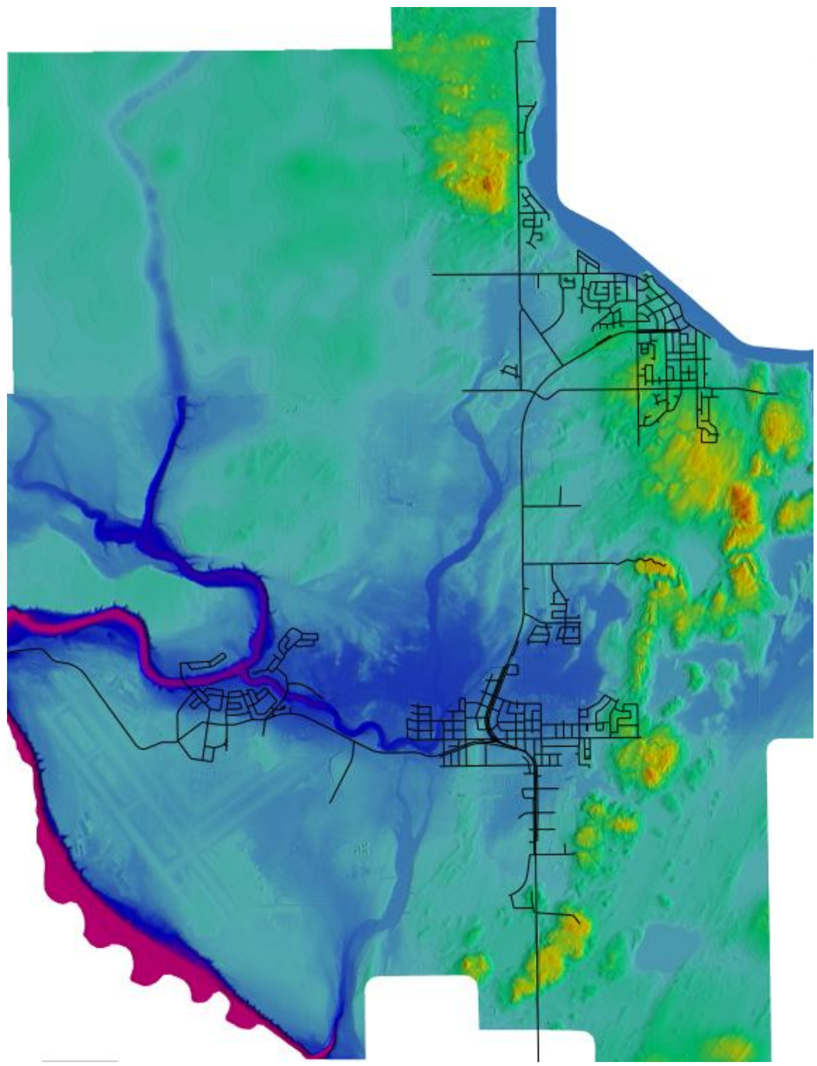
REPORT

City of Cold Lake
Drainage Master Plan



June 2014

Associated Engineering
GLOBAL PERSPECTIVE.
LOCAL FOCUS.

Executive Summary

The City of Cold Lake requested Associated Engineering (AE) to update the City's Master Drainage Plan from 2006.

The City has a number of unique challenges and constraints:

- The storm drainage system is relatively small but covers a large geographic extent owing to the City being so spread out, and different areas were developed to different vertical datums.
- Low-lying areas in the Meadows and adjacent to Palm Creek are difficult to drain and have challenging soils and groundwater conditions.
- Some previous developments have been completed without an adequately defined drainage outlet.
- Existing storm sewers, which were developed to previous standards, are overloaded and risk flooding private property, especially in South Cold Lake, south of the Meadows.
- The 43 Avenue Trunk is not fully implemented and there is risk of flooding adjacent developed areas.

Previous studies, including the 2006 Master Plan, recognized these issues and constraints but provided little guidance as to how they were to be addressed. Without such guidance, the City had little choice but to review drainage development applications on an individual basis.

Objectives of the present study were to address these issues and to provide an overall drainage plan that would provide guidance for future drainage planning and design so that they could be addressed in an integrated fashion to facilitate orderly drainage development.

The study included the following:

- Review of previous planning documents, reports, and other data for the Cold Lake area.
- Survey of pipe elevations and sizes throughout the City to a common datum to ensure reliable and accurate data.
- Review of storm drainage design criteria to establish level of service objectives that are appropriate for existing development areas, which may be slightly different from those criteria that apply to new development areas.
- Computer modeling of the existing storm drainage system using PCSWMM to identify system capacity, constraints, and flood-risk areas.
- Detailed assessment of known problem areas (the Meadows, Palm Creek, and the Palm Springs Golf Course Dam and Reservoir) in three Technical Memoranda attached as Appendices to this report.
- A geotechnical study to determine the soils and groundwater conditions underlying the Meadows and the constraints these conditions would place on the design and construction of storm drainage facilities in the area (attached as **Appendix F** to this report.)

- A field inventory of fish species in the Palm Springs Reservoir and downstream Palm Creek channel to assess the requirements for fish passage in the design of the reservoir outlets (attached as **Appendix I** to this report).
- Conceptual design of the reservoir outlet and drainage improvements on the east side of the 4Wing Base.
- Development of a drainage concept plan for the ultimate development of the project area.

Figure ES-1 provides an overview of the ultimate drainage concept plan. This plan covers most of the Inter-Municipal Plan (IDP) area, except a portion in the extreme northeast, and includes the present City as well as the proposed annexation area and outlying fringe areas that may be developed in the future. The drainage concept plan identifies the locations of stormwater management facilities (SWMFs), connecting pipes or channels, and the boundaries of tributary catchments. Details are provided in Appendix B.

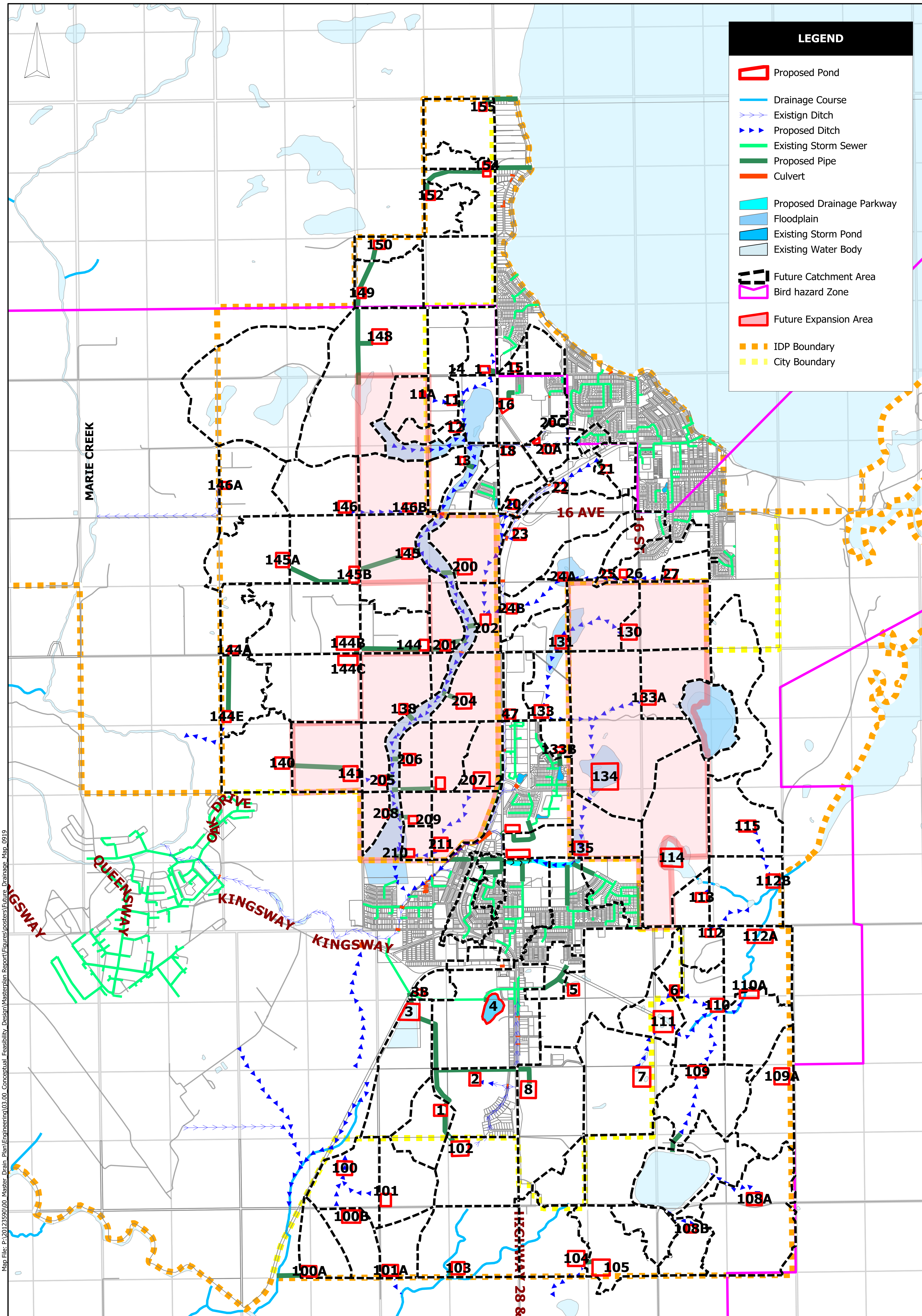
Proposed SWMFs are mostly planned as dry ponds, except for two existing wetland sites in the south of the City. The SWMFs will discharge at a maximum rate of 2.0 L/s/ha, the pre-development 1:100 year peak flow rate, based on the cumulative drainage area to each SWMF. The plan is only conceptual and is not meant to be prescriptive, as some details such as pond locations are subject to review at the time of development, based on conditions that exist at that time.

Components of the drainage concept will be implemented over time by the individual developers of areas they serve. In the meantime, the City faces a number of more immediate drainage issues that need to be resolved. These issues are summarized below along with recommendations as to how they should be addressed:

Existing Storm Sewer System:	**Recommendations:**
• Portions of the existing storm sewers, which were developed to a previous standard, are overloaded and risk flooding adjacent areas, especially in South Cold Lake.	• Selective upgrading as shown in Figures ES-2 and ES-3 at a cost of approximately \$5 Million in North Cold Lake and \$10 Million in South Cold Lake.
The Meadows:	**Recommendations:**
• The area is low-lying and poorly drained, has an inadequate outlet, and has significant soil and groundwater issues.	• Construct a Drainage Parkway as shown in Figures ES-4 and ES-5 to provide a drainage channel plus 150,000 m^3 of flood storage to serve existing development in South Cold Lake and future development in the Meadows at a cost of approximately \$ 15 Million. • Construct a new outfall trunk from the Drainage Parkway westward to the existing Meadows Ditch as shown in Figure ES-6. • Incorporate recommendations of the Geotechnical study in planning and design of proposed developments in the Meadows.

Palm Creek:	Recommendations:
• Extensive low-lying areas along Palm Creek cannot be drained by gravity which creates significant constraints to development. • Filling or pumping are expensive options. • Ownership status of the creek needs to be determined.	• Construct a drainage parkway from Township Road 634 to the existing channel at 53 Avenue at a cost of approximately $10 million (excluding possible land costs). • Follow up on discussions with Alberta Environment and Sustainable Resource Development and Provincial and Federal Fisheries to explore the feasibility of constructing the drainage parkway. • Create a drainage levy of approximately $7,200 per hectare for recovery of the front-end costs. • Provide a gravity outlet from Creekside to Palm Creek.
43 Avenue Basin:	**Recommendations:**
• The 43 Avenue wetland does not have an adequate outlet and risks flooding adjacent development. • Red Fox Estates does not have an adequate outlet. • Geotechnical issues need to be considered in the design of the stormwater management facilities.	• Complete the planned Fischer Estates SWMF and the permanent outlet to the 43 Avenue Trunk. • Undertake a detailed geotechnical study for the Fischer Estates SWMF. • Divert offsite runoff from the south of Fischer Estates by ditch or pipe around Fischer Estates to the 43 Avenue Trunk at Iron Horse Trail. • Secure an easement for the drainage diversion.
CFB Cold Lake (4 Wing):	**Recommendations:**
• Low-lying areas in the southeast of the base are poorly drained and are a constraint to proposed development near Medley Road. • Beaver dams and culvert blockage are recurring issues.	• Undertake preliminary design of four proposed drainage ditches based on conceptual drainage plans provided in this study. • Develop a plan to maintain the ditches and control beaver dams.
Palm Springs Golf Course Reservoir:	**Recommendations:**
• The Reservoir does not have an adequate outlet and the dam risks being overtopped and damaged or destroyed. • The new outlet will be required to provide passage for migration of smaller fish but not larger sport fish (Northern Pike).	• Undertake a geotechnical study and preliminary and detailed design to repair and raise the dam and construct a permanent outlet and provide fish passage from the reservoir.
Other:	**Recommendations:**
• Flows in Palm Creek are not measured to confirm the pre-development runoff estimates and water supply availability to the golf course.	• Monitor flows at one permanent site in Palm Creek and rainfall at two sites in Cold Lake • Routinely check and maintain the flow and rainfall data and equipment to ensure adequate

	Quality Control. • Include the DND Bird Hazard Zone and the design storm rainfall tables in the City's design criteria to ensure consistency in design.



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Associated Engineering
City of Cold Lake

CITY OF COLD LAKE
DRAINAGE MASTERPLAN

Figure ES-1
FUTURE DRAINAGE CONCEPT

PROJECT No.:2012-3590
DATE:3/28/2014
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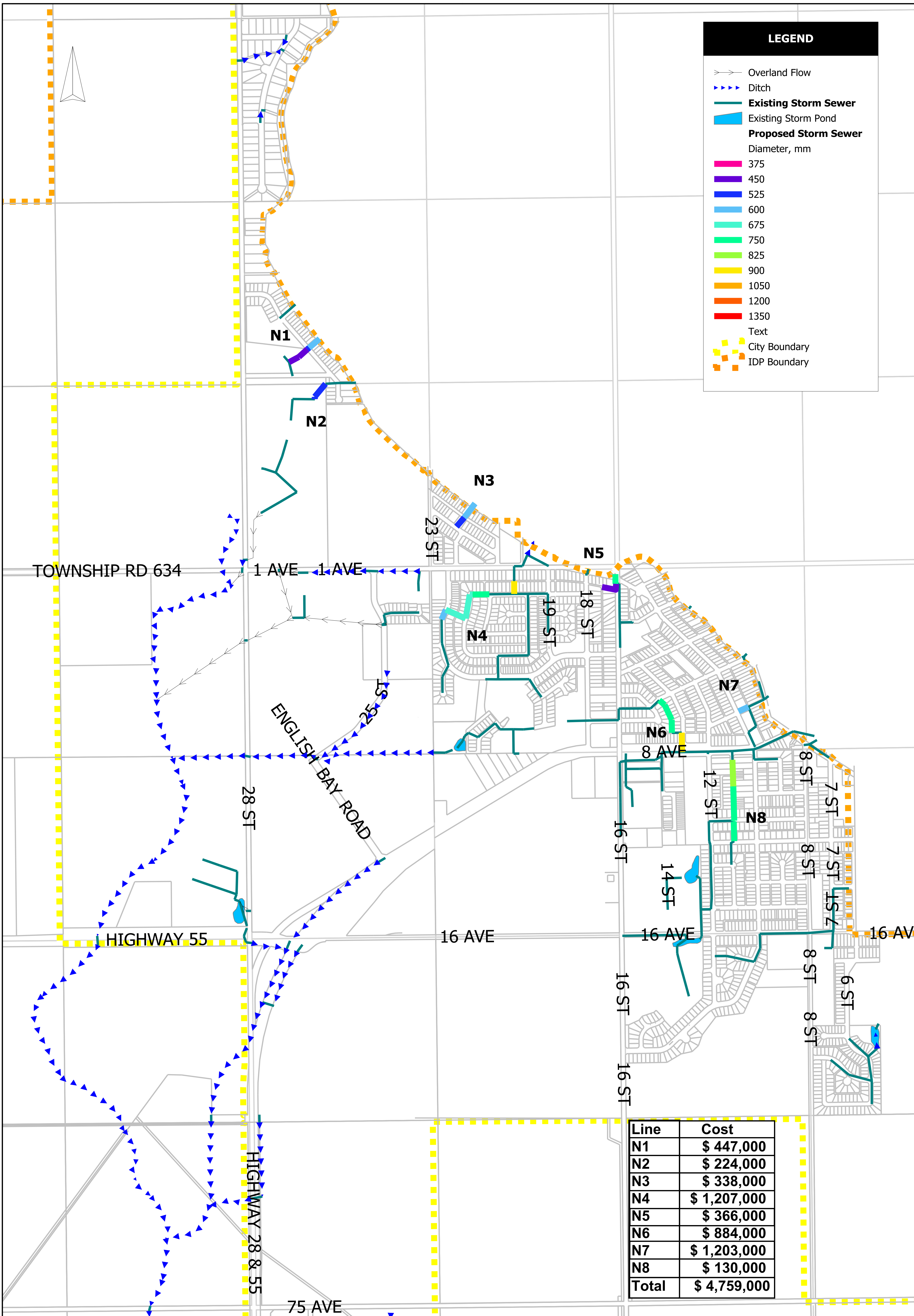

Line	Cost
N1	$ 447,000
N2	$ 224,000
N3	$ 338,000
N4	$ 1,207,000
N5	$ 366,000
N6	$ 884,000
N7	$ 1,203,000
N8	$ 130,000
Total	$ 4,759,000

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City of Cold Lake

CITY OF COLD LAKE
MASTER DRAINAGE PLAN

Figure ES-2
PROPOSED UPGRADES
TO EXISTING STORM SYSTEM (NORTH COLD LAKE)

PROJECT No.: 2012-3590
DATE: 3/19/2014
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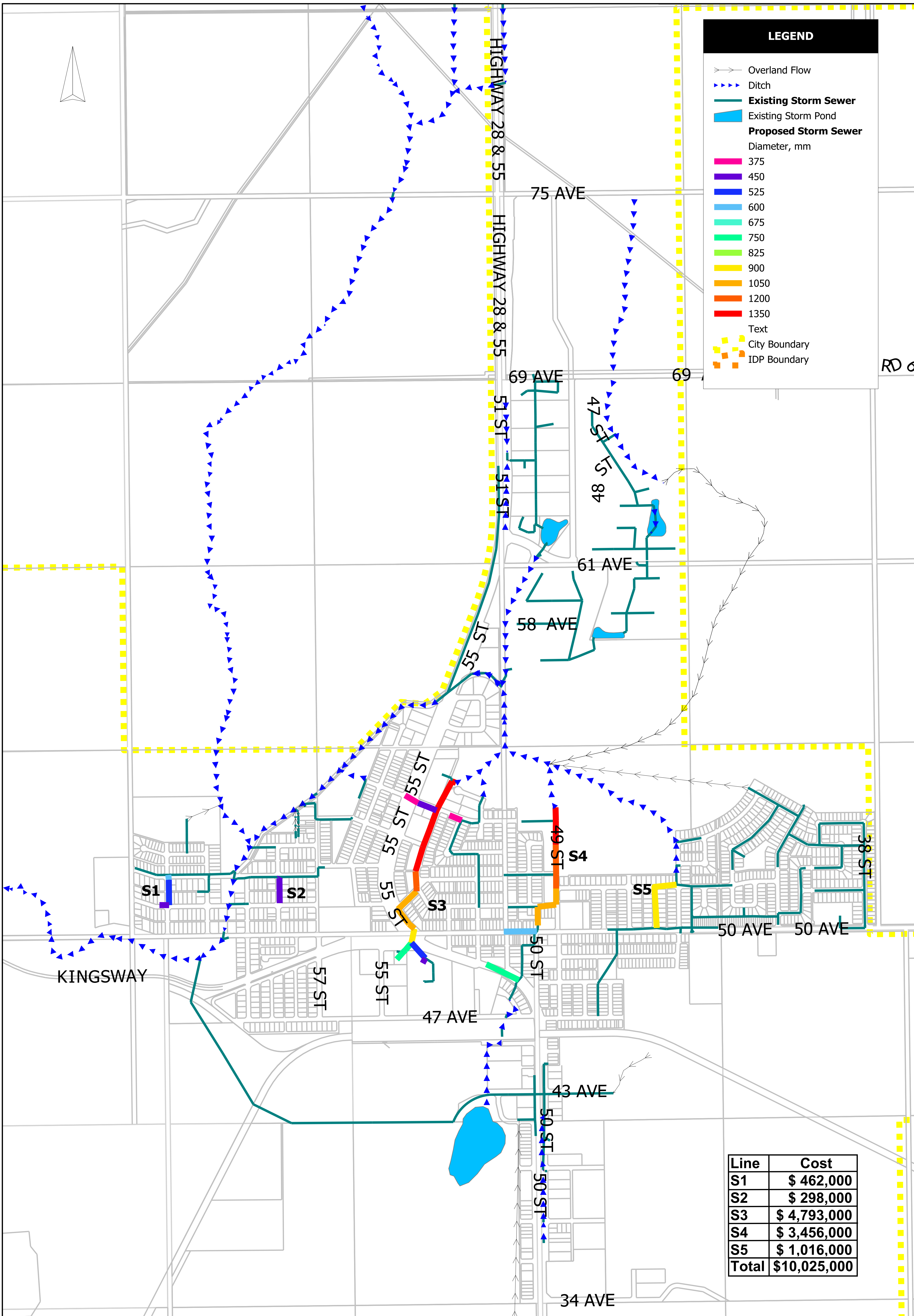

Line	Cost
S1	$ 462,000
S2	$ 298,000
S3	$ 4,793,000
S4	$ 3,456,000
S5	$ 1,016,000
Total	$10,025,000

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CITY OF COLD LAKE
MASTER DRAINAGE PLAN

Figure ES-3
PROPOSED UPGRADES
TO EXISTING STORM SYSTEM (COLD LAKE SOUTH)

PROJECT No.: 2012-3590

DATE: 3/19/2014

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Figure ES-4

City of Cold Lake

MASTER DRAINAGE PLAN

Concept: Meadows Drainage
Parkway Option
Plan View

LEGEND

Deciduous Trees

Coniferous Tree

Bench

Shrubs

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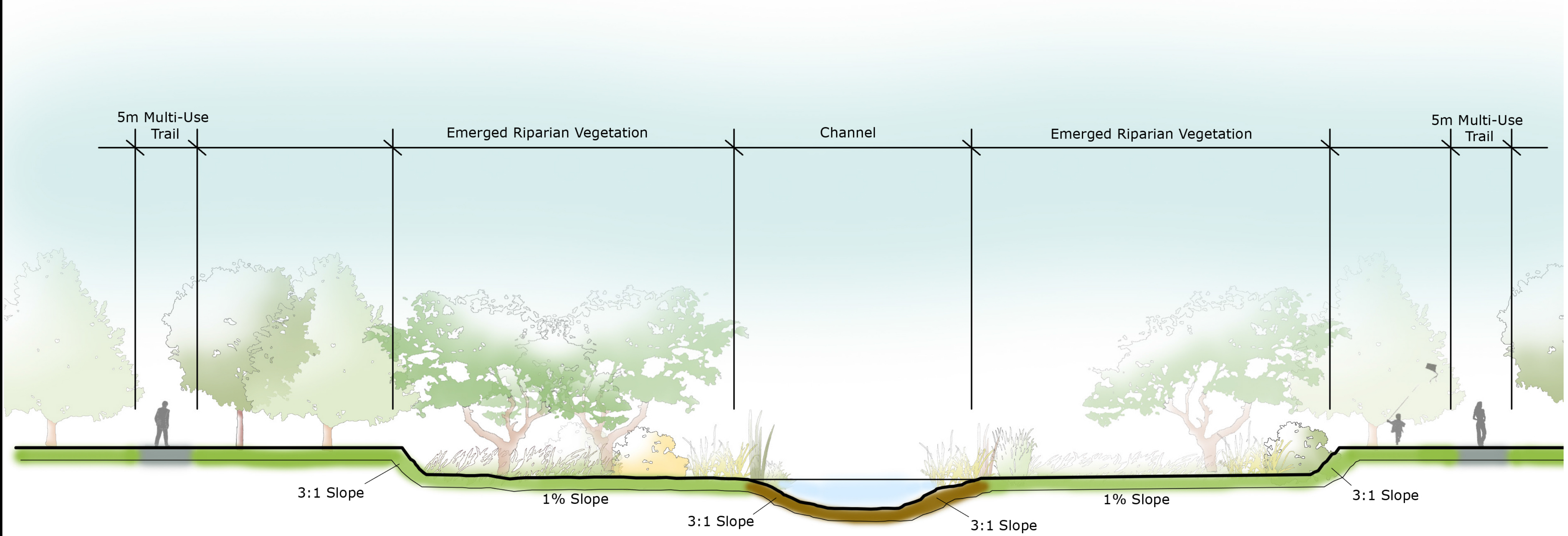

Figure ES-5

Associated Engineering

City of Cold Lake

MASTER DRAINAGE
CROSS SECTION A-A'

Concept: Meadows Drainage
Parkway Option
Cross-section View

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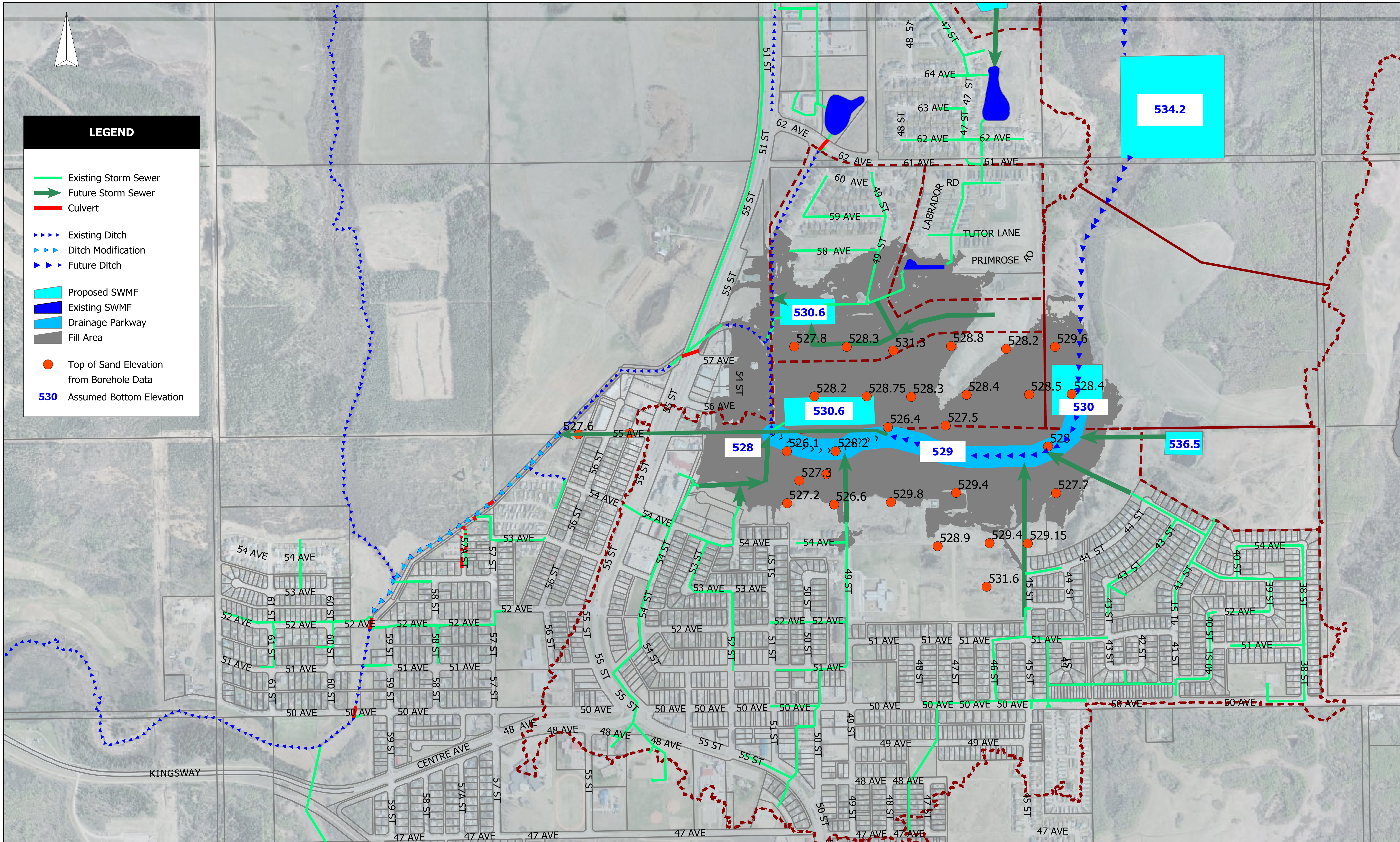

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CITY OF COLD LAKE
DRAINAGE MASTERPLAN
Figure ES-6
MEADOWS OPTION - C
DRAINAGE PARKWAY OPTION

PROJECT No.: 2012-3590
DATE: 3/26/2014
SCALE: 1:10,000

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Table of Contents

1 Introduction

In keeping with the proposed growth strategy for the City of Cold Lake, the City requested Associated Engineering (AE) to update its Stormwater Master Plan to ensure that the storm drainage system provides an adequate level of service, meets the current regulatory and environmental requirements, and provides for future development.

The 2013 Cold Lake Drainage Master Plan endeavours to identify improvements to the stormwater management system and drainage connectivity, to increase the quality of life for residents and protect them from potential flood hazards.

Figure 1-1 provides an overall view of the City of Cold Lake comprising of North Cold Lake, South Cold Lake, and the CFB - 4 Wing Area. There is a ridge along the northern portion of the City which separates North Cold Lake from the rest of the City. Most of the developed area in North Cold Lake drains north to the Lake. The remaining portion of the City drains south towards Palm Creek, which eventually joins Marie Creek and then the Beaver River. A part of the area in the east which is currently outside the City boundary, but included in the IDP boundary drains north east to the Lake.

1.1 PROJECT ISSUES

The key issues addressed in the Stormwater Master Plan for the City of Cold Lake are as follows:

Drainage of Low Lying Areas:

There are a number of low areas within the project area, especially the Meadows, where runoff collects during a major storm. The Meadows has historically had a high groundwater table and drainage issues. The present assessment examines this area in detail. The study also provides options to ensure proper drainage in this area to protect existing and future developments from flooding.

The south east area of the DND – 4 Wing area has also been identified for poor drainage. The current study identifies concepts to ensure proper drainage of this area.

Low areas along Palm Creek are also poorly drained, particularly to the north of Highway 55. This has required the use of pumping to drain the Creekside development and leaves several existing developments without an adequate outfall. In the south, the 43 Avenue wetland currently has no outlet, nor does Red Fox Estates, and the 43rd Avenue Trunk is not fully functional to drain the area south of Iron Horse Trail.

Development of Future Areas:

Several new developments have been proposed across the City, the prominent ones being North Shore ASP, Meadows ASP, Iron Horse ASP and Fischer Estates ASP. Additionally the City plans to annex areas outside the current City Limits and develop them in the future. The proposed developments will increase stormwater runoff and the demands on the storm drainage system. The present assessment will examine the drainage concepts and functionality of the entire system, rather than individually has been done in the past.

System Capacity:

Previous studies have defined the rate of allowable discharge to Palm Creek and the size of the proposed stormwater management facilities for attenuation to pre-development rate. The Master Plan in 2006 adopted an allowable discharge rate of 2.0 L/s/ha. However the City's storm sewer system itself has not been analyzed for hydraulic capacity. UMA Engineering did analyze the City's infrastructure for capacity in 1991 for North Cold Lake, but significant development has occurred since 1991.

Previous studies have identified constraints in the grades and capacities of the major drainage outlets from the area, Palm Creek and the Meadows ditch. The City has had to review developer drainage proposals on an individual basis, which has not always led to the best solutions.

Therefore, the current assessment will include the hydraulic capacity of the existing storm sewer system and major drainage channels and propose upgrades to mitigate flooding.

North Cold Lake, South Cold Lake, and 4 Wing were each developed to different vertical datums, and these datums were not always consistently applied. This creates challenges in planning regional drainage systems that sometimes interconnect. The present study uses one datum for all of the City of Cold Lake and DND datum for 4 Wing.

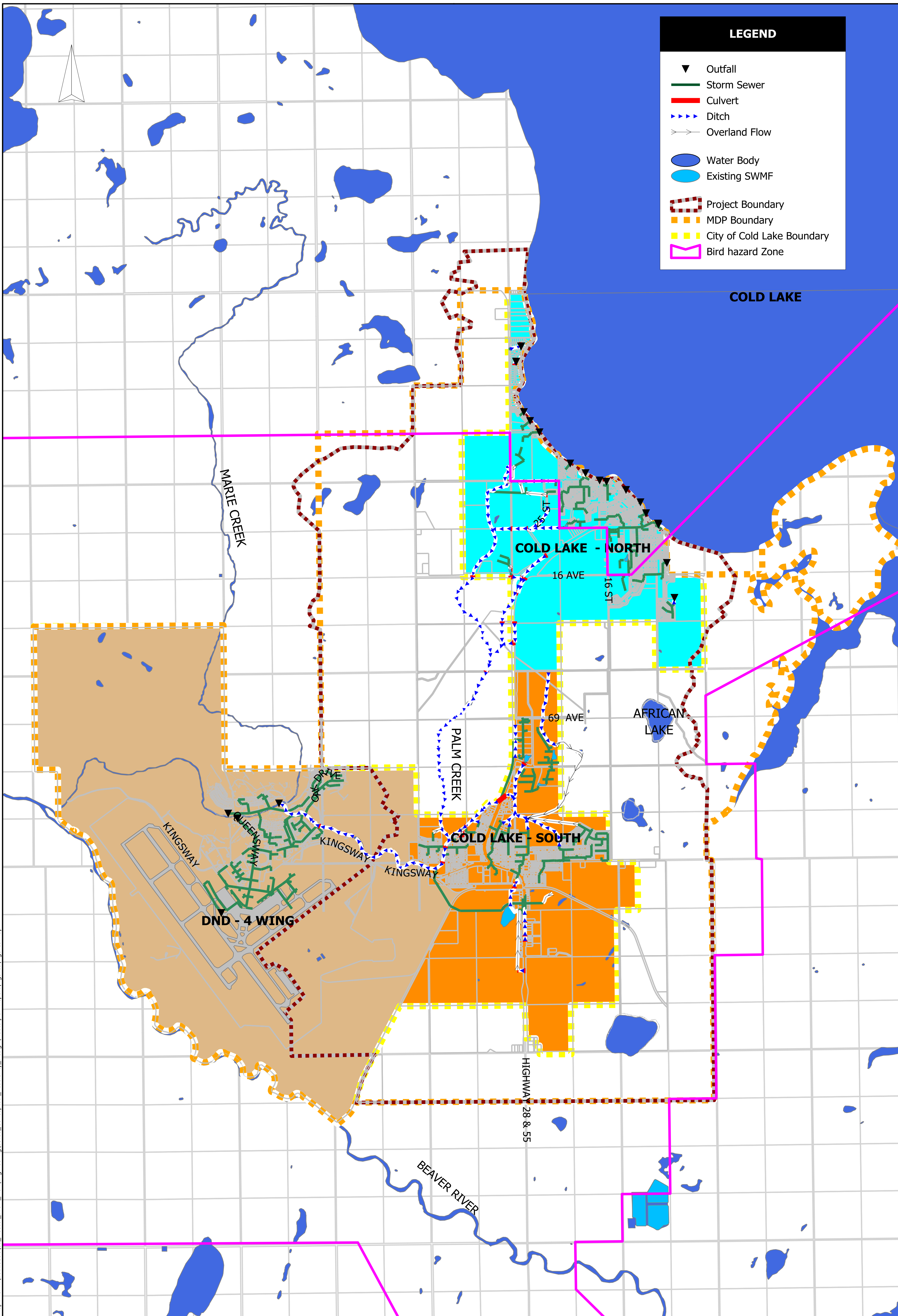
1.2 OBJECTIVES

The primary objectives of the study are:

- To ensure that stormwater management and conveyance are provided in areas with poor drainage.
- To identify storm sewer improvements to mitigate flooding.
- To provide a drainage concept plan for future development and guide the City in the implementation of future drainage development.

1.3 PROJECT BOUNDARY

The Project boundary has been shown in **Figure 1-1** and extends beyond the City boundary to encompass the Inter-Municipal Development Plan (IDP) boundary. A portion of the IDP in the northeast of Range Road 20 has not been considered in this study. The project area also includes the undeveloped areas in the south-east portion of 4-Wing, to the east of Medley Road, but not the developed areas of 4 Wing, which have already been analyzed by Associated Engineering previously in 1997, 1999 and 2008.



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City of Cold Lake

CITY OF COLD LAKE
MASTER DRAINAGE PLAN

Figure 1-1
PROJECT AREA

PROJECT No.: 2012-3590
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2 Project Background

2.1 PREVIOUS STUDIES

Various drainage studies have been undertaken in the past in Cold Lake. These are summarized in this section.

Associated Engineering's *Preliminary Design Report, North End Drainage, 1975* examined storm and groundwater drainage for the northeast area of the former Town of Grand Centre (now known as South Cold Lake). The need for dewatering to lower the water table and to provide comprehensive storm drainage facilities was identified in this report. The study recommended that a permanent groundwater dewatering system be maintained and a detention pond draining to a deepened ditch be provided to drain the proposed development by gravity.

The possibility of dewatering the shallow sand aquifer in the Meadows Area of now South Cold Lake was investigated from May to December of 1975 in the report titled *Grand Centre Dewatering Program.* Water was pumped from 5 locations for 58 days. The dewatering was stopped in December 1975 as the drainage ditch to which water was being pumped was blocked, and there was no place to discharge the pumped water. Results from the study indicated that the dewatering program reduced the groundwater levels by more than 1.5 m.

The program concluded that through the use of 6 completed dewatering wells it would be possible to lower the water levels in the majority of the area by 2 m or more with 6 months of pumping. That study did not address any impacts that such pumping could have on regional groundwater supplies.

The study also concluded that intercepting the runoff from the southern portion of the Town, south of CNR line by a storm sewer and diverting it to the west, across Highway 28/55, would help lower water levels in the Town of Grand Centre. The City has recently completed this trunk sewer (43 Avenue Trunk).

The *Well Water Survey for Town of Grand Centre, 1976* revealed that when conditions for the interim license were released by Alberta Environment, the Town of Grand Centre believed the conditions to be too broad, and thus decided to cancel the idea of developing the lands where the dewatering system was needed.

The hydraulic capacity of Palm Creek and the allowable discharge to Palm Creek have been considered in several studies since the flood of 1977 that caused widespread property damage in the vicinity of the Creek:

- Associated Engineering undertook "*The Stormwater Management Study in 1982*" to determine the allowable discharges to Palm Creek and the capacity of the creek. The study extended from Palm Creek at 50th Avenue to the confluence with Marie Creek.

The study concluded that the allowable discharges to the Palm Creek were 2.4 L/s/ha for a 1:100 year 24 hour storm. The study also concluded that the peak flow in the creek at 50th Avenue was 10.4 m^3/s during the 1:100 year 24 storm event. Findings from the study also concluded that the Dahl Dam (the present Palm Springs Golf Course Reservoir), with 5-675 mm culverts, had adequate capacity for a 1:5 year 24 hour storm only, and would need to be upgraded to provide capacity for a 1:100 year 24 hour storm. A number of changes have been made to the culverts over the years, and the outlet has recently been destroyed and replaced with a temporary rock fill.

- In 1986, the Town upgraded Palm Creek south of 53 Avenue, including:
  - lowering and widening the existing channel,
  - armouring the existing channel with gabion mats to prevent erosion of sandy and peaty soils,
  - replacement of culverts at 50 and 52 Avenues.

- A *Municipal Servicing Study* was conducted by Associated Engineering in 1988. In addition to recommending a storm water management approach and improvements to Palm Creek as mentioned in the previous studies, the study also recommended that areas south of the Canadian National Railway line (Iron Horse Trail) not be allowed to drain northward, into the developed areas. It recommended that runoff from these areas be directed northwest by an outfall storm sewer. The stormwater management approach involved sizing the proposed drainage facilities to serve their tributary areas at ultimate development and control the rate of runoff from the development area with stormwater management (ponds). The study recommended the use of dry ponds to prevent recharge of the sand aquifer and to meet the DND regulations.

- In 1991, UMA conducted an Infrastructure assessment for North Cold Lake, which concluded that the majority of the pipes had adequate capacity to meet the recommended standards. The study, however did recommend upgrades to 16 pipes and the addition of three culverts. The study reiterated that discharges to Palm Creek be controlled to the 100 year pre-development rate by attenuating runoff in storm water ponds designed for a 1:100 year storm.

- UMA/AECOM developed a *Master Drainage Plan in 2006* and focussed on the stormwater management approach recommended in previous studies. The study included the allowable discharges for stormwater management facilities discharging to Palm Creek to be 2.0 L/s/ha and proposed to limit the detention time in the pond to 96 hours (4 days) during a 1:100 year storm.

An extensive network of stormwater management facilities (SWMFs) was identified in the *Drainage Master Plan (AECOM 2006)* to achieve the level of service standards and protect the downstream receiving water bodies. A total of 41 SWMFs were identified to serve a total basin area of 2500 ha. The SWMFs would range from 0.37 ha to 7.0 ha in size and have a combined total area of 68 ha.

The 2006 report stated that all proposed SWMF's be designed as dry ponds, since the regulations by DND restrict the use of wet ponds due to bird hazards in the proximity of the Base. The report also stated that

Stormwater Management Ponds 4 and 5 (in South Cold Lake) were existing wetlands and therefore conversion to an engineered stormwater wet pond would not introduce new water bodies.

The *2006 Drainage Master Plan* also called for a detailed analysis of Palm Creek to assess its capacity and the allowable discharge to the Creek. The report assumed that all new developments would be built downstream of the existing developments. Hence, existing storm sewer capacities were not analyzed as a part of this study.

The *2006 Drainage Master Plan* does not discuss the high groundwater levels in this area. Given the high groundwater levels and the need for dry ponds, dewatering measures and major soil modification might be required which are not addressed in this report. These high groundwater conditions have led to construction challenges in the CFB 4 Wing area.

Like the previous studies the 2006 Drainage Master Plan recommended the diversion of runoff from the areas south of the Canadian National Railways (CNR) line to the west across Highway 28. This recommendation was implemented through the construction of the 43 Avenue Trunk in 2009. However, SWMF 4, proposed in the 2006 Drainage Master Plan to attenuate the runoff from Basin 4 has not been constructed yet and has only a temporary connection to the Trunk.

The 2006 Drainage Master Plan recommended that the stormwater management concept plan be followed by all new developments and that as a part of the subdivision approval process, developers be required to provide detailed stormwater management plans for each subdivision.

2.2 PLANNING STUDIES

Various Area Structure Places (ASPs) were assessed in this report to ascertain future land use, which was then used as a basis for estimating the development in each catchment. The size of the development was then used to estimate the storage volume for each SWMF in the present report.

The following ASPs and SWMPs (Stormwater Management Plans) listed below were reviewed:

- South East ASP
- Fischer Estates ASP
- Iron Horse ASP
- North Shore ASP
- Forest Heights ASP
- Cold Lake Central ASP
- Uplands ASP
- Tri City Estates SWMP
- Marina View Subdivision SWMP

Figure 2-1 shows the location of the various ASPs. **Table 2-1** provides the location, Consultant, date of preparation, and area for each ASP and SWMP.

Table 2-1
Summary of Areas Structure Plans

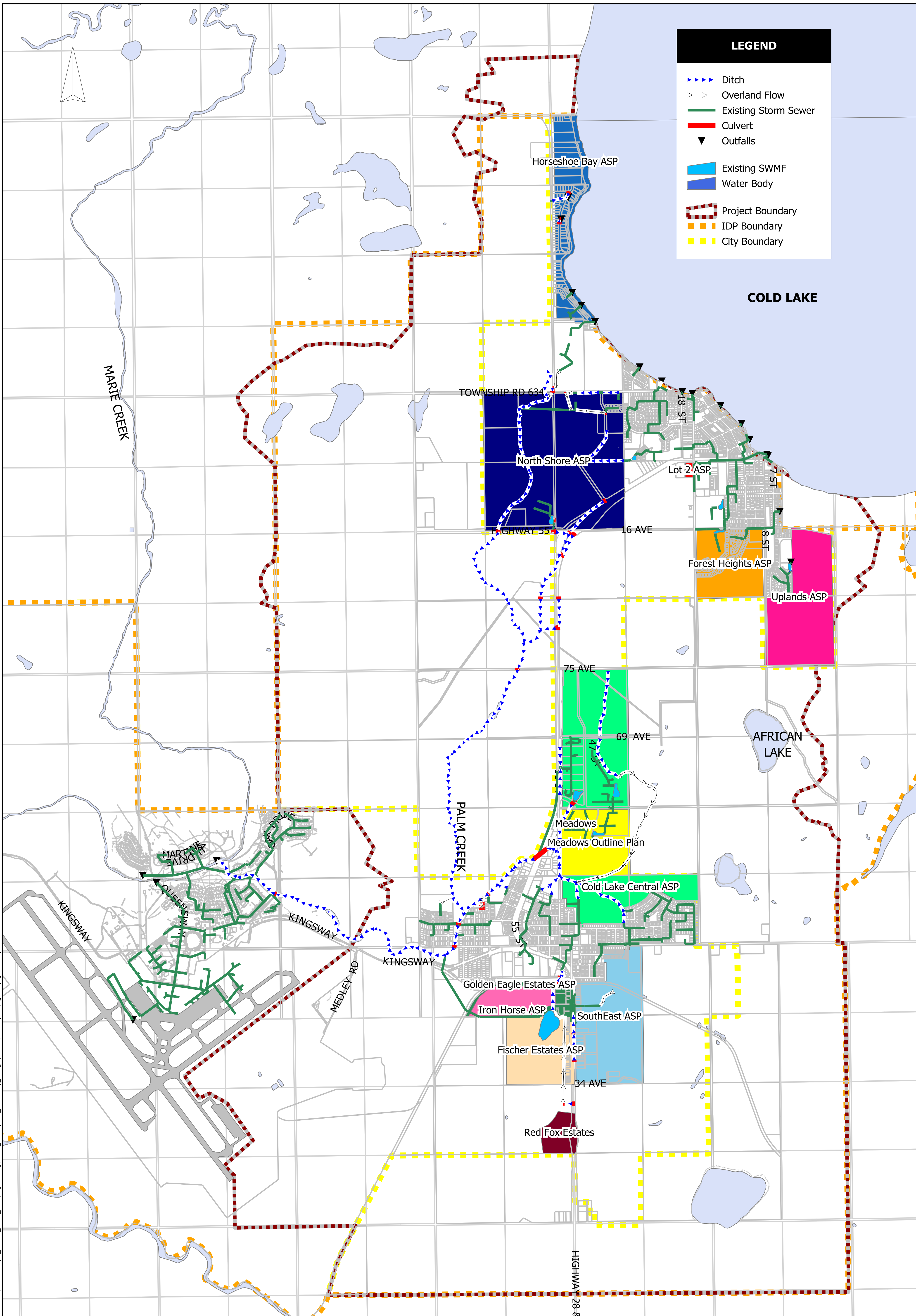
ASP/SWMP	Section Township Range	Location	Prepared by	Date	Area within ASP (ha)
South East ASP	36-62-2-4	East of 50th St, North of 34 Ave	Town of Grand Centre	1989	105
Fischer Estates ASP	36-62-2-4	West of 50th St, North of 34 Ave	Scheffer Andrew Ltd	Mar-03	63.5
Iron Horse ASP	34-62-2-4	West of 50th St, South of CNR ROW	SE Design & Consulting	Jul-05	30.77
North Shore ASP	23-63-2-4	NW Corner of Intersection of Highway 28 & 55	Focus	2007	245
Forest Heights ASP	13-63-2-4	West of 8th St, South of 16 Ave	SE Design & Consulting	Jun-07	64
Cold Lake Central ASP	11-63-2-4	West of Highway 28 & 55	Select Engineering Consultants Ltd	Nov-07	250.86
Uplands ASP	13-63-2-4	NE edge of City of Cold Lake	Scheffer Andrew Ltd	Jul-09	101.9
Tri City Estates SWMP	11-63-2-4	North of Town of Grand Centre	Associated Engineering	Jul-04	40
Marina View Subdivision SWMP	16-63-2-4	West of range Road 23, North of Township Rd 632	Associated Engineering	Jun-05	343

The above ASPs provided the conceptual design of SWMFs and use of existing wetlands or sloughs for stormwater management. The North Shore ASP, South East ASP, and Marina View Subdivision SWMP identified high groundwater levels in the project vicinity and proposed dewatering or major soil modification.

The drainage concepts in these reports have been incorporated into the stormwater management plan for existing and future conditions.

The *Inter-Municipal Development Plan* (IDP) and the *Municipal Development Plan* (MDP) define the extent and characteristics of the growth that the municipality is headed to in future. Future land use maps provided in these documents have been used in addition to the ASPs mentioned above to estimate the extent and type of development within the MDP and IDP boundary.

Figures 2-2 and **2-3** show the existing and future land use concepts for the City of Cold Lake.



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MASTER DRAINAGE PLAN

Figure 2-1
AREA STRUCTURE PLAN MAP

PROJECT No.: 2012-3590

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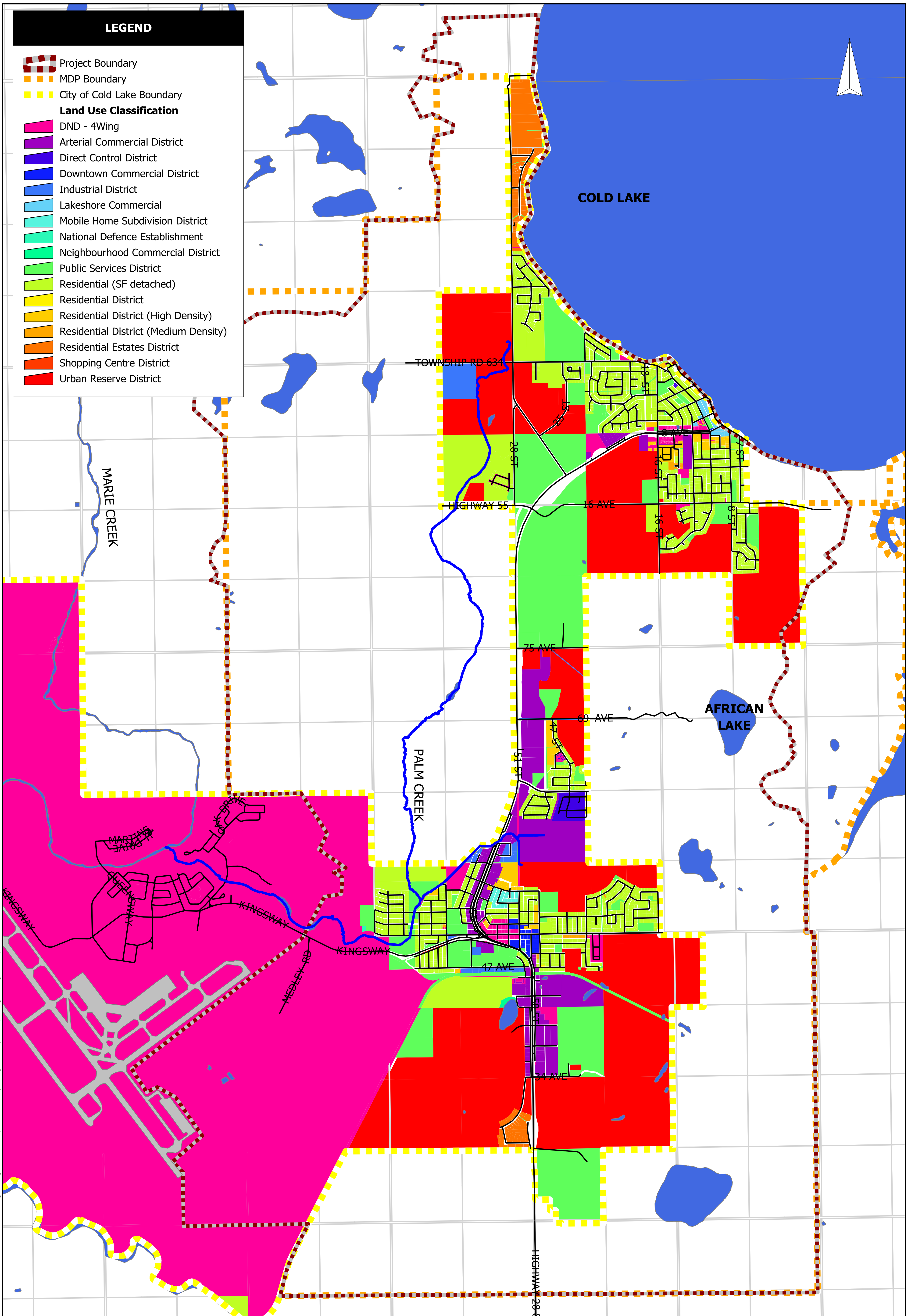

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MASTER DRAINAGE PLAN

Figure 2-2
Existing Land Use Map (City Boundary)

PROJECT No.: 2012-3590

DATE: 12/13/13

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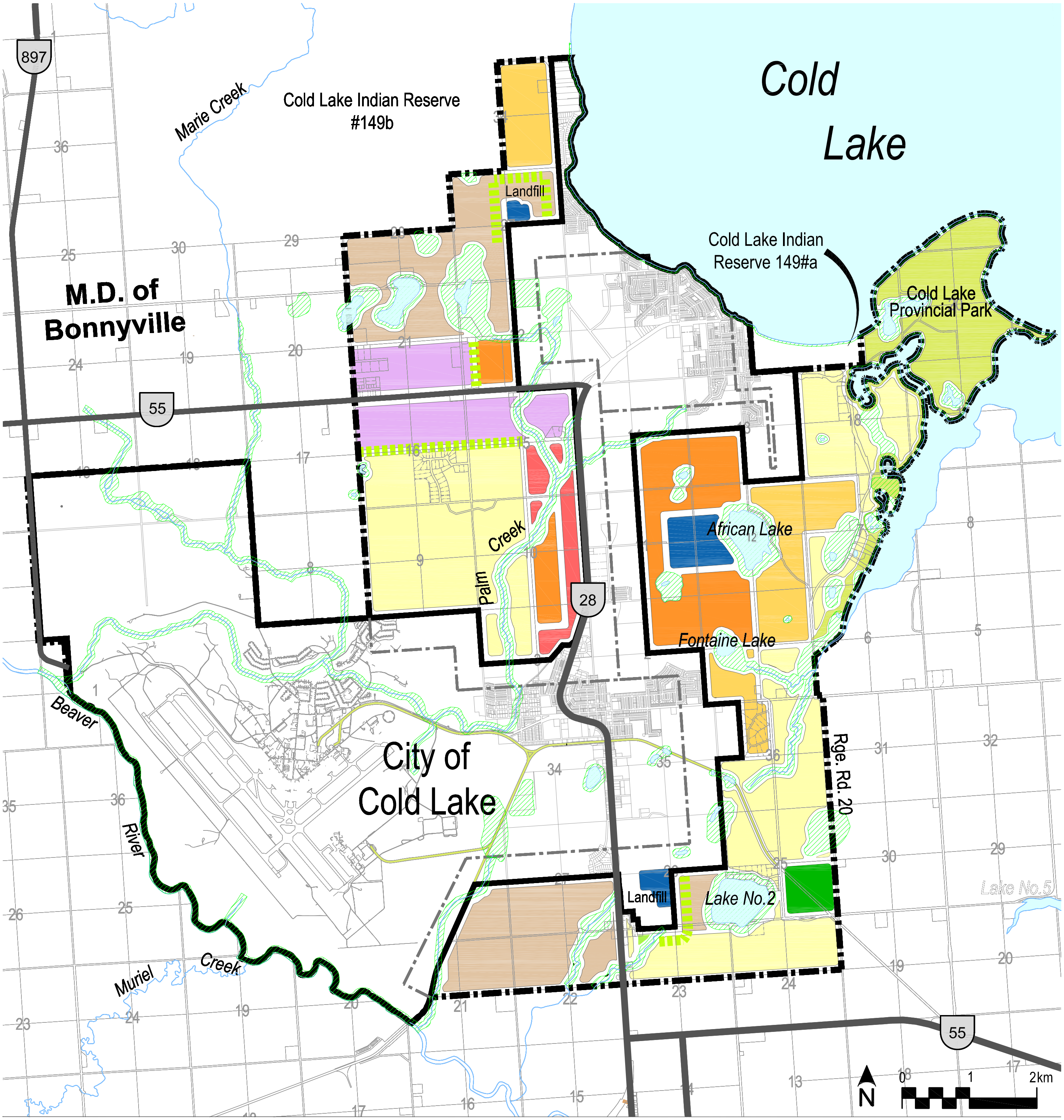

Legend

- Country Residential (2 acre + lots)
- Estate Residential (½ acre - 1 acre lots)
- Urban Residential (small lots / multi-family)
- Commercial
- Industrial
- Natural Areas
- Recreation -- Private
- Recreation -- Public
- Buffer
- Public Services
- Agricultural / Rural
- Airport
- Provincial Highway
- IDP Area Boundary
- IDP Inner Boundary
- City of Cold Lake Boundary

Map 7: Future Land Use Concept
City of Cold Lake and M.D. of Bonnyville No. 87
Intermunicipal Development Plan

City of Cold Lake
MUNICIPAL DISTRICT BONNYVILLE NO. 87
Armin A. Preiksaitis & Associates Ltd.
in association with: Associated Engineering

NOTE: This map is conceptual. Areas have been generalized and are approximate only. February 2009

FIGURE 2-3

3 Design Criteria

The City of Cold Lake has detailed stormwater design standards which have been attached in **Appendix G**. These standards are current at the time of the report but future designs will be based on the standards that apply at that time. Appendix G is prefaced with recommended changes to the design standards which will be discussed below.

The stormwater system consists of a minor system which includes pipes, manholes, catch basins and outfall structures, as well as a major system which consists of the streets, Storm Water Management Facilities (SWMF's), parkland, and overland runoff routes.

The City's design criteria are intended to apply to new development areas and contain provisions to minimize the inconvenience to residents, ensure un-interrupted traffic flow, and prevent flooding. Ponding depths are minimized through roadway grading design. These standards are rarely achievable in established urban areas that were developed to previous standards that did not recognize the significance of the major (surface) drainage systems, and where major regarding would be required to achieve the current standard. Therefore, in existing development areas, the goal of the system assessment and upgrade design will be to provide a minimum level of service sufficient to minimize the risk of flooding private property, not necessarily to eliminate ponding on roadways or to meet the detailed specifications for new drainage systems.

The design standards for the minor and major systems have been summarized below. Special exceptions required to suit existing development areas will be identified by italics in the discussion which follows:

3.1 MINOR SYSTEM

- The minor system shall convey runoff from snowmelt and rainfall events to an adequate receiving stream or pond without sustaining any surface ponding or excessive surface flows for up to a 1 in 5 year return period.
- For new developments the pipes should have adequate capacity to carry flows up to the 1:5 year storm. Storm sewer mains should be designed for gravity flow and a Manning's roughness coefficient of at least 0.013 is to be used to calculate the capacity of the sewer.
- Minimum and maximum flow velocities in any sewer shall be 0.60 m/s and 3.0 m/s respectively.
- The minimum depth of cover above the pipe obverts shall be 1.5 m.
- Storm sewer mains should be at least 300 mm in diameter with a minimum grade of 0.40%.
- Manholes should be spaced no greater than 150 m apart, and be installed at all changes in size, grade or alignment. The crowns of the pipes must be matched to maintain a continuous hydraulic gradeline.
- The flow channel depth through manholes should be at least one half of the diameter of the downstream sewer and be made to conform in shape and slope to that of the sewer.
- Catchbasin leads shall connect directly to a manhole with a 250 mm lead. All leads shall have a minimum grade of 1.0% and maximum length of 30 m.

- To prevent the occurrence of ponding, the maximum distance between catchbasins will be 150 m and road gutter flows shall not exceed 0.04 m^3/s between catchbasins during a 1:5 year storm.
- ***For existing developments, surcharging of the storm pipes may be permitted, provided that surcharge levels are below ground surface in a 1:5 year storm and the risk to private property is minimized in a 1:100 year storm. Manhole and pipe details will be required to meet the specifications if they are re-built or replaced for other reasons. These upgrades should be modeled to check the possibility of downstream impacts.***

3.2 MAJOR SYSTEM

During a 100 year storm event, the City requires the major storm drainage system to satisfy the following guidelines for all new development areas:

- No building should be inundated at its ground line.
- Continuity of the overland flow routes between adjacent developments shall be maintained.
- Depth of water at curb side should be less than 200 mm for all roadways.
- The maximum permitted distance for storm water to run continuously is 150 m on streets and 200 m on lanes
- The velocities and depths of flow in the major drainage system shall not exceed the values shown in **Table 2-1**:

Table 2-1
Permissible Depths for Submerged Objects

Depth of Flow (m)	Maximum Water Velocity (m/s)
0.8	0.5
0.3	1.0
0.2	2.0
0.1	3.0

- Trapped low storage should be implemented to offset peak flows where necessary to keep water velocities and depths below those noted above. Building elevations should be above trapped low ponding elevations and designed to drain surface runoff to the street or lane/utility right of way.
- ***For existing development areas, the goal should be to prevent flooding of buildings at the ground line. This requires assessment on an individual basis, but, generally, can be met by limiting the depth of ponding in the low areas to a maximum of 0.2 m. Other specifications may not strictly apply.***

3.3 COMPUTER MODELING

The City requires:

- The use of computer modeling for analysis of areas greater than 65 ha, design of stormwater management facilities, and for systems containing significant areas of undeveloped land.

- Stormwater models such as PCSWMM or XPSWMM are to be used to simulate major and minor systems with catchment areas less than 5 ha. The City also requires documentation about parameters used, drainage boundaries and network connectivity along with the model input and output to be submitted.
- Design storm hyetographs are to be developed using the Chicago Method. Shorter duration storms (1-4 hours) are to be used for design of storm collection systems and longer duration storms are to be used for design of stormwater management facilities.
- ***The storm hyetographs for the 4 hour Chicago storm and the 24 hour Huff storm (1st quartile, 50% probability) have been shown in Appendix G. These tables are currently not in the City's design standards and are recommended to be added to provide consistency in the use of design storm hyetographs for modeling exercises.***

3.4 STORM SERVICE DESIGN CRITERIA

- New storm sewers in re-development areas connecting to an existing main shall have a capacity which is the function of the ratio of the development area to the upstream area and the capacity of the existing main. It must not be greater than the 1:5 year discharge.
- Storm sewers for new development areas are to be designed for a 1:5 year discharge.
- ***In the present assessment, proposed upgrades were modelled to confirm their capacity and ensure they did not adversely impact downstream systems, which meets the intent of the two previous specifications.***

3.5 STORMWATER MANAGEMENT FACILITIES (SWMF)

SWMFs may be required to reduce peak flow rates to downstream sewer systems and/or watercourses, or to attenuate runoff for major drainage flows. Discussions will be limited to dry SWMFs only as DND's bird hazard restrictions prohibit wet SWMFs within the Bird Hazard Zone, which includes most of the City. **Figure 1-1** shows the outline of the current Bird Hazard Zone. ***The City's design criteria indicate that the restricted zone is within 3.2 km of the Airport Reference Point, which is not accurate and should be changed.***

- SWMFs are to be sized for 1:100 year storm volumes from the ultimate development with a maximum detention time of 96 hours.
- The SWMFs should have a maximum storage depth of 1.5 m and 0.6 m of freeboard above the 1:100 year high water level. The recommended interior side slopes are 7:1 (H:V), with a maximum length to width ratio of 4:1, minimum lateral and longitudinal slopes of 2% and 1% respectively.
- French drains should be provided where ground water tables are near the pond bottom elevation.
- Soil investigations shall be undertaken to determine specific soil permeability, salinity (or other potential contaminants), and groundwater table height.
- The Developer shall incorporate storm water treatment measures in the design of any SWMF to effect a minimum of 85% removal of sediments of particle size 75 microns or greater.
- Outflow from a SWMF system must be limited to 2 L/s/ha.

- The SWMF should be designed to attenuate volume from a 1:25 year design storm if an emergency outfall is provided. However if an emergency drainage route cannot be provided the SWMF should be designed to attenuate the volume from a 1:100 year storm with the outlet blocked.
- Grated outlet structures must be designed for twice their design capacity to account for clogging of inlets.
- Low flow by-pass for flows from minor events should be provided.

- ***Existing SWMFs are assessed to ensure they have adequate capacity for a 1:100 year storm plus a minimum of 0.5 m freeboard (preferably 1.0 m) or an emergency overflow at the 1:100 year level. Other provisions may not apply if they have not been built into the design of the SWMF.***

3.6 OUTFALLS

Outfall pipe obverts shall be above 5 year flood level and inverts shall be above winter ice level. Drop structures and energy dissipaters should be used where necessary to prevent erosion, and trash bars shall be installed to prevent unauthorized entry.

4 Methodology

A hydraulic and hydrologic model was developed using PCSWMM to evaluate the capacity of the existing storm sewer system. The model simulates the runoff volumes which are then routed to the nodes representing manholes, culvert upstream points, and ditch points. Flow conditions in the pipes are simulated to define water levels throughout the drainage system.

When the storm sewer system is surcharged, catch basins and manholes overflow to ground surface, where run-off is accumulated in low lying areas. The model simulates the depth of water that accumulates in these low areas in different storm events by assuming that an area of 400 m^2 is available for depth of ponding above the manhole at ground elevation. This approximates the ponding which occurs in trapped sags (low areas) in the major drainage system. The model also simulates backwater effects which raise water levels and restrict discharge rates.

The following sections provide details of the model development, the simulation of design storm events, and various options considered to improve the hydraulic performance of the storm drainage system.

4.1 EXISTING INFORMATION

The primary sources of information for assessing drainage conditions included the following:

- Survey Information.
- Municipal GIS database.
- CADD drawings of existing utilities.
- Land-use map.
- PDF format record plans.
- LiDAR data (approximate accuracy of +/- 0.30m).

4.2 GIS DATABASE

The City currently maintains a GIS database of its storm sewer infrastructure. However, much relevant information such as pipe size and inverts were missing from the database for approximately half of the pipes. There also exists a datum difference between the North and South Cold Lake, which would make it difficult to incorporate the storm infrastructure into one model.

4.3 SURVEY INFORMATION

SE Design was contracted to survey the entire storm infrastructure for the City, including manhole rim elevations, catch-basin locations, and pipe and culvert inverts. Field surveys were conducted at manhole, culvert, and outfall locations to measure invert elevations and pipe sizes. The survey information was then used for modeling. Assumptions were made for approximately 50 links where survey information was incomplete due to manholes that were too deep/wide, buried, or needed cleaning.

Overall, the number of model components which had to be estimated was relatively minor. Whereas-built data could not be corroborated, estimates were made to complete the model. These estimates will not significantly influence the modelling at the master plan level.

All missing invert and pipe sizes should be confirmed prior to design of any upgrades.

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4.4 MINOR SYSTEM

A model of the minor system was generated from the survey information. Overall, the model contains approximately 521 pipes, 90 ditches, 50 culverts, 8 orifices, 1 pump and 19 outfalls. The model network is shown in small scale in **Figure 2-1**, shown previously, and is described in more detail in following sections of this report. It does not include the 4 Wing storm sewer system which has been previously modelled.

4.5 MAJOR SYSTEM

The model contains several elements to describe key components of the major drainage system. Storage areas (basins) were added to the model to represent storm ponds and flood areas. Weirs were added to represent potential spills over roadways. Additional nodes/links were added to simulate overland flow routes. The model contains approximately 27 overland flow connections and 32 overflow weirs. As noted above, storage in low areas (trapped sags) was approximated with a surface area of 400 m^2 at each manhole, representing a street width of 10 m and a length of 40 m.

4.6 MODEL CATCHMENTS

Catchment areas for the City were delineated from the available LiDAR Data, using Manifold GIS. Catch basin locations and culvert inlets were obtained from the GIS database and formed the basis for determining the catchment areas. Approximately 807 catchments were defined with an average area of 3 ha as shown in **Figure 4-1**. **Appendix H** provides details of the catchments and other model parameters.

The various catchment parameters and their definitions are described below:

Width: The width of the catchment was calculated from its length, which in turn was calculated from the maximum and minimum elevations in the catchment and the slope of the catchment.

Area: The area of each catchment was estimated from GIS as the physical area of the catchment.

Outlet Node: An Outlet Node was assigned to each catchment based on location of the closest manhole to the catchbasin inlet which was used to define the catchment. In case of catchments upstream of culverts, the areas were assigned to the upstream node of the culverts.

Slope: The average slope of the catchment was calculated from the LiDAR DEM (Digital Elevation Model) data base using the Manifold GIS.

Percentage Impervious Area: The impervious percentage for each catchment was calculated by overlaying the land-use map on the catchment map in PCSWMM and calculating the weighted impervious area based on land-use. The imperviousness assigned to each individual land use is shown in **Table 4-1**. Note that the land-use designation applies to the lot area and does not include the streets. The road right-of-ways were deemed to be 50% impervious.

Table 4-1
Percent Imperviousness based on Land-Use

Municipal Land Use	Municipal Zoning	Percent (%) Impervious
Downtown Commercial District	C1	90
Arterial Commercial District	C2	90
Shopping Centre District	C3	90
Neighbourhood Commercial District	C4	90
Direct Control District	DC	40
Direct Control District	DC1	40
National Defence Establishment	FW	40
Industrial District	I	70
Lakeshore Commercial	LC	90
Public Services District	PS	40
Residential (SF detached)	R1	40
Residential (SF detached)	R1A	40
Residential (SF detached)	R1B	40
Residential (SF detached)	R1B-1	40
Residential (SF detached)	R2	40
Residential District	R2A	40
Residential District (Medium Density)	R3	60
Residential District (High Density)	R4	70
Residential Estates District	RE	40
Mobile Home Subdivision District	RMHS	40
Roads	TR	50
Urban Reserve District	UR	0

Values used for other catchment model parameters have been summarized in **Table 4-2**, below:

Table 4-2
Model Parameters

Parameter	PC SWMM Model (Urban-Greater than 10% Impervious)	PC SWMM Model (Rural-Less than 10% Impervious)
Impervious Area Manning's n	0.015	0.015
Pervious Area Manning's n	0.250	1.000
Impervious Depression Storage	5 mm	5 mm
Pervious Depression Storage	2 mm	2 mm
Minimum Infiltration Rate	2.5 mm/hr	0.5 mm/hr
Maximum Infiltration Rate	75 mm/hr	75 mm/hr
Decay Rate	4 /hr	2/hr
Drying Time	7 days	7 days

Infiltration in PCSWMM was modeled using the Horton's Equation. The equation is based on empirical observations showing that infiltration decreases exponentially from an initial maximum rate to some minimum rate over the course of a long rainfall event. Input parameters include the maximum and minimum infiltration rates, a decay coefficient that describes how fast the rate decreases over time, and the time it takes a fully saturated soil to completely dry (used to compute the recovery of infiltration rate during dry periods).

The estimates made in **Table 4-2** were tested with a sensitivity analysis. The Manning's n and Horton's parameters were modified for rural areas to obtain lower flows in the range of 2 L/s/ha in the 1:100 year storm, which is the estimated pre-development discharge rate in Cold Lake.

4.7 BOUNDARY CONDITIONS

Boundary conditions represent the water levels at the outlets from the storm drainage system **Figure 2-1**, shown previously, shows the locations of the storm outfalls.

The northern portion of the City primarily drains to Cold Lake through 15 outfalls. Most of the remaining portion of the City drains to Palm Creek. Other portions which drain east to an unnamed Lake have not been modeled. Palm Creek has been modelled as far downstream as its confluence with Marie Creek. Portions of 4 Wing that drain to Palm Creek have been included in the model as lumped catchments.

The outfalls were assumed to be flowing free without the influence of backwater conditions. This implies that the levels in Cold Lake or Marie Creek would not influence the model.

4.8 DESIGN STORMS

The design criteria requires the use of 1:5 year shorter duration storms (1-4 hours) for analyzing and designing the storm sewer, and 1:100 year longer duration storms (4-24 hours) for analyzing the storm water management facilities.

The design criteria specify that the rainfall hyetograph developed by the Chicago method be used for the analysis. However, rainfall hyetographs developed by the Chicago method are applicable to shorter duration (4 hour) storms only. Hence, the Huff first quartile rainfall hyetograph (50% probability) was used to represent the longer duration storms (24 hour).

The rainfall hyetographs for the Chicago method and the Huff first quartile method have been tabulated in **Appendix G**.

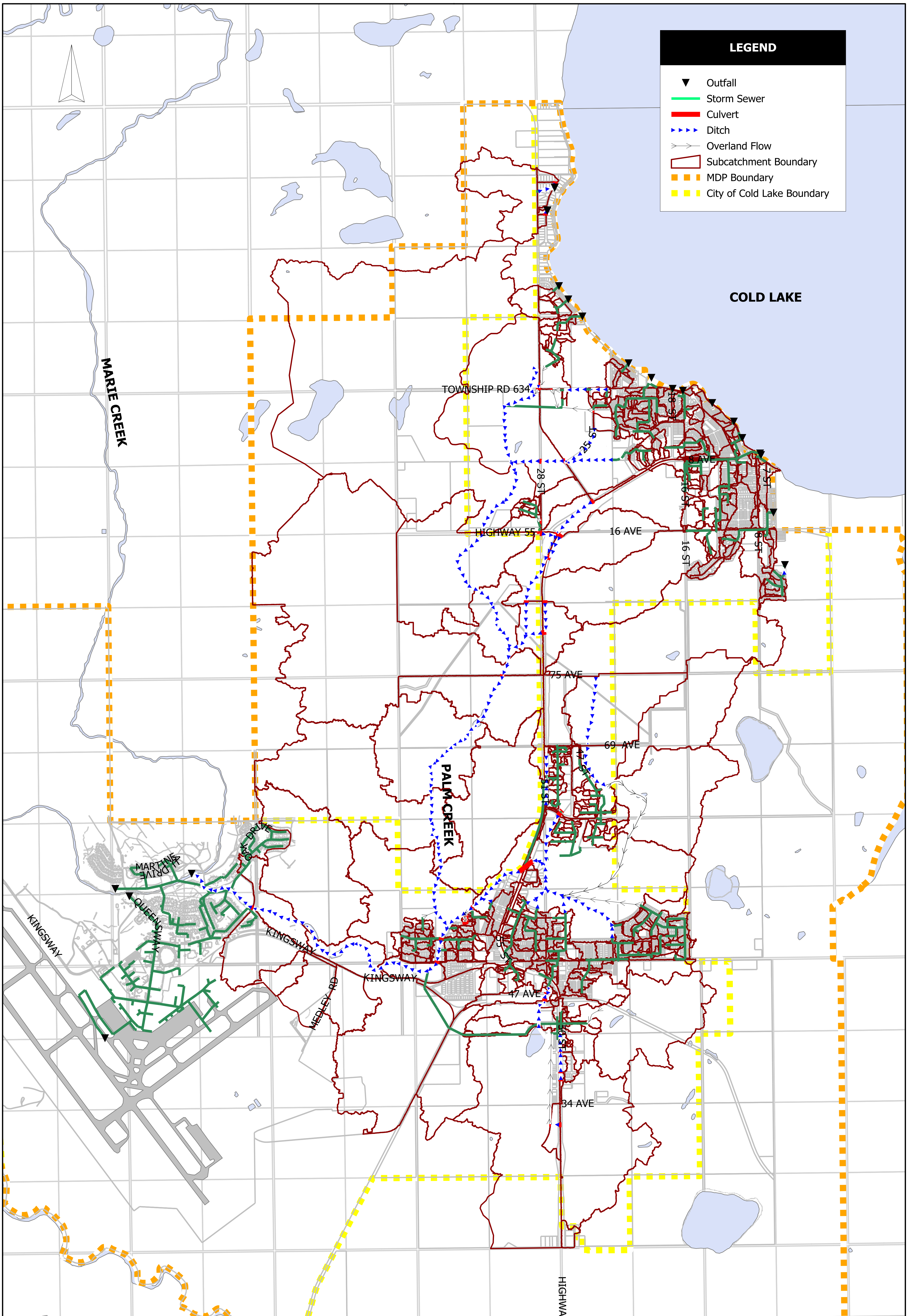

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Figure 4-1
Existing Sub-catchments Map

PROJECT No.: 2012-3590

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5 Existing System Performance

5.1 OVERALL SYSTEM CAPACITY - EXISTING CONDITION

The PCSWMM model of the City's storm sewer system was developed as discussed in the previous sections, and was used to simulate the 1:5 year and 1:100 year 4 hour and 24 hour design storms.

Figures 5-1 to **5-4** show the model results for the existing system:

- **Figures 5-1** and **5-2** show the modeled flow loading and surcharge levels during the 1:5 year 4 hour storm in the existing condition for North and South Cold Lake respectively.
- **Figures 5-3** and **5-4** show the modeled flow loading and surcharge levels during the 1:100 year 4 hour storm in the existing condition for North and South Cold Lake respectively.

The flow loading is the ratio of peak flow to pipe capacity. The blue lines show pipes carrying 100% to 150% of their design capacity, orange lines show pipes carrying 150% to 200 % of their pipe capacity and red lines show pipes carrying more than 200% of their capacity.

Modeled surcharge levels indicate the distance from ground surface to peak water level during the storm event simulation. Orange and red dots indicate locations where the hydraulic grade line rises above the ground surface by less than 0.20m or greater than 0.20 m respectively. At these locations water spills out of the manholes or ditches. Green dots indicate locations where hydraulic gradeline is contained within the manholes or ditches.

The model assumes that the hydraulic grade line elevation rises above the ground elevation when surcharged. A ponding area of 400 sq m was assigned to all non-storage nodes in the model to simulate ponding when the water surface level rises above the ground elevation.

The model results show that eight storm lines in North Cold Lake and five storm lines in the South Cold Lake do not have adequate capacity, which could lead to flooding in a major storm event. Each area of concern has been highlighted and identified on **Figures 5-3** and **5-4.**

5.2 PROPOSED UPGRADING TO EXISTING SYSTEM

The current Municipal standards require that flooding of private property be prevented during a 1:100 year storm. This objective can be achieved by limiting the surcharge in the storm system to below ground surface in the 1:5 year storm and less than 0.2 m above ground during a 1:100 year 4 hour storm.

Proposed upgrades were limited to areas with a history of flooding, trapped sags deeper than 0.2 m, and off-street drainage locations where the model results showed surcharge to ground level during a 1:5 year storm or surcharge above 0.2 m during a 1:100 year storm. The criteria for upgrading the storm sewer are summarized below. Upgrades to the storm system were proposed if the conditions in the **Table 5-1** were met.

Table 5-1
Criteria for Upgrading Existing Storm Sewer

Surcharge to ground during a 1:5 year Storm	**AND**	Sag Depths Greater than 0.2 m
OR		**OR**
Surcharge to 0.2 m above Ground During a 1:100 Year Storm		Off Street Drainage
		OR
		History of Flooding

Figures 5-5 and **5-6** show the proposed upgrades in North and South Cold Lake respectively.

A detailed assessment for each storm mainline has been summarized in **Appendix A**.

The model was then modified to simulate the performance of these upgrades in the 1:5 and 1:100 year 4 hour storms.

- **Figures 5-7** and **5-8** show the ability of proposed pipe upgrades to convey runoff in a 1:5 year storm.
- **Figures 5-9** and **5-10** show pipe flows and surcharge levels in the 1:100 year, 4 hour storm event.

The same color coding conventions have been used as in the existing condition.

Results show a significant improvement (reduction in flood risk) in both events. Note that it is not always possible or cost-effective to completely eliminate flooding in existing areas developed to previous standards, and that some risk of localized flooding still remains.

5.3 STORMWATER MANAGEMENT FACILITIES

Table 5-2 summarizes the performance of the existing SWMFs in the 1:100 year storm event compared with a the original design estimates. The model high-water level (HWL) is the higher of the 4 hour or 24 hour duration design storm elevation.

Comparison with the original design HWL indicates differences of as much as 1.0 m in water levels, with the modelled elevations typically being higher than the design HWL indicated in the record plans. As the original design assumptions are generally not available, the reason for these discrepancies could not be determined. It could be partly due to datum differences or to changes in development or drainage plans over time.

The right-most column in **Table 5-2** shows the available freeboard for each pond, being the vertical height between the model HWL and the lowest ground elevation around the pond. Most SWMFs provide more than 0.5 m of freeboard, which is the recommended minimum.

There are two exceptions:

- The Nelson Height dry pond has a very small outlet control orifice, resulting in the pond overtopping its banks in the 1:100 year storm. Replacing the orifice with one having a larger opening is a simple fix that would lower the HWL to its design value.

- The Lakeridge dry pond is also indicated to be overtopped but this could not be confirmed because record drawings were not available. The dry pond was modelled using topography from the LiDAR map and an assumed outflow rate of 2.0 L/s/ha, corresponding to the design value for Cold Lake. It appears that a higher overflow rate may have been used. The capacity of this pond is under review.

Table 5-2
Stormwater Management Facilities Summary

Model ID	Neighbourhood	Pond Bottom (m)	Model HWL (m)	Design HWL (m)	Spill Elevation (m)	Free Board	Notes
O-38	Nelson Heights	542.06	545.36	544.40	544.63	-0.73	Replace outlet control orifice
AE-O-37	Lakeridge Dry Pond	550.80	552.90	551.65	552.60	-0.30	To be confirmed (work in progress)
O-2889	Aspen Ridge	551.38	552.75	553.30	553.30	0.55	
AE-O-15	Lefebvre Heights	558.51	559.50	559.00	561.00	1.50	
O-3072	Creekside Estates	535.60	537.14	537.75	538.35	1.21	
AE-O-16	Tri-City Mall	533.93	535.63		536.50	0.87	
OUTF-67	Tri-City Residential	532.66	534.45	534.75	535.01	0.56	
AE-O-19	Fontaine Village	531.28	533.09	533.15	533.75	0.66	
DN_56	Meadows	530.64	531.91	531.40	532.70	0.79	

5.4 COST ESTIMATE FOR PROPOSED UPGRADING

A preliminary estimate of the cost of pipe upgrades is provided in Table 5-3 below. The cost of the proposed storm sewer pipe, manhole/catchbasins, surface works and landscaping is included. The cost also includes 50% for Engineering and contingencies. **Appendix A** provides details.

Table 5-3
Cost Summary for Proposed Upgrades

LINE	Preliminary Cost	Area
LINE N1	$ 447,000	Cold Lake North
LINE N2	$ 224,000	Cold Lake North
LINE N3	$ 338,000	Cold Lake North
LINE N4	$ 1,207,000	Cold Lake North
LINE N5	$ 366,000	Cold Lake North
LINE N6	$ 844,000	Cold Lake North
LINE N7	$ 1,203,000	Cold Lake North
LINE N8	$ 130,000	Cold Lake North
LINE S1	$ 462,000	Palm Creek
LINE S2	$ 298,000	Palm Creek
LINE S3	$ 4,793,000	Meadows
LINE S4	$ 3,456,000	Meadows
LINE S5	$ 1,016,000	Meadows
Total	**$14,784,000**	

2013 Dollars including Engineering and Contingencies (45%)

These costs reflect upgrades necessary to the existing system.

Expansion of the storm system will still be required to accommodate drainage for new developments in future. Generally, these requirements will be met through construction of new facilities that do not drain through existing facilities. Stormwater management concepts for future growth of the City have been discussed in the following Section.

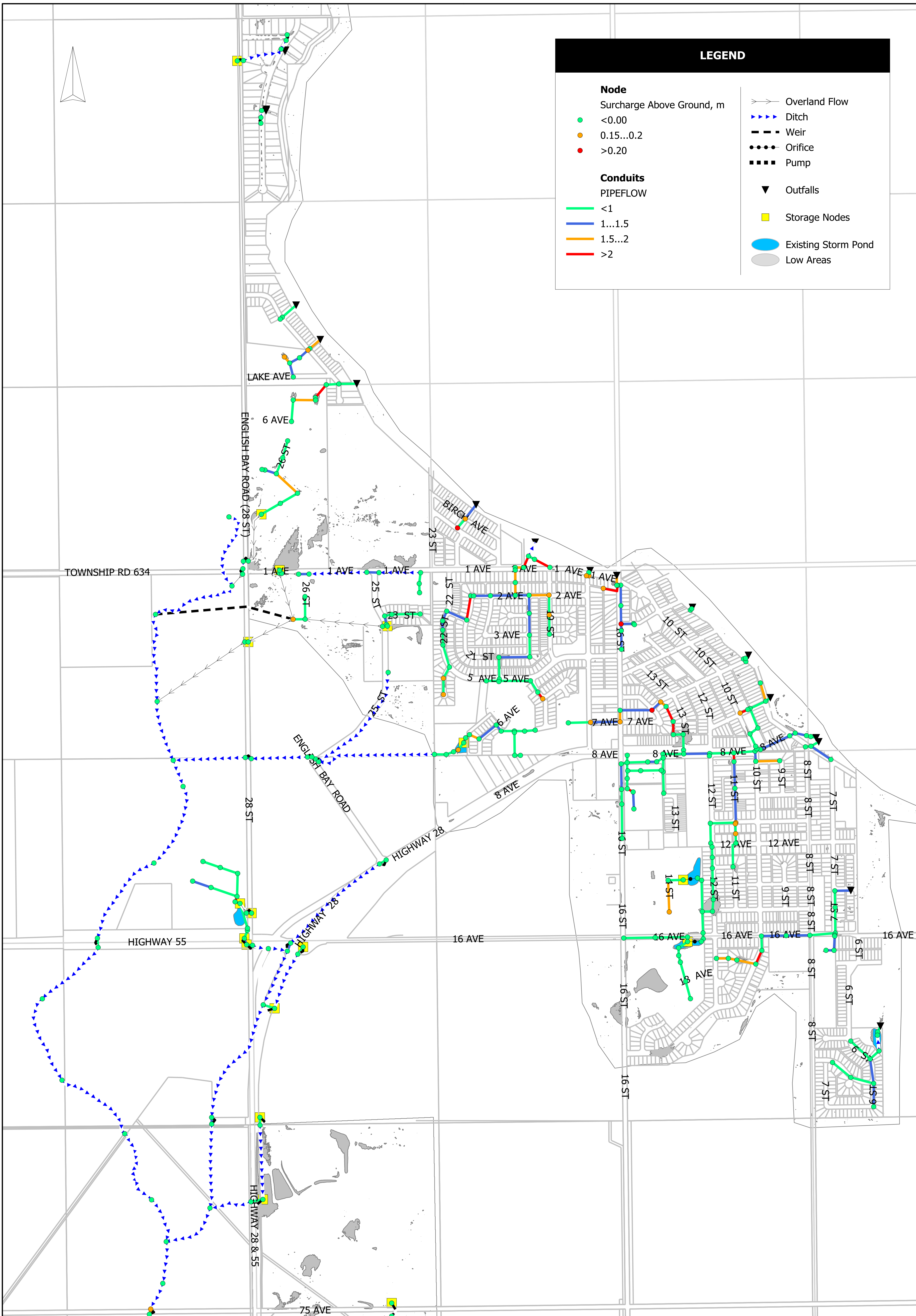

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Figure 5-1
MODEL FLOWS AND SURCHARGE LEVELS
1:5 YEAR STORM (NORTH COLD LAKE)

PROJECT No.: 2012-3590
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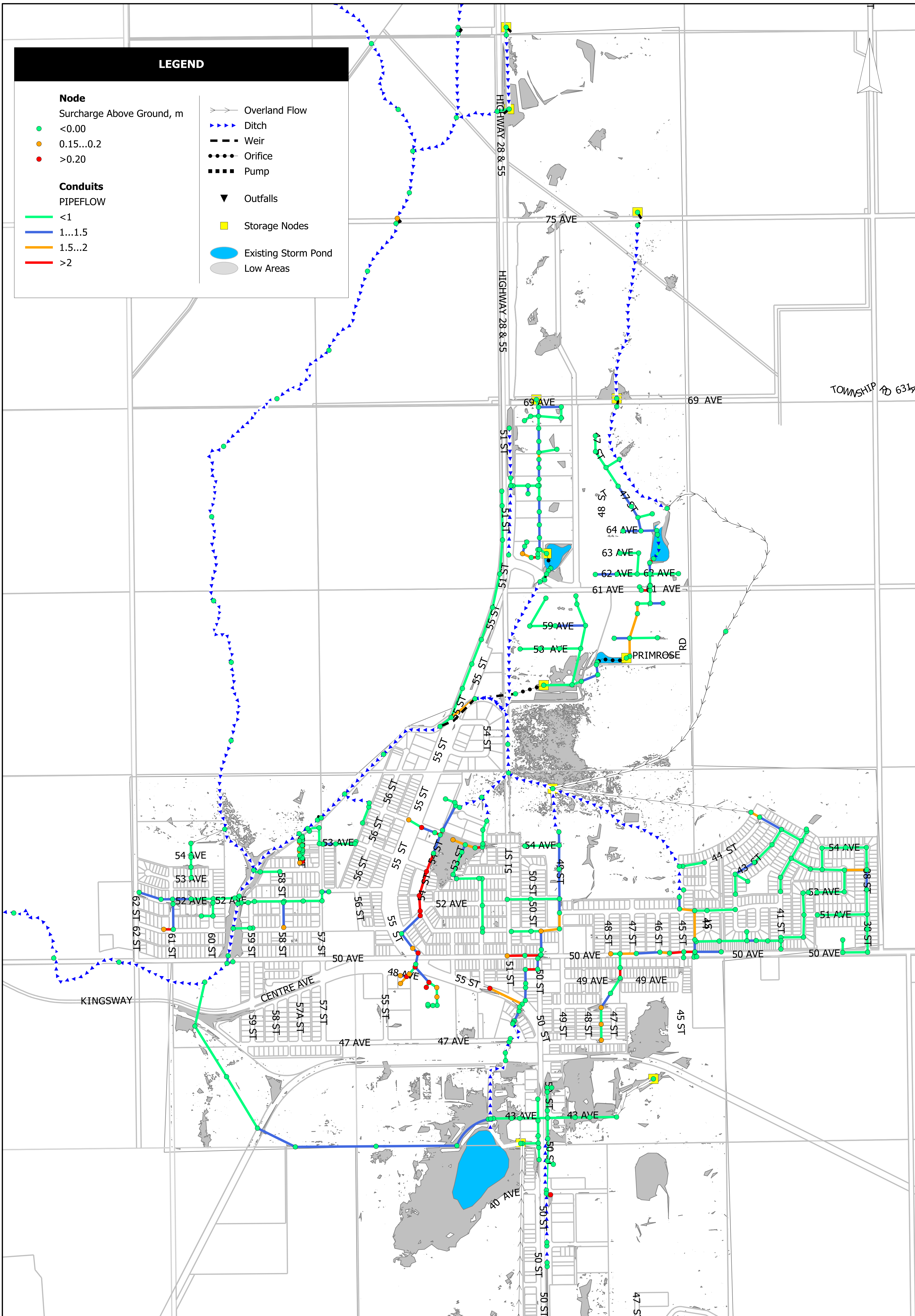

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Figure 5-2
MODEL FLOWS AND SURCHARGE LEVELS
1:5 YEAR STORM (SOUTH COLD LAKE)

PROJECT No.: 2012-3590
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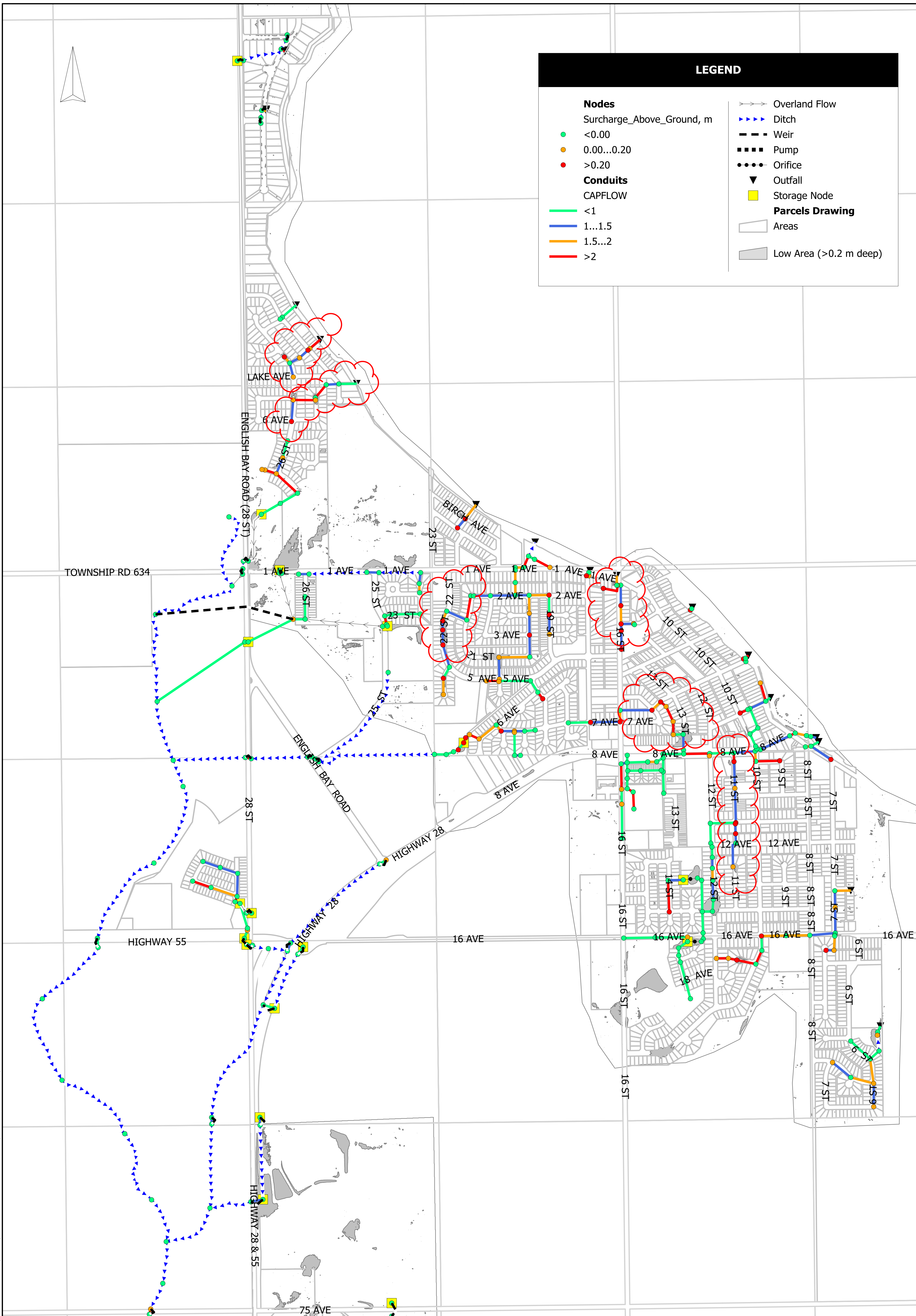

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Figure 5-3
MODEL FLOWS AND SURCHARGE LEVELS
1:100 YEAR 4 HOUR STORM (NORTH COLD LAKE)

PROJECT No.: 2012-3590
DATE: 12/16/13
SCALE: 1:15,000

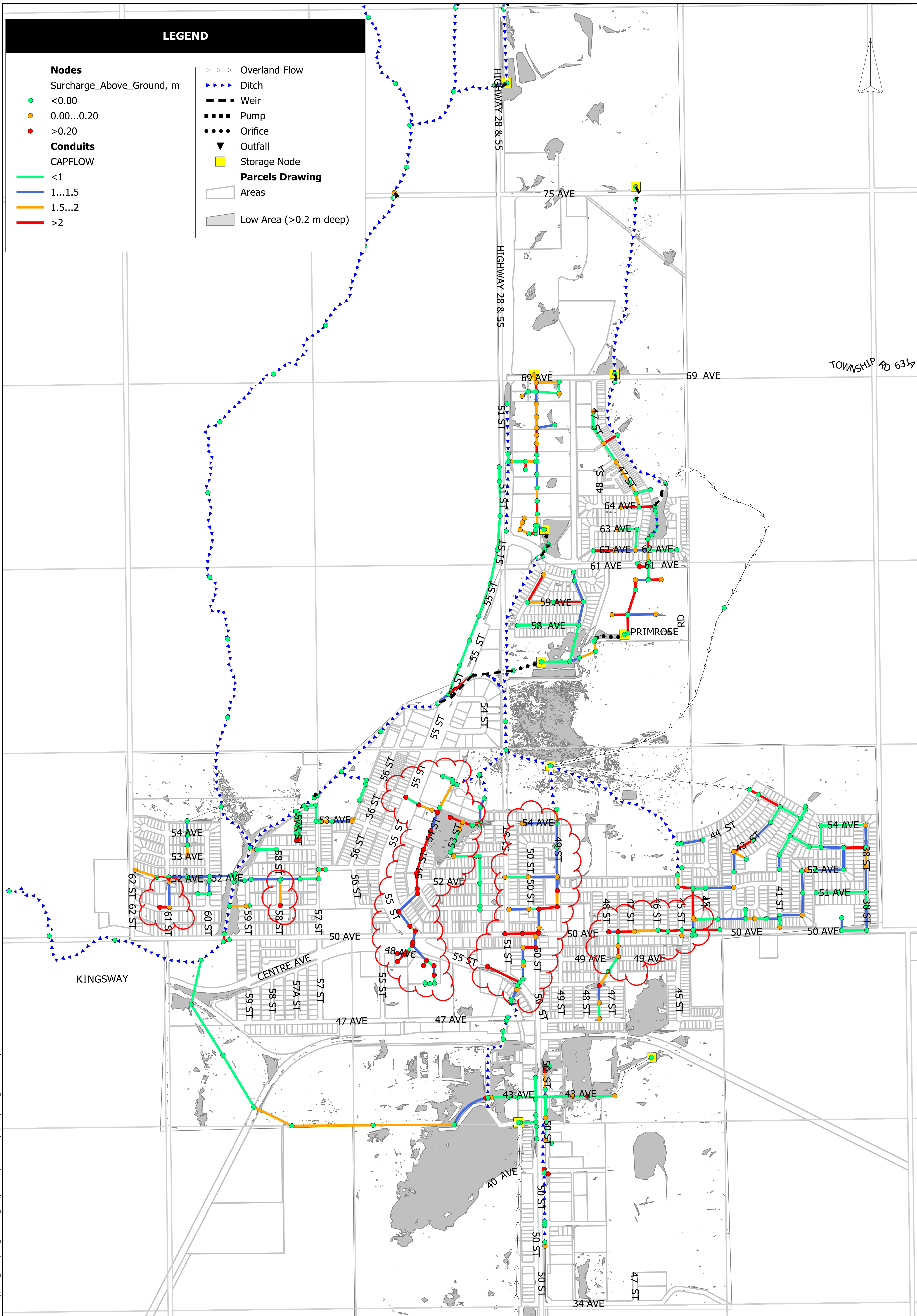

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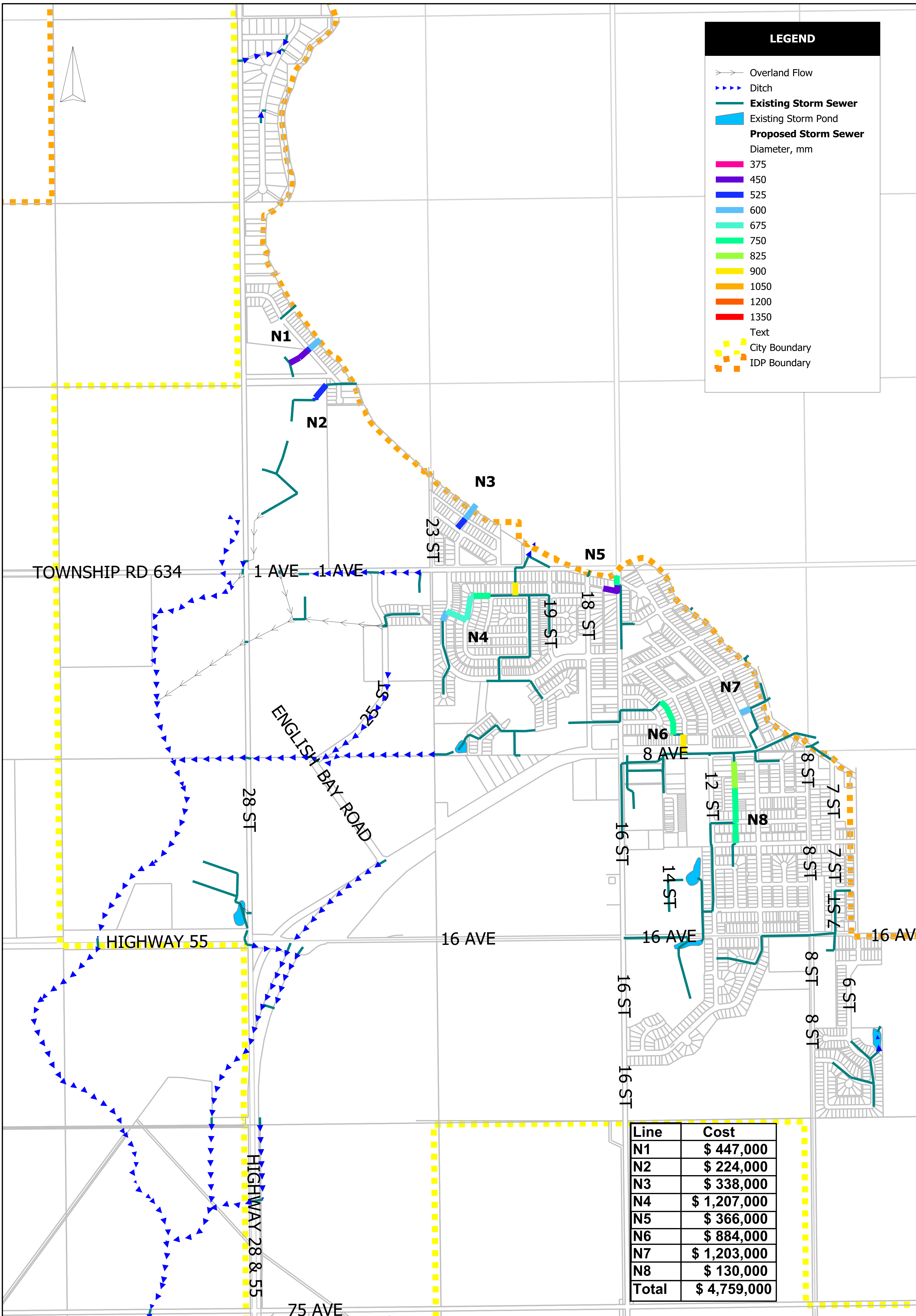
Figure 5-4
MODEL FLOWS AND SURCHARGE LEVELS
1:100 YEAR 4 HOUR STORM (SOUTH COLD LAKE)

PROJECT No.: 2012-3590

DATE: 12/16/13

SCALE: 1:15,000



Line	Cost
N1	$ 447,000
N2	$ 224,000
N3	$ 338,000
N4	$ 1,207,000
N5	$ 366,000
N6	$ 884,000
N7	$ 1,203,000
N8	$ 130,000
Total	$ 4,759,000

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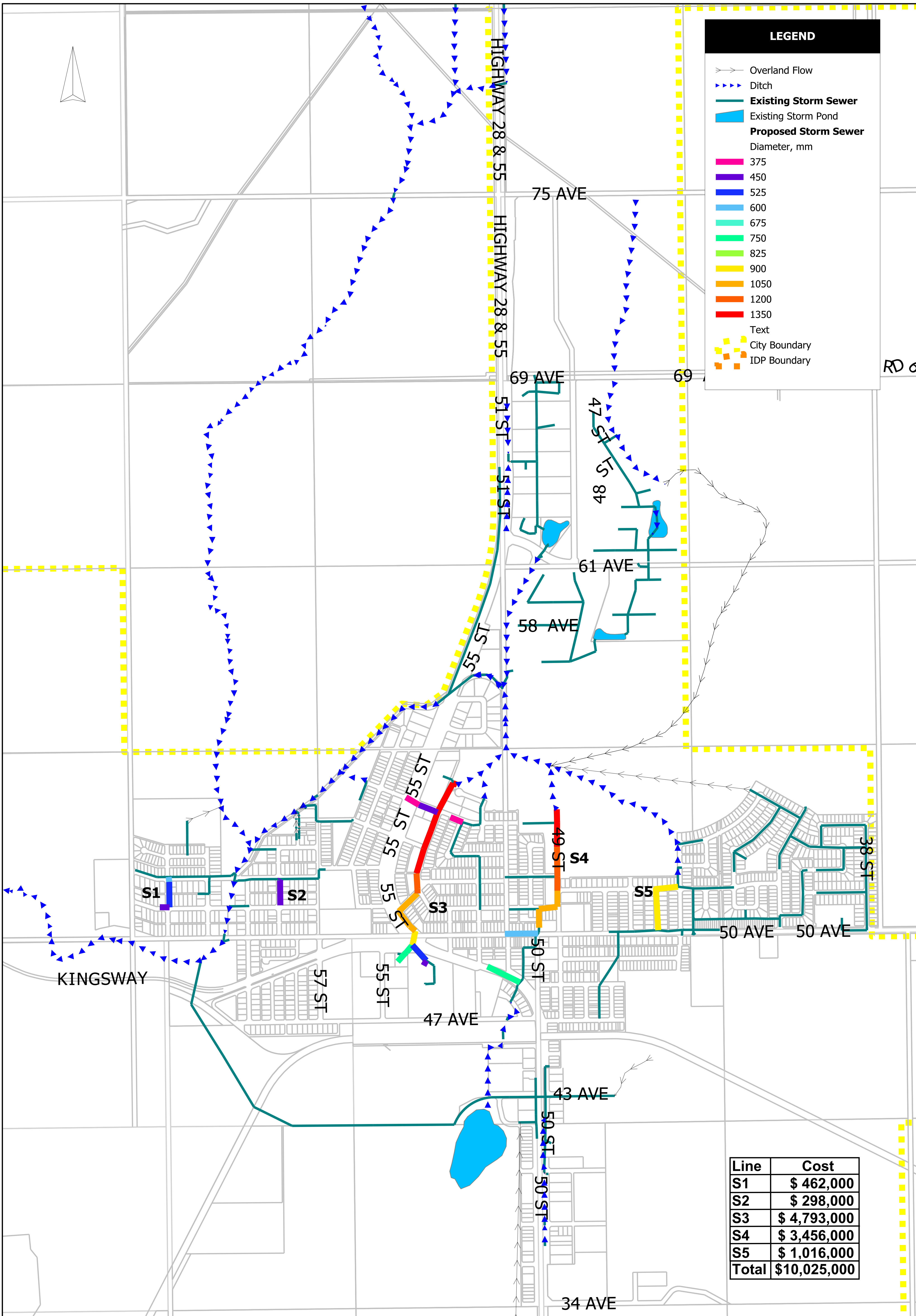
Figure 5-5
PROPOSED UPGRADES
TO EXISTING STORM SYSTEM (NORTH COLD LAKE)

PROJECT No.: 2012-3590

DATE: 3/19/2014

SCALE: 1:15,000



Line	Cost
S1	$ 462,000
S2	$ 298,000
S3	$ 4,793,000
S4	$ 3,456,000
S5	$ 1,016,000
Total	$10,025,000

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City of Cold Lake

CITY OF COLD LAKE
MASTER DRAINAGE PLAN

Figure 5-6
PROPOSED UPGRADES
TO EXISTING STORM SYSTEM (COLD LAKE SOUTH)

PROJECT No.: 2012-3590

DATE: 3/19/2014

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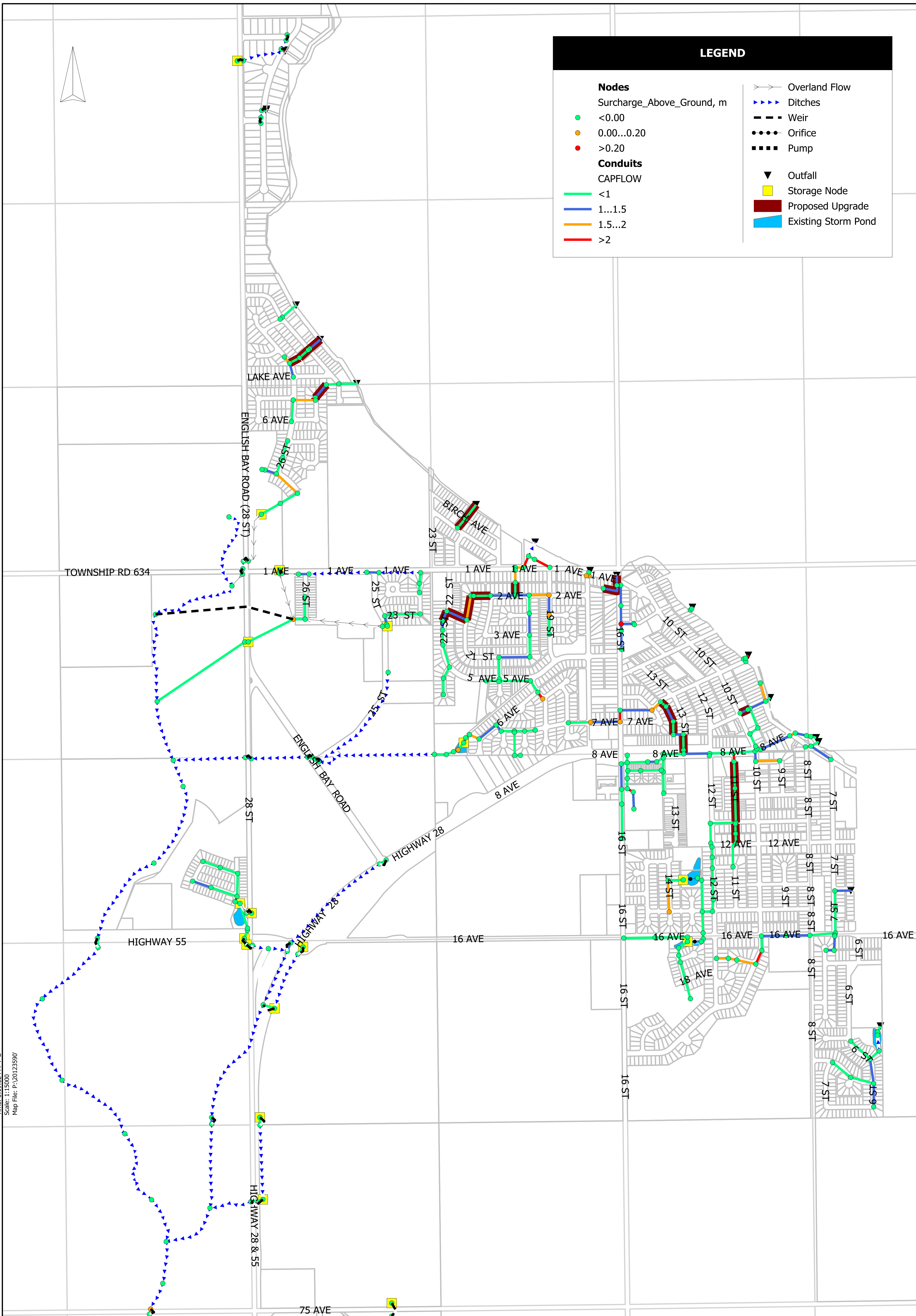

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CITY OF COLD LAKE

MASTER DRAINAGE PLAN

Figure 5-7

MODEL FLOWS AND SURCHARGE LEVELS

With UPGRADES TO EXISTING SYSTEM

1:5 YEAR STORM (NORTH COLD LAKE)

PROJECT No.: 2012-3590

DATE: 12/13/13

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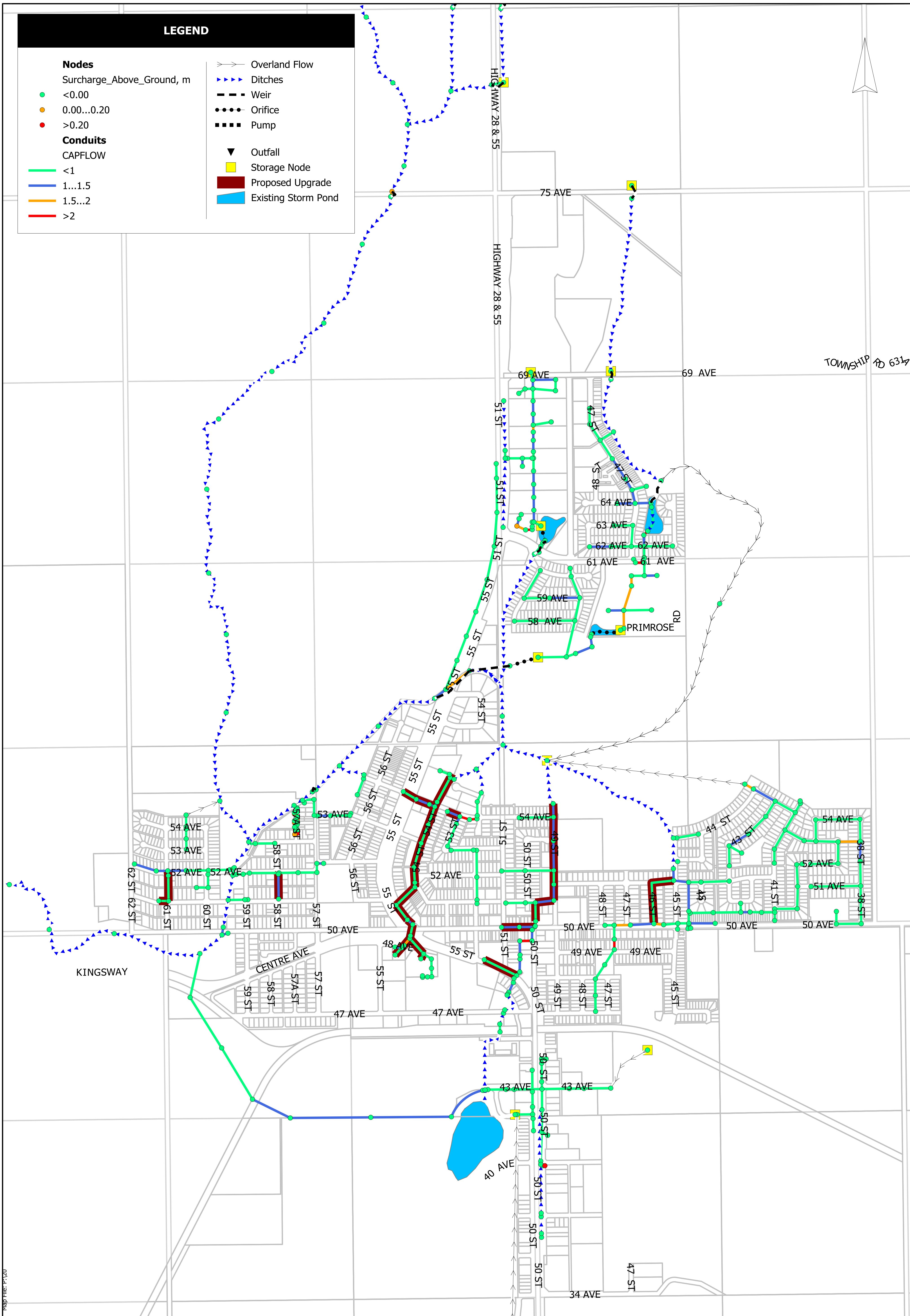

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City of Cold Lake

CITY OF COLD LAKE
MASTER DRAINAGE PLAN

Figure 5-8
MODEL FLOWS AND SURCHARGE
With UPGRADES TO EXISTING SYSTEM
1:5 YEAR STORM (SOUTH COLD LAKE)

PROJECT No.: 2012-3590
DATE: 12/13/13
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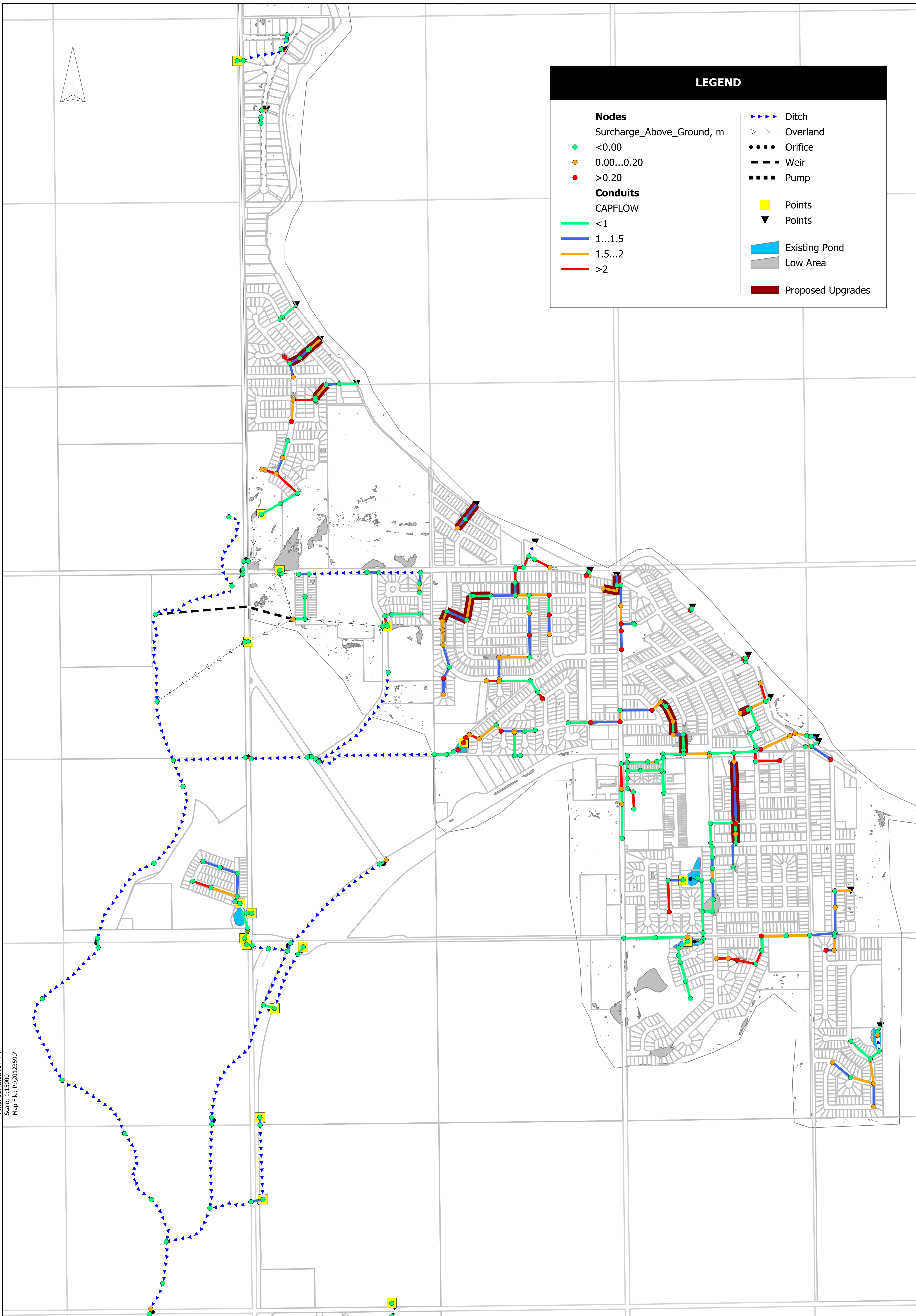

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CITY OF COLD LAKE

MASTER DRAINAGE PLAN

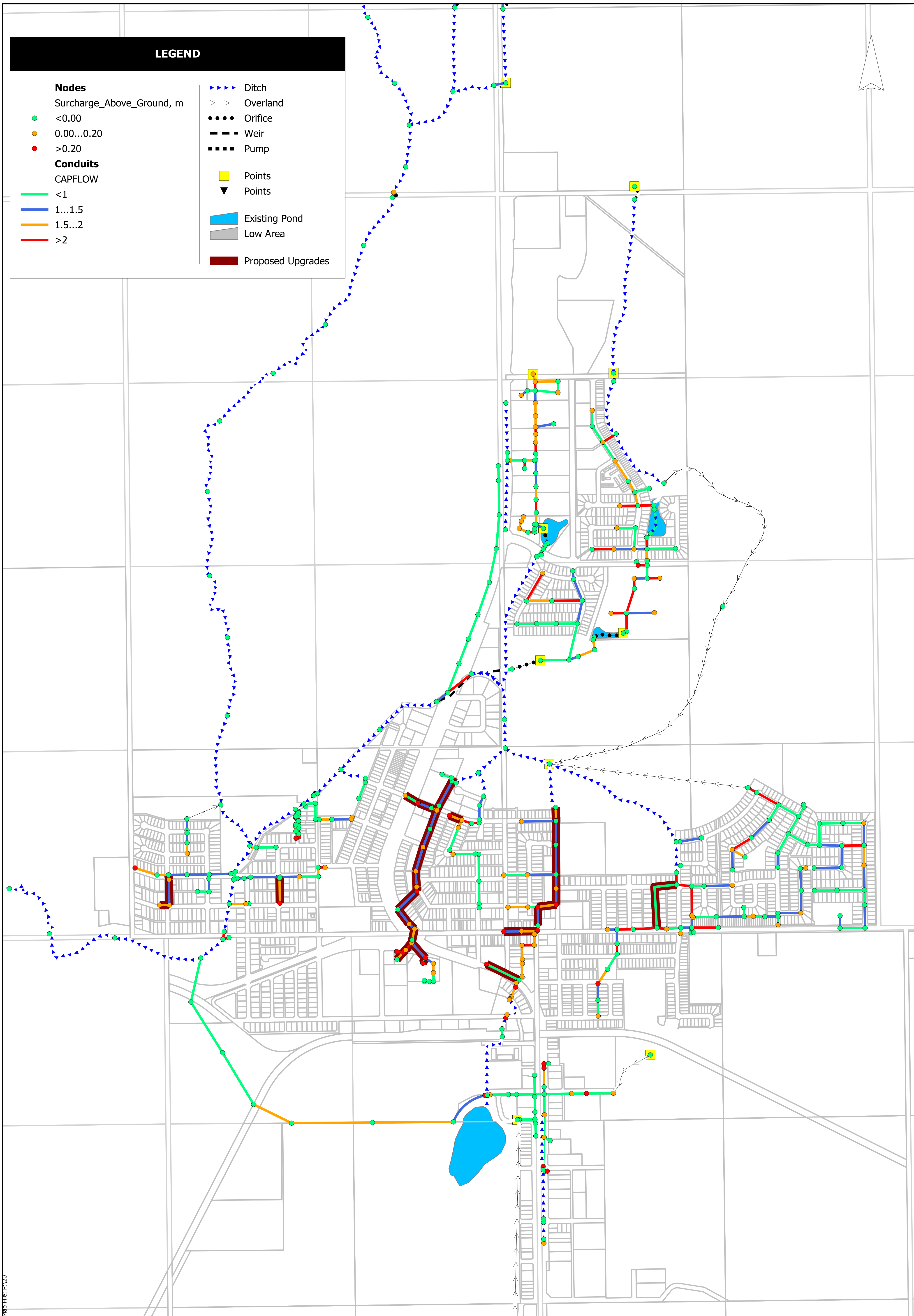
Figure 5-9

MODEL FLOWS AND SURCHARGE LEVELS
1:100 YEAR 4 HOUR STORM WITH
PROPOSED UPGRADES (NORTH COLD LAKE)

PROJECT No.: 2012-3590

DATE: 4/4/2014

SCALE: 1:15,000



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City of Cold Lake

CITY OF COLD LAKE
MASTER DRAINAGE PLAN

Figure 5-10
MODEL FLOWS AND SURCHARGE LEVELS
1:100 YEAR 4 HOUR STORM WITH
PROPOSED UPGRADES (SOUTH COLD LAKE)

PROJECT No.: 2012-3590

DATE: 4/4/2014

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6 Future System Assessment

6.1 DRAINAGE BASINS

The City of Cold Lake can be broadly divided into six major basins as shown in **Figure 6-1**.

- Cold Lake North Basin
- Meadows Basin
- 43 Avenue Basin
- Palm Creek Basin
- DND – 4Wing Basin
- African Lake Basin

Areas on the west, east, and south that drain away from the project area can be classified as fringe areas. These are also shown in **Figure 6-1**.

6.2 OVERALL DRAINAGE SYSTEM

Stormwater management facilities (SWMFs) were conceptually defined for future conditions. A total of 91 ponds have been identified.

Each of the Stormwater Management Facilities (SWMFs) has been conceptualized as a dry pond with 1.5 m of active storage and 1 m of free board. Where appropriate the SWMFs have also been designated as in-line facilities, to account for flows coming from upstream catchments and SWMFs.

Figure 6-2 shows the location of the future catchments, SWMFs, and drainage connections. A larger version is provided in **Appendix B** along with details of the proposed facilities.

Table B-1 in **Appendix B** provides a summary of the drainage area, land use, pond size, volume, pond bottom, and high water level for each SWMF.

Much of this information has been extracted from the previous *2006 Master Drainage Plan* and has been updated based on a review of topography, development patterns, and more recent planning information. Future land uses have been based on land uses outlined in the *Municipal Development Plan* (2007) and *Intermunicipal Development Plan* (2009), to estimate the runoff to, and consequently, the size of each SWMF.

The various drainage basins are discussed further below based on the existing and proposed drainage patterns.

6.3 NORTH COLD LAKE BASIN

The North Cold Lake Basin primarily consists of the areas along the Cold Lake shoreline that drain to the Lake as shown in **Figure 6-1**. The North Cold Lake Basin comprises approximately 708 ha.

The basin is currently zoned primarily as a Residential and Urban Reserve with a small portion of Commercial and Public Service land use. The basin also has offsite areas outside the City Limits contributing to it, primarily on the west and east sides.

6.3.1 Existing Drainage

The basin drains north to Cold Lake by storm sewers, overland flow, and ditches. There are 16 storm sewer outfalls in this basin. A ridge in North Cold Lake divides this basin from the areas draining south to Palm Creek. Portions of the basin along Lake Shore Drive have isolated storm catchbasins that drain directly to the Lake, and are included in the 16 outfalls mentioned previously.

The basin generally has relatively steep ground slopes and good drainage. Isolated instances of flooding can be attributed to pipe capacity issues which can be resolved by the pipe upgrades proposed in **Section 5.**

6.3.2 Proposed Drainage

The proposed drainage patterns for this basin will be retained and the basin will continue to drain to Cold Lake in the future. Some pipes are proposed to be upgraded in future to mitigate isolated instances of flooding as discussed in Section 5. New SWMFs and outfall pipes/ditches will be required to service the new development on the edge of this basin.

6.4 MEADOWS BASIN

The Meadows basin lies to the east of Highway 28 and extends to African Lake on the East, the Iron Horse Trail on the South, and Forest Heights ASP on the North. **Figure 6-1** shows the principal drainage features and the extent of the basin.

The Meadows catchment contains approximately 900 ha currently in a mix of Commercial, Residential, and Urban Reserve land uses. Approximately 244 ha of this catchment lie outside the current City Limits.

6.4.1 Existing Drainage

The Meadows is a low-lying area in the south-central portion of the basin. It was reportedly a lake in the early 20th Century, but over time a number of drainage improvements have been made, principally in constructing the Meadows Ditch which goes under Highway 28 and drains to Palm Creek. These improvements have provided some measure of drainage to the Meadows, but the ditch is too high to effectively drain the area. Lack of maintenance in the ditch has also contributed to backup of runoff in the ditch. The Highway 28 culvert is prone to icing in the winter, likely due to drainage of groundwater.

To compound these issues, the Meadows area is generally underlain by a layer of water-bearing sand at a depth of about 4 to 5 m below ground surface, as indicated in the geotechnical study provided in **Appendix F**. The area has historically had a high groundwater table, extending up to about one meter from ground level.   The underlying sands are water-bearing and appear to be a part of a regional groundwater aquifer with confined (pressurized) groundwater levels that reach ground surface in places.

These conditions provide challenges to the construction of underground services and often have required de-watering to permit such construction in the Cold Lake area. The confined aquifer conditions require that stormwater management facilities be located some height above the sand layer to prevent basal heave, instability of the side slopes, and impacts to regional groundwater supplies.

Most of the existing development in South Cold Lake, to the north of the Millennium Trail, drains to the Meadows through storm sewer systems. A network of ditches carries the runoff from the south, through the Meadows, to the Meadows Ditch at Highway 28. The ditches and the floodplain area are very flat and provide significant volumes of storage to help attenuate runoff from the development area.

Additional development has occurred in recent years to the north of the Meadows, on the east side of Highway 28, consisting of residential and commercial land uses. Individual development areas have been provided with stormwater management facilities designed to discharge at pre-development rates (1.8 to 2.0 L/s/ha).

The Meadows basin drains across Highway 28 to the Meadows Ditch through an 1800 mm concrete culvert that was recently installed with the Highway 28 twinning in the vicinity (previously there were two 900 mm diameter CSP pipes)   The culvert has a history of icing in the winter. The Meadows ditch is deep and has steep side slopes that are difficult to maintain. The Palm Creek channel, further downstream, between 53 Avenue and 62 Street, has had a history of flooding and was upgraded in the 1980's.

6.4.2 Proposed Drainage

Development of the low-lying areas of the Meadows will require special measures to deal with the drainage and geotechnical (soils and groundwater) conditions of the area.

Stormwater management (storage) will be required to control peak flows to the capacity of Palm Creek and the downstream drainage systems and to replace the existing storage area that has historically regulated the runoff from this area in the past. The SWMF(s) will need to control runoff from the proposed development as well as existing development in South Cold Lake that were developed without such facilities.

The basin outfall will need to carry the outflow from the Meadows SWMF(s) as well as the runoff from the other contributing areas of the basin, which will increase in volume as additional areas are developed in the future. Runoff from those future development areas will be controlled with a number of additional SWMFs in the basin, each discharging at a rate of 2.0 L/s/ha, which will contribute to the total flow carried by the outfall.

The Meadows drainage options were evaluated in detail in Technical Memorandum No. 1 (TM 1) in **Appendix C**. Several options were explored for draining the area and a detailed geotechnical investigation was recommended. The following options were considered for the outfall from the Meadows in the Technical Memorandum:

- Option 1: Existing Outfall
- Option 2: Lower Meadows Ditch
- Option 3: New Pipe to Meadows Ditch
- Option 4: New (Extended) Outfall to Palm Creek
- Option 5: New Outfall to 62 Avenue
- Option 6: Pumped Outfall

Figure 6-3 provides an overall view of these options.

The major issue with Option 1 is that the existing ditch and culvert are too high to provide an effective drainage outlet from the area. Lowering the ditch in Option 2 would be difficult due to the depth of the ditch and the extensive right-of-way that would be required to facilitate maintenance. Options 3, 4, and 5 involve a new outfall pipe that would be constructed at a lower elevation than the existing outfall and would provide a positive drainage outlet from the area. The principle differences between Options 3, 4, and 5 are the depth of pipe, requiring successively greater lengths and costs. Finally, the outflow could be pumped across Highway 28, which would require a force main that could be constructed at shallower depth and reduced cost but would require on-going operation and maintenance cost in perpetuity.

The analysis demonstrated that Option 3, a new piped outfall to Palm Creek was the most viable option. The increased length, depth, and cost of Option 4 would not be required, and Option 5 offered no advantage in pipe elevation, but had greater cost, compared with Option 3. A portion of the existing ditch upstream of 52 Avenue would be lowered in Option 3.

Following the recommendations in TM1, the City retained Solid Earth Inc. to conduct a detailed geotechnical investigation of the area. Results from the investigation indicated that a sand layer exists at an elevation of approximately 528 m and that ground water exists to an elevation of 532 m, essentially ground surface in the low areas of the Meadows. The report also stated that excavation below an elevation of 530 m may risk basal heave and extensive seepage from the bottom.

The geotechnical report also identified a number of additional measures that would be required in development of the area including filling of large portions of the development area to a height of 1-2 m above existing ground surface, foundation sub-soil preparation, surface and sub-surface drainage, and additional and more detailed geotechnical studies at each phase of development.

Based on the results from the geotechnical study, three stormwater management options have been evaluated for the area within the Meadows. These are outlined in **Figures 6-4** to **6-6**, respectively, and are as follows:

- Option A: One large pond to drain the entire area including existing development areas to the south.

- Option B: Three smaller ponds to drain sub-catchments of the basin area, with bottom elevations varied according to local conditions.

- Option C: A Drainage Parkway, consisting of an open channel to provide conveyance and a major drainage outlet, and a floodplain section in place of a dry pond, to provide flood storage for a major storm event.

Review with the City and Solid Earth indicated that Stormwater Management Option C, the Drainage Parkway, is the preferred option, along with an outfall pipe to Palm Creek (Outfall Option 3). The drainage parkway provides the most flexibility to accommodate the underling soils and groundwater conditions. It also provides the major and minor drainage outlets from the remainder of the basin and a valuable linear park with trails that would serve as an amenity to the neighbourhood and the City generally. The existing culvert and ditch, across Highway 28, would be left in service to provide a major drainage outlet (emergency overflow) from the area and the outlet from existing SWMFs to the north of the Meadows.

Figure 6-6 shows the approximate location of the drainage parkway, while **Figures 6-7** and **6-8** show the conceptual layout and cross section for this option. With the proposed development, the existing ditches will be eliminated and replaced with the drainage parkway for stormwater management. The drainage parkway will include a ditch section for conveyance and a floodplain section, to provide storage during severe rainstorm events, instead of the dry ponds which are proposed in options A and B.

The drainage parkway is proposed, conceptually, to have a channel with a 3 m bottom width and 1 m depth to carry low flows, and a floodplain of 50 m bottom width to store the major storm runoff. This configuration is similar to the existing Palm Creek valley between 50 Avenue and 62 Street to the west of Highway 2 as shown in Photo 6-1, and would facilitate the development of a stream-side park and trails to connect the existing trail network with future development areas to the northeast in the basin.

Photo 6-1
Existing Palm Creek East of 62 Street

Single family residential development has been proposed for the remainder of the undeveloped land in the Meadows basin. Considering the cost and difficulty of development in the area, caused by the challenging soils and groundwater conditions, a higher density development should be considered as a possible means to increase yields and recover the servicing costs.

Figure 6-9 shows the stormwater management plan proposed for the remainder of the Meadows basin lying to the north and east of the Meadows. Three existing and eight future SWMFs will provide stormwater management for the area and will be connected by ditches or pipes to the proposed Drainage Parkway and the existing and proposed outfalls.

Areas south of Iron Horse Trail that also previously drained to the Meadows have been diverted to a Trunk Sewer along 43 Avenue to reduce the flow in the Meadows Ditch and the proposed new outfall. This will also free up capacity in the storm sewer system draining to the Meadows, and will help alleviate local flooding problems in South Cold Lake. The 43 Avenue basin will be discussed below.

6.5 43 AVE TRUNK BASIN

The 43 Avenue Basin contains approximately 568 ha bounded by Millennium Trail on the North, Township Road 624 on the south, and Iron Horse Trail on the west.

The catchment is primarily undeveloped, with the exception of a small portion of Commercial land use along Highway 28 and Residential land use in Red Fox Estates.

6.5.1 Existing Drainage

Historically, this basin drained to the Meadows Basin, through a ditch draining north from 43 Avenue wetland (Fischer Estates). Runoff from the basin has been diverted to the 43 Avenue trunk sewer, which was recently constructed to service the area south of Millennium Trail. This diversion was recommended in previous drainage plans for the City and has reduced to volume of runoff to be accommodated in the South Cold Lake and the Meadows drainage system.

A limited storm sewer and ditch drainage system exists along Highway 28 to drain the Commercial areas, but does not have an outlet. Runoff is stored in the 43 Avenue wetland and floods onto the backs of the properties to the east and backs up into the trunk from the east. A temporary overflow has been constructed to the 43 Avenue Trunk, pending the construction of the SWMF to service Fischer Estates, at the site of the existing wetland, and the permanent outlet from the SWMF.

6.5.2 Proposed Drainage

The drainage patterns in this basin will change with development of Fischer Estates which will divert the runoff from the 43 Avenue catchment to the 43 Avenue trunk sewer and ultimately to Palm Creek. This concept has been proposed in various studies in the past and is currently on the road to being implemented.

Scheffer Andrew Ltd. has recently completed a pre-design of a stormwater management facility to replace the existing 43 Avenue wetland, and the necessary approvals have been obtained. Once the pond becomes operational, development of the Iron Horse and Fischer Estates developments will proceed.

The design of the 43 Ave Pond (Fischer Pond) is outlined in Scheffer Andrew's report "Fischer Stormwater Management Facility". The pond is proposed to service an area of 184.8 ha, with a surface area of 6.5 ha, storage volume of 118,000 m^3, and active storage depth of 2.0 m.

Figure 6-10 shows the future drainage boundaries, conceptual location of storm ponds, and drainage connections proposed for the 43 Avenue basin in the current study. Eight SWMFs are proposed to service the future development. SWMFs 4 and 5 will drain to the 43 Avenue Trunk at the existing wetland. The outflow from the remaining ponds will be directed to the west, to join the 43 Avenue Trunk at the Iron Horse Trail, where the Trunk has sufficient capacity.

In the interim, pending the ultimate development of the basin and construction of the SWMFs on the south, AE recommends that the outlet from Red Fox Estates be directed via ditch to the west of Fischer Estates so as to avoid overloading the Fischer Estates SWMF and the upstream portions of the 43 Avenue Trunk, which has a reduced capacity. The storm sewer has additional capacity between the Iron Horse Trail and its outlet to Palm Creek.

Stormwater Management for Red Fox Estates will be provided in SWMF #2 when its service area is developed. In the interim, an easement will be required for the diversion ditch.

6.6 PALM CREEK BASIN

Palm Creek extends south and west from Township Road 634 to its confluence with Marie Creek. For the purpose of this study, only the portion upstream of the Palm Springs Golf Course reservoir has been considered.

The drainage area to Palm Creek at 55 Avenue is approximately 24 m^2 (2411 ha). The basin is mostly undeveloped, but there are small parcels of recent development including the Healthcare Centre, Creekside, Lakewood Estates and Nelson Heights that drain to the Creek.

6.6.1 Existing Drainage

Figure 6-11 shows the existing drainage patterns for the Palm Creek basin along with several of the SWMFs required to support the future development of the basin.

The creek is characterized by flat slopes and shallow depths and has a wide floodplain. The yellow-highlighted areas in **Figure 6-11** are low-lying areas adjacent to the creek. The blue-highlighted areas represent the floodplain of Palm Creek and tributary drainage systems from the east.

Due to these constraints, Creekside Estates, in the northwest quadrant of the 28th Street and Highway 55 intersection, uses stormwater pumps to discharge the runoff from its SWMF to Palm Creek.
This not only added to the initial capital costs, but also requires operational and maintenance costs in perpetuity. There is also risk involved with the use of mechanical equipment. Our analysis shows that a gravity outfall to Palm Creek is possible, to the south along Highway 28, and AE recommends this be completed to replace the existing pumps.

Several Country Residential subdivisions drain to Palm Creek from the MD of Bonnyville, to the west of Palm Creek. These have been provided with SWMFs to control their runoff, and are located on higher ground outside of the creek floodplain.

Several small development areas to the north of Highway 55 drain to Palm Creek. SWMFs for these developments are poorly defined or non-existent and need to be formalized as the City continues to develop in this direction.

Small residential areas drain directly to the creek (without stormwater management) to the west of Highway 28, downstream of 52 Avenue in South Cold Lake. The Palm Creek Channel was upgraded through this reach in the 1980's to prevent flooding of this residential area. Storage in the channel and floodplain, and in the Palm Creek reservoir, helps to attenuate the runoff from this area.

6.6.2 Proposed Drainage

Areas south of Highway 55, and large areas to the north, are currently undeveloped. However the currently undeveloped area south of Highway 55 is proposed to be annexed and developed into Residential land uses after annexation by the City.

Previous reports have identified a concern that the creek is too shallow to provide a gravity outlet for significant portions of the area but have not identified a solution for this issue.

As the areas adjacent to Palm Creek continue to develop, several dry Storm Water Management Facilities (SWMFs) will be required to attenuate the storm water runoff from the future development areas. However, Palm Creek is not deep enough to provide a gravity outfall from some of these facilities, particularly in the area north of Highway 55.

TM2 in **Appendix D** assesses the following options for servicing the future development area and draining the SWMFs:

- Option 1: A storm trunk sewer running parallel to and below Palm Creek to carry the outflow from the SWMFs, discharging to Palm Creek in its lower reaches.
- Option 2: A drainage parkway (floodplain with a constructed deeper channel) to provide adequate capacity and grade to provide a gravity outlet from the SWMFs.
- Option 3: Pumping from stormwater ponds as has been done for Creekside Estates.
- Option 4: Filling of low areas to make them developable and facilitate drainage.
- Option 5: Development restrictions to preserve the low areas as undeveloped natural areas.

Each of these options has its challenges, and all involve significant costs:

- The storm trunk sewer is the most costly of the options and would need to be constructed in its entirety before the development upstream of Highway 55 could be completed.
- Channel improvements (lowering) could be constructed in stages but would involve significant disturbance to the creek that would require approval from Alberta Environment and Sustainable Resource Development (AESRD) and Fisheries and Oceans Canada (DFO). These impacts can be minimized through careful design and construction, with a view toward creating as natural a channel as possible. A biophysical assessment and Environmental Impact Assessment (EIA) would be required.
- Pumping would involve substantial capital costs and operation and maintenance costs in perpetuity, and is not consistent with sustainable development principles.
- Development restrictions would freeze development of large areas and would likely be opposed by landowners having development aspirations.

A detailed review of the options indicated that Option 1 involving a Trunk Sewer is very expensive and would cost approximately $43 Million. Considering the high groundwater levels and underlying saturated sand layer, installation of a gravity sewer would be very difficult and expensive, rendering this option impractical. Option 2, involving a drainage parkway, is substantially less costly with an approximate cost of $ 10 Million (excluding land costs). The costs of the pumping and landfill options have not been estimated but are likely to be significantly higher especially when operation and maintenance costs of pumping are considered. The final option, restricting development to the higher areas, has the least cost but would freeze significant areas from development, especially in the north where there are significant development pressures.

Considering these factors, Option 2 – Drainage Parkway – is the preferred option. The major advantage of this option is that it provides a positive drainage outlet from the region at a reasonable cost. It will also provide an amenity to the project area by creating a linear parkway that could be used for a trail network and utility corridor. Its major disadvantage is that it involves a significant disturbance to the Creek that will require the approval of Alberta Environment, Public Lands and Provincial and Federal Fisheries and/or the adjacent landowners.

The City could construct the parkway and establish a development levy that could be recovered from future landowner/developers at the time of subdivision. Alternatively, the parkway could be constructed by the adjacent landowners at the time of subdivision which would be viable if the area abutting the floodplain were to be developed in the near future.

The legal ownership of the creek is an issue as the Creek could potentially be claimed by the Crown under the Public Lands Act (an application for determination of ownership under the Public Lands Act has been made and a decision is pending). In the event that it is claimed by the Crown, the City would need approval from the Province and a licence of Occupancy from AESRD (Public Lands) in order to modify the channel. Alternatively, if the creek is deemed to be privately owned, the City will need an easement to permit its current and future discharge to the Creek and would likely need to purchase the lands prior to subdivision of the abutting properties to facilitate construction of the channel.

Appendix B provides details of the SWMF's proposed for this basin including the corresponding drainage area, pond size, pond bottom and high-water elevations, discharge rate, and cumulative discharge to Palm Creek.

6.7 CFB 4-WING DRAINAGE

The developed portions of the CFB 4-Wing Base have been analyzed for utility upgrades in the past and will not be considered here. However the undeveloped southeast portions of the Base, between Medley Road and Iron Horse Trail, have drainage issues and ponding water which have not been assessed previously. The current study addresses these issues and provides the conceptual drainage design for these areas.

6.7.1 Existing Drainage

Figure 6-12 shows the extent of the project area within the Base. The south east portion of the CFB 4-Wing base is a poorly drained area characterized by flat terrain and standing water. Drainage courses are flat and usually blocked by beaver dams. The area has extensive surface ponding and areas with drainage issues.

A field visit was conducted to ascertain the conditions on the ground and prepare an inventory of the size and condition of hydraulic structures. Some structures were buried completely and could not be located; others were plugged by beaver dams or other debris. Beaver dams were also seen to block drainage, resulting in standing water.

The poor drainage is attributable to the flat terrain, buried hydraulic structures, beaver dams, and absence of proper conveyance in channels. The area could generally benefit from improved drainage and increased maintenance.

6.7.2 Proposed Drainage

Four major drainage paths have been identified in the 4-Wing Area as shown in Figure 6-12. Each drainage path is proposed to be channelized, deepened, and constructed to a steeper slope. Existing culverts will be incorporated where possible and will need to be exposed and cleared of debris, and will be lowered where required to tie into the proposed ditches.

Figures 6-13 to 6-16 provide the plan-profiles of the proposed drainage improvements, showing the existing and proposed ditch profiles and intermediate hydraulic structures (culverts), at a conceptual level of detail.

Drainage patterns are not proposed to be changed but will be improved. Natural drainage courses with flat grade will be deepened and will be provided with adequate slope to drain the area. Hydraulic culverts are proposed for connectivity and are to be sized adequately for a 1:100 year storm.

The ditch plans and profiles are conceptual and subject to change during the pre-design phase. Site surveys will be required prior to final design and construction.

6.8 AFRICAN LAKE

African Lake is land-locked lake and has a small catchment with no surface outlet. The lake is at least 10 m deeper than the surrounding areas and is likely connected to the regional groundwater systems.

The catchment is proposed to be developed as Estate Residential in the Inter-municipal Development Plan. More detailed study of the groundwater levels and flows in the catchment is recommended, to ensure the water levels can be effectively managed, prior to any development in this basin. Consideration should be given to retaining this catchment as a natural area.

6.9 FRINGE AREAS

Portions of the project area drain away from the City and the basins described above. These fringe areas lie outside the City boundary, but within the IDP boundary.

West Fringe Area
Three small areas lie to the west of the Palm Creek catchment and drain to Marie Creek. The area to the north is identified in the IDP as industrial and two others to the south are identified as residential. To ensure continuity of development, these small areas could be drained westward to Marie Creek, with stormwater management to control their flows.

South Fringe Area
The South Fringe Areas lie to the south of the City between the City and IDP boundaries. The South Fringe Areas drain to the Beaver River through existing creeks and drainage courses, except for Basin 102 which drains North to Palm Creek through the 43 Avenue Trunk. SWMFs have been identified for these areas should they be developed in the future.

East Fringe Area
The East Fringe Areas lie in the south eastern part of the City, mostly between the City and IDP boundaries as shown in **Figure 6-2**. The areas drain to Cold Lake in the existing condition. The area is planned as Residential for future condition, and is proposed to have stormwater management as the area continues to develop.

The location and drainage connectivity of each of the catchments in the Fringe Areas has been shown in **Figure 6-2. Table A-1** in **Appendix A** provides the details of the SWMFs proposed in the Fringe Areas.

6.10 PALM SPRINGS GOLF COURSE DAM

The Palm Springs Golf Course Pond is located within CFB 4Wing, to the west of the City of Cold Lake in SW ¼ SEC. 4-63-2-W4. The pond is on Palm Creek which joins Marie Creek downstream of Glenwood Drive.

Figure 6-1 shows the location of the Golf Course reservoir and Dam. The reservoir was formed by a 3 m high embankment to supply water to the Palm Springs Golf Course. A pump-house on the north bank draws water from the reservoir and supplies water to the golf course irrigation system.

The pond has been in operation for at least 50 years and has become a valuable environmental amenity as a large water body.

The embankment originally had as many as six culverts to carry creek flow through the embankment. The embankment has had a history of culvert failures and overtopping in recent years. Subsequent to the last washout, Defence Construction Canada (DND) removed the culvert and installed loose rock fill in the washed out portion of the embankment. The blockage was a temporary measure to preserve water in the reservoir for golf course irrigation and to provide an outlet for low flows through the rock fill. However it does not have enough capacity to pass high flows in the creek and as a result the embankment has been overtopped on several occasions, which could result in failure of the embankment. This risk will increase as additional areas are developed in the catchment and the volume of runoff is increased.

The reservoir not only provides storage for irrigation to the golf course, but also provides a natural habitat for fish. Department of Fisheries and Oceans (DFO) have requested DND to provide fish passage for the reservoir.

Consequently DND requested Associated Engineering to consider alternatives to modify the reservoir by providing fish passage or providing other alternatives for water storage for irrigation if draining the reservoir was the only feasible option.

6.10.1 Review of Options

Four options were reviewed to identify a feasible solution for the fish passage, while considering the irrigation requirements for the golf course, and are reviewed in TM3, provided in **Appendix E**. These options are:

- Option 1: Isolated Pond
- Option 2: Natural Fish Bypass Channel
- Option 3: Reservoir within Pond
- Option 4: Eco Friendly Golf Course

The four options were reviewed for environmental impacts, feasibility of construction, and cost, and Option 2, a natural fish bypass channel, was found to be the preferred alternative. The analysis demonstrated that providing an alternative water supply for the golf course would be prohibitively expensive. Furthermore, the outlet must be re-built in order to accommodate normal and flood discharges from the reservoir and prevent the dam from being overtopped.

On behalf of the City, AE retained Enviromak Management Consultants Inc. to conduct a fish survey in the reservoir and Palm Creek in September 2013. Their report is included in **Appendix I**. The survey confirmed the presence of small fish in this reach, but no larger sport fish (Northern Pike) were found. White Sucker was found downstream of the reservoir but not upstream, suggesting that the dam is a barrier to their migration. Alberta Environment has indicated that the outlet design would not be required to provide passage of sport fish if they are not present in this reach of the creek.

With DND stating its preference for Option 2, a conceptual design was developed for this option. **Figure 6-17** shows the conceptual plan and profile view of the proposed outlet.

The outlet channel is proposed to be approximately 220 m long and will be lined with riprap to withstand the peak flood flows and to reduce velocities to facilitate fish passage. Three intermediate ponds are proposed to provide energy dissipation and resting areas for migrating fish. The dam will need to be raised approximately 1 m to provide freeboard above the design flood elevation. The loose rock riprap should be removed and replaced with competent fill.

AE recommends that the City and/or DND proceed immediately with preliminary design to define the cost of the proposed outlet works and the dam modifications and proceed to construction as soon as possible. A detailed geotechnical study is recommended to define the subsurface conditions and develop the design of the dam modifications.

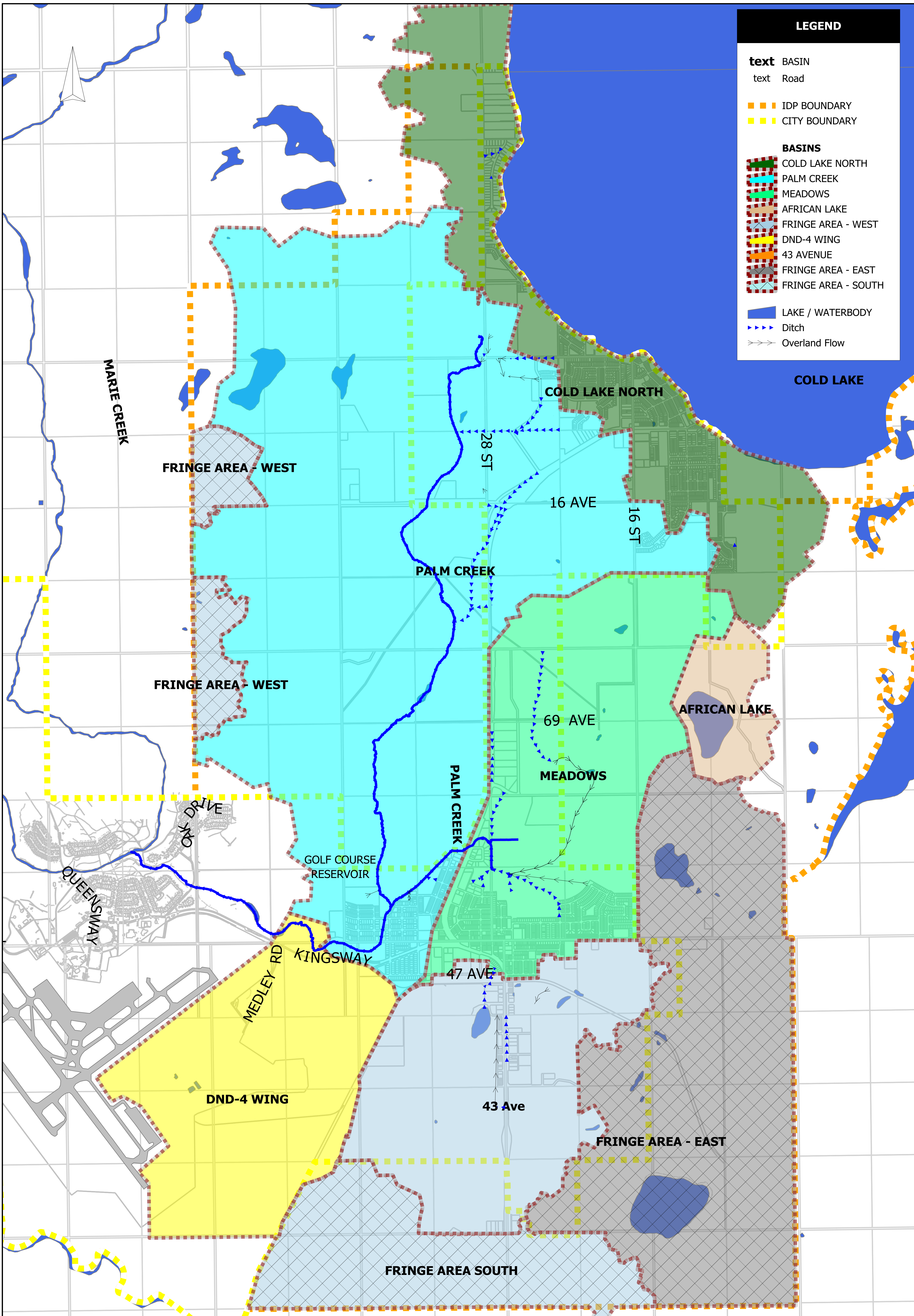
6.10.2 Stormwater Management Issues

The reservoir has a surface area of approximately 2.5 ha and a maximum depth of approximately 3 m, providing approximately 30,000 m^3 of permanent storage and approximately an additional 30,000 m^3 of flood storage. These volumes are easily doubled if ponding created by upstream beaver dams is considered.

Compared to the flood storage that will be required for future development, the 30,000 m^3 provided by the dam is relatively small. It does, however, provide storage of runoff from small areas that drain to the Creek without storage, such as South Cold Lake to the west of Highway 28, and it provides final attenuation of peak flow prior to discharging to Palm Creek.

DND requires that open water bodies be minimized in the vicinity of 4 Wing, which means that all SWMFs, with the exception of the Golf Course reservoir and existing wetlands in South Cold Lake, be constructed as dry ponds. Such dry pond provides limited water quality benefits.

Runoff from most of South Cold Lake is directed to Palm Creek and by extension to the Golf Course Reservoir. The dam is at risk of being destroyed in every flood event and should be repaired.



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No.	REVISION	DATE

(Name) (Date)
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City of Cold Lake

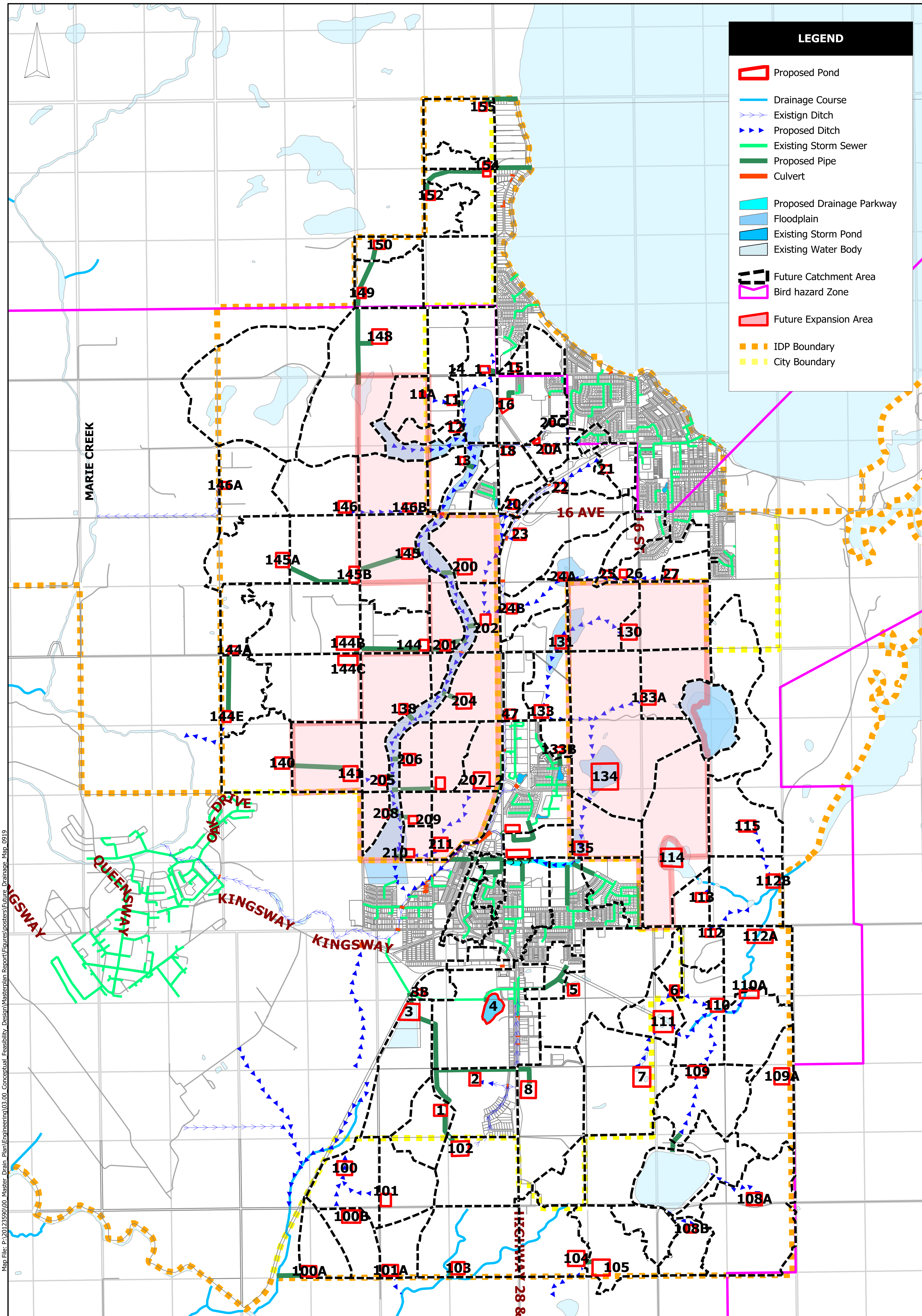
CITY OF COLD LAKE
MASTER DRAINAGE PLAN

Figure 6-1
BASINS MAP

PROJECT No.: 2012-3590

DATE: 3/26/2014

SCALE: 1:40,000



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Name	(Date)		

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City of Cold Lake

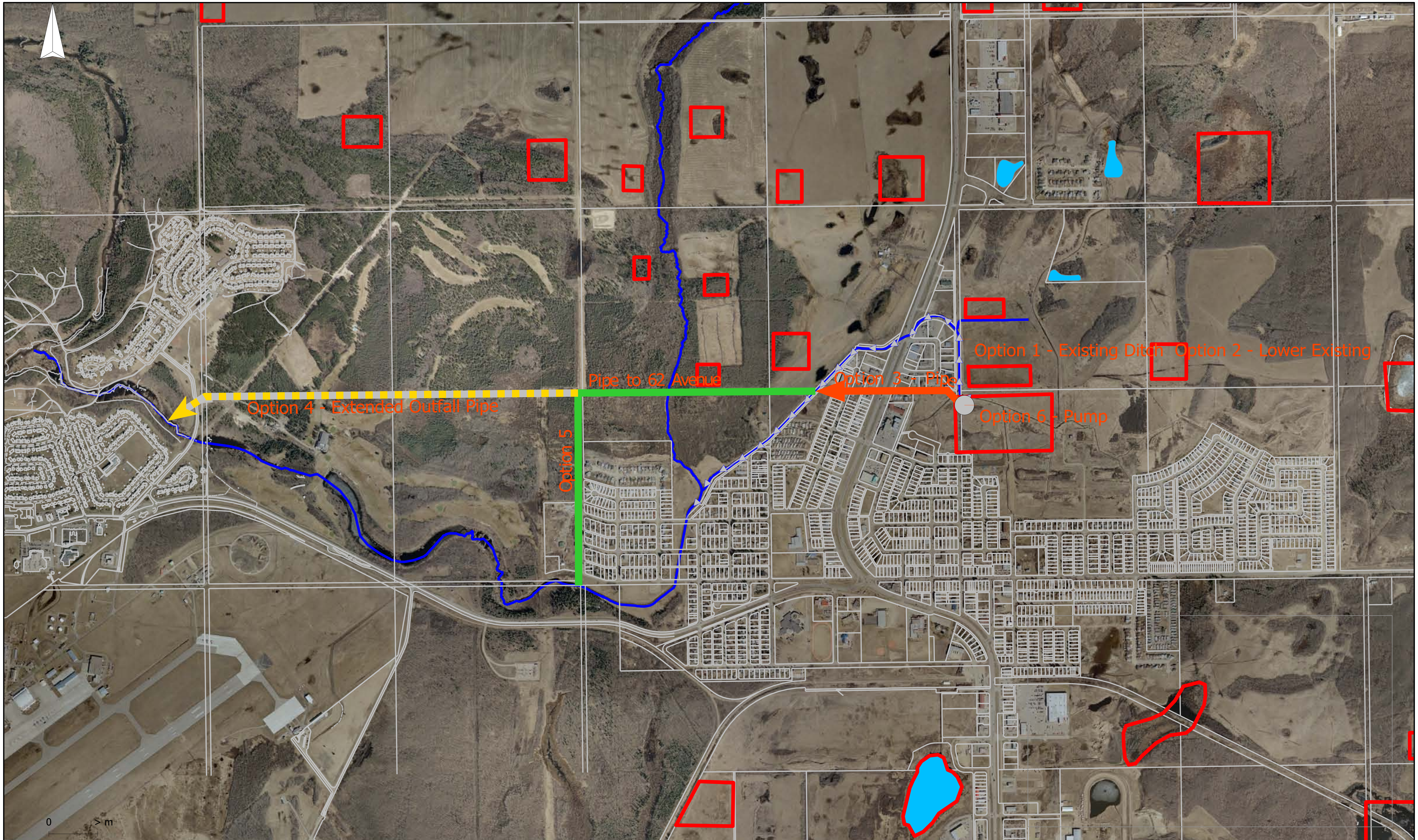
CITY OF COLD LAKE
DRAINAGE MASTERPLAN

Figure 6-2
FUTURE DRAINAGE CONCEPT

PROJECT No.:2012-3590

DATE:3/28/2014

SCALE: 1:40,000



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CITY OF COLD LAKE
DRAINAGE MASTERPLAN

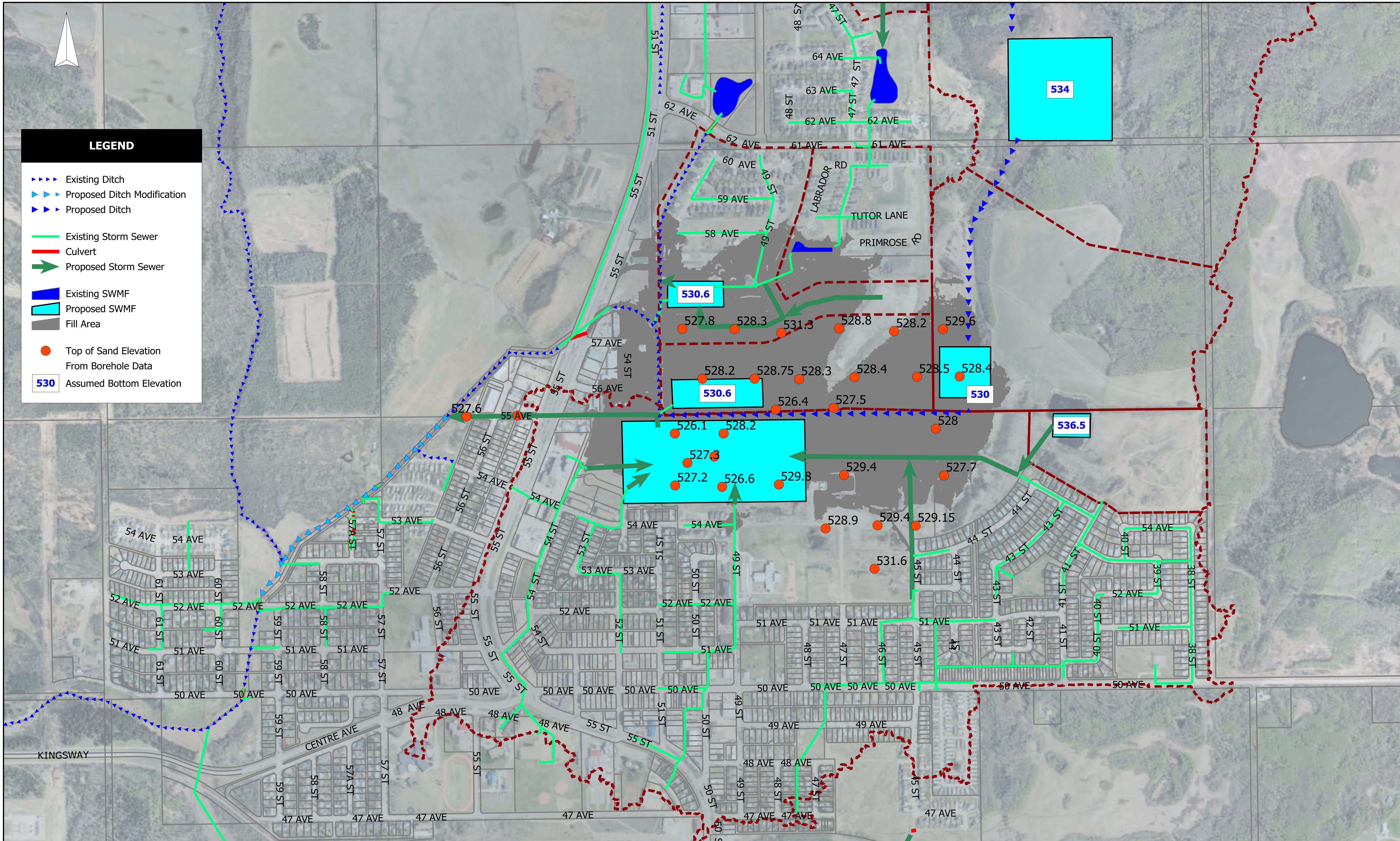
Figure 6-3

THE MEADOWS OUTFALL OPTIONS

PROJECT No.: 2012-3590

DATE: December, 2013

SCALE: 1:15,000



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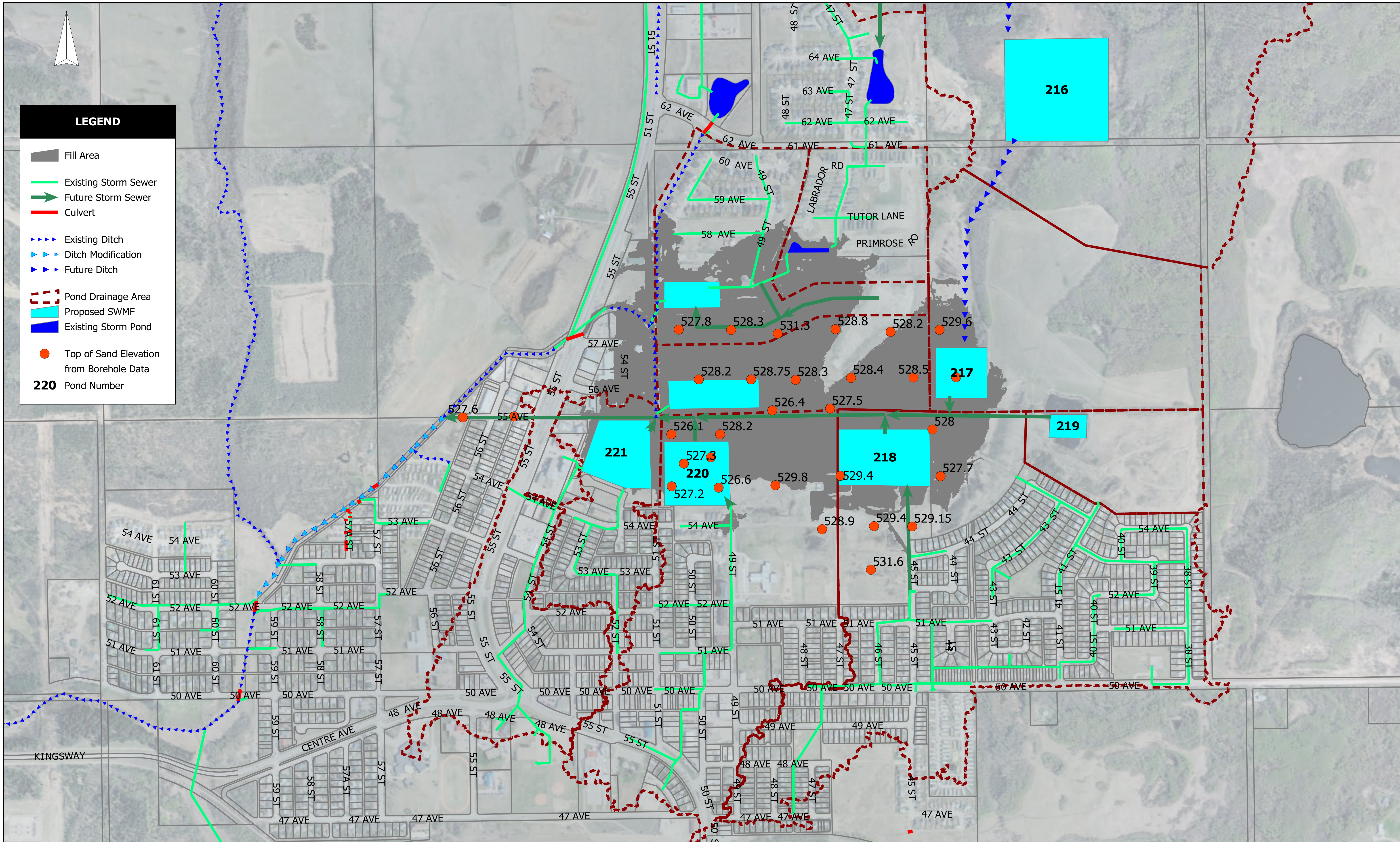
CITY OF COLD LAKE
DRAINAGE MASTERPLAN
Figure 6-4
MEADOWS OPTION - A
ONE POND OPTION

PROJECT No.: 2012-3590
DATE: 4/1/2014
SCALE: 1:10,000



CITY OF COLD LAKE
DRAINAGE MASTERPLAN
Figure 6-5
MEADOWS OPTION B
THREE PONDS OPTION

PROJECT No.: 2012-3590
DATE: 4/1/2014
SCALE: 1:10,000

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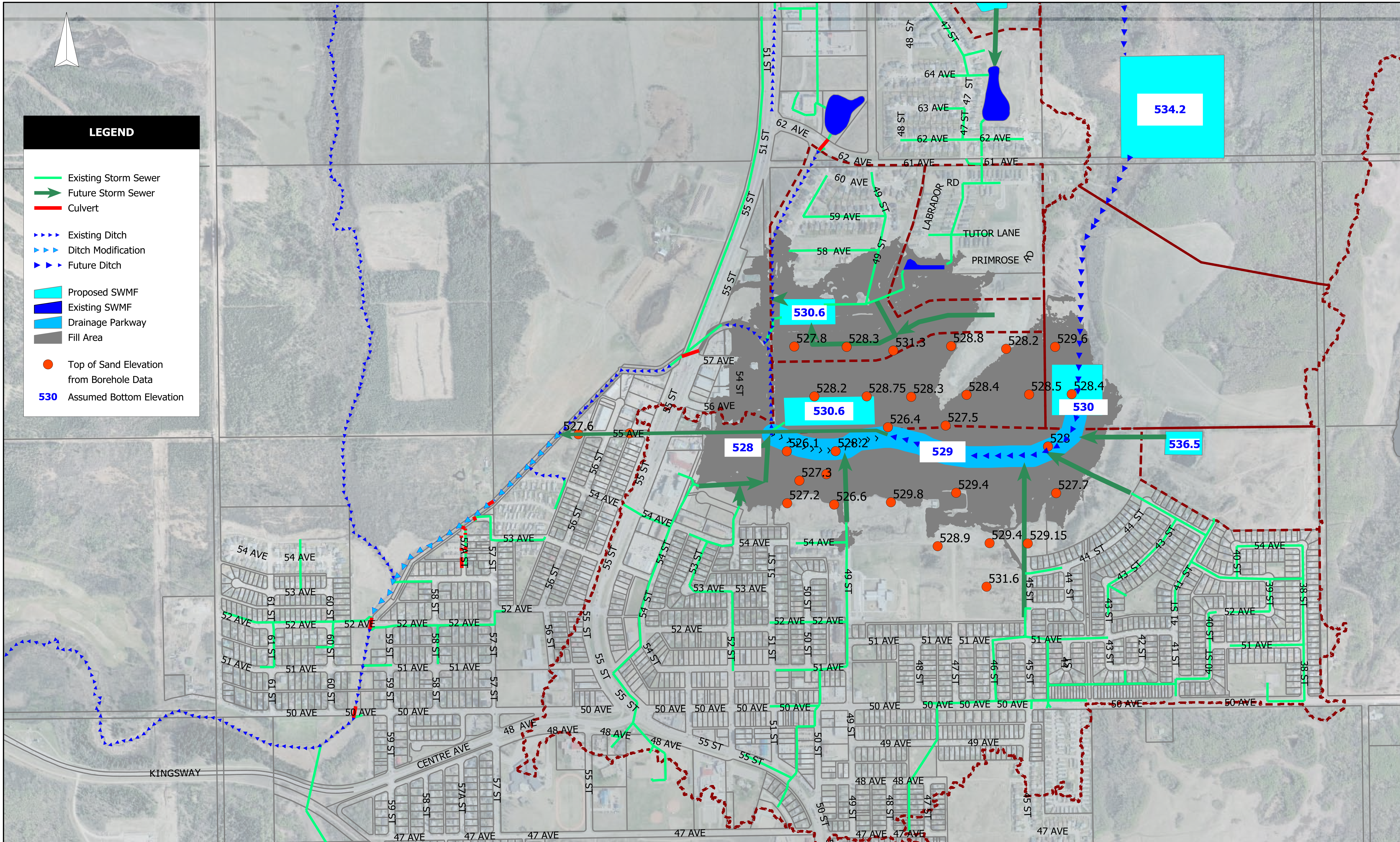
City of Cold Lake

No.	REVISION	DATE



CITY OF COLD LAKE
DRAINAGE MASTERPLAN

Figure 6-6
MEADOWS OPTION - C
DRAINAGE PARKWAY OPTION

PROJECT No.: 2012-3590

DATE: 3/26/2014

SCALE: 1:10,000

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City of Cold Lake

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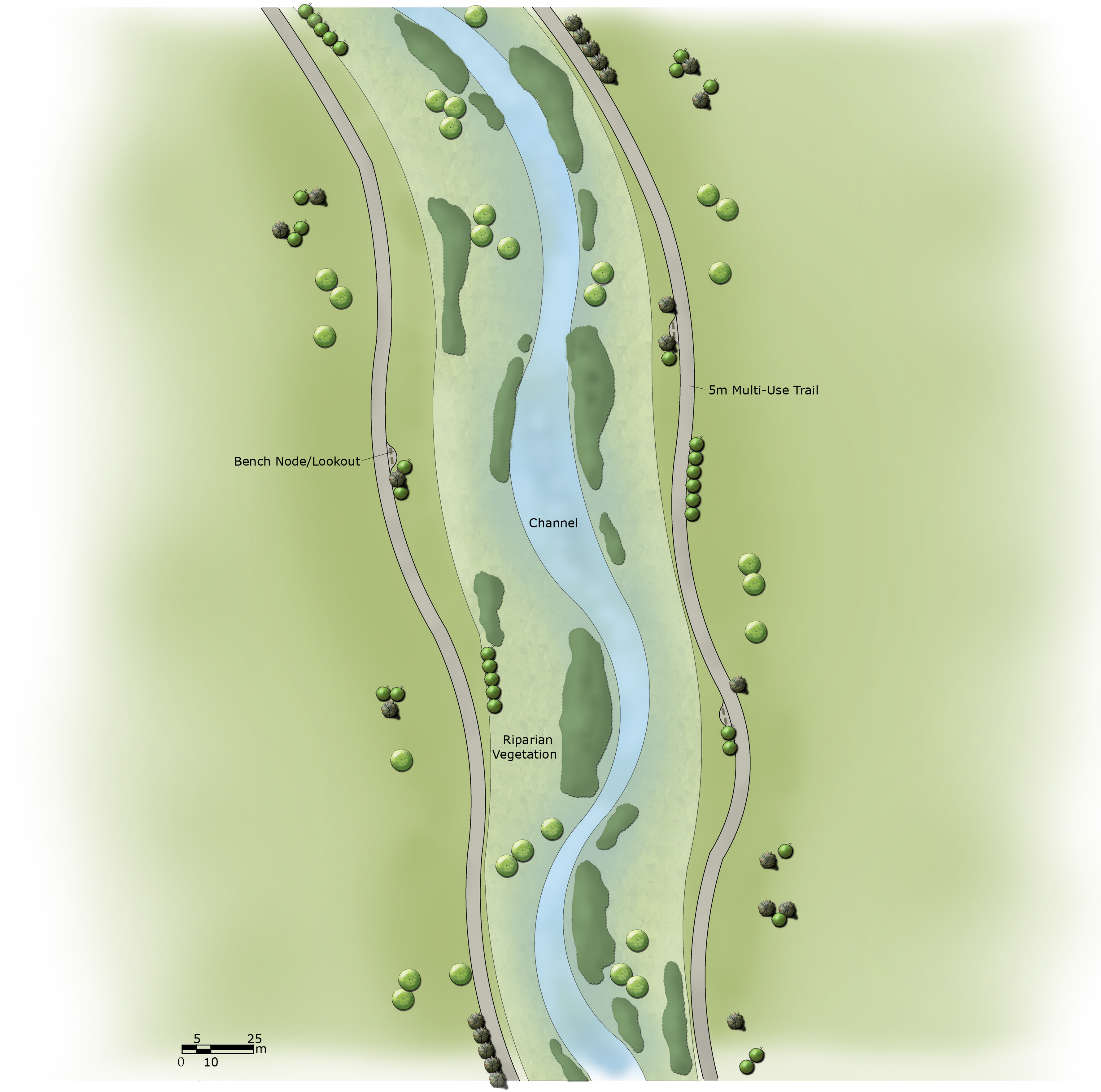

Figure 6-7

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City of Cold Lake

MASTER DRAINAGE PLAN

Concept: Meadows Drainage
Parkway Option
Plan View

LEGEND

Deciduous Trees

Coniferous Tree

Bench

Shrubs

SCALE 1:750
September. 2013

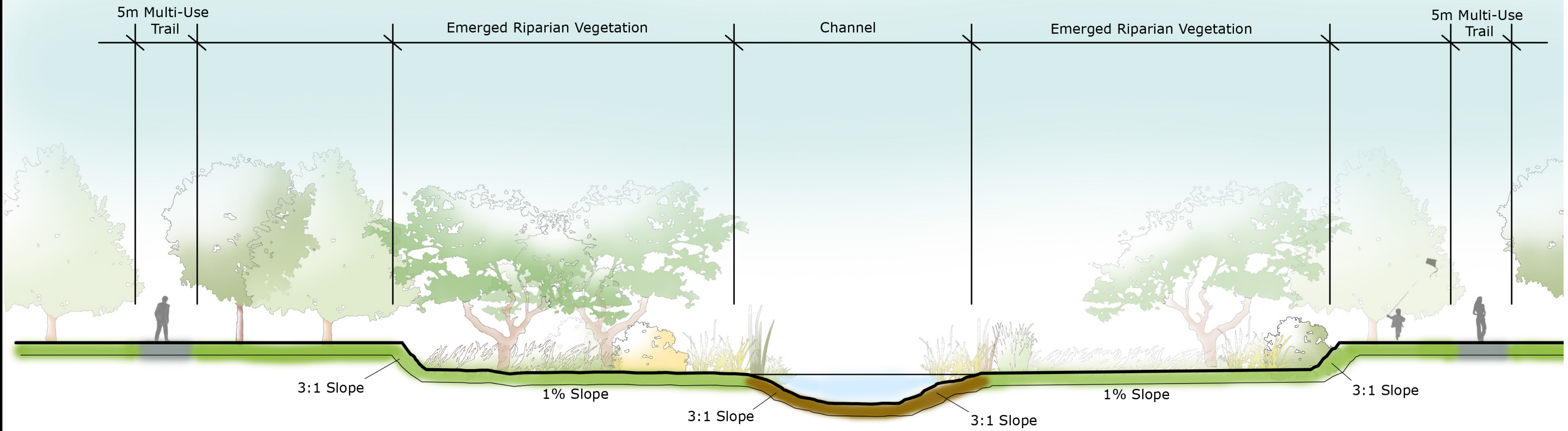

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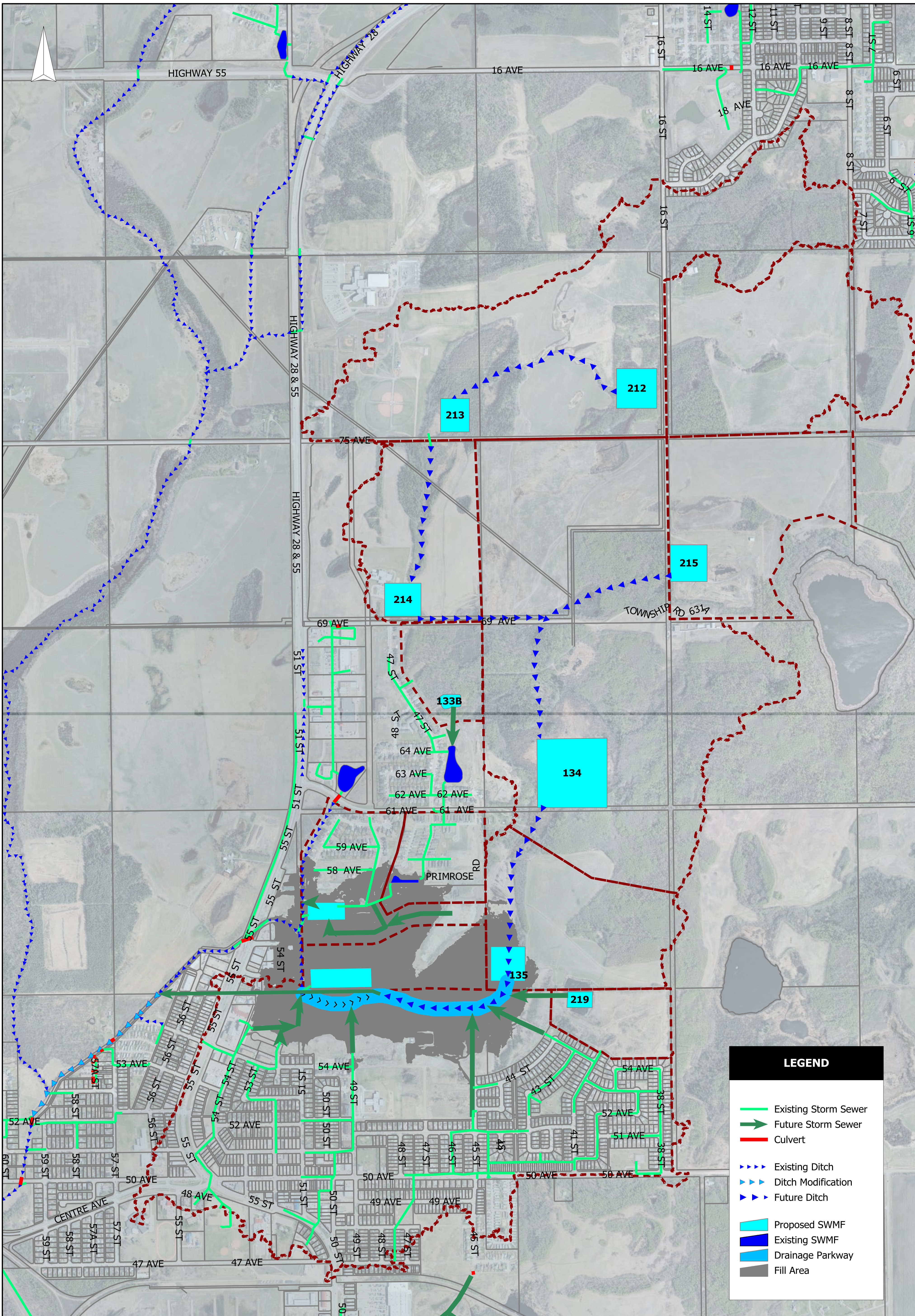
Figure 6-8

City of Cold Lake

MASTER DRAINAGE
CROSS SECTION A-A'

Concept: Meadows Drainage
Parkway Option
Cross-section View

SCALE 1:200
September. 2013



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			(Name) (Date)			

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City of Cold Lake

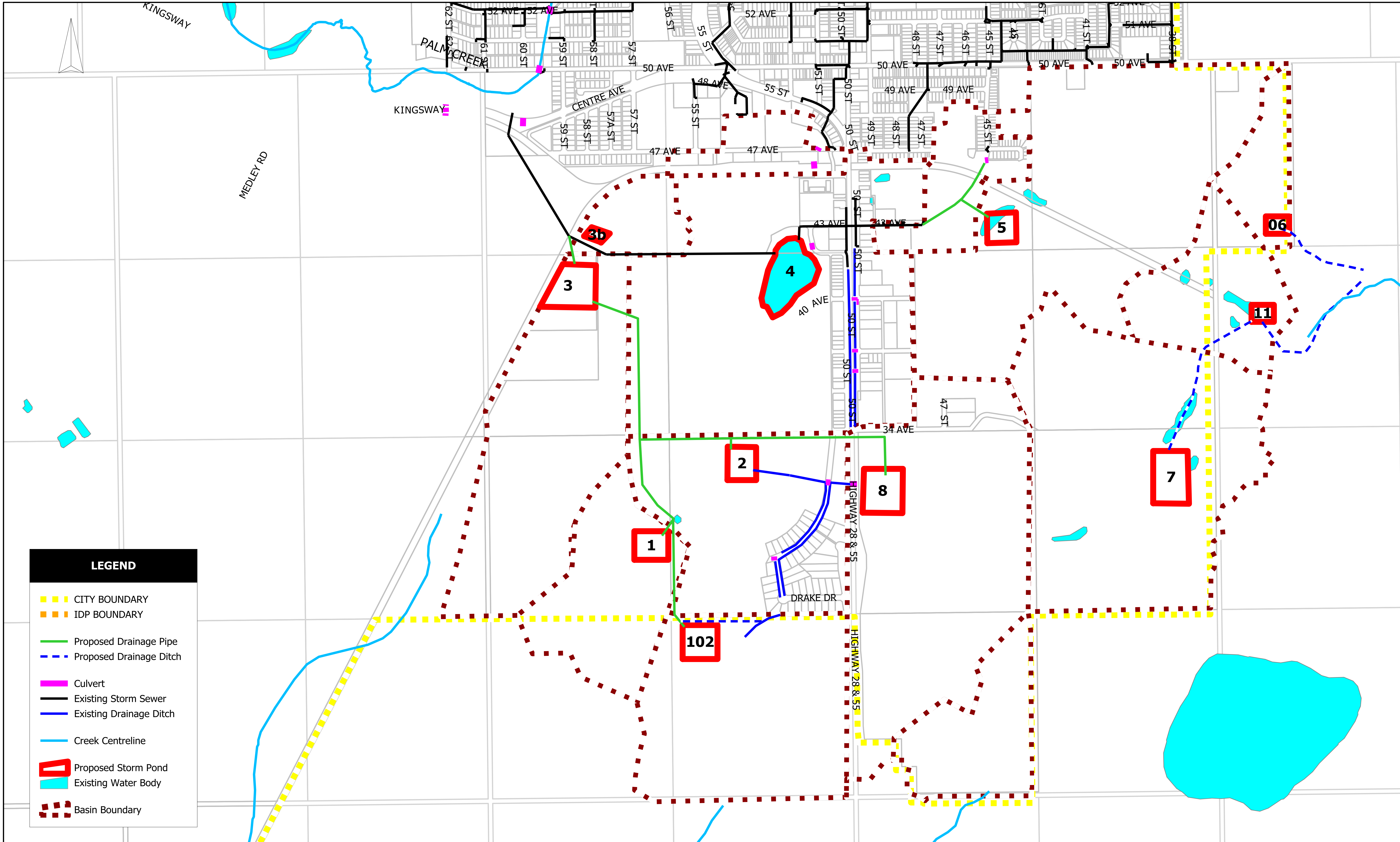
CITY OF COLD LAKE
DRAINAGE MASTERPLAN

Figure 6-9
MEADOWS BASIN
PROPOSED STORMWATER MANAGEMENT PLAN

PROJECT No.: 2012-3590

DATE: 4/1/2014

SCALE: 1:15,000



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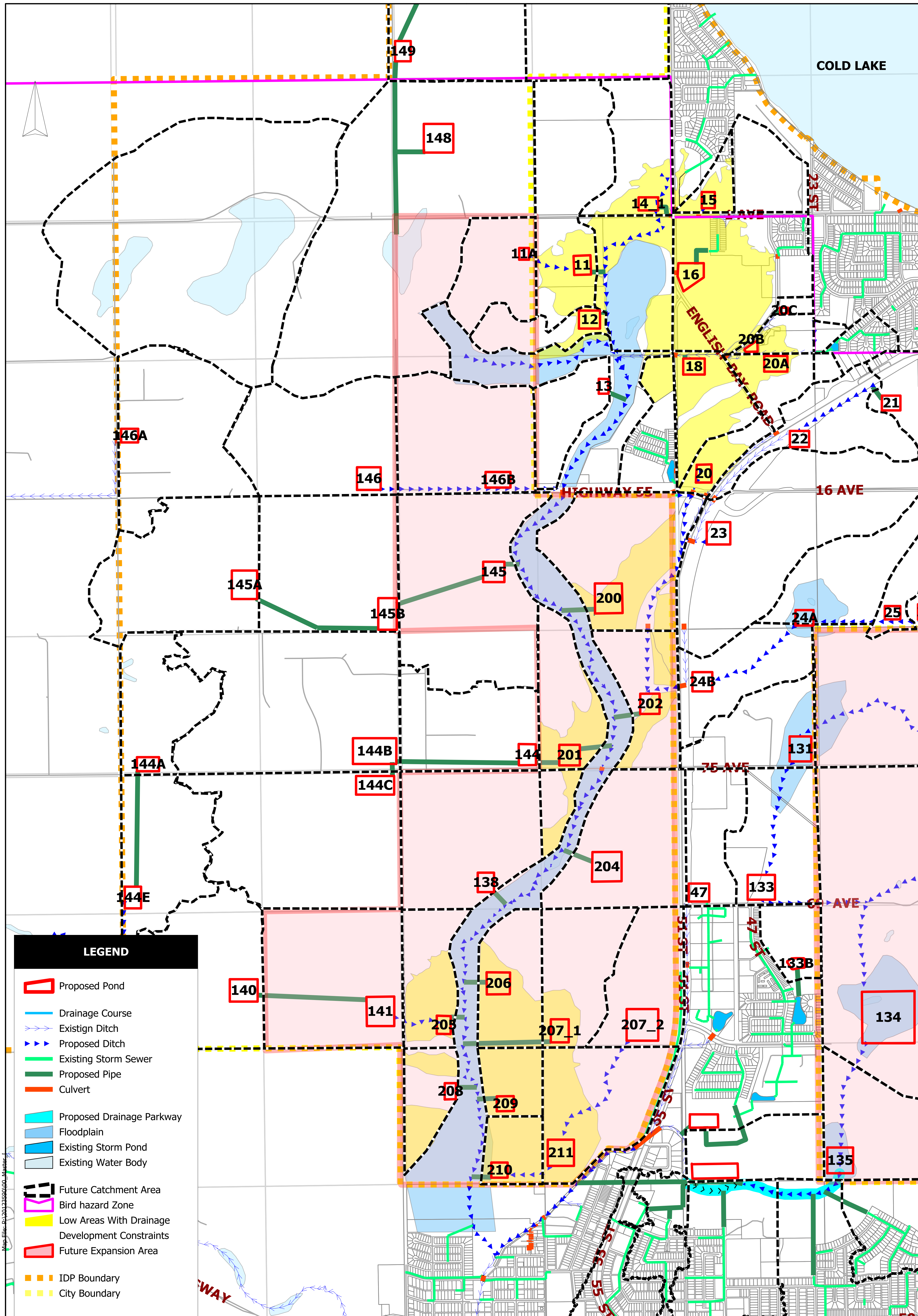
CITY OF COLD LAKE
43 AVE BASIN

Figure 6-10
PROPOSED DRAINAGE MAP

PROJECT No.: 2012-3590
DATE:4/1/2014
SCALE: 1:15000



No.	REVISION	DATE

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City of Cold Lake

CITY OF COLD LAKE
DRAINAGE MASTERPLAN

FIGURE 6-11
FUTURE DRAINAGE CONCEPT
WITH PALM CREEK LOW AREAS

PROJECT No.: 2012-

DATE: 3/28/2014

SCALE: 1:20,000

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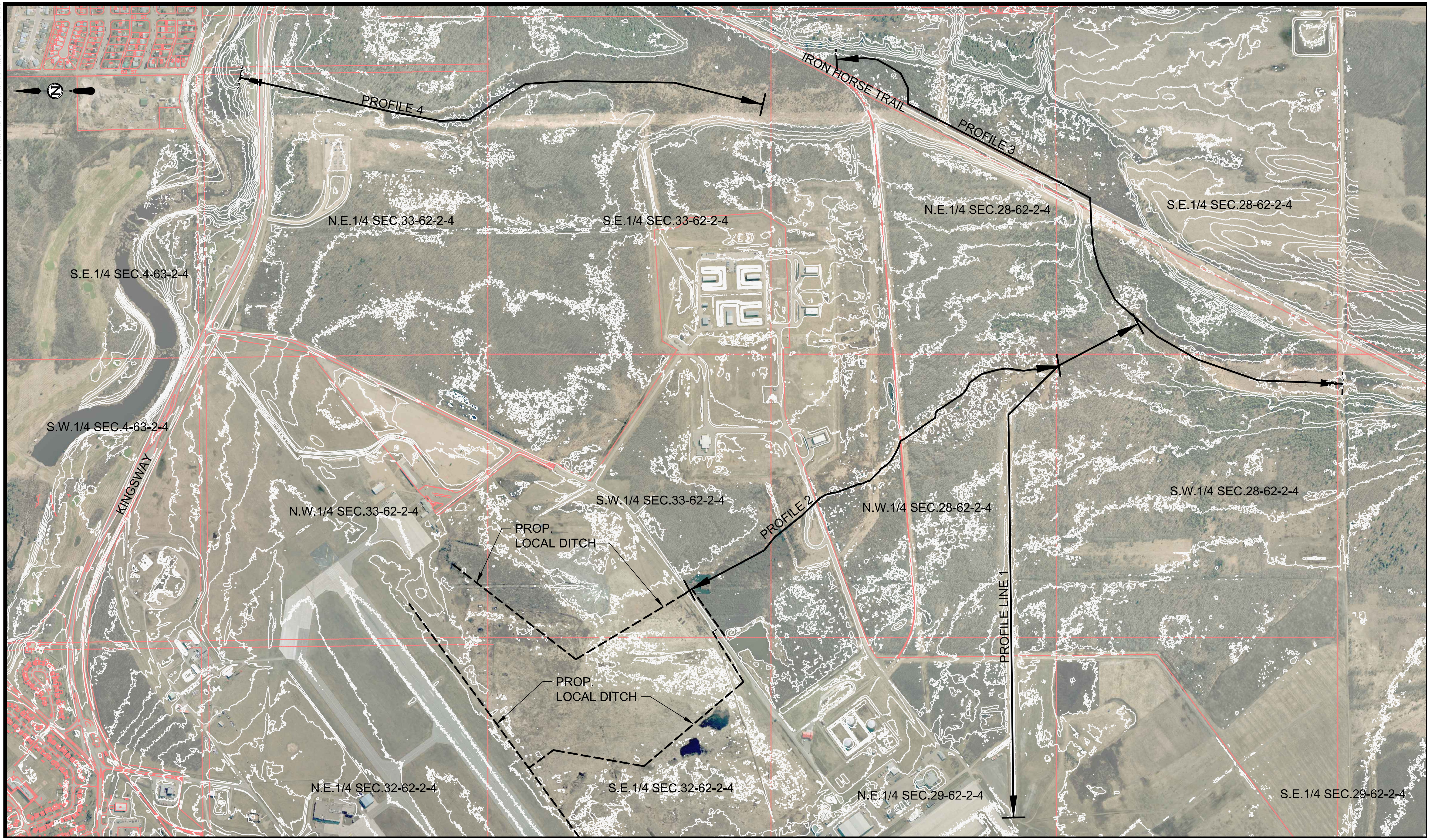

NO.	DATE	ENG.	BY	SUBJECT
A	2013-01-28	S.N.	K.G.	PRELIMINARY ISSUE

REVISIONS

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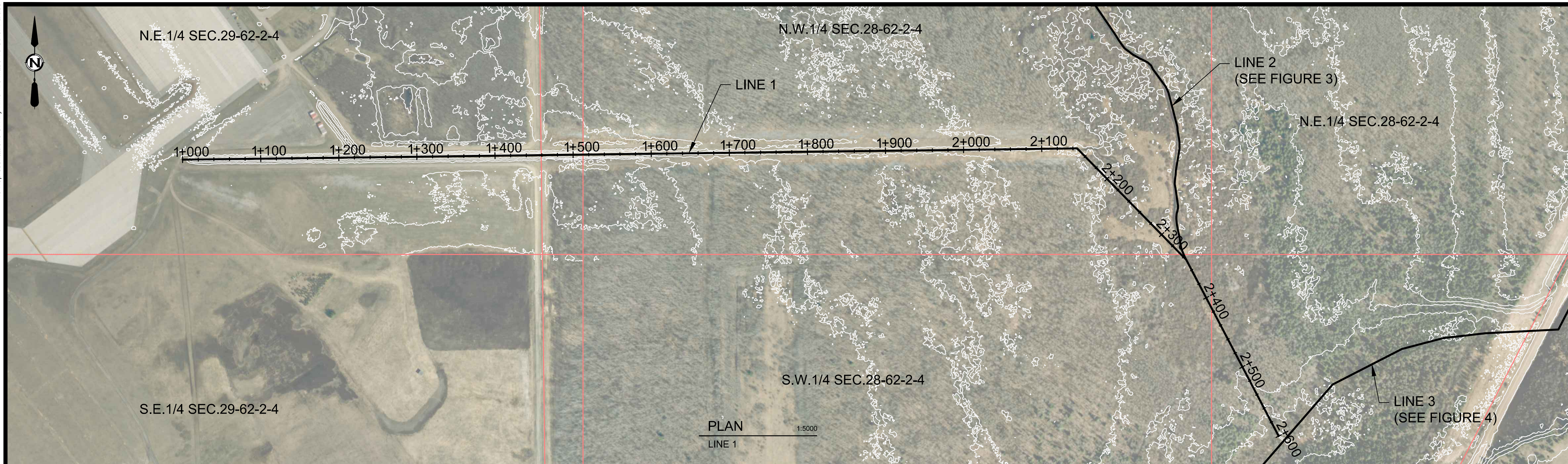
PROJECT No.	20123590
SCALE	1:5000
DRAWN	K. Grandish
DESIGNED	S. Nishtala

City of Cold Lake

INDEX PLAN

4 WING DRAINAGE IMPROVEMENTS

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 6-12	A	--



NOTES:

1. AIR PHOTO TAKEN IN MAY 2008
2. ELEVATIONS ARE TAKEN FROM LIDAR SURVEY IN 2009 AND ARE APPROXIMATE.

NO.	DATE	ENG.	BY	SUBJECT
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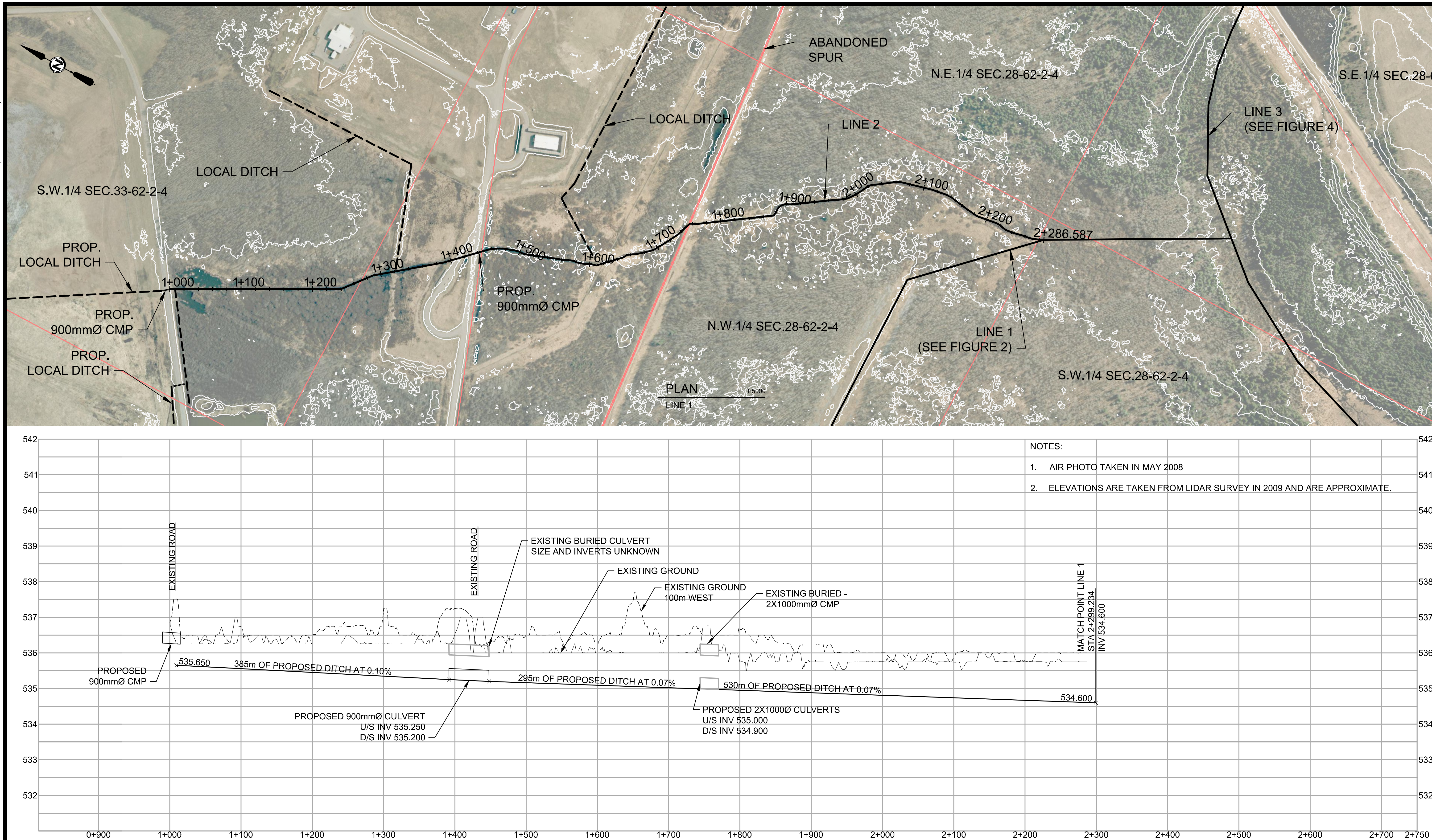
PROJECT No.	20123590
SCALE	H 1:5000 V 1:100
DRAWN	K. Grandish
DESIGNED	S. Nishtala

City of Cold Lake

4 WING DRAINAGE IMPROVEMENTS

PLAN / PROFILE 1

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 6-13	A	--



NO.	DATE	ENG.	BY	SUBJECT
A	2013-01-28	S.N.	K.G.	PRELIMINARY ISSUE

REVISIONS

Associated Engineering

PROJECT No.	20123590
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DRAWN	K. Grandish
DESIGNED	S. Nishtala

City of Cold Lake

PLAN / PROFILE 2

4 WING DRAINAGE IMPROVEMENTS

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 6-14	A	--

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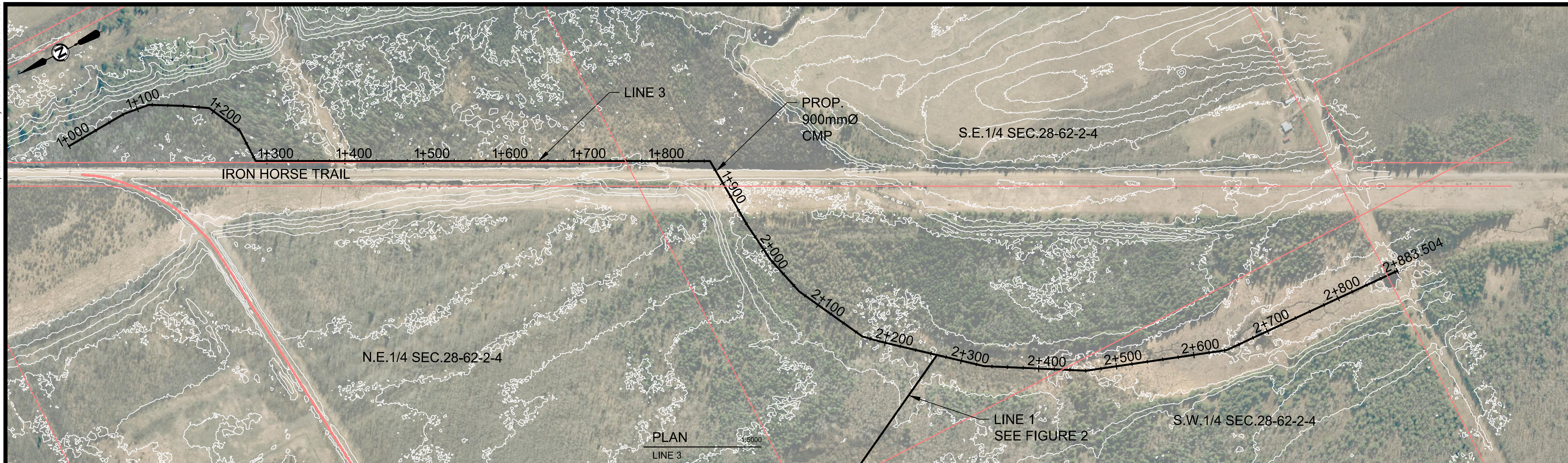

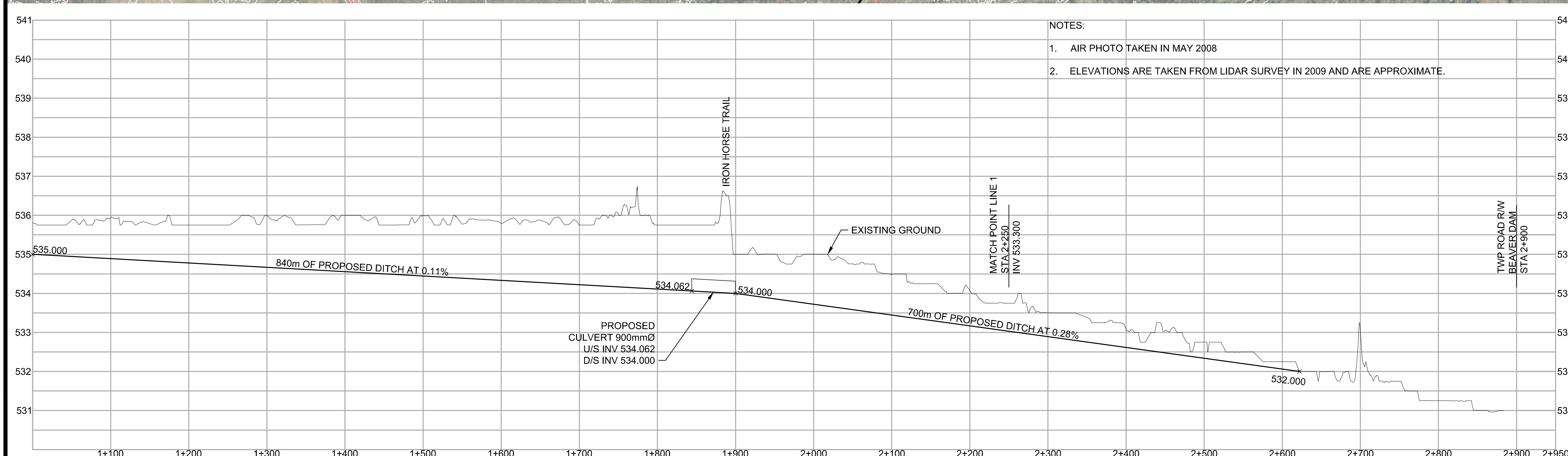

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A	2013-01-28	S.N.	K.G.	PRELIMINARY ISSUE

REVISIONS

Associated Engineering

PROJECT No.	20123590
SCALE	H 1:5000 V 1:100
DRAWN	K. Grandish
DESIGNED	S. Nishtala

City of Cold Lake

4 WING DRAINAGE IMPROVEMENTS

PLAN / PROFILE 3

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 6-15	A	--

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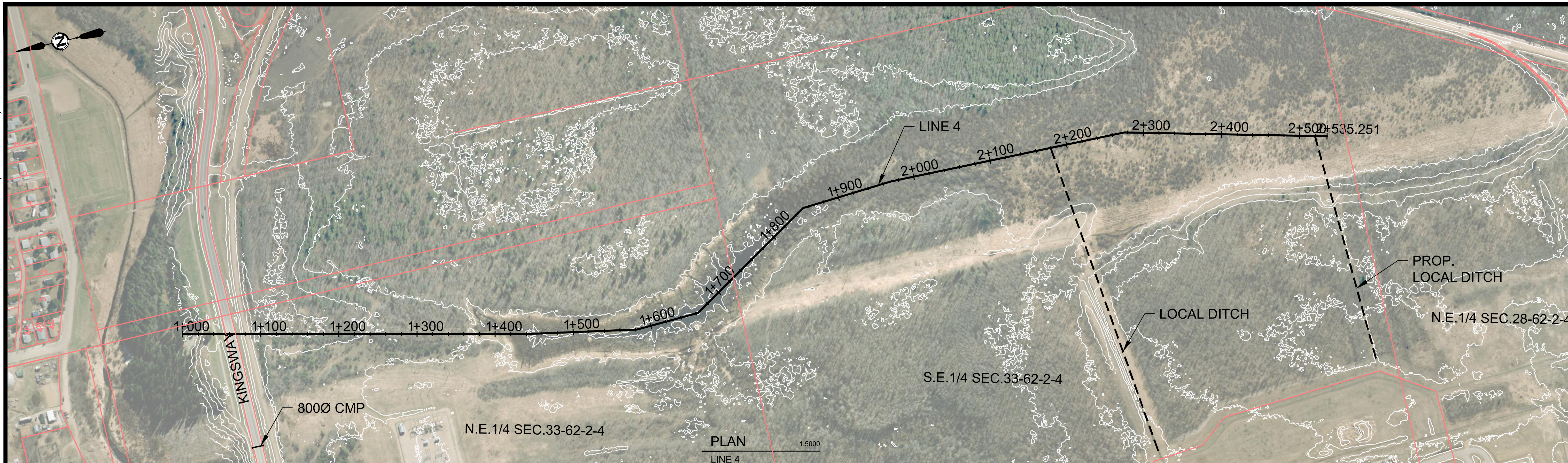


NOTES:

1. AIR PHOTO TAKEN IN MAY 2008
2. ELEVATIONS ARE TAKEN FROM LIDAR SURVEY IN 2009 AND ARE APPROXIMATE.

NO.	DATE	ENG.	BY	SUBJECT
A	2013-01-28	S.N.	K.G.	PRELIMINARY ISSUE

REVISIONS

Associated Engineering

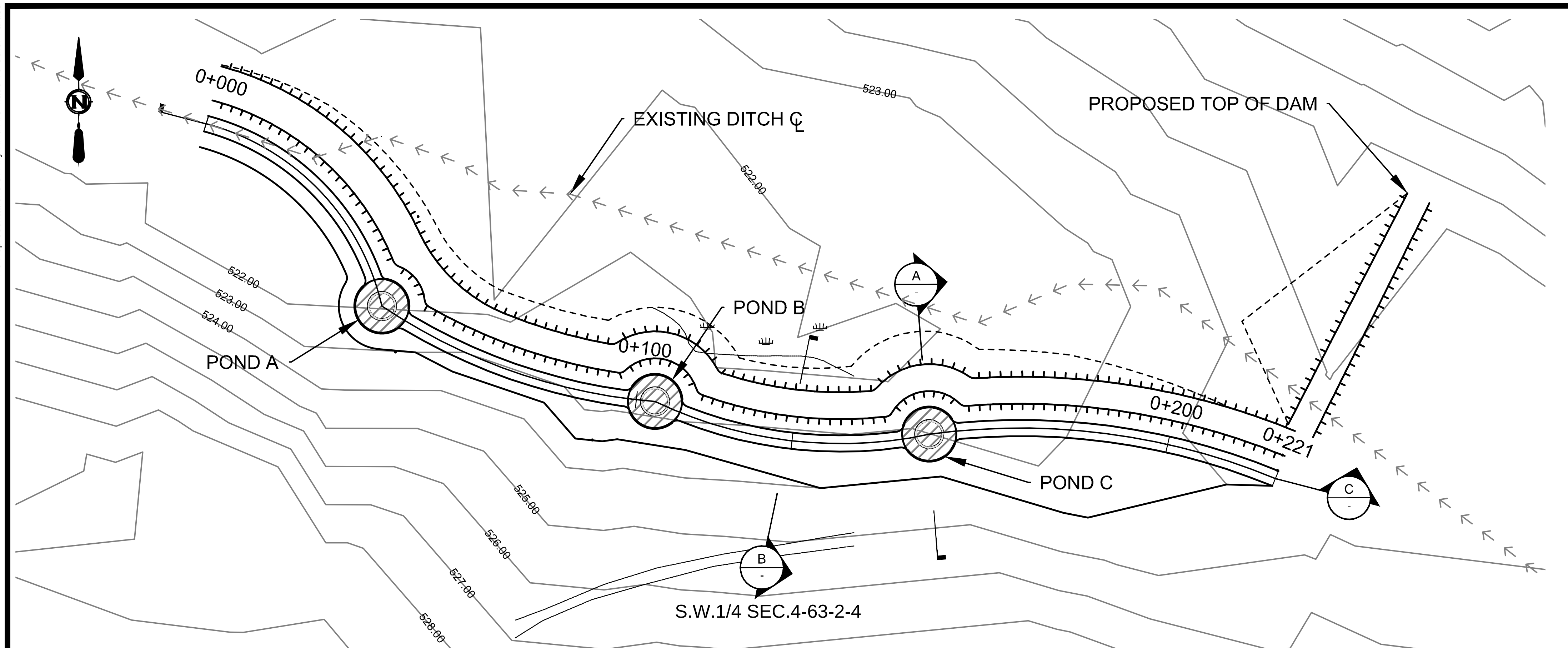
PROJECT No.	20123590
SCALE	H 1:5000 V 1:100
DRAWN	K. Grandish
DESIGNED	S. Nishtala

City of Cold Lake

4 WING DRAINAGE IMPROVEMENTS

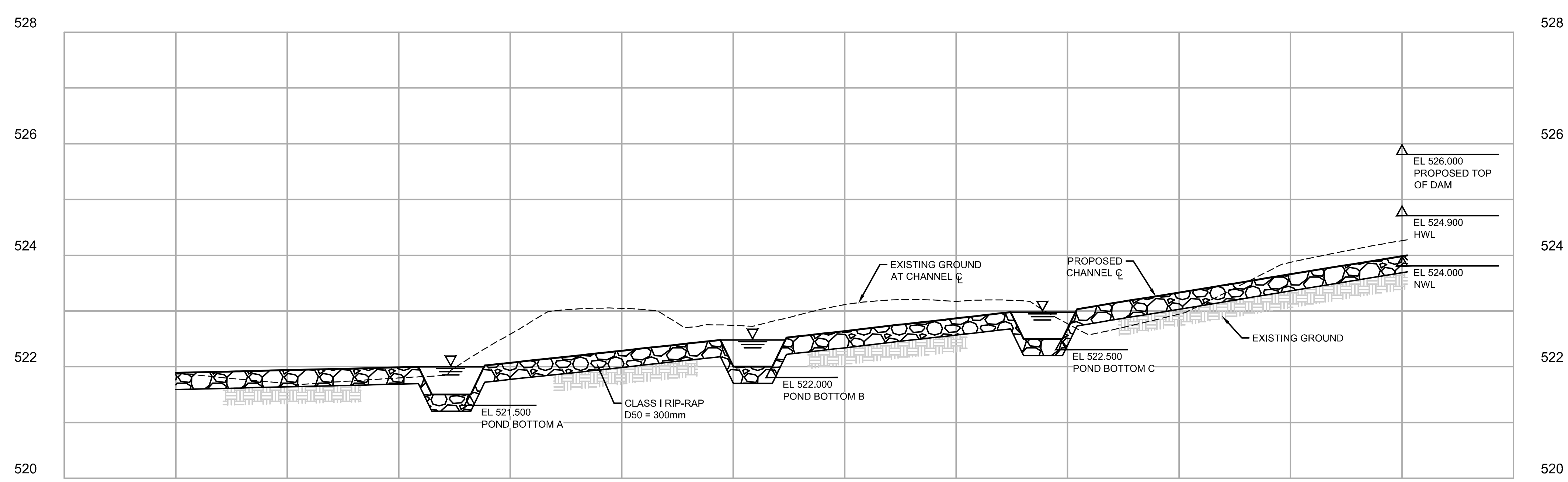
PLAN / PROFILE 4

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 6-16	A	--



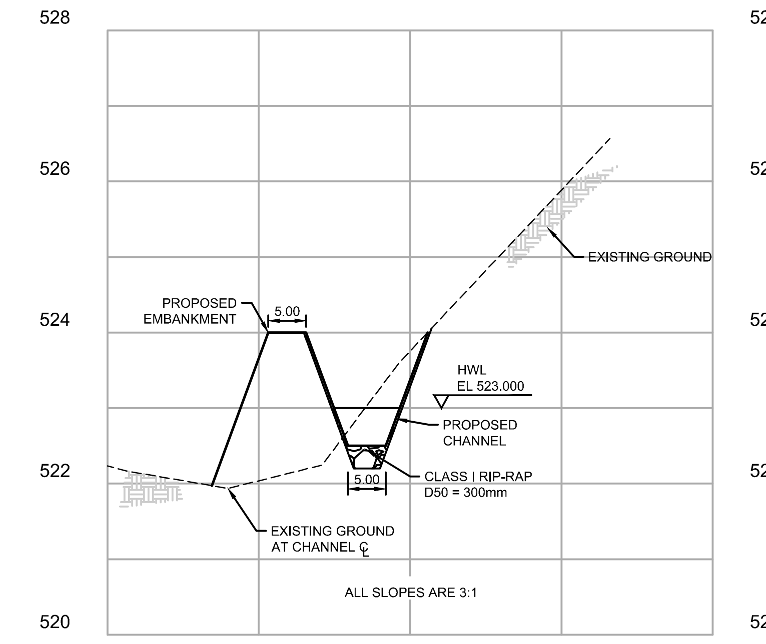
PLAN 1:500

PALM SPRING GOLF COURSE
OUTLET CHANNEL



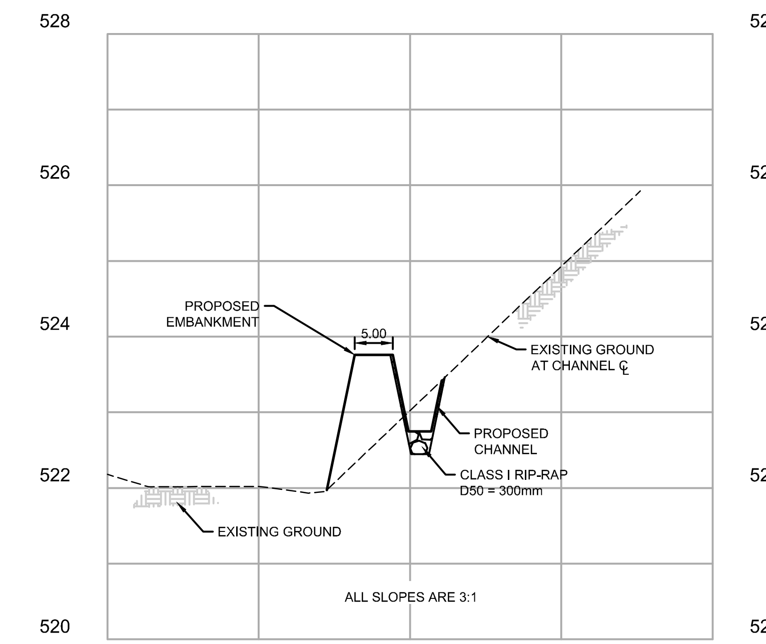
PROFILE H: 1:500 V: 1:50

C - C DITCH CENTER LINE



PROFILE H: 1:500 V: 1:50

A - A POND C



PROFILE H: 1:500 V: 1:50

B - B DITCH CHANNEL

NO.	DATE	ENG.	BY	SUBJECT
A	2013-05-30	L.B.	M.R.	CONCEPT DESIGN

REVISIONS

Associated Engineering

PROJECT No.	20123590-01
SCALE	AS NOTED
DRAWN	M. Revet
DESIGNED	L. Bodnanuk

City of Cold Lake

PALM CREEK PROFILE

PALM SPRING GOLF COURSE
OUTLET CHANNEL

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 6-17	A	--

7 Conclusions

From the analysis described above, it can be concluded that:

7.1 STORM SEWER SYSTEM

- Portions of the existing storm sewer system are overloaded and are at risk of flooding, particularly in South Cold Lake.
- The estimated cost of storm sewer upgrades is about $5 million in North Cold Lake and $10 million in South Cold Lake, for a total cost of approximately $15 million.
- Palm Creek and the Meadows Ditch, which serve as the main outlet channels from Cold Lake, lack the capacity and gradient to accommodate development in the basin.

7.2 THE MEADOWS

- A Stormwater Management Facility (drainage parkway) with approximately 150,000 m^3 of storage capacity is required for the Meadows in the existing and future conditions to control the discharge rate to Palm Creek to the pre-development flow of 2.0 L/s/ha. This includes storage of runoff from presently developed areas of South Cold Lake.
- The estimated cost of the Meadows Drainage Parkway and outfall is approximately $ 15 Million.
- The existing Meadows Ditch, which provides the outlet from the Meadows, is too high to facilitate draining of the area and the proposed SWMF and it creates a risk of flooding for the existing and future development.
- Significant modifications to the existing drainage in the Meadows and its outfall will have to be made to accommodate development of the area. A new outfall pipe to the Meadows Ditch and lowering a portion of the ditch to Palm Creek are the most practical and cost-effective solution.
- Soils and groundwater conditions in the Meadows will provide significant challenges to development and to the construction of drainage facilities in the area. Special measures will be required to limit the depth of stormwater management facilities, prevent excessive infiltration, and prevent basal heave.
- The Drainage Parkway option, consisting of a drainage channel to carry low flows and a floodplain section to store runoff from larger events, provides the most flexibility for stormwater management and to accommodate the soils and groundwater conditions of the area.

7.3 PALM CREEK

- The most feasible way to provide drainage for the Palm Creek basin is to construct a drainage parkway within the Palm Creek floodplain from Township Road 634, south to the existing channel at 53 Avenue that was constructed in 1986 to control flooding in the South Cold Lake area.
- If the drainage parkway is not constructed, large areas within the existing City boundary and the future annexation area cannot be drained by gravity, which will create significant constraints to the development of these areas.
- The cost of the drainage parkway is likely to be in the order of $10 Million which translates into an off-site cost of approximately $7,200 per hectare of benefitting lands.
- Significant environmental issues will need to be addressed and approval of Alberta Environment and Provincial and Federal Fisheries will be required.0

7.4 43 AVENUE BASIN

- The 43 Avenue wetland does not have an adequate outlet at present and risks flooding adjacent properties, until the permanent connection is constructed.
- The Fischer SWMF report by Scheffer Andrew Ltd. does not discuss the potential geotechnical constraints involved in designing the SWMF.

7.5 CFB – 4 WING

- The southeast portion of the 4-Wing base area is poorly drained due to flat terrain, buried hydraulic structures, and absence of adequate drainage channels, and this creates a constraint to development near Medley Road.
- Drainage improvements and maintenance are required to ensure proper drainage of the area.

7.6 GOLF COURSE RESERVOIR

- The Palm Springs Golf Course dam does not have an adequate outlet to provide for flood discharges or fish passage and is at risk of overtopping and damage.
- The new outlet will require passage to be provided for migration of smaller fish but likely not larger (sport) fish.

8 Recommendations

AE recommends the following measures to improve the drainage conditions in Cold Lake:

8.1 DESIGN CRITERIA

- That the City should include the DND Bird Hazard Zone, the Modified Chicago storm, and the Huff storm distributions in its Design Standards to ensure consistency in design.

8.2 STORM SEWER UPGRADES

- That the City mitigate surface ponding and flood risk in existing areas of the City by providing larger pipes as shown in **Figures 5-5** and **5-6** for an approximate cost of $ 15 Million.

8.3 THE MEADOWS

- That the City construct a drainage parkway in the Meadows to provide attenuation of runoff from existing and future development and a linear park for the community for an approximate cost of $15 Million.

- The new outfall pipe from the drainage parkway to the Meadows Ditch should be constructed to provide an adequate outlet from the area.

- That the existing Meadows Ditch and culvert across Highway 28 be left in place to act as an emergency major drainage system outlet from the area.

8.4 PALM CREEK

- That the City follow up on discussions with Alberta Environment and Provincial and Federal Fisheries to explore the feasibility of lowering Palm Creek (constructing the drainage parkway) and to define the mitigation required.

- That the City consider applying infrastructure funds or other grant money towards constructing the drainage parkway, so as to facilitate development in the basin, and create an offsite drainage levy of approximately $7,200 per hectare to facilitate recovery of these costs from all of the benefitting basin.

- That a gravity outfall be constructed for Creekside Estates to replace the existing pump station.

8.5 43 AVENUE BASIN

- Complete the Fischer Estates SWMF and the permanent outlet connection to the 43 Avenue Trunk.
- That offsite runoff from areas to the south of Fisher Estates, including Red Fox Estates, be diverted around Fischer Estates and that an easement be secured for this diversion.
- That a detailed geotechnical investigation like the one undertake for the Meadows be conducted for the Fischer Estates SWMF to determine the underling soils and groundwater conditions and their potential impact on the design and construction of this SWMF.

8.6 CFB-4 WING

- That DND undertake preliminary design of proposed drainage improvements in the poorly drained southeast area of the base, based on the conceptual plans provided in the current study.
- That DND develop a plan to maintain conveyance and control beaver dams in the ditches.

8.7 GOLF COURSE DAM

- That DND proceed immediately with a geotechnical study, preliminary, and detailed design to repair and raise the dam and to construct a permanent outlet and provide fish passage from the reservoir.

8.8 GENERAL

- That the stormwater management concept plan provided in **Figure 6.2** and **Appendix B** be adopted to provide guidance for future drainage development in the City.

8.9 FLOW AND RAINFALL MONITORING

- That the City monitor flows at one site in Palm Creek and rainfall at two sites in North and South Cold Lake.
- That the City routinely check flow and rainfall data to ensure Quality Control and perform regular maintenance of the flow and rainfall monitoring equipment.

Closure

This report was prepared for the City of Cold Lake to update the City's Master Drainage Plan from 2006.

The services provided by Associated Engineering Alberta Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering Alberta Ltd.

PROFESSIONAL ENGINEER LARRY E. BODNARUK ALBERTA

June 17, 2014

FOR Chris Skowronski, P. Eng.
Project Manager

Larry Bodnaruk, P. Eng.
Senior Water Resource Engineer

PROFESSIONAL ENGINEER SANTOSH V. NISHTALA ALBERTA

June 17, 2014.

Santosh Nishtala, P. Eng., PE
Project Engineer

ASSOCIATED ENGINEERING
QUALITY MANAGEMENT SIGN-OFF
Signature:
Date: June 17, 2014

APEGA Permit to Practice P 3979

Appendix A - Proposed Upgrades - Assessment and Cost Estimates

Appendix A
City of Cold Lake Drainage Master Plan
Table A1-Cost Upgrade Summary

LINE	**Preliminary Cost**	**Basin**
LINE N1	$447,000	Cold Lake North
LINE N2	$224,000	Cold Lake North
LINE N3	$338,000	Cold Lake North
LINE N4	$1,207,000	Cold Lake North
LINE N5	$366,000	Cold Lake North
LINE N6	$844,000	Cold Lake North
LINE N7	$1,203,000	Cold Lake North
LINE N8	$130,000	Cold Lake North
LINE S1	$462,000	Palm Creek
LINE S2	$298,000	Palm Creek
LINE S3	$4,793,000	Meadows
LINE S4	$3,456,000	Meadows
LINE S5	$1,016,000	Meadows
Total	**$14,784,000**	

Appendix A
City of Cold Lake - Drainage Master Plan
Table A 2 - Detailed Preliminary Cost Estimate

Line N1

Pipe Segment	Inlet Node	Outlet Node	Existing Pipe Diameter, mm	Length, m	Proposed Pipe Diameter, mm	Unit Cost	Preliminary Cost
P-623	MH-243	MH-246	375	48.837	450	$ 2,580	$ 126,000
P-624	MH-246	MH-244	375	50.08	450	$ 2,580	$ 129,000
P-625	MH-244	MH-363	450	10.333	525	$ 2,640	$ 27,000
P-7	MH-363	AE-O-2	450	60.378	600	$ 2,730	$ 165,000
Sub-Total							**$ 447,000**
Total							**$ 14,147,000**

Line N2

Pipe Segment	Inlet Node	Outlet Node	Existing Pipe Diameter, mm	Length, m	Proposed Pipe Diameter, mm	Unit Cost	Preliminary Cost
P-11	MH-172	MH-171	375	10.805	525	$ 2,640	$ 29,000
P-223	MH-171	MH-431	450	74.023	525	$ 2,640	$ 195,000
Sub-Total							**$ 224,000**

Line N3

Pipe Segment	Inlet Node	Outlet Node	Existing Pipe Diameter, mm	Length, m	Proposed Pipe Diameter, mm	Unit Cost	Preliminary Cost
C44	J2	J3	375	52.36	525	$ 2,640	$ 138,000
C45	J3	OF4	375	73.26	600	$ 2,730	$ 200,000
Sub-Total							**$ 338,000**

Line N4

Pipe Segment	Inlet Node	Outlet Node	Existing Pipe Diameter, mm	Length, m	Proposed Pipe Diameter, mm	Unit Cost	Preliminary Cost
P-12	MH-104	MH-106	600	108.484	675	$ 2,930	$ 318,000
P-17	MH-106	MH-105	600	12.558	675	$ 2,930	$ 37,000
P-25	MH-114	MH-102	525	46.225	600	$ 2,730	$ 126,000
P-255	MH-105	MH-107	675	73.357	750	$ 3,310	$ 243,000
P-261	MH-102	MH-104	600	95.379	675	$ 2,930	$ 279,000
P-50	MH-112	CBMH-26	750	56.216	900	$ 3,630	$ 204,000
Sub-Total							**$ 1,207,000**

Line N5

Pipe Segment	Inlet Node	Outlet Node	Existing Pipe Diameter, mm	Length, m	Proposed Pipe Diameter, mm	Unit Cost	Preliminary Cost
P-338	MH-96	MH-257	600	42.773	750	$ 3,310	$ 142,000
C50	J18	MH-95	300	87	450	$ 2,580	$ 224,000
Sub-Total							**$ 366,000**

Line N6

Pipe Segment	Inlet Node	Outlet Node	Existing Pipe Diameter, mm	Length, m	Proposed Pipe Diameter, mm	Unit Cost	Preliminary Cost
P-265	MH-306	MH-9000	525	31.278	750	$ 3,310	$ 104,000
P-266	MH-9000	MH-9001	525	72.591	750	$ 3,310	$ 240,000
P-267	MH-9001	MH-309	525	57.294	750	$ 3,310	$ 190,000
P-347	MH-151	MH-152	750	68.948	900	$ 3,630	$ 250,000
P-67	MH-2927	MH-151	750	16.648	900	$ 3,630	$ 60,000
Sub-Total							**$ 844,000**

Line N7

Pipe Segment	Inlet Node	Outlet Node	Existing Pipe Diameter, mm	Length, m	Proposed Pipe Diameter, mm	Unit Cost	Preliminary Cost
P-384	MH-186	MH-148	750	116.703	825	$ 3,480	$ 406,000
P-385	MH-182	MH-186	675	150.455	750	$ 3,310	$ 498,000
P-387	MH-375	MH-183	525	43.405	750	$ 3,310	$ 144,000
P-475	MH-183	MH-182	525	5.586	750	$ 3,310	$ 18,000
C11	MH-482_1	MH-375	525	41.47	750	$ 3,310	$ 137,000
Sub-Total							**$ 1,203,000**

Line N8

Pipe Segment	Inlet Node	Outlet Node	Existing Pipe Diameter, mm	Length, m	Proposed Pipe Diameter, mm	Unit Cost	Preliminary Cost
P-373	MH-143	MH-142	450	36.716	600	$ 2,730	$ 100,000
P-374	MH-142	MH-323	450	10.925	600	$ 2,730	$ 30,000
Sub-Total							**$ 130,000**

Line S1

Pipe Segment	Inlet Node	Outlet Node	Existing Pipe Diameter, mm	Length, m	Proposed Pipe Diameter, mm	Unit Cost	Preliminary Cost
P-101	MH-264	MH-75	450	111.611	525	$ 2,640	$ 295,000
P-102	MH-263	MH-264	300	42.228	450	$ 2,580	$ 109,000
P-99	MH-75	MH-265	450	21.229	600	$ 2,730	$ 58,000
Sub-Total							**$ 462,000**

Line S2

Pipe Segment	Inlet Node	Outlet Node	Existing Pipe Diameter, mm	Length, m	Proposed Pipe Diameter, mm	Unit Cost	Preliminary Cost
P-123	MH-274	MH-275	375	6.333	450	$ 2,580	$ 16,000
P-130	MH-277	MH-274	375	109.244	450	$ 2,580	$ 282,000
Sub-Total							**$ 298,000**

Line S3

Pipe Segment	Inlet Node	Outlet Node	Existing Pipe Diameter, mm	Length, m	Proposed Pipe Diameter, mm	Unit Cost	Preliminary Cost
P-146-1	MH-56	MH-2555	750	23.198	1350	$ 4,760	$ 110,000
P-146-2	MH-2555	MH-249	750	121.608	1350	$ 4,760	$ 579,000
P-149	MH-55	MH-57	300	62.029	450	$ 2,580	$ 160,000
P-152	CBMH-206	CBMH-121	750	85.864	1350	$ 4,760	$ 409,000
P-154	MH-199	CBMH-125	300	58.536	375	$ 2,560	$ 150,000
P-162	MH-197	CBMH-206	750	110.897	1350	$ 4,760	$ 528,000
P-169	CBMH-196	MH-197	750	67.675	1200	$ 4,360	$ 295,000
P-171	MH-346	MH-83	750	114.051	1050	$ 3,930	$ 448,000
P-172	MH-82	MH-346	750	80.788	1050	$ 3,930	$ 317,000
P-174	MH-344	MH-284	600	50.477	900	$ 3,630	$ 183,000
P-190	MH-83	CBMH-196	750	19.971	1200	$ 4,360	$ 87,000
P-2551	MH-249	OUTF-2549	900	18.627	1350	$ 4,760	$ 89,000
P-2590	MH-2590	MH-342	525	41.023	750	$ 3,310	$ 136,000
P-289	MH-2973	MH-55	300	66.031	375	$ 2,560	$ 169,000
P-344_(1)	MH-516	MH-70	375	90.82	525	$ 2,640	$ 240,000
P-345	MH-515	MH-516	375	24.77	450	$ 2,580	$ 64,000
P-436	MH-342	MH-343	600	15.905	750	$ 3,310	$ 53,000
P-437	MH-343	MH-70	600	40.132	750	$ 3,310	$ 133,000
P-438	MH-70	MH-344	600	12.354	900	$ 3,630	$ 45,000
P-504	CBMH-121	MH-56	750	85.708	1350	$ 4,760	$ 408,000
P-505	MH-57	MH-56	300	25.796	450	$ 2,580	$ 67,000
P-708	MH-284	MH-82	750	31.257	1050	$ 3,930	$ 123,000
Sub-Total							**$ 4,793,000**

Line S4

Pipe Segment	Inlet Node	Outlet Node	Existing Pipe Diameter, mm	Length, m	Proposed Pipe Diameter, mm	Unit Cost	Preliminary Cost
P-181	MH-60	MH-200	1050	130.648	1200	$ 4,360	$ 570,000
P-182	MH-61	MH-60	1050	61.537	1200	$ 4,360	$ 268,000
P-185	MH-63	MH-61	900	70.377	1050	$ 3,930	$ 277,000
P-193	MH-1	MH-63	900	81.75	1050	$ 3,930	$ 321,000
P-201	MH-66	MH-1	900	81.611	1050	$ 3,930	$ 321,000
P-202	MH-68	MH-67	450	77.482	600	$ 2,730	$ 212,000
P-262	MH-201	MH-2448	1200	59.173	1350	$ 4,760	$ 282,000
P-419	MH-213	MH-211	300	158.107	750	$ 3,310	$ 523,000
P-511	MH-200	MH-201	120	104.48	1350	$ 4,760	$ 497,000
P-658	MH-67	MH-65	450	67.75	600	$ 2,730	$ 185,000
Sub-Total							**$ 3,456,000**

Line S5

Pipe Segment	Inlet Node	Outlet Node	Existing Pipe Diameter, mm	Length, m	Proposed Pipe Diameter, mm	Unit Cost	Preliminary Cost
C32	MH-310	CBMH-92	N/A	280	900	$ 3,630	$ 1,016,000
Sub-Total							**$ 1,016,000**

Appendix A Summary of Cost for Meadows Drainage Parkway

	Average Depth, m	**Area of Cross Section, sq m**	**Length, m**	**Volume of Cut, cu m**	**Unit Cost, $/Cu m**	**Unit Cost, $/m**	**Preliminary Cost**
Drainage Parkway	3.5	138.4	626	86638	$30		$2,599,000
Floodway	2.5	132.4	346	45810	$30		$1,374,000
Outfall Pipe (Jack & Bore)			620			$8,000	$4,960,000
Outfall Pipe (Outfall Pipe)			350			$3,000	$1,050,000
Sub-Total							$9,983,000
Total							$14,974,500

* Includes Engineering (10%) and Contingency(40%)

Appendix A
Table A3 - Storm Collection System Unit Cost Estimates

Storm Sewer

Undeveloped Lands

Item	**200mm**	**250mm**	**300mm**	**375mm**	**450mm**	**525mm**	**600 mm**		**750mm**		**900 mm**	**2.4X1.8 CBC**	**1200 mm RCP**	**1200 mm PVC**
Topsoil Stripping and Stockpile (assume depth of 0.4m)	$ 17.50	$ 17.50	$ 17.50	$ 20.00	$ 20.00	$ 20.00	$ 22.50		$ 25.00		$ 27.50	$ 35.00	$ 30.00	$ 30.00
Trenching and backfilling	$ 270.00	$ 270.00	$ 270.00	$ 315.00	$ 315.00	$ 315.00	$ 360.00		$ 360.00		$ 405.00	$ 500.00	$ 450.00	$ 450.00
Pipe Zone Material	$ 25.00	$ 25.00	$ 25.00	$ 50.00	$ 50.00	$ 50.00	$ 75.00		$ 75.00		$ 100.00	$ 150.00	$ 125.00	$ 125.00
Supply and Install ASTM C76 CL-4 Pipe	$ 45.00	$ 50.00	$ 58.45	$ 72.15	$ 85.70	$ 124.75	$ 156.35		$ 324.60		$ 460.60	$ 2,872.00	$ 665.00	$ 500.00
Place Topsoil, compact and seed	$ 35.00	$ 35.00	$ 35.00	$ 40.00	$ 40.00	$ 40.00	$ 40.00		$ 45.00		$ 50.00	$ 75.00	$ 65.00	$ 65.00
Manholes (1 every 100 m)	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00		$ 200.00		$ 200.00	$ 200.00	$ 200.00	$ 200.00
Miscellaneous (Mob/De-Mob, Survey, Signage) (10%)	$ 59.25	$ 59.75	$ 60.60	$ 69.72	$ 71.07	$ 74.98	$ 85.39		$ 102.96		$ 124.31	$ 125.00	$ 153.50	$ 137.00
Engineering and Contingency (45%)	$ 293.29	$ 295.76	$ 299.95	$ 345.09	$ 351.80	$ 371.13	$ 422.66		$ 509.65		$ 615.33	$ 1,780.65	$ 759.83	$ 678.15
Total	$ 945.04	$ 953.01	$ 966.49	$ 1,111.95	$ 1,133.57	$ 1,195.85	$ 1,361.89		$ 1,642.21		$ 1,982.74	$ 5,737.65	$ 2,448.33	$ 2,185.15
Total (rounded)	**$ 950.00**	**$ 950.00**	**$ 970.00**	**$ 1,110.00**	**$ 1,130.00**	**$ 1,200.00**	**$ 1,360.00**		**$ 1,640.00**		**$ 1,980.00**	**$ 5,740.00**	**$ 2,450.00**	**$ 2,190.00**

Developed Lands

Item	**200mm**	**250mm**	**300mm**	**375mm**	**450mm**	**525mm**	**600 mm**	**675mm**	**750mm**	**825mm**	**900 mm**	**2.4X1.8 CBC**	**1050mm**	**1200mm**	**1350mm**
Asphalt Pavement Removal	$ 45.00	$ 45.00	$ 45.00	$ 75.00	$ 75.00	$ 75.00	$ 75.00	$ 75.00	$ 100.00	$ 113.00	$ 125.00	$ 310.00	$ 150.00	$ 175.00	$ 200.00
Granular Base Removal and Disposal	$ 30.00	$ 30.00	$ 30.00	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 75.00	$ 87.50	$ 90.00	$ 230.00	$ 105.00	$ 120.00	$ 135.00
Curb,Gutter, Sidewalk Removal	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 50.00	$ 130.00	$ 50.00	$ 50.00	$ 50.00
Trenching and Backfilling	$ 370.00	$ 370.00	$ 370.00	$ 415.00	$ 415.00	$ 415.00	$ 415.00	$ 415.00	$ 460.00	$ 460.00	$ 460.00	$ 1,150.00	$ 460.00	$ 460.00	$ 460.00
Pipe Zone Material	$ 25.00	$ 25.00	$ 25.00	$ 50.00	$ 50.00	$ 50.00	$ 75.00	$ 75.00	$ 75.00	$ 87.50	$ 100.00	$ 250.00	$ 125.00	$ 150.00	$ 175.00
Supply and Install ASTM C76 CL-4 Pipe	$ 45.00	$ 50.00	$ 58.45	$ 72.15	$ 85.70	$ 124.75	$ 156.35	$ 280.20	$ 324.60	$ 392.60	$ 460.60	$ 2,872.00	$ 586.15	$ 786.40	$ 971.45
Monolitic Sidewalk Curb and Gutter	$ 190.00	$ 190.00	$ 190.00	$ 190.00	$ 190.00	$ 190.00	$ 190.00	$ 190.00	$ 190.00	$ 190.00	$ 190.00	$ 480.00	$ 190.00	$ 190.00	$ 190.00
Existing Pavement Repair	$ 200.00	$ 200.00	$ 200.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 400.00	$ 400.00	$ 400.00	$ 1,000.00	$ 400.00	$ 400.00	$ 400.00
Reconnect Services	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00
Manholes (1 every 100 m)	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 200.00	$ 500.00	$ 200.00	$ 200.00	$ 200.00
Miscellaneous (Mob/De-Mob, Survey, Signage) (10%)	$ 135.50	$ 136.00	$ 136.85	$ 160.22	$ 161.57	$ 165.48	$ 171.14	$ 183.52	$ 207.46	$ 218.06	$ 227.56	$ 712.20	$ 246.62	$ 273.14	$ 298.15
Engineering and Contingency (45%)	$ 670.73	$ 673.20	$ 677.38	$ 793.06	$ 799.77	$ 819.10	$ 847.12	$ 908.42	$ 1,026.93	$ 1,079.40	$ 1,126.42	$ 3,525.39	$ 1,220.74	$ 1,352.04	$ 1,475.82
Total	$ 2,161.23	$ 2,169.20	$ 2,182.68	$ 2,555.43	$ 2,577.04	$ 2,639.33	$ 2,729.60	$ 2,927.14	$ 3,308.99	$ 3,478.06	$ 3,629.58	$ 11,359.59	$ 3,933.51	$ 4,356.58	$ 4,755.41
Total (rounded)	**$ 2,160.00**	**$ 2,170.00**	**$ 2,180.00**	**$ 2,560.00**	**$ 2,580.00**	**$ 2,640.00**	**$ 2,730.00**	**$ 2,930.00**	**$ 3,310.00**	**$ 3,480.00**	**$ 3,630.00**	**$ 11,360.00**	**$ 3,930.00**	**$ 4,360.00**	**$ 4,760.00**

Notes

1. Pipe Installation / Replacement, depth to invert, 3-4 m
2. Includes engineering (15%) & Contingencies (30%)
3. For planning purposes only; subject to review in detailed design

Appendix A
Table A-4
City of Cold Lake Drainage Master Plan
Existing Pipe Upgrade Criteria

Line	Surcharge to Ground (1:5Y)	Surcharge 0.2 > ground (1:100 Y)	Sag Depth>0.2 m	Off Street Drainage	History of Flooding	Upgrade (Y/N)	Comments
N1	Y	Y	Y	Y	Y	Y	Sag > 0.2 m on 26 St; Flooding on 26 STREET, right next to the sag; sanitary backup at BEACH AVENUE
N2	Y	Y	Y	Y	N	Y	
N3	Y	Y	Y	Y	N	Y	Sanitary Backup at PINE AVENUE, could be due to I/I from Trapped sag
N4	Y	Y	Y	Y	Y	Y	Flooding on MILLER CRESCENT; Sanitary sewer Backup on MILLER CRESCENT, 22 STREET; sag >0.2 m deep on Miller Cres and 22 St.
N5	Y	Y	Y	N	Y	Y	outfall pipe might need upgrades due to flooding on 16 STREET. Rest of the system has good drainage. No trapped sags along 16th st. at 3rd ave
N6	Y	Y	Y	Y	N	Y	Huge trapped sag on intersection of 8 Ave and 13 St; storm line goes through lanes.back of lots and could potentially flood private property.
N7	Y	Y	Y	Y	Y	Y	Flooding on 11 STREET, trapped sag >0.2 m in a lane between 11 Ave and 12 Ave, between 12 and 10 St
N8	Y	Y	N	Y	N	Y	Major drainage path along Clarke property.
S1	Y	Y	Y	N	Y	Y	Flooding on 51 AVENUE, 52 AVENUE
S2	Y	Y		N	Y	Y	Flooding on 58 Street, 51 AVENUE, Sewer backup 58 STREET, 52 AVENUE
S3	Y	Y		Y	Y	Y	Flooding on 54 STREET, 53 STREET, 53 AVENUE, off street drainage between 54 St and 53 St. 6 locations of Sanitary sewer backup on 54 st between 52 Ave and 54 Ave
S4	Y	Y		N	Y	Y	Flooding on 50 AVENUE
S5	Y	Y	Y	N	Y	Y	Sag depths > 0.2 m on 47 Ave , 48 Ave between 48 st and 47 St; on 49 Ave, on 45 St; Flooding on 50 AVENUE

Appendix B - Future Drainage Concept

Appendix B
City of Cold Lake Drainage Master Plan
Table B-1

Pond ID	Drainage Area (ha)	Land use	Drainage Area Cumulative (ha)	Outflow (Local) (L/s)	Outflow (Cumulative) (L/s)	Storage Volume (cu m)	Pond Area (ha)	Bottom, m	HWL, m	Freeboard EL, m
100A	36.4	Residential	36.4	73	73	18000	1.9	536.8	538.3	539.3
101A	33.6	Residential	33.6	67	67	16500	1.7	537.5	539.0	540.0
103	85.7	Residential	85.7	171	171	41500	4.3	537.5	539.0	540.0
104	62.7	Residential	62.7	125	125	30500	3.3	541.0	542.5	543.5
105	56.7	Residential	56.7	113	113	27500	2.9	540.5	542.0	543.0
108B	28.3	Residential	28.3	57	57	27000	1.5	544.0	545.5	547.5
108A	126.3	Residential	126.3	253	253	61000	8.1	539.0	540.5	541.5
101	49.4	Residential	49.4	99	99	24000	2.6	537.0	538.5	539.5
100B	36.1	Residential	36.1	72	72	17500	1.8	537.0	538.5	539.5
100	56.1	Residential	105.5	112	211	27000	2.9	535.0	536.5	537.5
102	72.9	Residential	72.9	146	146	35200	3.9	540.0	541.5	542.5
8	47.1	Industrial (73%); Commercial (22%)	104.9	94	210	32400	3.6	536.8	538.3	539.3
2	67.4	Residential (88%); Commercial (7%)	67.4	135	135	34000	3.8	536.5	538.0	539.0
5	140.7	Residential	140.7	281	281	61000	3.6	534.0	536.5	537.5
4	169.5	Residential (61%); Commercial (36%)	300.1	339	600	92000	5.5	533.0	535.5	536.5
3	79.6	Residential	372.1	159	744	38500	4.3	536.0	537.5	538.5
1	42.0	Residential	114.9	84	230	20500	2.2	538.5	540.0	541.0
3B	13.9	Residential	13.9	28	28	6700	0.8	537.5	539.0	540.0
108C	190.8	Residential (SWM in Lake)	407.4	382	815	116000				
10	32.0	Not developable due to proximity to Landfill		64	0					
108D	30.1	Residential (SWM in Lake)		60	0					
109	72.2	Residential	479.6	144	959	38000	4.3	539.5	541.0	542.0
7	117.1	Residential	117.1	234	234	56500	7.2	539.5	541.0	542.0
6	24.1	Residential	24.1	48	48	12000				
111	79.8	Residential	220.9	160	442	38500	4.3	540.0	541.5	542.5
110	58.4	Residential	727.0	117	1454	28500	3.1	539.0	540.5	541.5
110A	56.1	Residential	783.1	112	1566	27500	3.0	538.5	540.0	541.0
112A	65.9	Residential	848.9	132	1698	32000	3.5	538.0	539.5	540.5
112	23.8	Residential	23.8	48	48	11500	1.2	538.0	539.5	540.5
113	22.4	Residential	22.4	45	45	11000	1.2	534.5	536.0	537.0
114	127.5	Residential (SWMF in Lake)	127.5	255	255	66000	5.2	537.0	539.0	540.0
115	63.0	Residential	63.0	126	126	30500	3.3	534.0	535.5	536.5
112B	69.7	Residential	1085.6	139	2171	34000	3.8	533.0	534.5	535.5
130	65.1	Residential	65.1	130	130	32500	3.6	546.0	547.5	548.5
131	92.4	Residential	157.5	185	315	43500	5.1	540.5	542.0	543.0
133	37.9	Residential	195.3	76	391	18500	2.0	536.0	537.5	538.5
133A	52.2	Residential	52.2	104	104	25500	2.6	540.0	541.5	542.5
133B	13.9	Residential	13.9	28	28	6700	0.8	534.0	535.5	536.5
134	187.3	Residential	434.8	375	870	90500	7.5	534.5	536.0	537.0
135	45.4	Residential	480.2	91	960	22000	2.2	530.0	531.5	532.5
Meadows	222.0	Residential	702.2	444	1404	107000	9.2	530.0	532.0	533.0
47	24.1	Residential	24.1	48	48	12000	1.0	536.0	537.5	538.5
155	53.0	Residential	53.0	106	106	25500	2.7	554.0	555.5	556.5
152	27.0	Residential	27.0	54	54	13000	1.4	549.5	551.0	552.0
153	37.8	Residential	64.8	76	130	18500	2.0	548.5	550.0	551.0
154	14.9	Residential	79.7	30	159	7500	0.8	548.0	549.5	550.5
151	69.7	Landfill		139						
150	19.4	Residential	19.4	39	39	9500	1.0	542.5	544.0	545.0

Appendix B
City of Cold Lake Drainage Master Plan
Table B-1

Pond ID	Drainage Area (ha)	Land use	Drainage Area Cumulative (ha)	Outflow (Local) (L/s)	Outflow (Cumulative) (L/s)	Storage Volume (cu m)	Pond Area (ha)	Bottom, m	HWL, m	Freeboard EL, m
149	47.3	Residential	66.7	95	133	23000	2.4	542.0	543.5	544.5
11A	26.7	Residential	26.7	53	53	13000	1.4	539.0	540.5	541.5
11	51.4	Residential	78.1	103	156	25000	2.7	536.0	537.5	538.5
12	14.5	Residential	14.2	29	28	7000	0.8	535.5	537.0	538.0
14_1	30.1	Residential	30.1	60	60	14500	1.5	538.5	540.0	541.0
13	20.0	Residential	20.0	40	40	10000	1.1	537.5	539.0	540.0
146A	63.5	Industrial	63.5	127	127	31000	3.4	540.5	542.0	543.0
146	58.6	Industrial	58.6	117	117	28500	4.4	537.5	539.0	540.0
146B	53.3	Industrial	112.0	107	224	35500	4.0	537.0	538.5	539.5
145A	67.7	Industrial	67.7	135	135	41500	4.8	538.0	539.5	540.5
145B	64.9	Industrial	132.5	130	265	43500	5.1	537.5	539.0	540.0
145	85.7	Industrial (65%); Residential (30%)	218.2	171	436	52000	6.4	537.0	538.5	539.5
144A	34.8	Residential	34.8	70	70	17000	1.8	540.0	541.5	542.5
144E	42.9	Residential	77.7	86	155	21000	2.2	537.0	538.5	539.5
144C	87.1	Residential	87.1	174	174	42000	4.8	535.5	537.0	538.0
144B	100.4	Residential	187.5	201	375	48500	5.8	534.5	536.0	537.0
144	41.3	Residential	228.9	83	458	20000	2.1	534.0	535.5	536.5
201	28.0	Commercial	256.9	56	514	21500	2.3	532.5	534.0	535.0
138	60.2	Residential	60.2	120	120	29000	3.1	534.0	535.5	536.5
140	67.5	Residential	67.5	135	135	32500	3.6	533.5	535.0	536.0
141	66.6	Residential	134.1	133	268	32500	3.6	532.0	533.5	534.5
205	25.2	Residential	159.3	50	319	12500	1.3	531.5	533.0	534.0
208	16.8	Residential	16.8	34	34	8500	0.9	528.5	530.0	531.0
15	7.4	Residential	7.4	15	15	4000	0.5	535.5	537.0	538.0
16	49.3	Residential	56.8	99	114	24000	2.5	534.5	536.0	537.0
20A	13.5	Residential	15.9	27	32	6500	0.7	537.0	538.5	539.5
20B	8.0	Residential	8.0	16	16	3900	0.5	537.5	539.0	540.0
20C	2.1	Residential	2.1	4	4	1000	0.2	538.0	539.5	540.5
18	22.6	Residential	38.5	45	77	11000	1.2	535.0	536.5	537.5
20	10.1	Commercial	10.1	20	20	7000	0.8	536.0	537.5	538.5
21	21.5	Commercial	21.5	43	43	14500	1.5	545.0	546.5	547.5
22	31.5	Commercial (19%); Residential (76%)	53.0	63	106	17000	1.8	539.0	540.5	541.5
23	96.1	Public Services	149.1	192	298	37500	4.2	535.5	537.0	538.0
27	16.7	Residential	16.7	33	33	8000	0.9	554.0	555.5	556.5
26	35.0	Residential	51.7	70	103	17000	1.8	544.5	546.0	547.0
25	28.3	Residential	80.0	57	160	14000	1.5	544.0	545.5	546.5
24A	36.5	Residential	116.4	73	233	17600	1.9	538.0	539.5	540.5
24B	31.6	Public Services	148.1	63	296	12500	1.3	537.5	539.0	540.0
202	29.0	Commercial	336.2	58	672	22000	2.3	532.5	534.0	535.0
200	57.4	Residential	57.4	115	115	28000	3.0	535.0	536.5	537.5
47	24.1	Commercial	24.1	48	48	22000	2.3	536.0	537.5	538.5
204	52.1	Residential (40%); Commercial (55%)	52.1	104	104	33500	3.7	534.0	535.5	536.5
207_1	33.6	Residential	33.6	67	67	16500	1.8	529.5	531.0	532.0
206	28.5	Residential	28.5	57	57	14000	1.5	531.0	532.5	533.5
207_2	34.0	Commercial	34.0	68	68	26000	2.8	532.5	534.0	535.0
211	46.4	Residential (40%); Commercial (55%)	80.4	93	161	30000	3.3	527.5	529.0	530.0
210	13.6	Residential	94.0	27	188	6500	0.7	527.0	528.5	529.5
209	14.2	Residential	14.2	28	28	7000	0.8	527.5	529.0	530.0

Associated Engineering	City of Cold Lake

CITY OF COLD LAKE
DRAINAGE MASTERPLAN

FUTURE DRAINAGE CONCEPT
COLD LAKE NORTH

PROJECT No.: 2012-3590

DATE: 3/28/2014

SCALE: 1:12,500

CITY OF COLD LAKE **DRAINAGE MASTERPLAN**		PROJECT No.: 2012-3590
FUTURE DRAINAGE CONCEPT COLD LAKE SOUTH		DATE: 3/28/2014
		SCALE: 1:12,500

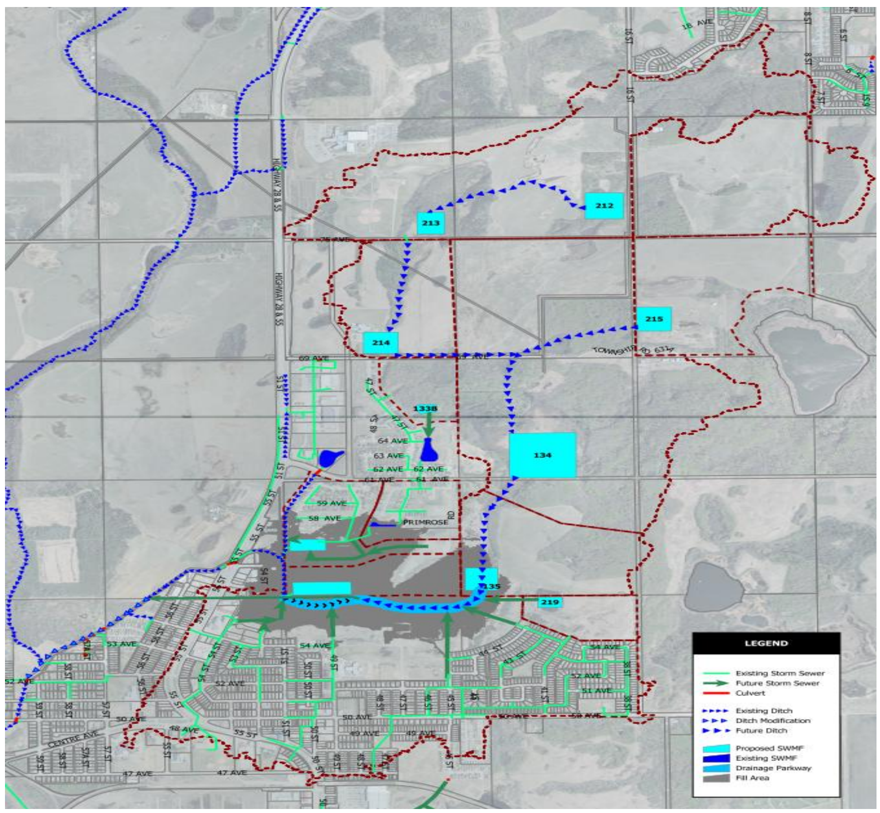
Appendix C - Technical Memorandum #1 - The Meadows

Associated Engineering | GLOBAL PERSPECTIVE. LOCAL FOCUS.

TECHNICAL MEMORANDUM

City of Cold Lake

Meadow Drainage Plan



April 2014

CANADA'S BEST MANAGED COMPANIES

Table of Contents

1 Background

This Technical Memorandum assesses stormwater management options for the future development areas which drain to the Meadows and to Palm Creek.

Figure 1 shows the principal drainage features, the outlines of the primary basins within the project area and the overall drainage basins in Cold Lake. The Meadows is a low lying area in South Cold Lake.

Most of the existing development area in South Cold Lake drains to the Meadows. This area is flat and poorly drained, and is underlain by saturated sands and high groundwater tables that present challenges to the drainage of these lands.

This Technical Memorandum provides an overview of the existing and future drainage patterns, soil and groundwater issues, and stormwater management requirements in the Meadows area of Cold Lake and outlines several options to drain the Meadows which are key to developing a drainage plan to service both the existing and future development of Cold Lake.

The outfall options were explored first, and their feasibility was investigated by geotechnical analysis. The outfall option was finalized based on the geotechnical analysis, preliminary costs, constructability and the service area, after which the options for providing stormwater management for this area were explored and finalized. The Technical Memorandum has been organized in the same order.

2 Existing Drainage Conditions

The project area was reportedly a lake in the early 20th Century, but over time a number of drainage improvements have been made, principally in constructing the Meadows Ditch which goes under Highway 28 and drains to Palm Creek. These improvements have provided some measure of drainage to the Meadows but the area is still poorly drained.

To compound these issues, the Meadows area is generally underlain by a layer of water-bearing sand at a depth of about 4 to 6 m below ground surface. The area has historically had a high groundwater table, up to about one meter below ground level. These conditions make the construction of underground services difficult and often require de-watering to permit such construction.

The Meadows catchment includes an area of approximately 904 ha, extending about 5 km from north to south and 2 km from east to west. This area can be subdivided into three sub-catchments, identified as Basins I, II and III in Figure 1. The three areas collectively drain to the Meadows Ditch through an 1800 mm culvert across Highway 28, and then to Palm Creek.

Basin I: This basin, immediately east of Highway 28 covers approximately 394 ha. Portions of this sub-catchment (Basin 1A) have been developed with stormwater management facilities (SWMFs) discharging at a controlled rate of 2 L/s/ha. Runoff drains through existing ditches to the Meadows Ditch on the east side of Highway 28. The remaining portion of this sub-catchment (Basin 1B) is currently undeveloped.

Basin II: This basin, to the north and east of the Meadows, consists of approximately 244 ha of undeveloped land. This area drains to the Meadows but currently lies outside the existing City boundary.

Basin III: This basin, to the south of Meadows, is mostly developed and drains through several storm sewer systems to the Meadows. The area comprises approximately 266 ha, of which 200 ha is developed. The land use is primarily residential and commercial.

A network of ditches carries the runoff from the south to the Meadows Ditch at Highway 28. The ditches are very flat, and runoff is usually stored in the low lying areas.

3 Outfall Options

Figure 2 displays a more detailed view of the Meadows. As mentioned previously, the outfall options were explored prior to the geotechnical analysis and stormwater management, which is the order in which this report has been organized.

Single/Multi Family Residential and commercial developments have been proposed for the project area. With the proposed development, the existing ditches are to be eliminated and replaced by a storm sewer system and one or more stormwater management facilities discharging at a controlled rate of 2.0 L/s/ha.

The preliminary calculations for the proposed SWMF indicate that approximately 150,000 m^3 of storage capacity will be required for the 1:100 year 24 hour storm. The design of the SWMF will need to accommodate the drainage of existing storm sewers from South Cold Lake and provide drainage from the local area when it is developed.

The existing outfall ditch that drains this area is not low enough to provide positive drainage for this catchment and its stormwater ponds. Hence, in addition to providing stormwater management it is necessary provide a well-defined outlet for this catchment. Six outfall options were explored by varying the depth of the pond as necessitated by the depth of the outfall pipe. The outfall options are discussed below.

3.1 OPTION 1: EXISTING OUTFALL

Option I involves draining the SWMF by gravity, utilizing the existing drainage ditch. Figures 3 and 4 show the longitudinal profile of Palm Creek, downstream from the Meadows Ditch to Marie Creek.
Figure 5 shows the longitudinal profile for this option from the SWMF to Palm Creek.

As shown in Figure 5, the elevation of the pond bottom is limited by the elevation of the 1800 mm culvert under Highway 28. The existing ground elevation around the pond would have to be raised by at least 1 m to an elevation of 533 m to provide the required storage and freeboard.

This option requires a 13.6 ha SWMF with a 750 mm outfall pipe. The outfall pipe would be connected by ditch or pipe to the culvert under Highway 28.

3.2 OPTION 2: LOWER MEADOWS DITCH

Option 2 involves lowering the Highway 28 culvert and the existing Meadows ditch from the proposed SWMF to 52 Ave, to facilitate drainage of the local area. Figure 5 shows the conceptual ditch profile for this option.

A SWMF with an area of 9.9 ha is required with a 750 mm outfall pipe. Lowering the ditch would require additional right-of-way to be purchased and the side slopes flattened to 3:1 to facilitate maintenance. The existing culvert under Highway 28, which was recently replaced during the highway widening project, would need to be lowered, as would the existing culvert under 57 Street.

The existing grades in Palm Creek downstream of the Meadows ditch control the elevation of the proposed SWMF, to a minimum elevation of 528.5. This elevation would be low enough to drain the existing storm sewers in South Cold Lake. However, it will be difficult to achieve adequate cover for frost protection and adequate grade to drain the local area, meaning that either the development area will need to be raised (filled) or a surface drainage system of streets and swales will be required. Either option would create significant development constraints for the remaining undeveloped land in the Meadows.

3.3 OPTION 3: NEW PIPE TO MEADOW DITCH

Option 3 involves a new pipe outfall to drain the SWMF to avoid the deep ditch cut and culvert replacements of Option 2. Figure 6 shows a schematic of the plan view while Figure 7 provides a plan and profile for this option.

Option 3 involves a new 1200 mm storm sewer pipe to drain the Meadows SWMF and the runoff from Basin III. Existing and future (controlled) runoff from Basin I would continue to discharge to the existing ditch or, alternatively, the new pipe could be made larger to drain all three areas. The Meadows ditch is proposed to be lowered between the new outfall and 52 Avenue as a part of this option, and the existing ditch and culvert under Highway 28 would remain in service as an overland flow spill route from the Meadows.

Pipe and ditch grades are limited by the existing elevations of Palm Creek downstream of 52 Avenue. The SWMF would have the same bottom elevation and foot print as in Option 2 and would have the same servicing constraints and issues. Its chief advantages compared to Option 2 is that it reduces the length of Meadows ditch that would have to be lowered, avoids the deep cut and culvert replacement at Highway 28 and provides a pipe outlet.

3.4 OPTION 4: NEW (EXTENDED) OUTFALL TO PALM CREEK

Option 4 involves constructing a proposed SWMF with a bottom elevation of 526.5 mm, and extending the new storm trunk further downstream through the Palm Springs Golf Course as shown in Figure 8 to facilitate drainage of the local area. The proposed storm sewer would be approximately 3500 m in length, and would cross under the Meadows Ditch and Palm Creek as shown in Figures 9 and 10.

The outfall pipe would be 1200 mm in size to provide capacity for Basins II and III. The downstream portion could be oversized to provide capacity for the Palm Creek trunk and thus would service a much larger area.

Basin I would continue to drain to the Meadows ditch in this option or the new outfall pipe could be made larger to carry the additional flow. In either case, the existing Meadows ditch should be left in service to provide a major drainage system overland flow outlet from the Meadows in case of a more severe storm that exceeds the design event.

As shown in Figures 9 and 10, the new outfall pipe could be made larger on the west side of Palm Creek to accommodate a possible new trunk sewer along Palm Creek that would drain future development on the west side of Highway 28. Other options for draining the Palm Creek catchment are examined in Appendix D. The bottom of the SWMF is proposed to be at 526.5 in this option, and would have a plan area of 5.1 ha.

Lowering the SWMF in this alternative would facilitate drainage and development of the area adjacent to the SWMF and would reduce the area of the SWMF. It would also help to drain groundwater and lower the water table in the vicinity of the SWMF and in South Cold Lake. However, the proposed depth is constrained by the presence of a water-bearing sand layer that underlies the SWMF. A detailed geotechnical investigation was undertaken for this area which rendered this option impractical. The details of the geotechnical investigation are discussed in the next section.

3.5 OPTION 5: NEW OUTFALL TO 62 AVENUE

Option 5 involves draining the proposed SWMF by an outfall pipe to Palm Creek at 62 Street as shown in Figure 11. The proposed storm sewer would be approximately 2500 m long and would intercept the Meadows Ditch. The SWMF would have an area of 10.28 ha.

Figures 12 and 13 show the plan profile for this option. A 1200 mm storm pipe would be required upstream of the Meadows ditch, to drain the runoff from Basins II and III and 1500 mm after the storm sewer intercepts the Meadows ditch. As in other options the pipe could be made larger to drain the controlled flow from Basin I.

A bottom elevation of 529 m is proposed for the SWMF for this option, which is 0.5 m higher than Options 2 and 3 and does not provide any apparent advantage when compared to Options 2 and 3.

3.6 OPTION 6: PUMPED OUTFALL

Option 6 involves a lift station to pump the stormwater runoff from the SWMF to the existing ditch, which is above the proposed pond bottom. It would avoid lowering the Meadows ditch or constructing a new outfall pipe. This option is technically feasible but would require a substantial pump station and incur significant operating costs in perpetuity, and should only be considered if other options are not feasible.

3.7 COMPARISON OF OPTIONS

Table 3-1 summarizes the pond size, pond bottom elevation, pond discharge, high water level (HWL), top of bank (TOB), and free board for each of the options discussed above.

Table 3-1
Pond Summary

Option	Pond Size	Bottom Elevation	Pond Discharge	HWL	TOB	Free Board
	ha	m	cu m/s	m	m	m
Option 1 (Existing Ditch)	13.56	530.3	1.8	532.4	533	0.6
Option 2 (Lower Ditch)	9.86	528.5	1.8	531	532	1
Option 3 (Pipe to Meadows Ditch)	9.86	528.5	1.02/1.8	531	532	1
Option 4 (Pipe to Palm Creek)	5.1	526.5	1.02/3.02	531	532	1
Option 5 (Pipe to 62 Ave)	10.28	529	1.02/1.8	531.4	532	0.6
Option 6 (Pump)	9.86	528.5	0.53	531	532	1

Based on the above discussions, Option 1 (existing outfall) would not be hydraulically feasible without filling the area by at least 1 m, to an elevation of 533 m, since the SWMF bottom elevation is constrained by the elevation of the culvert across Highway 28 (529.82) and the upstream elevation of the ditch connecting the SWMF to the highway culvert (530.3). Additionally this option would require the existing ground within the development area to be raised by about one meter to provide storage for a 100 year 24 hour storm.

The SWMF could be lowered to an elevation of 528.5 m as proposed in Option 2 (about 1.8 m below Option 1) by lowering the Meadows Ditch and the existing culvert across Highway 28. This would require significant land acquisition for the right of way for a ditch as deep as 8 m. The SWMF would be too shallow to provide adequate cover and grade for the tributary storm sewers, which might require an open ditch (surface) drainage system. This could pose significant constraints to the future development area and will require significant fill.

Option 3, an outfall pipe to the Meadows Ditch, would reduce the length and depth of the ditch required to be lowered in Option 2, and would also avoid deep cut and culvert replacement at Highway 28. It would allow the SWMF to be lowered to an elevation of 528.5 m as in Option 2 and would have the same constraints for the area to be developed.

Option 4, a new pipe to the downstream of the Palm Springs Golf Course, would allow the SWMF to be lowered, potentially by about 2 m below the elevation proposed in options 2 and 3. Its chief advantage is that it would provide better drainage for The Meadows. It could also provide an outlet for a storm trunk along Palm Creek to drain the area west of Highway 28. However, the results from the geotechnical investigation for Meadows indicate that this option is feasible. The details of the results from the geotechnical investigation will be discussed in the next section.

There is no advantage to Option 5, a shorter outfall to Palm Creek, as it would result in SWMF elevations that are higher than options 2, 3, and 4. Additionally the storm sewer would intercept the Meadows ditch and will need extra capacity to carry the intercepted flows.

Option 6, a lift station to drain the SWMF, would provide the most flexibility in SWMF elevations but would require additional operation and maintenance costs of pumping all the runoff water from the tributary catchment. Also this option relies on mechanical equipment which increases its risk.

Considering all the constraints, the most practical option appears to be Option 3, a new outfall pipe to the Meadows Ditch.

The existing Meadows ditch should be left in service as an emergency overland flow route in all options. The permissible depth of the SWMF for all the above options is subject to the groundwater conditions and the depth of the sand layer and therefore, detailed geotechnical investigations are recommended.

4 Soil and Groundwater Issues

The high groundwater table and saturated sand layer in the Meadows area could potentially affect the construction and maintenance of stormwater management facilities.

Geotechnical studies were undertaken for the Town of Grand Centre as a part of the Grand Centre Dewatering Program by Hydrogeological Consultants Ltd in March 1976. The report indicated that the elevation of the saturated sand layer ranges from 528.8 to 525.8 in the vicinity of the proposed pond (about 3 to 6 m below ground elevation). The groundwater elevations were determined by drilling a number of groundwater wells in the area.

A dewatering program was conducted in 1975 by pumping from several groundwater wells drilled in the Meadows. Pumping lowered the groundwater table by approximately 1.5 m after about 8 months. The program was discontinued in December 1975.

Recently, geotechnical investigations by Sabatini Earth Technologies for the area north of the Meadows indicated that the groundwater table extended to about 1 m below the surface. The soil conditions were found to be poor for residential development. Mitigative measures to minimize groundwater effects such as seepage, soft subgrade and frost action were recommended.

To address these concerns, the City of Cold Lake retained Solid Earth Geotechnical to undertake a geotechnical study for the project area in May 2013. Objectives were to

- Identify the elevation of the sand layer anticipated within the development area.
- Assess the soil and groundwater conditions and their impact on the design, construction, and long term operation of the SWMF
- Provide guidelines for the development of the residential subdivision including house foundations, roadway pavements, and installation of underground utilities.
- Evaluate the impact of the SWMF on the overall groundwater levels.

The field investigation was undertaken in June and July 2013, and involved drilling and logging of 31 test holes and installation of standpipe piezometers in all boreholes. Nested standpipes were installed in nine of the boreholes, with the lower standpipe installed in the underlying sand layer and the second standpipe installed in the overlying clay layer to measure the piezometric pressures in the two zones.

The study generally confirms that developing the site and building a SWMF in this area will be challenging. Results of the geotechnical investigation are contained in Solid Earth's report which is attached as Appendix G. The following is a brief summary:

- The general stratigraphy is one of clay, clay fill, and/or clay fill overlying sand at a depth of about 3-5 m over most of the project area.
- Portions of the project area have clay fill to a thickness of 1.6 m.
- Groundwater levels were measured at a depth of 0.1 to 2.6 m below ground surface in the shallow piezometers and 0 to 3.7 m below ground surface in the deeper piezometers.
- In general, the groundwater levels were higher in the deep piezometers than in the shallow piezometers, indicating that the sand appears to be under confined aquifer conditions.

The study concluded that, in general:

- Pond excavation below 530 m (2 m below existing ground surface) may risk basal heave and extensive seepage.
- The soft and wet soil conditions would be unsuitable for building and road foundations and would either need to be conditioned or replaced with more suitable (drier) soils.

The report recommends that house foundations should be a minimum of 0.5 m above the shallow zone groundwater levels and road elevations should be a minimum of 1.5 m above the shallow zone groundwater levels. This implies that the low areas of the site will need to be raised (filled) to a depth of 1 to 2 m above the existing ground elevation (ie to an elevation of approximately 533 to 534 m).

Final elevations may vary depending on local conditions and groundwater levels that may change over time, and should be confirmed with site-specific geotechnical evaluation by a professional geotechnical engineer. Implementation of a surface water management plan was identified as a priority.

Figure 14 shows the location of the boreholes and the elevation of the sand layer at each of the locations. The Figure also shows the areas requiring fill throughout the project area, derived from LIDAR data provided by the City, and the outline and proposed bottom elevation of the proposed stormwater management facilities.

5 Stormwater Management Options

After the analysis of the outfall options and geotechnical investigations indicated that outfall option 3 was most practical and cost effective, several options for the SWMF configurations were investigated as discussed below.

5.1 OPTION A: ONE POND

To provide the required storage volume, a large pond of approximately 10 ha in area and 2.5 m in depth would be required to attenuate the runoff from the project area and the existing developed area to the south of Meadows. This concept is shown in Figure 14. It would require the project area to be filled to a minimum elevation of 533 m to permit an underground drainage system. The stormwater management facility would need to be developed as a dry pond to meet 4-Wing waterfowl restrictions.

5.2 OPTION B: THREE PONDS

Due to the varying depth of the sand layer at the location of the SWMF and the requirement to fill the site, a large dry pond may not be feasible. Option B involves three smaller ponds. Multiple ponds might be preferable to a large pond as it would be more flexible to accommodate the variability in depth of the sand layer and could therefore avoid the areas where the layer is particularly high. In general the ponds are proposed to be at least 0.5 m above the sand layer.

Figure 15 shows the location of the storm ponds in the Meadows, as well as the ponds located further upstream. The upstream areas are currently undeveloped and are not currently a part of the City, however, the City plans to annex these areas in the future. A ditch/pipe is proposed along the southern end of the Meadows sub-division to convey the flows from the undeveloped upstream areas in the existing condition. When this area is developed in the future runoff will be attenuated in the SWMFs and discharged at a predevelopment rate of 2 L/s/ha.

The multiple ponds will be connected to this pipe/ditch and will outfall to the Meadows ditch as described in Option C of this Technical Memorandum.

Table 5-1 shows a summary of the relevant information for all the ponds that form a part of this system.

Table 5-1
Pond Summary: Option B

Pond No.	Drainage Area, ha	Pond Bottom	Pond HWL	Pond Berm	Pond Area, ha	Storage Volume (cu m)	Peak outflow (L/s)
218	91.98	530	531.5	532.5	4.56	83600	184
219	14.07	536.5	538	539	0.79	14000	28
220	63.82	530	531.5	532.5	3.5	65200	128
221	46.9	530	531.5	532.5	3.4	49300	98

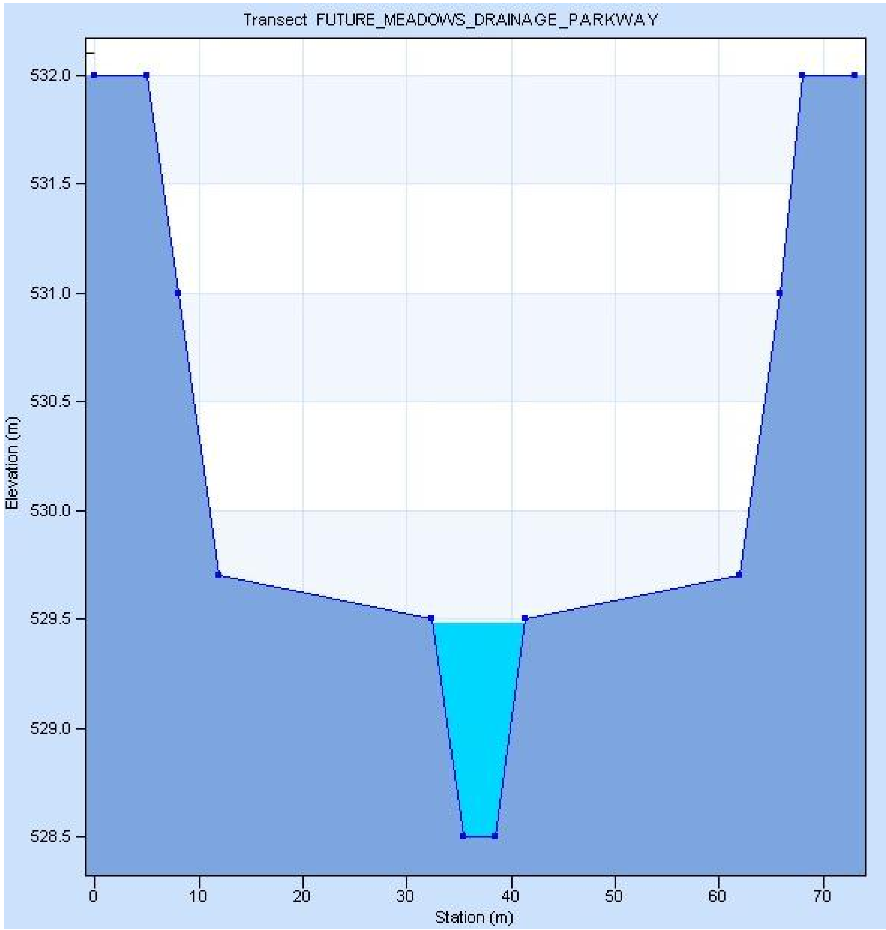
The pond and outfall sizes were verified by the PCSWMM Model for future conditions, and the model confirmed the HWL and peak outflow values from the conceptual design. The existing drainage ditch and the 1.8 m culvert across Highway 28 will be left in place as an emergency outfall.

5.3 OPTION C: DRAINAGE PARKWAY

Option C involves a drainage parkway approximately 1000m long, with a 750 mm control structure and a 1200 mm outfall pipe. Figure 16 shows a map for this concept. Upstream ponds are proposed to tie into the drainage parkway.

The drainage parkway is assumed to have a channel bottom width of 3 m and 1 m depth to carry low flows. A floodplain with 50 m bottom width and 1:3 side slopes would store to carry the flood flows. The top footprint of the drainage parkway would be approximately 74 m wide. A cross section of the proposed drainage parkway is shown in Figure 17. Details of the floodway configuration may change depending on soil conditions encountered.

Figure 17
Drainage Parkway Cross Section



This option would provide the most flexibility to accommodate the variability in depth of the sand layer and could therefore avoid areas where the layer is particularly high. The Drainage Parkway was proposed to maximize the area available for development, while addressing the issues connected to the depth of saturated sand layer and stormwater management.

The drainage parkway is proposed to have a outlet control orifice of 750 mm to control the discharge coming from this area into Meadows ditch and eventually to Palm Creek, however, during peak water levels, the outflow is controlled by back water effects from downstream. The existing drainage ditch and culverts across Highway 28 will be left in place as an emergency outfall, and Meadows ditch between the outfall pipe and the 52 Avenue is proposed to be lowered to accommodate the outfall pipe as proposed in Outfall Option 3.

The design assumptions for storage volume in the drainage parkway were verified by modelling the cross section in the PCSWMM model of future conditions. Figure 18 shows a time graph of the water surface elevation in centre of the drainage parkway. Figure 19 shows a time graph of the discharge from the control structure and Figure 20 shows the time graph of outflows through the existing overflow ditch to the Highway 28 culvert. The Highway 28 culvert also drains additional developed areas. Figure 21 shows a profile of the drainage parkway and the outfall pipe and Figure 22 shows the profile through the Highway 28 culverts. Figures 18 to 22 have been obtained from the PCSWMM model.

Therefore, the proposed drainage parkway would control outflows from the Meadows to the capacity of the downstream drainage system.

Modelling indicates the following:

- The peak high water level in the parkway is an elevation of 531.2 in the 1:100 year storm. At least 1.0 m of freeboard should be provided above this elevation to allow for more severe storms.
- Both the new outfall pipe and the Highway 28 culvert will be operating in the 1:100 year storm and will carry peak flows of approximately 1.2 and 1.6 m3/s respectively.
- Downstream culverts art 52 Avenue and 50 Avenue, which were designed for a basin discharge of 1.8L/s/ha, are overloaded but not to the level that would overtop the roadways or flood adjacent property.
- The Glenwood Road culvert would also be surcharged but water levels would be well below the roadway elevation.

6 Conclusions

From the analysis described above, it can be concluded that:

- The soils and groundwater conditions in the Meadows will provide significant constraints to the development of the area and to the design of stormwater management facilities.
- The existing Meadows Ditch, which provides the outlet from the Meadows, is too high to facilitate draining of the area and the proposed SWMF and creates a risk of flooding for the existing and future development.
- Significant modifications to the existing drainage in the Meadows and its outfall will have to be made to accommodate development of the area. Outfall Option 3, a new outfall pipe to Meadows Ditch and lowering a portion of the ditch to Palm Creek, is the most practical and cost-effective solution, but it leaves significant constraints to the development of an effective drainage system to service the future development area in the Meadows.
- Three smaller ponds, instead of one large pond can better accommodate the variable depths and groundwater conditions.
- The Drainage Parkway will provide conveyance and flood storage for the development, while maintaining a natural and eco-friendly habitat and flexibility to adapt to local conditions.

7 Recommendations

The following recommendations are made to improve the drainage conditions in the Meadows:

- Outfall Option 3 which consists of an outfall pipe from Meadows catchment to the Meadows ditch be adopted.

- The drainage parkway concept (SWMF Option C) be adopted to provide flood storage for the project area, conveyance to carry flows from the upstream basin, and a park facility for the development area.

- The design of the drainage parkway and the subdivision itself will need to be reviewed and adapted on and on-going basis as additional site specific geotechnical studies are completed and more experience in dealing with the local soils and groundwater conditions is gained.

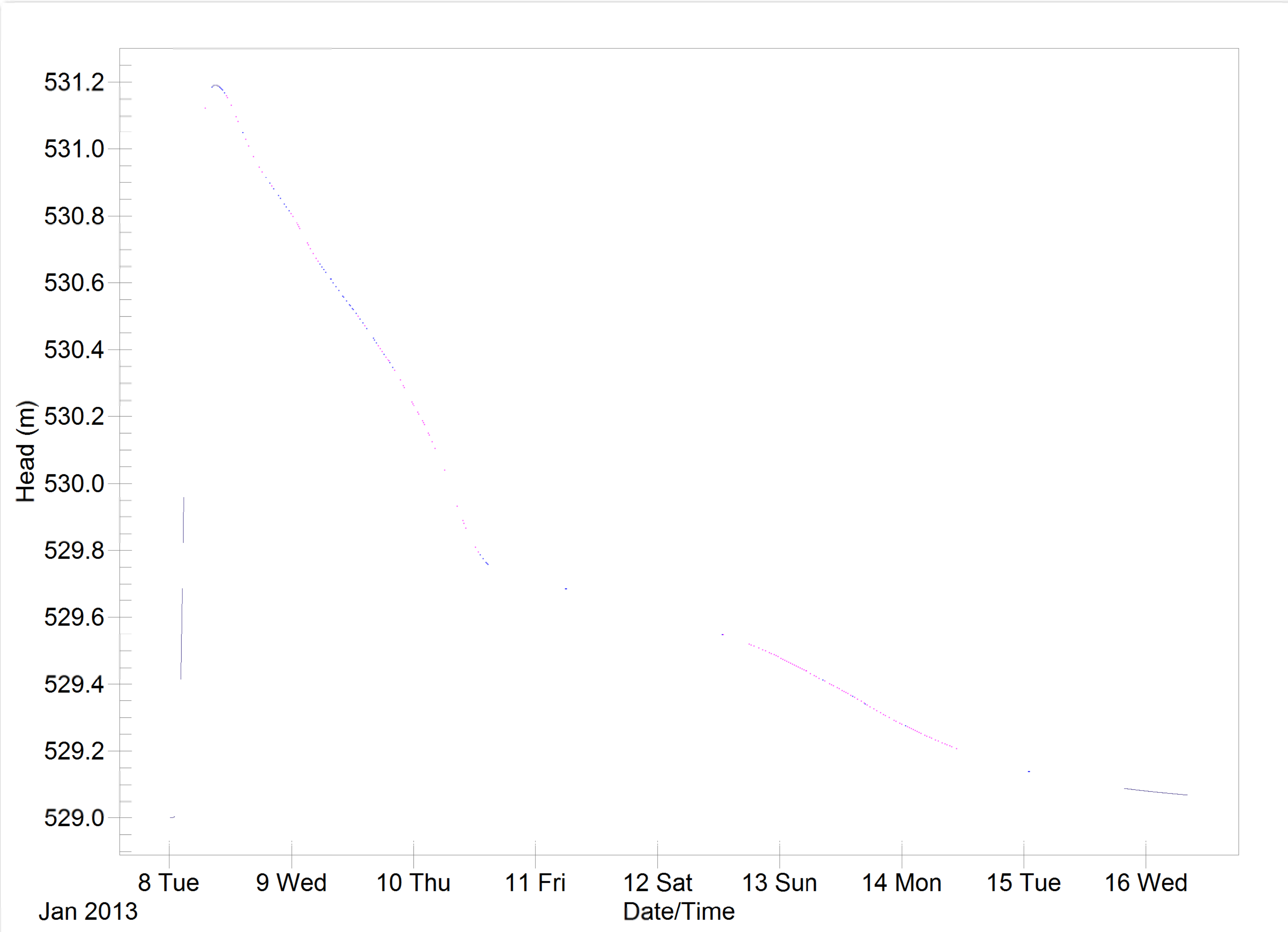


Figure 18
MEADOWS DRAINAGE PARKWAY
-Water Surface Elevation

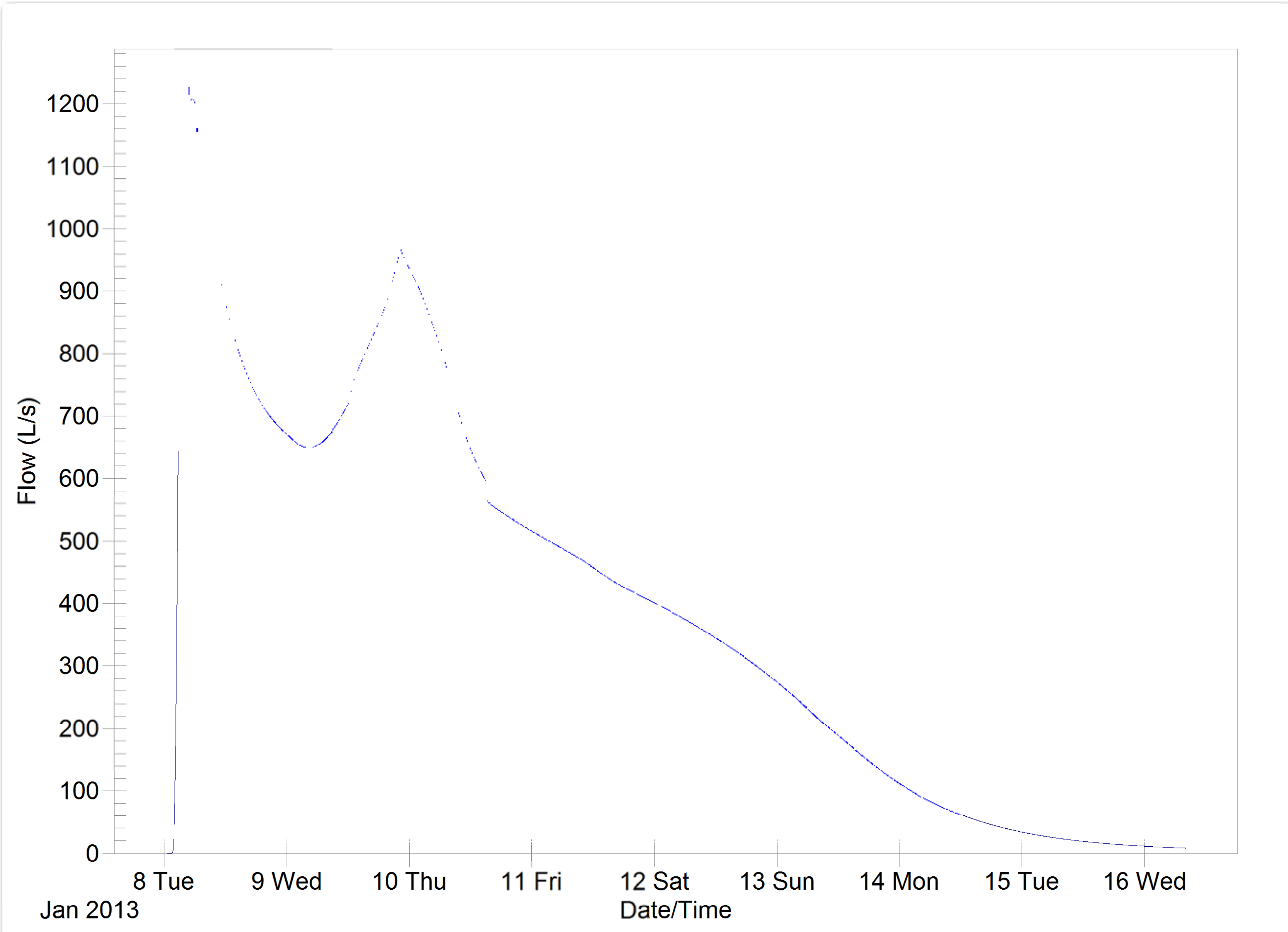


FIGURE 19
MEADOWS DRAINAGE PARKWAY
Outflow Hydrograph - Proposed Outfall Pipe

FIGURE 20
MEADOWS DRAINAGE PARKWAY
Outflow Hydrograph - Overflow Ditch

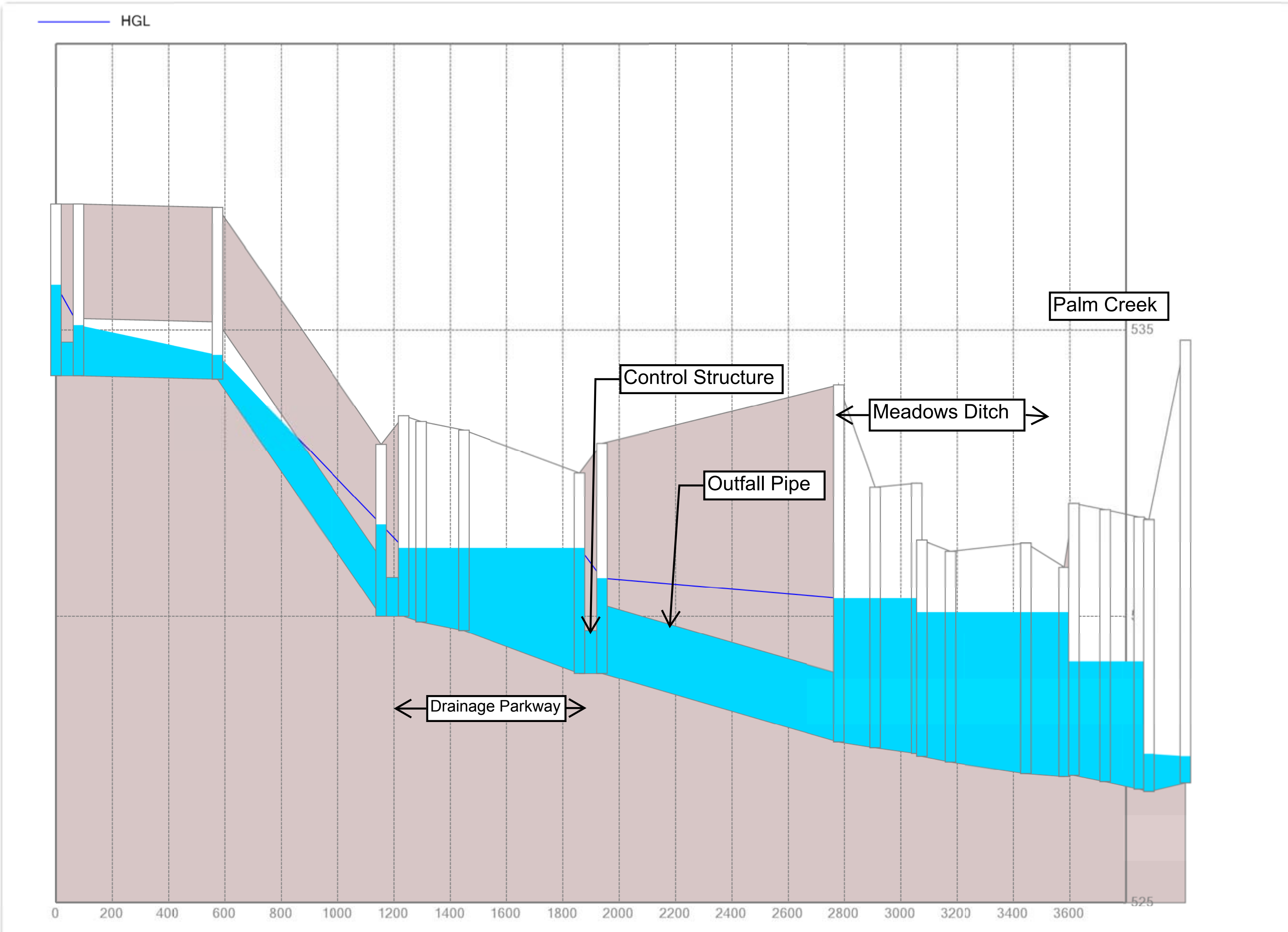


FIGURE 21
Profile Through Outfall Pipe

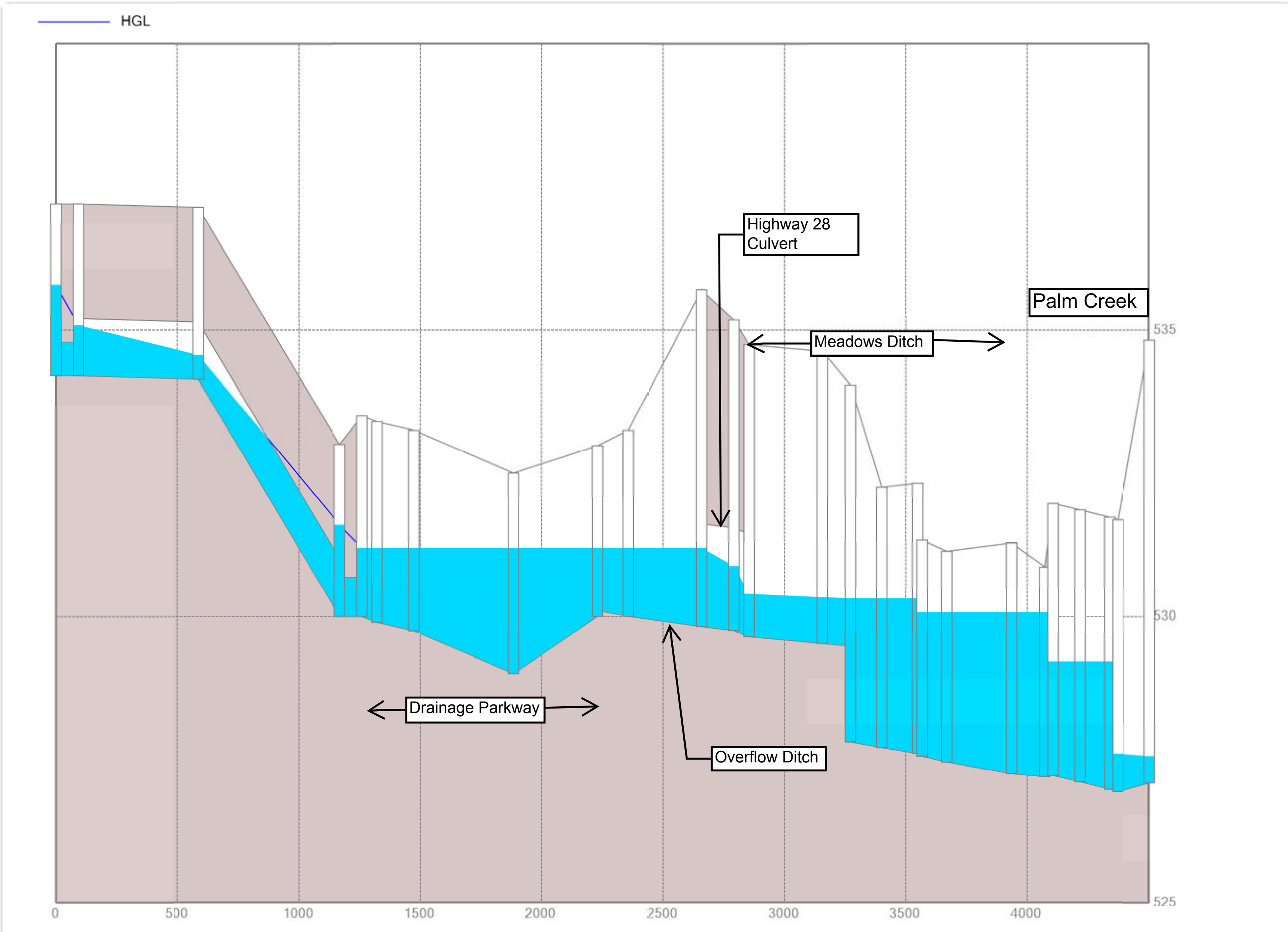
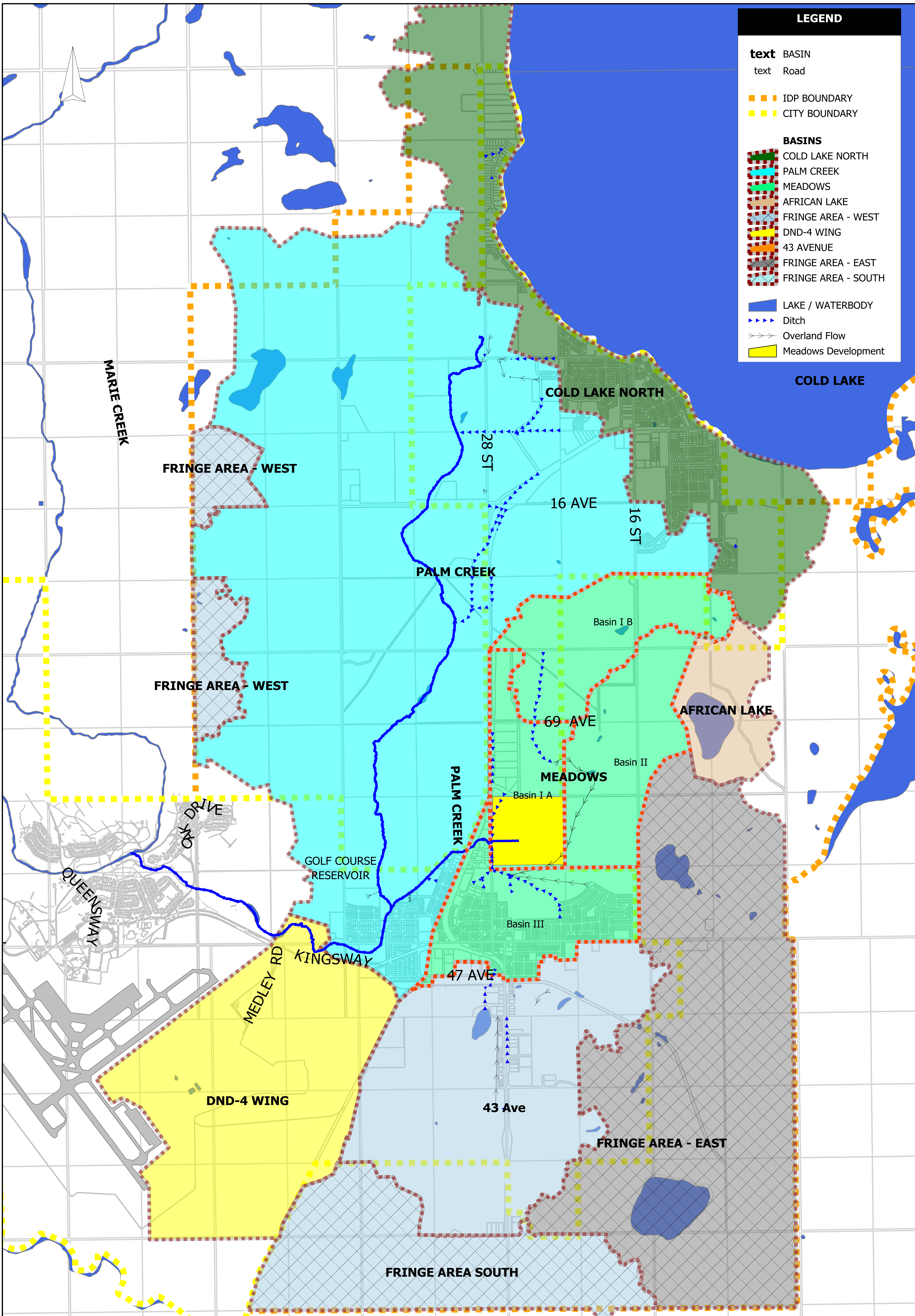


FIGURE 22
Profile Through Highway 28 Culvert



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CITY OF COLD LAKE
MASTER DRAINAGE PLAN

Figure 1
BASINS MAP

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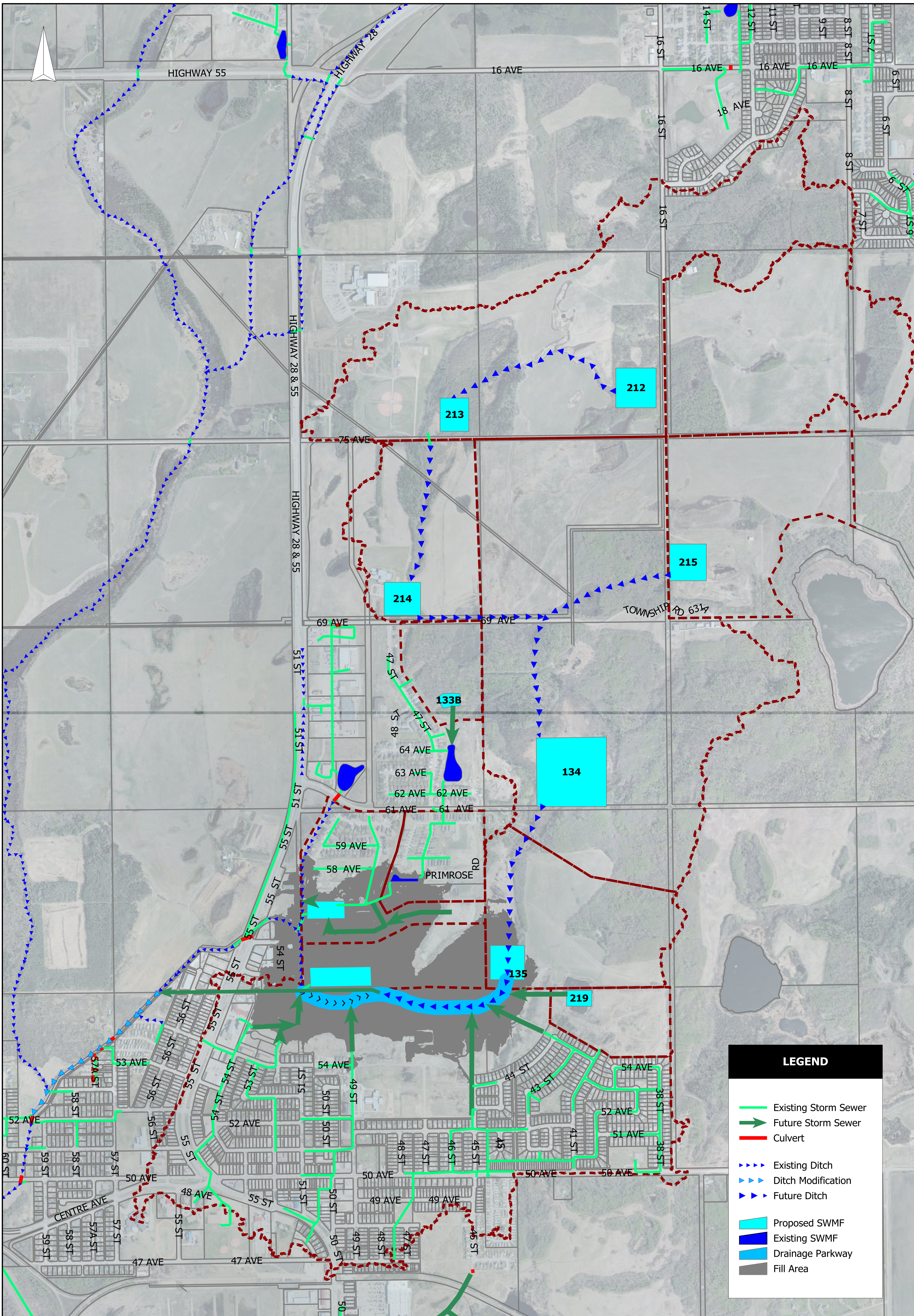
SCALE: 1:40,000



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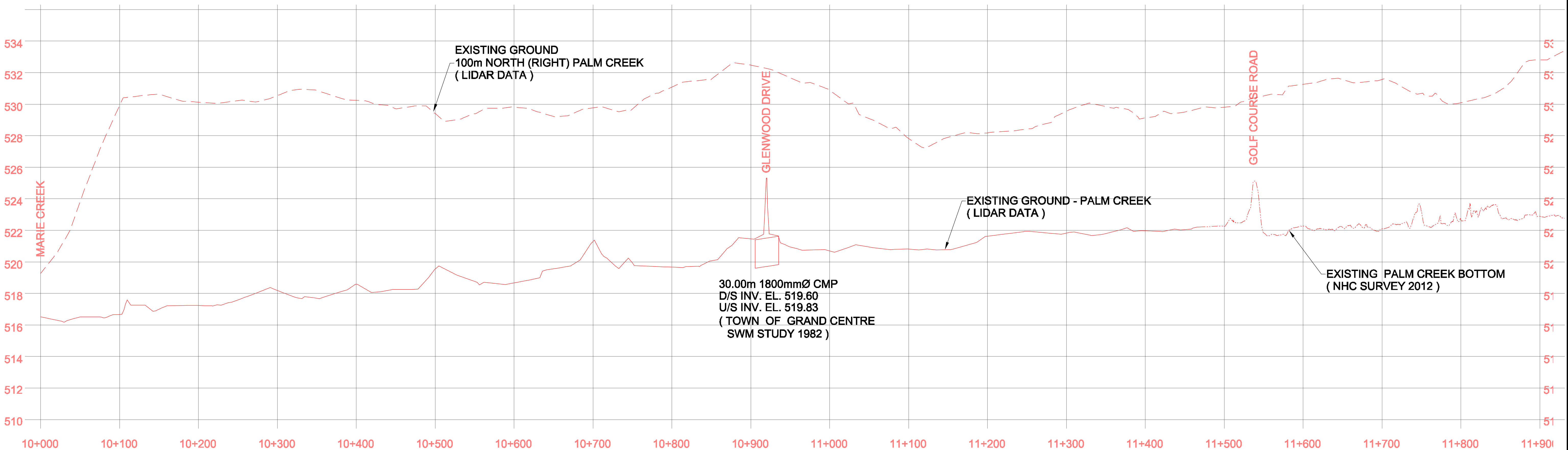
CITY OF COLD LAKE
DRAINAGE MASTERPLAN

Figure 2
MEADOWS BASIN
PROPOSED STORMWATER MANAGEMENT PLAN

PROJECT No.: 2012-3590

DATE: 4/1/2014

SCALE: 1:15,000



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MASTER DRAINAGE PLAN UPDATE

PALM CREEK PROFILE

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 3	A	--

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PALM CREEK PROFILE

MASTER DRAINAGE PLAN UPDATE

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 4	A	--

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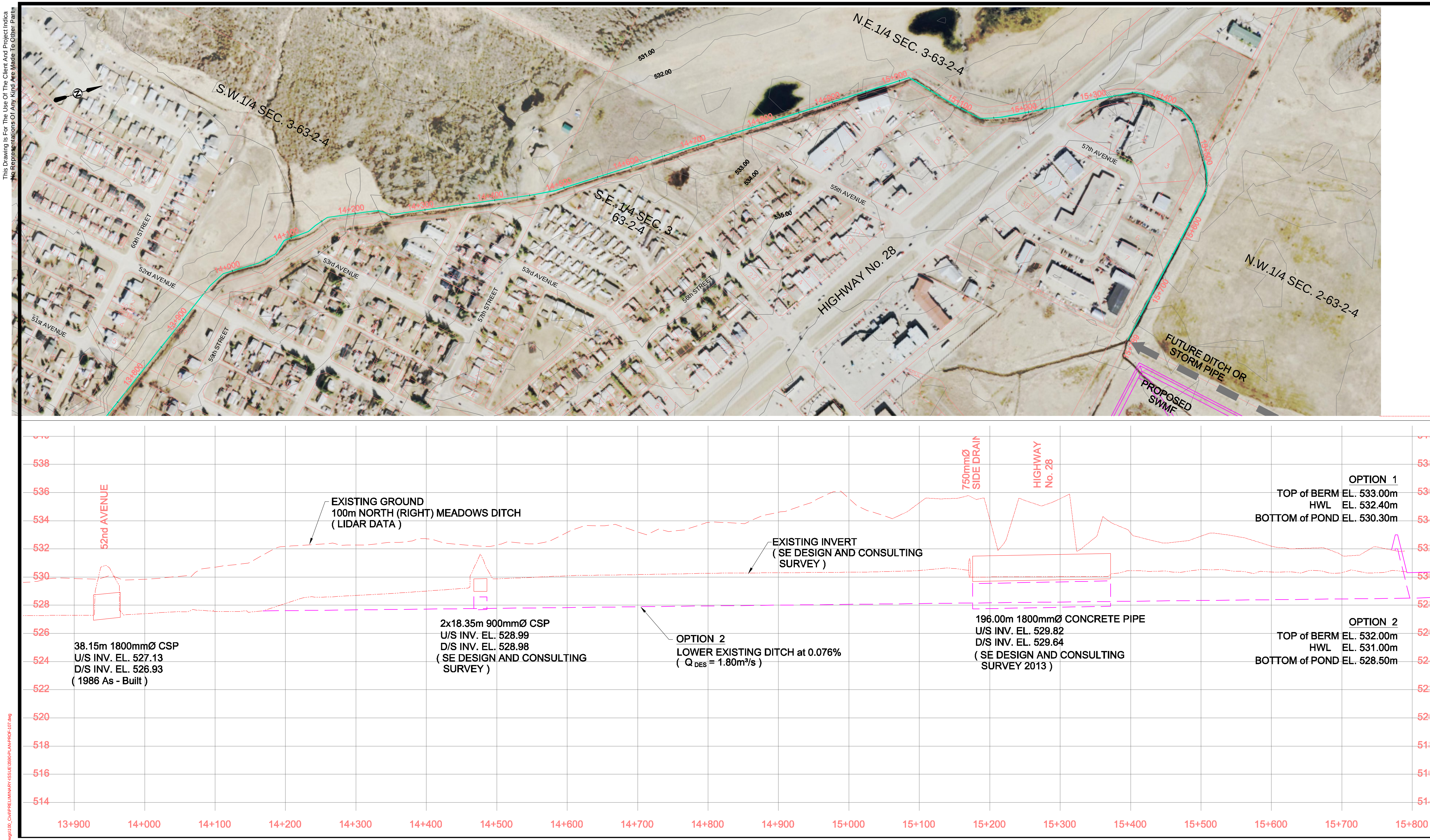

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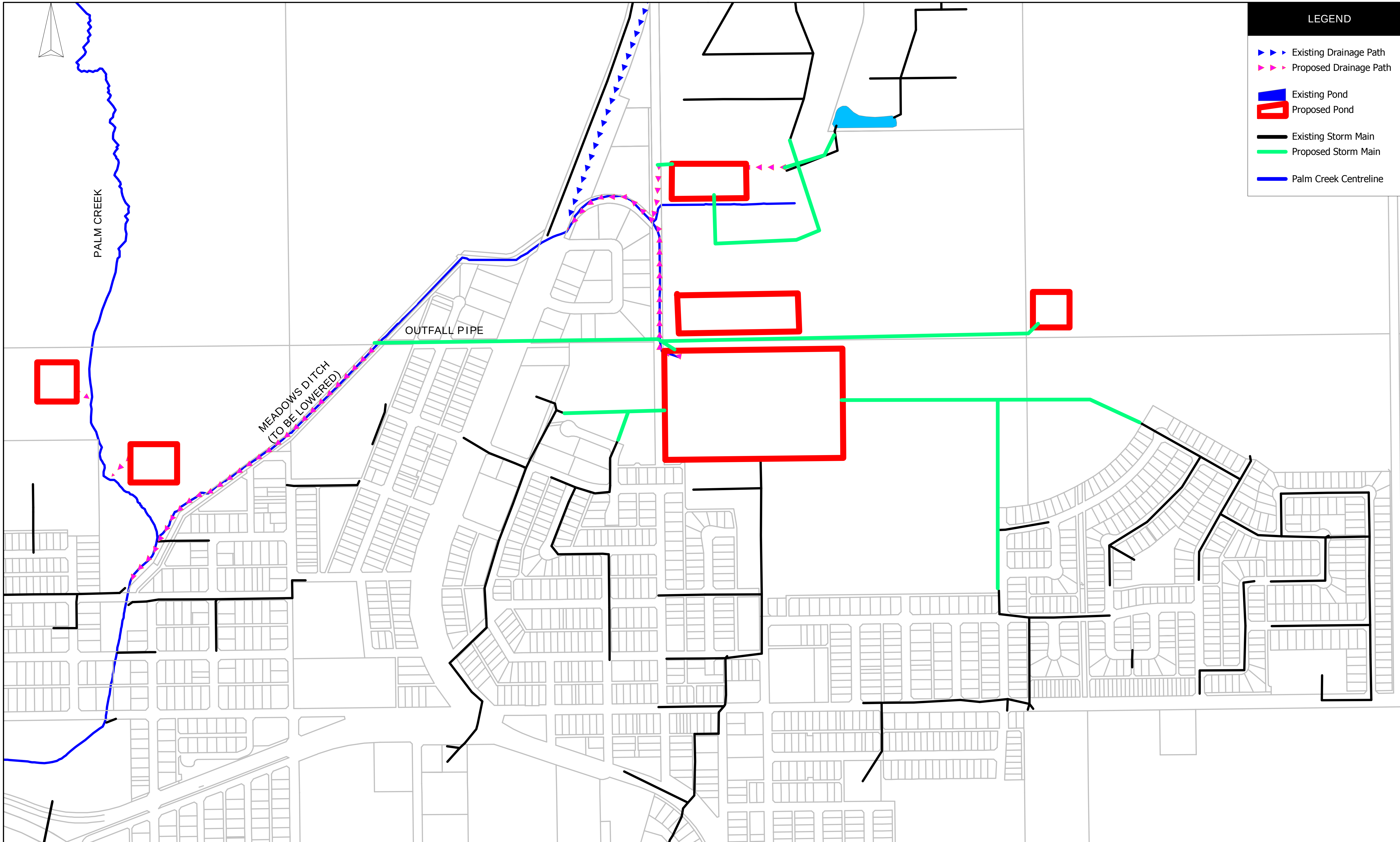
CITY OF COLD LAKE

PLAN PROFILE
MEADOWS DITCH - OPTIONS _ 1 & 2

MASTER DRAINAGE PLAN UPDATE

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 5	A	--



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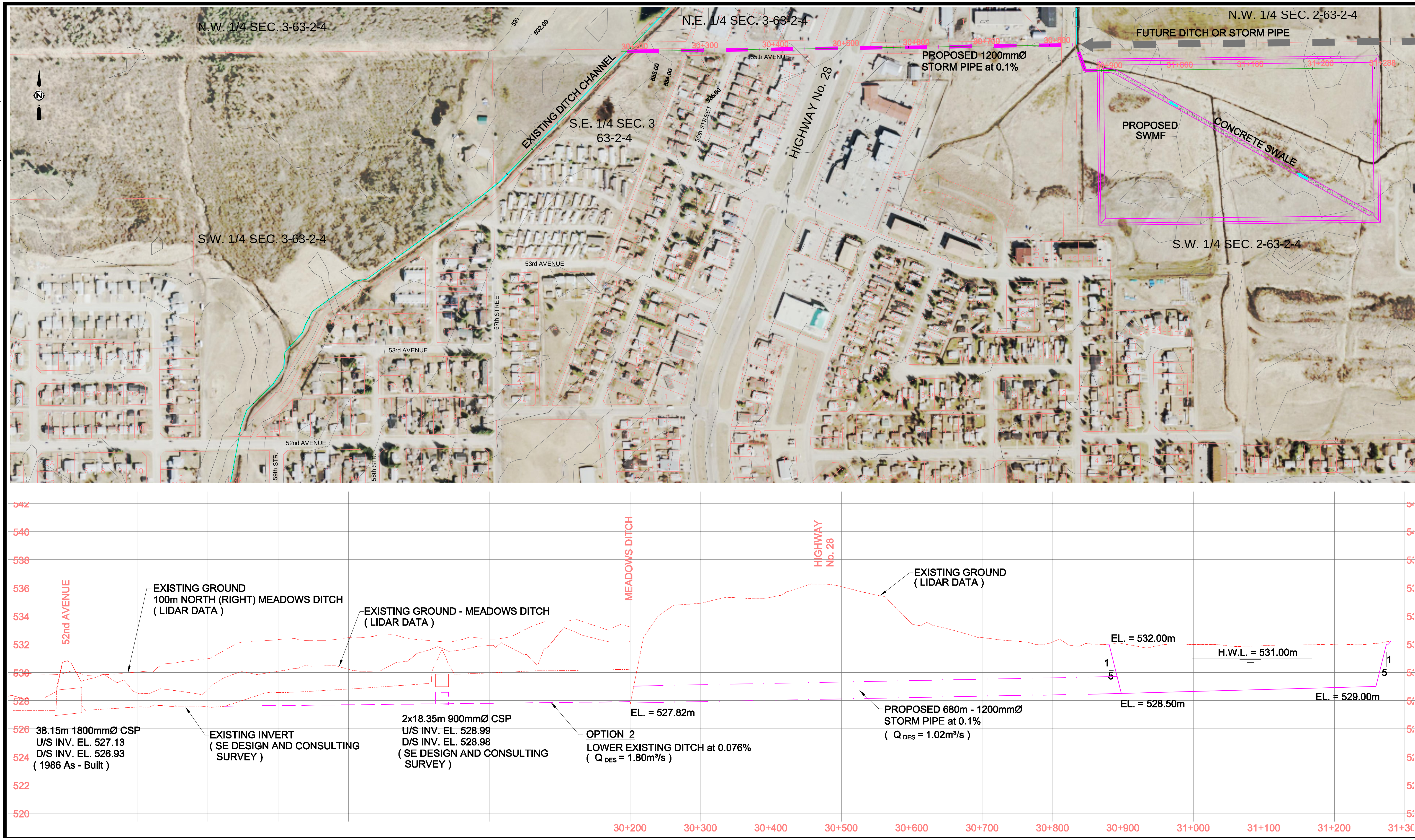
CITY OF COLD LAKE
DRAINAGE MASTERPLAN

Figure 6
PIPE TO MEADOWS DITCH

PROJECT No.: 2012-3590

DATE: 4/15/2013

SCALE: 1:10,000



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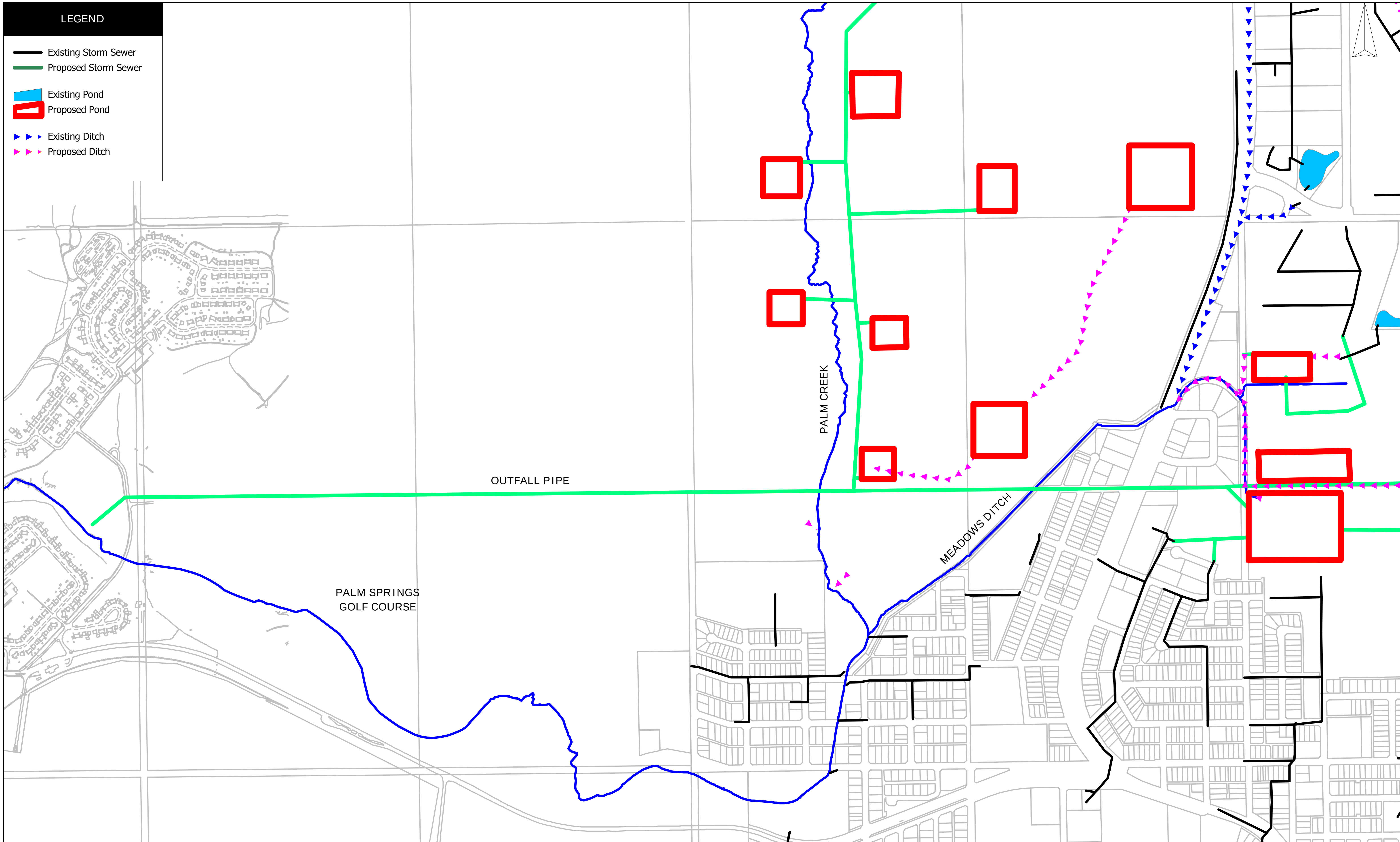
CITY OF COLD LAKE

MASTER DRAINAGE PLAN UPDATE

MEADOWS OUTFALL PROFILE - 3

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 7	A	--



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CITY OF COLD LAKE
MASTER DRAINAGE PLAN
Figure 8
MEADOWS SWMF - OPTION 4
(PIPE TO PALM CREEK)

PROJECT No.: 2012-3590
DATE:4/15/2013
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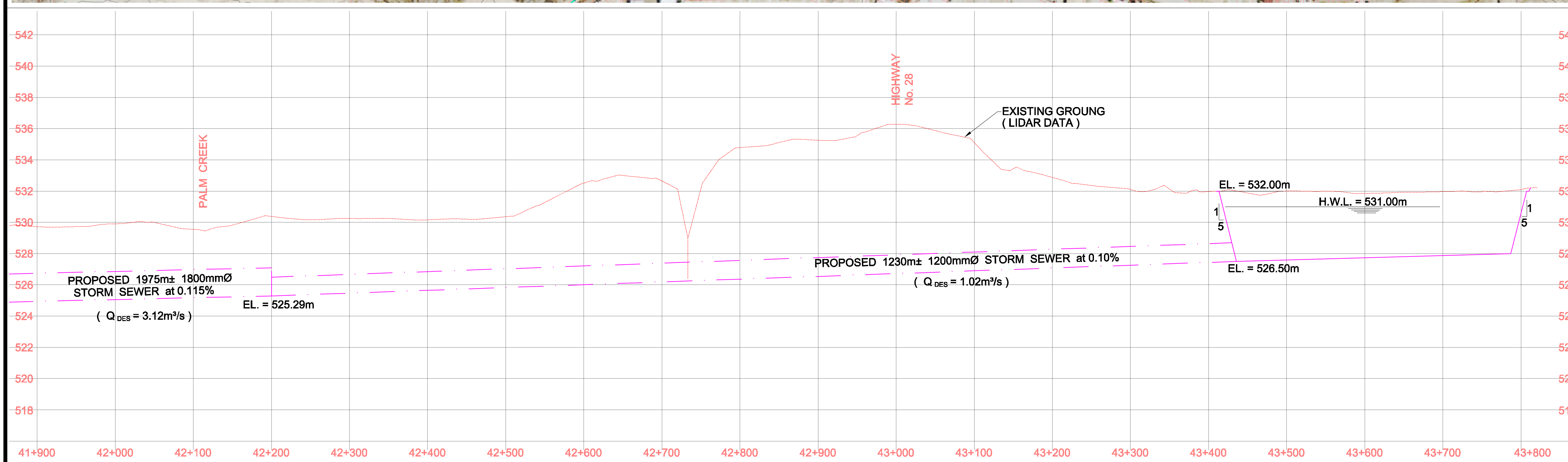

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PLAN PROFILE
MEADOWS OUTFALL - OPTION 4

MASTER DRAINAGE PLAN UPDATE

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 9	A	--

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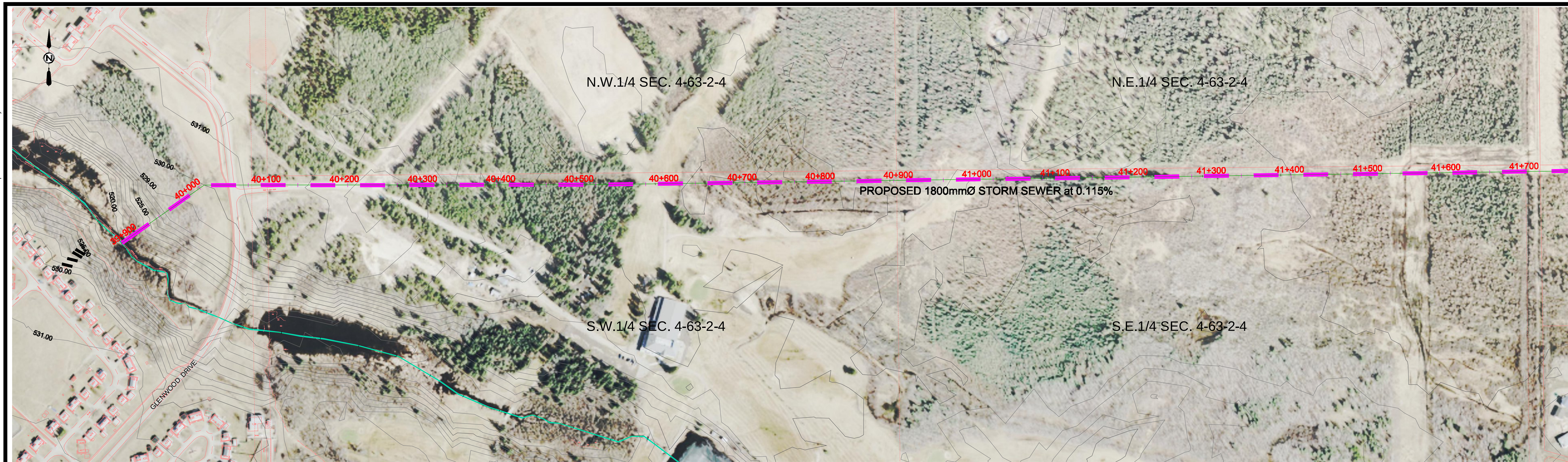

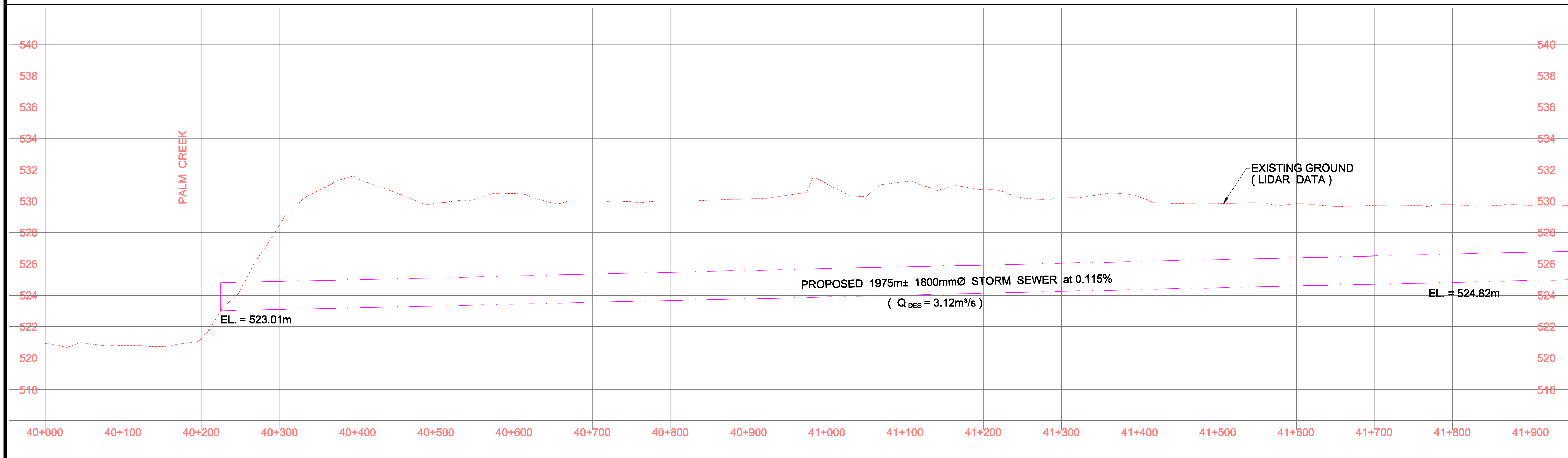

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PLAN PROFILE
MEADOWS OUTFALL - OPTION 4

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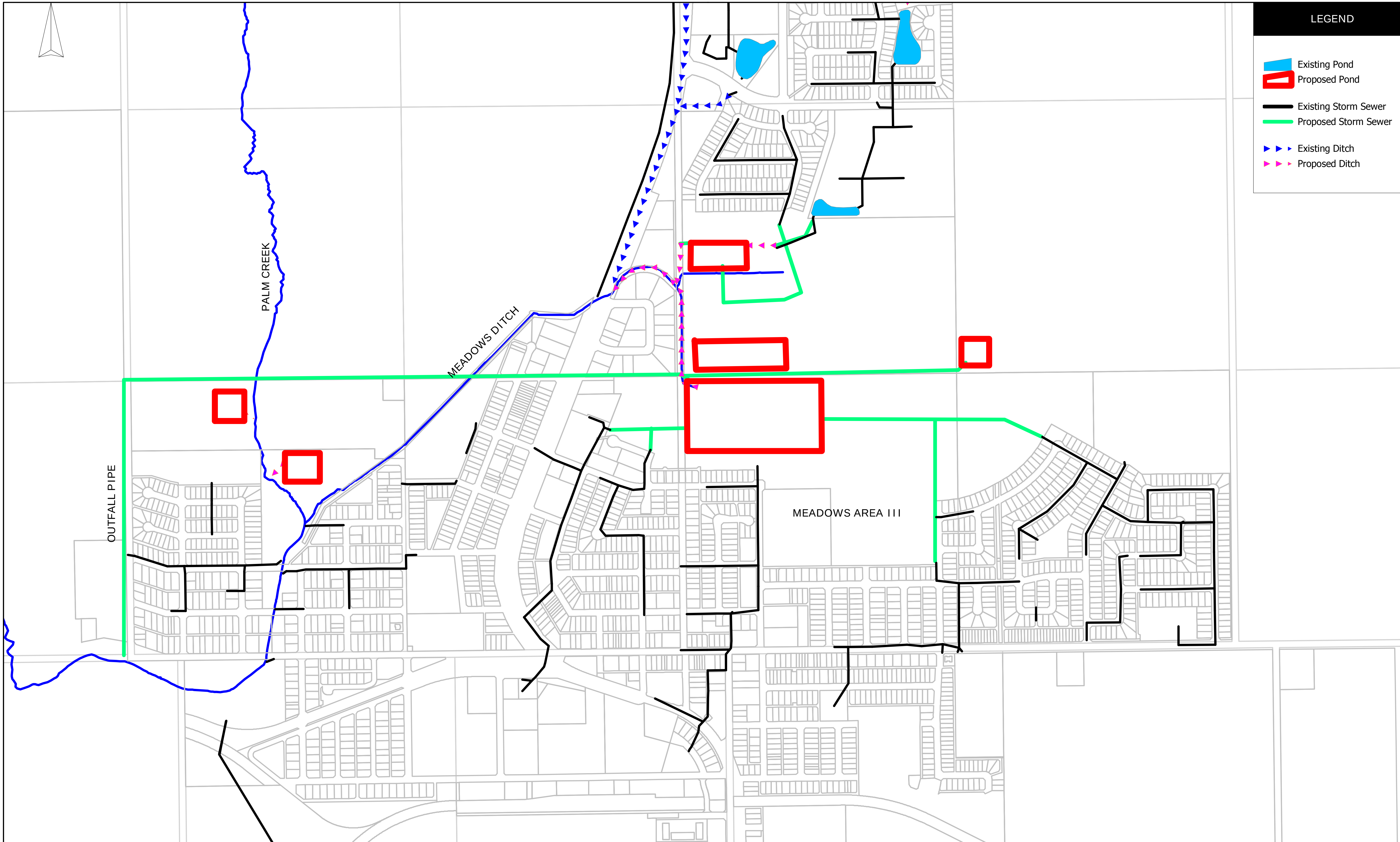
DRAWING NUMBER	REV. NO.	SHEET
FIGURE 10	A	--



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CITY OF COLD LAKE
DRAINAGE MASTERPLAN

OPTION 5
PIPE ALONG 62 STREET

PROJECT No.: 2012-3590
DATE: 4/15/2013
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Figure 11

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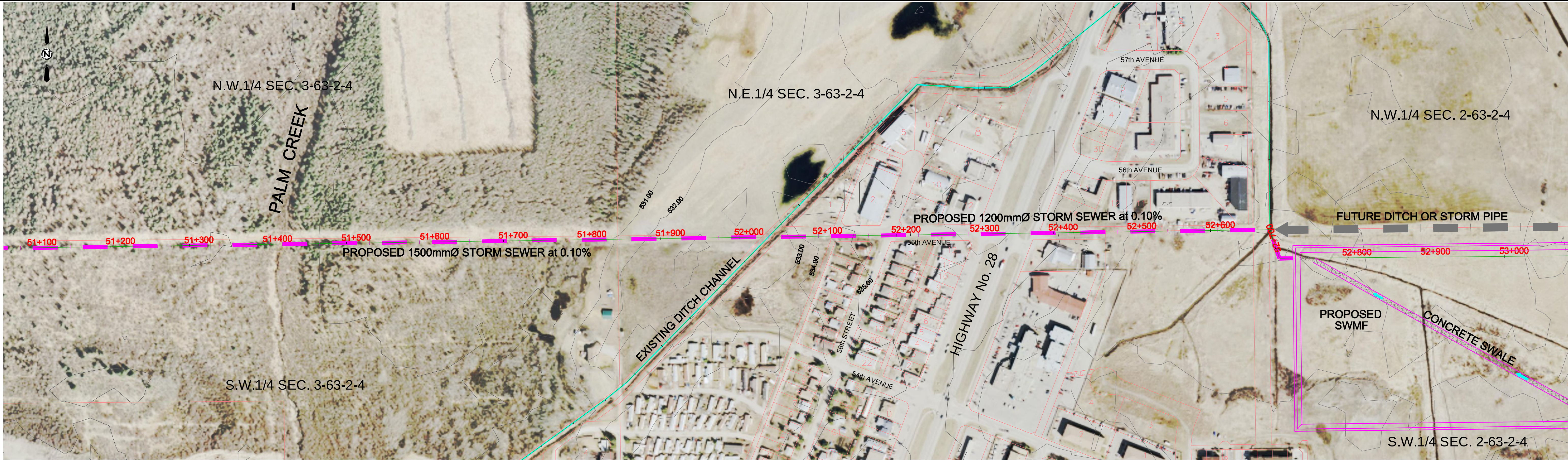

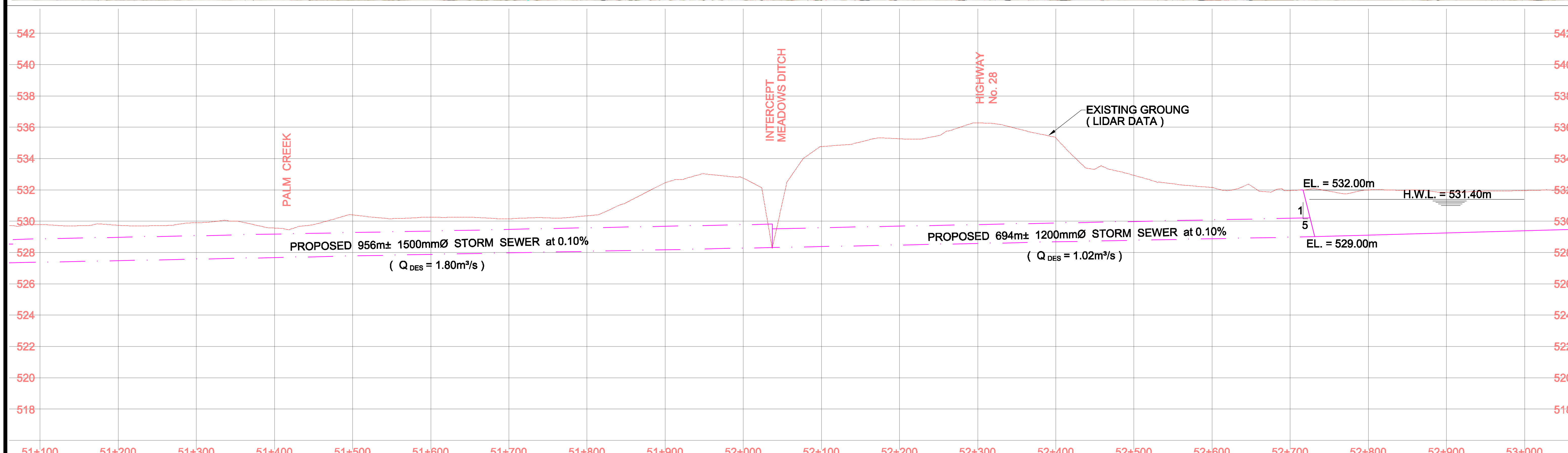

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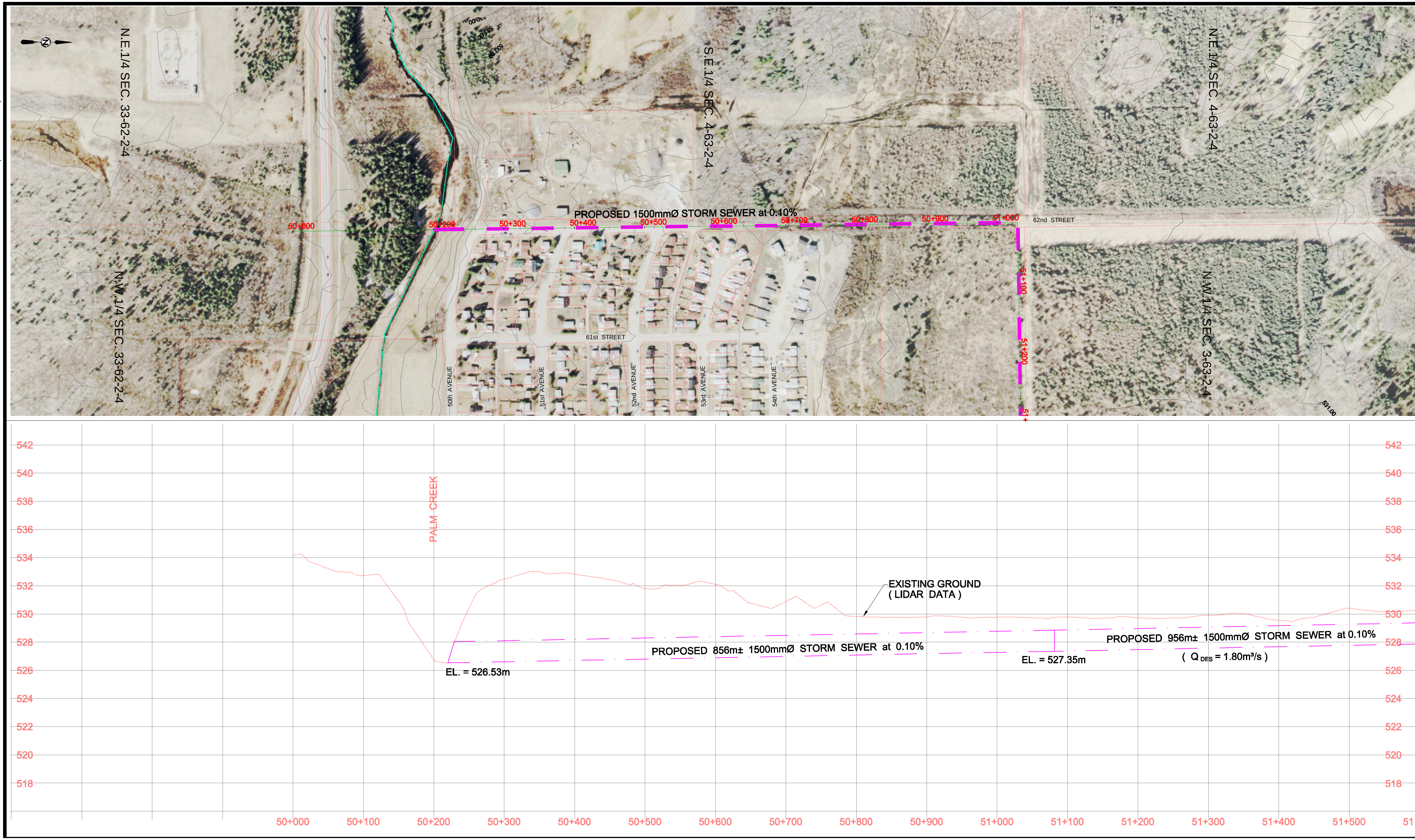
MASTER DRAINAGE PLAN UPDATE

PLAN PROFILE
MEADOWS OUTFALL - OPTION 5

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 12	A	--



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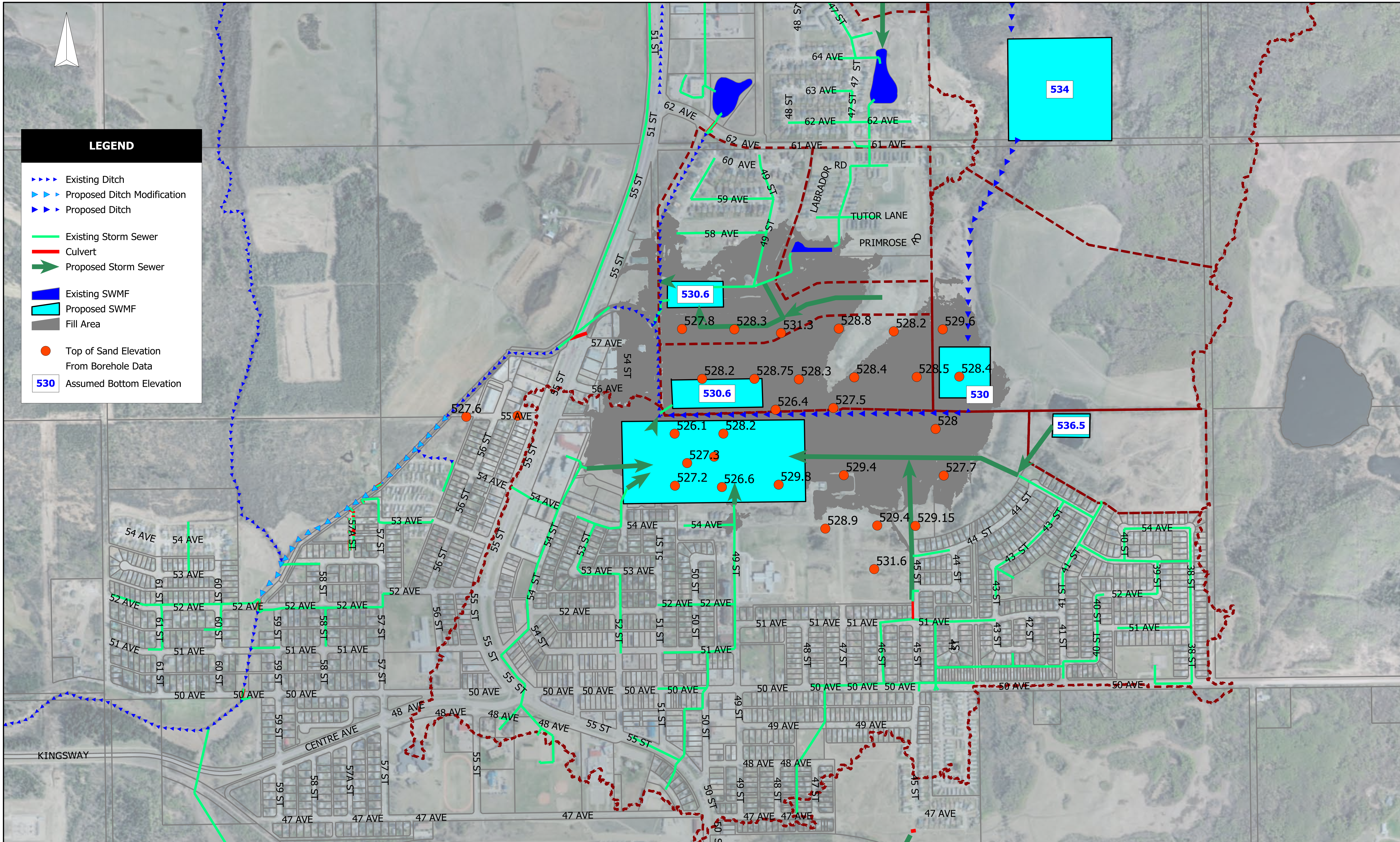
MASTER DRAINAGE PLAN UPDATE

PLAN PROFILE
MEADOWS OUTFALL - OPTION 5

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 13	A	--



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CITY OF COLD LAKE
DRAINAGE MASTERPLAN
Figure 14
MEADOWS OPTION - A
ONE POND OPTION

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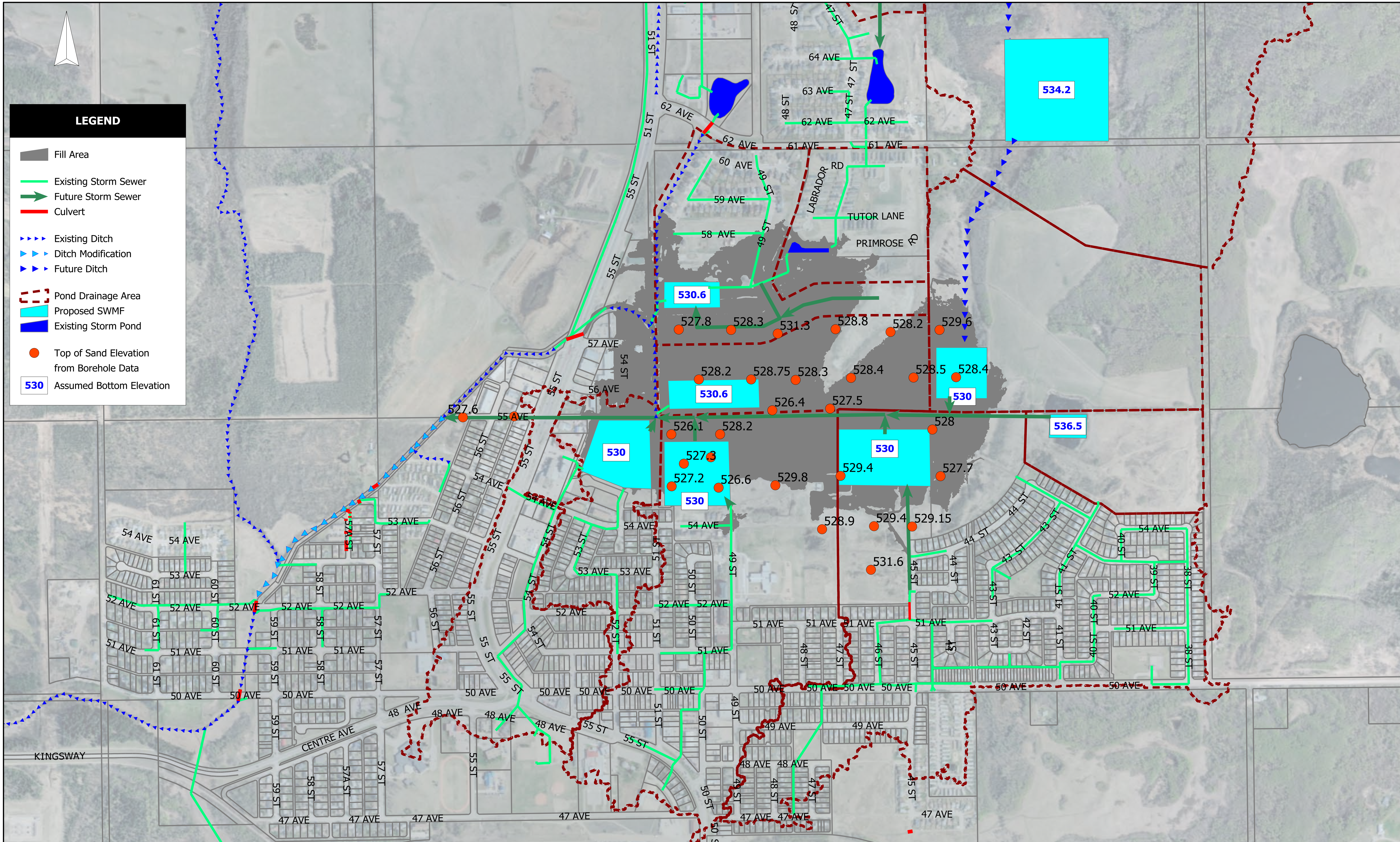

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DRAINAGE MASTERPLAN
Figure 15
MEADOWS OPTION B
THREE PONDS OPTION

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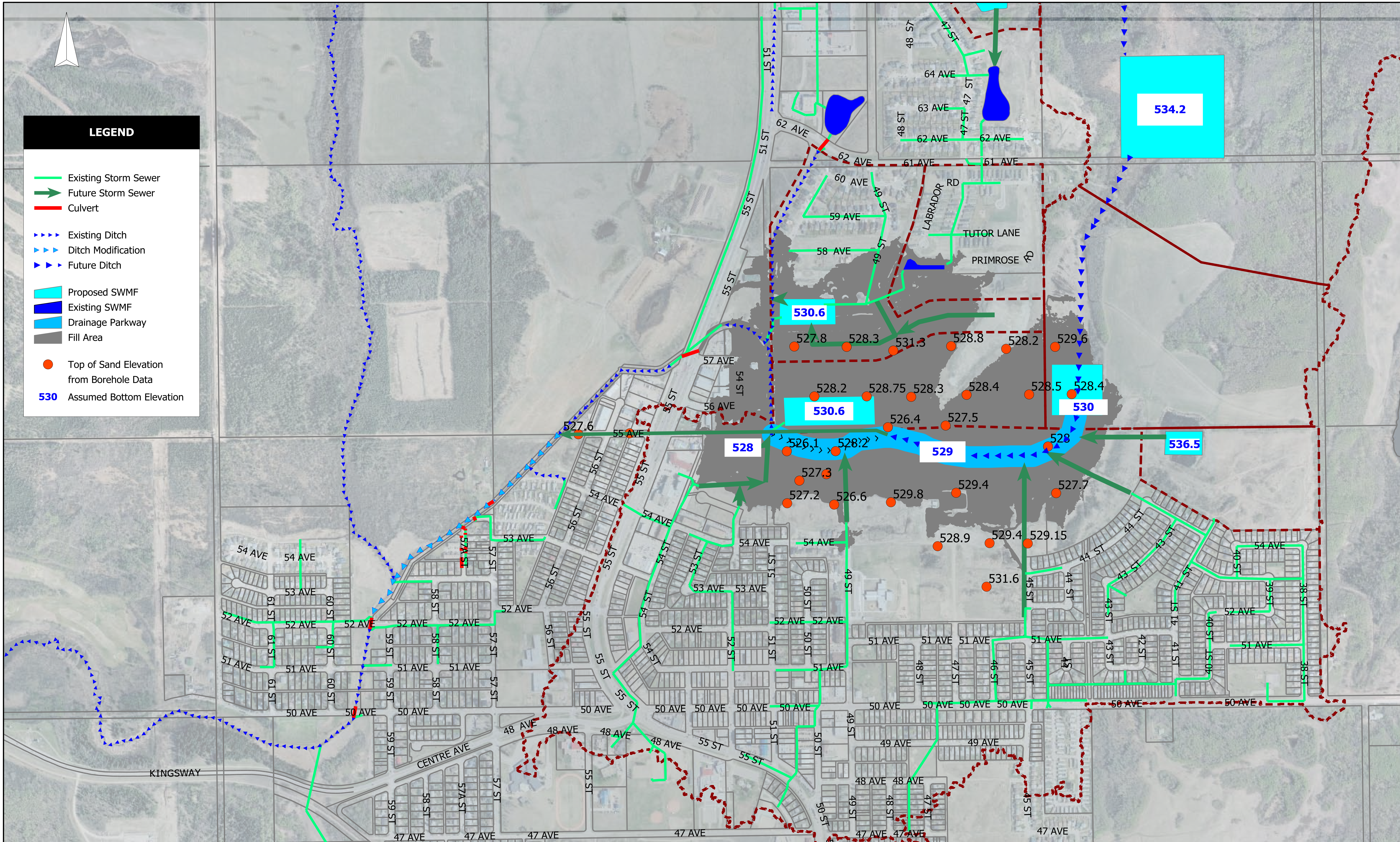

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CITY OF COLD LAKE
DRAINAGE MASTERPLAN
Figure 16
MEADOWS OPTION - C
DRAINAGE PARKWAY OPTION

PROJECT No.: 2012-3590
DATE: 3/26/2014
SCALE: 1:10,000

03.00_Conceptual_Feasibility_Design\Masterplan Report\Figures\posters\Meadows_New_Options.map

Closure

This technical memorandum was prepared for the City of Cold Lake to assess stormwater management options for the future development areas which drain to the Meadows and to Palm Creek.

The services provided by Associated Engineering Alberta Ltd. in the preparation of this report were conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty expressed or implied is made.

Respectfully submitted,
Associated Engineering Alberta Ltd.

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QUALITY MANAGEMENT SIGN-OFF

Signature: C Skowronski

Date: April 3, 2014

APEGA Permit to Practice P 3979

Appendix D - Technical Memorandum #2 - Palm Creek

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GLOBAL PERSPECTIVE.
LOCAL FOCUS.

TECHNICAL MEMORANDUM

City of Cold Lake

Palm Creek
Creekside Servicing

April 2014

CANADA'S BEST MANAGED COMPANIES

Table of Contents

1 Introduction

The following analysis investigates two options to create an adequate gravity outlet from the Palm Creek area, involving a trunk sewer running parallel to Palm Creek and a drainage parkway which would entail construction of a deeper channel within the Palm Creek floodplain to provide adequate capacity and grade. It also investigates options for draining Creekside Estates, an existing and ongoing development immediately north of Highway 55, located within the project area.

Figure 1 shows the existing drainage patterns for Palm Creek. Palm Creek extends from Township Road 634 to its confluence with Marie Creek. For the purpose of this study, the portion of Palm Creek between Township Road 634 and 53 Ave has been considered, as the future expansion areas lie within this boundary. The drainage area to Palm Creek at 55 Avenue is approximately 24 sq km (2411 ha).

Figure 2 provides a view of the stormwater management proposed for the future development in Cold Lake.. Note that significant portions of the basin lie within the Inter-Municipal Development Plan Area and are likely to be incorporated into to the City in the future.

The red rectangles show the potential locations of stormwater management facilities (dry ponds) that will be required in the future. Yellow areas on this map show the low lying areas that pose significant constraints to drainage and where a gravity outfall to Palm Creek may not be possible.

The creek itself is characterized by flat slopes and shallow depths. As the area adjacent to Palm Creek continues to develop, dry Storm Water Management Facilities (SWMFs) are proposed to be constructed to attenuate the storm water runoff from the future sewer system. Palm Creek is not deep enough to provide a gravity outfall from some of these facilities.

Considering the above constraints, Creekside Estates, in the northwest quadrant of the 28th Street and Hwy 55 intersection, uses stormwater pumps to discharge the runoff from its SWMF to Palm Creek. However, as this development continues to grow, each new phase would have to use storm water pumps, which would not only add to the initial capital costs, but also operational and maintenance costs. There is also risk involved with the use of mechanical equipment.

2 Palm Creek Drainage Options

Figure 3 shows the proposed drainage patterns, drainage catchments, and SWMFs required for the future development of the area. Table 1 summarizes the corresponding drainage area, pond size, pond bottom and high-water elevations, discharge rate, and cumulative discharge to Palm Creek.

Table 1
Palm Creek SWMFs Summary: Trunk Sewer Option

Areas East of Palm Creek											
Pond ID	Drainage Area (ha)	Land use	Drainage Area Cumulative (ha)	Outflow (Local) (L/s)	Storage Volume (cu m)	Pond Area (sq m)	Bottom, m	HWL, m	Freeboard EL, r	Cumulative Trunk Flow (L/s)
14_1	30.1	Residential	30.1	60	14500	1.5	538.5	540.0	541.0	
15	7.4	Residential	7.4	15	4000	0.5	535.5	537.0	538.0	
Existing Hospital	7.4			15						
16	49.3	Residential	91.4	99	24000	2.5	534.5	536.0	537.0	189
20A	13.5	Residential	15.9	27	6500	0.7	537.0	538.5	539.5	
20B	8.0	Residential	8.0	16	3900	0.5	537.5	539.0	540.0	
20C	2.1	Residential	2.1	4	1000	0.2	538.0	539.5	540.5	
Offsite+Nelson Heights	13.2			26						
18	22.6	Residential	61.8	45	11000	1.2	535.0	536.5	537.5	307
20	10.1	Commercial	10.1	20	7000	0.8	536.0	537.5	538.5	366
CreekSide	19.0			38						
200	57.4	Residential	57.4	115	28000	3.0	535.0	536.5	537.5	480
21	21.5	Commercial	21.5	43	14500	1.5	545.0	546.5	547.5	
22	31.5	Commercial (19%); Residential (76%)	53.0	63	17000	1.8	539.0	540.5	541.5	
23	96.1	Public Services	149.1	192	37500	4.2	535.5	537.0	538.0	
27	16.7	Residential	16.7	33	8000	0.9	554.0	555.5	556.5	
26	35.0	Residential	51.7	70	17000	1.8	544.5	546.0	547.0	
25	28.3	Residential	80.0	57	14000	1.5	544.0	545.5	546.5	
24A	36.5	Residential	116.4	73	17600	1.9	538.0	539.5	540.5	
24B	31.6	Public Services	148.1	63	12500	1.3	537.5	539.0	540.0	
202	29.0	Commercial	368.5	58	22000	2.3	532.5	534.0	535.0	1133
204	52.1	Residential (40%); Commercial (55%)	52.1	104	33500	3.7	534.0	535.5	536.5	1237
206	28.5	Residential	28.5	57	14000	1.5	531.0	532.5	533.5	1294
207_1	33.6	Residential	33.6	67	16500	1.8	529.5	531.0	532.0	1361
209	14.2	Residential	14.2	28	7000	0.8	527.5	529.0	530.0	1389
207_2	34.0	Commercial	34.0	68	26000	2.8	532.5	534.0	535.0	
211	46.4	Residential (40%); Commercial (55%)	80.4	93	30000	3.3	527.5	529.0	530.0	
210	13.6	Residential	94.0	27	6500	0.7	527.0	528.5	529.5	1577

Much of this information has been extracted from the previous 2006 Master Drainage Plan and has been updated based on a review of topography, development patterns, and more recent planning information. Previous reports, which are summarized later in this document, have identified a concern that the creek is too shallow to provide a gravity outlet for significant portions of the area but have not identified how this issue should be resolved. The following provides two options for addressing this issue.

2.1 OPTION 1: TRUNK SEWER

Figures 4 to 7 show the conceptual plan/profile of the Palm Creek storm sewer option, along with the proposed SWMFs which are shown conceptually in Figure 2. The Palm Creek storm sewer would drain to Palm Creek, downstream of Glenwood Drive, which corresponds to Option 4 presented in the Meadows Drainage Technical Memorandum (Appendix C). The conceptual design of the Palm Creek Trunk Sewer assumes that runoff from developed areas to the east of Palm Creek will be attenuated in the SWMFs, and will be discharged to the trunk sewer. Offsite areas to the west of the Creek will continue to drain to Palm Creek, as in the existing condition. This is to avoid the storm sewers crossing the Creek to discharge the Palm Creek Trunk Sewer.

The estimated cost of the Palm Creek Trunk Sewer is shown in Table 2. Approximately 7 km of trunk would be required to be installed at a preliminary cost of approximately $27 million for the portion shown in Figures 4 to 7. The cost includes Engineering (15%) and Contingencies (50%). The extension of the trunk to Palm Creek downstream of Glenwood Drive, should it be required, would require an additional 2300 m of pipe to be installed. The cost estimate for the additional pipe required has not been included in Table 2 but would add at least $15 million, bringing the total cost of this Option to $43 million.

Table 2
Summary of Cost for Palm Trunk Sewer

Proposed Pipe Size	Length	Average Depth to Pipe Invert	Unit Cost (per linear m)	Preliminary Cost
525	400	3.64	$1,380	$552,000
675	400	3.61	$1,670	$668,000
900	1300	6.29	$3,270	$4,251,000
1050	1100	7.30	$4,070	$4,477,000
1200	700	6.14	$4,080	$2,856,000
1350	1800	7.77	$5,490	$9,882,000
1350	800	4.57	$3,570	$2,856,000
1500	500	4.87	$4,100	$2,050,000
Total				**$27,592,000**

Note that all cost estimates are based on a conceptual level of analysis and are intended for preliminary planning purposes only.

The chief advantage of this option is that it minimizes the disturbance and potential impact to Palm Creek by avoiding the Creek entirely. However, it requires a large cost ($43 million) and would have to be completed over its entire length to be effective. In addition, it would tend to reduce the Creek flow by diverting water away from the Creek, which would impact the aquatic habitat and the supply of water to the golf course. It would require construction through a number of properties which would lead to difficult land negotiations and acquisitions. Finally, the construction costs could vary substantially depending on the underlying soil conditions encountered.

2.2 OPTION 2: DRAINAGE PARKWAY

The Palm Creek Drainage Parkway involves deepening of Palm Creek from Township Road 634 to upstream of 52 Ave, and reconstructing it with a 5 m bottom width and 1:3 side slopes as shown in Figures 8 to 11.

Table 3 shows the drainage areas and cumulative discharge to the drainage parkway. All future developments and undeveloped areas are assumed to drain at a controlled rate of 2 L/s/ha.

The estimated cost of the Palm Creek Drainage Parkway is shown in Table 4. The preliminary cost of the drainage parkway is approximately $ 10 Million, assuming that the excavated earth can be used to fill the surrounding areas. The approximate length of the drainage parkway is 7.7 km. The cost also includes the cost of compensation for wetlands/Crown lands disturbed by the construction of the drainage parkway.

Note that this cost does not include the potential cost of acquiring the land required for the parkway as this cost will depend on whether the Crown claims ownership. Application has been made to Sustainable Resources Development (Public Lands) for a determination of Crown ownership and a decision is pending.

Note that the Creek has been heavily disturbed in the past as shown in Figure 12 which contains air-photos of the project area at roughly 10-year intervals since 1951. It appears that much of the creek has been channelized at some point in the past. These works are more evident in the larger scale views provided in Figure 13. The historic disturbance could be a factor in determining whether the waterbody is Crown Land, whether an approval will be granted, and what mitigation may be required.

Alberta Environment may require compensation to be provided for all wetlands that are disturbed by authorization under the Water Act. The total area of 112 ha in the Palm Creek floodplain will be disturbed by construction of the Drainage Parkway. Spencer Environmental Management Services prepared a report titled “Assessment of a Wetland on Section 34-62-2-W4M (Cold Lake Alberta) and a Compensation Plan to Mitigate Wetland Loss”. The report estimates that the unit cost of creating new wetlands is approximately $4800 per hectare. Since the report dates back to 2007, a 15% allowance for cost increases has been included, bringing the total cost to $5,500/ha. Alberta Environment also calls for a compensation ratio of 3:1.

Table 3
Palm Creek SWMFs Summary: Drainage Parkway Option

Areas West of Palm Creek

Pond ID	Drainage Area (ha)	Land use	Drainage Area Cumulative (ha)	Outflow (Local) (L/s)	Outflow (Cumulative) (L/s)	Storage Volume (cu m)	Pond Area (sq m)	Bottom, m	HWL, m	Freeboard EL, r
11A	26.7	Residential	26.7	53	53	13000	1.4	539.0	540.5	541.5
11	51.4	Residential	78.1	103	156	25000	2.7	536.0	537.5	538.5
12	14.5	Residential	14.2	29	28	7000	0.8	535.5	537.0	538.0
13	20.0	Residential	20.0	40	40	10000	1.1	537.5	539.0	540.0
146A	63.5	Industrial	63.5	127	127	31000	3.4	540.5	542.0	543.0
146	58.6	Industrial	58.6	117	117	28500	4.4	537.5	539.0	540.0
146B	53.3	Industrial	112.0	107	224	35500	4.0	537.0	538.5	539.5
145A	67.7	Industrial	67.7	135	135	41500	4.8	538.0	539.5	540.5
145B	64.9	Industrial	132.5	130	265	43500	5.1	537.5	539.0	540.0
145	85.7	Industrial (65%); Residential (30%)	218.2	171	436	52000	6.4	537.0	538.5	539.5
144C	87.1	Residential	87.1	174	174	42000	4.8	535.5	537.0	538.0
144B	100.4	Residential	187.5	201	375	48500	5.8	534.5	536.0	537.0
144	41.3	Residential	228.9	83	458	20000	2.1	534.0	535.5	536.5
201	28.0	Commercial	256.9	56	514	21500	2.3	532.5	534.0	535.0
138	60.2	Residential	60.2	120	120	29000	3.1	534.0	535.5	536.5
140	67.5	Residential	67.5	135	135	32500	3.6	533.5	535.0	536.0
141	66.6	Residential	134.1	133	268	32500	3.6	532.0	533.5	534.5
205	25.2	Residential	159.3	50	319	12500	1.3	531.5	533.0	534.0
208	16.8	Residential	16.8	34	34	8500	0.9	528.5	530.0	531.0
Areas East of Palm Creek										
Pond ID	Drainage Area (ha)	Land use	Drainage Area Cumulative (ha)	Outflow (Local) (L/s)	Outflow (Cumulative) (L/s)	Storage Volume (cu m)	Pond Area (sq m)	Bottom, m	HWL, m	Freeboard EL, r
14_1	30.1	Residential	30.1	60	60	14500	1.5	538.5	540.0	541.0
15	7.4	Residential	7.4	15	15	4000	0.5	535.5	537.0	538.0
16	49.3	Residential	56.8	99	114	24000	2.5	534.5	536.0	537.0
20A	13.5	Residential	15.9	27	32	6500	0.7	537.0	538.5	539.5
20B	8.0	Residential	8.0	16	16	3900	0.5	537.5	539.0	540.0
20C	2.1	Residential	2.1	4	4	1000	0.2	538.0	539.5	540.5
18	22.6	Residential	38.5	45	77	11000	1.2	535.0	536.5	537.5
20	10.1	Commercial	10.1	20	20	7000	0.8	536.0	537.5	538.5
21	21.5	Commercial	21.5	43	43	14500	1.5	545.0	546.5	547.5
22	31.5	Commercial (19%); Residential (76%)	53.0	63	106	17000	1.8	539.0	540.5	541.5
23	96.1	Public Services	149.1	192	298	37500	4.2	535.5	537.0	538.0
27	16.7	Residential	16.7	33	33	8000	0.9	554.0	555.5	556.5
26	35.0	Residential	51.7	70	103	17000	1.8	544.5	546.0	547.0
25	28.3	Residential	80.0	57	160	14000	1.5	544.0	545.5	546.5
24A	36.5	Residential	116.4	73	233	17600	1.9	538.0	539.5	540.5
24B	31.6	Public Services	148.1	63	296	12500	1.3	537.5	539.0	540.0
202	29.0	Commercial	336.2	58	672	22000	2.3	532.5	534.0	535.0
200	57.4	Residential	57.4	115	115	28000	3.0	535.0	536.5	537.5
47	24.1	Commercial	24.1	48	48	22000	2.3	536.0	537.5	538.5
204	52.1	Residential (40%); Commercial (55%)	52.1	104	104	33500	3.7	534.0	535.5	536.5
207_1	33.6	Residential	33.6	67	67	16500	1.8	529.5	531.0	532.0
206	28.5	Residential	28.5	57	57	14000	1.5	531.0	532.5	533.5
207_2	34.0	Commercial	34.0	68	68	26000	2.8	532.5	534.0	535.0
211	46.4	Residential (40%); Commercial (55%)	80.4	93	161	30000	3.3	527.5	529.0	530.0
210	13.6	Residential	94.0	27	188	6500	0.7	527.0	528.5	529.5
209	14.2	Residential	14.2	28	28	7000	0.8	527.5	529.0	530.0

The cost of compensating for wetlands disturbed by the Palm Creek Drainage Parkway is estimated below.

- Area of Palm Creek disturbed: 112 ha
- Compensation required: 336 ha (assuming a 3:1 Compensation ratio)
- Unit Cost of creating a new wetland: $5500/ha
- Preliminary cost of compensating for wetlands disturbed by drainage parkway: $1,848,000

As a minimum, this work will require approval under the Water Act. Channel modifications will also require the approval of Provincial and Federal Fisheries authorities and they should be consulted as soon as possible to determine what mitigation might be required.

Table 4
Summary of Cost for Palm Creek Drainage Parkway

Average Depth of Drainage Parkway, m	Length, m	Volume of Cut, Cu m	Unit Cost $/Cu m	Preliminary Cost
2	3800	83600	$15	$1,254,000
3.2	2500	116800	$15	$1,752,000
4	1400	95200	$15	$1,428,000
Sub-Total				$4,434,000
Wetland Compensation				$1,848,000
Engineering (10%) and Contingencies (50 %)				$3,769,200
Total Cost				**$10,051,200**

The Drainage Parkway option involves lower capital cost than a trunk sewer, and also accounts for the drainage from the undeveloped areas in addition to the developed areas.

The major advantage of this option is that it provides a positive drainage outlet from the region at a reasonable cost. It will also provide an amenity to the project area by creating a linear parkway that could be used for a trail network and utility corridor. Its major disadvantage is that it involves a significant disturbance to the Creek that will require the approval of Alberta Environment, Public Lands and Provincial and Federal Fisheries.

These impacts can be minimized through careful design and construction, with a view toward creating as natural a channel as possible.

Considering the high groundwater levels and underlying saturated sand layer, installation of a gravity sewer would be very difficult, and very expensive, and would make the Drainage Parkway the only practical option.

2.3 OFF SITE SERVICING COSTS

The service area for Palm Creek has been shown in Figure 1. The assumed service area for Palm Creek is approximately 14 sq. km, of which 6.4 sq. km is within the City Limits. The remaining 7.6 sq. km comprises the City's future expansion area.

The preliminary cost of constructing the drainage parkway which would service an area of about 14 sq. km is approximately $ 10 Million. Thus, the cost of the drainage parkway for the service area would be approximately $7,200 per hectare. Considering the extent of ditch improvements and the costs involved, three options have been identified to finance the construction:

2.3.1 Option 1: Palm Creek Fund

Option 1 involves maintenance of a Levy fund by the City for the Palm Creek Drainage Parkway. The City can collect funds from the developers based on the area of proposed development, at a unit rate of $7,200 per ha and use the funds to construct the drainage parkway in the future. Interim servicing may be required until the permanent works are completed. The developer will be responsible for their own on-site drainage and stormwater management cost in addition to the cost of the interim servicing.

2.3.2 Option2: Construction of Drainage Parkway in Parts

Instead of contributing to the City for the Drainage Parkway fund, the developers can choose to construct their portion of the drainage parkway based on the area of proposed development.

Since drainage of some developments is not feasible until the Palm Creek improvements are constructed, interim servicing would be required. However, since constructing the drainage parkway in small parts would aggravate the disturbance to Palm Creek, this option is not feasible.

2.3.3 Option 3: City Construction and Financing

In this scenario, the City would use infrastructure grants to construct the drainage parkway up front, and would recover the costs over time from future developments through a levy fund. The advantage of this option is that the required improvements are available immediately. Interim servicing costs, and the associated operating and maintenance costs, are not required. If funding can be arranged, this is the most cost effective option.

3 Creekside Estates Service Options

Previous studies were reviewed for servicing options for Creekside Estates, including the City of Cold Lake Master Drainage Plan, Creekside Estates Stormwater Management Plan, and Northshore Area Structure Plan. Those portions of these documents which are relevant to Creekside Estates stormwater management have been briefly summarized below.

3.1 2006 DRAINAGE MASTER PLAN

The City of Cold Lake's existing Drainage Master Plan was prepared by AECOM in August 2006. Creekside Estates is located in portions of Basins 17 and 18 west of English Bay Road. Figure 14 shows a map of the drainage basins from the Master Plan prepared by AECOM. The hydrologic details for Basins 17 and 18 from the Master Plan are given below in Table 5.

Table 5
Summary of Relevant Stormwater Pond Details from 2006 Master Drainage Plan

Basin	Catchment Area	Pond Size	Storage Volume	Discharge
17	34.3	1.41	20,100	0.07
18	25.2	1.02	13,600	0.05

The Master Plan report assumes a pond depth of 2 m and a freeboard of 0.6 m. However, the report does not take into consideration the relative elevation of the storm ponds with respect to Palm Creek and thus does not identify the constraints involved in draining the ponds.

3.2 2007 CREEKSIDE STORMWATER MANAGEMENT PLAN

Focus Corporation prepared a Stormwater Management Plan for Creekside Estates in August 2007. The report describes two options to drain Creekside Estates.

Option 1 involves a storm pond in the Southeast corner of Creekside Estates which would drain to Palm Creek at a controlled rate of 2 L/s/ha. The remaining area of this development would drain directly to Palm Creek which was identified as a special study area in this report.

Option 2 assumes that the special study area will not be used for stormwater management purposes. Stormwater management would be provided in a storm pond in the southeast corner, and two SWMFs would be located immediately east of the special study area as shown in Figure 15. Another SWMF would be located immediately west of the special study area. The Figure has been taken from the Stormwater Management Plan for Creekside Estates by Focus Corporation.

The report identifies that the special study area is relatively shallow compared to the land to be developed, and might require pumping to discharge the SWMFs to the special study area. It does not mention how the special study area would be drained.

The report also identifies that the areas upstream of the Creekside Estates will also discharge to Palm Creek at a controlled rate through their SWMFs.

3.3 2008 CREEKSIDE ESTATES STAGE 1A

Focus Corporation prepared a plan and profile for the outlet from the Creekside Estates SWMF in the southeast corner of the development in August 2008. A culvert across Highway 55 and a culvert across English Bay Road were proposed to direct the runoff from this SWMF eastwards and then to a natural drainage course to Palm Creek. Figure 16 shows a plan/profile of this ditch as surveyed by Focus Corporation. Figure 17 shows the profile of the interim outfall culverts for the SWMF, and Figure 18 shows a plan/cross section of the SWMF.

Focus Corporation also prepared the record drawings for the Creekside Estates, which show that pumping was required to drain the SWMF. The pumped runoff is directed eastwards through the culverts, as proposed in August 2008, and then south to Palm Creek. The SWMF in the southeast corner would attenuate runoff for Phases I, II and III of Creekside Estates. However, there is no mention of a permanent outfall to drain the SWMF by gravity in the drawings. Record drawings show the pond bottom at 535.75 and the pond berm at 538.35.

3.4 NORTHSHORE AREA STRUCTURE PLAN (ASP)

The Northshore ASP further develops the concepts presented in Option 1 of the Creekside Stormwater Management Plan where the areas not draining to the SWMF in the southeast corner are proposed to be drained to Palm Creek, designated as a special study area for stormwater management. The ASP does not indicate how the ponds or shallow areas of Palm Creek would be drained, which would be difficult, considering the low relief. Figure 19 shows the stormwater management concepts shown in the Northshore ASP.

3.5 CREEKSIDE ESTATES PHASES I, II AND III

Phases I, II and III of Creekside Estates drain to the storm pond in the southeast quadrant of the development, as mentioned previously in this report. A temporary pump station has been constructed, and a culvert under Highway 55 has been installed to direct runoff from the storm pond to the east and then to a drainage course along Hwy 28 and south to Palm Creek, as shown in Figures 17 and 18.

A permanent gravity outfall for Creekside Estates should be constructed such that the pump station is phased out and the Creekside Estates pond drains by gravity. To facilitate drainage by gravity, the existing drainage course will have to be deepened and the culverts lowered, as shown in Figure 20.

3.6 CREEKSIDE ESTATES PHASE IV AND V

Previous studies have indicated that storm water management for Phases IV and V of Creekside Estates be provided either in permanent ponds outside the Creek, or in the Creek itself. Previous studies have also indicated that the Creek is shallow and have identified the need to pump from the stormwater pond unless the creek is lowered.

As mentioned previously, it is proposed that the developer construct a stormwater management facility to service the development, and pay a levy for the ultimate development of the Palm Creek Parkway.

In view of the constraints to gravity drainage created by the shallow creek, a pump station is proposed as an interim option to drain the pond to Palm Creek. The installation, operation and maintenance cost of the interim pump station, and the cost of abandoning the pump station, would be an additional cost to the development.

4 Conclusions

Based on the analysis described above, Associated Engineering concludes the following:

1. The most feasible way to provide drainage for the Palm Creek basin is to construct a drainage parkway within the Palm Creek floodplain from Township Road 634, south to the existing channel at 53 Avenue that was constructed in 1986 to control flooding in the South Cold Lake area.

2. If the drainage parkway is not constructed, large areas within the existing City boundary and the future annexation area cannot be drained by gravity, which will create significant constraints to the development of these areas.

3. The cost of the drainage parkway is likely to be in the order of $ 10 Million which translates into an off-site cost of approximately $7,200 per hectare of benefitting lands.

4. Significant environmental issues will need to be addressed, and approval of Alberta Environment and Provincial and Federal Fisheries will be required.

5 Recommendations

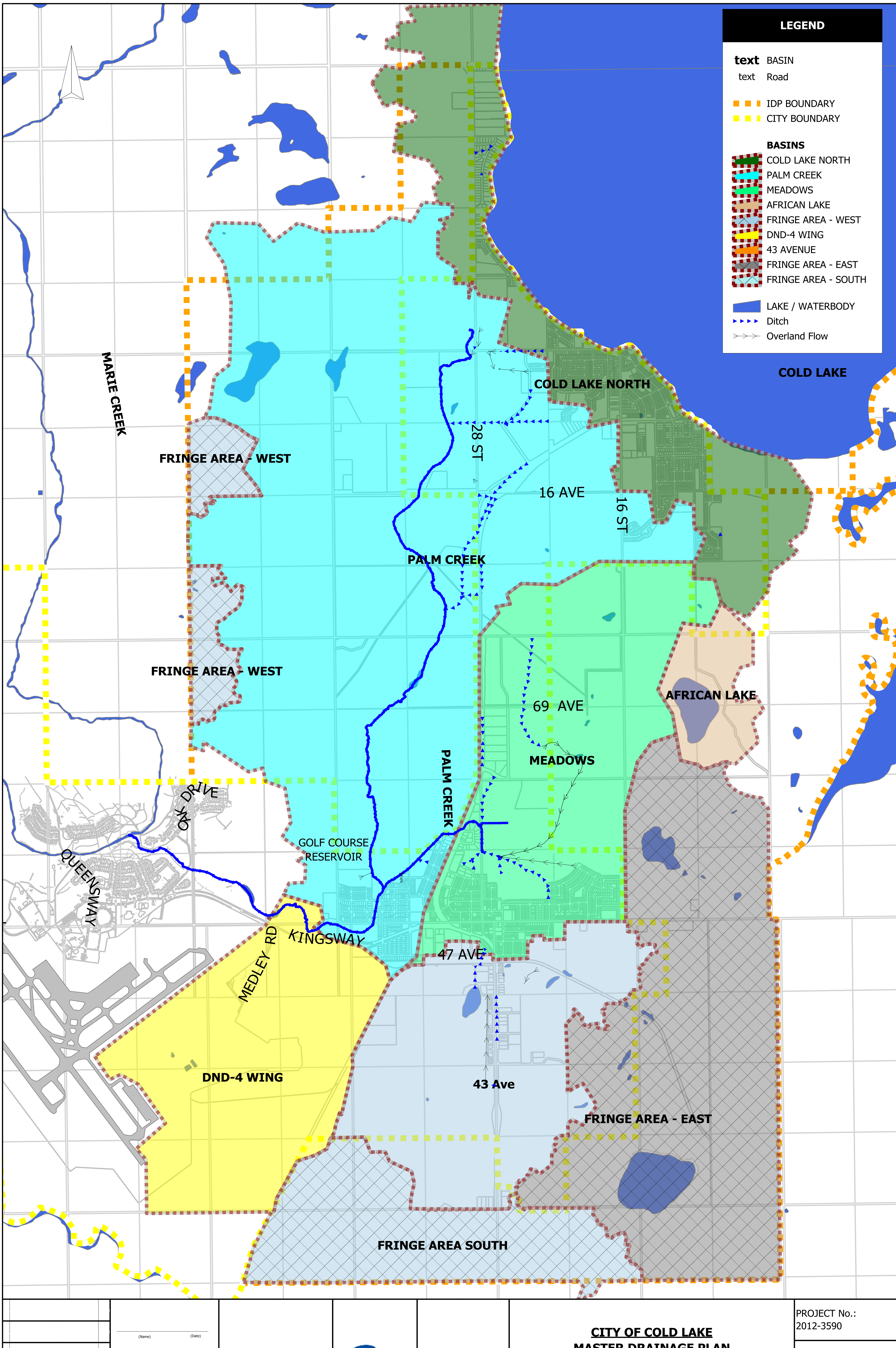
Associated Engineering recommends the following:

1. That the City of Cold Lake initiate discussions with Alberta Environment and Provincial and Federal Fisheries to explore the feasibility of lowering Palm Creek (constructing the drainage parkway) and to define the mitigation required.

2. That the City of Cold Lake consider applying infrastructure funds or other grant money towards constructing the drainage parkway, so as to facilitate development in the basin.

3. That the City establish an off-site levy for the sharing of costs required to construct the parkway, to apply to all of the benefitting basin.

4. That the interim servicing plan for Creekside Stages IV and V include a permanent stormwater management facility (dry pond) and an interim pump station, plus provision for the operation and maintenance costs and the cost of the ultimate abandonment of the pump station.



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Associated Engineering
City of Cold Lake

CITY OF COLD LAKE
MASTER DRAINAGE PLAN

Figure 1
BASINS MAP

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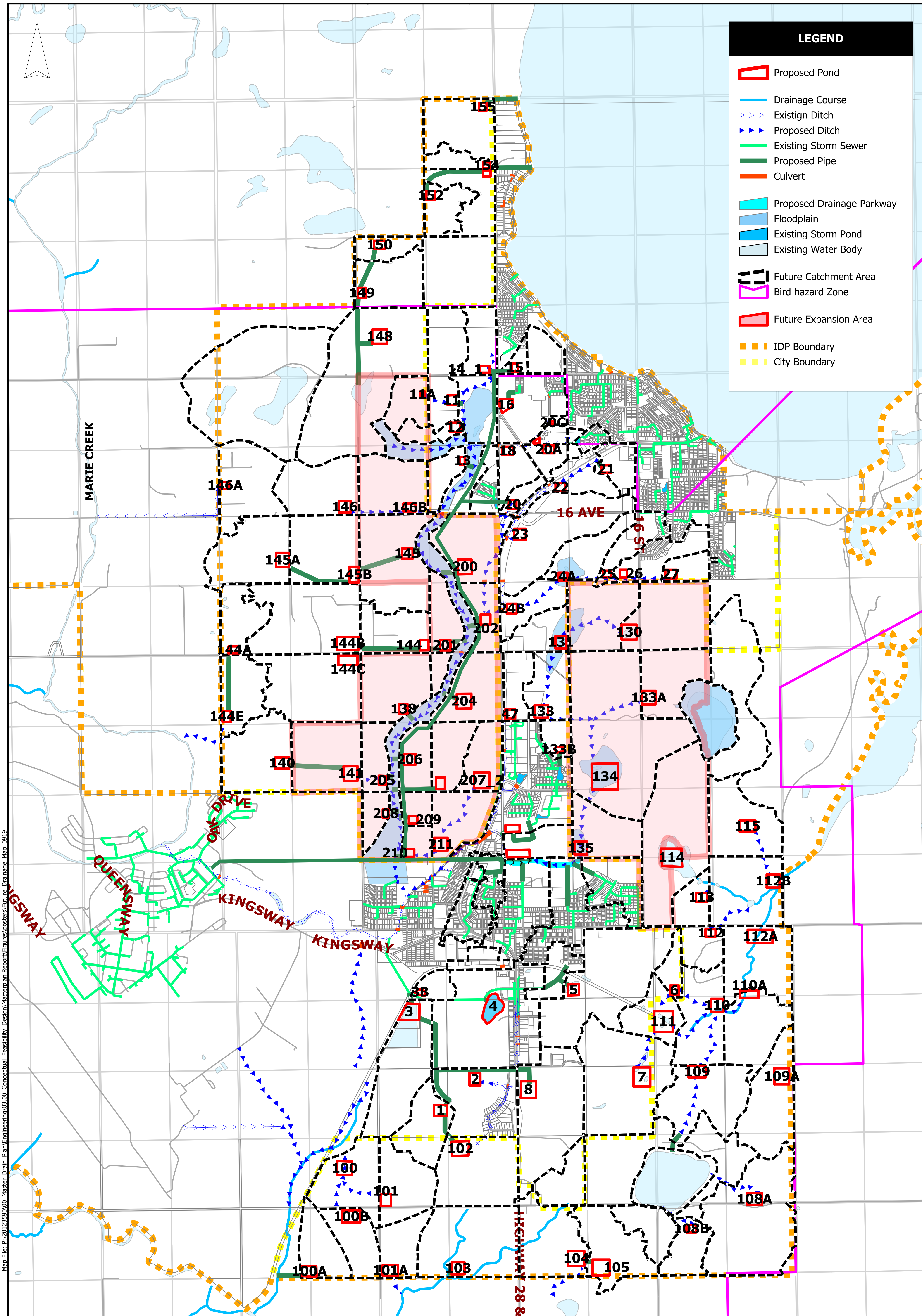

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Associated Engineering
City of Cold Lake

CITY OF COLD LAKE
DRAINAGE MASTERPLAN

Figure 2
FUTURE DRAINAGE CONCEPT

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