Winnipeg

WINNIPEG WATER AND WASTE DEPARTMENT

GEOTECHNICAL INVESTIGATION AND RIVERBANK STABILTY ASSESSMENT CRANE – WILLOW INTERCEPTOR SEWER REPLACEMENT

FINAL REPORT

NOVEMBER, 2007

KGS GROUP

KONTZAMANIS ▪ GRAUMANN ▪ SMITH ▪ MACMILLAN INC.
CONSULTING ENGINEERS & PROJECT MANAGERS

KGS GROUP

KONTZAMANIS ▪ GRAUMANN ▪ SMITH ▪ MACMILLAN INC.
CONSULTING ENGINEERS & PROJECT MANAGERS

November 22, 2007

File No.07-107-11

The City of Winnipeg
Water and Waste Department
110 – 1199 Pacific Avenue
Winnipeg, Manitoba
R3E 3S8

ATTENTION: Mr. Kas Zurek, P.Eng.
Project Manager

RE: Geotechnical Investigation and Riverbank Stability Final Report
Crane-Willow Interceptor Sewer Replacement

Dear Mr. Zurek:

Please find enclosed three (3) copies of our final report detailing the results of the geotechnical investigation and riverbank stability assessment performed for the proposed Crane-Willow Interceptor Sewer Replacement in Winnipeg, Manitoba.

This report is suitable to be submitted in support of a Water and Waste Department application for a Waterways Permit.

Please do not hesitate to contact the undersigned at (204) 896-1209 in that regard.

Yours truly,

PROVINCE OF MANITOBA
Nov. 28/07
D.E.S. ANDERSON
Member
2048
REGISTERED PROFESSIONAL ENGINEER

David Anderson, M.Sc., P.Eng.
Geotechnical Engineer

Reviewed by,

Nov 30/07

Robert M. Kenyon, Ph.D., P.Eng.
Geotechnical Group Manager

DA/jr
Enclosure

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1.0 INTRODUCTION

This report presents the results of KGS Group's geotechnical investigation and riverbank slope stability assessment in the vicinity of the proposed subsurface directionally drilled interceptor sewer under the Red River between St. Vital Park and South Drive Park in Winnipeg, Manitoba. The location is shown on KGS Drawing 07-107-11 01.

The scope of work included:

- ***Geotechnical Site Investigation*** - performed a subsurface drilling investigation along the existing pipe alignment.
- ***Riverbank Stability Assessment*** - assessed the impact of the proposed works on the stability of existing riverbank by site reconnaissance, air photo review and the results of a numerical slope stability assessment.
- ***Report*** - present results of work and a vertical alignment of the proposed pipe.

The City of Winnipeg Water and Waste Department completed site surveying in December 2006.

2.0 BACKGROUND

2.1 PROJECT DETAILS

The project is understood to comprise the underground directional drilling and installation of two dual contained 800 mm (32 inch) inner diameter HDPE interceptor sewer pipes. The existing sewer pipe is a gravity/siphon system, which is comprised of a 525 mm (20 inch) diameter pipe that will be backfilled and abandoned as part of this project. Details of the proposed replacement are shown on KGS Drawing 07-107-11 01.

2.2 SITE DESCRIPTION AND LOCATION

The project crosses the Red River between St. Vital and South Drive Parks in Winnipeg, Manitoba. The directionally drilled pipeline will be approximately 200 m projected horizontal distance, connecting to a siphon inlet chamber on the north side of the river and to a siphon outlet chamber on the south side as shown in plan and section.

The St. Vital Park site is located at the downstream end of a sweeping inside bend along the south bank of the Red River. South Drive Park is on the opposite outside bend (north bank) of the same stretch of the Red River.

St. Vital Park Riverbank Geometry (South Side of Red River)

Riverbank geometry on the St. Vital Park side is dominated by alluvial bank morphology. Beginning at the existing siphon chamber at approximately Elev. 227.5 m±, the riverbank slopes to the crest of the riverbank at 12H to 1V over a distance of approximately 25 m. Below the crest the bank slopes down at 2.2H to 1V to Regulated Summer River Level (RSRL) at Elev. 223.7 m±. An approximately 7 m± wide bench extends from RSRL to Unregulated Winter River Level (UWRL) Elev. 222.2 m±, below which the riverbank slopes at 3.1H to 1V down to the bottom of the river channel.

South Drive Park Riverbank Geometry (North Side of Red River)

Riverbank geometry on the St. Vital Park side is dominated by lacustrine bank morphology. An at-grade siphon inlet chamber is located on the north bank at approximately Elev. 229.1 m±. The riverbank is relatively flat from Crescent Drive to the chamber. Approximately 9 m± from the chamber towards the river there is a historic headscarp as shown on Dwg. 07-07-11 01 with the chamber approximately 14 m± from the crest of the riverbank at Elev. 228.75 m±. The riverbank slopes down below the crest at 5.3H to 1V to the bottom of the channel at Elev. 218.2 m±.

2.3 AIR PHOTO REVIEW

Stereo aerial photographs from 1988 and 1992 were reviewed to assess the historical riverbank conditions on either side of the existing pipe alignment. The air photo stereo coverage used in the review included:

Photo Reference Line	Year	Scale
AS88012	1988	1:5000
AS92072	1992	1:5000

1988 Air Photos

These photographs were taken in April 1988 with the Red River between its natural winter and summer river levels and no foliage on the trees.

St. Vital Park (South Side of Red River)

The aerial photos show that there significant tree cover growing along the riverbank with a small clearing in the trees, approximately 5 m wide, in the vicinity of the pipe crossing. There is no evidence of rockfill riprap along the shoreline either upstream or downstream of the pipe crossing. Evidence of ordinary shoreline erosion (exposed near vertical banks) is noted along the riverbank but no overall riverbank instability is evident directly adjacent the pipe crossing.

Approximately 15 m upstream of the crossing there is a headscarp present, which extends approximately 300 m± upstream of the pipe.

South Drive Park (North Side of Red River)

The photographs show that the area within the park is relatively flat and grass covered with numerous trees growing along the upstream, downstream and river sides of the park. An approximately 10 m± wide swath has been cut through the trees from the crest of the riverbank down to the waters edge along the pipe crossing. There is evidence of rockfill or concrete rubble along the shoreline that appears to have been placed probably only between summer and winter river levels and which extends approximately 70 m± upstream and 30 m± downstream of the pipe crossing. Evidence of shoreline erosion, retrogressive slumping and overall riverbank instability is evident for at least 450 m± upstream of the pipe crossing.

1992 Air Photos

These photographs were taken in October 1992 with the Red River at its natural winter river level and no foliage on the trees.

St. Vital Park (South Side of Red River)

Generally, the riverbank looks to be in a similar condition as it was in 1988 with ongoing erosion of the shoreline both upstream and downstream of the pipe crossing.

South Drive Park (North Side of Red River)

Generally, the riverbank looks to be in a similar condition as it was in 1988 with ongoing erosion of the shoreline both upstream and downstream of the riprap section and pipe crossing. The cleared area on the riverbank appears to have trees and bushes now growing on it versus 1988. Upstream of the rockfill, the shoreline shows signs of continued erosion and cutting back, which has led to the crest of the riverbank moving back approximately 2 to 3 m± since the 1988 photos.

2.4 SITE INSPECTION

The air photo interpretation was confirmed by a KGS Group site inspection.

St. Vital Park (South Side of Red River)

Presently there are numerous large mature deciduous and evergreen trees and smaller bushes growing along the riverbank and down to the river water edge. The riverbank shows no signs of overall bank instability. However, as seen on the aerial photography, approximately 15 m± upstream of the pipe crossing a headscarp is present along the crest of the riverbank as shown on Photo 1. There is also evidence of ongoing erosion along the shoreline of the riverbank in the vicinity upstream and downstream of the pipe crossing as shown on Photo 2. The upstream headscarp is a result of erosion of the bank, which leads to oversteepening of the bank face and result in shallow sloughing or slides.

South Drive Park (North Side of Red River)

Numerous large mature trees and small bushes presently grow along the riverbank between the crest of the riverbank to the river water edge and along the upstream and downstream property limits of the park. As was seen on the aerial photos, there is concrete rubble along the shoreline. Photo 3 shows some erosion that is occurring along the shoreline even with the concrete rubble in place. Photos 4 and 5 show a historic headscarp along the riverbank upstream and downstream of the park respectively.

3.0 INVESTIGATION PROGRAM

3.1 TEST HOLE DRILLING PROGRAM

The test hole drilling program consisted of the drilling of three test holes into bedrock at locations shown on KGS Drawing 07-107-11 01. First, during the week of July 13, 2006, KGS Group supervised the drilling of two test holes, one in South Drive Park (TH06-01) and one in St. Vital Park (TH06-02). The test holes were drilled with a truck mounted Acker MP5-T drill rig contracted from Paddock Drilling Ltd. of Brandon, Manitoba. The drilling was advanced using 125 mm solid stem augers to refusal in the underlying till. Upon refusal, HQ core barrel was used to core through the till and down 6.1 m (20 feet) into the underlying bedrock. Representative soil samples were collected directly off the auger flights at 1.5 m intervals or at any change in soil strata and then visually classified in the field. Clay samples were tested with a Field Torvane to evaluate consistency and estimate undrained shear strength. During coring a continuous rock core sample was obtained from the bedrock. Upon completion of the drilling, a standpipe piezometer was installed in the bedrock in each of the test holes.

A third test hole was completed under the supervision of KGS Group during the week of August 7, 2007 and consisted of the drilling of one test hole in the Red River (TH07-01). The test hole was drilled with a barge mounted Acker SX drill rig contracted from Paddock Drilling Ltd. of Brandon, Manitoba. The drilling was advanced using a HQ core barrel through the river bottom sediments, till and 6.1 m (20 feet) into the bedrock. During coring a continuous core sample was obtained from the till and bedrock. Upon completion of the drilling, the test hole was backfilled with bentonite grout.

Summary soil logs incorporating all field observations are placed in Appendix A. Photo logs of the rock core are placed in Appendix B.

4.0 GEOTECHNICAL SITE STRATIGRAPHY

KGS Group's interpretation of the stratigraphy is based upon three test holes drilled along the existing interceptor sewer pipe alignment. That interpreted stratigraphy is shown on KGS Drawing 07-107-11 01.

4.1 NORTH SIDE OF RED RIVER – SOUTH DRIVE PARK (TH06-01)

In general, the stratigraphy consisted of organic topsoil over clay fill underlain by silty clay over silt till and bedrock.

A thin layer of organic topsoil was present at ground surface, underlain by clay fill that extended to Elev. 228.2 m±. The clay fill was black, dry to damp, crumbly, of low to intermediate plasticity, and contained trace amounts of sand, silt, organics and rootlets. Below the clay fill, silty clay of lacustrine origin was encountered to Elev. 216.9 m±. The clay was brown in colour to Elev. 221.9 m± and grey below. It was damp, stiff (upper brown clay) to soft (lower grey clay) in consistency with estimated undrained shear strengths ranging from 15 to 90 kPa, as measured from the Field Torvane. The clay was of high plasticity and contained trace amounts of silt, organics and oxidation. A layer of silt till extended from Elev. 216.9 m± to Elev. 213.0 m±. The silt till was light grey to grey in colour and became red below Elev. 214.2 m±, dry to damp, dense, crumbly, and contained trace amounts of clay, coarse to fine grained sand, gravel and cobbles. Power auger refusal was encountered at Elev. 215.38 m. Sample and core recovery was poor, consistent with a non-cemented silt matrix containing gravel and cobbles. Approximately 0.2 m± (8 inches) of solid core was recovered when coring through the till.

The silt till was underlain by limestone bedrock which extended at least to Elev. 206.9 m where coring was stopped. Detailed core logs are attached at the end of this report along with photos of each core run. The limestone was mottled tan to white in colour and contained some horizontal and vertical fractures. Core recovery was excellent with recoveries of 100% for each run in TH06-01. RQD values ranged from 31% to 60% resulting in a description of the bedrock quality as Poor to Fair.

4.2 SOUTH SIDE OF RED RIVER – ST. VITAL PARK (TH06-02)

Silty clay of alluvial origin was encountered at ground surface and extended to Elev. 218.7 m±. The silty clay was brown in colour at surface and became grey at the 5.8 m depth. It was damp, firm to stiff in consistency with estimated undrained shear strengths ranging from 35 to 60 kPa, as measured from the Field Torvane. The silty clay was of intermediate to high plasticity and contained trace amounts of silt, rootlets, sand, organics, and oxidation. Below the silty clay, a layer of silt till extended from Elev. 218.7 m± to Elev. 213.3 m± throughout its depth. The silt till was tan in colour, contained sand and gravel, and was wet and very soft down to Elev. 216.8 m±. Below Elev. 216.8 m± the silt till became dry and dense and power auger refusal was encountered at Elev. 216.22m±. While coring through the silt till, occasional limestone or granite boulders up to 0.3 m in diameter were encountered with only minimal core recovery except for some gravel and cored boulders.

The silt till was underlain by limestone bedrock to at least Elev. 207.1 m where coring was stopped. The bedrock was mottled beige and yellow in colour and contained some horizontal and vertical fractures. Core recovery was excellent with recoveries ranging from 90% to 100% for each run in TH06-02. RQD values ranged from 37% to 67% resulting in a description of the bedrock quality as Poor to Fair.

4.3 MIDDLE OF RED RIVER CHANNEL – (TH07-01)

In general, the stratigraphy consisted of thin river sediments over silt till underlain by bedrock.

Below 0.6 m± of river sediments, silt till was encountered from Elev. 217.8 m± to 213.8 m±. The silt till was brown in colour, moist, uncemented from Elev. 217.8 m± to 214.9 m± and cemented from Elev. 214.9 m± to 213.8 m±. The till matrix contained some coarse to fine grained sand, subrounded to subangular fine to coarse gravel and cobbles and trace amounts of clay.

Till was underlain by limestone bedrock to at least Elev. 207.1 m where coring was stopped. Detailed core logs are attached at the end of this report along with photos of each core run. The bedrock was mottled tan to white in colour and contained some horizontal and vertical fractures.

Core recovery was excellent with recoveries of 100% for each run in TH07-01. RQD values ranged from 9% to 73% resulting in a description of the bedrock quality as Very Poor to Fair.

As observed in TH07-01, uncemented till was encountered during the geotechnical investigation program. Based upon sample recovery, the uncemented till matrix was interpreted to consist of medium to coarse grained gravel and cobbles with any fines being washed out during the coring. With the uncemented till consisting primarily of granular materials, difficulties could be anticipated if directional drilling were advanced through this layer.

Based upon the bedrock coring at this site KGS Group has concluded that generally the limestone bedrock quality varied from Very Poor to Fair within the three test holes, a variability that is consistent with KGS Group's experience of coring the limestone bedrock throughout the City of Winnipeg.

4.4 GROUNDWATER CONDITIONS

The depth to groundwater in the standpipe in TH06-01 was 5.27 m (Elev. 226.83 m) on November 13, 2007, while the depth to groundwater in the standpipe in TH06-02 was 3.32 m (Elev. 224.18 m) on. The standpipe response zone for each standpipe is within the limestone bedrock.

Groundwater elevations vary seasonally and in response to river levels and precipitation.

5.0 SLOPE STABILITY ASSESSMENT

Recent riverbank slope movements on older pre-existing headscarps on the South Drive Park side of the crossing may have impacted the existing pipe. It is understood that the St. Vital Park side of the pipe has suffered no such distress. The stability analysis detailed herein was completed in order to estimate the setback the pipe profile must be placed in order to be located beyond the zone of potential riverbank movements. The slope stability analysis was completed using Slope/W, a two-dimensional computer program developed by GeoSlope International Ltd. of Calgary, Alberta. The analysis was conducted using the Morgenstern-Price Method, and assumed static groundwater conditions.

5.1 ST. VITAL PARK *(SOUTH SIDE)*

The cross section used to analyze the stability, the interpreted stratigraphy and potential slip surfaces for the St. Vital Park analysis are included on Dwg. 07-107-11 01. The assigned effective shear strength properties of the alluvial clay were a friction angle, ϕ', of 20^{o} and cohesion, c', of 5 kPa.

In order to assess the stability and potential impacts upon the proposed pipes, two slip surfaces were analyzed. The most critical slip surface (SS1), was a shallow near surface rotational slip. Slip Surface 1 was estimated analytically to be the most critical under critical bank stability conditions of saturated riverbank and rapid drawdown from flood stage to Regulated Summer River Level (RSRL). Slip surface 2 (SS2) represents a potential slip surface that impacts upon the minimum setback location of the pipes and has a minimum Factor of Safety of 1.3 for the same critical conditions. Table 1 summarizes the estimated factors of safety (FS) for each potential slip surface under the assumed groundwater conditions.

With Regulated Summer River Level (RSRL) (Elev. 223.7 m$\pm$) and saturated groundwater conditions, the estimated FS for SS1 is 1.24 and SS2 has an estimated FS of 1.51. Under the conditions of Unregulated Winter River Level (UWRL) (Elev. 222.2 m$\pm$) and saturated groundwater conditions, the estimated FS for SS1 is 1.09 and SS2 has an estimated FS of 1.40. The estimated factors of safety for RSRL and saturated groundwater conditions represent the

critical geotechnical assumptions for an alluvial riverbank, which has become completely saturated following flooding and after the river is dropped down to RSRL.

5.2 SOUTH DRIVE PARK *(NORTH SIDE)*

The cross section used to analyze the stability, the interpreted stratigraphy and potential slip surfaces for the South Drive Park analysis are included on Dwg. 07-107-11 01. Since riverbank movements have occurred in the past and may have impacted the existing pipe at this location, shear strengths of the soil were separated into intact strengths and failed (residual) strengths. The failed or residual strength materials were assumed to be on the riverside of the historic headscarp shown on Dwg. 07-107-11 01, and the intact strength materials were assumed to be up-slope of the historic headscarp. The intact effective shear strength properties of the lacustrine clay were assumed to be a friction angle, ϕ', of 14^{o} and cohesion, c', of 5 kPa and the failed (residual) effective shear strength were back analyzed to be a friction angle, ϕ', of 12^{o} and cohesion, c', of 4 kPa.

In order to assess the stability and potential impacts upon the proposed pipes, two slip surfaces were analyzed. The most critical slip surface (SS3), was a shallow near surface rotational slip. Slip Surface 3 was estimated analytically to be the most critical (factor of safety near unity) under critical bank stability conditions of saturated headscarp at Unregulated Winter River Level (UWRL). For a lacustrine bank, with existing tension cracks and headscarps, the critical conditions are bank saturation and UWRL with bank saturation occurring when the tension cracks fill with water during either rainfall events or melting of snow. Slip surface 4 (SS4) represents a potential slip surface that impacts upon the minimum setback location of the pipes and has a minimum Factor of Safety of 1.3 for those design conditions.

Table 2 summarizes the estimated factors of safety (FS) for each potential slip surface and under the assumed groundwater conditions. Under the conditions of Unregulated Winter River Level (UWRL) (Elev. 222.2 m$\pm$) and saturated riverbank, SS3 has an estimated FS of <1.0 (0.89), and SS4 has an estimated FS of 1.30. With Regulated Summer River Level (RSRL) (Elev. 223.7 m$\pm$) and saturated groundwater conditions, the estimated FS for SS3 is <1.0 (0.93) and SS4 has an estimated FS of 1.33.

6.0 DISCUSSION

Typically, it is recommended by KGS Group that all critical infrastructure on a riverbank be placed behind a line defined by an estimated FS of 1.3 for a critical geotechnical assumption of RSRL and saturated riverbank for alluvial banks and UWRL and saturated riverbank for lacustrine banks. The estimated FS for a potential slip surface that impacts upon the proposed minimum setback locations of the pipes on either side of the river is at or above 1.3. Therefore the pipes would not experience any adverse impacts assuming the riverbank geometry were to remain unchanged and as shown on Dwg. 07-107-11 01 throughout the lifespan of the pipe.

As shown on Dwg. 07-107-11 01, no additional erosion protection is being proposed by the City of Winnipeg Water and Waste Department to be placed along either shoreline. Based upon KGS Group's experience, typically riverbank erosion can lead to the cutting back of the crest of the riverbank by an average of 1 foot per year. Therefore, with an expected lifespan of the pipes of 50 years, the pipes should be offset an additional 15 m (50 feet) in order to prevent any adverse impact to the pipes due to potential riverbank movements during the lifespan. That increased set back is shown on these report drawings and the tender package.

7.0 RECOMMENDATIONS

KGS Group has reviewed the riverbank stability along the Crane-Willow Interceptor Sewer and recommends the following:

On the St. Vital Park side, the minimum setback distance for the pipe has an estimated FS of 1.3 for the most critical design condition of RSRL and saturated bank as shown on KGS Drawing 07-107-11 01. KGS Group recommends that the pipes be offset an additional minimum of 15 m (50 feet) back from the minimum setback line in order to prevent any adverse impact to the pipes during the expected 50 year lifespan of the pipes.

On the South Drive Park side, the minimum offset distance is estimated to be behind a factor of safety in the order of 1.3 under either summer or winter river levels and saturated groundwater conditions as shown on KGS Drawing 07-107-11 01. That setback recognizes that bank movements have occurred in the past along this riverbank, which have impacted upon the existing pipe and there is a need to minimize any potential impact on the new pipes in the future. KGS Group recommends that the pipes must be offset an additional of 15 m (50 feet) behind the minimum setback line in order to prevent any adverse impact to the pipes due to riverbank movements during the expected 50 year design lifespan of the sewer crossing.

The sewer pipe profile shown on KGS Drawing 07-107-11 01 meets KGS Group recommendations for the design lifespan of the pipes.

KGS Group recommends that the proposed works be granted a Waterway Permit on the basis that:

- The proposed works results in no adverse hydraulic impact on river flows.
- The proposed works result in no adverse impact on existing bank stability.
- The proposed works are set back sufficiently from any anticipated riverbank movements.

TABLES

TABLE 1

ESTIMATED FACTORS OF SAFETY
ST. VITAL PARK

CASE	POTENTIAL SLIP SURFACE	RIVER LEVEL	GWL	ESTIMATED FS
Existing Riverbank	SS1	UWRL	SAT	1.09
	SS2	UWRL	SAT	1.40
	SS1	RSRL	SAT	1.24
	SS2	RSRL	SAT	1.51

Notes:

1. See Dwg. 07-107-11 01 for the slope geometry and the location of potential slip surfaces.
2. GWL Groundwater Level
   RSRL Regulated Summer River Level (Elev. 223.7 m)
   UWRL Unregulated Winter River Level (Elev. 222.2 m)
   FS Factor of Safety
   SAT Saturated riverbank groundwater conditions
3. Alluvial Clay Shear Strengths $c' = 5$ kPa, $\phi' = 20^{o}$
   Glacial Till Shear Strengths $c' = 5$ kPa, $\phi' = 35^{o}$

TABLE 2

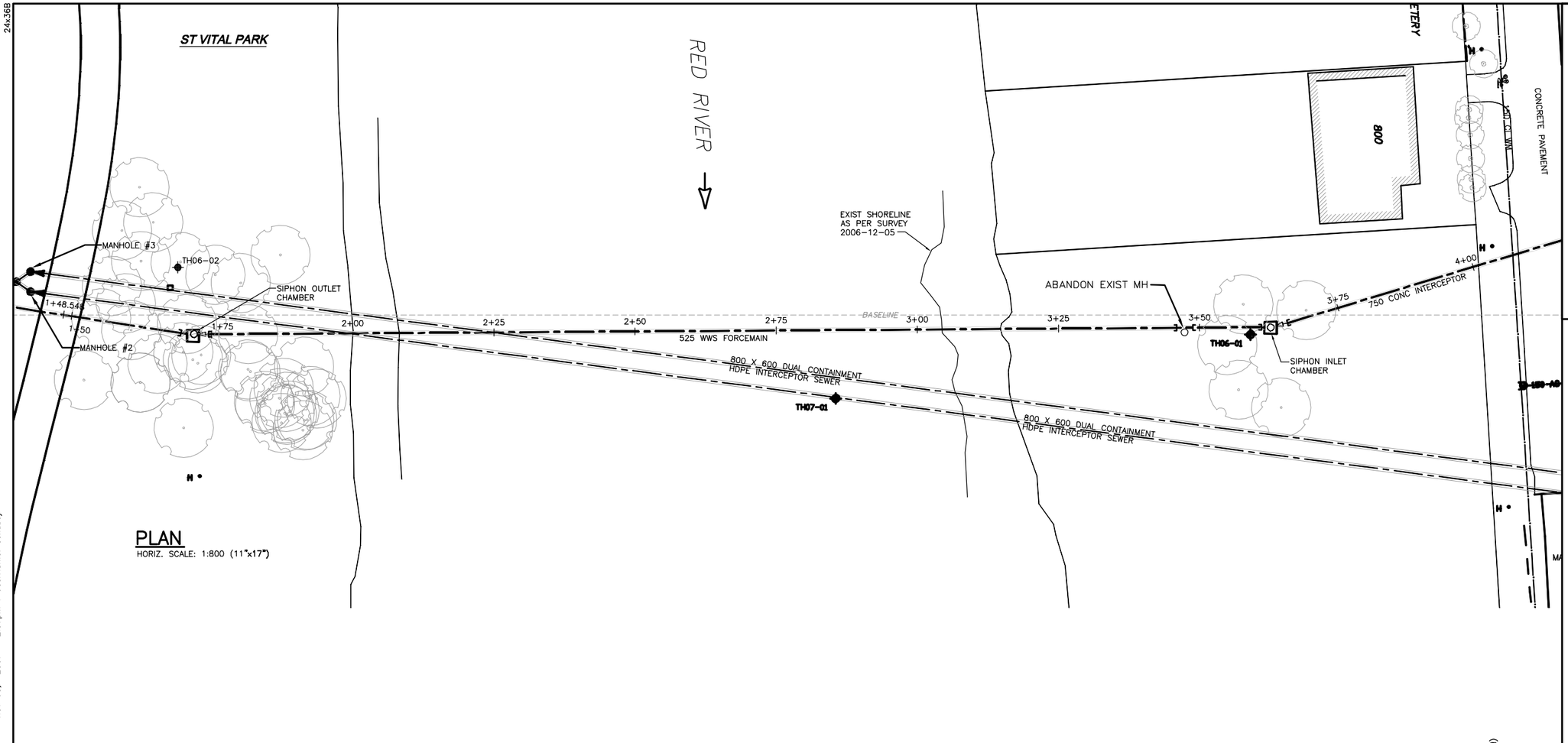
ESTIMATED FACTORS OF SAFETY
SOUTH DRIVE PARK

CASE	POTENTIAL SLIP SURFACE	RIVER LEVEL	GWL	ESTIMATED FS
Existing Riverbank	SS3	UWRL	SAT	<1.0 (0.89)
	SS4	UWRL	SAT	1.30
	SS3	RSRL	SAT	<1.0 (0.93)
	SS4	RSRL	SAT	1.33

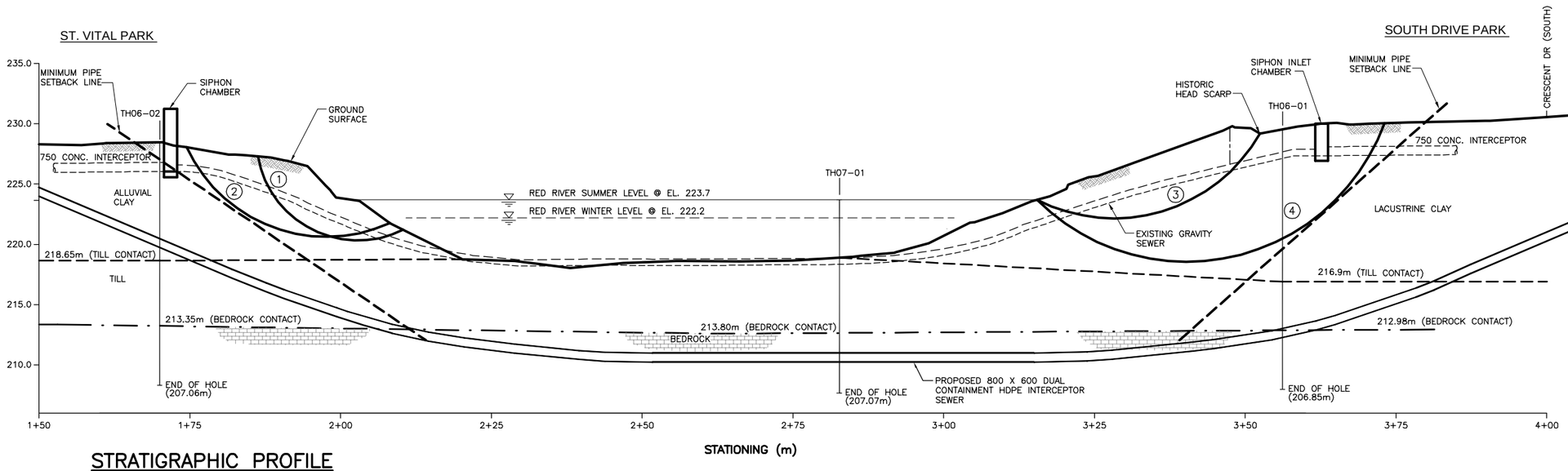
Notes:

1. See Dwg. 07-107-11 01 for the slope geometry and the location of potential slip surfaces.
2. GWL Groundwater Level
   RSRL Regulated Summer River Level (Elev. 223.7 m)
   UWRL Unregulated Winter River Level (Elev. 222.2 m)
   FS Factor of Safety
   SAT Saturated riverbank groundwater conditions
3. Intact Lacustrine Clay Shear Strengths c' = 5 kPa, ϕ' = 14^{o}
   Residual Lacustrine Clay Shear Strengths c' = 4 kPa, ϕ' = 12^{o}
   Glacial Till Shear Strengths c' = 5 kPa, ϕ' = 35^{o}

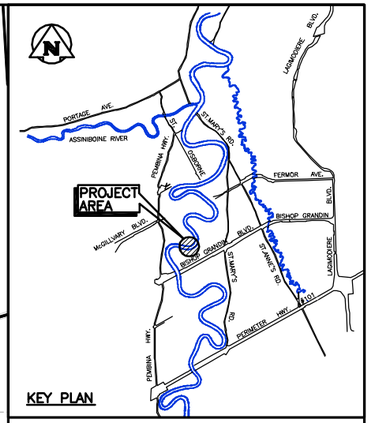
FIGURE



PLAN
HORIZ. SCALE: 1:800 (11"x17")



STRATIGRAPHIC PROFILE
HORIZ. SCALE: 1:400 (24"x36")
1:800 (11"x17")
VERT. SCALE: 2 TIMES EXAGGERATION



KEY PLAN

LEGEND:

- MINIMUM PIPE SETBACK LINE
- TH06-1 TEST HOLES BY KGS (2006 & 2007)
- ④ POTENTIAL SLIP SURFACE

NOTES:

1. EXISTING PROFILE AND GRAVITY SEWER ALIGNMENT BASED UPON CITY OF WINNIPEG SURVEY, DEC. 5, 2006.
2. PROPOSED PROFILE AND GRAVITY SEWER ALIGNMENT PROVIDED BY CITY OF WINNIPEG.
3. STATIONING SHOWN ARE ALONG GRAVITY SEWER ALIGNMENT.
4. TH06-01 AND TH06-02 DRILLED BY KGS GROUP IN JULY 2006, TH07-01 DRILLED BY KGS GROUP IN AUGUST, 2007.

NO.	DATE	REVISIONS	BY	CKD.	APP.
00	11/08/07	ISSUED WITH FINAL REPORT			RKe

REVISIONS / ISSUE

A. SECTION LETTER OR DETAIL NUMBER
B. DRAWING WHERE SECTION OR DETAIL IS DRAWN
OR
DRAWING WHERE SECTION OR DETAIL WAS INDICATED
— SECTION OR DETAIL SHOWN ON SAME DRAWING

KGS GROUP
CONSULTING ENGINEERS & PROJECT MANAGERS
WINNIPEG (204) 896-1209
THUNDER BAY (807) 345-2233

CLIENT: CITY OF WINNIPEG
WATER AND WASTE DEPARTMENT

PROJECT:
2007 REPLACEMENT OF THE CRANE/ WILLOW INTERCEPTOR SEWER
RED RIVER CROSSING

DWG. DESCRIPTION:
GRAVITY SEWER ALIGNMENT
PLAN AND STRATIGRAPHIC PROFILE

ENG. STAMP

DESIGNED: BY: DA CHECKED: RKe
DRAWN: BY: ESM CHECKED:
APPROVED:
SCALE: AS NOTED
DATE: SEPT. 2007
KGS DWG. NO. 07-0107-11 01
CLIENT DWG. NO.
REV: 00

PHOTOS

PHOTO 1 – HEADSCARP 15 M UPSTREAM OF PIPE CROSSING IN ST. VITAL PARK

PHOTO 2 – SHORELINE EROSION ALONG ST. VITAL PARK SIDE OF RED RIVER AT THE PIPE CROSSING

PHOTO 3 – SHORELINE EROSION ALONG SOUTH DRIVE PARK SIDE OF RED RIVER AT PIPE CROSSING

PHOTO 4 – HISTORIC HEADSCARP 30 M UPSTREAM OF PIPE CROSSING ON SOUTH DRIVE PARK SIDE OF RED RIVER

PHOTO 5 – HISTORIC HEADSCARP 30 M DOWNSTREAM OF PIPE CROSSING ON SOUTH DRIVE PARK SIDE OF RED RIVER

APPENDICES

APPENDIX A

TESTHOLE LOGS

KGS GROUP

SUMMARY LOG

HOLE NO. **TH06-01** SHEET 1 of 3

CLIENT CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT
PROJECT
SITE South Drive Park
LOCATION 3 m South of Gate Chamber
DRILLING METHOD 125 mm ø Solid Stem Auger and HQ Core Barrel, Acker MP5-T

JOB NO. 06-107-12
GROUND ELEV. 229.1 m
TOP OF PVC ELEV.
WATER ELEV.
DATE DRILLED 13-Jul-06
UTM (m) N 5,521,693
E 633,711

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE TYPE	NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲ 40 80 120	Cu TORVANE (kPa) ◆ 20 40 60 80	PL MC LL % 20 40 60 80
	0			TOPSOIL (OL)								
				CLAY FILL (CL-CI) - Black, dry to damp, crumbly, low to intermediate plasticity, trace silt, trace sand, trace organics, trace rootlets.								
	1	5		SILTY CLAY (LACUSTRINE) (CH) - Brown, damp, stiff, trace to some silt, trace organics, mottled brown, dark brown, trace oxidation.				S1			◆	
	2											
	3	10						S2			◆	
	4	15						S3			◆	
	5											
	6	20		- Mottled grey to brown below 6.10 m.				S4			◆	
	7	25		- Grey below 7.16 m.				S5			◆	

SAMPLE TYPE Auger Grab Core Barrel

CONTRACTOR Paddock Drilling Ltd.
INSPECTOR R. DOBSON
APPROVED DOB DATE 21/11/07

SPT & TORVANE 2 (SANS CORE) P:\PROJECTS\2006\06-0107-12\GEO\LOGS\06-107-12LOGS.GPJ

KGS GROUP

SUMMARY LOG

HOLE NO. **TH06-01**

SHEET 2 of 3

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE TYPE	NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲	Cu TORVANE (kPa) ◆	PL	MC	LL	%
										40 80 120	20 40 60 80				20 40 60 80
	9	30		- Soft below 8.84 m.			S	6							
				- Hole squeezing below 9.14 m.											
				- Trace to some coarse grained sand, trace gravel below 9.45 m.											
	10			- Suspected boulder at 10.06 m.											
		35					S	7							
	11														
	12						S	8							
		40		**SILT TILL** - Light grey to grey, dry to damp, dense, crumbly, trace clay, trace coarse to fine grained sand, trace gravel, trace cobbles (up to 5" in diameter).											
	13														
		45		**POWER AUGER REFUSAL AT 13.72 m.**			S	9							
	14			- No water in hole after completion of 125 mm solid stem drilling.											
				- Contractor switched to HQ coring at 13.72 m.											
	15	50		- Red below 14.94 m.											
	16			- Bedrock encountered at 16.12 m.											
		55													
	17														

SAMPLE TYPE Auger Grab Core Barrel

CONTRACTOR Paddock Drilling Ltd.

INSPECTOR R. DOBSON

APPROVED DCP DATE 21/11/07

SPT & TORVANE 2 (SANS CORE) P:\PROJECTS\2006\06-0107-12\GEO\LOGS\06-107-12LOGS.GPJ

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH06-01**

CLIENT CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT

PROJECT

SITE South Drive Park

LOCATION 3 m South of Gate Chamber 5,521,693 N 633,711 E

DRILLING METHOD 125 mm ø Solid Stem Auger and HQ Core Barrel, Acker MP5-T

JOB NO. 06-107-12

GROUND ELEV. 229.1 m

TOP OF PVC ELEV.

WATER ELEV.

DATE DRILLED 13-Jul-06

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
	17 55 18 60 19 65 20 70 21 75 22 23 24		**LIMESTONE (MUDSTONE TO WACKESTONE (16.12 m to 22.20 m)** (Overall description of cored bedrock) - Mottled, tan-white, dense, trace pinpoint porosity. Crumbly and loose from 18.24 m to 18.52 m. Dolomite limestone from 19.76 m to 20.07 m and then again from 20.63 m to 20.73 m. Dolomitic limestone was mottled pink, red and beige. R1 (16.12 m to 17.63 m): Limestone (mudstone to wackestone) - Mottled, tan-white, dense, trace pinpoint porosity. horizontal fractures at 16.38 m, 16.53 m, 16.66 m, 16.74 m, 16.84 m, 16.92 m, 17.22 m. Horizontal fractures are tight to part open, rough texture, trace manganese. Highly fractured horizontally and vertically from 17.12 m to 17.37 m. Vertical fracture from 16.54 m to 16.66 m and from 16.76 m to 17.12 m. Vertical fractures are tight and smooth. R2 (17.63 m to 19.15 m): Limestone (mudstone to wacketone) - Mottled tan-white, dense from 17.63m to 18.24 m, crumbly and loose from 18.24 m to 18.52 m, dense from 18.52 m to 19.15 m, trace pinpoint porosity in dense core, vuggy from 18.24 m to 18.52 m. Horizontal fractures at 17.86 m, 18.24 m, 18.08 m. Horizontal fractures in dense core are tight to part open, rough texture, trace manganese. Highly fractured horizontally and vertically from 18.08 m to 19.15 m. Vertical fractures are tight and smooth. R3 (19.15 m to 20.68 m): Limestone (mudstone to wackestone) - Mottled tan-white, dense, trace pinpoint porosity from 19.15 m to 19.76 m. Highly fractured horizontally and vertically from 19.15 m to 19.76 m. Dolomitic limestone, mottled pink, red and beige, dense from 19.76 m to 20.07 m. Horizontal fractures at 19.76 m, 19.99 m and 20.07 m. The rock changes back to limestone (mudstone to wackestone) at 20.07 m, mottled tan-white, dense, trace pinpoint porosity, horizontal fractures at 20.19 m, 20.24 m, 20.29 m, 20.40 m and 20.45. Vertical fracture from 20.07 m to 20.19 m, trace dolomitic limestone at the end of the run (5 cm). Fractures in this run are tight to part open, rough texture with trace amount of manganese. Vertical fractures are tight and smooth. R4 (20.68 m to 22.20 m): Trace of dolomitic limestone at the start of the run (5 cm). Followed by limestone (mudstone to wackestone), mottled tan-white, dense, trace pinpoint porosity. Highly fractured horizontally and vertically from 20.68 m to 21.29 m. Sound limestone core recovered from 21.29 m to 22.20 m. Horizontal fractures at 21.54 m, 21.77 m, 21.97 m and 22.12 m. Horizontal fractures are tight to part open, rough texture, trace manganese. Vertical fracture from 21.67 m to 22.20 m fracture is part open and rough texture.		17.68 18.29 22.25	R1 R2 R3 R4	9 3 9 5	100 100 100 100	53 31 40 60
			END OF HOLE AT 22.25 m						

CONTRACTOR Paddock Drilling Ltd.

INSPECTOR R. DOBSON

APPROVED

DATE 21/11/07

CORE P:\PROJECTS\2006\06-0107-12\GEO\LOGS\06-107-12LOGS.GPJ

KGS GROUP

SUMMARY LOG

HOLE NO. **TH06-02** SHEET 1 of 3

CLIENT CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT

PROJECT

SITE St. Vital Park

LOCATION

DRILLING METHOD 125 mm ø Solid Stem Auger and HQ Core Barrel, Acker MP5-T

JOB NO. 06-107-12
GROUND ELEV. 227.5 m
TOP OF PVC ELEV.
WATER ELEV.
DATE DRILLED 14-Jul-06
UTM (m) N 5,521,518
E 633,636

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	SAMPLE TYPE	NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲ 40 80 120	Cu TORVANE (kPa) ◆ 20 40 60 80
	1			SILTY CLAY (ALLUVIAL) (CI-CH) - Brown, damp, stiff, intermediate to high plasticity, trace sand, trace organics, trace rootlets, trace oxidation.					PL MC LL; % 20 40 60 80
		5				S1			
	2			- Firm, increase in moisture content, no sand, decrease in organics and rootlets below 1.53 m.					
	3	10				S2			
				- No organics and rootlets below 3.35 m.					
	4					S3			
		15							
	5					S4			
				- Silty clay becomes grey, trace oxidation below 5.79 m.					
	6	20							
				- Firm at 6.71 m.					
	7								
		25		- Softer, increase in silt content, no oxidation below 7.32 m.		S5			

SAMPLE TYPE Auger Grab

CONTRACTOR Paddock Drilling Ltd. INSPECTOR R. DOBSON APPROVED DCL DATE 21/9/07

SPT & TORVANE 2 (SANS CORE) P:\PROJECTS\2006\06-0107-12\GEOLOGS\06-107-12LOGS.GPJ

KGS GROUP

SUMMARY LOG

HOLE NO. **TH06-02**

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	SAMPLE TYPE	NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲	Cu TORVANE (kPa) ◆
				- Seepage at 7.92 m.				40 80 120	20 40 60 80
						S6			PL MC LL
	9	30		SILT TILL - Tan, wet, very soft, with sand, with gravel.					% 20 40 60 80
	10					S7			
		35		- Dry and dense below 10.67 m.					
	11					S8			
				AUGER REFUSAL AT 11.28 m					
				- Small amount of water in the testhole at the end of drilling.					
				- Contractor switched to HQ coring at 11.28 m.					
				- Limestone bedrock was encountered at 14.15 m.					
	12	40							
	13								
		45							
	14								
	15								
		50							
	16								
		55							
	17								

SAMPLE TYPE Auger Grab

CONTRACTOR Paddock Drilling Ltd.

INSPECTOR R. DOBSON

APPROVED

DATE 21/9/07

SPT & TORVANE 2 (SANS CORE) P:\PROJECTS\2006\06-0107-12\GEO\LOGS\06-107-12LOGS.GPJ

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH06-02**

CLIENT CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT

PROJECT

SITE St. Vital Park

LOCATION 5,521,518 N 633,636 E

DRILLING METHOD 125 mm ø Solid Stem Auger and HQ Core Barrel, Acker MP5-T

JOB NO. 06-107-12

GROUND ELEV. 227.5 m

TOP OF PVC ELEV.

WATER ELEV.

DATE DRILLED 14-Jul-06

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
	15	50		**LIMESTONE (MUDSTONE TO WACKESTONE (14.15 m to 20.42 m))** (Overall description of cored bedrock) - Mottled beige and yellow, dense, trace pinpoint porosity. Light beige to yellow below 17.32 m, trace vugs below 18.87 m. Dolomitic limestone encountered from 18.02 m to 18.62 m and then again from 19.08 m to 19.35 m. Dolomitic limestone was mottled pink, red and beige. R1 (14.15 m to 15.85 m): Limestone (mudstone to wackestone) - Mottled beige and yellow, dense, trace pinpoint porosity. Horizontal fractures at 14.27 m, 14.40 m, 14.45 m, 14.53 m, 14.55 m, 14.68 m, 14.76 m, 14.81 m, 14.88 m, 14.91 m, 15.01 m, 15.04 m, 15.06 m, 15.11 m, 15.19 m, 15.24 m, 15.29 m, 15.44 m. Fractures are tight to part open, rough texture, trace manganese. Vertical fractures from 14.22 m to 14.30 m. Fracture is tight and smooth. Limestone is highly fractured and broken into small peieces from 15.44 m to 15.85 m.			R1	19	90	37
	16	55		R2 (15.85 m to 17.32 m): Limestone (mudstone to wackestone) - Mottled beige and yellow, trace pinpoint porosity. Limestone is highly fractured and broken into small pieces from 15.85 m to 15.98 m. Horizontal fractures at 16.03 m, 16.08 m, 16.13 m, 16.31 m, 16.46 m, 16.84 m, 16.87 m, 17.07 m, 17.12 m, 17.23 m, 17.30 m. Subangular fractures at 17.48 m and 17.50 m. Fractures are tight to part open, rough texture. Limestone becomes mottled tan-white at 17.53 m. Vertical fractures from 15.98 m to 16.08 m and 17.22 m to 17.32 m. Vertical fractures are tight to part open, brown stained, and rough texture.			R2	15	100	62
	17	60		R3 (17.32 m to 18.87 m): Limestone (mudstone to wackestone) - Light biege to yellow in color, trace pinpoint porosity, dense. Dolomitic limestone from 18.02 m to 18.62 m. The dolomitic limestone was mottled pink, red and beige. Horizontal fractures at 17.42 m, 17.45 m, 17.68 m, 17.86 m, 17.98 m, 18.03 m, 18.06 m, 18.11 m, 18.19 m, 18.34 m, 18.42 m, 18.52 m, 18.62 m, 18.64 m, 18.67 m. First 3 fractures are tight to part open, brown stained, rough texture. Limestone is heavily fractured from 17.68 m to 17.78 m. Fractures are tight to part open, brown stained, rough texture. The rest of the horizontal fractures are tight to part open, rough texture with a trace of brown staining. Vertical fracture from 17.32 m to 17.86 m. Fracture is tight to part open, brown stained, rough in texture.			R3	16	100	38
	19	65		R4 (18.87 m to 20.42 m): Limestone (mudstone to wackestone) - Light biege to yellow in color, dense, trace pinpoint porosity, trace vugs. Horizontal fractures at 19.08 m, 19.30 m, 19.76 m, 19.81 m, 19.89 m, 19.96 m, 19.99 m, 20.07 m, 20.32 m. Fractures are tight to part open, rough texture. Horizontal fracture at 19.89 m, 19.35 m,19.43 m. Fractures are open and rough. Angular fracture from 19.56 m to 19.63 m. Fracture is tight to part open, yellow chalky texture. Dolomitic limestone extends from 19.08 m to 19.35 m. Limestone is mottled pink, red and biege in color, dense with a trace of pinpoint porosity.			R4	13	100	67
	21	70		**END OF HOLE AT 20.42 m.** Notes: 1. While coring through silt till and an occassional limestone or granite boulder was cored through up to 30 cm in diameter. 2. Some gravel and cored boulders were recovered in core barrel.						
	22									

CONTRACTOR Paddock Drilling Ltd.

INSPECTOR R. DOBSON

APPROVED

DATE 22/11/07

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH07-01**

CLIENT CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT

PROJECT SEWER RIVER CROSSING

SITE Willow-Crane Interceptor River Crossing

LOCATION Downstream of pipe alignment 5,521,620 N 633,697 E

DRILLING METHOD HQ Core Barrel - Barged Mounted

JOB NO. 07-107-11

RIVER ELEV. 223.80 m

TOP OF PVC ELEV.

WATER ELEV.

DATE DRILLED 08-Aug-07

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
	0			**WATER**						
	1									
		5								
	2									
	3									
		10								
	4									
		15								
	5									
218.4				**RIVER SEDIMENT**						
217.8	6			**UNCEMENTED SILT TILL** - Recovered medium to coarse grained subrounded subangular gravel and cobbles in core barrel. Cored approx 0.15 m diameter granite cobble.						
		20								
	7									
		25								
	8						S1		26	
214.9	9			**CEMENTED SILT TILL** - Brown, moist, dense, some fine to coarse grained sand, some fine to coarse grained subrounded to subangular gravel, trace clay.						
		30					S2		100	

CONTRACTOR Paddock Drilling Ltd.

INSPECTOR D. ANDERSON & S. KINGSLEY

APPROVED _____ DATE 21/11/07

CORE (RIVER) P:\PROJECTS\2007\07-0107-11\GEO\LOGS\07-107-11LOGS.GPJ

KGS GROUP

SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH07-01**

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	RUN	JOINTS PER RUN	RECOVERY %	R.Q.D. %
213.8				**LIMESTONE BEDROCK** - Mottled tan and yellow, predominantly mudstone, trace areas of wackestone, trace vugs throughout, trace pinpoint porosity. Highly fractured zone between 10.03 m and 10.29 m.			R1	13	100	13
	11	35		- Vugs between 11.82 m and 11.89 m.			R2	16	100	58
	12	40								
	13	45		- Purple mottled with tan between 13.46 m and 13.72 m. - Tan mottled with yellow at 13.72 m.			R3	18	97	9
	14			- Weathered/ oxidized zone, bedrock brittle between 14.05 m and 14.15 m.						
	15	50					R4	10	100	73
	16									
207.3		55		**END OF HOLE AT 16.54 m.**						
	17			Notes 1. Contractor drilled casing advancer to 7.47 m and began HQ coring at 7.47 m. 2. No sample recovery from 5.36 m to 7.47 m. 3. Water elevation 223.8 m measured on August 8, 2007 at Fort Gary Bridge						
	18	60								
	19									
	20	65								
	21	70								

CONTRACTOR Paddock Drilling Ltd.

INSPECTOR D. ANDERSON & S. KINGSLEY

APPROVED DQ

DATE 21/11/07

CORE (RIVER) P:\PROJECTS\2007\07-0107-11\GEOLOGS\07-107-11LOGS.GPJ

KGS GROUP	GEOLOGICAL DETAIL FRACTURE LOG	Hole No.	TH07-01
		Sheet	1 of 3
Site / Location	Willow-Crane Interceptor River Crossing	Client	City of Winnipeg
Contractor	Paddock Drilling Ltd.	Project	River Sewer Crossings
Core Diameter	63.5 mm	Project No.	07-107-11
Method	HQ Core Barrel	Logged By	SJK
		Date	August 8, 2007
Bearing of Hole	Not Applicable	River Level	223.8
Angle From Horizontal	90	Date	August 8, 2007
Depth to Rock Surface	10.03 m		

DEPTH (m)	DISCONT-INUITY JOINT FOLIATION BEDDING PLANE FAULT. SHEARING ZONE ETC.	ANGLE WITH CORE AXIS	DESCRIPTION																				
													JOINT FILLING										
			HAIRLINE	TIGHT	OPEN (IN)	SMOOTH	ROUGH	SLICKENSIDED	PLANOR	CURVED	WEATHERED	STAINED (IRON)	CLAY	CHLORITE	RUST	GYPSUM	TALC	QUARTZ	SERPENTINE	CARBONATE	SILT		
10.03-10.29	BZ				X		X				X												
10.36	H	90			X		X				X												
10.34-10.41	SV	20			X		X				X		X										
10.54	H	90			X				X														
10.58	H	90			X				X														
10.62	H	90			X		X																
10.64	H	90			X				X														
10.69	H	90			X				X		X		X										
10.77	H	80			X		X				X		X										
10.85	H	90			X	X																	
10.96	H	90			X		X				X												
11.15	H	90			X	X																	
11.16-11.35	V	0			X				X		X												
11.38	H	90			X				X				X										
11.43-11.56	BZ				X		X																
11.60	SH	70			X		X				X		X										
11.82	H	90			X		X				X												
11.82-12.24	V	0	X	X			X				X												
11.91	H	90			X		X																
11.96	H	90			X				X				X										
12.34	H	90			X	X																	

APPROVED:	SHIFT:	DATE:

LEGEND:	BZ – Broken Zone	H – Horizontal	V – Vertical
	MB – Machine Break	SH- Sub-Horizontal	SV - Sub-Vertical

KGS GROUP	GEOLOGICAL DETAIL FRACTURE LOG	Hole No.	TH07-01
		Sheet	2 of 3
Site / Location	Willow-Crane Interceptor River Crossing	Client	City of Winnipeg
Contractor	Paddock Drilling Ltd.	Project	River Sewer Crossings
Core Diameter	20 mm	Project No.	07-107-11
Method	HQ Core Barrel	Logged By	SJK
		Date	August 8, 2007
Bearing of Hole	Not Applicable	River Level	223.8
Angle From Horizontal	90	Date	August 8, 2007
Depth to Rock Surface	10.03 m		

DEPTH (m)	DISCONT-INUITY JOINT FOLIATION BEDDING PLANE FAULT. SHEARING ZONE ETC.	ANGLE WITH CORE AXIS	DESCRIPTION																				
													JOINT FILLING										
			HAIRLINE	TIGHT	OPEN (IN)	SMOOTH	ROUGH	SLICKENSIDED	PLANOR	CURVED	WEATHERED	STAINED (IRON)	CLAY	CHLORITE	RUST	GYPSUM	TALC	QUARTZ	SERPENTINE	CARBONATE	SILT		
12.37	H	90			X		X						X										
12.62	H	90		X					X														
12.67	H	90			X		X																
12.67-12.98	V	10			X		X					X											
12.75	H	90			X		X																
12.80	H	90			X		X																
12.80-13.08	V	5	X	X					X														
12.88	H	90			X		X				X												
13.08	H	90			X				X														
13.21	H	80		X			X				X												
13.21-13.39	V	10			X		X				X												
13.32	H	90			X		X				X												
13.32-13.41	BZ				X		X																
13.55	H	90		X					X														
13.72	H	90			X		X				X												
13.74	H	90			X		X				X												
13.82	H	90			X	X																	
13.89	H	90			X		X																
13.89-14.06	V	5			X		X																
14.07	H	80			X		X				X	X											
14.17	H	75			X		X				X	X											

APPROVED:	SHIFT:	DATE:

LEGEND:	BZ – Broken Zone	H – Horizontal	V – Vertical
	MB – Machine Break	SH- Sub-Horizontal	SV - Sub-Vertical

KGS GROUP	GEOLOGICAL DETAIL FRACTURE LOG	Hole No.	TH07-01
		Sheet	3 of 3
Site / Location	Willow-Crane Interceptor River Crossing	Client	City of Winnipeg
Contractor	Paddock Drilling Ltd.	Project	River Sewer Crossings
Core Diameter	20 mm	Project No.	07-107-11
Method	HQ Core Barrel	Logged By	SJK
		Date	August 8, 2007
Bearing of Hole	Not Applicable	River Level	223.8
Angle From Horizontal	90	Date	August 8, 2007
Depth to Rock Surface	10.03 m		

DEPTH (m)	DISCONT-INUITY JOINT FOLIATION BEDDING PLANE FAULT. SHEARING ZONE ETC.	ANGLE WITH CORE AXIS	DESCRIPTION																				
													JOINT FILLING										
			HAIRLINE	TIGHT	OPEN (IN)	SMOOTH	ROUGH	SLICKENSIDED	PLANOR	CURVED	WEATHERED	STAINED (IRON)	CLAY	CHLORITE	RUST	GYPSUM	TALC	QUARTZ	SERPENTINE	CARBONATE	SILT		
14.17-14.55	V	0		X					X														
14.33	H	90			X		X				X												
14.43	H	90			X		X				X												
14.57	SH	60		X			X																
14.61	H	90			X		X				X												
14.76	H	90		X			X																
14.90	H	90			X				X		X												
14.97	H	90			X	X																	
15.05	H	90			X		X																
15.21	H	90			X		X			X	X												
15.21-15.35	V	0			X		X				X	X											
15.54	H	90			X				X														
15.75	H	90			X				X		X												
15.95	H	90			X		X																
16.13	H	90			X	X				X													
16.22	H	90			X		X				X				X								
16.28	H	90			X		X				X												
16.34	H	90			X		X				X												
16.43	H	90			X		X				X												

APPROVED:	SHIFT:	DATE:

LEGEND:	BZ – Broken Zone	H – Horizontal	V – Vertical
	MB – Machine Break	SH- Sub-Horizontal	SV - Sub-Vertical

KGS GROUP	GEOLOGICAL DETAIL FRACTURE LOG	Hole No.	TH07-01
		Sheet	1 of 3
Site / Location	Willow-Crane Interceptor River Crossing	Client	City of Winnipeg
Contractor	Paddock Drilling Ltd.	Project	River Sewer Crossings
Core Diameter	63.5 mm	Project No.	07-107-11
Method	HQ Core Barrel	Logged By	SJK
		Date	August 8, 2007
Bearing of Hole	Not Applicable	River Level	223.8
Angle From Horizontal	90	Date	August 8, 2007
Depth to Rock Surface	10.03 m		

DEPTH (m)	DISCONT-INUITY JOINT FOLIATION BEDDING PLANE FAULT. SHEARING ZONE ETC.	ANGLE WITH CORE AXIS	DESCRIPTION																				
													JOINT FILLING										
			HAIRLINE	TIGHT	OPEN (IN)	SMOOTH	ROUGH	SLICKENSIDED	PLANOR	CURVED	WEATHERED	STAINED (IRON)	CLAY	CHLORITE	RUST	GYPSUM	TALC	QUARTZ	SERPENTINE	CARBONATE	SILT		
10.03-10.29	BZ				X		X				X												
10.36	H	90			X		X				X												
10.34-10.41	SV	20			X		X				X		X										
10.54	H	90			X				X														
10.58	H	90			X				X														
10.62	H	90			X		X																
10.64	H	90			X				X														
10.69	H	90			X				X		X		X										
10.77	H	80			X		X				X		X										
10.85	H	90			X	X																	
10.96	H	90			X		X				X												
11.15	H	90			X	X																	
11.16-11.35	V	0			X				X		X												
11.38	H	90			X				X				X										
11.43-11.56	BZ				X		X																
11.60	SH	70			X		X				X		X										
11.82	H	90			X		X				X												
11.82-12.24	V	0	X	X			X				X												
11.91	H	90			X		X																
11.96	H	90			X				X				X										
12.34	H	90			X	X																	

APPROVED:	SHIFT:	DATE:

LEGEND:	BZ – Broken Zone	H – Horizontal	V – Vertical
	MB – Machine Break	SH- Sub-Horizontal	SV - Sub-Vertical

KGS GROUP	GEOLOGICAL DETAIL FRACTURE LOG	Hole No.	TH07-01
		Sheet	2 of 3
Site / Location	Willow-Crane Interceptor River Crossing	Client	City of Winnipeg
Contractor	Paddock Drilling Ltd.	Project	River Sewer Crossings
Core Diameter	20 mm	Project No.	07-107-11
Method	HQ Core Barrel	Logged By	SJK
		Date	August 8, 2007
Bearing of Hole	Not Applicable	River Level	223.8
Angle From Horizontal	90	Date	August 8, 2007
Depth to Rock Surface	10.03 m		

DEPTH (m)	DISCONT-INUITY JOINT FOLIATION BEDDING PLANE FAULT. SHEARING ZONE ETC.	ANGLE WITH CORE AXIS	DESCRIPTION																				
													JOINT FILLING										
			HAIRLINE	TIGHT	OPEN (IN)	SMOOTH	ROUGH	SLICKENSIDED	PLANOR	CURVED	WEATHERED	STAINED (IRON)	CLAY	CHLORITE	RUST	GYPSUM	TALC	QUARTZ	SERPENTINE	CARBONATE	SILT		
12.37	H	90			X		X						X										
12.62	H	90		X					X														
12.67	H	90			X		X																
12.67-12.98	V	10			X		X					X											
12.75	H	90			X		X																
12.80	H	90			X		X																
12.80-13.08	V	5	X	X					X														
12.88	H	90			X		X				X												
13.08	H	90			X				X														
13.21	H	80		X			X				X												
13.21-13.39	V	10			X		X				X												
13.32	H	90			X		X				X												
13.32-13.41	BZ				X		X																
13.55	H	90		X					X														
13.72	H	90			X		X				X												
13.74	H	90			X		X				X												
13.82	H	90			X	X																	
13.89	H	90			X		X																
13.89-14.06	V	5			X		X																
14.07	H	80			X		X				X	X											
14.17	H	75			X		X				X	X											

APPROVED:	SHIFT:	DATE:

LEGEND:	BZ – Broken Zone	H – Horizontal	V – Vertical
	MB – Machine Break	SH- Sub-Horizontal	SV - Sub-Vertical

KGS GROUP	GEOLOGICAL DETAIL FRACTURE LOG	Hole No.	TH07-01
		Sheet	3 of 3
Site / Location	Willow-Crane Interceptor River Crossing	Client	City of Winnipeg
Contractor	Paddock Drilling Ltd.	Project	River Sewer Crossings
Core Diameter	20 mm	Project No.	07-107-11
Method	HQ Core Barrel	Logged By	SJK
		Date	August 8, 2007
Bearing of Hole	Not Applicable	River Level	223.8
Angle From Horizontal	90	Date	August 8, 2007
Depth to Rock Surface	10.03 m		

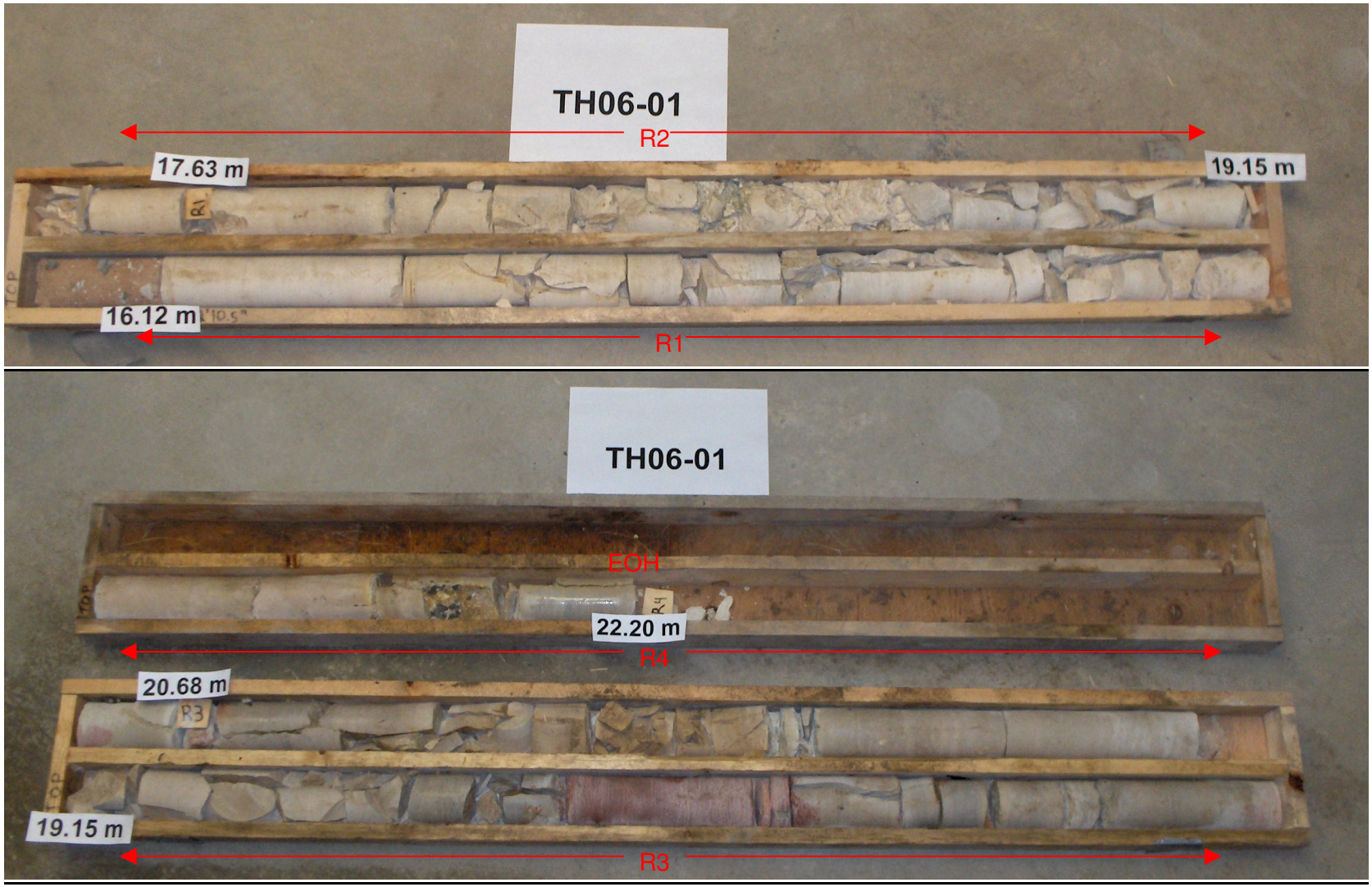
DEPTH (m)	DISCONT-INUITY JOINT FOLIATION BEDDING PLANE FAULT. SHEARING ZONE ETC.	ANGLE WITH CORE AXIS	DESCRIPTION																				
													JOINT FILLING										
			HAIRLINE	TIGHT	OPEN (IN)	SMOOTH	ROUGH	SLICKENSIDED	PLANOR	CURVED	WEATHERED	STAINED (IRON)	CLAY	CHLORITE	RUST	GYPSUM	TALC	QUARTZ	SERPENTINE	CARBONATE	SILT		
14.17-14.55	V	0		X					X														
14.33	H	90			X		X				X												
14.43	H	90			X		X				X												
14.57	SH	60		X			X																
14.61	H	90			X		X				X												
14.76	H	90		X			X																
14.90	H	90			X				X		X												
14.97	H	90			X	X																	
15.05	H	90			X		X																
15.21	H	90			X		X			X	X												
15.21-15.35	V	0			X		X				X	X											
15.54	H	90			X				X														
15.75	H	90			X				X		X												
15.95	H	90			X		X																
16.13	H	90			X	X				X													
16.22	H	90			X		X				X				X								
16.28	H	90			X		X				X												
16.34	H	90			X		X				X												
16.43	H	90			X		X				X												

APPROVED:	SHIFT:	DATE:

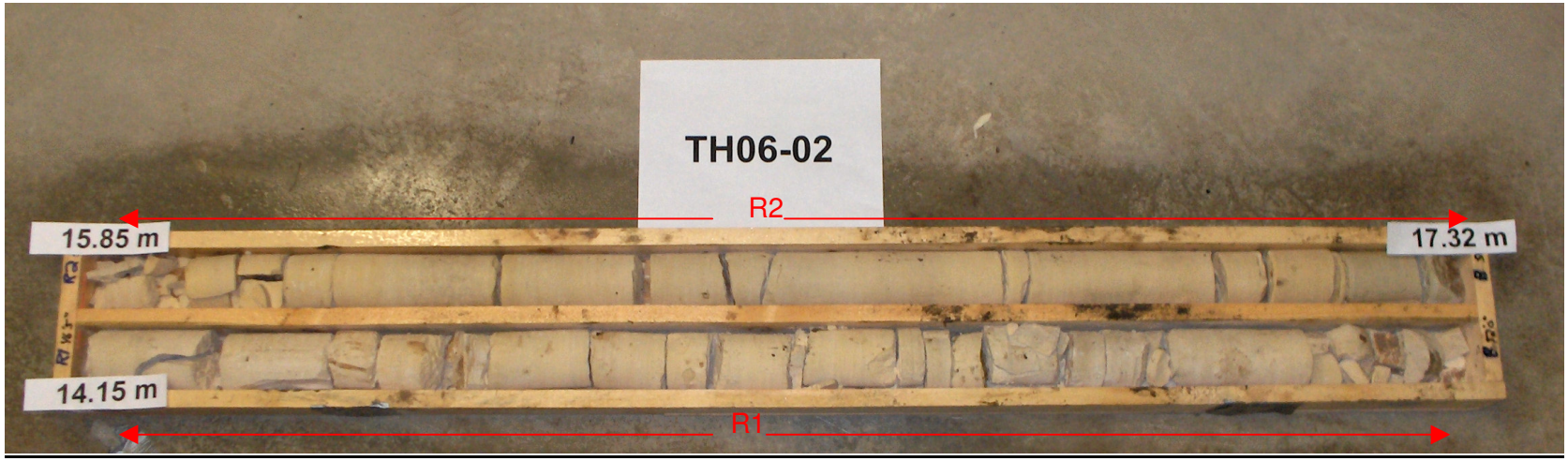
LEGEND:	BZ – Broken Zone	H – Horizontal	V – Vertical
	MB – Machine Break	SH- Sub-Horizontal	SV - Sub-Vertical

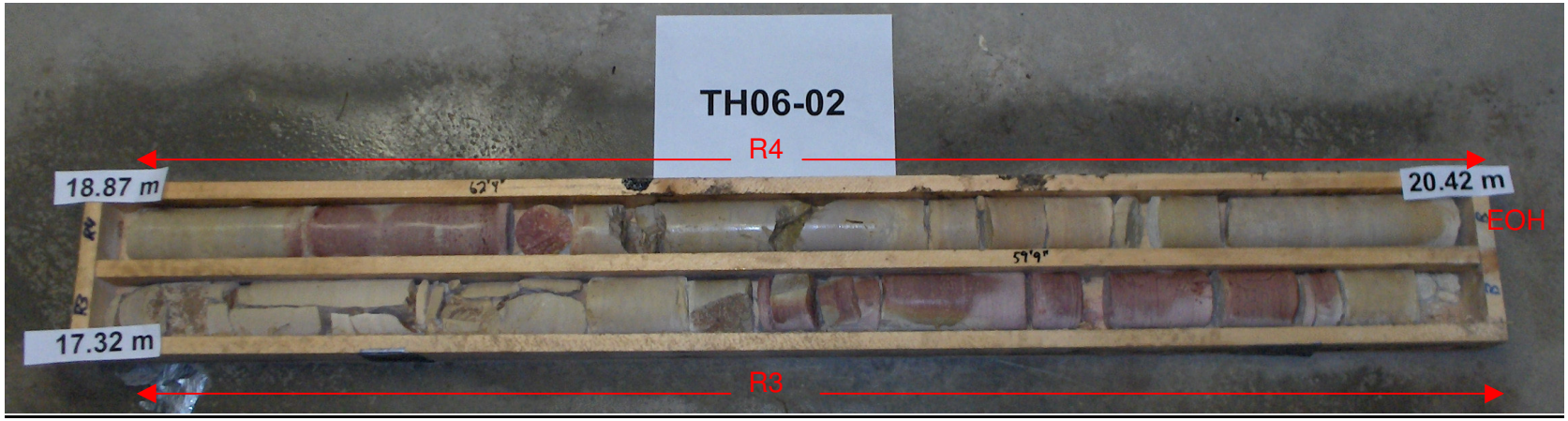
APPENDIX B

CORE PHOTOS

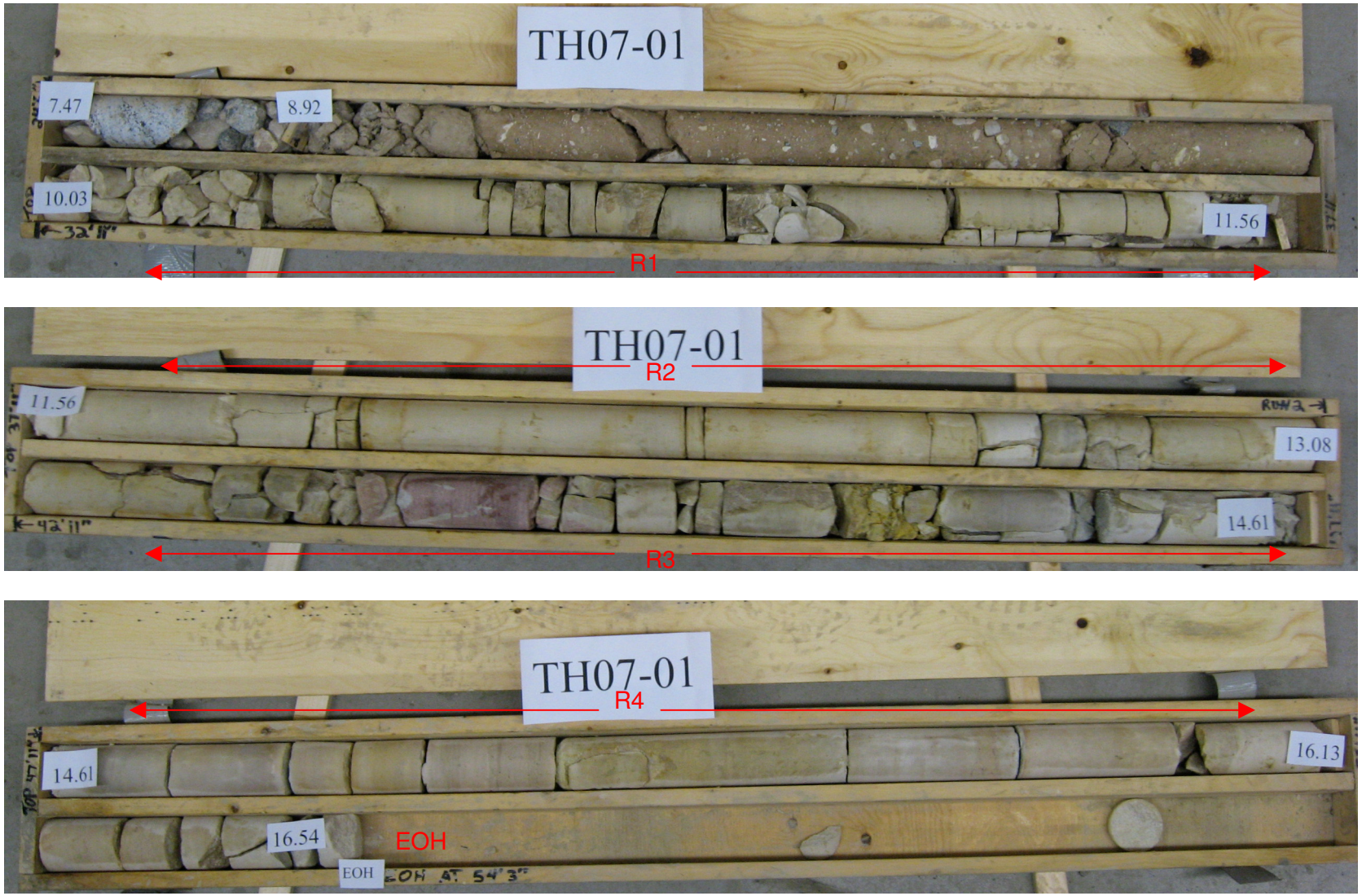


Refer to TH06-01 in Appendix A for detailed description of core





Refer to TH06-02 in Appendix A for detailed description of core



Refer to TH07-01 in Appendix A for detailed description of core