ISL Engineering and Land Services

Inflow-Infiltration Program

City of Cold Lake

Final Report

September 2018

ISL Engineering and Land Services

ISL Engineering and Land Services Ltd. is an award-winning full-service consulting firm dedicated to working with all levels of government and the private sector to deliver planning and design solutions for transportation, water, and land projects.

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September 10, 2018

Our Reference: 26367

City of Cold Lake
5513 – 48 Avenue
Cold Lake, Alberta, T9M 1A1

Attention: Rezaur Bhuiyan, MSc., P.Eng., Engineering Manager – Infrastructure Services

Dear Sir:

Reference: City of Cold Lake – Inflow-Infiltration Program – Final Report

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Enclosed is the final report for the City of Cold Lake Inflow-Infiltration Program study. We trust that it meets your needs.

The key objective of this project was to review the sanitary wet weather flow rates in the system as well as assess the City's current sanitary conveyance infrastructure capacity and the future needs for projected City populations. The program will provide the City with direction on infrastructure implementation to service the projected populations, while ensuring infrastructure remains fully functional in providing appropriate level of service. This information will aid in making informed decisions on capital projects, and will provide solutions for efficient, economic and sustainable municipal services to residents. In addition, the Inflow-Infiltration Program highlights high inflow-infiltration areas that can be remediated to increase system conveyance and treatment capacity.

We sincerely appreciate the opportunity to undertake this project on your behalf. Should you have any questions or concerns, please do not hesitate to contact the undersigned at (403) 254-0544.

Sincerely,

Garnet Dawes, P.Eng., DBIA
Lead, Community Infrastructure

Corporate Authorization

This document entitled "Inflow-Infiltration Program" has been prepared by ISL Engineering and Land Services Ltd. (ISL) for the use of the City of Cold Lake. The information and data provided herein represent ISL's professional judgment at the time of preparation. ISL denies any liability whatsoever to any other parties who may obtain this report and use it, or any of its contents, without prior written consent from ISL.

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Executive Summary

Introduction

ISL Engineering and Land Services Ltd. was retained by the City of Cold Lake to undertake an Inflow-Infiltration Program. This Program includes a review of the sanitary wet weather flow rates in the system as well as an assessment of the City's current sanitary conveyance infrastructure capacity and the future needs for projected City populations. For that purpose a robust hydrologic/hydraulic model has been constructed and calibrated using the state-of-the-art hydrodynamic MIKE URBAN software developed by DHI to enable the comprehensive assessment of the sanitary system. The project was initiated in response to a need to ensure sound sanitary system planning. The intent of this project is to provide a comprehensive road map to Council and the administration for assessing the capability of the infrastructure to accommodate new development in the short-term and long-term. In addition, there is a desire to highlight high inflow-infiltration areas that can be remediated to increase system conveyance and treatment capacity.

Study Objectives

The study was prepared to achieve the following objectives:

- Compilation and assessment of the existing sanitary data
    - Populate missing manhole rim and invert elevations
    - Confirm sizing of certain sewers
    - Perform calibration to accurately represent the City's sanitary network
- Analysis of infrastructure under existing and future growth scenarios including:
    - Stage 1 – Build-out of Existing System (imminent development)
    - Stage 2 – Build-out to Current City Boundary (short to medium-term development)
    - Stage 3 – Build-out of Annexation Areas (long-term development)
    - Stage 3+ - Build-out of Annexation Areas plus Additional Three Quarter Sections in the North (long-term development)
- Identification of the required upgrades to the infrastructure to meet existing and future needs
    - Rehabilitation of existing sewers based on the field investigation and findings obtained through smoke testing
    - Construction of additional infrastructure to alleviate flows on existing system
    - Implementation of additional infrastructure to accommodate future developments
- Development of cost estimates for all required upgrades
- Review of existing inflow-infiltration rates observed under wet weather conditions and compare against various design storms, determination of possible sources of inflow-infiltration, and recommendation of remedial measures
- Development of a staging plan for implementing infrastructure upgrades in terms of short- and long- term needs
    - Existing Upgrading Options
    - Stage 1 – Build-out of Existing System Upgrading Concept
    - Stage 2 – Build-out to Current City Boundary Upgrading Concept
    - Stage 3 – Build-out of Annexation Areas Upgrading Concept
    - Stage 3+ - Build-out of Annexation Areas plus Additional Three Quarter Sections in the North Upgrading Concept

Conclusions

Conclusions for the I-I Program are as follows:

1. The performance of the existing system was assessed under the following four scenarios:
   - Constant I-I allowance of 0.29 L/s/ha
   - Constant I-I allowance of 0.60 L/s/ha – used only for illustration and comparison purposes under the existing conditions
   - 1 in 25 year, 24 hour, 3rd quartile Huff Storm
   - 1 in 50 year, 24 hour, 3rd quartile Huff Storm
2. The City's existing sanitary collection system performs generally adequately under the 1 in 25 year, 24 hour, 3rd quartile Huff storm as well as the 1 in 50 year, 24 hour, 3rd quartile Huff storm.
3. Under the City's design standard of 0.29 L/s/ha, simulation results suggest that Building 3 Lift Station is under capacity causing significant backups upstream. It is recommended that the City performs a detailed review of the performance of both the lift station and forcemain to determine if this hydraulic system can be optimized to reduce the stipulated upgrades.
4. Under a constant I-I rate of 0.60 L/s/ha, the sanitary conveyance system was found to perform quite adequately as no critical surcharge conditions were observed. In terms of the pumping capacity at the major lift stations, constraints were found to exist at the Building 3 and Building 9 Lift Stations. This was transpired in the form of significant backups in the upstream sewer reaches. It is noted that this scenario was deemed to be excessively conservative and thus inappropriate to assess the performance of the lift stations, hence was simulated for illustration purposes only. It is not recommended that this scenario be used to determine any necessary upgrades at the lift stations.
5. The major constraint in the City's sanitary collection system was found to be at the Building 3 Lift Station under a conservative constant I-I rate of 0.29 L/s/ha scenario. As mentioned above, further analysis would be required to determine if the performance of the hydraulic system (pumps and forcemains) can be optimized to reduce the stipulated upgrades. It should also be noted that the proposed extension of the associated forcemain will result in a higher TDH required to convey the estimated future peak wet weather flows due to an increase in frictional and minor losses.
6. Inflow-Infiltration rates in the City's system can be summarized as follows:
   - Site 6 – Extreme observed and projected I-I rates that are very unusual
   - Site 1 – Elevated observed I-I rates typical for an older system
   - Sites 3, 8 (2015) and 8 (2016) – Elevated projected I-I rates exceeding the City's design standard of 0.29 L/s/ha
   - Remaining Sites – Below the City's design standard of 0.29 L/s/ha
7. The smoke testing program found 154 incidents, including manhole covers that are not sealed, as well as service connections and cleanout caps that showed smoke release. The results indicated that there were 12 incidents that were identified as a high level of smoke intensity and one incident with very high inflows.
8. Servicing concepts were determined for Stages 2, 3 and 3+. It is noted that all of the development areas anticipated for growth in Stage 1 are expected to tie directly into the existing system, thus no servicing concept was required.
9. Performance of the existing system under future population and area growth scenarios for Stages 1, 2, and 3 were assessed under the following design storms:
   - Constant I-I allowance of 0.29 L/s/ha
   - 1 in 25 year, 24 hour, 3rd quartile Huff Storm
   - 1 in 50 year, 24 hour, 3rd quartile Huff Storm

   It is noted that Stage 3+ was not modelled, as there are no catchments that tie back into the existing system.
10. Nine upgrades to the existing system under future conditions were identified through the assessment process; one under Stage 1, seven under Stage 2 and one under Stage 3. The majority of these

upgrades involve increasing the capacities at lift stations, including Building 3, Building 4, and Building 9 Lift Stations.

Recommendations

Recommendations for the I-I Program are as follows:

1. The following upgrades under existing conditions are recommended. These upgrades are shown in Figure 6.19 in detailed in Section 6.0.
   - Install pressure gauges at all headers at both the Building 1 and Building 3 Lift Stations. It is noted that since the completion of the Draft Final version of this report, pressure gauges have been installed at both lift stations.
   - Upgrade the capacity of Building 3 Lift Station by 15 L/s, for a total capacity of 76 L/s. Alternatively, as additional upgrades to this lift station are required in multiple growth horizons, it may be beneficial for the City to complete all the upgrades at once. That said, the total required capacity at the Building 3 Lift Station under the ultimate conditions is 86 L/s, which correlates to a 25 L/s increase.
     i. It is recommended that the City performs a detailed review of the performance of both the lift station and forcemain to determine if this hydraulic system can be optimized to reduce the stipulated upgrades.
     ii. It should also be noted that the proposed extension of the associated forcemain will result in a higher TDH required to convey the estimated future peak wet weather flows due to an increase in frictional and minor losses
   - The total cost of completing the upgrades noted above (assuming that the capacity of Building 3 Lift Station increases to the interim 76 L/s) is approximately $232,000.
   - Monitor the performance of the City's five major lift stations, and consider a forcemain hydraulics assessment to determine if any forcemains are candidates for pigging.
2. To reduce inflow-infiltration in the City, the following are recommended:
   - Smoke test the remaining sewers not included in the 2016/2017 smoke testing program (roughly 33 km (39%) remaining).
   - Consider micro flow monitoring to pin-point the sources of inflow in areas with identified high I-I rates.
   - Ensure all manholes experiencing high levels of smoke intensity are sealed (i.e. seal lid, plug holes), while ensuring that appropriate exhaust and ventilation systems are implemented
   - Conduct CCTV testing on sewers exhibiting large amounts of inflow-infiltration which could be carried out as part of an over-arching Asset Management Condition Assessment Framework.
   - Consider a sewer relining program for older sewers where replacement is not required
   - Develop an education program to encourage residents to:
     i. Disconnect sump pumps from the sanitary system
     ii. Direct roof leaders onto the ground surface
     iii. Ensure positive drainage away from their homes to reduce flows to weeping tiles
3. It is advised to resolve the incidents highlighted during the smoke testing program in order to reduce the sources of inflow-infiltration.
   - After this point in time, it is recommended that the City undertakes additional flow monitoring in the following years to determine if issues upstream of Sites 1 and 6 have been resolved, or to pinpoint the sources of inflow-infiltration.
4. The servicing concepts outlined in Section 8.2, and depicted in Figures 8.7 to 8.12 are recommended to accommodate the growth in Stages 2, 3, and 3+.
   - The total cost of implementing the aforementioned infrastructure are as follows:
     i. Stage 2 – Total Cost of $37.8M
     ii. Stage 3 – Total Cost of $113.1M
     iii. Stage 3+ - Total Cost of $127.6M

5. The following upgrades to the existing system in order to accommodate future growth under Stages 1, 2, and 3 are recommended. These upgrades are illustrated in Figures 9.37, 9.38, 9.39 and 9.40 in Section 9.0.
   - Stage 1 – Total Cost of $75,000
     i. Upgrade the capacity of the Building 3 Lift Station to a capacity of 81 L/s. It is noted that depending on how the City chooses to stage this upgrade, this might have been completed as part of the existing system upgrades noted above.
   - Stage 2 – Total Cost of $23.8M
     i. Upgrade the capacity of the Building 3 Lift Station to an ultimate capacity of 86 L/s. It is noted that depending on how the City chooses to stage this upgrade, this might have been completed as part of the existing system upgrades noted above.
     ii. Upgrade the capacity of the Building 4 Lift Station by 100 L/s, for a total capacity of 382 L/s.
     iii. Divert flows from 22nd Street to 23rd Street. The majority of the work for this upgrade was confirmed to be completed after the Draft Final version of this report, thus only the plug requires implementation.
     iv. Reconnect Building 3 Forcemain directly to the Building 4 Lift Station.
     v. Complete the Forest Heights Phase 2 900 mm to 1050 mm Trunk.
     vi. Upgrade the capacity of the Building 9 Lift Station to a capacity of 950 L/s. This may be done in stages (upgrade by 650 L/s initially (Stage 2) and an additional 400 L/s (Stage 3) afterwards) or all at once, for an ultimate capacity of 1,350 L/s.
     vii. Upsize the section of sewer running from 47th Street between 51st Avenue and 50th Avenue, then 50th Avenue between 47th Street and 44th Street from 200 mm to 300 mm.
   - Stage 3 – Total Cost of $5.8M
     i. Upgrade the capacity of the Building 9 Lift Station by 400 L/s, for an ultimate capacity of 1,350 L/s. It is noted that depending on how the City chooses to stage this upgrade, this might have been completed as part of the Stage 2 upgrades noted above.
6. This document should be revisited after significant periods of growth or every five years to update the hydrodynamic model and analysis with any capital upgrades completed by Cold Lake, the most up-to-date growth plans, and new available rain gauge and flow monitoring data.

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ABBREVIATIONS

Abbreviation	Meaning
AEP	Alberta Environment and Parks
ASP	Area Structure Plan
BF	Baseflow Time Constant
BLDG	Building
CCTV	Closed Captioned Television
CFB	Canadian Forces Base
CKif	Interflow Time Constant
Ckof	Overland Flow Time Constant
City	The City of Cold Lake
CQof	Overland Flow Coefficient
DWF	Dry Weather Flow
FM	Forcemain
GIS	Geographic Information System
HGL	Hydraulic Grade Line
ICI	Industrial, Commercial, Institutional
I-I	Inflow-Infiltration
IMDP	Intermunicipal Development Plan
ISL	ISL Engineering and Land Services Ltd.
L	Root Zone Moisture
LiDAR	Light Detection and Ranging
Lmax	Root Zone Storage
LP	Longitudinal Profile
MDP	Municipal Development Plan
Program	Inflow-Infiltration Program
PE	Polyethylene
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
RDII	Rainfall Dependent Inflow-Infiltration
RDII %	Percent Area contributing to RDII
RE	Rainfall Event
SMP	Sanitary Master Plan
STG	Stage
TA	Time-Area
TDH	Total Dynamic Head
Umax	Surface Storage
VFD	Variable Frequency Drive
WaPUG	Wastewater Planning Users Group
WWF	Wet Weather Flow

UNITS

Unit	Meaning
%	Percentage
ha	Hectare
hr	hour
hr	Hour
km	Kilometre
L	Litre
L/ha/d	Litre per hectare per day
L/p/d	Litre per person per day
L/s	Litre per second
L/s/ha	Litre per second per hectare
m	Metre
m/s	Metre per second
m^2	Square metre
m^3	Cubic metre
m^3/d	Cubic metre per day
m^3/ha/d	Cubic metre per hectare per day
min	Minute
mm	Millimetre
mm/hr	Millimetre/hour
persons/household	Persons per household

GLOSSARY

1:X Year Event – A rainfall event that has a 1/X chance of occurring in any given year.

Annex – When one jurisdiction incorporates land from another jurisdiction into their own.

ArcGIS – A program for mapping and spatial analysis.

As-Builts – The final drawings showing what was built.

Asbestos Cement – A type of concrete pipe made from a mixture of cement and asbestos fiber, commonly found in sanitary networks.

Baseflow – Constant flows generally representing infiltration into the system, separate from user generated flows.

Calibrate – To adjust model parameters such that model results match known (measured) values.

Capacity – The maximum flow a sewer can handle, typically Manning's capacity which assumes no surcharge.

Catchment – An area connected to a particular point with specific characteristics relating to flow.

Commercial – Any development that is used for an activity with the purpose of generating a profit.

Concrete – A rigid material composed of aggregates, cement, water and occasionally admixtures, often used for sewers.

Cross-connection – An inappropriate connection to a network. For example a catchbasin or downspout connecting to the sanitary network.

Delineate – To generate spatially.

Design Storm – A storm that uses typical rainfall patterns and a statistically determined rate, as opposed to a natural storm.

Diurnal – A daily flow pattern.

Dry Weather Flow – Baseflow and user generated flow, excludes storm effects.

Dummy – A part of the model that does not exist physically, but is included to model connections or other data.

Flooding – When network water levels rise above ground level.

Flow Monitoring – A study of the physical system where devices are installed that are capable of recording the flow through a sewer at the location. Typically put in place for several weeks.

Forcemain – A sewer where water is pumped as opposed to a gravity conduit.

Full Build-Out – All land within the boundary of Cold Lake is fully developed according to current plans.

Generation Rate – The rate at which sanitary is generated in a catchment, typically tied to either catchment population or area.

Grade Break – When the vertical path is interrupted, for example when an upstream sewer settles more than a downstream sewer.

Gravity Sewer – A sewer when water flows by way of gravity, as opposed to a forcemain.

Head – The energy of a fluid expressed as the equivalent height of the fluid as a static column.

Hydraulic Grade Line – The surface of the water in a sewer, or where the water would surface if the sewer is under pressure.

Hydraulic System – The physical parts of a model where water flows, such as sewers, manholes and lift stations.

Hydrodynamic – Analysis of fluids in motion and their interaction with solids.

Imperviousness – The limiting of the infiltration of stormwater, a roadway has high imperviousness and a field has a low imperviousness.

Industrial – Any developments that are used for manufacturing, such as factories.

Inflow – Stormwater that enters the sewer systems through improperly connected catchbasins, downspouts, sump pumps and foundation drains, or cross connections between the storm and sanitary sewers.

Infiltration – Groundwater that seeps into sewers through damaged or deteriorated sewers and manholes.

Institutional – Any developments that are used for the public's interest, such as schools, hospitals and recreation centers.

Invert – The elevation of the lowest inside part of a sewer cross-section.

Lagoon – In-ground earthen basins in which the sanitary is detained for a specified time and then discharged.

Land Use – Classification of urban zones into different categories.

Level Control Settings – The water levels that a lift station control system are set at, for instance the level which a pump turns on at.

Lift Station – A facility that moves sanitary flows from a lower elevation to a higher elevation, typically when a gravity sewer is impractical.

Light Detection and Ranging – Remote sensing method that uses a pulsed laser to measure ranges.

Longitudinal Profile – A cross-section cut along the length of sewer(s).

Losses – The energy lost to flowing water as it moves through the network, for instance as friction as it travels along a sewer.

Manhole – A sewer access chamber.

Manning's Formula – An empirical formula for open channel flow. The Manning's coefficient, n, is an empirical value indicating the channel's resistance to flow or roughness.

Master Plan – A guiding plan for a municipality regarding issues like upgrading, maintenance, and preparing for future usage.

Mixed-Use – A development that is designed to accommodate a mix of commercial and residential use within a single site. The use mix may be horizontal or vertical.

Node – A calculation point in a network model.

Parcel – The aggregate of the one or more areas of land described in a Certificate of Title or described in a Certificate of Title by reference to a plan filed or registered in a Land Titles Office.

Polyvinyl Chloride – A synthetic plastic polymer, often used for sewers.

Pump Curve – A relation of head and flow that a pump is capable of operating at.

Rain Gauge – A device that measures and records rainfall depths.

Rainfall Derived Inflow Infiltration – The increased water flow into the sanitary sewer system occurring during or shortly after a wet weather event.

Rainfall Dependent Inflow-Infiltration Method – Stormwater inflow modeling method that determines short, intermediate and long-term response from each rainfall period.

Rainfall Event – Rainfall over a period of time, with a varying intensity that begins and ends at zero.

Residential – Any developments that are used for housing a municipality's population.

Rim Elevation – The top elevation of a manhole, typically also the ground elevation.

Roughness – The degree a surface will resist fluid flow. A sewer's roughness will depend on factors such as age and material.

Sanitary Flow – Municipal sanitary flow is water that has been degraded by human activity. Typically it is collected and treated before release.

Sewer – An underground conduit for carrying fluid.

Shapefile – An Esri developed digital format for GIS data that carries both spatial and attribute information.

Slope – A comparison of a line's vertical and horizontal change.

Smoke Testing – A test to look connections to a sewer network. A non-toxic smoke is introduced into the network, and the emergence of the smoke can indicate cross-connections or network defects.

Spare Capacity – How much additional flow a sewer can carry.

Spatial Analysis – Analysis of data based on location.

Surcharge – When flow exceeds pipe capacity. In a network water levels in a manhole will be above the top of the pipe.

Time-Area Method – A simple surface runoff calculation method.

Topography – The terrain features in three dimensions.

Trunk – A major sewer line.

Upgrade – To enable a section of the system to handle a greater capacity.

Weighted Inlet Energy – The energy level is calculated as the weighted average of the inlet flows to the manhole.

Wet Weather Flow – Dry weather flow, with the addition of flow from a rainfall event.

Wet Well – A holding pit for sanitary flows in a lift station. Typically pumps will turn on when wet well water reaches a specified level, and pump until the water reaches a specified lower level before turning off.

1.0 Introduction

1.1 Authorization

ISL Engineering and Land Services Ltd. (ISL) was retained by the City of Cold Lake (City) to undertake an Inflow-Infiltration (I-I) Program (Program). This Program includes a review of the sanitary wet weather flow rates in the system as well as an assessment of the City's current sanitary conveyance infrastructure capacity and the future needs for projected City populations. For that purpose a robust hydrologic/hydraulic model was constructed and calibrated using the state-of-the-art hydrodynamic MIKE URBAN software developed by DHI to enable the comprehensive assessment of the sanitary system. The project was initiated in response to a need to ensure sound sanitary system planning. The intent of this project is to provide a comprehensive road map to Council and the administration for assessing the capability of the infrastructure to accommodate new development in the short-term and long-term. In addition, there is a desire to highlight high inflow-infiltration areas that can be remediated to increase system conveyance and treatment capacity.

1.2 Background

The City of Cold Lake is situated on the eastern edge of central Alberta, adjacent to the Saskatchewan – Alberta provincial border. In 1996, the communities of the Town of Cold Lake, the Town of Grand Centre, and Medley (Canadian Forces Base (CFB)) were amalgamated to form what is currently known as the City of Cold Lake. Today, Cold Lake South represents what was previously known as the Town of Grand Centre, while Cold Lake North is the former Town of Cold Lake. The northern portion of the City sits on the southwestern shoreline of Cold Lake, with Cold Lake South situated east of the CFB.

The City's 2016 population of approximately 16,725 was used (note that the 2015 population totaled approximately 15,725, the additional thousand occurred in 2016 after discussions with the City to identify any developments that would have come online since the 2015 flow monitoring period), with a projected population of roughly 60,000 at the build-out to the current City boundary stage and roughly 88,500 at the build-out of annexation areas stage (includes additional annexed area in the east which is part of Stage 3, but not the additional three quarter sections in the north that are considered as part of Stage 3+). The I-I Program includes build-out of the existing system (imminent development), build-out of the current City boundary (short to medium-term development), and build-out of the annexation areas (long-term development) growth horizons. These growth horizons were established in order to provide the City with cost-effective and socially, politically, and environmentally conscious servicing solutions.

1.3 Purpose of Study

The purpose of developing a Master Plan for any municipality is outlined below:

- To inventory and analyze the existing infrastructure under existing conditions.
- To determine if any upgrades are required to the existing system in order to properly meet the needs of the municipality.
- To determine if any upgrades are required to allow future growth to occur.
- To develop plans for future growth. Locations and timing may be dependent on the following:
    - Availability of sufficient servicing needs
    - Annexed land locations
    - Community planning
- To provide cost estimates related to required infrastructure upgrades.
- To comment on possible staging options of upgrades.

Specific to Cold Lake, the I-I Program/Sanitary Master Plan Update includes the following:

- Compilation and assessment of the existing sanitary data
    - Populate missing manhole rim and invert elevations
    - Confirm sizing of certain sewers
    - Perform calibration to accurately represent the City's sanitary network
- Analysis of infrastructure under existing and future growth scenarios including:
    - Stage 1 – Build-out of Existing System (imminent development)
    - Stage 2 – Build-out to Current City Boundary (short to medium-term development)
    - Stage 3 – Build-out of Annexation Areas (long-term development)
    - Stage 3+ – Build-out of Annexation Areas plus Additional Three Quarter Sections in the North (long-term development)
- Identification of the required upgrades to the infrastructure to meet existing and future needs
    - Rehabilitation of existing sewers based on the field investigation and findings obtained through smoke testing
    - Construction of additional infrastructure to alleviate flows on existing system
    - Implementation of additional infrastructure to accommodate future developments
- Development of cost estimates for all required upgrades
- Review of existing inflow-infiltration rates observed under wet weather conditions to compare against various design storms, determination of possible sources of inflow-infiltration, and recommendation of remedial measures
- Development of a staging plan for implementing infrastructure upgrades for short- and long- term needs
    - Existing Upgrading Options
    - Stage 1 – Build-out of Existing System Upgrading Concept
    - Stage 2 – Build-out to Current City Boundary Upgrading Concept
    - Stage 3 – Build-out of Annexation Areas Upgrading Concept
    - Stage 3+ - Build-out of Annexation Areas plus Additional Three Quarter Sections in the North Upgrading Concept

2.0 Study Area

2.1 Location

The City of Cold Lake is situated on the eastern edge of central Alberta, adjacent to the Saskatchewan – Alberta provincial border. The City is divided into three areas, including Cold Lake North, Cold Lake South, and the CFB. The City is bounded by Beaver River in the south and Cold Lake in the north. Cold Lake North and Cold Lake South are largely connected by 51^{st} Street, which is known as the Northern Woods and Water Route south of the City and roughly continues north as 28^{th} Street. The overall study area of the I-I Program includes all developments that are serviced within the existing City boundary, and any annexed land for future growth horizon considerations.

It is noted that the study has not taken into account the Canadian Forces Base, as the base is considered its own entity in this respect, with a sanitary system separate from the City's network. The study area encompasses two distinct areas (Cold Lake North and Cold Lake South), amounting to a sewershed of over 2,500 ha (this excludes the CFB) within the current City boundary. In all, the study area including future annexation lands is over 3,800 ha. Figure 2.1 highlights the area that was considered as part of the I-I Program.

The portion of the City that is within the current City boundary primarily falls within an elevation between 496 m at Beaver River southeast of the CFB and 590 m in the north in the southeast corner of quarter section 13-63-02 W4. Generally, the topography falls from the east to the west towards Palm Creek and from the north to the south towards Beaver River. A topographical map of the City of Cold Lake is shown in Figure 2.2.

2.2 Land Use

In terms of land use, the City of Cold Lake was required to be divided as primarily residential, commercial, industrial, or institutional areas. The type of land use influences sanitary generation rates, therefore obtaining an appropriate classification was vital in order to ensure that an accurate representation of the City's sanitary conveyance system could be achieved.

When determining land use classification for existing areas in the City, input from the Municipal Development Plan (MDP) was used. The land uses were compared to aerial maps and Google Street View to confirm that parcels were properly categorized. In this manner, the City was classified by a number of unique land use types, as stated below:

- Low Density Residential
- Medium Density Residential
- High Density Residential
- Commercial
- Industrial
- Park/Recreation
- Institutional

Proposed land uses of future development areas were assumed by a combination of the available area structure plans, the Municipal Development Plan, the Intermunicipal Development Plan (IMDP), as well as input and feedback provided by the City. As a result, the future development areas were able to be divided into the land use categories stated above.

2.3 Population Statistics

This analysis addressed four population scenarios: the estimated 2016 population of 16,725, the imminent growth horizon of roughly 17,200, the short to medium-term horizon of roughly 60,000, and the long-term growth horizon of roughly 88,500. Additionally, a variant of the long-term growth horizon was considered, in which three quarter sections in the north, west of Horseshoe Bay Estates, were included which resulted in a population of roughly 93,500. The 2016 population represented the existing scenario that was analyzed, while the remaining three growth horizons represented the future scenarios. The future scenarios were selected as they represent critical milestones for the City's proposed development. As there is a great degree of variability of the rate in which the City of Cold Lake grows, it is uncertain when each of the targeted population horizons will be achieved. Thus, any assessments and analysis of Cold Lake's future system were considered on a population basis, instead of a time basis. As the actual rate at which the City will grow is uncertain, an increase in population of 42,700, 28,600, or even 5,000 may not be realized until well into the future, potentially beyond the service life of some of the City's current infrastructure. This will be a key factor to note under the future system analysis (Sections 8.0 and 9.0), keeping in mind that these stages may not be fully built-out for potentially numerous decades. A summary of the population scenarios is provided in Table 2.1 below. Figure 2.3 illustrates at which growth horizon each parcel/quarter section is expected to be developed. Further information pertaining to the determination of populations under growth horizons is discussed in Section 8.1.

Table 2.1: Summary of Growth Horizons

Scenario	Horizon	Horizon Population	Total Scenario Population	Horizon Area	Total Scenario Area
				ha	
Existing	2016	0	**16,725**	0	**507**
Stage 1	Imminent	438	**17,163**	43	**550**
Stage 2	Short to medium	42,701	**59,864**	1,056	**1,606**
Stage 3	Long-term	28,618	**88,482**	1,410	**3,067**
Stage 3+	Long-term +	5,043	**93,525**	136	**3,203**

2.4 Existing Sanitary Trunk Sewer System

The City of Cold Lake's sanitary system is composed of a number of manholes, sewers, lift stations, and forcemains that convey sewage to the City's sanitary lagoon located south of the City. Sewers range in diameter from 200 mm to 900 mm, with the majority of the sewers being 200 mm. In all, there is a total of 113 km of sanitary sewers in the City, consisting of both gravity sewers and forcemains. From the sewer material data that is available for the sanitary sewers in Cold Lake, polyvinyl chloride (PVC) appears to be the most predominant. In addition to PVC, there are also concrete and asbestos cement sewers evident throughout the City. Forcemains range from 50 mm to 900 mm, and have been constructed using either polyvinyl chloride or polyethylene. There are a total of five major lift stations housing thirteen pumps. The five major lift stations include Building 1, Building 3, Building 4, Building 8, and Building 9. In addition to these lift stations, there are four minor lift stations (Building 049, Building 413, Building 414, and a small lift station in Horseshoe Bay Estates) that have been excluded from modelling. Their upstream contributing catchments were connected to the first downstream manhole being modelled. For the purpose of modelling the system, the aforementioned minor lift stations and sanitary service connections have not been included in the model, which is a typical approach applied at the Master Planning level.

Drawings of the sanitary sewer network can be found in Figures 2.4 to 2.13 in terms of sewer size and lift station locations, sewer material, sewer installation period, full-flow sewer capacity, and manhole depths, in Cold Lake North and South respectively. It is noted that full-flow sewer capacity is a function of the sewer's slope, thus sewers with same diameters can vary in terms of full-flow sewer capacities depending on their slopes. A summary of the total lengths with respect to both sewer diameter and sewer material is detailed below in Table 2.2, while total lengths with respect to sewer installation period are summarized in Table 2.3.

Table 2.2: Sanitary System Summary – Sewer Diameter and Material

Diameter	Total Length	Material	Total Length
mm	m		m
Gravity Sewers			
150	287	Asbestos Cement	8,105
200	64,445	Concrete	214
225	67	Polyvinyl Chloride	34,103
250	3,096	Unknown	46,437
300	6,011		
350	173		
375	5,479		
400	2,085		
450	2,478		
500	479		
525	915		
600	1,616		
675	1,521		
900	94		
Unknown	114		
Sub-Total	**88,860**	**Sub-Total**	**88,860**
Forcemains			
50	256	Polyethylene	13,671
75	1,535	Polyvinyl Chloride	4,007
100	490	Unknown	6,550
150	136		
200	1,441		
300	1,550		
350	856		
500	4,832		
750	1,217		
800	8,804		
900	3,111		
Sub-Total	**24,228**	**Sub-Total**	**24,228**
Total	**113,088**	**Total**	**113,088**

Table 2.3: Sanitary System Summary – Sewer Installation Period

Sewer Installation Period	Number of Sewers	Total Length (m)
Gravity Sewers		
1955 - 1960	40	3,504
1960 - 1965	121	10,088
1965 - 1970	5	418
1970 - 1975	105	8,380
1975 - 1980	99	6,980
1980 - 1985	140	11,494
1985 - 1990	55	4,715
1990 - 1995	79	7,132
1995 - 2000	23	1,793
2000 - 2005	91	6,849
2005 - 2010	180	13,805
2010 - Present	152	10,885
Unknown	42	2,815
Sub-Total	**1,132**	**88,860**
Forcemains		
1960 - 1965	2	1,309
1975 - 1980	1	494
1980 - 1985	38	13,913
1990 - 1995	10	1,199
1995 - 2000	2	801
2000 - 2005	1	105
2005 - 2010	1	136
2010 - Present	4	3,568
Unknown	3	2,702
Sub-Total	**62**	**24,228**
Total	**1,194**	**113,088**

Sanitary sewage flows within the City's sewershed generally flow from the north/south inwards in Cold Lake North, after which they are conveyed west, then south towards Cold Lake South. In Cold Lake South, sewage generally flows from the north/south/east/west inwards, towards Building 9 Lift Station, where the flows are then discharged through two forcemains to the City's lagoon. A number of sanitary trunk systems are noted, and highlighted in Figures 2.14 and 2.15 for Cold Lake North and South, respectively.

- **Cold Lake North Trunk Sewer 1 (LP #N1)** – A trunk sewer ranging from 200 mm to 450 mm in the northwest portion of the City. This trunk conveys flows generally from the north to the south from communities such as Horseshoe Bay Estates and Lakewood Estates.
- **Cold Lake North Trunk Sewer 2 (LP #N2)** – This trunk sewer varies from 250 mm to 675 mm gravity sewers in the central north part of the City near Nelson Heights. Flows are conveyed by gravity to the Building 1 Lift Station, where sewage is then pumped through a 300 mm forcemain into a downstream

section of 400 mm gravity sewers followed by 600 mm gravity sewers and finally a 675 mm gravity sewer. At the downstream end of this system, sewage is discharged into the Building 4 Lift Station from which flows are pumped through a 500 mm forcemain, ultimately to the Building 9 Lift Station.

- **Cold Lake North Trunk Sewer 3 (LP #N3)** – This trunk system consists of mainly 375 mm gravity sewers, which convey flows north to Building 3 Lift Station, where sewage is pumped through a 300 mm forcemain into a receiving 375 mm gravity sewer. This trunk sewer then connects with the Cold Lake North Trunk Sewer 2 on 23rd Street. It is noteworthy to mention that there is a 900 mm storage sewer upstream of the Building 3 Lift Station which forms a part of this trunk system.
- **Cold Lake North Trunk Sewer 4 (LP #N4)** – Ranging from 250 mm to 350 mm, this sewer network conveys flows entirely by gravity. This sewer tees off of the Cold Lake North Trunk Sewer 3 on 12th Avenue, and reconnects with the aforementioned trunk sewer upstream of the 900 mm storage sewer.
- **Cold Lake North Trunk Sewer 5 (LP #N5)** – A trunk sewer ranging from 200 mm to 300 mm in the northeast, along Forest Drive and 10th Street. This trunk sewer conveys sewage by gravity to the north, where it connects to Cold Lake North Trunk Sewer 3 at the intersection of 10th Street and 12th Avenue.
- **Cold Lake North Trunk Sewer 6 (LP #N6)** – Recently installed in 2015, this trunk sewer varies in size from 200 mm to 675 mm. Currently only Phase 1 of this gravity sewer (known as the Forest Heights Trunk Sewer) has been completed, with Phase 2 intended to occur in the future. At the moment this trunk sewer connects to the Cold Lake South Trunk Sewer 1 (see below), however once Phase 2 is complete it will independently continue south to the Building 9 Lift Station.
- **Cold Lake South Trunk Sewer 1 (LP #S1)** – Ranging from 300 mm to 375 mm, this sewer system conveys flows by gravity from north to south. At the downstream end of the system, the sewer connects with Cold Lake South Trunk Sewer 4.
- **Cold Lake South Trunk Sewer 2 (LP #S2)** – This trunk system begins in the northern part of Cold Lake South, and conveys flows to the south via gravity sewers ranging from 250 mm to 600 mm directly to the Building 9 Lift Station. From there, sewage is pumped to the south via 800 mm and 900 mm forcemains to the City's lagoons.
- **Cold Lake South Trunk Sewer 3 (LP #S3)** – This 300 mm gravity sewer conveys flows from east to west, starting at the intersection of 62nd Avenue and 47th Street along Cold Lake South Trunk Sewer 2 and connecting downstream on 61st Avenue on Cold Lake South Trunk Sewer 1.
- **Cold Lake South Trunk Sewer 4 (LP #S4)** – This trunk system ranges in diameter from 450 mm to 600 mm, conveying flows south to north followed by west to east to the Building 9 Lift Station. From there, sewage is pumped to the south via 800 mm and 900 mm forcemains to the City's lagoons.
- **Cold Lake South Trunk Sewer 5 (LP #S5)** – A trunk sewer ranging from 300 mm to 600 mm, conveying flows from the Red Fox Estates community to the north. This trunk sewer connects to Cold Lake South Trunk Sewer 4 at 49th Street.
- **Cold Lake South Trunk Sewer 6 (LP #S6)** – This trunk sewer varies from 250 mm to 275 mm in the southeast, and collects sewage from Brady Heights. Flows are generally conveyed to the northwest, where they are discharged to the Building 9 Lift Station. From there, sewage is pumped to the south via 800m m and 900 mm forcemains to the City's lagoons.
- **Cold Lake South Trunk Sewer 7 (LP #S7)** – This 300 mm gravity sewer conveys flows from south to north, where is ultimately reaches the Building 9 Lift Station. From there, sewage is pumped to the south via 800 mm and 900 mm forcemains to the City's lagoons.

As mentioned above, there are a total of five major lift stations that have been included in the model for assessment. Drawdown testing was undertaken by the City at each of the five major lift stations, in order to determine the performance of each lift station and forcemain by means of measuring flows and resultant pressures (where applicable) under various operational conditions. Following this, the pumped volume and discharge rates were determined for multiple operational sequencing logics (i.e. one pump turned on, two pumps turned on, etc.). A summary of the drawdown testing has been included in Appendix A. The tables below summarize characteristics of the lift stations (Table 2.4), pump parameters (Table 2.5) and set points (Table 2.6).

The City installed pressure gauges at the Building 1 and 3 Lift Stations and conducted drawdown tests following the draft report as recommended below in Section 6.2. The results below in Table 2.5 consist of the original drawdown tests for Building 4, 8, and 9 Lift Stations and the revised drawdown tests for Building 1 and 3 Lift Stations after the pressure gauges were installed. Pumping capacities used for modelling were all from the original drawdown testing results, as the revised tests were performed after the draft report submission. At both lift stations, the pump capacities from the original drawdown tests were less than the 2018 drawdown test, resulting in a more conservative analysis. The original drawdown test results are summarized in Appendix A.

Table 2.4: Lift Station and Forcemain Parameters and Capacities

Lift Station	Wet Well Area	Forcemain Type	Forcemain Length	Forcemain Capacity[1]
	m^2		m	L/s
Building 1	7.07	300 mm PVC	750	141
Building 3	7.07	300 mm PVC	800	141
Building 4	23.30	500 mm PE	4,850	393
Building 8	22.43	350 mm PVC	850	192
Building 9	34.50	900 mm PVC	3,000	1,272
		800 mm PE	8,800	1,005

[1] *Forcemain capacity determined based on the velocity of 2.0 m/s*

Table 2.5: Pump Parameters

Lift Station	Number of Pumps	Pump Type	Pump ID	Actual Pump Capacity[1]	Total Dynamic Head[2]	VFD (Yes/No)
				L/s	m	
Building 1	2	NP3203.180 HT	Pump 1	89.08	10.61	No
			Pump 2	100.63	11.32	
			Pump 1 + 2	125.03	16.63	
Building 3	2	CP 3231/605	Pump 1	93.36	33.76	Yes
			Pump 2	107.02	35.19	
			Pump 1 + 2	112.23	38.45	
Building 4	3	NT 3315 MT 3~ 638	Pump 1	165.4	24.31	Yes
			Pump 2	180.56	24.31	
			Pump 3	174.52	22.91	
			Pump 1 + 2	234.94	27.83	
			Pump 2 + 3	219.81	27.83	
			Pump 1 + 3	282.49	Not Recorded	
Building 8[3]	3	NT 3171 MT 3~ 434	Pump 1	146.68	12.01	Yes
			Pump 2	138.91	12.04	
			Pump 1 + 2	218.94	16.67	
Building 9	3	C3232/735	Pump 1	195.62	28.86	Yes
			Pump 2	154.04	29.78	
			Pump 3	129.41	29.37	
			Pump 1 + 2	276.06	45.28	
			Pump 2 + 3	295.09	43.35	

[1] *Actual pump capacity based on the drawdown tests performed by the City from April to July, 2016 and in 2018.*
[2] *Total dynamic head determined from the pressure readings during the drawdown tests.*
[3] *The third pump at Building 8 was out for repair at the time when drawdown testing occurred.*

Table 2.6: Wet Well Level Control Settings

Lift Station	Pump 1		Pump 2		Pump 3	
	Start Elevation	Stop Elevation	Start Elevation	Stop Elevation	Start Elevation	Stop Elevation
	m					
Building 1	530.900	529.950	531.050	530.150	N/A	N/A
Building 3	530.840	530.440	531.040	530.540	N/A	N/A
Building 4	528.960	528.160	529.260	528.160	529.460	528.160
Building 8	523.050	522.790	523.200	523.150	523.250[1]	522.790[1]
Building 9	523.930	523.430	524.230	523.530	524.430	523.730

[1] *Pump 3 at the Building 8 Lift Station was out for repair at the time when drawdown tests were performed, thus start and stop elevations were not recorded. The elevations presented above were obtained from the Building 8 Lift Station Upgrades As-Built drawing.*

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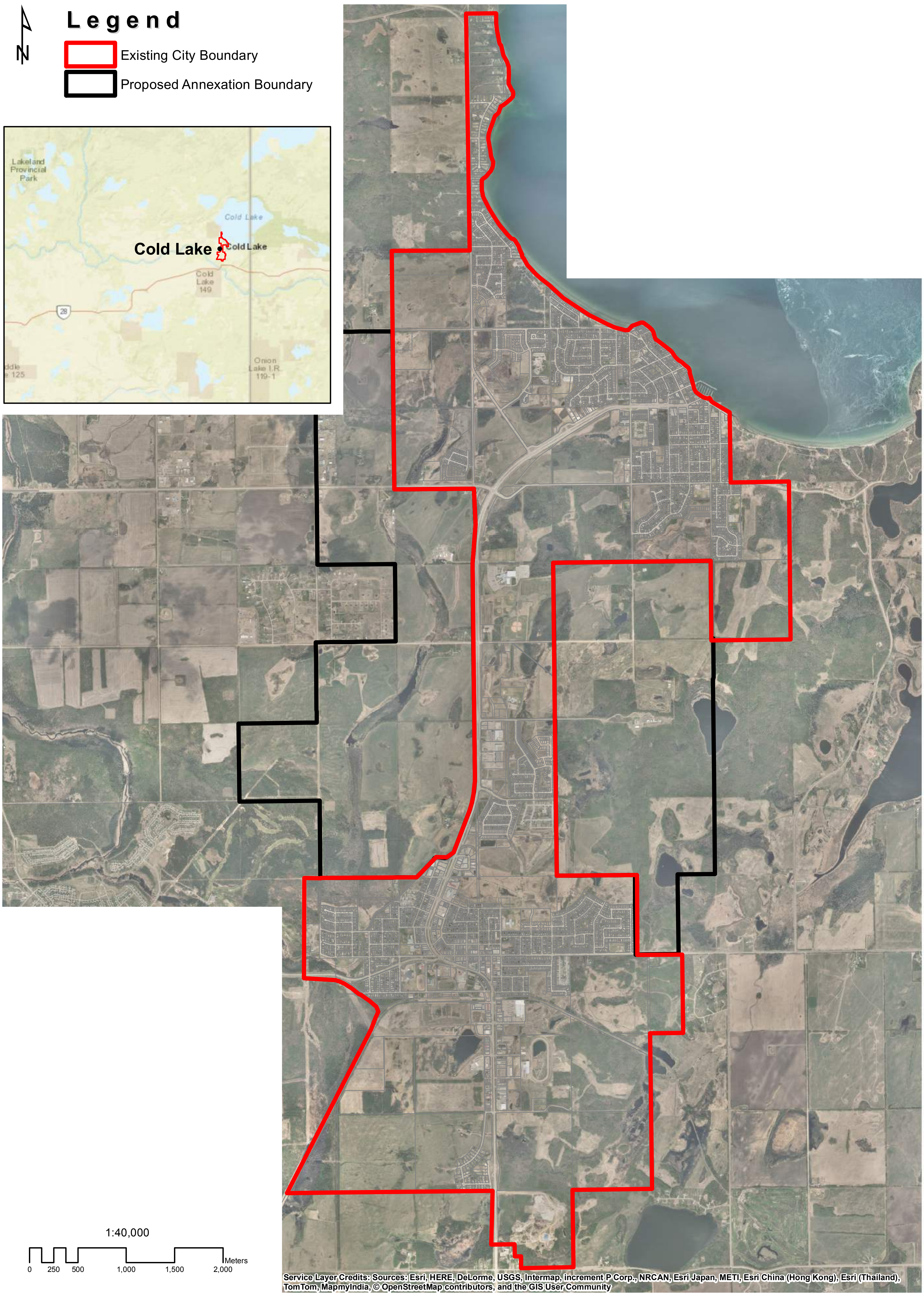
FIGURE 2.1



City of Cold Lake

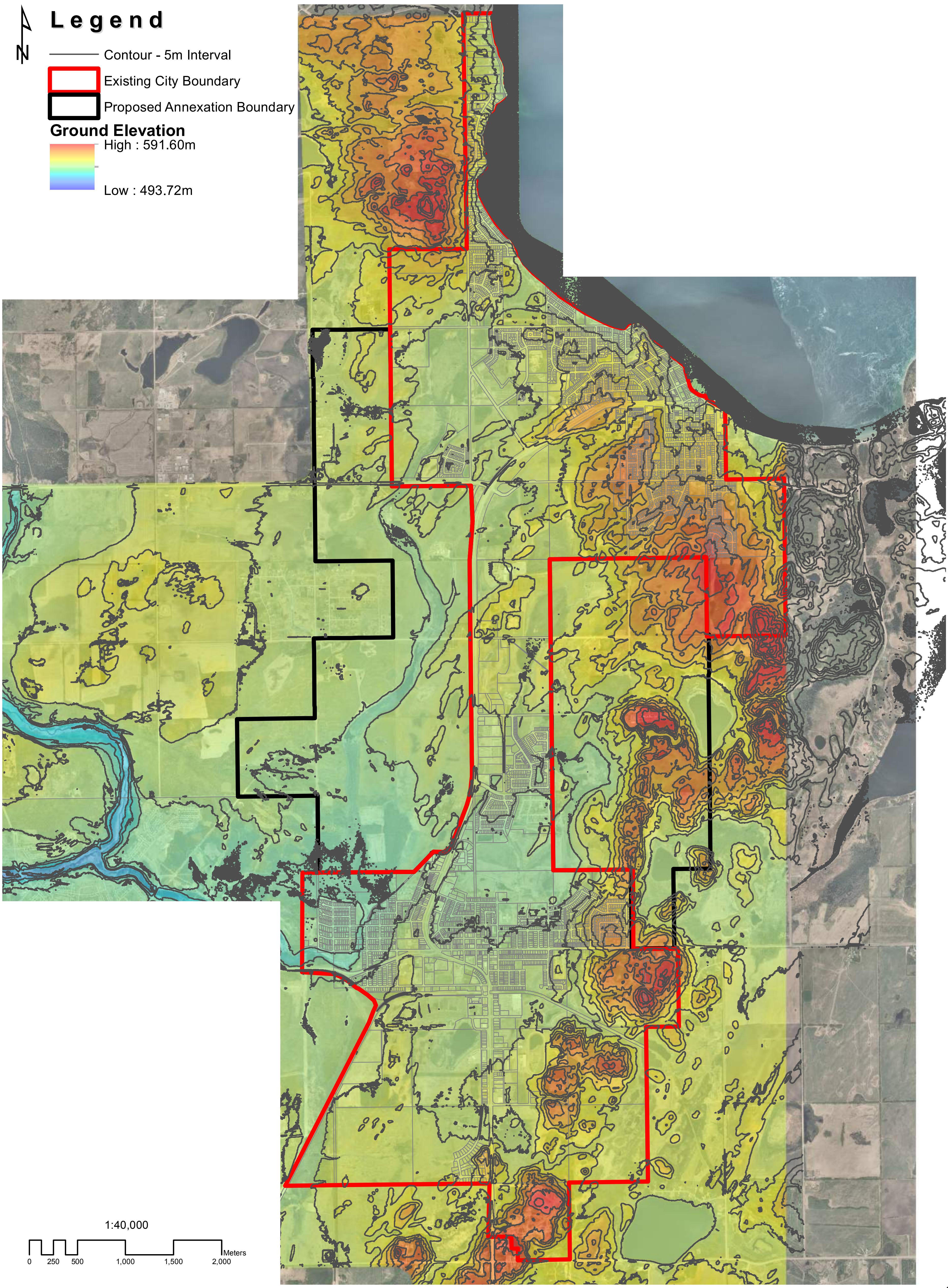
THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

STUDY AREA
OVERVIEW

ISL Engineering and Land Services

Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\2.0 Study Area\Figure 2.1 - Study Area Overview.mxd

FIGURE 2.2



City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

STUDY AREA
TOPOGRAPHY

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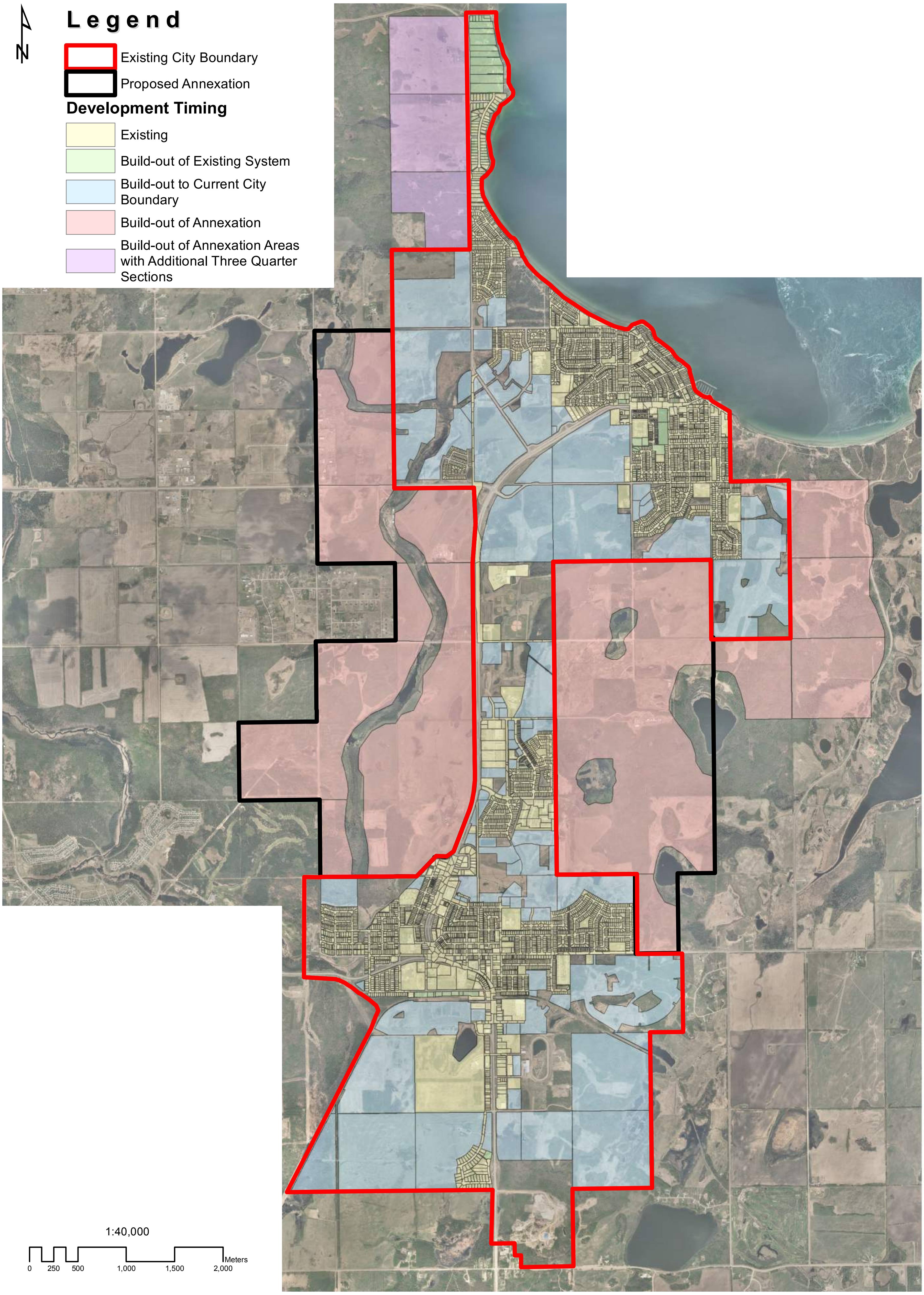
FIGURE 2.3



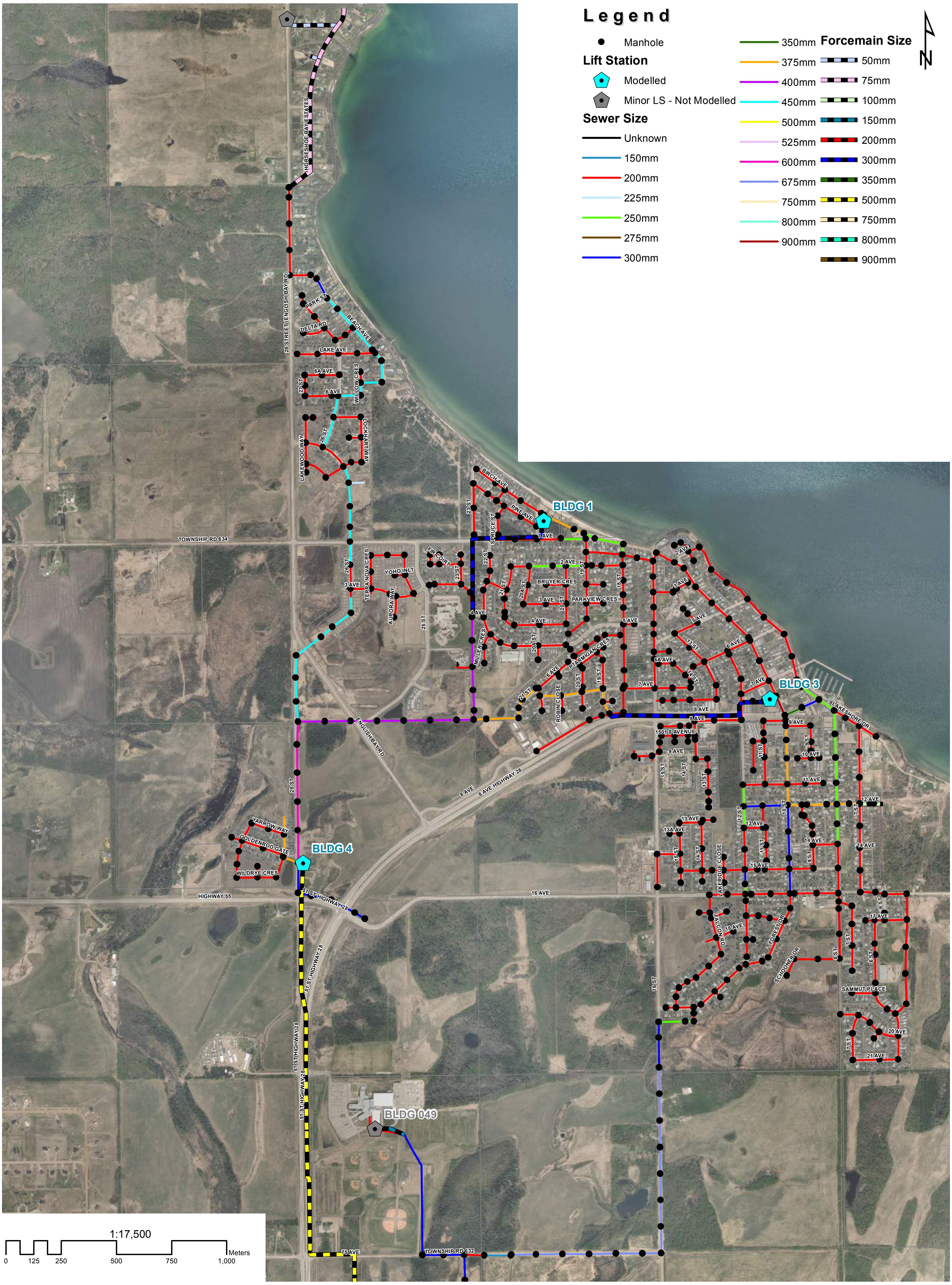
City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

STUDY AREA
DEVELOPMENT TIMELINE

ISL Engineering and Land Services

FIGURE 2.4



Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\2.0 Study Area\Figure 2.4 - Pipe Diameters_North.mxd

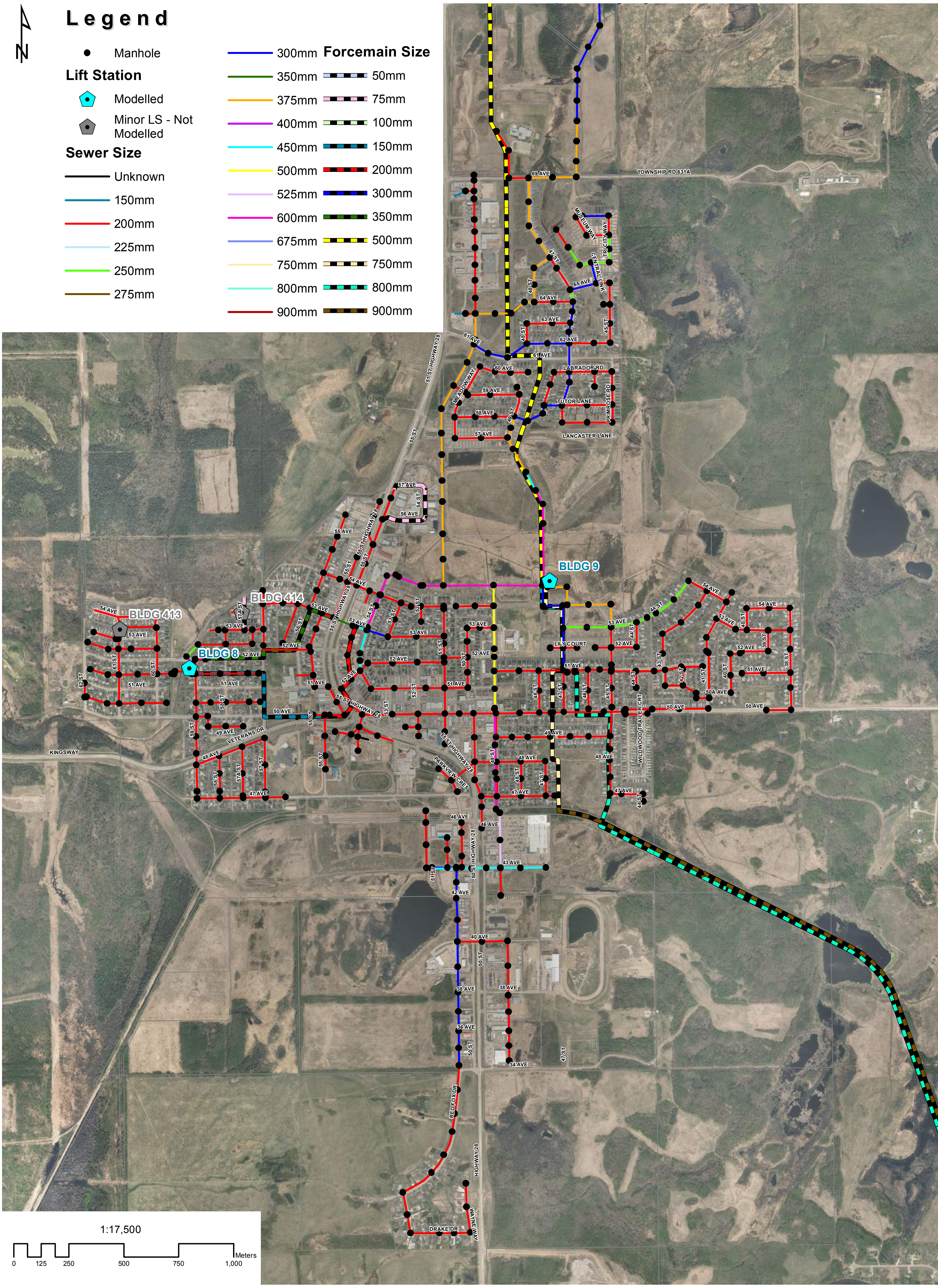
City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - NORTH
SEWER SIZE

ISL Engineering and Land Services

FIGURE 2.5



THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - SOUTH
SEWER SIZE

City of Cold Lake

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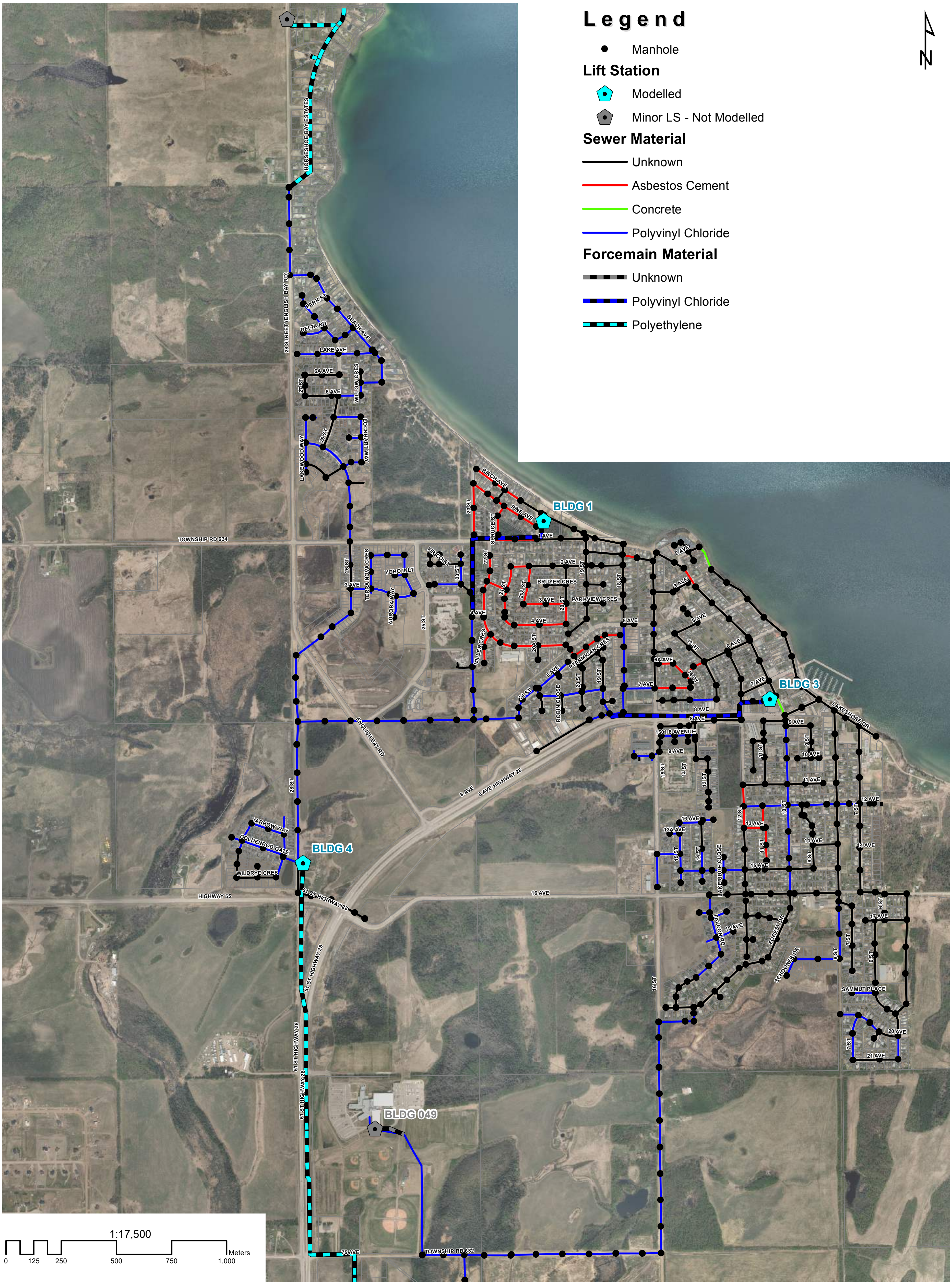
FIGURE 2.6



City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - NORTH
SEWER MATERIAL

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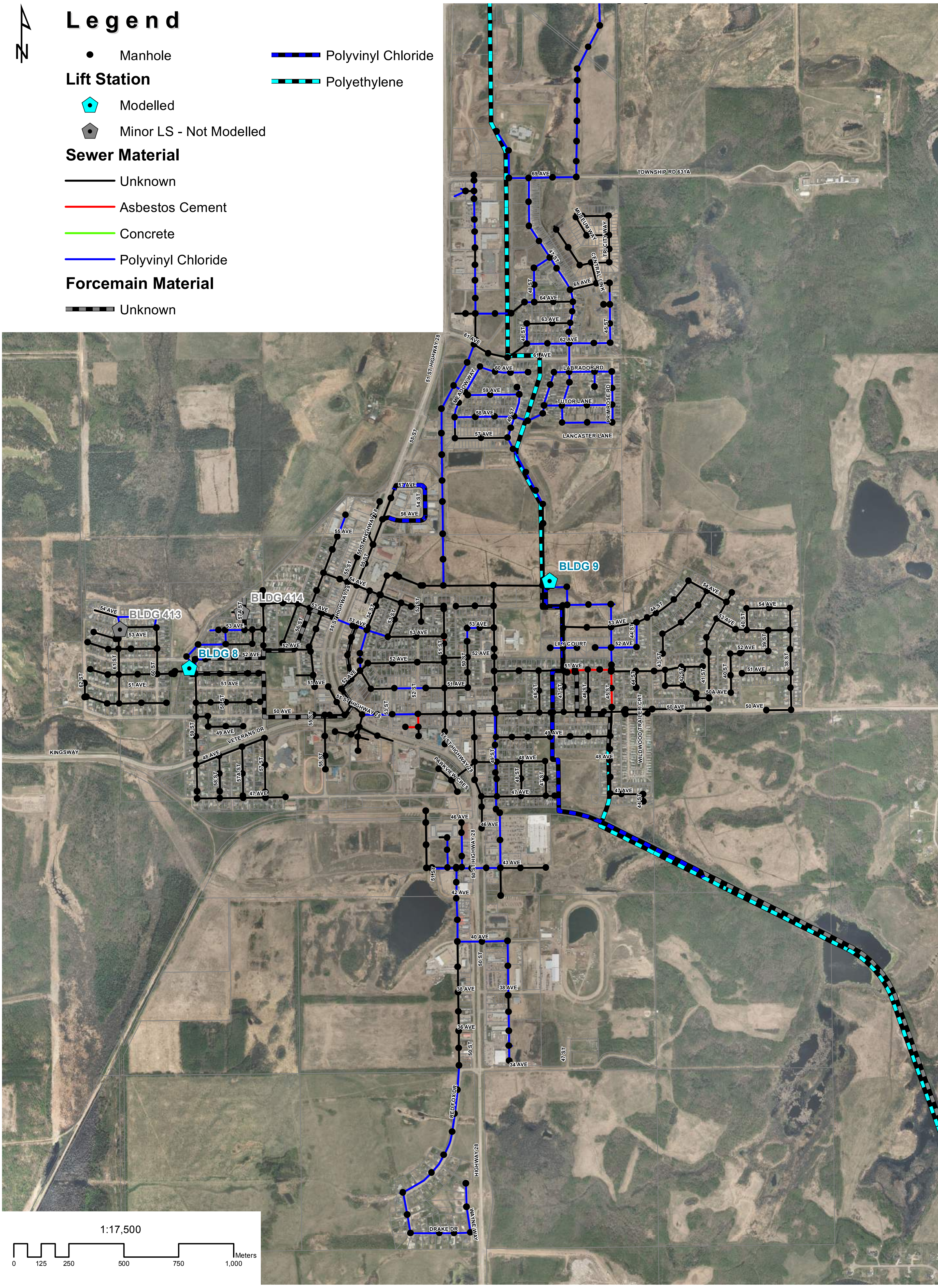
Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\2.0 Study Area\Figure 2.6 - Pipe Materials_North.mxd

FIGURE 2.7



THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - SOUTH
SEWER MATERIAL

City of Cold Lake

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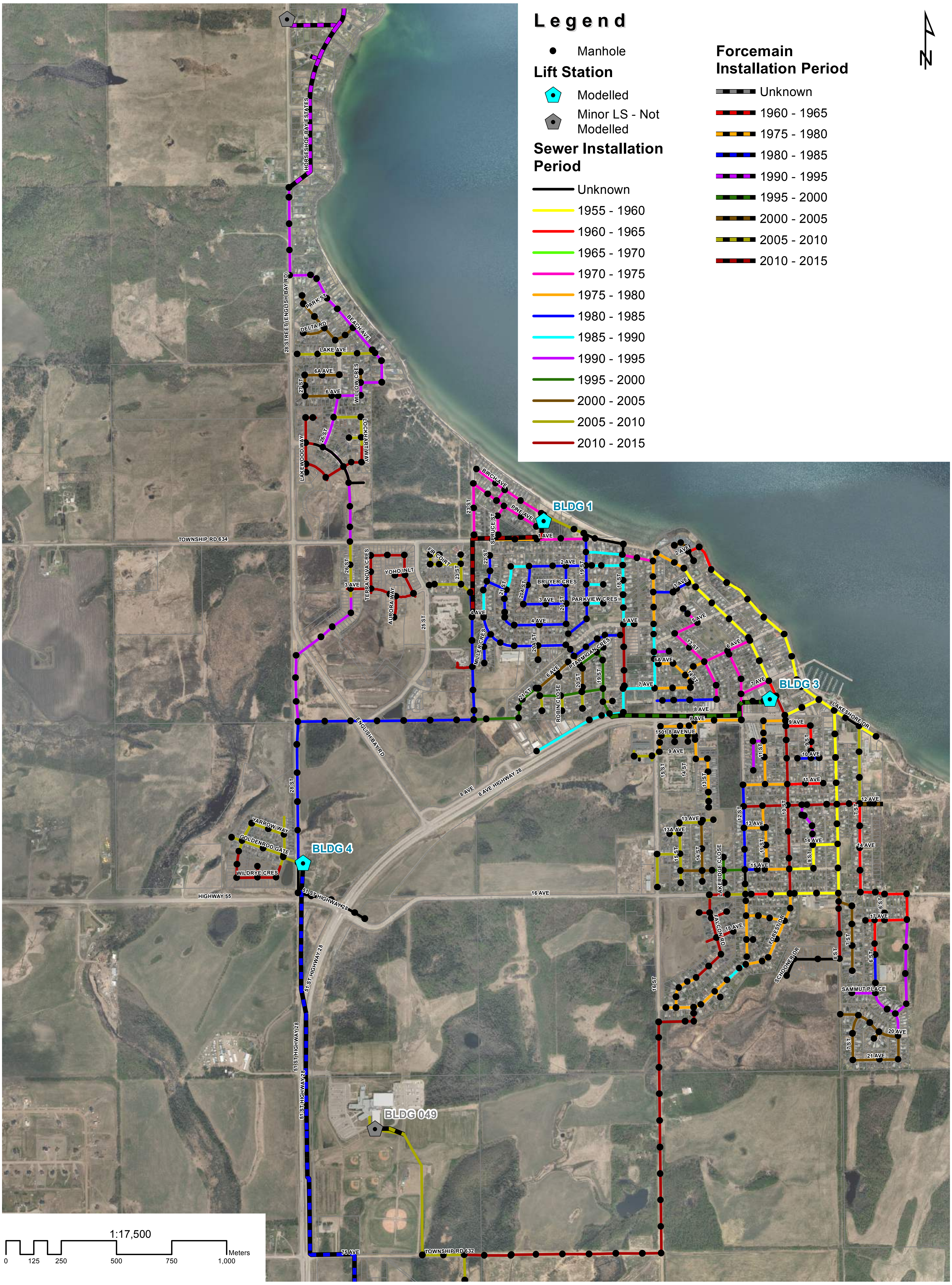
Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\2.0 Study Area\Figure 2.7 - Pipe Materials_South.mxd

FIGURE 2.8



City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - NORTH
SEWER INSTALLATION PERIOD

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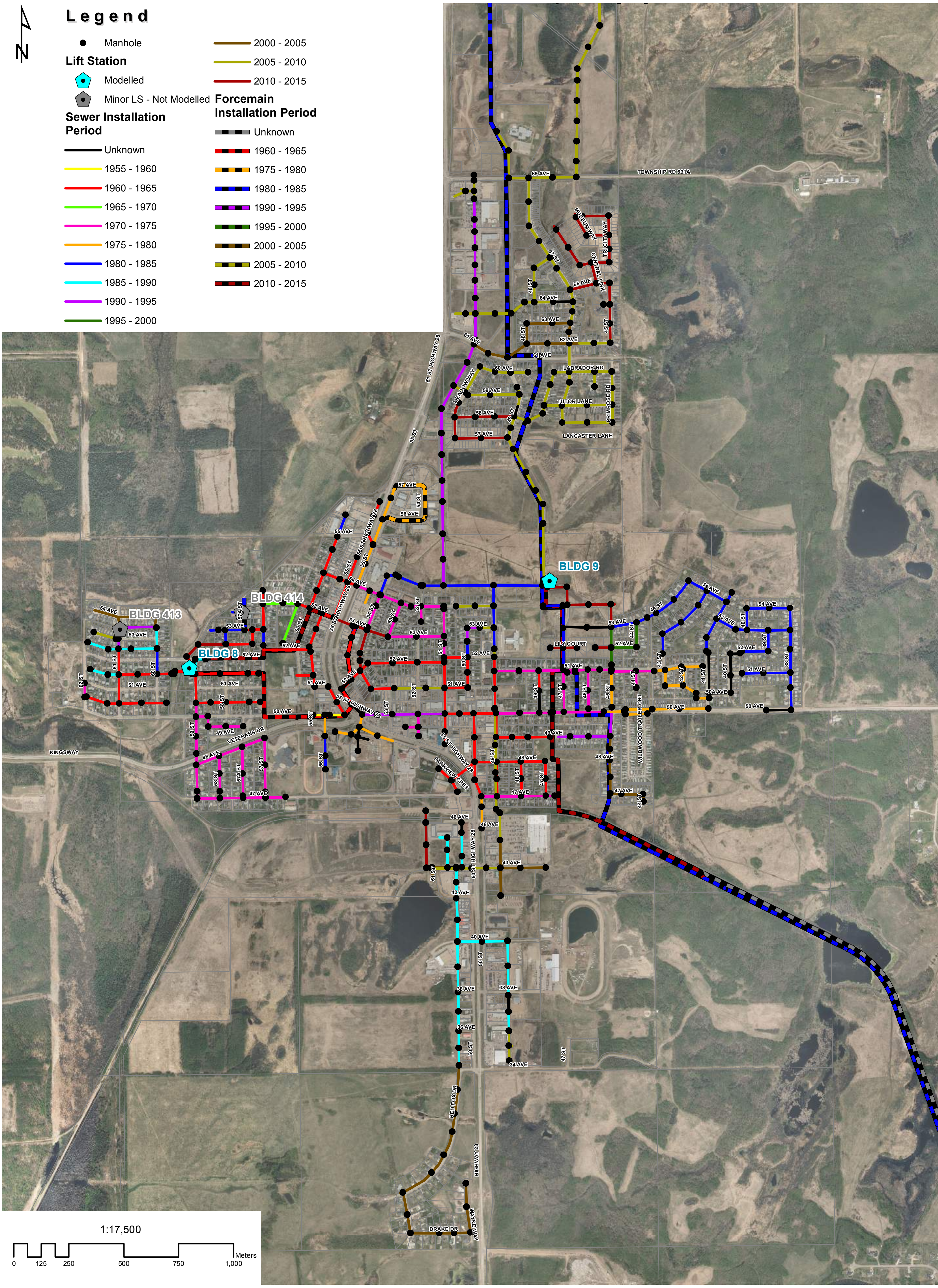
Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\2.0 Study Area\Figure 2.8 - Pipe Installation Years_North.mxd

FIGURE 2.9



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INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - SOUTH
SEWER INSTALLATION PERIOD

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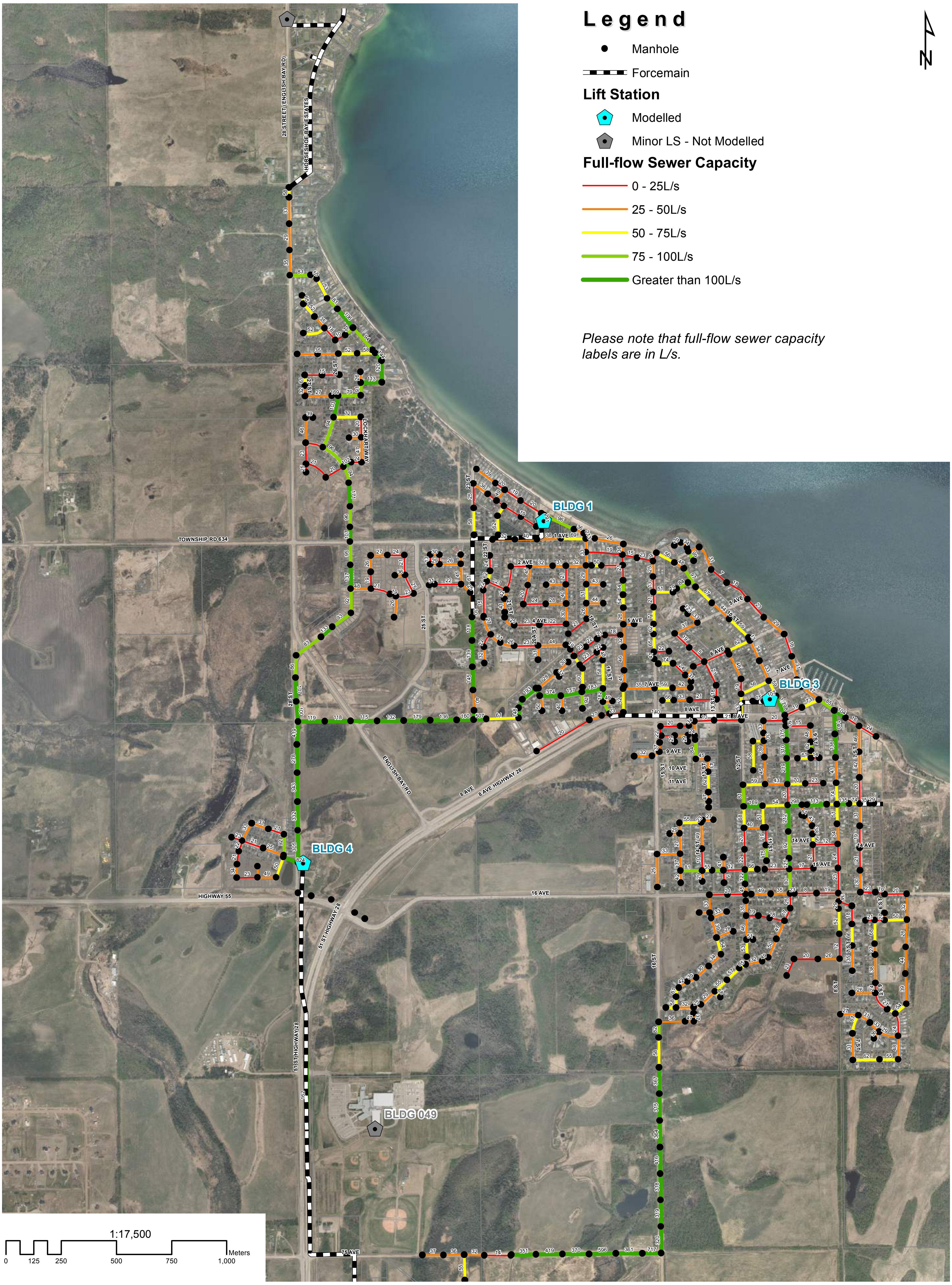
Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\2.0 Study Area\Figure 2.9 - Pipe Installation Years_South.mxd

FIGURE 2.10

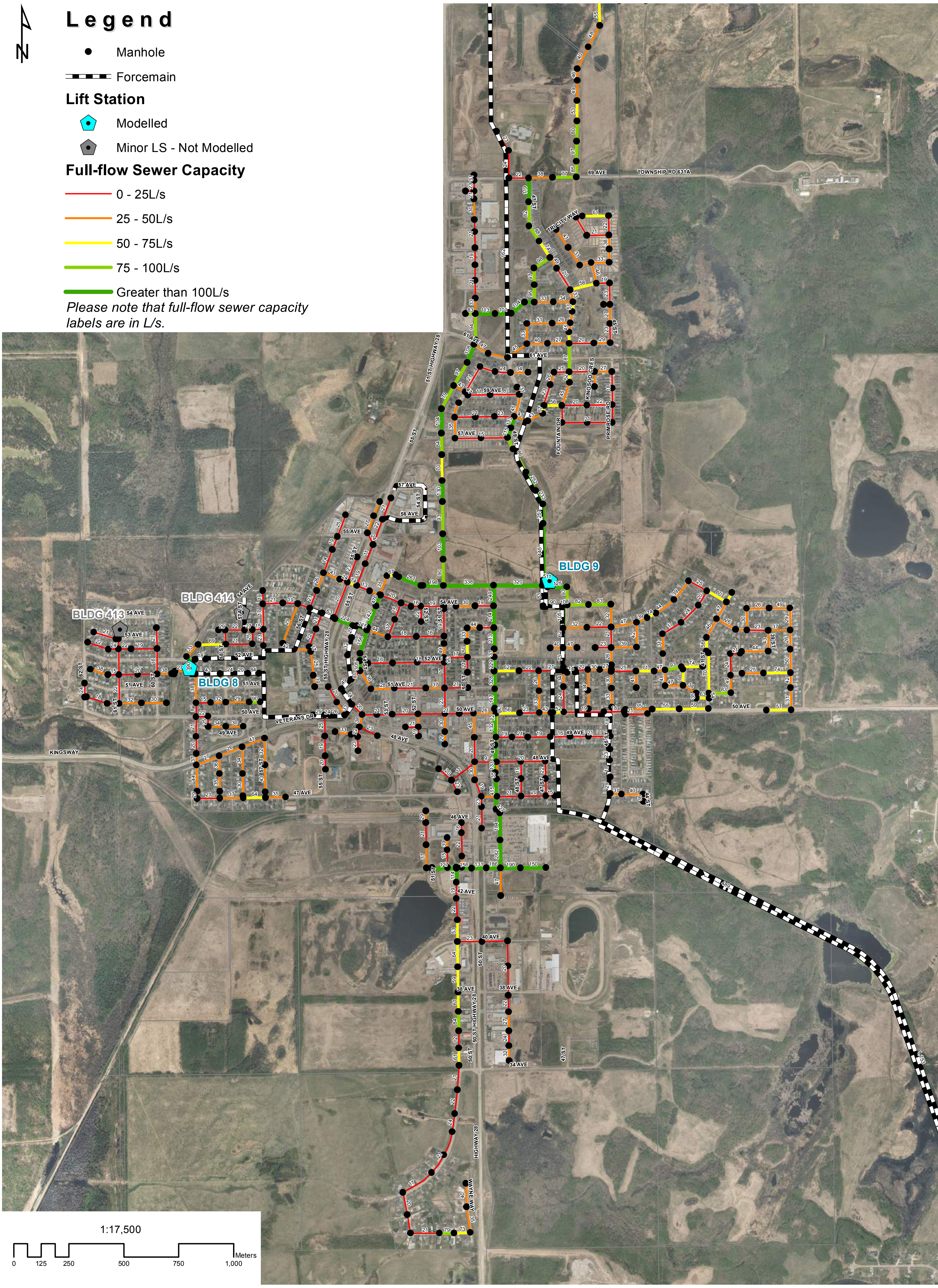


THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - NORTH
FULL-FLOW SEWER CAPACITY

Date: 1/10/2018 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\2.0 Study Area\Figure 2.10 - Full-flow Pipe Capacity_North.mxd

FIGURE 2.11



City of Cold Lake

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INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - SOUTH
FULL-FLOW SEWER CAPACITY

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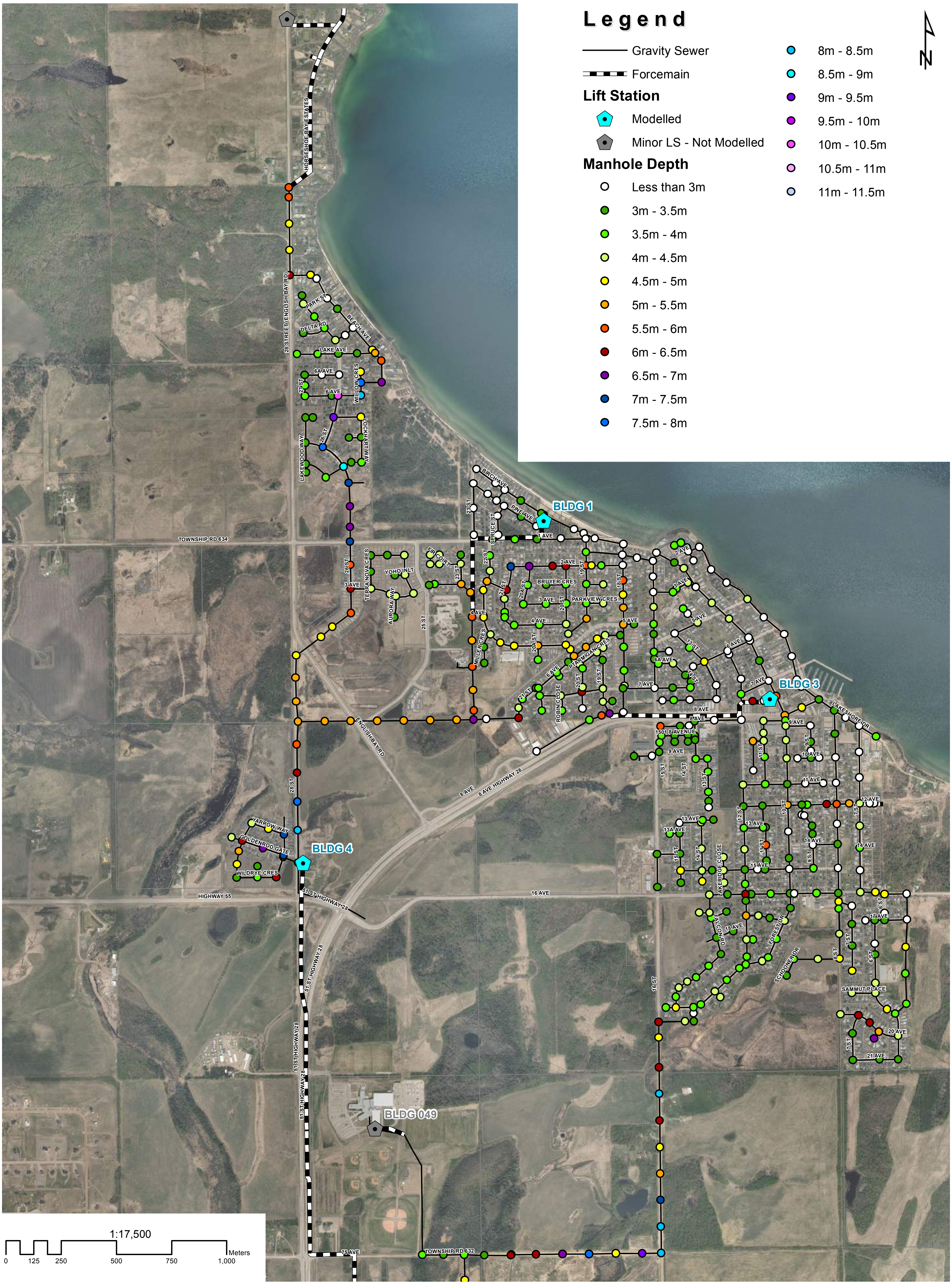
Date: 1/10/2018 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\2.0 Study Area\Figure 2.11 - Full-flow Pipe Capacity_South.mxd

FIGURE 2.12



City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - NORTH
MANHOLE DEPTH

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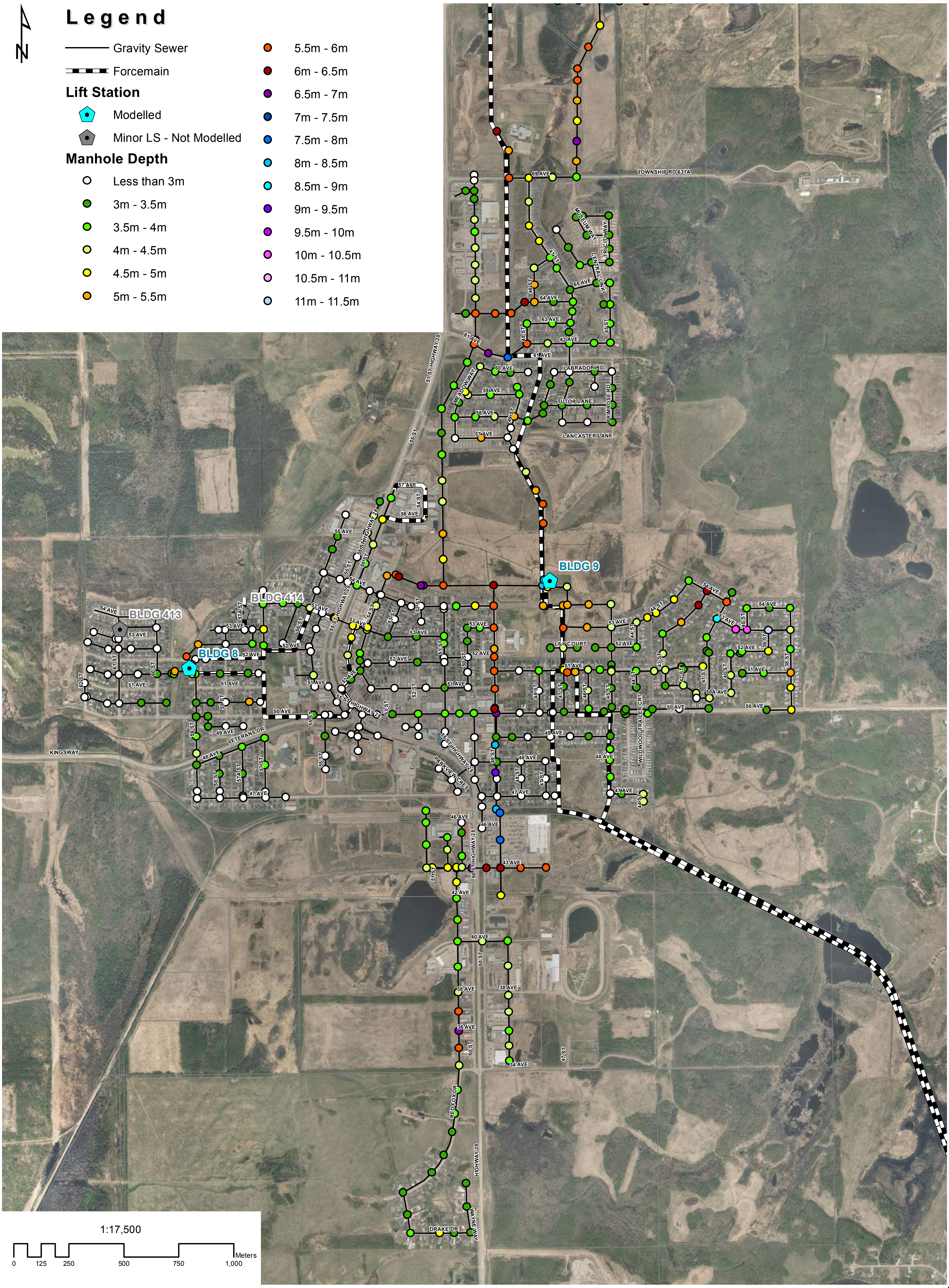
Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\2.0 Study Area\Figure 2.12 - Sewer Depth_North.mxd

FIGURE 2.13

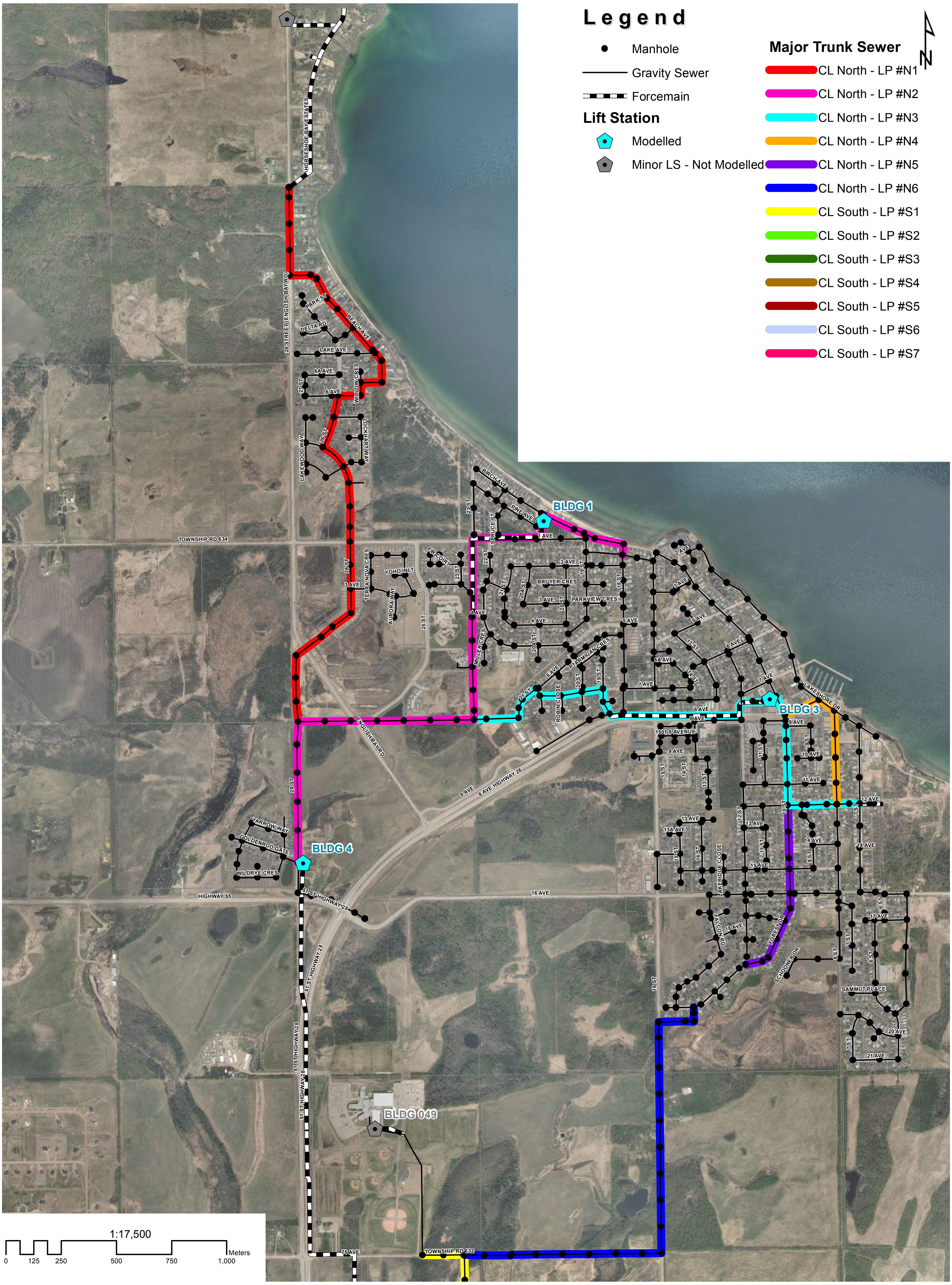


THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - SOUTH
MANHOLE DEPTH

Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\2.0 Study Area\Figure 2.13 - Sewer Depth_South.mxd

FIGURE 2.14



City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - NORTH
MAJOR TRUNK SEWERS

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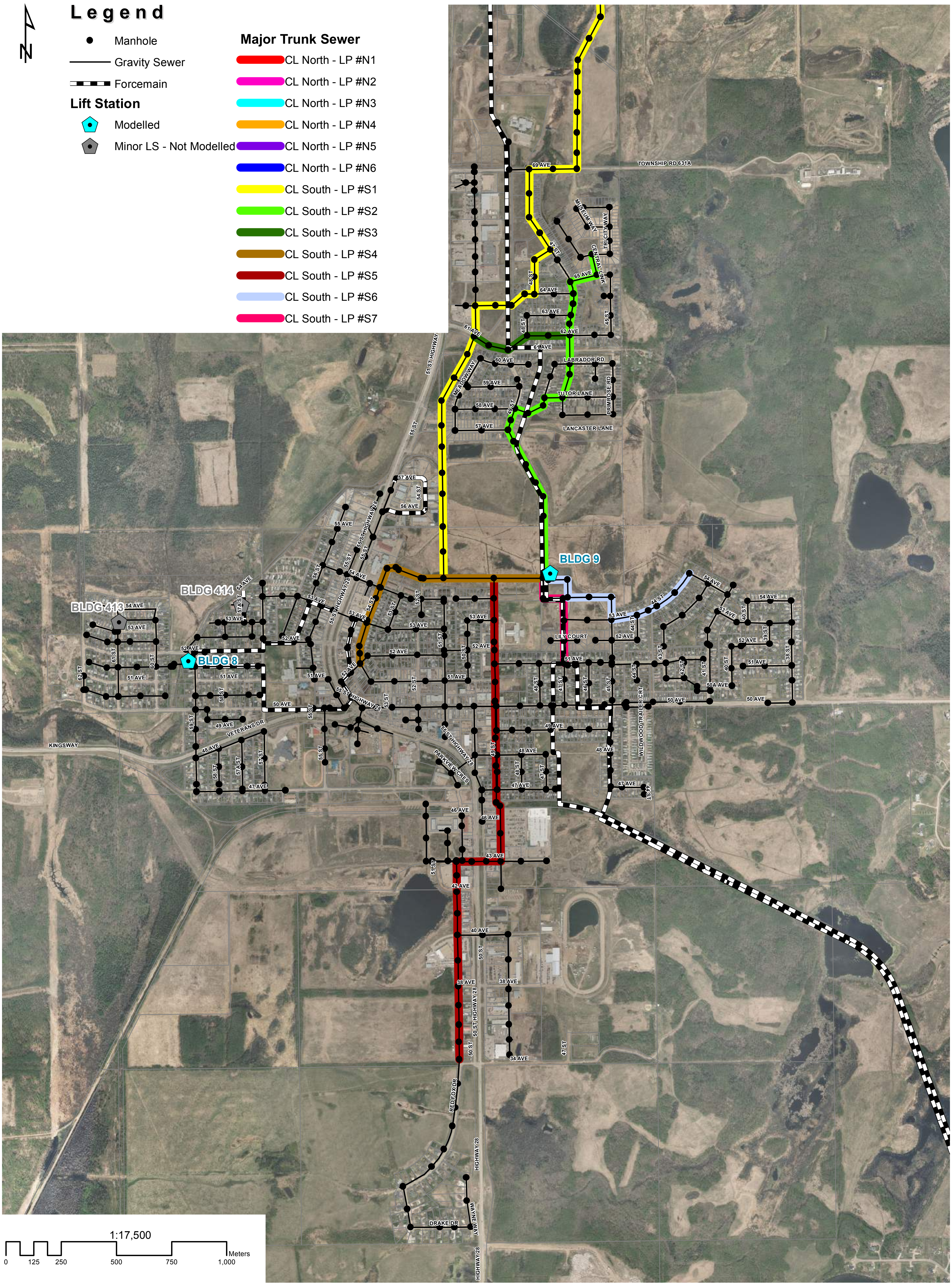
Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\2.0 Study Area\Figure 2.14 - Major Sewer Trunks_North.mxd

FIGURE 2.15



THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - SOUTH
MAJOR TRUNK SEWERS

City of Cold Lake

ISL Engineering and Land Services

Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\2.0 Study Area\Figure 2.15 - Major Sewer Trunks_South.mxd

3.0 Hydraulic Model Development

3.1 Model Set-Up

The computer model utilized to assess the City's sanitary collection system was MIKE URBAN 2016 by DHI. MIKE URBAN is a powerful analysis tool that computes inflow from sewage generation rates and rainfall dependent inflow-infiltration, and routes it through the hydraulics system. Based on the hydraulic simulation the model can be used to evaluate which locations have surcharge or flooding conditions. Sewer flows are also determined, and based on peak flows, over-capacity sewers can be identified. The MIKE URBAN model is significantly integrated with the ArcGIS platform, and this was used to assist in the construction of the model.

To set-up the model, all available geographic information system (GIS) data relevant to the sanitary sewer system in the study area received from the City was reviewed in detail. Manholes and sewers were then imported into the MIKE URBAN model using the provided shapefiles. Light Detection and Ranging (LiDAR) data was obtained from the City in order to populate any missing manhole rim elevations. Elevations were populated using a powerful spatial analyst tool, which extracted the elevation from the LiDAR data at each targeted manhole and assigned it as the rim elevation.

Once the data was imported it was inspected to determine what data appeared missing or erroneous. Generally speaking, the only missing data was manhole inverts and a small number of sewer diameters. In addition to this, it was determined that approximately half the City's sanitary sewers were missing details on the sewer material. Where applicable, erroneous data such as flat sewers, inverse sloping sewers and grade breaks were inspected via block profiles that were provided by the City. Any information that was still outstanding at this point was flagged for surveying. ISL surveyed a number of manholes across the City to determine accurate invert and rim elevations. Once all the required information was surveyed, the invert and rim elevations were populated into the model. Losses were calculated using Weighted Inlet Energy formulation where links came together or where a sharp turn was involved, otherwise Flow-Through was assumed. The model was inspected one last time by performing a series of quality assurance/quality control (QA/QC) tasks to ensure that all of the data was detailed and accurate.

The five lift stations that were mentioned in the previous section of this report were then added into the model. The lift station sites include a storage node representing a wet well, pumps, a dummy node at the downstream end of the pumps, and a forcemain. Wet well dimensions, level control settings, pump curves, forcemain diameters and all required inverts were then populated from provided engineering documents or from the data provided following the drawdown tests. It is noted that pump curves were input into the model for completeness only – as the City performed a number of drawdown tests at each major lift station, the modelled pumps were set-up accordingly. As mentioned above, the original 2016 pump capacities were used for modelling as the 2018 drawdown tests took place after the draft report submission.

3.2 Catchment Delineation

Following the set-up of the physical sanitary sewer system model, it was necessary to delineate the study area into catchments for the purpose of generating dry weather flow (DWF) and wet weather flow (WWF). The catchments were delineated based on individual lots and the land use classification mentioned in Section 2.2, including low, medium, and high density residential, commercial, industrial, park/recreation, and institutional. The population densities stipulated in the Sanitary Master Plan Update Report (AECOM, 2015) were scaled using a weighted approach method in order to match the required population of 16,725, as summarized below in Table 3.1 for each residential catchment type.

Table 3.1: Summary of Population Densities

Land Use Type	Original Population Density	Scaled Population Density
	Persons/household	
Low Density Residential	3.5	3.21
Medium Density Residential	3.0	2.75
High Density Residential	2.5	2.30

The area was then divided into catchment areas based on the spatial location of the sanitary system, land use, and locations of flow monitors in the sewer system in both 2015 and 2016. Overall residential, commercial, industrial, and institutional areas, and the total population were calculated for each of these larger catchment areas. This information was then used during the calibration process, which will be discussed in further detail in Section 4.0.

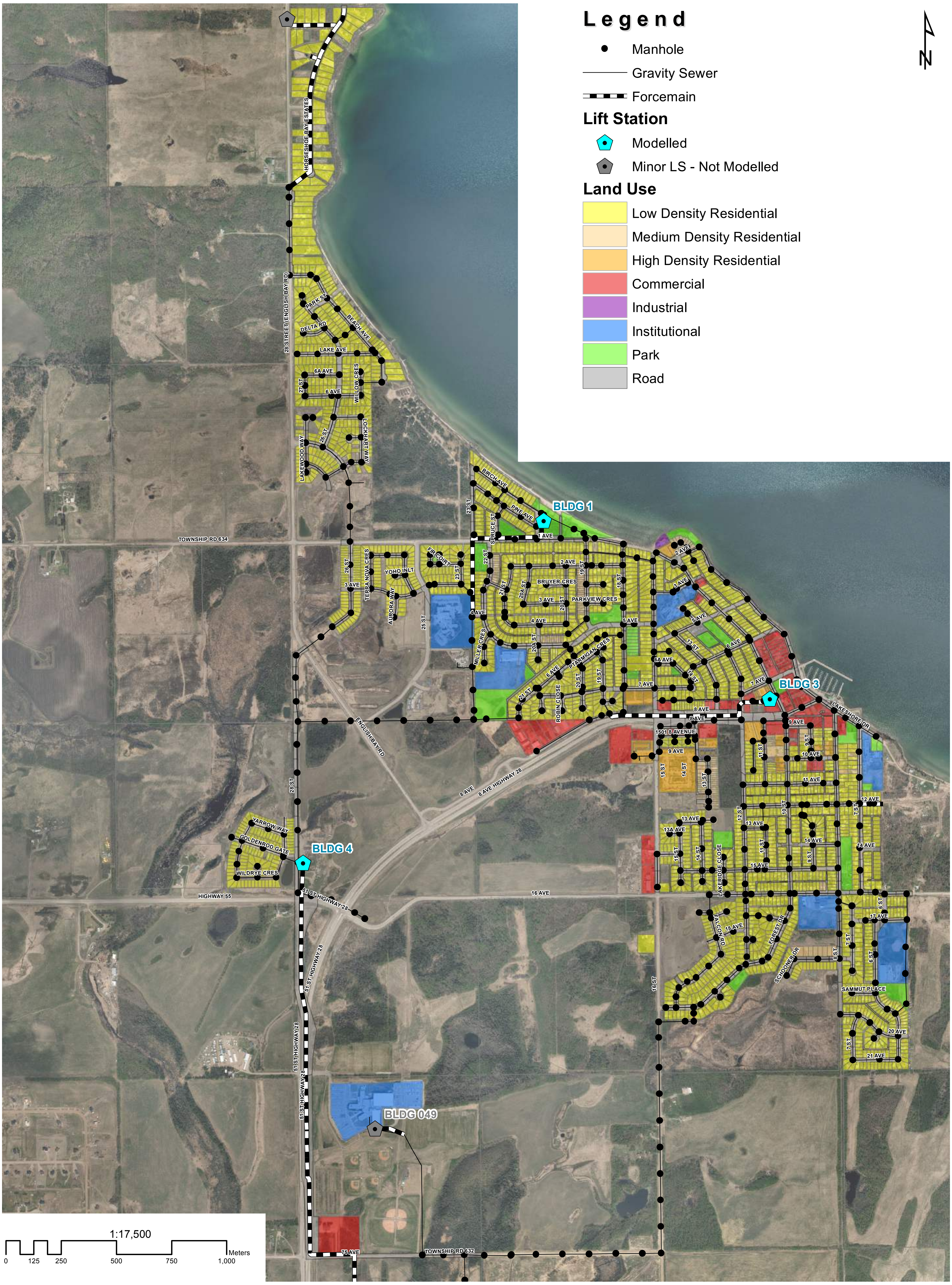
A summary of the individual sanitary catchments is found in Table 3.2 below, and illustrated in Figure 3.1 and Figure 3.2 for Cold Lake North and South, respectively.

Table 3.2: Summary of Existing Sanitary Catchments

Land Use Type	Number of Lots	Total Population	Total Area (ha)
Low Density Residential	4,968	14,625	336
Medium Density Residential	231	641	8
High Density Residential	634	1,459	13
Commercial	413	N/A	96
Industrial	21	N/A	5
Institutional	22	N/A	50
Total	**6,289**	**16,725**	**507**

Following delineation of catchment areas, model construction proceeded to development of diurnals and dry weather flows as part of the calibration process. All MIKE URBAN files developed as part of this project can be found in Appendix B.

FIGURE 3.1

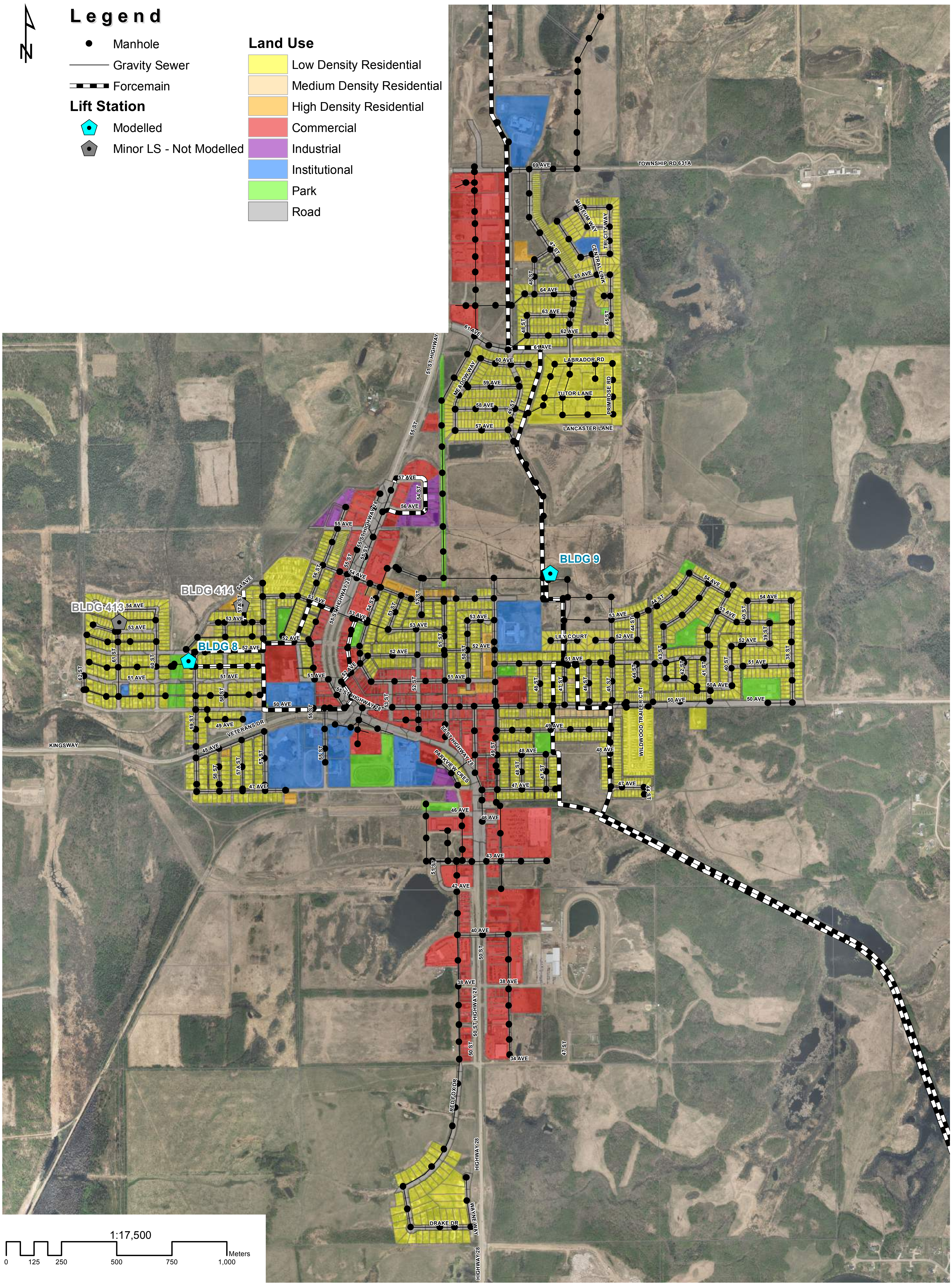


THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - NORTH
EXISTING CATCHMENT AREAS
WITH ASSOCIATED LAND USES

Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\01_GIS Figures\3.0 Hydraulic Model Development\Figure 3.1 - Delineated Catchment Areas_North.mxd

FIGURE 3.2



THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - SOUTH
EXISTING CATCHMENT AREAS
WITH ASSOCIATED LAND USES

Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\3.0 Hydraulic Model Development\Figure 3.2 - Delineated Catchment Areas_South.mxd

4.0 Model Calibration

4.1 Flow Monitoring

Using the catchments delineated from the study area, the next step was to establish dry and wet weather flows for the study area. To assist in developing realistic sewer flows, a total of nine flow monitors were installed at various locations in the City in both 2015 and 2016. Flow monitor locations generally remained consistent between the two years, however the few differences are noted below. This flow monitoring data, as shown in Figures 4.1 and 4.2 for Cold Lake North and Cold Lake South, could then be used in conjunction with rain gauge data in the area to allow for model calibration for both dry and wet conditions based on flows and rainfall.

The nine flow monitoring sites within the study area are summarized below:

- **Site 1 2015 & 2016** – This flow monitor was located in a manhole at the intersection of 10th Street and 8th Avenue in Cold Lake North on the upstream end of the outgoing 450 mm sewer. The majority of the upstream service area are residential developments, with some commercial and institutional areas.
- **Site 2 2015 & 2016** – The Site 2 flow monitor was located in Kinosoo Beach, northwest of the 19th Street and 1st Avenue intersection in Cold Lake North. The flow monitor was installed on the downstream end of the incoming 375 mm sewer in both 2015 and 2016. Site 2's upstream catchments consist of roughly 90% residential developments and 10% institutional developments.
- **Site 3 2015 & 2016** – This flow monitor was installed in a manhole on 28th Street just south of the 25th Street and 28th Street intersection in Cold Lake North, on the downstream end of the incoming 450 mm sewer. The upstream catchment is entirely residential.
- **Site 4 2015** –In 2015, Site 4 was installed in the downstream end of a 525 mm sewer on 49th Street, directly north of the 49th Street and 50th Avenue intersection in Cold Lake South. Upstream catchments consist of residential and commercial developments.
- **Site 4 2016** – In 2016, this flow monitor was installed upstream in a manhole located at the 50th Street and 43rd Avenue intersection in the downstream end of the incoming 450 mm sewer. This site consists of mainly commercial catchments upstream, with about a third of the catchments being residential.
- **Site 5 2015 & 2016** – This flow monitor is located in Cold Lake South, north of the 51st Street and 54th Avenue intersection on the downstream end of the incoming 375 mm sewer. Upstream catchments include residential, commercial, industrial, and institutional developments.
- **Site 6 2015 & 2016** – Site 6 was installed southeast of the 49th Street and 57th Avenue intersection in Cold Lake South, in the downstream end of the incoming 375 mm sewer. The upstream service area is entirely residential.
- **Site 7A 2015 & 2016** – The Site 7A flow monitor was installed north of the 46th Street and 51st Avenue intersection in Cold Lake South on the downstream end of the incoming 375 mm sewer. Site 7A consists of 100% residential developments upstream of its location.
- **Site 7B 2015** – This flow monitor was located at the 47th Street and 54th Avenue intersection in the downstream end of the incoming 300 mm sewer in 2015. The majority of the upstream catchment areas are residential, with a small fraction of which being commercial.
- **Site 7B 2016** – This flow monitor was located at the 47th Street and Lily Court intersection in the downstream end of the incoming 300 mm sewer in 2016. The majority of the upstream catchment areas are residential, with a small fraction of which being commercial.
- **Site 8 2015** – In 2015, the Site 8 flow monitor was installed west of 59th Street in Cold Lake South between 51st Avenue and 52nd Avenue in the downstream end of the incoming 200 mm sewer. The upstream catchment areas consist of a mix between residential, commercial, and institutional developments.

- **Site 8 2016** –In 2016, the flow monitor was installed just east of 60th Street, between 51st Avenue and 52nd Avenue in the downstream end of the incoming 200 mm sewer. The upstream catchment areas are almost entirely residential, with only approximately 1% being commercial.

In 2017, an additional year of flow monitoring was conducted by SFE. The major purpose of the 2015 and 2016 flow monitoring data was to collect dry weather and wet weather observed flows in order to calibrate the existing model, and to perform assessments on inflow and infiltration. The 2017 flow monitoring locations were selected in order to gain more insight into areas with high I-I rates, by focusing on more of a micro flow monitoring approach. This allows the City to further focus their I-I reduction efforts Additionally, two of the 2017 locations were selected in order to gain a better understanding of the flow split which separates Sites 5 and 6. The selected flow monitoring locations in 2017 are also illustrated in Figures 4.1 and 4.2 for Cold Lake North and Cold Lake South, respectively.

The 2015, 2016 and 2017 Sanitary Sewer Flow Monitoring Final Reports compiled by SFE Global have been provided in Appendix C. Flow monitoring and rainfall data was compiled for use of the calibration of the MIKE URBAN hydraulic model of the sanitary sewer system in the City of Cold Lake.

4.2 Dry Weather Model Calibration

Following the hydraulic model construction and compilation of the flow monitoring data, calibration of the sanitary model was then initiated. Calibration was crucial in order to accurately represent flows under both dry weather and wet weather conditions.

The first step was to determine a period from the flow monitoring data with little to no rainfall influence on the network for each of the flow monitoring sites. The following weeks were chosen to represent the sanitary system under dry weather flow conditions:

- May 9th to May 16th, 2016 – Sites 1, 3, 5, 6 and 8 (2016)
- July 6 to July 13th, 2015 – Site 2
- June 5th to June 12, 2015 – Site 4
- July 11th to July 18th, 2016 – Site 7A
- June 16th to June 23rd, 2016 – Site 7B
- June 20th to June 27th, 2015 – Site 8 (2015)

It is noted that the model was calibrated in terms of dry weather conditions in 2015, and recalibrated on a number of sites in 2016 as additional flow monitoring and rainfall data was made available. Six of the nine sites were recalibrated, due to either weirs being installed in 2016 as a result of observed low flow conditions, or large differences in flows between the two years. Site 8 was calibrated twice, as the location completely changed between 2015 and 2016, representing an entirely new upstream catchment area. Though some of the selected dry weather periods did experience some rainfall, it was decided to use those periods nonetheless, as a visual investigation indicated that during these periods a typical diurnal pattern was observed.

After the dry weather flow dates were deduced, it was necessary to establish residential, commercial, industrial and institutional diurnals. This first involved determining baseflows that generally represent infiltration to the system. Baseflows were initially assumed to be 80% of minimum flows (typically nighttime flows), and were adjusted as needed in order to derive accurate diurnals.

Following the establishment of baseflows, to further proceed towards dry weather flow calibration, diurnals were developed. Diurnals were derived by taking the difference between recorded flow rates and the determined baseflow, dividing this value by the average flow from each day, and deducing the average per hour. With this, weekday, Saturday and Sunday diurnals were produced for all flow monitoring sites.

Diurnals were adjusted slightly in many cases in order to meet the peak flows that were observed in the monitored data. In all, twelve diurnals were created; graphical representations of the diurnals can be found in Figures 4.3 to 4.14.

Once the baseflows and diurnals were defined, to further proceed towards dry weather flow calibration, a combination of determination and adjustment of diurnals as well as identification and adjustment of dry weather sewage flow generation rates was undertaken.

Dry weather sewage generation rates were estimated by considering the difference between the average flow rates and the defined baseflows, then taking the difference and dividing it by upstream residential populations and non-residential (commercial, industrial, and institutional) areas based on anticipated flow rates, where applicable.

On this basis, residential dry weather flow rates were preliminarily estimated, and tweaked along with the diurnals as necessary. A similar approach was followed for commercial, industrial, and institutional dry weather flow rates.

Successful calibration results will produce volume and peak flow errors less than ±10% as stipulated by the industry best practices promoted by the Wastewater Planning User Group's (WaPUG) guidelines. The following table, Table 4.1, indicates that none of the calibration errors surpassed the recommended values. At this point, the dry weather flow calibration of the model was deemed to be complete. Final dry weather week flow comparison plots are shown in Figures 4.15 through 4.24 inclusive, and final dry weather flow generation rates employed for the study are shown in Figures 4.25 and 4.26.

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Table 4.1: Dry Weather Flow Calibration Results

Year	Flow Monitor	DWF Period	Generalized Min. Flow	Baseflow	Baseflow Flow Rate	Upstream Total Contributing Area	Upstream Total Contributing Population	Residential DWF Rate	Commercial DWF Rate	Industrial DWF Rate	Institutional DWF Rate	Peak Flow Monitored	Peak Flow Modelled	Peak Flow Difference	Volume Monitored	Volume Modelled	Volume Difference
			L/s	L/s	L/s/ha	ha		L/p/d	$m^3/ha/d$	$m^3/ha/d$	$m^3/ha/d$	L/s	L/s	%	m^3	m^3	%
2015	Site 2	July 6 to July 13	1.75	1.40	0.039	36.31	1,555	205.00	0.00	0.00	1.00	23.00	21.78	-5.59	3,197	3,470	7.87
2015	Site 4	June 5 to June 12	3.05	1.98	0.050	39.77	151	350.00	5.00	0.00	0.00	5.20	5.05	-2.97	2,439	2,589	5.81
2015	Site 8	June 20 to June 27	2.80	2.24	0.089	25.30	627	375.00	5.00	0.00	10.00	8.00	7.29	-9.76	3,300	3,559	7.27
2016	Site 1	May 9 to May 16	2.40	0.96	0.013	72.95	3,082	160.00	5.00	0.00	1.00	11.40	11.32	-0.73	3,786	3,962	4.43
2016	Site 3	May 9 to May 16	8.00	6.80	0.155	43.73	1,452	300.00	0.00	0.00	0.00	17.13	16.44	-4.25	6,932	7,119	2.64
2016	Site 5	May 9 to May 16	8.00	6.40	0.114	55.93	1,285	350.00	15.00	5.00	10.00	22.00	21.18	-3.89	9,085	9,588	5.25
2016	Site 6	May 9 to May 16	0.80	0.32	0.019	16.49	722	200.00	0.00	0.00	0.00	5.50	5.91	6.93	1,496	1,601	6.56
2016	Site 7A	July 11 to July 18	2.00	1.20	0.059	20.46	912	225.00	0.00	0.00	0.00	4.55	4.52	-0.74	1,968	2,009	2.01
2016	Site 7B	June 16 to June 23	0.90	0.36	0.012	29.05	1,518	150.00	5.00	0.00	0.00	5.51	5.34	-3.07	1,668	1,729	3.54
2016	Site 8	May 9 to May 16	0.30	0.06	0.004	13.53	569	200.00	0.00	0.00	10.00	3.20	3.15	-1.44	794	843	5.82

Note:

- Adjusted BFs from original 80% of minimum flows
- Land use type not observed in upstream contributing area
- Generalized Peak Flows
- Within +/- 10% Error Margin

4.3 Wet Weather Model Calibration

After completion of dry weather flow calibration, it was necessary to perform wet weather flow calibration to ensure the model was accurately representing the amount of inflow-infiltration (I-I) to the sanitary sewer system during wet weather events. To do so, it was necessary to establish wet weather periods during which a response to wet weather was observed in the flow monitoring data. Based on a review of rainfall and flow monitoring data for the monitoring period during 2016, the best wet weather periods were identified, noting that no ideal response was observed at Site 2, thus the 2015 flow monitoring data was utilized for that site:

- September 30th to October 7th, 2016 (peak occurring on October 1st) – Site 1
- July 13th to July 20th, 2015 (peak occurring on July 13th) – Site 2
- August 21st to August 28th, 2016 (peak occurring on August 22nd) – Site 3
- August 8 to August 15th, 2016 (peak occurring on August 9th) – Sites 4 (August 8th to 12th only a four day period due to faulty data), 5, 6 and 8
- May 27th to June 3rd, 2016 (peak occurring on May 28th) – Site 7A
- July 2nd to July 9th, 2016 (peaks occurring on July 3rd and July 8th) – Site 7B

For modelling the wet weather flow in MIKE URBAN, two separate wet weather flow generation models were used, integrated together to replicate the inflow (i.e. fast system response) and infiltration (slow system response). Consequently, the Time-Area surface runoff method in conjunction with the Rainfall Dependent Inflow-Infiltration (RDII) model, were used to create a robust replication of surface and subsurface processes, respectively. The WWF calibration consisted of an extensive sensitivity analysis performed on a number of Time-Area and RDII parameters. The most notable parameters are as follows:

- Time-Area Model
  - Percent Imperviousness
- Rainfall Dependent Inflow-Infiltration Model
  - Percent Area Contributing to RDII (RDII %)
  - Surface Storage (Umax)
  - Root Zone Storage (Lmax)
  - Overland Coefficient (CQof)
  - TC Overland Flow (CKof)
  - TC Interflow (CKif)
  - TC Baseflow (BF)

Prior to calibrating the said parameters, the Root Zone Moisture (L) parameter was set to 70 mm from the default value of 0 mm to initialize soil moisture conditions. By doing so, this approach assumes realistic antecedent moisture conditions, and has been successfully proven from a number of past studies that were undertaken by ISL.

The final wet weather flow calibration parameters for the study area are summarized in Table 4.2 below.

Table 4.2: Wet Weather Flow Calibration: Time-Area (TA) and RDII Parameters

Parameter	Units	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7A	Site 7B	Site 8
Model A										
Imperviousness	%	0.70	0.65	1.00	0.30	0.55	0.45	0.65	0.20	0.40
Initial Loss	mm	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Time of Concentration	min	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
TA Curve		TA Curve 1	TA Curve 1	TA Curve 1	TA Curve 1	TA Curve 1	TA Curve 1	TA Curve 1	TA Curve 1	TA Curve 1
Reduction Factor		0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
RDII Model										
RDI %	%	5.00	1.00	10.00	1.00	5.00	35.00	5.00	5.00	15.00
Snow Melt		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Umax	mm	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Lmax	mm	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0	140.0
Cqof		0.90	0.90	0.90	0.30	0.15	0.95	0.90	0.50	0.90
Carea		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Ckof	hr	10	10	10	10	10	10	10	10	10
Ckif	hr	50	50	50	50	50	50	50	50	50
BF	hr	150	150	150	150	150	150	150	150	150
TOF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TIF		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TG		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sy	mm	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
GWLmin	m	0	0	0	0	0	0	0	0	0
GWLBFO	m	10	10	10	10	10	10	10	10	10
GWLFL1	m	0	0	0	0	0	0	0	0	0
U	mm	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
L	mm	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0	70.0
GWL	m	10	10	10	10	10	10	10	10	10
OF	mm/hr	0	0	0	0	0	0	0	0	0
IF	mm/hr	0	0	0	0	0	0	0	0	0

The results of the WWF calibration, where the aforementioned parameters were adjusted until an acceptable agreement between the modelled and observed peak flows as well as volumes were achieved are tabulated in Table 4.3.

Table 4.3: Wet Weather Flow Calibration Results

Flow Monitor	Calibration Period	Peak Flow			Volume		
		Monitored	Modelled	Difference	Monitored	Modelled	Difference
		L/s	L/s	%	m^3	m^3	%
Site 1	September 30 to October 7, 2016	20.3	20.2	-0.6	3,753	4,336	13.4
Site 2	July 13 to July 20, 2015	34.6	35.2	1.9	7,448	8,381	11.1
Site 3	August 21 to August 28, 2016	23.3	23.4	0.2	7,458	7,429	-0.4
Site 4	August 8 to August 12, 2016	5.9	6.1	2.6	1,196	1,209	1.1
Site 5	August 8 to August 15, 2016	27.8	29.1	4.6	8,516	9,800	13.1
Site 6	August 8 to August 15, 2016	9.0[1]	9.2	1.8	2,072	1,884	-9.9
Site 7A	May 27 to June 3, 2016	5.8[1]	5.6	-3.6	2,166	2,168	0.1
Site 7B	July 2 to July 9, 2016	5.7	6.0	6.1	1,894	1,812	-4.5
Site 8	August 8 to August 15, 2016	4.6	5.0	6.9	933	967	3.5

[1] *Assumed a generalized peak flow.*

Comparative graphical calibration results of modelled versus monitored flows during the analyzed period can be seen in Figures 4.27 to 4.35 for all nine scenarios, based on high quality wet weather flow data availability. Additionally, the final percent imperviousness values are shown in Figures 4.36 and 4.37 for Cold Lake North and South, respectively and the percent area contributing to RDII values are shown in Figures 4.38 and 4.39 for Cold Lake North and South, respectively.

For wet weather flow calibration, it is recommended that the peak flow error ranges from 25% to -15% and the volume error ranges from 20% to -10% as per the WaPUG's guidelines. In this case, all of the events fall within the recommended ranges. Overall, the wet weather flow results are therefore suitable for the model. As a result, the network has been deemed calibrated on the basis of visual inspection and by statistical analysis of the peak flows and volume results.

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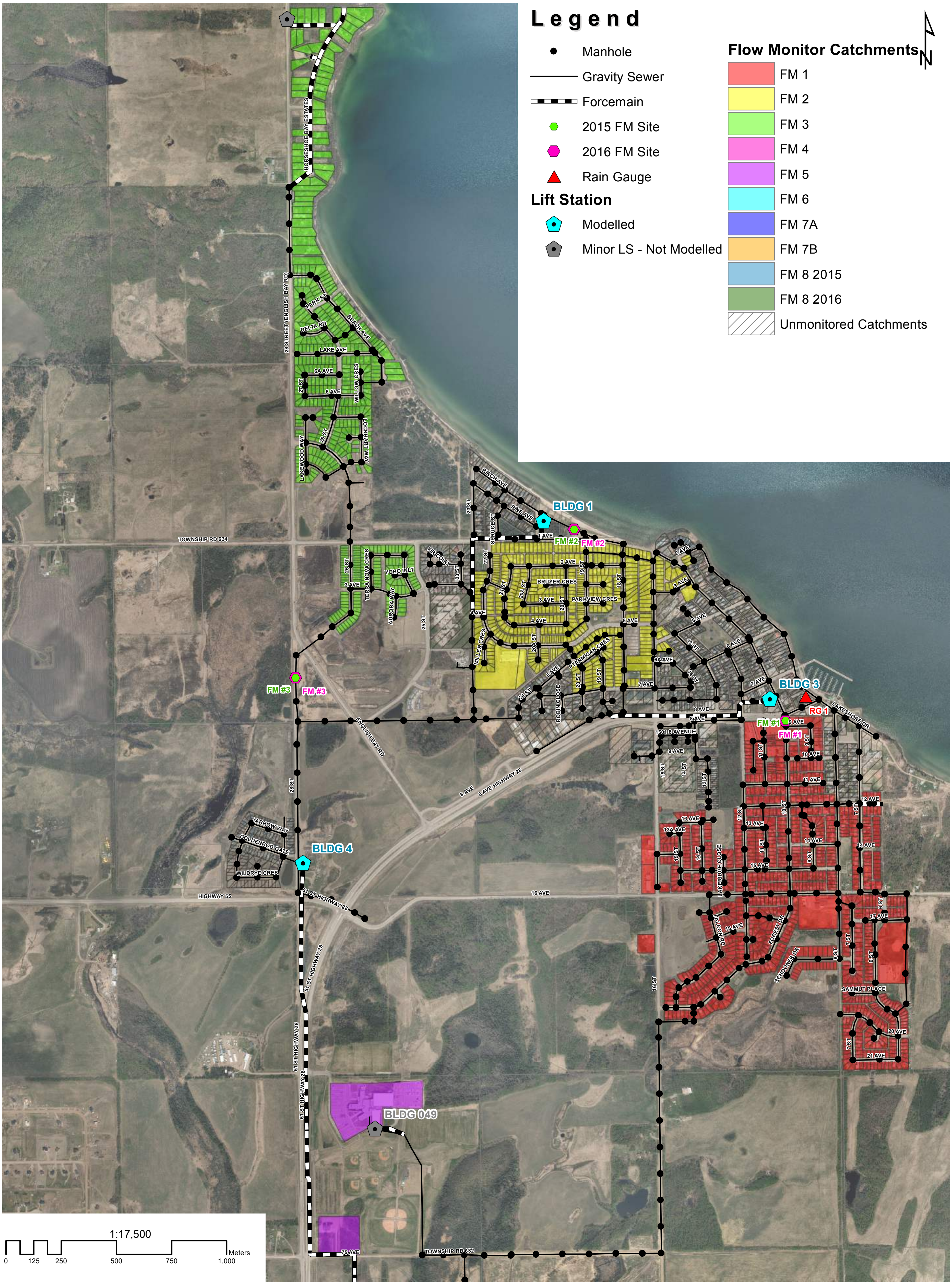
FIGURE 4.1



THE CITY OF COLD LAKE
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SANITARY COLLECTION SYSTEM
EXISTING NETWORK - NORTH
FLOW MONITORING LOCATIONS

City of Cold Lake

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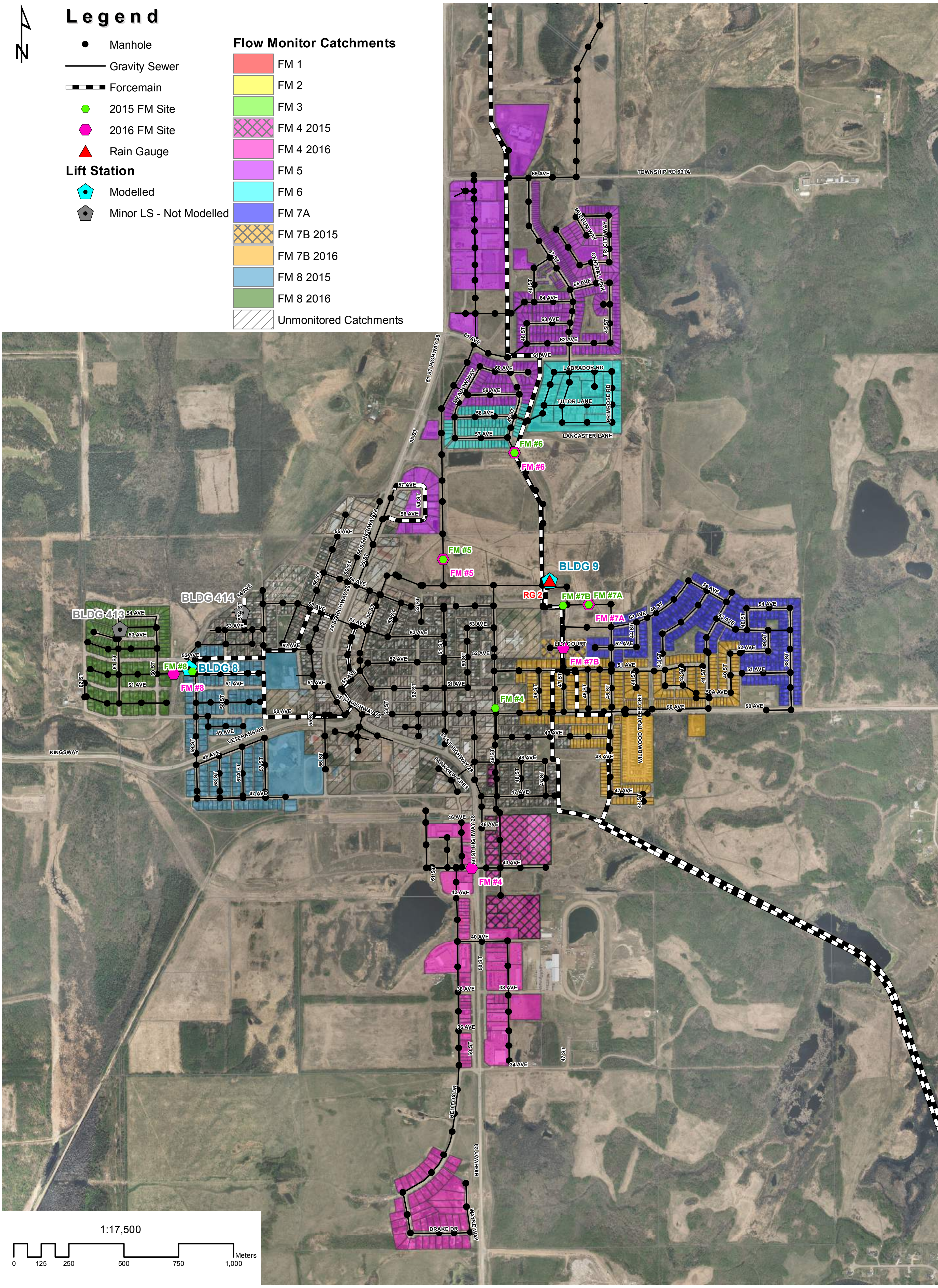
FIGURE 4.2



THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - SOUTH
FLOW MONITORING LOCATIONS

City of Cold Lake

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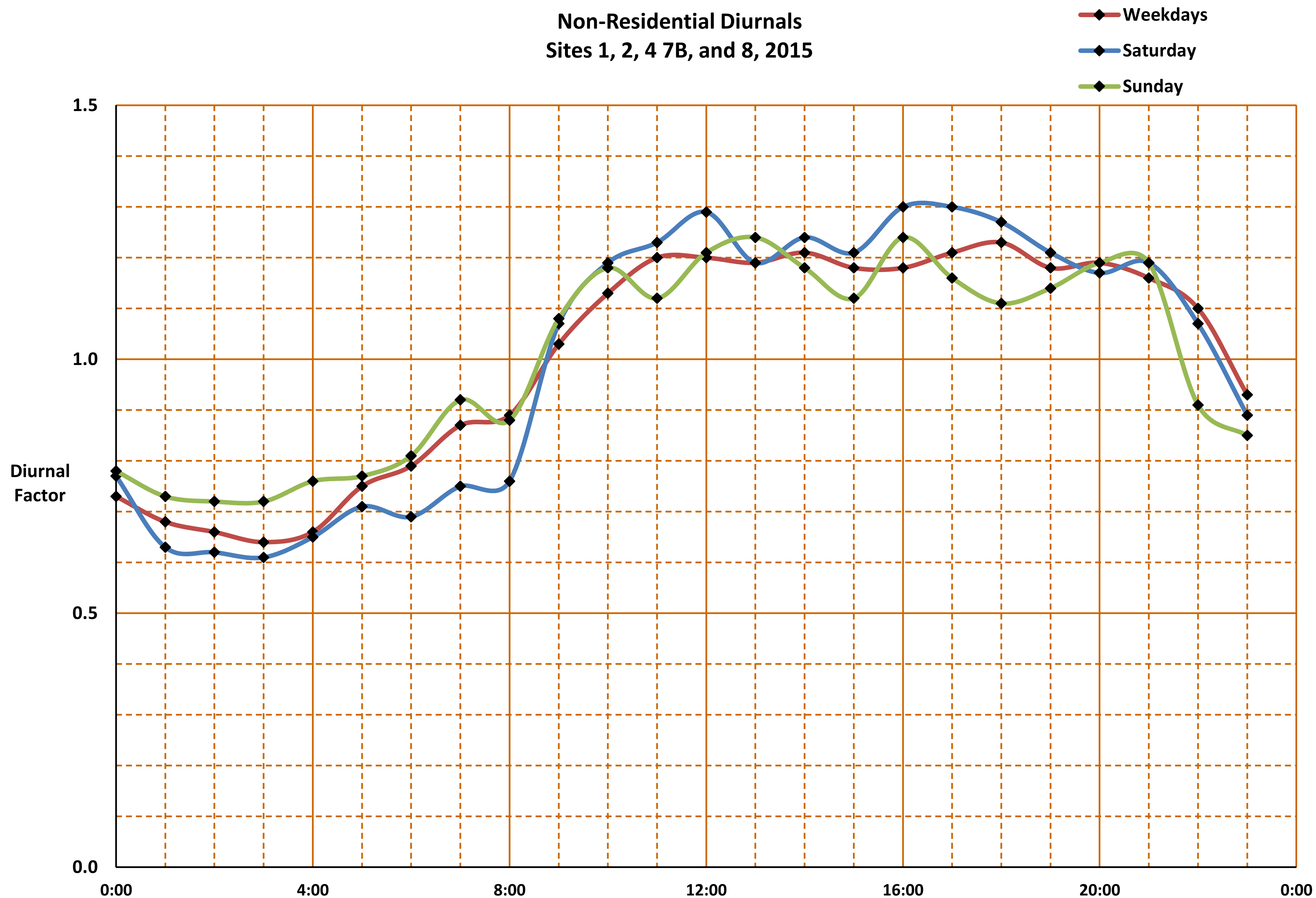
FIGURE 4.3

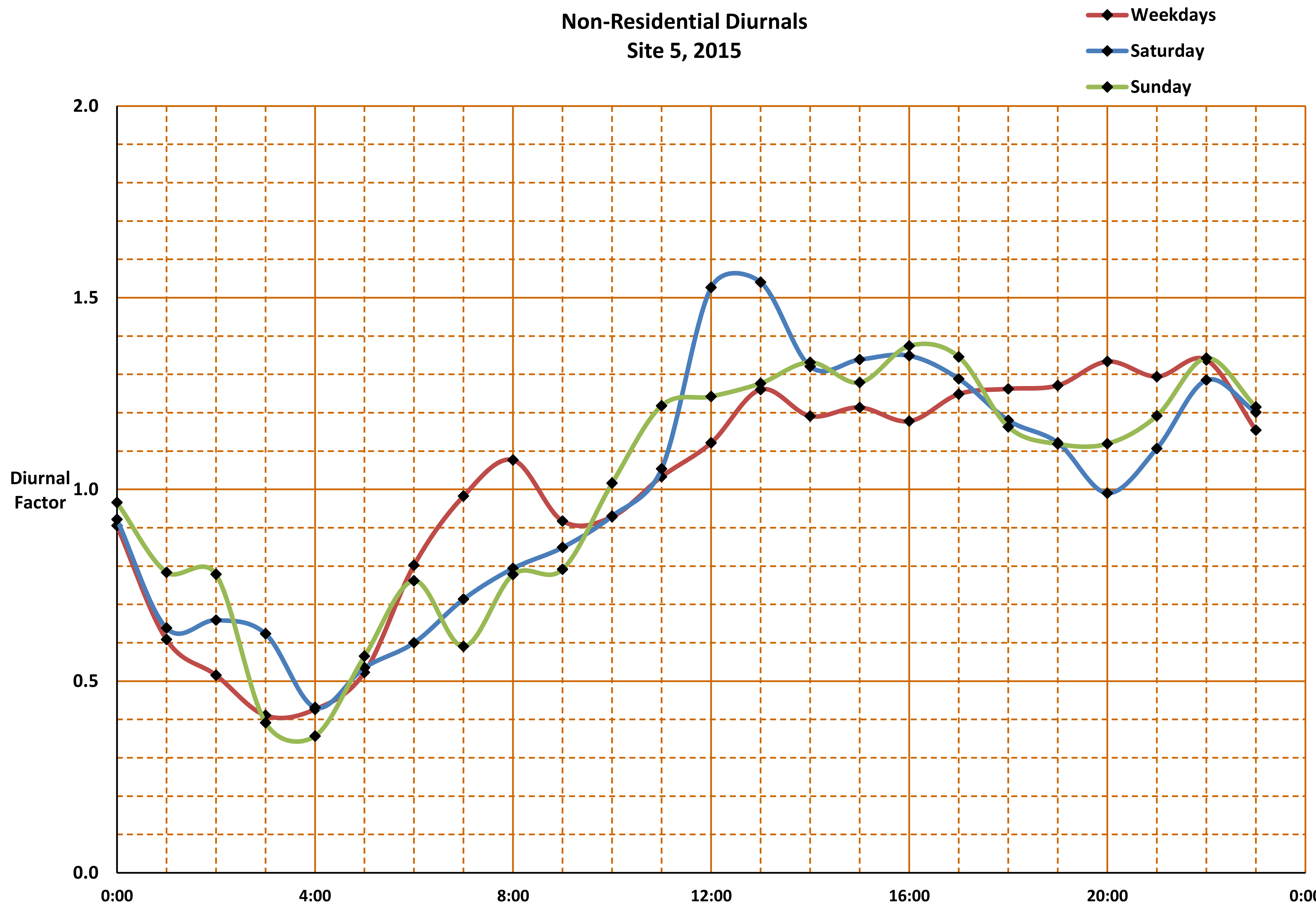


THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
NON-RESIDENTIAL DIURNALS
SITES 1, 2, 4, 7B, 8, 2015

ISL Engineering and Land Services

FIGURE 4.4



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DRY WEATHER FLOW CALIBRATION
NON-RESIDENTIAL DIURNALS
SITE 5, 2015

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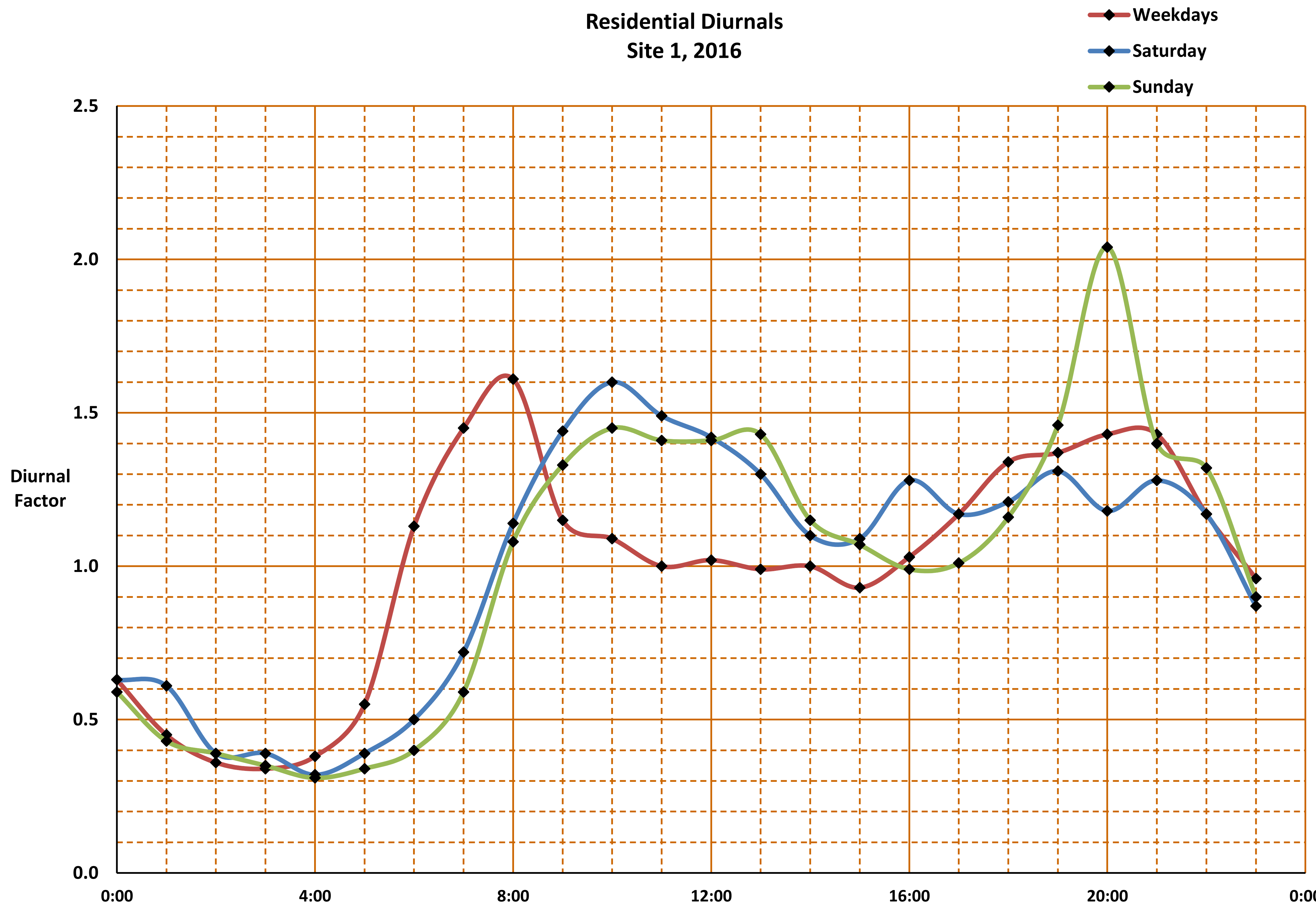
FIGURE 4.5



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INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
RESIDENTIAL DIURNALS
SITE 1, 2016

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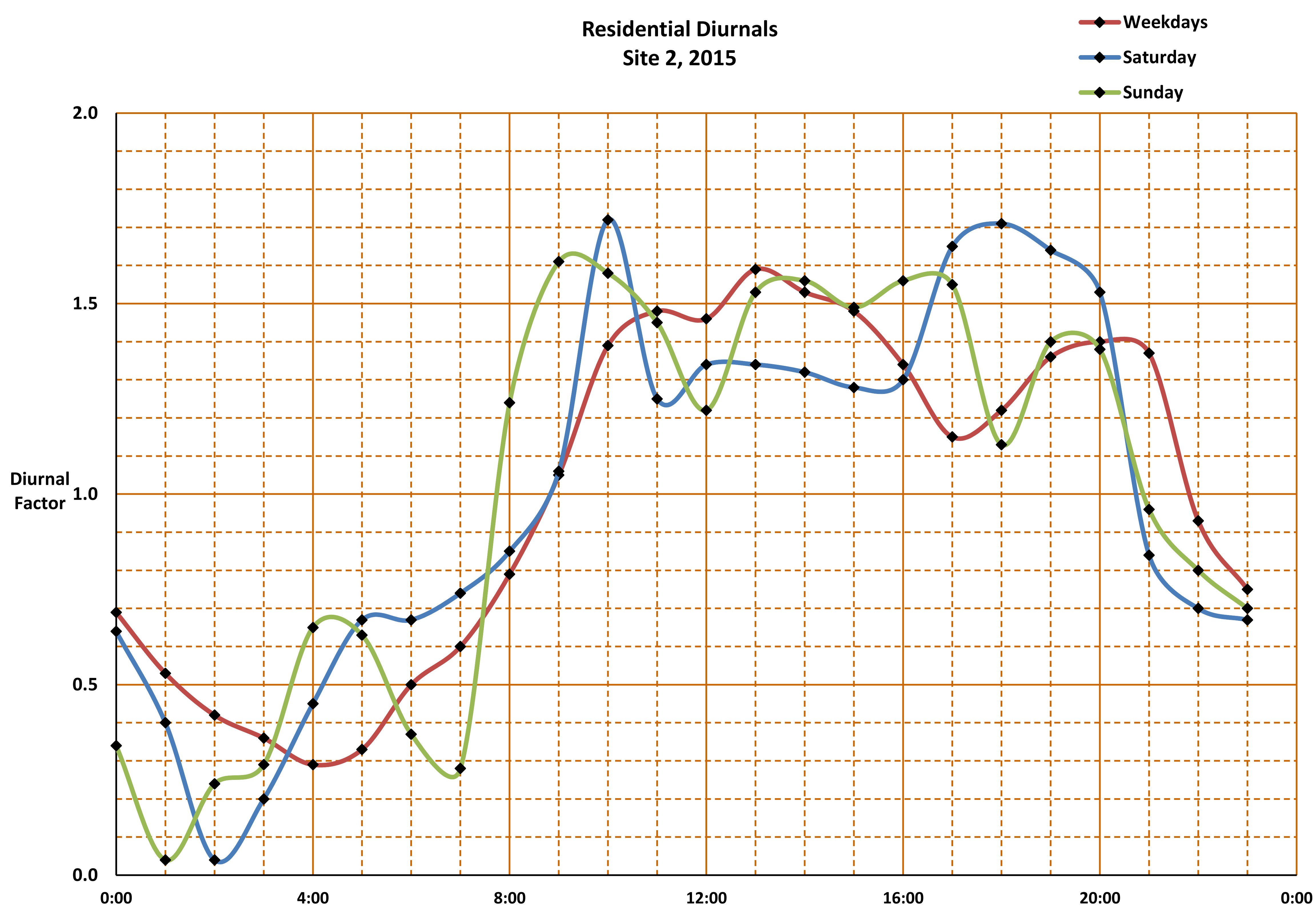
FIGURE 4.6



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DRY WEATHER FLOW CALIBRATION
RESIDENTIAL DIURNALS
SITE 2, 2015

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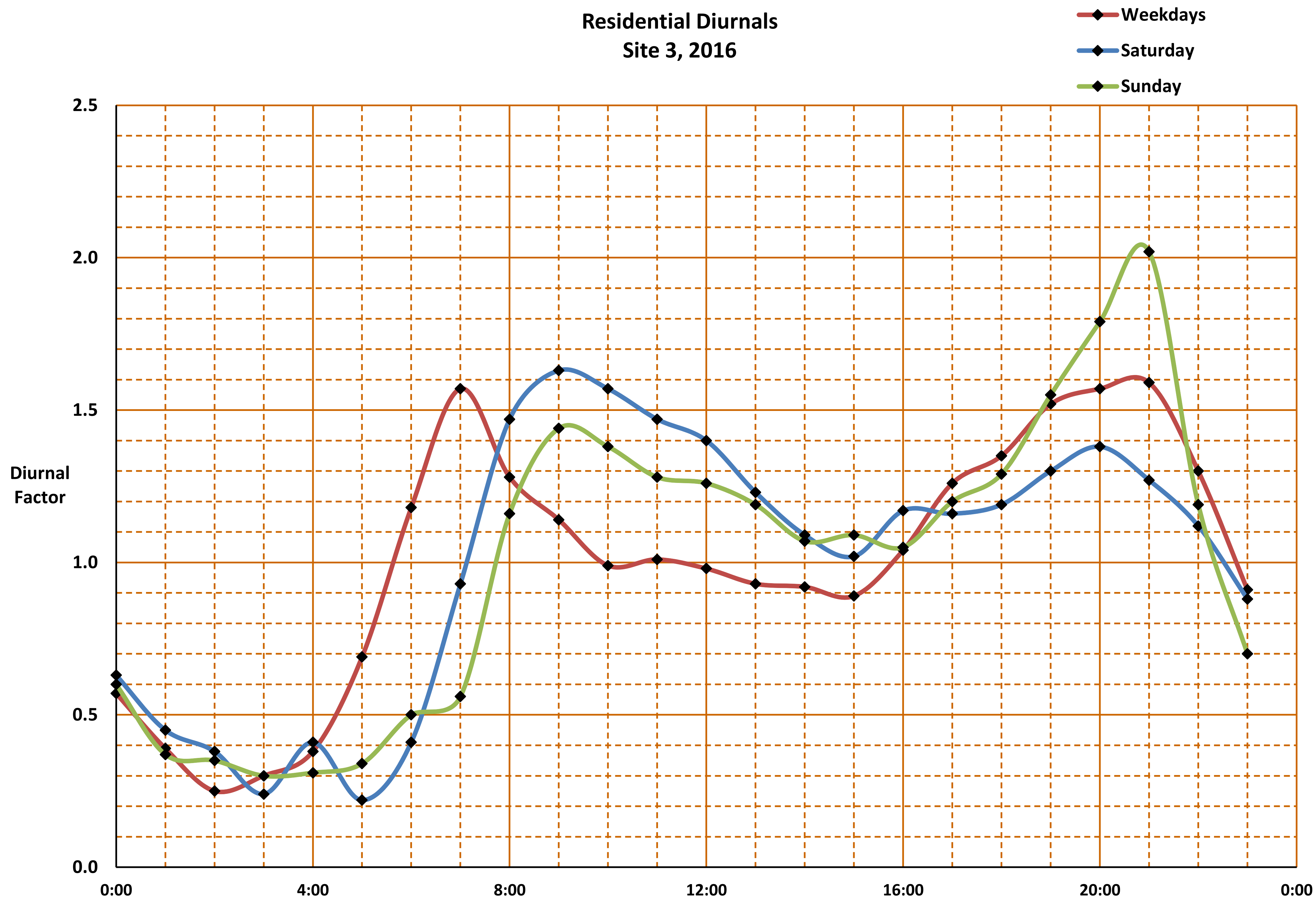
FIGURE 4.7



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DRY WEATHER FLOW CALIBRATION
RESIDENTIAL DIURNALS
SITE 3, 2016

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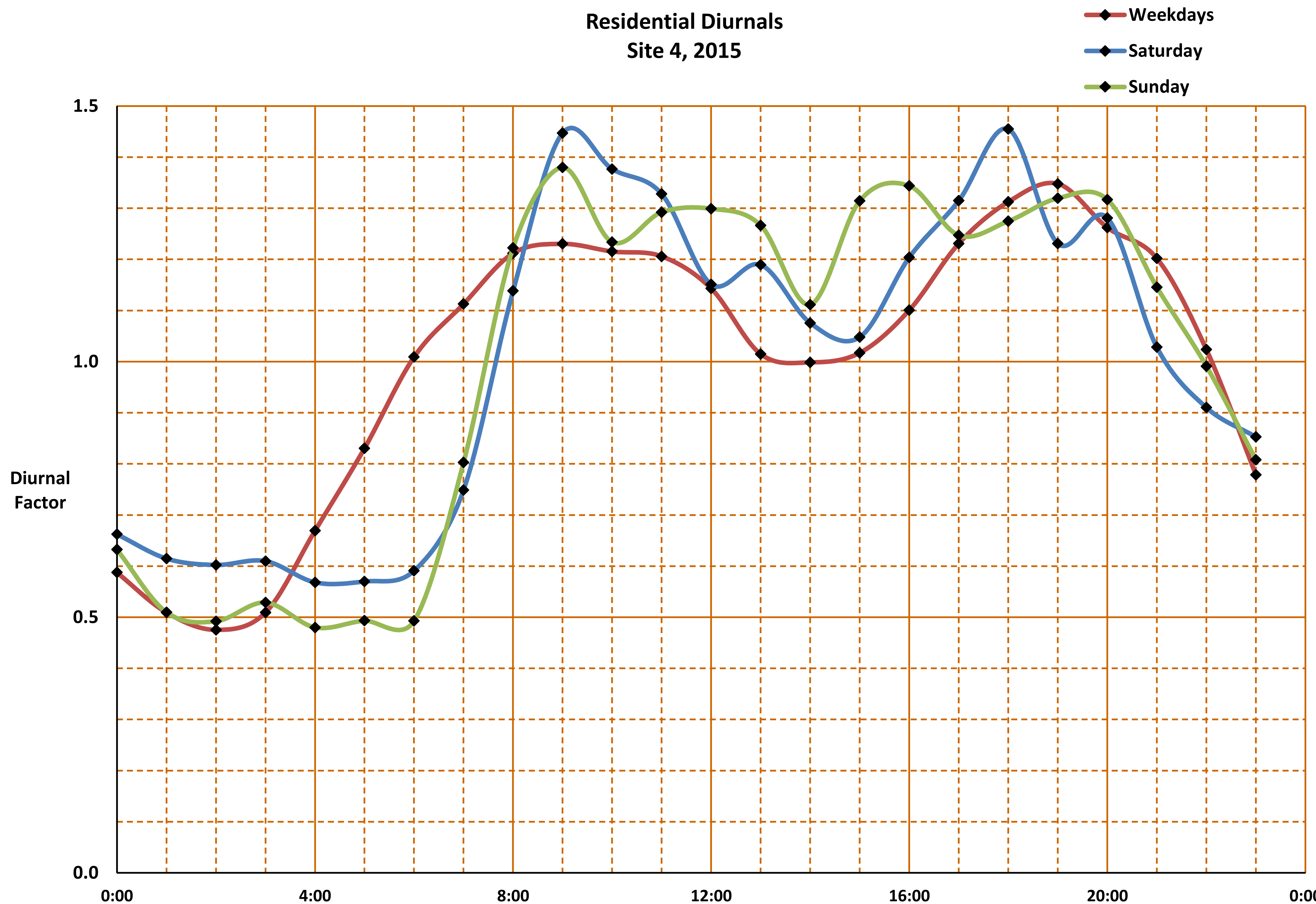
Date: 1/8/2017



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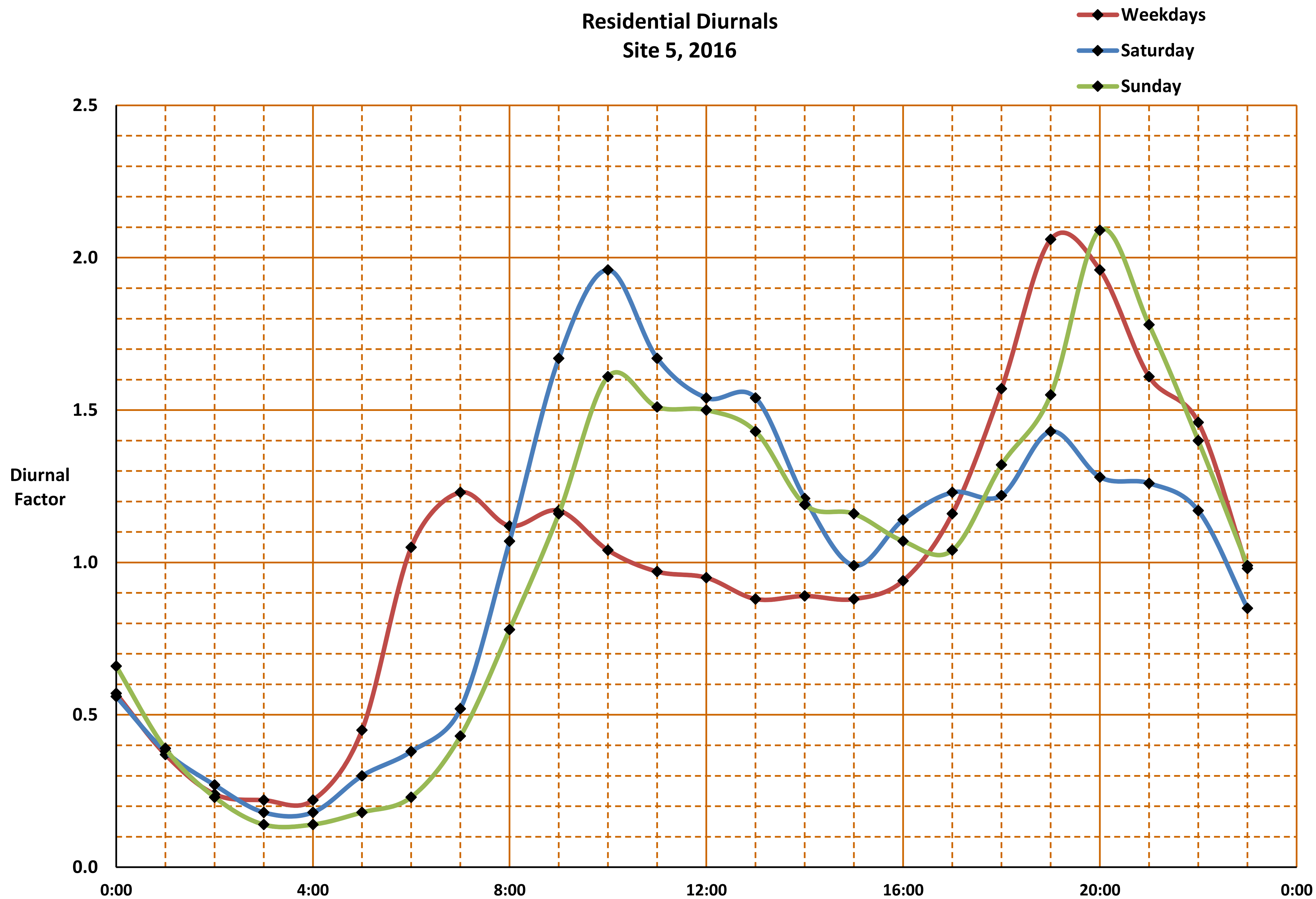
DRY WEATHER FLOW CALIBRATION
RESIDENTIAL DIURNALS
SITE 4, 2015

ISL Engineering and Land Services

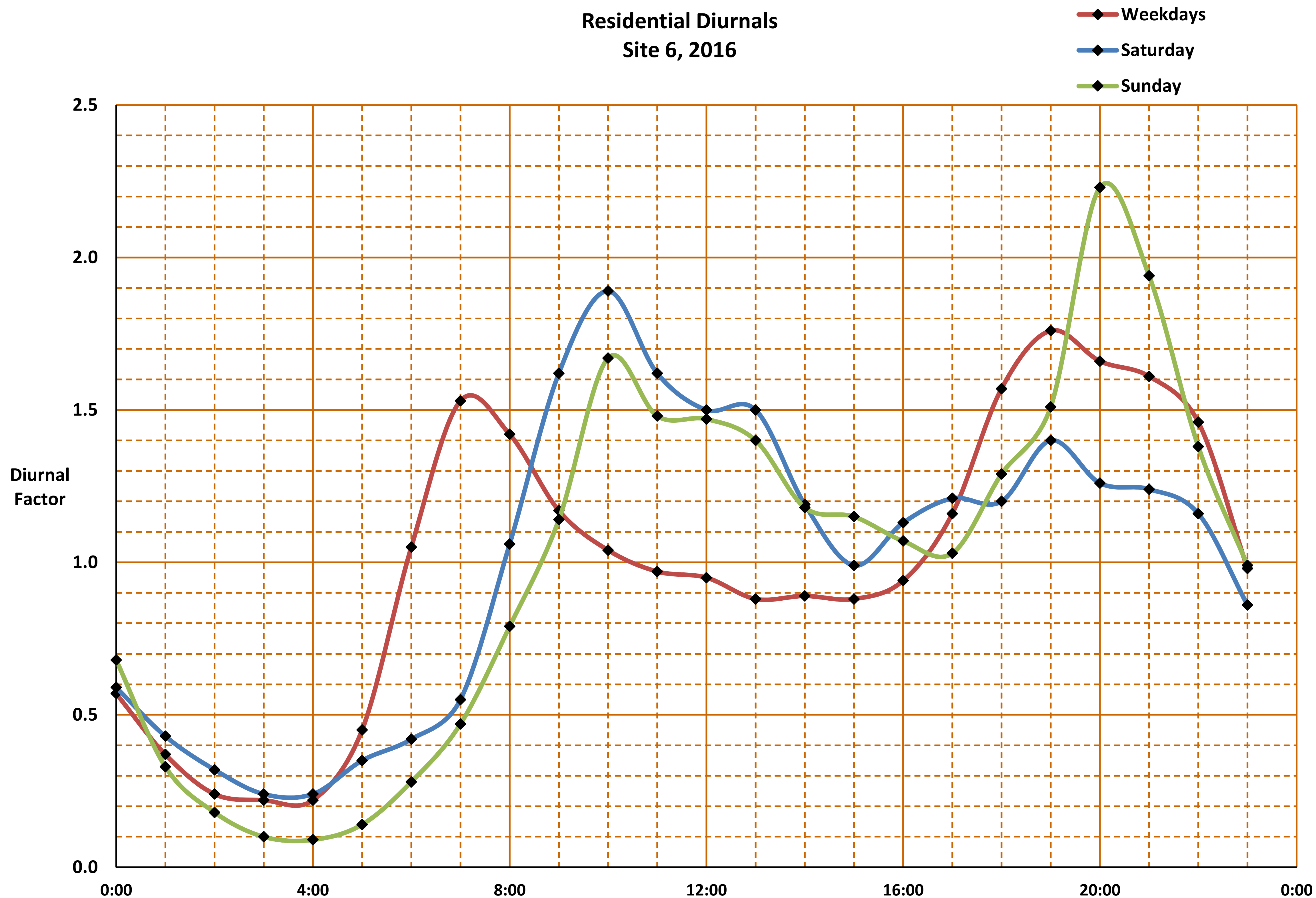


THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
RESIDENTIAL DIURNALS
SITE 5, 2016

ISL Engineering and Land Services

FIGURE 4.10

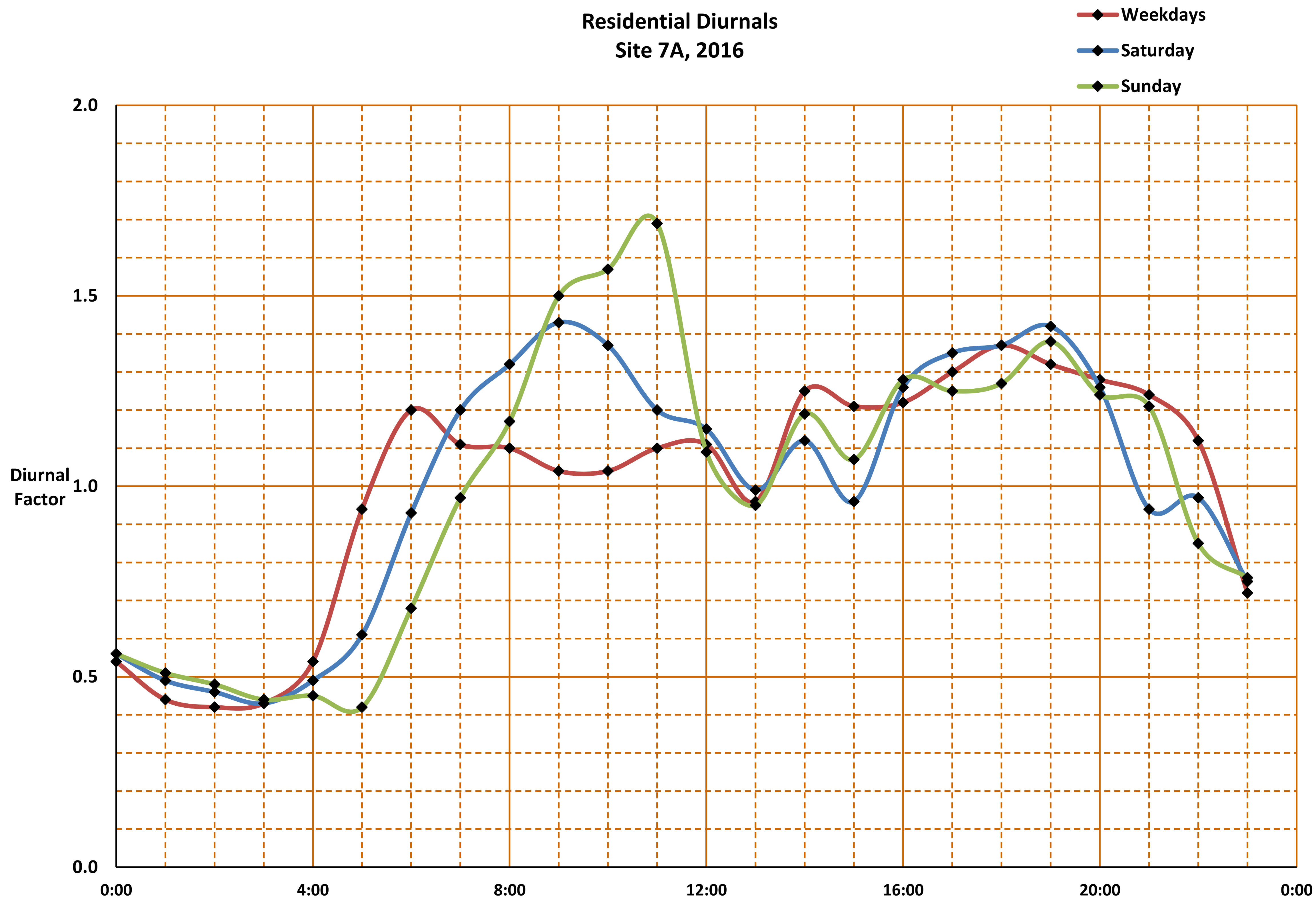


THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
RESIDENTIAL DIURNALS
SITE 6, 2016

ISL Engineering and Land Services

FIGURE 4.11



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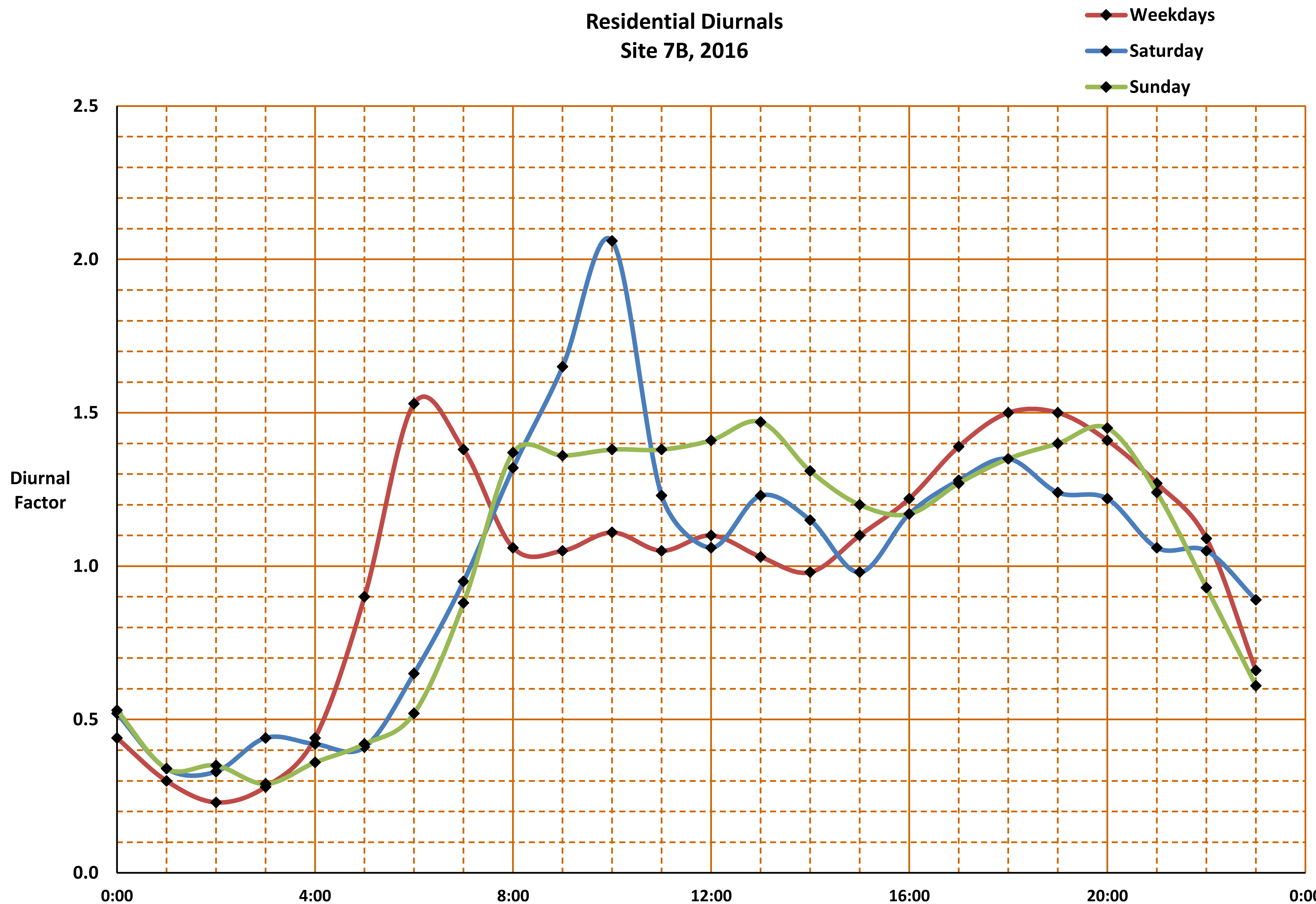
DRY WEATHER FLOW CALIBRATION
RESIDENTIAL DIURNALS
SITE 7A, 2016

FIGURE 4.12



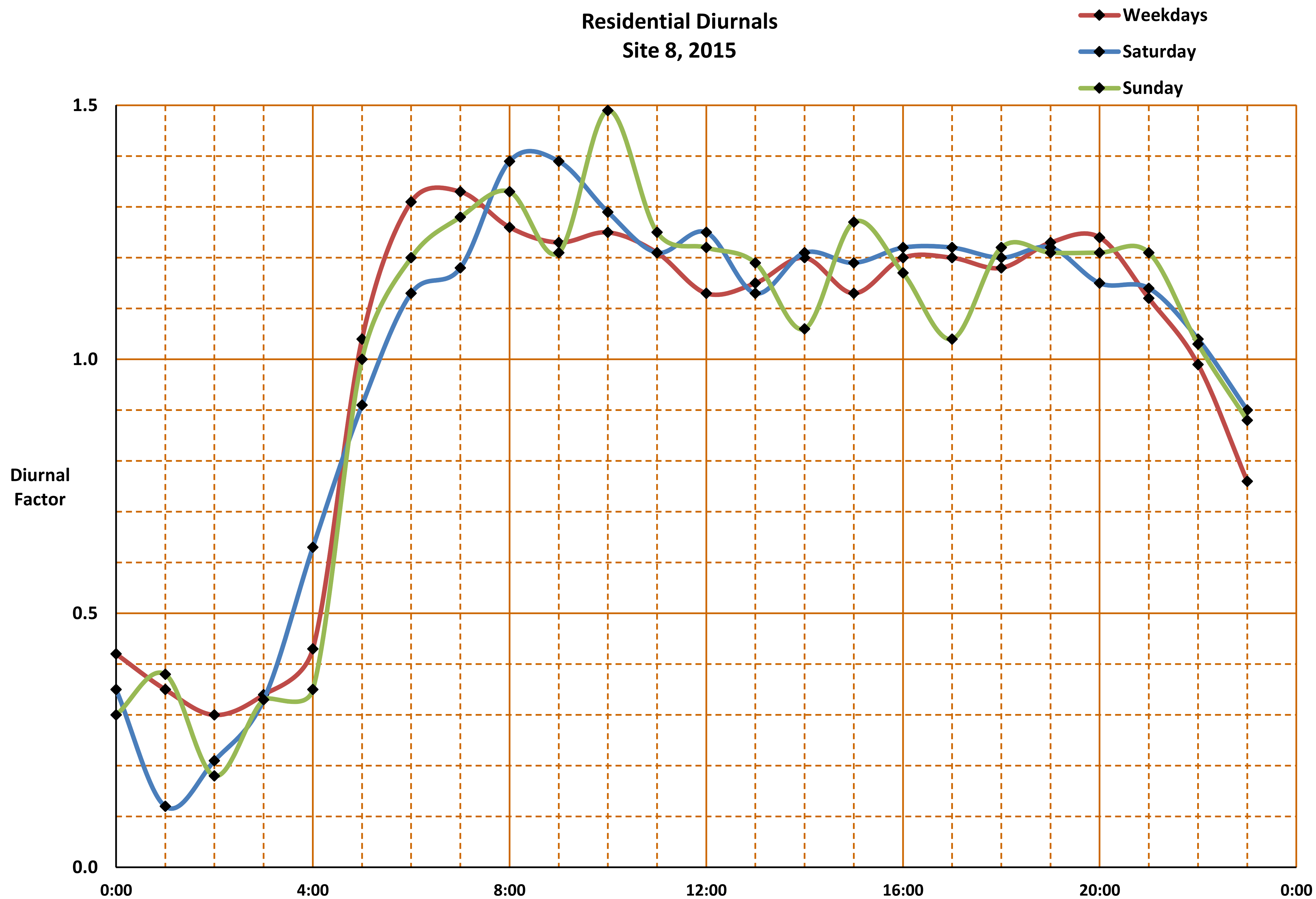
City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
RESIDENTIAL DIURNALS
SITE 7B, 2016

ISL Engineering and Land Services

FIGURE 4.13



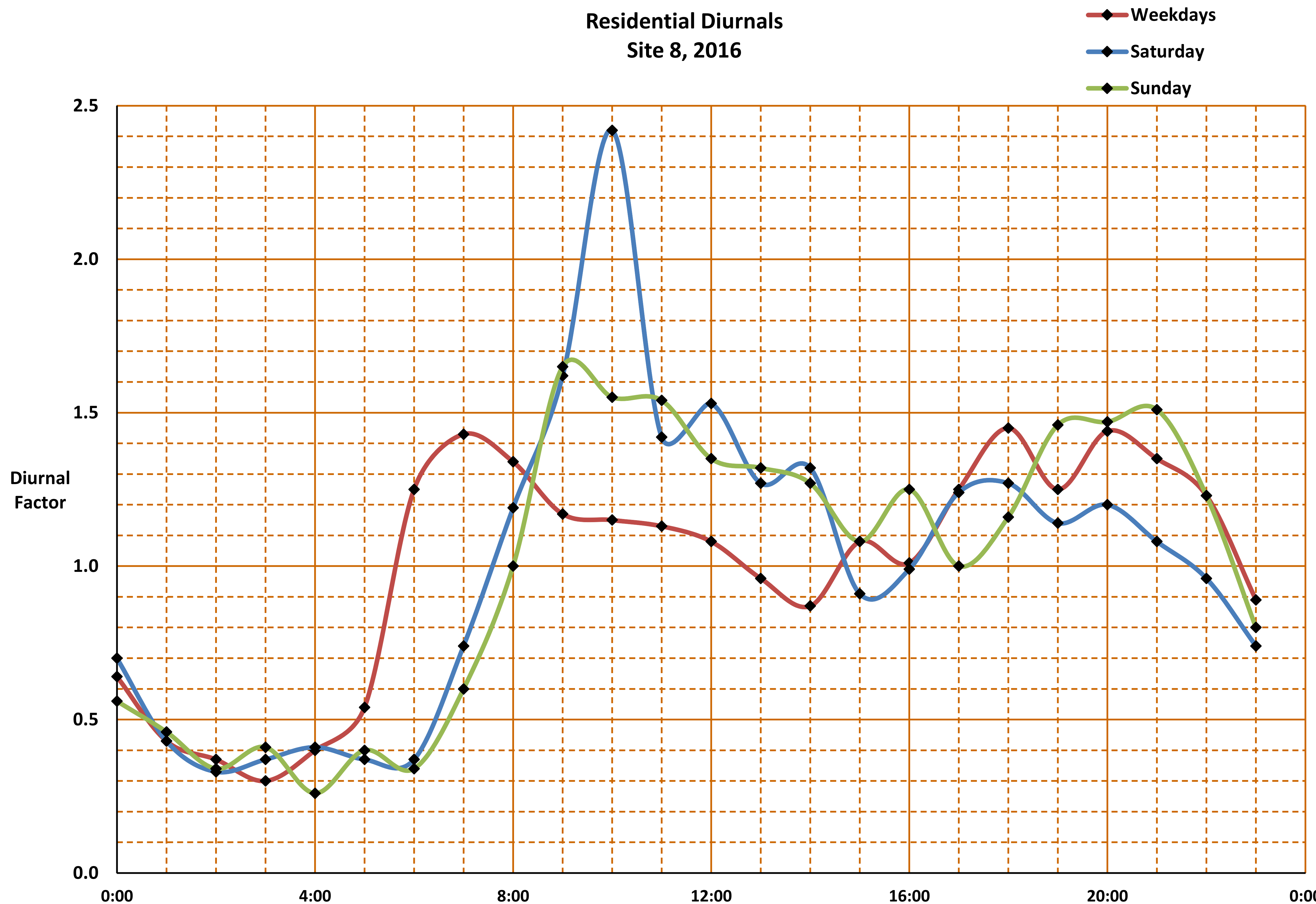
City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
RESIDENTIAL DIURNALS
SITE 8, 2015

ISL Engineering and Land Services

FIGURE 4.14

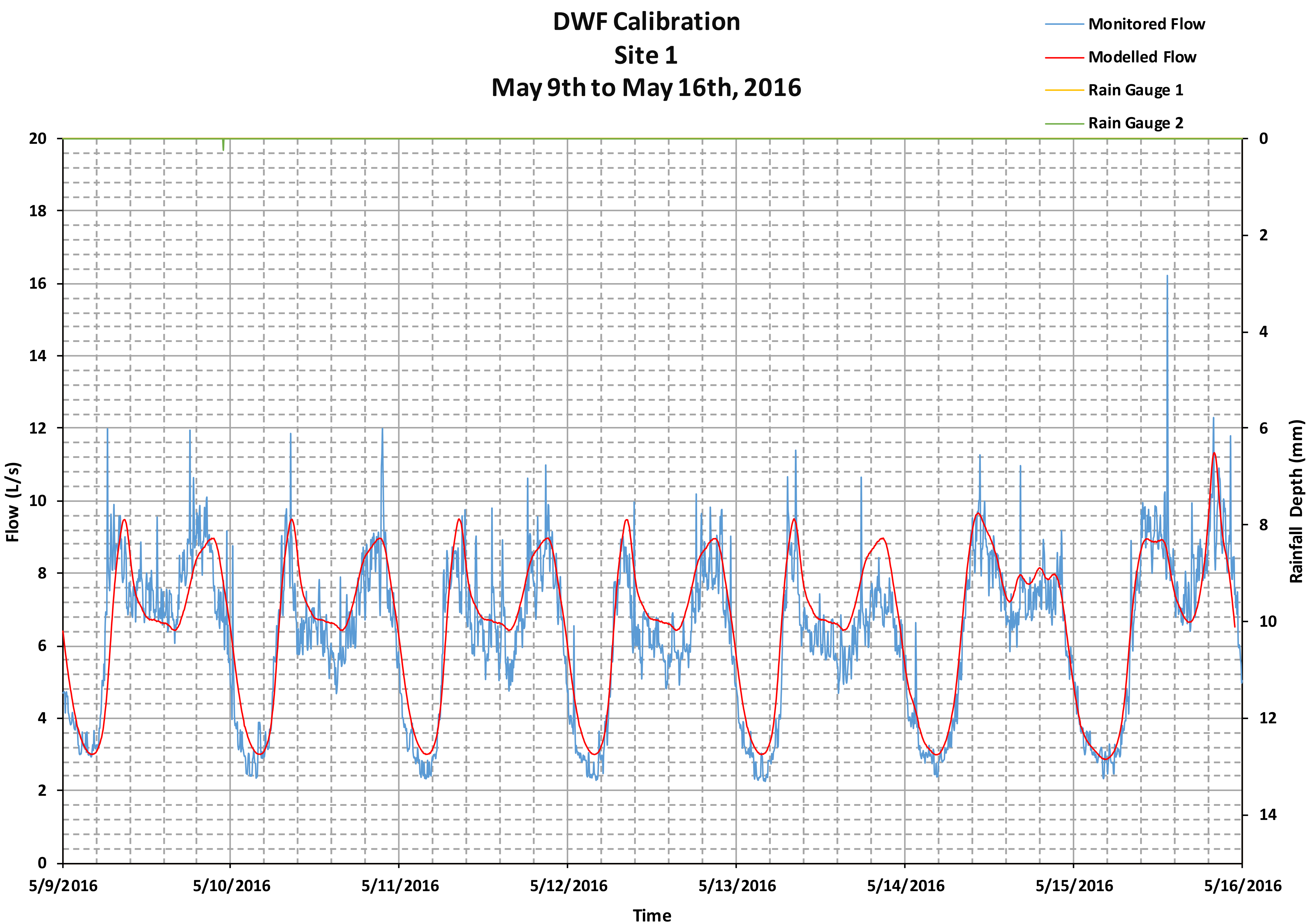


THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
RESIDENTIAL DIURNALS
SITE 8, 2016

ISL Engineering and Land Services

FIGURE 4.15



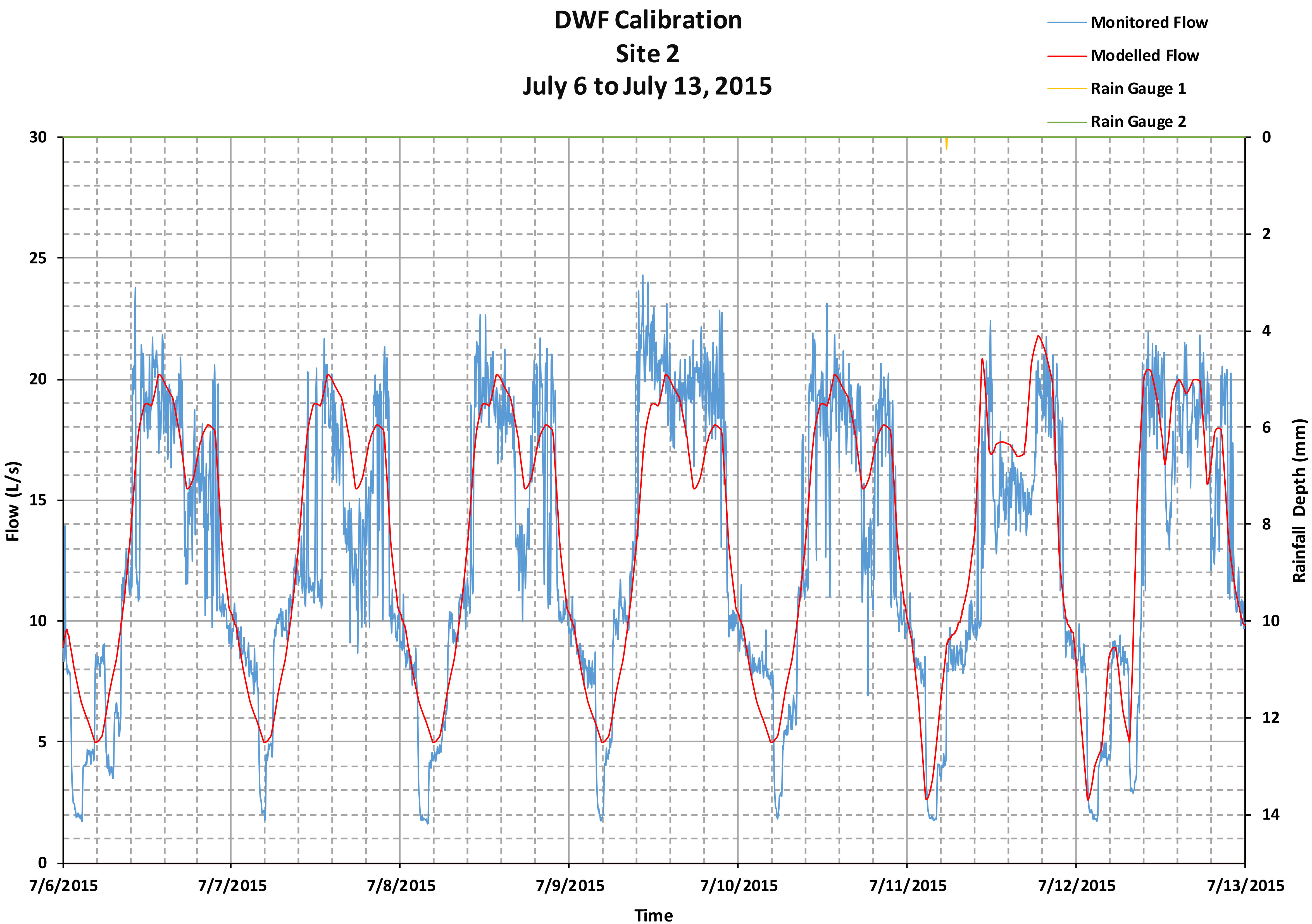
City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
SITE 1
MAY 9 TO 16, 2016

ISL Engineering and Land Services

FIGURE 4.16



City of Cold Lake

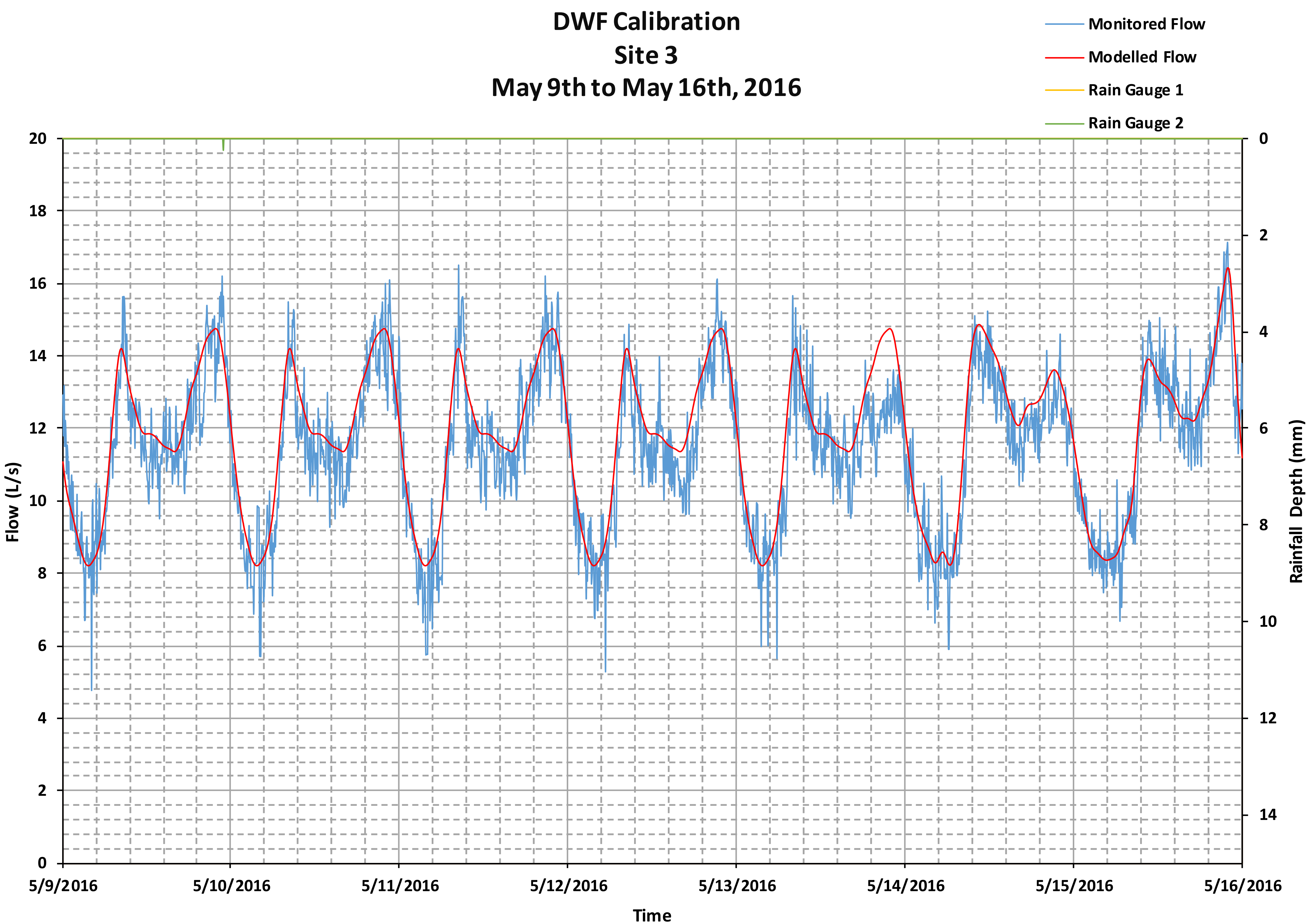
THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
SITE 2
JULY 6 TO 13, 2015

ISL Engineering and Land Services

Date: 1/8/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\4.0 Model Calibration\Figure 4.16 - DWF Site 2 2015.mxd

FIGURE 4.17



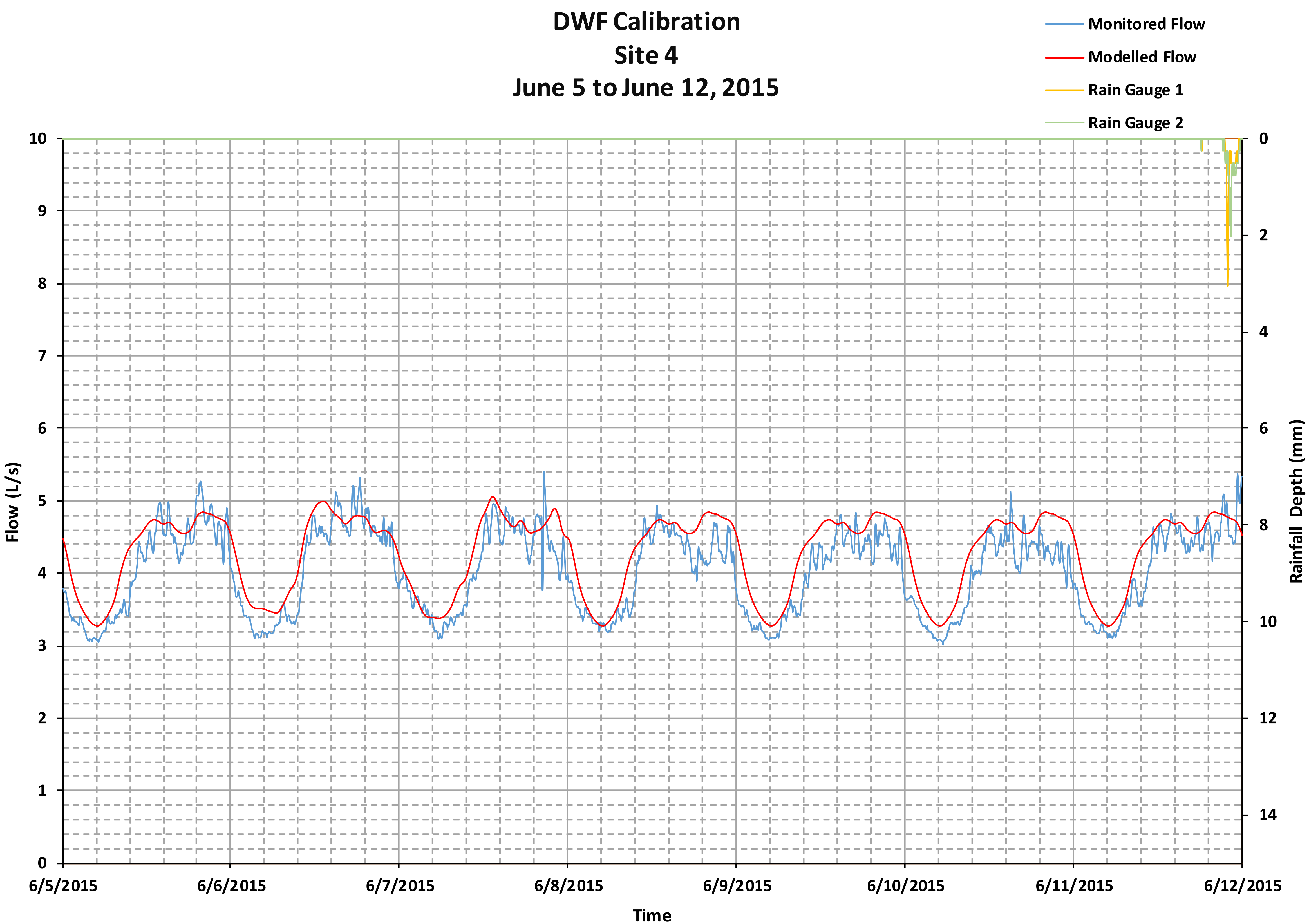
City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
SITE 3
MAY 9 TO 16, 2016

ISL Engineering and Land Services

FIGURE 4.18



City of Cold Lake

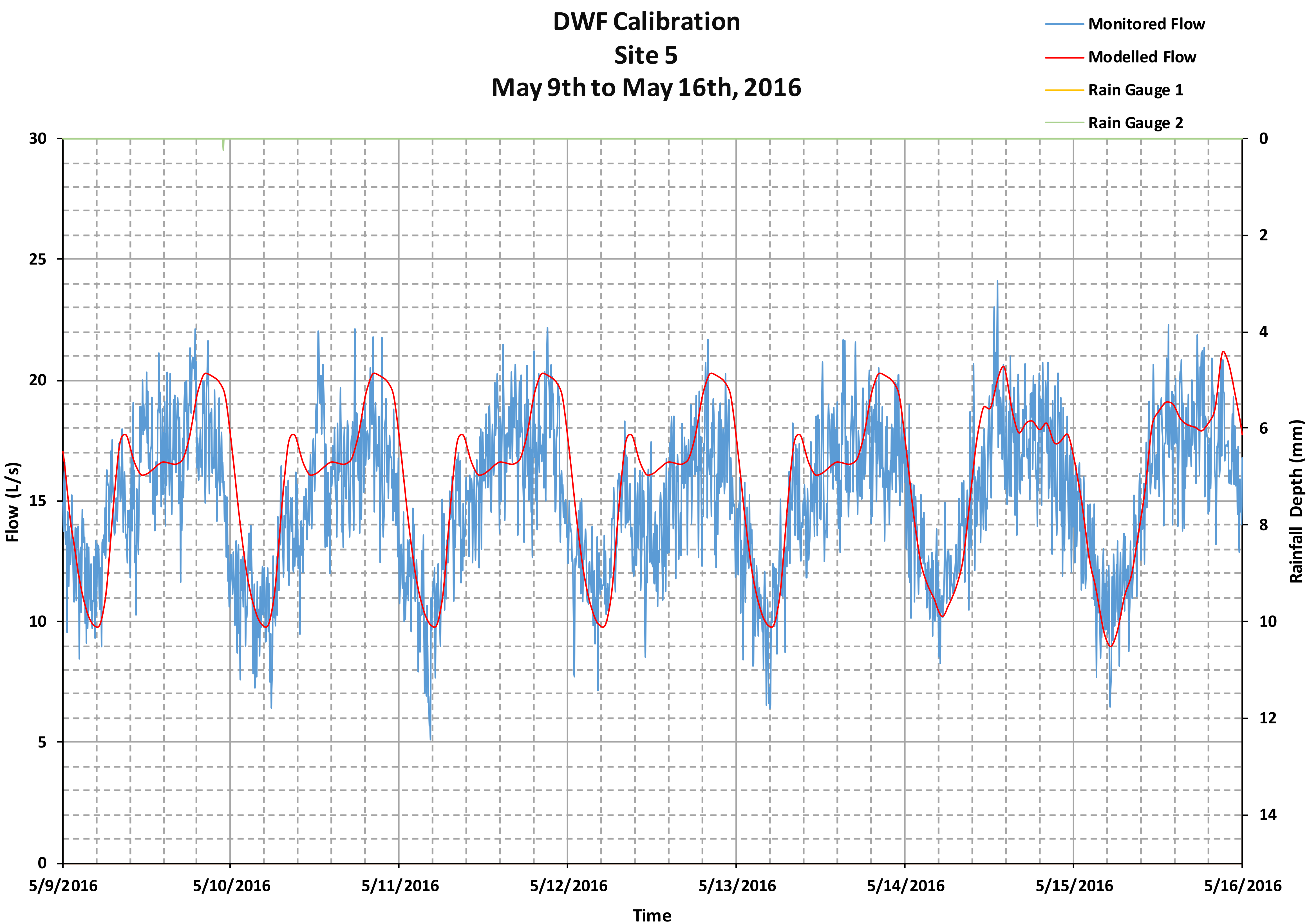
THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
SITE 4
JUNE 5 TO 12, 2015

ISL Engineering and Land Services

Date: 1/8/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\4.0 Model Calibration\Figure 4.18 - DWF Site 4 2015.mxd

FIGURE 4.19



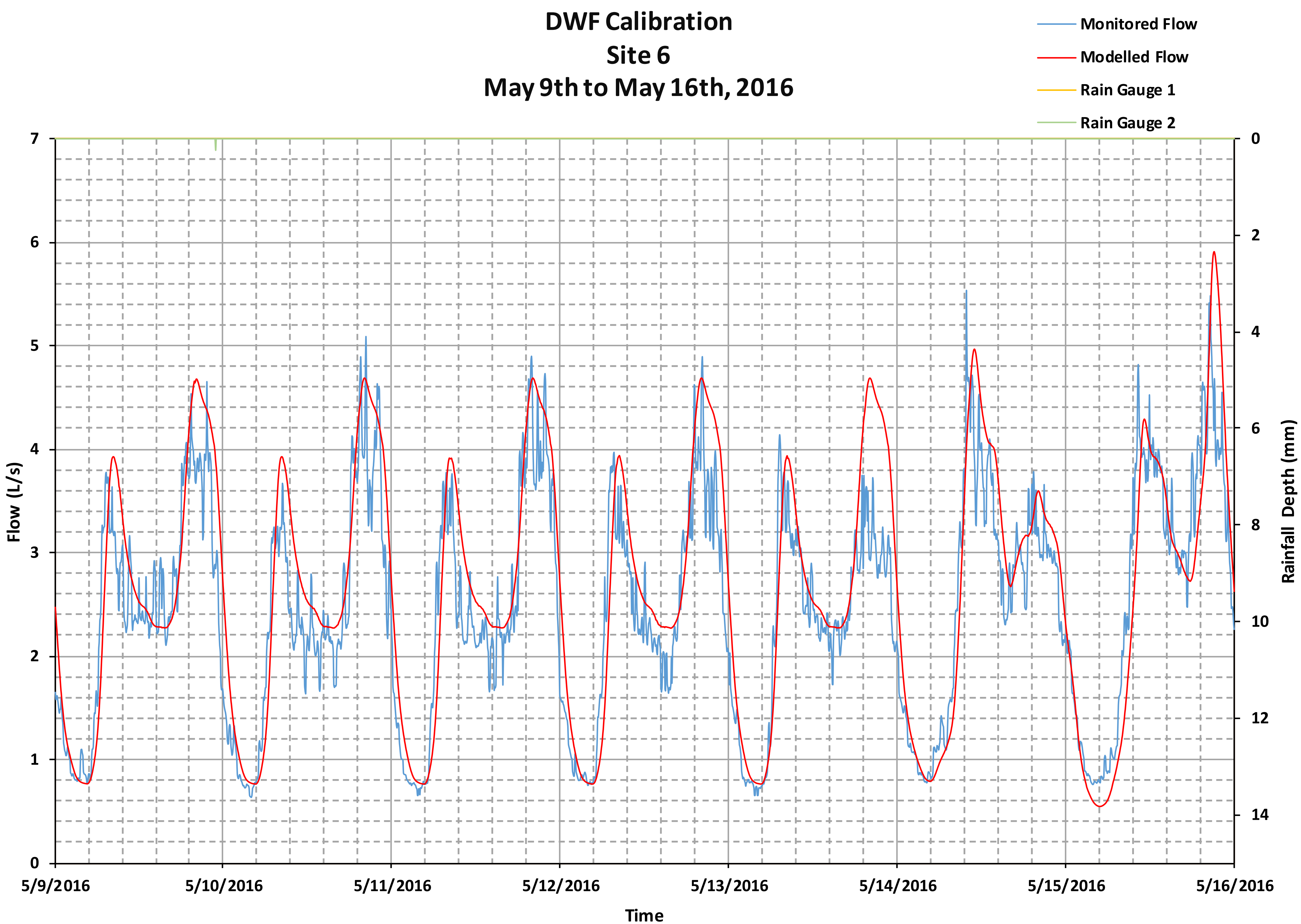
City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
SITE 5
MAY 9 TO 16, 2016

ISL Engineering and Land Services

FIGURE 4.20



City of Cold Lake

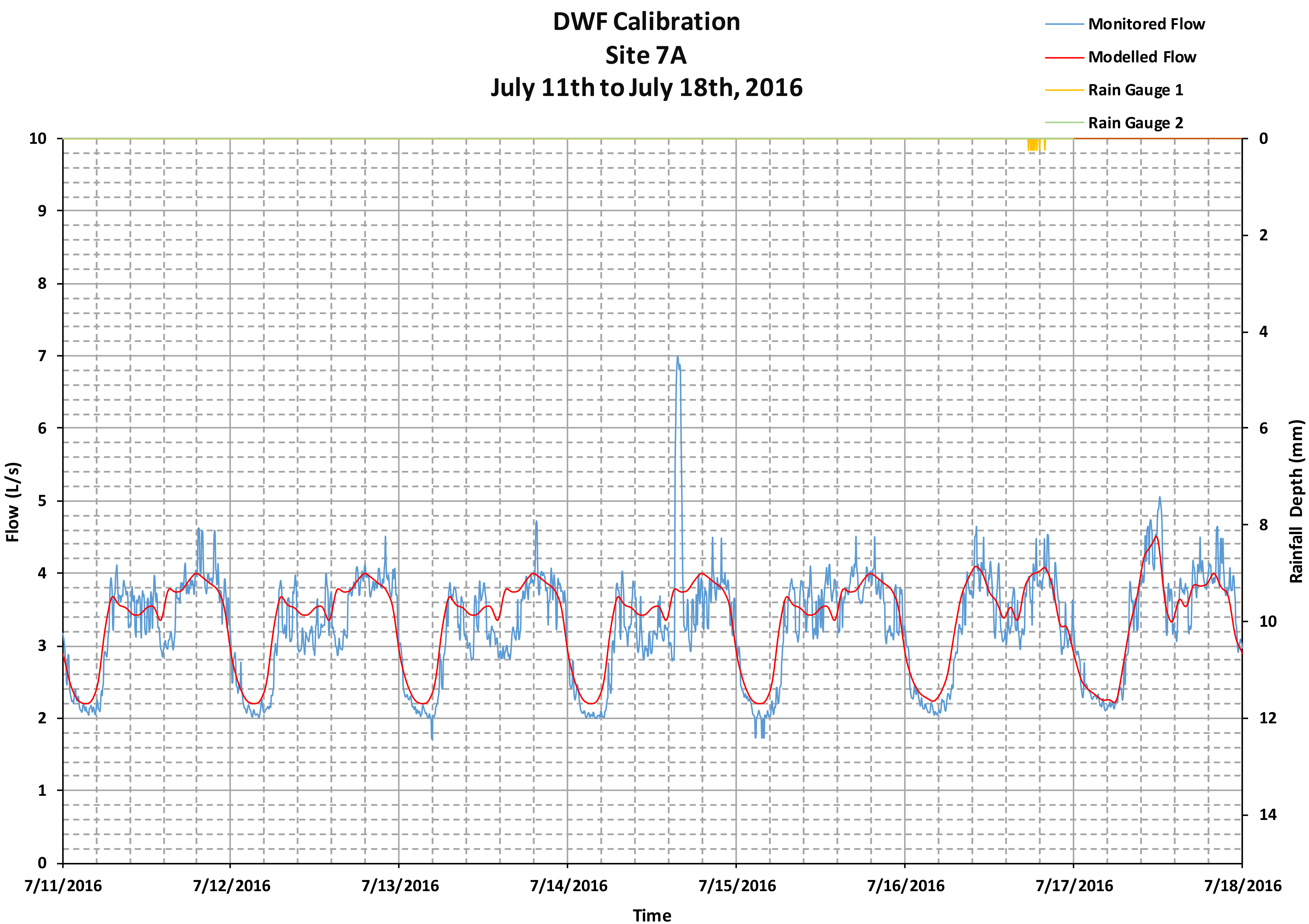
THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
SITE 6
MAY 9 TO 16, 2016

ISL Engineering and Land Services

Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\4.0 Model Calibration\Figure 4.20 - DWF Site 6 2016.mxd
Date: 1/8/2017

FIGURE 4.21



City of Cold Lake

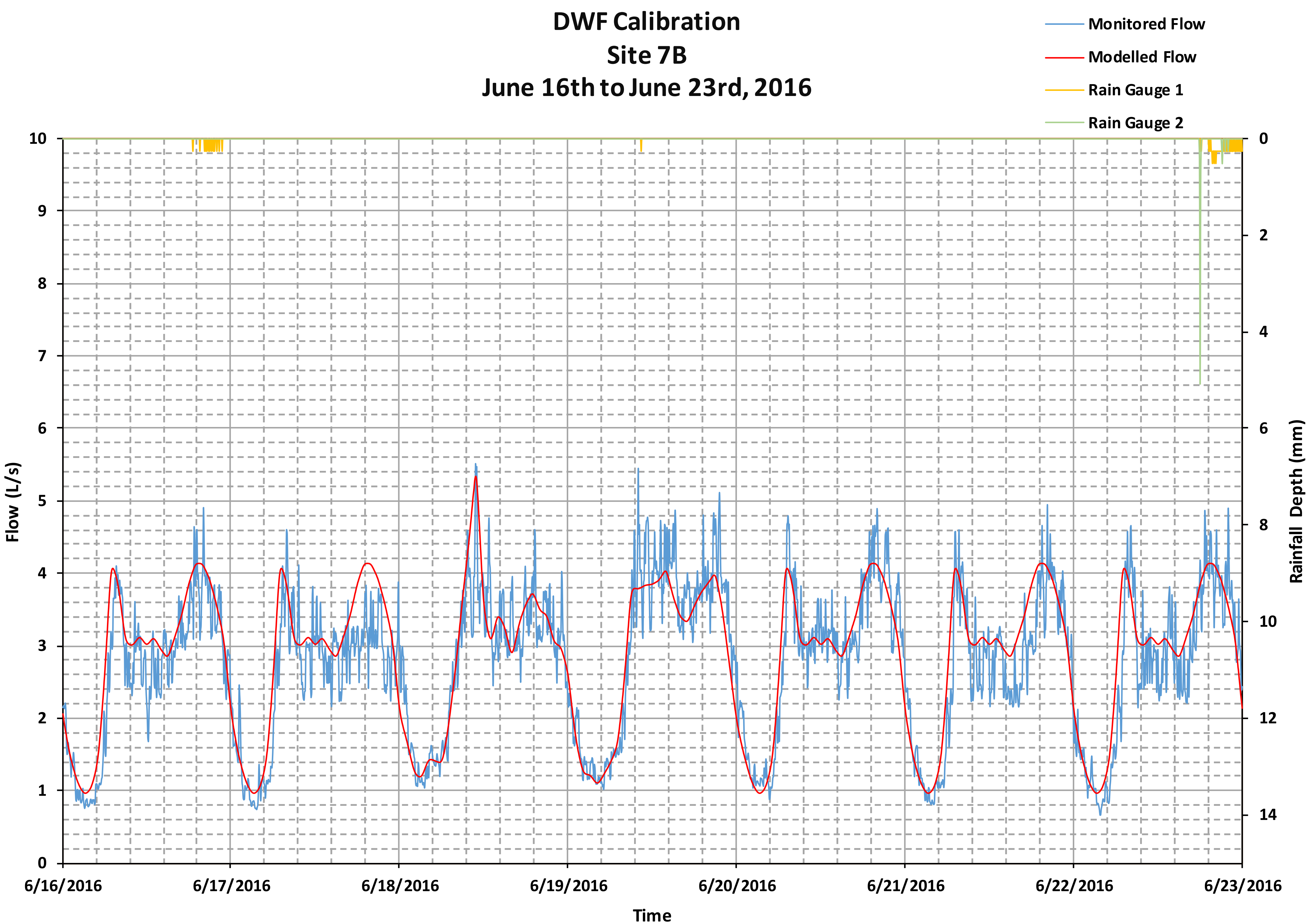
THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
SITE 7A
JULY 11 TO 18, 2016

ISL Engineering and Land Services

Date: 1/8/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\4.0 Model Calibration\Figure 4.21 - DWF Site 7A 2016.mxd

FIGURE 4.22



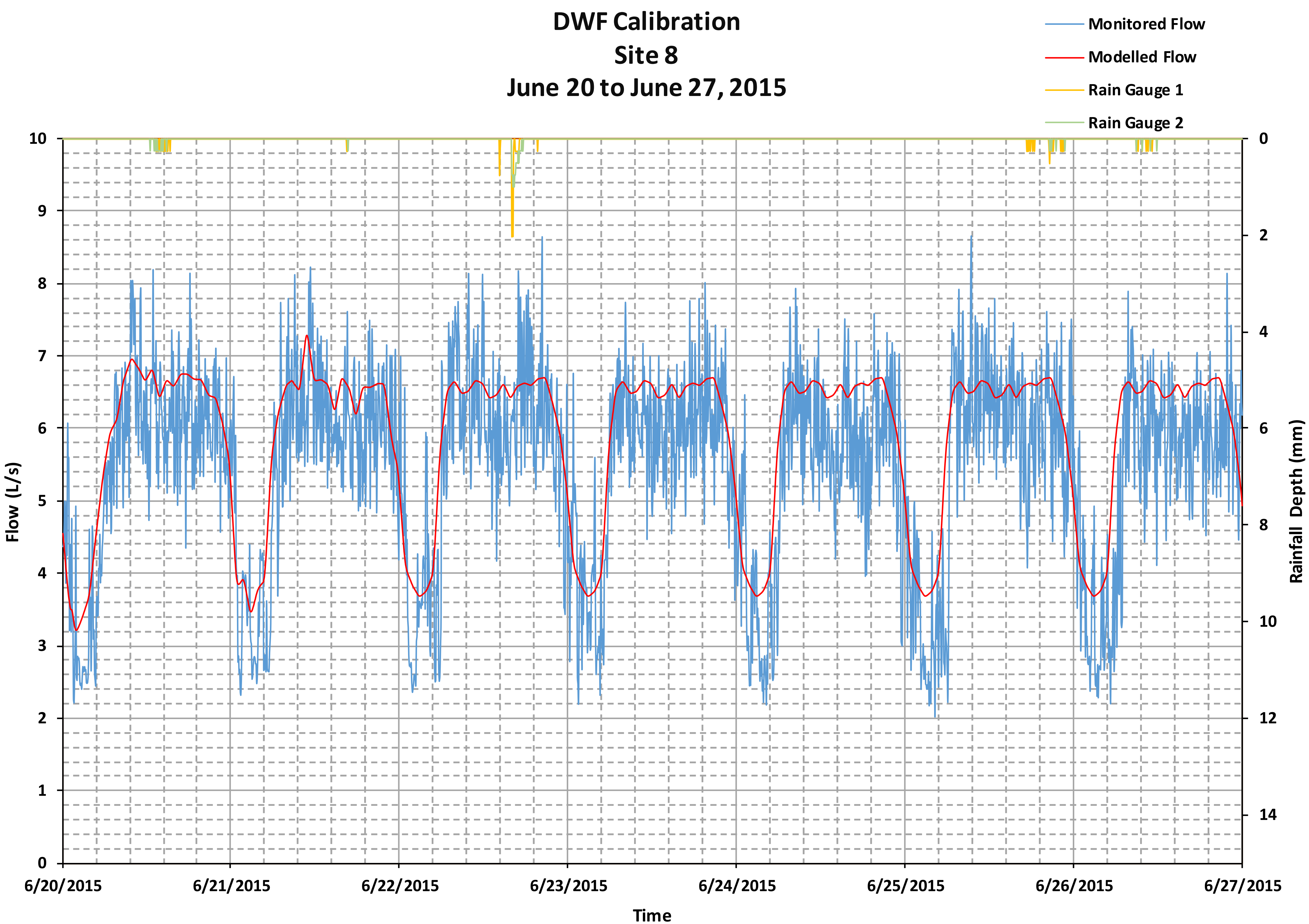
City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
SITE 7B
JUNE 16 TO 23, 2016

ISL Engineering and Land Services

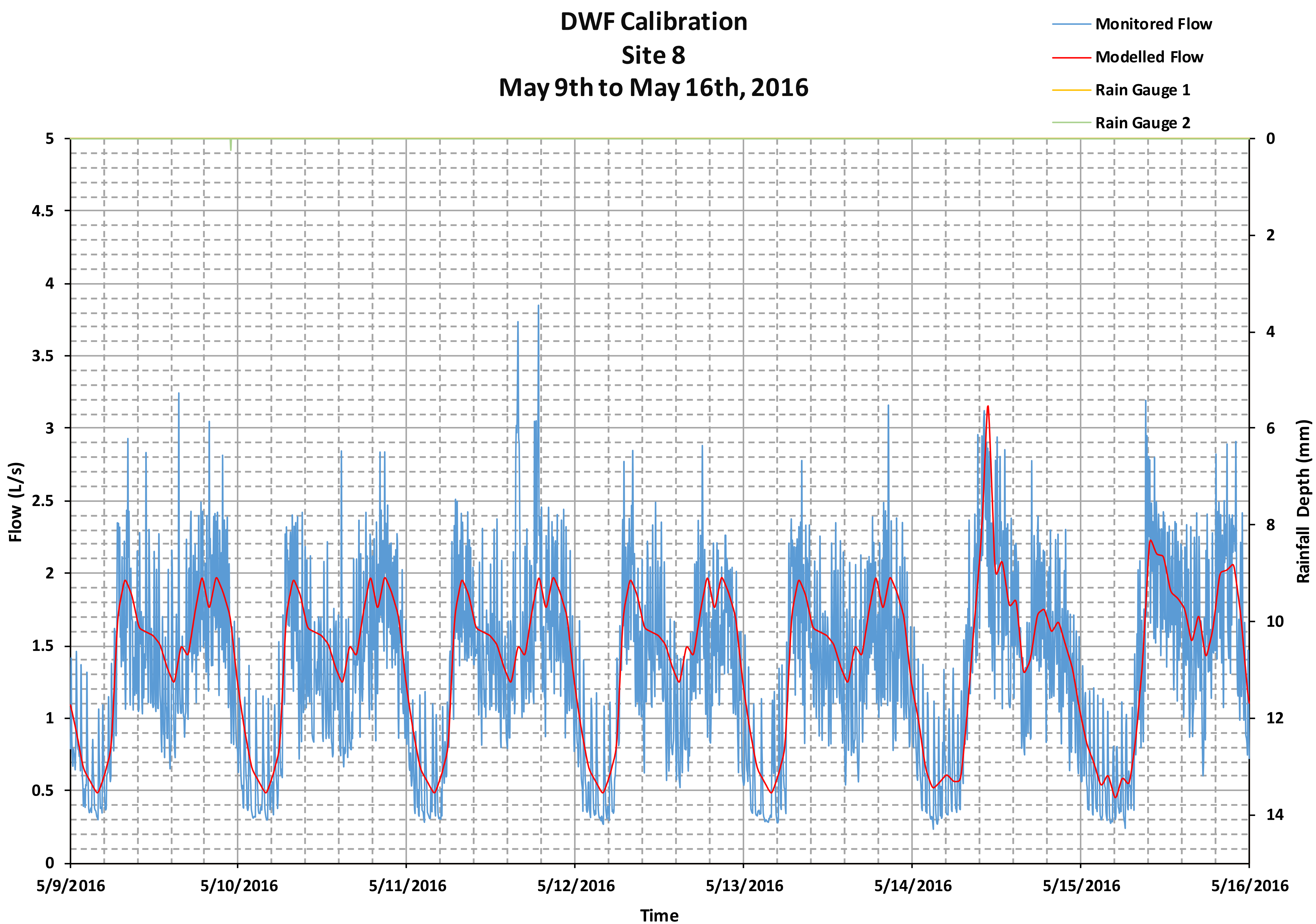
FIGURE 4.23



THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
SITE 8
JUNE 20 TO 27, 2015

ISL Engineering and Land Services



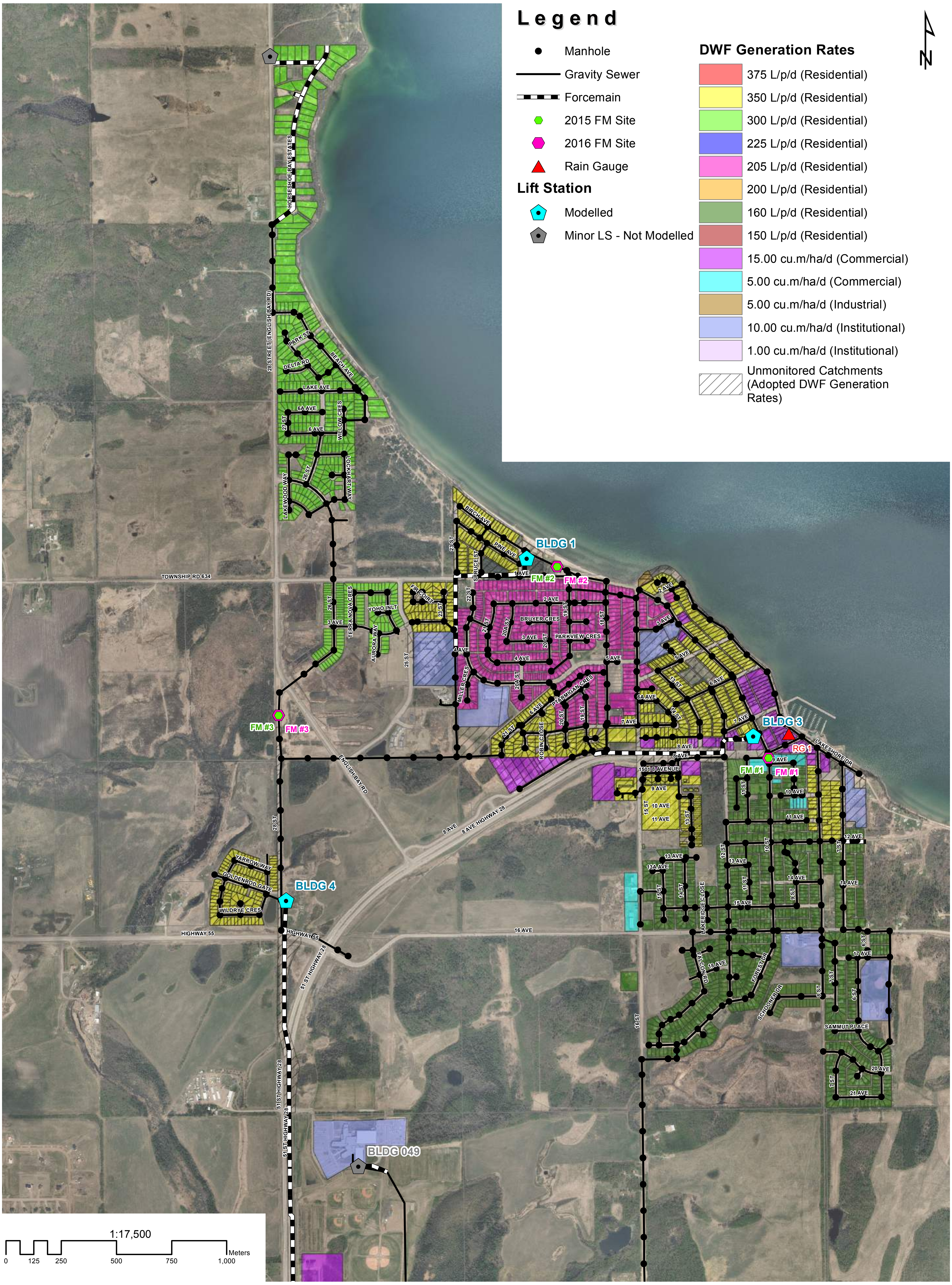
City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

DRY WEATHER FLOW CALIBRATION
SITE 8
MAY 9 TO 16, 2016

ISL Engineering and Land Services

FIGURE 4.25



THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

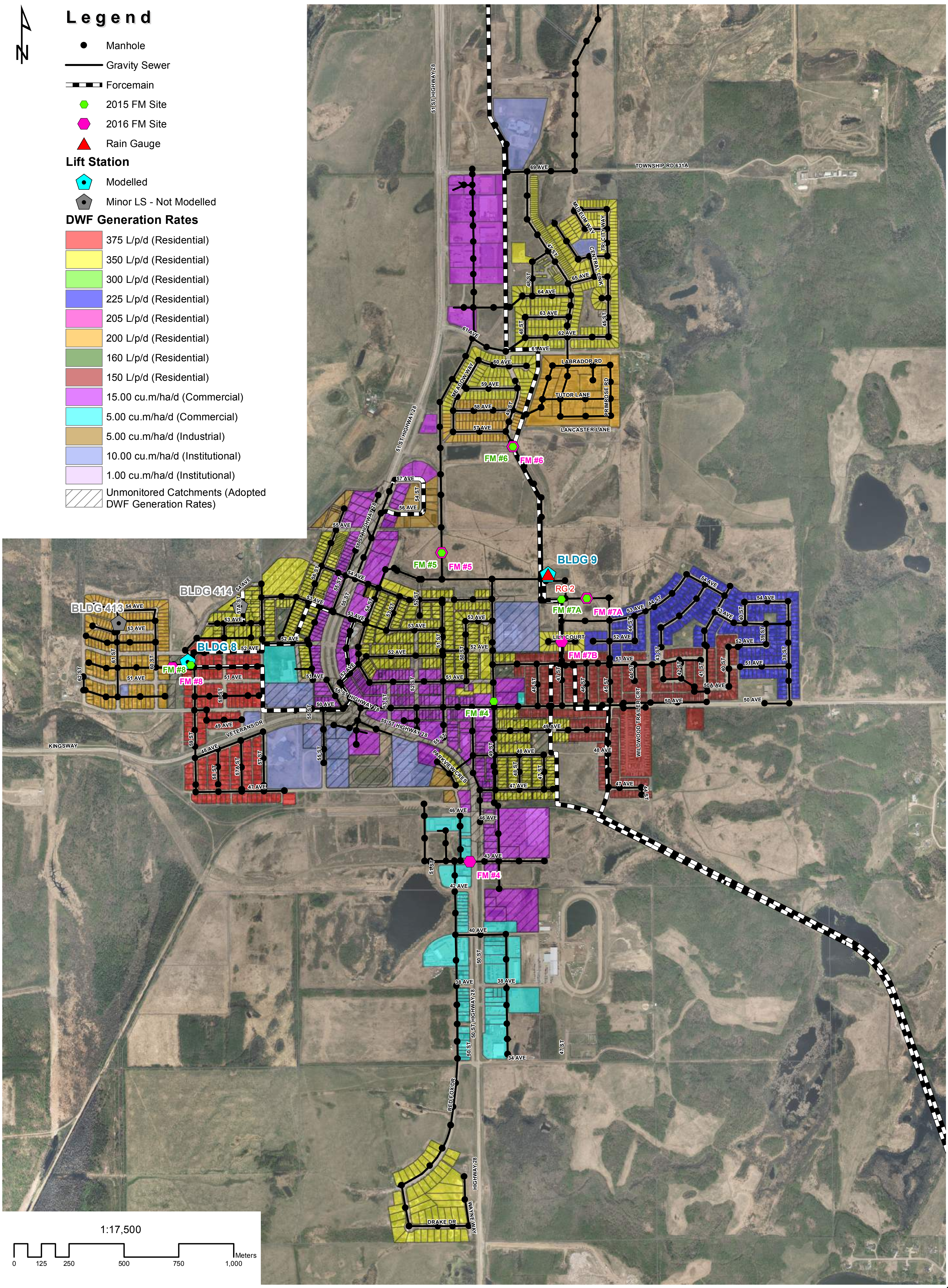
SANITARY COLLECTION SYSTEM
EXISTING NETWORK - NORTH
DRY WEATHER FLOW CALIBRATION
GENERATION RATES

City of Cold Lake

ISL Engineering and Land Services

Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\4.0 Model Calibration\Figure 4.25 - DWF Generation Rates_North.mxd

FIGURE 4.26



THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - SOUTH
DRY WEATHER FLOW CALIBRATION
GENERATION RATES

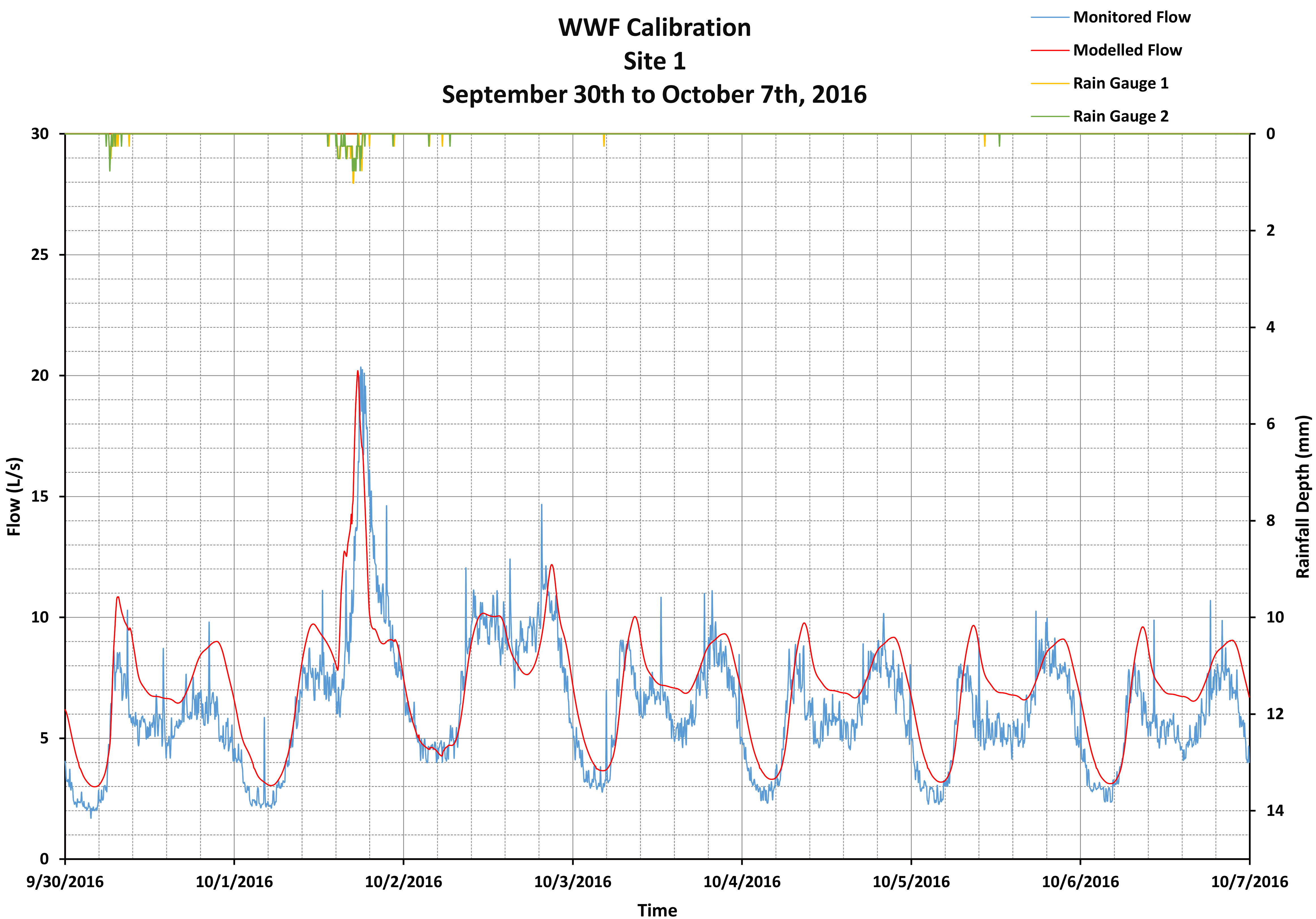
City of Cold Lake

ISL Engineering and Land Services

Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\4.0 Model Calibration\Figure 4.26 - DWF Generation Rates_South.mxd

FIGURE 4.27

WWF Calibration
Site 1
September 30th to October 7th, 2016



City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

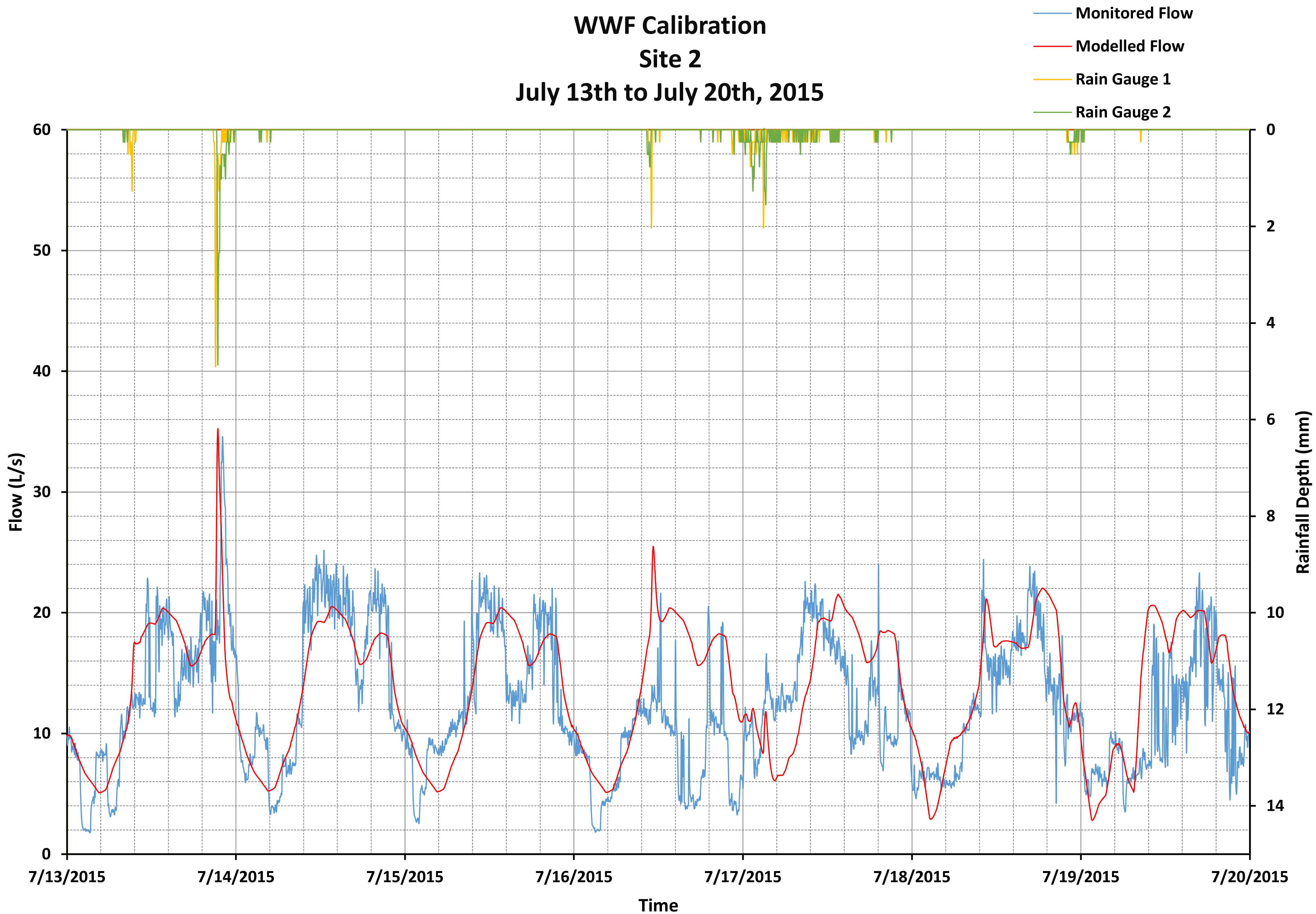
WET WEATHER FLOW CALIBRATION
SITE 1
SEPTEMBER 30 TO OCTOBER 7, 2016

ISL Engineering and Land Services

Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\4.0 Model Calibration\Figure 4.27 - WWF Site 1 2016.mxd

Date: 1/8/2017

FIGURE 4.28



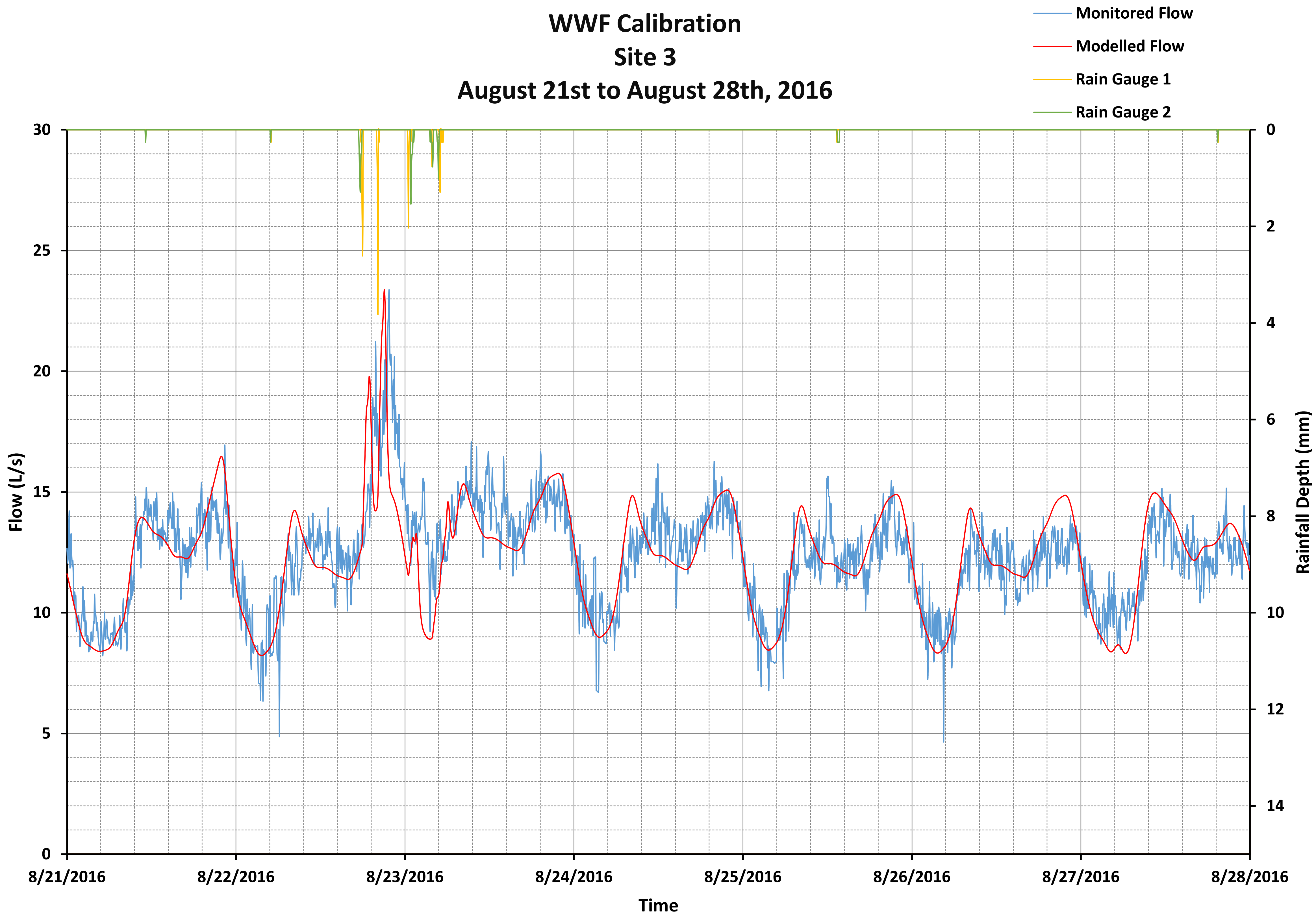
THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

WET WEATHER FLOW CALIBRATION
SITE 2
JULY 13 TO JULY 20, 2015

Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\4.0 Model Calibration\Figure 4.28 - WWF Site 2 2015.mxd

Date: 1/8/2017

FIGURE 4.29



City of Cold Lake

THE CITY OF COLD LAKE INFLOW - INFILTRATION PROGRAM

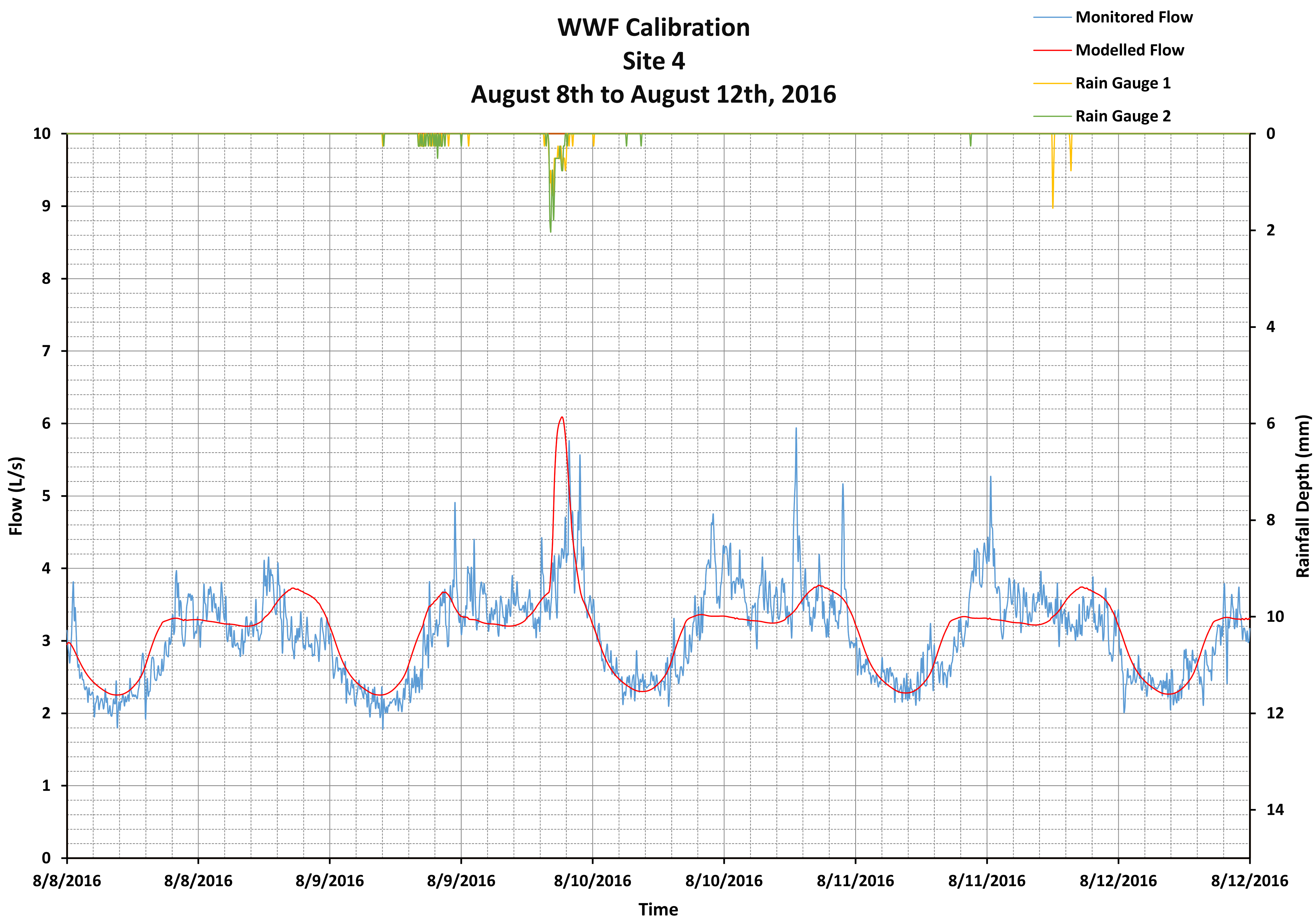
WET WEATHER FLOW CALIBRATION
SITE 3
AUGUST 21 TO AUGUST 28, 2016

ISL Engineering and Land Services

Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\4.0 Model Calibration\Figure 4.29 - WWF Site 3 2016.mxd

Date: 1/8/2017

FIGURE 4.30

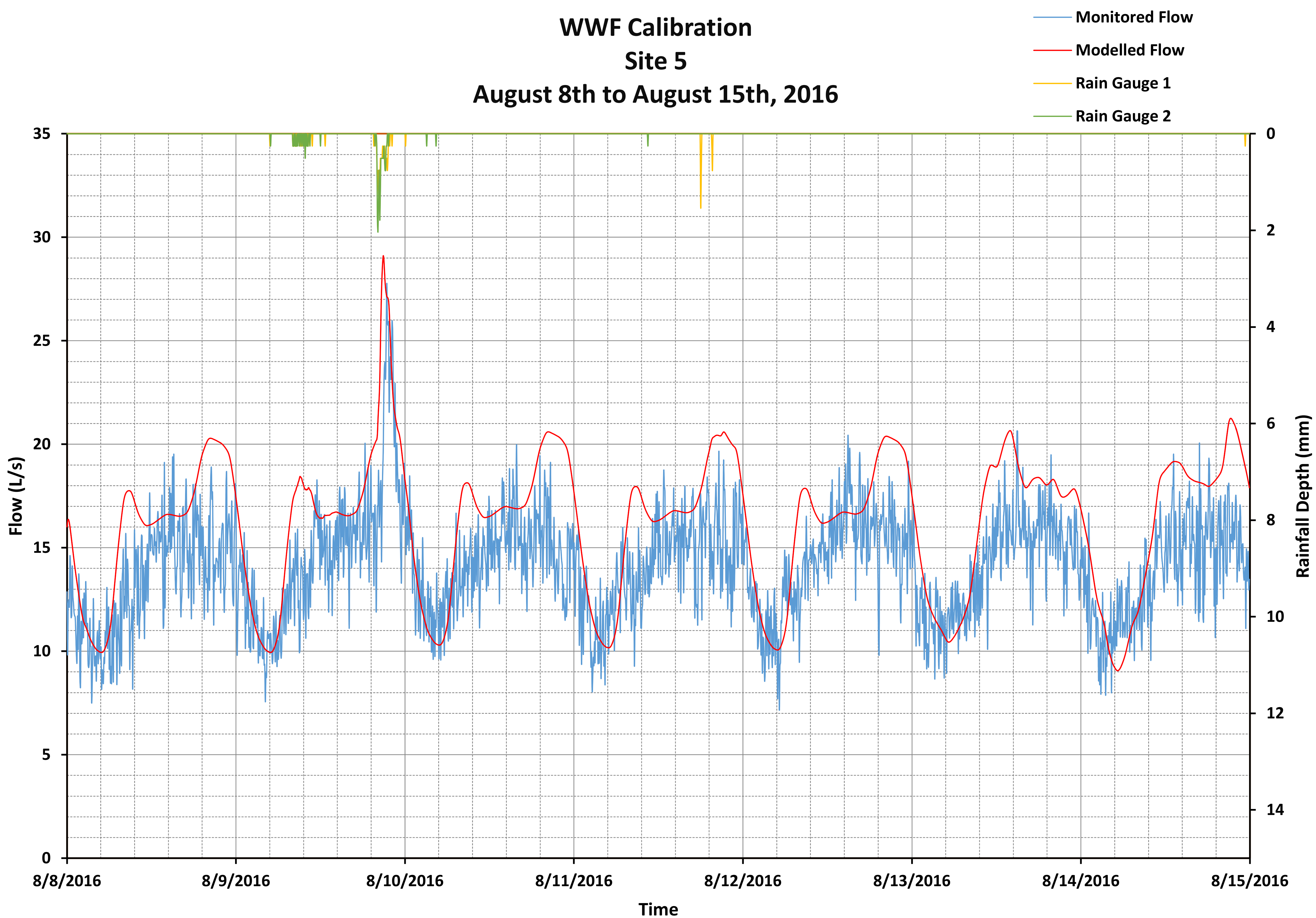


THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

WET WEATHER FLOW CALIBRATION
SITE 4
AUGUST 8 TO AUGUST 12, 2016

ISL Engineering and Land Services

FIGURE 4.31



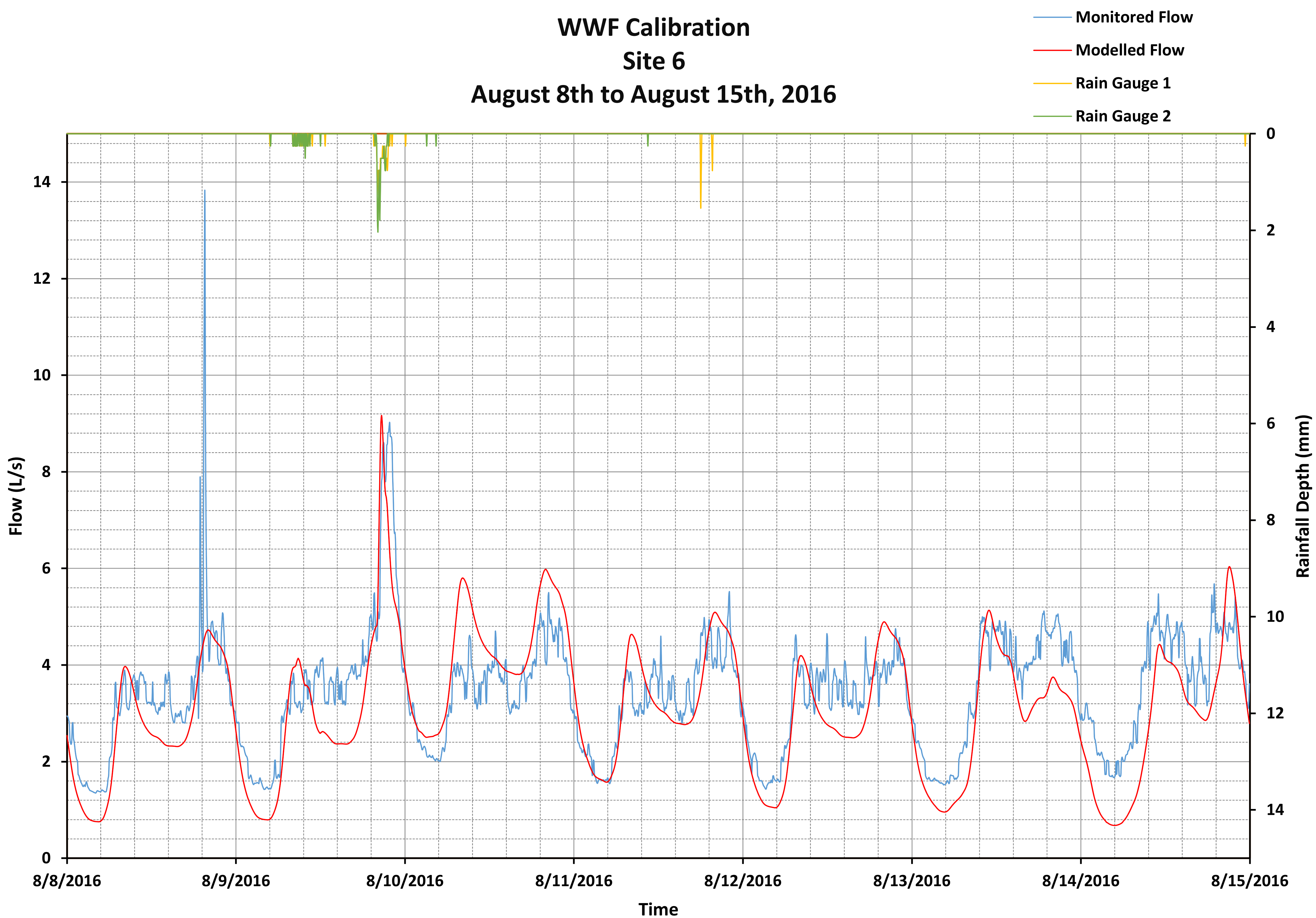
City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

WET WEATHER FLOW CALIBRATION
SITE 5
AUGUST 8 TO AUGUST 15, 2016

ISL Engineering and Land Services

FIGURE 4.32



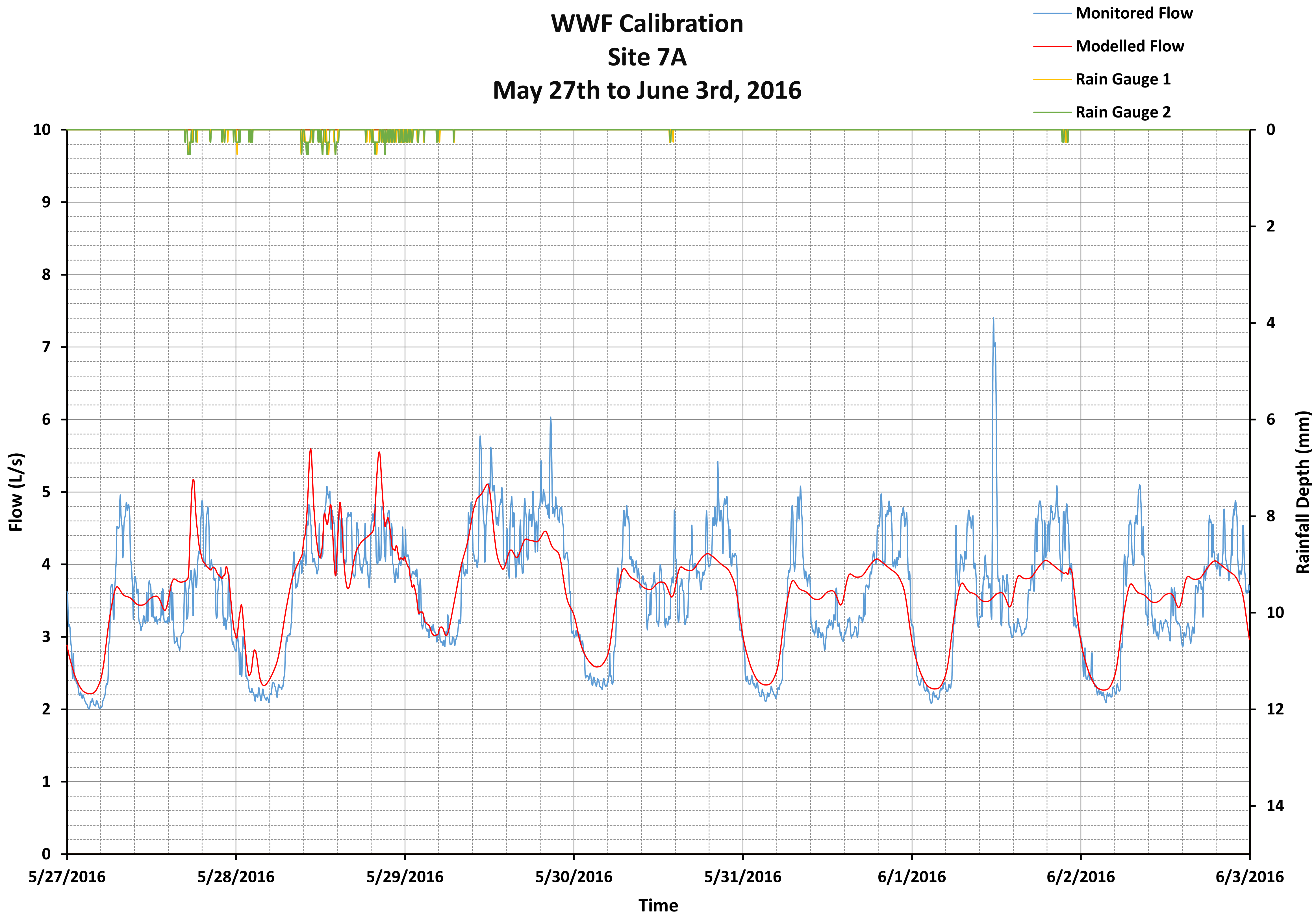
City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

WET WEATHER FLOW CALIBRATION
SITE 6
AUGUST 8 TO AUGUST 15, 2016

ISL Engineering and Land Services

FIGURE 4.33



City of Cold Lake

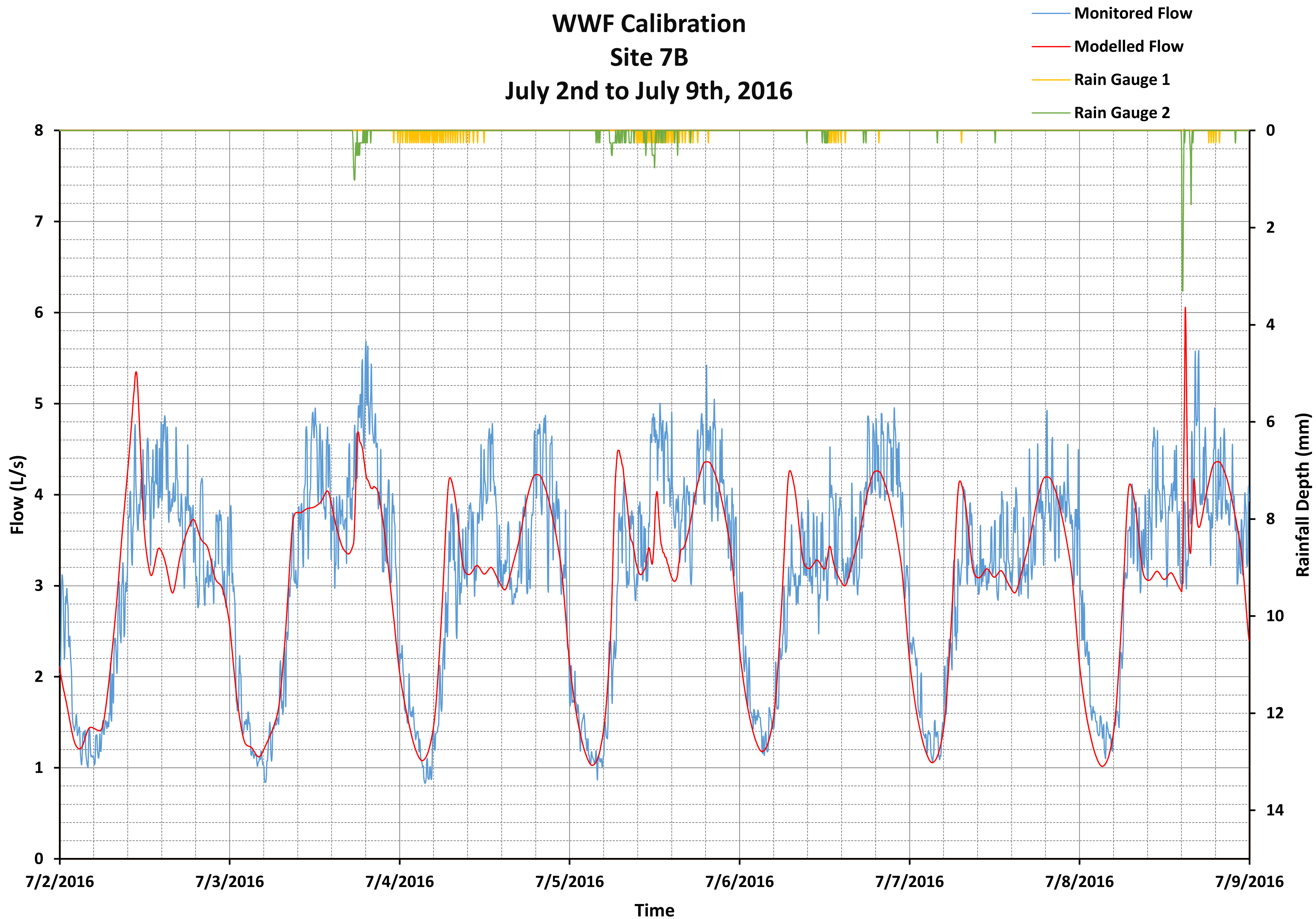
THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

WET WEATHER FLOW CALIBRATION
SITE 7A
MAY 27 TO JUNE 3, 2016

ISL Engineering and Land Services

Date: 1/8/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\4.0 Model Calibration\Figure 4.33 - WWF Site 7A 2016.mxd

FIGURE 4.34



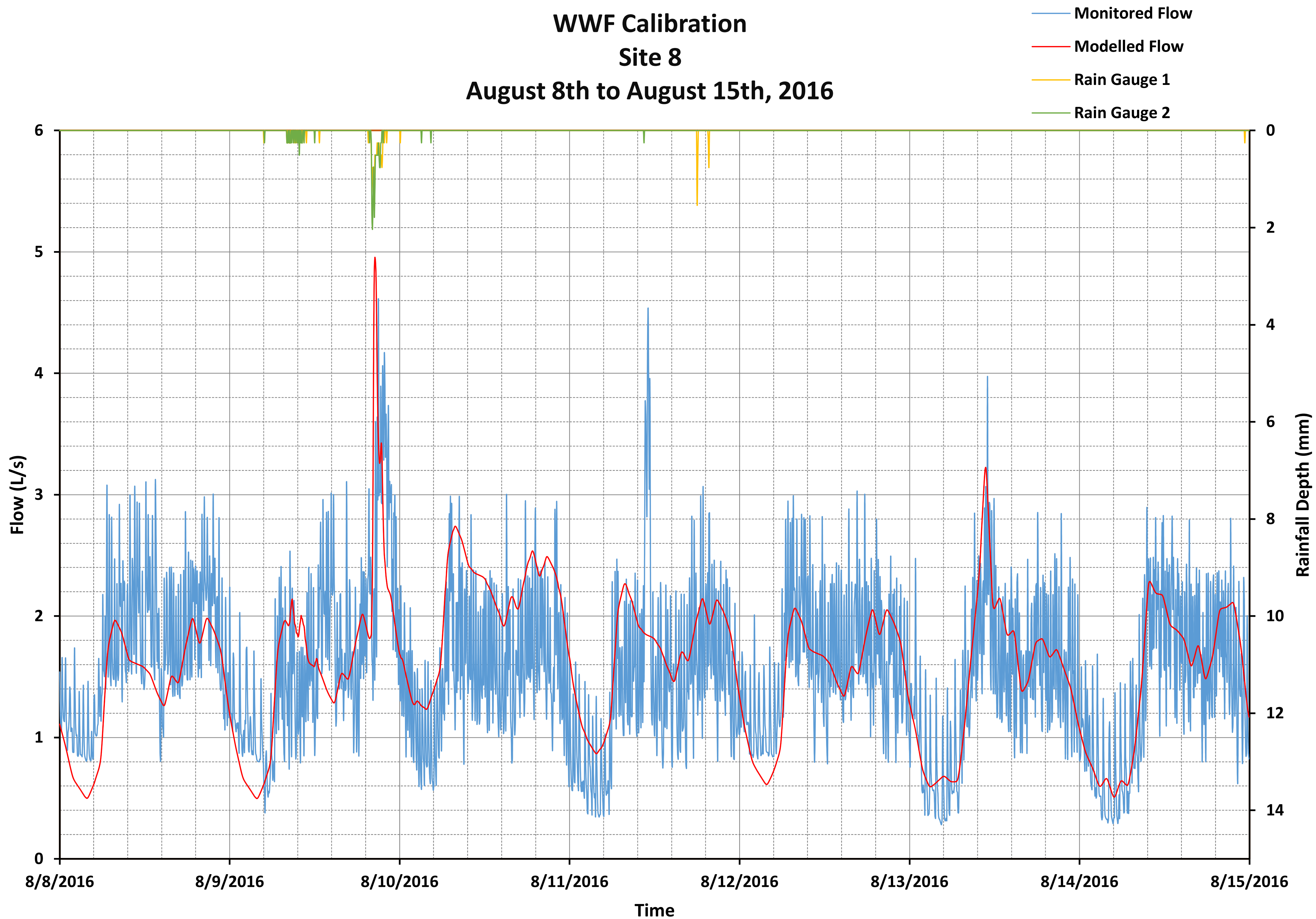
City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

WET WEATHER FLOW CALIBRATION
SITE 7B
JULY 2 TO JULY 9, 2016

ISL Engineering and Land Services

FIGURE 4.35



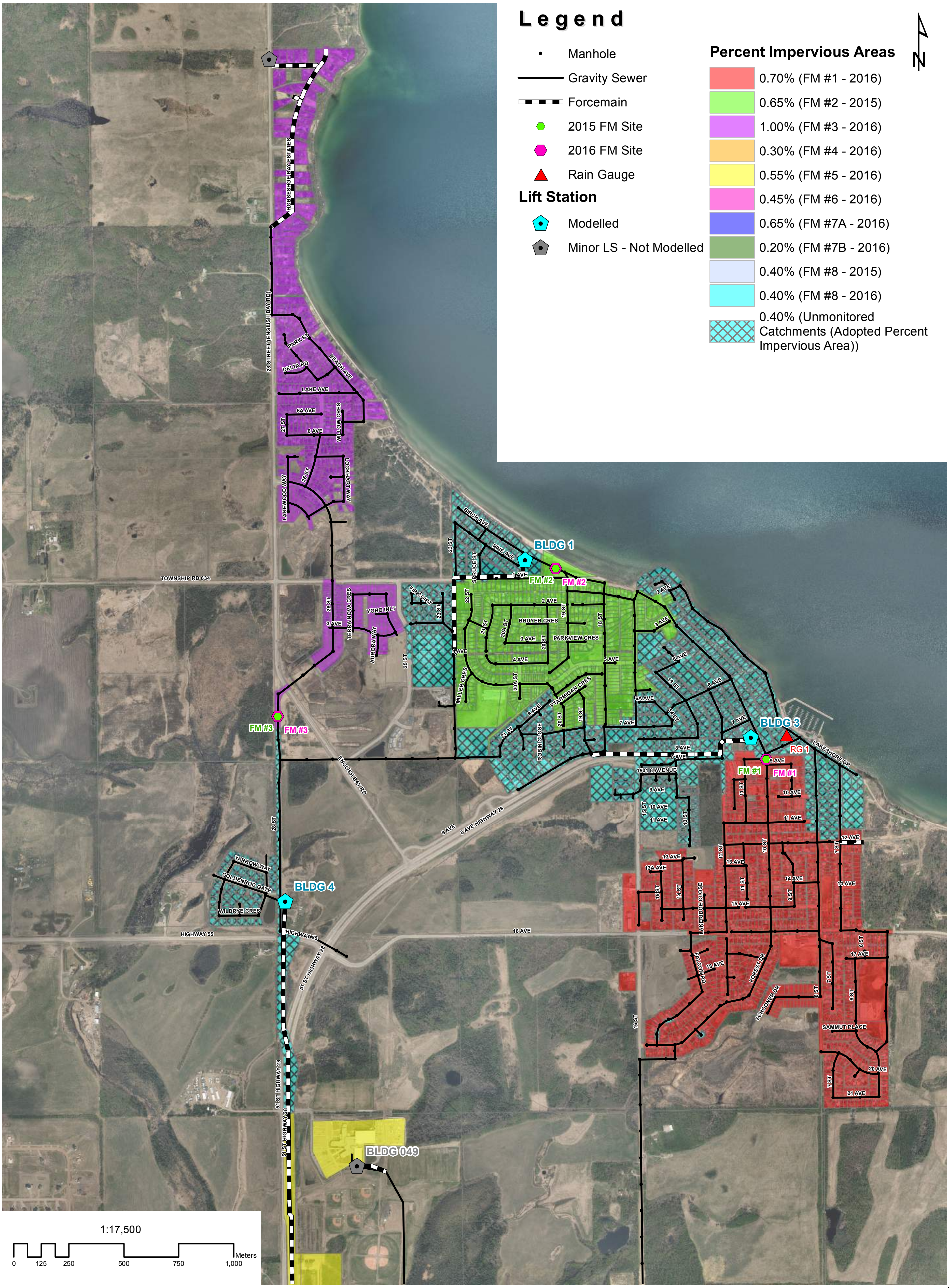
City of Cold Lake

THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

WET WEATHER FLOW CALIBRATION
SITE 8
AUGUST 8 TO AUGUST 15, 2016

ISL Engineering and Land Services

FIGURE 4.36



THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

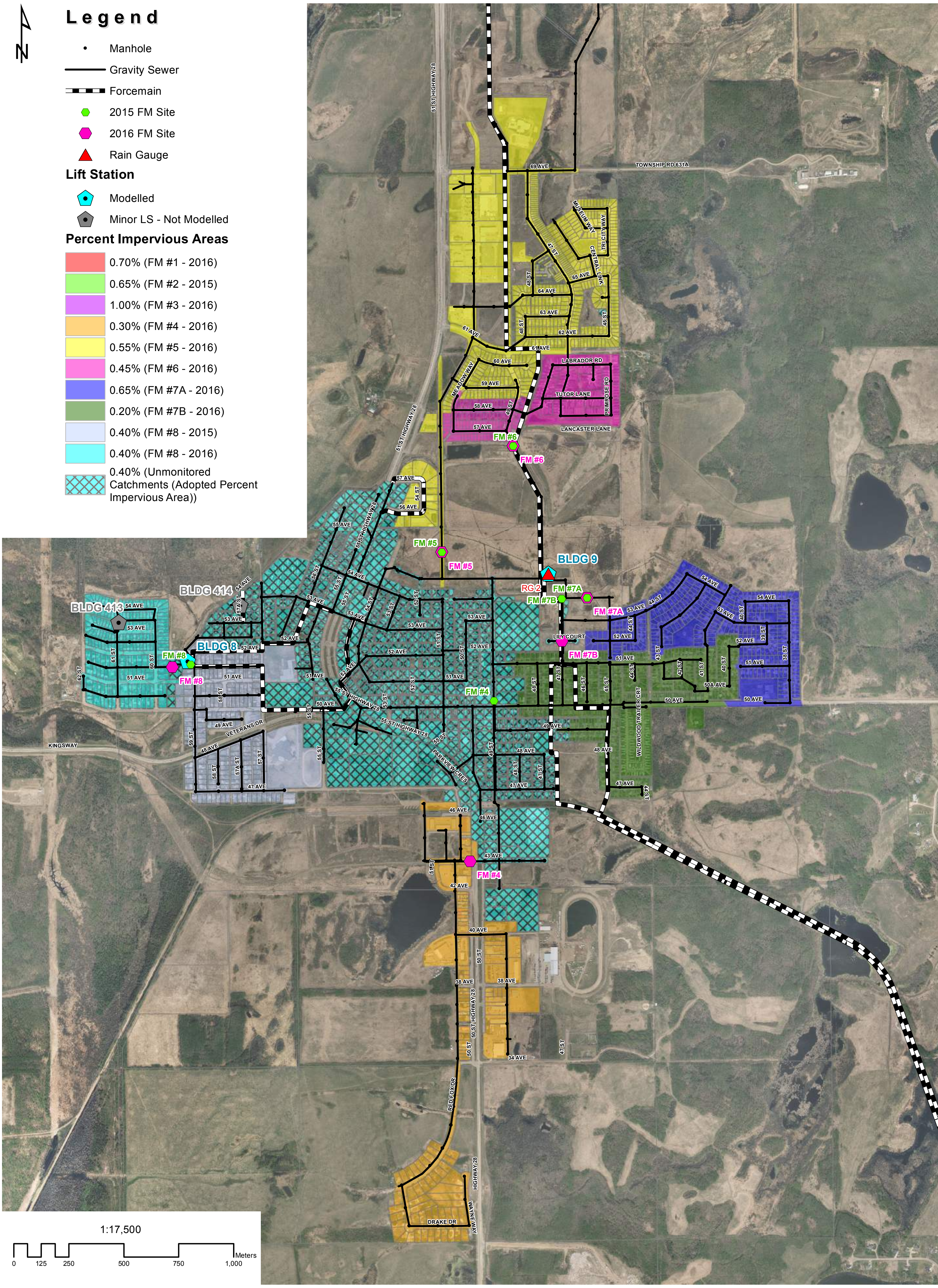
SANITARY COLLECTION SYSTEM
EXISTING NETWORK - NORTH
WET WEATHER FLOW CALIBRATION
PERCENT IMPERVIOUS AREAS

City of Cold Lake

ISL Engineering and Land Services

Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\4.0 Model Calibration\Figure 4.36 - WWF Percent Impervious Areas_North.mxd

FIGURE 4.37



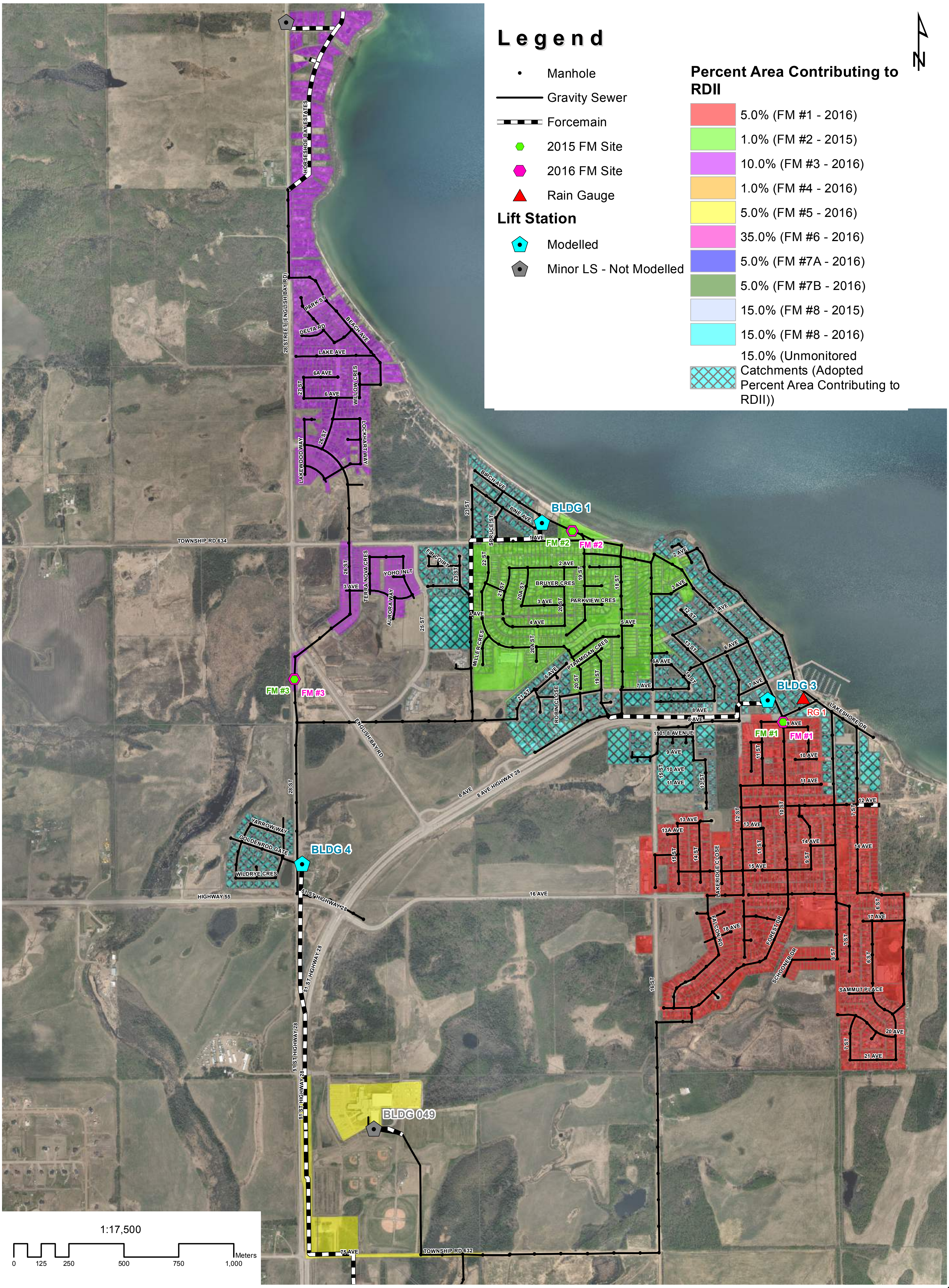
THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM
SANITARY COLLECTION SYSTEM
EXISTING NETWORK - SOUTH
WET WEATHER FLOW CALIBRATION
PERCENT IMPERVIOUS AREAS

City of Cold Lake

ISL Engineering and Land Services

Date: 10/19/2017 Document: M:\26300\26367_Cold_Lake_I-I_Program\02_CADD\20_Drafting\201_GIS Figures\4.0 Model Calibration\Figure 4.37 - WWF Percent Impervious Areas_South.mxd

FIGURE 4.38



THE CITY OF COLD LAKE
INFLOW - INFILTRATION PROGRAM

SANITARY COLLECTION SYSTEM
EXISTING NETWORK - NORTH
WET WEATHER FLOW CALIBRATION
PERCENT AREA CONTRIBUTING TO RDII

City of Cold Lake

ISL Engineering and Land Services

5.0 Assessment Analysis

5.1 Level of Service

To properly consider level of service, it was necessary to consider what the required level of service in terms of wet weather flow is in the City's sanitary sewer system. The level(s) of service that were applied when assessing the sanitary network are summarized below, for existing and future system assessments.

5.1.1 Existing/Future System LOS

Under the existing system assessment, four storm events were considered to assess wet weather flow in the sanitary system. For consideration of the future system assessment, three storm events were considered. These include:

- Inflow-Infiltration (I-I) allowance of 0.29 L/s/ha as per the City of Cold Lake's Sanitary Design Standards
- I-I allowance of 0.60 L/s/ha (for the existing system assessment only)
- The City of Cold Lake's 1 in 25-year 24-hour 3rd Quartile Huff Storm
- The City of Cold Lake's 1 in 50-year 24-hour 3rd Quartile Huff Storm

Inflow-Infiltration Allowance of 0.29L/s/ha

The City's design standard of 0.29 L/s/ha of I-I is considered conservative for assessing surcharge when compared to an observed or design rainfall event. Under this scenario, the model was set-up and run for a constant 0.29 L/s/ha I-I rate on top of the existing dry weather flows. In this fashion, system utilization can be determined by taking the defined peak dry weather flow plus 0.29 L/s/ha of I-I divided by the sewer capacity. It is noted that this I-I rate is essentially equal to the design rate of 0.28 L/s/ha for new developments as per the Alberta Environment and Parks' (AEP) design guidelines.

Inflow-Infiltration Allowance of 0.60L/s/ha

Similar to the 0.29 L/s/ha scenario, this scenario is considered to be a more conservative approach for assessing surcharge when compared to an observed or design rainfall event. Under this scenario, the model was set-up and run for a constant 0.60 L/s/ha I-I rate on top of the existing dry weather flows. This scenario was chosen for illustrative purposes under the existing system assessment only as this rate was found to occur relatively frequently in other communities and typically results in failure of systems based on ISL's previous experience, however is considered quite conservative. As a result, the system could be tested under a relatively substantial I-I allowance to indicate any weak points.

1 in 25-year 24-hour 3rd Quartile Huff Storm

The 25 year 24 hour Q3 Huff Storm was one of the design storms assessed in the previous Sanitary Master Plan. It is noted that upon further investigation, the alternative design storm that was previously assessed (the 5 year 24 hour Huff Storm) was determined to not be the most effective design storm for assessing the City's sanitary sewer system, thus has not been modelled. A Huff rainfall distribution replicates a storm with a moderate peak intensity, which is ideal for sanitary system analysis. In the case of the 25 year 24 hour Q3 Huff Storm, the peak intensity is 9.708 mm/hr for a duration of 1.2 hours or 72 minutes, while the total rainfall depth produced over the entire duration is 75.16 mm. The initial RDII boundary condition for the root zone storage (Lini) for each catchment was adjusted during the wet weather calibration stage such that the L/Lmax ratio was 50% at the beginning of the design storm simulations. The rainfall hyetograph for this event is shown in Figure 5.1.

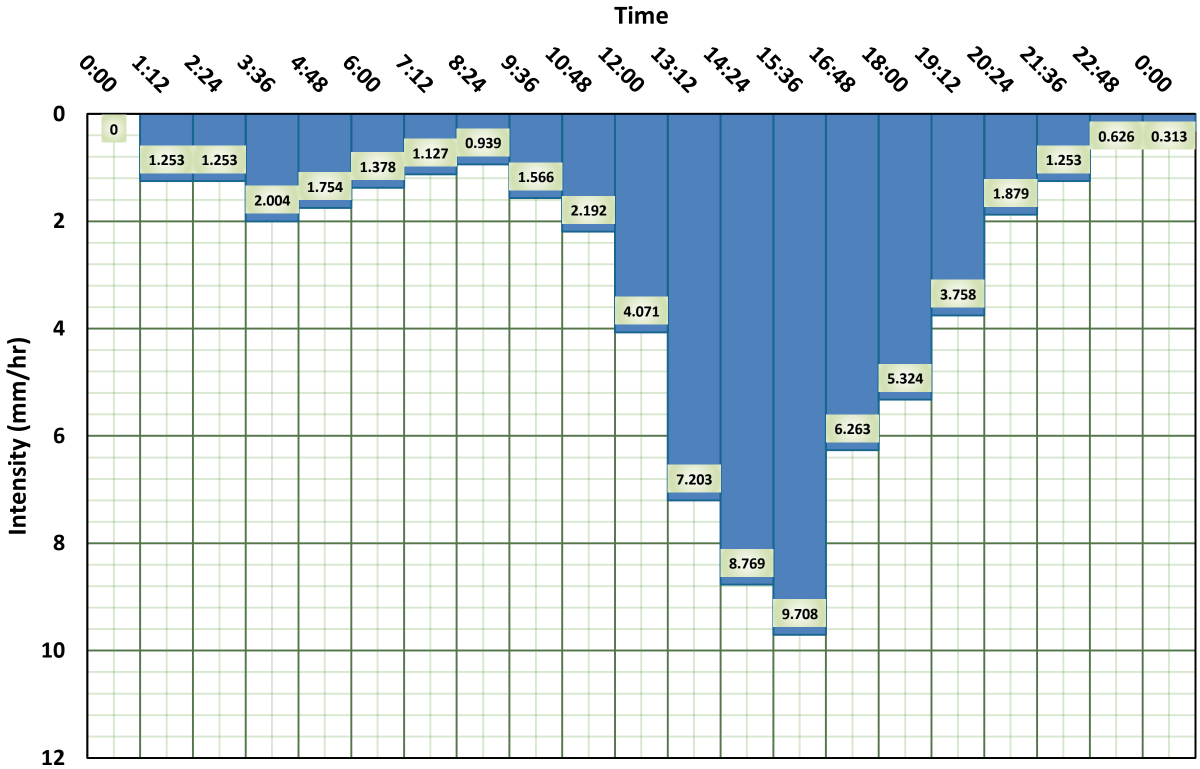


Figure 5.1: 25 Year 24 Hour Q3 Huff Storm Rainfall Hyetograph

1 in 50-year 24-hour 3rd Quartile Huff Storm

The 50 year 24 hour Q3 Huff Storm was selected after the initial analysis of the 25 year 24 hour Q3 Huff Storm indicated that the City's sanitary sewer system was quite robust under the modelled scenario. Once again, a Huff rainfall distribution replicates a storm with a moderate peak intensity, which is ideal for sanitary system analysis. In the case of the 50 year 24 hour Q3 Huff Storm, the peak intensity is 10.895 mm/hr for a duration of 1.2 hours or 72 minutes, while the total rainfall depth produced over the entire duration is 84.35 mm. The initial RDII boundary condition for the root zone storage (Lini) for each catchment was adjusted during the wet weather calibration stage such that the L/Lmax ratio was 50% at the beginning of the design storm simulations. The rainfall hyetograph for this event is shown in Figure 5.2.

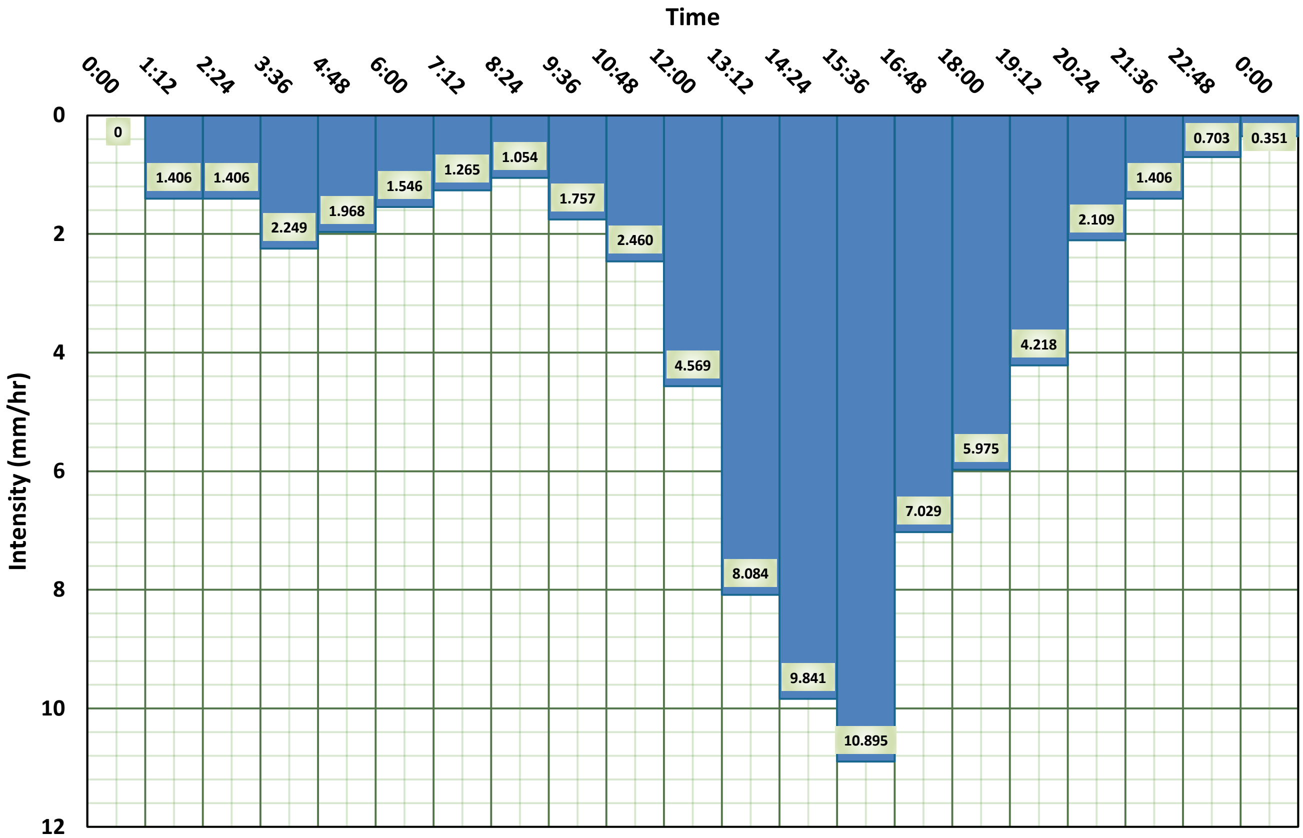


Figure 5.2: 50 Year 24 Hour Q3 Huff Storm Rainfall Hyetograph

5.2 Assessment Criteria

A number of additional sanitary system design parameters and guidelines were established in order to move forward with the assessment and servicing option evaluation. General design specifications are provided below. Design criteria pertaining specifically to the future sanitary system is summarized in Section 5.2.1.

The maximum allowable surcharge in the gravity portion of the sanitary sewer systems must remain at least 2.5 m from the ground surface during a design storm scenario. The following exceptions to this criterion are as follows:

- Catchment areas that have experienced re-occurring basement flooding following less than 50-year return period rainfall events in the past. In those instances upgrades may be triggered even if modelling results indicate that the surcharge level is below 2.5 m from the ground surface.
- In gravity sewer sections where there are no service connections and therefore no basements, the freeboard may be less than 2.5 m. For example:
    - Sewers running within green spaces
    - Siphon locations at creek/water body crossings (when applicable)

Existing forcemains should be analyzed, and future forcemains should be sized to maintain a minimum velocity of 1.0 m/s however should not exceed a velocity of 3.0 m/s, with the preferred velocity being 2.5 m/s. Existing siphons should be analyzed (when applicable), and future siphons should be sized to maintain a minimum velocity of 1.1 m/s based on average DWF conditions reaching a velocity of 1.1 m/s at least once a day, with two times being preferred.

The performance of the sanitary network was assessed in terms of two relationships as follows:

- **Maximum Hydraulic Gradeline (HGL) Elevation Relative to the Ground** – the amount of freeboard between the maximum water elevation and ground elevation at each manhole at the moment when maximum flow passes through.

Hence, the Maximum HGL Elevation Relative to the Ground with a value of:

- Greater than 0.00 m is denoted as a red dot – indicating surcharge/back-up to surface
- Between -2.50 m and 0.00 m is denoted as an orange dot – maximum HGL peaks within 2.5 m below the ground indicating possible basement back-ups
- Between -3.50 m and -2.50 m is denoted as a yellow dot – maximum HGL peaks within 2.5 m and 3.5 m below the ground indicating no basement back-ups but possibly an elevated HGL
- Less than -3.50 m is denoted as a green dot – maximum HGL peaks 3.5 m below the ground

- **Peak Discharge Relative to Sewer Capacity** – indicates the ratio peak flow to sewer capacity in wet weather conditions; as a corollary to this, the data can be interpreted to indicate the amount of spare capacity during peak flows. This is calculated by taking the ratio of the modelled flow in a sewer and its corresponding capacity. Sewers with ratios higher than one are considered to have no spare capacity thus indicating a section of trunk that might require upgrading, particularly where the length of the section is long enough to cause surcharge conditions immediately in the upstream reach.

Hence, the Peak Discharge Relative to Sewer Capacity with a ratio of:

- Greater than 1.00 is denoted as a red line – over capacity, or in another words the capacity is diminishing as the maximum flow theoretically occurs at roughly 93% of the sewer's diameter. This means that in principle, sewers with a Q/Q_{man} ratio equal to or less than 1.05 have their flow still contained within the sewer.
- Between 0.86 and 1.00 is denoted as an orange line – less than 14% of spare capacity available
- Less than 0.86 is denoted as a green line – spare capacity available

Both relationships should be looked at in conjunction to pin point any potential capacity deficiencies in the system. For example:

- The **Maximum HGL Elevation Relative to the Ground** with a value that is between -2.50 m and 0.00 m (an orange dot) may indicate a location with a possible basement back-up, however the **Peak Discharge Relative to Sewer Capacity** ratio at the same location could have a value of less than 0.86 (a green line) indicating the sewer is not surcharged. This could suggest a relatively shallow sewer. An exception to this rule are sewer trunks immediately upstream of both lift stations and siphons, where a possible back-up could occur due to inadequate capacity of the lift station or siphon.
- Please note that the ratio of **Peak Discharge Relative to Sewer Capacity** for both forcemains and siphons is always above 1.00 as these operate under pressurized conditions by nature, thus should not be of any concern.

In addition to these two scenarios, the **Spare Capacity** of each sewer was determined. This indicates the amount of additional flow each sewer can handle before it becomes completely utilized. The amount of **Spare Capacity** ranges from less than 0 L/s to over 100 L/s, with the least capacity illustrated in red and the most capacity depicted in green. In determining the **Spare Capacity**, it becomes evident which sewers are available to handle any additional flows due to future development, and which sewers should remain untouched.

5.2.1 Future Design Criteria

For the purpose of developing a sanitary servicing network within undeveloped areas a spreadsheet approach was utilized, while the impact of the development of these lands on the existing sanitary system was assessed using the calibrated hydrodynamic model. As a result, one needs to understand what design parameters were applied in each case. These are discussed in detail below.

DWF Generation Rates

In all cases, the DWF generation rates applied to the Stage 1, Stage 2, Stage 3, and Stage 3+ growth scenarios were employed from the City of Cold Lake's Municipal Engineering Servicing Standards and Standard Construction Specifications document dated January, 2008. The following rates were therefore applied:

- Residential Areas (Population Generated) – 350 L/p/d
- Non-Residential Areas (Area Generated) – 18.0 m^3/ha/d

Peaking Factors

Servicing Network Design
Peaking factors for the future sanitary system were calculated in accordance with the City's Municipal Standards mentioned above, and generally align with the AEP's guidelines. These include the following:

- Peaking factor derived based on Harmon's formula for residential areas:

$$PF = 1 + \frac{14}{4 + P^{\frac{1}{2}}}$$

  - Where, P is the design contributing population in thousands.
  - It is noted that PF must be at least 3.
- Peaking factor for non-residential areas:

$$PF = 10(Q_{Ave}^{-0.45})$$

  - Where, Q_{Ave} is 0.20 L/s/ha.
  - It is noted that PF must be at least 2.5.

Consequently, the residential peaking factors ranged from 3.00 to 4.33, with an average value of 3.49. The non-residential factors ranged from 2.50 to 11.91, with an average value of 2.95.

Assessment of the Impact on the Existing System
Peaking factors derived during the DWF calibration process, based on the observed flow monitoring data, were applied to the future growth scenario catchments for both the residential and non-residential land uses. As expected, the observed modelled peaking factors tend to be lower than those stipulated by the AEP's guidelines. The peaking factors fluctuate between 1.65 and 1.98 for residential areas, and 1.34 and 1.54 for non-residential areas.

WWF Component

Servicing Network Design

A constant inflow-infiltration allowance of 0.29 L/s/ha as per the City's Municipal Engineering Servicing Standards and Standard Construction Specifications document was applied to each growth catchment to simulate wet weather response.

Assessment of the Impact on the Existing System

The wet weather flow response for all future catchments were produced based on the LOS criteria mentioned above. This included the constant inflow-infiltration allowance of 0.29 L/s/ha, the 25 year 24 hour Q3 Huff Storm and the 50 year 24 hour Q3 Huff Storm. Catchments were assigned calibrated hydrological properties reflective of a similar hydrologic characteristics as development areas within the existing City's boundary that produced relatively conservative I-I rates. Consequently, the percent impervious area and percent area contributing to RDII of 0.40% and 15.00%, respectively, were applied. A groundwater infiltration (DWF baseflow) rate of 0.033 L/s/ha for greenfield developments was also incorporated in the model as per typical modelling guidelines.