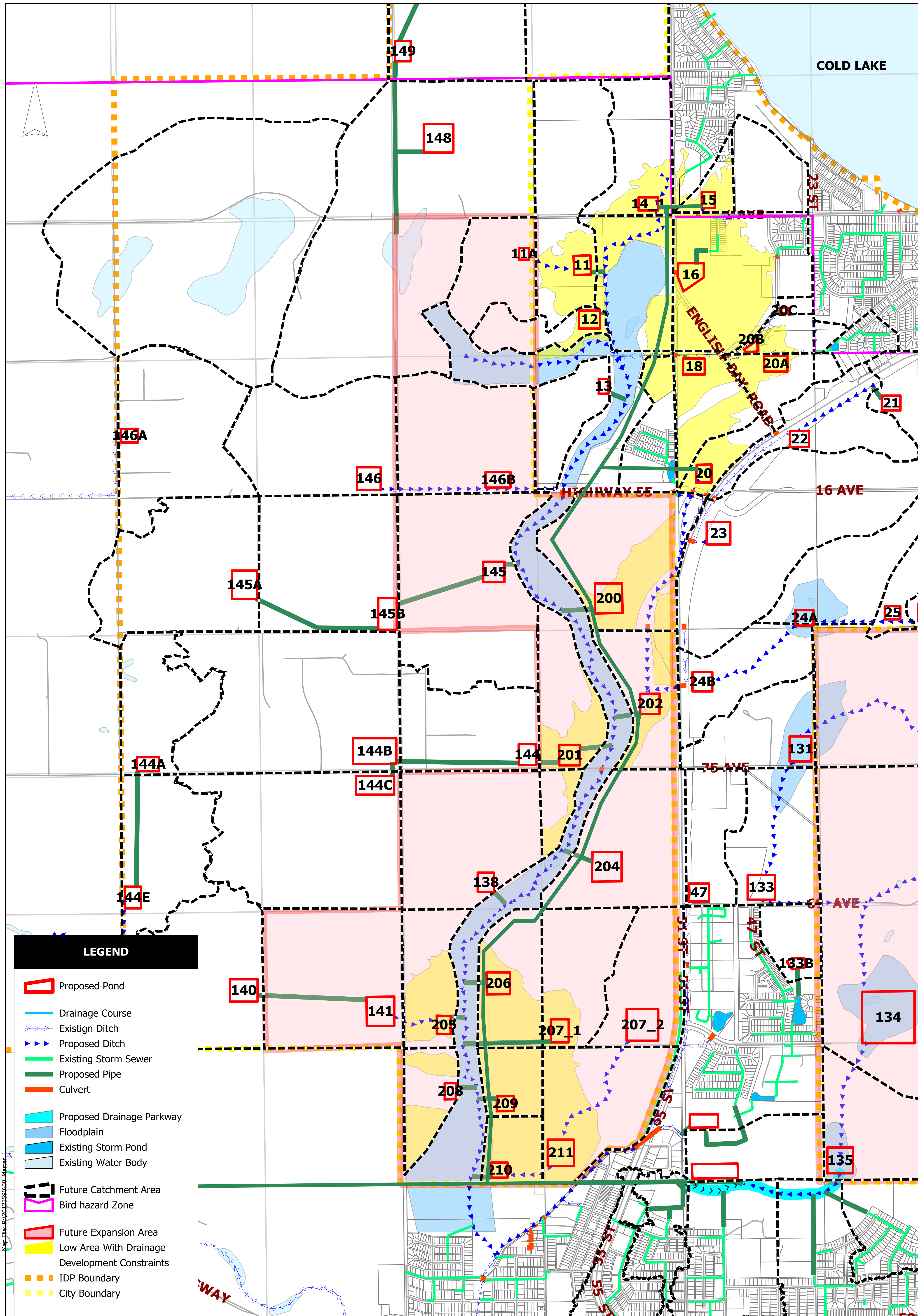
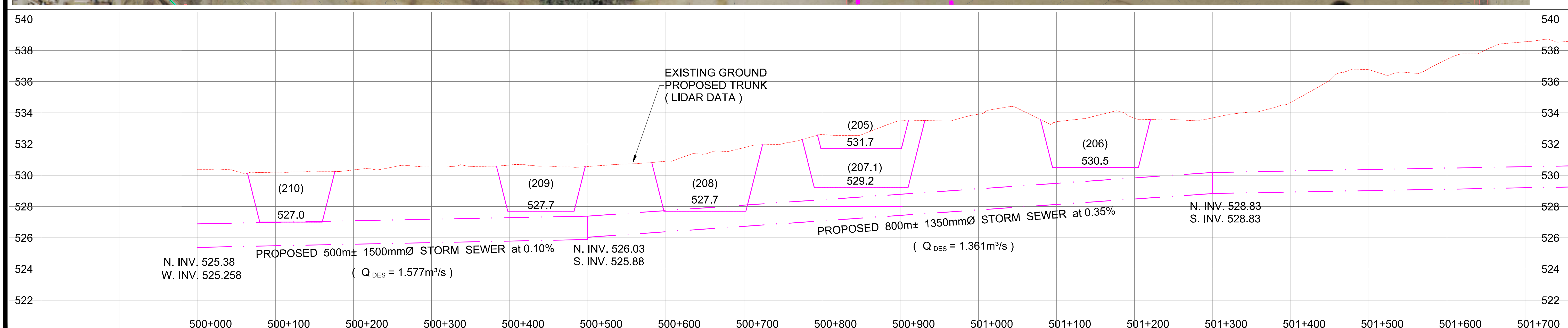


No. REVISION DATE	Name (Date)	**CITY OF COLD LAKE** **DRAINAGE MASTERPLAN** Figure 3 FUTURE DRAINAGE CONCEPT WITH PALM CREEK LOW AREAS	PROJECT No.: 2012- DATE: 3/30/2014 SCALE: 1:20,000

Associated Engineering
City of Cold Lake



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

REVISIONS

Associated Engineering

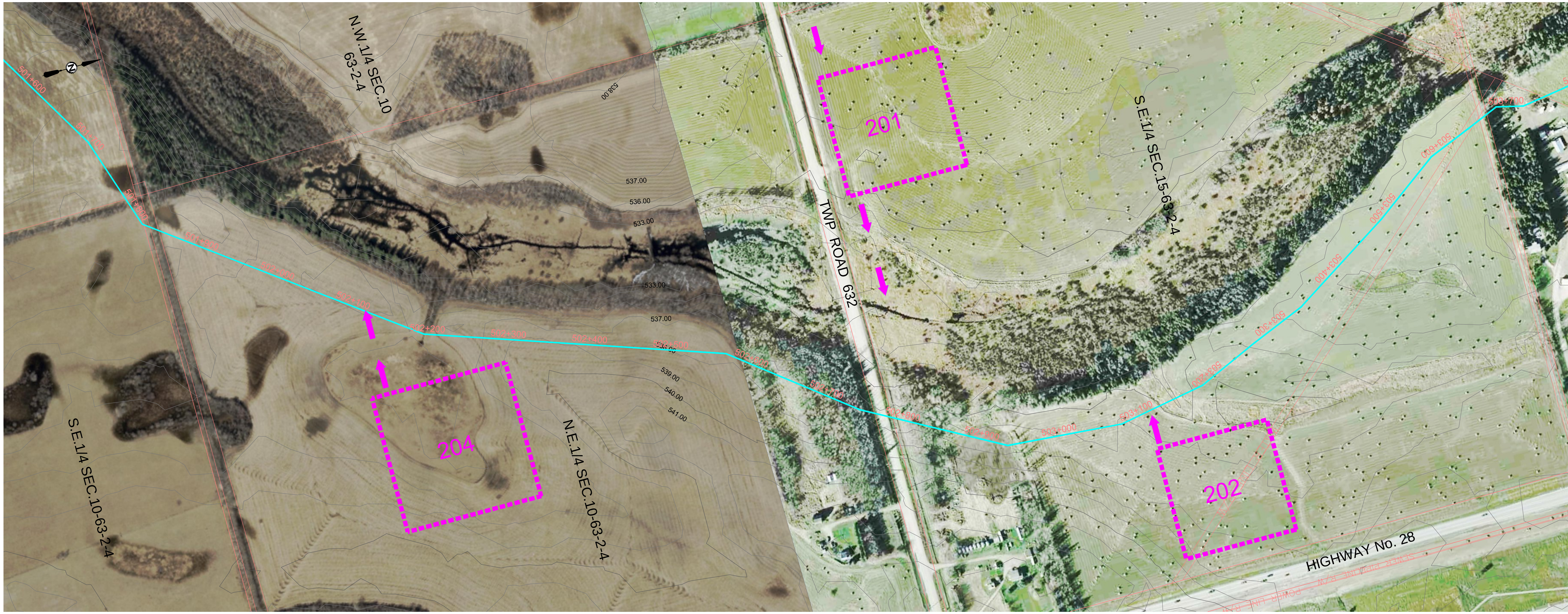
PROJECT No.	20123590
SCALE	HOR. 1:5000 VERT. 1:250
DRAWN	B. Wong
DESIGNED	S. Nishtala

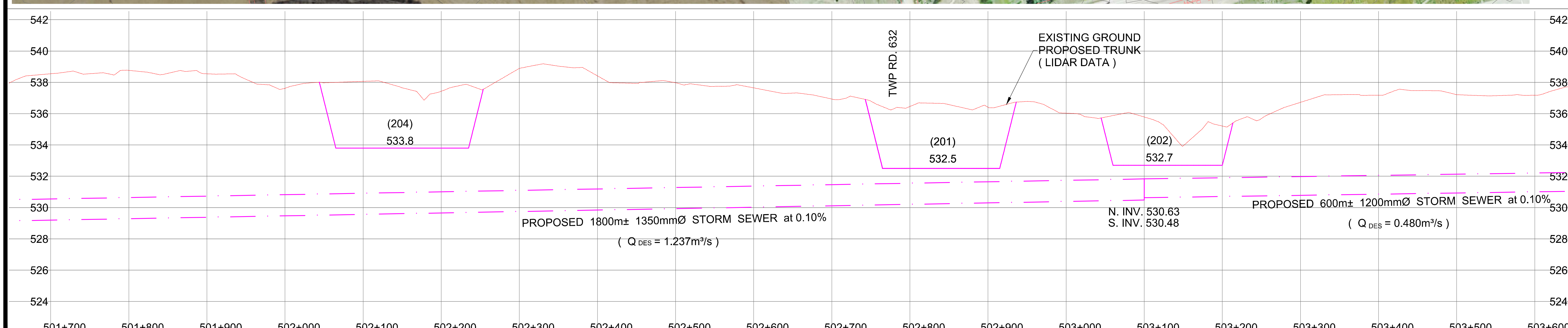
City of Cold Lake

PALM CREEK PROFILE

MASTER DRAINAGE PLAN UPDATE

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





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

REVISIONS

Associated Engineering

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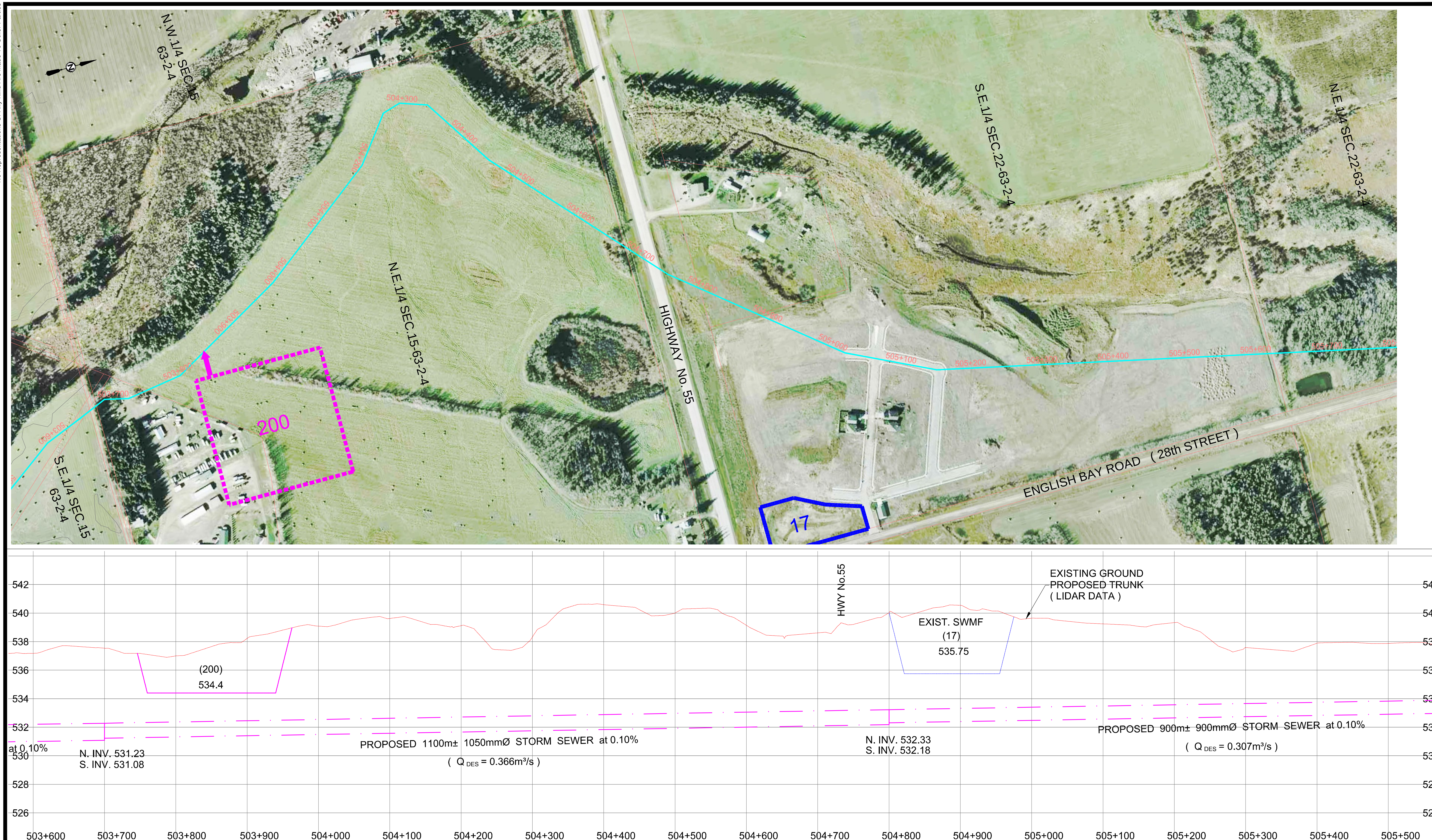
SCALE	HOR. 1:5000 VERT. 1:250
DRAWN	B. Wong
DESIGNED	S. Nishtala

City of Cold Lake

MASTER DRAINAGE PLAN UPDATE

PALM CREEK PROFILE

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



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

REVISIONS

Associated Engineering

PROJECT No.	20123590
SCALE	HOR. 1:5000 VERT. 1:250
DRAWN	B. Wong
DESIGNED	S. Nishtala

City of Cold Lake

MASTER DRAINAGE PLAN UPDATE

PALM CREEK PROFILE

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

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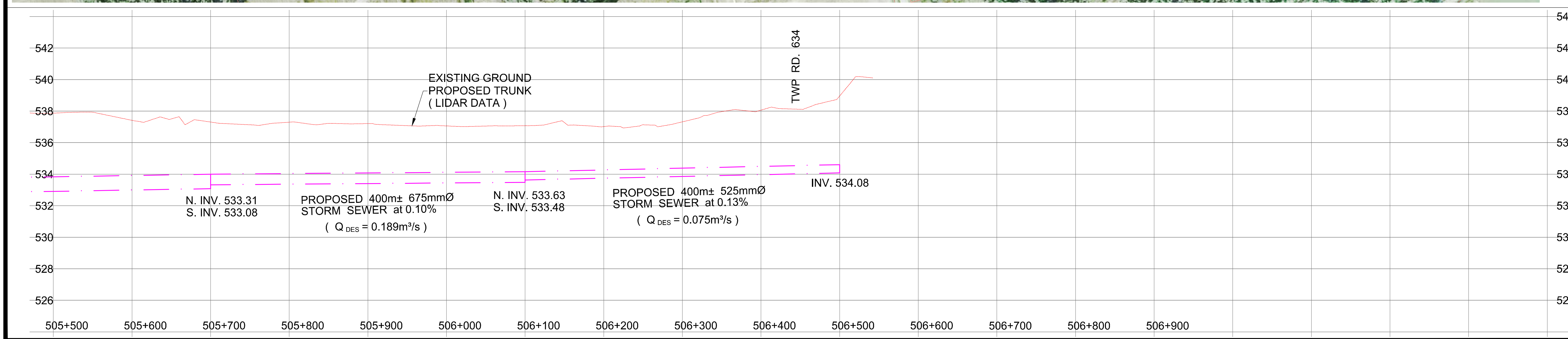

NO.	DATE	ENG.	BY	SUBJECT
A	2013-01-28	S.N.	W.W.	PRELIMINARY ISSUE

REVISIONS

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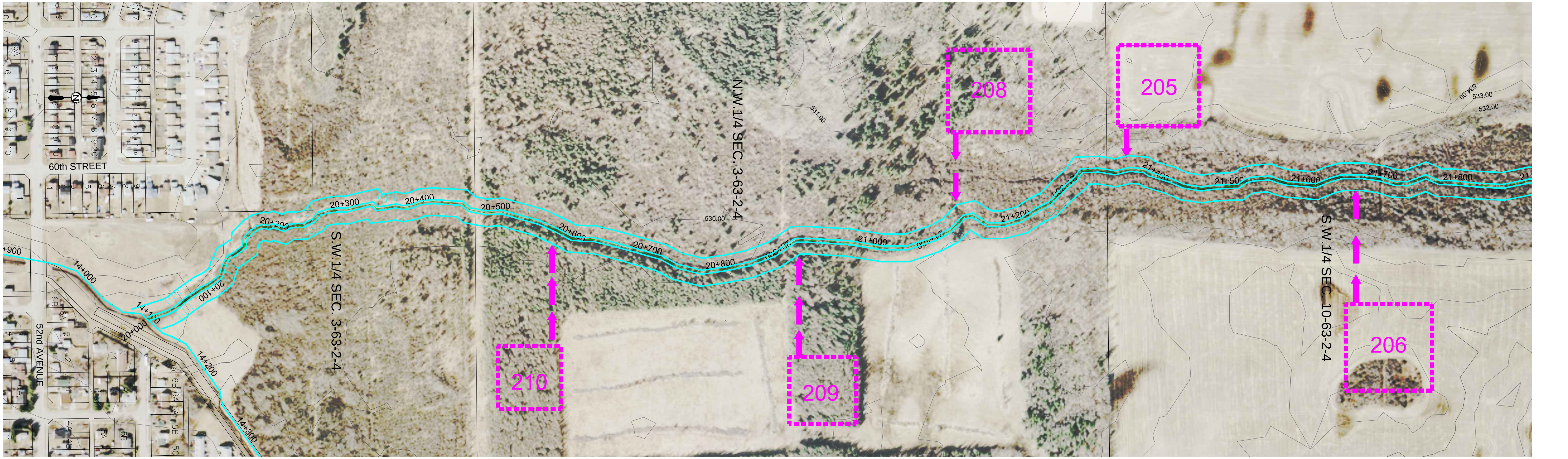
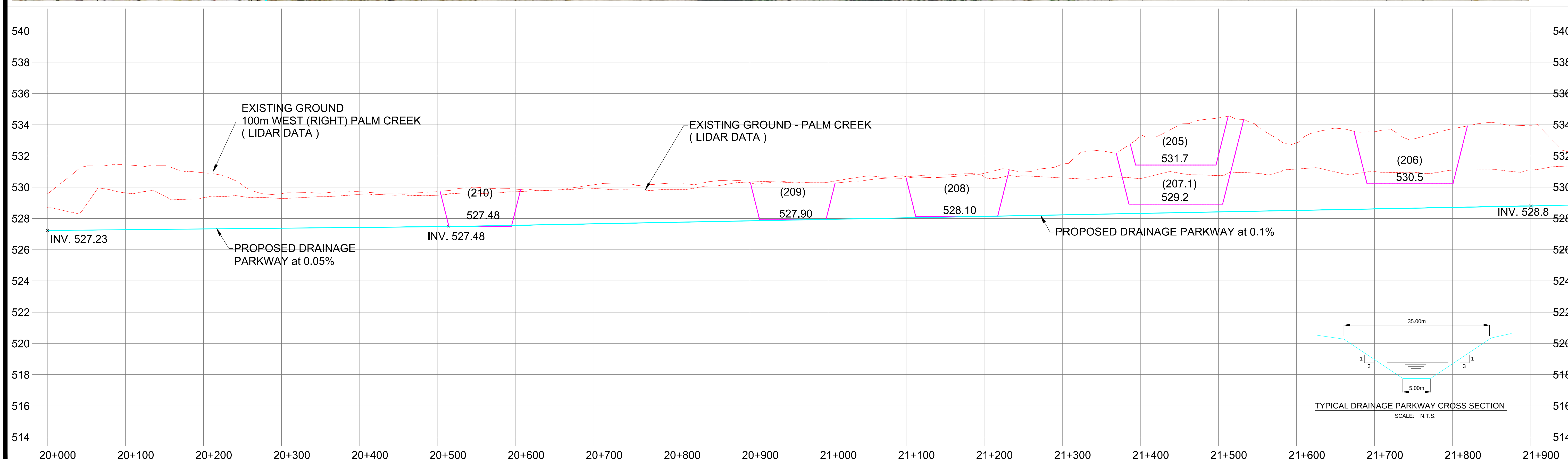
City of Cold Lake

MASTER DRAINAGE PLAN UPDATE

PALM CREEK PROFILE

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





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

REVISIONS

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PROJECT No.	20123590
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DRAWN	B. Wong
DESIGNED	S. Nishtala

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MASTER DRAINAGE PLAN UPDATE

PALM CREEK PROFILE

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 8	A	-

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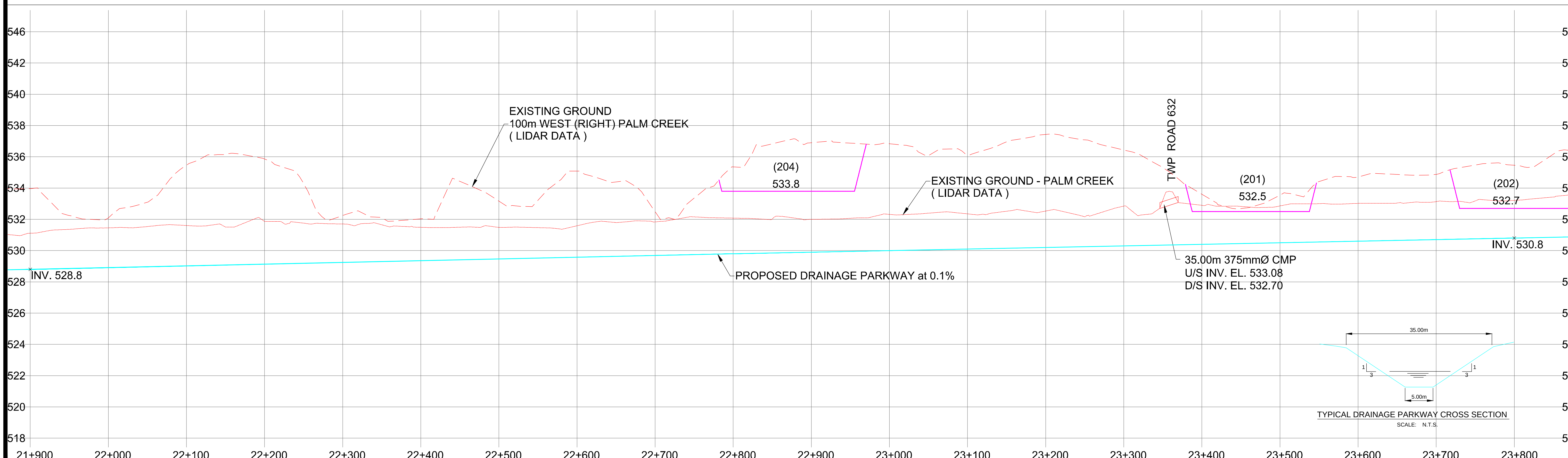

NO.	DATE	ENG.	BY	SUBJECT
A	2013-01-28	S.N.	W.W.	PRELIMINARY ISSUE

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PROJECT No.	20123590	
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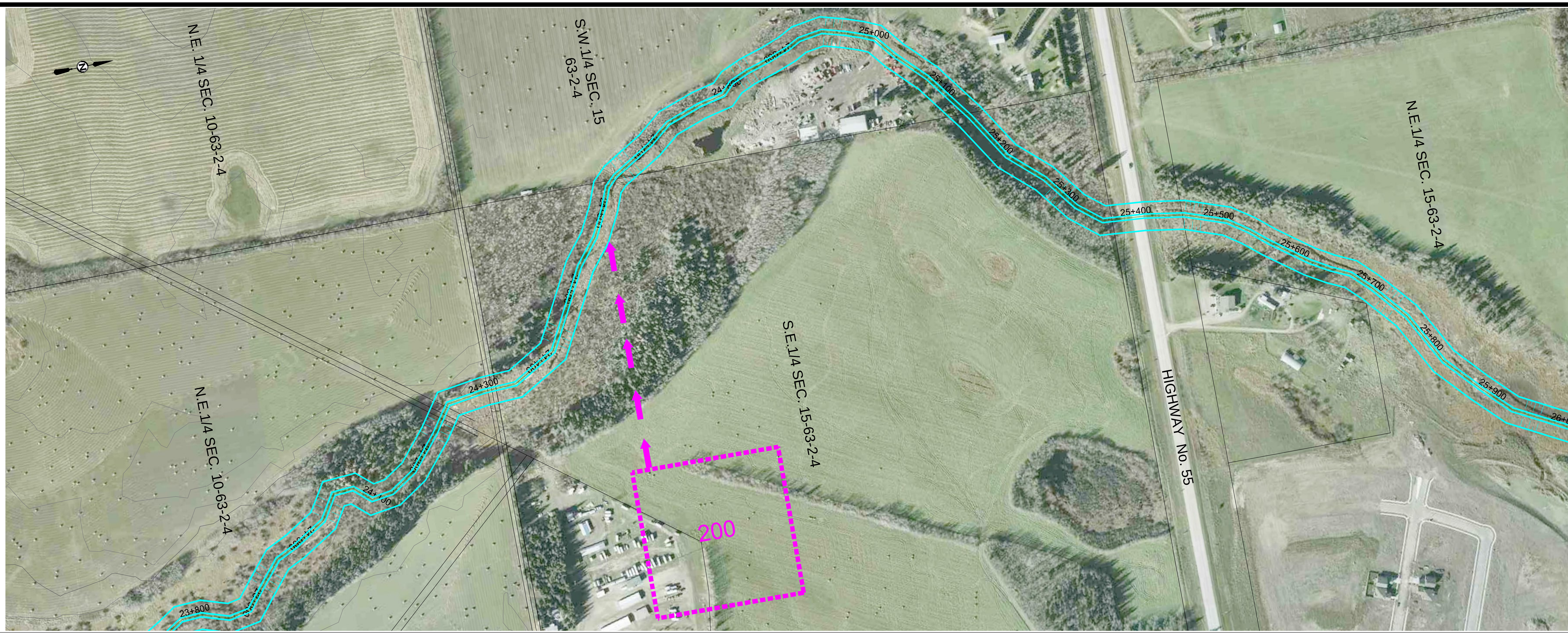
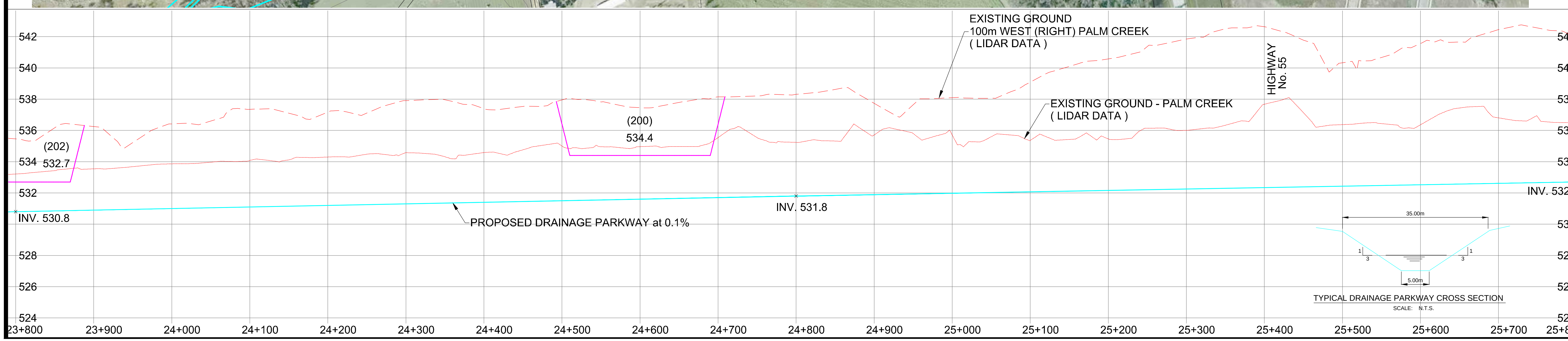
City of Cold Lake

MASTER DRAINAGE PLAN UPDATE

PALM CREEK PROFILE

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





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

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Associated Engineering

PROJECT No.	20123590
SCALE	HOR. 1:5000 VERT. 1:250
DRAWN	B. Wong
DESIGNED	S. Nishtala

City of Cold Lake

MASTER DRAINAGE PLAN UPDATE

PALM CREEK PROFILE

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

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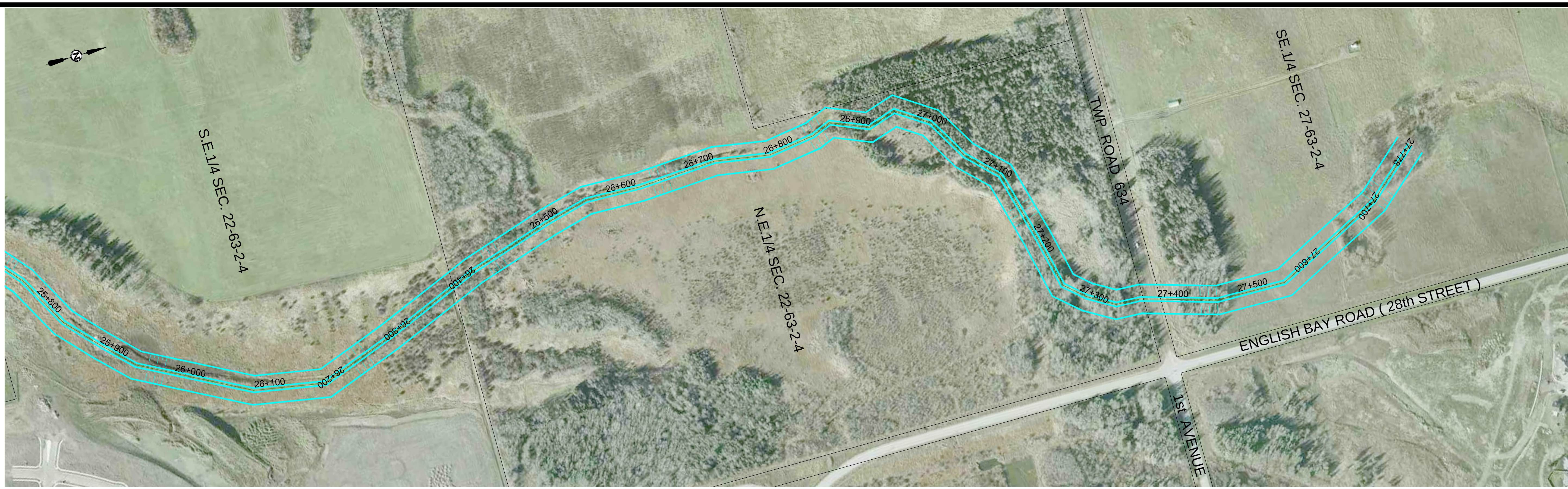
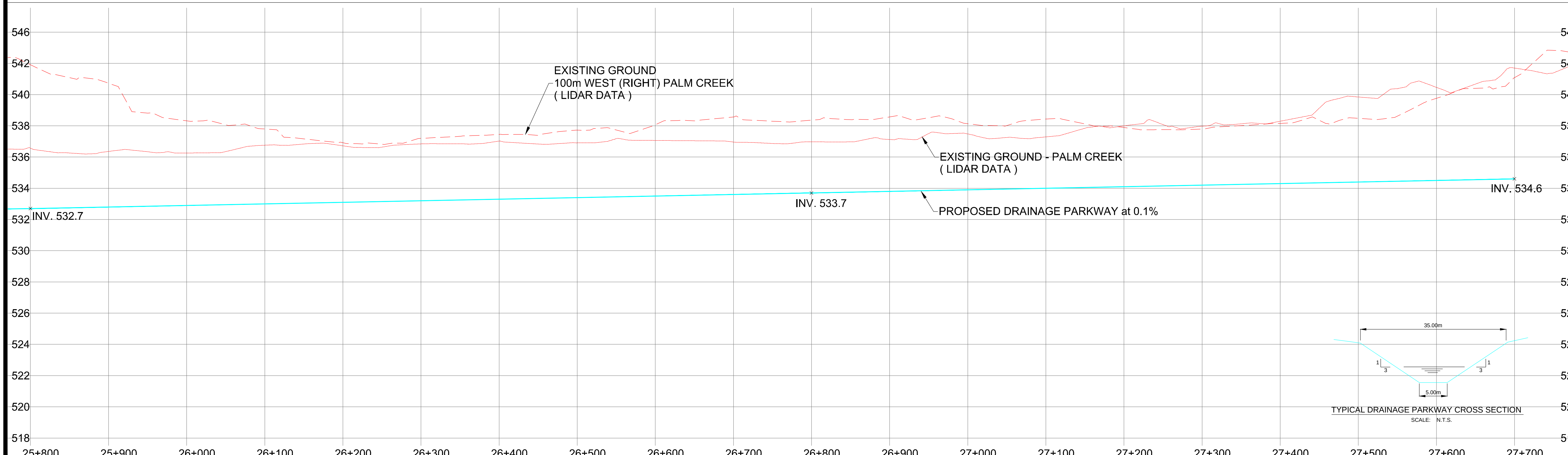




NO.	DATE	ENG.	BY	SUBJECT
A	2013-01-28	S.N.	W.W.	PRELIMINARY ISSUE

REVISIONS

Associated Engineering

PROJECT No.	20123590
SCALE	HOR. 1:5000 VERT. 1:250
DRAWN	B. Wong
DESIGNED	S. Nishtala

City of Cold Lake

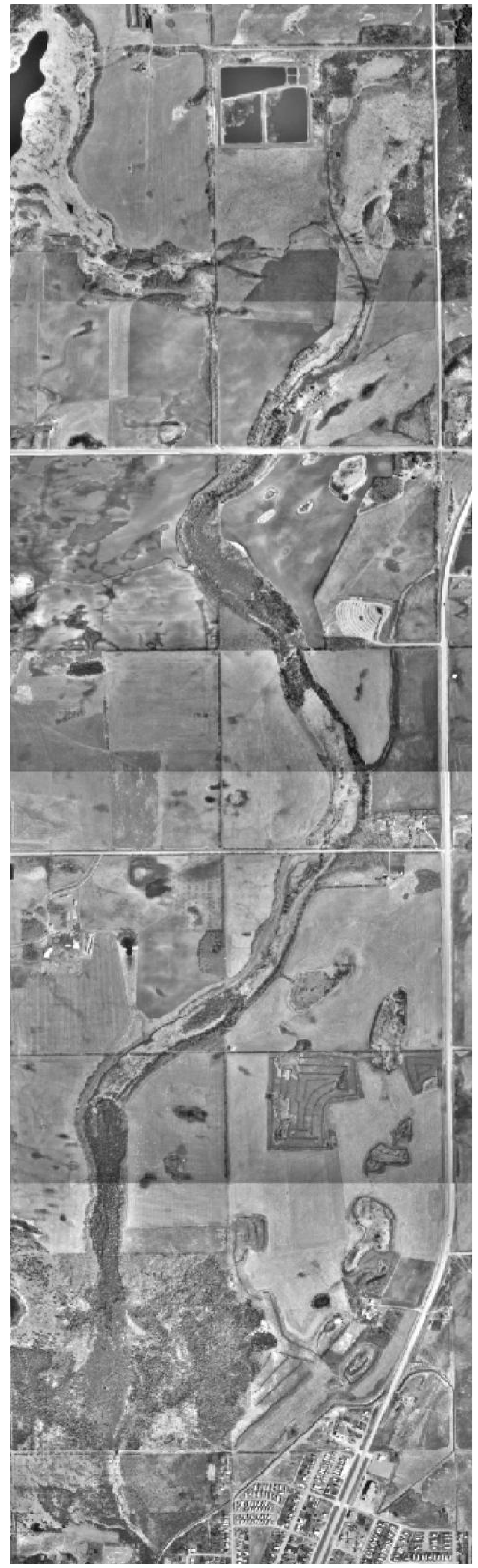
MASTER DRAINAGE PLAN UPDATE

PALM CREEK PROFILE

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 11	A	- --

May 6
1951

1967



May 2
1976

October 24
1990

2010

Associated Engineering

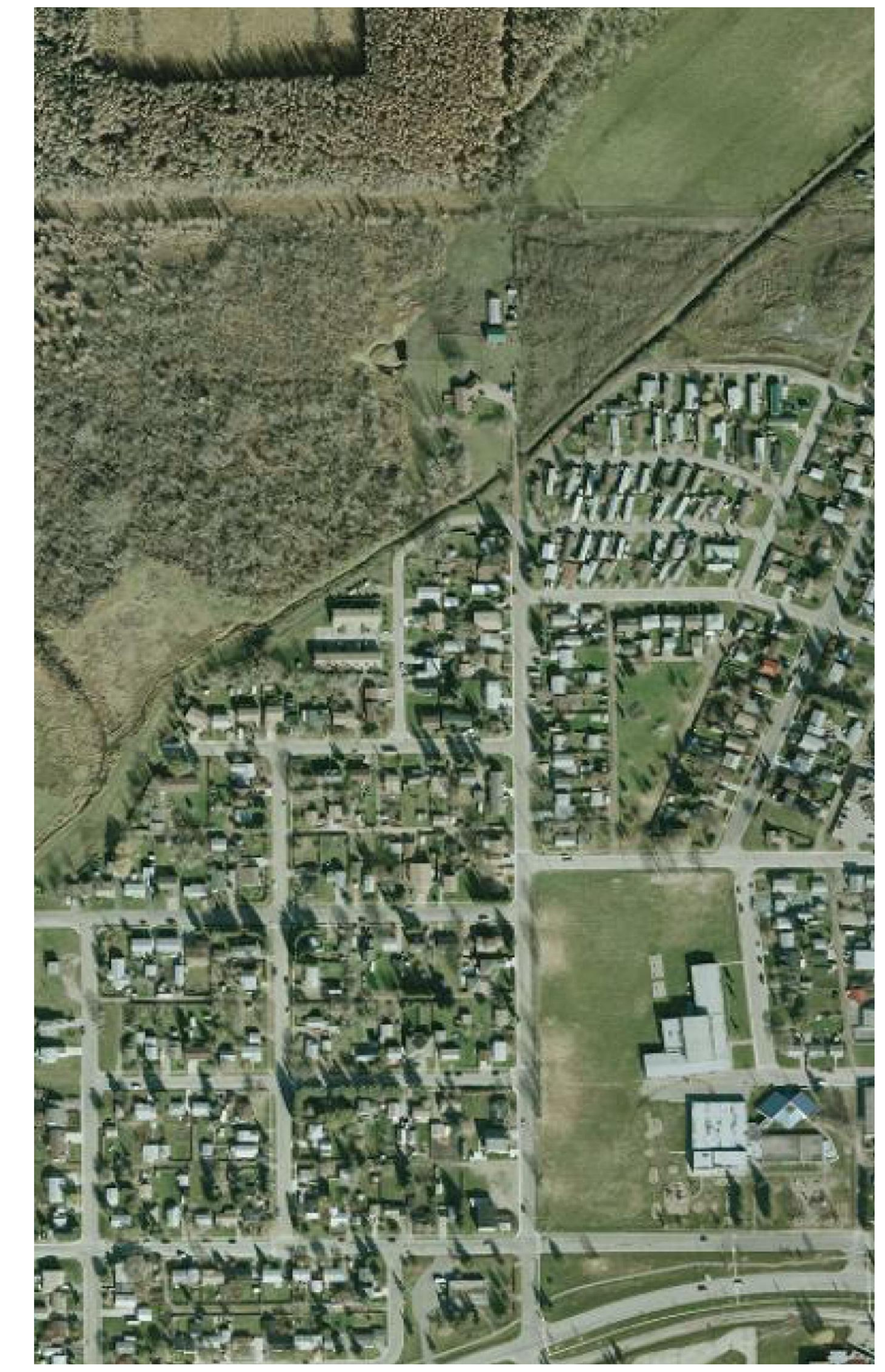
City of Cold Lake

PALM CREEK
HISTORIC AIR PHOTOS

PROJECT No:
2012-3590.000

DATE: 5/15/2013

FIGURE 12



DETAIL A

DETAIL B

Construction Dates 1967-1976

DETAIL C

Construction Dates 1976-1990

DETAIL D

Construction Dates 1976-1990

DETAIL E

Construction Dates 1951-1967

Associated Engineering

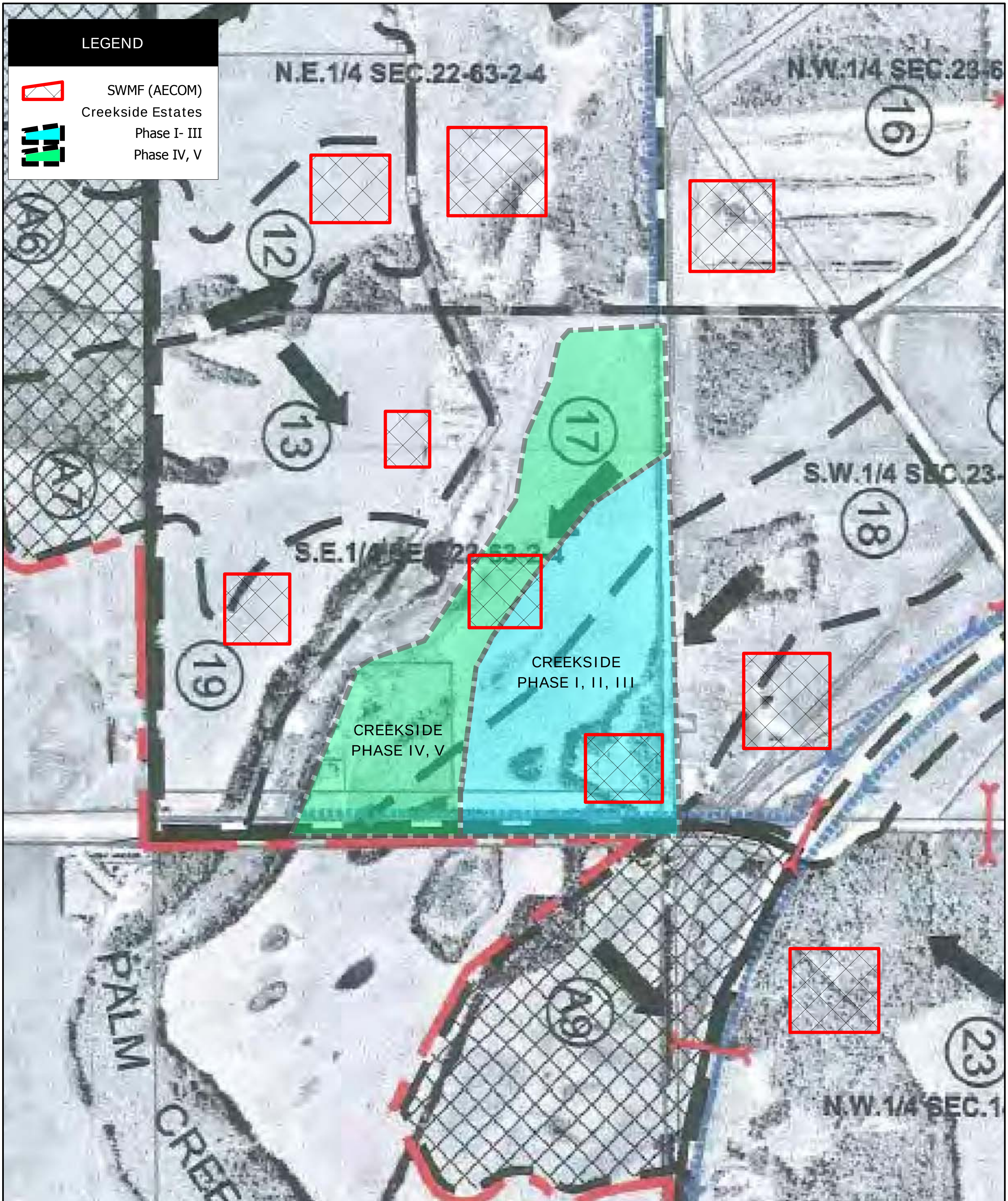
City of Cold Lake

PALM CREEK
2010 AIR PHOTOS
DETAILS

PROJECT No: 2012-3590.000

DATE: 5/15/2013

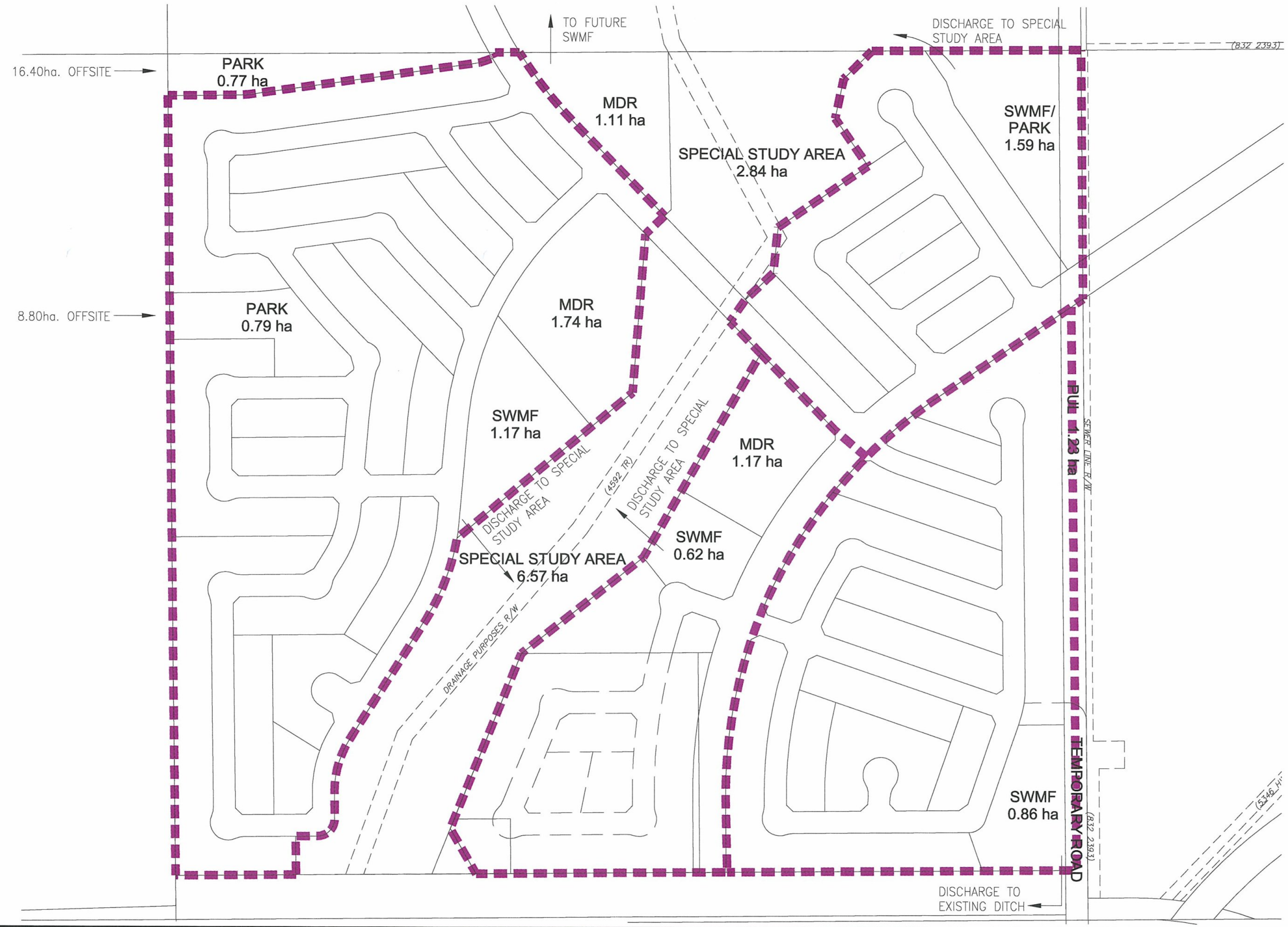
FIGURE 13



REVISION	(Name) (Date)	CITY OF COLD LAKE	PROJECT No: 2012-3590
	(Name) (Date)	MASTER DRAINAGE PLAN	DATE:5/16/2013
	(Name) (Date)	DRAINAGE MAP	SCALE:1:7,500
		(2006 Master Drainage Plan - AECOM)	FIGURE 14
		Creekside Estates	

Associated Engineering

City of Cold Lake



FOCUS

FOCUS Corporation
1000, 9925 - 109 Street
Edmonton, AB, Canada T5K 2J8

Main: 780.466.6555
Fax: 780.421.1397

www.focus.ca

LEGEND:

CATCHMENT BOUNDARIES

PROJECT:

CREEKSIDE ESTATES
CITY OF COLD LAKE
STORMWATER MANAGEMENT PLAN - OPTION 2
SCALE: 1:4000

102255-20	AUGUST, 2007	FIGURE 2.0

N:\102255 – Cold Lake ASP\Engineering\102255-20\Engineering\Drawing Files\Preliminary Design\Figure1-Stormwater Management Plan Option1.dwg 8/28/2007 9:08:53 AM MDT

FIGURE 15

REVISION NO.	DESCRIPTION	BY	APPD.	DATE
A	BASED ON SURVEY TAKEN 2008-07-14	TBK		23.07.08
B	ADDED SURVEY TAKEN 2008-07-31	TBK		06.08.08
C	ADDED REPLACEMENT CULVERTS	TBK		08.08.08

ENGINEERS STAMP

PERMIT

FOCUS

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Edmonton, AB, Canada T5K 2J8

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Fax: 780.421.1397

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Client
GALT DEVELOPMENTS LTD.

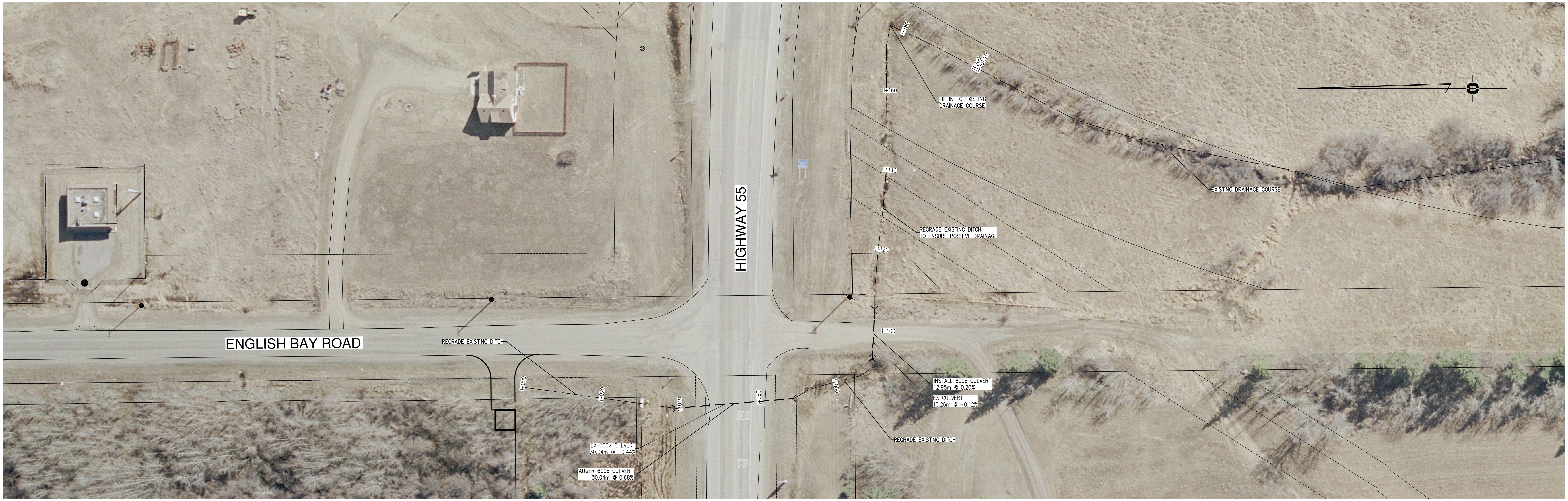
Project
CREEKSIDE ESTATES
STAGE 1A
City of Cold Lake, Alberta

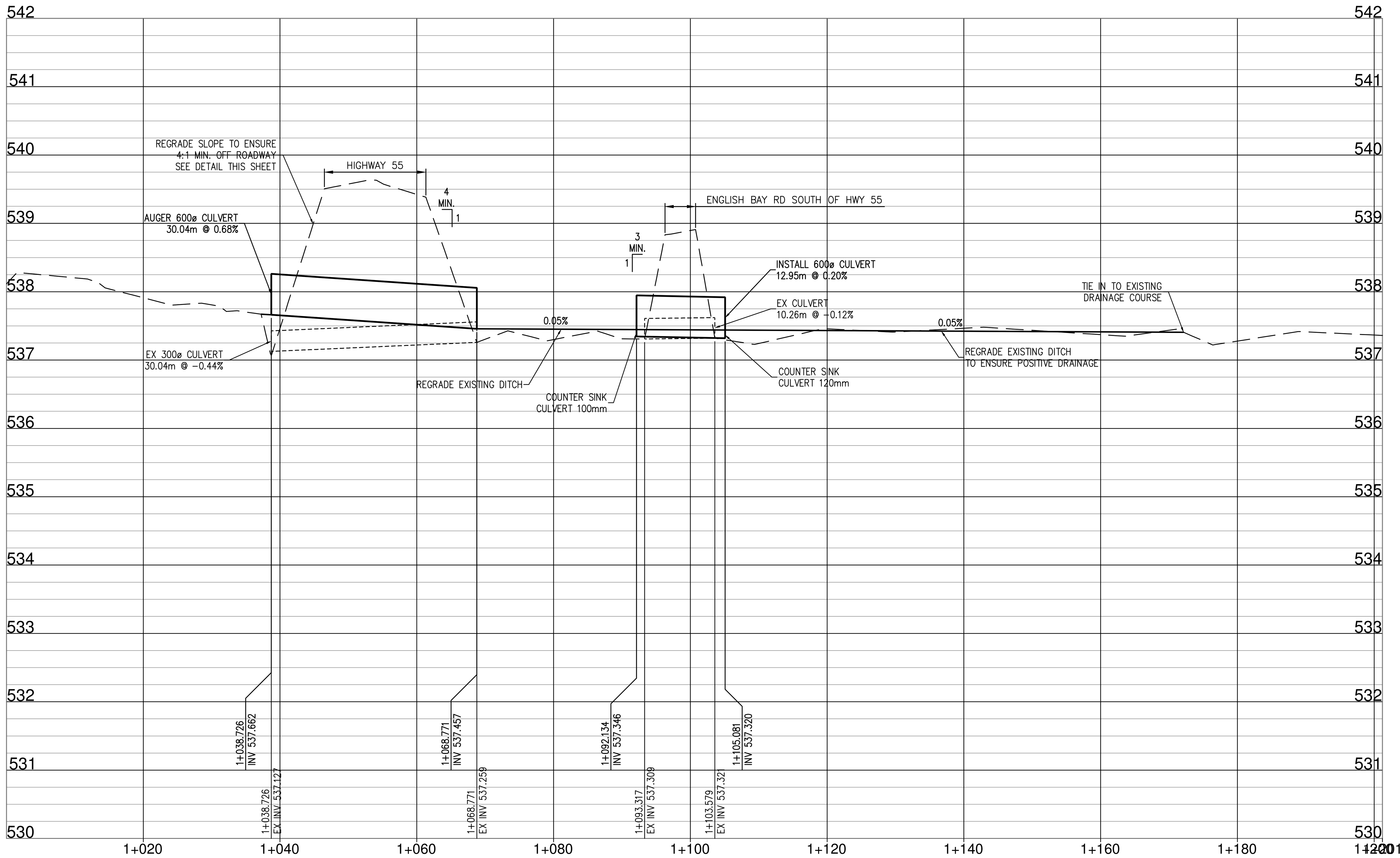
EXISTING SOUTH DRAINAGE
PLAN PROFILES

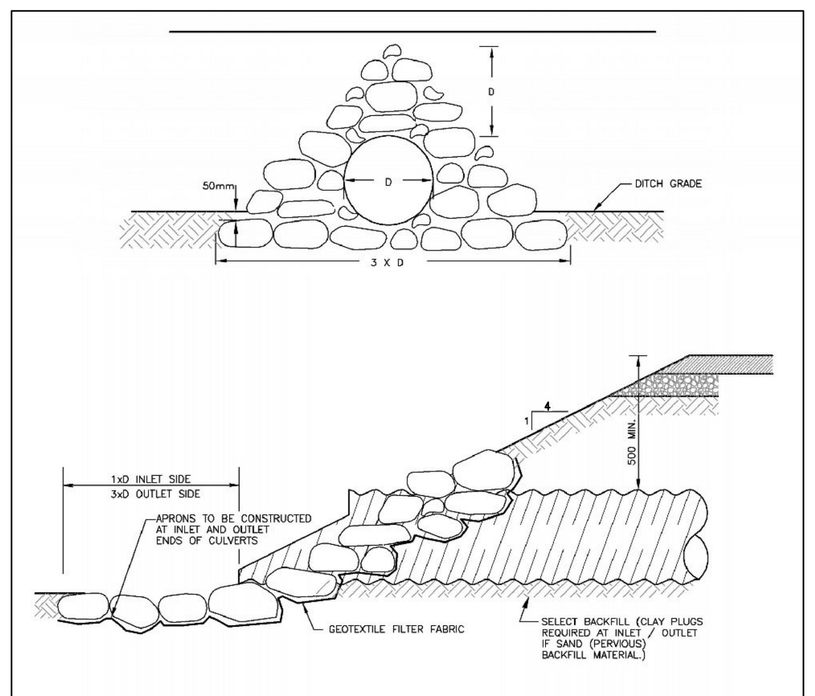
Designed	Scale	Date
T.B.K.	1:2000	AUGUST 2008
Drawn	Project No.	
T.B.K.	102255-22	
Checked	Drawing No.	Rev.
Approved	X05	C

CAD FILE NAME: N:\102255 - Creekside Estates - Cold Lake ASP\Engineering\102255-22\Drawing Files\Detail Design\102255-22 South Drainage.dwg
DATE PLOTTED: August 8, 2008

FIGURE 16







NOTES:

(1) ROCKS AND BOULDERS SHALL BE SELECTED AS NEARLY CUBICAL IN FORM AS PRACTICABLE AND OF A SIZE GREATER THAN 150mm.

(2) THE STONES SHALL BE PLACED WITH THEIR BEDS AT RIGHT ANGLES TO THE SLOPE, THE LARGER STONES BEING USED IN THE BOTTOM COURSES AND THE SMALLER STONES AT TOP.

(3) THEY SHALL BE LAID IN CLOSE CONTACT SO AS TO BREAK JOINTS AND IN SUCH MANNER THAT THE WEIGHT OF THE STONES IS CARRIED BY THE EARTH AND NOT BY THE ADJACENT STONES.

TYPICAL CULVERT END TREATMENT

N.T.S.

REVISION NO.	DESCRIPTION	BY	APPD.	DATE
A	ISSUED FOR CONSTRUCTION	T.K.		28.01.09
B	ALTERED CULVERTS TO REFLECT CONST. CONDITIONS	T.K.		10.02.09

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Client

NORTHSHORE LIMITED PARTNERSHIP

Project

CREEKSIDE ESTATES

STAGE 1A

City of Cold Lake, Alberta

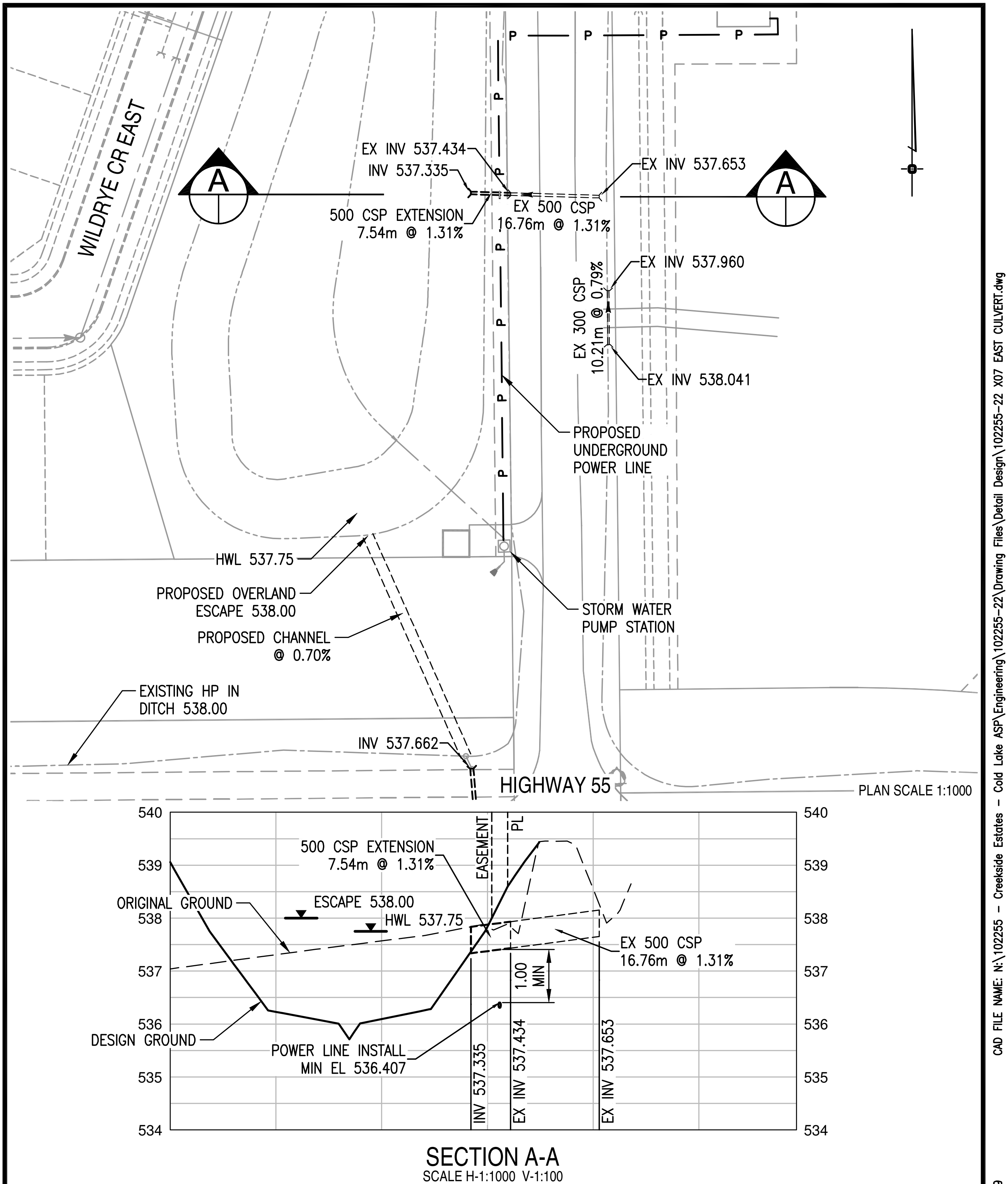
PLAN & PROFILE
SOUTH DRAINAGE

Designed	Scale	Date
T.K.	H 1:500 V 1:50	FEBRUARY 2009
Drawn	Project No.	
T.K.	102255-22	
Checked	Drawing No.	Rev.
	C14A	B
Approved		

CAD FILE NAME: N:\102255 – Creekside Estates – Cold Lake ASP\Engineering\102255-22\Drawing Files\Detail Design\102255-22 South Culvert Crossing.dwg

DATE PLOTTED: February 10, 2009

FIGURE 17



FOCUS

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Fax: 780.421.1397
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Description

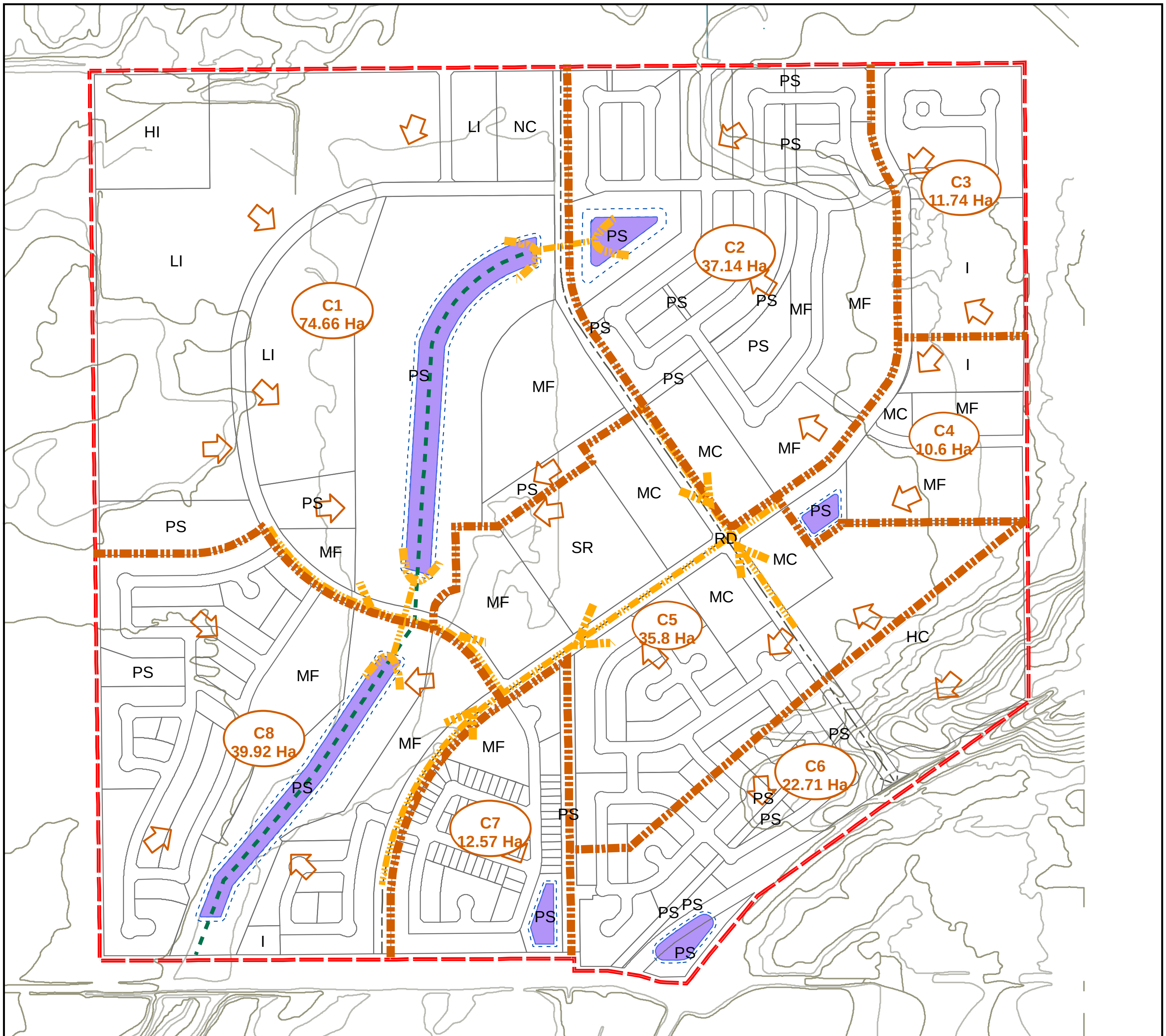
EAST CULVERT
PLAN AND SECTION

Project

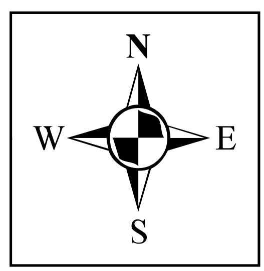
CREEKSIDE ESTATES
STAGE 1A
City of Cold Lake, Alberta

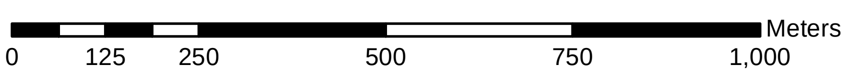
102255–22	May 2009	X07

FIGURE 18



Area Structure Plan Boundary
Proposed Storm Management Facility
Drainage
Storm Water Basin Boundary
Proposed Storm Water
CX xx xx Ha StormCatchment
Major Storm Flow





Source: NorthShore ASP
Focus Corporation - 2011

MAP 8 - Stormwater Servicing

FIGURE 19

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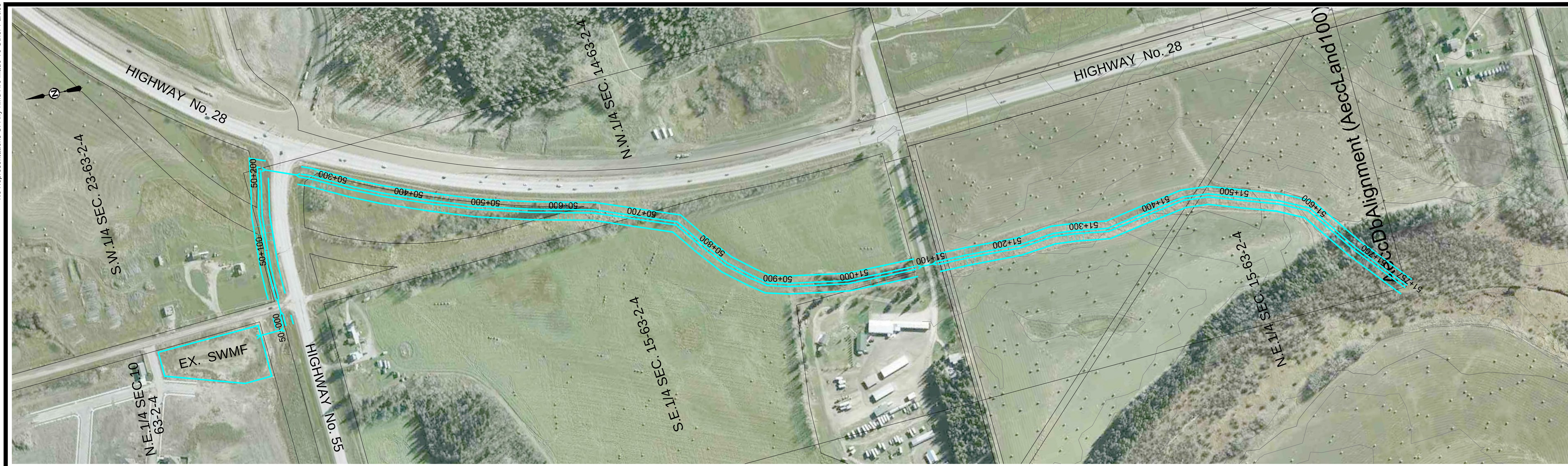

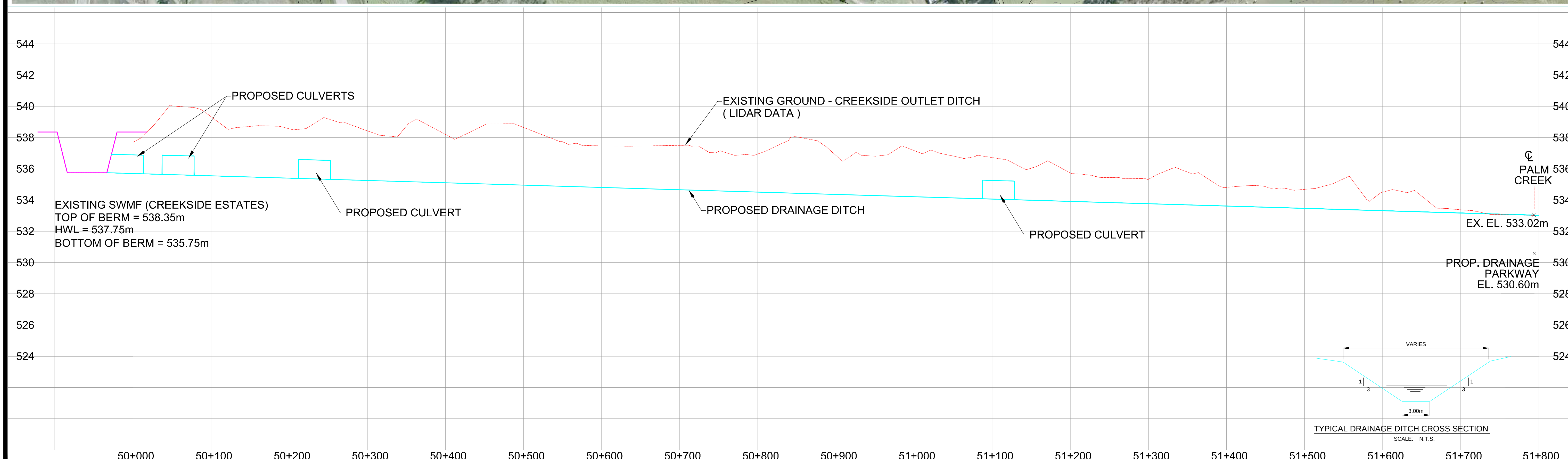

NO.	DATE	ENG.	BY	SUBJECT
A	2013-01-28	S.N.	W.W.	PRELIMINARY ISSUE

REVISIONS

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PROJECT No.	20123590
SCALE	HOR. 1:5000 VERT. 1:250
DRAWN	B. Wong
DESIGNED	S. Nishtala

City of Cold Lake

MASTER DRAINAGE PLAN UPDATE

PROPOSED CREEKSIDE OUTLET DITCH PROFILE

DRAWING NUMBER	REV. NO.	SHEET
FIGURE 20	A	- --

Closure

This technical memorandum was prepared for the City of Cold Lake to investigate 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.

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 ALBERTA
CHRIS SKOWRONSKI
April 3, 2014

Chris Skowronski, P.Eng.
Project Manager

PROFESSIONAL ENGINEER ALBERTA
LARRY E. BODNARUK
Apr 3, 2014

Larry Bodnaruk, P.Eng.
Senior Water Resource Engineer

PROFESSIONAL ENGINEER ALBERTA
SANTOSH V. NISHTALA
APR 3, 2014

Santosh Nishtala, P.Eng.
Project Engineer

ASSOCIATED ENGINEERING
QUALITY MANAGEMENT SIGN-OFF
Signature: C. Skowronski
Date: April 3, 2014

APEGA Permit to Practice P 3979

Appendix E - Technical Memorandum #3 – Palm Springs Golf Course

Associated Engineering
GLOBAL PERSPECTIVE.
LOCAL FOCUS.

TECHNICAL MEMORANDUM

City of Cold Lake

Golf Course
Pond Outlet




June 2014

CANADA'S BEST MANAGED COMPANIES

Table of Contents

1 Introduction

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 1 shows the overall project area. The pond was formed by a 3 m high embankment to supply water to the Palm Springs Golf Course. A pumphouse 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 many as five culverts to carry creek flow through the embankment (AE, 1982). The embankment has had a history of culvert failures and overtopping in recent years. Subsequent to the last washout, Defence Construction Canada (DND) blocked the reservoir from draining by installing 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, but it does not have enough capacity to pass high flows in the Creek. As a result the embankment has been overtopped on several occasions, which could result in failure of the embankment.

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) has requested DND to provide fish passage for the reservoir as part of any rehabilitation.

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.

2 Background

The embankment has washed out every year for the past four years.

Photo 1 shows the culvert washout in April 2011. DND reported that the failure was caused by ice lifting the inlet to the culvert. They also reported that prior to the construction of the storm outfall from Cold Lake the creek carried no winter flow, and that it now flows year-round except during drought conditions. From the site photos it appears that the washout may have been the result of piping along the culvert. The failure was repaired by installing two 800 mm diameter culverts, mitered to match the slope.

Photo 1: Embankment washout apparently due to culvert piping in April 2011.

In June 2011, the embankment was overtopped in a heavy rainstorm that exceeded the capacity of the two culverts, and the culverts failed again. Photo 2 shows the embankment being overtopped.

In June 2011, prior to the June washout, SNC Lavalin provided a "Golf Course Washout Assessment Report" (SLI, 2011) that evaluated several repair options. Their preferred option was a fish ladder with an estimated cost of $130,000, plus additional works (not specified) to carry flood discharges in the creek and traffic across the road crossing.

Photo 2: Embankment overtopping in June 2011.

In January 2012, SNC Lavalin assessed the alternative of supplying the golf course irrigation system with treated water from the base's domestic water supply ("Golf Course Washout", SLI, 2012). The alternative was not deemed to be practical due to the excessive demands it would place on the distribution system, storage reservoirs, and water treatment facilities.

Photo 3 shows the site in June 2012 after the latest washout was repaired with large rock fill. Currently it operates as a flow-through embankment, with water flowing between the large rocks placed to fill the breach. During higher flows, water spills around the south side of the embankment.

Photo 3: Embankment in June 2012.

The current rock fill is only a temporary solution as it is vulnerable to being overtopped in larger runoff events. A more permanent solution is required that will provide capacity for flood flows that occur presently and for increased runoff in the future as Cold Lake is further developed, and will ensure a supply of water to the golf course.

DFO has informed the Base that fish passage will be required in any rehabilitation plan for the crossing. DND and DFO have identified four options that are considered below.

3 Design Criteria

Enviromak has laid down certain criteria for design of fish passages which are listed below:

- The connectivity for small fish smaller forage fish such as Brook stickleback, Fathead minnow and Lake chub shall be maintained by avoiding drops and by limiting velocities during low flow conditions to a maximum of 0.18 m/s over long distances. Higher velocities of 0.3 m/s could be tolerated over distances up to 1 m long.
- For sport fish (Northern Pike), velocity is not to exceed 1.2 m/s for distances up to 10 m or 0.18 m/s for distances exceeding 40 m during higher flows from April 15 to May 31. These velocities could be exceeded for three days during flood flows. Gradients should not exceed 1% for a long stretch. DFO has indicated that sport fish passage is required only if they are present in Palm Creek.
- Meandering along with intermittent pools and channel roughness will help to achieve the passage requirements.

The pond outlet will also have to pass flood discharges in Palm Creek. Based on a basin area of 43 km^2 and a discharge rate of 2.0 L/s/ha as recommended by AECOM in 2006, the 1:100 year flood discharge is estimated to be 8.6 m^3/s.

4 Pond Survey

Associated Engineering commissioned a hydrometric survey in September 2012 which developed underwater contours to define the depth and storage volume of the pond. Figure 1 shows the results of the survey, combined with ground surface contours for the above-water area. The survey indicated the pond has a depth of about 3.0 m below the water surface near the toe of the embankment. A deeper area at the water intake to the pumphouse has a depth of about 4.5 m below water surface. The water surface elevation on the date of survey was 524.73 (to 4 Wing datum which is about 0.17 m lower than Cold Lake datum), and was nearly to the top of the embankment.

The embankment has subsequently been observed to be overtopped, most recently in June 2013.

Additionally, Enviromak staff conducted a site inspection on October 12, 2012 and reported that the pond is a functional Class V Wetland that has considerable value. The watercourse and wetland were confirmed to be fish-bearing as one fish (Brook stickleback) was captured and numerous others were observed. The watercourse was flowing through the existing rock berm that blocks the channel, such that fish passage upstream does not likely occur even under high flows and flooding. The overflow on the left bank of the berm appeared to be stable and no evidence of erosion was evident.

Subsequent to the pond survey, AE retained Enviromak Management Consultants Inc. to conduct a fish survey in the reservoir and Palm Creek in September 2013. The study concluded that Sport fish are not present in Palm Creek. Hence per DFO guidelines, passage for sport fish is not required.

5 Geotechnical Conditions

In December 2011, AMEC Environment & Infrastructure provided a geotechnical report to determine the subsurface soil and groundwater conditions at the site, and to provide geotechnical recommendations pertaining to replacing the existing embankment with a low head weir structure. The assessment included three boreholes advanced to a depth of 7 to 10 m (one located in the embankment), and two piezometers for monitoring of groundwater levels. The assessment indicated that the embankment was built over organic soils using poor quality fill material. The report identified significant geotechnical challenges to the

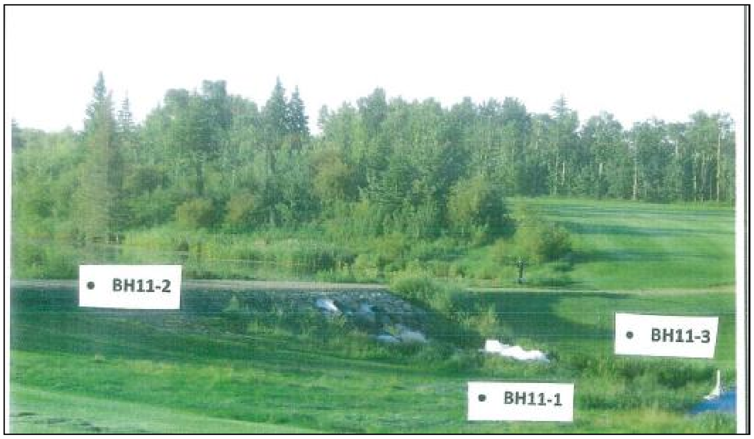


Photo 4: Embankment in 2011 from Amec Geotechnical Report.

design and construction of a weir at the embankment, including a significant organic layer, loose sand, and high groundwater levels that could create unfavorable foundation conditions and generate significant seepage during construction. Photo 4 shows the site conditions and the locations of the three boreholes.

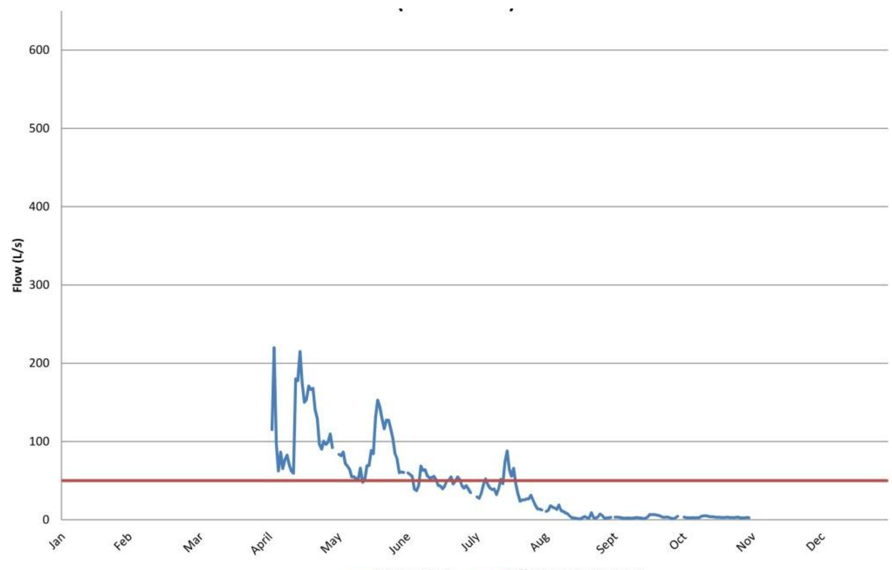
6 Storage Requirement for Golf Course Irrigation

The Palm Creek reservoir is currently being used by the Palm Springs Golf Course for irrigation. The capacity of the sprinkler system is 50 L/s (800 gpm). Assuming the sprinklers are operated for six hours per day, twice a week, at a rate of 50 L/s, the volume of water required is approximately 8,640 m^3 per month.

There are no flow measurements in Palm Creek with which to estimate the flow and volume of water available for golf course water supply. Therefore, streamflows were estimated from flow data for Moose Hills Creek, near Elk Point which is about 100 km south of Cold Lake. The gross drainage area of Moose Hills Creek is 37.7 sq km, which is comparable to Palm Creek's drainage area of 42 sq km.

Flow data from Moose Hills Creek were obtained from Environment Canada for a period of 29 years from 1980 to 2009. The flow data was then converted to unit flows and multiplied by the drainage area of Palm Creek to estimate the flow in Palm Creek. The average flow for Palm Creek obtained from the above analysis is shown in **Figure 2.** The required flow of 50 l/s for the golf course is also shown on the same plot and indicates that in even in an average year the creek flow is too low to supply the golf course irrigation requirements for about three months after the middle of July. Storage of runoff would be required to ensure supply of water.

Figure 2: Palm Creek Average Flows based on Moose Hills Creek near Elk Point (1980-2009)



Estimated stream flows for two other years representing the 1:5 year low flow (2005) and the 1:10 year low flow (1982) are shown in Figures 3 & 4 along with the daily requirement of 50 l/s for the golf course. From these Figures it is evident that Palm Creek would not be able to supply the required 50 l/s, without storage, for extended periods of time.

Figure 3: Palm Creek 1:5 Year Low Flows based on Moose Hills Creek near Elk Point for 2005

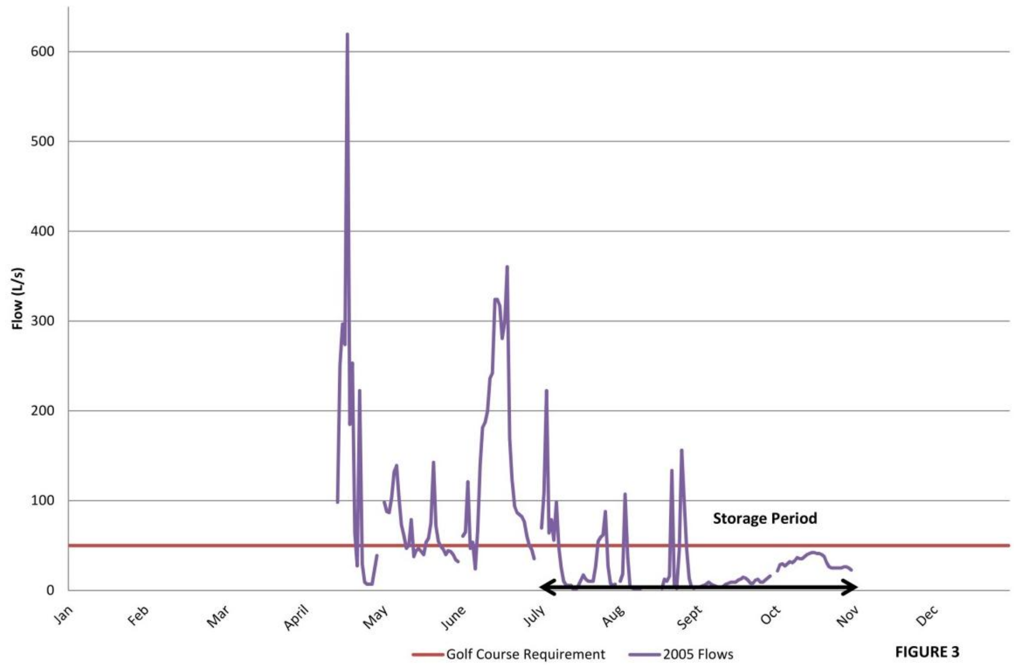
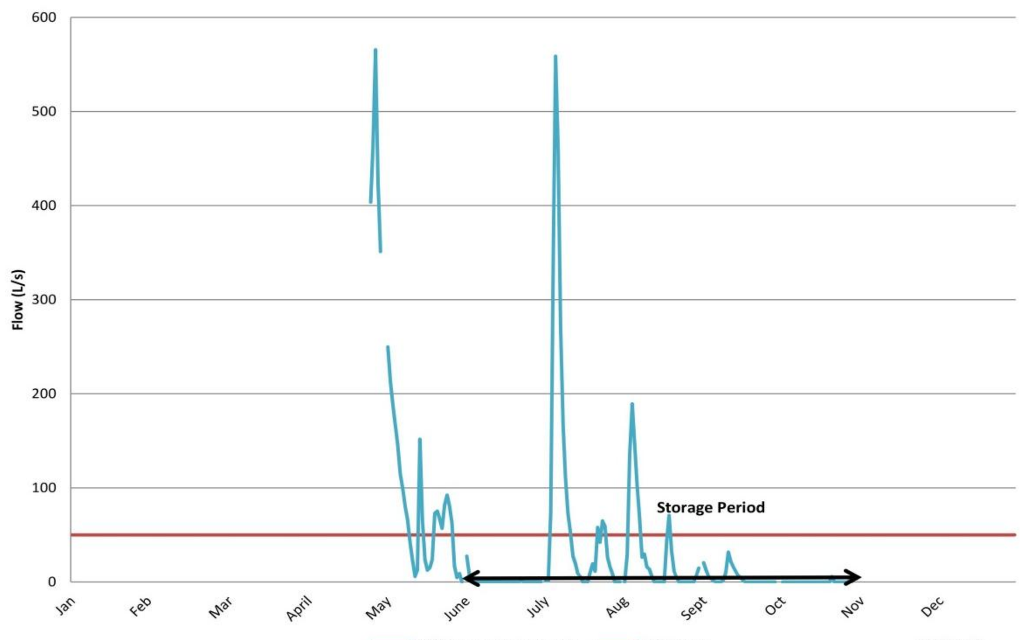


Figure 4: Palm Creek 1:10 Year Low Flows based on Moose Hills Creek near Elk Point for 1982.



For the 1:5 dry year, 4 months of storage is required or a total volume of 34,560 m^3.

For the 1:10 dry year, 5 months of storage is required or a total volume of 43,200 m^3.

7 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. Each of the four option have been discussed below.

7.1 OPTION 1: ISOLATED POND

Option 1 involves breaching the embankment and abandoning the Palm Springs Golf Course reservoir to restore fish passage. Since storage would no longer be provided in the reservoir, an isolated pond or storage tank away from the existing reservoir would be required.

As discussed above, the tank will be required to provide storage for four months from July to October. For the 1:5 dry year 4 months of storage is required or 34560 cu m. Approximate size of the tank would be (100m X 90 m X 4 m). Assuming a $ 1,500 /cu m, approximate cost of a storage tank would be $ 54 million.

For the 1:10 year dry 5 months of storage is required or 43200 cu m. Approximate size of the tank would be (110m X 100 m X 4 m). Assuming a $ 1,500 /cu m, approximate cost of the tank would be $ 66 million.

These costs render this option impractical. There would be an additional cost involved in conveying the runoff to the tank.

- Advantages of this option:
  - The proposed tank provides irrigation for the golf course when the existing Palm Creek Reservoir is opened.
  - This option would restore fish passage through the reach and over time would restore the original creek channel by removing the dam.
- Disadvantages:
  - High initial cost involved in construction of the tank of the order of $60 million.
  - Capital and operational cost involved in transporting the water stored in the tank to the pump station.
  - Destruction of existing aquatic habitat in the reservoir.

7.2 OPTION 2: NATURAL FISH BYPASS CHANNEL

Option 2 involves preserving the existing reservoir on the Palm Springs Golf Course, and providing an outlet channel for fish passage. Figure 5 illustrates this concept. The outlet channel would be provided with intermediate ponds to lower velocities in the channel and provide mobility to smaller fish. The upstream end of the outlet channel would be at the same elevation as the water level in the reservoir and the downstream end would be at the natural creek elevation downstream of the reservoir.

- Advantages of this option:
  - The natural habitat in the reservoir will be preserved.
  - The riparian channel and intermediate ponds will provide fish passage from the reservoir.
  - The reservoir provides storage for golf course irrigation at a substantially lower cost than that required for construction and maintenance of a tank.
  - The outlet channel will prevent washout of the embankment and the golf course road during higher flows.
  - The reservoir will also provide settling of suspended solids and nutrients in runoff from Cold Lake and reduce their potential impact on downstream water bodies.

- Disadvantages:
  - Cost involved in construction of the outlet channel for fish passage.
  - Modification of Golf Course Road.

7.3 OPTION 3: RESERVOIR WITHIN POND

Option 3 involves construction of a tank inside the existing reservoir, assuming that the existing golf course dam will be breached, and the road opened up, to allow fish passage. A concrete reservoir of dimensions 100X90X4 m would be required to store runoff to irrigate the golf course, as mentioned in Option 1.

This option would involve similar costs as Option 1. However, water would not have to be conveyed to the tank for irrigation as it would be located within the creek valley near the intake.

- Advantages of this option:
  - The proposed tank provides irrigation for the golf course when the existing Palm Creek Reservoir is opened.
  - Avoids maintenance costs involved with diverting water to the pump station.

- Disadvantages:
  - Destruction of the aquatic habitat in the reservoir.
  - High cost involved in the construction of the storage tank.
  - Unsightly tank in the creek valley.

7.4 OPTION 4: ECO FRIENDLY GOLF COURSE

Option 4 involves the design of an eco friendly golf course. A typical golf course uses about 1.1 million litres of water a day to keep its grass green. To conserve water and facilitate its reuse to limit wastage, some of the best golf courses across North America have implemented eco friendly practices to reduce their water demands. Examples are listed below:

- Cabot Links Golf Course in Nova Scotia uses mixed fescue grasses that require less irrigation. It also uses treated effluent from the Town for irrigation.
- Craik & District Golf Course uses treated water and compost to keep the golf course in shape, and nesting boxes draw purple martins that keep the mosquitoes in check.
- The Ocean Course at Kiawah Island Golf resort, South Carolina has 14 miles of drains under the course to collect all the water that falls onto the green and cart paths picking up 300,000 gallons of freshwater a day.
- Mirimichi Championship Course in Millington, Tennessee uses an irrigation system that in addition to collecting the excess water, filters pollutants from parking lots and cart paths.
- The Ocean Courses at The Resort at Pelican Hill, in Newport Coast California uses a high tech irrigation system with five underground rainwater collection cisterns, which has helped conserve 50 million gallons of water annually.
- The Mountain Golf Course in Colorado Springs, Colorado uses a sophisticated computer controlled irrigation system to reuse water and keep the grass green.

Based on the above examples, the following eco friendly techniques can be used to limit the storage required for golf course irrigation:

- Use of grasses that require less irrigation.
- Use of treated effluent for irrigation.
- Installation of a collection system to collect, store, and reuse runoff from irrigation and rainwater drainage.
- Sophisticated control of the irrigation system.

The above examples demonstrate that techniques are available in the design of a golf course for storage and reuse of water, thus minimizing the water use and storage requirements for the golf course. However, they require extensive modification to an existing golf course that would be expensive.

Advantages of this option are:

- The reuse of irrigation water minimizes the storage requirement.
- Use of treated effluent eliminates the requirement for freshwater for irrigation.
- Installing of a sophisticated irrigation system and drought-tolerant grass ensures the optimal use of water.

- Disadvantages:
  - High capital cost involved with use of collection and storage systems, sophisticated irrigation systems or replacing existing grass with low irrigation requirement grass.
  - The golf course will need to be closed for a couple of seasons to accommodate the construction.
  - Storage will be required.

The cost of retrofitting the golf course with low-water use measures was deemed to be too great to make this option viable.

7.5 PREFERRED OPTION

The four options mentioned above were reviewed with Defence Construction Canada (DND) and the City of Cold Lake for environmental benefits and impacts, feasibility of construction, and cost. Option 2 was found to be the preferred alternative because it would preserve the existing water supply to the golf course while providing fish passage as requested by DFO.

With DND stating its preference for Option 2, a conceptual design was developed for the same. Figure 5 shown previously provides the plan and profile views of the fish passage. It includes the following features:

- The fish passage is proposed to be approximately 220 m long with three intermediate pools to provide energy dissipation and resting areas for migrating fish.
- The channel will follow along the south valley wall of Palm Creek and will be contained by a berm on the north side so as to minimize the excavation and disturbance of treed areas.
- The fish passage channel will be approximately 5 m wide at the bottom and will be lined with riprap to prevent erosion at high flows and to reduce velocities for migrating fish at low to intermediate flows.
- The upstream bed of the fish passage will be at the normal water level and downstream bed will tie into the existing Palm Creek, at the existing steel frame footbridge on Hole 7.

The options and conceptual design were reviewed in a meeting with DFO on June 26, 2013. DFO expressed support for the proposed concept, but stated that a fish survey should be undertaken to confirm the presence of sport fish (Northern Pike) in Palm Creek. If sport fish are not present in Palm Creek, DFO would not require the structure to be designed for this species. Further discussion with Provincial Fisheries was also recommended. Subsequently, Associated Engineering retained Enviromak Environmental Management Consultants to complete a fish survey in Palm Creek to determine if sport fish were present. Their report is provided in a separate Appendix I of the main report, identifies the presence of smaller species but no Northern Pike. Therefore the dam outlet structure will likely not be required to provide passage of sport fish.

The existing dam will need to be raised approximately 1.0 m to provide adequate freeboard above the high-water level in the reservoir. The existing loose rock fill in the embankment will need to be removed and replaced with competent fill to prevent flow through the dam.

8 Conclusions

The following conclusions were made from this study:

- The Golf course dam is currently blocked by boulders and does not provide for fish passage. Water seeps through the boulders, and the dam is overtopped at higher flows.
- Fish passage is required to provide mobility for smaller fish and to provide a safe outlet from the reservoir. Passage for larger (sport) fish is not required, as they are not present in Palm Creek.
- Option 2 which involves an outlet channel designed to provide fish passage in low flows and to provide conveyance for flood flows, while maintaining the reservoir in its natural state, was found to be the most feasible option.

9 Recommendations

The following are recommended:

- That DND undertake pre-design/detailed design to construct Option 2 on a prioirity basis as the existing dam is vulnerable to being overtopped and damaged or destroyed.
- That the existing dam be raised approximately 1.0 m to provide adequate freeboard above the high-water level in the reservoir, and the existing loose rock fill in the embankment be removed and replaced with competent fill to prevent flow through the dam. Services of a geotechnical engineer will be required for the design of the dam modifications.

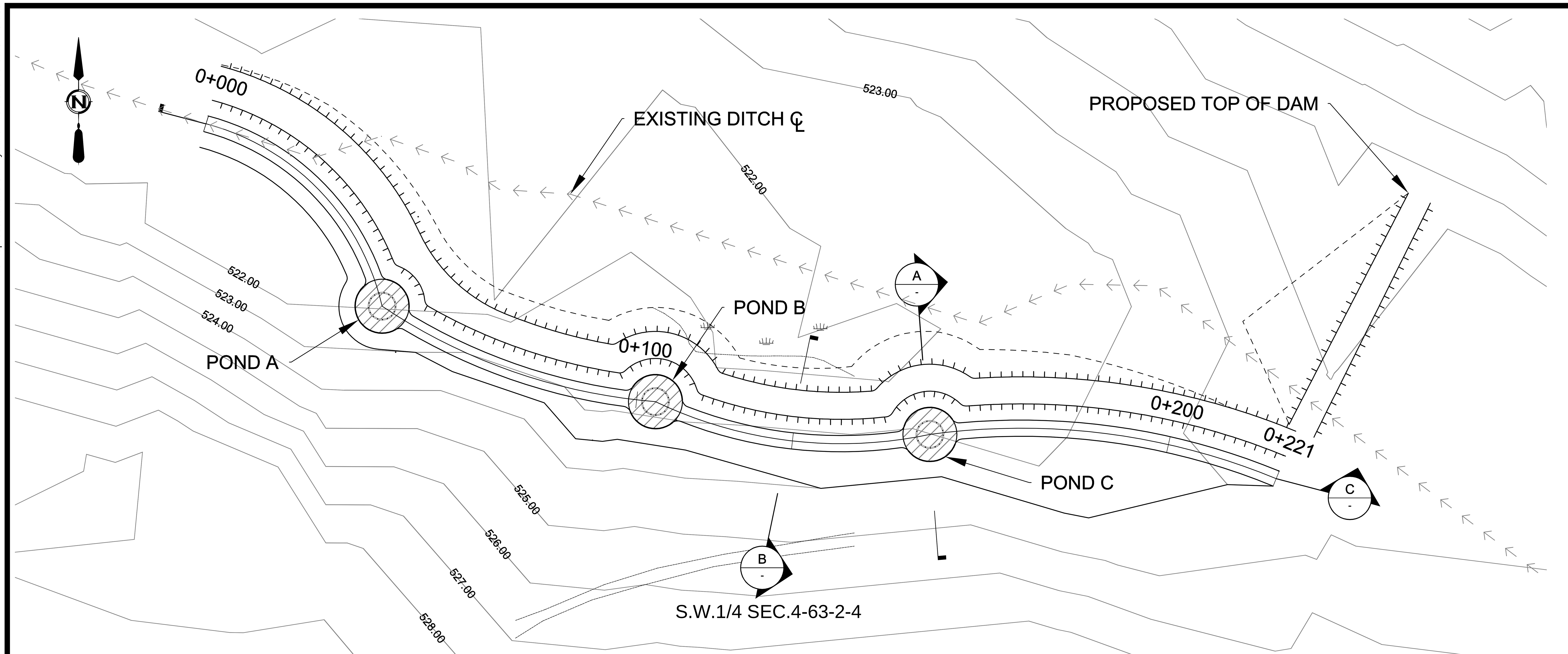
No.	REVISION	DATE

(Name) (Date)
(Name) (Date)
(Name) (Date)

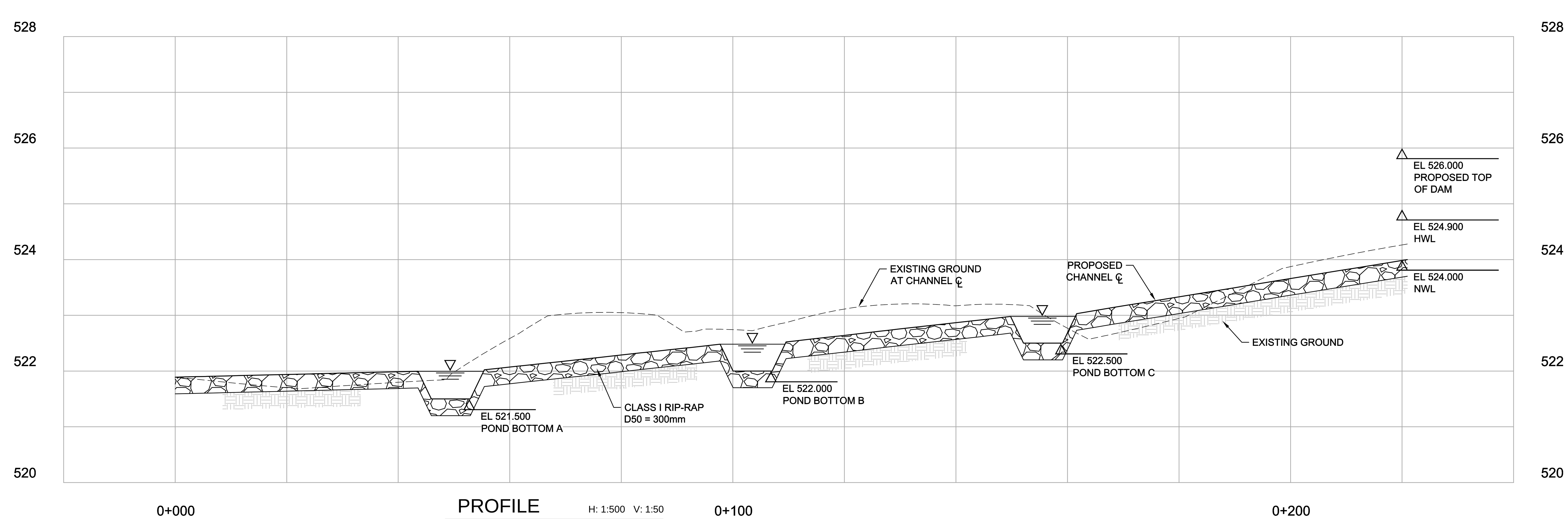
CITY OF COLD LAKE
DRAINAGE MASTERPLAN
PALM SPRING GOLFCOURSE
FIGURE 1

PROJECT No.: 2012-3590.000
DATE: 7/5/2013
SCALE: 1:2500

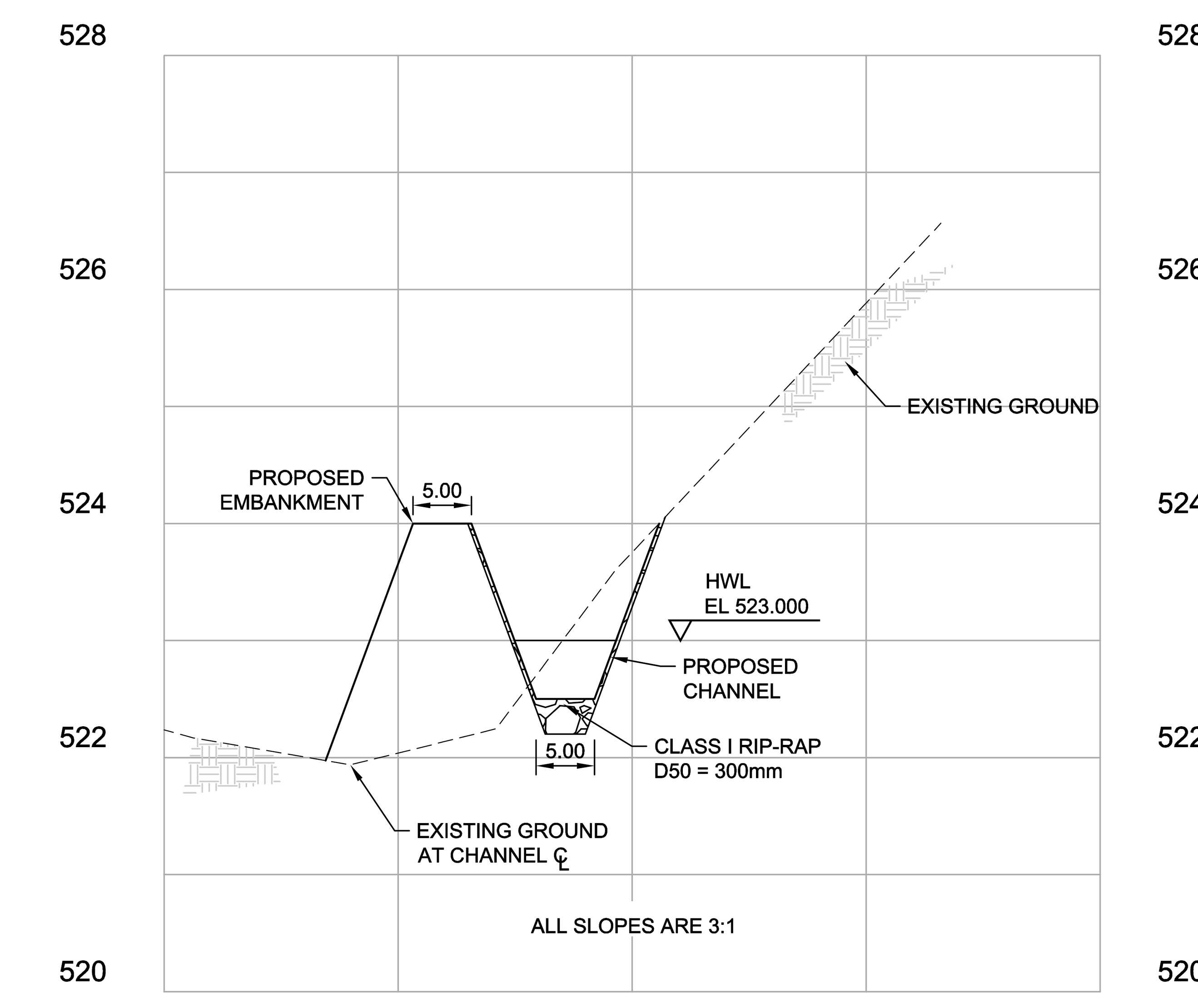
Time: 2:49:06 PM I Date: 7/5/2013
Scale: 1:2500
Map File: P:\20123590\00_Master_Drain_Plan\Engineering\01.00_Background_Data_Collection\Golf Course\Golf_Course_Dam_0.5m_Contours.map



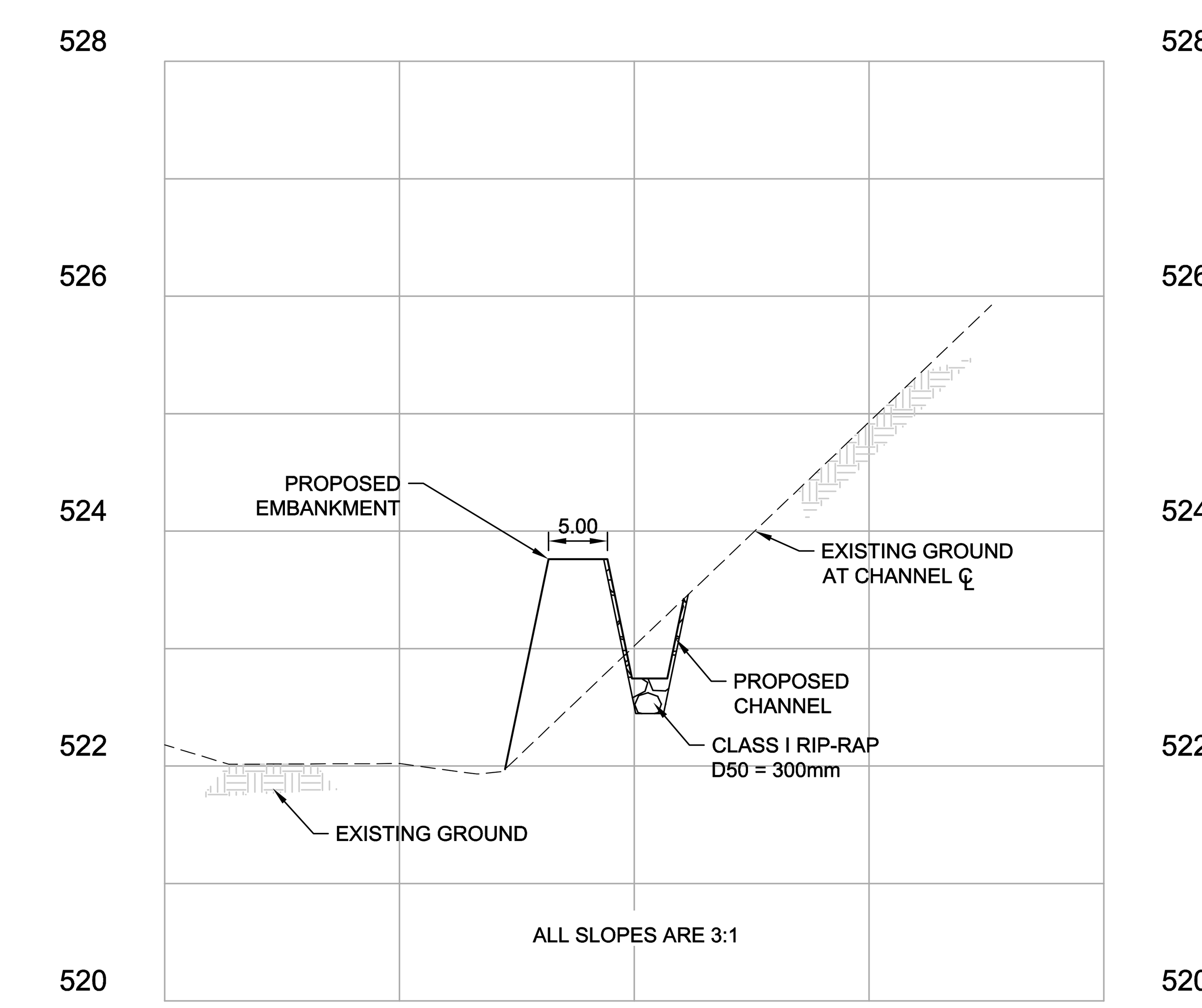
PLAN 1:500
PALM SPRING GOLF COURSE
OUTLET CHANNEL



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 5.0	A	--

Closure

This report was prepared for the City of Cold Lake to consider alternatives to modify the reservoir by providing fish passage or providing other alternatives for water storage for irrigation.

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 F - The Meadows Geotechnical Study

GEOTECHNICAL INVESTIGATION

Proposed Meadows Residential Subdivision
W1/2 2-63-2 W4M
Cold Lake, Alberta

Prepared for:

City of Cold Lake, Alberta

Date:

Draft Submittal:	**11 October 2013**
Final Submittal:	**5 November 2013**

Project File #:

PG13-1059

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1.0 INTRODUCTION

This report presents the results of the geotechnical investigation conducted for the proposed Meadows Residential Subdivision within the City of Cold Lake, Alberta. The geotechnical investigation was carried out by SolidEarth Geotechnical Inc. (SolidEarth) at the request of Mr. Azam Khan, P.Eng. of the City of Cold Lake (City).

2.0 PROJECT DESCRIPTION AND INVESTIGATION SCOPE

2.1 PROJECT DESCRIPTION

Based on information provided to SolidEarth it was understood that the City is considering the development of the Meadows Residential Subdivision within a portion of W1/2 2-63-2 W4M. As part of the development plan, the City is planning the construction of a stormwater management facility (SWMF), stormwater outfall, and a residential subdivision. The intent of the SWMF is to collect surface water runoff from the development area. Collected water will be diverted via the stormwater outfall to Palm Springs Creek.

The following project details were understood from the conceptual design information provided to SolidEarth.

The Meadows Subdivision

The footprint of the proposed subdivision is approximately 800 by 1000 m. The proposed subdivision is bound by 51st Street and right-of-way to the west, existing residential developments to the south, undeveloped land to the east, and the existing Meadows and Fontaine Village subdivisions to the north.

The area of the proposed subdivision is currently a low-lying and poorly drained area with an anticipated high groundwater table. Drainage ditches currently exist within the project area to manage surface water runoff and to control flooding.

The area is predominantly flat and gently sloping to the west (to the proposed location of the SWMF). Based on LIDAR information, it is expected the ground surface elevation within the proposed development area ranges between elevations of 530 and 534 m.

SWMF

Two options for the SWMF were presented during the preliminary site development plan. The first option consisted of a dry pond with a footprint measuring approximately 200 by 400 m, and extending to approximately 3.5 to 5.5 m below the existing ground surface.

The second option consisted of constructing a drainage pathway as well as multi-use walkways on either side of the drainage pathway. The overall width of the drainage pathway and walkways will be in the order of 150 m.

Stormwater Outfall

The stormwater outfall will consist of a 1,200 mm diameter pipe extending from the SWMF west across Highway 28. The alignment of the stormwater outfall will follow the 55th Avenue right-of-way, extend through developed areas, and will cross Highway 28.

The depth of the outfall pipe along its alignment will range between 4 and 10 m below the existing ground surface. The shallower depth will be near the outlet of the SWMF, and the deeper sections will be under Highway 28 and the developed area to the west (along 55th Avenue).

2.2 INVESTIGATION SCOPE

The scope of the geotechnical investigation was developed to assess the subsurface soil and groundwater conditions at selected locations within the proposed development areas, and to provide geotechnical assessment and recommendations pertaining to the proposed development as it relates to:

- overall site development options and challenges
- subgrade conditions and required subgrade preparation
- delineation of the sand layer across the project area
- groundwater elevation
- installation of site services
- design and construction of the SWMF
- construction of roadways
- design and installation of the Stormwater Outfall

The scope of work included drilling boreholes within the project area, conducting laboratory review and testing, and preparation of this report. Due to the conceptual nature of the project at this stage, the geotechnical report was focused on the overall site suitability and challenges associated with the proposed development.

3.0 SITE DESCRIPTION

At the time of the field investigation, the proposed Meadows residential subdivision and SWMF area was vacant undeveloped land with grass cover and standing water particularly within the central portion of the proposed subdivision footprint. The alignment of the proposed outfall followed the 55^{th} Avenue right-of-way, which contained underground and overhead utilities.

Photographs showing site conditions that existed at the time of the field investigation are presented in Appendix A.

4.0 FIELD AND LABORATORY INVESTIGATION

4.1 PRE-DRILLING ACTIVITIES

The borehole locations were selected by SolidEarth based on a proposed site development plan provided by the City, and surveyed/marked in the field by SE Design and Consulting Inc. (SE Design) of Cold Lake, Alberta.

Prior to field drilling, SolidEarth completed ground disturbance procedures that included placing an “Alberta One Call” and conducting a secondary sweep, at specific locations, using a private line locator. Before starting onsite work, a daily field hazard assessment/tailgate meeting was conducted by the SolidEarth representative and was communicated with all workers involved. The field program was completed without any near misses or incidents.

4.2 FIELD DRILLING AND TESTING

SolidEarth subcontracted Canadian Geological Drilling Ltd., of Edmonton, Alberta and All Service Drilling of Airdrie, Alberta to drill the boreholes. Drilling was completed using both a truck-mounted and track-mounted auger drill rig utilizing 150 mm solid-stem continuous flight and 200 mm hollow stem augers.

The field investigation was undertaken between 18 and 21 June 2013 and on 18 July 2013, and consisted of drilling a total of 31 boreholes within the three proposed development areas. The boreholes were drilled to depths ranging between 5.8 and 13.7 m below the existing ground surface. An additional five boreholes were planned but were not drilled. These borehole locations were either inaccessible at the time of the field investigation (within the Meadows footprint), or there was conflict with underground/overhead lines and relocating the borehole to a nearby location was not possible (outfall alignment on the east side of Highway 28). The borehole location plan is presented as Figure 1.

During drilling, soil samples were collected at approximately 0.75 m intervals along the depth of the boreholes. Pocket penetrometer testing was conducted on selected cohesive soil samples to obtain an indication of the unconfined compressive strength of disturbed soil samples from the auger. Standard Penetration Tests (SPT’s) were conducted at selected depths (typically every 1.5 m) to assess the in-situ strength of the soils encountered. The soil sampling and testing sequences are shown on the borehole logs.

A SolidEarth geotechnical engineer monitored the drilling operations and logged the recovered soil samples from the auger cuttings and the SPT samples. The soils were logged according to the Modified Unified Soil Classification System, which is described in the Explanation of Terms and Symbols in Appendix B. Due to the method by which the soil cuttings were returned to surface, the depths noted on the borehole logs may vary by ± 0.3 m from those recorded.

Groundwater seepage conditions were monitored during and immediately following completion of drilling. Standpipe piezometers were installed in all boreholes to allow for short term measurement of groundwater levels.

Nested standpipes were installed in nine of the boreholes. In general, one standpipe was installed into the sand layer while the second standpipe was installed within the clay layer above the sand. The nested standpipes at a given location were labelled as “A” and “B”, corresponding to the deeper and shallower wells, respectively. An attempt was made to install both nested standpipes in the same borehole space. At the locations where significant sloughing was encountered and the deeper standpipe was installed through slough material, a second borehole was drilled adjacent to the first borehole for the installation of the shallower standpipe.

The standpipes were constructed using 25 mm diameter PVC solid and hand slotted pipes. In general, drill cuttings were used to backfill the borehole space. Bentonite chips were placed above the screen to confine the screen interval. At some locations, excessive sloughing was encountered during the installation of the deeper standpipe, and as such, slough (predominantly native sand) was inevitable within the standpipe’s screen intervals.

The coordinates (northing, easting, and elevation) of the ground surface at the borehole locations as surveyed by SE Design and are shown on the borehole logs, presented as Figures 4 through 34.

4.3 LABORATORY TESTING PROGRAM

All collected samples were returned to the laboratory for further examination and testing. Laboratory testing conducted included:

- visual examination of all collected soil samples
- determination of the natural moisture content
- Atterberg limits and grain size distribution analysis
- moisture-density relationship test (standard Proctor)
- hydraulic conductivity test on a remolded soil sample

One sample from the proposed SWMF footprint was submitted for moisture-density relationship (standard Proctor) test and for hydraulic conductivity testing. The sample was collected as a composite sample to account for the special variability in the composition of the clayey material, and to mimic future site development in which soil mixing will likely be encountered.

The results of the laboratory index testing are shown on the borehole logs. The results of the moisture-density relationship test and the hydraulic conductivity test are provided as Figures 35 and 36, respectively.

5.0 SUBSURFACE CONDITIONS

5.1 SOIL CONDITIONS

The general subsurface stratigraphy encountered at the borehole locations consisted mainly of topsoil/organic soils followed by clay then clay till, and underlain by sand. Clay fill was encountered at the ground surface (above the topsoil) at a few borehole locations particularly the southern half of the SWMF footprint and the southeastenr portion of the proposed Meadows residential subdivision footprint.

A brief summary of the subsurface conditions is presented below. A detailed description of the subsurface conditions encountered at each borehole location is provided on the borehole logs. Cross-sections of subsurface conditions across the development area are presented as Figures 2 and 3. It is to be noted that soil conditions across the proposed development area may vary from what was encountered at the borehole locations.

Clay Fill

Clay fill was encountered at the ground surface of BH13-19 through -23 and BH13-30 through -32 (southern half of the proposed SWMF footprint and the southeastern portion of the proposed Meadows subdivision footprint). The clay fill ranged in thickness between 0.6 and 1.6 m, and varied from clayey fill with topsoil inclusions to a heterogeneous mixture of clay and organic (topsoil) materials.

The clay fill was generally clayey in nature, of medium plasticity, firm in consistency, and moist to wet. It is expected that the clay fill was placed as a general fill without any control of its quality or placement density.

Topsoil/Organics

Topsoil and/or organic soils were encountered at the ground surface of the majority of the boreholes, and below the fill (where present). The thickness of the near surface topsoil/organics ranged between 0.3 and 0.6 m. The thickness of the buried organic layers ranged between 0.1 to 0.7 m. The topsoil/organics were black, contained roots and were generally wet.

Clay

Clay was encountered below the organics or fill at the majority of the boreholes, and ranged between 0.6 and 5 m. The clay was generally classified as “clay, sandy, silty, trace gravel”, was grey, low to medium plastic, and was very moist. The consistency of the clay was assessed, based on the SPT N values, as soft to firm.

The natural moisture content of the clay ranged between 16 and 33 percent, with an average of 24 percent. Liquid and plastic limits of samples of the clay were in the order of 28 to 33 percent, and 13 to 17 percent, respectively. It is expected that the average natural moisture content of the clay till was approximately 7 to 9 percent above its optimum moisture content.

Sand

Sand was encountered below the clay till (lower sand) in all boreholes except (BH13-03, -16, and -32) and extended to below the exploration depth. Sand was also encountered interbedded within the clay or clay till deposits (upper sand) at various depths at some borehole locations.

The lower sand was generally encountered at an approximate elevation ranging between 526 to 531.5 m. Within the proposed SWMF footprint, the lower sand was generally encountered between elevation 526 and 528 m, while within the Meadows Subdivision footprint, the lower sand was encountered between elevation 527.5 and 531.5 m.

The sand was generally classified as “sand, some silt to silty, trace clay, trace gravel to gravely”, was fine grained, poorly graded, brown, and wet.

Clay Till

Clay till was encountered below the clay at most borehole locations and extended to the top of the lower sand layer. At a few borehole locations, the clay till extended to beyond the exploration depth. The clay till was generally classified as “clay, sandy, silty, trace gravel”, was grey, low to medium plastic, and moist to very moist. The consistency of the clay till was assessed, based on the SPT N values, as firm to stiff.

The natural moisture content of the clay till ranged between 10 and 33 percent, with an average of 18 percent. Liquid and plastic limits of samples of the clay were in the order of 22 to 36 percent, and 11 to 15 percent, respectively. It is expected that the average natural moisture content of the clay till was approximately 3 to 7 percent above its optimum moisture content.

5.2 MEASURED GROUNDWATER LEVELS

The measured groundwater levels at the completion of drilling and on 8 July 2013 are shown in Tables 1 and 2 below.

Table 1: Measured Groundwater Levels
Deep Standpipes (Intercepting the sand Layer)

Borehole ID	Depth of Borehole (mbgs) Note 1	Ground Elevation (m) Note 2	Groundwater Levels			
			At Drilling Completion		On 8 July 2013	
			mbgs	Elv. (m)	mbgs	Elv. (m)
BH13-01A	5.5	532.1	1.0	531.1	1.0	531.1
BH13-02	5.8	532.1	0.9	531.2	0.7	531.4
BH13-03	5.8	532.1	1.2	530.9	3.7	528.4
BH13-04	5.8	532.8	1.2	531.6	0.8	532.0
BH13-05A	5.8	533.2	2.4	530.8	0.9	532.3
BH13-06	5.8	532.7	0.3	532.4	0.2	532.5
BH13-07	5.8	532.0	1.2	530.8	0.6	531.4
BH13-08	5.8	532.1	0.6	531.5	0.5	531.6
BH13-09A	5.8	532.6	2.1	530.5	0.8	531.8
BH13-10	5.8	532.5	1.8	530.7	0.5	532.0
BH13-11	5.8	532.4	0.6	531.8	0.1	532.3
BH13-12	5.8	532.6	0.9	531.7	0.0	532.6
BH13-13	5.8	532.1	2.1	530.0	0.2	531.9
BH13-14	Borehole was not drilled due to access restriction					
BH13-15A	6.1	532.5	0.9	531.6	0.4	532.1
BH13-16A	5.8	533.4	1.8	531.6	1.1	532.3
BH13-17	Borehole was not drilled due to access restriction					
BH13-18	6.3	532.7	0.9	531.8	0.2	532.5
BH13-19	5.8	533.5	1.5	532.0	2.9	530.6
BH13-20	5.8	534.7	1.8	532.9	2.2	532.5
BH13-21	5.8	533.6	1.2	532.4	1.0	532.6
BH13-22	5.8	Not surveyed	2.1	N/A	Pipe destroyed	
BH13-23A	5.8	535.1	2.1	533.0	2.6	532.5
BH13-24	7.3	531.9	0.9	531.0	1.0	530.9
BH13-25	7.3	532.0	0.3	531.7	0.5	531.5
BH13-26	7.3	531.9	2.1	529.8	1.0	530.9
BH13-27A	7.3	532.1	0.6	531.5	0.1	532.0
BH13-28A	7.3	532.1	1.5	530.6	0.6	531.5
BH13-29	Borehole was not drilled due to access restriction					
BH13-30	7.3	533.6	4.0	529.6	2.1	531.5
BH13-31	7.3	533.0	2.1	530.9	1.7	531.3
BH13-32A	5.8	533.7	2.4	531.3	1.7	532.0
BH13-33	Borehole was not drilled due to conflict with utility lines					
BH13-34	Borehole was not drilled due to conflict with utility lines					
BH13-35	13.7	535.7	1.8	533.9	Pipe destroyed Note 3	
BH13-36	11.1	535.4	2.9	532.5	3.6	531.8 Note 3

Note 1: mbgs – metres below existing ground surface
Note 2: Based on survey data provided by SE Design and Consulting Inc.
Note 3: Measurement made on 10 October 2013

Table 2: Measured Groundwater Levels
Shallow Standpipes (Screened in the clay above the sand Layer)

Borehole ID	Depth of Borehole (mbgs) Note 1	Ground Elevation (m) Note 2	Groundwater Levels			
			At Drilling Completion		On 8 July 2013	
			mbgs	Elv. (m)	mbgs	Elv. (m)
BH13-01B	1.5	532.1	1.2	530.9	1.2	530.9
BH13-05B	3.7	533.2	2.4	530.8	1.3	531.9
BH13-09B	3.0	532.6	2.1	530.5	1.8	530.8
BH13-15B	3.7	532.5	0.9	531.6	0.4	532.1
BH13-16B	3.0	533.4	1.8	531.6	0.3	533.1
BH13-23B	2.4	535.1	2.1	533.0	2.6	532.5
BH13-27B	3.7	532.1	0.6	531.5	1.4	530.7
BH13-28B	3.4	532.1	1.5	530.6	0.1	532.0
BH13-32B	3.0	533.7	2.4	531.3	1.7	532.0

Note 1: mbgs – metres below existing ground surface
Note 2: Based on survey data provided by SE Design and Consulting Inc.

The depth of the groundwater table is expected to fluctuate seasonally depending upon several factors that include the local geology, hydrogeology, and surface infiltration.

In analyzing the groundwater level measurements, the following observations were made:

- The groundwater levels along the western portion of the site were in the range of 531 to 531.5 m, compared to the 532 to 532.5 m along the eastern portion of the site. This is indicative of generally east to west groundwater flow gradient.
- The groundwater levels within the proposed SWMF were in range of 530.5 to 532 m.
- The measured groundwater levels in nested wells generally showed that the water levels in the deeper wells (that penetrated into the lower sand) were higher than the shallower ones (screened above the lower sand). This is indicative of an upward water gradient and that the lower sand exhibited a confined aquifer condition.

6.0 GEOTECHNICAL ANALYSIS AND DISCUSSION

Geotechnical considerations associated with site development, and the design and construction of the SWMF and Stormwater Outfall are provided in this Section. Due to the conceptual nature of the project at this stage, the analysis and discussions provided are focused on the overall site suitability and challenges associated with the proposed development as opposed to specific and detailed recommendations. Additional engineering evaluations will be required for specific areas and development elements as the overall site development plan is established.

6.1 SUBDIVISION SITE DEVELOPMENT CHALLENGES

The overall subsurface conditions across the development area were considered poor. The shallow groundwater table and weak near surface soils will likely pose significant challenges and restraints on site development. Both of these items are discussed below.

6.1.1 Groundwater Conditions

There appear to be two groundwater phreatic surfaces across the development area, a shallow perched groundwater table within the clay (above the sand), and a confined aquifer in the sand.

Shallow Perched Groundwater Table

The shallow perched groundwater table appeared very close to the ground surface in the boreholes advanced within the central portion of the Meadows subdivision footprint, where there was a low lying area with standing water (BH13-15B, -16B, and -28B). The measured shallow groundwater levels at these locations ranged between 0.1 to 0.4 m below the existing ground surface.

Across the remainder of the site and at the locations of BH13-01B, -05B, -09B, -27B, and -32B, the measured shallow groundwater table ranged between 1.2 and 1.8 m below existing ground surface. At the location of BH13-23B (southeast corner of the site), the shallow groundwater table was measured at 2.6 m below the existing ground surface.

The shallow perched groundwater table is expected to respond to surface infiltration and surface water ponding. It is expected to be shallower in poorly drained areas with standing water, and deeper in well drained areas. The shallow groundwater table is also expected to fluctuate seasonally and to rise following heavy rain and snow melt events.

The shallow perched groundwater table will have the most impact on site development. It will affect site services and infrastructure as well as residential development. Proper surface water management and adequate permanent drainage of surface infiltration will be key in lowering the shallow perched groundwater table across the site. This will also reduce the risk of the shallow groundwater table impacting site development (such as frost heaving for roadways, flooding of residential developments, etc.).

Confined Groundwater Table

A confined aquifer condition was observed in the lower sand layer across the site. The water head in the lower sand layer across the site was measured at an elevation ranging between 530.5 and 532.5 m, with an average of 532 m. The measured levels corresponded to a phreatic surface ranging between the existing ground surface and 2.9 m below the existing ground surface, with an average of 1 m below the existing ground surface.

The confined aquifer generally would have major impact on deep utility lines that extend into the lower sand, as significant water seepage would be encountered requiring dewatering measures. Permanent excavation should be designed with the base of the excavation well above the lower sand to prevent bottom blowout. Long-term and permanent water seepage should be anticipated in all permanent excavations (such as basement structures) requiring permanent and positive groundwater management systems (subdrainage systems).

6.1.2 Soil Conditions

The near surface subgrade generally consisted of a weak clay deposit below the surficial organics and/or heterogeneous fill. The clay and clay fill soils were generally very moist and soft to firm in consistency. These soils were assessed to be very poor and will adversely impact the proposed development in the following aspects.

Subgrade Support

The mineral soils below the organics are expected to provide weak subgrade support for grade supported installation (e.g., roadways, sidewalks, slab-on-grade, etc). Subgrade modification and improvement will be required to achieve acceptable bearing support. It is anticipated that soil replacement or stabilization will be required where grade support is required.

Bearing Capacity for Residential Units

Limited bearing capacity should also be anticipated for residential housing foundations. Subgrade modification below the foundation bearing surfaces (such as soil densification or replacement) and/or the use of non-conventional foundations systems (such as piles) may be required at this site.

Settlement and Volume Change

When subjected to surcharge loads (such as new fill or structural loads) and causing the groundwater table to subside (following site drainage), the weak soils will undergo consolidation settlement. The magnitude of the consolidation settlement will depend on the magnitude of the surcharge load and the depth of the groundwater table. Based on a generalized subsurface profile, it is expected that settlement in the order of 30 to 50 mm and 40 to 80 mm would be encountered under 1 and 2 m of grade raising fill, respectively.

The estimated settlement will not have a major impact on roadways and sidewalks, but may have more pronounced impact on buried utilities and residential housing foundations.

Frost Susceptibility and Heave Issues

Frost heave of the subgrade soils is generally related to the particle size distribution of the soils, moisture content, and the presence of a relatively shallow groundwater table. The very moist to wet, low to medium plastic clay soils coupled with the relatively shallow groundwater table encountered in the upper 3 m across the site, will result in a moderate susceptibility to frost heaving and formation of ice lenses. This may result in poor performance of grade supported installation such as roadway, sidewalks, and driveways.

6.2 PRELIMINARY SUBDIVISION SITE DEVELOPMENT OPTIONS

6.2.1 Site Grading

During initial grading, all surficial organics and topsoil should be stripped and removed from the development area. The thickness of the near surface topsoil/organics as encountered at the borehole locations ranged between 0.3 and 0.6 m. Organic material should not be mixed with mineral soils nor should it be used as engineered fill material. The topsoil may be stockpiled at an approved location for future landscaping use.

Where fill (and buried organics) are present, the fill (and buried organics) may be kept in place under general fill areas but should be removed from areas requiring subgrade support.

Soft subgrade conditions should be anticipated across the site requiring subgrade modification and improvement. The extent of subgrade improvement will depend on the depth of groundwater table and the amount of cut/fill required to achieve the final design grade. Based on current groundwater elevation, it is anticipated that the perched groundwater table will be within 0.5 to 1 m of the exposed subgrade following removal of organics. As such, improvements and strengthening of the subgrade may be very challenging as rutting and spongy-like behavior in the subgrade may result from dynamically compacting the subgrade. Subgrade modification, replacement and/or placement of imported dry clays to raise the site grades will likely be the more suitable approach.

For preliminary design purposes, the following may be assumed:

- Within the roadways and sidewalks: a minimum of 0.8 to 1.2 m of imported dry clay should be placed and compacted as engineered fill above the native mineral subgrade (or 0.4 to 0.6 m of cement/lime stabilized subgrade) and below the roadway pavement granular base coarse structure. This separation above the weak native subgrade will allow for the construction of a stable subgrade for the roadway structure.

- The final site grades should be such that the shallow perched groundwater table is not shallower than 1.5 m below final design ground surface within the roadways and not shallower than 0.5 m below the underside of footings within the residential building pockets.

6.2.2 Design and Installation of Buried Utilities

Buried utilities can be successfully installed at this site. For preliminary design purposes, the temporary trench excavation associated with utility line installation should be maintained a minimum of 0.5 to 1 m above the lower sand layer to minimize the risk of basal heave and cracking leading to significant groundwater flow into the trench excavations.

Trenches within the clayey soils above the lower sand layer will likely encounter groundwater infiltration into the trench excavation. It is expected that conventional measures such as sump-pump systems would be sufficient to provide groundwater control. Deeper excavation extending into the lower sand will likely require non-conventional dewatering measures, such as well point systems.

The lower sand was generally encountered at an approximate elevation ranging between 526 to 531.5 m. Within the proposed SWMF footprint, the lower sand was generally encountered between elevation 526 and 528 m, while within the Meadows subdivision footprint, the lower sand was encountered between elevation 527.5 and 531.5 m.

Depending on final design grades, thermal insulation may be used to reduce the required soil cover for utility lines and to allow for the installation of the utility lines well above the lower sand layer.

6.2.3 Foundation for Residential Units

Soft to firm soils were encountered within the upper 2 to 3 m of the soil profile across the majority of the development area. These soils are generally considered weak and unsuitable for the support of shallow footings for residential foundations.

For the design and construction of residential foundations, two options are provided:

- Replacement of the upper 1 m of the clay subgrade below the footing bearing surface with suitable material placed as engineered fill.

- Use of deep pile foundations. Driven steel or screw piles are expected to be the most suitable and economical foundation alternatives.

6.3 SWMF DESIGN AND CONSTRUCTION CONSIDERATIONS

Geotechnical considerations associated with the soil and groundwater conditions as related to the design, construction, and long term performance of the SWMF are presented in this sub-section.

6.3.1 Safe Long-term Depth of the SWMF

As discussed above, a confined aquifer condition was observed in the lower sand layer across the SWMF footprint. The sand was generally encountered between elevations 527 and 528 m. The water head in the lower sand layer was measured at an approximate elevation of 532 m.

It is recommended that the base of the SWMF be maintained above elevation 530 m. Long-term excavation below elevation 530 m is considered risky due to the potential of basal heave leading to cracking and extensive groundwater seepage from the bottom.

6.3.2 Temporary and Permanente Excavations into the Lower Sand

Temporary excavations into the lower sand may be necessary during the construction of the SWMF. In these cases, dewatering the lower sand will be required for achieving a dry work area and to prevent groundwater flow from the sand from flooding the excavation. The temporary excavation will have to be backfilled with clayey soils to elevation of 530 m before stopping the dewatering system.

Permanent excavation into the sand will result in large volumes of groundwater flow from the sand into the excavation. This will likely be considered a groundwater diversion requiring approval and permitting from Alberta Environment and Sustainable Resource Development.

Predicting the long-term groundwater discharge rate (yield) of the sand, potential impact on the aquifer, and on current groundwater users in the area will require a hydrogeological assessment (which is beyond the scope of this investigation). Such assessment will include the installation of drawdown well(s) with monitoring location and the completion of a drawdown and recovery test.

6.3.3 Excavation and Groundwater Seepage During Construction

Soft to firm soils were encountered within the upper 2 to 3 m at the borehole locations advanced within the SWMF footprint. These soils generally consisted of clay soils with near surface or buried organics and topsoil. These soils can be readily excavated with standard size earth moving equipment. These soils are expected to be sensitive to disturbance by construction equipment and large ruts and deformation should be anticipated during construction.

Surface Seepage

To reduce the potential of water seepage from the near surface organics and from run-on following rain events into the pond excavation, consideration should be given to the construction of a clay cut-off wall/berm around the perimeter of the SWMF area. The cut-off wall can be built by excavating a trench in the organics/sand layers and backfilling it with clayey soils. The trench should extend 0.5 m past the bottom of the organics/sand and be keyed-into the clayey soils.

Alternatively, a perimeter trench may be excavated to intercept any water seepage. Pumping of collected water will be required in this case.

Seepage from the Clay

The main soil formation below the organics is clayey in nature with relatively low permeability (and thus low yield potential). Seepage from the walls and base of the pond excavation below the organics will likely be encountered but is expected to be relatively low and can be controlled with drainage sumps equipped with pumps.

The volume of water seeping into excavations will increase with increasing size and depth of the excavation. The rate of water seepage is also expected to increase if the excavation encounters saturated silt or sand layers. If the lateral and vertical extents of such layers are relatively small, then they can be drained relatively easily with a sump pump system.

6.3.4 Long-term Impact on the Shallow Groundwater Table

The SWMF is expected to impact the shallow groundwater table in its vicinity. If permanent water storage is proposed within the SWMF, then seepage from the SWMF is expected to elevate the shallow groundwater table within its immediate vicinity.

This effect can be managed by setting restrictions on the development distance from the SWMF and sealing off any exposed organic or sand layer intercepted by the SWMF excavation by clayey soils. The native clayey soils onsite are expected to have relatively low permeability when compacted.

6.4 OUTFALL DESIGN AND INSTALLATION CONSIDERATIONS

It is expected that Horizontal Directional Drilling (HDD) method such as Horizontal Boring (Slip-Bore or Auger and Push) is being considered for the outfall line installation to avoid open trench excavations across Highway 28. The preliminary trajectory and HDD hole diameter have not been established at the time of preparation of this report. The findings of the geotechnical investigation will be used in selecting the HDD parameters.

In general, the soil stratigraphy assessed from the results of the geotechnical investigation was considered suitable for a HDD type crossing. It is recommended to place the drill path within the clay till deposit and above the lower sand layer. The lower sand layer as observed at the location of BH13-24, -35, and -36 was encountered between elevations and 526.5 and 527.5 m. Locating the drill path well within the clay till would also avoid the problematic saturated sand which is prone to heaving and collapse.

6.4.1 Concerns During Drilling

Exit and Entry

It is expected that the entry of the HDD would be located on the east side of the highway and the exit on the west side. However, the drilling contractor should review the soil conditions presented herein before selecting the entry and exit locations. Generally, drilling from lower ground elevation to higher ground elevation would reduce the required groundwater management effort and will result in the entry pit (that will be open for a longer period of time) being shallower in depth.

The shallow perched groundwater table is expected to be close to the surface at both exit and entry locations. However, as the predominant soils at both locations are clayey in nature (clay fill and clay till) with limited water yield potential, an open short-term excavation may be possible with some groundwater management.

Subsurface Conditions

The main concern during HDD at this crossing is the potential collapse or blow out of the saturated sand during drilling of the hole. Both the collapse and blow out concerns within the aforementioned layers could be mitigated by placing the drill path well above the expected depth of the saturated sand deposit.

The HDD path should be located within clay till. These cohesive deposits are generally favorable for constructing and installing a directional drill as they usually provide good steering of the drill hole. These soils are also expected to provide good wall support without major sloughing or collapse.

Significant water seepage should be anticipated if the drill trajectory intercepted the lower sand layer or if the drill path was too close to the sand causing blow out into the drill hole. If the drill path is maintained in the clay till, some water seepage should be anticipated but can be managed using conventional groundwater control techniques.

6.4.2 Concerns During Pull Through

The low to medium plastic clay tills encountered are suitable for pull through operations. However, some softening, swelling, and squeezing of the clay till into the borehole might be encountered during drilling. These conditions, if encountered, could cause drag on the pipe during pull through operations. The conditions inside the hole could also degrade if the hole is left open for a long time. It is therefore recommended that the hole be conditioned immediately before pulling/pushing the pipe through the hole to reduce the drag on the pipe. Drilling equipment selected for the HDD should have enough power to deal with potential drag forces.

Cobbles or boulders are typically expected to be encountered within glacial till deposits. If encountered along the HDD drill path, cobbles and boulders could damage the pipe when pulled through the hole. To mitigate such risks, the hole could be reamed to a larger diameter up to the zones where cobbles or boulders were encountered during the HDD drilling. Another option would be to change the drill path around problematic areas during the HDD drilling.

7.0 OVERVIEW AND RECOMMENDATIONS FOR SUBDIVISION DEVELOPMENT

7.1 OVERVIEW

As discussed in this report, the current subsurface conditions were considered very poor for the proposed development. For the proposed development to be feasible, three items need to be addressed: (i) surface water management, (ii) near surface subgrade condition and strength, and (iii) bearing surface subgrade condition and strength.

Surface Water Management

The first step that should be implemented is proper surface water management across the site. This measure will likely have positive impact in lowering the perched groundwater table, and “drying” of the near surface soil. Without proper surface water drainage, surface infiltration will pond on the ground surface and seep into the subsoil resulting in a shallow groundwater table and saturated subgrade. Having said that, it is difficult to predict with certainty the extent of the positive impact that proper site drainage will have on the site, or to quantify post drainage parameters such as the depth to the groundwater table, or extent of “drying" of the subgrade.

Near Surface Subgrade Condition

The second item that should be considered is improvement of the near surface mineral soil so that adequate subgrade support can be established of surface installations such as roadways and sidewalks. This may be achieved through several methods, including:

- Subgrade modification such as stabilizing with cement or lime. Both of these catalysts will reduce the moisture content of the soil and will allow for proper placement and compaction of the subgrade.
- Subgrade drying and densification. This method may be considered during periods when generally good weather conditions prevail. This method will involve excavation, drying, and re-compacting of the soils in an engineered manner.

- Subgrade replacement. This would involve sub-excavating the weak and wet soils and replacing them with dry material.

For preliminary budgeting purposes, it may be assumed that approximately 0.4 to 0.6 m of cement/lime stabilized subgrade or approximately 0.8 to 1.2 m of densified/replaced subgrade will be required under roadways and sidewalks.

Bearing Surface Subgrade Condition

Similar to the near surface soil, the subgrade at the anticipated bearing surface for residential houses was rather weak and unsuitable for the support of shallow footings. The bearing soils should be improved during site development (made part of the site development condition) or restrictions placed on using deep pile foundations for residential units.

For preliminary budgeting purposes, it may be assumed that approximately 1 m of densified/replaced subgrade will be required under footing bearing surfaces as part of the bearing surface improvement.

7.2 RECOMMENDATIONS

It is recommended that a cost-benefit analysis be conducted for the proposed development to assess if the benefit of the overall development will outweigh the costs and restrictions. If the proposed development was deemed favorable, the following additional engineering evaluations are recommended.

- Following the implementation of the surface water management plan, re-measure the depth of the shallow perched groundwater table above the sand. This should be done during the design stage of every phase of the proposed development. The depth of the shallow groundwater table will impact the amount of required grade raising fill (if any).
- The moisture content and strength of the subgrade should also be assessed during the design stage of every phase of the proposed development. It is possible/likely that the subgrade soils will become drier following the implementation of proper surface water management, and thus the extent and means of subgrade improvement may be modified for different stages of the development.
- Commission a site specific geotechnical investigation for any large structure or multi-family development.
- Involve a professional geotechnical engineer in the review of the development plan of each stage once the design grades and the proposed execution plan have been established.
- Have adequate involvement of a professional geotechnical engineer during each stage of the proposed development to verify that adequate subgrade improvement measures have been implemented and that adequate subgrade support has been achieved.

8.0 CLOSURE

The recommendations presented in this report are based on the results of soil sampling and testing at 31 boreholes advanced across the proposed development area during this investigation. Soil conditions by nature can vary across any given site. If different soil conditions are encountered at subsequent phases of this project, SolidEarth should be notified immediately and given the opportunity to evaluate the situation and provide additional recommendations as necessary.

The recommendations presented in this report should not be used for another site or for a different application at the same site. If the intended application of the site is changed or if the assumptions outlined in this report became invalid, SolidEarth should be notified and given the opportunity to assess if the recommendations presented should be modified.

This report has been prepared for the exclusive use of the City of Cold Lake and its authorized users for the specific application outlined in this report. No other warranties expressed or implied are provided. This report has been prepared within generally accepted geotechnical engineering practices.

Respectfully submitted,
SolidEarth Geotechnical Inc.

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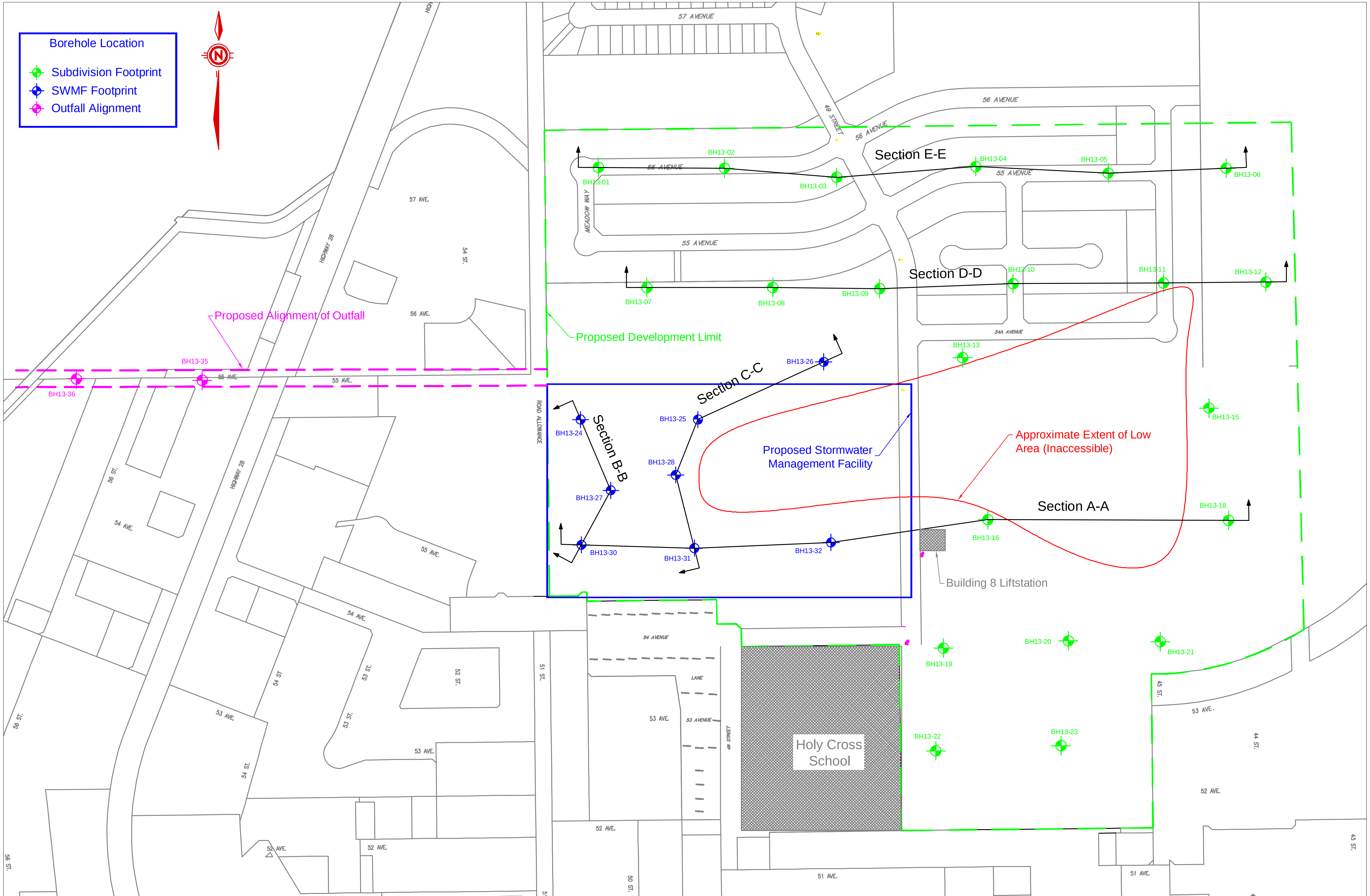
Geotechnical Engineer

Jay Jaber, M.Sc., P.Eng.
Senior Geotechnical Engineer
Managing Director

APEGA Permit to Practice # 11884

Figures:



CLIENT: City of Cold Lake

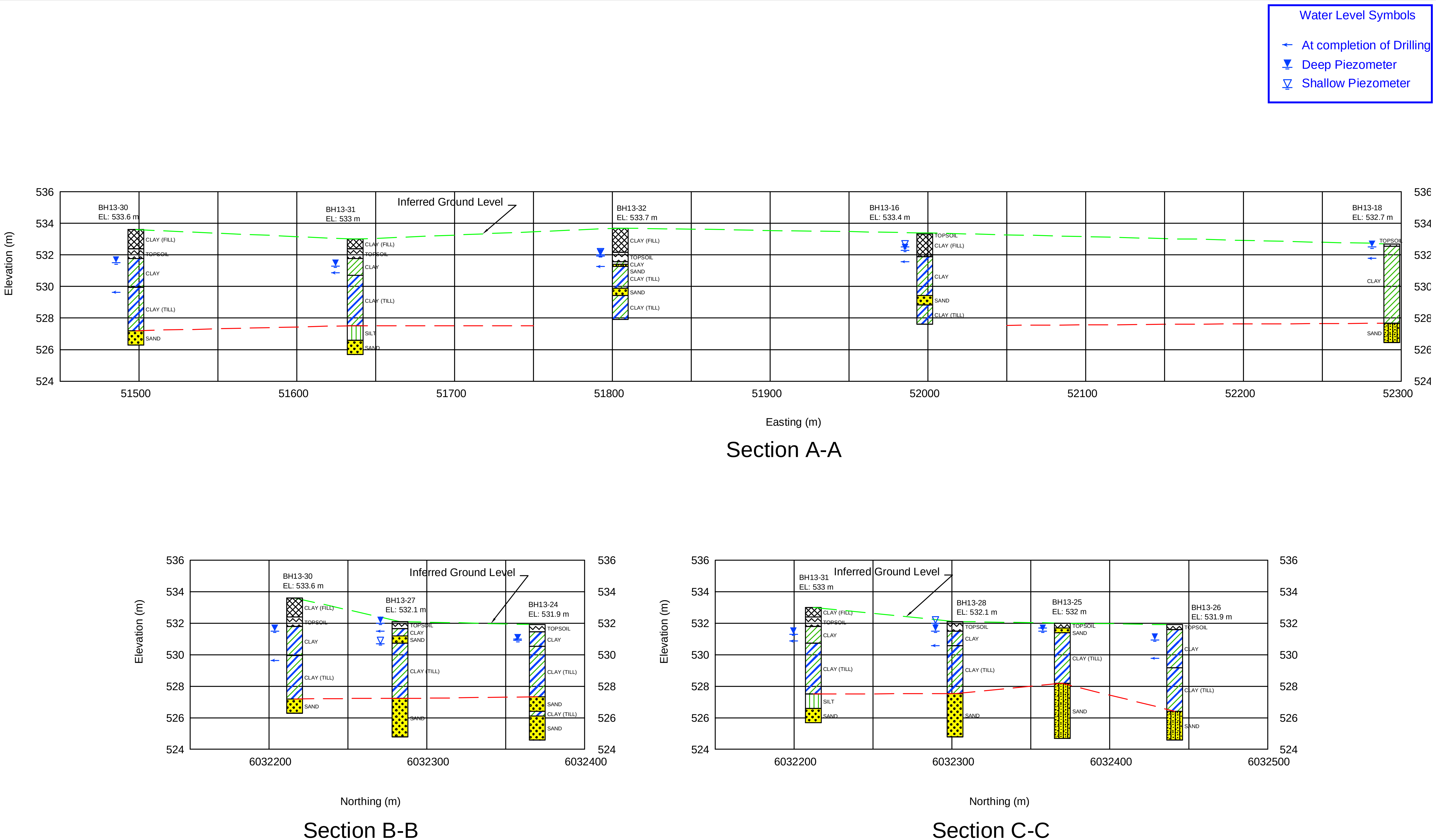
PROJECT NAME: Proposed Maedows Subdivision City of Cold Lake

DRAWING TITLE: Site Layout and Borehole Location Plan

FIGURE No.	1
PROJECT NO:	PG13-1059
DWN BY:	JJ
DATE:	July 2013
SCALE:	AS SHOWN
DATUM:	XXX

SolidEarth Geotechnical

SolidEarth Geotechnical Inc.
#105-4604 50 St., Cold Lake, AB, T9M 1S6



CLIENT: City of Cold Lake

PROJECT NAME: Proposed Maedows Subdivision City of Cold Lake

DRAWING TITLE: Cross-sections of Subsurface Profile Within the Stormwater Management Facility

FIGURE No.: 2

PROJECT NO: PG13-1059

SolidEarth GEOTECHNICAL

DWN BY: JJ

DATE: July 2013

SCALE: AS SHOWN

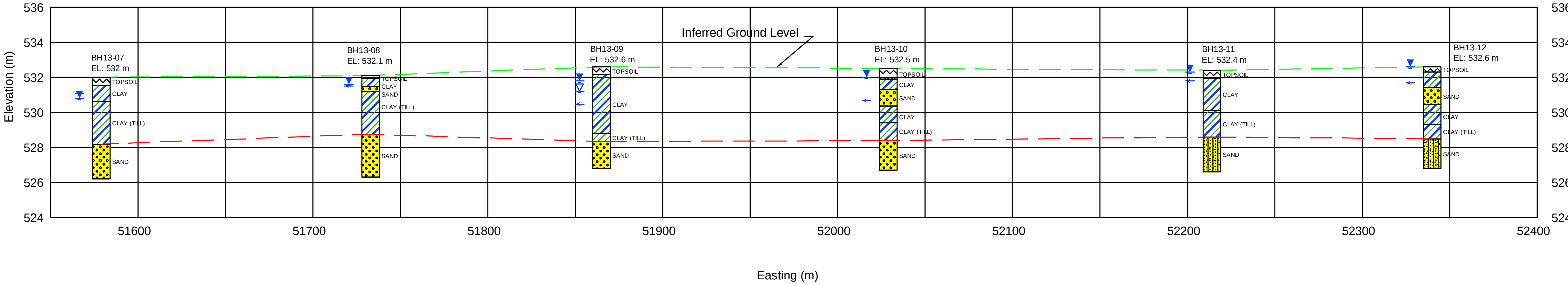
DATUM: XXX

SolidEarth Geotechnical Inc.

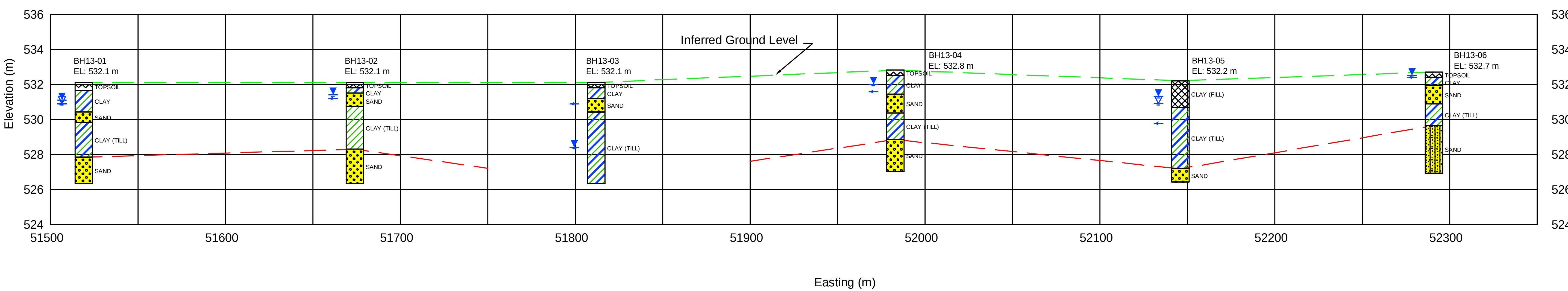
#105-4604 50 St., Cold Lake, AB, T9M 1S6

Water Level Symbols

- At completion of Drilling
- Deep Piezometer
- Shallow Piezometer



Section D-D



Section E-E

CLIENT: City of Cold Lake

PROJECT NAME: Proposed Maedows Subdivision, City of Cold Lake

DRAWING TITLE: Cross-sections of Subsurface Profile Within the Proposed Subdivision

FIGURE No.: 3

PROJECT NO: PG13-1059

DWN BY: JJ

DATE: July 2013

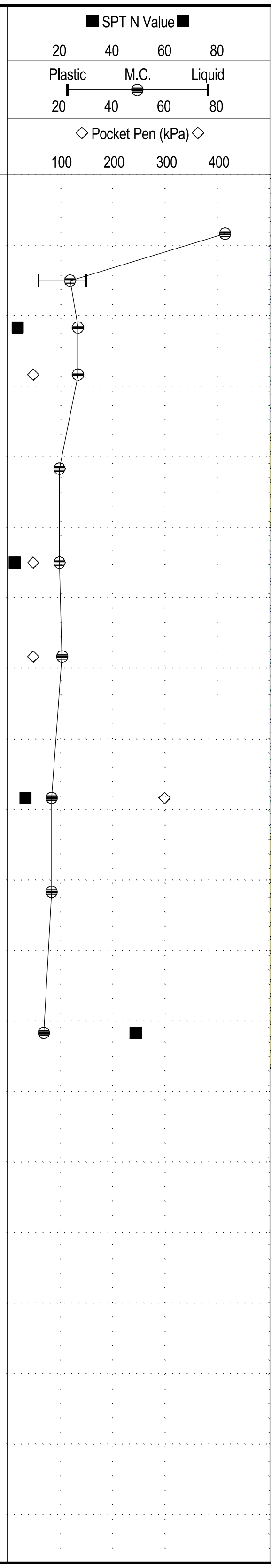
SCALE: AS SHOWN

DATUM: XXX

SolidEarth Geotechnical Inc.

#105-4604 50 St., Cold Lake, AB, T9M 1S6

Project Name: Meadows Subdivision	Borehole #: **BH13-01**	SolidEarth GEOTECHNICAL	
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032680 Easting: 51519	Driller: Canadian Geological Drilling Ltd.	Completion Date: 20/6/13	
Elevation: 532.1 m	Drill Method: 150mm Solid Stem	Page 1 of 1	



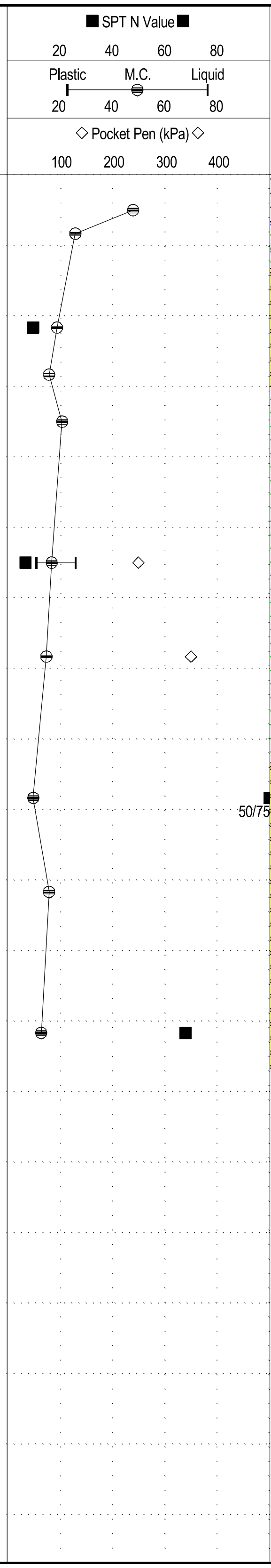
Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
0	OR	**TOPSOIL**, black, roots, saturated	1			532
	CI	**CLAY**, silty, trace sand, trace gravel, firm, medium plastic, grey, very moist	2		Liquid Limit: 30 % Plastic Limit: 12 %	
1			3	4		531
		- sand lenses	4			
2	SP	**SAND**, fine grained, silty, trace clay, trace gravel, loose, grey, saturated	5			530
	CI	**CLAY**, silty, trace sand, trace gravel, firm, medium plastic, grey, very moist	6	3		
3			7			529
	CI	**CLAY (TILL)**, sandy, silty, trace gravel, soft, medium plastic, grey, very moist				
4		- becoming firm, moist	8	7		528
	SP	**SAND**, fine to medium grained, silty, trace clay, gravelly, dense, grey, saturated	9		Low auger recovery between 4.3 and 5.3 m below ground surface	
5						527
		- gravel sizes, dense	10	49		
6		**<u>COMPLETION DEPTH: 5.8 m below ground surface</u>**			Water Level: Well A - 1.0 m below ground surface on 8 July 2013. Well B - 1.2 m below ground surface on 8 July 2013.	526
7						525
8						524
9						

Columns also shown: Soil Symbol, Sample Symbol, SLOTTED PIEZOMETER, SLOTTED PIEZOMETER

At Completion
Accumulation of water at 1.2 m below ground surface
Accumulation of slough at 3.0 m below ground surface
Slotted Standpipe A -
Installed to 5.8 m below ground surface
Slotted Standpipe B -
Installed to 1.5 m below ground surface
Backfilled with drill cuttings and bentonite plug

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-02**		SolidEarth GEOTECHNICAL
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032679 Easting: 51674	Driller: Canadian Geological Drilling Ltd.	Completion Date: 20/6/13	
Elevation: 532.1 m	Drill Method: 150mm Solid Stem	Page 1 of 1	



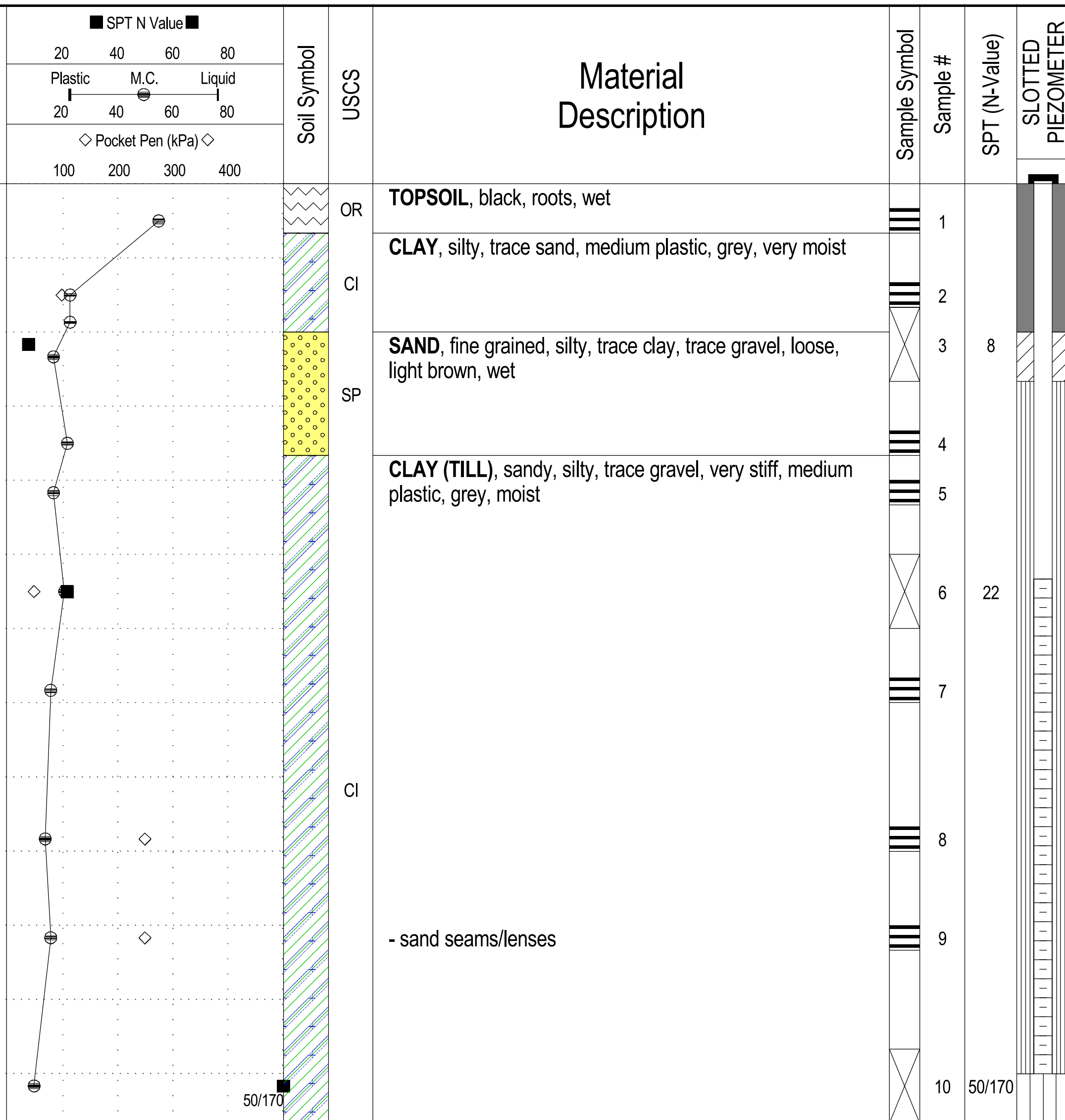
Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
0	OR	**TOPSOIL**, black, roots, wet	1			532
	CI	**CLAY**, sandy, silty, stiff, medium plastic, grey, moist	2			
1	SP	**SAND**, fine grained, silty, trace clay, trace gravel, compact, brown, wet	3	10		531
			4			
	CL	**CLAY (TILL)**, and sand, silty, trace gravel, firm, low plastic, grey, very moist	5			
2		- seepage	6	7	Liquid Limit: 26 % Plastic Limit: 11 % Grain Size Distribution: Gravel: 1 % Sand: 45 % Silt: 31 % Clay: 23 %	530
3		- sand lenses, moist	7			529
4	SP	**SAND**, fine to medium grained, trace silt, trace clay, gravelly, dense, grey, wet	8	50/75	Low auger recovery between 3.8 and 5.3 m	528
		- becoming brown, wet	9			
5		- becoming grey	10	68		527
6		**COMPLETION DEPTH: 5.8 m below ground surface**			Water Level: 0.7 m below ground surface on 8 July 2013.	526
7						525
8						524
9						

At Completion
Accumulation of water at 0.9 m below ground surface
Accumulation of slough at 2.4 m below ground surface
Slotted standpipe installed to 5.8 m below ground surface
Backfilled with drill cuttings and bentonite plug

Soil Symbol | Sample Symbol | SLOTTED PIEZOMETER

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-03**		
Client Name: City of Cold Lake	Project #: PG13-1059		SolidEarth GEOTECHNICAL
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032668 Easting: 51812	Driller: Canadian Geological Drilling Ltd.		Completion Date: 20/6/13
Elevation: 532.1 m	Drill Method: 150mm Solid Stem		Page 1 of 1



Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
0	OR	**TOPSOIL**, black, roots, wet	1			532
	CI	**CLAY**, silty, trace sand, medium plastic, grey, very moist	2			
1	SP	**SAND**, fine grained, silty, trace clay, trace gravel, loose, light brown, wet	3	8		531
			4			
2	CI	**CLAY (TILL)**, sandy, silty, trace gravel, very stiff, medium plastic, grey, moist	5			530
			6	22		
3			7			529
4			8		SPT sampler in contact with rock	528
		- sand seams/lenses	9			
5						527
			10	50/170		
6		**<u>COMPLETION DEPTH: 5.8 m below ground surface</u>**			Water Level: 3.7 m below ground surface on 8 July 2013.	526
7						525
8						524
9						

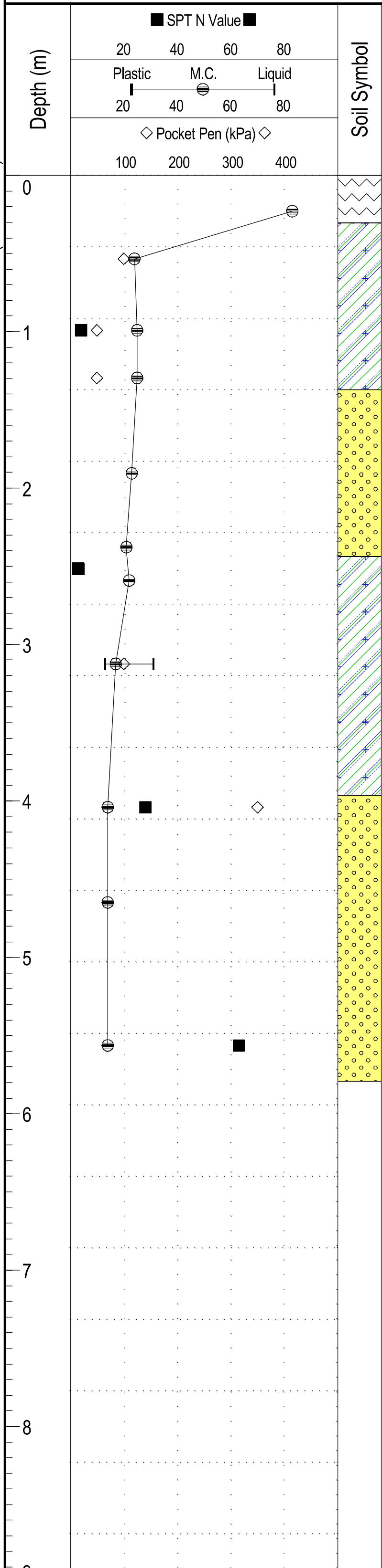
At Completion
Accumulation of water at 1.2 m below ground surface
Accumulation of slough at 1.2 m below ground surface
Slotted standpipe installed to 5.5 m below ground surface
Backfilled with drill cuttings and bentonite plug

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-04**
Client Name: City of Cold Lake	Project #: PG13-1059
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ
Northing: 6032681 Easting: 51983	Driller: Canadian Geological Drilling Ltd.
Elevation: 532.8 m	Drill Method: 150mm Solid Stem

SolidEarth GEOTECHNICAL

Completion Date: 21/6/13



USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
OR	**TOPSOIL**, black, roots, saturated	1			
CI	**CLAY**, sandy, silty, trace gravel, medium plastic, brown, oxides, very moist	2			532
	- sand lenses	3	4		
		4			
SP	**SAND**, fine grained, trace silt, trace clay, trace gravel, very loose, brown, moist	5			531
CI	**CLAY (TILL)**, sandy, silty, trace gravel, soft, medium plastic, grey, moist	6	3		530
		7		Liquid Limit: 31 % Plastic Limit: 13 %	529
SP	**SAND**, fine to medium grained, silty, trace clay, gravelly, compact, grey, moist	8	28		
		9			528
	- becoming very dense	10	63		
	COMPLETION DEPTH: 5.8 m below ground surface			Water Level: 0.8 m below ground surface on 8 July 2013.	527

At Completion
Accumulation of water at 1.2 m below ground surface
Accumulation of slough at 2.7 m below ground surface
Slotted standpipe installed to 5.0 m below ground surface
Backfilled with drill cuttings and bentonite plug

Elevation (m): 526, 525, 524

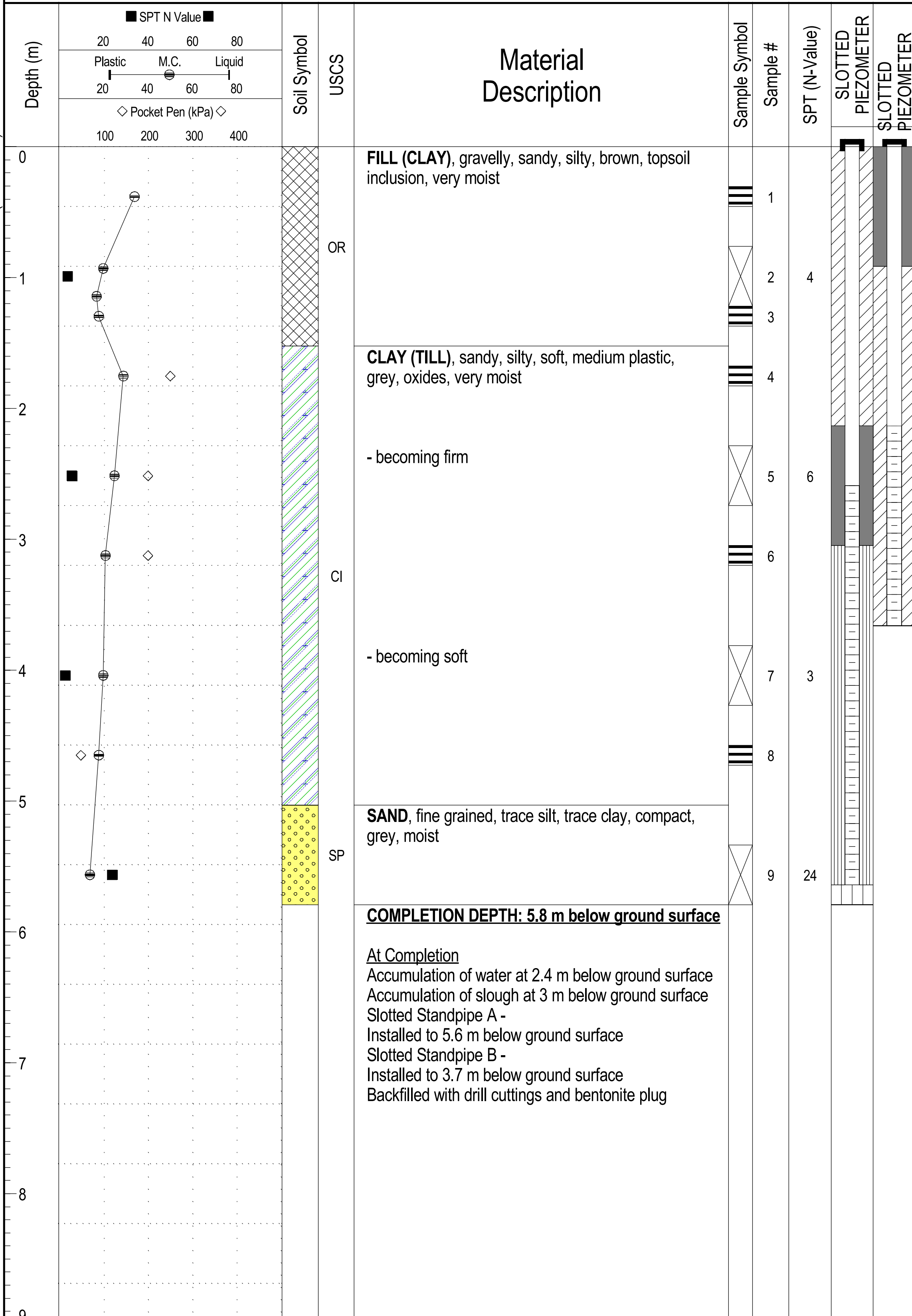
Sample Symbol: Shelby Tube, No Recovery, SPT Test (N), Grab Sample, Split-Pen, Core

Backfill Symbol: Bentonite, Pea Gravel, Slough, Grout, Drill Cuttings, Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-05**		
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032673 Easting: 52146	Driller: Canadian Geological Drilling Ltd.	Completion Date: 21/6/13	
Elevation: 533.2 m	Drill Method: 150mm Solid Stem	Page 1 of 1	

SolidEarth GEOTECHNICAL

Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Elevation (m)
0	OR	**FILL (CLAY)**, gravelly, sandy, silty, brown, topsoil inclusion, very moist	1		533
1			2	4	
			3		532
	CI	**CLAY (TILL)**, sandy, silty, soft, medium plastic, grey, oxides, very moist	4		
2					531
		- becoming firm	5	6	
3			6		530
4		- becoming soft	7	3	529
			8		
5	SP	**SAND**, fine grained, trace silt, trace clay, compact, grey, moist	9	24	528
6		**COMPLETION DEPTH: 5.8 m below ground surface**			527
7					526
8					525
9					



At Completion
Accumulation of water at 2.4 m below ground surface
Accumulation of slough at 3 m below ground surface
Slotted Standpipe A -
Installed to 5.6 m below ground surface
Slotted Standpipe B -
Installed to 3.7 m below ground surface
Backfilled with drill cuttings and bentonite plug

Additional Data & Notes:
Water Level:
Well A - 0.9 m below ground surface on 8 July 2013.
Well B - 1.3 m below ground surface on 8 July 2013.

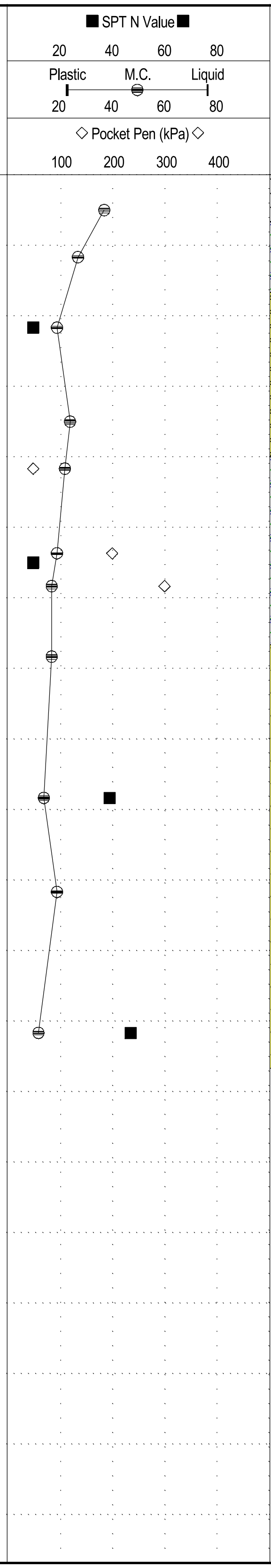
Sample Symbol: Shelby Tube, No Recovery, SPT Test (N), Grab Sample, Split-Pen, Core

Backfill Symbol: Bentonite, Pea Gravel, Slough, Grout, Drill Cuttings, Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-06**
Client Name: City of Cold Lake	Project #: PG13-1059
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ
Northing: 6032679 Easting: 52291	Driller: Canadian Geological Drilling Ltd.
Elevation: 532.7 m	Drill Method: 150mm Solid Stem

SolidEarth GEOTECHNICAL

Completion Date: 21/6/13



Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes
0	OR	**TOPSOIL**, black, roots, wet	1		
	CI	**CLAY**, sandy, silty, trace gravel, medium plastic, grey, sand lenses, very moist	2		
1	SP	**SAND**, fine grained, silty, trace clay, trace gravel, compact, light brown, wet	3	10	
			4		
2	CI	**CLAY (TILL)**, sandy, silty, trace gravel, stiff, medium plastic, grey, moist	5		
			6	10	
			7		
3	SM	**SAND**, fine to medium grained, silty, clayey, gravelly, dense, grey, wet	8		Low auger recovery between 3.1 and 3.8 m
4			9	39	
			10		
5			11	47	

Elevation (m): 532, 531, 530, 529, 528, 527, 526, 525, 524

Depth (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

COMPLETION DEPTH: 5.8 m below ground surface

At Completion
Accumulation of water at 0.3 m below ground surface
Accumulation of slough at 1.8 m below ground surface
Slotted standpipe installed to 3.7 m below ground surface
Backfilled with drill cuttings and bentonite plug

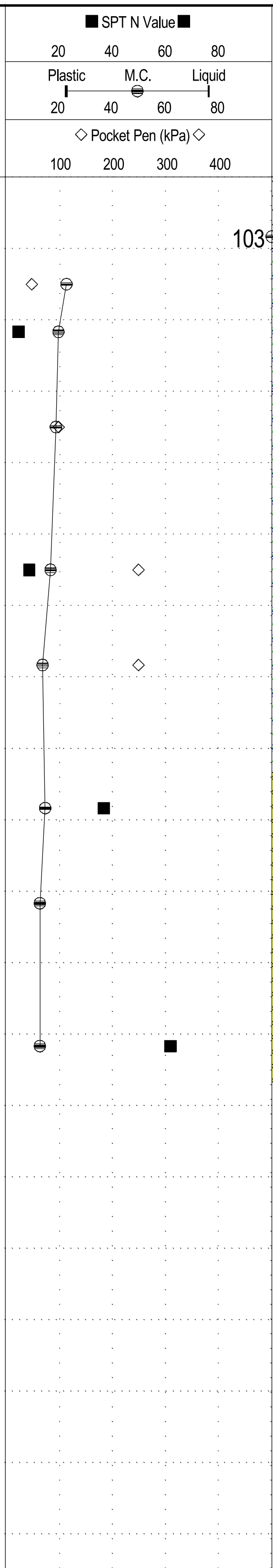
Water Level:
0.2 m below ground surface on 8 July 2013.

SLOTTED PIEZOMETER

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-07**		
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032532 Easting: 51579	Driller: Canadian Geological Drilling Ltd.	Completion Date: 20/6/13	
Elevation: 532 m	Drill Method: 150mm Solid Stem	Page 1 of 1	

SolidEarth GEOTECHNICAL



Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
0	OR	**TOPSOIL**, black, roots, saturated	1			
	CI	**CLAY**, sandy, silty, trace gravel, medium plastic, grey, sand lenses, very moist	2			
1			3	5		531
	CI	**CLAY (TILL)**, sandy, silty, trace gravel, firm, medium plastic, grey, oxides, moist	4			
2						530
		- becoming stiff	5	9		
3			6			529
	SP	**SAND**, fine to medium grained, trace silt, trace clay, trace gravel, dense, grey, wet			Low auger recovery between 3.8 and 5.3 m	
4			7	37		528
		- gravel sizes	8			
5						527
			9	62		
6		**<u>COMPLETION DEPTH: 5.8 m below ground surface</u>**			Water Level: 0.6 m below ground surface on 8 July 2013.	526
7						525
8						524
9						

SLOTTED PIEZOMETER

<u>At Completion</u>
Accumulation of water at 1.2 m below ground surface
Accumulation of slough at 2.4 m below ground surface
Slotted standpipe installed to 5.2 m below ground surface
Backfilled with drill cuttings and bentonite plug

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

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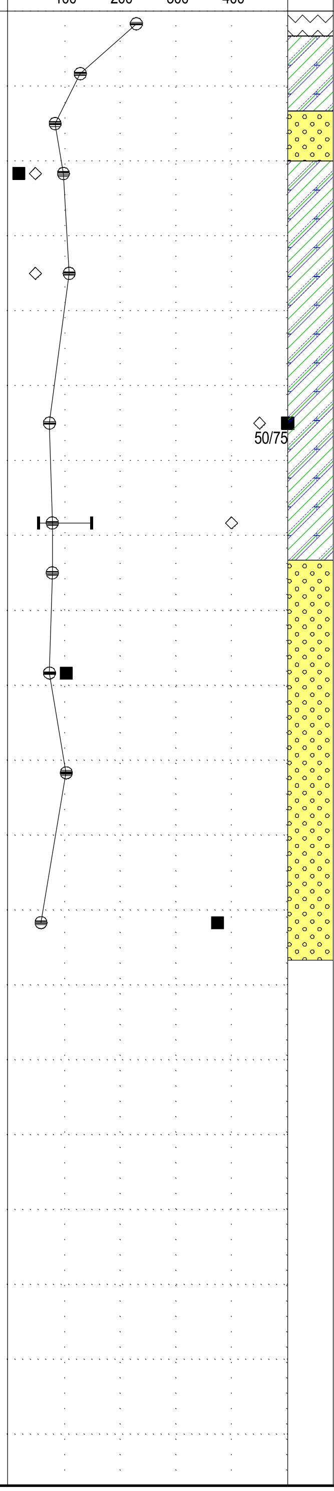
Project Name: Meadows Subdivision	Borehole #: **BH13-08**
Client Name: City of Cold Lake	Project #: PG13-1059
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ
Northing: 6032533 Easting: 51733	Driller: Canadian Geological Drilling Ltd.
Elevation: 532.1 m	Drill Method: 150mm Solid Stem

SolidEarth GEOTECHNICAL

Completion Date: 20/6/13

Chart header: ■ SPT N Value ■ (20, 40, 60, 80); Plastic — M.C. — Liquid (20, 40, 60, 80); ◇ Pocket Pen (kPa) ◇ (100, 200, 300, 400)



Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
0	OR	**TOPSOIL**, black, roots, wet	1			532
	CI	**CLAY**, sandy, silty, trace gravel, medium plastic, grey-brown, very moist	2			
	SP	**SAND**, silty, clayey, loose, brown, wet	3			
1	CI	**CLAY (TILL)**, sandy, silty, trace gravel, soft, medium plastic, grey, very moist	4	4		531
		- oxides, stiff	5			
2						530
		- hard, moist	6	50/75		
3			7		Liquid Limit: 30 % Plastic Limit: 11 %	529
	SP	**SAND**, fine to medium grained, silty, trace clay, and gravel, compact, brown, moist	8			
4		- becoming grey	9	21		528
			10			
5		- gravel sizes	11	75		527
6		**COMPLETION DEPTH: 5.8 m below ground surface**			Water Level: 0.5 m below ground surface on 8 July 2013.	526
7						525
8						524
9						

At Completion
Accumulation of water at 0.6 m below ground surface
Accumulation of slough at 1.8 m below ground surface
Slotted standpipe installed to 5.8 m below ground surface
Backfilled with drill cuttings and bentonite plug

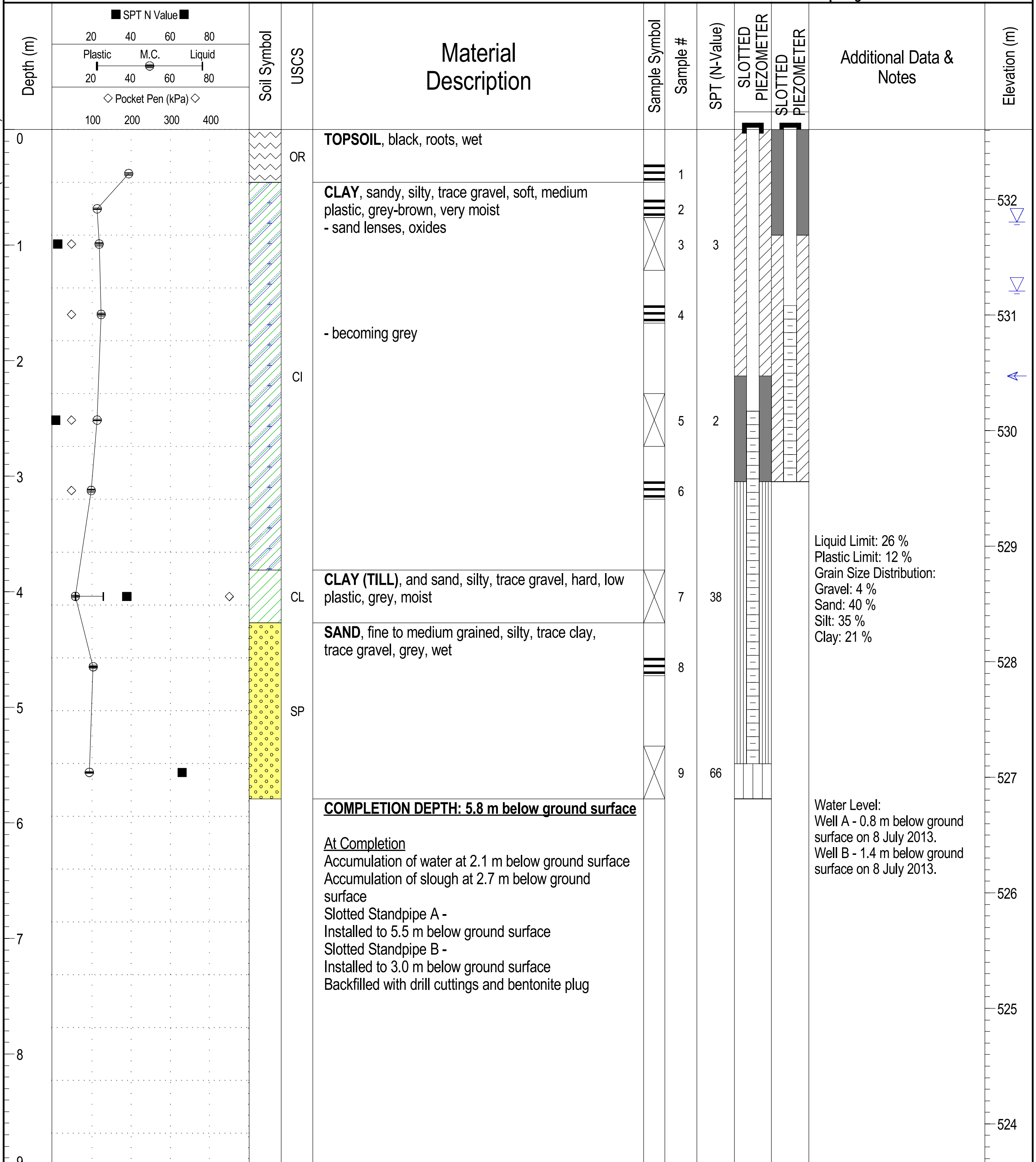
Sample Symbol: Shelby Tube, No Recovery, SPT Test (N), Grab Sample, Split-Pen, Core

Backfill Symbol: Bentonite, Pea Gravel, Slough, Grout, Drill Cuttings, Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-09**
Client Name: City of Cold Lake	Project #: PG13-1059
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ
Northing: 6032531 Easting: 51865	Driller: Canadian Geological Drilling Ltd.
Elevation: 532.6 m	Drill Method: 150mm Solid Stem

SolidEarth GEOTECHNICAL

Completion Date: 20/6/13



Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)
0	OR	**TOPSOIL**, black, roots, wet	1	
	CI	**CLAY**, sandy, silty, trace gravel, soft, medium plastic, grey-brown, very moist - sand lenses, oxides	2	
1			3	3
		- becoming grey	4	
2			5	2
3			6	
4	CL	**CLAY (TILL)**, and sand, silty, trace gravel, hard, low plastic, grey, moist	7	38
	SP	**SAND**, fine to medium grained, silty, trace clay, trace gravel, grey, wet	8	
5			9	66

COMPLETION DEPTH: 5.8 m below ground surface

At Completion
Accumulation of water at 2.1 m below ground surface
Accumulation of slough at 2.7 m below ground surface
Slotted Standpipe A -
Installed to 5.5 m below ground surface
Slotted Standpipe B -
Installed to 3.0 m below ground surface
Backfilled with drill cuttings and bentonite plug

Additional Data & Notes

Liquid Limit: 26 %
Plastic Limit: 12 %
Grain Size Distribution:
Gravel: 4 %
Sand: 40 %
Silt: 35 %
Clay: 21 %

Water Level:
Well A - 0.8 m below ground surface on 8 July 2013.
Well B - 1.4 m below ground surface on 8 July 2013.

Elevation (m): 532, 531, 530, 529, 528, 527, 526, 525, 524

Sample Symbol: Shelby Tube, No Recovery, SPT Test (N), Grab Sample, Split-Pen, Core

Backfill Symbol: Bentonite, Pea Gravel, Slough, Grout, Drill Cuttings, Sand

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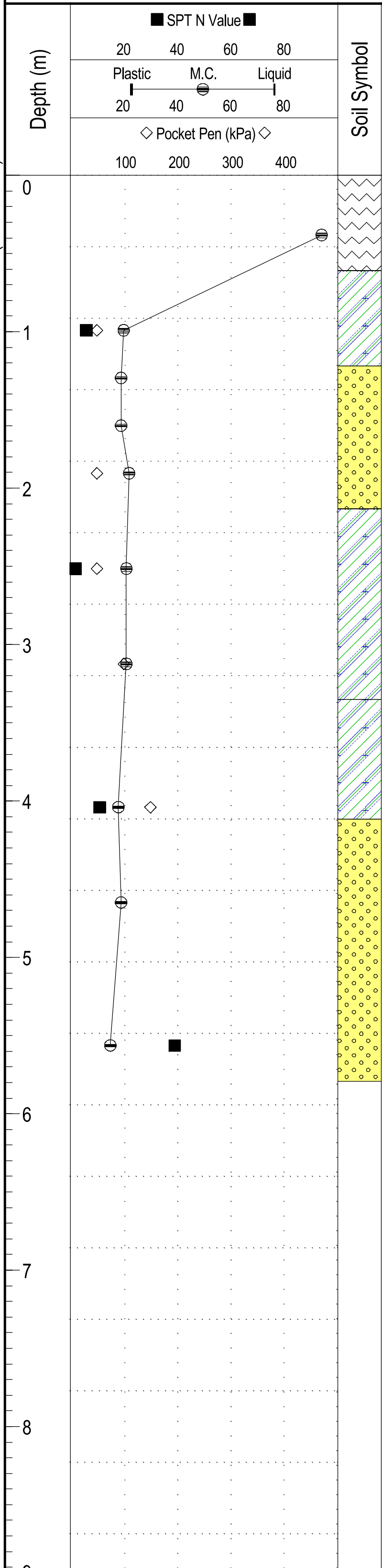
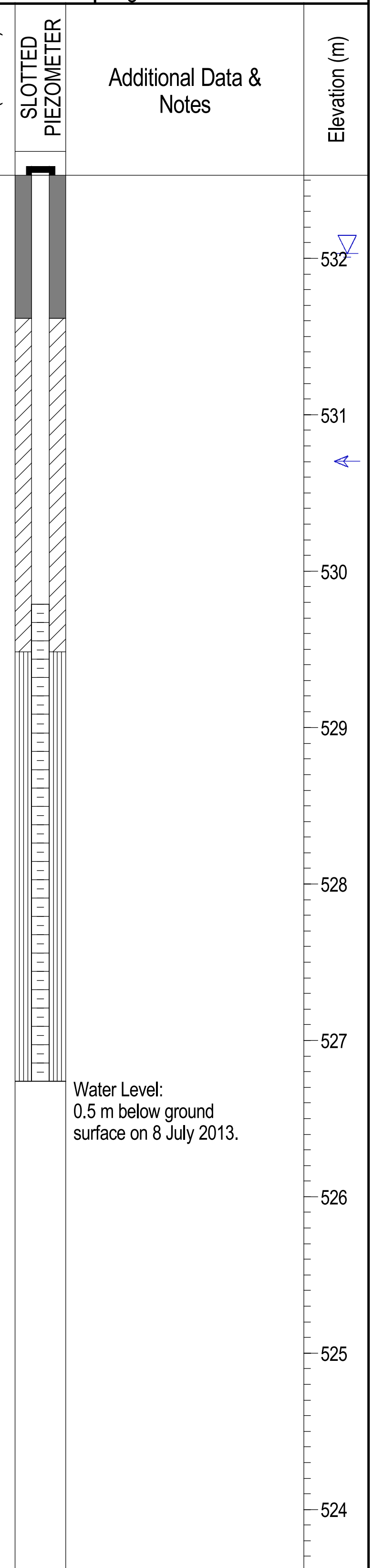
Project Name: Meadows Subdivision	Borehole #: **BH13-10**		
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032537 Easting: 52029	Driller: Canadian Geological Drilling Ltd.	Completion Date: 20/6/13	
Elevation: 532.5 m	Drill Method: 150mm Solid Stem	Page 1 of 1	



USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes
OR	**TOPSOIL**, black, roots, saturated	1		
CI	**CLAY**, sandy, silty, trace gravel, firm, medium plastic, grey-brown, very moist	2	6	
SP	**SAND**, fine grained, trace silt, trace clay, trace gravel, very loose, red-brown, very moist	3, 4, 5		
CI	**CLAY** , sandy, silty, trace gravel, firm, medium plastic, grey-brown, very moist	6, 7	2	
CI	**CLAY (TILL)**, and sand, silty, trace gravel, very soft, medium plastic, grey, seepage, very moist - becoming stiff	8	11	
SP	**SAND**, fine to medium grained, silty, trace clay, gravelly, dense, grey, wet	9, 10	39	
	COMPLETION DEPTH: 5.8 m below ground surface			Water Level: 0.5 m below ground surface on 8 July 2013.

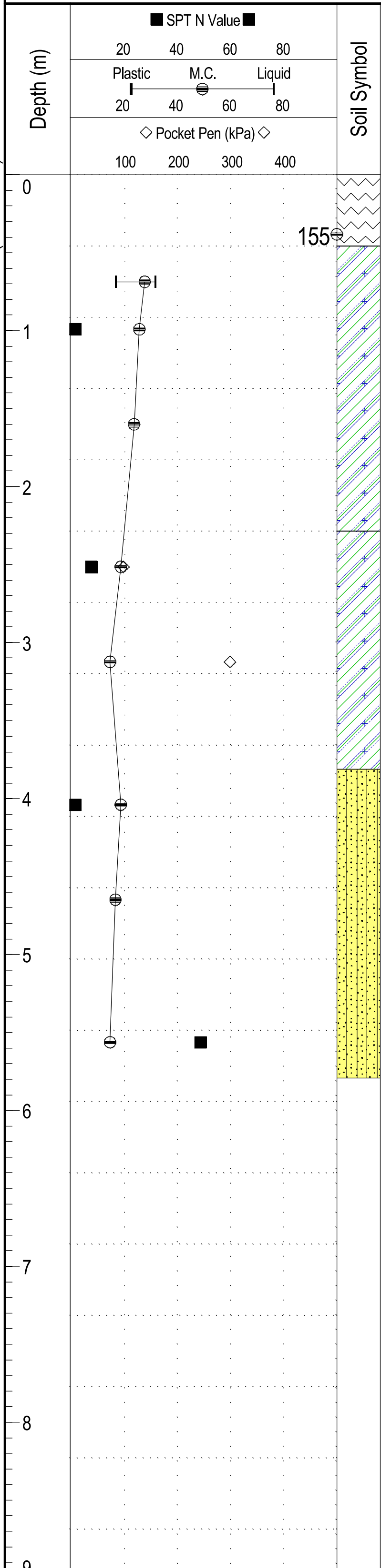
At Completion
Accumulation of water at 1.8 m below ground surface
Accumulation of slough at 3.1 m below ground surface
Slotted standpipe installed to 5.8 m below ground surface
Backfilled with drill cuttings and bentonite plug



Sample Symbol: Shelby Tube, No Recovery, SPT Test (N), Grab Sample, Split-Pen, Core

Backfill Symbol: Bentonite, Pea Gravel, Slough, Grout, Drill Cuttings, Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-11**		SolidEarth GEOTECHNICAL
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032538 Easting: 52214	Driller: Canadian Geological Drilling Ltd.		Completion Date: 21/6/13
Elevation: 532.4 m	Drill Method: 150mm Solid Stem		Page 1 of 1



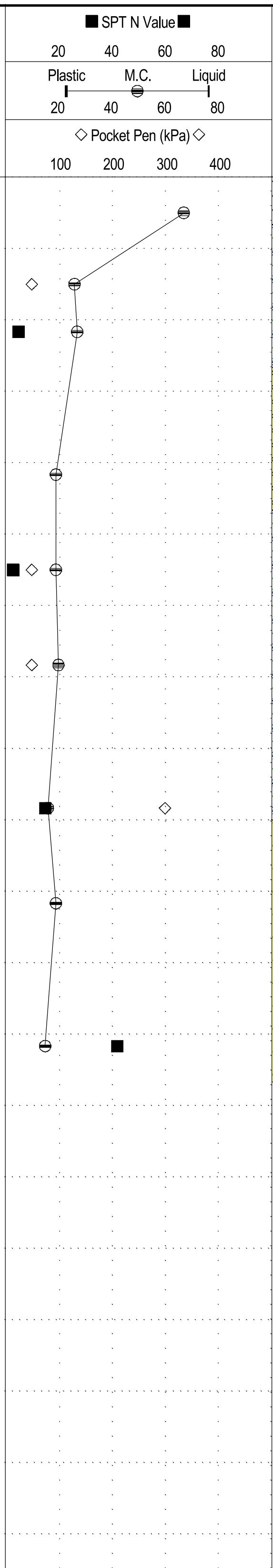
Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
0	OR	**TOPSOIL**, black, roots, wet	1			532
	CI	**CLAY**, sandy, silty, soft, medium plastic, grey, very moist	2			
1		- oxides	3	2	Liquid Limit: 32 % Plastic Limit: 17 %	
		- sand lenses	4			531
2	CI	**CLAY (TILL)**, sandy, silty, stiff, medium plastic, dark grey, moist	5	8		530
3			6			529
4	SM	**SAND**, fine to medium grained, silty, clayey, trace gravel, gray, very loose, very moist	7	2	Low auger recovery between 3.8 and 4.3 m	528
			8			
5		- becoming very dense	9	49		527
6		**<u>COMPLETION DEPTH: 5.8 m below ground surface</u>**			Water Level: 0.1 m below ground surface on 8 July 2013.	526
7						525
8						524
9						

At Completion
Accumulation of water at 0.6 m below ground surface
Accumulation of slough at 0.6 m below ground surface
Slotted standpipe installed to 4.9 m below ground surface
Backfilled with drill cuttings and bentonite plug

SLOTTED PIEZOMETER

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-12**	SolidEarth GEOTECHNICAL	
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032539 Easting: 52340	Driller: Canadian Geological Drilling Ltd.	Completion Date: 21/6/13	
Elevation: 532.6 m	Drill Method: 150mm Solid Stem	Page 1 of 1	



Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Elevation (m)
0 – 0.3	OR	**TOPSOIL**, black, roots, wet	1		
0.3 – 1.2	CI	**CLAY**, sandy, silty, trace gravel, firm, medium plastic, grey, very moist	2	5	532
1.2 – 2.1	SP	**SAND**, fine grained, silty, and clay, trace gravel, grey, very loose, very moist	4		531
2.1 – 3.3	CI	**CLAY**, sandy, silty, trace gravel, soft, medium plastic, grey, very moist	5, 6	3	530
3.3 – 4.1	CI	**CLAY (TILL)**, sandy, silty, trace gravel, stiff, medium plastic, grey, moist - seepage	7	15	529
4.1 – 5.8	SM	**SAND**, fine to medium grained, and silt, and clay, gravelly, compact, grey, wet	8, 9	42	528, 527

Depth (m): 0 1 2 3 4 5 6 7 8 9

Elevation (m): 532 531 530 529 528 527 526 525 524

SLOTTED PIEZOMETER

COMPLETION DEPTH: 5.8 m below ground surface

At Completion
Accumulation of water at 0.9 m below ground surface
Accumulation of slough at 1.5 m below ground surface
Slotted standpipe installed to 5.8 m below ground surface
Backfilled with drill cuttings and bentonite plug

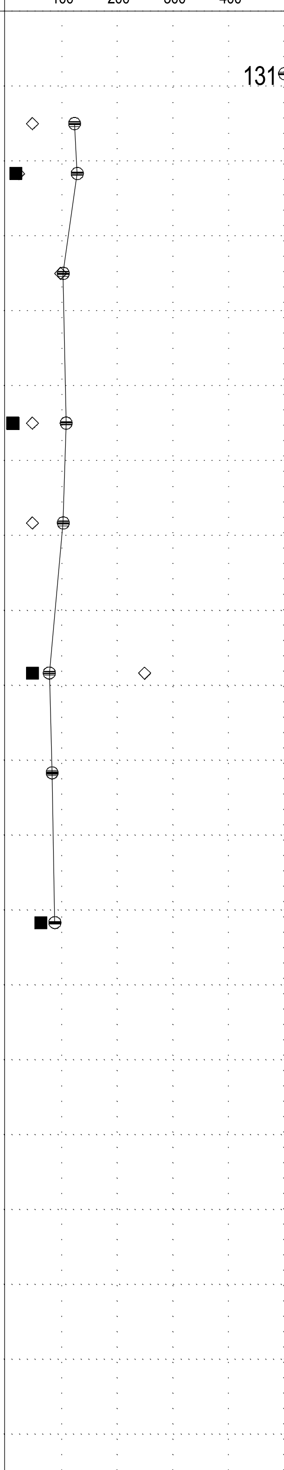
Additional Data & Notes:
Water Level:
At ground surface
on 8 July 2013.

Sample Symbol: Shelby Tube | No Recovery | SPT Test (N) | Grab Sample | Split-Pen | Core

Backfill Symbol: Bentonite | Pea Gravel | Slough | Grout | Drill Cuttings | Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-13**	SolidEarth GEOTECHNICAL	
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032446 Easting: 51967	Driller: Canadian Geological Drilling Ltd.	Completion Date: 20/6/13	
Elevation: 532.1 m	Drill Method: 150mm Solid Stem		

■SPT N Value■ (20, 40, 60, 80); Plastic — M.C. — Liquid (20, 40, 60, 80); ◇Pocket Pen (kPa)◇ (100, 200, 300, 400)



Depth (m)	Soil Symbol	USCS	Material Description	Sample Symbol	Sample #	SPT (N-Value)	SLOTTED PIEZOMETER	Additional Data & Notes	Elevation (m)
0		OR	**TOPSOIL**, black, roots, saturated						532
			CLAY, sandy, silty, firm, medium plastic, grey, very moist	Grab Sample	1				
				Grab Sample	2				
1				SPT Test (N)	3	4			531
			- oxides	Grab Sample	4				
2		CI							530
				Grab Sample	5	3			
3				Grab Sample	6				529
			CLAY (TILL), sandy, silty, trace gravel, stiff, medium plastic, grey, moist						
4		CI		SPT Test (N)	7	10			528
			- and sand						
			SAND, fine to medium grained, and silt, and clay, and gravel, compact, grey, saturated	Grab Sample	8				
5		SM							527
				SPT Test (N)	9	13			
6			**COMPLETION DEPTH: 5.8 m below ground surface**					Water Level: 0.2 m below ground surface on 8 July 2013.	526
7									525
8									524
9									

At Completion
Accumulation of water at 2.1 m below ground surface
Accumulation of slough at 2.7 m below ground surface
Slotted standpipe installed to 5.8 m below ground surface
Backfilled with drill cuttings and bentonite plug

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-15**	SolidEarth GEOTECHNICAL
Client Name: City of Cold Lake	Project #: PG13-1059	
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ	
Northing: 6032384 Easting: 52270	Driller: Canadian Geological Drilling Ltd.	Completion Date: 21/6/13
Elevation: 532.5 m	Drill Method: 150mm Solid Stem	Page 1 of 1

Depth (m)	SPT N Value / Plastic, M.C., Liquid / Pocket Pen (kPa)	Soil Symbol	USCS	Material Description	Sample Symbol	Sample #	SPT (N-Value)	SLOTTED PIEZOMETER	SLOTTED PIEZOMETER	Additional Data & Notes	Elevation (m)
0	158		OR	**TOPSOIL**, black, roots, saturated		1					532
			CL	**CLAY**, sandy, silty, trace gravel, soft, low plastic, grey, very moist		2					
1						3	3				
				- sand lenses, oxides		4					531
2				- becoming moist		5	2			Liquid Limit: 28 % Plastic Limit: 13 %	530
3						6					529
			CI	**CLAY (TILL)**, and sand, silty, trace gravel, very stiff, medium plastic, grey, sand lenses, moist		7	19				
4						8					528
			SM	**SAND**, fine grained, and silt, and clay, very loose, green-grey, very moist		9					
5				- trace silt, trace clay		10	2				527
6				<u>**COMPLETION DEPTH: 6.1 m below ground surface**</u>						Water Level: Well A - 0.4 m below ground surface on 8 July 2013. Well B - 0.4 m below ground surface on 8 July 2013.	526
7				<u>At Completion</u> Accumulation of water at 0.9 m below ground surface Accumulation of slough at 0.9 m below ground surface Slotted Standpipe A - Installed to 6.1 m below ground surface Slotted Standpipe B - Installed to 3.7 m below ground surface Backfilled with drill cuttings and bentonite plug							525
8											524
9											

Graph scales: SPT N Value 20, 40, 60, 80; Plastic / M.C. / Liquid 20, 40, 60, 80; Pocket Pen (kPa) 100, 200, 300, 400

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-16**	SolidEarth GEOTECHNICAL
Client Name: City of Cold Lake	Project #: PG13-1059	
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ	
Northing: 6032247 Easting: 51998	Driller: Canadian Geological Drilling Ltd.	Completion Date: 19/6/13
Elevation: 533.4 m	Drill Method: 150mm Solid Stem	Page 1 of 1

■ SPT N Value ■ (20, 40, 60, 80)
Plastic — M.C. — Liquid (20, 40, 60, 80)
◇ Pocket Pen (kPa) ◇ (100, 200, 300, 400)

Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes
0	OR	**TOPSOIL (50mm)**, black, roots, saturated			
		CLAY, sandy, silty, trace gravel, very soft, medium plastic, grey, moist	1		Liquid Limit: 31 % Plastic Limit: 15 % Grain Size Distribution: Sand: 32 % Silt: 40 % Clay: 28 %
1		- oxides	2	6	
			3		
2	CI	- becoming very moist	4	2	
3			5		
4	SP	**SAND**, fine grained, silty, trace clay, trace gravel, very loose, brown, saturated	6	3	
	CI	**CLAY (TILL)**, sandy, silty, trace gravel, stiff, medium plastic, grey, very moist	7		
5			8	11	
6		**COMPLETION DEPTH: 5.8 m below ground surface**			Water Level: Well A - 1.1 m below ground surface on 8 July 2013. Well B - 0.9 m below ground surface on 8 July 2013.

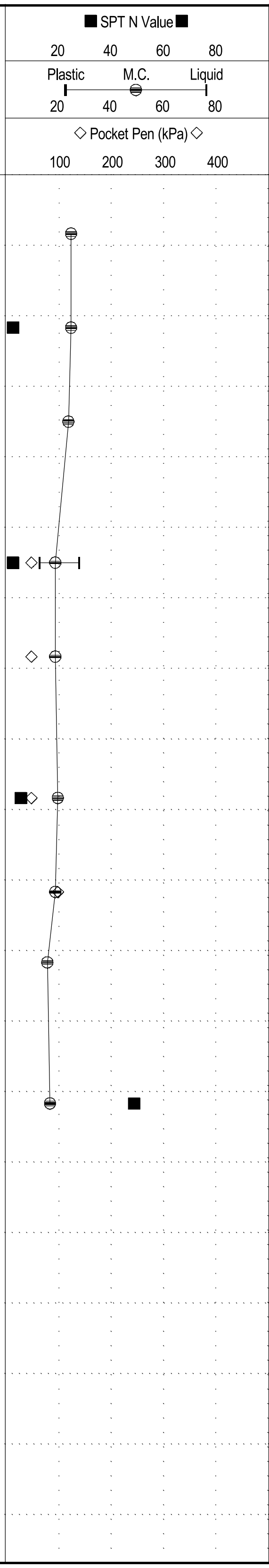
At Completion
Accumulation of water at 1.8 m below ground surface
Accumulation of slough at 3 m below ground surface
Slotted Standpipe A -
Installed to 5.8 m below ground surface
Slotted Standpipe B -
Installed to 3.0 m below ground surface
Backfilled with drill cuttings and bentonite plug

Columns: Soil Symbol; Sample Symbol; SLOTTED PIEZOMETER; SLOTTED PIEZOMETER; Elevation (m): 533, 532, 531, 530, 529, 528, 527, 526, 525. Depth (m): 0–9.

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-18**		
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032246 Easting: 52294	Driller: Canadian Geological Drilling Ltd.	Completion Date: 20/6/13	
Elevation: 532.7 m	Drill Method: 150mm Solid Stem		

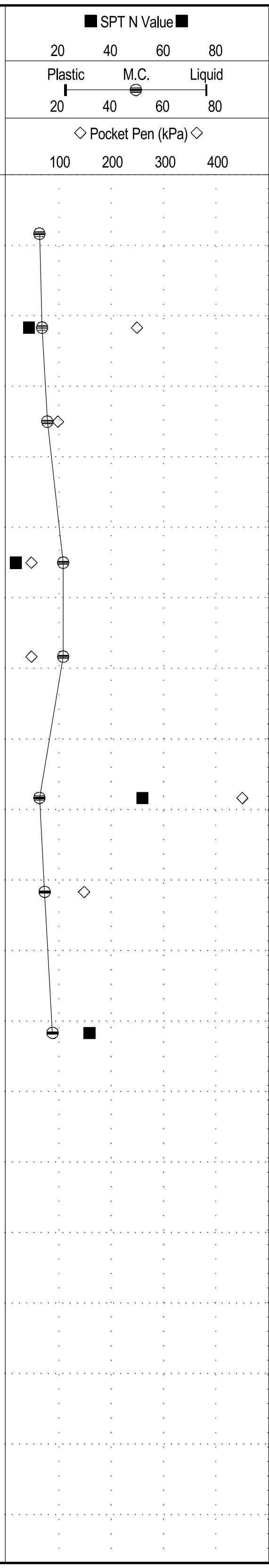
SolidEarth GEOTECHNICAL



Depth (m)	Soil Symbol	USCS	Material Description	Sample Symbol	Sample #	SPT (N-Value)	SLOTTED PIEZOMETER	Additional Data & Notes	Elevation (m)
0		OR	**TOPSOIL**, black, roots, wet						
			CLAY, and sand, silty, soft, low plastic, grey, very moist	Grab Sample	1				532
1				SPT Test	2	3			
				Grab Sample	3				531
2		CL	- becoming moist	SPT Test	4	3		Liquid Limit: 28 % Plastic Limit: 13 %	530
3				Grab Sample	5				529
4			- becoming firm	SPT Test	6	6			
				Grab Sample	7				528
5		SM	**SAND**, fine to medium grained, gravelly silty, and clay, loose, grey, moist	Grab Sample	8				527
6			- becoming dense	SPT Test	9	49			
			COMPLETION DEPTH: 6.3 m below ground surface					Water Level: 0.2 m below ground surface on 8 July 2013.	526
7			At Completion Accumulation of water at 0.9 m below ground surface Accumulation of slough material at 0.9 m below ground surface Slotted standpipe Installed to 6.0 m below ground surface Backfilled with drill Cuttings and bentonite plug						525
8									524
9									

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-19**	SolidEarth GEOTECHNICAL
Client Name: City of Cold Lake	Project #: PG13-1059	
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ	
Northing: 6032089 Easting: 51943	Driller: Canadian Geological Drilling Ltd.	Completion Date: 18/6/13
Elevation: 533.5 m	Drill Method: 150mm Solid Stem	Page 1 of 1



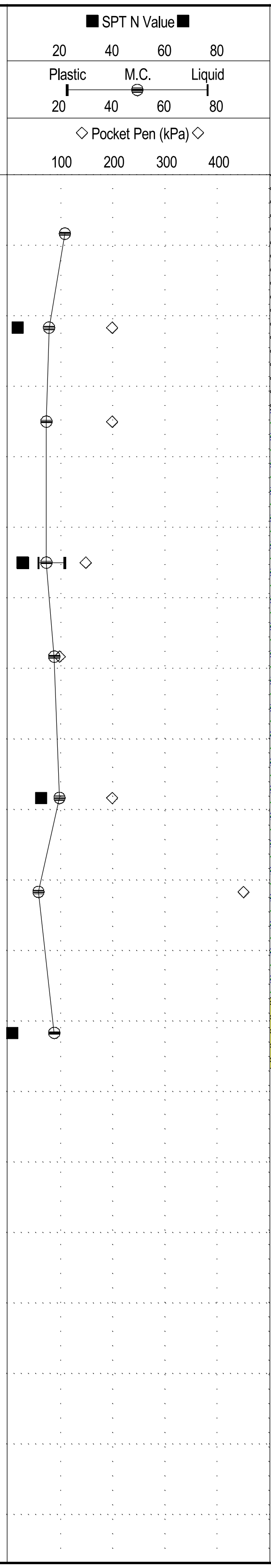
Depth (m)	USCS	Material Description	Sample Symbol	Sample #	SPT (N-Value)	Slotted Piezometer	Additional Data & Notes	Elevation (m)
0	OR	**TOPSOIL (50mm)**, black, roots, moist				Bentonite		
	CI	**FILL (CLAY)**, sandy, silty, trace gravel, medium plastic, brown, topsoil inclusions, moist	Grab Sample	1				533
1			SPT Test (N)	2	9	Drill Cuttings		
	OR	**TOPSOIL (50mm)** , black, moist						
	CI	**CLAY**, sandy, silty, trace gravel, medium plastic, sand lenses, grey, moist	Grab Sample	3				532
2	SM	**SAND**, fine grained, silty, clayey, gray, wet						
	CI	**CLAY**, sandy, silty, trace gravel, firm, medium plastic, grey, very moist	SPT Test (N)	4	4	Slotted		531
3		- seepage	Grab Sample	5				
	CI	**CLAY (TILL)**, sandy, silty, trace gravel, hard, medium plastic, grey, moist						530
4			SPT Test (N)	6	52			529
	SP	**SAND**, fine to medium grained, silty, trace clay, trace gravel, dense, grey, wet	Grab Sample	7			Low recovery between 4.7 and 5.3 m	
5						Slough		528
			SPT Test (N)	8	32			
6		**COMPLETION DEPTH: 5.8 m below ground surface**					Water Level: 2.9 m below ground surface on 8 July 2013.	527
7								526
8								525
9								

At Completion
Accumulation of water at 1.5 m below ground surface
Accumulation of slough material at 3 m below ground surface
Slotted standpipe installed to 5.2 m below ground surface
Backfilled with drill cuttings and bentonite plug

Sample Symbol: Shelby Tube | No Recovery | SPT Test (N) | Grab Sample | Split-Pen | Core

Backfill Symbol: Bentonite | Pea Gravel | Slough | Grout | Drill Cuttings | Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-20**		SolidEarth GEOTECHNICAL
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032098 Easting: 52097	Driller: Canadian Geological Drilling Ltd.		Completion Date: 18/6/13
Elevation: 534.7 m	Drill Method: 150mm Solid Stem		Page 1 of 1



Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
0	CI	**FILL (CLAY)**, sandy, silty, trace gravel, firm, medium plastic, brown, moist	1			534
1			2	4		
	CI	**CLAY (TILL)**, sandy, silty, trace gravel, firm, medium plastic, grey-brown, moist	3			533
2			4	6	Liquid Limit: 22 % Plastic Limit: 12 %	532
3			5			531
4		- seepage, sand lenses, stiff, grey	6	13		
			7			530
5	SP	**SAND**, fine grained, silty, trace clay, trace gravel, grey, very loose, wet	8	2		529
6		<u>**COMPLETION DEPTH: 5.8 m below ground surface**</u> <u>At Completion</u> Accumulation of water at 1.8 m below ground surface Accumulation of slough at 5.5 m below ground surface Slotted standpipe installed to 5.5 m below ground surface Backfilled with drill cuttings and bentonite plug			Water Level: 2.2 m below ground surface on 8 July 2013.	528
7						527
8						526
9						

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-21**	SolidEarth GEOTECHNICAL	
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032097 Easting: 52210	Driller: Canadian Geological Drilling Ltd.	Completion Date: 19/6/13	
Elevation: 533.6 m	Drill Method: 150mm Solid Stem	Page 1 of 1	

Column headings: Depth (m) | ■ SPT N Value ■ (20, 40, 60, 80); Plastic, M.C., Liquid (20, 40, 60, 80); ◇ Pocket Pen (kPa) ◇ (100, 200, 300, 400) | Soil Symbol | USCS | Material Description | Sample Symbol | Sample # | SPT (N-Value) | SLOTTED PIEZOMETER | Additional Data & Notes | Elevation (m)

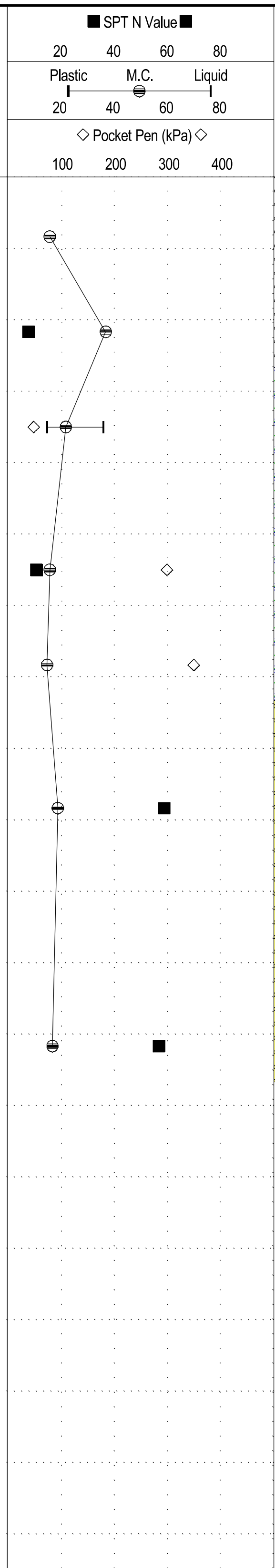
Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes
0	CI	**FILL (CLAY)**, sandy, silty, trace gravel, firm, medium plastic, grey-brown, moist	1		
1	OR	**TOPSOIL**, black, saturated	2	4	
	CI	**CLAY** , sandy, silty, trace gravel, sand lenses, medium plastic, grey brown, moist	3		
2	SP	**SAND**, fine grained, little silt, trace clay, trace gravel, loose, brown grey, wet	4		Grain Size Distribution Sand & Gravel: 88 % Silt & Clay: 12 %
	CI	**CLAY (TILL)**, sandy, silty, trace gravel, firm, medium plastic, grey, moist	5	3	
3			6		
4		- seepage	7		- SPT sampler in contact with rock
			8		
	SP	**SAND**, fine grained, trace silt, trace clay, gravelly, compact, grey, wet			Low auger recovery between 4.4 and 5.3 m
5			9		
			10	20	
6		**<u>COMPLETION DEPTH: 5.8 m below ground surface</u>**			Water Level: 1.0 m below ground surface on 8 July 2013.

<u>At Completion</u>
Accumulation of water at 1.2 m below ground surface
Accumulation of slough at 2.4 m below ground surface
Slotted standpipe installed to 3.9 m below ground surface
Backfilled with drill cuttings and bentonite plug

Depth scale (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Elevation scale (m): 533, 532, 531, 530, 529, 528, 527, 526, 525

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-22**		SolidEarth GEOTECHNICAL
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: Easting:	Driller: Canadian Geological Drilling Ltd.		Completion Date: 18/6/13
Elevation:	Drill Method: 150mm Solid Stem		Page 1 of 1

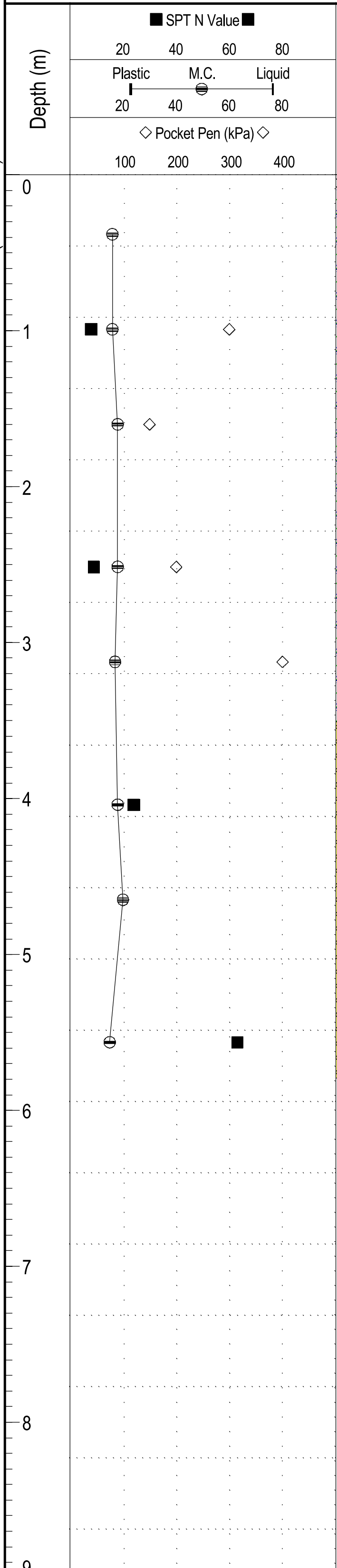


Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes
0	OR/CI	**FILL (CLAY & TOPSOIL)**, sandy, silty, medium plastic, moist	1		
		- becoming wet	2	8	
1	CI	**CLAY (TILL)**, sandy, silty,, trace gravel, firm, medium plastic, brown, moist	3		Liquid Limit: 36 % Plastic Limit: 15 % Grain Size Distribution Sand: 31 % Silt: 34 % Clay: 35 %
2		- becoming, stiff, sand lenses, grey	4	11	
3			5		
	SP	**SAND**, fine grained, little silt, trace clay, very dense, light brown, wet			
4			6	59	Low recovery between 3.8 and 5.3 m
		- seepage			
5		- trace gravel	7	57	
6		<u>**COMPLETION DEPTH: 5.8 m below ground surface**</u>			Standpipe Destoyed on 8 July 2013.
7					
8					
9					

<u>At Completion</u>
Accumulation of water at 2.1 m below ground surface
Accumulation of slough at 3.0 m below ground surface
Slotted standpipe installed to 5.8 m below ground surface
Backfilled with drill cuttings and bentonite plug

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-23**		SolidEarth GEOTECHNICAL
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6031969 Easting: 52088	Driller: Canadian Geological Drilling Ltd.		Completion Date: 18/6/13
Elevation: 535.1 m	Drill Method: 150mm Solid Stem		Page 1 of 1



Soil Symbol	USCS	Material Description	Sample Symbol	Sample #	SPT (N-Value)	Slotted Piezometer	Slotted Piezometer	Additional Data & Notes	Elevation (m)
	OR	**TOPSOIL (75mm)**, black, roots, saturated							535
	CI	**CLAY (TILL)**, sandy, silty,, trace gravel, stiff, medium plastic, brown, oxides, sand lenses, moist	Grab Sample	1					
			SPT Test (N)	2	8				534
			Grab Sample	3					
									533
			SPT Test (N)	4	9				
			Grab Sample	5					532
	SP	**SAND**, fine grained, little silt, trace clay, trace gravel, compact, brown, wet						Low auger recovery between 3.8 and 5.2 m	
			SPT Test (N)	6	24				531
		- seepage	Grab Sample	7					
									530
		- very dense	SPT Test (N)	8	63				
		COMPLETION DEPTH: 5.8 m below ground surface						Water Level: Well A - 2.6 m below ground surface on 8 July 2013. Well B - 2.6 m below ground surface on 8 July 2013.	529
		At Completion Accumulation of water at 2.1 m below ground surface Accumulation of slough at 3.0 m below ground surface Slotted Standpipe A - Installed to 5.8 m below ground surface Slotted Standpipe B - Installed to 2.4 m below ground surface Backfilled with drill cuttings and bentonite plug							528
									527

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

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Project Name: Meadows Subdivision	Borehole #: **BH13-24**
Client Name: City of Cold Lake	Project #: PG13-1059
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ
Northing: 6032370 Easting: 51497	Driller: Canadian Geological Drilling Ltd.
Elevation: 531.9 m	Drill Method: 150mm Solid Stem

SolidEarth GEOTECHNICAL

Completion Date: 19/6/13

■ SPT N Value ■ (20, 40, 60, 80) — Plastic, M.C., Liquid (20, 40, 60, 80) — ◇ Pocket Pen (kPa) ◇ (100, 200, 300, 400)

Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
0	OR	**TOPSOIL**, organic, roots, black, saturated	1			
	CI	**CLAY**, silty, trace sand, soft, medium plastic, grey, wet	2			
1			3	3		531
	CI	**CLAY (TILL)**, and sand, and silt, stiff, medium plastic, grey brown, moist	4			
2					Grain Size Distribution Sand: 36 % Silt: 35 % Clay: 29 %	530
		- seepage, grey	5	10		
3			6			529
4			7		SPT sampler in contact with rock	528
	SP	**SAND**, fine grained, silty, trace clay, grey, wet	8			
5						527
	CI	**CLAY (TILL)**, sandy, silty, hard, medium plastic, grey, moist	9	57		
6	SP	**SAND**, fine to medium grained, silty, trace clay, very dense, grey, wet			Low auger recovery between 5.8 and 6.3 m	526
					Grain Size Distribution Sand & Gravel: 91 % Silt & Clay: 9 %	
7			10	77/350		525
		<u>**COMPLETION DEPTH: 7.3 m below ground surface**</u>			Water Level: 1.0 m below ground surface on 8 July 2013.	
8						524
9						523

Plot values: 108 (M.C. near 0.4 m); 77/350 (SPT at 7 m).

Piezometer column: SLOTTED PIEZOMETER

<u>At Completion</u>
Accumulation of water at 0.9 m below ground surface
Accumulation of slough at 5.5 m below ground surface
Slotted Standpipe Installed to 5.5 m below ground surface
Backfilled with Drill Cuttings and Bentonite Plug

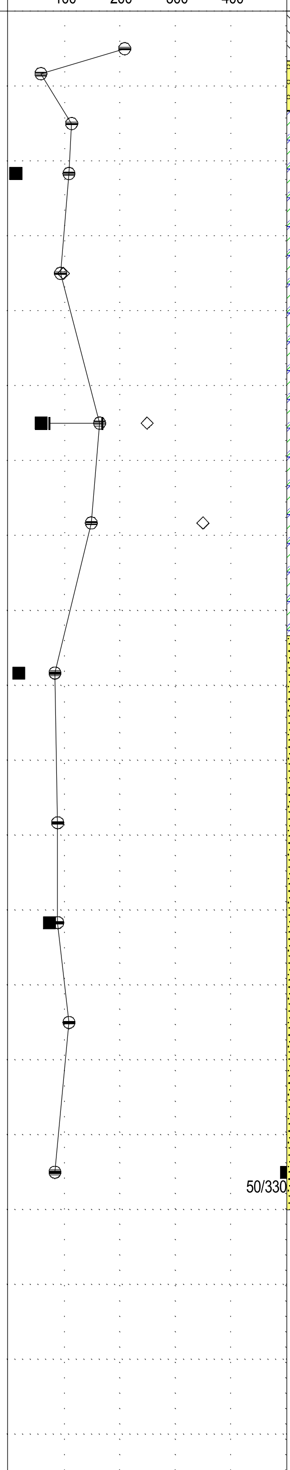
Sample Symbol: Shelby Tube, No Recovery, SPT Test (N), Grab Sample, Split-Pen, Core

Backfill Symbol: Bentonite, Pea Gravel, Slough, Grout, Drill Cuttings, Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-25**
Client Name: City of Cold Lake	Project #: PG13-1059
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ
Northing: 6032370 Easting: 51642	Driller: Canadian Geological Drilling Ltd. — Completion Date: 20/6/13
Elevation: 532 m	Drill Method: 150mm Solid Stem — Page 1 of 1

SolidEarth GEOTECHNICAL

Depth (m) | ■ SPT N Value ■ 20 40 60 80 | Plastic M.C. Liquid 20 40 60 80 | ◇ Pocket Pen (kPa) ◇ 100 200 300 400 | Soil Symbol | USCS | Material Description | Sample Symbol | Sample # | SPT (N-Value) | SLOTTED PIEZOMETER | Additional Data & Notes | Elevation (m)



Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
0	OR	**TOPSOIL**, black, roots, saturated	1			
	SP	**SAND**, fine grained, silty, clayey, gravelly, gray, saturated	2			
		CLAY (TILL), and sand, silty, sand lenses, soft, medium plastic, grey, oxides, wet	3			
1			4	3		531
			5			
2	CI	- becoming stiff			Liquid Limit: 34 % Plastic Limit: 15 % Grain Size Distribution: Sand: 38 % Silt: 33 % Clay: 29 %	530
			6	12		
3			7			529
4		**SAND**, fine to medium grained, silty, clayey, trace gravel, grey, loose, wet	8	4		528
5			9		Grain Size Distribution Sand & Gravel: 31 % Silt & Clay: 69 %	527
	SM		10	15		
6			11		Low auger recovery between 5.3 and 6.8 m	526
7		- becoming very dense	12	50/330		525
		COMPLETION DEPTH: 7.3 m below ground surface			Water Level: 0.5 m below ground surface on 8 July 2013.	
8		At Completion Accumulation of water at 0.3 m below ground surface Accumulation of slough at 0.3 m below ground surface Slotted Standpipe Installed to 5.5 m below ground surface Backfilled with Drill Cuttings and Bentonite Plug				524
9						

Sample Symbol: Shelby Tube | No Recovery | SPT Test (N) | Grab Sample | Split-Pen | Core

Backfill Symbol: Bentonite | Pea Gravel | Slough | Grout | Drill Cuttings | Sand

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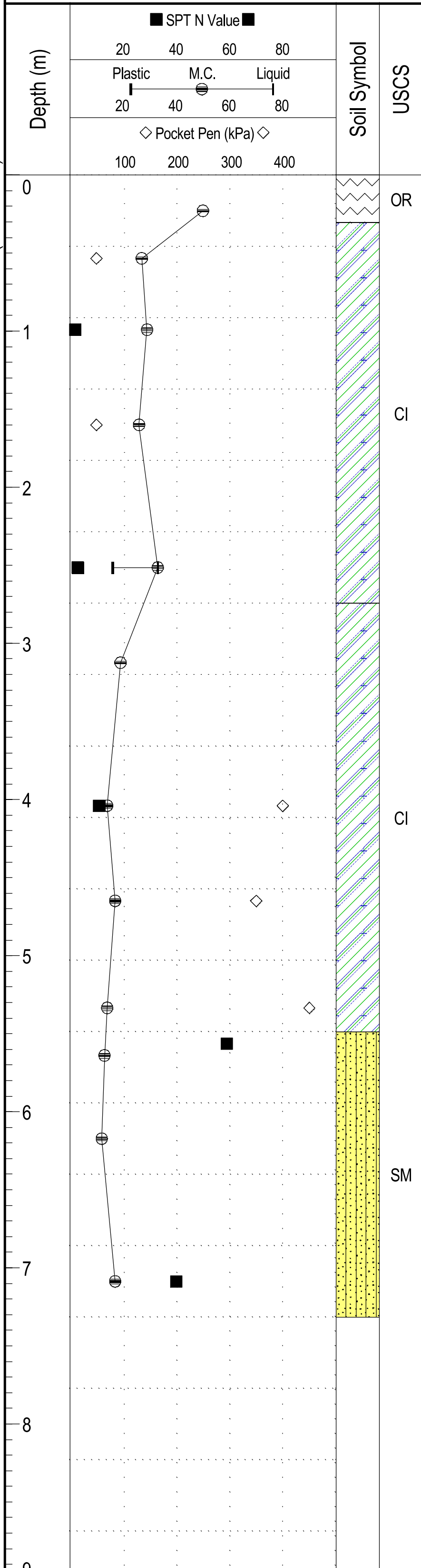
Project Name: Meadows Subdivision	Borehole #: **BH13-26**		
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032441 Easting: 51796	Driller: Canadian Geological Drilling Ltd.	Completion Date: 20/6/13	
Elevation: 531.9 m	Drill Method: 150mm Solid Stem	Page 1 of 1	

SolidEarth GEOTECHNICAL



Material Description	Sample #	SPT (N-Value)	Additional Data & Notes
TOPSOIL, black, organic, roots, saturated	1		
CLAY, sandy, silty, trace gravel, oxides, soft, medium plastic, grey, wet	2		
	3	2	
	4		
- and sand	5	3	Liquid Limit: 33 % Plastic Limit: 16 % Grain Size Distribution Gravel: 1 % Sand: 37 % Silt: 33 % Clay: 29 %
CLAY (TILL), sandy, silty, stiff, medium plastic, grey, moist	6		
	7	11	
	8		
SAND, fine to medium grained, silty, clayey, trace gravel, dense, grey, moist	9	59	
	10		
	11	40	
COMPLETION DEPTH: 7.3 m below ground surface			Water Level: 1.0 m below ground surface on 8 July 2013.

At Completion
Accumulation of water at 2.1 m below ground surface
Accumulation of slough at 6.4 m below ground surface
Slotted Standpipe Installed to 6.4 m below ground surface
Backfilled with drill cuttings and bentonite plug

SLOTTED PIEZOMETER

Elevation (m): 531, 530, 529, 528, 527, 526, 525, 524, 523

Sample Symbol: Shelby Tube, No Recovery, SPT Test (N), Grab Sample, Split-Pen, Core

Backfill Symbol: Bentonite, Pea Gravel, Slough, Grout, Drill Cuttings, Sand

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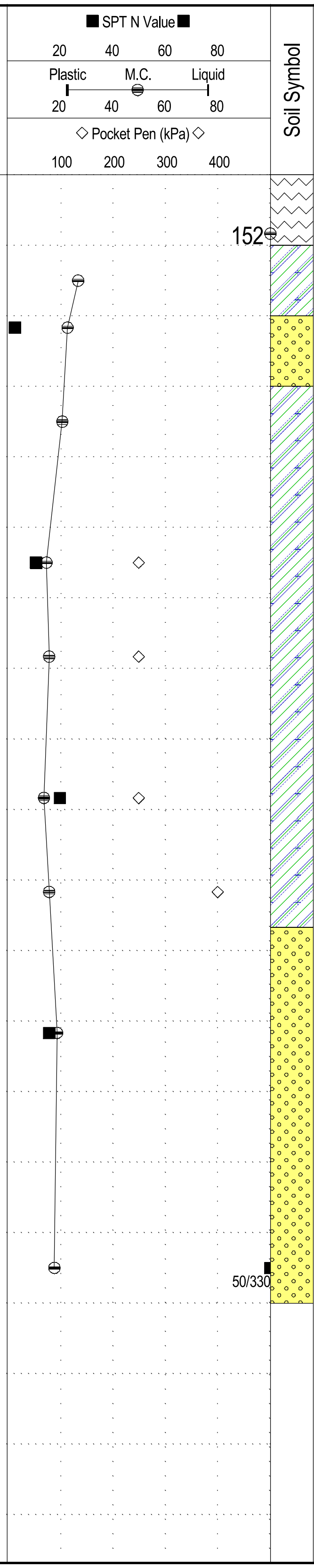
Project Name: Meadows Subdivision	Borehole #: **BH13-27**		SolidEarth GEOTECHNICAL
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032283 Easting: 51534	Driller: Canadian Geological Drilling Ltd.		Completion Date: 19/6/13
Elevation: 532.1 m	Drill Method: 150mm Solid Stem		Page 1 of 1

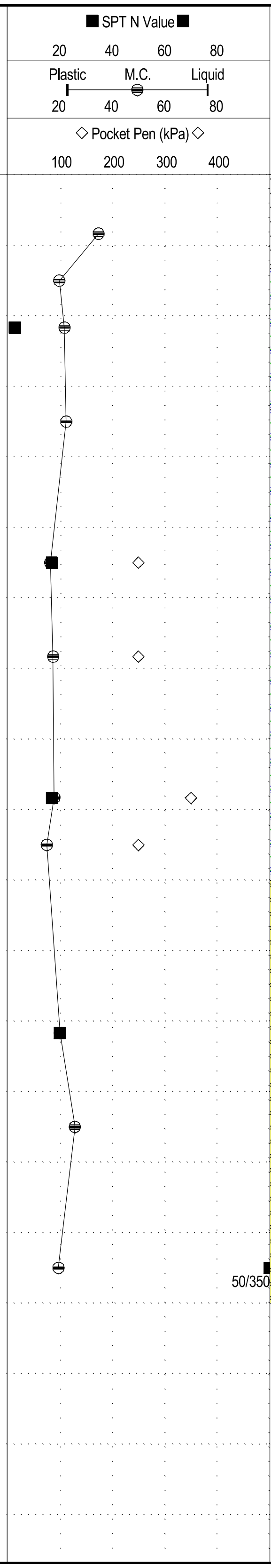


Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
0	OR	**TOPSOIL**, organic, roots, saturated, black	1			532
	CI	**CLAY**, silty, trace sand, soft, medium plastic, grey, moist - seepage	2			
1	SP	**SAND**, fine grained, silty, clayey, some gravel, very loose, brown, saturated	3	3		531
	CI	**CLAY (TILL)**, and sand, silty, some gravel, medium plastic, brown, very moist	4			
2		- becoming grey, sandy, stiff, moist	5	11		530
3	CI		6			529
4		- becoming very stiff	7	20		528
			8			
5	SP	**SAND**, fine to medium grained, silty, trace clay, trace gravel, compact, grey, wet	9	16	Very low auger recovery between 5.3 and 6.8 m	527
6	SP					526
7		- becoming very dense	10	50/330		525
8		**<u>COMPLETION DEPTH: 7.3 m below ground surface</u>** <u>At Completion</u> Accumulation of water at 0.6 m below ground surface Accumulation of slough at 3.7 m below ground surface Slotted Standpipe A - Installed to 5.5 m below ground surface Slotted Standpipe B - Installed to 3.7 m below ground surface Backfilled with drill cuttings and bentonite plug			Water Level: Well A - 0.1 m below ground surface on 8 July 2013. Well B - 1.4 m below ground surface on 8 July 2013.	524
9						

Sample Symbol: Shelby Tube, No Recovery, SPT Test (N), Grab Sample, Split-Pen, Core

Backfill Symbol: Bentonite, Pea Gravel, Slough, Grout, Drill Cuttings, Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-28**	SolidEarth GEOTECHNICAL	
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ		
Northing: 6032302 Easting: 51614	Driller: Canadian Geological Drilling Ltd.	Completion Date: 19/6/13	
Elevation: 532.1 m	Drill Method: 150mm Solid Stem	Page 1 of 1	

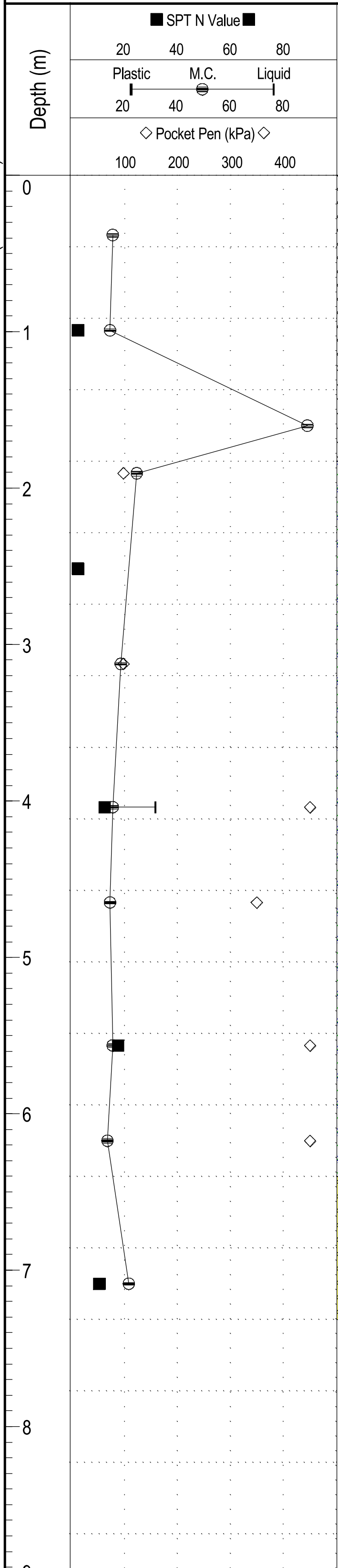


Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
0	OR	**TOPSOIL**, organic, black, roots, saturated	1			532
	CL	**CLAY**, and sand, silty, soft, medium plastic, grey, sand lenses, very moist	2			
1			3	3		531
	CI	**CLAY (TILL)**, sandy, silty, trace gravel, soft, medium plastic, grey-brown, very moist	4			
2		- becoming very stiff, grey, moist	5	17		530
3			6			529
		- sand lenses				
4			7	17		528
			8			
5	SP	**SAND**, fine to medium grained, silty, trace clay, compact, grey, wet				527
			9	20	Low auger recovery between 4.6 and 6.8 m	
6			10			526
7			11	50/350		525
8		**COMPLETION DEPTH: 7.3 m below ground surface** At Completion Accumulation of water at 1.5 m below ground surface Accumulation of slough at 5.5 m below ground surface Slotted Standpipe A - Installed to 5.5 m below ground surface Slotted Standpipe B - Installed to 3.4 m below ground surface Backfilled with drill cuttings and bentonite plug			Water Level: Well A - 0,6 m below ground surface on 8 July 2013. Well B - 0.1 m below ground surface on 8 July 2013.	524
9						

Columns: Soil Symbol, Sample Symbol, SLOTTED PIEZOMETER, SLOTTED PIEZOMETER

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-30**	SolidEarth GEOTECHNICAL
Client Name: City of Cold Lake	Project #: PG13-1059	
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ	
Northing: 6032216 Easting: 51498	Driller: Canadian Geological Drilling Ltd.	Completion Date: 18/6/13
Elevation: 533.6 m	Drill Method: 150mm Solid Stem	Page 1 of 1

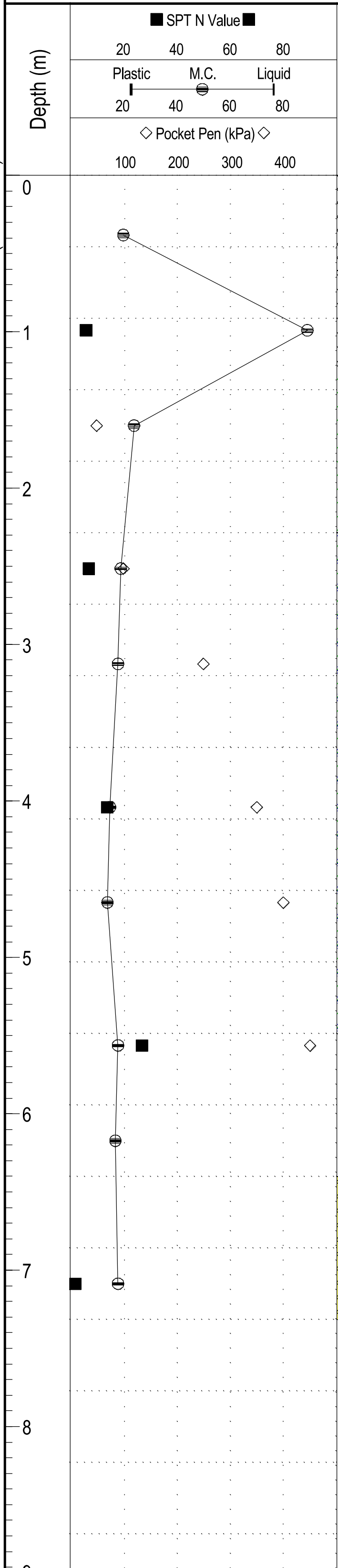


Depth (m)	Soil Symbol	USCS	Material Description	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
0 – 1.2	Fill	CI	**FILL (CLAY)**, silty, sandy, trace gravel, soft, medium plastic, brown, topsoil inclusions/roots, very moist	1 (Grab), 2 (SPT)	3		533
1.2 – 1.8	Topsoil	OR	**TOPSOIL**, black, roots, wet	3 (Grab)			532
1.8 – 3.6	Clay	CI	**CLAY**, sandy, silty, trace gravel, soft, medium plastic, brown, moist	4 (Grab), No Recovery, 5 (Grab)	3		531
3.6 – 6.4	Clay (Till)	CI	**CLAY (TILL)**, sandy, silty, trace gravel, stiff, medium plastic, brown, moist - becoming grey, very stiff	6 (SPT), 7 (Grab), 8 (SPT), 9 (Grab)	13, 18	Liquid Limit: 32 % Plastic Limit: 14 %	530, 529, 528
6.4 – 7.3	Sand	SP	**SAND**, fine to medium grained, trace silt, trace clay, fine, grey, wet	10 (SPT)	11		527
7.3			**COMPLETION DEPTH: 7.3 m below ground surface** At Completion Accumulation of water at 4.0 m below ground surface No accumulation of slough material Slotted standpipe installed to 7.3 m below ground surface Borehole backfilled with drill cuttings and bentonite plug			Water Level: 2.1 m below ground surface on 8 July 2013.	526, 525

SLOTTED PIEZOMETER: Bentonite 0 – 0.9 m; Drill Cuttings 0.9 – 7.3 m; slotted section approx. 4.3 – 7.3 m.

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision		Borehole #: **BH13-31**	SolidEarth GEOTECHNICAL
Client Name: City of Cold Lake		Project #: PG13-1059	
Site: Cold Lake South		Logged By: MH / Reviewed By: JJ	
Northing: 6032212 Easting: 51637		Driller: Canadian Geological Drilling Ltd.	Completion Date: 18/6/13
Elevation: 533 m		Drill Method: 150mm Solid Stem	Page 1 of 1



USCS	Material Description	Sample Symbol	Sample #	SPT (N-Value)	Slotted Piezometer	Additional Data & Notes	Elevation (m)
Fill	**FILL (CLAY)**,, sandy, silty, medium plastic, brown, organics, moist	Grab Sample	1		Bentonite		
OR	**TOPSOIL**, black, roots, saturated	SPT Test (N)	2	6	Bentonite / Drill Cuttings		532
CL	**CLAY**, silty, trace sand, trace gravel, firm, low plastic, grey, moist	Grab Sample	3		Drill Cuttings		531
CI	**CLAY (TILL)**, sandy, silty, some gravel, firm, medium plastic, grey-brown, moist	SPT Test (N)	4	7	Drill Cuttings		530
		Grab Sample	5				
	- becoming stiff, grey, oxides	SPT Test (N)	6	14	Slotted		529
		Grab Sample	7				528
	- becoming very stiff						
ML	**SILT**, sandy, clayey, hard, low plastic, grey, moist	SPT Test (N)	8	27			527
		Grab Sample	9				
SP	**SAND**, fine to medium grained, silty, trace clay, trace gravel, very loose, grey, wet	SPT Test (N)	10	2	Slough		526
	<u>**COMPLETION DEPTH: 7.3 m below ground surface**</u>					Water Level: 1.7 m below ground surface on 8 July 2013.	525

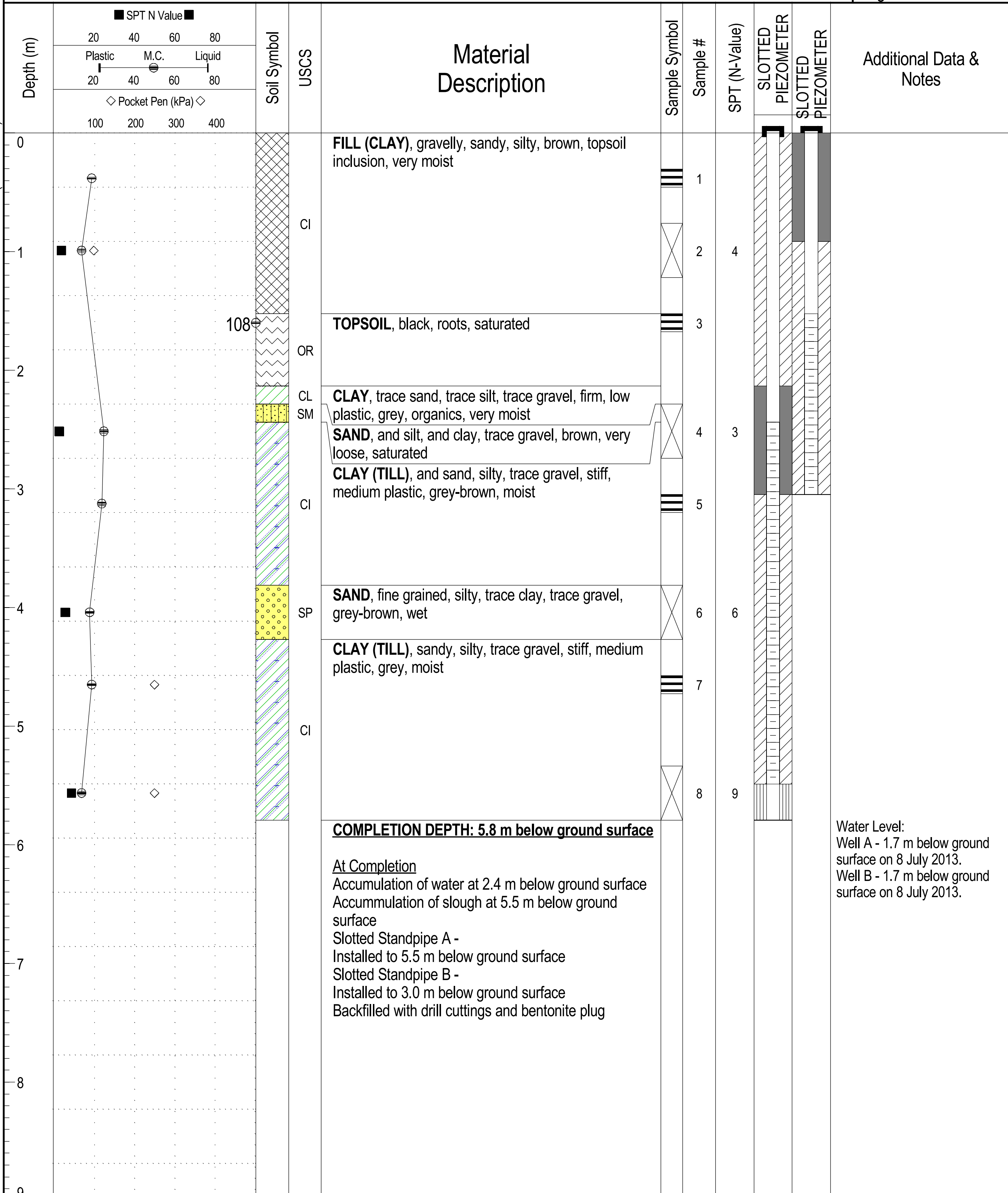
<u>At Completion</u>
Accumulation of water at 2.1 m below ground surface
Accummulation of slough material at 6.7 m below ground surface
Slotted standpipe installed to 6.7 m below ground surface
Backfilled with drill cuttings and bentonite plug

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-32**
Client Name: City of Cold Lake	Project #: PG13-1059
Site: Cold Lake South	Logged By: MH / Reviewed By: JJ
Northing: 6032219 Easting: 51805	Driller: Canadian Geological Drilling Ltd.
Elevation: 533.7 m	Drill Method: 150mm Solid Stem

SolidEarth GEOTECHNICAL

Completion Date: 18/6/13



Depth (m)	USCS	Material Description	Sample #	SPT (N-Value)
0 – 1.5	CI	**FILL (CLAY)**, gravelly, sandy, silty, brown, topsoil inclusion, very moist	1, 2	4
1.5 – 2.1	OR	**TOPSOIL**, black, roots, saturated	3	
2.1 – 2.3	CL	**CLAY**, trace sand, trace silt, trace gravel, firm, low plastic, grey, organics, very moist		
2.3 – 2.5	SM	**SAND**, and silt, and clay, trace gravel, brown, very loose, saturated	4	3
2.5 – 3.8	CI	**CLAY (TILL)**, and sand, silty, trace gravel, stiff, medium plastic, grey-brown, moist	5	
3.8 – 4.3	SP	**SAND**, fine grained, silty, trace clay, trace gravel, grey-brown, wet	6	6
4.3 – 5.8	CI	**CLAY (TILL)**, sandy, silty, trace gravel, stiff, medium plastic, grey, moist	7, 8	9

COMPLETION DEPTH: 5.8 m below ground surface

At Completion
Accumulation of water at 2.4 m below ground surface
Accummulation of slough at 5.5 m below ground surface
Slotted Standpipe A -
Installed to 5.5 m below ground surface
Slotted Standpipe B -
Installed to 3.0 m below ground surface
Backfilled with drill cuttings and bentonite plug

Additional Data & Notes

Water Level:
Well A - 1.7 m below ground surface on 8 July 2013.
Well B - 1.7 m below ground surface on 8 July 2013.

Elevation (m): 533, 532, 531, 530, 529, 528, 527, 526, 525

Depth (m): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

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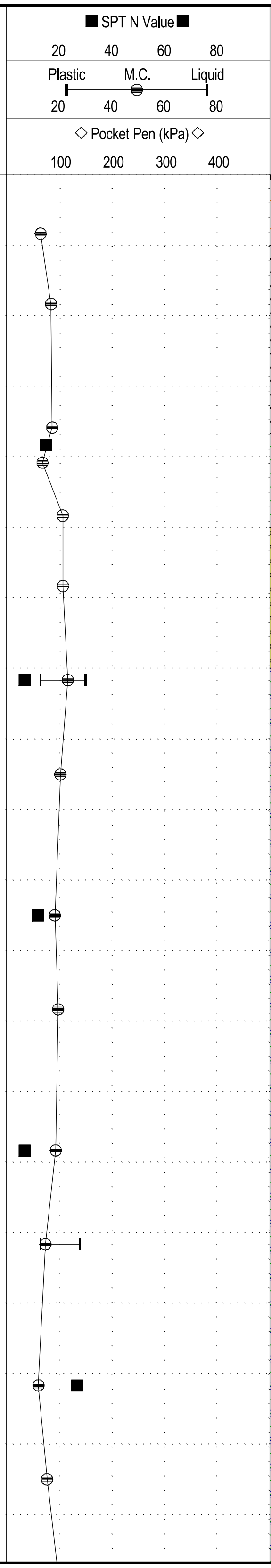
Project Name: Meadows Subdivision	Borehole #: **BH13-35**
Client Name: City of Cold Lake	Project #: PG13-1059
Site: Cold Lake South	Logged By: TF / Reviewed By: JJ
Northing: 6032428 Easting: 51015	Driller: All Service Drilling Inc.
Elevation: 535.7 m	Drill Method: 150mm Solid Stem

SolidEarth GEOTECHNICAL

Completion Date: 18/7/13



Depth (m)	USCS	Material Description	Sample Symbol	Sample #	SPT (N-Value)	Additional Data & Notes	Elevation (m)
0		**ASPHALT (50mm)**					
		FILL, some gravel, some sand, some silt, some clay, brown, moist	Grab Sample	1			
		FILL (CLAY), sandy, silty, trace gravel, medium plastic, grey, moist, trace organcis	Grab Sample	2			535
1							
	CL	**CLAY (TILL)**, and sand, silty, trace gravel, firm, low plastic, light grey, moist, sand pockets/lenses	SPT Test (N)	3	15		534
2			Grab Sample	4			
		SAND, fine grained, some silt, some clay, brown, wet	Grab Sample	5		Grain Size Distribution: Sand: 60 % Silt: 22 % Clay: 18 %	533
3	CI	**CLAY**, and sand, and silt, medium plastic, grey, very moist	SPT Test (N)	6	7	Liquid Limit: 30 % Plastic Limit: 13 %	532
4		**CLAY (TILL)**, sandy, silty, trace gravel, firm to stiff, medium plastic, grey, moist, trace oxides	Grab Sample	7			
			SPT Test (N)	8	12		531
5			Grab Sample	9			530
6	CI	- and sand	SPT Test (N)	10	7		529
7		- becoming very stiff	Grab Sample	11		Liquid Limit: 28 % Plastic Limit: 13 % Grain Size Distribution: Gravel: 1 % Sand: 39 % Silt: 35 % Clay: 25 %	528
8			SPT Test (N)	12	27		
			Grab Sample	13			527
9							

SLOTTED PIEZOMETER

Sample Symbol: Shelby Tube, No Recovery, SPT Test (N), Grab Sample, Split-Pen, Core

Backfill Symbol: Bentonite, Pea Gravel, Slough, Grout, Drill Cuttings, Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-35**
Client Name: City of Cold Lake	Project #: PG13-1059
Site: Cold Lake South	Logged By: TF / Reviewed By: JJ
Northing: 6032428 Easting: 51015	Driller: All Service Drilling Inc.
Elevation: 535.7 m	Drill Method: 150mm Solid Stem

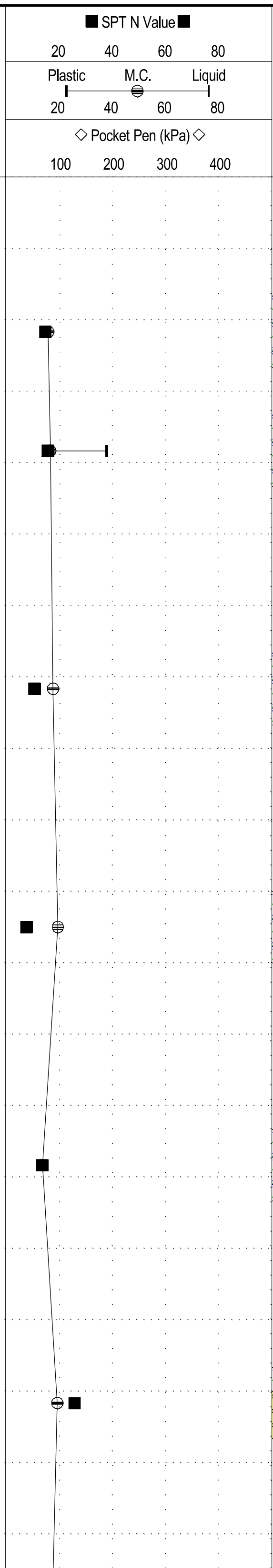
SolidEarth GEOTECHNICAL

Completion Date: 18/7/13

Depth (m)	SPT N Value / Plastic M.C. Liquid / Pocket Pen (kPa)	Soil Symbol	USCS	Material Description	Sample Symbol	Sample #	SPT (N-Value)	SLOTTED PIEZOMETER	Additional Data & Notes	Elevation (m)
9			CI							
				SAND, fine grained, trace silt, trace clay, grey, wet	Grab Sample	14			Grain Size Distribution: Sand and Gravel: 95 % Silt and Clay: 5 %	526
10										525
11										524
12										523
13										522
				COMPLETION DEPTH: 13.7 m below ground surface At Completion Accumulation of water at 1.8 m below ground surface Accummulation of slough at 5.9 m below ground surface Slotted Standpipe Installed to 7.9 m below ground sur					Standpipe was found destroyed on 10 October 2013	
14										521
15										520
16										519
17										518
18										

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

Project Name: Meadows Subdivision	Borehole #: **BH13-36**	SolidEarth GEOTECHNICAL	
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: TF / Reviewed By: JJ		
Northing: 6032416 Easting: 50889	Driller: All Service Drilling Inc.	Completion Date: 18/7/13	
Elevation: 535.4 m	Drill Method: 200mm Hollow Stem	Page 1 of 2	



Depth (m)	Soil Symbol	USCS	Material Description	Sample Symbol	Sample #	SPT (N-Value)	Slotted Piezometer	Additional Data & Notes	Elevation (m)
0									535
1		CI	**CLAY (TILL)**, sandy, silty, trace gravel, stiff, medium plastic, grey-brown, moist, sand/silt pockets	SPT	1	15			534
2		CI	**CLAY (TILL)**, sandy, silty, trace gravel, stiff, medium plastic, grey-brown, moist, sand pockets	SPT	2	16		Liquid Limit: 38 % Plastic Limit: 17 %	533
3		CI	**CLAY (TILL)**, sandy, silty, trace gravel, firm, medium plastic, grey-brown, moist, trace oxides	SPT	3	11			532
4									531
5		CI	**CLAY (TILL)**, sandy, silty, trace gravel, firm, medium plastic, grey, moist to very moist	SPT	4	8			530
6		CI	**CLAY (TILL)**, sandy, silty, trace gravel, firm, medium plastic, grey, moist	SPT	5	14			529
7									528
8		CI	**CLAY (TILL)**, sandy, silty, trace gravel, firm, medium plastic, grey, moist	SPT	6	26			527
			SAND, fine grained, trace silt, trace clay, compact, grey, wet						
9									

Sample Symbol	Shelby Tube	No Recovery	SPT Test (N)	Grab Sample	Split-Pen	Core
Backfill Symbol	Bentonite	Pea Gravel	Slough	Grout	Drill Cuttings	Sand

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Project Name: Meadows Subdivision	Borehole #: **BH13-36**		SolidEarth GEOTECHNICAL
Client Name: City of Cold Lake	Project #: PG13-1059		
Site: Cold Lake South	Logged By: TF / Reviewed By: JJ		
Northing: 6032416 Easting: 50889	Driller: All Service Drilling Inc.		Completion Date: 18/7/13
Elevation: 535.4 m	Drill Method: 200mm Hollow Stem		Page 2 of 2

Depth (m)	SPT N Value / Plastic M.C. Liquid / Pocket Pen (kPa)	Soil Symbol	USCS	Material Description	Sample Symbol	Sample #	SPT (N-Value)	SLOTTED PIEZOMETER	Additional Data & Notes	Elevation (m)
9										
				SAND, fine grained, trace silt, trace clay,, compact, grey, wet	SPT	7	39		Grain Size Distribution: Sand and Gravel: 98 % Silt and Clay: 2 %	526
10										525
	50/150			**SAND**, fine grained, trace silt, trace clay, compact, grey, wet	SPT	9	50/150		Water Level: 3.6 m below ground surface on 10 Ocotber 2013	
11				**COMPLETION DEPTH: 11.1 m below ground surface**						524
				At Completion Accumulation of water at 2.9 m below ground surface Accummulation of slough at 4.0 m below ground surface Slotted Standpipe Installed to 7.0 m below ground sur						
12										523
13										522
14										521
15										520
16										519
17										518
18										

SPT N Value axis: 20 40 60 80; Plastic M.C. Liquid axis: 20 40 60 80; Pocket Pen (kPa) axis: 100 200 300 400

Sample Symbol: Shelby Tube, No Recovery, SPT Test (N), Grab Sample, Split-Pen, Core

Backfill Symbol: Bentonite, Pea Gravel, Slough, Grout, Drill Cuttings, Sand

SolidEarth Geotechnical Inc.
www.solidearth.ca

Moisture - Density Relationship Report

Project Name: Meadows Subdivision
Project No.: PG13-1059
Location: Cold Lake
Client: City of Cold Lake

E-Mail To:

Sample No.: BH 24
Date Sampled: 21-Jun-13
Sampled By: SolidEarth/JS
Date Received: 21-Jun-13
Sample Source: BH 24 (0.8m to 2.3 m)

Rammer Type
[X] Auto
[ ] Manual

Preparation
[X] Dry
[ ] Moist

Percent Retained on:
[ ] 4.75 mm Sieve
[ ] 9.50 mm Sieve
[ ] 19.0 mm Sieve

MAXIMUM DRY DENSITY: 1901 kg/m^3

OPTIMUM MOISTURE CONTENT: 12.6 %

Moisture Content (%)	Dry Density (kg/m^3)
10.2	1853
13.1	1899
15.1	1863
17.0	1798
18.8	1717

SOIL DESCRIPTION:

CLAY

COMMENTS:

SolidEarth Geotechnical Inc.

Thomas Feeley, P.Eng

Compaction Standard: [X] **ASTM D698** [ ] **ASTM D1557** [ ] **ASTM D558** **Method:** [ ]

J.R. Paine & Associates Ltd.

CONSULTING AND TESTING ENGINEERS

EDMONTON - GRANDE PRAIRIE - WHITEHORSE - PEACE RIVER

COEFFICIENT OF PERMEABILITY

CLIENT:	SolidEarth Geotechnical Inc.	**DATE:**	July 27, 2013
PROJECT:	Meadows Subdivision	**TECH:**	LK
LOCATION:	Cold Lake, Alberta	**SAMPLE:**	BH 24
JOB NO.:	4695-1	**DEPTH:**	0.8-2.3m
REMARKS:	Sample Delivered by Client		

Mass of mold (g)	2023.3
Mass of mold & initial sample (g)	2624.0
Mass of mold & final sample (g)	2632.1
Mass of mold & dry sample (g)	2545.5
Calculated dry mass (g)	522.2
'L' length of sample (cm)	3.52
Diameter of sample (cm)	10.15
'A' area of sample (cm^2)	80.9
Calculated dry density (kg/m^3)	1835
Sample compaction (%)	96.5
Hydraulic driving head (psi)	10.0
'h' Hydraulic driving head (cm H_20)	703.0

Moisture Content Determination

Mass of wet initial sample (g)	600.7
Moisture content of initial sample (%)	15.037%
Mass of wet final sample (g)	608.8
Moisture content of final sample (%)	16.6%
Standard Proctor density (kg/m^3)	1901
Optimum moisture (%)	12.6
Specific Gravity of Soil	2.70
Initial Zero Air Voids Density (kg/m^3)	1920

Reading	Date (MM/DD/YY HH:MM)	Burette reading (cm^3)	Burette refilled to (cm^3)	Flow Volume 'V' (cm^3)	Duration 't' (s)	Flow Rate 'Q' =V/t (cm^3/s)
1	29/07/2013 8:21	---	96.6	---	---	---
2	29/07/2013 20:22	91.3	91.3	5.3	43260	1.23E-04
3	30/07/2013 7:10	87.2	87.2	4.1	38880	1.05E-04
4	30/07/2013 17:15	83.2	83.2	4.0	36300	1.10E-04
5	31/07/2013 7:00	78.2	78.2	5.0	49500	1.01E-04
6	31/07/2013 17:28	74.4	74.4	3.8	37680	1.01E-04
7	01/08/2013 6:59	69.6	69.6	4.8	48660	9.86E-05

'Q' Average Flow Rate (cm^3/s) = 1.03E-04

COEFFICIENT OF PERMEABILITY

$$k\ (cm/s) = \frac{Q\ (cm^3/s) \times L\ (cm)}{h\ (cm) \times A\ (cm^2)} = 6.38\text{E-}09\ cm/s$$

'**k**' Coefficient of Permeability = 6.38E-09 cm/s

= 6.38E-11 m/s

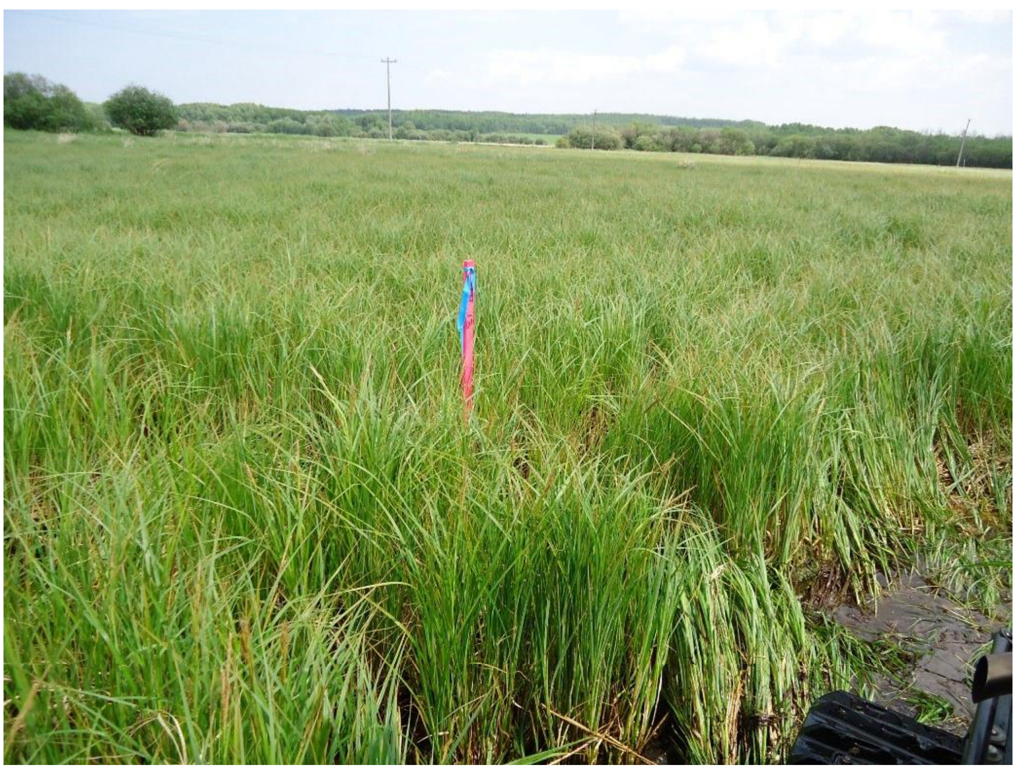
Appendix A

Photographs Taken During the Field Investigation

Photograph 1: Near BH13-35 looking west (55th Avenue right-of-way)

Photograph 2: North of lift station (Building 8) looking west

Photograph 3: Near BH13-13 (north of lift station) looking north



Photograph 4: Looking northeast from BH13-13

Photograph 5: Near BH13-25 looking south

Photograph 6: Near BH13-31 looking west

Photograph 7: North of 49th Street and 54th Avenue intersection looking north

Photograph 8: North of 49th Street and 54th Avenue intersection looking east

Photograph 9: North of BH13-21 looking north

Appendix B

Explanation of Terms and Symbols

EXPLANATION OF TERMS & SYMBOLS

The terms and symbols used on the borehole logs to summarize the results of the field investigation and laboratory testing are described on the following two pages.

1. VISUAL TEXTURAL CLASSIFICATION ON MINERAL SOILS

CLASSIFICATION	APPARENT PARTICLE SIZE	VISUAL IDENTIFICATION
Boulders	> 200 mm	> 200 mm
Cobbles	75 mm to 200 mm	75 mm to 200 mm
Gravel	4.75 mm to 75 mm	5 mm to 75 mm
Sand	0.075 mm to 4.75 mm	Visible particles to 5 mm
Silt	0.002 mm to 0.075 mm	Non-plastic particles, not visible to naked eye
Clay	< 0.002 mm	Plastic particles, not visible to naked eye

2. TERMS FOR CONSISTENCY & DENSITY OF SOILS

Cohesionless Soils

DESCRIPTIVE TERM	APPROXIMATE SPT "N" VALUE
Very Dense	> 50
Dense	30 to 50
Compact	10 to 30
Loose	4 to 10
Very Loose	< 4

Cohesive Soils

DESCRIPTIVE TERM	UNDRAINED SHEAR STRENGTH	APPROXIMATE SPT "N" VALUE
Hard	>200 kPa	> 30
Very Stiff	100 to 200 kPa	15 to 30
Stiff	50 to 100 kPa	8 to 15
Firm	25 to 50 kPa	4 to 8
Soft	10 to 25 kPa	2 to 4
Very Soft	< 10 kPa	< 2

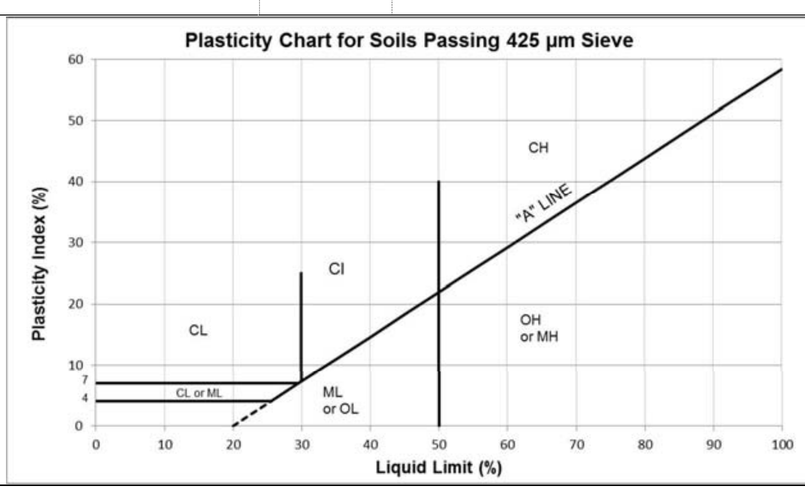
* SPT "N" Values – Refers to the number of blows by a 63.5 kg hammer dropped 760 mm to drive a 50 mm diameter split spoon sampler for a distance of 300 mm after an initial penetration of 150 mm.

3. SYMBOLS USED ON BOREHOLE LOGS

SYMBOL	DESCRIPTION	SYMBOL	DESCRIPTION
N(■)	Standard Penetration Test (CSA A119 1-60)	SO_4	Concentration of Water-Soluble Sulphate
N_d	Dynamic Cone Penetration Test	C_u	Undrained Shear Strength
pp (♦)	Pocket Penetrometer Strength	γ	Unit Weight of Soil or Rock
q_u	Unconfined Compressive Strength	γ_d	Dry Unit Weight of Soil or Rock
w (●)	Natural Moisture Content (ASTM D2216)	ρ	Density of Soil or Rock
w_L	Liquid Limit (ASTM D 4318)	ρ_d	Dry Density of Soil or Rock
w_P	Plastic Limit (ASTM D 4318)	▽	Short-Term Water Level
I_P	Plastic Index	▼	Long-Term Water Level

MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

MAJOR DIVISION			GROUP SYMBOL	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 75 µm)	**GRAVELS** (MORE THAN HALF COARSE GRAINS LARGER THAN 4.75mm)	CLEAN GRAVELS (LITTLE OR NO FINES)	**GW**	WELL GRADED GRAVELS AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	$C_u = D_{60}/D_{10} > 4$ $C_c = (D_{30})^2/(D_{10} \times D_{60}) = 1$ to 3	
			GP	POORLY GRADED GRAVELS AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		GRAVELS (WITH SOME FINES)	**GM**	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW 'A' LINE I_p LESS THAN 4
			GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE 'A' LINE I_p MORE THAN 7
	SANDS (MORE THAN HALF COARSE GRAINS SMALLER THAN 4.75mm)	CLEAN SANDS (LITTLE OR NO FINES)	**SW**	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_u = D_{60}/D_{10} > 6$ $C_c = (D_{30})^2/(D_{10} \times D_{60}) = 1$ to 3	
			SP	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	NOT MEETING ALL GRADATION REQUIREMENTS FOR SW	
		SANDS (WITH SOME FINES)	**SM**	SILTY SANDS, SAND-SILT MIXTURES	CONTENT OF FINES EXCEEDS 12%	ATTERBERG LIMITS BELOW 'A' LINE I_p LESS THAN 4
			SC	CLAYEY SANDS, SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE 'A' LINE I_p MORE THAN 7
FINE GRAINED SOILS (MORE THAN HALF BY WEIGHT SMALLER THAN 75 µm)	**SILTS** (BELOW 'A' LINE NEGLIGIBLE ORGANIC CONTENT)	$W_L < 50$ %	**ML**	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (SEE BELOW)	
		$W_L > 50$ %	**MH**	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS		
	CLAYS (ABOVE 'A' LINE NEGLIGIBLE ORGANIC CONTENT)	$W_L < 30$ %	**CL**	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS		
		30 % $< W_L <$ 50 %	**CI**	INORGANIC CLAYS OR MEDIUM PLASTICITY, SILTY CLAYS		
		$W_L > 50$ %	**CH**	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS (BELOW 'A' LINE)	$W_L < 50$ %	**OL**	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY		
		$W_L > 50$ %	**OH**	ORGANIC CLAYS OF HIGH PLASTICITY		
HIGHLY ORGANIC SOILS			**Pt**	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOUR OR ODOUR, AND OFTEN FIBROUS TEXTURE	
BEDROCK			**BR**	SEE REPORT DESCRIPTION		



Appendix G - City of Cold Lake – Drainage Criteria

Appendix G
Proposed Revisions to Servicing Standards

1. Wet detention Ponds (Section 4.3)

Figure G-1 provides the outline of the bird hazard zone where wet ponds will normally be prohibited unless specifically approved by the Department of National Defence.

2. Computer Modelling (Section 1.6)

Tables G-1 and G-2 provide the design storm hyetographs for the 1:5 year and 1:100 year 4 hour Chicago storm and the 1:100 year 24 hour Huff storm (1st quartile, 50% probability), respectively, to provide consistency in the use of design storm hyetographs for modeling exercises. The 1:5 year storm is to be used for modelling minor drainage systems and the 1:100 year 4 hour storm is to be used for modelling major drainage systems. The 1:100 year 24 hour storm is to be used for modelling stormwater management facilities (wet or dry ponds).

3. Existing Development Areas (New Section 6)

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 re-grading would be required to achieve the current standard. Therefore existing development areas will be evaluated on a case-by-case basis with the goal of providing a minimum level of service sufficient to minimize the risk of flooding private property to the extent practical, not necessarily to eliminate ponding on roadways or to meet the detailed specifications for new drainage systems.

Where possible, infill development or re-development of existing neighbourhoods should meet the standards for new construction, and will be subject to individual review.

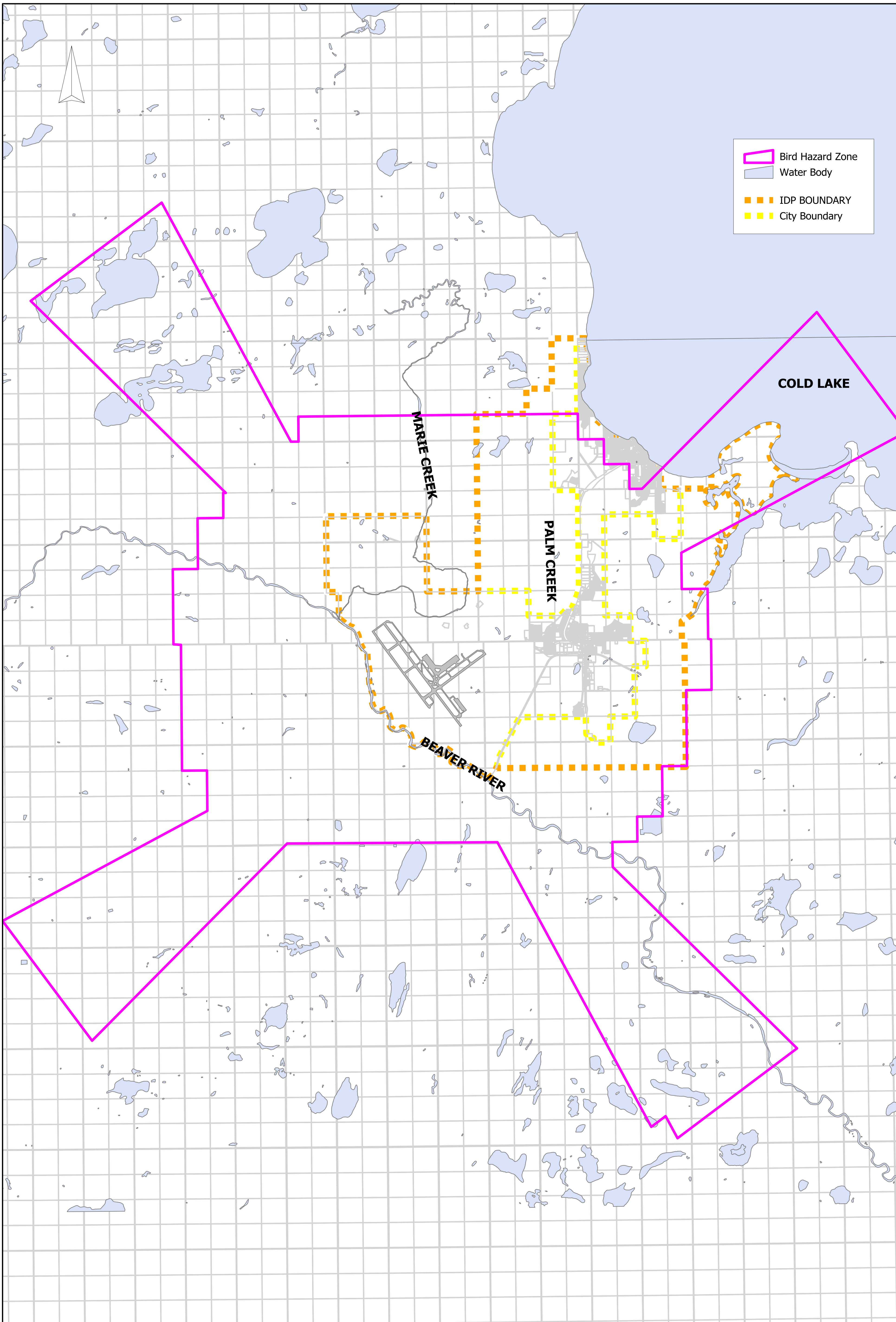
The guidelines for evaluation of existing development areas are summarized below:

- ***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 for new construction if they are re-built or replaced for other reasons. These upgrades should be modeled to check the possibility of downstream impacts.***

- ***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.***

- ***Proposed upgrades should be modelled to confirm their capacity and ensure they do not adversely impact downstream systems, which meets the intent of other specifications.***

- ***Existing SWMFs should 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 1100 year level. Other provisions may not apply if they have not been built into the design of the SWMF.***



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No.	REVISION	DATE

(Name) (Date)
(Name) (Date)
(Name) (Date)

CITY OF COLD LAKE
MASTER DRAINAGE PLAN

Figure G-1
BIRD HAZARD MAP

PROJECT No.: 2012-3590

DATE: 3/19/2014

SCALE: 1:40,000

Appendix G
City of Cold Lake Drainage Master Plan
Table G-1 4 Hour Modified Chicago Rainfall Distribution

Time (H:M)	5Y4H Rainfall Intensity (mm/hr)	100Y4H Rainfall Intensity (mm/hr)
0	0.00	0.00
0:05	1.05	2.25
0:10	2.10	4.50
0:15	2.30	4.75
0:20	2.50	5.00
0:25	2.70	5.30
0:30	2.90	5.60
0:35	3.25	6.00
0:40	3.60	6.40
0:45	4.20	7.00
0:50	4.80	7.60
0:55	6.15	8.55
1:00	7.50	9.50
1:05	12.95	11.45
1:10	18.40	13.40
1:15	48.30	21.30
1:20	78.20	29.20
1:25	51.35	83.25
1:30	24.50	137.30
1:35	18.60	81.75
1:40	12.70	26.20
1:45	10.65	21.75
1:50	8.60	17.30
1:55	7.55	15.35
2:00	6.50	13.40
2:05	5.90	12.25
2:10	5.30	11.10
2:15	4.90	10.35
2:20	4.50	9.60
2:25	4.20	9.05
2:30	3.90	8.50
2:35	3.65	8.05
2:40	3.40	7.60
2:45	3.25	7.30
2:50	3.10	7.00
2:55	2.95	6.70
3:00	2.80	6.40
3:05	2.70	6.20
3:10	2.60	6.00
3:15	2.50	5.80
3:20	2.40	5.60
3:25	2.30	5.45
3:30	2.20	5.30
3:35	2.15	5.15
3:40	2.10	5.00
3:45	2.05	4.90
3:50	2.00	4.80
3:55	1.95	4.70
4:00	1.90	4.60

Appendix G
City of Cold Lake Drainage Master Plan
Table G-2   100 Year 24 Hour Huff Rainfall Distribution

Time (H:M)	Rainfall Intensity (mm/hr)
0:00	0
0:05	0.23
0:10	0.47
0:15	0.7
0:20	0.94
0:25	1.17
0:30	1.41
0:35	1.64
0:40	1.87
0:45	2.11
0:50	2.34
0:55	2.58
1:00	2.81
1:05	3.13
1:10	3.44
1:15	3.75
1:20	4.38
1:25	5
1:30	5.63
1:35	6.26
1:40	6.89
1:45	7.52
1:50	8.14
1:55	8.76
2:00	9.38
2:05	10
2:10	10.62
2:15	11.24
2:20	11.66
2:25	12.08
2:30	12.5
2:35	12.63
2:40	12.75
2:45	12.88
2:50	12.97
2:55	13.07
3:00	13.17
3:05	13.3
3:10	13.42
3:15	13.55
3:20	13.64
3:25	13.74
3:30	13.84
3:35	13.77
3:40	13.69
3:45	13.62
3:50	13.45
3:55	13.27
4:00	13.1
4:05	12.9
4:10	12.7
4:15	12.5
4:20	12.3
4:25	12.11
4:30	11.91
4:35	11.73
4:40	11.56
4:45	11.39
4:50	11.19
4:55	10.99
5:00	10.79
5:05	10.59
5:10	10.39
5:15	10.2
5:20	9.97
5:25	9.75
5:30	9.53
5:35	9.33
5:40	9.13
5:45	8.93
5:50	8.73
5:55	8.53
6:00	8.34
6:05	8.19
6:10	8.04
6:15	7.89
6:20	7.71
6:25	7.53
6:30	7.35
6:35	7.18
6:40	7.02
6:45	6.85
6:50	6.68
6:55	6.51
7:00	6.35
7:05	6.19
7:10	6.03
7:15	5.87
7:20	5.75
7:25	5.62
7:30	5.5
7:35	5.38
7:40	5.26
7:45	5.14
7:50	5.01
7:55	4.89
8:00	4.77
8:05	4.65
8:10	4.52
8:15	4.4
8:20	4.3
8:25	4.21
8:30	4.12
8:35	4.07
8:40	4.02
8:45	3.97
8:50	3.92
8:55	3.87
9:00	3.82
9:05	3.77
9:10	3.72
9:15	3.67
9:20	3.62
9:25	3.56
9:30	3.51
9:35	3.47
9:40	3.42
9:45	3.37
9:50	3.32
9:55	3.27

Appendix G
City of Cold Lake Drainage Master Plan
Table G-2 100 Year 24 Hour Huff Rainfall Distribution

Time (H:M)	Rainfall Intensity (mm/hr)
10:00	3.22
10:05	3.17
10:10	3.12
10:15	3.07
10:20	3.03
10:25	2.98
10:30	2.93
10:35	2.88
10:40	2.83
10:45	2.78
10:50	2.74
10:55	2.7
11:00	2.66
11:05	2.61
11:10	2.57
11:15	2.52
11:20	2.48
11:25	2.44
11:30	2.4
11:35	2.35
11:40	2.31
11:45	2.27
11:50	2.23
11:55	2.19
12:00	2.14
12:05	2.12
12:10	2.09
12:15	2.07
12:20	2.04
12:25	2.02
12:30	1.99
12:35	1.97
12:40	1.95
12:45	1.93
12:50	1.9
12:55	1.88
13:00	1.85
13:05	1.83
13:10	1.8
13:15	1.78

Time (H:M)	Rainfall Intensity (mm/hr)
13:20	1.75
13:25	1.72
13:30	1.7
13:35	1.67
13:40	1.65
13:45	1.62
13:50	1.6
13:55	1.57
14:00	1.55
14:05	1.52
14:10	1.49
14:15	1.47
14:20	1.45
14:25	1.43
14:30	1.41
14:35	1.41
14:40	1.4
14:45	1.4
14:50	1.39
14:55	1.38
15:00	1.38
15:05	1.37
15:10	1.37
15:15	1.36
15:20	1.35
15:25	1.35
15:30	1.34
15:35	1.33
15:40	1.33
15:45	1.32
15:50	1.32
15:55	1.31
16:00	1.31
16:05	1.3
16:10	1.3
16:15	1.29
16:20	1.29
16:25	1.29
16:30	1.28
16:35	1.28

Time (H:M)	Rainfall Intensity (mm/hr)
16:40	1.27
16:45	1.27
16:50	1.26
16:55	1.26
17:00	1.25
17:05	1.24
17:10	1.24
17:15	1.23
17:20	1.22
17:25	1.22
17:30	1.21
17:35	1.21
17:40	1.2
17:45	1.2
17:50	1.19
17:55	1.19
18:00	1.18
18:05	1.18
18:10	1.17
18:15	1.16
18:20	1.16
18:25	1.15
18:30	1.15
18:35	1.14
18:40	1.14
18:45	1.13
18:50	1.13
18:55	1.12
19:00	1.12
19:05	1.11
19:10	1.1
19:15	1.09
19:20	1.08
19:25	1.07
19:30	1.06
19:35	1.04
19:40	1.03
19:45	1.01
19:50	1
19:55	0.99

Appendix G
City of Cold Lake Drainage Master Plan
Table G-2 100 Year 24 Hour Huff Rainfall Distribution

Time (H:M)	Rainfall Intensity (mm/hr)
20:00	0.97
20:05	0.96
20:10	0.95
20:15	0.93
20:20	0.92
20:25	0.91
20:30	0.9
20:35	0.89
20:40	0.89
20:45	0.88
20:50	0.87
20:55	0.86
21:00	0.86
21:05	0.85
21:10	0.84
21:15	0.83
21:20	0.83
21:25	0.82
21:30	0.81
21:35	0.8
21:40	0.79
21:45	0.78
21:50	0.77
21:55	0.76
22:00	0.75
22:05	0.74
22:10	0.73
22:15	0.72
22:20	0.71
22:25	0.69
22:30	0.68
22:35	0.67
22:40	0.66
22:45	0.65
22:50	0.64
22:55	0.63
23:00	0.62
23:05	0.61
23:10	0.59
23:15	0.58

Time (H:M)	Rainfall Intensity (mm/hr)
23:20	0.57
23:25	0.56
23:30	0.55
23:35	0.54
23:40	0.53
23:45	0.52
23:50	0.5
23:55	0.49

1. STORMWATER DESIGN STANDARDS

1.1 General

The storm sewer system must be designed with consideration for the existing drainage area boundaries established by the City for each storm trunk system. All pertinent data regarding the subdivision should be discussed with the Engineer prior to design proceedings.

In general, storm mains 1200 mm or grater, as well as storm water storage facilities and associated outlet piping, will be designated “Trunk Storm Mains”, and the cost of these mains are included in the Storm Off Site Levy rate. The current Trunk Storm Mains are identified in the most recent council approved Off Site Levy Report.

This section provides a brief summary of the design standards and guidelines for storm drainage systems in the City of Cold Lake.

1.2 Storm Water Management

These guidelines have been established pursuant to the City’s Master Drainage Plan and are the basis for storm water management in all developable land, including land upstream of existing pipe systems.

.1 Ensure that the hydraulic capacities of existing pipe systems and/or watercourses are not exceeded.

.2 Reduce to acceptable levels (1:100 year probability of occurrence, where reasonably attainable), the potential risk of property damage from flooding within new development areas, and in existing downstream developments.

.3 Reduce to acceptable levels (1:5 year probability of occurrence, where reasonably attainable), the inconvenience caused by surface ponding within development areas.

Based on the preceding criteria, storm water management is to be implemented for all developable land unless approved otherwise by the Engineer.

1.3 Major/Minor System

The storm drainage system shall be designed using a dual drainage concept consisting of a minor system and a major system.

The minor system, comprised of pipes, manholes, catch basins, storm water storage facilities and outfall structures, shall convey run off from snowmelt and rainfall events to an adequate receiving stream or pond without sustaining any surface ponding or excessive surface flows for events up to a 1 in 5 year return period.

The major system comprises the street system, storm water storage facilities, parkland and any other routes required to convey run off during rainfall events up to a 1 in 100 year return period, to the receiving water body. The major system shall be evaluated in manner sufficient to determine that no flooding that may cause significant property damage (flooding of building) occurs during the 100 year storm event.

1.4 Rainfall Intensity – Duration – Frequency

The following formulas define the intensity – duration – frequency curves (IDF curves) developed by Atmospheric Environment Services of Environment Canada for the Cold Lake Regional Airport.

ATMOSPHERIC ENVIRONMENT SERVICE

RAINFALL INTENSITY – DURATION FEQUENCY VALUES
GUMBEL – METHOD OF MOMENTS – 1990

TABLE 1 - COLD LAKE REGIONAL AIRPORT

YEAR	5 MIN	10 MIN	15 MIN	30 MIN	1 HR	2 HR	6 HR	12 HR	24 HR
1966	11.4	18.5	22.9	25.9	34.0	34.0	34.0	34.0	34.0
1967	7.6	10.4	13.2	14.7	15.0	15.2	15.2	19.3	20.1
1968	4.3	1.8	5.8	7.1	7.9	11.7	21.1	31.7	47.2
1969	4.3	7.6	7.9	8.4	9.4	14.2	29.0	41.9	52.1
1970	9.4	11.4	12.2	13.0	13.0	18.0	22.9	30.5	54.1
1971	9.4	14.2	16.5	26.4	30.5	42.9	42.9	42.8	48.3
1972	5.1	8.6	9.4	10.7	13.2	17.8	24.6	24.6	25.4
1973	5.6	7.1	7.4	8.1	11.4	14.5	23.4	30.0	33.0
1974	11.4	15.5	19.6	21.1	23.4	23.4	25.1	33.0	36.3
1975	8.6	11.7	12.4	15.2	18.0	20.1	32.3	48.5	62.0
1976	4.8	9.1	11.7	12.2	12.2	12.2	18.8	24.4	31.5
1977	7.6	12.7	15.7	21.3	21.8	22.1	22.1	24.6	38.6
1978	2.7	4.4	5.1	7.2	11.2	11.4	17.5	25.9	37.2
1979	9.6	17.4	20.4	24.0	24.0	26.8	28.6	29.0	29.4
1980	4.6	5.8	6.2	7.4	11.2	13.6	23.5	32.3	43.3
1981	6.3	11.0	12.2	12.9	15.2	22.0	24.4	27.6	28.9
1982	2.9	3.8	4.0	5.4	9.2	13.9	15.5	23.7	23.7
1983	3.8	5.4	6.1	7.5	13.5	19.2	20.9	30.1	30.3
1984	3.1	5.4	7.1	8.3	9.4	9.6	23.9	37.4	48.8
1985	4.4	5.4	5.7	8.5	11.7	16.9	29.1	30.9	35.5
1986	2.4	3.6	5.3	10.3	15.8	22.5	30.6	30.8	38.0
1987	8.2	15.2	22.2	39.8	51.1	52.8	52.8	52.8	52.8
1988	7.3	12.5	17.5	23.7	26.4	28.5	51.2	81.2	103.6
1989	5.8	9.1	12.8	17.8	18.2	19.0	35.7	46.3	46.8
1990	10.9	17.2	21.5	21.5	22.4	22.4	29.1	36.6	46.8

NOTE: - 99.90 INDICATES MSG DATA

# YRS	25	25	25	25	25	25	25	25	25
MEAN	6.5	9.9	12.0	15.1	18.0	21.0	27.8	34.8	41.9
STD DEV	2.8	4.6	6.1	8.4	9.8	10.0	9.7	12.7	16.7
SKEW	0.33	0.34	0.44	1.16	1.87	1.79	1.29	2.22	2.14
KURTOSIS	2.24	2.26	2.21	4.55	7.49	6.77	4.77	9.68	10.17

WARNING: - YEAR 1987 HAD VALUE GREATER THAN 100 YEAR STORM

ATMOSPHERIC ENVIRONMENT SERVICE

RAINFALL INTENSITY – DURATION FREQUENCY VALUES
GUMBEL – METHOD OF MOMENTS - 1990

TABLE 2 – COLD LAKE AIRPORT

DURATION	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR	# YRS
5 MIN	6.0	8.5	10.1	12.2	13.8	15.3	25
10 MIN	9.2	13.2	15.9	19.3	21.9	24.4	25
15 MIN	11.0	16.4	19.9	24.4	27.7	31.0	25
30 MIN	13.8	21.2	26.2	32.4	37.0	41.6	25
1 HR	16.4	25.0	30.8	38.0	43.4	48.7	25
2 HR	19.3	28.2	34.1	41.5	47.0	52.5	25
6 HR	26.2	34.8	40.4	47.6	52.9	58.2	25
12 HR	32.7	43.9	51.4	60.8	67.8	74.7	25
24 HR	39.2	53.9	63.6	76.0	85.1	94.2	25

RETURN PERIOD RAINFALL RATES (MM/HR) – 95% CONFIDENCE LIMITS

DURATION	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
5 MIN	72.0 +/- 12.2	101.9 +/- 20.5	121.7 +/- 27.7	146.7 +/- 37.4	165.3 +/- 44.7	183.7 +/- 52.1
10 MIN	54.9 +/- 10.0	79.4 +/- 16.8	95.6 +/- 22.6	116.0 +/- 30.5	131.1 +/- 36.5	146.2 +/- 42.5
15 MIN	44.2 +/- 8.7	65.5 +/- 14.7	79.7 +/- 19.8	97.6 +/- 26.7	110.9 +/- 32.0	124.1 +/- 37.3
30 MIN	27.5 +/- 6.1	42.4 +/- 10.2	52.3 +/- 13.8	64.8 +/- 18.6	74.1 +/- 22.3	83.3 +/- 26.0
1 HR	16.4 +/- 3.5	25.0 +/- 5.9	30.8 +/- 8.0	38.0 +/- 10.8	43.4 +/- 12.9	48.7 +/- 15.1
2 HR	9.7 +/- 1.8	14.1 +/- 3.0	17.0 +/- 4.1	20.8 +/- 5.5	23.5 +/- 6.6	26.2 +/- 7.7
6 HR	4.4 +/- .-6	5.8 +/- 1.0	6.7 +/- 1.3	7.9 +/- 1.8	8.8 +/- 2.1	9/7 +/- 2.5
12 HR	2.7 +/- 0.4	3.7 +/- 0.6	4.3 +/- 0.9	5.1 +/- 1.2	5.6 +/- 1.4	6.2 +/- 1.6
24 HR	1.6 +/- 0.2	2.2 +/- 0.4	2.7 +/- 0.6	3.2 +/- 0.8	3.5 +/- 0.9	3.9 +/- 1.1

ATMOSPHERIC ENVIRONMENT SERVICE

RAINFALL INTENSITY – DURATION FREQUENCY VALUES

GUMBEL – METHOD OF MOMENTS – 1990

TABLE 3 – COLD LAKE AIRPORT

INTERPOLATION EQUATIONS: R=A *T **B
R= RAINFALL RATE
T = TIME IN HOURS

STATS	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
MEAN OF R	25.9	37.7	45.6	55.5	62.9	70.2
STD DEV. R.	25.6	36.7	44.1	53.5	60.4	67.3
STD. ERROR	5.8	11.0	14.5	18.9	22.2	25.4
COEFF (A)	15.4	22.2	26.7	32.3	36.5	40.7
EXPONENT (B)	-0.693	-0.709	-0.715	-0.721	-0.724	-0.726
MEAN % ERROR	6.1	9.0	10.3	11.5	12.1	12.6

This IDF data shall be used for all new storm basins. For established basins, the current three year intensity curve may be used at the discretion of the Engineer. Rainfall intensity (mm/hr) for the three year storm is defined by the following formula:

1.5 Rational Method Design

The Rational Method of analysis shall be used to determine design flows for piped storm sewer systems of predominantly residential, commercial, and/or industrial land up to 65 ha (160 ac) in area. Alternatively, computer modeling may be used (see clause 1.6 of this section). The rational method formula is:

Q = (CiA)/360

Where: Q is the design peak flow rate (m3/sec)

C is the run off coefficient
"i" is the rainfall intensity (mm/hr) corresponding to the time of concentration
A is the area of contributing run off surface (ha)

.1 Run off coefficients (C)

Minimum recommended run off coefficient (C) values to be used in the rational method are as follows:

Land Use or Surface Characteristics	5 Year Storm Frequency	10 year Storm Frequency
Residential	0.40	0.60
Apartments	0.70	0.80
Downtown Commercial	0.80	0.90
Neighborhood Commercial	0.65	0.80
Lawn, Parks, Playgrounds	0.20	0.30
Undeveloped Land (farmland)	0.10	0.20
Paved Streets	0.90	0.95
Gravel Streets	0.25	0.65

In a development area where a mixture of land uses or surface characteristics are proposed, the weighted average of pervious and impervious area run off coefficients shall be used.

.2 Storm Duration

The storm duration used to determine the rainfall intensity for the Rational Method is equal to the time of concentration for the catchment (which equals the inlet time plus the time of travel in the sewer). The inlet time is the time taken for run off from the furthest reach of the catchment to flow overland to the first inlet and normally should not exceed 10 minutes. The time of travel is the time taken for flow from the furthest inlet to reach the point of design; based on full flow pipe velocities.

<u>1.6 Computer Modeling</u>

.1 Computer models shall be used to determine design flow conditions in sewer systems with drainage areas of 65 ha (160 ac) or larger. They may be used for smaller systems as an alternative to the rational method.

.2 Computer models shall be used to determine design flows and the sizing of systems that contain non pipe storm water management facilities (detention ponds) or systems that include a significant amount of undeveloped land.

.3 When large parcels of 65 ha (160 acres) or larger are being developed and will connect to the existing storm water facilities, the Consulting Engineer shall prepare a storm water model that simulates both major and minor systems. As a general rule, this model will have sub basins no larger than 5 ha. The modeling shall be generated utilizing software that is input/output compatible with XP-SWMM.

The selection of an appropriate computer model shall be based on an understanding of their principles, assumptions and limitations in relation to the system being designed. Acceptable computer models must be compatible with XP-SWMM, The City intends on maintaining their infrastructure modeling utilizing XP-SWMM.

Wherever possible, the computer model shall be calibrated. In all analyses, the parameters used, the drainage boundaries, the pipe network and its connectivity shall be clearly identified on an overall drawing and submitted to the city along with computer model input and output and a design summary report.

The design storm hyetograph shall be developed using the Chicago Method unless otherwise approved by the Engineer.

The storm duration used for modeling simulations will depend on the type of system being analyzed. Depending on basin characteristics and outlet rates, short duration storms (1 – 4 hour) will generally govern the design of the storm sewer systems and the longer duration storms (6 – 24 hours) will generally govern the design of detention ponds and major system components. Therefore, several design storms should be evaluated to determine the worst run off result for the system being designed.

Historical, continuous rainfall data in one hour increments, over the past 24 or more years, may be routed through the storm run off model to provide statistical frequency analysis of various flow and storage characteristics of the catchment in question.

1.7 Service Connections

Effluent from sanitary sewers or surface drainage from industrial, agricultural or commercial operations that may be contaminated shall not be discharged to the storm sewer.

Connections from roof leaders shall not be made to the storm sewer system. Roof drainage from residential housing units, apartments, commercial and industrial buildings shall discharge to grassed or pervious areas except where building density makes this impractical (central business district).

Weeping tile connections to the storm sewer shall be provided for in all new construction where the groundwater table is at or above the 2.0 meter level. The storm sewer system shall be designed to handle weeping tile flow and reviewed and accepted the City of Cold Lake. Other alternatives also may be submitted to the City of Cold Lake for review.
Where the storm sewer service will be higher than the footing elevation, the connection shall be made using a sump pump and approved by the City of Cold Lake Engineering Department.

.1 Site Drainage and Storm Sewer Service Restrictions
All developments are required to provide a detailed site grading drawing identifying storm drainage patterns, on site detention, storm sewers, manholes and catch basins.

Where a storm sewer exists adjacent to a property and the site is larger than 0.2 ha (0.5 acres) in size, the installation of on-site catch basins and connection to the City's storm sewer system are generally required.

If the site is between 0.2 ha and 0.4 ha and a large portion of the site is landscaped, on site catch basins and storm sewer connection requirements may not be required at the discretion of the Infrastructure Services Department.

Calculations for storm sewer and detention sizing must be provided for sites larger than 0.4 ha.

.2 Storm Service Design Criteria

The storm service size is to be determined based on the following, depending on the capacity of the downstream storm sewer system:

.1 Redevelopment Areas

Where a new service is being connected to an existing main , the allowable capacity for the development will be based on the following formula:

$$\text{Allowable Capacity} = \frac{\text{Development area X Capacity of Main}}{\text{Upstream Catchments Area}}$$

The calculated capacity of the service will likely be less than a 1:5 year storm discharge, but the allowable discharge shall not be greater than the 1:5 year discharge as calculated for new development areas.

.2 New Development Area

Where the new service is being connected to an existing main in a recently developed area of the City Service, the allowable capacity of the development will be determined using the 1:5 year rainfall IDF curve and the appropriate run off coefficient.

.3 Major Drainage Ponding

The 1:25 year storm is to be detained on site with an emergency drainage route for the 1:100 year event being provided. The 1:100 year storm must be detained on site if an emergency route cannot be provided.

Information regarding the intensity duration frequency curves (IDF Curves) run off coefficient (C) and design methods to be used to determine the storm service size is included in the design guidelines.

1.8 Length of Run

Surface water should not be permitted to run a distance greater than 150 m in streets or 200 m in lanes and swales without interception by a catch basin.

1.9 Back of Lot Drainage

The following will apply to back of lot drainage in lane less subdivisions:

.1 For back to back lots, and lots backing onto a park, a grass swale is to be constructed along the rear property lines within a City Easement to direct the drainage to a street. Grass swales are to be constructed with continuous grade lines with a minimum 0.8% slope to convey rear lot drainage to a catch basin located in a street or utility right of way.

.2 The flow from rear lot swales shall not be allowed to cross a sidewalk in order to prevent ice build up and dirt accumulation on the sidewalk. A catch basin or other suitable means of conveyance approved by the City of Cold Lake is required at back of walk to intercept these flows.

2. STORM SEWER MAINS (MINOR SYSTEM)

2.1 General

Storm sewer mains shall be designed for gravity flow unless approved otherwise by the Engineer. Pipe for Storm sewer mains shall be concrete pipe (sulphate resistant cement) conforming to ASTM C76 reinforced concrete pipe, latest revision thereof or IPEX PVC Ultra Rib pipe. Pipe for catchbasin leads shall be PVC DR35 conforming to CAN B182.2 and ASTM D3034.

2.2 Flow Capacity and Velocities

Sewer hydraulics shall be calculated using Manning's equation. Manning's in value shall be 0.013 for concrete and P.V.C. For other pipes and open channels, the values suggested in modern sewer design shall be used but shall not be less than 0.013.

The minimum and maximum flow velocities in any sewer shall be 0.60 m/s and 3.0 m/s, respectively. Designs containing velocities in excess of 3.0 m/s shall require special provisions and the approval of the City of Cold Lake

2.3 Pipe Strength

The strength of pipe shall be sufficient to carry the loads due to trench backfill and live loads. The strength of pipe shall be calculated on the basis of the external loads, trench conditions and bedding class provided. Class B Sand bedding is the minimum bedding requirements.

2.4 Depth of Cover

All sewers shall be designed so that the top of the main shall be located not shallower than 1.5m to the obvert, unless otherwise approved by the Engineer. Where conditions dictate that the depth of bury be less than 2.5 m, the main/service is to be approved by the City of Cold Lake Infrastructure Services Department.

2.5 Minimum Sizes

The minimum size of a storm sewer main shall be 300 mm in diameter with a minimum grade of 0.40%.

2.6 Minimum Slopes

Sewer velocities shall not be less than 0.60 m/sec when flowing full. Flow velocities of less than 0.9 m/sec are not recommended. When the flow velocity exceeds 3.0m/sec, special consideration shall be given to the design of junctions and bends in the system. See minimum design slopes for storm sewer in Alberta Environmental Protections publication titles standards and guidelines for municipal waterworks, wastewater and storm drainage systems in Alberta.

2.7 Curved Sewers

Although it is recommended that storm sewers be laid with straight alignments between manholes, curved sewer will be permitted with the following restrictions:

.1 The sewer shall be laid as a simple curve with a radius equal to or greater than that recommended by the pipe manufacturer. Minimum radius shall not be less than 60 .m

.2 Manholes shall be located at the beginning and end of curves, and at intervals not greater than 90 m along the curve unless approved otherwise by the Engineer.

.3 The curve shall run parallel to the street centre line.

.4 The minimum grade for sewers on curves shall be 50% grater than the minimum grade required for straight runs of sewer.

2.8 Alignment

Storm sewers shall be located on the standard alignment shown on drawing 021 for streets A minimum separation of 2.5 m from water mains shall be provided. Consistent alignments shall be used along the entire length of a street lane or public utility lot.

2.9 Manholes

Manholes shall be installed at the end of each line, at all changes in size, grade or alignment, at all junctions and at a spacing of no greater than 150 m along the length of the sewer.

To maintain a continuous energy gradient through manholes, the obvert (crown) elevation of the lowest upstream pipe shall be equal to or higher than the obvert of the downstream pipe. Where a bend in pipe alignment occurs in a manhole, the invert elevation of the downstream pipe shall be at least 50 mm below that of the lowest upstream pipe.

Storm sewers for weeping tile connections are to be extended 1.5 m past the last house service lead, with the exception of storm mains in cul de sacs where service leads may be connected directly to the end of the line manhole provided that the lead enters the manhole less than 0.60 m above the invert of the main.

Manhole sections shall be precast reinforced concrete sections conforming to ASTM C478, latest revision thereof.

Manhole frames and covers shall be cast iron conforming to Class 20 ASTM A48 latest revision thereof.

Manhole steps shall be standard safety type of hot dipped galvanized iron or aluminum.

The flow channel through manholes shall be made to conform in shape and slope to that of the sewer. The depth of the flow channel should be at least one half the diameter of the downstream sewer.

Standard 1200 mm diameter precast manhole shall be used on storm sewer mains and shall be perched when the main size is 600mm to 1050mm inside diameter unless otherwise approved in writing by the City of Cold Lake. Precast manhole vaults or an oversized manhole barrel shall be used on mains of 900 mm in diameter or greater. A Tee-riser manhole shall be used on mains 1050 mm in diameter and larger, providing there is no deflection in alignment or grade.

2.10 Catch Basins and Catch Basin Manholes

.1 General

Catch basins at street intersections shall normally be located at beginning or end of the curb return. Catch basins are not to be located within the limits of a paraplegic ramp. Invert crossings of street (swales) are not permitted unless approved by the City of Cold Lake Public Works and Infrastructure Services Department.

.2 Catch Basin Leads

Catch basin leads shall connect directly to a manhole. If a twin catch basin is required to drain an area, the twinned unit shall consist of a catch basin and a catch basin manhole interconnected by means of 240 mm pipe. The lead from the catch basin manhole to main line manhole shall be a 300 mm pipe. Single catch basins require 250 mm leads. All leads shall have a minimum grade of 1.0%.

The length of catch basin leads shall not exceed 30 m. If it is required to extend a lead more than 30 m, a catch basin manhole shall be used.

.3 Design Capacity

Spacing and capacity of catch basins shall be such that ponding shall not occur during a 1:5 year storm. Road gutter flows shall not exceed 0.04 cubic meters per second per gutter between catch basins during a 1: 5 year storm. The maximum distance between catchbasins will be 150 meters. Catchbasins to be supplied with weepage holes at the sub grade level.

For design purposes, catch basin capacities in litres/second are approximately as follows:

Norwood Model	Sump Condition *	Continuous Slope ** Capture	Continuous Slope ** Overflow
F-51 (with side inlet)	190	30	95
F-51 (grate only)	155	35	85
F-33	75	10	30
F-39	80	15	40
F-49	105	20	50

* based on 100 mm depth of ponding
** based on 50 mm depth on 1% slope

.4 Types of Catch Basins and Catch Basin Manholes

Catch basins shall be built with a 900 mm barrel. Catch basin manholes shall be built with a 1200 mm barrel. Catch basins and catch basin manholes shall be built with a 350 mm deep sump.

The type of inlet assembly as illustrated in the contract specifications to be used for catch basin and catch basin manholes shall be as follows:

.1 Type K-1 catch basin assembly is to be used in conjunction with standard curb and gutter and standard monolithic sidewalk construction.

.2 Type K-3 catch basin assembly is to be used in conjunction with lane construction.

.3 Type K-4 catch basin is to be used in conjunction with rolled monolithic sidewalk construction.

.4 Type K-6 catch basin assemblies may be used to drain landscape areas and swales.

.5 Type SK-7 and Type DK-7 catch basin assemblies are to be used for expressways and arterial roadways.

.6 CRD trash grate may be used to drain ditches.

Manhole bases shall be precast slab, concrete poured bases, vaults or precast tees.

3. MAJOR DRAINAGE SYSTEM

3.1 General

The grading of streets and the layout of the major drainage system shall be assessed relative to the following guidelines during the 100 year storm event:

.1 No building shall be inundated at its ground line.

.2 Continuity of the overland flow routes between adjacent developments shall be maintained.

.3 The depth of water at curb side should be less than 200 mm for all roadways. If downstream constraints require a gutter flow in excess of 200 mm, special modeling and design calculations shall be submitted to the City of Cold Lake for review. The City of Cold Lake shall determine the extend, if any, of a relaxation of the maximum 200 mm gutter flow standard on an individual.

.4 The velocities and depths of flow in the major drainage system shall not exceed the following values:

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

.5 Trapped low storage should be implemented to offset peak flows where necessary to keep water velocities and depths below those noted above. Overland flow capacities of typical local and collector street cross sections and a typical trap low storage area must be illustrated in the submitted engineering drawings.

The Developer shall recommend a building elevation to the lot purchaser that is above trapped low ponding elevations and designed to drain surface run off to the street or lane/utility right of way.

4. STORM WATER MANAGEMENT (SWM) FACILITIES

4.1 Design Requirements Common to Storm water Management Storage Facilities

.1 General

The use of storm water storage facilities may be required to reduce peak flow rates to downstream sewer systems and /or watercourses, or to provide a temporary receiving area for peak major drainage flows. Their approximate location and size must be identified at the time of the subdivision Outlining Plan approval to avoid conflicts with adjacent land uses. The effects of the maximum pond water levels shall be considered in the design of the minor system and lot grading. If possible, the crown elevations of the pipes in the first manhole upstream of a pond shall be at or above the maximum pond level during the five year storm event.

Storm water detention ponds, if required, shall be designed in accordance with the "Storm water Management Guidelines" as published by Alberta Environment and in accordance with good engineering practice.

Ponds shall be classified as either "wet" or "dry" depending on whether the installation is intended to permanently retain water or temporarily store peak flows, respectively.

Storm water detention ponds are to be sized for the volume of water produced by a 1:100 year storm for the ultimate development contributory area.

.2 Geotechnical Considerations

Soils investigation specific to the detention facility shall be undertaken to determine the soils permeability and salinity (or other potential contaminant) and the height of the groundwater table. Where the facility is sited above a shallow aquifer the potential for groundwater

.3 Minimum Storm water Quality Standards

The following is an excerpt from the Wastewater and Storm Drainage Regulations published by Alberta Environment:

Storm outfalls without due consideration for water quality will not be allowed. Storm water management techniques to improve water quality shall be included to effect a minimum of 85% removal of sediments of particle size 75 microns or greater. Additional quality measures shall be required, based on site specific conditions.

Based on the preceding statement, the Developer shall incorporate storm water treatment measures in the design of any storm water storage facility

.4 Erosion and Sediment Control

An Erosion and Sediment Control Plan as detailed in Section 6 is required as part of the Storm Water Management Study to define measures which must be undertaken for the control of sediment into the storm water storage facility and into the receiving water body.

.5 Storage Alternates

.1 General

The review of the storm water management alternatives for application to a specific area should consider the storage methods listed

.2 Dry Pond (Detention) Storage

Dry pond storage is the storm water management method where the storm run off is collected and the excess runoff is temporarily detained for a short period of time and released after the storm run off from the contributing are has ended. Generally, low flows do not enter the pond.

.3 Wet Pond (Retention) Storage

Wet pond storage functions the same as dry pond detention except that a portion of the storm water is permanently retained.

.6 Outflow Control

The outlet from a storm water management storage system must incorporate appropriate means for the control of outflow and to limit the rate of discharge to the recommended flow rate of 2 liters per second per hectare.(2 l/s/ha). These release rates have been determined based the City of Cold Lake Master Drainage Plan August 2006 prepared by UMA Engineering. The proposed release rates are to be confirmed by detailed modeling of the existing storm sewer system and are to be based on any proposed changes in the release rate to the receiving water body and revisions to the basin boundaries.

.7 Emergency Spillway Provisions

The feasibility of an emergency overflow spillway is to be evaluated for each storage facility (wet or dry) design and where feasible, such provisions are tot be incorporated in the pond design.

As part of the pond design process, the probable frequency of operation of the spillway should be determined. Where it is not possible to provide an emergency spillway route, the design is to include an analysis of the impact of over topping the pond and a significant freeboard above the 100 year level.

The functional requirements of the spillway and the impact analysis for the absence of one, are to consider the possible consequences of blockage of the system outlet or overloading due to the run off events, such that the storage capacity of the facility may be partially or completely unavailable at the beginning of a run off event.

.8 Land Dedication for Storm Water Management Facilities

The requirements for dedication of land on which a storm water management facility is to be situated will be in accordance with City of Cold Lake Master Drainage Plan and determined as part of the Development Agreement process.

.9 Landscaping Requirements

Detention pond landscaping requirements are detailed in Section 12.

.10 Detention Pond Development Costs

Detention pond financing and construction responsibility is detailed in Section 12.

.11 Signage for Safety

The design of storm water management facilities shall include adequate provisions for the installation of signage to warn of anticipated water level fluctuations, with demarcation of maximum water levels to be expected for design conditions. Warning signs will be designed by the Developer and approved by the Engineer.

4.2 DRY DETENTION PONDS

.1 General

Dry ponds should have gentle side slopes and be aesthetically contoured and landscaped to provide an attractive feature for the subdivision. Where possible, and as approved by the Planning and Development Department, they should be associated with municipal reserve areas to take advantage of the joint use ability of the facilities (extension of sports fields into the detention pond). Active park uses should not be located adjacent to the inlet/outlet facilities nor in areas that flood frequently (more than twice per year on average). The

Infrastructure Services Department should be consulted to provide input to the design of detention facilities from the concept stage through to detailed design and construction.

.2 Safety Provisions at Inlets and Outlets

All inlet and outlet structures associated with dry ponds shall have grates provided over their openings to restrict access and prevent entry into the sewer by unauthorized persons. A maximum clear bar space of 100 mm shall be used for gratings.

Grated outlet structures are to be designed with a hydraulic capacity of at least twice the required capacity to allow for possible plugging. The velocity of the flow passing through the grating should not exceed 1.0 m/sec. Appropriate fencing and guardrails are to be provided to restrict access and reduce the hazard presented by the structure head and wing walls.

.3 Design Parameters

The following general design parameters must be considered for a dry pond in a residential subdivision:

.1 Storage capacity for up to the 1 in 100 year storm event

.2 Detention time to be determined based on downstream capacity, recommended maximum detention time is 96 hours

.3 Maximum active retention storage depth of 1.5 m.. The maximum water level should be below adjacent house basement footings (a greater freeboard may be required if an emergency overflow route cannot be provided).

.4 Maximum interior side slopes of 5:1 (7:1 is recommended).

.5 Minimum freeboard of 0.6 m above 1:100 year high water levels.

.6 Provision of an emergency overland flow route. If an emergency overland route cannot be provided, the minimum freeboard shall be raised to the higher water level generated by the 1:100 year storm under a plugged outlet scenario.

.7 Maximum 4:1 ratio of effective length to effective width measured at 100 year high water level.

.8 Dimensions must be acceptable to the city Planning and Development Department when the bottom of the pond is to be used for recreation facilities.

.9 Minimum lateral slope in the bottom of the pond of 2.0% and minimum longitudinal slope of 1.0%.

.10 Low flow bypass for flows from minor events to be provided.

.11 French drains are to be provided within pond bottom where water table is near pond bottom.

.12 Address all safety issues (particularly during operation).

.13 The pond bottom and slopes shall be landscaped to the satisfaction of the City of Cold Lake. All improvements, such as playing fields, park furniture, planted areas, etc., shall be subject to approval by the City of Cold Lake.

4.3 Wet Detention Ponds (Residential Subdivision)

The current Transport Canada Regulation TP1247 does not recommend the construction of wet ponds within the 3.2 km radius from the reference point of the 4 Wing aerodrome. However, their use may be approved by Council and 4 Wing as an exception to the Policy. If approved, the Developer will be responsible for all construction. All communication to 4 Wing for any variance of the current policy must go through the City of Cold Lake's Infrastructure Services Department.

Design of a wet pond is to be in accordance with the Alberta Environmental Protection publication entitled "Storm Water Management Guidelines for the Province of Alberta" and the location of which must be approved by the City of Cold Lake . An overflow channel and overland drainage route must be provided to the satisfaction of the City of Cold Lake General design parameters and permitted water level fluctuations must ensure the following:

.1 The lowest basement weeping tile of any building on a lot adjacent to the lake shall be a minimum of 300 mm above the high water level.
.2 The lowest manhole invert shall be at or above the normal water level elevation.
.3 The pipe obverts at the lowest manhole upstream of the pond shall be above the high water level during a one in five year storm event.
.4 A minimum distance of six meters shall be maintained from any basement wall to the high water level.

.5 The inlet to the pond must be above the normal water level or below ice level.
.6 The minimum depth of the body of the pond, at normal water level,shall be 2 meters.
.7 The lake bottom and side slopes shall be composed of an impervious material
.8 No dead bay areas shall be permitted.
.9 Shoreline improvements shall be subject to review and approval by the City of Cold Lake.
.10 Easements, in favor of the City of Cold Lake, shall be granted over any private property situated between the normal and high water levels.
.11 The design shall incorporate a semi-annual turnover at average annual precipitation.
.12 Submerged inlets/outlets are preferred and shall be constructed such that the tops are a minimum of 0.6 m below normal water level.
.13 Inlets/outlets not submerged shall require fencing along adjacent shoreline for 5.0 m in each direction from the center line of pipe. In addition all exposed inlets/outlets shall be provided with a grate permanently fixed to the structure.
.14 Vegetative plantings shall be utilized to enhance water quality.
.15 Minimum width of the water surface at the normal water level shall be 25 meters.
.16 A silt trap shall be provided at the inlet of each pond. A defined path via publicly owned land or established drainage courses shall be identified and designed to carry flows when the design storage is exceeded.
.17 2.0 ha minimum water surface area
.18 Maximum interior side slopes of 7H:1V between the high water level and 1.0 m below normal permanent water level, 4H : 1V on inside slopes from high water level to top of bank, maximum outside slopes 4H : 1V.
.19 Maximum 1:100 year storage depth of 1.5m
.20 Sediment fore bays are required at each inlet
.21 Hard edge treatment required along lake perimeter
.22 Minimum freeboard depth of 0.6 m. House footings must be above freeboard elevation.
.23 Water recirculation and make up system required
.24 Provide access for maintenance and emergency equipment
.25 Design of outlet control structure to be capable of maintaining permanent pool depth and capable of draining the permanent pool for maintenance purposes.
.26 When possible, preserve existing wetlands by incorporating them into the storm water management plan.

5. MISCELLANEOUS DESIGN CONCERNS

5.1 Outfalls

Obverts of outfall pipes shall be above the five year flood level in the receiving stream. Inverts of outfall pipes shall be above winter ice level. Outfalls shall be located to avoid damage from moving ice during break up. Drop structures and energy dissipaters shall be used where necessary to prevent erosion. Trash bars shall be installed which will prevent entry or access by children.

Inlet/outlet structures in detention ponds are to be aesthetically blended into the landscape, design include adequate erosion protection, require low maintenance and have trash bars to preclude access by children. Discharge rates shall be kept below pre-development flow rates or as approved by municipal and provincial authorities.

5.2 Temporary Drainage System

Temporary drainage systems to intercept agricultural drainage and snowmelt shall be provided adjacent to new development. The temporary system may involve berming and/or ditching to detain or redirect the run off to the storm system.

5.3 Receiving Waters

Measures such as detention ponds should be incorporated in new developments to prevent any increase in the amount of erosion and downstream flooding to existing receiving streams.

Where erosion control or bank stability work must be done, preservation of watercourse aesthetics and wildlife habitat must be considered.

5.4 Culverts and Bridges

Culvert and bridge design should consider backwater effects over a range of flows. The design of a hydraulic structure requires assessment of both its nominal design capacity and its performance during the 100 year storm event as well as the 100 year ice level and break up.

END OF SECTION

Appendix H - Model Details

Appendix I - Fish Survey

ENVIRO MAK Inc. Environmental Management Consultants

September 26, 2013 *File Reference #12-20-02*

Associated Engineering Ltd.
10909 Jasper Ave NW
Edmonton, Alberta
T5J 5B9

Attention: Larry Bodnaruk

RE: FISH AND FISH HABITAT ASSESSMENT OF PALM CREEK (MARIE CREEK TRIBUTARY) IN 3, 4 AND 5-63 AND 33 AND 34-62-2-W4M

1.0 INTRODUCTION AND BACKGROUND

The purpose of this fish and fish habitat assessment is to determine whether or not a reservoir control structure (i.e. a dam) on Palm Creek will require fish passage upstream. The dam and reservoir currently provide a water source for the Department of National Defence (DND) in Cold Lake. The dam is currently being assessed for replacement and an engineering design is being developed to improve the existing structure.

Provincial and federal regulators have been participating in the review of the current control structure and have recommended that further fish studies be conducted to assist in the development of the engineering design.

The purpose of this correspondence is to provide Associated Engineering Ltd. with information on the fish and fish habitat assessment conducted in conjunction with the structure improvements.

2.0 OBJECTIVES

The objectives of this report are to determine the fish distribution, fish composition and fish habitat features in the lower reaches of Palm Creek, from the confluence of Marie Creek to 52 Avenue in the Town of Cold Lake.

3.0 LOCATION

The assessment area incorporates Palm Creek (Marie Creek Tributary) in the Town of Cold Lake (Figure 3.1; Photographs in Appendix 11.1). The immediate area of the crossing and the areas upstream and downstream of the crossing were within the County of Bonnyville.

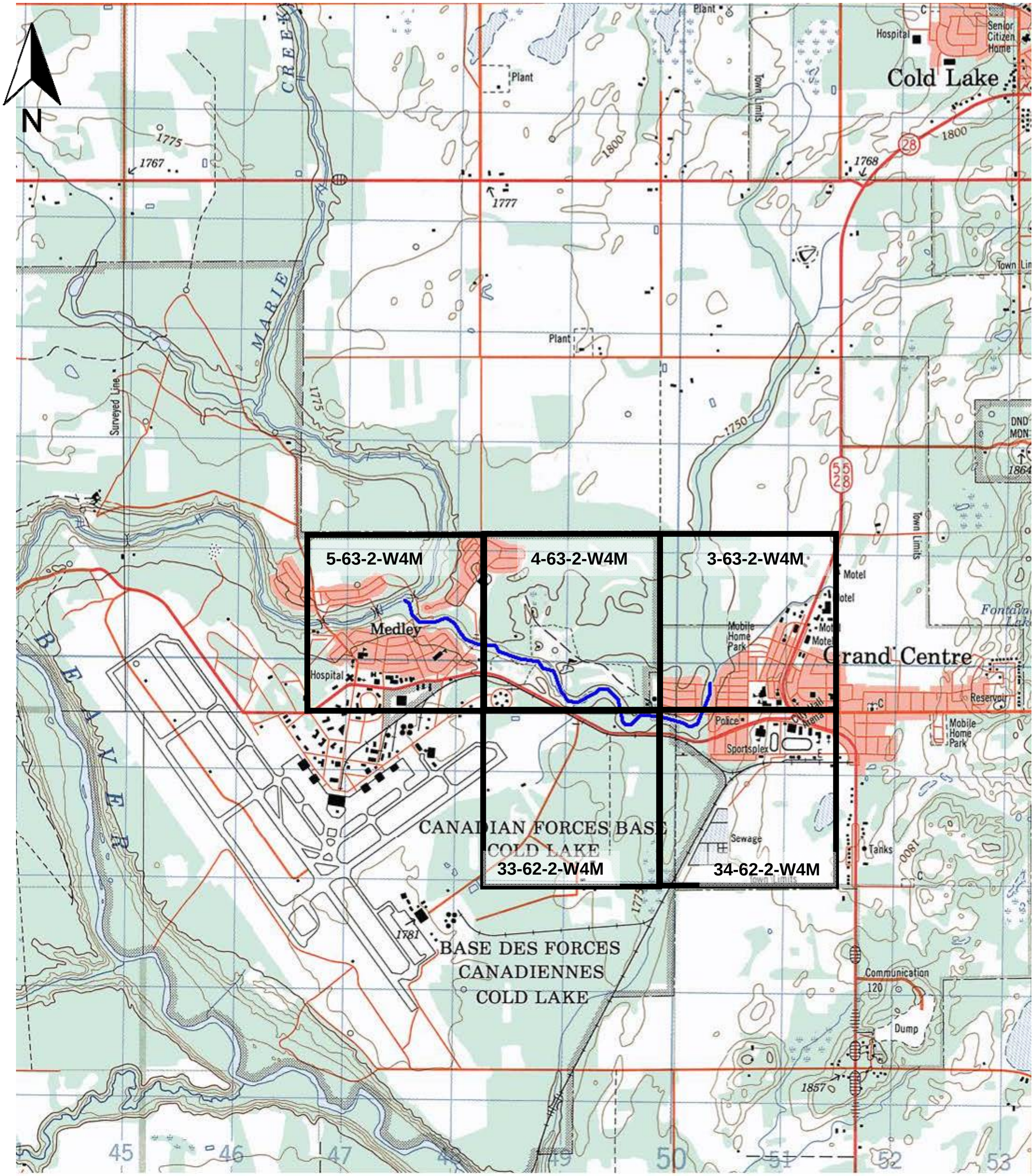

Figure 3.1. General area of drainage in the Town of Cold Lake at Palm Creek (Marie Creek Tributary) (1:50,000 Etopo National Topographic Series Map 73L08, 1993).

4.0 METHODOLOGY

This aquatic assessment was supported by information that provided the basic site description information, construction specifications, existing biological information, field assessment information and overall assessment. Map and aerial photography assessment and existing information research including existing database queries were undertaken. Information on Elements-At-Risk was collected from a variety of sources. Elements-At-Risk include plants and animals considered at risk due to being restricted to a small portion of their former range or extent based on a combination of Alberta Conservation Information Management System (ACIMS 2013) tracking and watch lists, federal endangered species lists (COSEWIC 2010), provincial at risk and may be at risk species list (AESRD 2010), Fish and Wildlife Management Information System (FWMIS 2013) and other sources.

Various fish collection and sampling techniques were utilized in the field to determine fish distribution and composition. The techniques utilized included minnow traps, electrofishing, gill nets and human observations. The field work was conducted under the authorization of Fisheries Research Licence #13-2832 issued by AESRD.

The field assessment consisted of obtaining fish and fish habitat information from various sites within the assessment area as outlined below and in Figure 4.1:

Reach 1 - Confluence of Marie Creek to McKenzie Drive - Sites 1, 2, 3 and 14

Reach 2 - McKenzie Drive to the Golf Course Reservoir - Sites 4 and 5

Reach 3 - Golf Course Reservoir - Sites 6, 7, 8 and 9

Reach 4 - Reservoir to 51 Avenue - Sites 10 and 11

Reach 5 - 51 Avenue to 52 Avenue - Sites 12 and 13

5.0 EXISTING INFORMATION

5.1 Ecoregion, Soils and Topography

The assessment area was located in the Low Boreal Mixedwood (Strong and Leggat, 1992) (Table 5.1). The site was within the Dark Gray - Gray Soil Zone of northeast-central Alberta (Soil Correlation Area 12, Pedocan Land Evaluation Ltd. 1993). The area was characterized by Orthic and Dark Gray Luvisols with some Dark Gray and Black Chernozemics. Gleysolic and Organic soils occurred in depressional areas (Pedocan 1993). The landscape was generally undulating moraine.

According to the Alberta Geological Survey web maps (2009) the site does fall within an unknown type deposit with aggregate resource potential. The Quantification of Aggregate Minerals in Alberta Map produced by EnviroMak Inc. (2000) shows no private or public land aggregate extraction pits near this site.

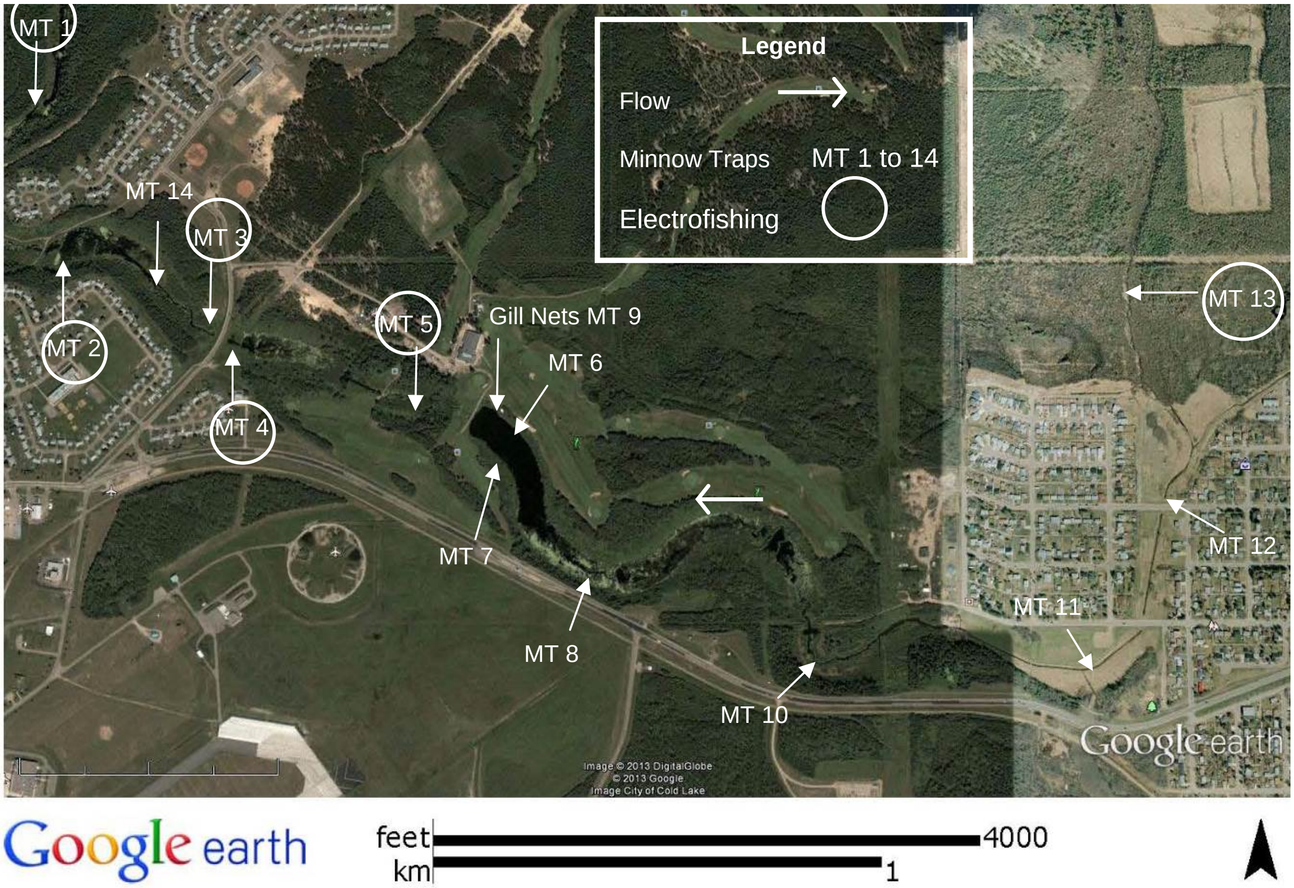

Figure 4.1 Minnow trap, electrofishing and gill net locations in the Town of Cold Lake at Palm Creek (Marie Creek Tributary) 3, 4 and 5-63 and 33 and 34-62-2-W4M.

Climate data was gathered from Environment Canada (2010) which maintains a weather station at Cold Lake. Cold Lake temperature averages 1.7 °C annually; the July mean is 16.9 °C, and; the January mean is -16.6 °C. Mean annual precipitation is 426.6mm with approximately 30% occurring as snow. Rainfall averages 322mm.

The growing season lasts approximately 175 – 180 days (Pedocan Land Evaluation 1993). Agroclimate is 3H (moderate heat limitations). Growing season is P-PE= -150 to -200mm and snow cover persists throughout the winter (Pedocan 1993).

According to the soil capability classification map (1:1,000,000 scale Canada Land Inventory Soil Capability for Agriculture), the area surrounding the proposed subdivision is classified as $6^{M}_{T,}$ 0. Class 6 indicates soils are capable of producing perennial forage crops only and Class 0 indicates organic soils (Alberta Soil Survey with the support of ARDA, Canada Department of Forestry and Rural Development 1967; and Canada Land Inventory, Lands Directorate, Environmental Management Service, Environment Canada 1976, from the agriculture capability inventory provided by the Alberta Soil Survey).

Table 5.1. General location descriptors of Palm Creek (Marie Creek Tributary) in the Town of Cold Lake.

Descriptor	Specific Location
Legal Land Description	3, 4 and 5-63 and 33 and 34-62-2-W4M
[1]Soil Correlation Area	SC 12
[2]Ecoregion	Low-Boreal Mixedwood
Municipality	County of Bonnyville
[3]Environmentally Significant Area	Not Environmentally Significant

[1] Pedocan Land Evaluation 1993 [2] Strong & Leggat 1992 [3] ACIMS Map 2009

5.2 Watershed Characteristics

This watercourse drained into Marie Creek as part of the Beaver River basin. The specific area being assessed was located in the lower area of the Beaver River watershed. The drainage area of Palm Creek upstream of the crossing point is approximately 30 km^2. There appeared to be approximately 10 km of stream channel upstream of the crossing (Table 4.2). Palm Creek is designated a Class C according to the Alberta Water Act Code of Practice for Watercourse Crossings Maps (2006).

Table 5.2. Watershed characteristics of Palm Creek (Marie Creek Tributary) at 3, 4 and 5-63 and 33 and 34-62-2-W4M.

Drainage Characteristic	Measure
Watershed (River Basin)	Beaver River Basin
General Location in Basin	Lower
Drainage Area Upstream of Crossing	30 km^2
Stream Length Upstream of Crossing	10 km
Downstream Distance to Nearest Watercourse	~1.8 km to Marie Creek (Class C)
Stream Order	3rd
Alberta Water Act Code of Practice for Watercourse Crossings Classification	Class C (RAP April 16 to June 30)

Determined from National Topographic Series Maps 1:50,000 scale and Alberta *Water Act* Code of Practice for Watercourse Crossings Maps (2006) RAP—Restricted Activity Period

5.3 Environmentally Significant Areas

The Alberta Conservation Information Management System (ACIMS) Environmentally Significant Areas Provincial map (2009) does not identify any environmentally significant areas at the location. The property does not contain any ecological reserves, special wildlife projects or recorded environmentally sensitive areas. A data search of the area around the site in Alberta Conservation information Management System (ACIMS) online system did not identify any recorded occurrences of elements on tracking lists (Online ACIMS Database 2012).

5.4 Fish Resources – Existing Information

Existing information contained on the AESRD Fish and Wildlife Management Information System (FWMIS) provided references for numerous fish species in Marie Creek downstream of Palm Creek (FWMIS Internet Mapping Framework 2013). AESRD indicates that the common fish species in Marie Creek near the crossing location are:

- Northern pike, *Esox lucius*
- Fathead minnow, *Pimephales promelas*
- Iowa darter, *Etheostoma exile*
- Burbot, *Lota lota*
- White sucker, *Catostomus commersoni*
- Spottail shiner, *Notropis hudsonius*
- Yellow perch, *Perca flavescens*
- Lake chub, *Couesius plumbeus*
- Brook stickleback, *Culaea inconstans*
- Finescale dace, *Phoxinus neogaeus*
- Pearl dace, *Margariscus margarita*

5.5 Wildlife Resources

A search of the Alberta Conservation Information Management System (ACIMS) databases did not identify the presence of any threatened, rare or endangered species of plants or animals within a 2km buffer area around this site (ACIMS Online Database 2013). The Fish and Wildlife Management Information System (FWMIS) identified the presence of Broad-winged hawk (*Buteo platypterus*) within a 2km radius of the assessment location (FWMIS Internet Mapping Framework 2013) (Table 5.5)

Table 5.5. Species of concern which have been identified within a 2km radius of the assessment area according to the Fish and Wildlife Management Information System (FWMIS) and the Alberta Conservation Information Management System (ACIMS).

Common Name	Scientific Name	Provincial Status[1]	Federal Status[2]
Broad-winged Hawk	*Buteo platypterus*	Sensitive	Not listed

[1] AENV 2010 http://www.wildspecies.ca/searchtool.cfm?lang=e
[2] COSEWIC 2012 http://www.cosewic.gc.ca/eng/sct1/searchform_e.cfm

6.0 RESULTS

6.1 Stream Morphometric and Fish Habitat Characteristics

A summary of the characteristic of each reach is provided below. Specific features are provided in Table 6.1 and photographs are provided in Appendix 11.1)

6.1.1 Reach 1 - Confluence of Marie Creek to McKenzie Drive - Sites 1, 2, 3 and 14

- This lower reach was characterized by a valley having a width of 80m to 100m that was frequently flooded by beaver dams and ponds.
- Reach length 958m
- Wet widths ranged from 4.2m to 35m
- mean wet width 13.7m
- bank height 3m
- fish cover 100% (50% deep pool. 40% instream vegetation, 5% overhanging vegetation, 5% undercut banks)
- Aquatic and riparian vegetation 20 species (Appendix 11.2)

6.1.2 Reach 2 - McKenzie Drive to the Golf Course Reservoir - Sites 4 and 5

- This second lower reach was characterized by a valley having a width of 80m that was frequently flooded by beaver dams and ponds.
- Reach length 632m
- Wet widths ranged from 1.8m to 80m
- mean wet width 16m
- bank height 2.5m
- fish cover 100% (50% deep pool. 40% instream vegetation, 5% overhanging vegetation, 5% undercut banks)
- Aquatic and riparian vegetation 20 species (Appendix 11.2)

6.1.3 Reach 3 - Golf Course Reservoir - Sites 6, 7, 8 and 9

- This middle reach was the reservoir.
- Reach length 520m
- Wet widths ranged from 35m to 90m

- mean wet width 65m
- bank height 2.6m
- fish cover 100% (75% deep pool. 20% instream vegetation, 3% overhanging vegetation, 2% undercut banks)
- Aquatic and riparian vegetation 20 species (Appendix 11.2)

6.1.4 Reach 4 - Reservoir to 51 Avenue - Sites 10 and 11

- This upper reach was characterized by a defined valley having a receding width of approximately 40m to 10m that was frequently flooded by beaver dams and ponds.
- Reach length 1064m
- Wet widths ranged from 1.5m to 6m
- mean wet width 2.0m
- bank height 0.8m
- fish cover 70% (20% deep pool. 20% instream vegetation, 20% overhanging vegetation, 10% undercut banks)
- Aquatic and riparian vegetation 7 species (Appendix 11.2)

6.1.5 Reach 5 - 51 Avenue to 52 Avenue - Sites 12 and 13

- This upper reach was characterized by a shallow valley having a gradual valley that was frequently flooded by beaver dams and ponds.
- Reach length 714m
- Wet widths ranged from 1.5m to 3m
- mean wet width 1.6m
- bank height 0.7m
- fish cover 60% (10% deep pool. 20% instream vegetation, 20% overhanging vegetation, 10% undercut banks)
- Aquatic and riparian vegetation 5 species (Appendix 11.2)

Table 6.1. Morphometric and fish habitat characteristics of Palm Creek at 4 and 5-63-2-W4M on August 12 and 13, 2013.

Reach	Sites	Channel length (m)	Channel width (m)	Wet width (m)	Bank height (m)	Fish Cover (%)	Comments
1	1, 2, 3, 14	958	80	13.7	3	100	Fish present
2	4, 5	632	80	16	2.5	100	Fish present
3	6, 7, 8, 9	520	90	65	2.6	100	Fish present
4	10, 11	1064	10	2	0.8	70	Fish present
5	12, 13	714	3	1.6	0.7	60	Fish present
Total	**14**	**3,888**					**Fish present**

6.2 Fish Captured

Minnow traps, electrofishing, gill nets and human observations were used at fourteen locations along the drainage area including the reservoir on August 12-13, 2013. 1841 fish including Brook stickleback (*Culaea inconstans*), Finescale dace (*Chrosomus neogaeus*), Fathead minnow (*Pimephales promelas*), Lake chub (*Couesius plumbeus*), and White sucker (*Catostomus commersoni*) representing at least 4 age classes were captured (Table 6.2). Considerable fish-habitat was present in the area, and there were few limitations to fish associated with the location. The watercourse at this location is a suitable habitat for fish.

Table 6.2. Summary of fishing effort at Palm Creek (Marie Creek Tributary) in the Town of Cold Lake in association with the Cold Lake Drainage project on August 12 and 13, 2013.

Location	Electrofishing			Minnow Trapping		Gill netting		All Methods - Total Fish Caught
	Area (m^2)	Time (sec)	Number & Species of Fish Caught	Effort/ Time (hrs)	Number & Species of Fish Caught	Effort/ Time (hrs)	Number & Species of Fish Caught	
Site 1	100	292	8 LKCH 1 WHSC	24.0	0	-	-	**8 LKCH 1 WHSC**
Site 2	200	182	6 LKCH 1 WHSC 5 Unknown	6.25	1 BRST 6 FTMN 30 LKCH 1 WHSC	-	-	**1 BRST 6 FTMN 36 LKCH 2 WHSC 5 Unknown**
Site 3	100	507	4 FTMN 3 LKCH 5 WHSC	18.5	1 BRST 35 FTMN 563 LKCH 2 WHSC	-	-	**1 BRST 39 FTMN 566 LKCH 7 WHSC**
Site 4	100	403	15 BRST 11 FTMN 33 LKCH	1.0	1 BRST	-	-	**16 BRST 11 FTMN 33 LKCH**
Site 5	100	600	2 BRST 29 FTMN 179 LKCH	24.0	3 BRST 4 FNDC 122 FTMN 103 LKCH	24.0	0	**5 BRST 4 FNDC 151 FTMN 282 LKCH**
Site 6	-	-	-	2.0	96 FTMN 21 LKCH	-	-	**96 FTMN 21 LKCH**

Location	Electrofishing			Minnow Trapping		Gill netting		All Methods - Total Fish Caught
	Area (m^2)	Time (sec)	Number & Species of Fish Caught	Effort/ Time (hrs)	Number & Species of Fish Caught	Effort/ Time (hrs)	Number & Species of Fish Caught	
Site 7	-	-	-	1.5	2 BRST 32 FTMN 279 LKCH	-	-	**2 BRST 32 FTMN 279 LKCH**
Site 8	-	-	-	21.75	1 BRST 17 LKCH	-	-	**1 BRST 17 LKCH**
Site 9	-	-	-	-	-	-	-	-
Site 10	-	-	-	1.0	0	-	-	**0**
Site 11	-	-	-	1.0	1 BRST 11 FTMN 35 LKCH	-	-	**1 BRST 11 FTMN 35 LKCH**
Site 12	-	-	-	19.0	13 FTMN 124 LKCH	-	-	**13 FTMN 124 LKCH**
Site 13	100	552	17 BRST 2 FTMN 16 LKCH	-	-	-	-	**17 BRST 2 FTMN 16 LKCH**
Site 14	-	-	-	18.0	0	-	-	**0**
Total	**700**	**2536**	**34 BRST 46 FTMN 245 LKCH 7 WHSC 5 Unknown**	**138**	**10 BRST 4 FNDC 315 FTMN 1172 LKCH 3 WHSC**	**24.0**	**0**	**44 BRST 4 FNDC 361 FTMN 1417 LKCH 10 WHSC 5 Unknown Total=1841**

BRST – Brook stickleback (*Culaea inconstans*)
FTMN – Fathead minnow (*Pimephales promelas*)
WHSC – White sucker (*Catostomus commersoni*)
FNDC – Finescale dace (*Chrosomus neogaeus*)
LKCH – Lake chub (*Couesius plumbeus*)

Table 6.3. Fish species and size composition of fish captured in Palm Creek (Marie Creek Tributary) in the Town of Cold Lake on August 12-13, 2013.

Fish Species	Fork Length (mm) of Fish Captured										
	<30	30 - 49	50 - 69	70 - 89	90 - 109	110 - 149	150 - 199	200 - 249	250 - 299	>300	Total
BRST	28	11	5	0	0	0	0	0	0	0	44
FNDC	0	3	1	0	0	0	0	0	0	0	4
FTMN	8	187	155	11	0	0	0	0	0	0	361
LKCH	66	467	792	82	2	7	0	1	0	0	1417
WHSC	0	1	1	0	4	4	0	0	0	0	10
Unknown	5	0	0	0	0	0	0	0	0	0	5
Total	107	669	954	93	6	11	0	1	0	0	1841

BRST – Brook stickleback (*Culaea inconstans*)
FTMN – Fathead minnow (*Pimephales promelas*)
WHSC – White sucker (*Catostomus commersoni*)
FNDC – Finescale dace (*Chrosomus neogaeus*)
LKCH – Lake chub (*Couesius plumbeus*)

6.3 Wildlife Observed

No site-specific studies have been conducted to determine if any threatened or endangered wildlife species occur. No rare species were observed near the existing crossing during the visit on August 12 and 13, 2013.

7.0 DISCUSSION AND CONCLUSIONS

The following provides some discussion and conclusions associated with the fish and fish habitat assessment on the lower reaches of Palm Creek (Marie Creek Tributary).

1. Fish Composition

   The lower reaches of Palm Creek did contain at least 5 species of fish that included

   - 77% Lake chub
   - 19.6% Fathead minnow
   - 2.4% Brook stickleback
   - 0.5% White sucker
   - 0.2% Finescale dace
   - 0.3% Unidentified fry

   All fish species did includes multiple age classes.

   Marie Creek located downstream did contain 11 fish species including Northern pike, Burbot and Yellow perch (Fish and Wildlife Management Information System - FWMIS)

2. Fish Distribution

   Fish were found in all reaches from the confluence with Marie Creek to 52 Avenue in Cold Lake a total distance of 3,888 m. The golf course reservoir in reach 3 did not contain any White sucker or any game fish; however, did contain other species with multiple age classes.

   White sucker were absent above the dam at the downstream end of the reservoir

3. Fish Abundance

   A total of 1841 fish of at least 5 fish species were collected and released. Generally fish were abundant from the confluence with Marie Creek to 52 Avenue in Cold Lake. In these upper sites trapping and electrofishing resulted in at least 3 fish species exceeding 160 fish of multiple age classes.

4. Fish Habitat Suitability

   Fish habitat was suitable in all 5 reaches for several fish species.

Limitations in areas upstream of the reservoir are associated with limited flow in dry years or during winter. The presence of deep pools is provided by beaver dams and in so doing, does create overwintering habitats as evidenced by the multiple age classes.

The presence of multiple age classes of White sucker indicates that Palm Creek does provide spawning habitat for this spring-spawning species that migrates into suitable spawning areas. The lower reaches of Palm Creek could provide spawning for other fish species including Northern pike and Yellow perch.

The minimal winter flows and the habitat type is likely not suitable for Burbot spawning which are winter spawners that are also present in Marie Creek.

5. Fish Passage

   The dam located at the reservoir is likely a fish passage barrier. White sucker present downstream might be resident in the reservoir depending on overwintering suitability. Since three other species with multiple age classes are present in the reservoir, this habitat may be also suitable for other species such as White sucker.

   Normally, if White sucker are able to access areas then other spring spawners may also be using such habitats for spawning and rearing.

   If fish passage was present some species would likely use these habitats including the reservoir for spawning and rearing.

6. Reservoir - Wetland and Fish Habitat Values

   The reservoir does provide a useful wetland (Class V under the Stewart and Kantrud classification system) that provides fish and wildlife values as well as hydrological values in sustaining downstream flows.

8.0 RECOMMENDATIONS

From the results of the fish and fish habitat assessment on Palm Creek (Marie Creek Tributary), the following recommendations are offered:

- The suitability of the wintering fish habitat reservoir for White sucker and other fish species could be assessed during the winter. The determination of the reservoir as a permanent fish habitat for other species could be further assessed.
- The development of fish passage to the reservoir and upstream areas would allow for potential fish habitats to be utilized by existing species that inhabit Palm Creek and some species that inhabit Marie Creek. This would be a benefit to the fish resources.

- If fish passage is to be provided it should be designed to pass spawning anguilliform fish species as well as providing connectivity for cyprinid fish species.

Please contact EnviroMak Inc. by telephone at (780) 425-2461 (office) or email to ray@enviromak.com or kyla@enviromak.com with any questions or concerns.

Sincerely,

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ALBERTA SOCIETY of Professional Biologists
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PROFESSIONAL BIOLOGIST

Cc: *Chris Skowronski*

Attachments: *Bibliography and Appendices*

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10.0 APPENDICES

11.1 PHOTOGRAPHS

Photograph 1. Fish and fish habitat assessment of Palm Creek; looking northwest at Site #1 on August 12, 2013.

Photograph 2. Fish and fish habitat assessment of Palm Creek; looking south at Site #2 on August 12, 2013.

Photograph 3. Fish and fish habitat assessment of Palm Creek; looking west at Site #3 on August 12, 2013.

Photograph 4. Fish and fish habitat assessment of Palm Creek; looking east at Site #4 on August 12, 2013.

Photograph 5. Fish and fish habitat assessment of Palm Creek; looking north at Site #5 on August 12, 2013.

Photograph 6. Fish and fish habitat assessment of Palm Creek; looking south at Site #6 on August 12, 2013.

Photograph 7. Fish and fish habitat assessment of Palm Creek; looking east at Site #7 on August 12, 2013.

Photograph 8. Fish and fish habitat assessment of Palm Creek; looking north at Site #8 on August 12, 2013.

Photograph 9. Fish and fish habitat assessment of Palm Creek; looking north at Site #10 on August 12, 2013.

Photograph 10. Fish and fish habitat assessment of Palm Creek; looking southeast at Site #11 on August 12, 2013.

Photograph 11. Fish and fish habitat assessment of Palm Creek; looking east at Site #12 on August 12, 2013.

Photograph 12. Fish and fish habitat assessment of Palm Creek; looking north at Site #13 on August 12, 2013.

Photograph 13. Fish and fish habitat assessment of Palm Creek; looking south at Site #14 on August 12, 2013.

Photograph 14. Fish and fish habitat assessment of Palm Creek; Reach 1 on September 12, 2013.

Photograph 15. Fish and fish habitat assessment of Palm Creek; Reach 1 on September 12, 2013.

Photograph 16. Fish and fish habitat assessment of Palm Creek; Reach 1 on September 12, 2013.

Photograph 17. Fish and fish habitat assessment of Palm Creek; Reach 2 on September 12, 2013.

Photograph 18. Fish and fish habitat assessment of Palm Creek; Reach 2 on September 12, 2013.

Photograph 19. Fish and fish habitat assessment of Palm Creek; Reach 4 on September 12, 2013.

Photograph 20. Fish and fish habitat assessment of Palm Creek; Reach 4 on September 12, 2013.

Photograph 21. Fish and fish habitat assessment of Palm Creek; Reach 5 on September 12, 2013.

11.2 AQUATIC AND RIPARIAN VEGETATION IN PALM CREEK ON AUGUST 12, 2013

	Common Name	**Scientific Name**
Aquatic Vegetation	Common duckweed	*Lemna minor*
	Ivy leaved duckweed	*Lemna trisulca*
	Narrow-leaved water-plantain	*Alisma gramineum*
	Giant bur-reed	*Sparganium eurycarpum*
	Small-leaf pondweed	*Potamogeton pusillus*
	Sedge	*Carex* sp.
	Arrowhead	*Sagittaria cuneata*
	Water-plantain	*Alisma sp.*
	Arum lilies	*Arum sp.*
	Tufted hair grass	*Deschampsia caespitosa*
	Filamentous green algae	*Cladophora* sp
	Moss	*Drepanocladus* sp.
Riparian Vegetation	Red osier dogwood	*Cornus stolonifera*
	Reed canary grass	*Phalaris arundinacea*
	Sedge	*Carex* sp.
	Willow	*Salix* sp.
	Cattail	*Typha latifolia*
	Timothy	*Phleum pratense*
	Canada thistle	*Cirsium arvense* L.
	Marsh marigold	*Caltha palustris*
	Water parsnip	*Sium* sp.
	Slough grass	*Beckmannia syzigachne*
	Tall manna grass	*Glyceria grandis*