Winnipeg

Water and Waste Department • Service des eaux et des déchets

DEC 2 8 2017

Client File No.: 1069.10, 1071.00
Our File No(s): S-1111, EMS
020-17-08-11-00
020-17-08-11-0N

Manitoba Sustainable Development
Climate Change and Environmental Protection Division
Environmental Approvals Branch
Suite 160 – 123 Main Street (Box 80)
Winnipeg, MB R3C 1A5

Attention: Ms. Tracey Braun, M.Sc., Director

Dear Ms. Braun:

RE: Notice of Alteration Request for NEWPCC and SEWPCC

The Water and Waste Department is requesting an alteration to the NEWPCC and SEWPCC licences, to remove the requirement for a sleeve encasement around river crossings. Please see the attached NOA forms and NOA detailed report to support this request.

Should you have any questions on this NOA request, please contact Duane Griffin at 204-986-4483 or by email at dgriffin@winnipeg.ca.

Yours truly,

Chris Carroll, P. Eng., MBA
Manager of Wastewater Services Division

Attachment

MP/jl

c: M.L. Geer, CPA, CA, Water and Waste Department (email)
G.K. Patton, P.Eng., Water and Waste Department (email)
R. Grosselle, Water and Waste Department (email)
D.E. Griffin, P.Eng., Water and Waste Department (email)
K. Zurek, P.Eng., Water and Waste Department (email)

Notice of Alteration Form

Manitoba
Sustainable Development

MANITOBA SUSTAINABLE DEVELOPMENT
ENVIRONMENTAL APPROVALS BRANCH
JAN 03 2018
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Client File No.: 1071.00	Environment Act Licence No.: 2684RRR
Legal name of the Licencee: City of Winnipeg	
Name of the development: North End Water Pollution Control Centre	
Category and Type of development per Classes of Development Regulation: Waste Treatment and Storage — Wastewater treatment plants	
Licencee Contact Person: Chris Carroll, P.Eng Mailing address of the Licencee: 1199 Pacific City: Winnipeg Province: MB Postal Code: R3E 1G5 Phone Number: (204) 986-7435 Fax: Email: ccarroll@winnipeg.ca	
Name of proponent contact person for purposes of the environmental assessment (e.g. consultant): Duane Griffin	
Phone: (204) 986-4483 Fax:	Mailing address: 1199 Pacific
Email address: dgriffin@winnipeg.ca	
Short Description of Alteration *(max 90 characters)*: Requesting that Clause 19b be struck from the licence, as per attached NOA detailed report	
Alteration fee attached: Yes: ☐ No: ☑ If No, please explain: As per phone conversation on November 30 with MSD, this is a minor alteration	
Date: 2017-12-20	Signature: Printed name:

A complete Notice of Alteration **(NoA)** consists of the following components:

- ☑ **Cover letter**
- ☑ **Notice of Alteration Form**
- ☑ **4 hard copies and 1 electronic copy of the NOA detailed report** (see "Information Bulletin - Alteration to Developments with Environment Act Licences")
- ☐ **$500 Application fee, if applicable** (Cheque, payable to the Minister of Finance)

Submit the complete NOA to:

Director
Environmental Approvals Branch
Manitoba Sustainable Development
Box 80, Suite 160, 123 Main Street
Winnipeg, Manitoba R3C 1A5

For more information:

Phone: (204) 945-8321
Fax: (204) 945-5229
http://www.gov.mb.ca/sd/eal

Note: Per Section 14(3) of the Environment Act, Major Notices of Alteration must be filed through submission of an Environment Act Proposal Form (see "Information Bulletin – Environment Act Proposal Report Guidelines")

AECOM

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Winnipeg, MB, Canada R3P 0Y7
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204 477 5381 tel
204 284 2040 fax

Technical Memorandum

To	Stacy Cournoyer, P. Eng.	Page	1
CC	Kas Zurek, P. Eng.		
Subject	**NE Interceptor Siphon Upgrades – Clarification of Approach to Meet Current NEWPCC Operating Licence Monitoring Requirements**		
From	Adam Braun, P. Eng., Chris Macey, P. Eng.		
Date	December 7, 2017	Project Number	60509089 (507)

As requested by the City, this Technical Memorandum addresses AECOM's review of the current Environment Act Licence No. 2684 RRR, the operating licence for the North End Wastewater Pollution Control Centre (NEWPCC) and identifies a technical approach for meeting the requirements of the current licence for the proposed capacity upgrade of the Northeast Interceptor siphon crossing of the Red River.

As the crossing includes both existing pipelines and a new siphon crossing, its Licence requirements are covered under Clauses 18 (existing pipelines) and 19 (new crossings) of the Environment Act Licence No. 2684 RRR dated June 2009. The technical objective of both Clauses is to preclude inadvertent discharge of wastewater to the environment.

The specific language of Clauses 18 and 19 are outlined in detail herein, but include the following general technical requirements:

- Utilization of leak detection and monitoring to confirm the hydrostatic integrity of existing and newly constructed crossings.
- The requirement of a sleeve encasement for newly constructed crossings to facilitate continuous monitoring and as a secondary barrier for new crossings.
- A provision to repair and/or replace portions of crossings found to be leaking wastewater to the environment.

While the prevention of inadvertent or unplanned wastewater discharge to the environment is a common requirement for regulatory controls across Canada and the US, and indeed a primary technical objective for the City for its river crossing infrastructure; the specific requirement for the use of sleeve encasement for new crossings is unique to Manitoba regulations and not a specific requirement in any other jurisdiction that we are aware of. Indeed, its inclusion for a water crossing is contrary to development the most robust failure mitigation approach in accordance with standards such as CSA Z662[1] as the use of a casing pipe compromises the ability to assess pipeline integrity through condition monitoring with the necessary degree of certainty to intervene over time before the pipeline fails. Cased pipeline crossings are not utilized for water crossings system with significant environmental ramifications such as oil and gas pipeline systems, for this reason (i.e. it compromises pipeline integrity management).

[1] *CAN/CSA-Z662-15 - Oil and gas pipeline systems*

The enclosed Memorandum outlines the technical approach for upgrading of the existing Northeast Interceptor siphon crossing of the Red River in a manner that is fully compliant with the technical objectives of the current Licence and has been developed in accordance with Annex B – Guidelines for risk assessment of existing pipelines; Annex D – Guidelines for in-line inspection of pipelines, and Annex N – Guidelines for pipeline integrity management systems of CSA Standard Z662, to preclude inadvertent or unplanned discharge of pipeline fluids to the environment.

1. Background

1.1 Proposed System Upgrades

The proposed upgrades to the Northeast Interceptor siphon crossing of the Red River are intended to increase capacity of the river crossing in order to meet the following core objectives:

- To accommodate future development and reduce basement flooding risk in the upstream system east of the Red River.
- To increase reliability of the existing siphons by providing sufficient redundancy to accommodate routine condition assessment and, if necessary, pre-emptive repairs.

The project includes the installation of a 900 mm third siphon to supplement the existing 500 and 800 mm siphons; originally constructed in 1970, see Figure 1 below. Preliminary profiles are attached to this Memorandum as Appendix A for installation of the new pipe by either micro-tunnel boring machine (MTBM) or horizontal directional drilling (HDD) installation methods.

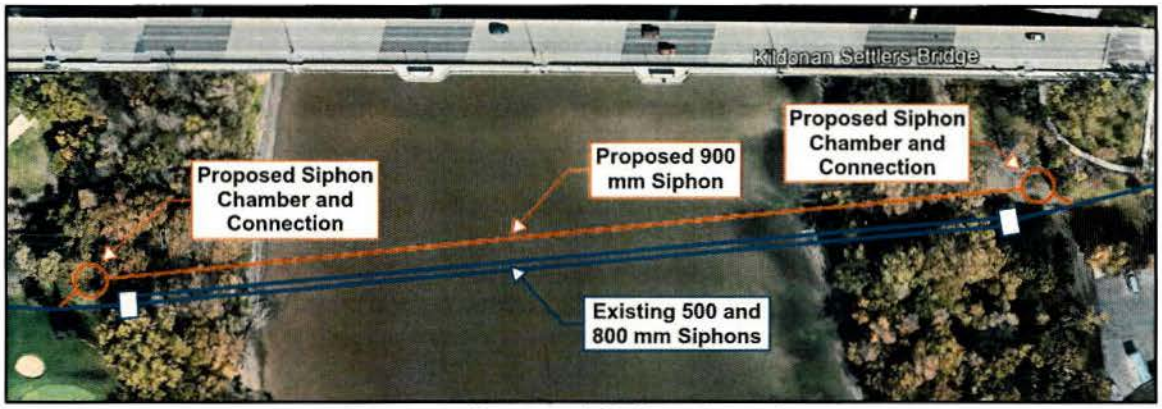


Figure 1 - Proposed Siphon Upgrades

1.2 Environmental Licence Requirements and Technical Approach for Compliance

The primary objectives of Clauses 18 and 19 of Environmental Act Licence No. 2684 RRR are to prevent discharge of wastewater to the environment at river crossings and to mandate timely intervention in the event that a loss of hydrostatic integrity is detected.

Clause 18 in the Environmental Act Licence covers existing installations and it specifically states:

"18 The Licencee shall:

a) Submit a proposal for a leak detection program, on or before June 30, 2006 for existing pipes which transport wastewater via river crossings, to the Director, including leak detection technologies and monitoring practices to be implemented;
b) Implement the leak detection program, as approved by the Director;
c) Continuously measure and record the data gathered by the leak detection program; and
d) *Repair and replace all portions of the piping where leaks are detected in accordance with Clause 5 of this Licence."*

Clause 19 in the Environmental Act Licence covers new installations and it specifically states:

"19 The Licencee shall, from the date of issuance of this Licence, construct and maintain new pipes which transport wastewater via river crossings by taking the following actions:

a) Submit a proposal for a leak detection program, for the approval of the Director, including leak detection technologies and monitoring practices to be applied;
b) Construct and maintain a sleeve encasement around the piping;
c) Implement the leak detection program, as approved by the Director;
d) Continuously measure and record the data gathered by the leak detection program; and
e) Repair and replace all portions of the piping where leaks are detected in accordance with Clause 5 of this Licence."

The language of Clause 19 includes a requirement for "sleeve" encasement. The background of this requirement includes:

- The "sleeve" encasement referenced in Clause 19, is not typically a "sleeve" encasement. As clarified in the proposed monitoring plan provided by the Water & Waste Department (WWD) and AECOM in late 20072 for the current licence and accepted by the Director; the "sleeve" is typically achieved by installation of "dual encasement pipe".
- A "dual encasement" pipe is a special style of double walled pipe configuration; engineered and installed in one pass. It is a system that was intended to facilitate leakage monitoring of river crossing installations where a large differential pressure exists between the primary carrier pipe and atmospheric or piezometric pressures. As an indirect indicator of leakage from the carrier pipe it is primarily applicable to pressure pipe applications (where large differential pressures exist), however, even in pressure pipe applications it does not directly report on condition of the pipe and can only be used to infer failure of the primary carrier pipe.
- Further, the use of dual encasement style of crossing pipes in river crossings does not protect the river crossing system many primary failure modes of this type of system, failures due to riverbank instability and for shallower crossings erosion of the river bed.
- Lastly, the use of mandatory sleeve encased or dual encased systems increases the installation risk of new crossings considerably which results in increased exposure to situations where the:
    - Installation process could cause damage to fish habitat (through hydro-fracture of drilling fluids due to the large diameter of the bore)

[2] *Final Report for Trial Program to Monitor Wastewater Sewer Pipeline River Crossings for Leaks In Compliance with Revised Environmental Act License No. 2669E (Draft), UMA Engineering, April 2007.*

- Installed crossing pipe could leak at locations that are not readily repairable without considerable destruction of fish habitat due to the complexity of dual wall fusion in diameters of this size (in situations where HDPE piping materials are used).

We believe installation related leakage risk can be effectively managed by staying within the established technical envelope for technology used. In the case of the Northeast Interceptor new crossing, the installation is intended to be by trenchless methods such as microtunnel boring methods (MTBM) or horizontal directional drilling (HDD) as depicted in Appendix A. Both technologies have lower installation risk profiles by limiting the size of the crossing.

From a practical perspective, the new crossing would be installed in bedrock strata which would provide an additional barrier from the river if no hydraulic connection exists between the river and the aquifer. Well drawdown tests are currently scheduled to be undertaken to confirm whether there is any direct hydraulic connection between the groundwater levels in the bedrock and the river channel and in either case; the installation approach will be one that follows established DFO guidelines and protocol to preclude inadvertent discharge of fluids to the environment during the installation process.

The technical approach proposed herein to prevent wastewater discharge to the environment is four phased; to address both the proposed additional siphon and the two existing ones as per Clauses 18 and 19 of the existing Licence. It will include:

- Continuous review of the hydrostatic integrity of the crossings as well as boundary conditions to confirm that no wastewater is being or can be discharged to the environment.
- Increased redundancy at the crossing to accommodate planned and systematic condition assessment.
- Systematic condition assessment to ascertain whether active deterioration processes are present.
- Planned intervention to arrest any hydrostatic integrity failures and/or schedule repairs/rehabilitation prior to failures occurring.

The Northeast Interceptor Crossing is a critical river crossing in the City's inventory and needs to meet stringent operating objectives for capacity and reliability. The work being contemplated under this construction program is an upgrading of an existing crossing location, intended to increase capacity of the crossing to accommodate growth as well as providing an increase in reliability of the Northeast Interceptor Crossing system. Due to the very large service area associated with the Northeast Interceptor, the overall crossing system is intended to have the following risk management approach:

- Full redundancy (i.e. individual siphon pipes can be taken out of service) under peak dry weather and a range of wet weather flow conditions to facilitate regular condition assessment and repairs if necessary.
- Routine condition assessment at prescribed intervals.
- Continuous monitoring of all three crossings (the proposed crossing and the two existing ones) to confirm the hydrostatic integrity of each of the siphon/river crossings and to confirm that local hydraulic boundary conditions preclude the discharge of wastewater to the environment should unanticipated events occur between condition assessment cycles.
- The frequency of condition assessment inspections would be determined by last observed condition and a key technical objective for each condition assessment would be to determine the future inspection frequency such that no failures would occur that would compromise the

structural or hydrostatic integrity of the conduit. This approach is consistent with Risk Management techniques mandated under CSA Z662 oil and gas pipeline systems which includes the installation, operation and maintenance of oil and gas pipelines under river crossings[3].

The balance of systematic condition assessment in conjunction with continuous hydrostatic integrity monitoring in this application is a far more robust risk management technique than leak detection alone as it is designed to detect the potential onset of failure before it occurs with observations designed to determine whether active deterioration processes are present and acting on the pipe as well as monitoring. Further, conventional leak detection methods can only detect large failures in low pressure crossings such as siphons with hydraulic operating characteristics such as the Northeast Interceptor and would not meet the technical objectives of the Licence.

The increased level of redundancy provided by the upgrades will also facilitate repair, if necessary, and design features will be incorporated into the crossing that will accommodate repair processes with no environmental impact to habitat (e.g. access and flow control considerations to facilitate trenchless repair/rehabilitation). The increased redundancy in conjunction with the other measures provided will provide a higher level of protection than dual encasement in conjunction with conventional "leakage" monitoring.

The specific means to monitor for hydrostatic integrity and carry out condition monitoring are detailed in the following sections.

2. Continuous Hydrostatic Integrity Monitoring

Continuous hydrostatic integrity monitoring will be based on the actual hydraulic response of the siphon under known flow conditions as well as the external environment around the siphon.

For wastewater from the siphon to be released to the river, the hydraulic grade line (HGL) within the siphon must be higher than that of either the groundwater head (piezometric head) or the river level. A loss of hydrostatic integrity in any of the siphons would induce groundwater and/or river flow into the siphon unless the HGL was high enough to discharge out of the pipe to the surrounding environment.

At this specific location, the HGL of the siphon under peak dry weather operating conditions (and a range of wet weather conditions) is below both the normal river level and the piezometric head of the groundwater in the surrounding soils and bedrock formations. Thus, should a hydrostatic breach occur a net inflow of water to the siphon would occur and the effects would be readily detectable by continuously monitoring the HGL of the siphon in conjunction with monitoring the upstream flow rate. A series of rating curves would be developed prior to commissioning and then calibrated in conjunction with commissioning to develop the known relationship between the upstream flow rate and head loss through the siphon. This technique has been successfully used in the Shoal Lake Aqueduct to detect flow variations due to potential pipe failure and/or inflow into the pipe since 2004 and the City's current combined sewer overflow monitoring program which balances the use of direct level measurement techniques in conjunction with the known hydraulic response characteristics of the system to confirm whether overflow events occur and estimate their magnitude.

[3] *CAN/CSA-Z662-15 - Oil and gas pipeline systems*

To ascertain whether the flow conditions at the crossing can physically discharge to the environment requires a site specific review of HGL versus external boundary conditions. The downstream system HGL is controlled by pump operations at NEWPCC, which under dry weather conditions utilizes a pump set point between -12' James Ave (218.1 m) and -13' James Ave (217.8 m). Under the 2037 peak dry weather design conditions, the following HGL's are predicted for the siphon:

- Upstream Trunk Sewer: 219.75 m
- Downstream Trunk Sewer: 217.0 to 218.7 m

As a result, under both current and future conditions (2037 design horizon), the HGL of the proposed 900 mm siphon will be less than 219.75 m.

Normal winter ice levels for the Red River are 221.77 m as measured at the James Ave Pumping Station[4]. Based on monitoring between 2013 and 2017, groundwater levels vary between 222.1 m and 226.0 m in the underlying bedrock, till, and surficial clays and alluvial soils.[5]

As noted in Figure 2, these hydraulic conditions both preclude discharge of the siphon to the environment and will facilitate detection of a loss in hydrostatic integrity by continuous HGL level monitoring in response to a known upstream flow rate.

The proposed monitoring strategy will include upstream flow monitoring and both upstream and downstream water level monitors (see Figure 3) within the siphon chambers to confirm that regular operational conditions are present and to alert operators to any changes in the system HGL's that are consistent with a loss of hydrostatic integrity. The proposed level sensor monitoring system will be configured to report to the City's existing SCADA monitoring system. Variability in river elevations will also be monitored in real time using existing City of Winnipeg instrumentation installed at the adjacent Kildonan Settlers Bridge.

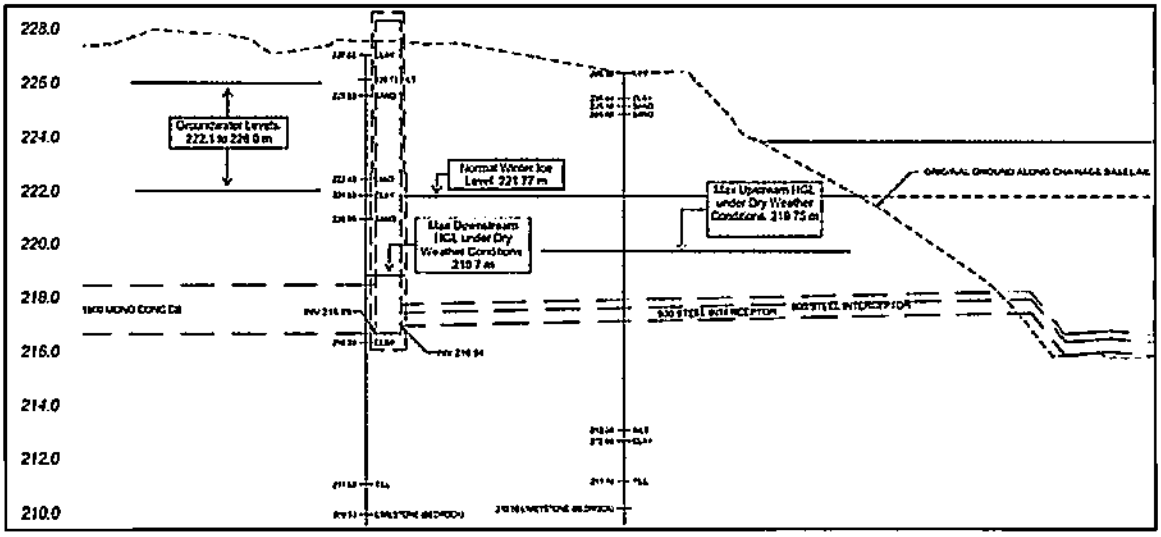


Figure 2 - Siphon - Hydraulic Grade Line (HGL)

[4] *City of Winnipeg River Levels: http://www.winnipeg.ca/publicworks/pwddata/riverlevels/*
[5] *Northeast Interceptor Sewer Red River Crossing Geotechnical Report, AECOM, July 2017.*

In summary, given the unique hydraulics at the site, hydrostatic integrity and response trigger to prevent discharge of untreated wastewater to the environment will be monitored by:

- Installing upstream flow monitoring capability and level sensors for HGL measurement of the system on both the upstream and downstream sides of the river crossing and linking the data output into the City's existing SCADA system.
- Calibrating the installation post-installation.
- Utilizing the existing river level sensors and knowledge of overall system hydraulics to develop alarms which clearly identify:
    - Situations in which hydrostatic integrity has been compromised.
    - Situations in which the compromised HGL could facilitate the discharge of wastewater to the environment.
- An internal response protocol would be developed in response to any loss in hydrostatic integrity to isolate the leaking siphon until such time that repairs could be undertaken.

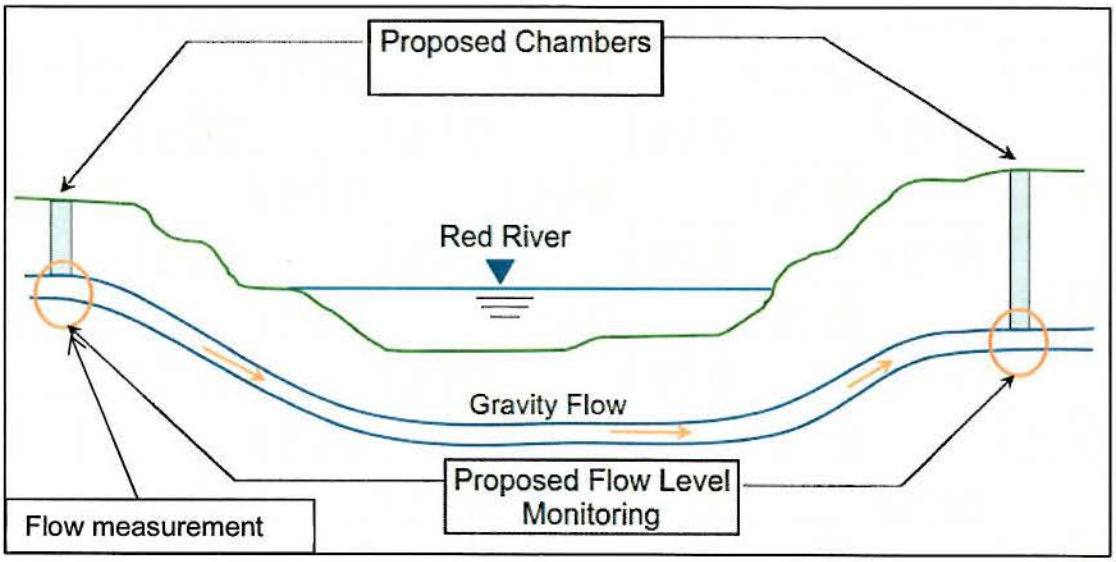


Figure 3 - Continuous Level Sensor Monitoring Locations

3. Monitoring of Pipeline Integrity

The 2nd component of the risk management strategy would involve systematic condition assessment of the existing siphons at an interval intended to preclude unanticipated failure and routinely schedule repairs or mitigative work before the onset of failure. The technical approach is consistent with existing City policy for ensuring reliability of high consequence collection system assets.

As previously noted, the configuration of the existing and proposed siphons and control structures are such that once the proposed 900 mm siphon is installed, the Northeast Interceptor siphon crossing will be fully redundant for peak dry weather flow conditions permitting isolation of any of the three siphons for condition assessment and repairs/rehabilitation if necessary.

As noted in AECOM's (UMA Engineering) previous study on all of the City's Sewer River Crossings[6], the primary modes of failure for river crossings relate to:

1. Potential riverbank instability failures that could engage the pipe,
2. Erosion of the river bed that engages the pipe or reduces its cover which can induce buoyancy failure, and
3. Active deterioration mechanisms acting on the pipe itself.

While material degradation is a significant risk in the Winnipeg area, its drivers are well understood and readily monitored by routine condition assessment. By far the greatest factor in river crossing failures has been riverbank instabilities or riverbed erosion, which a secondary carrier pipe provides no protection against. Its mitigation as well is best managed by routine and regularly scheduled monitoring.

The riverbank stability at the site was assessed in conjunction with this design and was currently found to be absent of any conditions that could engage any of the siphon crossings. As part of WWD's normal maintenance at the site, routine stability would be reviewed annually and an alert would be provided as to any change in site conditions that are consistent with active bank instabilities. An alert would initiate a more formal review to categorize bank instability risk.

Formal bank stability and riverbed erosion reviews would be also conducted in conjunction with pipe assessment at the same frequency prescribed for re-inspection of the pipe as noted below. Erosion reviews would include inspection of the crossing with bathymetric and side scanning sonar techniques to confirm the integrity of the shallower crossings.

All siphon pipes at the crossing location will be inspected with recognized condition assessment approaches to ascertain whether the pipe is being impacted by any active deterioration processes. Based on the pipe materials present, condition assessment methods would include:

1. CCTV for pipes that can readily be de-watered.
2. Sonar for pipes that cannot readily be dewatered.
3. For metallic pipes, where full wall penetration corrosion is a risk, any of the technically viable wall thickness measurement technologies would be used which includes remote field eddy current (RFEC), enhanced electromagnetic (EEM), magnetic flux leakage (MFL) and/or continuous ultrasonic thickness (UST)) measurement.

As recognized in the development of current Risk Management programs for other critical crossing pipelines such as oil and gas pipelines, the use of sleeve encasement is problematic for reliable condition assessment and while once a common feature in road crossings to reduce stress it is no longer mandated in the most current version of CSA-Z662-15 and pipeline integrity concerns discourage its use for road crossings and is not at all considered as mitigation for water crossings. The dual encasement or double sleeved crossing introduces the following features that are undesirable from the perspective of pipeline integrity monitoring programs:

- In metallic pipe crossings, it compromises corrosion protection/control systems.
- In metallic piping, it introduces interference that reduces the reliability of both electromagnetic and leak detection assessment tools.

[6] *UMA/AECOM, "WWS River Crossing Risk Assessment", Report for the WWD, December 2006*

- In non-metallic piping systems it reduces the value of both CCTV and Sonar technologies, as it shields these review methods from the pipe-soil interaction process which is essential to understand in assessing the onset of potentially progressive failure modes.

Therefore, the use of a sleeve encasement in a new crossing would increase the risk of unanticipated failure not reduce it and would not be recommended.

The City's current recommended frequency of inspection for river crossing inspections is based on the last observed condition for Category A Sewer Assets (i.e. the City's highest designation of criticality) and is summarized in Table 1 below. Table 1 is based on the Recommended Risk Based approach for Critical Asset condition monitoring proscribed in the WRc's Sewerage Rehabilitation Manual[7] and previously adopted by the City in the Sewer Management Study[8].

Table 1 - Recommended Re-inspection Frequency based on Last Observed SPG

Assessed Condition (Structural Performance Grade – SPG)	Implication of Structural Performance Grade	Re-inspection frequency
5	Failed or in a state of incipient failure	N/A
4	Moderate to severe defects; failure could occur due to random event	*See note 1
3	Minor to Moderate defect; further deterioration likely	3 years
2	Minor defects, further deterioration unlikely	5 years
1	No defects	10 years

**Note 1 - where rehabilitation is not planned in the immediate future sewer condition should be monitored frequently to prevent unanticipated failure.*

4. Conclusion

In summary, the City desires to install an additional siphon at the Northeast Interceptor crossing of the Red River to:

- Accommodate future development and reduce basement flooding risk in the upstream system east of the Red River.
- Increase reliability of the existing siphons by providing sufficient redundancy to accommodate routine condition assessment and, if necessary, pre-emptive repairs.

AECOM has proposed a monitoring and inspection approach for pipeline integrity management in conjunction with the proposed upgrades to the Northeast Interceptor siphon crossing of the Red

[7] *Water Research Centre (WRc), "Sewerage Rehabilitation Manual, Fourth Edition", 2001*
[8] *AECOM (UMA Engineering), "Sewer Management Study - Technical Memoranda For Sewer Condition Assessment, Sewer Rehabilitation Design, And Sewer Maintenance Management For The City Of Winnipeg", July 2001*

River. As outlined herein it meets the core intent of Clauses 18 and 19 of the current NEWPCC operating licence, Environmental Act Licence No. 2684 RRR in that it is designed to reliably preclude the discharge of wastewater to the environment. The technical approach to achieve this includes a balanced approach in accordance with the core concept of Clauses 18 and 19 and other recognized best practices for pipeline river crossing management in that it includes:

- Continuous monitoring to confirm hydrostatic integrity of the siphons as well as monitoring to confirm that the prevalent operating hydraulic condition precludes discharge to the environment;
- Systematic monitoring of riverbank stability and riverbed erosion processes that could engage the pipes;
- Systematic condition assessment for the life of the installation to ascertain whether active deterioration processes are acting on the pipes, and
- Increased redundancy and operational flexibility to isolate individual siphons to facilitate both condition assessment and pre-emptive repairs, if necessary.

We trust this information meets your requirements on this matter. Should you have any queries or require further information or clarification, please do not hesitate to contact either of the writers.

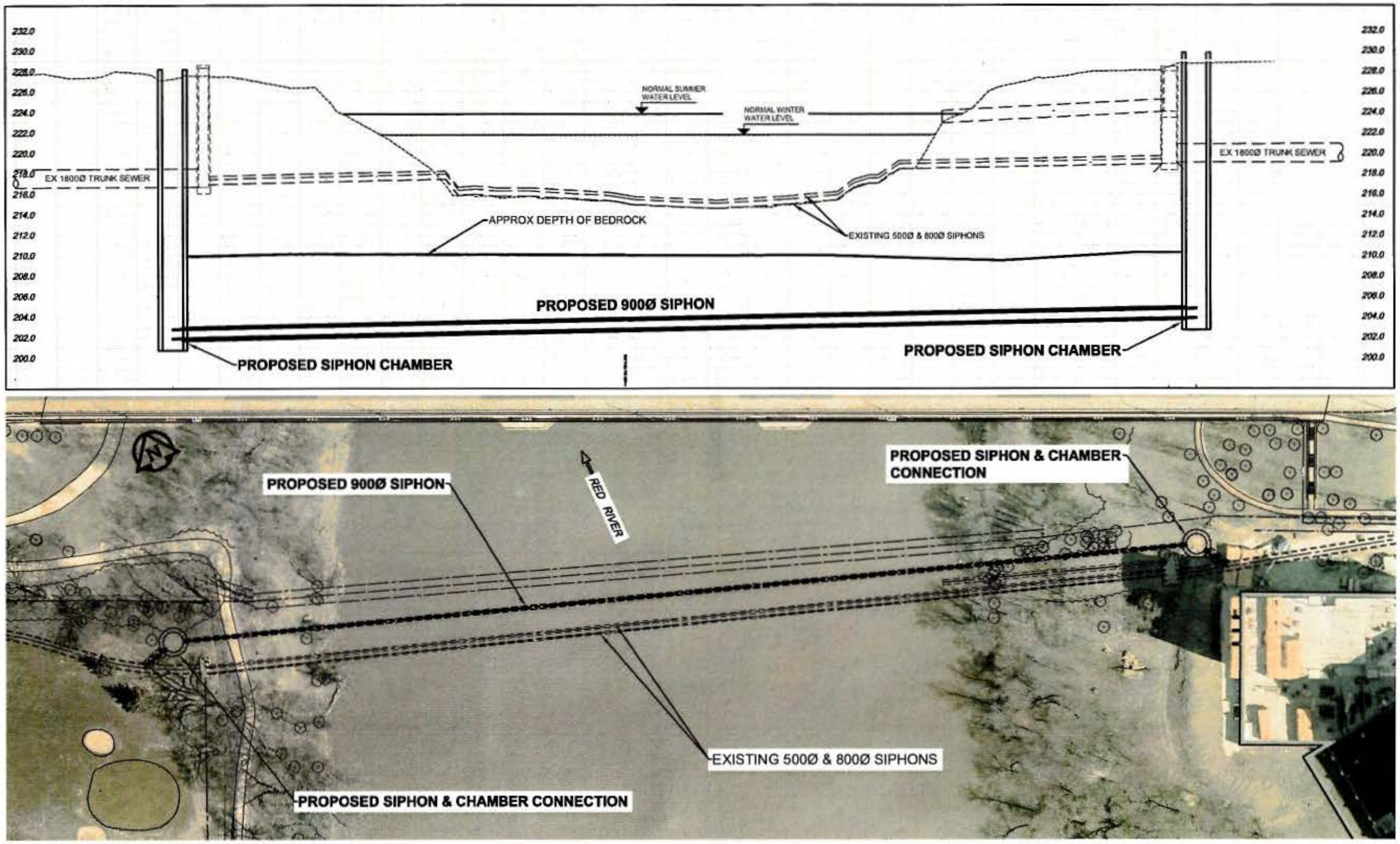
Sincerely,
AECOM Canada Ltd.

Adam Braun, P. Eng.
Municipal Engineer
Conveyance
ADB/CCM/pab

Chris Macey, P. Eng.
Americas Technical Practice Leader
Condition Assessment and Rehabilitation

AECOM

Appendix A



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Issue Status: DRAFT

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Figure: 01

MICROTUNNELING OPTION

NORTH EAST INTERCEPTOR CROSSING

CITY OF WINNIPEG

Project No.: 60509089 Date: 2017-11-07

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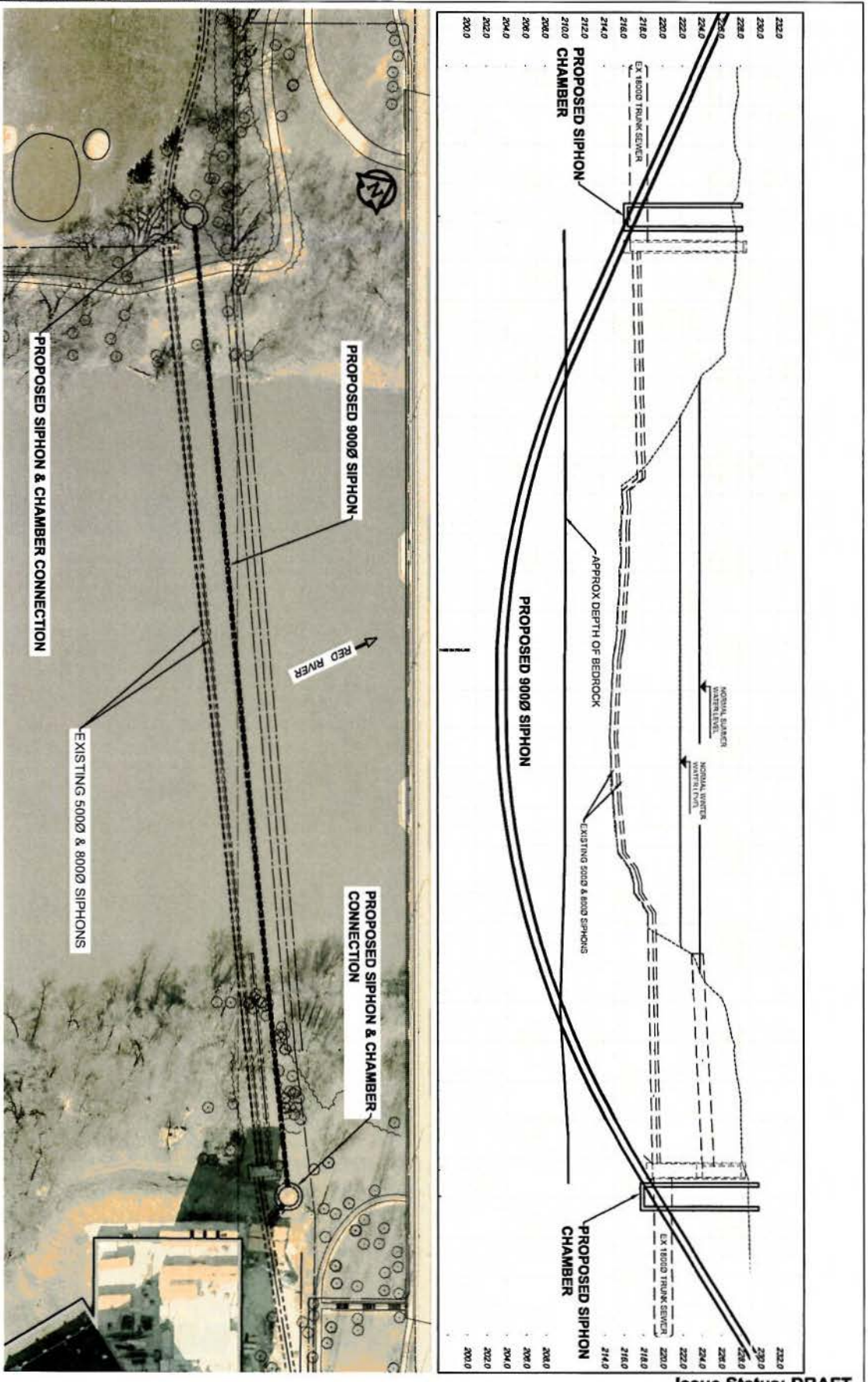

Issue Status: DRAFT

NORTH EAST INTERCEPTOR CROSSING HORIZONTAL DIRECTIONAL DRILLING OPTION

CITY OF WINNIPEG
Project No.: 60509089 Date: 2017-11-07

AECOM

Figure: 02