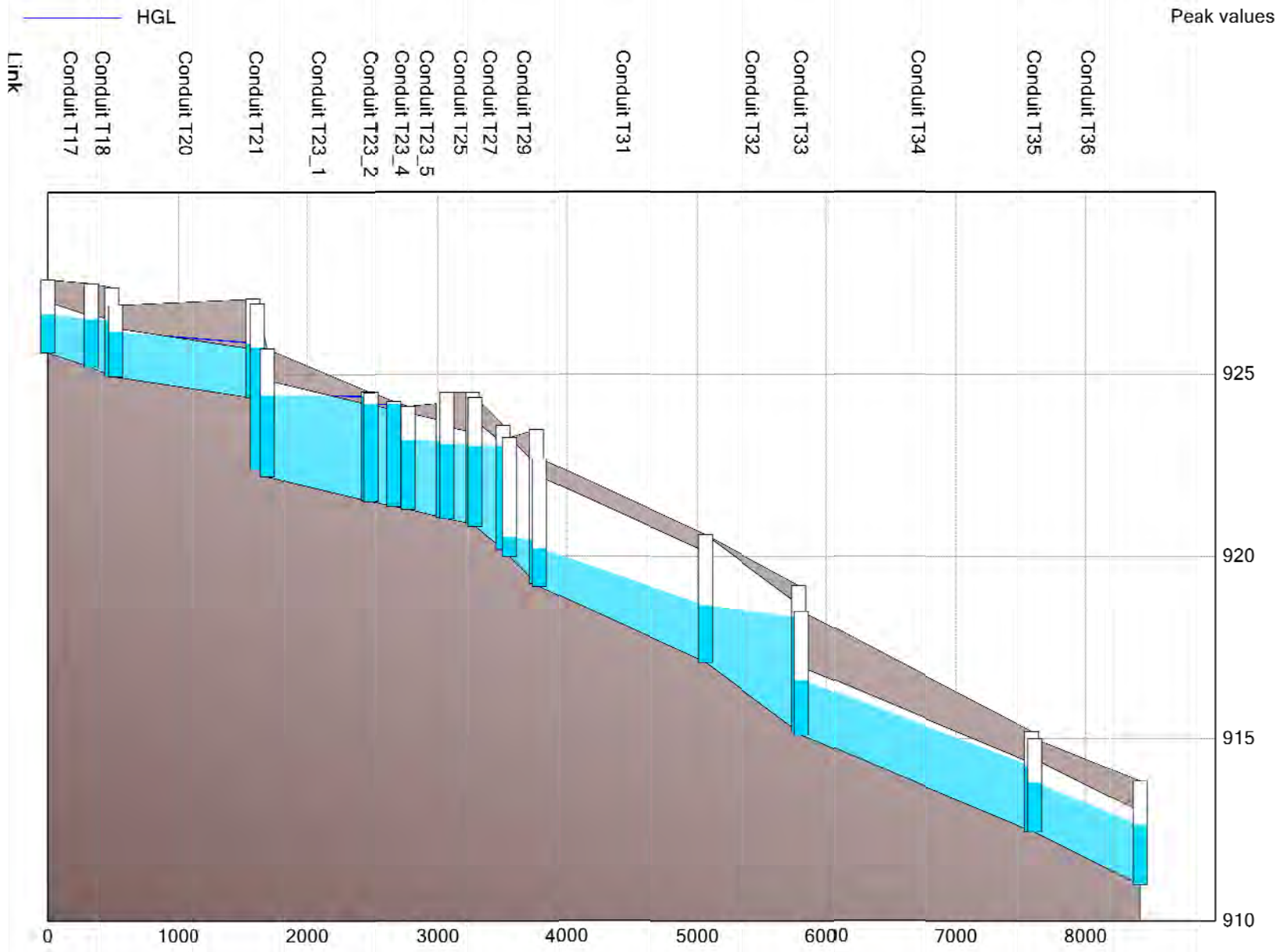

HGL
Peak values
Links: T1 T2 T3 T4 T5 T6
935
930
925
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000
Nodes: H=936.827 m H=936.5094 m H=936.5067 m H=934.2997 m H=934.2581 m H=930.6111 m H=928.4448 m



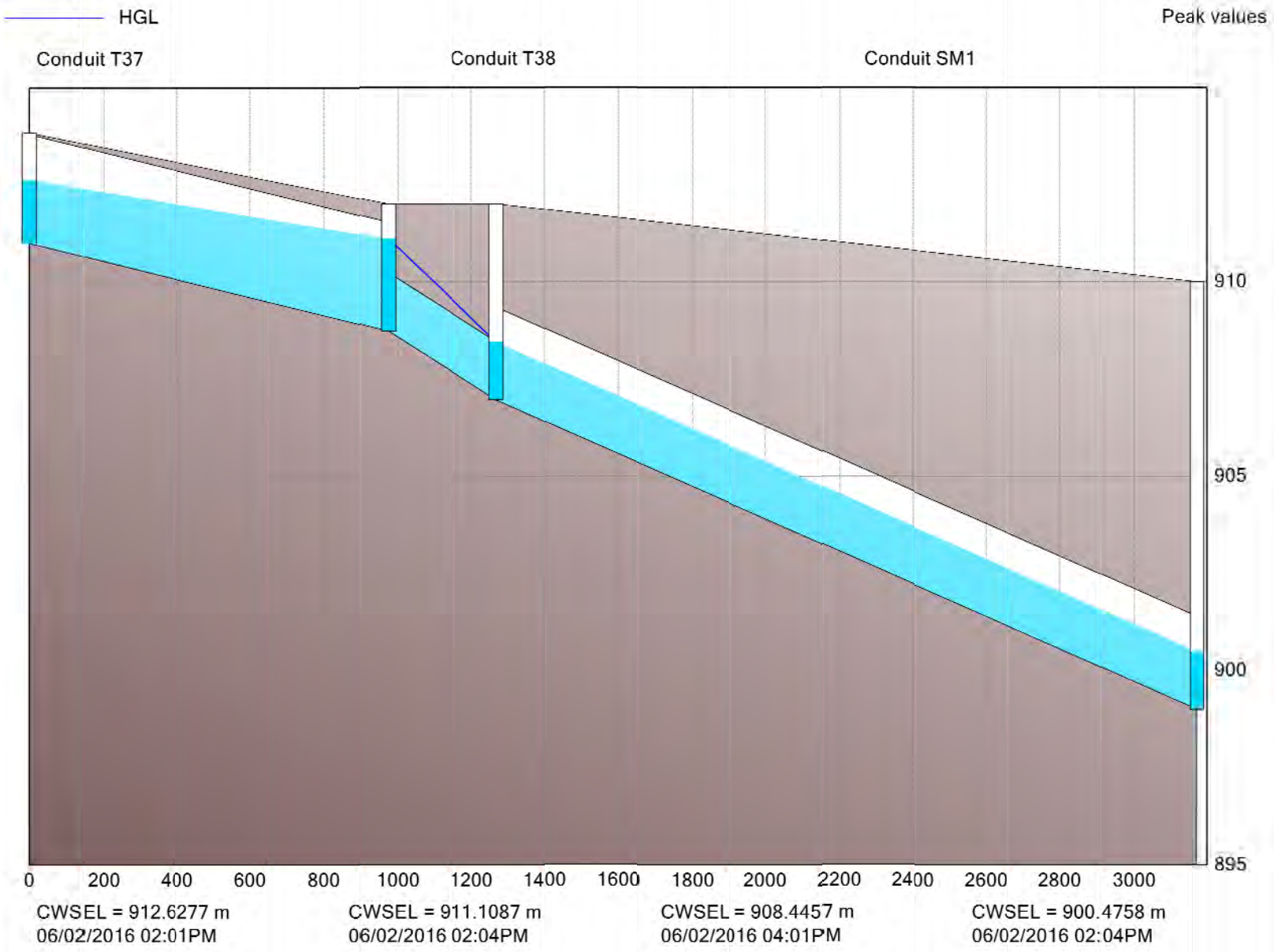
Tiffin Drain
Sheet 2 of 5



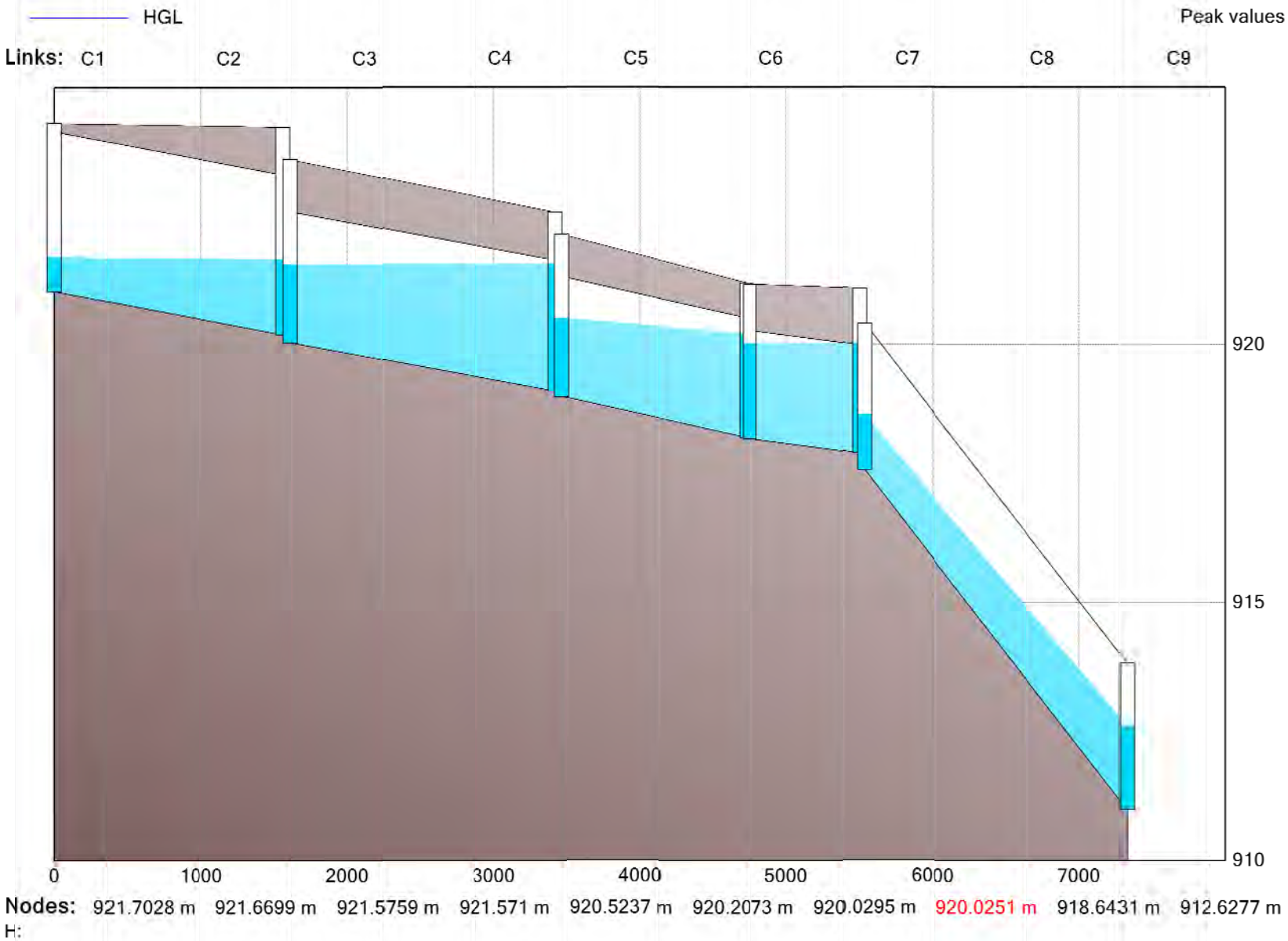
Tiffin Drain
Sheet 3 of 5



Tiffin Drain
Sheet 4 of 5



Tiffin Drain
Sheet 5 of 5



Crombrez Drain
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