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GEOLOGICAL REPORT

RIVER BANK STABILITY STUDY

UNIVERSITY OF ALBERTA

EDMONTON, ALBERTA

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UNIVERSITY OF ALBERTA

EDMONTON, ALBERTA

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INTRODUCTION

General Remarks

This report summarizes the results of a surface and subsurface geologic investigation of the northern part of the campus of the University of Alberta, Edmonton, Alberta. The work was financed by the Department of Public Works, Province of Alberta. The Department of Civil Engineering, University of Alberta, administered the work, which was part of the River Bank Stability Study.

Location

The area of most detailed study is located in the city of Edmonton, and bounded on the south by 87 Avenue, on the east by 112 Street, on the west by 116 Street and on the north by the North Saskatchewan River. The geology of areas adjacent to the campus was investigated in less detail.

Purpose of Study

The purpose of this study is to define the geologic setting of the area and to delineate the geologic factors which affect the construction and stability of engineering structures. Specifically, attention is directed to the geologic factors that contribute to the stability of the south bank of the North Saskatchewan River.

Scope and Methods

Information in this report was obtained from field examination of exploratory test-hole drill samples and examination of outcrops along the river bank. Aerial photographs were studied stereoscopically to establish

the geomorphic units in the area. An aerial photograph mosaic was used as a base map for compilation of the data. (Plate 1).

Drilling was done mainly by the wet method which is not satisfactory for detailed study of the deposits encountered, especially during winter months, but sufficient information was obtained for the purpose of this report. Test holes were located to obtain maximum geologic control with a minimum number of holes; the locations of the test holes are shown in Figure 1. All holes were drilled to bedrock. Piezometers have been installed in some of the holes by the Civil Engineering Department.

A reconnaissance geologic study was made of areas adjacent to the area of the report. Field examination entailed location and description of outcrops and determination of the stratigraphic succession in gullies along the steep banks of the river valley. Good exposures are rare and widely spaced. Springs were also located.

All lithologic details of deposits described in field localities are recorded in Appendix A and those encountered in test holes in Appendix B. The aerial photograph mosaic (Plate 1) and the geologic map (Figure 1) show the distribution of deposits described in the report. The cross sections (Figure 2) show the subsurface conditions. Reference should be made to these illustrations to facilitate understanding the information presented in the report.

PREVIOUS WORK

Previous work dealing specifically with the area of this report is lacking. A considerable amount of work has been done in the Edmonton area as a whole, but on a more regional basis. Taylor (1934) studied the

bedrock and surficial materials exposed in the valley of the North Saskatchewan River. The bedrock geology was described thoroughly by Ower (1958) and the Edmonton coalfields by Dowling (1910). Sediments of Glacial Lake Edmonton have been studied by Hughes (1958) and the surficial geology by Bayrock and Hughes (1962) and Duff (1955). Buried valleys have been grossly delineated by Farvolden (1963). Two reports presently being prepared by the Research Council of Alberta will add greatly to the knowledge of the buried valleys in the region. A very recent study of geologic deposits in downtown Edmonton has been completed by L. A. Bayrock and T. Berg of the Research Council of Alberta. This work by the Research Council was done in response to the recognized need for numerous details of geology for engineering projects in the metropolitan area. Long term meteorological records for the city of Edmonton are available from the Dominion Public Weather Office (1965) at Edmonton.

GEOMORPHOLOGY

General Remarks

The major geomorphic units present in the area include a glaciolacustrine plain (Glacial Lake Edmonton), the deeply eroded valley of the North Saskatchewan River and an extensive alluvial terrace within the valley. Many minor landforms occur within these major geomorphic units. The composition of the materials making up the landforms is discussed in the section of the report on stratigraphy.

Glaciolacustrine Plain

Both north and south of the North Saskatchewan River is a very gently rolling glaciolacustrine plain. In the area of the campus, the

plain is featureless except for a very low broad topographic rise trending north-south (Figure 1 and Plate 1). Subsurface information indicates that this rise is the topographic reflection of an extensive glacial sand deposit which has been nearly obscured by later (and in part contemporaneous) deposition of lacustrine silts and clays. The deposits are discussed more fully in another part of this report.

North Saskatchewan River Valley

The North Saskatchewan River valley borders the northern part of the campus. The valley is about 170 feet deep and has steep sides with an average slope of about 30 degrees, close to the repose angle for non-cohesive material. In the western part of the area the valley sides slope directly down to the river but in the eastern part the valley wall adjoins an alluvial terrace.

A distinctive feature of the valley sides is subdued slump topography. As shown in Figure 1 extensive slump topography is present in the eastern part of the area; a small area of slump topography also occurs in the extreme northwestern part of the map sheet.

Minor features of the valley sides include small fresh landslides and steep-sided gullies. The gullies are as much as 40 feet deep in the area north of the Agriculture and Biological Sciences Building. The landslides are described in detail in the section on engineering geology.

Alluvial Terrace

The northeastern part of the area is occupied by a well pronounced alluvial terrace of the North Saskatchewan River. The surface of the terrace is very slightly undulating, but slopes generally to the east. The top of

the terrace is about 40 feet above the present level of the river. The bank below the terrace has a slope of about 35 degrees. A large borrow pit is present in the terrace just to the west of the High Level Bridge and is about 20 feet deep.

STRATIGRAPHY

General Remarks

Deposits of four ages are present in the area: (1) Upper Cretaceous; (2) the Saskatchewan sand and gravel; (3) glacial; and (4) postglacial or Recent. The deposits are described in order from the oldest to the youngest. Preglacial erosion has removed all Tertiary deposits of the area and also some Upper Cretaceous rocks.

Upper Cretaceous Rocks

Sedimentary rocks of Upper Cretaceous age crop out for a short distance along the river bank (Plate 2) and belong to the Edmonton Formation. The regional dip is about 20 feet to the mile towards the southwest (Bayrock and Hughes, 1962, p. 16). The strata consist of interbedded grey shale, grey sandstone, greenish grey bentonitic sandstone, coal and bentonite.

In outcrop shale is the most common rock. A coal bed occurs about 20 feet above the river at localities 3 & 5'. The coal is two to three feet thick and is underlain by a thin greyish green bentonite bed. The shales are only slightly indurated as are some of the sandstones but well cemented sandstones may occur in the area.

In the subsurface beneath the campus shale is the most common rock, but two thin bentonite zones are present. One zone is known within

the elevation range 2125 and 2140 in the vicinity of test holes U 65-3 and U 65-4; the other zone occurs at an elevation of about 2078 along the river bank between localities 2 & 3. These bentonite beds may be of considerable lateral extent. Soft sandstone and bentonitic sandstone beds also occur in the subsurface but are not persistent.

The upper surface of the Edmonton Formation ranges in elevation from 2090 to 2190 feet, that is, local relief of the bedrock surface is about 100 feet as shown in Figure 1. This local relief is a direct result of long-continued river erosion prior to the deposition of the Saskatchewan sands and gravels. The northwestern part of the campus is underlain by the east flank of a large buried valley. As a result in some places the Saskatchewan sands and gravels overlie the Edmonton Formation and in other places glacial deposits overlie the Edmonton Formation. This upper contact of the Edmonton Formation is abrupt and defines an erosional unconformity of considerable magnitude.

Saskatchewan Sands and Gravels

Unconsolidated sediments of preglacial age include only the Saskatchewan sands and gravels in this report. (This formation is also known as Saskatchewan Gravels). Recent summaries of the regional extent and character of this formation are given by Westgate (1965).

Under the campus the Saskatchewan sands and gravels are absent south of the 2160 foot bedrock topographic contour line. At locality 3 (Figure 1) the unit is partly exposed and can be generally divided into a lower sandy gravel zone and an upper clayey sand zone. The sandy gravel is up to 20 feet thick and the sand is up to 60 feet thick. Both units attain their maximum thickness in the northwestern part of the campus and

decrease in thickness to the southeast. Their distribution and range in thickness is given in Figure 2.

Glacial Deposits

Glacial deposits form most of the surficial materials. Three main types of glacial deposits have been recognized: (1) glacial till; (2) lacustrine sediment; and (3) ice-contact shallow-water sand.

Glacial Till

A sheet of glacial till occurs below the lacustrine deposits and above the Edmonton formation and Saskatchewan sands and gravels in the area. It is present everywhere except in test-hole U 66-G5. The till is mainly 50 to 60 feet thick but may be as much as 100 feet thick at test-hole U 66-G8.

The till is medium brown to dark grey in colour; the brown colour is usually restricted to the upper 20 feet of the till. There are very few pebbles or boulders in the till which is generally clayey but locally quite sandy. It is everywhere of high density. Some minor sand lenses occur in the till but are usually very thin and not continuous laterally.

Lacustrine Sediment

Lacustrine deposits form most of the surficial material in the area. The sequence of silty clay, clay, and some sand accumulated in Glacial Lake Edmonton. Deposits of Lake Edmonton overlie glacial till everywhere except in test-hole U 66-G5 where they overlie glacial outwash sand and gravelly sand. The average thickness of the lake deposits is about 30 feet with little variation.

In some places two materials can be identified in the Lake Edmonton deposits, an upper clay and a lower silt or sand.

Ice-Contact Shallow-Water Sand

An extensive, slightly sinuous, elongate sand deposit occurs between the upper part of the till and the bottom of the Lake Edmonton deposits. The sand body trends in a north-south direction and is expressed topographically as a low, broad ridge, readily detected on aerial photographs. The ridge is indicated on Plate I by dotted lines. The general extent of the sand was confirmed by the test-holes on the campus. The eastern limit of the sand has not been well defined.

The sand is very light brown in colour, fine to medium grained, with some pebble bands, thinly to thickly cross-bedded, and of medium density. The maximum thickness is 53 feet in the area of the Administration Building. The sand is thinner to both east and west. The character of the sand was examined in the excavation of the new Students' Union Building (Locality 9) and is illustrated in Plates 4 and 5. Here, as in many of the test holes, a thin layer of till-like material was found to overlie the sand; at depth the sand overlies a thick till. The overlying thin layer of till-like material is here interpreted as being a flow till, derived from a glacier which was very close during the time of formation of the sand deposit. Also at this locality, the upper layers of sand are interbedded with clay and silt layers of lacustrine origin. This indicates that the sand was deposited at the same time as the early deposits of Lake Edmonton. The sand is inferred to be an ice-contact deposit, laid down at the margin of a glacial lake. Cross-beds in the sand dip gently (about 5°) to the south at locality 9, indicating a southerly flow to the current which deposited the sand.

Recent Material

Recent material includes all surficial deposits which have accumulated since the complete removal of water of Glacial Lake Edmonton. Included in this group of materials are: (1) river terrace deposits; (2) mass movement deposits; (3) alluvial deposits; and (4) man-made fill. Outcrops of the latter two units are very limited, so these units are not described separately.

River Terrace Deposits

River terrace deposits consist mainly of medium to dark brown, clayey, sandy silt, with some gravel lenses. These deposits are generally poorly exposed in the area and were not extensively studied.

Mass-Movement Deposits

Mass-movement deposits are accumulations of soil or rock due to the action of gravity. Three types are present in the area: (1) slump topography; (2) colluvial deposits; and (3) fresh landslides.

1. Slump topography: There are two locations of slump topography in the area, as described under geomorphology. The composition of the materials forming slump topography is unknown since these areas were studied mainly by aerial photographs; outcrops were not discovered. Some test holes penetrated the slump areas but outcrops or excavations are required to adequately describe the deposits.

The slump topography northeast of the campus was formed when the North Saskatchewan River was not as deeply entrenched as it is at present, prior to the formation of the adjacent alluvial terrace. The landslides (slumps) which formed this slump topography are believed to have been deep-seated compared to the small fresh slides discussed in the following

paragraphs.

2. Colluvial Deposits: Colluvial deposits are present on all slopes within the area, especially on the slopes of the river bank. The deposits are almost entirely the result of soil creep but some may result in part from human traffic (Plate 2). Adequate exposures are lacking, but in general the colluvial deposits are composed of a mixture of fill, clay, silt, sand, pebbles and bedrock fragments and may show some form of lamination parallel to the slope surfaces.

3. Fresh Landslides: Three small landslides occurred along the river-bank during the summer of 1965 and are referred to as fresh slides (Figure 1). The landslides are at localities 2, 3, and 5. All three slides are shallow-seated compared to the older slumps described in a preceding paragraph. The surface material at locality 3 is fill as much as eight feet thick. The original failure took place in lacustrine clay underlying the fill. The deposit formed by the slide consist of a jumbled mass of fill, clay, and trash originally buried in the fill. The landslides at localities 2 and 5 affected both bedrock and the overlying Saskatchewan Sands and Gravels. Because the displacement of the material by these slides is limited, the material is not as badly mixed as the deposit of the slide at locality 3. The nature and inferred origin of the slides are discussed in the section on engineering geology.

GEOLOGIC HISTORY

General Remarks

The following information is presented as an aid to the interpretation of the consolidation history of the rock and surficial materials

in the area of the campus.

Cretaceous Deposition

During the latter part of Cretaceous time, the Edmonton area was covered with a shallow continental sea which extended far to the north and south and was bounded on the west by land masses of the central Cordilleran Region. To the east, in the area of Saskatchewan, the continental sea was deeper. Clay, silt and sand derived from local and distant land areas were deposited in numerous shallow bays, channels and tidal flats. Parts of the area were occupied by extensive swamps. Organic matter accumulating in these swamps became buried and later compacted by overlying sediments to form the extensive coal deposits of the Edmonton Formation. Volcanic activity to the west occurred spasmodically and deposited extensive "blankets" of volcanic ash present today as highly plastic bentonite beds or bentonitic sandstones. Most of the area was subject to deposition of clay minerals along with some intermixed silt and sand; these deposits form the widespread shales of the Edmonton Formation.

Paleocene Deposition and Subsequent Erosion

Deposition of Paleocene sediments probably occurred in the area but there is no record of this deposition. Regional considerations indicate that this is a reasonable interpretation. After deposition of the Paleocene strata, the area was subjected to uplift and erosion. Remnants of Paleocene rocks are found west of Edmonton and in isolated areas such as the Swan Hills, where Paleocene strata are about 1000 feet thick. Erosion continued to a time prior to the deposition of the Saskatchewan sands and

gravels. Thus it is possible that sedimentary rock at least 1000 feet and perhaps as much as 2000 feet thick has been removed from the area during this long interval of erosion.

Partial Valley Filling

Prior to the only recorded glacial advance in the Edmonton area, the valley systems eroded into the bedrock were partly filled with sand and gravel comprising the Saskatchewan sands and gravels. From the lithology of these sediments it is obvious that all of the material came from local bedrock areas or from the Rocky Mountains to the west.

Glaciation

Continental glacial ice covered the Edmonton area and extended far to the south. Bayrock and Hughes (1962, p. 28) presume a thickness of 5,000 feet of ice in the Edmonton area. This ice sheet deposited an extensive layer of glacial till in the area. Associated with this till are minor sand lenses, which are deposits from short-lived glacial streams flowing through the ice.

Deglaciation

As the ice wasted away, the natural easterly drainage was impeded by the front of the glacier and by glacial deposits. The blockage of drainage resulted in ponding of water forming widespread glacial lakes. Deposits of Glacial Lake Edmonton are a good example of material that accumulated as the result of ponding. The large sand body, referred to as ice-contact shallow-water sand in this report, may represent the first stages of formation of a large deltaic complex that formed in Lake Edmonton

adjacent to the melting glacial ice. As more and more water was impounded, the water in Lake Edmonton became deeper. Thick clay and silt deposits, some varved, accumulated in this water forming the uppermost deposits of Lake Edmonton sediments. When the water reached a certain level, it flowed over the rim of the basin. The main avenue of escape was the Gwynne outlet (Bayrock and Hughes, 1962) to the south of Edmonton; the character of this outlet indicates the water from Lake Edmonton was removed rapidly.

Modern Valley Cutting

The main event in the area since the removal of water of Lake Edmonton was the formation of the present North Saskatchewan River valley, with its tributary valleys, abandoned terraces, slump topography and present day gravel bars. Valley widening is inferred to have taken place mainly by vigorous bank erosion and large scale slumping. Only minor bank erosion and small scale slumping is known today, indicating that the river is not nearly as powerful an erosional agent as it was during initial stages of valley formation.

ENGINEERING GEOLOGY

General Remarks

The objective of this section of the report is to describe and evaluate the geologic factors which are important in the assessment of the stability of the south bank of the North Saskatchewan River immediately to the north of the proposed Biological Sciences Building.

Geologic Setting

The building site is located above the southeast flank of a buried valley which was a major tributary of the preglacial North Saskatchewan River. Bedrock of the Edmonton formation, composed of shale, sandstone, bentonitic sandstone, bentonite, and coal, occurs up to 20 feet above the river (elevation about 2090) near the building site (locality 3) and forms the floor of the buried valley. The buried valley is filled by the Saskatchewan sands and gravels which are overlain by glacial till which is in turn overlain by lacustrine sand and clay and fill (test hole U 65-7, Figure 2, and locality 3, Appendix A & B.)

Edmonton Formation

Fractured water-bearing coal seams and plastic bentonitic beds in the Edmonton formation contribute to the occurrence of shallow-seated landslides along the river bank, which is presently being undercut by the river. These conditions render the bank unstable. However, there is no direct evidence of deep-seated movement.

Buried Valley

The bottom of the buried valley is sloping towards the northeast and is quite extensive in the area (Figure 1). It is partly filled by a potential aquifer, the Saskatchewan sands and gravels. The only likely recharge of any significant magnitude into the buried valley is groundwater from possible bedrock aquifers present in the southeast bank of the buried valley. The North Saskatchewan River has cut completely through the buried valley both in the north and southwest. Only small amounts of groundwater in the aquifer are expected from surface infiltration because of the impervious nature of the lake deposits and particularly the

glacial till.

Groundwater discharge in the buried valley or from bedrock aquifers is therefore not a major hazard near the building site with "normal" amounts of precipitation; however, under abnormally wet conditions, such as the summer of 1965 (Dominion Public Weather Office, 1965, page 34), groundwater discharge will add significantly to the instability of the river bank near the building site and will foster the recurrence of shallow-seated slides described in following paragraphs.

Since the Saskatchewan sands and gravels are up to 80 feet thick along the river bank in the vicinity of the building site, the area is very well drained. Ice accumulations have been observed on the bank in the past, indicating that groundwater pressure build-up during the winter is possible.

Glacial Deposits

Glacial till is quite uniform throughout the area. Most of the buildings of the campus have foundations embedded in the till.

Minor sand lenses of low to medium density occur in the till but their extent is usually limited; these may be delineated by detailed drilling.

The ice-contact shallow-water sand deposit that is extensively developed in the subsurface on the campus does present a problem since the lower part is usually water-bearing. Tunnel construction may encounter this medium dense sand deposit anywhere in the area outlined in Figure 1. Groundwater occurs about 30 to 40 feet below the surface in most test-holes which encountered the sand. Detailed drilling would delineate this sand deposit more fully for specific engineering projects.

Construction in lacustrine clays which form most of the surface

deposits in the area is usually avoided if possible because of the expansive character of the clay.

Mass Movement

Fresh Landslides

As shown in Figure 1, three fresh landslides are present but all are small. Shallow-seated slides of this scale, however, will continue, and they will be especially prevalent at times of abnormally high precipitation. Rapid bank erosion will normally occur approximately at the same time, which may accelerate the growth of the slides. Features that are associated with these slides are trees inclined toward the river, tension cracks in the vicinity of the footpath just above the river, and ground water discharge from the bank. A description of the fresh landslides is given in the following paragraphs.

At locality 3, the upper part of the gully failed by slumping and initiated a narrow confined earthflow that travelled down slope to within 30 feet of the river level.

On July 3, 1965, a few days after the Edmonton area had received four inches of rain in two days, the slide consisted mainly of a block that had settled only one foot. The block was seven feet across, and extended along the bank about 20 feet. A pile of water-soaked mud and plant debris about 3.5 feet high was present at the lower part of the slide, within a small gully. By September 7, 1965, the original block was gone, and the area of the slide had expanded to a semicircular depression 41.5 feet across, with vertical walls about 10 feet high. Fragments of the block were strewn down the bottom of the gully. The sod bordering the slide scarp had sagged toward the depression. The slide now appears much as it

did in September.

A small sand run (Plate 3) developed in a sand deposit below the clay and above the till at this locality subsequent to the landslide.

The surface material at locality 3 is fill and is unusually thick (up to 8 feet thick) as judged from outcrop and test-hole drilling in the parking lot immediately to the south. It is also an area of a distinct shallow depression (Figure 1). On this basis this locality is interpreted as the site of a natural drainage depression which has been smoothed out by man in the process of landscaping without due regard to preserve avenues of escape for the original natural runoff.

The landslide at locality 2 (Plate 2) is described in detail in Appendix A. It is a combination rotational slump and mudflow, mostly in bedrock, in which occurs a thin band of bentonite, but the lower part of the Saskatchewan sands and gravels is also involved (see locality 6, Appendix A). Along the top of the Edmonton Formation from locality 2 east to locality 4, the ground was observed to be very wet, with pools of water in places; this water is groundwater discharge from the buried valley that is located beneath the campus. This slump is believed to result in part from undercutting of the bank by river erosion and in part from the observed ground water discharge.

Soil Creep

Soil creep phenomena will continue on all slopes of the area, especially steep slopes such as the river bank. No quantitative evaluation of the erosion hazard of soil creep is available for the area but creep will affect the stability of shallow structures and road embankments along slopes in the area to some extent.

Slump Topography

The areas of old slump topography are related to initial valley-widening of the North Saskatchewan river and appear to be stable under present conditions. The slump topography in the northeast part of the area is associated with shale bedrock of the Edmonton Formation which rises 100 feet higher above the river than in the vicinity of the proposed building site. The Saskatchewan sands and gravels under the building site are much less likely to slide than the shale bedrock.

CONCLUSIONS

1. The building site is underlain by the following sequence of sediments (youngest to oldest): man-made fill; glaciolacustrine clay and some sand; glacial till; sand and sandy gravel of the Saskatchewan sands and gravels; shale, coal, sandstone and bentonite of the Edmonton Formation.
2. The presence of a thick deposit (80 feet) of permeable Saskatchewan sands and gravels contributes to the stability of the bank in that it provides good drainage and reduces build-up of hydrostatic pressure.
3. The Saskatchewan sands and gravels presently allow a small but unknown quantity of ground water to seep out along the river bank to the north of the building site.
4. There is no present evidence of deep-seated mass movement of the river bank at the building site. There are two locations of old deep-seated slump deposits which were active when the river was actively undercutting at these two localities. The possibility of a future catastrophic failure seems remote but

cannot be entirely discounted.

5. Shallow-seated slides are active near the building site and will continue to be an erosion hazard especially during times of abnormally high rainfall and bank erosion resulting from high river levels. The valley wall is at the angle of repose of non-cohesive materials and drops directly to the river just north of the campus.

6. The main cause for the slide that occurred at locality 3 during the summer of 1965 is believed to be artificial blocking of a natural drainage depression in the process of routine landscaping.

7. From regional considerations the amount of sedimentary rock that has been removed from the Edmonton area prior to the deposition of the Saskatchewan sands and gravels is estimated to be from 1,000 to 2,000 feet.

8. Up to 5,000 feet of ice is presumed to have covered the area at least once during glacial time.

Description of Plates 2 and 3

Plate 2 Fresh landslide: view looking southwest from the north side of the river (Figure 1, Locality 2 and 6).

(1) Toe of slide partly eroded by the river;

(2) Small block of soil at the surface of the slide;

(3) Zone of bentonite occurrence;

(4) Pink shale;

(5) Faculty Club building.

Plate 3 View looking south from the north side of the river showing gully that is directly north of the parking lot (Figure 1, Locality 3).

(1) Gully channel filled with debris of fresh landslide;

(2) Scarp of landslide;

(3) Sand run in glacial outwash sand associated with lacustrine deposit;

(4) Scarp of small landslide in till;

(5) Small terracettes developed by human traffic or soil creep processes in sand of Saskatchewan sands and gravels.

PLATE 2

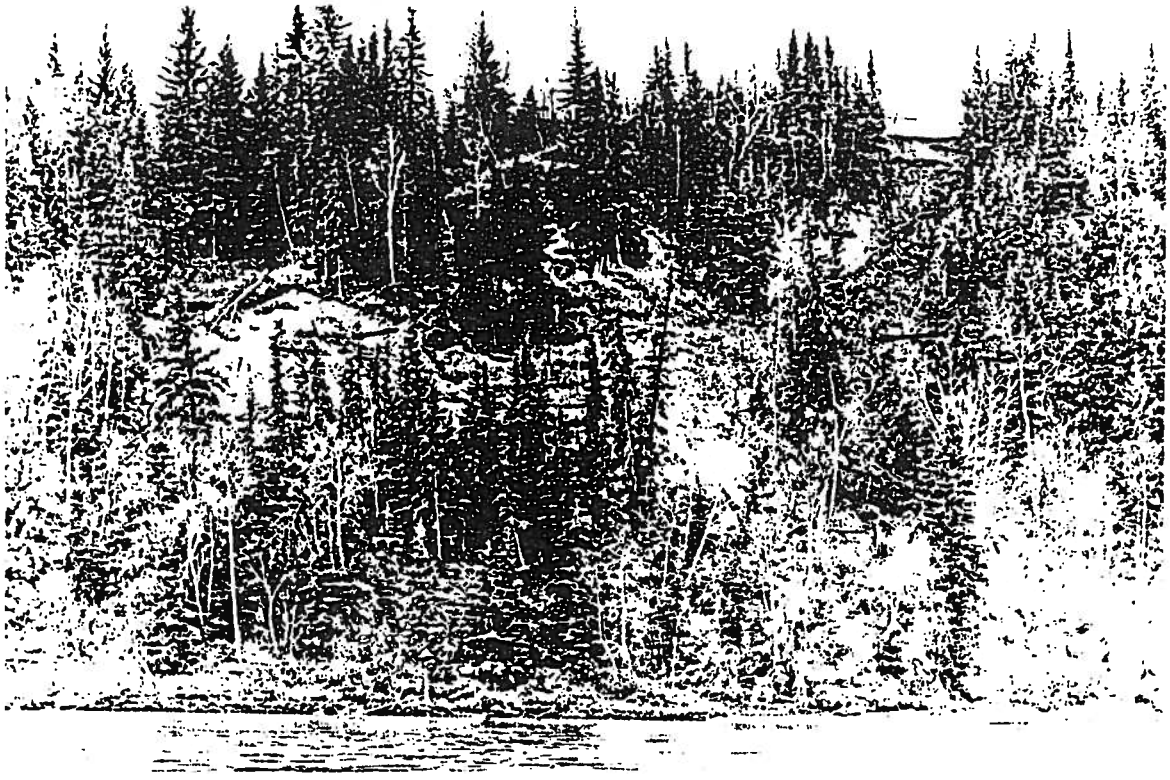

PLATE 3

Description of Plates 4 and 5

Plate 4 View looking north showing south wall of excavation at locality 9 (Figure 1).

(1) Athabasca Hall;

(2) Cross-bedded sand of ice-contact shallow-water sand deposit. Section is perpendicular to the trend of the cross-beds;

(3) Area of Plate 5.

Plate 5 Close-up of 3 in Plate 4 showing detail of contact between lacustrine clay (dark sediment on top) and ice-contact shallow-water bedded sand and clay (light coloured at bottom).

(1) Small low-angle reverse fault;

(2) Small graben structure;

(3) Tongue of clay protruding through bedded sand. All these features are typical of ice-contact sediments;

(4) Lacustrine clay in which thin discontinuous bands of till occur.

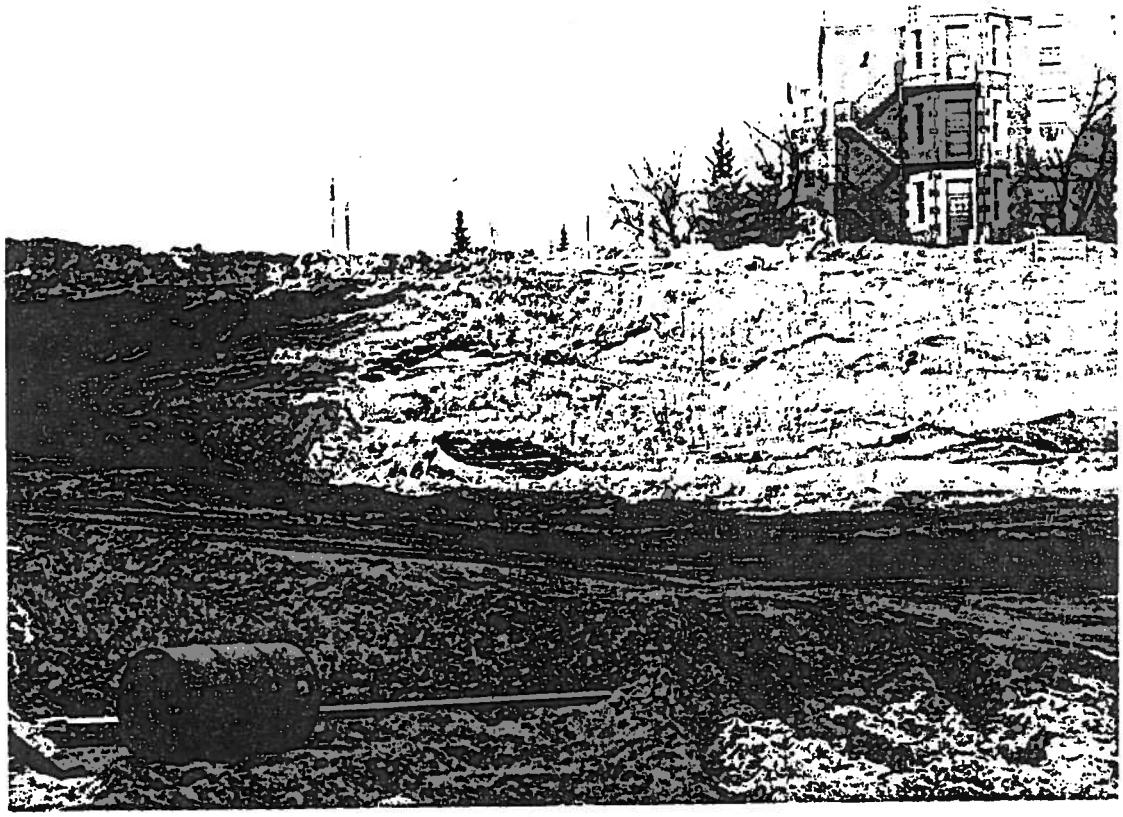

PLATE 4

PLATE 5

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APPENDIX A

BANK STABILITY STUDY - FIELD NOTES

Whitemud Creek Section

Located on south side of the North Saskatchewan River, opposite Edmonton Country Club. Section described in general only (top to bottom).

Lithologic Description	Thickness
Clay, yellow brown to light brown, very thinly bedded, some fine grained sand interbeds.	15'
Sand, very light brown, very fine grained, silty, very thickly bedded; upper contact gradational, lower contact very irregular - sand interfingers with underlying light to medium greenish grey till.	10'
Till, light to medium greenish grey, clayey; abrupt lower contact.	10' (approx)
Sand, light rusty brown to rusty greyish green, very fine to fine grained; thin to very thinly bedded (Saskatchewan gravels and sand). Sand overlies shale bedrock abruptly (Edmonton Formation).	80' (approx)

Locality 1

Located on a cutbank on the south side of Emily Murphy road. Cutbank is about 20 feet high. The following general description was recorded (top to bottom) - thicknesses approximate:

Lithologic Description	Thickness (feet)
Clay, silty, medium grey.	4
Sand, fine to medium grained; very wet.	8
Till with 2 to 3 feet of pebbly sand as possible lenses in upper 5 feet.	10

Locality 2

Located on footpath on the south side of the North Saskatchewan River 245 feet east of the east edge of the ski hill (Plate 2).

Small rotational slump (see Plate 2) with expanded toe (toe partially eroded by high stage of river); main scarp is 60 feet wide and 4 1/2 feet high; scarp surface dips toward the river at an angle of 55° at the centre, is steeper near the flanks. The slump appears to have moved northward, towards the river, a distance of 15 to 20 feet (footpath has been displaced).

The scarp is approximately 30 feet above the river level (October, 1965); bedrock outcrops up to 20 feet above the river level on the river bank on the east side of the slump (see Plate 2).

Locality 3

Gully on the south side of the North Saskatchewan River bank, to the northwest of the Biological Sciences Building site. Section measured from top to bottom (Plate 3).

Lithologic Description	Thickness (feet)
Top soil and fill.	3 to 5
Clay, medium brown, very silty, slightly moist, low plasticity, medium dry strength.	5

Clay, medium brown to dark grey, some light brown; laminated and very thinly bedded; highly plastic, very moist, high dry strength; shrinkage cracks 1/4 inch wide, greater than 1/4 inch deep.	5
Silt, medium brown, very thinly bedded (3/8" to 1/8" bands); lower four feet beds are wavy; contact with underlying sand irregular, appears to conform with undulating surface of cross-bedded sand.	4
Sand, very light brown, fine to very coarse grained, very thinly cross-bedded (cross-beds up to 1 foot thick but rare); some horizontal bands of pebbles--pebbles up to 1/2"; very slightly moist; 8 inches of very fine sand at bottom.	3 1/2
Till, dark grey, sandy.	1
Sand, medium brown, very fine grained, silty, moist.	1/2
Till, medium rusty brown, quite stony, minor sand lenses.	1
Till, medium grey, very clayey, slightly sandy, dense, hard. This interval poorly exposed.	approx. 36
Sand, medium brown to yellow brown, very fine to fine grained; well sorted; rare gravel lens-pebbles mainly quartzite--no granite; gravel beds common near bottom. Interval poorly exposed;	

contact with overlying till not exposed (within about 3 feet); contact with underlying bedrock not exposed - poor exposure occurs 25 feet east of gully along footpath. Elevation of bedrock contact approximately 2085.	86
Mainly covered, may be occupied by very light greyish green sandy bentonite bed which outcrops 25 feet to the east.	1
Coal, bright, shiny, bedded, badly fractured.	3 1/2
Coaly shale.	2
Covered to river level - probably shale of the Edmonton Formation.	10 1/2

Locality 4

Footpath shows minor tension crack 30' long, 5 inches (min.) wide. Developed in silty, fine grained sand, probably alluvial.

Trees on terrace 10' above river north of tension cracks are 15° off vertical, leaning towards river.

Small gravel bar along river's edge just west of locality.

Locality 5

Just west of gully (Locality 3); slump here, 20' section above river affected; appears to be Saskatchewan gravel and sand overlying coal bedrock - contact not exposed; coal well fractured, open, 2 joint directions - strike 225° Azimuth, dip vertical; strike 300° Azimuth, dip 80° north.

Locality 6

Section along river bank, 17 feet thick,:

Lithologic Description	Thickness (feet)
Soil profile and colluvium.	2 1/2
Bentonitic sandstone, soft (whitish band in Plate 2).	1 1/2
Interbedded shale and soft sandstone, 2-4" bentonite near top of section - To west bentonite associated with pink (?burnt) shale and with a coaly shale.	13

Locality 7

On west side of road directly below the north edge of Saskatchewan Drive traffic bridge south of 105 Street. General Section:

Lithologic Description	Thickness (feet)
Lacustrine clay - covered; top excavated?	2-4
Till, light yellow brown, rust-stained, very sandy; contact not exposed.	10-12
Sand, clayey, bentonitic, pebbles, light greyish green to medium grey' rust-stained.	8
Shale, dark grey, badly fractured to angular chunks 1/4 to 1/2 inch in size; rust-stained, weathered.	2 1/2

Locality 8

Cliff facing west along Saskatchewan Crescent, West, overlooking North Saskatchewan River; only top part of section exposed: 4 to 5 feet

clayey silt and clay overlying at least 6 feet of silty, clayey till. Outcrop is hard, appears well drained - no evidence of movement in this vicinity.

Locality 9

Description of materials exposed in excavation at building site of new Students' Union Building (Plate 4 and 5).

@#1 Southwest corner of excavation.

Lithologic Description	Thickness (feet)
Till	2-4
Till, sandy clay, medium brownish grey, interbedded with lenses of very thin cross-bedded sand and clay - lenses out eastward to middle of excavation.	1-2 1/2
Sand (partly covered), very light brown, fine to medium grained, moderately well sorted, bedded, some pebbles in bands; bands 1/4" to 2" thick; thickly to very thickly cross-bedded - up to 15 feet long, 3 to 5° dip in easterly direction.	

@#2 Northwest corner of excavation.

In northwest corner, sand is contorted and faulted in upper part; contorted bed is two feet thick, a mixture of clay and unbedded sand, and has large angular inclusions of bedded sand, up to 1 1/2' long. Contorted

layer is overlain by about 3 feet of clay containing 1 foot band of till but relationship obscure; clay overlain by 2 to 5 feet of till.

Sand below contorted layer is faulted - high angle reverse and normal faults and one prominent thrust fault (Plate 5).

@#3 North wall of excavation

East-west face of excavation on north end; very thickly cross-bedded sand, cross-beds up to 5 feet thick and 30 feet long; fine to medium grained, moderately well sorted, very light brown; same bands 1/8" to 10" thick, rare silty bands; coal pebbles up to 2" diameter common, subangular. Believed to be a section perpendicular to current direction because of trough-like form of cross-beds (Plate 4).

@#4 Centre of west wall of excavation

Section exposed here is 2 feet to 3 feet of fill overlying 3 feet to 4 feet of till overlying 2 feet of clay which overlies sand (contorted). Till definitely identified at this station.

APPENDIX B

DRILL HOLE LOGS

U-65-1 — Elevation 2231 (±2)

Lithologic Description	Interval (feet)
Topsoil with gravel.	0 - 2
Sand, with interbeds of dry clay.	2 - 11
Till, stiff, clayey, sandy, some coal, rust traces.	11 - 22
Till, as above but with sandy pockets.	22 - 32
Till, brown, clayey, lenses of rust, coal particles; coal boulder (?) at 48'.	32 - 57
Till (?) pebbly, brown, clayey, pebbles increase in number downward.	57 - 80
?Sand, clayey, gravel lenses, some cobbles in lower 20 feet. (N.B. this interval originally interpreted as sandy and gravelly till).	80 - 139
Shale, brown, soft.	139 - 149
Sandstone, bentonitic.	149 - 159
Coal seam.	159 - 160.5
?Shale (originally described as till).	160.5 - 164

U-65-2 — Elevation 2091.11

Lithologic Description	Interval (feet)
Topsoil	0 - 1.5
Sand, clayey, low plasticity.	1.5 - 17
Silt, clayey.	17 - 19
Sand, grey, silty; begin bedrock	19 - 20
Silt, with some shells and coal.	20 - 21

Lithologic Description	Interval (feet)
Shale, sandy and silty, fractured; harder with increasing depth;	21 - 28
@ 24' hard nuggety structure.	
@ 27' hard dark brown shale, slightly fractured.	
Sandstone, soft.	28 - 29.5
Silt, sandy.	29.5 - 30
Shale	30 - 31
Sandstone, grey, medium hard.	31 - 38

U-65-3 Elevation 2240.71

Lithologic Description	Interval (feet)
Topsoil	0 - 3
Clay, brown, silty; between 16-18 clay is light brown with some pebbles.	3 - 34
Till, sandy	34 - 52
Till, greyish, some coal chunks.	52 - 56
Sand	56 - 59
Till	59 - 62
Sand, fine grained, dense.	62 - 72
Gravel, pebble size.	72 - 82
Sand, clayey, some cohesion, some gravel at top and at bottom of interval; some coal pebbles.	82 - 101
Shale, rusty to grey, soft, some coal, fractured, medium hard, some brown shale.	101 - 111
Bentonite, greyish green, highly plastic, soft.	111 - 114
Shale, brown to medium grey, fractured.	114 - 120

U-65-4 Elevation 2242.83

Lithologic Description	Interval (feet)
Topsoil	0 - 1
Sand, silty, clayey	1 - 3.5
Clay, medium to dark brown, plastic, mottled, some slicken sides; @ 9' soft and rust streaks.	3.5 - 15
Till, sandy, clayey.	15 - 18
Sand, fine grained, light brown, fluffy; becomes wetter with depth.	18 - 34
Till, medium brown, sandy, pebbly, coal fragments.	34 - 54
Till, grey, sandy, some gravel lenses (?)	54 - 80
Sand, brown, some gravel (?)	80 - 92
Sandstone and shale, interbedded, shale grey and soft.	92 - 96
Shale, grey, some sandstone, rare thin bentonite lens.	96 - 113
Sandstone, mainly	113 - 118
Bentonite, green.	118 - 121
Shale, brown, changing to grey; sandstone interbeds @ 128'.	121 - 140
Shale, light grey mainly, interbedded with sandstone.	140 - 160

U-65-5 Elevation: 2233.53

Lithologic Description	Interval (feet)
Topsoil	0 - 2
Clay, silty, sandy near bottom.	2 - 19
Sand, silty, coarse grained.	19 - 20.5
Clay, very sandy.	20.5 - 22
Till, dark brown, sandy, pebbles common.	22 - 55

Sand, traces of pebbles.	55 - 65
Till, sandy; thin sand layer @ 72'.	66 - 78
Sand, silty, some pebbles; (? layers of till at intervals); coal cobble @ 96'.	78 - 95
Sand, grey, gravelly throughout.	95 - 151
Shale.	151 - 157
Bentonite, traces.	157 - 158
Shale, brown, carbonaceous.	158 - 162

U-65-6 Hole drilled adjacent to U-65-5, therefore same log.

U-65-7 Elevation: 2235.68

Lithologic Description	Interval (feet)
Topsoil	0 - 2
Clay, greyish brown, silty, some sandy clay.	2 - 8
Clay, silty, dense, trace of pebbles near bottom.	8 - 17
Till, coal specks, pebbles.	17 - 22
Sand, fine grained, silty, dense.	22 - 34
Till, sandy, coal fragments.	34 - 44
Till, sandy, grey, rust stained.	44 - 57
Sand, grey, coarse grained, silty.	57 - 59
Till, sand pockets.	59 - 68
Sand, greyish brown, medium grained (some till described in this interval but probably sand).	68 - 84
Sand; grey, some thin gravel beds; gravel common in lower 20 feet.	84 - 141
Shale, interbedded light grey and dark brown shale, fractured.	141 - 151

Sandstone, bentonitic.	151 - 154
Shale.	154 - 155.5
Bentonite, green, sticky.	155.5 - 157
Shale.	157 - 157.5

U-65-8 Elevation: 2236.3

Lithologic Description	Interval (feet)
Topsoil	0 - 1.5
Till	1.5 - 5
Clay, light brown.	5 - 18
Clay, silty.	18 - 19
Till	19 - 23
Sand	23 - 31
Till, dark brown, sandy, some light brown till in lower 4 feet.	31 - 49
Sand, medium grained, gravel bands.	49 - 59
Gravel	59 - 69
Shale, dark grey, hard, some light grey and dark brown bands.	69 - 78
Sandstone, grey, soft.	78 - 79
Shale, brown, soft.	79 - 80
Sandstone, bentonite	80 - 82
Shale, dark brown, hard.	82 - 92

U-65-9 Elevation: 2090.51

Lithologic Description	Interval (feet)
Topsoil	0 - 1.5
Sand, light brown, clayey.	1.5 - 19
Till, sandy, possible gravel lenses, coal fragments.	19 - 30
Gravel, pea-size.	30 - 32
Sandstone, bentonitic, medium hard to hard.	32 - 42
Shale, dark brown, banded.	42 - 43.5
Sandstone, bentonitic	43.5 - 49.5
Coal seam	49.5 - 50.5
Shale, brown to light green, banded.	50.5 - 52.5

U-65-10 Elevation: 2127.49

Lithologic Description	Interval (feet)
Topsoil	0 - 1.5
Sand, light brown to rust brown, silty and clayey.	1.5 - 5.5
Clay, light brown, silty.	5.5 - 24
Coal seam	24 - 26
Shale, light grey, soft to hard at bottom.	26 - 36
Bentonite	36 - 36.4
Shale	36.4 - 43
Sandstone, bentonitic, medium hard.	43 - 45
Shale, light brown, light grey, dark brown, interbedded; hard, fractured; 2 inches bentonite at 48'; 6" coal at 57'.	45 - 59
Bentonite	59 - 60.5
Coal	60.5 - 62
Shale, greyish brown; hard sandstone at 72'.	62 - 75

U-65-13 Elevation: 2267

Lithologic Description	Interval (feet)
Clay, greyish-green; dark brown topsoil and wood fragments.	0 - 2
Dark brown sawdust and wood fragments.	2 - 5
Clay, greenish grey, scattered sand, rare 1/4" pebble, some organic material. Shelby tube sample @ 6-7' L@7'.*	5 - 7
Sand, greenish brown, fine grained, some silt, slightly clayey; some foreign material, rare pebble.	7 - 8
Sand, fine grained, silty, slightly clayey; hit pebble or boulder at 9-10 feet; L@10-11.	8 - 10
Sand, light greenish grey, very fine to fine grained, slightly silty, rare coal fragment. (driller remarked that sand is very common in this part of campus).	10 - 12
Sand, light greenish grey, fine to medium grained, well sorted. L@12-14.	12 - 15
Sand, medium brown, fine grained, well sorted.	15 - 16
Sand, light brownish grey, fine grained, very slightly silty. L@17-18.	16 - 18
As for 16-18 but 6" band of rust-brown, clayey silt @ 19'. Penetration test @ 20': 140 lbs. dropped from 30", 6" intervals---10 - 12 - 14; (medium dense sand). L@20 is light gray, fine to medium grained sand, moderately well sorted (poorly graded), loose, very dry, slightly silty, 1/2" band very fine grained silty sand in split tube.	18 - 23

* L indicates lithologic sample

Sand, very fine to fine grained, light greyish brown, moderately well sorted. Some caving around this interval. L@24.	23 - 25
Sand, light greenish grey, very fine grained, moderately well sorted, very slightly moist.	25 - 27
Sand, very fine grained, silty, light greenish grey, slightly moist, possibly slightly clayey; coaly flecks @32; L@27-29.	27 - 32
Sand, very fine grained, mainly light greenish grey, some distinct bands of carbonaceous material in laminae 1/16" to 1/8" apart (bedding or stratification).	32 - 33
Sand, fine grained, light brown grey, moderately well sorted, very slightly moist.	33 - 34
Begin wet drilling.	
Poor recovery, sand as for 33-34; some pink ?feldspathic grains but could be quartzite.	34 - 40
No recovery except coal fragments; probably sand.	40 - 50
Sand as for 34-40; very soft drilling, poor recovery.	50 - 62.5
Till, medium grey, sandy, very clayey. Shelby tube sample at 62.5' ... did not go all the way in, sitting on a pebble; no recovery. L @ 70. Cobble of coal @ 83' (may be up to a foot in diameter).	62.5 - 85
Sand, fine to coarse grained, poorly sorted.	85 - 86
Till, medium grey, sandy, very clayey.	86 - 87
Gravel, very coarse to pebble size; L @ 87-88.	87 - 88
Till, medium grey, sandy, very clayey, dense, some pebbles; rare gravel stringer, pebbles mainly cream to grey quartzite and some granitic pebbles.	88 - 101.5

U-65-13 contd.

Sand, medium brown, fine grained, very dense. Penetration test @ 101.5: 40-223 (penetrated only 4"), indicates very dense sand.	101.5 - 105
Gravel, ?pebble size.	105 - 106
Sand, light to medium brown, very fine grained, clayey and silty; thin gravel band @ 116'; L@122'. Minor gravel lenses in lower 4' with pebble size gravel (less than 2" diameter).	106 - 128.5
Gravel, pebbles 2" to 4", minor sand interbeds; very slow drilling.	128.5 - 132.5
Sand, very fine grained, poor recovery.	132.5 - 133.5
Interbedded sand and gravel; approximately 2 to 4" of pebble gravel alternating with 6 to 12" of fine grained sand beds.	133.5 - 146
Distinct change in drilling ability at 146'; no recovery but probably hit bedrock shale at 146'.	146 - 150
Shale, medium grey to blueish grey, some medium brown shale fragments.	150 - 159
Total depth; bottomed in shale of the Edmonton Formation.	159

U-65-G1 Elevation: 2240 (±2)

Lithologic Description	Interval (feet)
Topsoil	0 - 3
Clay, medium brown, plastic.	3 - 7
Clay, brown and medium grey; Penetration test @ 10: 3-6-10.	7 - 10

Clay, light to medium brown, slightly silty.	10 - 29
Till, medium grey, slightly sandy, rare pebbles; sample @ 35'; boulder @ 37' and 61'; becomes denser below 45'.	29 - 65
Sand, medium brown, very fine grained, clayey, rare pebble; may be some till interbeds or lenses in upper 5 feet; penetration test @ 71': 95-141. Sample from penetration tube @ 71-72': sand, medium brown, very fine grained, clayey, with 1/2" dark brown sandy silt layer.-- poor returns 75 to 98.	65 - 98
Clay (or shale?), medium brown, soft.	98 - 103
Clay, sandy.	103 - 111
Shale, light to medium grey, plastic, some interbeds of clayey sand.	111 - 121

U-65-G2 Elevation: 2250 (±2)

Lithologic Description	Interval (feet)
Clay, medium brown, plastic.	0 - 4
Clay, light grey, plastic.	4 - 14
Clay, medium brown, sandy; becomes very sandy at bottom (skidded north 10' here due to poor surface seal).	14 - 19
Sand, clayey.	19 - 21
Clay, medium brown, sandy, silty.	21 - 38
Till, medium grey, very few pebbles; sample 54-56'.	38 - 108
Sand, medium brown, very fine grained, clayey; sample 111-115.	108 - 121

Sand, light to medium grey, fine grained, rare pebble; pebble band at 125'.	121 - 134
Sand, medium brown, fine grained, with some pebbles; gravel band @ 147'.	134 - 151
Shale, medium grey; coal band @ 153; layer of bentonitic sandstone 158-159.	151 - 160

U-65-G3 Elevation: 2245 (±2)

Lithologic Description	Interval (feet)
Clay, medium brown, very slightly silty, plastic; sample @ 8'; penetration test: 8-17-23 @ 10-11.5'.	0 - 8
Clay as above, but silty; penetration test: 14-29-47 @ 15-16.5'; sample @ 16'.	8 - 15
Till, medium brown, rust-stained; sandy, some pebbles, dense.	15.0 - 17.5
Clay, medium brown, very silty, high water content, rare coarse sand grain; (?thin interbeds of till); sample @ 17.5-18'; penetration test: 9-29-58 @ 20-21.5'.	17.5 - 19.5
Sand, light brown, very fine grained, very slightly clayey; sample @ 20-21.5; penetration test: 23-41-71 @ 30'. @ 30' sand is fine grained and clean; some 1/4" rust-stained bands in tube sample. @ 33' sand is fine grained and very wet; free water in hole; sample @ 34'; penetration test: 24-61-120 @ 34-35.5'.	19.5 - 38
Till, medium, brown, sandy; changed to dark grey at about 60'; penetration test: 22-50-105 @ 38-39.5'; sample @ 50'.	38 - 98

Sand, light brown, very fine grained, slightly clayey; some gravel @ 130-135'; sample @ 130'.	98 - 150
Shale, dark grey some light brown; sample @ 150-155.	150 - 160

U-66-G4 Elevation: 2246 (±2)

Lithologic Description	Interval (feet)
Topsoil and fill	0 - 8
Clay, light brown, plastic; sample @ 15'.	8 - 15
Clay, medium brown, slightly silty and sandy, rare pebble.	15 - 25
Clay, medium brown, some sand lenses.	25 - 41
Till, medium grey, dense, coal fragments common, pebbles rare; sample @ 43'.	41 - 51
Till, as for 41-51 but very dense.	51 - 62
Shale, light greyish green.	62 - 63
Shale, medium gray, slightly plastic, soft; sample @ 64'.	63 - 74
Shale, silty, medium greyish green.	74 - 76
Sandstone, light grey, fine grained, clayey, bentonitic, soft.	76 - 84

U-66-G5 Elevation 2254 (±2)

Lithologic Description	Interval (feet)
Topsoil and fill.	0 - 6
Clay, light brown, some fine sand; sample 10-12'.	6 - 15
Clay, medium brown, sandy, rare pebble and coal fragments.	15 - 19

Clay, medium brown.	19 - 24
Clay, medium brown, sandy, some pebbles and coal fragments.	24 - 48
Sand, medium brown, fine to coarse grained, coal fragments--some medium brown clay, lost circulation--sand believed to be water-bearing.	48 - 66
Gravel or gravelly sand, granitic pebbles--gravel interbedded with fine grained sand beds.	66 - 84
Shale, light greenish grey, bentonitic; sample 84-88'; includes sample of gravel (66-84).	84 - 88
Shale, medium brown.	88 - 92
Sandstone, light grey, fine grained, clayey, bentonitic.	92 - 96

U-66-G6 Elevation 2254 (±2)

Lithologic Description	Interval (feet)
Topsoil and fill.	0 - 5
Clay, light and medium brown, plastic, minor sand beds; sample @ 25'.	5 - 28
Sand, light brown, fine to medium grained, some pebble bands (granitic pebbles) and coal fragments.	28 - 35
Clay, medium brown, silty, some medium grey clay, plastic.	35 - 47
Till, medium brownish grey, sandy, rare pebble, dense; changes to medium gray; gravel band @ 62'; sample @ 48-50.	47 - 63
Shale, interbedded medium grey and light green, some dark brown, plastic; sample 65-70.	63 - 73

Shale, brown, slightly plastic.	73 - 75

U-66-G7 Elevation: 2244 (±2)

Lithologic Description	Interval (feet)
Topsoil	0 - 1
Clay, medium grey to medium brown, generally banded, plastic; part fill?	1 - 6
Clay, light brown with numerous coal fragments, sample @ 10'.	6 - 11
Clay, medium brown, slightly silty, plastic, partly banded, splintery.	11 - 16
Clay, medium brownish grey, plastic, some rust coloured bands.	16 - 30
Clay, medium grey, plastic, very slightly silty.	30 - 32
Till, medium greyish brown, slightly sandy, soft; sample @ 40'.	32 - 44
Clay, medium grey, very sandy.	44 - 46
Till, dark grey, sandy, dense, rare pebble.	46 - 58
Sandstone, light grey, some interbedded brown shale.	58 - 60
Shale, medium greyish green, plastic.	60 - 66

U-66-G8 Elevation: 2246 (±2)

Lithologic Description	Interval (feet)
Topsoil and fill.	0 - 3
Clay, medium brown, mattled with rust stains, plastic.	3 - 20
Clay, medium brown, very plastic, slightly silty.	20 - 35

Till, medium brown, sandy, rare pebble; becomes denser with depth; sample @ 38'.	35 - 45
Till, medium to light grey, clayey and sandy, rare pebble; may have clayey sand interbeds; hit boulder at 89' (changed to rock bit here).	45 - 90
Till, as above but returns poor.	90 - 132
Sand? or sandy clay--poor returns; sample @ 132.	132 - 148
Shale; sample @ 148'.	148 - 160*

* (N.B. An error of +10 feet was made while plotting the till of this section in Figure 2; the till should be 97 feet thick instead of 107 as shown in Figure 2).

FIGURE 1

GEOLOGIC MAP LEGEND

0 1MI 2MI 3MI FEET

- EROSIONAL SCARP
- SLUMP TOPOGRAPHY
- CONTACT, APPROXIMATE
- TEST-HOLE LOCATION
- SP SPRING
- 4 FIELD LOCALITY
- MEASURED SECTION
- GROUND PHOTO DIRECTION
- 2100' BEDROCK TOPOGRAPHY
- BENTONITE OUTCROP
- TR RIVER TERRACE DEPOSITS
- COL COLLUVIAL DEPOSITS
- LK LACUSTRINE DEPOSITS
- APPROXIMATE SUBCROP BOUNDARY ICE-CONTACT GLACIO-FLUVIAL SAND DEPOSIT (from aerial photographs)

Geology by M.A.Rood February 26, 1966
Department of Geology
University of Alberta Edmonton

UNIVERSITY of ALBERTA
CAMPUS

CONTOURS
DEPRESSION CONTOURS
ROADS
LANES
TRAILS
BUILDINGS
RIVER
MUD OR SAND
TREES

A. S. PROJECT NO. 14/65

Compiled By Photogrammetric Methods from Air Photographs taken in 1962.

AERIAL SURVEYS SECTION
TECHNICAL DIVISION
DEPT. OF LANDS & FORESTS

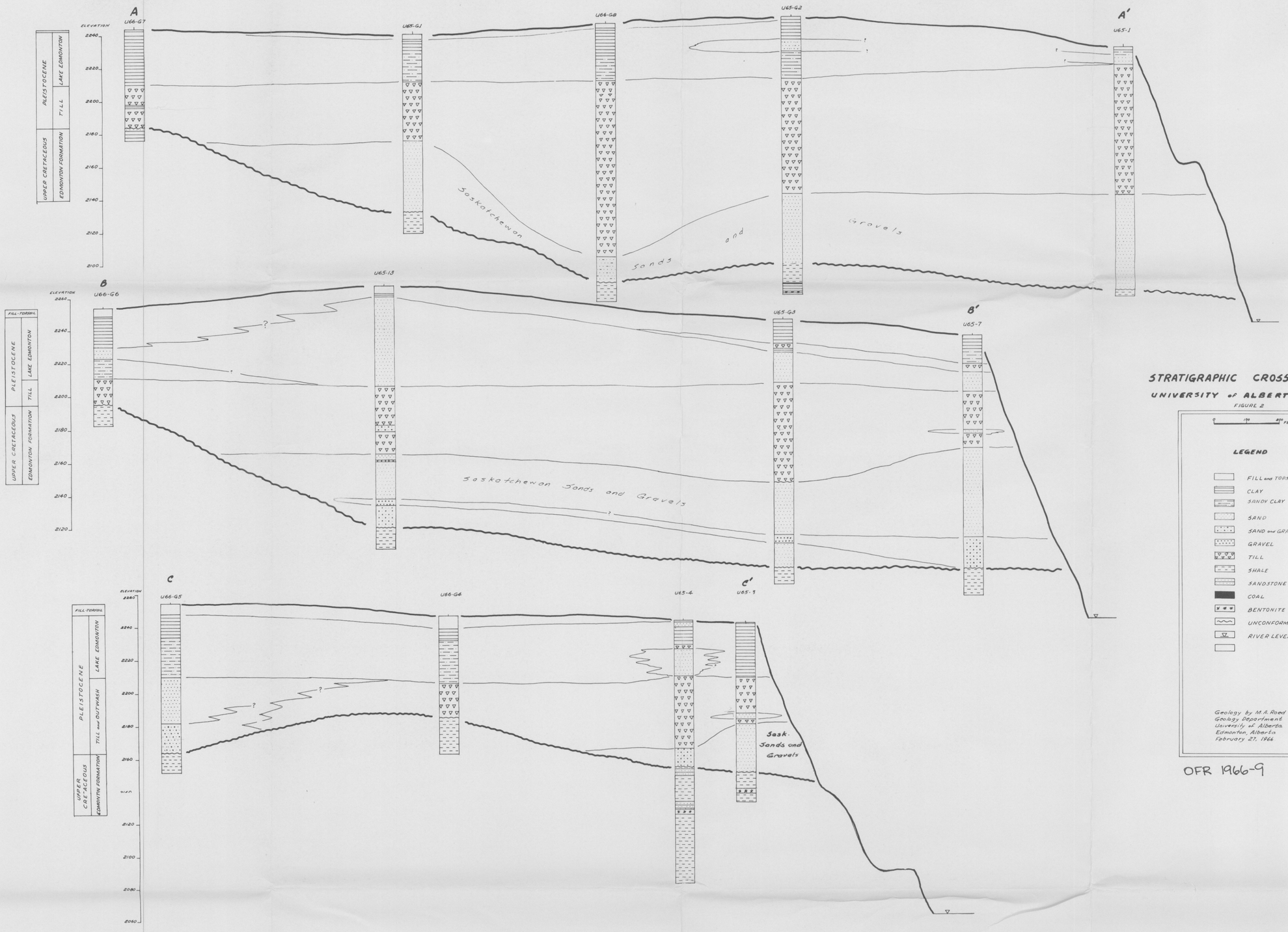
ELEVATIONS ARE ARBITRARY
DATED SEPT. XVth. 1965. CONTOUR INTERVAL - 2ft.

OFR 1966-9

TH SASKATCHEWAN RIVER

Plate 3

Plate 2



STRATIGRAPHIC CROSS-SECTIONS

UNIVERSITY of ALBERTA CAMPUS

FIGURE 2

0 100 400 FEET

LEGEND

- FILL and TOPSOIL
- CLAY
- SANDY CLAY
- SAND
- SAND and GRAVEL
- GRAVEL
- TILL
- SHALE
- SANDSTONE
- COAL
- BENTONITE
- UNCONFORMITY
- RIVER LEVEL

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Edmonton, Alberta
February 27, 1966

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