2 Stormwater Management Release Rates

AE evaluated three possible stormwater management release rates to be simulated for future developments during a 1:100 year design event. These release rates were based on findings in TM No. 3.

- 1.5 L/s/ha
- 3.0 L/s/ha
- 5.0 L/s/ha

These release rates were applied uniformly to all future development areas, assuming each will be controlled to the same rate of discharge. The model update and model results are discussed below.

2.1 MODEL UPDATE

Boundary flows used in the existing model (TM No. 4) were updated based on the future developments and potential range of release rates. **Table 2-1** summarizes creek flows at key locations within the basin for existing conditions and with future development releasing at 1.5, 3.0, or 5.0 L/s/ha. For comparison, the existing or "pre-development" discharges rates are also provided in **Table 2-1**.

Overall it was observed that a release rate of 5.0 L/s/ha would significantly increase peak flows in the basin. Results indicate that flows would increase by 20-25% in Whitemud Creek, by about 40% in Blackmud Creek, and as much as 100% in Irvine Creek. With a release rate of 3.0 L/s/ha, the impacts would be much more modest, with peak flows increasing slightly in Whitemud and Deer Creeks and as much as 50% in Irvine Creek. A release rate of 1.5 L/s/ha would result in decreased flows or similar flows compared to existing conditions and would minimize the potential impacts to the creek system.

The potential impacts of the different release rates, in terms of costs, flood depth and extent, and erosion potential are discussed below.

Appendix A provides details of the boundary inflows applied within the model.

Table 2-1
Creek Flows at Various Locations

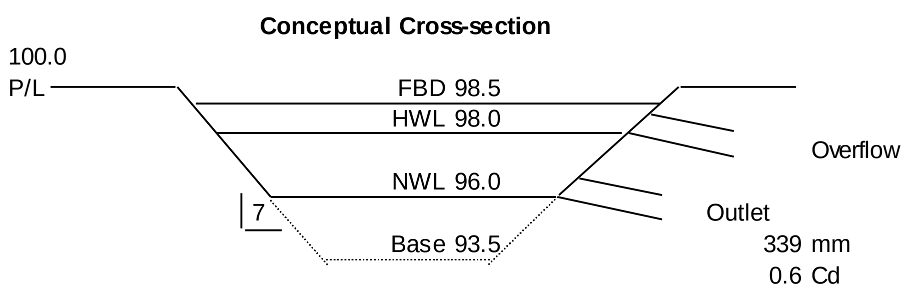
Location	Basin Condition				
	Pre-development Flows (L/s/ha)	Existing Flow (m^3/s)	Future Development Flow (m^3/s)		
			1.5 L/s/ha	3.0 L/s/ha	5.0 L/s/ha
Clearwater Creek at the mouth	1.1	23	23	23	23
Irvine Creek at the mouth	1.1	16	17 (+6%)	24 (+50%)	32 (+100%)
Blackmud Creek WSC Gauge	1.1	92	95 (+3%)	110 (+20%)	131 (+42%)
Whitemud Creek WSC Gauge	2.9	99	86 (-13%)	100 (+1%)	119 (+20%)
Deer Creek at the mouth	2.9	25	22 (-12%)	26 (+4%)	31 (+24%)
Whitemud Creek at NSR		229	215 (-6%)	244 (+7%)	284 (+24%)

2.2 STORMWATER MANAGEMENT COSTS

AE estimated the stormwater management costs that would accrue to typical development assuming the release rates of 1.5, 3.0, and 5.0 L/s/ha. These estimates were based on the following:

- A typical service area draining to a stormwater management facility (SWMF) of 65 ha.
- Storage volumes and draining times were estimated using the Modified Rational Method and storm durations of 1 to 24 hours.
- City of Edmonton design standards were used in developing the conceptual design of a typical SWMF resulting in a conceptual pond cross-section shown in **Figure 2-1**.
- To be conservative all SWMFs were assumed to be wet ponds in which a permanent pool of water is provided. Dry ponds or constructed wetlands could also be used and would yield a reduced cost.
- Construction costs were based on typical unit rates in the Edmonton area.
- Lot yield of 35 lots per net hectare as proposed by the Capital region Board (approximately 27 dwelling units per gross hectare). It is noted that all the municipalities aspire to achieve greater densities in the future which would reduce the SWM costs per hectare.
- Residential development was assumed for the typical SWMF service area. Note that multi-family development is likely to occur on some parcels and commercial/industrial development is likely to occur along the Highway 2 corridor, which would also reduce the cost per dwelling unit or equivalent.

Figure 2-1
Typical Pond Cross-Section



Design Parameters						
Item	Elevation m	Area ha	Total Volume ha.m.	Storage Volume m3	Discharge m^3/s	Depth m
Minimum property line	100.0	4.0	16.3	121345	0.470	6.5
Freeboard	98.5	3.2	10.8	66658	0.366	5.0
HWL	98.0	3.0	9.3	**51050**	**0.325**	4.5
Normal water level	96.0	2.1	4.2	0	0.000	2.5
Base of pond	93.5	1.2	0.0		0.000	0.0
Storage capacity				**51050**		
Average existing ground	100.0	4.0	16.3			
Side slope	7.0	H:V				

Table 2-2 provides the estimated SWMF costs, expressed in dollars per net hectare and per lot. Results indicate the typical SWMF cost will vary between approximately $4,000 per lot if a design release rate of 5.0 L/s/ha is adopted, to $6,000 per lot with 3.0 L/s/ha and $8,000 per lot at 1.5 L/s/ha. These results show that the SWMF costs are relatively small in the range of release rates considered.

Table 2-2
Estimated SWMF Costs

			Pond - 1.5 L/s/ha		Pond - 3.0 L/s/ha		Pond - 5.0 L/s/ha	
Description	Units	Unit Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Clearing and grubbing	ha	$50,000	8.2	$410,000	6.7	$335,000	4.7	$235,000
Stripping	ha	$50,000	8.2	$410,000	6.7	$335,000	4.7	$235,000
Excavation and grading	m^3	$15	383000	$5,745,000	303000	$4,545,000	197700	$2,965,500
Topsoil Replacement	ha	$50,000	8.2	$410,000	6.7	$335,000	4.7	$235,000
Landscaping	ha	$100,000	2.9	$290,000	2.6	$260,000	2.1	$210,000
Shoreline Treatment	m	$200	920	$184,000	810	$162,000	650	$130,000
Control Structure c/w inlet and outlet pipes	LS	$200,000	1	$200,000	1	$200,000	1	$200,000
Sub-Total				$7,649,000		$6,172,000		$4,210,500
Overhead, Administration, Engineering and Contingency		50%		$3,824,500		$3,086,000		$2,105,250
GST		5%		$573,675		$462,900		$315,788
Total Cost				**$12,047,175**		**$9,720,900**		**$6,631,538**
Cost/Unit (net)				**$7,859**		**$6,180**		**$4,076**

It was noted that the drawdown time (the time required to drain the SWMF) is considerably more sensitive to release rate than is cost, varying in direct proportion to the release rate. The pond drawdown time is an important consideration as it affects the time required to empty the pond after a storm event. An extended drawdown time increases the risk that the pond will be partly full when the next storm event occurs. This could potentially increase the required storage volume and pond size required to contain the 1:100 year design event. This could also lead to citizen concerns that the pond is not emptying quickly enough.

In light of this concern, the City of Edmonton has adopted a practice of requiring 90% of the pond storage capacity to be emptied within 96 hours (4 days) of the design 1:100 year storm. This typically requires a design release rate of 5.0 L/s/ha. This provision essentially assumes two 1:100 year design events occurring within 4 days, which is a conservative assumption.

One option to meet this design standard is to increase the pond size to provide sufficient storage volume so that the available capacity, after 96 hours of drawdown, is 90% of the volume required for the 1:100 year design event. This approach has been adopted by the City of Edmonton in a recent development. Table 2-3 provides a summary of required pond storage volumes, pond size, and construction cost to meet this criterion, as has been assumed in Table 2-2.

Table 2-3
Typical SWMF Parameters for Various Release Rates with 96 Hour Drawdown Time*

	1.5 L/s/ha	3.0 L/s/ha	5 L/s/ha
Storage Volume Provided (m^3)	120,000 m^3	95,000 m^3	62,000 m^3
Storage Volume Provided (m^3/ha)	1,846 m^3/ha	1,462 m^3/ha	954 m^3/ha
Surface Area (ha)	8.2 ha	6.7 ha	4.7 ha
Construction Cost	$12.0 million	$9.7 million	$6.6 million
Construction Cost per Unit	$7,859 /Unit	$6,180 /Unit	$4,076 /Unit
Time to Drain to 90% of Required Storage	4 days	4 days	4 days

*65 ha development area at 35 units/ha net (27 units/ha gross)

Previous modelling in the Big Lake Basin Drainage Study demonstrated that the release rate could be reduced to as low as 1.5 L/s/ha without excessively affecting the storage volume. This implies that the City of Edmonton design standard for pond drawdown could be modified to adopt a longer duration. Table 2-4 provides a summary of drawdown time for the various (peak) release rates as well as the storage volume and construction cost (per lot), without the 96 hour drawdown time constraint. A design release rate of 3.0 L/s/ha would increase the drawdown time to 8 days after the 1:100 year storm event.

Table 2-4
Typical SWMF Parameters with Extended Drawdown*

	1.5 L/s/ha	3.0 L/s/ha	5 L/s/ha
Storage Volume Required (m^3)	72,000 m^3	68,000 m^3	62,000 m^3
Storage Volume Required (m^3/ha)	1,1108 m^3/ha	1,046 m^3/ha	954 m^3/ha
Surface Area (ha)	5.3 ha	5.1 ha	4.7 ha
Construction Cost	$7.6 million	$7.2 million	$6.6 million
Construction Cost per Unit	$4,719 /Unit	$4,452 /Unit	$4,065 /Unit
Time to Drain	17 days	8 days	4 days

*65 ha development area at 35 units/ha net (27 units/ha gross)

Comparing Table 2-3 and Table 2-4 demonstrates that the stormwater management costs could potentially be reduced by about $2,000 per lot or $50,000 per gross hectare if a release rate of 3.0 L/s/ha is adopted. AE recommends that further study be undertaken to refine the design standard for pond drawdown, to include continuous long-term simulation of pond performance, with a goal of reducing the servicing cost.

It was also noted that design criteria for SWMFs are similar for the various municipalities except for the design storm which is somewhat greater in the City of Edmonton's design standards than in the other municipalities. Table 2-5 compares the various design standards.

Table 2-5
SWMF Design Standards in the Edmonton Region

Parameter	City of Edmonton	City of Leduc	Town of Beaumont	Strathcona County	Leduc County	Proposed for Planning
Design storm	most critical: 100 year 24 hour Huff, July 1937, July 1978, July 2004, July 2012	100 years 4 hr or 24 hr	most critical: 100 year 24 hour huff, July 1937, July 1978	100 years	100 years	100 year 24 hour storm
IDF Curve	COE 2014 based on upper bound of 13 rain gauges from 1984-2010	EIA 1914-1995	EIA 1914-1995	EIA 1914-1995	EIA IDF curves	COE 2014 IDF curve
Maximum release rate		7.5 L/s/ha	1.8 L/s/ha			
Maximum drawdown time	5yr event within 24 hours		5yr event within 24 hours	2 yr event >=24 hours	5yr event within 24 hours	
	25 yr event within 48 hours		25 yr event within 48 hours	5 yr event within 48 hours	25 yr event within 48 hours	
	90% of full storage volume within 96 hours	90% of full storage volume within 96 hours	90% of full storage volume within 96 hours	90% total storage volume within 96 hours	95% of 100 yr event within 96 hours	
Minimum depth at WML	2.5m	2.5 m	2.5m	2.5m	2m	2.5m
Maximum storage depth		2.0m				2.0 m
Minimum size			2ha	2ha		
side slopes	3:1 to 1.0m below nwl, 7:1 above	7:1 from 1.5 m below the nwl to 0.5 m above 1:100 water level	3:1 to 1.0m below nwl, 7:1 above	3:1 to 1.0m below nwl, 5:1 up to nwl, 7:1 to hwl, 4:1 above hwl	3:1 to 1.0m below nwl, 7:1 to 0.6m above hwl	7:1
freeboard	0.3m to lowest landscape grade or building openings	0.5 m freeboard above the 1978 event hwl in absence of overflow	0.5m to footing elevation swmf backing lots	0.3m to lowest basement weeping tile	0.6m to lowest ground surface for adjacent property	0.5 m above overflow elevation
	0.5m in absence of overflow	0.3m to floor elevation of pond backing lot	0.3m to lowest landscaped level of adjacent buildings/building opening			
		0.5m to building opening pond backing lot	0.6m in absence of overflow			

The City of Edmonton's design criteria have the effect of increasing the required storage volume in SWMFs by about 40%. AE recommends that the differences in design criteria be rationalized and that a uniform design criteria be adopted for the basin. The final column in **Table 2-5** provides the parameters that were adopted for this study.

The potential impact of climate change should also be considered in the adoption of a basin water management strategy. Review of recent research indicates that rainfall rates are expected to increase in the coming century but that the impact is most likely to be felt in short-duration high-intensity thunderstorms. Recent research by the City of Edmonton and the University of Alberta suggest that summers are likely to become wetter in north-central Alberta, but that the volume of rainfall in a major 24-hour storm event of the magnitude used for SWMF design is projected to decline slightly. Based on these estimates it is concluded that climate change is unlikely to have a significant impact on the basin drainage strategy, at least compared with other sources of uncertainty.

2.3 FLOOD EXTENT AND DEPTH

Figures 2-2 to 2-5 show the simulated flood extent for existing conditions and for future development with the different release rates during the 1:100 year design event. These maps correspond to different locations along Blackmud Creek, Irvine Creek, Deer Creek, and Whitemud Creek, respectively. In general, the model results in minor differences in the flood extent based on the different release rates.

Figures 2-6 to 2-9 show the difference in flood depth between the existing flows and future flows for each release rate, at various chainages along Blackmud Creek, Whitemud Creek, Deer Creek, and Irvine Creek, respectively. The results show a maximum rise of about 0.5 m in flood levels with a release rate of 5.0 L/s/ha and lesser impacts with the lower release rates. In general the rise in water level is not deemed to be significant.

2.4 CHANNEL VELOCITIES AND EROSION RATES

As stated in TM No. 4, bank erosion is common throughout the lower reaches of Blackmud and Whitemud Creeks. In general, the rate of bed and bank erosion is related to the velocity of water flowing in the channel. Vertical changes in these velocities produce shear forces that are parallel to the bed. These shear forces act on the bed of a channel and cause bedload transport or erosion. The rate of erosion is generally higher where the velocity is higher, and the velocity generally increases with depth, flow, and slope of the channel which, in Whitemud Creek, occurs in the downstream direction.

In-stream erosion is actively occurring at many meander bends throughout the lower reaches of Blackmud and Whitemud Creeks. In part measure this is due to the higher velocities at these locations and in part due to other processes that govern the lateral migration that occurs naturally at bends. Increasing flows with development will tend to increase velocities which in turn will increase erosion rates.

To estimate the magnitude of these impacts the 1D and 2D models were used to simulate in-channel velocities for release rates of 1.5, 3.0, and 5.0 L/s/ha. The future velocities were then compared with existing velocities at the same location. Maps were then prepared which depict the relative velocity which represents the change from existing conditions to the three scenarios with different release rates for future drainage.

Appendix B provides the mean in-channel velocity computed with the 1D model for the different scenarios (Existing Conditions and Development at 1.5, 3.0, and 5.0 L/s/ha).

Appendix C presents the velocities along Blackmud and Whitemud Creeks computed with the 2D model for the 1.5, 3.0, and 5.0 L/s/ha release rates during the 1:100 design event.

Appendix D presents the velocity ratio maps which compare the in-channel velocity for the future scenarios as a ratio to the velocities for existing conditions for Blackmud and Whitemud Creeks within the City of Edmonton boundary during the 1:100 design event.

Figures 2-10 to **2-12** present the most relevant results at the critical reach of Whitemud and Blackmud Creeks upstream of their confluence at 23 Avenue, where erosion is actively occurring at present. These maps show that the main-channel velocity will increase up to 50% throughout most of this reach if a release rate of 5.0 L/s/ha is adopted. This impact will be less, but still significant, if a release rate of 3.0 L/s/ha is adopted. To limit erosion rates to the existing condition will require release rates to be reduced to 1.5 L/s/ha or less.

It is noted that the City of Edmonton has previously used a release rate of 5.0 L/s/ha for existing development upstream of 23 Avenue. It is likely that the existing development has contributed to the erosion occurring in the creeks.

Hydraulic theory indicates that the rate of sediment transport is proportional to the 3rd power of velocity or, alternatively, the shear stress raised to a power of 1.5, other factors such as bed and bank materials remaining the same. This implies that erosion rates are very sensitive to changes in velocity. Based on this, the rate of erosion or sediment transport within the Blackmud and Whitemud Creeks is expected to remain the same or increase by about 50% if a release rate of 3.0 L/s/ha is adopted. This rate of erosion could increase by double or more if a release rate of 5.0 L/s/ha is adopted.

As discussed earlier, instream erosion is actively occurring at many meandering bends throughout the lower reaches of Blackmud and Whitemud Creeks. Peak flows will increase and velocities will also increase during flood conditions, resulting in increased erosion rates. The magnitude of this impact depends on the release rates adopted which implies that the release rates should be as low as possible.

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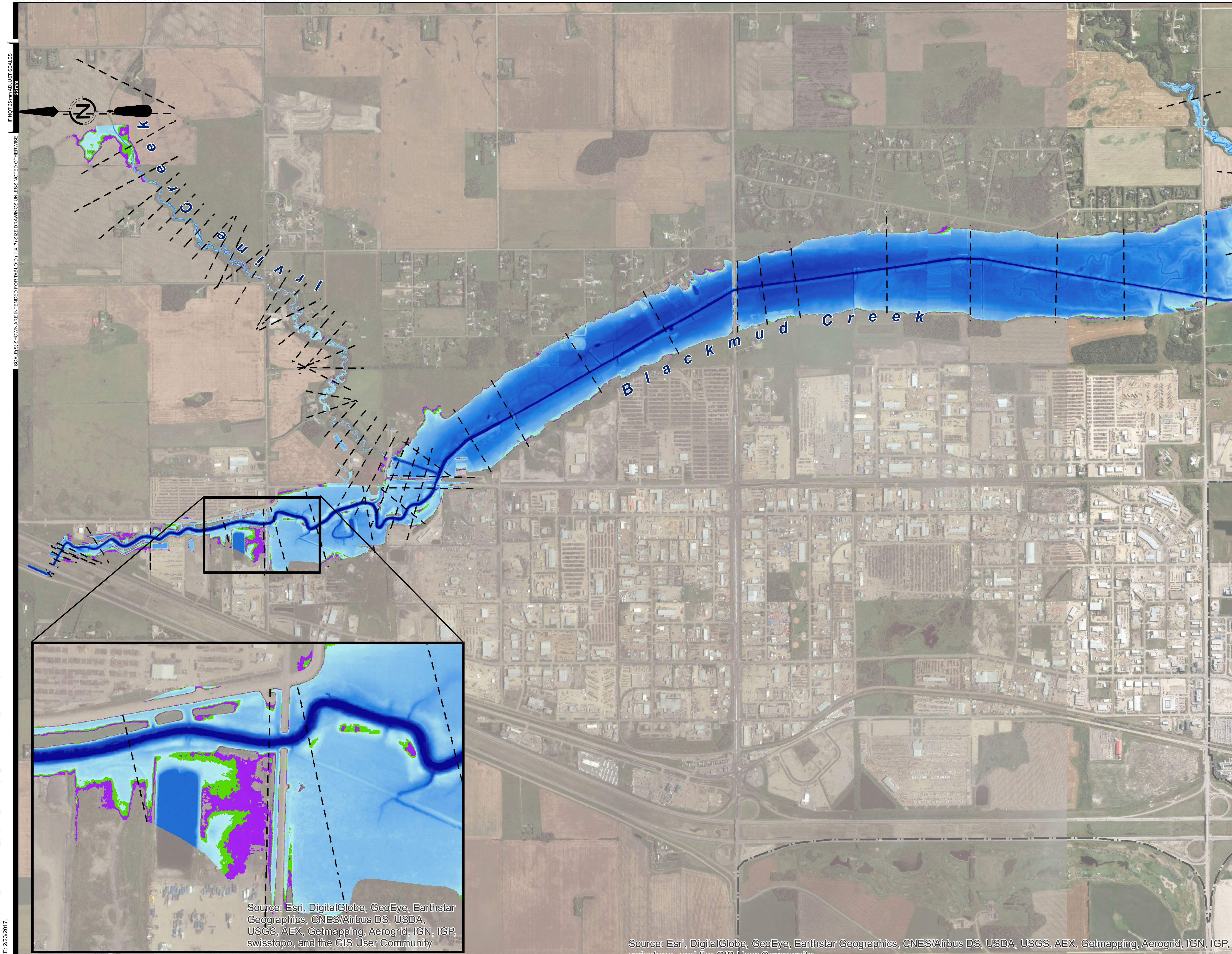

IF NOT 25 mm ADJUST SCALES

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

Associated Engineering

Legend:

- Cross Section
- Existing
- 1.5 l/s /ha
- 3.0 l/s /ha
- 5.0 l/s ha

FIGURE No. 2-2

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

Flood Extent - Blackmud Creek

AE PROJECT No.	2016-3785
SCALE	1:25,000
APPROVED	
DATE	2017 FEBRUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

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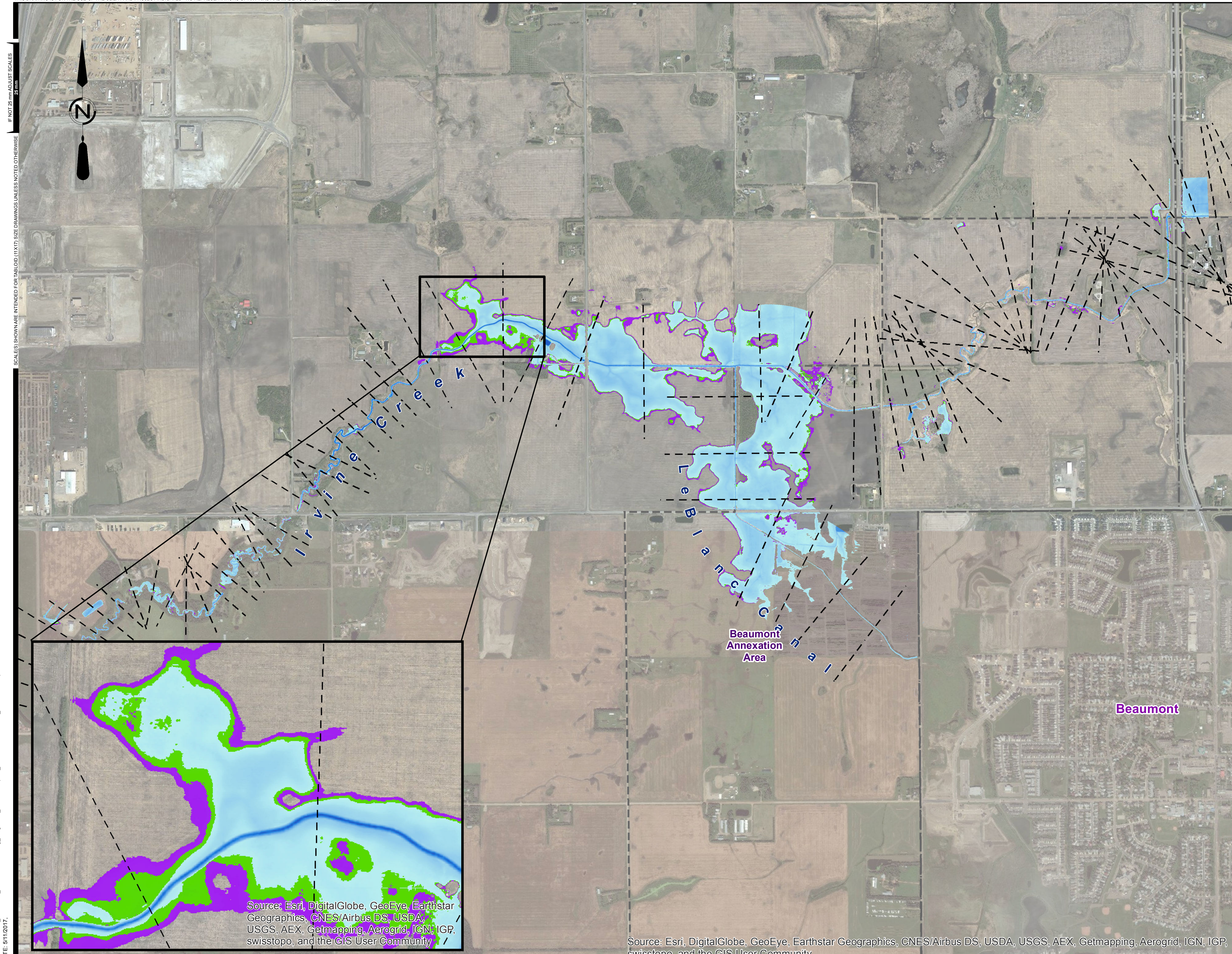
DATE: 2/23/2017,



Associated Engineering

Legend:
- Cross Section
- Water Depth (100 Year)
- 1.5 l/s /ha
- 3.0 l/s /ha
- 5.0 l/s ha

FIGURE No. 2-3

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

FLOOD EXTENT - IRVINE CREEK

AE PROJECT No.	2016-3785
SCALE	1:20,000
APPROVED	
DATE	2017 FEBRUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

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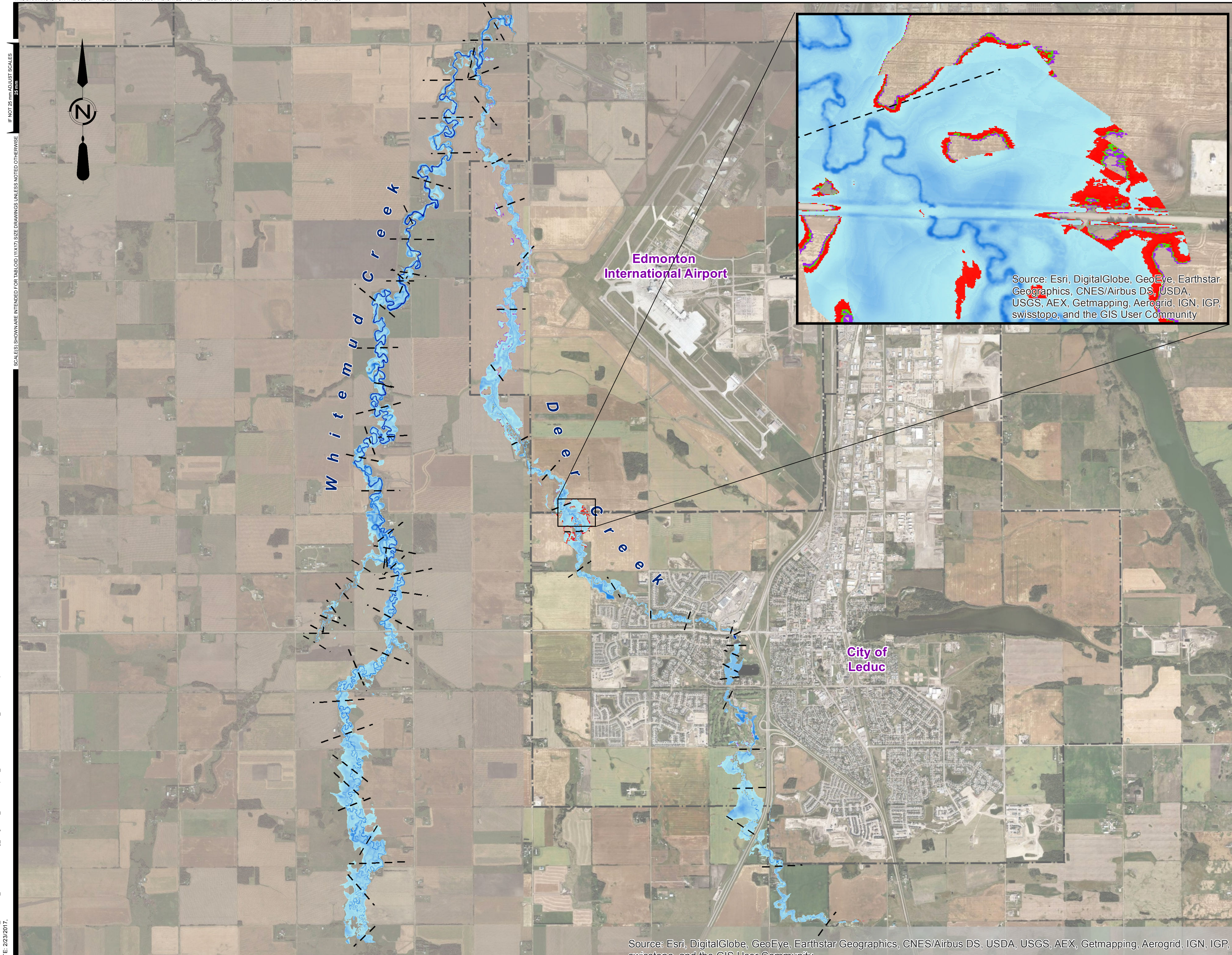

Associated Engineering

Legend:

- Cross Section
- Existing
- 1.5 l/s /ha
- 3.0 l/s /ha
- 5.0 l/s ha

FIGURE No. 2-4

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

Flood Extent - Upper Whitemud and Deer Creeks

AE PROJECT No.	2016-3785
SCALE	1:50,000
APPROVED	
DATE	2017 FEBRUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

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DATE: 2/23/2017,

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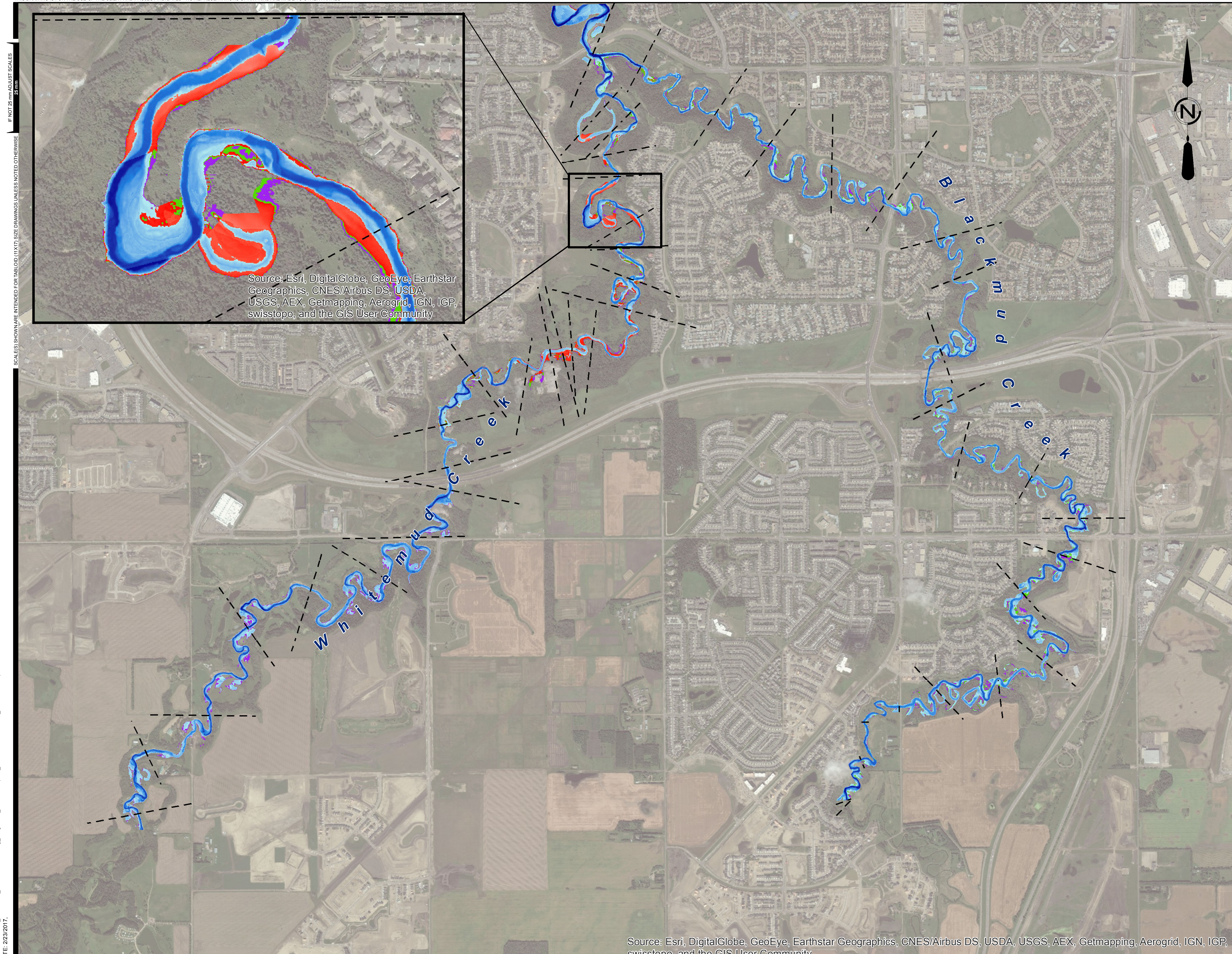
IF NOT 25 mm ADJUST SCALES 25 mm

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE



Associated Engineering

FIGURE No. 2-5

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

Flood Extent - Lower Whitemud and Blackmud Creeks

AE PROJECT No.	2016-3785
SCALE	1:25,000
APPROVED	
DATE	2017 FEBRUARY
REV	
DESCRIPTION	ISSUED FOR REPORT

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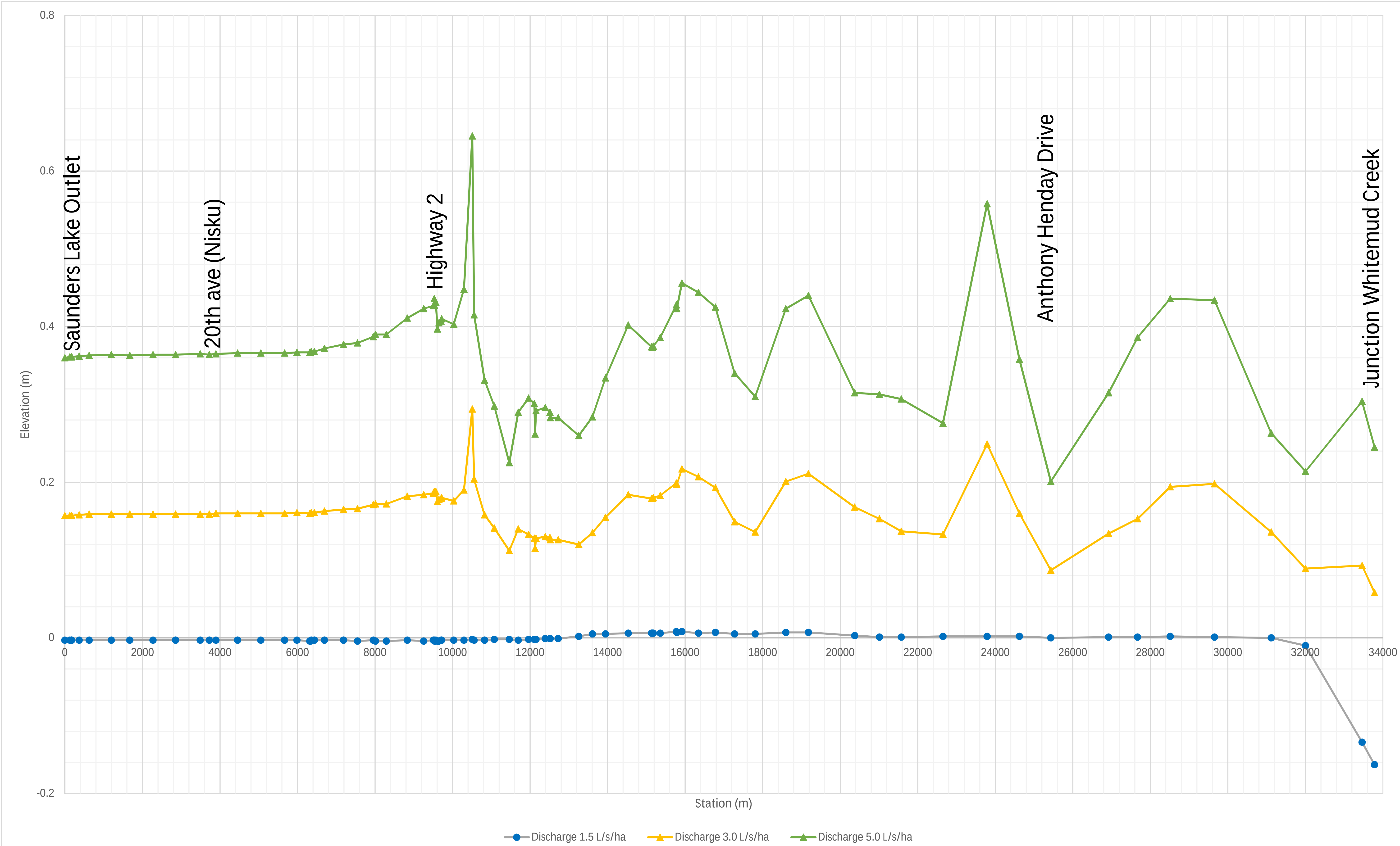
DATE: 2/23/2017,

Figure 2-6: Blackmud Creek
Depth Variation from Existing Flows



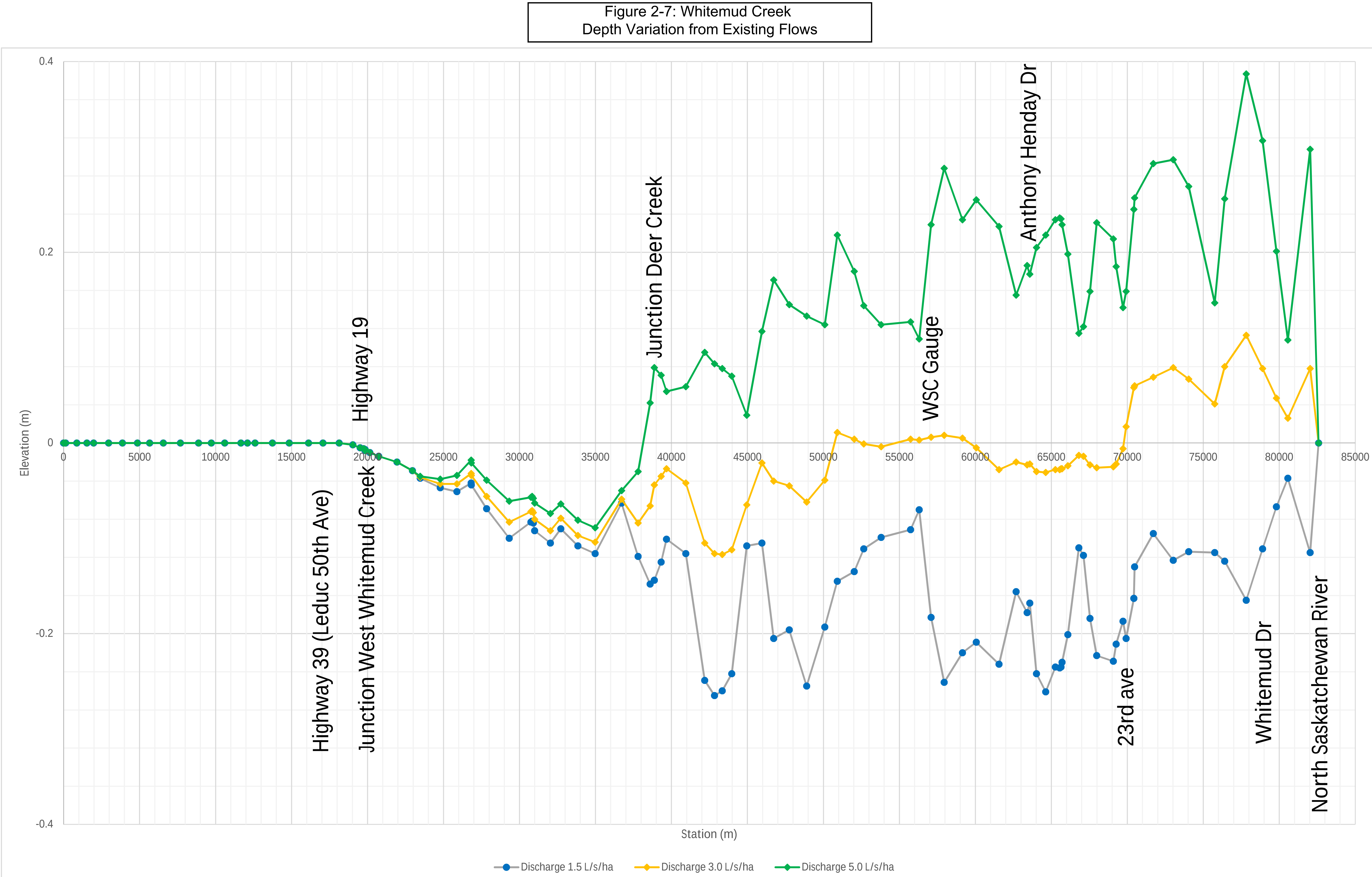
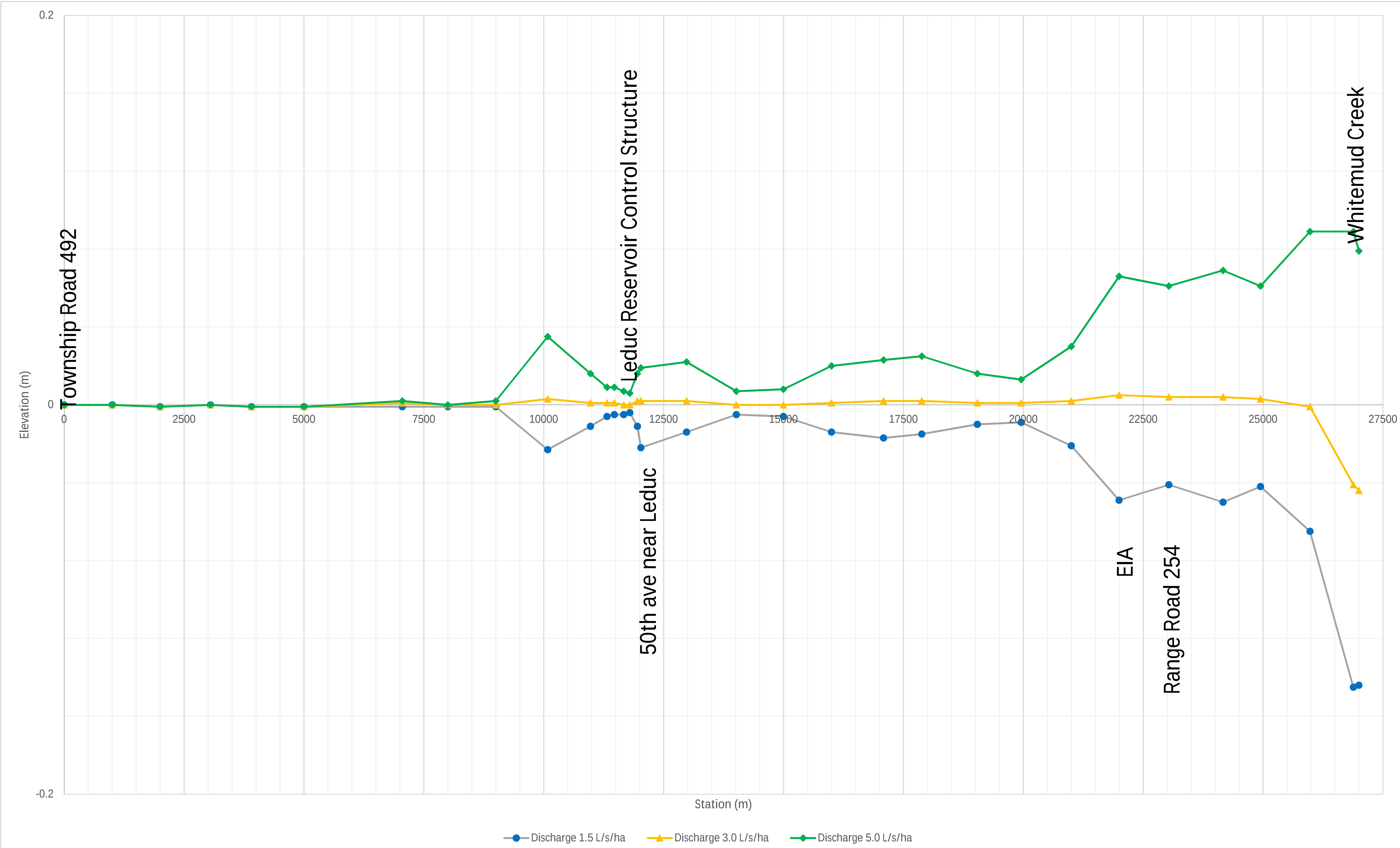


Figure 2-7: Whitemud Creek
Depth Variation from Existing Flows
Elevation (m)
Station (m)
0.4
0.2
0
-0.2
-0.4
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
Highway 39 (Leduc 50th Ave)
Highway 19
Junction West Whitemud Creek
Junction Deer Creek
WSC Gauge
Anthony Henday Dr
23rd ave
Whitemud Dr
North Saskatchewan River
Discharge 1.5 L/s/ha
Discharge 3.0 L/s/ha
Discharge 5.0 L/s/ha

Figure 2-8: Deer Creek
Depth Variation from Existing Flows



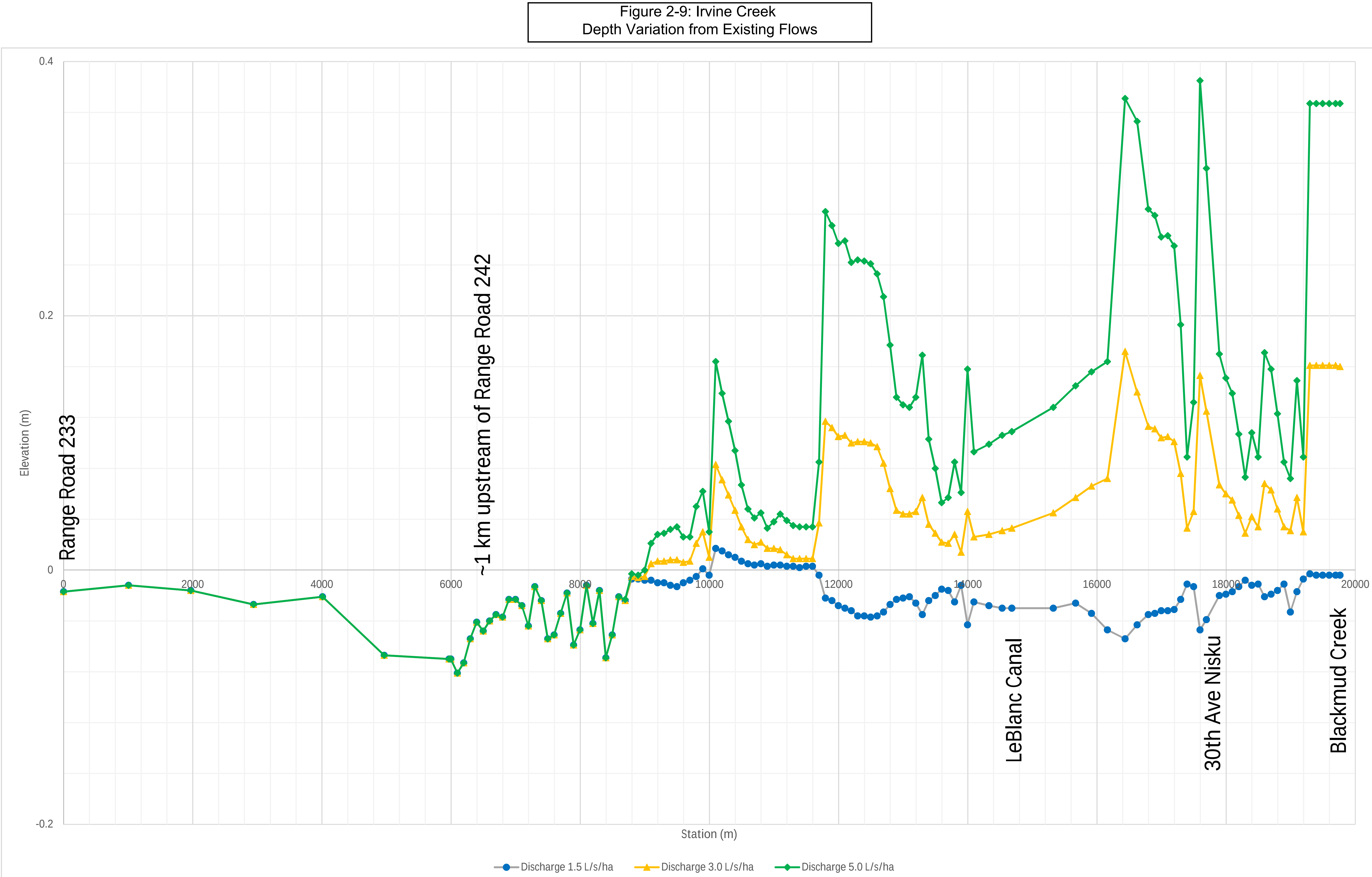


Figure 2-9: Irvine Creek
Depth Variation from Existing Flows
Elevation (m)
Station (m)
Range Road 233
~1 km upstream of Range Road 242
LeBlanc Canal
30th Ave Nisku
Blackmud Creek
Discharge 1.5 L/s/ha
Discharge 3.0 L/s/ha
Discharge 5.0 L/s/ha
0.4
0.2
0
-0.2
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000

Associated Engineering

Legend:

✚ Erosion Site

1.5 L/s/ha Ratio to Existing

- ≥ 1.4
- > 1.3 - 1.4
- > 1.2 - 1.3
- > 1.1 - 1.2
- > 1.0 - 1.1
- ≤ 1.0

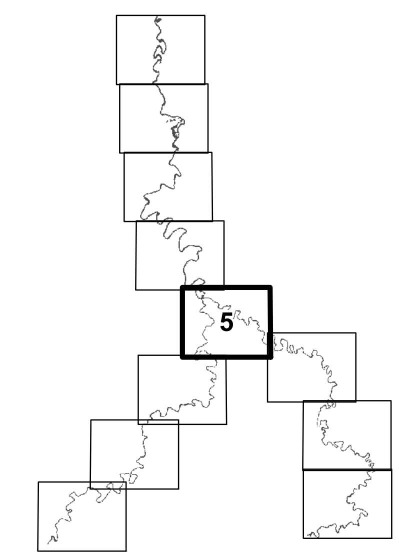


FIGURE No. 2-10

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

FUTURE DEVELOPMENT DISCHARGE RATE
1.5 L/s/ha RATIO TO EXISTING -
100 YEAR FLOOD VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 MARCH
REV	
DESCRIPTION	ISSUED FOR REPORT

IF NOT 25 mm ADJUST SCALES 25 mm
SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

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DATE: 3/24/2017,

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

IF NOT 25 mm ADJUST SCALES

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_FutureDevelopment_Velocity.mxd

DATE: 3/24/2017,

Associated Engineering

Legend:

✚ Erosion Site

3.0 L/s/ha Ratio to Existing

- ≥ 1.4
- > 1.3 - 1.4
- > 1.2 - 1.3
- > 1.1 - 1.2
- > 1.0 - 1.1
- ≤ 1.0

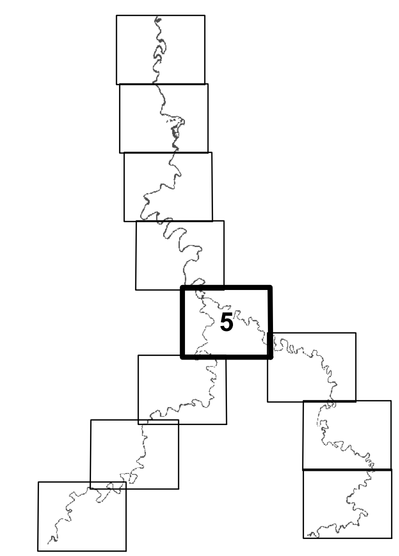

FIGURE No. 2-11

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

FUTURE DEVELOPMENT DISCHARGE RATE
3.0 L/s/ha RATIO TO EXISTING -
100 YEAR FLOOD VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 MARCH
REV	
DESCRIPTION	ISSUED FOR REPORT

Associated Engineering

Legend:

- ✚ Erosion Site

5.0 L/s/ha Ratio to Existing

- ≥ 1.4
- > 1.3 - 1.4
- > 1.2 - 1.3
- > 1.1 - 1.2
- > 1.0 - 1.1
- ≤ 1.0

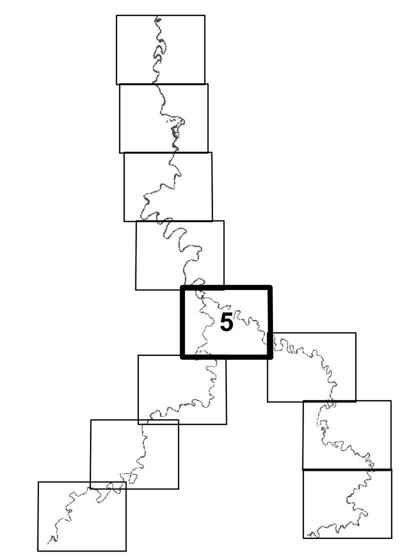

FIGURE No. 2-12

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

FUTURE DEVELOPMENT DISCHARGE RATE 5.0 L/s/ha RATIO TO EXISTING - 100 YEAR FLOOD VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 MARCH
REV	
DESCRIPTION	ISSUED FOR REPORT

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

IF NOT 25 mm ADJUST SCALES

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\xxx_FutureDevelopment_Velocity.mxd
DATE: 3/24/2017,

2.5 EFFECTS OF INCREASED RUNOFF VOLUME

Regardless of the release rate adopted for future stormwater management, the volume of runoff will also increase with development due to conversion of pervious agricultural surfaces to impervious paved roads and rooftops, unless the runoff volume is controlled at the source through low-impact development practices. The available streamflow data indicate that the average runoff in the basin is about 5-10% of annual precipitation at present. Those areas that will be developed are estimated to generate runoff of about 50-60% of precipitation in the future.

Table 2-5 compares the annual runoff volumes (annual average streamflow) at various locations in the basin, estimated for the proposed development in the adopted growth area. These data indicate that the annual runoff volume will increase by about 50% in Blackmud and Whitemud Creeks. Other factors being equal, the amount of sediment transport, or rate of erosion, is directly proportional to runoff volume, which means that the amount of erosion in Whitemud and Blackmud Creeks will increase by about 50% due to the increase in runoff volume alone. Adding the increase due to increasing flood peaks as noted above, the rate of erosion is expected to double in the currently-eroding areas, and the extent of erosion will similarly increase.

Table 2-6
Estimated Runoff Volumes

Location	Existing (1,000 m^3)	Future (1,000 m^3)	Ratio
Clearwater Creek at the mouth	2,200	2,200	1.0
Irvine Creek at the mouth	3,400	11,300	3.4
Blackmud Creek WSC Gauge	14,200	25,500	1.8
Whitemud Creek WSC Gauge	9,000	12,100	1.3
Deer Creek at the mouth	1,100	5,300	4.7
Whitemud Creek at NSR	35,000	51,700	1.5

2.6 ISSUES AND CONSTRAINTS

Table 2-6 provides a summary of the projected impacts of development on peak flow, flood extent, runoff volume, and erosion rate in the basin. As noted above, the erosion problems in Whitemud and Blackmud Creek will increase over time, with the main concerns being the increase in runoff volume due to conversion of agricultural lands to paved surfaces and the potential increase in discharge rates. All future development will have stormwater management to control peak flows, and the magnitude of the impact will depend on the release rate adopted

In the progress meeting on February 24, 2017 the Group agreed on a maximum allowable release rate of 3.0 L/s/ha for planning of all future development in the basin, with a provision that individual municipalities could adopt a lower release rate to minimize the downstream impacts.

Floodplain lands are at risk of flooding and provide valuable environmental spaces. They should be preserved as Environmental Reserve and no development of these lands should be permitted.

In addition, stream channels are relatively small, shallow, and poorly defined, especially in Irvine Creek and Deer Creek and in the upper reaches of West Whitemud Creek. This constraint will potentially impact development of adjacent lands that drain to the creeks in that these stream channels are too shallow to provide an outfall from a piped drainage system. This issue will be explored in the following section of this report.

Table 2-7
Projected Impacts of Development in the Basin

Peak Flow	Significant -13% to 100% depending on release rate and location
Flood Extent **Flood Depth**	Relatively minor (localized) <0.4M
Runoff Volume	Significant 1-5x depending on location
Erosion Rate and Extent	Significant 0-2x depending on release rate and location