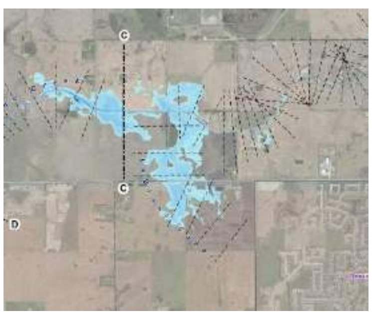
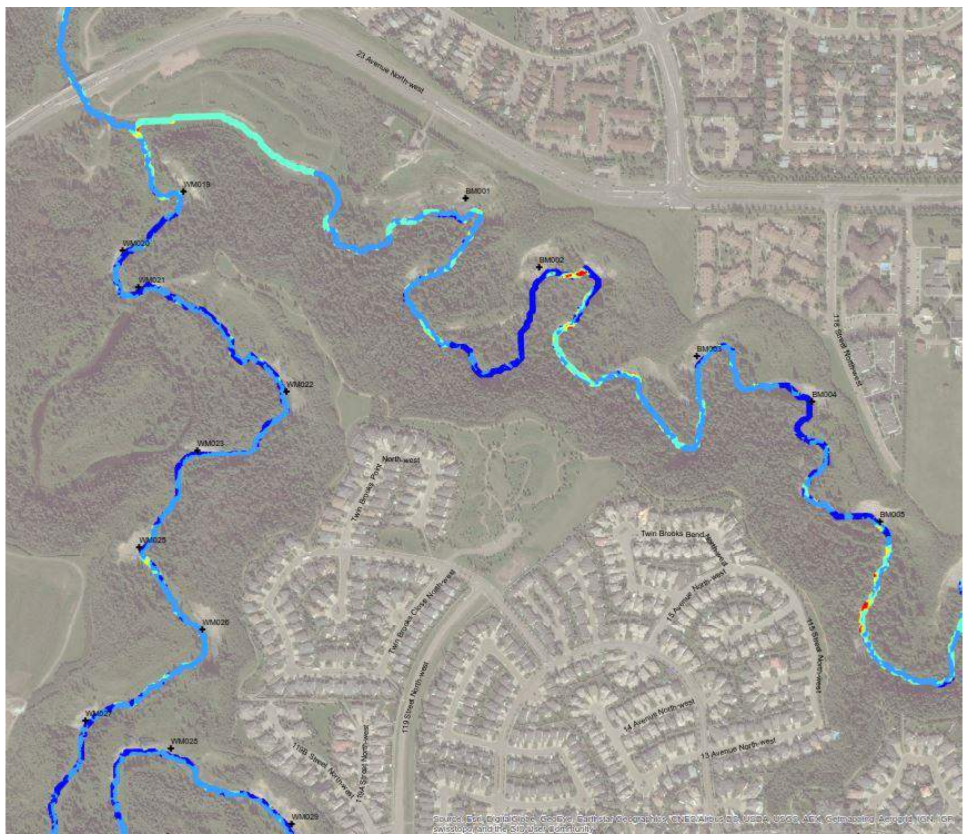
REPORT

Blackmud/Whitemud Creek
Surface Water Management Group

Blackmud/Whitemud Creek
Surface Water Management Study
Final Report



July 2017

Executive Summary

The Blackmud/Whitemud Surface Water Management Group (the Group) commissioned Associated Engineering (AE) to complete the Blackmud/Whitemud Creek Surface Water Management Study. This study involved hydrologic, hydraulic, and environmental analyses of the Blackmud and Whitemud Creek basins to develop a stormwater management strategy to accommodate future development in the basin.

The Blackmud/Whitemud basin spans portions of five separate municipalities and experiences a number of drainage, flooding and erosion control issues. Sustainable development requires a consistent and coherent approach among the member municipalities that respects the water management needs and concerns of the basin. Unfortunately, this has not always been the case as evidenced by the fact that different stormwater management policies have been adopted by the different municipalities, and that the release rates have varied over time.

The objective of this project was to prepare a Surface Water Management Plan (SWMP) in accordance with the Stormwater Management Guidelines for the Province of Alberta and the Alberta Wetland Policy (September 2013), to ensure that cumulative effects on the watershed are understood and will be appropriately mitigated and managed. The goal was to recommend policies and design criteria for use in comprehensive plans for drainage implementation that will be required in the future, and to achieve consensus among member municipalities on a maximum discharge rate and general recommendations for a future water management plan in the basin. If approved by Alberta Environment and Parks this plan will expedite drainage planning and approvals by establishing a memorandum of understanding among member municipalities on the maximum discharge rate.

The project involved several key tasks which are outlined as follows:

- Review of background data, including information on historic and existing drainage projects in the basin.
- A physical inventory of watershed features, flooding and erosion conditions, and natural areas and wetland resources.
- A hydrologic analysis to document key hydrologic characteristics of Whitemud and Blackmud Creeks.
- Hydrologic and hydraulic modelling to define the flow regime of Whitemud and Blackmud Creeks under existing development and with future development conditions and to evaluate various drainage control options.
- Erosion and flooding assessment to define the potential impacts of increased peak flows and increasing runoff volume under various development scenarios.
- Identify drainage constraints and opportunities and alternatives for stormwater management and a drainage concept plan for the basin.
- Stakeholder consultation and decision-making workshops.

- Project management and advisory services to ensure the project meets its goals on time and on budget.

The analysis undertaken in this study is documented in five Technical Memoranda that are appended to the main report. It indicated that the flooding and erosion problems in the basin are expected to increase over time. The main concerns will be the increase in runoff volume and discharge rate due to conversion of agricultural lands to paved surfaces and the potential increase in discharge rates, with the magnitude of the impact depending on the release rate adopted. All future development will need to have stormwater management to control peak flows. The following table provides a summary of the projected impacts of development up to the limits currently anticipated by the Capital Region Board within the basins:

Peak Flow	Significant -13% to +100% increase 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 to 200% increase depending on release rate and location

The main body of the report provides a summary of the study process and the main findings. It outlines a five-point strategy for water management in the basin to achieve the following key objectives:

- Prevent flooding of private property and protect floodplain lands for future generations.
- Minimize and mitigate erosion along stream courses (especially Whitemud Creek).
- Retain and adapt existing wetlands for wildlife habitat and water quality enhancement.
- Preserve and enhance stream course water quality.
- Facilitate orderly and sustainable development and expedite approvals.

Details of the overall strategy are provided in Section 7 of the report. Specific recommendations are as follows:

1. The Blackmud and Whitemud basins should adopt a maximum release rate of 3.0 L/s/ha which produces flows that are similar to the existing flows within most of the creeks except Irvine creek and LeBlanc Canal. A higher release rate could be considered in the EIA zones of control to minimize concerns about bird hazards.

2. Protect floodplain land within the Blackmud and Whitemud basins from further development with a floodplain overlay in the municipal lands use bylaws and dedicate them as Environmental Reserves

at the time of subdivision. A policy for protecting floodplains that recognizes the flood risk and the environmental values that floodplains provide should be developed.

3. Where extensive overland flooding is found to occur, it is not always practical to sterilize large areas from development, and these locations should be considered as possible sites for stormwater management facilities or wetlands.

4. Two viable concepts (channel improvement and trunk sewers) were identified to mitigate the impacts of future development within the Blackmud and Whitemud basins. A network of outfall trunk sewers adjacent to the existing stream channels is a more environmentally sensitive option to carry the releases from the connected stormwater management facilities to a downstream location where adequate channel capacity and depth are available. Existing channels should be preserved to carry the runoff from upstream undeveloped lands and disturbance of these channels should be minimized. More detailed study is recommended to develop the details and further evaluate these proposed concepts.

5. More detailed drainage planning and floodplain modelling will be required during subsequent planning stages to define the extent of the floodplains and the design requirements for any drainage option that might be adopted.

6. All proposed drainage works must be constructed in an environmentally sensitive manner.

7. Further detailed analyses will be required to integrate existing wetlands into the urban fabric and to establish the appropriate water management strategy and water levels for existing and proposed wetlands. Cawes Lake should be retained, adapted and provided with a defined outlet to manage lake levels for habitat enhancement and to prevent flooding of the adjacent lands. A regional wetland is proposed to replace the flood storage that would otherwise be lost with channelization of Irvine Creek. Existing floodplain areas should be preserved as Environmental Reserve and protected from further development.

8. Promote the construction and use of wet ponds and wetlands (not dry ponds) within the basins, except in the EIA exclusion zone.

9. Promote LID to reduce runoff volumes from the Blackmud and Whitemud basins.

10. Repair and remediate erosion sites as necessary.

11. Further studies will be required to determine a mechanism for future costs and cost sharing for offsite improvements and erosion repairs.

12. Develop monitoring programs for water quality, rainfall and flow data within the basins. This will aid in monitoring the impacts of development.

13. Water quality assessment is recommended to gain a more thorough understanding of baseline water quality for all areas of the watershed. This would include water quality testing at additional locations in the watersheds focusing on the upper reaches and an expanded list of parameters for analysis. This assessment would support the development of a watershed protection plan, which could include detailed source protection policy and management.

14. Coordination planning between municipalities within the basins by adopting a water management plan for the basin and ensuring their stormwater management design criteria are consistent.

15. The Group will need to communicate with AEP to coordinate “Fenceline” approvals for future development within the Blackmud and Whitemud Creek basins.

16. Further study should be undertaken to refine the design standard for pond drawdown, to include continuous long-term simulation of pond performance, with a view toward reducing the servicing cost.

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1 Introduction

The pace of development in the Edmonton-Leduc corridor has been increasing recently. In order to determine the cumulative effects of additional stormwater discharges to the Blackmud and Whitemud Creeks, the Blackmud/Whitemud Surface Water Management Group (the Group) was formed. The Group consists of Leduc County, the City of Edmonton, the City of Leduc, the Town of Beaumont, Strathcona County, and the North Saskatchewan Watershed Alliance (NSWA).

The Group commissioned Associated Engineering (AE) to complete the Blackmud/Whitemud Creek Surface Water Management Study. The study involved hydrologic, hydraulic and environmental analyses of the Blackmud and Whitemud Creek basins to develop a stormwater management strategy to accommodate future development in the basin.

Large portions of the Blackmud/Whitemud Creek watershed are expected to be intensively developed in the foreseeable future by the surrounding municipalities. This development will place additional stresses on Blackmud and Whitemud Creeks, which have already been impacted by previous development.

Key drainage issues within the basin are related to topography, soil conditions, land use, legislations, data availability, natural and man made processes. These issues include the following:

- **Flooding and drainage constraints:** Project study area channels are small and poorly defined except for the downstream reaches of Blackmud and Whitemud Creek. The creeks are also subject to flooding in places. Overbank flooding poses a constraint on development. This could be aggravated by development if peak flows are not adequately managed.

- **Bed and bank erosion:** Serious bed and bank erosion are occurring in the lower reaches of the Blackmud and Whitemud Creeks where flows have increased as a result of previous development. Local erosion is occurring elsewhere. Increasing runoff volumes and peak flows due to urban development could increase the bed and bank erosion rates.

- **Municipal servicing strategies and stormwater management criteria:** The basin lies within the jurisdiction of five different municipalities that have their own, and sometimes differing, servicing standards and development policies. These differences need to be understood and rationalized to develop a consistent and effective approach to the surface water management issues in the basin. Municipal boundaries are likely to change in the future but the basin issues will remain the same; simply stated, the stormwater management needs of the basin span the municipal boundaries and affect all municipalities.

- **Pre-development runoff rates:** These vary throughout the basin due to variations in topography and need to be understood in order to define the existing flood and erosion potential and to develop a coordinated strategy for the future.

- **Stakeholder Perspectives:** These need to be recognized and respected. Stakeholder perspectives with respect to surface water management need to be reconciled to develop a consistent strategy that respects the needs of the basin. Such a strategy must also respect the views of Alberta Environment and Parks (AEP) who ultimately is responsible for environmental management in the basin.

In general, runoff from most developments is being controlled with SWM facilities, but not always to the same standard. Drainage standards have also become more restrictive over time. **Table 1-1** presents the discharge release rates that have been previously adopted by each municipality as estimated in **Appendix A**. Some older areas within the City of Edmonton, the City of Leduc, and Leduc County (Nisku) were developed without stormwater management (SWM).

Table 1-1
Summary of SWM Discharge Release Rate

Municipality	SWM Discharge Release Rate (L/s/ha)
City of Edmonton	5
City of Leduc	2 – 8.8*
Leduc County	3.1 – 4.2
Town of Beaumont	1.8 – 6.7

* Estimated based on outlet pipe and drainage catchment

In addition, significant drainage changes and channelization have occurred due to agricultural drainage practices and historic land clearing to create farmland, throughout much of the basin. These changes have undoubtedly increased the flows in the study area streams. As development continues in the Blackmud and Whitemud basins, the runoff rates and volumes will increase. As a result, flooding and erosion issues will likely increase unless stormwater releases are mitigated.

The objective of this project was to prepare a Surface Water Management Plan (SWMP) in accordance with the Stormwater Management Guidelines for the Province of Alberta and the Alberta Wetland Policy (September 2013), to ensure that cumulative effects on the watershed are understood and will be appropriately mitigated and managed. The goal was to recommend policies and design criteria for use in comprehensive plans for drainage implementation, and to achieve consensus among member municipalities on a maximum discharge rate. In addition, recommendations for a future water management plan in the basin were required. If approved by Alberta Environment and Parks this plan will expedite drainage planning and approvals by establishing a memorandum of understanding among member municipalities on the maximum discharge rate.

The study involved several key tasks which are outlined as follows:

- Review of background data, including information on historic and existing drainage projects in the basin.

- A physical inventory of watershed features, flooding and erosion conditions, and natural areas and wetland resources.
- A hydrologic analysis to document key hydrologic characteristics of Whitemud and Blackmud Creeks.
- Hydrologic and hydraulic modelling to define the flow regime of Whitemud and Blackmud Creeks under present pre-development conditions and with future development conditions and to evaluate various drainage control options.
- Channel morphology and flooding assessment to define the potential impacts of increased peak flows and increasing runoff volume under various development scenarios.
- Identify drainage constraints and opportunities and alternatives for stormwater management and a drainage concept plan for the basin.
- Stakeholder consultation and decision-making workshops.
- Project management and advisory services to ensure the project meets its goals on time and on schedule.

As part of the study, AE developed five technical memoranda discussing different aspects of the basin. The technical memoranda are listed below and are included as Appendices to this report:

- Technical Memorandum No. 1: Background Data Collection and Review (**Appendix A**)
- Technical Memorandum No. 2: Blackmud/Whitemud Creek Natural Areas and Aquatic Ecosystem Assessment (**Appendix B**)
- Technical Memorandum No. 3: Hydrology Assessment (**Appendix C**)
- Technical Memorandum No. 4: Hydrologic and Hydraulic Modelling (**Appendix D**)
- Technical Memorandum No. 5: Concept Development (**Appendix E**)

2 Hydrology

2.1 BASIN OVERVIEW

Figure 2-1 shows the Blackmud and Whitemud Creek catchment boundaries and the major watercourses. The Blackmud/Whitemud Basin covers an area of approximately 1,200 km^2 and includes the sub basins of Whitemud Creek, Blackmud Creek, and several tributaries.

The southern headwaters of Blackmud Creek drain into Saunders Lake, southeast of Nisku. Blackmud Creek has been modified through Nisku and drains into the City of Edmonton before discharging into Whitemud Creek. Whitemud Creek originates in the farmland south of the Edmonton International Airport (EIA) and continues northwards to the North Saskatchewan River in the City of Edmonton.

The study area includes a number of tributaries and creeks. Tributary watercourses located within the study area are: Irvine Creek, Clearwater Creek, Deer Creek and the LeBlanc Canal.

Figure 2-2 presents an overview of the basin topography derived from a 15 m resolution LiDAR data. The LiDAR data was used to delineate boundaries for the study area as shown in Figure 2-1. The overall direction of drainage is north towards the City of Edmonton.

Portions of the basin are flat and poorly drained and there are numerous wetlands. The upper catchment of Blackmud Creek contains several large lakes, namely: Saunders, Ord, Telford, Looking Back, and Cawes Lakes. These lakes cover an area of approximately 4.2 km^2 and drain an area of 249 km^2, thus providing significant streamflow routing potential and reduction of peak flows. The upper basin also contains vast areas of knob-and-kettle terrain that store runoff and reduce peak flows.

The Blackmud and Whitemud basin is being developed and this trend is envisioned to continue in the future. Developed areas that are currently discharging into the Whitemud and Blackmud Creeks include the following:

- City of Edmonton extending south to 41st Avenue SW;
- City of Leduc;
- Leduc County's Nisku Industrial Park;
- Town of Beaumont; and
- Edmonton International Airport.

A more detailed basin description is presented in Appendix C.

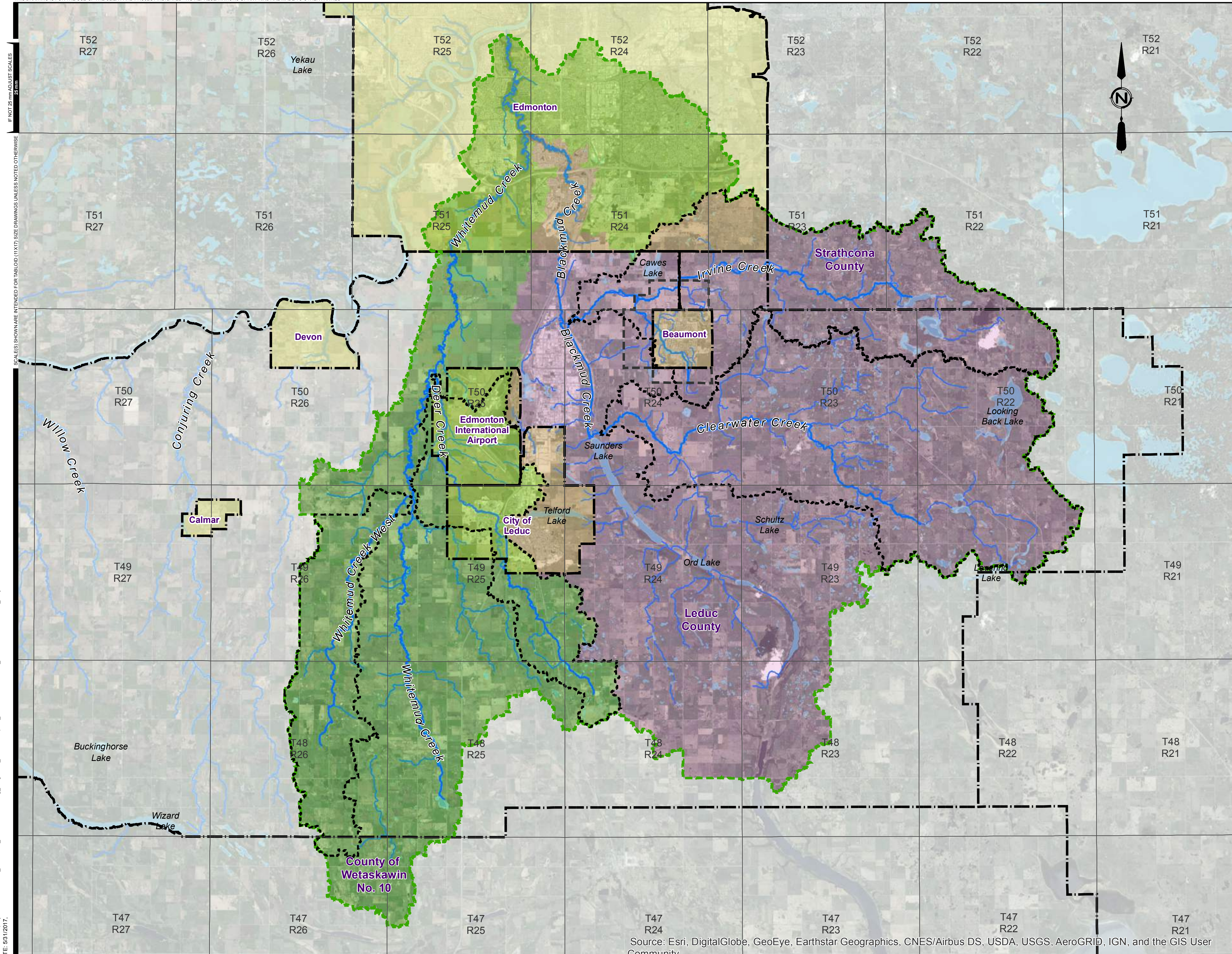
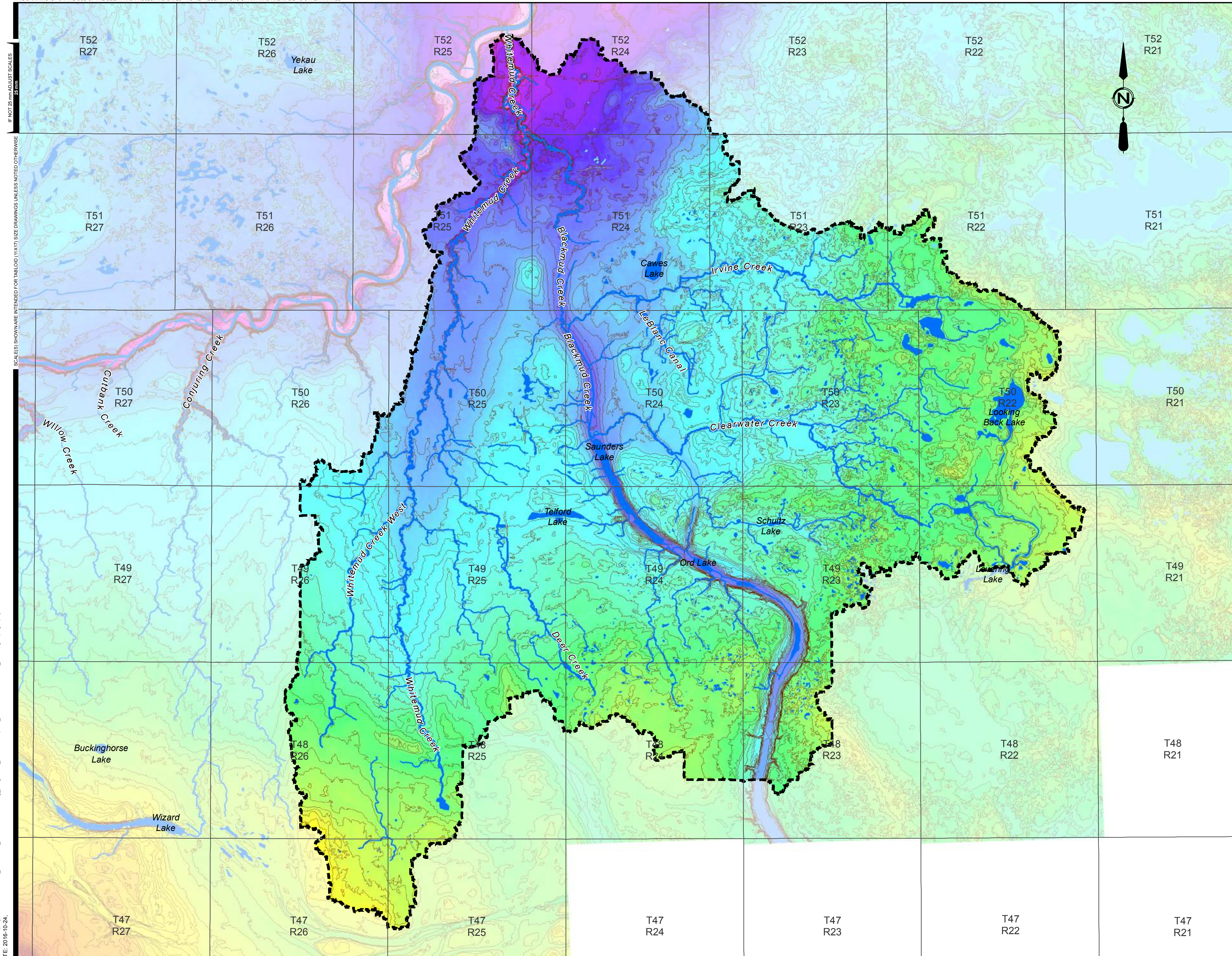


FIGURE No. 2-1

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

STUDY AREA

AE PROJECT No.	2016-3785
SCALE	1:200,000
APPROVED	
DATE	2017 JULY
REV	
DESCRIPTION	ISSUED FOR REPORT



Associated Engineering

Legend:
- Whitemud Watershed
- Creek Centreline
- 5 m Contour

Elevation
- 880 m
- 840 m
- 800 m
- 760 m
- 720 m
- 680 m
- 640 m

FIGURE No. 2-2

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

EXISTING TOPOGRAPHY

AE PROJECT No.	2016-3785
SCALE	1:200,000
APPROVED	
DATE	2017 JULY
REV	
DESCRIPTION	ISSUED FOR REPORT

2.2 RUNOFF VOLUMES

The climate of the study area is characterized by warm summers and cold winters, with a relatively even distribution of precipitation throughout the year. The annual runoff regime is characterized by high flows in the spring due to snowmelt, followed by several typically smaller peak events during the summer generated by rainfall. **Figure 2-3** shows the average season distribution of runoff in the two sub-basins.

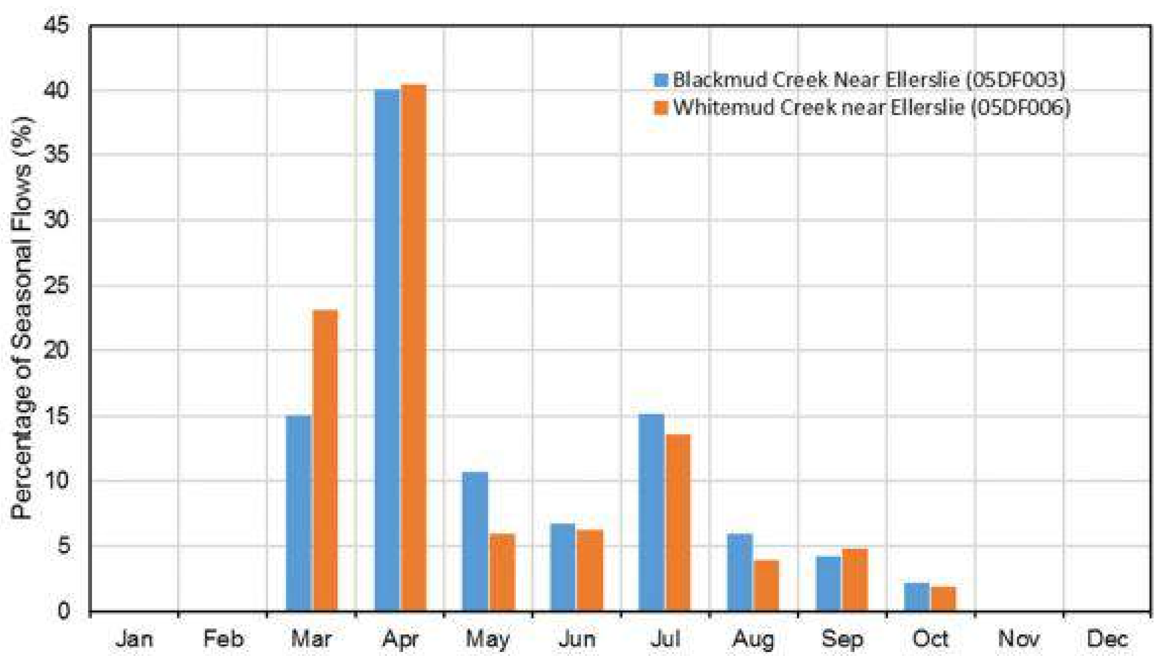


Figure 2-3
Seasonal Distribution of Runoff in the Project Area

Figure 2.4 compares the annual runoff volume in the Whitemud and Blackmud Creek basins, expressed as a unit depth of runoff (runoff volume divided by gross drainage area). This figure shows that on a unit area basis, the Blackmud and Whitemud basins generate relatively similar runoff depths. The temporal variation of runoff, as reflected in peak flow, is affected by lake and upstream storage routing effects which are more significant in the Blackmud basin.

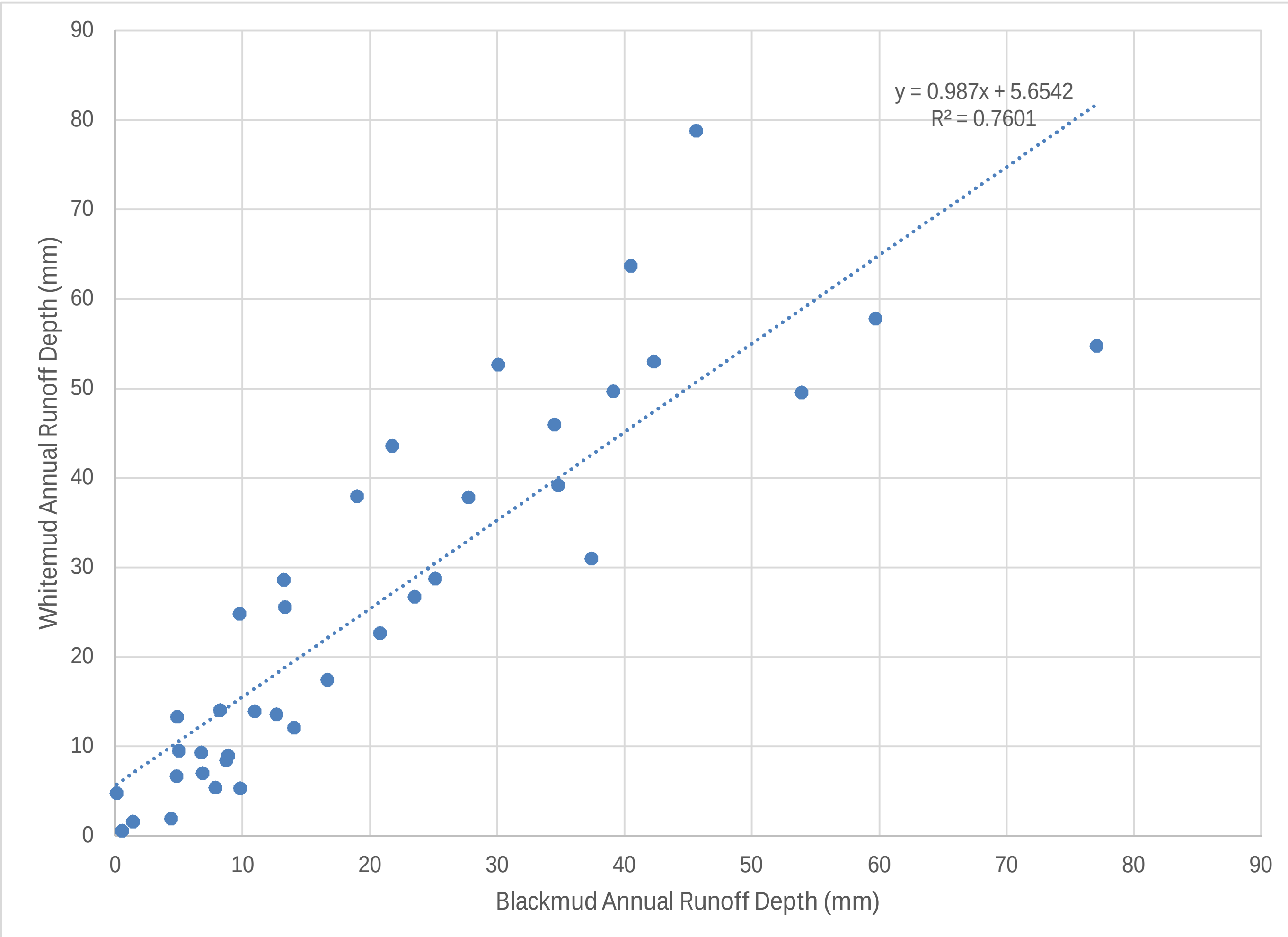


Figure 2-4
Annual Runoff Depth Comparison

2.3 PEAK FLOW ANALYSIS

The flood frequency analysis was updated using the most recent Water Survey of Canada (WSC) flow data (up to 2014) to estimate the peak streamflow at various locations in the study area as presented in **Appendix C**. These streamflow estimates provide the baseline against which potential impacts of future post-development flows can be assessed.

Table 2-1 summarizes the available hydrometric data within the study area. There is one (1) gauge located on Blackmud Creek and three (3) along Whitemud and West Whitemud Creeks. **Figure 2-5** shows the gauge locations and the outlines of their catchment areas.

Table 2-1
WSC Gauges

Gauge	Description	Gross Drainage Area (km^2)	Effective Drainage Area (km^2)	Years of Available Data
05DF003	Blackmud Creek near Ellerslie	643	375	1935 + 1977 - 2016
05DF006	Whitemud Creek near Ellerslie	330.4	300	1969 - 2016
05DF007	West Whitemud Creek near Ireton	65.4	53	1976 - 2016
05DF009	Whitemud Creek at Edmonton	1107.8	800	2013 - 2016

A flood frequency analysis was conducted using the available data up to 2014. Where maximum instantaneous values were not available, they were estimated based on a linear relationship between maximum daily values and maximum instantaneous values.

Calculations were based on the analysis and comparison of Pearson Type III, Log Pearson Type III, Log Normal and Gumbel frequency distributions. This analysis includes the 2013 and 2014 peak flows from the WSC gauge stations, and therefore yields slightly different values than previous studies.

Table 2.2 provides the flood frequency estimates for key locations along with the gross and effective drainage area and the unit discharge rates per hectare calculated from the peak flow estimate and the gross drainage area.

The unit discharge rates range from 1.1 to 2.9 L/s/ha for the 1:100 year return period when calculated using the gross drainage area. In general, the lowest runoff rates occur in the Blackmud Creek sub-basin and the highest rates occur in the Whitemud Creek sub-basin, reflecting differences in topography. As noted in **Section 1**, existing development was designed to release at rates ranging from 1.8 to 8.8 L/s/ha. Older areas that were developed without stormwater management have higher release rates.

The analysis demonstrated a need for additional monitoring of streamflow and climate in the project area. There is only one weather station within the basin, located at the Edmonton International Airport which provides a good long-term database of temperatures, precipitation and general climate. However, it is not adequate to capture the variability of rainfall which governs the summer runoff in the basin. This will increasingly be important as large areas of the basin are developed. As a minimum, AE recommends that additional rain gauges be installed as other areas are developed to complement the City of Edmonton's monitoring program.

There is no flow data in the tributary streams other than in West Whitemud Creek. There is a need to monitor flows in Irvine Creek where extensive development is planned in the near future and where impacts are likely to be greatest. The new hydrometric gauge 05DF009 in Whitemud Creek in the City of Edmonton (at Whitemud Drive) will provide valuable data on creek flow as the upstream basin is developed.

Details of the hydrology assessment are presented in **Appendix C**

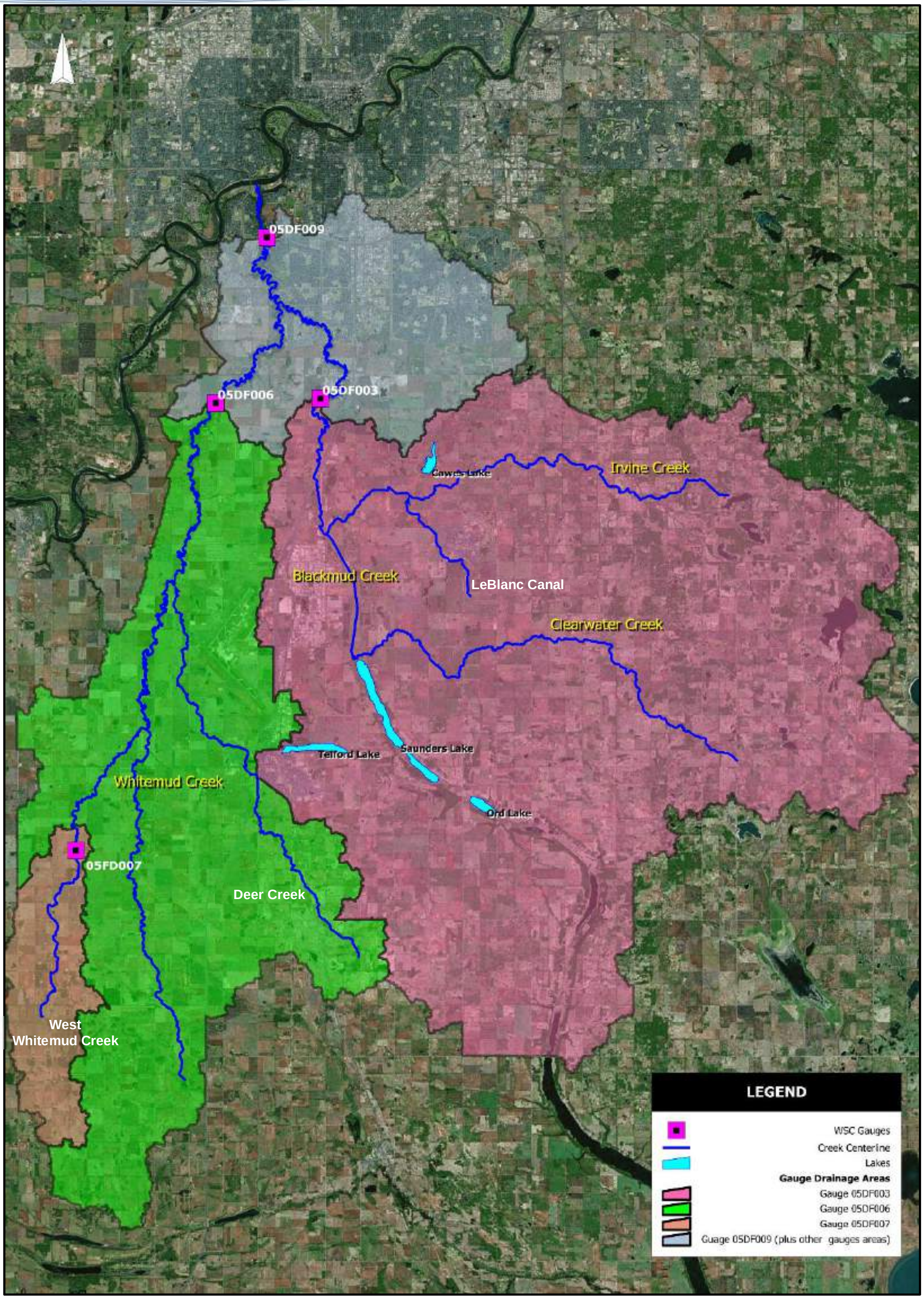


Figure 2-5
WSC Gauge Locations and Catchment Areas

Table 2-2
Flood Frequency Estimates

	Blackmud Creek WSC 05DF003	Whitemud Creek WSC 05DF006	West Whitemud Creek WSC 05DF007	Clearwater Creek at the mouth	Irvine Creek at the Mouth	Blackmud Creek at the Mouth	Whitemud Creek above Blackmud Creek
Gross Drainage Area (km^2)	643	330.4	65.4	208	158	683	385.9
Effective Drainage Area (km^2)	375	300	53	200.92	153.28	415	326.67
Return Period (years)	**Maximum Instantaneous Flood Estimates (m^3 /s)**						
2	4.6	10.1	2.6	5.7	4.8	5.0	10.7
5	16.6	24.9	4.6	13.7	11.4	17.8	26.3
10	27.6	37.9	5.7	20.3	17.0	29.6	40.1
25	43.9	57.7	6.9	30.0	25.0	47.0	61.1
50	57.3	75.1	7.8	38.0	31.7	61.3	79.5
100	71.5	95	8.5	46.8	39.1	76.5	100.6
Return Period (years)	**Unit Discharge Rates (L/s/ha) Based on Gross Drainage Area**						
2	0.1	0.3	0.4	0.3	0.3	0.1	0.3
5	0.3	0.8	0.7	0.7	0.7	0.3	0.7
10	0.4	1.1	0.9	1.0	1.1	0.4	1.0
25	0.7	1.7	1.1	1.4	1.6	0.7	1.6
50	0.9	2.3	1.2	1.8	2.0	0.9	2.1
100	1.1	2.9	1.3	2.3	2.5	1.1	2.6

3 Environmental Assessment

An ecological assessment was conducted to document the environmental features within the Study Area (**Appendix B**). The study primarily focused on key aspects of watershed health. These focus areas include riparian condition and wetland area, which are two attributes of a watershed that are directly related to stream erosion and water quality degradation. Healthy watersheds require native woody riparian vegetation and wetlands on the landscape because they function to attenuate flood water, reduce peak velocities and improve water quality. Much of this riparian vegetation occurs within the floodplains and along the stream courses.

3.1 RIPARIAN ANALYSIS

Riparian areas provide important functions such as trapping and storing sediments, stabilizing banks and shorelines, slowing flood water, recharging aquifers, reducing contaminants and nutrients entering water bodies, reducing water velocity, and maintaining biodiversity across the landscape. Riparian condition in the study area was analyzed by evaluating land cover within a 100-metre buffer of major creeks.

The land cover analysis indicated that over half of the total lands within creek buffers have been altered by human development (**Figure 3-1**). Lands in the upper reach of the Whitemud, Blackmud, Clearwater, and Irvine Creek buffers were dominated by semi-natural land cover used primarily for agricultural activities. In many locations in the upper portions of these creeks, there are no naturally vegetated buffers between agricultural lands and creek channels. In some locations, the ephemeral headwaters of Whitemud Creek are being farmed.

Overall, forested land cover was estimated to comprise 22% of the riparian buffer. However, some portions of the Whitemud and Blackmud Creeks were significantly lower. For example, the upper portion of the Blackmud Creek sub-basin includes only 3% forested land cover and the upper portion of the Whitemud Creek sub-basin includes only 8% forested land cover. Lower reaches have increasing amounts of forest cover in the riparian buffer, which is related to the steep valley walls that preclude development near the creek edge.

A significant portion of the riparian area in the upper reaches of the study area has been modified for agricultural purposes. The removal of native woody vegetation and native plant species, along with the introduction of invasive species, has decreased the riparian area's resiliency to erosion and flooding. Therefore, a significant opportunity exists to restore native woody riparian vegetation to build resiliency into the watershed.

3.2 WETLAND INVENTORY AND FUNCTIONAL ANALYSIS

Wetlands in the study area were mapped and evaluated using a landscape-level approach to assess wetland function. The best available data was combined and a common classification system was applied to each wetland. The wetland mapping and classification data was used to perform a landscape level analysis and rating of capacity for wetlands to provide both water quality and hydrologic functions using existing GIS data. Results provide baseline data on wetland location and function in the study area and can be used as a decision-making tool for land use planning.

Detailed maps of wetland locations and their functional analysis are presented in **Appendix B**. **Table 3-1** provides a summary. The survey identified over 2,000 wetlands in the project area covering an area of apprximately 1,700 ha which is about 1.5% of the total basin area. Most (over 90%) of these wetlands are depressional and the remainder are riverine and lake fringe.

Table 3-1
Project Area Wetlands

Potential Functional Rating	HGM Wetland Class					
	Depressional		Riverine		Lake Fringe	
	Numbers of Wetlands	Area of Wetlands (ha)	Numbers of Wetlands	Area of Wetlands (ha)	Numbers of Wetlands	Area of Wetlands (ha)
Water Quality Function						
Low	82	9.3	0	0	0	0
Medium	1912	546.3	93	128.1	10	293.1
High	54	21.8	105	306	12	406.6
Hydrologic Function						
Low	82	9.3	0	0	10	260.6
Medium	1613	324.3	172	416.6	9	390.8
High	353	243.8	26	17.6	3	48.3
Wetland Totals						
Total	2048	577.3	198	434.2	22	699.8

Wetlands provide a number of functions that are valuable to society. For example, wetlands are capable of intercepting nonpoint sources of nitrate from agriculture, which provides a value as it benefits the community with improved water quality. Two key areas relate to surface water management: water quality and hydrologic functions.

Water quality improvements relate to a wetland's filtering capabilities. As surface runoff water passes through, the wetlands retain excess nutrients and some pollutants, and remove sediment. Hydrologic functions include flood storage and erosion protection. Flood storage functions relate to the ability of wetlands to retain and slowly release surface water and to contain vegetation that can reduce "speed" of flood waters. The water storage and braking action can lower downstream flood heights and reduce erosion.

Retaining wetlands on the landscape is critical to watershed health. Land use planning should evaluate potential loss of both wetland area and function on a local scale. Wetlands lost to development are replaced through the regulatory process. However, it's important to understand where these losses cannot be afforded.

Mitigating wetland loss is accomplished through replacing wetlands as part of the regulatory process. Wetland replacement in Alberta primarily occurs through in-lieu fee payment to a wetland restoration agent, and the sites are often located outside the sub-basin where wetland loss took place. Provincial wetland policy can be augmented by municipal policies in order to ensure that local priorities are part of the decision-making process.

Opportunities associated with municipal wetland policy include:

- Establish local wetland conservation plans
- Develop detailed wetland inventories with site-specific function analyses and use the information as a tool for land use planning
- Include wetlands in policy development; consider identifying wetland areas where onsite replacement instead of in-lieu fee payment should take place
- Establish wetland replacement opportunities within the sub-basin (i.e., a wetland mitigation bank) to help ensure wetlands functions and values are retained on a local-level
- Develop regulatory framework to protect wetland buffers
- Incorporate wetlands into park systems and environmental reserves

The broad assessment of wetland function in this study is an overview. Opportunity exists to increase its utility for land-use planning as more detailed mapping and analyses are completed.

3.3 EROSION ASSESSMENT

A reconnaissance level survey of erosion sites was conducted along Blackmud and Whitemud Creeks through a review of aerial photos and satellite imagery, existing reports, and a field reconnaissance. In total, 114 sites were identified along the Blackmud and Whitemud Creek channels with visible erosion concerns.

Of the 114 sites, 63 sites were identified along Whitemud Creek and 51 sites identified along Blackmud Creek.

Bank erosion was primarily attributed to in-stream erosion as opposed to slope instability. However, undercutting of stream banks at the outside of channel bends due to increased peak flows is an important factor in slope stability that causes slumping and subsequent mass wasting of soil material into the creeks. The in-stream erosion issues can be correlated to decreases in native woody vegetation, which provide root depth and root zone diversity that binds soils together along the banks and increases roughness thereby reducing flow velocities. Woody vegetation also has a significant influence on hillslope hydrology and can remove excess soil moisture that makes soils heavier and more prone to slumping.

3.4 WATER QUALITY ANALYSIS

Existing surface water quality data for significant watercourses and water bodies were reviewed to establish baseline conditions and assess potential impacts on water quality resulting from continued development.

Surface water quality data for general water quality parameters are readily available for the lower reaches of Whitemud and Blackmud Creeks. Data for the upper reaches of the Blackmud/Whitemud watersheds, key tributaries of the Blackmud and Whitemud Creeks, and lakes are distinctly lacking making it difficult to assess source-specific impacts and contaminant loads. There is a significant lack of baseline surface water quality data in all areas of the watersheds related to metals and other organic parameters, which would provide better information on potential impacts resulting from continued industrial or commercial development activities in the watersheds.

Some key observations are summarized below:

- Based on observed concentrations of total suspended solids and biochemical oxygen demand, surface water quality near urban developments (e.g., residential, commercial, and industrial developments) may contribute to localized impacts on surface water quality when compared to the upper reaches associated with mostly agricultural activity.
- Slightly elevated concentrations of total phosphorus, and nitrate and nitrite concentrations, in the lower reaches of Whitemud and Blackmud Creeks over time may suggest some susceptibility to nutrient enrichment. However, further monitoring would be required to accurately assess the potential impact.
- Current development practices (i.e., development plans and practices, policy) appear to be sufficient in terms of maintaining surface water quality in the lower reaches of Blackmud and Whitemud Creeks. However, with projected increases in development for the area, this may not be the case, which would warrant the implementation of a more robust water quality monitoring program.
- Dilution may play an important role in the lower reaches of Blackmud and Whitemud Creeks in mitigating cumulative effects and long-term anthropogenic impacts in these watercourses, as other general water quality parameters were relatively consistent over time. However, no conclusion

could be drawn for the upper reaches of the Blackmud and Whitemud Creeks and their associated tributaries.

Further surface water quality assessment is recommended to gain a more thorough understanding of baseline water quality for all areas of the watershed. This would include water quality testing at additional locations in the watersheds focusing on the upper reaches and an expanded list of parameters for analysis. This assessment would support the development of a watershed protection plan, which could include detailed source protection policy and management.

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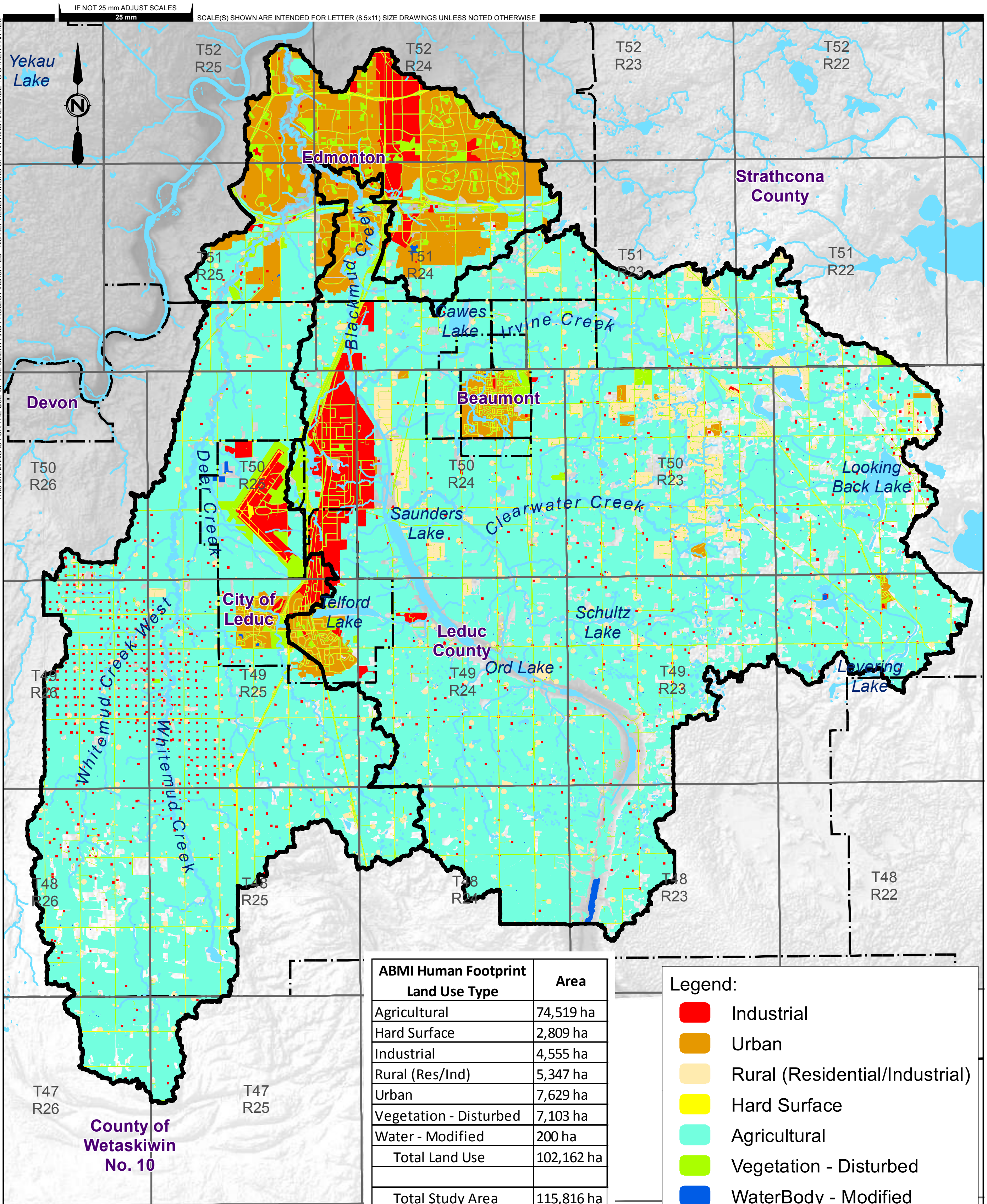

ABMI Human Footprint Land Use Type	Area
Agricultural	74,519 ha
Hard Surface	2,809 ha
Industrial	4,555 ha
Rural (Res/Ind)	5,347 ha
Urban	7,629 ha
Vegetation - Disturbed	7,103 ha
Water - Modified	200 ha
Total Land Use	102,162 ha
Total Study Area	115,816 ha

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FIGURE No. 3-1

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

EXISTING LAND USE

4 Hydrology and Hydraulic Modelling

The purpose of the basin modelling was to estimate flows, water levels, and velocities at various locations throughout the basin for the existing conditions of development. The model results were used to evaluate the potential impacts of further development within the basin and to develop a surface water management strategy to minimize and mitigate these impacts.

Based on the scope and objectives, a lumped[1] conceptual model was adopted to simulate the key hydraulic processes in the basin. A lumped model has a relatively coarse discretization of sub-catchments. A conceptual model has a low level of detail in simulating the key hydrological processes and an intermediate level of detail in simulating water levels throughout the project area. The key deliverables are maps of flood depth, extent, velocity, and shear stress for the various scenarios.

Selection of modelling methodology was based on the following considerations:

- Modelling objectives; to estimate flood levels, extent, and velocity throughout the project area drainage system for various scenarios.
- Available precipitation data at one location and hydrometric data at four locations limit our ability to calibrate the model for rainstorm events.
- Lack of a good model of snowmelt processes limits our ability to simulate the snowmelt runoff processes in Whitemud and Blackmud Creeks. A runoff model calibrated for rainfall events tends to under-estimate snowmelt runoff due to frozen ground conditions in the Canadian prairies.
- Model run times are governed by the spatial and temporal resolution of the model and the need to preserve computational stability.

Modelling was conducted using the commercially available MIKE software-modeling package developed and marketed by Danish Hydraulic Institute (DHI). This software is widely used and contains one dimensional (1D), two dimensional (2D) and three dimensional (3D) modules for urban and rural environments. The MIKE11 – 1D and MIKE21 FM – 2D modules were used for this study as illustrated in **Figure 4-1**. Below is a summary of the models used:

- A 1D model was developed using MIKE11 to simulate water levels and flows in all of the creeks.
- A 2D model was developed using MIKE21 for the lower reaches of the Whitemud and Blackmud Creeks to simulate local hydraulic conditions in more detail and to give a qualitative assessment of erosion potential.

The models were run in a steady state condition for the 2-year, 5-year, and 100-year design events. In a steady-state model a single design value of inflow rate is input for each sub-catchment and the model is used to aggregate the flows in a downstream direction and to simulate water levels throughout the channel system. This approach is different from a dynamic approach in which the inflows are varied continuously

[1] Lumped model – Type of model in which parameters are not spatially dependent.

over a long period of time to simulate the long-term behaviour of the system. Simply stated, the dynamic approach provides a moving picture of conditions over time and the steady-state approach provides a snapshot in time during the critical design event.

A pilot model was first developed and run for the Irvine Creek sub-basin from Beaumont to the Blackmud Creek to test the feasibility of a continuous long-term simulation model and to determine the dynamic flood routing effects on dampening of peak flows. Results of the pilot model are included in **Appendix D**. These results demonstrated the following:

- Floodplain routing would reduce peak flows by only about 5% in Irvine Creek compared with a steady state approach.
- Model run times for a dynamic model would be excessive, in the order of 30 days for a single run, which limits the practicability of a dynamic model to predict flood levels and extent for different scenarios.
- A steady state model would provide a reasonable estimate of flood levels and extent and would be slightly conservative, which is appropriate for a planning study.

Details of the model set-up, parameters, boundary conditions, and simulation results are provided in **Appendix D**. Model results depend directly on the model inflows which were estimated from the results of the hydrology assessment in **Appendix B**. The design flows used for modelling are summarized in **Table 4-1** below:

Table 4-1
Design Flows at Key Locations

			Unit Flow (L/s/ha)			Design Flow (m^3/s)		
Basin	Type	Area (km2)	2 year	5 year	100 year	2 year	5 year	100 year
Beaumont (to Irvine Creek)	Urban controlled + U/S rural	18	0.38	0.57	3.00	0.68	1.03	5.40
Irvine	Rural	140	0.07	0.26	1.11	0.98	3.64	15.54
Saunders	Rural lake controlled	153	0.13	0.32	1.05	1.93	4.94	16.10
Clearwater	Rural	207	0.07	0.26	1.11	1.45	5.38	22.98
Leduc + Nisku	Urban direct	18.5	2.85	3.75	7.92	5.27	6.94	14.65
	Urban controlled	15.4	0.61	0.91	4.80	0.94	1.40	7.39
Blackmud Local excl Beaumont and Saunders)	Rural	91.1	0.07	0.26	1.11	0.64	2.37	10.11
Total		643				11.9	25.7	92.2
Blackmud WSC Gauge		643				4.6	16.6	71.5
NHC estimate		643				9.4	23.4	78.0
West Whitemud	Rural (UD)	65.4	0.31	0.75	2.88	2.03	4.91	18.84
West Leduc (to Deer Creek)	Urban direct (Duc)	2.75	3.65	4.84	10.10	1.00	1.33	2.78
	Urban controlled (DC)	3.84	0.95	1.43	7.50	0.36	0.55	2.88
	Leduc Reservoir	2.59	0.31	0.75	2.88	0.08	0.19	0.75
EIA (to Deer Creek)	Semi-urban controlled	10.23	0.31	0.75	2.88	0.32	0.77	2.95
Deer Creek	Rural (UD)	55.09	0.31	0.75	2.88	1.71	4.13	15.87
Whitemud	Rural (UD)	190.5	0.31	0.75	2.88	5.91	14.29	54.86
Total at WSC gauge		330.4				11.4	26.2	98.9
Whitemud WSC Gauge		330.4	0.31	0.75	2.88	10.1	24.9	95.0
Lower Basin (WSC gauges to NSR)	Rural	15.18	0.31	0.75	2.88	0.47	1.14	4.37
	Urban Direct D/S of 23 Ave	16.2	2.14	2.81	5.94	3.46	4.56	9.62
	Urban controlled (U/S of 23 Ave)	48.5	0.63	0.95	5.00	3.07	4.61	24.25
Whitemud at NSR		1053.3				30.3	62.2	229.3

4.1 1D MODEL RESULTS

The 1D model included:

- Whitemud Creek - 83 km.
- West Whitemud Creek - 22 km.
- Deer Creek - 27 km.
- Blackmud Creek - 34 km.
- Clearwater Creek - 29 km.
- Irvine Creek - 20 km.
- LeBlanc Canal - 2 km.
- The developed and undeveloped areas or sub-catchments within the basin that drain into the modelled creeks.

Figure 4-1 provides a schematic plan of the 1D and 2D models and their principal components. For simplicity, not all sub-catchments or cross-sections are shown in **Figure 4-1**. Flows from the City of Leduc into Blackmud Creek were added immediately downstream of Saunders Lake. In reality, some flows from the City of Leduc discharge directly into Saunders Lake and the headwaters of Blackmud Creek begin upstream of Saunders Lake.

Cross sections of the creeks were obtained from surveyed data, 1m resolution LiDAR, Northwest Hydraulic Consultant's (NHC's) HEC-RAS model of Blackmud Creek, and Stantec's MIKE 11 model of Irvine Creek (TM 3). A total of 478 cross-sections were used in the 1D model averaging approximately one cross-section for every 500 m. Seventy-two (72) of these cross-sections were surveyed and the remainder were estimated from LiDAR data and/or the previous studies.

Each sub-catchment was divided into one of three categories, namely: developed-controlled, developed-uncontrolled, and undeveloped areas and inflows from each sub-catchment were estimated according to the design flows summarized in **Table 4-1**.

Results of the modelling are presented in detail in **Appendix D** and are summarized below.

The maximum flows, water depths, and velocities for existing conditions were simulated for the 1:2, 1:5, and 1:100 year design events. Maps depicting the maximum extent of flooding were developed by overlaying the simulated water surface on the 1m ground LiDAR surface within the MIKE 11 software.

Figure 4-2 presents the flood map and the water depths for the entire basin for the simulated 1:100 year design event. The results of the model simulation show significant flooding along Irvine Creek, LeBlanc Canal, Blackmud Creek upstream of Highway 2, and more localized flooding along Whitemud and Clearwater Creeks.

Figures 4-3 to **4-6** show the flood extent and water depths in greater detail for the simulated 1:100 year design event at critical locations along Blackmud Creek, Irvine Creek, Deer Creek, and Whitemud Creek, respectively. Cross-sections referenced on **Figures 4-3** to **4-6** are included in **Appendix D**.

The following observations were made from the modelling results:

- Generally, flows generated for the existing conditions are confined within all channel banks during the 1:2 year design event. Localized flooding occurs along the creeks during the 1:5 year design event. Overland flooding occurred during the 1:100 year design event.

- Most of the creeks within the basin have limited hydraulic capacity to convey runoff generated from existing and any future development. The lower reaches of Blackmud and Whitemud Creeks have deeper valleys such that flooding is not a concern. However, erosion is a significant concern due to higher flows and velocities.

- The upper reaches of the Blackmud Creek experience flooding over a wide floodplain that geologically formed the outlet from glacial Lake Edmonton. Flooding is mostly confined to the valley. Flows are mostly confined to the Blackmud Creek channel as they approach the City of Edmonton. Some overbank flooding occurs in Nisku.

- The upper reaches of Whitemud Creek experience flooding within the valley. Flows in the lower reaches were mostly confined to the creek channel.

- Portions of the Irvine Creek and LeBlanc Canal near Beaumont experience significant overland flooding due to limited channel capacity for the 1:5 and 1:100 year design events. These areas had been channelized in the past to provide agricultural drainage but do not have the capacity to prevent flooding during a major runoff event. The lower reaches of the LeBlanc Canal also experience backwater effects from Irvine Creek.

- Deer Creek has limited channel capacity to convey runoff and this results in overland flooding along the creek. Creek flows have increased significantly due to runoff from Leduc.

4.2 2D MODEL RESULTS

To better understand the rate and extent of erosion in Whitemud and Blackmud Creeks, a detailed 2D model was developed for the lower reaches within the City of Edmonton. This model was used to determine velocity distribution and bed shear stresses and to form the baseline against which to measure changes due to development.

The 2D model uses the Flexible Mesh approach of Mike21-FM which allows for finer resolution in the stream channel and coarser resolution in the overbank areas. Mesh sizes of 5 m were used in the channel and 10-100 m in the overbank areas. The model mesh was generated from 1 m resolution LiDAR data. Bed elevations were lowered by 1 m in the channel portion to account for the typical depth of water in the LiDAR data. The model uses a finite element approach to calculate flows and velocities in two dimensions (with a single value for the vertical axis) using the fully-dynamic equations of flow known as the St. Venant Equations.

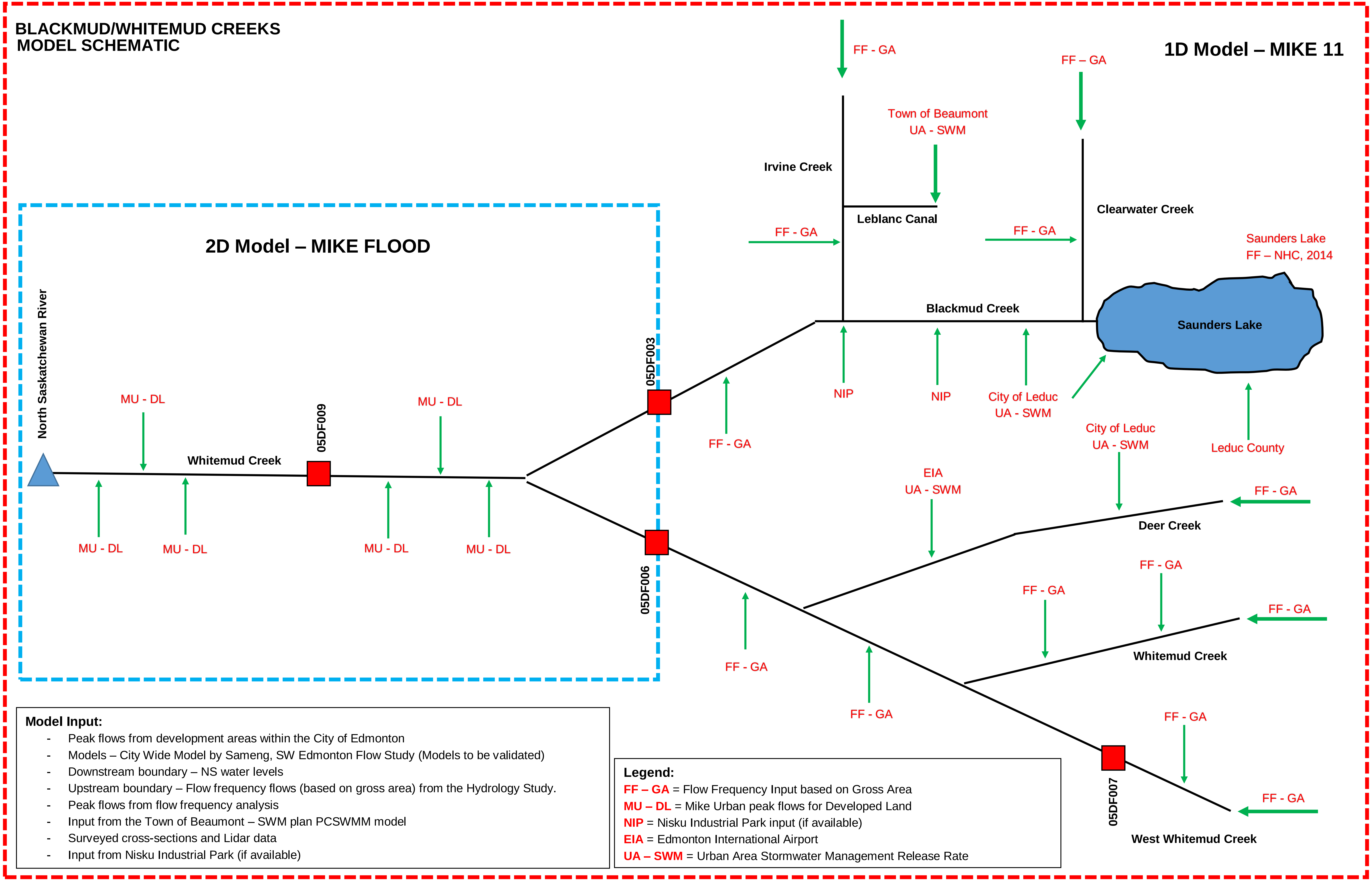
Figures 4-7 to **4-9** present the simulated velocities for the 1:2, 1:5 and 1:100 year design flow conditions for a representative site located at the junction of Whitemud and Blackmud Creeks upstream of 23 Avenue. These maps show that the flow is mostly confined to the channel in the 1:2 year flood and some overbank flow occurs in the 1:5 year and 1:100 year floods. These maps clearly show that the velocities are higher in the channel than in the floodplain, and that they increase with increasing flow. Typically, the highest velocities occur at the outside of the meander bends, as expected.

Appendix D presents more detailed 2D model results for other locations in the 1:2, 1:5 and 1:100 year design events.

In-stream erosion is actively occurring at many meander bends throughout the lower reaches of Blackmud and Whitemud Creeks. In part 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.

The erosion process is complicated and depends on a number of factors such as bed and bank materials and local hydraulic effects. 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.

Increasing the creek flow with development will increase the local velocities and therefore the rate of erosion and sediment transport. These effects are evaluated in the following section.


BLACKMUD/WHITEMUD CREEKS
MODEL SCHEMATIC
1D Model – MIKE 11
2D Model – MIKE FLOOD
North Saskatchewan River
Whitemud Creek
05DF009
05DF003
05DF006
05DF007
MU - DL
FF - GA
FF – GA
Irvine Creek
Town of Beaumont
UA - SWM
Leblanc Canal
Clearwater Creek
Saunders Lake
FF – NHC, 2014
Blackmud Creek
Saunders Lake
NIP
City of Leduc
UA - SWM
Leduc County
EIA
UA - SWM
Deer Creek
Whitemud Creek
West Whitemud Creek
Model Input:
- Peak flows from development areas within the City of Edmonton
- Models – City Wide Model by Sameng, SW Edmonton Flow Study (Models to be validated)
- Downstream boundary – NS water levels
- Upstream boundary – Flow frequency flows (based on gross area) from the Hydrology Study.
- Peak flows from flow frequency analysis
- Input from the Town of Beaumont – SWM plan PCSWMM model
- Surveyed cross-sections and Lidar data
- Input from Nisku Industrial Park (if available)
Legend:
FF – GA = Flow Frequency Input based on Gross Area
MU – DL = Mike Urban peak flows for Developed Land
NIP = Nisku Industrial Park input (if available)
EIA = Edmonton International Airport
UA – SWM = Urban Area Stormwater Management Release Rate

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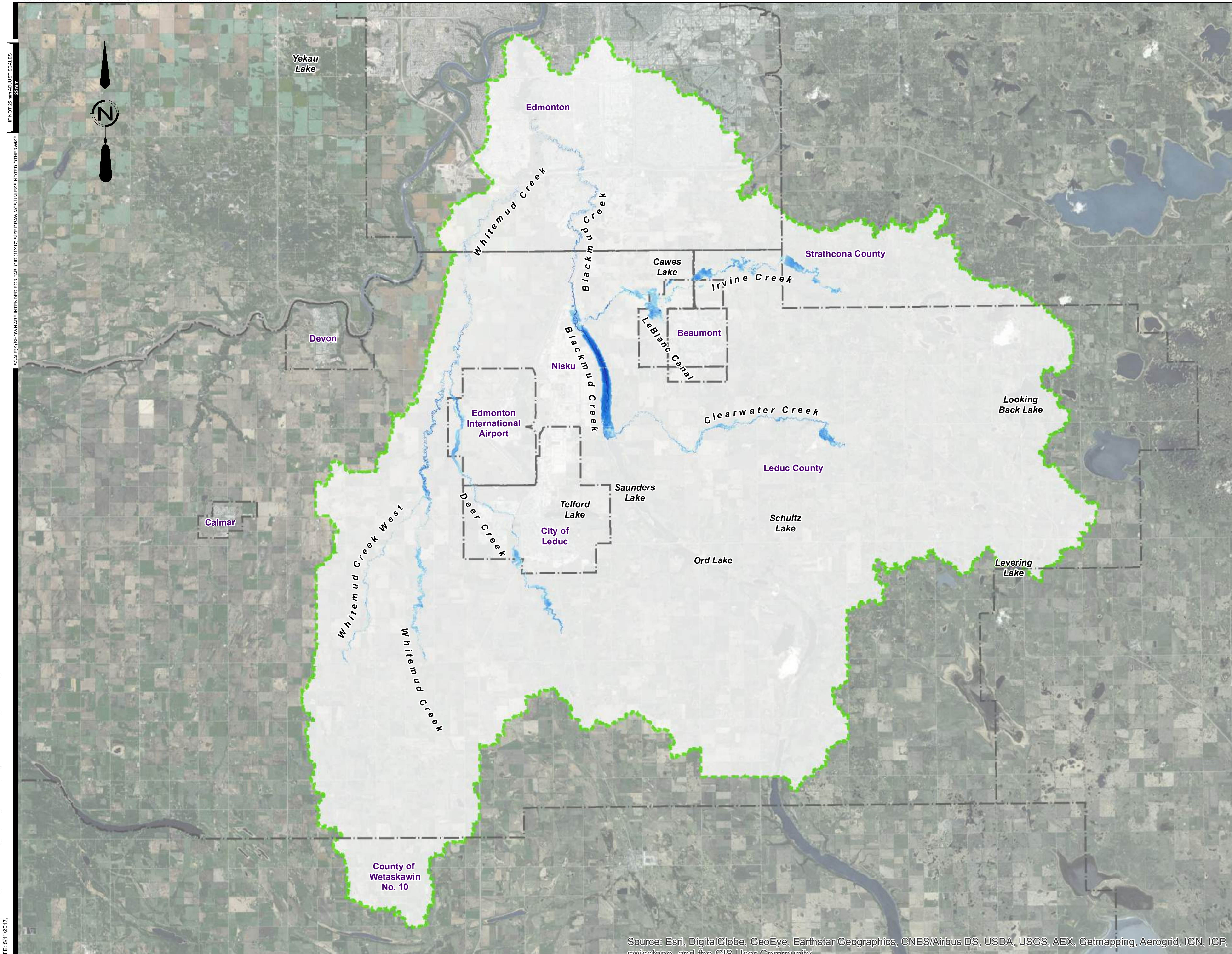

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Legend:

Water Depth

High

Low

Whitemud Watershed

Municipal Boundary

FIGURE No. 4-2

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

1:100 YEAR FLOOD MAP

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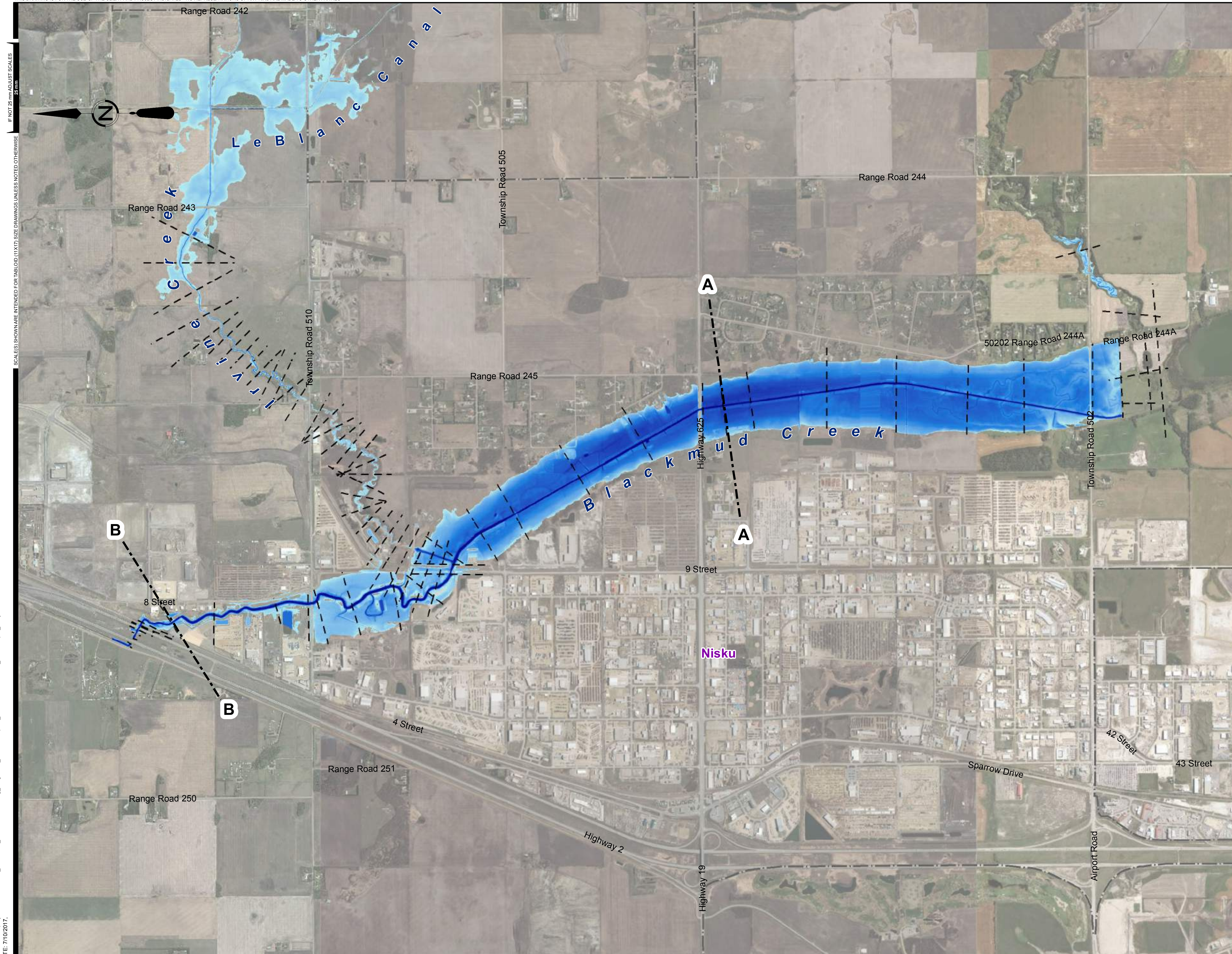


Legend:

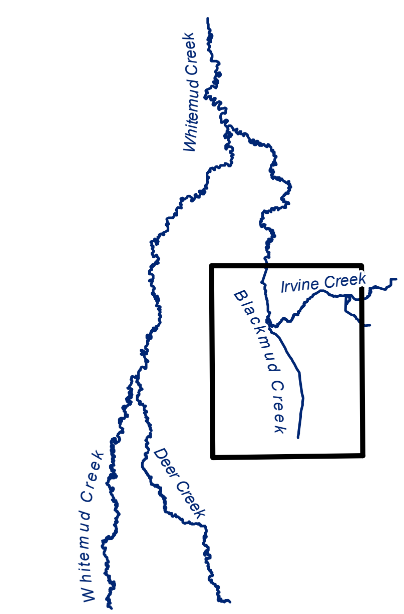
Water Depth (100 Year)

High (4.1 m)

Low (0 m)

Cross Section

Municipal Boundary



Associated Engineering

FIGURE No. 4-3

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

BLACKMUD CREEK 1:100 YEAR FLOOD EXTENT

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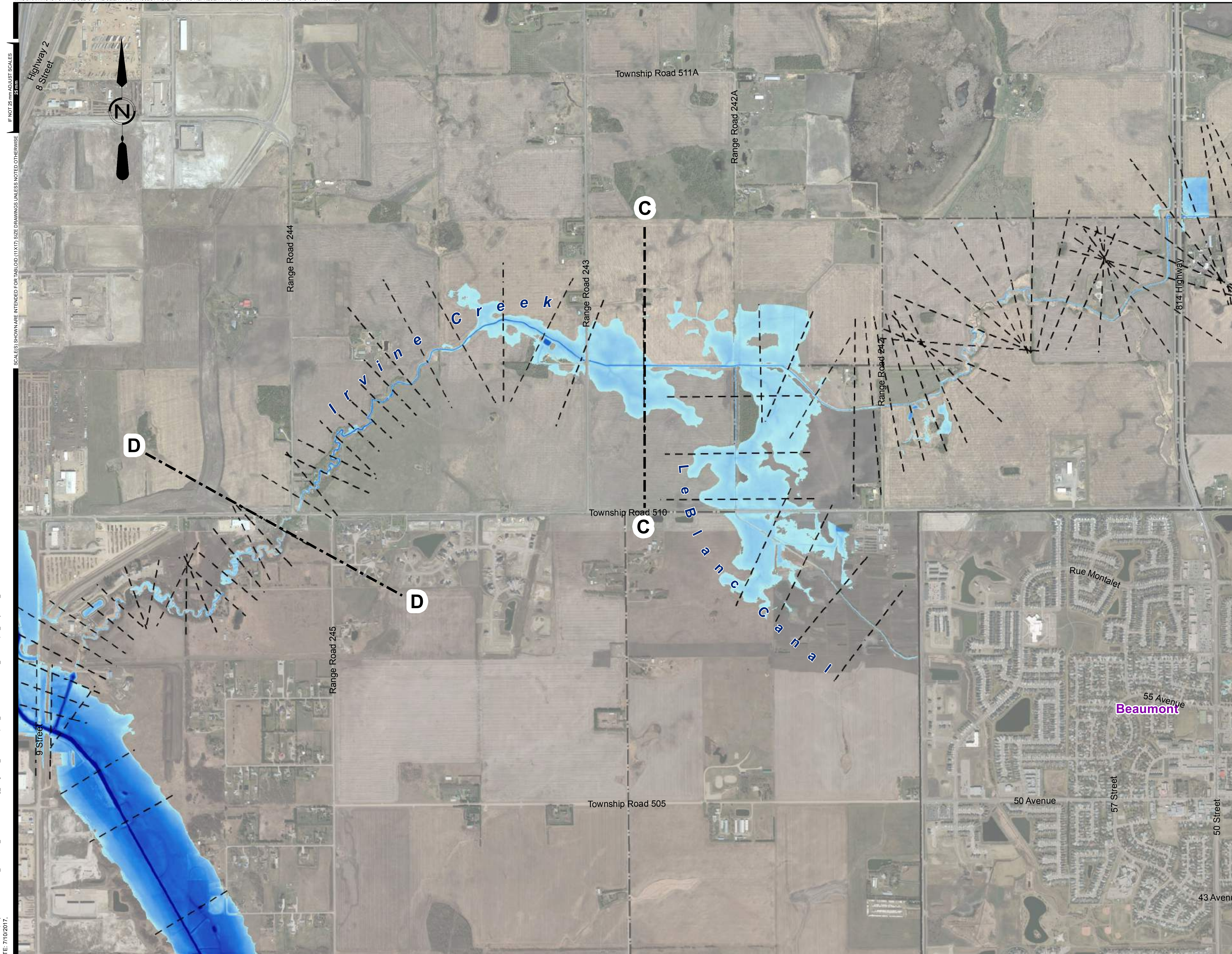


Legend:

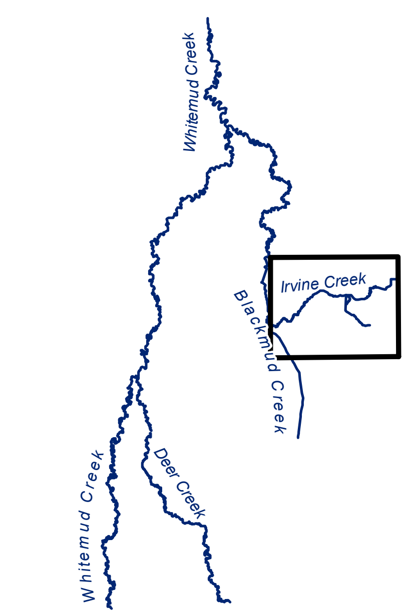
Water Depth (100 Year)

High (3.7 m)

Low (0 m)

Cross Section

Municipal Boundary



Associated Engineering

FIGURE No. 4-4

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

IRVINE CREEK 1:100 YEAR FLOOD EXTENT

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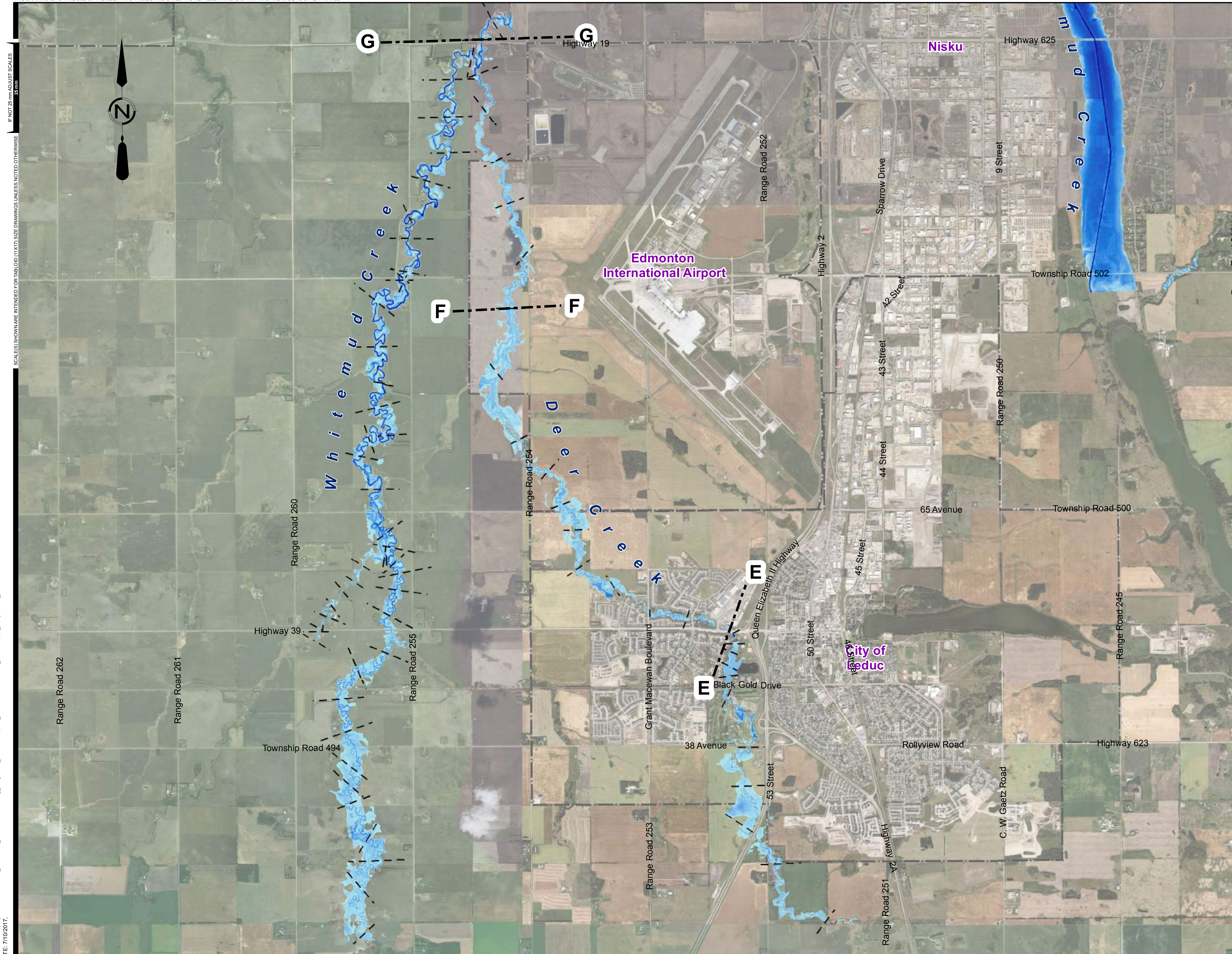

Legend:

Water Depth (100 Year)

High (4.1 m)

Low (0 m)

Cross Section

Municipal Boundary

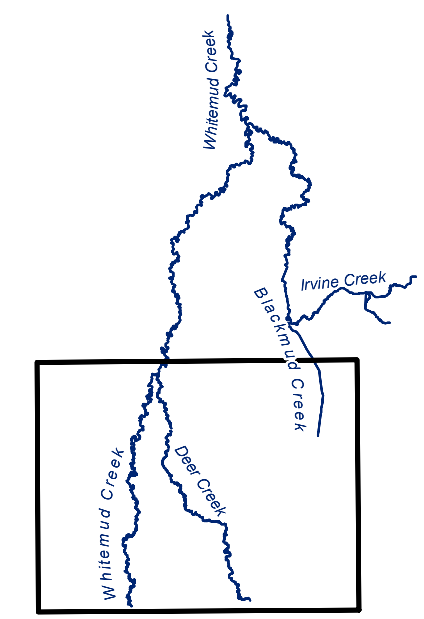

FIGURE No. 4-5

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

DEER CREEK 1:100 YEAR FLOOD EXTENT

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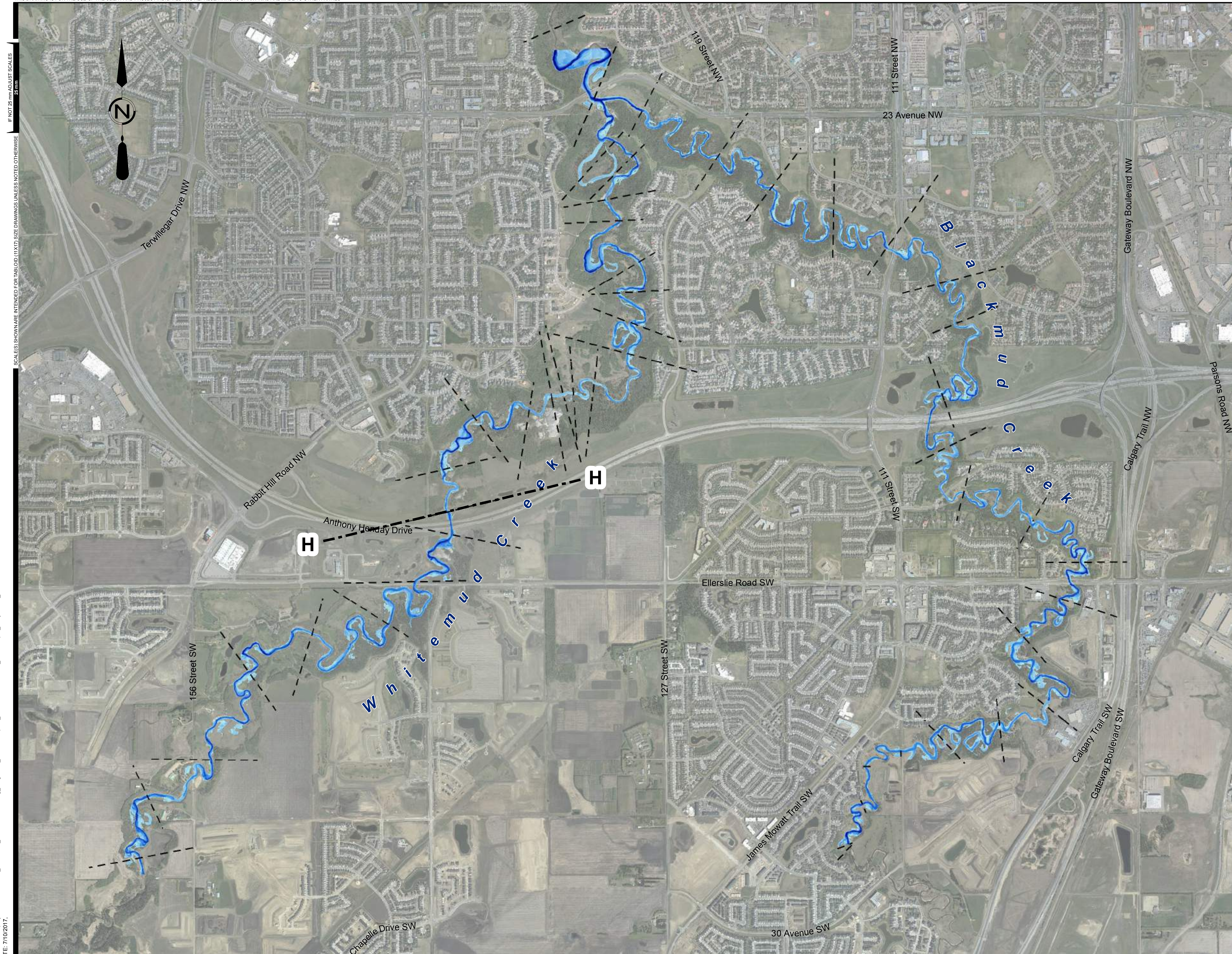

Associated Engineering

Legend:

Water Depth (100 Year)

High (4.1 m)

Low (0 m)

Cross Section

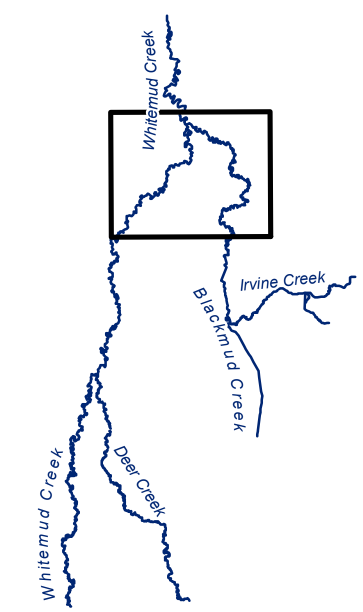

FIGURE No. 4-6

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

BLACKMUD/WHITEMUD CREEK 1:100 YEAR FLOOD EXTENT

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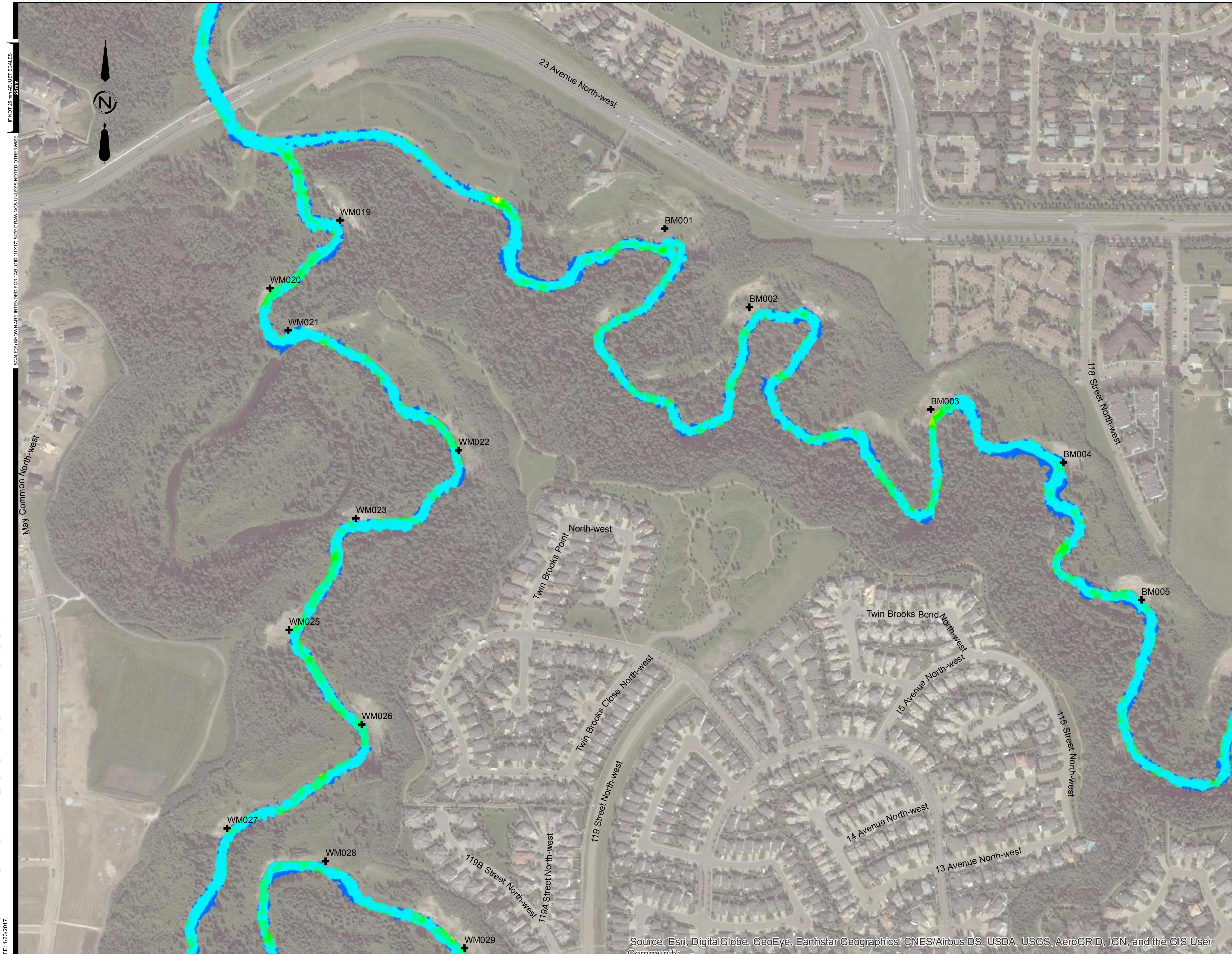

Associated Engineering

Legend:

- ✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5

FIGURE No. 4-7

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

1:2 YEAR VELOCITY RESULTS
BLACKMUD/WHITEMUD CONFLUENCE

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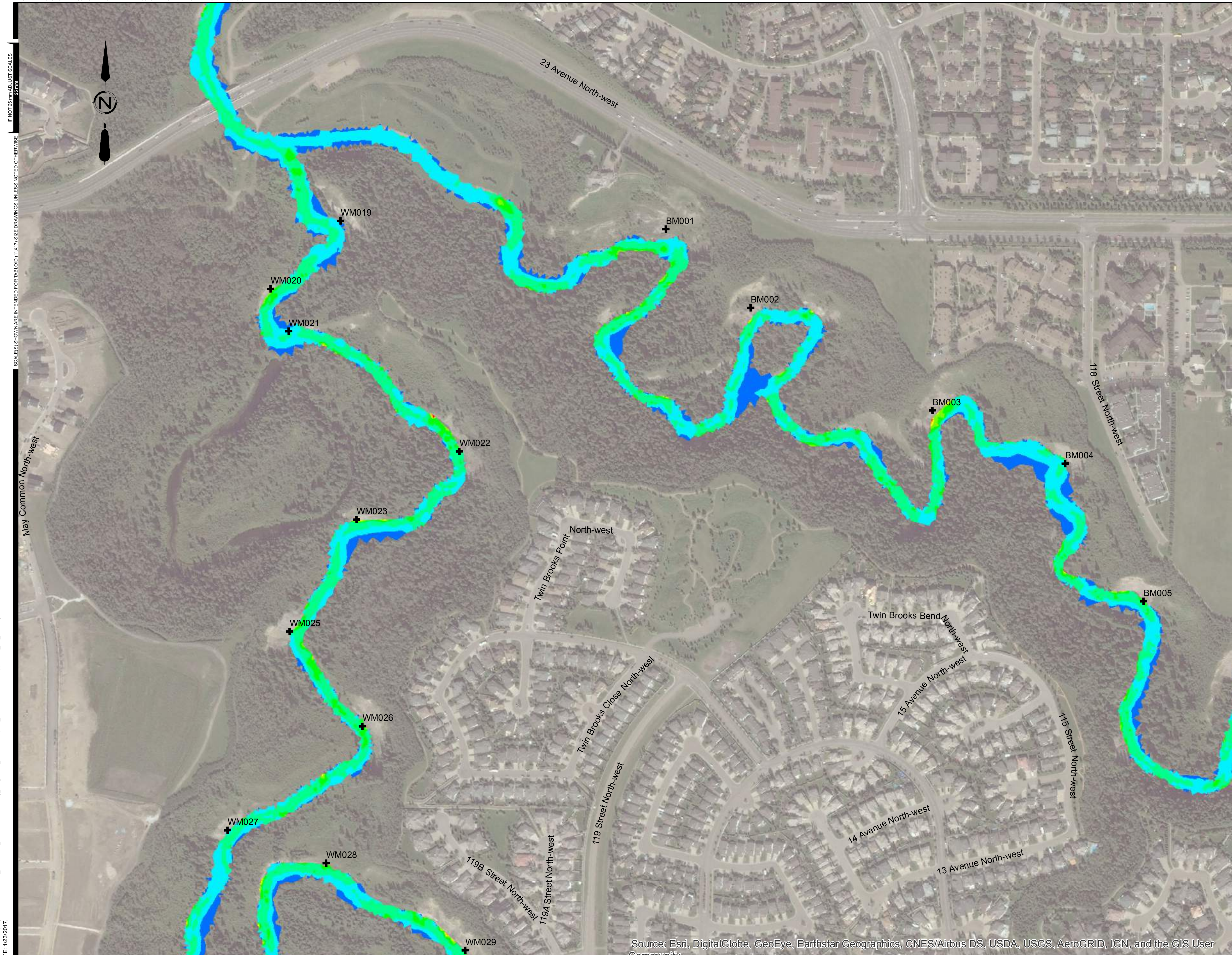

Associated Engineering

Legend:

- ✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5

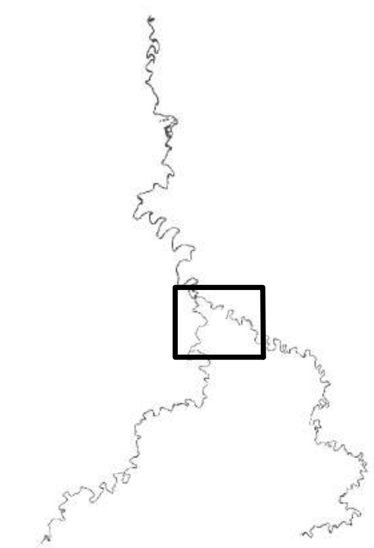

FIGURE No. 4-8

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

1:5 YEAR VELOCITY RESULTS
BLACKMUD/WHITEMUD CONFLUENCE

AE PROJECT No.	2016-3785
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DATE	2017 JULY
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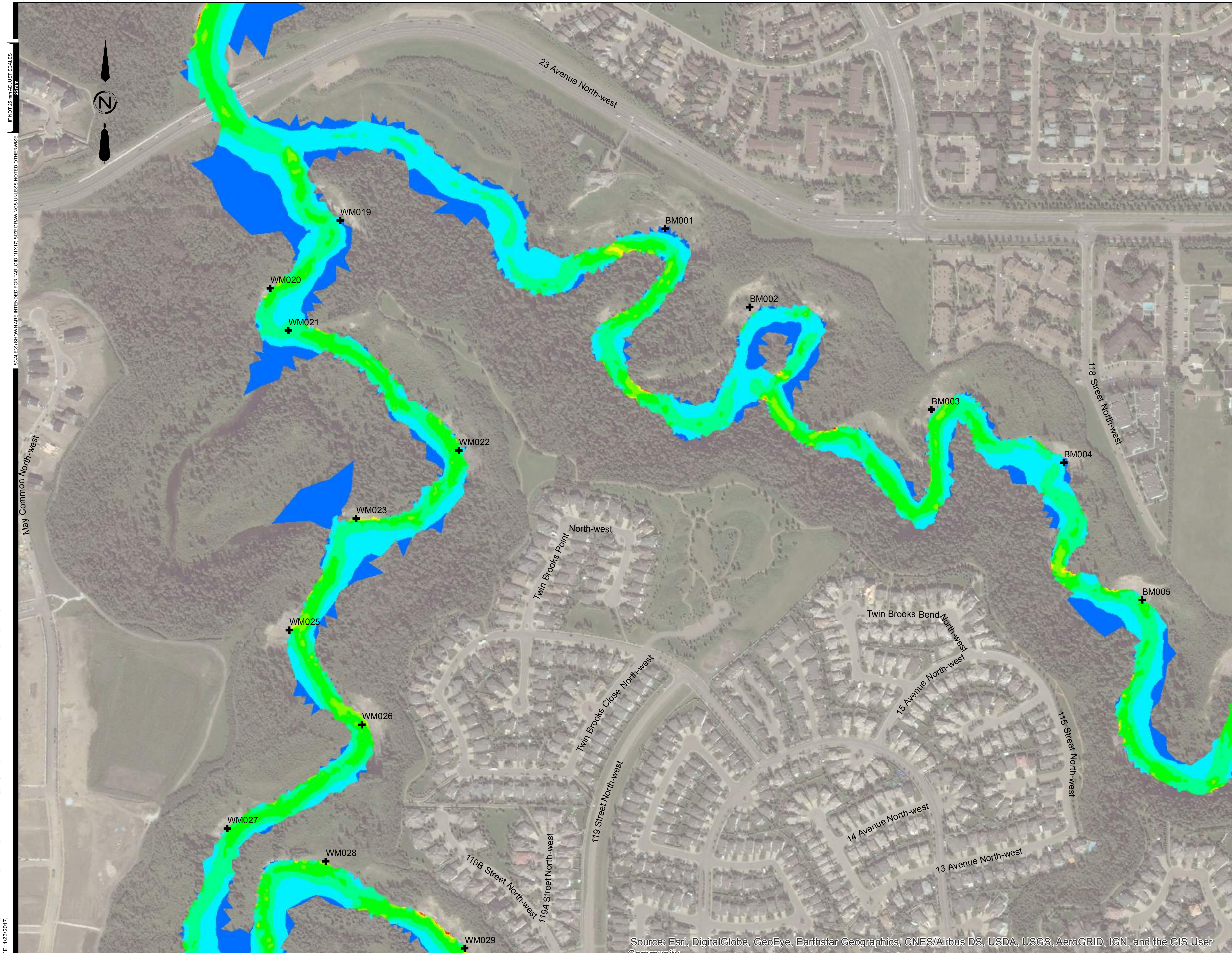

Associated Engineering

Legend:

- ✚ Erosion Site

Velocity (m/s)

- >3.5 - 4.0
- >3.0 - 3.5
- >2.5 - 3.0
- >2.0 - 2.5
- >1.5 - 2.0
- >1.0 - 1.5
- >0.5 - 1.0
- >0.0 - 0.5

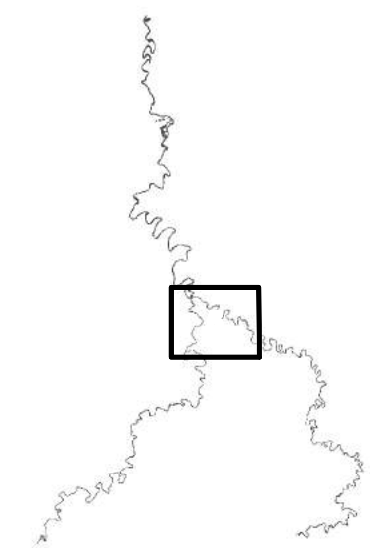

FIGURE No. 4-9

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

1:100 YEAR VELOCITY RESULTS
BLACKMUD/WHITEMUD CONFLUENCE

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5 Potential Impacts of Development

The Blackmud/Whitemud basin model was used to asses the potential impacts of future development within the basin and to develop a surface water management strategy to minimize and mitigate these impacts.

In Workshop #3 on December 16, 2016 the Group agreed that the Capital Region Board (CRB) Edmonton Metropolitan Region Growth Plan (2016) would be used as the future development boundary. **Figure 5-1** presents the existing and planned development areas, overlaid on a map of the basin. Note that no proposed developments (approved Area Structure Plan areas) were included as existing development.

5.1 SWM RELEASE RATES

Three stormwater management release rates were evaluated for future development during a 1:100 year design event. These release rates were based on findings in the hydrology assessment summarized in **Section 2** of this report:

- 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 in the model, assuming each will be controlled to the same rate of discharge. This assumption was adopted to ensure that stormwater management is easily and effectively applied across the basin. In the future, the same release rate could be applied to development outside the area shown. The model simulation results are discussed below. **Appendix E** presents details of the model update and model results.

Table 5-1 summarizes creek flows at key locations within the basin for comparison of the existing conditions and the future development releasing at 1.5, 3.0, or 5.0 L/s/ha.

Table 5-1
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 Assumes no future development in sub-basin	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%)

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.

5.2 STORMWATER MANAGEMENT FACILITY COSTS

The typical Stormwater Management Facility (SWMF) construction costs, assuming the release rates of 1.5, 3.0, and 5.0 L/s/ha were prepared. Analyses were based on the City of Edmonton 2014 IDF curves. It should be noted that recent changes to the City of Edmonton's design criteria (updated March 2015) have the effect of increasing the required storage volume in SWMFs by about 40%.

Appendix E presents details of the estimated stormwater management construction costs based on the proposed CRB density of 35 dwelling units/ha net (27 units/ha gross).

Table 5-2 provides the estimated SWMF costs, expressed in dollars per unit assuming a gross development area of 65 ha. Results indicate the typical SWMF cost will vary between approximately $4,000 per lot at a release rate of 5.0 L/s/ha, to $6,000 per lot at a release rate of 3.0 L/s/ha, and $8,000 per lot at 1.5 L/s/ha. These results show that the difference in SWMF costs between release rates are relatively small.

Table 5-2
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**

Cost per lot based on 35 units/ha net (27 units/ha gross)

5.3 POND DRAWDOWN TIME

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. Pond drawdown time is inversely proportional to the design release rate.

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 100-year design event. This approach has been adopted by the City of Edmonton in a recent development.

Table 5-3 provides a summary of required pond storage volumes, pond size, and construction cost to meet this criterion, as has been assumed in **Table 5-2**.

Table 5-3
Typical SWMF Parameters for Various Release Rates with 96 Hour Drawdown Time

	1.5 L/s/ha	**3.0 L/s/ha**	**5.0 L/s/ha**
Storage Volume	1,846 m^3/ha	1,462 m^3/ha	954 m^3/ha
Construction Cost	$7,859 /unit	$6,180 /unit	$4,076 /unit
Time to Drain	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 design standard for pond drawdown could be modified to adopt a longer duration. **Table 5-4** 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 5-4
Typical SWMF Parameters with Extended Drawdown

	1.5 L/s/ha	3.0 L/s/ha	5.0 L/s/ha
Storage Volume	1108 m^3/ha	1046 m^3/ha	954 m^3/ha
Construction Cost	$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 5-3** and **Table 5-4** 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.

5.4 FLOOD EXTENT AND DEPTH

Figures 5-2 to **5-5** 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.

Model results indicate that flood depth would increase by about 0.3 m on average if a release rate of 5.0 L/s/ha were to be adopted and would decrease slightly, by less than 0.1 m, with a design release rate of 1.5 L/s/ha.

In general, the change in flood depth and extent is not deemed to be significant.

5.5 CHANNEL VELOCITIES AND EROSION RATES

To estimate the magnitude of impacts due to future developments, the 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.

Figures 5-6 to **5-8** 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. The increase will be less, but still significant, if a release rate of 3.0 L/s/ha is adopted. More detailed results are provided in **Appendix E**.

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. Based on this, the rate of erosion or sediment transport within the Blackmud and Whitemud Creeks is expected to double if a release rate of 5.0 L/s/ha is adopted and will increase by about 50% if a release rate of 3.0 L/s/ha is adopted. To limit erosion rates to the existing condition would require release rates to be reduced to 1.5 L/s/ha or less. However, this needs to be balanced against the increase in pond size, cost, drawdown time, increased risk of overloading the facility, and flooding adjacent properties.

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. The City of Edmonton has developed a strategy of armouring the creek banks where active erosion threatens private property along the top of bank.

5.6 EFFECTS OF INCREASED RUNOFF VOLUME

Regardless of the release rate adopted for future stormwater management, the volume of runoff will 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 in **Appendix B** indicate that the average runoff in the basin is currently about 5-10% of annual precipitation. Those areas that will be developed are estimated to generate runoff of about 50-60% of precipitation in the future.

Table 5-4 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 the Blackmud and Whitemud Creeks. Other factors being equal, the amount of sediment transport, or rate of erosion, is directly proportional to runoff volume. This means that the amount of erosion in the Whitemud and Blackmud Creeks will increase by approximately 50% due to the increase in runoff volume alone. Considering the increase due to higher 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 5-5
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

5.7 CLIMATE CHANGE IMPACTS

Potential impacts of climate change on the SWMF were reviewed as presented in **Appendix E**. Based on the information available at the time of writing this report it was concluded that climate change is unlikely to have a significant impact on storage volumes, release rates, and the basin drainage strategy.

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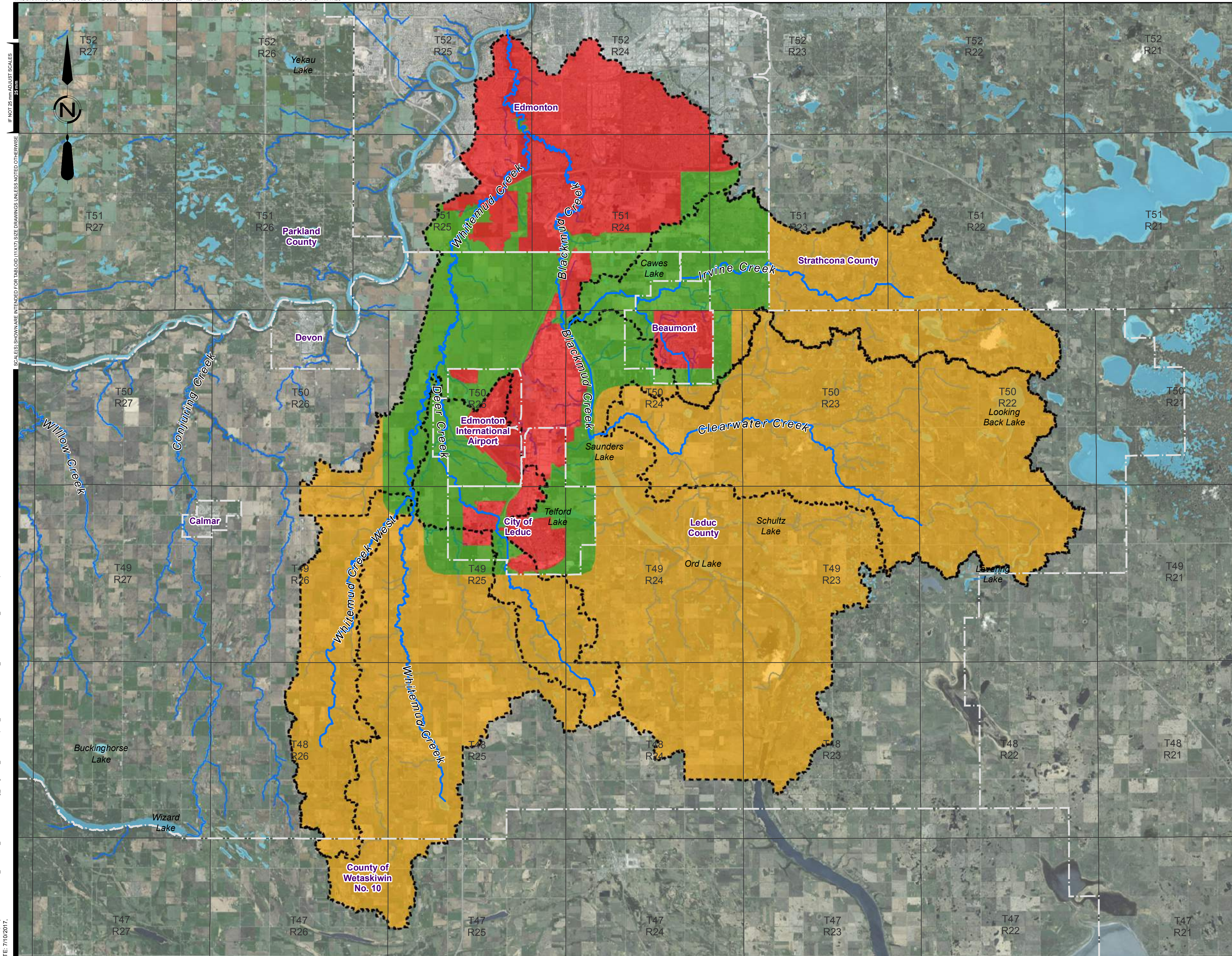


Associated Engineering

Legend:
- Catchment

Classification
- Existing Development
- Future Development Within the Basin
- Rural
- Creek Centreline
- Municipal Boundary

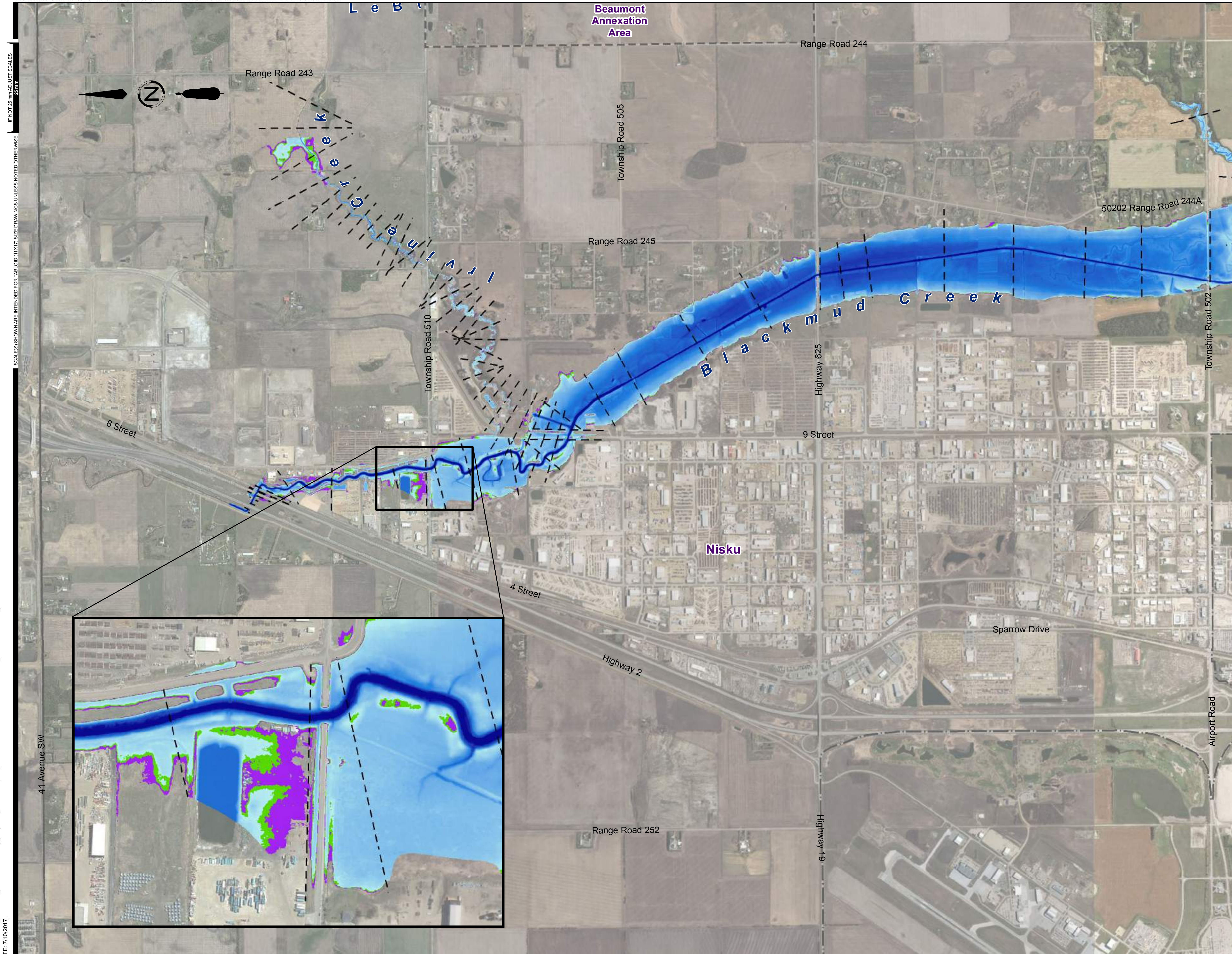
FIGURE No. 5-1

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

FUTURE DEVELOPMENT AREAS

AE PROJECT No.	2016-3785
SCALE	1:200,000
APPROVED	
DATE	2017 JULY
REV	
DESCRIPTION	ISSUED FOR REPORT

DATE: 7/10/2017,



Associated Engineering

Legend:
- Cross Section
- Existing
- 1.5 L/s/ha
- 3.0 L/s/ha
- 5.0 L/s/ha

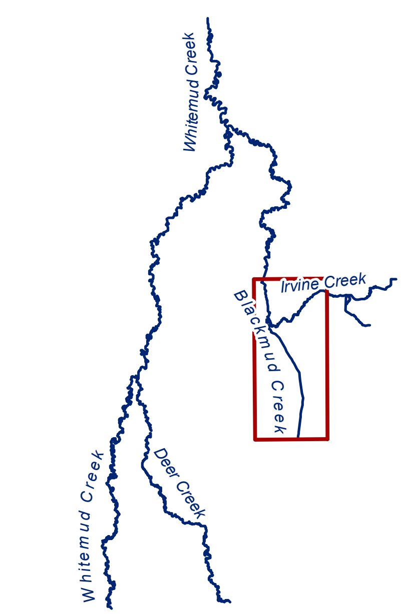


FIGURE No. 5-2

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

COMPARISON OF FUTURE FLOOD EXTENT
BLACKMUD CREEK

AE PROJECT No.	2016-3785
SCALE	1:30,000
APPROVED	
DATE	2017 JULY
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

P:\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\FutureFloodExtents\5-2_FutureFloodExtent_Blackmud.mxd
DATE: 7/10/2017,

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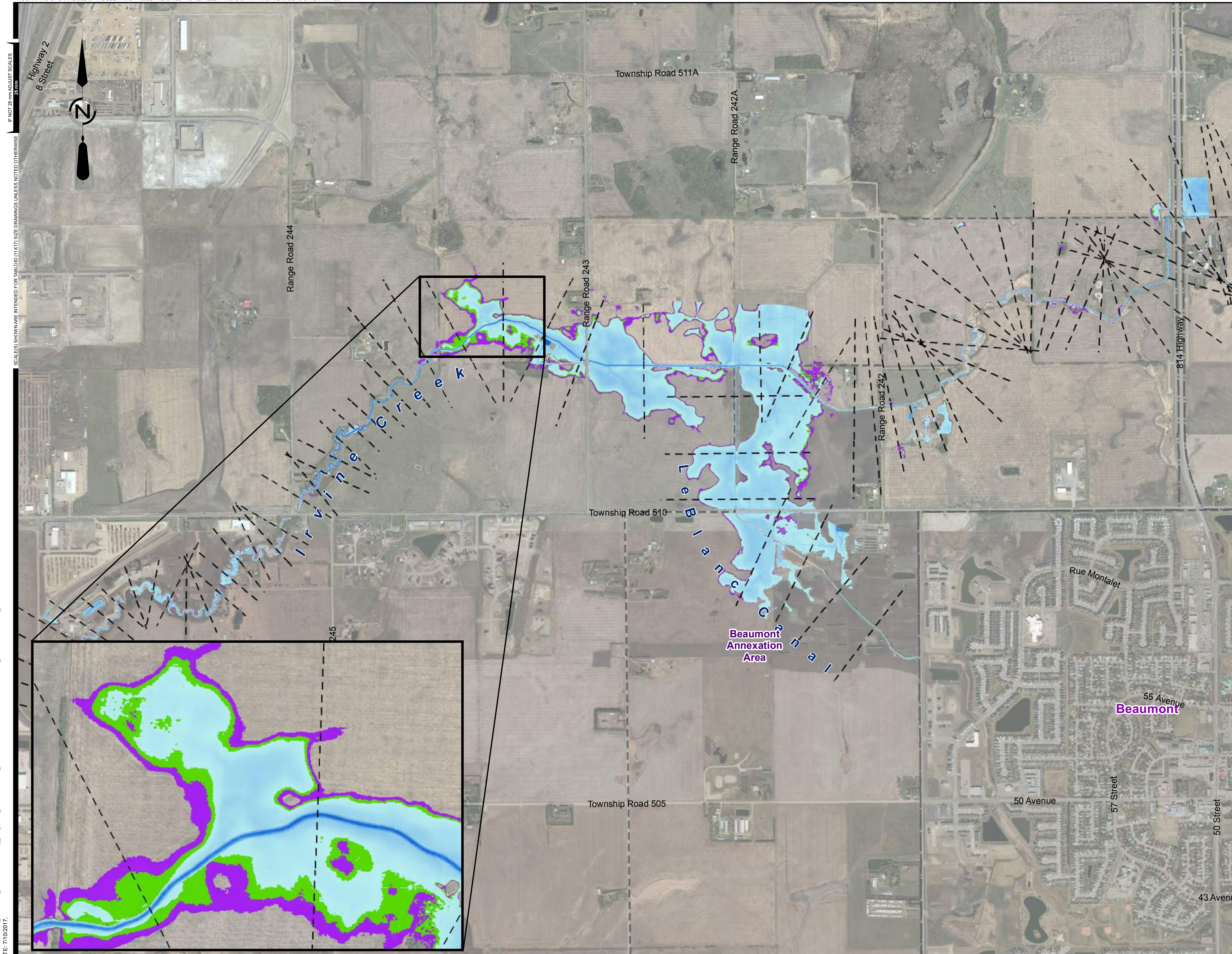

Associated Engineering

Legend:

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

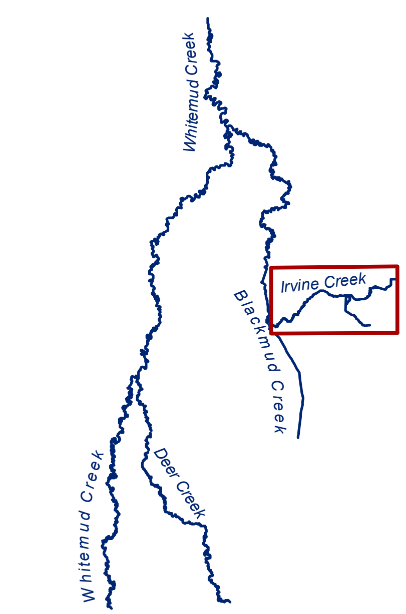

FIGURE No. 5-3

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

COMPARISON OF FUTURE FLOOD EXTENT IRVINE CREEK

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

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

IF NOT 25 mm ADJUST SCALES 25 mm

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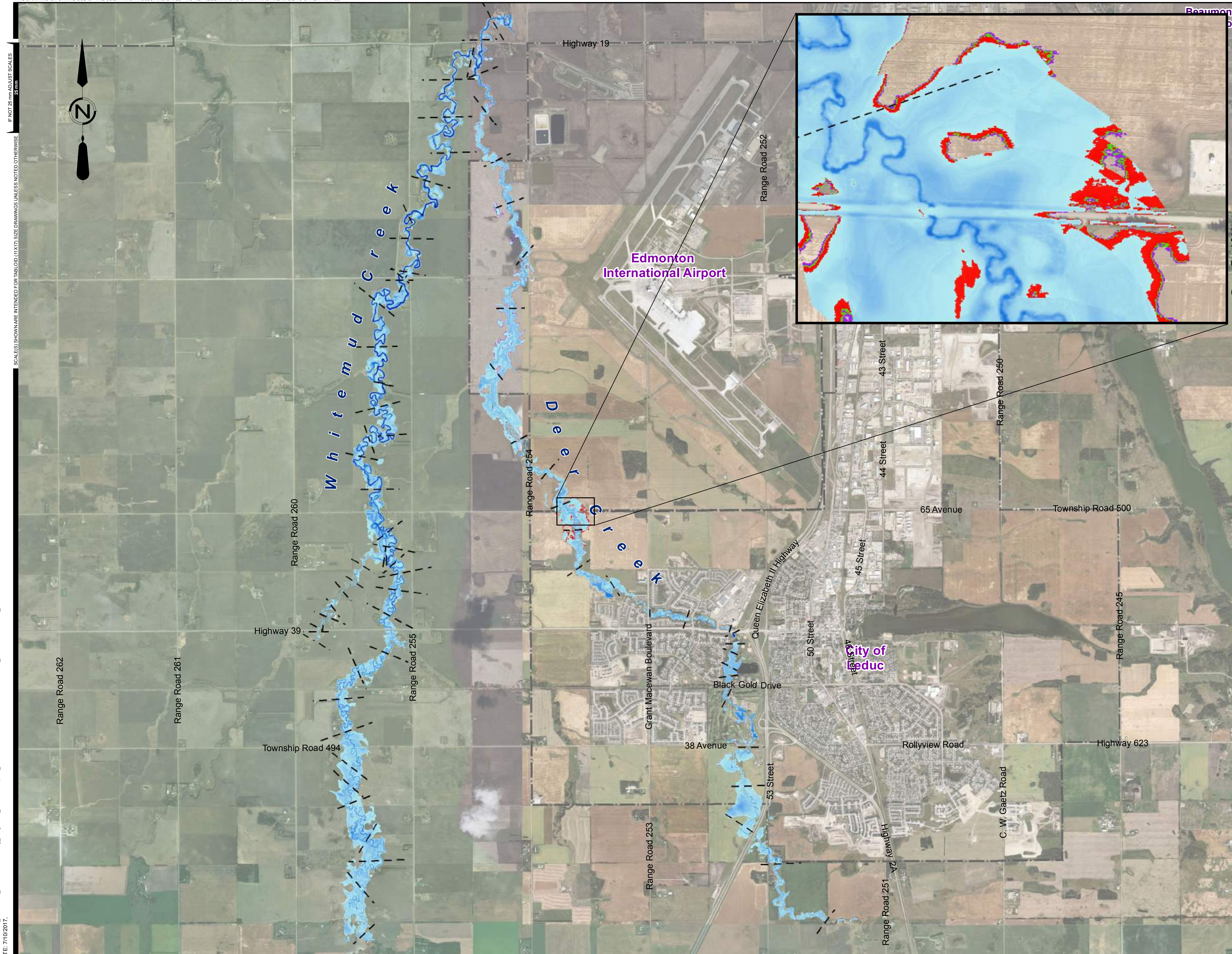
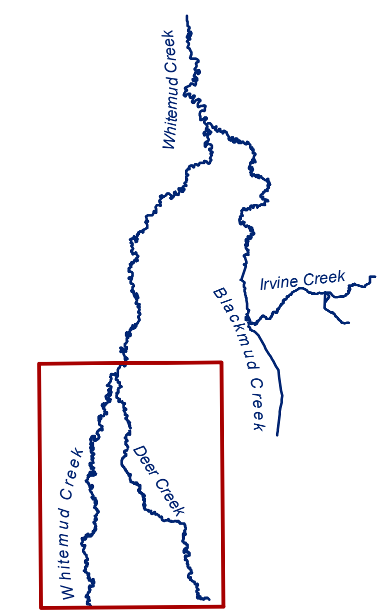




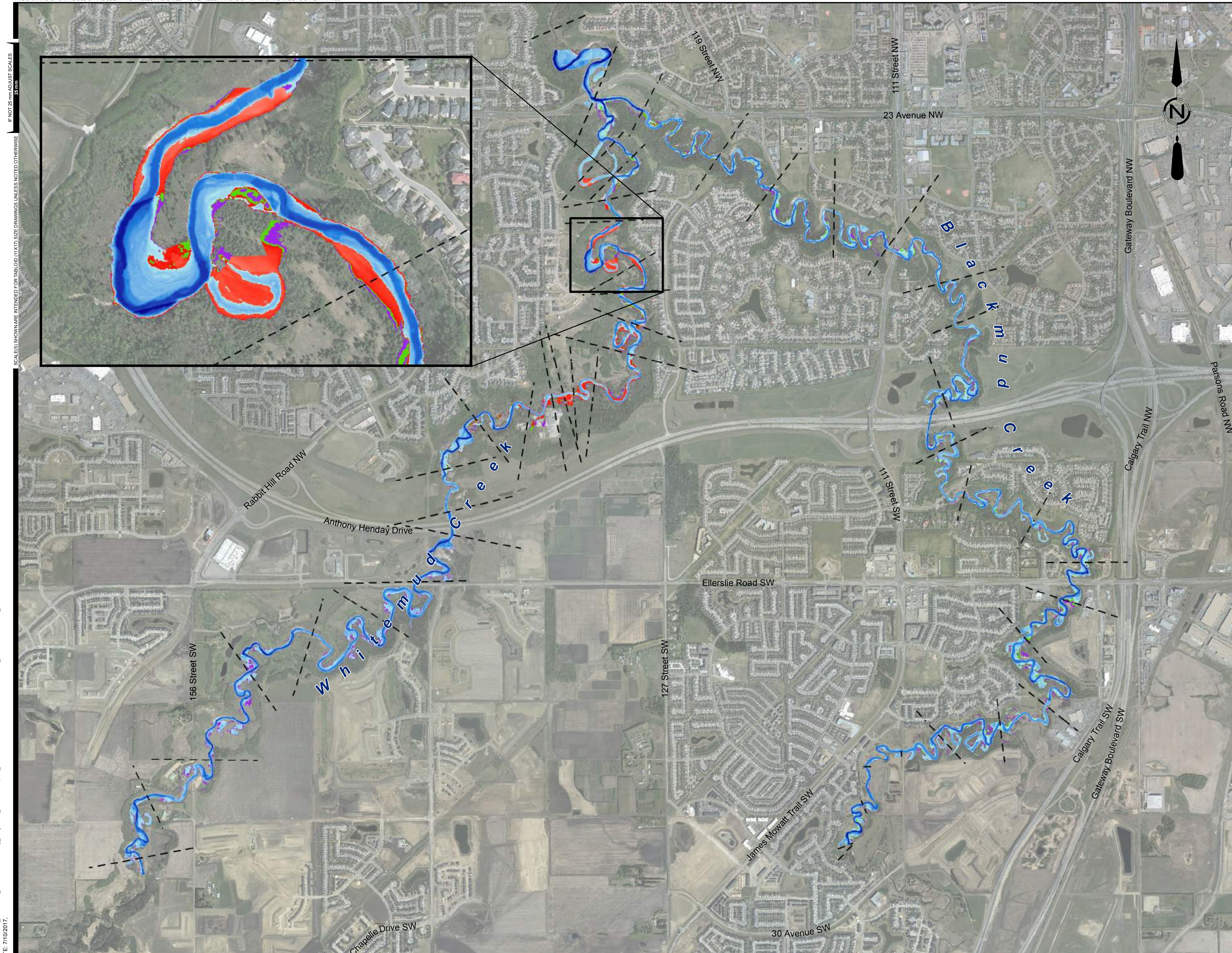
Associated Engineering

FIGURE No. 5-4

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

COMPARISON OF FUTURE FLOOD EXTENT
UPPER WHITEMUD AND DEER CREEKS

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



Associated Engineering

Legend:

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

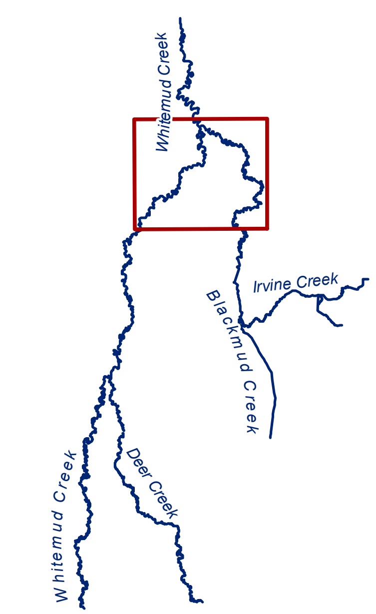
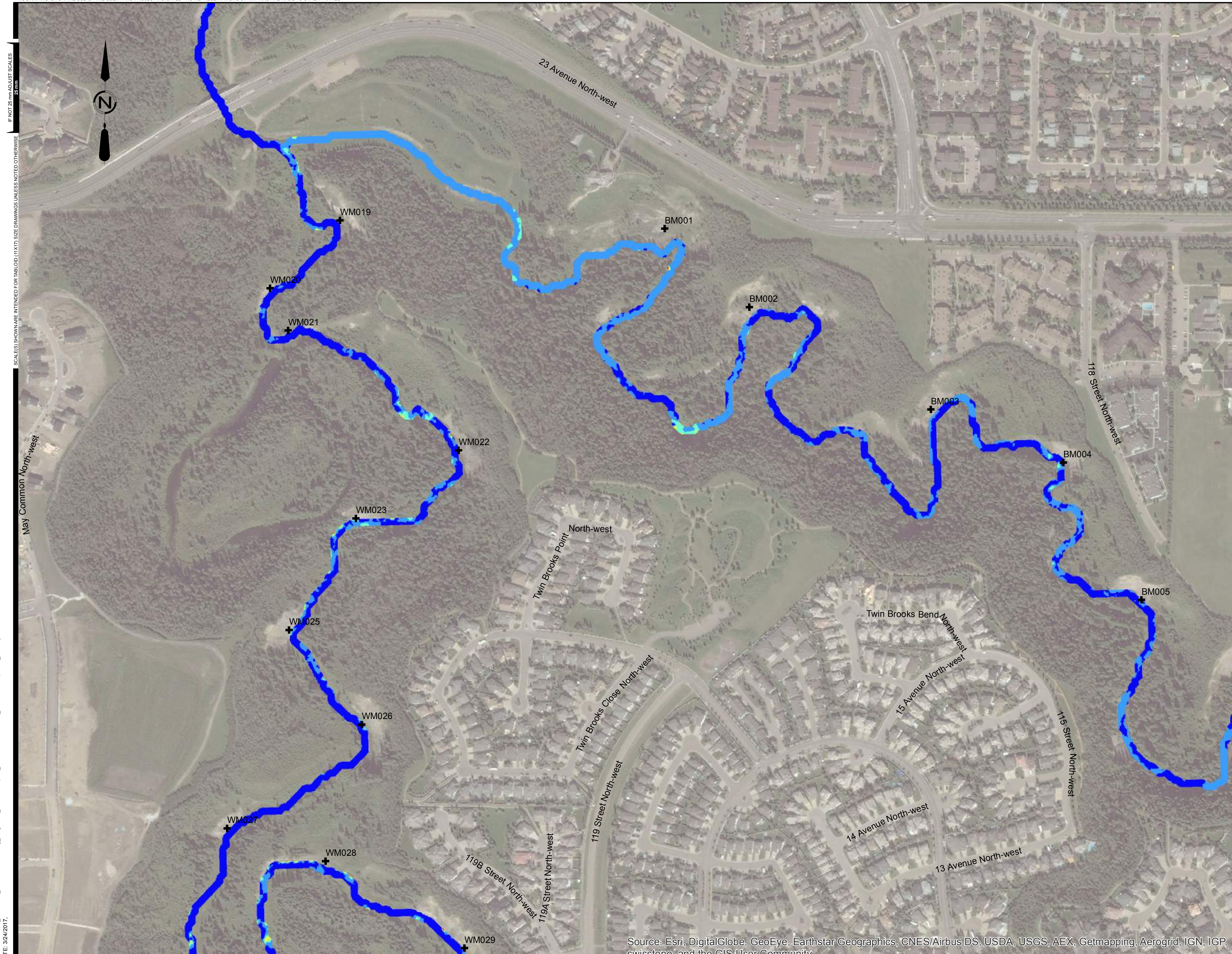


FIGURE No. 5-5

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

COMPARISON OF FUTURE FLOOD EXTENT LOWER WHITEMUD & BLACKMUD CREEKS

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



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

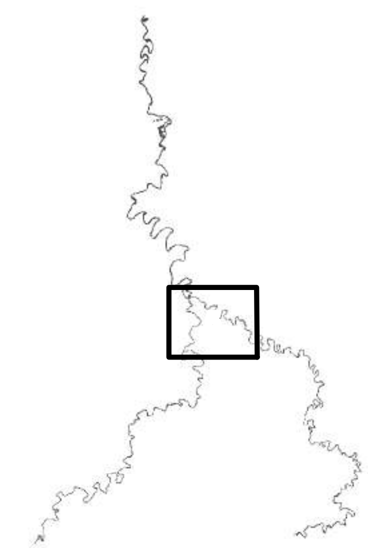


FIGURE No. 5-6

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

VELOCITY RATIO
1.5 L/s/ha COMPARED TO EXISTING
100 YEAR FLOOD VELOCITY

AE PROJECT No.	2016-3785
SCALE	1:5,000
APPROVED	
DATE	2017 JULY
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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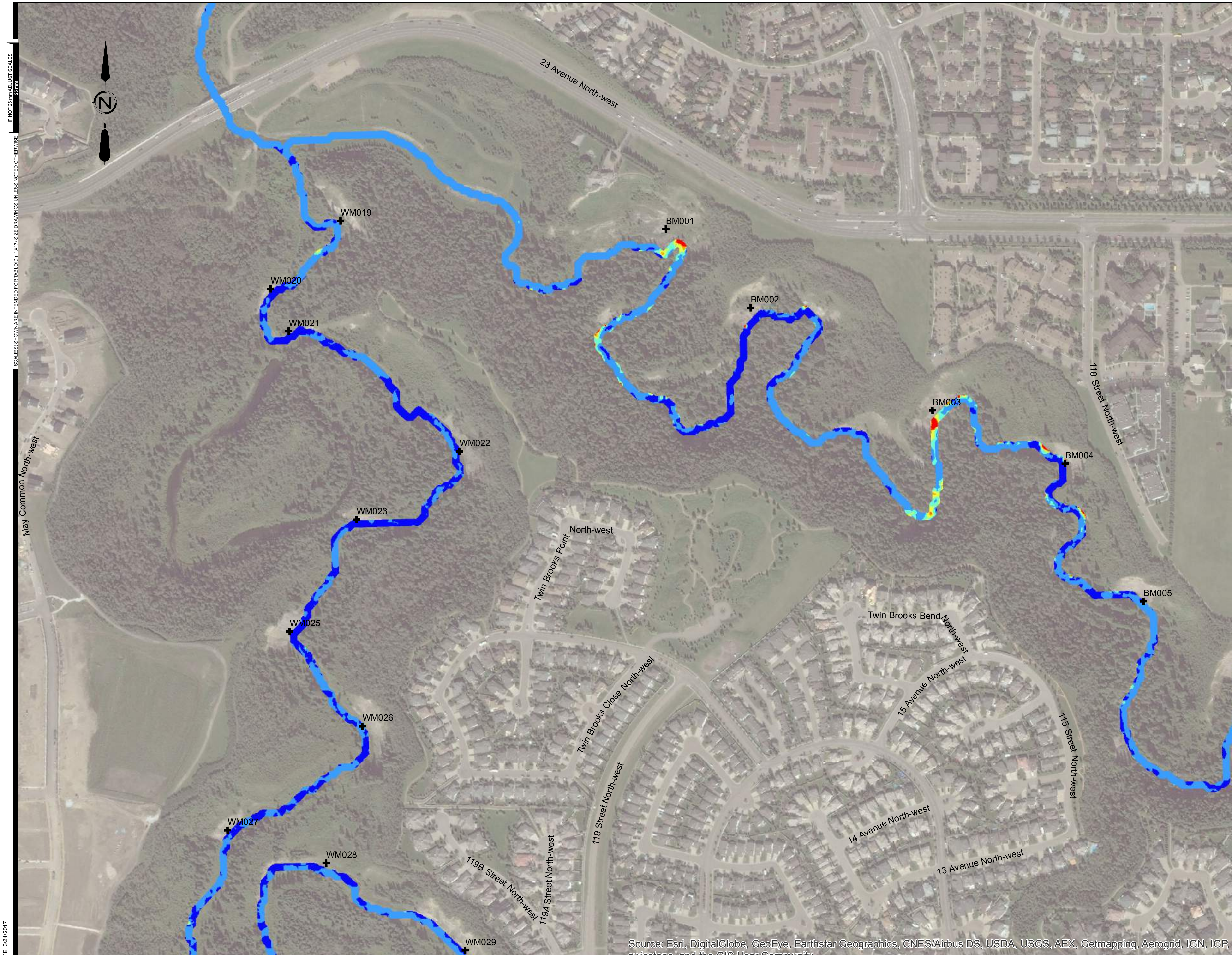

SCALE(S) SHOWN ARE INTENDED FOR TABLOID (11X17) SIZE DRAWINGS UNLESS NOTED OTHERWISE

IF NOT 25 mm ADJUST SCALES

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

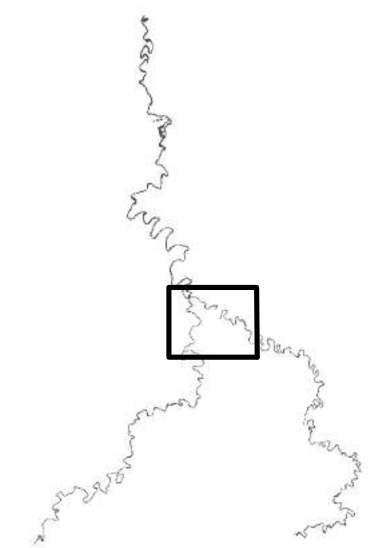

FIGURE No. 5-7

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

VELOCITY RATIO
3.0 L/s/ha COMPARED TO EXISTING
100 YEAR FLOOD VELOCITY

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

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DATE: 3/24/2017,

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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

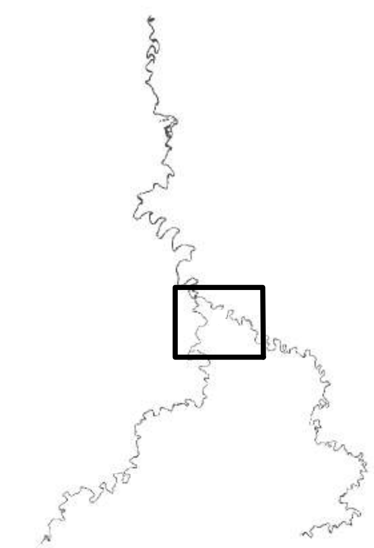

FIGURE No. 5-8

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

VELOCITY RATIO
5.0 L/s/ha COMPARED TO EXISTING
100 YEAR FLOOD VELOCITY

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

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

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DATE: 3/24/2017,

6 Drainage Concepts

There are several options to mitigate or control the impact of development due to drainage within the basin. These include but are not limited to the following:

- Construction of diversion structures, real time control structures, dikes and levees
- Water retention facilities (wetlands, inline and offsite storage)
- Channel improvements
- Storm sewer system (piping)
- Dredging to increase channel capacity
- Limit development and development restriction
- Low impact development (LID)
- Flood adapted infrastructure
- Bio-engineering

Two alternative drainage concepts were investigated to provide drainage for future development and developed to address the issues and constraints identified within the basin. These concepts involve the following:

- Channel improvement (lowering) to facilitate drainage of the worst flood-impacted areas and development of the adjacent lands.

- A trunk storm sewer system that would parallel the existing stream channels, connecting the various SWMFs and draining to a defined stream channel that has sufficient depth and capacity. In this scenario, the existing stream courses would convey the runoff from un-developed portions of the basin.

6.1 CHANNEL IMPROVEMENT

The main goal of channel improvements would be to lower the creek channel in places to facilitate drainage of the adjacent, tributary lands. The existing channels of Irvine Creek and Deer Creek would be lowered to provide an outlet of sufficient capacity for an underground piped system. Lowering the channels would also lower the flood levels and reduce the extent of flooding which would facilitate development of the benefitting lands.

Figure 6-1 illustrates the drainage parkway concept in plan view and cross-section. It involves deepening the existing channel or constructing a new channel within the floodplain to provide the required conveyance. The channel would be aligned to preserve existing treed areas wherever possible and would meander to mimic a natural channel. The existing floodplain would be preserved to provide wildlife habitat and migration corridors.

Figure 6-2 shows the extent of the proposed channel improvements that would be required. Drainage parkways would extend along Irvine Creek and Deer Creek from the CRB boundary to their confluences with Blackmud and Whitemud Creek, respectively. LeBlanc Canal would also be deepened to provide more capacity. Drainage parkways would also be constructed along two existing channels carrying runoff into Whitemud Creek southwest of the Edmonton International Airport and west of the City of Leduc.

Local trunk mains would provide drainage from connected SWMFs into the proposed parkways (not all are shown).

Cawes Lake would be provided with an outlet channel to Irvine Creek to control the lake levels and convey the outflow from developing areas to the north. Current development plans call for the Decoteau Neighborhood to the north and east to drain to Cawes Lake through an inter-connected system of stormwater management facilities. Further study of Cawes Lake will be required to determine the optimum water level for wildlife habitat and to prevent flooding of adjacent lands.

A large regional wetland is also proposed at the junction of the LeBlanc Canal and Irvine Creek. Its main purpose will be to replace the flood storage that would otherwise be lost if the Irvine Creek channel is deepened and thus to prevent increasing peak flows downstream.

Figure 6-3 and 6-4 show longitudinal profiles of Deer Creek and Irvine Creek, respectively, with channel improvement locations noted.

Note that the proposed channel improvements are intended to facilitate drainage, not necessarily to reduce flooding. Reducing flood levels would require the constructed channels to be deeper and larger.

Channel improvements must be done in an environmentally sensitive manner. Detailed environmental impact studies will be required to establish the appropriate environmental design measures to minimize the environmental impacts and provide a valuable amenity to the development.

6.2 TRUNK SEWERS

Figure 6-5 illustrates the trunk outfall concept for the Blackmud/Whitemud basin.

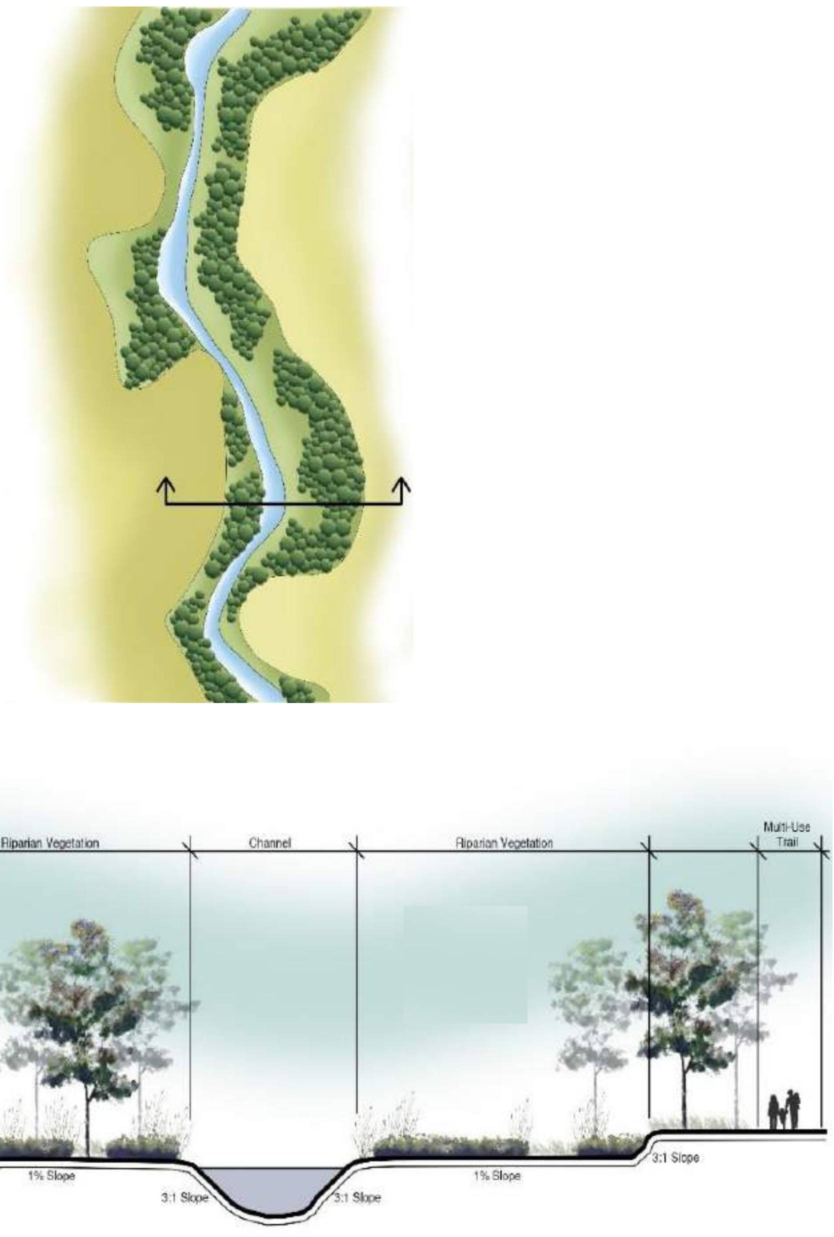
This concept provides drainage and discharge at downstream creek locations where there is more capacity for increased flow. In the cases of Deer Creek and Irvine Creek where existing capacity is limited, trunks will be required to bypass drainage.

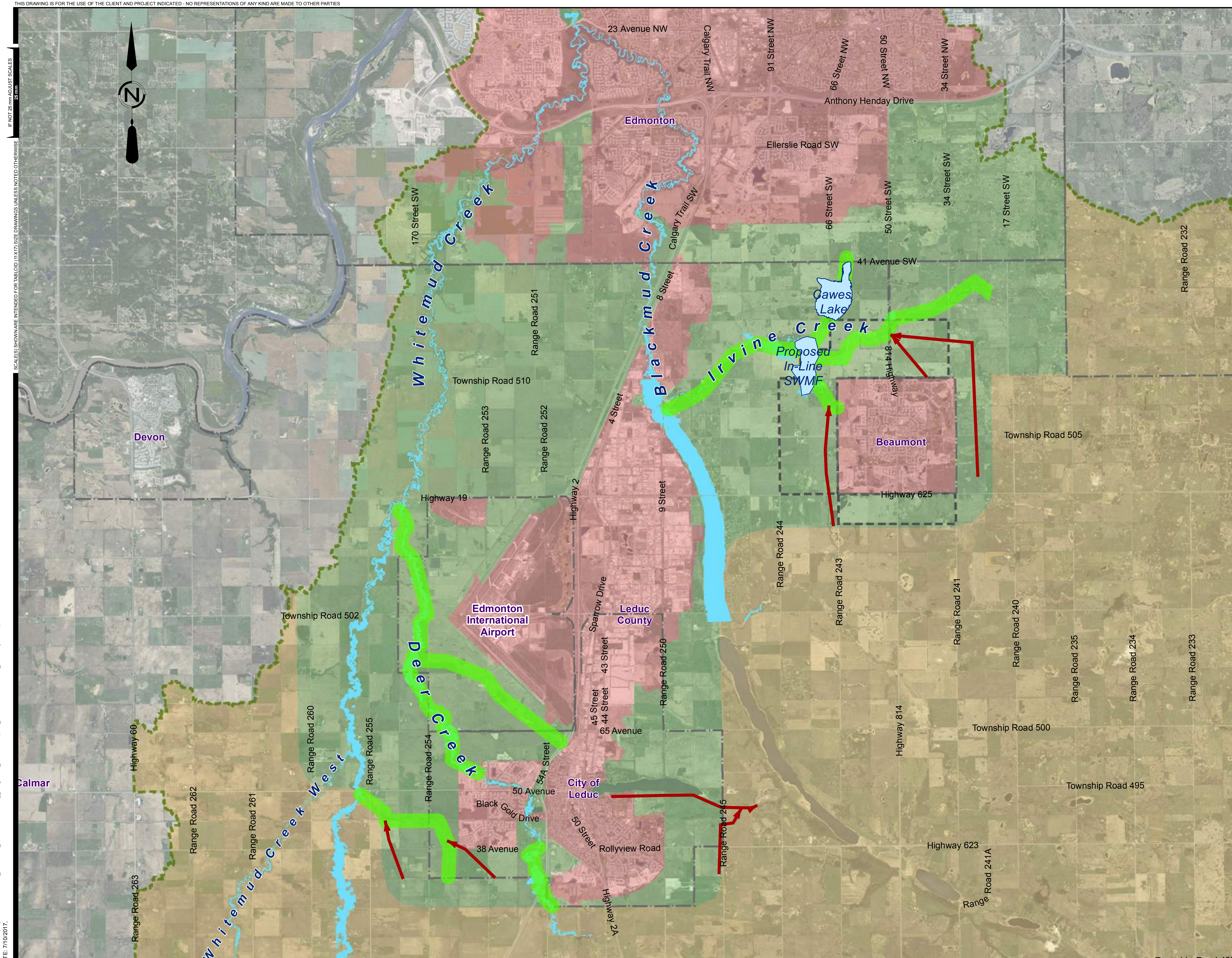
This concept involves deep trunk sewers that would collect the runoff from local areas and would discharge to the creek at locations where there is sufficient creek depth and capacity. This option would mostly apply to Deer Creek and Irvine Creek which are too shallow to service the adjacent lands if they are developed with an underground piped drainage system. The main advantage of this option would be to avoid disturbing the channels of Irvine and Deer Creeks and to avoid the associated environmental impacts.

This concept also provides for a defined outlet from Cawes Lake to maintain a controlled water level and an outlet to Irvine Creek. Cawes Lake will receive runoff from southeast Edmonton (Decoteau Neighborhood) and discharge into the proposed trunk.

Preliminary modeling was conducted to better understand the effects of the proposed concepts on the adjacent reaches of stream channels. Details are provided in **Appendix E**. Results indicate that the lowering of water levels would be relatively minor unless the trunks and channel improvements were designed to have substantial capacity. Therefore, the primary benefits of either scheme are to facilitate development of the adjacent lands which are too low to be drained to the existing creek channels, rather than to reduce flooding. Floodplain lands would still need to be protected as Environmental Reserve to prevent flooding of adjacent properties. Therefore, the preferred option would be to preserve the existing creek channels and floodplains and to provide trunk sewers for drainage where required.

Figure 6-1
Proposed Drainage Parkway Concept





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Legend:

- Outfall
- 3.0 l/s /ha Extent
- Channel Improvement
- Beaumont Annexation

Classification

- Existing Development
- Future Development
- Rural

FIGURE No. 6-2

BLACKMUD/WHITEMUD CREEK WATERSHED MANAGEMENT STUDY

PROPOSED DRAINAGE PARKWAY CONCEPT

AE PROJECT No.	2016-3785
SCALE	1:100,000
APPROVED	
DATE	2017 JULY
REV	
DESCRIPTION	ISSUED FOR REPORT

Figure 6-3:
Deer Creek Proposed Longitudinal Profile

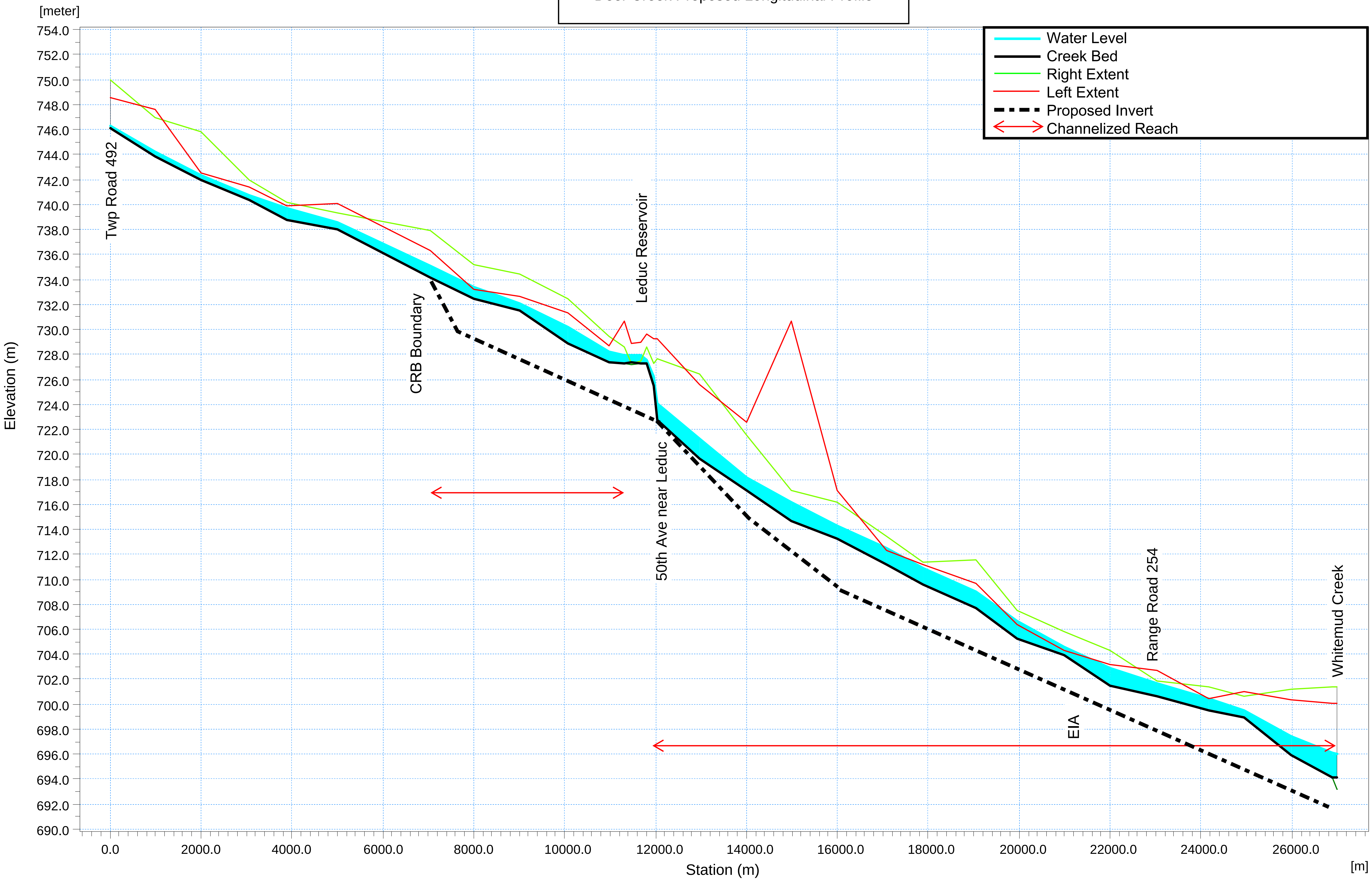
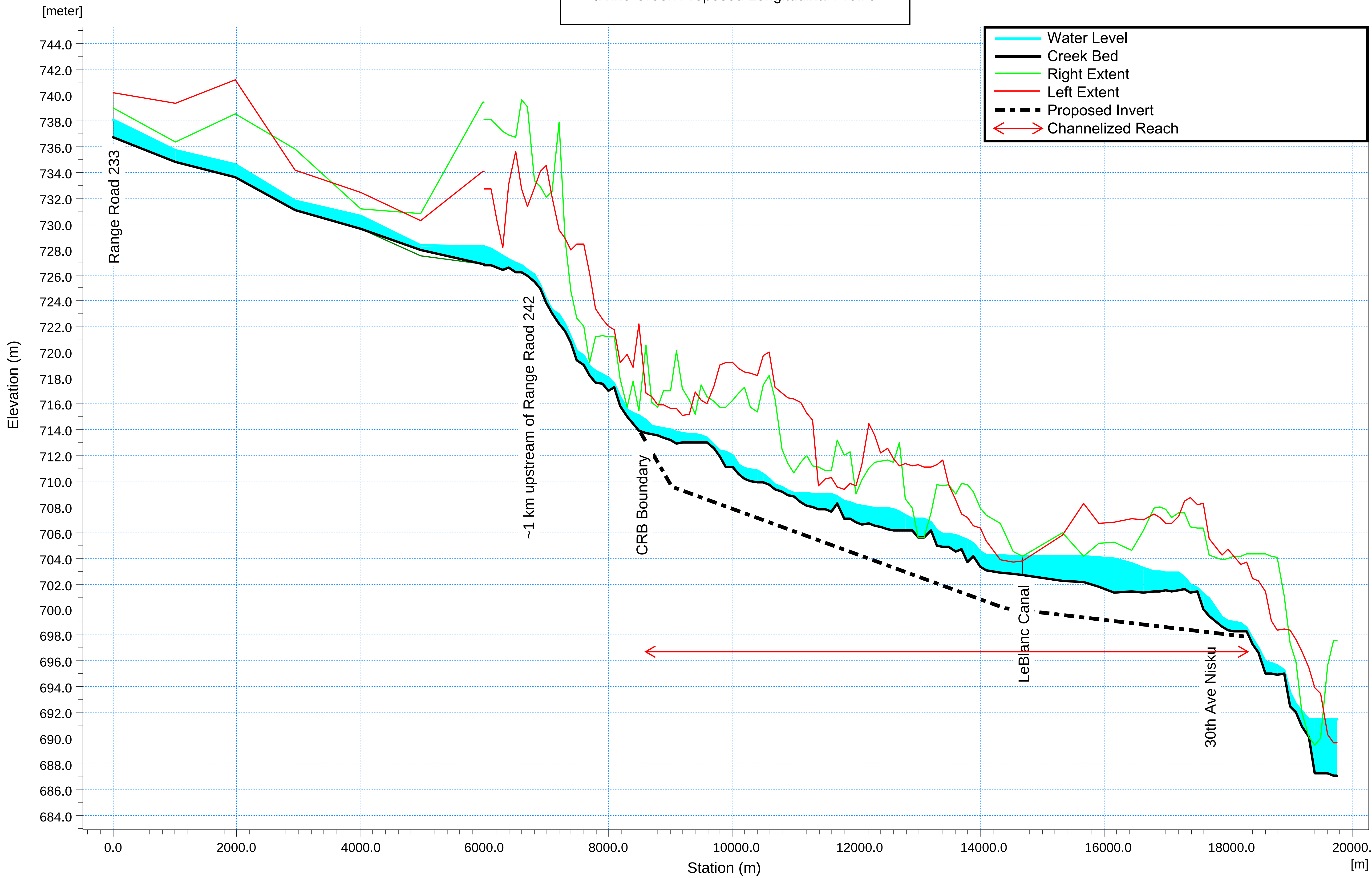


Figure 6-4:
Irvine Creek Proposed Longitudinal Profile



THIS DRAWING IS FOR THE USE OF THE CLIENT AND PROJECT INDICATED - NO REPRESENTATIONS OF ANY KIND ARE MADE TO OTHER PARTIES

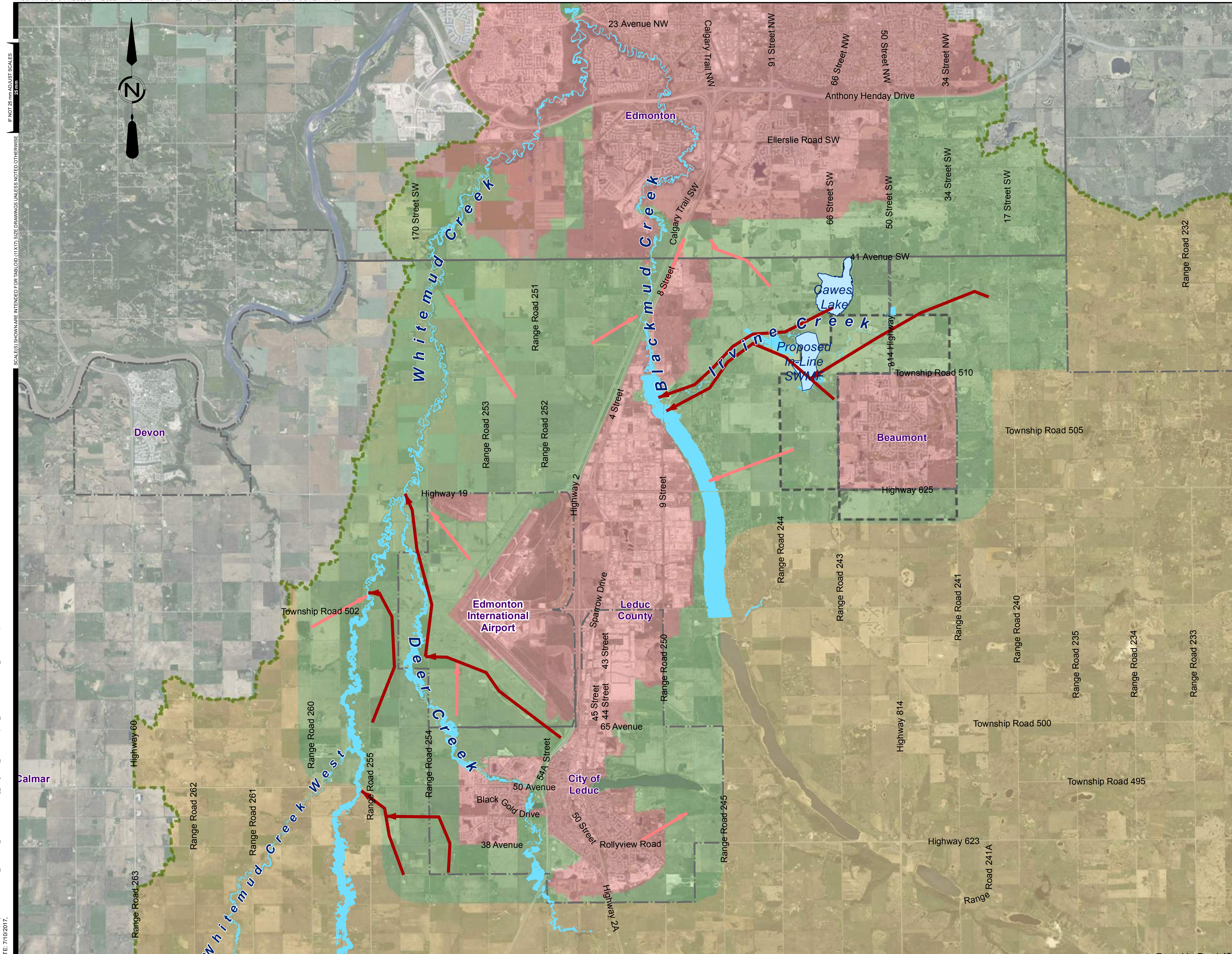


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FIGURE No. 6-5

BLACKMUD/WHITEMUD CREEK
WATERSHED MANAGEMENT STUDY

TRUNK CONCEPT

AE PROJECT No.	2016-3785
SCALE	1:100,000
APPROVED	
DATE	2017 JULY
REV	
DESCRIPTION	ISSUED FOR REPORT

\\s-edm-fs-01\projects\20163785\00_Blackmud_Whitemud\Working_Dwgs\010_GIS\ArcMap\02_WaterResources\6-5_TrunkConcept.mxd
DATE: 7/10/2017,

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

7 Proposed Drainage Plan Strategy

7.1 ISSUES AND CONSTRAINTS

The analysis of the basin's existing condition and proposed future development has identified several issues and constraints as summarized below.

- The majority of the creeks within the basin have complex geometry, are small, lack well defined channels, and have limited channel capacity to convey runoff flows from the existing development. These conditions will constrain future development due to extensive flooding.

- As development continues within the Blackmud and Whitemud basins, the runoff rates and volumes will increase. As a result, flooding and erosion issues will likely increase unless stormwater releases are minimized in the future.

- Localized flooding is expected to occur along the existing creeks during design storm events with the three stormwater management release rates considered for future development (1.5, 3.0, and 5.0 L/s/ha).

- The extent of flooding will constrain development. In some locations along the Blackmud Creek, Irvine Creek, Deer Creek and Leblanc Canal, the flood-risk areas are extensive. The Municipal Government Act empowers municipalities to preserve floodplain areas as Environmental Reserve (land subject to flooding) at the time of development, however, these powers are not always applied consistently. Where extensive overland flooding is found to occur, it is not always practical to sterilize large areas from development, and these locations should be considered as possible sites for stormwater management ponds or wetlands. A policy for protecting floodplains that recognizes the flood risk and the environmental value that floodplains create should be developed.

- Along with the extensive flooding, some of the creek channels, in the same locations as above, are too shallow to permit drainage of adjacent development using a conventional underground pipe system. Typically, a depth of 4 m from adjacent land areas to channel bottom is required and in many places this does not exist.

- Erosion issues in Whitemud and Blackmud Creek are understood in only a general way and could be aggravated by increasing runoff volumes and flood peak discharges resulting from further development in the basin. There are no reliable models of the erosion process to give ***quantitative*** estimates of the erosion rates and the impacts of the changing flow regime that will occur with development, but a ***qualitative*** estimate is possible from the model-simulated velocities, shear stresses and morphological principles that relate these hydraulic parameters to the rate of sediment transport. These estimates indicate that the rate of erosion will double if a release rate of 5.0 L/s/ha is adopted throughout the basin and will increase by about 50% if a release rate of 3 L/s/ha is adopted.

- In general, runoff from most developments within the basin is being controlled with SWM facilities, but not always to the same standard. The various municipalities and the Edmonton International Airport have different forms of SWM designed to provide varying levels of control and service level.

- Numerous wetlands exist throughout the basin and provide valuable habitat and hydrologic and water quality functions, but they are being lost due to agricultural drainage and land development practices. They will continue to be lost unless a proactive approach to protecting them is adopted.

- Facilitating orderly and sustainable development within the basin is a key to the success of any surface water management plan within the basin. A successful sustainable development program will depend on municipal coordination and consistent servicing standards.

7.2 DRAINAGE PLAN STRATEGY

As previously stated, large portions of the Blackmud / Whitemud Creek watershed are expected to be intensively developed in the foreseeable future by the surrounding municipalities. This development will place additional stresses on Blackmud and Whitemud Creeks, which have already been impacted by existing development. As development continues within the Blackmud and Whitemud basins, the runoff rates and volumes will increase. As a result, flooding and erosion issues will increase unless a consistent drainage plan strategy is adopted by all of the municipalities.

A proposed drainage plan strategy for the Blackmud and Whitemud basins is summarized below. This drainage plan strategy is divided into five different categories and identifies the objectives, issues and constraints as described earlier.

7.2.1 Floodplain Management

Objectives:

- Prevent flooding of private property
- Protect floodplain lands for future generations

Issues:

- Low-lying areas along the stream courses are subject to flooding
- Floodplains are valuable wildlife habitat and migration corridors

Constraints:

- Topography, soils, vegetation
- Environmental legislation
- Land subject to flooding – Municipal Government Act
- Cover for standard urban drainage systems

Strategies:

- Protect floodplain lands from further development with a floodplain overlay in the land use bylaws
- Dedicate floodplain lands as Environmental Reserve at time of subdivision
- Minimize channel disturbances
- Design any channel improvements in an environmentally sensitive manner
- Develop joint-project levies

7.2.2 Erosion Control

Objectives: Minimize and mitigate erosion along stream courses (especially Whitemud Creek)	
Issues: • Natural and man-made processes • On-going erosion will increase with development • Projected ~1.5-2x existing rates of erosion	**Constraints:** • Hydraulic conditions (velocities) • Topography, soils, vegetation • Existing development • Natural rates of erosion
Strategies: • SWM for all new development • Maximum 3.0 L/s/ha (higher in EIA control zone varying with distance from runway) • Repair and remediate as necessary • Further study to determine a mechanism for future costs and cost sharing for offsite improvements and erosion repairs • Promote LID to reduce runoff volumes	

7.2.3 Wetland Preservation

Objectives:	
• Retain and adapt existing wetlands for wildlife habitat and water quality enhancement	
Issues: • Existing wetlands are being lost to development	**Constraints:** • Topography – low and shallow • Catchment area • Wetland size • Legislation – Water Act • Increasing runoff with increasing densities
Strategies: • Retain and adapt existing wetlands where possible • Constructed wetlands for SWM facilities • Managed outlet from Cawes Lake • New regional wetland near Beaumont • Drainage parkways for connectivity	

7.2.4 Water Quality

Objectives: • Preserve and enhance stream course water quality	
Issues: • Urban runoff contains various pollutants (sediment, nutrients, hydrocarbons, heavy metals)	**Constraints:** • Urban lifestyle and land use • Increasing densities • SWM removal: ➢ Nutrients ~40-50% ➢ Sediment 80-90%
Strategies: • SWM for all new development • Wet ponds or wetland (not dry ponds) – except in EIA exclusion zone • Implement joint water quality monitoring • Retain and protect existing wetlands and integrate them into the urban drainage fabric	

7.2.5 Sustainable Development

Objectives:

- Facilitate orderly and sustainable development
- Expedite approvals

Issues:

- Development is most efficient if it is coordinated

Constraints:

- Numerous parties involved
- Conflicting objectives
- Different servicing standards
- Limited flow/climate data

Strategies:

- Regional coordination (CRB)
- Adopt water management plan for basin
- Additional planning (Area Structure Plans and Municipal Development Plans) to expand on concepts
- Development levies for major facilities
- Additional flow and rainfall monitoring

8 Conclusions

Following are the key findings of the study:

1. Development will place additional stresses on Blackmud and Whitemud Creeks, which have already been impacted by both agricultural and urban development. Potential impacts include increased peak flows and runoff volumes. As a result, flooding and erosion issues will likely increase.

2. The majority of the creeks within the basin have complex geometry, are small, lack well defined channels, and have limited channel capacity to convey runoff flows from the existing development. These conditions will constrain future development.

3. The pre-development unit discharge rates within the basin range from 1.1 to 2.9 L/s/ha for the 1:100 year return period when calculated using the gross drainage area.

4. The various municipalities and the Edmonton International Airport have different forms of SWM designed to provide varying levels of control and service level. The unit area runoff rates used for design of these facilities range from 1.8 to 8.8 L/s/ha and are somewhat higher than the pre-development runoff rates estimated herein and in previous studies. Therefore, they are not sufficiently conservative with respect to flooding and erosion potential.

5. A significant portion of the riparian area has been modified for agricultural purposes. The removal of native woody vegetation and native plant species, along with the introduction of invasive species, has decreased the riparian area's resiliency to erosion and flooding.

6. The project area creeks have capacity for peak flows that will occur in a 1:2 to 1:5 year return period flood. Localized flooding will occur in the 1:100 year event but is mostly confined to the natural creek floodplains, except in portions of Irvine Creek, LeBlanc Canal, Deer Creek, and the glacial spillway valley of Blackmud Creek in Leduc County where extensive overbank flooding occurs.

7. Localized flooding is expected to occur along the existing creeks during the design storm event with the three stormwater management release rates considered for future development (1.5, 3.0, and 5.0 L/s/ha).

8. Channel velocities in Blackmud and Whitemud Creeks generally increase from upstream to downstream, reflecting the increase in discharge and longitudinal slope, and generally correlate with the bank erosion processes that have been observed. These erosion processes are the results of natural and human influences including previous historic development in the basin since the land was first cleared for agriculture and urban development.

9. Velocities and runoff volumes in the creeks will increase with development and will aggravate the ongoing erosion issues in Whitemud and Blackmud Creeks. The magnitude of this impact will depend on the release rate adopted for new development and can be minimized by adopting the lowest release rate that is reasonably practical. Continuing the existing standard for the City of Edmonton, 5.0 L/s/ha, could cause erosion rates to increase by double or more compared with the existing condition. Adopting a release rate of 3.0 L/s/ha would minimize the impacts and would produce flows that are similar to the existing flows within most of the creeks except Irvine creek and LeBlanc Canal and is a reasonable compromise.

10. Two viable alternative drainage concepts were identified for consideration to address the issues and constraints identified within the basin. These concepts involve the following:

    i. Constructing drainage parkways along Irvine Creek and Deer Creek to provide capacity and facilitate drainage of the adjacent lands which are otherwise too low to be drained with an underground drainage system.
    ii. Constructing a network of outfall trunk sewers adjacent to the same stream channels to carry the releases from the connected stormwater management facilities to a downstream location where adequate channel capacity and depth are available.
    iii. The final concept plan might include a combination of the above concepts.

11. The extent of flooding will constrain development. In some locations along the Blackmud Creek, Irvine Creek, Deer Creek, and LeBlanc Canal the flood-risk areas are extensive. The Municipal Government Act empowers municipalities to preserve floodplain areas as Environmental Reserve (land subject to flooding) at the time of development but these powers are not always applied consistently or uniformly. Where extensive overland flooding occurs, it is not always practical to sterilize large areas from development, and these locations should be considered as possible sites for stormwater management ponds or wetlands.

12. Numerous wetlands exist throughout the basin and provide valuable habitat and hydrologic and water quality functions, but they are being lost due to agricultural drainage and land development practices. They will continue to be lost unless a proactive approach to protecting them is adopted.

13. Current development practices (i.e., development plans and practices, policy) appear to be sufficient in terms of maintaining surface water quality in the lower reaches of Blackmud and Whitemud Creeks. However, with projected increases in development for the area, this may not be the case, which would warrant the implementation of a more robust water quality monitoring program.

14. Coordination between the various municipalities and Alberta Environment and Parks with a mutually agreed water management plan is required to facilitate orderly development in the basin.

15. Based on the best information currently available it is concluded that climate change is unlikely to have a significant impact on storage volumes, release rates, and the basin drainage strategy.

16. Poorly defined creek channels and minimal creek channel depth will make conventional urban drainage systems difficult (lack of cover).

9 Recommendations

Associated Engineering recommends the following:

1. The Blackmud and Whitemud basins should adopt a maximum release rate of 3.0 L/s/ha which produces flows that are similar to the existing flows within most of the creeks except Irvine creek and LeBlanc Canal. A higher release rate could be considered in the EIA zones of control to minimize concerns about bird hazards.

2. Protect floodplain land within the Blackmud and Whitemud basins from further development with a floodplain overlay in the municipal lands use bylaws and dedicate them as Environmental Reserves at the time of subdivision. A policy for protecting floodplains that recognizes the flood risk and the environmental values that floodplains provide should be developed.

3. Where extensive overland flooding is found to occur, it is not always practical to sterilize large areas from development, and these locations should be considered as possible sites for stormwater management facilities or wetlands.

4. Two viable concepts (channel improvement and trunk sewers) were identified to mitigate the impacts of future development within the Blackmud and Whitemud basins. A network of outfall trunk sewers adjacent to the existing stream channels is a more environmentally sensitive option to carry the releases from the connected stormwater management facilities to a downstream location where adequate channel capacity and depth are available. Existing channels should be preserved to carry the runoff from upstream undeveloped lands and disturbance of these channels should be minimized. More detailed study is recommended to develop the details and further evaluate these proposed concepts.

5. More detailed drainage planning and floodplain modelling will be required during subsequent planning stages to define the extent of the floodplains and the design requirements for any drainage option that might be adopted.

6. All proposed drainage works must be constructed in an environmentally sensitive manner.

7. Further detailed analyses will be required to integrate existing wetlands into the urban fabric and to establish the appropriate water management strategy and water levels for existing and proposed wetlands. Cawes Lake should be retained, adapted and provided with a defined outlet to manage lake levels for habitat enhancement and to prevent flooding of the adjacent lands. A regional wetland is proposed to replace the flood storage that would otherwise be lost with channelization of Irvine Creek. Existing floodplain areas should be preserved as Environmental Reserve and protected from further development.

8. Promote the construction and use of wet ponds and wetlands (not dry ponds) within the basins, except in the EIA exclusion zone.

9. Promote LID to reduce runoff volumes from the Blackmud and Whitemud basins.

10. Repair and remediate erosion sites as necessary.

11. Further studies will be required to determine a mechanism for future costs and cost sharing for offsite improvements and erosion repairs.

12. Develop monitoring programs for water quality, rainfall and flow data within the basins. This will aid in monitoring the impacts of development.

13. Water quality assessment is recommended to gain a more thorough understanding of baseline water quality for all areas of the watershed. This would include water quality testing at additional locations in the watersheds focusing on the upper reaches and an expanded list of parameters for analysis. This assessment would support the development of a watershed protection plan, which could include detailed source protection policy and management.

14. Coordination planning between municipalities within the basins by adopting a water management plan for the basin and ensuring their stormwater management design criteria are consistent.

15. The Group will need to communicate with AEP to coordinate “Fenceline” approvals for future development within the Blackmud and Whitemud Creek basins.

16. Further study should be undertaken to refine the design standard for pond drawdown, to include continuous long-term simulation of pond performance, with a view toward reducing the servicing cost.

REPORT

Closure

This report was prepared for the Blackmud/Whitemud Creek Surface Water Management Group to provide a drainage strategy for the Whitemud/Blackmud Creek basin.

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

Respectfully submitted,
Associated Engineering Alberta Ltd.

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QUALITY MANAGEMENT SIGN-OFF
Signature:
Date: AUG 28 /17

APEGA Permit to Practice P 3979

Appendix A - TM No. 1 Background Data Collection and Review

Appendix B - TM No. 2 Natural Areas and Aquatic Ecosystem Assessment

Appendix C - TM No. 3 Hydrology Assessment

Appendix D - TM No. 4 Hydrologic and Hydraulic Modelling

Appendix E - TM No. 5 Concept Development