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I hereby recommend that the thesis prepared under my supervision by Robert Laurence Olson

entitled Engineering Geology and Relative Stability of Ground Adjacent to the Sawyer Place Area, Cincinnati, Ohio

be accepted as fulfilling this part of the requirements for the degree of Master of Science

Approved by:

David M. Johnson

Mark J. Bowers

[illegible]

ENGINEERING GEOLOGY AND RELATIVE STABILITY OF GROUND ADJACENT TO SAWYER PLACE CINCINNATI, OHIO

A thesis submitted to the

Division of Graduate Studies and Research
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ROBERT LAURENCE OLSON

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Frontispiece. Destruction of retaining wall by shallow landsliding in the Sawyer Place area. (Photo by Robert Olson, 1988).

ABSTRACT

An engineering geologic study was conducted in the Sawyer Place development, a 2.5 km^2 area of ground along the northern bluffs of the Ohio River in eastern Cincinnati.

Maps of altitude of top of bedrock and thickness of overburden compiled from soil borings show deep bedrock valleys are loci for deep landslides. Landslides are either translational, occurring in thin colluvium on the steep slopes above Columbia Parkway, or rotational slumps, occurring in thick deposits of fill below the parkway. The velocity of landsliding in the area is so slow, that all but the most recent slide features are destroyed by weathering and erosion.

A relative stability map, compiled from subsurface maps and the engineering geologic map, shows areas of stable, potentially unstable and moving ground in the Sawyer Place area, and is intended for use by city planners, engineering firms and architects in the planning stages of development of the area. The relative stability map includes recommendations of the kinds of geotechnical investigations that should be required by the city prior to review of development plans.

ACKNOWLEDGEMENTS

I would like to thank my friend and advisor Dr. Arvid Johnson for sharing with me his knowledge and patience needed to complete this thesis. Also, I would like to thank Dr. Mark Bowers and Dr. Thomas Lowell for sharing their expertise in their courses and many helpful suggestions in reviewing the manuscript of this thesis.

I also thank George Webb, Bob Lennertz and Merle Nethero of the H. C. Nutting Company for their invaluable reports and boring logs and Dr. Richard Durrell for other data I used for the completion of altitude of top of bedrock and thickness of overburden.

Last but not least I extend appreciation to my family, particularly my parents Bertel and Elizabeth Olson, and my wife Lisa, for their guidance and encouragement which made this thesis possible.

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CHAPTER 1. INTRODUCTION

The primary purpose of this study has been to conduct an engineering geologic analysis of an area of ground adjacent to Columbia Parkway and Eastern Avenue on the northern bluffs of the Ohio River, in eastern Cincinnati. The study area is bounded laterally by I-471 to the west and Torrence Avenue to the east (Fig. 1). The northern boundaries are Columbia Parkway from I-471 to Kemper and the top of the hillslope from Kemper to Torrence. The southern boundary is the Ohio River. The area is on the cutbank of a large meander of the Ohio River; the hillsides are steep and range in slope angle from five to forty degrees. The hillsides generally have a thick tree cover of white ash, sugar maple and sweet buckeye.

The area is primarily residential on the upper slopes, well above Columbia Parkway, as well as on either side of Eastern Avenue. Houses immediately above and below Columbia Parkway were razed fifty years ago. Larger structures, such as schools, churches and warehouses, are along the southern edge of Eastern Avenue.

Within the study area is the future site of the Sawyer Place community, a joint-venture development of a building complex funded by the City of Cincinnati and a private developer, thus a geologic analysis of the area can aid future development plans.

A secondary purpose of this research has been to study geotechnical borehole logs and to thereby determine the distribution of Pleistocene river valleys and their sediment fills in the area of downtown Cincinnati, to the west of the engineering geology study area.

Cincinnati lies on the northern flank of a broad but very low, elongate structure known as the Cincinnati arch. This subtle structural feature trends north-northeast through central Kentucky and southwestern Ohio. The plunge of the

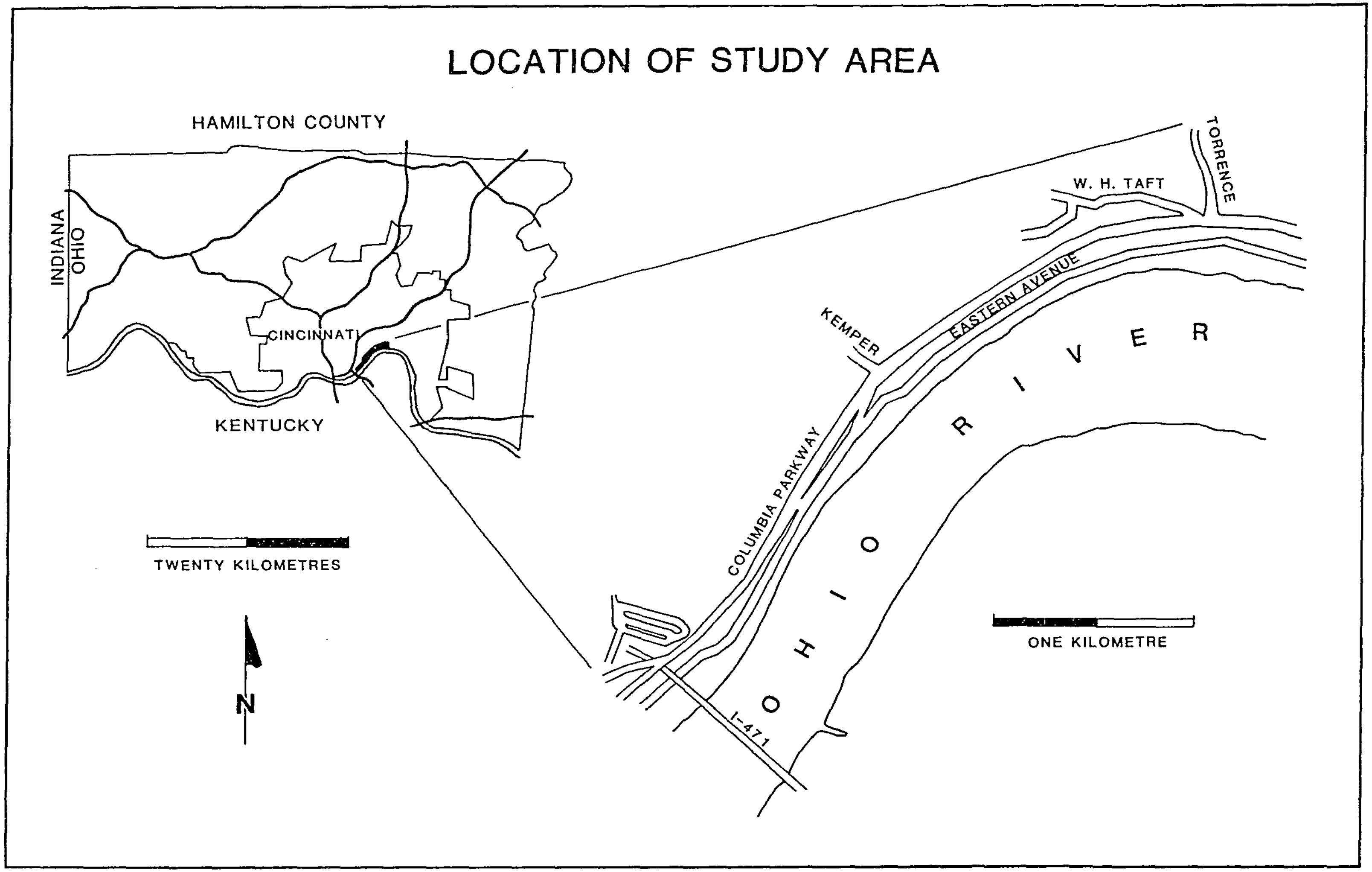


Figure 1. The engineering geologic study area.

rocks in the arch in the Cincinnati area is 2 metres per kilometre, making the dip of the beds in this area essentially zero.

The exposed and underlying bedrock in the area consists of shallow marine limestones and terrigenous shales of late Ordovician age known as the Fairview and Kope formations.

The surficial materials overlying bedrock present more problems to proper planning and development than the bedrock itself. The proximity of the study area to Pleistocene glaciers and to several ancient valleys of the Ohio River as well as to steep slopes and heavy urbanization all contribute to a diverse overburden of natural and man-made fill. The natural valley fill includes glacial lake clay and till, colluvium, landslide debris and alluvium.

Precipitation in Cincinnati averages one hundred three centimetres each year, forty-one of which are snowfall. There is no regular season of high precipitation, although spring is somewhat wetter than other seasons; the five months of March through July have 49 percent of the annual precipitation (U.S.D.A., 1982 and Ruffner and Blair, 1985). The yearly precipitation has an irregular pattern, at least for the years 1948 to 1986 (Fig. 2A), and the pattern does not correlate with landslide activity in Cincinnati (Fleming and others, in prep.). The activity of deep landslides, however, correlates well with the three-year running average rainfall (Fig. 2B). The three-year average shows peak rainfall years in 1950, 1957, 1974, 1979, and 1984. The years 1974, 1979 and 1984 were all years of increased deep landslide movement (Fleming and others 1981).

The study of the Sawyer Place area culminates in an interpretative, relative stability map which is based on maps of structures of landslides, top of bedrock and thickness of overburden. Perhaps the relative stability map will provide information of value to planning and engineering of future segments of the Sawyer

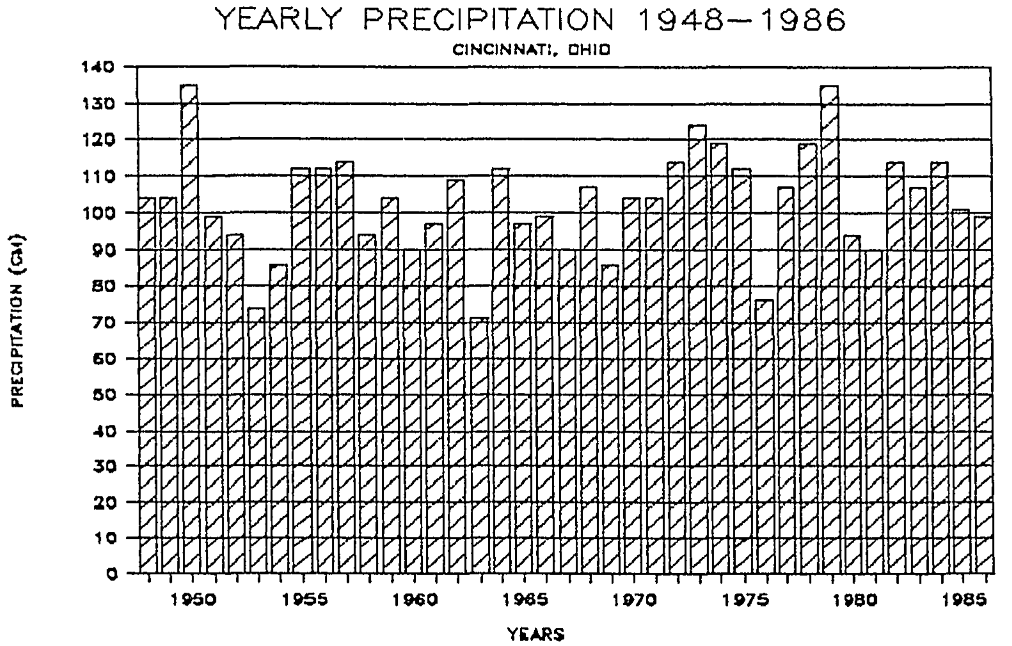


Figure 2A) Yearly precipitation in Cincinnati.

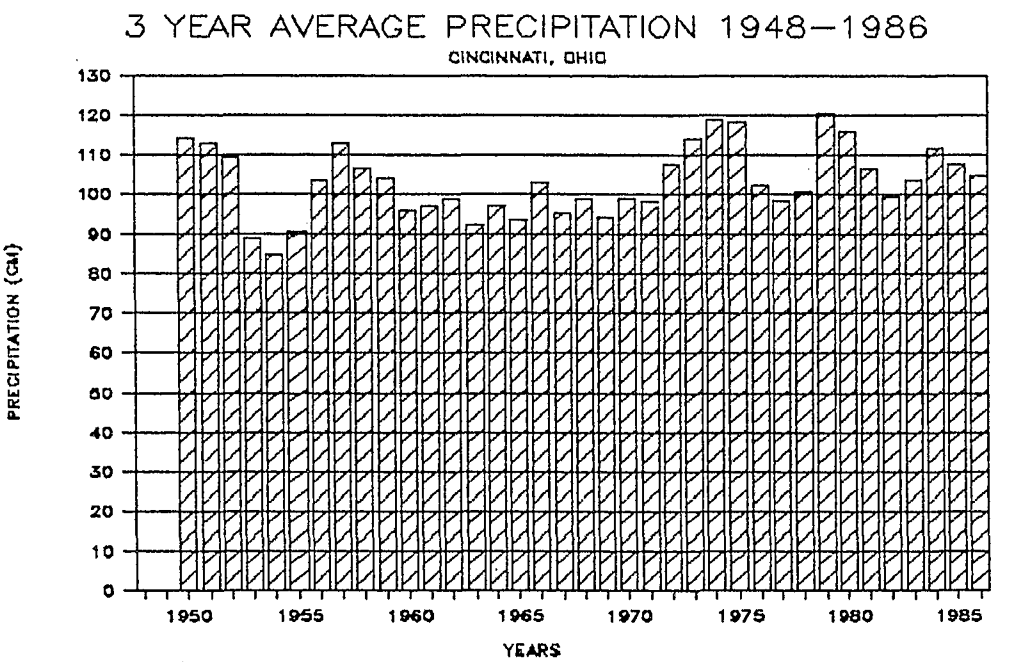


Figure 2B) Three-year running average precipitation in Cincinnati.

Point project. Perhaps the other maps will provide a framework for understanding landslides in developed parts of the area.

CHAPTER 2. THICKNESS OF OVERBURDEN IN DOWNTOWN CINCINNATI

Since the Pleistocene, the topography of the Cincinnati area has been greatly altered from a gently rolling peneplain into an area of many steep hills and deep valleys as a result of several glacial periods and their river systems. The glaciers and rivers caused steep hillsides, which are now areas of instability, and filled the valleys with a diverse range of sediments, both pose design difficulties to the geotechnical engineer. A study of top of bedrock and thickness of fill was compiled using borehole logs and previous bedrock studies of the downtown area, then compared with a theory of the glacial history in Cincinnati by Durrell (1977). Perhaps this study will provide an understanding of how and why the sediments are distributed throughout downtown Cincinnati.

Our present knowledge of the Pleistocene history of the greater Cincinnati area is largely based on the research of Fenneman (1916); Rich (1956) and Durrell (1961, 1977). The following account is due to Durrell (1961, 1977).

Cincinnati has been invaded by at least three major glacial advances in the past two million years. The three glacial periods were the pre-Illinoian, Illinoian and the Wisconsinan (Durrell, 1961 and 1977).

DEEP STAGE OHIO

Before the first of the Pleistocene glaciations (Fig. 3A and 3B)(Durrell 1977), the Cincinnati region was a vast rolling plain known as the Lexington peneplain. The major drainage system in the Midwest was the northwest-flowing, Teays River (Fig. 3A), one of its tributaries, the Teays-age Licking river flowed through central Cincinnati, another, the Eagle River, flowed through Boone County (Fig. 3B). These rivers, which joined near Hamilton, entrenched their channels to a depth of fifty to seventy metres below the current hilltops.

TEAYS RIVER

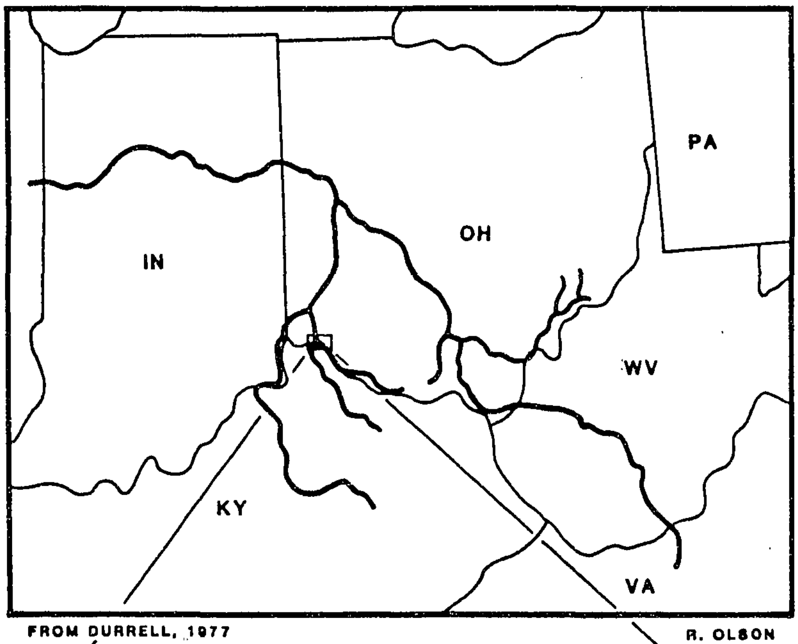


Figure 3A). Teays River in the midwest.

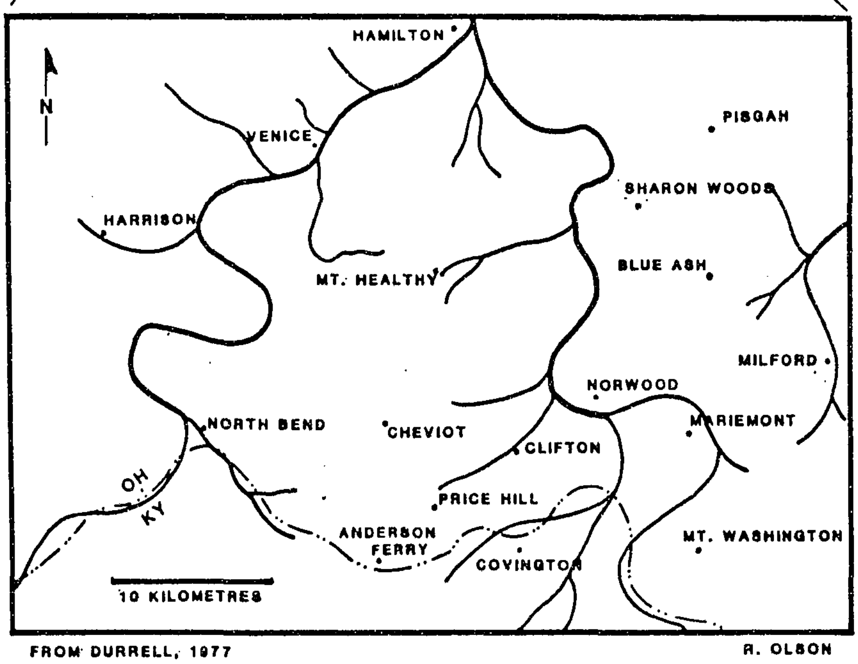


Figure 3B). Teays-age drainage in the greater Cincinnati area.

The pre-Illinoian ice sheet formed its southernmost terminus in the Cincinnati area from Harrison to Pisgah (Fig. 4), and the Teays-age River was diverted westward through Harrison, then southwestward to Louisville. Thus the ancestral Ohio River drained southwestward at that time. As the ice sheet melted, the river incised its channel to a depth of 150 metres. This channel is known as the Deep Stage Ohio (Fig. 5).

In order to investigate the configuration of the Deep Stage Ohio River near downtown Cincinnati, borehole logs from various geotechnical engineering firms and results of previous bedrock studies were compiled in order to construct a map of altitude of top of bedrock for the area of Downtown Cincinnati (Fig. 6). The borehole locations and logs and are in Appendix B.

The map of altitude of top of bedrock (Fig. 6) shows that the deepest areas are about 110 metres a.s.l. and occur roughly along the present Mill Creek valley and between I-75 and Central Parkway. A topographic high separates the valleys. The closure of the contours suggests a northward flowing channel, which is consistent with the flow direction of the Deep Stage Ohio.

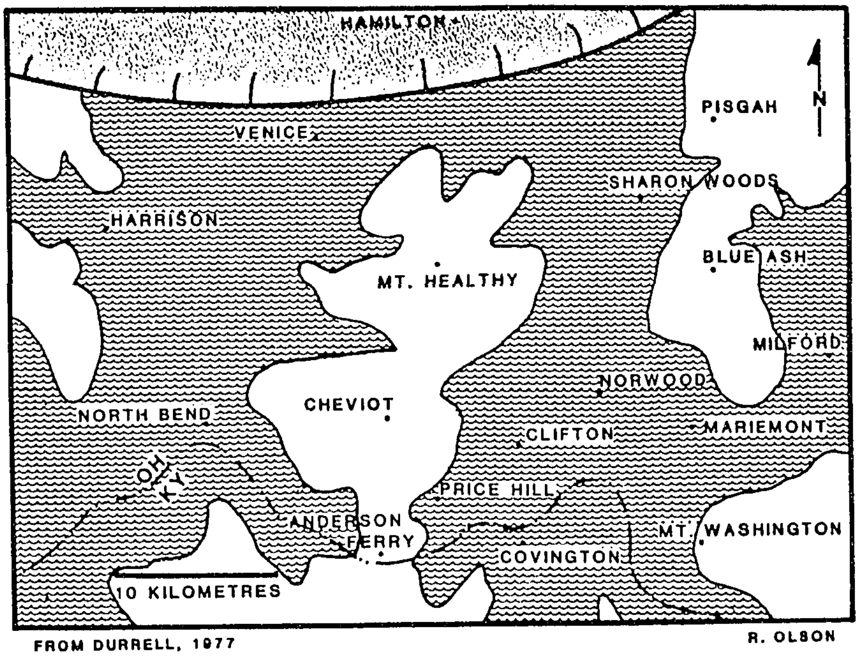
There is a narrow valley draining toward the southwest parallel to the present I-71 in the northeast area of downtown and the Mt. Adams area. However it apparently was only a minor tributary of the Deep Stage.

A newly discovered valley of the Deep Stage trending east-west is seen between Mt. Adams and Riverfront stadium (Fig. 6). The new valley, the Finn Valley, was discovered by plotting records of borings that had been unavailable to Durrell (Fig. 7).

THICKNESS OF OVERBURDEN

The Illinoian ice sheet advanced from the northeast out of Ontario and covered most of southwestern Ohio. Figure 8 represents a stage of the ice sheet

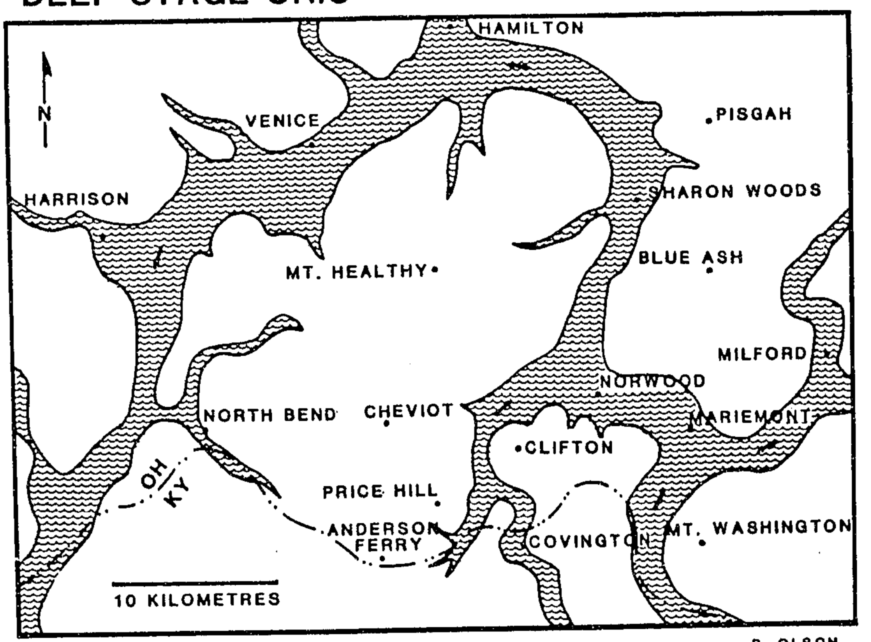
PRE-ILLINOIAN GLACIATION



FROM DURRELL, 1977 R. OLSON

Figure 4. Pre-Illinoian glaciation in the Cincinnati area (not shown at maximum extent).

DEEP STAGE OHIO



FROM DURRELL, 1977 R. OLSON

Figure 5. Deep Stage Ohio flowing through greater Cincinnati.

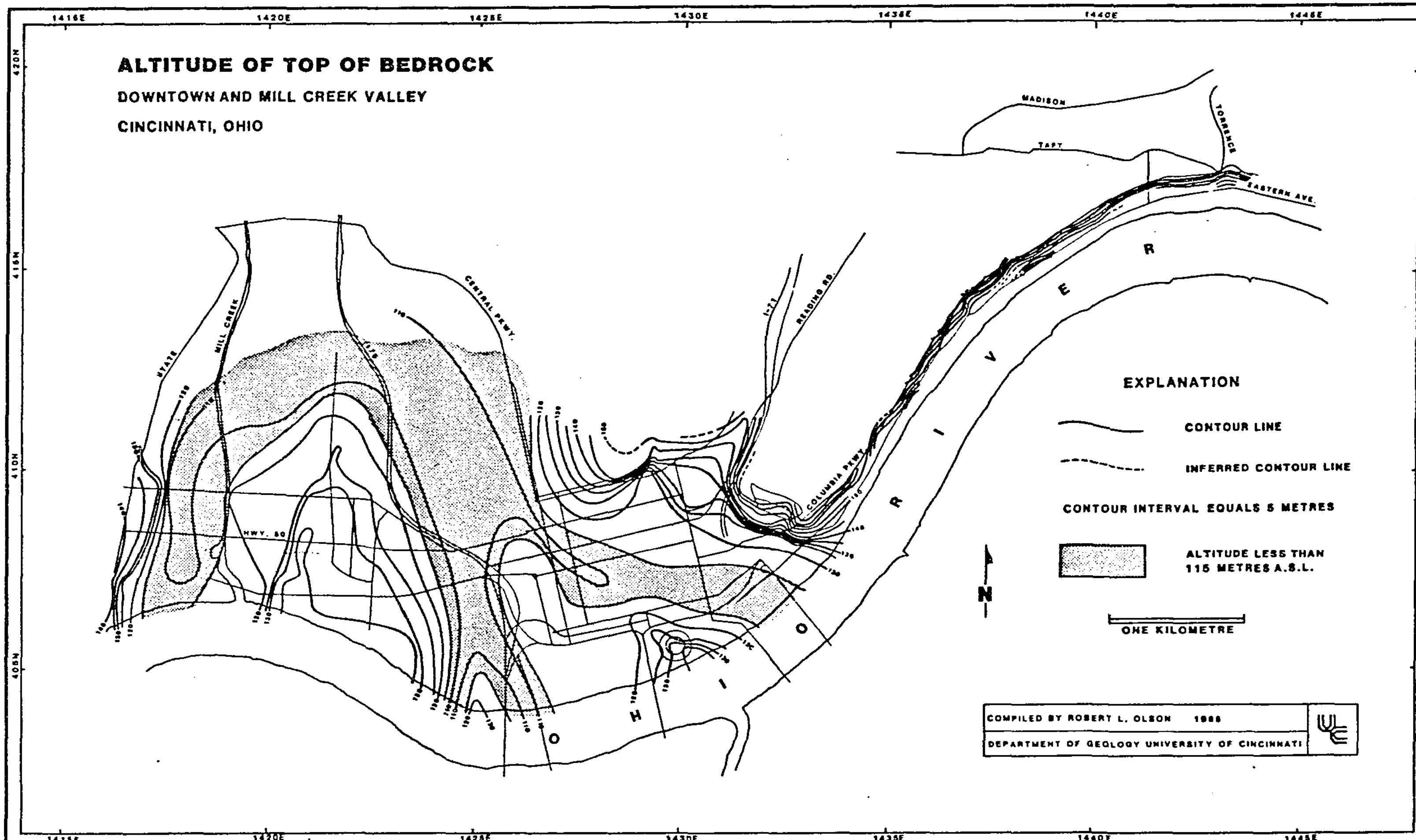


Figure 6. Altitude of top of bedrock in the downtown Cincinnati area.

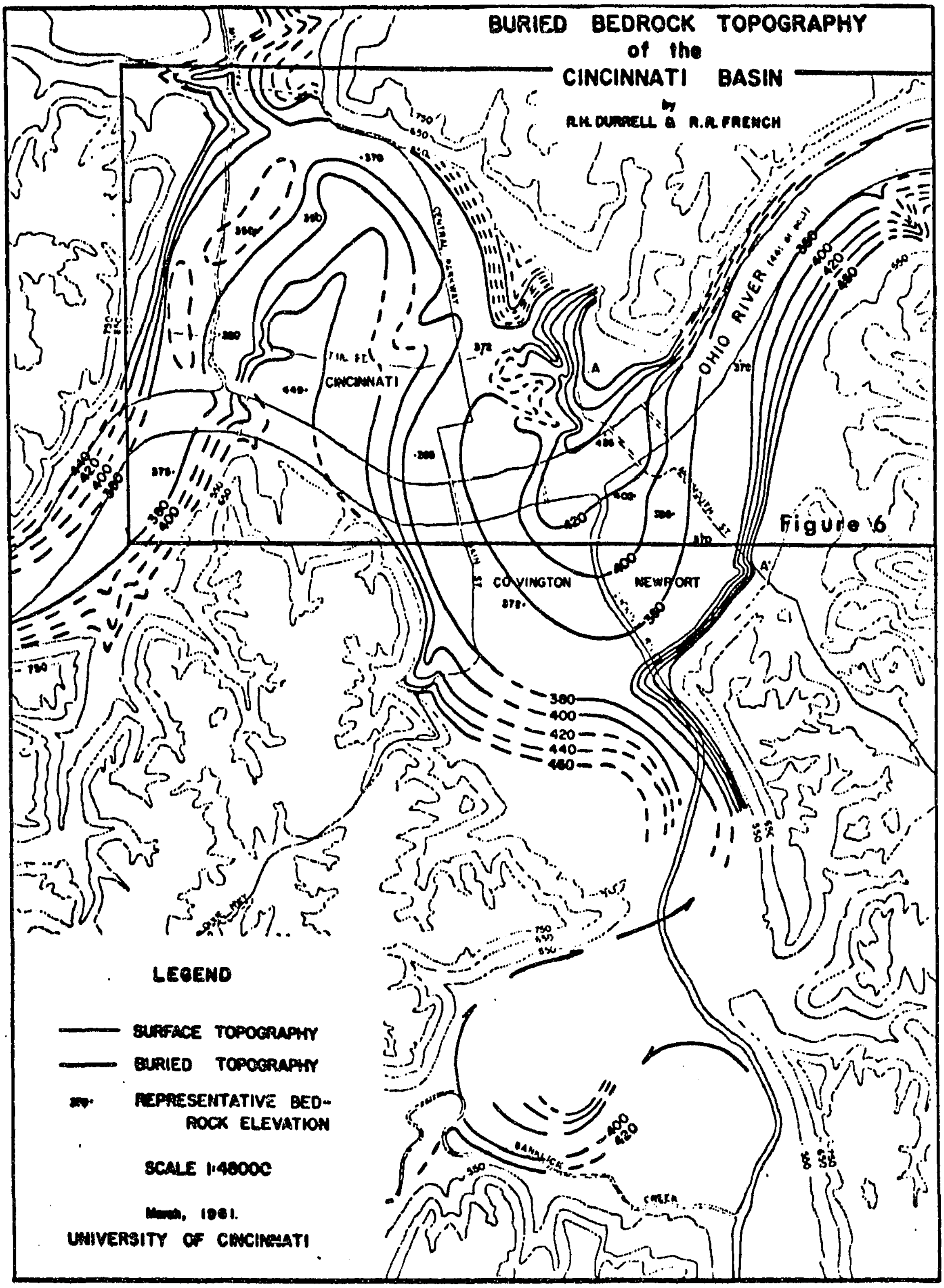


Figure 7. Buried bedrock topography of the Cincinnati Basin.

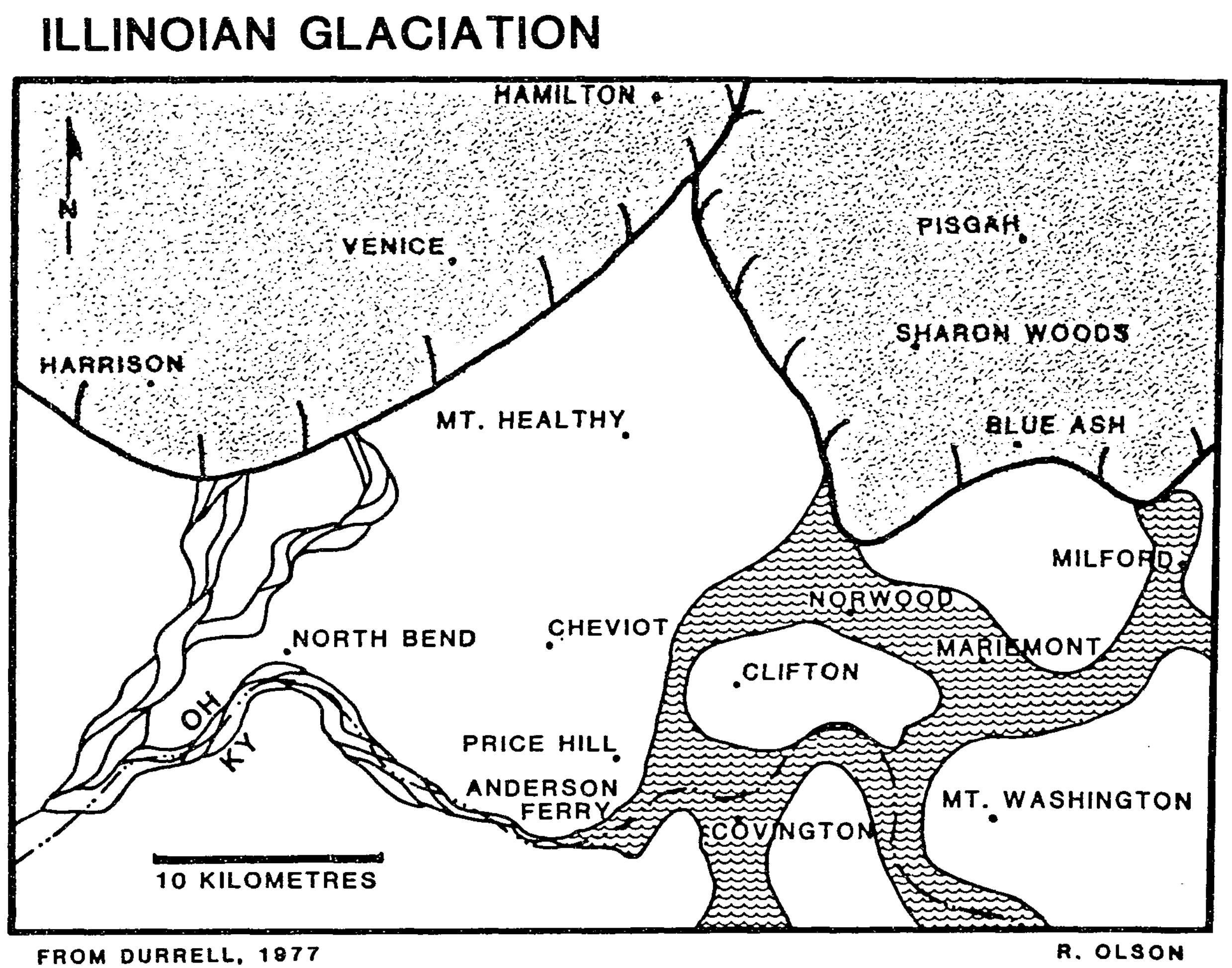


Figure 8. Illinoian glaciation in the Cincinnati area (not shown to maximum extent).

short of its maximum. The glacier and large rivers reshaped the landscape and left large thicknesses of unconsolidated deposits. For example, the intersection of I-71 with Eggleston Avenue and the approach to the I-471 bridge marks the center of an elliptical, northwest-trending deposit of what the H. C. Nutting Co. interpreted as varved lake clay (Fig. 9). The deposit thins but continues southeastward into the subsurface beneath the Ohio River and northwest to the Reading Road exit of I-71, where it terminates. Near its center the deposit is up to 24 metres thick and occurs at a depth of 30 metres (Fig. 9). Standard penetration values of the clay are from 2 to 5 and water contents are up to 34 percent, so the material is extremely soft (Nutting, 1974).

Other deposits in the downtown area besides the lake clay are sand, colluvium, clay and man-made fill. The age of the deposits are unknown.

The Wisconsinan ice sheet formed its terminus in the greater Cincinnati area between Harrison eastward to Pisgah (Fig. 10). This glacier remained in the area for a few hundred years and then retreated, leaving a rolling belt of glacial till (Durrell 1977). Although the ice sheet did not reach Cincinnati, its effects were felt here by increased runoff from glacial meltwater.

Figure 11 shows thickness of overburden on bedrock in the downtown and Mill Creek valley areas of Cincinnati. The overburden is all the deposits that filled the river valleys since the time of Deep Stage. This map of thickness of overburden almost mirrors the map of altitude of bedrock, such that the deepest river channels contain the thickest deposits and deposits thin over highs. The valley between I-75 and Central Parkway contains deposits with thicknesses of forty to fifty metres, and about 55 metres in central downtown Cincinnati. The deposits are thin along the present Ohio River in the Sawyer Place area (Fig. 11).

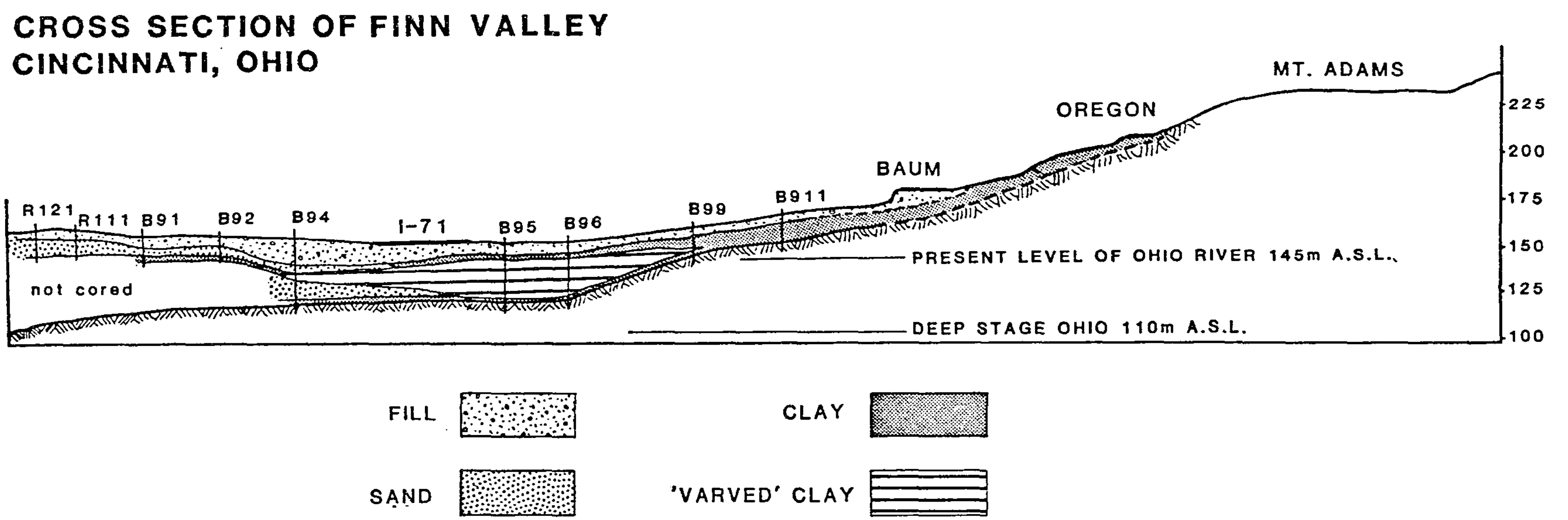


Figure 9. Cross section of Finn Valley from Mt. Adams to I-71 Cincinnati.

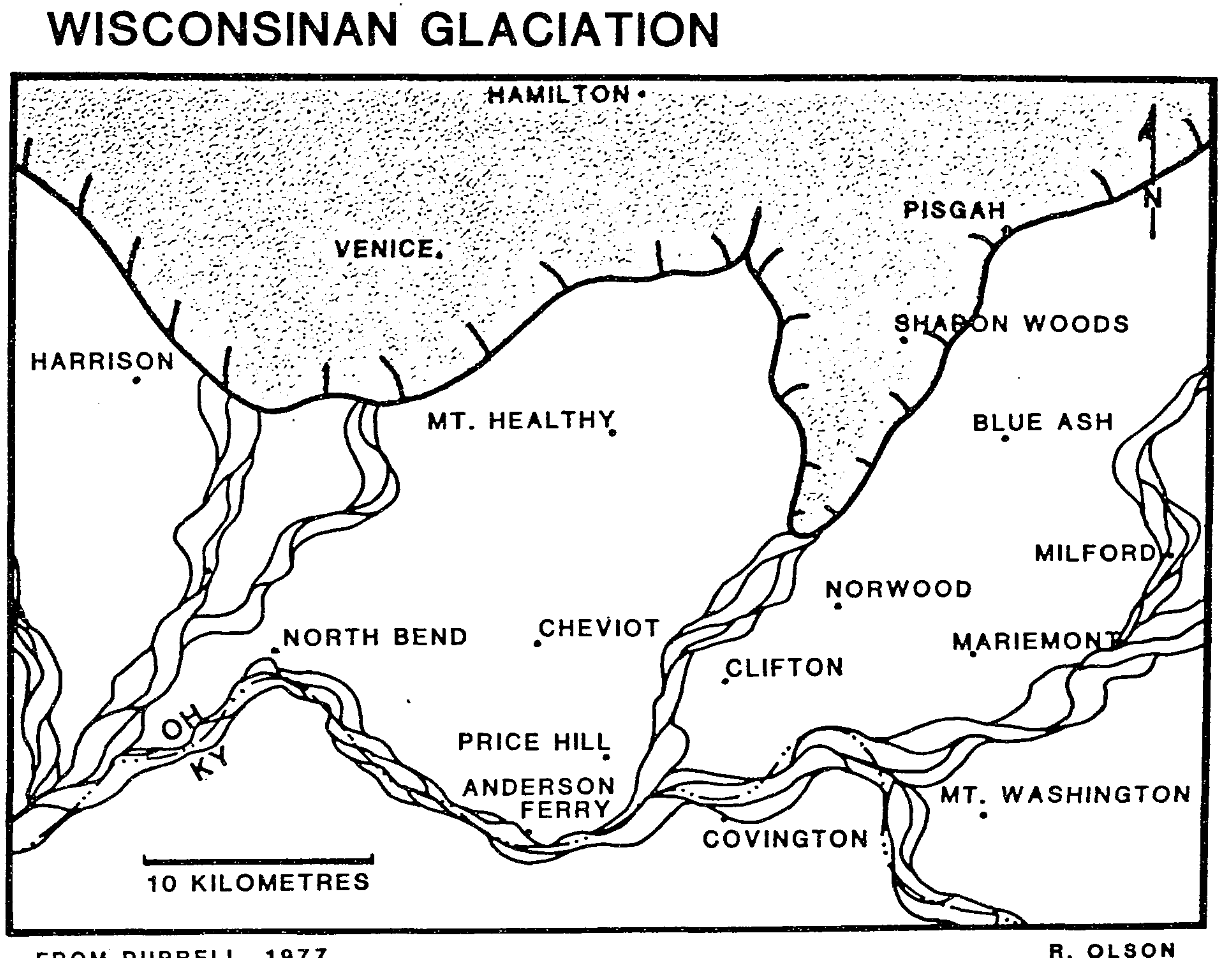


Figure 10. Wisconsinan glaciation in greater Cincinnati.

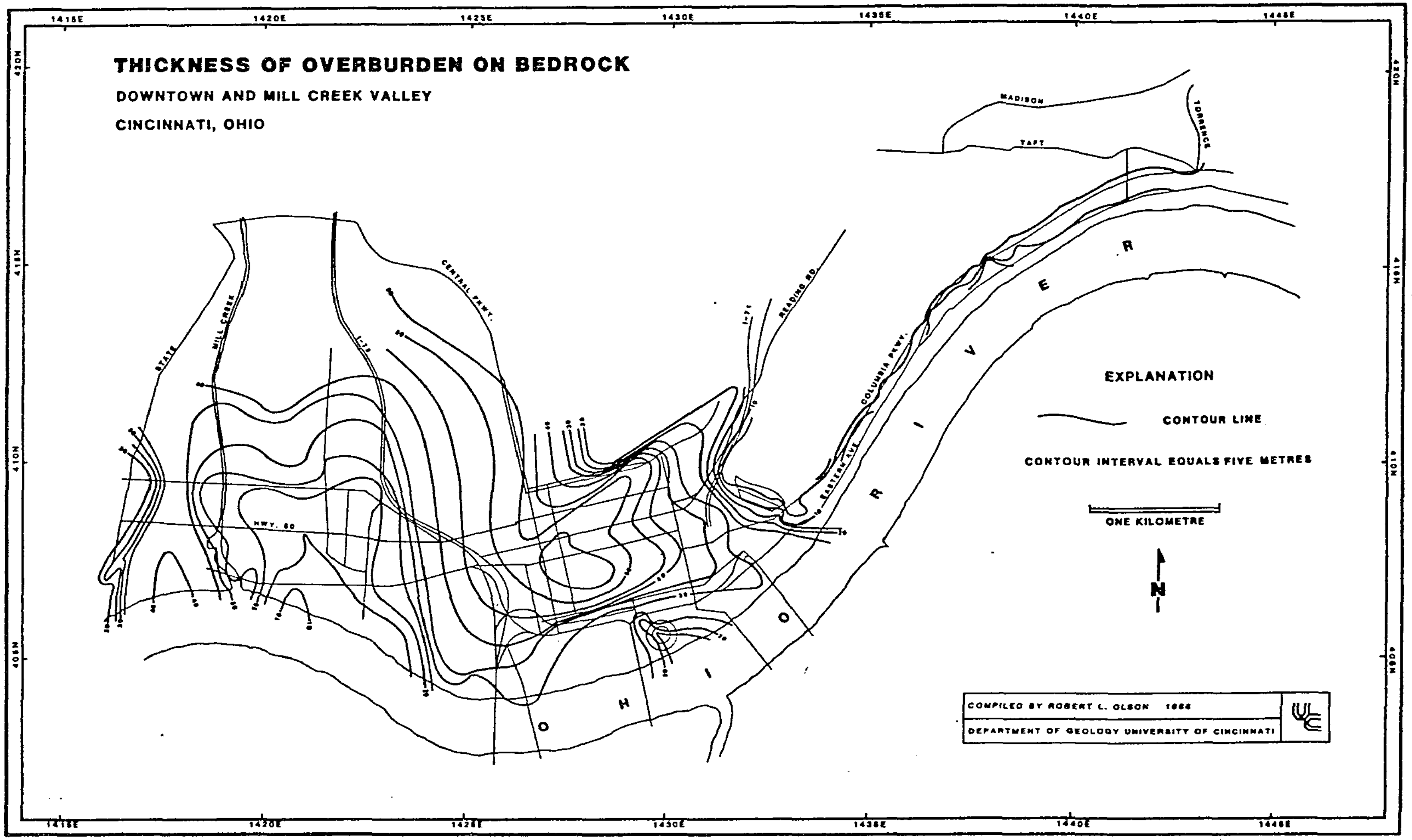


Figure 11. Thickness of overburden on bedrock in the downtown Cincinnati area.

CHAPTER 3. ENGINEERING GEOLOGY OF THE SAWYER PLACE AREA

GEOLOGIC MATERIALS

The proximity of the study area to the terminus of Pleistocene glaciers, and to several valleys of the ancient Ohio River which produced the steep slopes, and heavy urbanization all contribute to a diverse overburden on bedrock that complicates geotechnical engineering. A generalized description of the surficial materials encountered in the Sawyer Place area is presented here.

Bedrock

Bedrock in the Sawyer Place area, the Fairview and Kope formations, is shale with thin limestone interbeds. The altitude of formation contact is 213 metres (about 700 ft.), roughly 25 metres above Columbia Parkway (Gibbons, 1973). Unweathered bedrock is highly stable and the best material for foundations.

The Fairview Formation is composed of interbedded limestone and shale, each comprising about fifty percent of the rock, occurring in beds approximately eight centimetres thick.

Seventy-five to eighty percent of the Kope Formation is medium grey to light bluish-grey, laminated, calcareous and silty shale occurring in beds up to two metres thick. Limestone comprises twenty to twenty-five percent of the formation. The limestone is grey in color and occurs in regular to irregular beds which average less than 20 centimetres thickness (Mahan and Harrison, 1980)

The clay minerals in the Kope and Fairview are chlorite, vermiculite (degraded chlorite or volcanic ash) and mixed layer illite (Bassarab 1965).

Nutting (1986) reports that the limestone layers of the Kope Formation in the Sawyer Place area are severely jointed and fractured and carry significant quantities of groundwater. Standard penetration values of the bedrock start from a low of 80. Standard penetration resistance is the number of blows needed for a 140 lb hammer dropping 30 in to move a split-spoon soil sampler the second plus the third 6 in into the soil which provides "blows per foot of penetration." Water contents are low, with values of 6 to 15 percent weight of dry solids. (Nutting, 1986).

Colluvium

Colluvium in the area is weathered shale and limestone bedrock which has been transported down slope by soil creep (for example, Bloom, 1979). Colluvium occurs along the entire length of slopes above Columbia Parkway, and, according to geotechnical borings, above bedrock throughout much of the area.

Colluvium at the ground surface is brittle and hard during dry periods, however, it becomes highly plastic and quite soft after periods of heavy rainfall. Standard penetration values of colluvium are 6 to 27 at depths of 1 to 20 metres, respectively. The corresponding water contents range from 11 to 22 percent (Nutting, 1986).

Alluvium

Exposures of alluvium occur along the banks of the Ohio River. The deposits range from a silty clay west of Mt. Adams to coarse sand and gravel near the I-471 approach. In the Sawyer Place area, alluvial deposits occur only in a narrow band below Eastern Avenue.

Standard penetration values of the alluvial deposits range from 8 to 85 at a depth of 28 metres and at a water content of 10 percent near the I-471 approach (Nutting, 1974).

Man-made Fill

The most diversified unit is man-made fill which varies in composition from cinders, bricks, rock fragments, wood, clay, sand, rubble fill and gravel to exotics such as spark plug fragments. Fill occurs throughout the area wherever roadways, railroad tracks, housing and almost any other man-made structures exist and ranges in thickness from 2 metres on Columbia Parkway to 20 metres at the overpass of the I-471 approach at Eggleston Avenue. Standard Penetration values range from 1 in cinders to 80 in rubble fill, and water contents of the fill range from 8 to 30 percent (Nutting 1974, 1986).

ALTITUDE OF TOP OF BEDROCK AND THICKNESS OF OVERBURDEN IN THE SAWYER PLACE AREA

Borehole logs were compiled from throughout the Sawyer Place area in order to determine the depth to stable bedrock, the locations of buried valleys and the thickness of overburden composed of the geologic materials discussed in the previous section (Figs. 12 and 13).

The map of altitude of top of bedrock (Fig. 12) shows that, directly below Mt. Adams and along Columbia Parkway, bedrock slope angles range from 11 degrees under Mt. Adams to 17 degrees 600 metres east of Kemper Lane.

Figure 12 shows tributary ravines of the Ohio River at the following locations: directly above Kemper, under the intersection of Kemper and Columbia Parkway, 500 metres east of Kemper under Columbia Parkway, 150 metres west of Collins and directly under Torrence.

Tributary ravines of the Ohio River are significant because they have been covered by natural and man-made fill and tend to be loci of deep landsliding. For example, Figure 12 shows two ravines in the bedrock in the foot of Mt. Adams. The same ravines are reflected by two areas of unusually thick overburden (Fig.

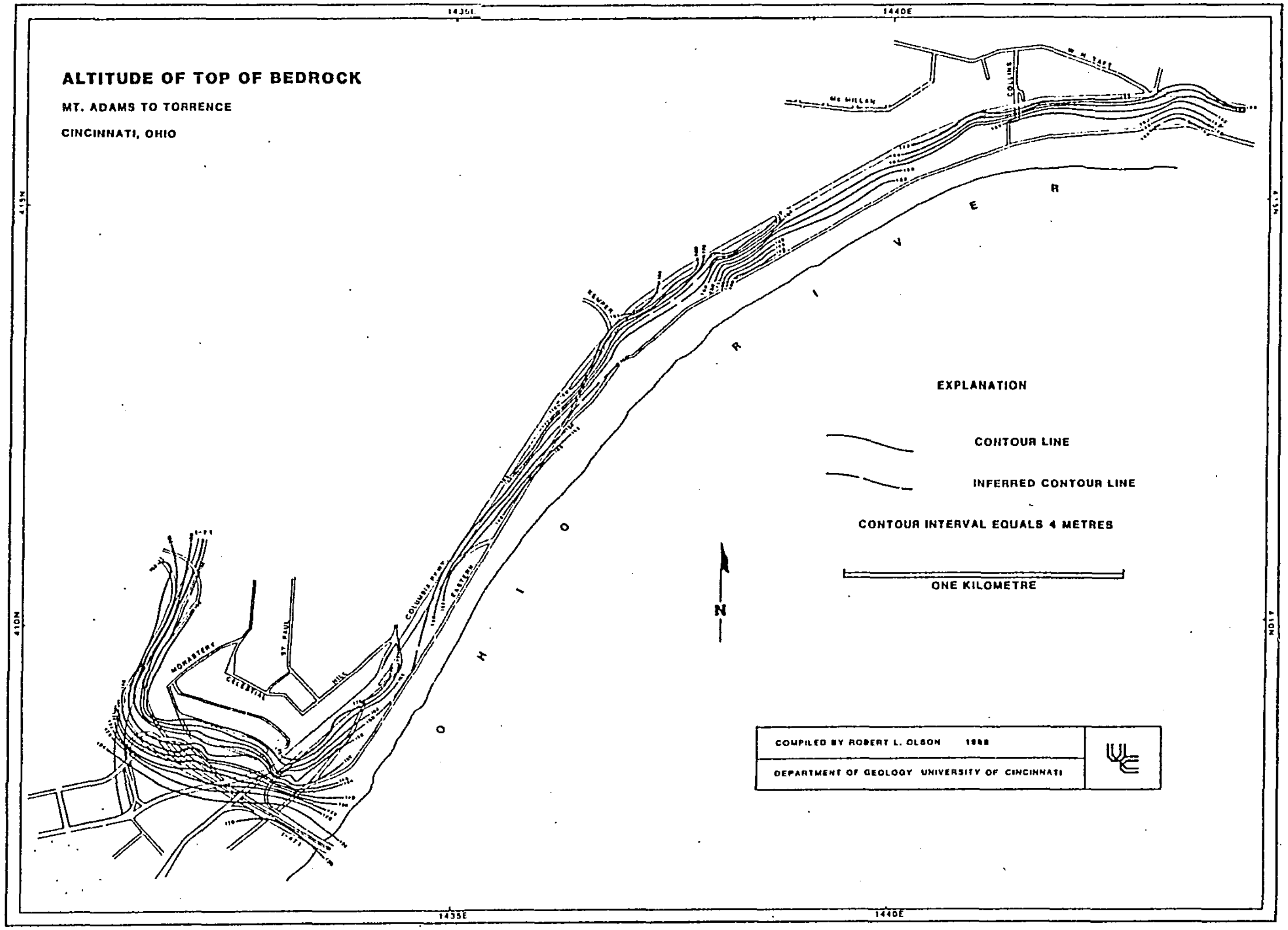


Figure 12. Altitude of top of bedrock in the Sawyer Place area.

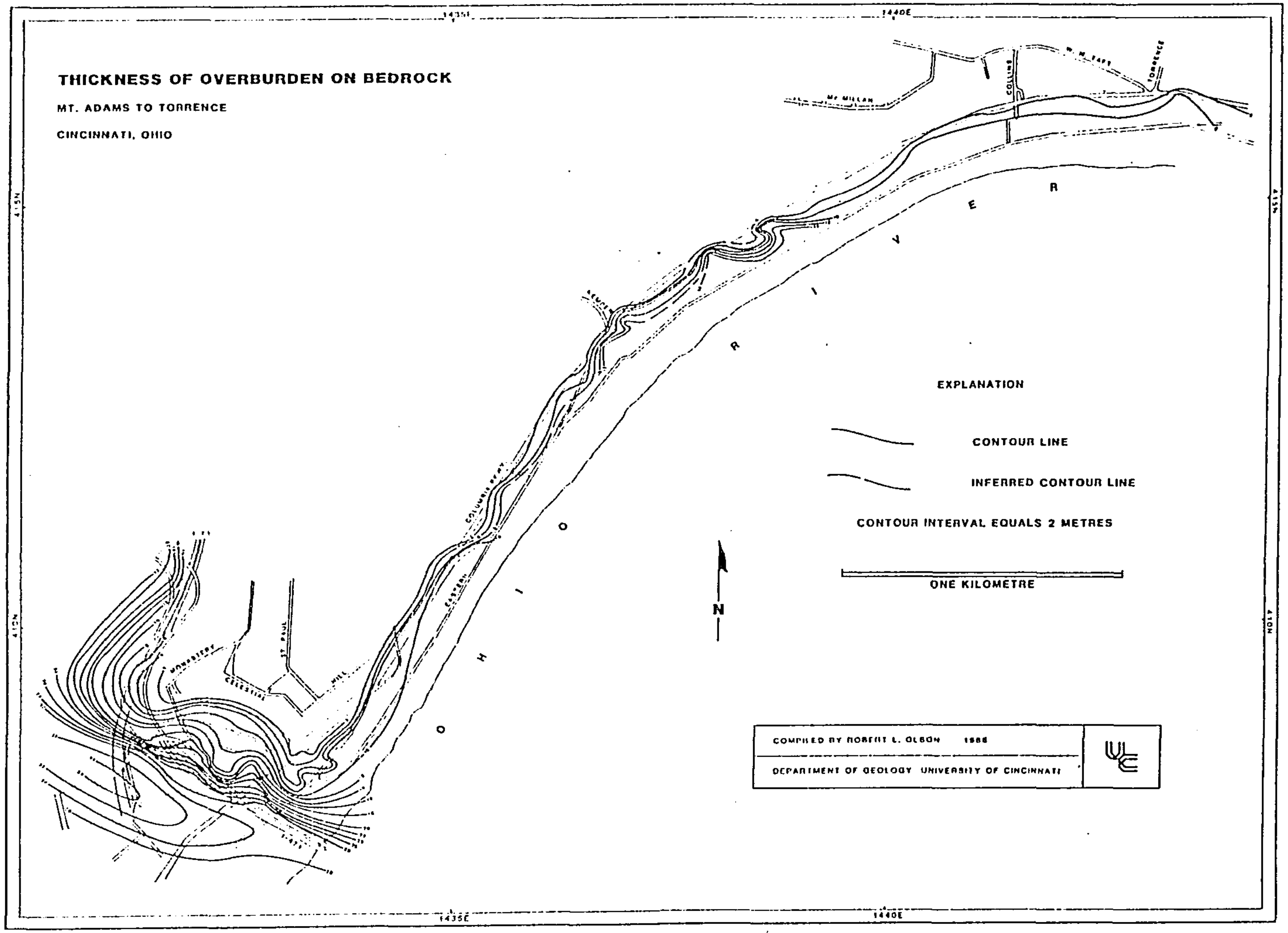


Figure 13. Thickness of overburden on bedrock in the Sawyer Place area.

13). These ravines and thick deposits correspond to the locations of the two landslides that activated in the early 1970's and were responsible for repairs costing on the order of 22 million dollars (Shannon and Wilson, 1974).

Figure 13 shows deposits in the tributaries along Columbia Parkway which range from 4 to 14 metres in thickness.

MASS MOVEMENT

The geologic processes in the area that pose problems to engineering design are soil creep, landsliding, flooding, erosion and consolidation. Stabilization of hillsides and design of foundations depend on knowledge of these processes. Problems of flooding are confined to areas below the hillslopes on the alluvial plain along the Ohio River. Problems of consolidation will be greatest in the same area. Problems of erosion will be most common in areas of steep slopes under construction and along the river bank.

This study has focused on processes of landsliding and soil creep, and the engineering geologic map (Plate I) was constructed to delineate areas of landsliding, soil creep and seepage.

Landslides

By far the most damaging geologic process in the Sawyer Place area that affects engineering design is landsliding (Plate I). Ignorance of landsliding in the area on behalf of engineering firms and developers can lead to premature aging and decay of buildings, roads and utilities such as is seen throughout much of Cincinnati, particularly the hillsides (e.g., Figs 14, 15, 16 and 17). There may be a gross failure as well, but if it is similar to others in Cincinnati, it will not be catastrophic nor sudden.

Landslides are referred to as either deep seated, with shear planes deeper than 1.5 metres, or shallow seated, with shear planes shallower than 1.5 metres. Many of the deeper landslides are slumps or rotational slips along a failure surface (Fleming and others, 1981) whereas shallow landslides are debris slides, where a thin layer of colluvium has translated downslope (Richards 1983; Riestenberg, 1981; Fleming and others, 1989).

The part of the Sawyer Place area from I-471 to Bains Street shows the least amount of landsliding (Plate I). Most landslides in this area are shallow, inactive and isolated from each other. Failures are localized and disrupt older retaining walls and foundations, as on Martin Street (Fig. 14).

The only deep landslide in the area has cuspate tensional cracks in the pavement of Columbia Parkway and a thick toe ending just above Eastern Avenue. Another deep landslide may exist just west of Bains Street (Plate I).

The area between Bains Street and Kemper Lane is transitional from dormant, inactive landslides into large, active deep landslides. Houses bordering Columbia Parkway and Eastern Avenue have been razed. A large deep landslide begins just east of Bains Street, where it is mostly inactive, to Kemper Lane, where it is active. The head scarp occurs in fill which forms the embankment of Columbia Parkway, and reaches within a few metres of the Parkway. The toe intersects the sidewalk, and overrides Eastern Avenue and Kemper Lane (Figs. 15 and 16).

There is failure in Columbia Parkway and the sidewalk above Weeks Street (Fig. 17). A large excavation was made in a deep-seated landslide for two school buildings on weeks street. The result of the excavation was numerous cracks and severe bowing of the retaining wall behind the buildings directly below the Columbia Parkway. One of the school buildings has been razed (Figs. 18 and 19).

Figure 14. Razed housing along Martin Street. (Photo by Robert Olson, 1988).

Figure 15. Encroachment of soil from deep landslide onto Kemper Lane results in disruption of roadway and rotation of sidewalk. (Photo by Robert Olson, 1988).

Figure 16. Broken sidewalk on Kemper Lane caused by deep landsliding. (Photo by Robert Olson, 1988).

Figure 17. Bowing sidewalk and retaining wall caused by deep landslide movement under Columbia Parkway at Weeks Street. (Photo by Robert Olson, 1988).

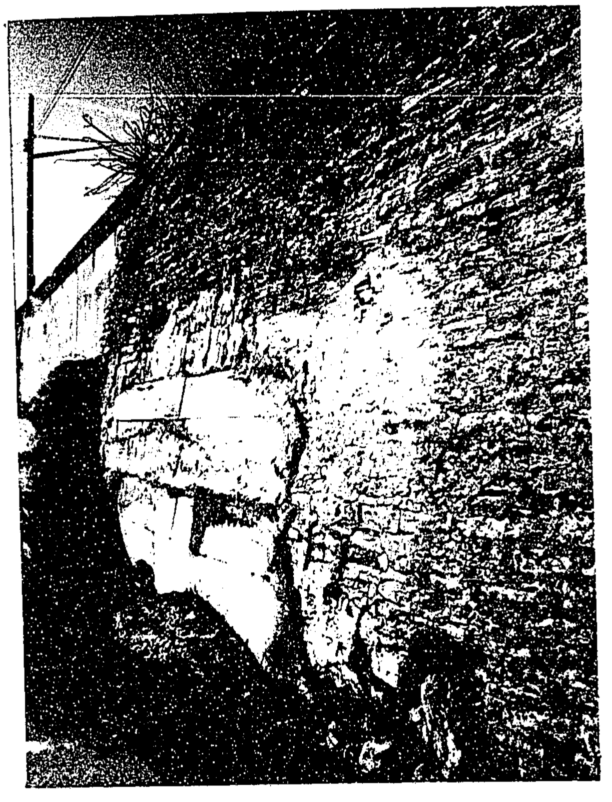


Figure 18. Bowing retaining wall of Columbia Parkway at Weeks Street shows several attempts at patching failures. (Photo by Robert Olson, 1988).

Figure 19. Bowing sidewalk of Avenue caused by previous movement of toe of deep landsliding in front of excavated toe. (Photo by Robert Olson, 1988).

The area between Kemper Lane and Lancaster Street/Salutaris Avenue contains intense landsliding, both above and below Columbia Parkway (Plate I). Damage to bridges and roadways is severe. Here landslides become greatly elongated, with their long dimensions running perpendicular to the hillslopes. Headscarps occur within two or three metres of the parkway, in some places cutting through several meters of roadway if not through the roadway entirely. The toes occur at either Conrail railroad tracks or Eastern Avenue (Fig. 20).

Thin, translational, and mostly inactive landslides occur above Columbia Parkway east of Kemper and cause little damage besides occasional failure and encroachment onto the roadway below. A large intermittent stream valley above Columbia Parkway contains several shallow landslides with toes in the streambeds (Plate I).

East of Kemper Lane, a deep landslide is distressing the Parkway bridge and has already displaced 20 cm in shear as well as 10 cm in differential vertical movement (Fig. 21). Approximately 400 metres east of Kemper Lane the headscarp of a large deep-seated landslide cuts through the entire width of Columbia Parkway. The sides of the landslide disrupt the Conrail tracks and the landslide terminates at Eastern Avenue (Fig. 20).

Landslides above the parkway are deep and active east of the intermittent stream valley and beneath the new high- rise residences along Grandview Avenue and Salutaris Avenue (Plate I). The outer, east-bound lanes of Columbia Parkway are distressed due to landsliding between Lancaster Street/ Salutaris Avenue and Collins Avenue (Fig. 22).

Landslides above the parkway become shallow again 425 metres east of Salutaris Avenue, where the high-rise residences end. A transition between the deep and shallow landslides occurs below the parkway, 200 metres west of Collins Avenue.

Figure 20. Rotation and displacement of telephone poles in toe of deep landslide terminating at Eastern Avenue (on left). (Photo by Arvid Johnson, 1984)

Figure 21. Right lateral shear of 20 cm in Columbia Parkway bridge at Kemper Lane. (Photo by Robert Olson, 1988).

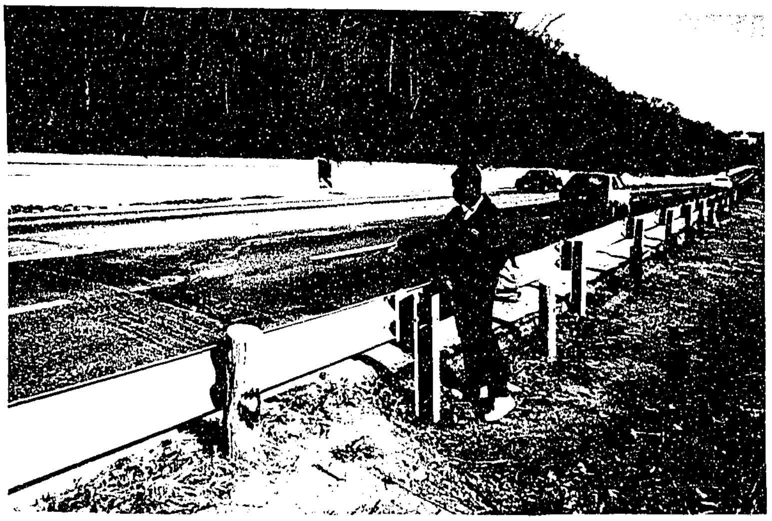


Figure 22. Headscarp cutting through pavement of Columbia Parkway (note vertical displacement of roadway at Brian's feet). (Photo by Robert Olson, 1988).

Deep landslides continue above the parkway and under the high rise residences where foundations and roadways have been destroyed. Makeshift repairs to the parkway necessitated by deep landsliding have failed, showing that landslide activity continues (Fig. 23).

A deep landslide exists above the parkway, 150 metres west of Collins, where half of the slide has been excavated and a high-rise residence constructed. Although movement within the remainder of the landslide is small, new tensional cracks of 16 centimetres wide have appeared in the parking lot directly above the existing half of the landslide (Fig. 24).

The steep hillslopes above the parkway between Collins Avenue and Torrence Avenue contain numerous inactive landslides in colluvium. Landsliding below the parkway is in the fill used for the embankment of the parkway and disturbs the parkway and sidewalk continuously from 150 metres east of Collins to Torrence. The slide elements are difficult to distinguish because of man-made changes along Gladstone (Figs. 25, 26 and 27).

A deep landslide occurs 60 metres east of Collins. It is responsible for the distress of retaining walls of houses, warp in railroad tracks, and displacement of houses.

Soil Creep

Soil creep is the slow, imperceptible deformation of slope materials under low stress levels, which only affects the shallow portion of the slope, but can be deep-seated where a weak zone exists. It results from gravitational and seepage forces, and is indicative of conditions favorable for sliding (Hunt, 1984), and exists throughout the entire area in the unconsolidated deposits along the hillsides above and below Columbia Parkway. Soil creep is typified by tension cracks, tilting and displacement of pavement and walls, rotation of vegetation, and encroachment of soil on or over roads and walls (Bloom, 1979). Creep cannot be

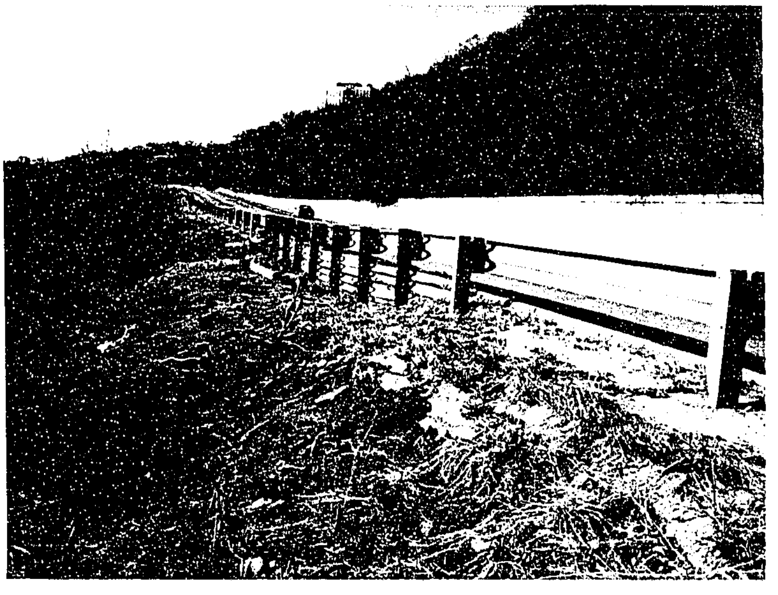


Figure 23. Makeshift repairs to the pavement of Columbia Parkway as a result of landslide movement. (Photo by Robert Olson, 1988).

Figure 24. Tensional Cracks in pavement of parking lot located above deep landslide at Bond Place. (Photo by Robert Olson, 1988).

Figure 25. Bowing and rotation of retaining wall caused by deep landsliding under gladstone. (Photo by Robert Olson 1988).

Figure 26. Warping of Conrail tracks by deep landsliding under Gladstone. (Photo by Robert Olson, 1988).

Figure 27. Toe of deep landslides under Gladstone. (Photo by Robert Olson, 1988).

recognized in areas of landsliding, so the description of creep is limited to areas of little or no landsliding.

Creep causes disruption of walls and soil encroachment over sidewalks in the area between I-471 and Bains Street. Most notable examples of creep are downslope from Martin Street, Parsons Street and Whittaker Street (Fig. 28). Small trees on the slopes of Riverview Playground are rotated by soil creep.

Soil creep dominates the slope immediately to the east of Bains, between Bains Street and Kemper Lane, where the left flank of a deep landslide becomes indeterminable, and immediately to the east of the headscarp of the same landslide. Retaining walls, once disrupted by deep slide movement, now show only creep as the dominant geological force acting upon them.

Soil creep may be responsible for the small toes on Eastern Avenue just below Kemper in the area between Kemper Lane and Lancaster Street, as well as the disruption of retaining walls and foundations, and the rotation of much of the vegetation on the steep slopes above the parkway that have not yet been affected by landslide movement.

Retaining walls and to a lesser extent foundations of housing along most of Eastern Avenue have been disturbed by soil creep. Along the west side of Collins, north of the parkway, there is severe disruption of retaining walls, foundations and rotation of vegetation.

To the east of Collins, rotation of vegetation is evident along the slopes above the parkway. Below the Conrail railroad tracks only slight disruption of structures has occurred from soil creep.

The engineering geology of the Sawyer Place area has been discussed by examining the different engineering materials and their thickness which overlies bedrock in conjunction with a map showing landslides and soil creep. A Relative

Figure 28. Soil creeping over retaining wall onto sidewalk of Eastern Avenue at Parsons. (Photo by Robert Olson, 1988).

Stability study combines the geologic factors previously discussed into a map which shows areas of different stability types of ground.

CHAPTER 4. RELATIVE STABILITY OF GROUND IN THE SAWYER PLACE AREA

A Relative Stability Map was constructed to show the author's assessment of stability of ground in the Sawyer Place area. The map (Plate II) was derived from the engineering geologic map which shows areas of landsliding and soil creep, logs of soil borings, which show types of engineering materials and their thickness, and field observations.

The map is designed for city planners, architects and engineering companies who can better develop the land if they account for stability problems in the area. The interpretations shown on the map are necessarily broad, therefore planning development of specific parts of the area should be based on additional engineering-geologic and geotechnical studies.

The relative stability map is divided into three categories of stability; stable ground, potentially unstable ground and moving ground, and each of these is divided according to thickness.

The areas of moving ground, deep landsliding and shallow landsliding, comprise a large part of the Sawyer Place development and is responsible for structural damage to roadways, bridges, retaining walls and foundations.

The most noticeable feature is the deep landsliding that occurs from 150 m east of Kemper Lane to 270 m west of Collins both above and below the Columbia Parkway. Smaller areas of deep landsliding are Weeks to Kemper, in the areas of Bains Place and on Gladstone. There is no deep landsliding in the Martin Street area.

Shallow active landsliding usually occurs on the flanks of deep landsliding as seen in the area from Kemper to Grandview. Linking the areas of deep and shallow moving ground shows an almost undisturbed 2.2 km stretch of ground from Weeks Street to Collins. Other areas of shallow landsliding include ground from Collins to Torrence above and below the Columbia Parkway, and Martin Street at Eastern Avenue.

Potentially unstable ground is composed of non-moving <u>deep</u> <u>landslides</u> and <u>shallow</u> <u>landslides</u>, and adjacent areas of possible instability. In potentially unstable areas disruption of structures and ground can be seen, but has been weathered, or is weathering faster than failure can appear.

An area of potential instability is found linking the two areas of deep landsliding at Bains and Weeks. Other areas of potential instability are the dormant landslide underneath the bridge of the Columbia Parkway at Kemper Lane, the eastern end of Martin Street, and surrounding the areas of deep and shallow landsliding throughout the area.

Stable ground is divided into the categories of <u>deep</u> <u>unconsolidated</u> and <u>shallow</u> <u>unconsolidated</u> ground. Shallow unconsolidated consists of thin colluvium and fill on bedrock while deep unconsolidated consists of primarily of thick deposits of alluvium and fill.

Stable deep unconsolidated ground is located below the Columbia Parkway to the Ohio River in areas not considered unstable or potentially unstable. Stable deep deposits present settlement problems to engineering design because of the diverse materials encountered and high water contents. Stable shallow unconsolidated ground is located above the hillslopes of the Columbia Parkway and pose little difficulties to development.

Descriptions of the types and depths of ground movement and future studies that should be initiated in the event of development, are presented in figure 29 and Plate II.

Future geotechnical studies of the Sawyer Place area must include correct monitoring and thorough geotechnical exploration of ground in unstable areas, and are of great importance to the developer, architects, engineers and the people of Cincinnati. Incorrect or poor monitoring and inadequate exploration of ground will result in inadequate design or over-design, leading to failure of both ground and structures or resulting in unnecessarily high costs.

Here are simple ways to monitor types of ground:

In deep ground:

1. Borings should be used to determine the locations, types of materials and groundwater levels in the area.
2. Place inclinometers throughout the area in question, particularly in areas of suspect stability. Monitor for at least several months,preferably several years prior to development and several years after development.
3. Piezometers placed throughout the area can determine pore-water pressures, and should be monitored as above.

In shallow ground:

1. Borings and trenches will determine the areal extent of materials and groundwater levels.
2. Trenches should be used to expose shear surfaces and materials.

In the event of development in the Sawyer Place area, such geotechnical investigations can greatly reduce the risk of building incorrectly in areas of unstable ground and can thus avoid future failure of "engineered" structures.

TYPE OF MOVEMENT	FUTURE STUDIES
Moving Ground:	
Deep landsliding: Active landsliding greater than 1.5 metres deep.	1. Is the landslide active? 2. What are the depth and lateral boundaries of landsliding? 3. What are the pore-water pressures? 4. How would proposed development stabilize ground?
Shallow Landsliding: Active landsliding less than 1.5 metres deep.	1. What is the depth and lateral extent of landsliding? 2. How would the ground be stabilized as a result of development?
Potentially Unstable Ground:	
Deep Landslides: Dormant landslides greater than 1.5 metres deep and surrounding areas of possible deep instability.	1. What are the depth and lateral boundaries of potential landslides? 2. What are the pore-water pressures? 3. Is there active landsliding? 4. What is the factor of safety against sliding? 5. How will stability be maintained?
Shallow Landslides: Dormant landslides less than 1.5 metres thick and surrounding areas of possible shallow instability.	1. What are the depth and lateral extent of potential landslides? 2. How will stability be maintained?
Stable Ground:	
Deep Unconsolidated: Areas not exhibiting movement. Dominated by deep deposits of alluvium, colluvium and fill.	1. What are the materials, their distribution and engineering properties? 2. Where is the groundwater table? 3. How much settlement will occur as a result of development? 4. How could instability be introduced by proposed development?
Shallow Unconsolidated: Areas not exhibiting movement. Dominated by thin deposits of colluvium and Fill.	1. Found structures on bedrock.

Figure 29. Types of stability and recommendations for future studies.

CHAPTER 5. CONCLUSIONS

In the 2.7 km^2 Sawyer Point area along the Ohio River in Cincinnati, Ohio, the depth of landslides seems to be controlled by the topography of the bedrock. Deep landslides occur over deep bedrock ravines, Also, knowledge of the areas of thick deposits of overburden over ravines helped in determining areas of deep ground in the relative stability study.

Landslides occur throughout the area regardless of slope or materials, however, in areas of shallow colluvium over bedrock, the landslides are mostly translational, while in areas of deep unconsolidated deposits, landslides are rotational slumps. Velocity of the landsliding in the area is so slow that all but very recent landslide features are disrupted by erosion. Soil creep in the area is a major cause for the disruption of retaining walls.

The relative stability study shows that a large area of ground in the Sawyer Place area is moving or potentially unstable, so that new development may lead to gross failures. Further development on or near steep slopes or other areas of known instability identified on the relative stability map should be allowed by the City of Cincinnati only after the areas have been investigated by competent geotechnical engineers and engineering geologists. Otherwise a high cost of restabilization of ground after development has taken place, will be borne by the city.

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APPENDIX A. A DECADE OF ENGINEERING GEOLOGY IN CINCINNATI

This thesis marks the end of a decade of relatively intense work in engineering geology at the University of Cincinnati. The previous studies formed the basis of this study, so the works will be briefly reviewed here. Between 1978 to 1988, several engineering geology theses and other related publications in landsliding and hydrology were compiled by graduate students at the University of Cincinnati, to provide new insights in the engineering geologic problems of the Cincinnati area. These studies were conducted under the supervision of Arvid Johnson, Professor of Engineering Geology and Geomechanics during that time. The studies are in the Cincinnati area, and provide engineering firms, architects, developers and the public with valuable information about the engineering geology of the metropolitan area. It is to the following list that this study will be added.

William Haneberg and A. Onder Gokce (1988) described rapid fluctuations of piezometric levels in a shallow colluvium landslide on Delhi Pike, 15 km west of downtown Cincinnati (Fig. 30). Instruments to record rainfall and piezometric levels at 15 minute intervals were installed and data collected from late March through mid May, 1980. The piezometric levels produced a characteristic asymmetrical hydrograph, with a steep rising limb and a flatter sigmoidal falling limb with respect to the intensity, duration and distribution of rainfall through time.

Haneberg and Gokce had shown that the asymmetrical hydrographs are characteristic responses to rainfall when the porosity of the colluvium is low. Also noted was that the piezometric level increases with the square root of rainfall.

Ralph Liebing and others prepared the Earth Movement Task Force Report (1982) for Hamilton County, a document which identified the problems and types of landsliding and the effect of damage to public and private property in Hamilton County, Ohio. The report addressed the possibility of geologic and geotechnical

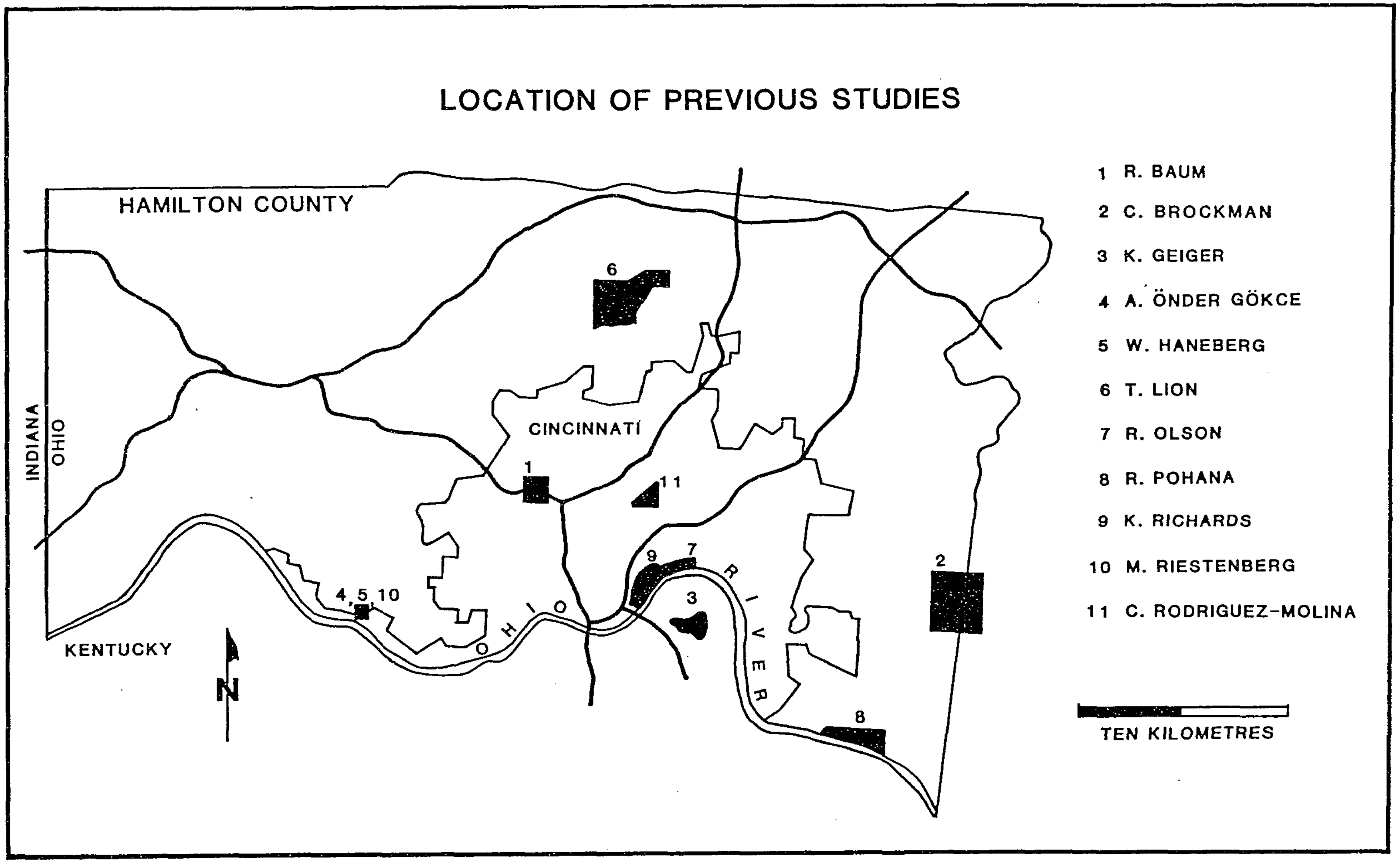

Figure 30. Location of previous studies.

studies of undeveloped areas in Hamilton County in order to avoid the high cost of repairing structures which will be damaged or destroyed by future landsliding. Also studied were the practices and laws of other, more progressive, cities that already have developed and implemented laws which protect the taxpayer from overexpenditures from poor city and county planning.

Thomas Lion (1983) mapped an area of approximately 4.7 km^2 within Springfield Township, 16 km north of downtown Cincinnati, south of Winton Lake and north of the intersection of Winton Road and Compton Road (Fig. 30). Lion was the first to make detailed engineering geologic and relative stability maps in the Cincinnati area. About seventy percent of the land is currently used for residences, schools and commercial buildings.

Lion made special investigations of the thickness of overburden, and the distribution of sinkholes, landslides and glacial lake clays. The sinkholes, which range in area from forty to sixty-eight hundred square meters, are mostly in bedrock above the Belleview Limestone. Most of the landslides are in glacial till and lake clay. The largest, deepest and most damaging landslides are earth-blockglide-extrusions involving lake clay deposits.

Ken Richards (1982) started his field work shortly after Lion. He studied the engineering geology of a 3.9 km^2 of ground in the Mt. Adams area and made special studies of the large landslide at Mt. Adams and the thin colluvium landslides above Columbia Parkway. His research was a demonstration project of the kind of engineering geologic evaluation that should be required prior to planning of development in landslide-prone hillslopes in Cincinnati.

Scott Brockman (1983) studied the engineering geology of the Dry Run Creek area, 5.9 km^2 in Anderson Township, eastern Hamilton County, bounded by Route 32 on the north, Clough Pike on the south, Little Dry Run Road on the west and the Clermont County line on the east (Fig. 30). Brockman's thesis focused on the Pleistocene history, engineering geology and relative stability and the causes of landsliding in the Dry Run Creek Area. The landslides occur in Illinoian deposits and colluvium, and landslide activity depends on thickness of till, slope angle, presence of woody roots, and pore water pressure.

Rex Baum (1983) reported that landslides in the area of Faye Apartments, in north Fairmont, Cincinnati, Ohio, are largely results of poor engineering practice (Fig. 30). The Faye Apartments were constructed on a hilltop that was leveled in 1959-60. Fill, placed on the hillsides surrounding the apartments, slid and destroyed property downslope. Baum did three dimensional analyses of some of the landslides. He also analyzed the development of unusually high pore water pressure at the colluvium-bedrock interface.

Kenneth Geiger (1983) made engineering geologic maps of part of northern Kentucky. Geiger mapped a 3.4 km^2 area which included parts of Newport, Bellevue and Ft. Thomas in Campbell County, Kentucky. The area is bounded by Covert Run Pike, Rossford Avenue, Memorial Parkway and Taylor Avenue (Fig. 30). Besides making engineering geologic and relative stability maps, Geiger evaluated the potential for flooding of Covert Run Creek and summarized the history of earthquakes in southern Ohio and northern Kentucky.

Richard Pohana (1983) presented an engineering geologic and relative stability analysis of a 3.6 km^2 area in Anderson Township, southern Hamilton County. The study area is bounded by Five Mile Road, Ayers Road, Asbury Road, and U.S. Route 52, which contains the subdivisions of Rio Grande Homesites, Reagants Park and Brystal Manors (Fig. 30). Pohana studied the Pleistocene deposits in the area and the grading ordinances in Hamilton County. Findings were that the steep slopes, extensive grading and clearing of trees have caused slope instability. Potential for deep seated slides corresponded with the pre-glacial valley.

Carlos Rodriguez-Molina (1983) studied the engineering geology and relative stability of a 3.2 km^2 area of Avondale, Cincinnati, Ohio which is bounded to the south by Forest Avenue the west by Vine Street, north by Clinton Springs Street and east by Glenwood Avenue (Fig. 30). Rodriguez-Molina reported damage to man-made structures as a result of differential settlement resulting from poor construction techniques by developers. Landslide damage exists on colluvial slopes averaging 12 degrees and on glacial deposit slopes which averaged 14 degrees.

A. Onder Gokce, Arvid Johnson, and Bob Fleming, (in prep), studied landslides involving mechanisms of extrusion and block gliding at Huffman Court and McKelvey Road, Cincinnati, Ohio, an area known for slides which resulted in the loss of several residences. The landsliding in the area occurred on low slopes of five to fifteen degrees, at velocities of eight to fifteen centimetres per year. All the landslides appeared to move with the combined mechanisms of extrusion of glacial lake clay near the basal shear zone, and of translational gliding along the shear zone, with "blocks" of stiff glacial till riding on top. Velocity profiles determined with a tiltmeter device show that the underlying layer of softer lake clay moves at a higher velocity than the overlying landslide block. Theoretical calculations indicate that the factor of safety is reduced to eighty percent in one landslide and fifty percent in the other if extrusion of the lake clays is considered in the analysis, so effects of extrusion should not be ignored for these landslides.

Mary Riestenberg (1981, 1987) investigated the effects of woody vegetation on stabilizing the hillslopes in the Rapid Run Creek area, Cincinnati, Ohio (Fig. 30). In her master's thesis, Riestenberg reconstructed the sequence of sliding of the Rapid Run landslide by using striations in the slip surface which recorded the movement of the slide elements from original to final positions of the slide elements. She also studied the addition to the factor of safety against landsliding caused by tree roots, and concluded that the tree roots supply much of the reinforcement for the retention of thin colluvium on steep slopes in the Cincinnati area.

Riestenberg's Ph.D. research suggests that certain species of trees may be associated with failed and anchored soil masses. For the study, the "pull out resistances" of tree roots of sugar maple and white ash were determined by placing fresh, excavated roots into a modified boat winch that could measure tensile strength of the root at failure. The study addressed the ability of the white ash and the sugar maple to anchor colluvium and found that the white ash was less able to stabilize the colluvium because of its shallow root system. Her study showed that the "pull out resistance" could be a large factor in resistance to failure of very steep hillslopes underlain by a half meter of colluvium, but not of the typical hillslopes, underlain by one or more metres of colluvium.

John Smale (1987) led various technical groups in Cincinnati to evaluate the problems of the city's infrastructure. This much heralded document has come to be known as the Smale Report. It was the charge of members of the John L. Rich Geomechanics Laboratory at the University of Cincinnati, including Arvid Johnson, Thomas Lowell, David Nash and several graduate students, to assess damage to the city's roadways and retaining walls due to landsliding.

The group mapped several areas which were prone to landsliding, inspected retaining walls in various states of disrepair, and then compared the findings with the city's data. Briefly, the conclusions were that the city has a poor data base and no way of evaluating geologic hazards in areas of new construction.

The suggestions of the committee were that the city implement a geotechnical division to evaluate the relative stability of future development of hillside sites within the city. The group concluded that future damage and high cost of repair can be greatly reduced if the recommendations are followed.

APPENDIX B: GEOTECHNICAL BOREHOLES LOGS AND THEIR LOCATIONS

WELL # 83-1 LOCATION 410N 1435E ELEVATION 160.8m

ELEVATION	STD. PEN.	DESCRIPTION
160.8		GROUND SURFACE.
159.0	6-10-16	BROWN SILTY CLAY WITH ROCK FRAGMENTS AND TOPSOIL, STIFF (FILL).
157.8	16-26-44	GREY LIMESTONE FRAGMENTS WITH CLAY (FILL), SLIGHTLY MOIST, VERY DENSE.
157.0	10-20-24	GREY LIMESTONE FRAGMENTS AND SILTY CLAY, (FILL), VERY MOIST, DENSE.
156.3	-51-	GREY SOFT SHALE.
155.5		GREY SHALE, THIN BEDDED, SOFT TO MEDIUM HARD, CALCAREOUS, CLAYEY WITH 7.6cm LIMESTONE BEDS.

WELL # 83-2 LOCATION 410N 1435E ELEVATION 163.6m

ELEVATION	STD. PEN.	DESCRIPTION
163.6		GROUND SURFACE.
162.3	4-5-10	BROWN SILTY CLAY WITH LIMESTONE FRAGMENTS, (FILL), MOIST, STIFF, (CS 6%, FS 5%, ST 34%, CL 55%, LL 40, PI 19, WC 20%).
162.0	-90-	BROWN SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, STIFF.
160.5	7-9-15	BROWN SILTY CLAY BROWN SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, VERY STIFF.
157.8	14-24-39	BROWN GREY SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, HARD, (A 10%, CS 7%, FS 4%, ST 33%, CL 46%, LL 39, PI 21, WC 17%).
159.0	45-55	BROWN GREY SOFT WEATHERED SHALE, (WC 15.2%).
158.9	-50-	BROWN GREY SOFT WEATHERED SHALE, (WC 10.5%).
155.8		GREY SHALE, BROKEN, SILTY, CALCAREOUS, CLAYEY, SOFT TO HARD.

WELL # 83-3 LOCATION 411N 1435E ELEVATION 168.2m

ELEVATION	STD. PEN.	DESCRIPTION
168.2		GROUND SURFACE.
167.6	4-6-4	DARK GREY SILTY CLAY WITH CINDERS, BLACKTOP, ROCK AND BRICK FRAGMENTS, (FILL), MOIST, STIFF.
166.8	4-5-7	GREY BROWN SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, STIFF.
165.9	3-4-6	BROWN GREY SILTY CLAY, MOIST, STIFF.
165.2	6-50	BROWN AND GREY SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, MOIST, STIFF.
163.6	12-21-23	BROWN SOFT TO VERY SOFT WEATHERED SHALE AND LIMESTONE FRAGMENTS.
162.0	-65-	BROWN AND GREY SOFT WEATHERED SHALE.
160.4		INTERBEDDED GREY SHALE 80% AND LIMESTONE 20%, SHALE-THIN BEDDED, MEDIUM HARD, CALCAREOUS LIMESTONE-THIN BEDDED 15.2cm, OCCURS IN MIDDLE.

WELL # 83-4 LOCATION 411N 1435E ELEVATION 171.4m

ELEVATION	STD. PEN.	DESCRIPTION
171.4		GROUND SURFACE.
171.3		CONCRETE WALK.
169.9	1-2-3	GREY AND BROWN SILTY CLAY WITH ROCK FRAGMENTS AND CINDERS, (FILL), MOIST, STIFF, (WC 27.0%).
169.5	12-9-15	BROWN VERY SOFT WEATHERED SHALE, (WC 16%).
168.4	12-23-27	BROWN SOFT WEATHERED SHALE WITH THIN LIMESTONE LAYERS.
166.9	-50-	BROWN SOFT WEATHERED SHALE WITH THIN LIMESTONE LAYERS, (CS 1%, FS 4%, ST 4%, CL 48%, LL 37%, PI 18, WC 12.8%).
163.8		INTERBEDDED BROWN GREY CLAY 85%, WEATHERED CLAYEY SHALE AND LIMESTONE 15%, LIMESTONE- VERY THIN BEDDED, EVIDENCE OF JOINTING.
160.8		GREY SHALE, THIN TO MEDIUM BEDDED, CALCAREOUS, MEDIUM HARD TO HARD, LIMESTONE- THIN BEDDED, HARD.

WELL # 83-6 LOCATION 411N 1435E ELEVATION 175.5m

ELEVATION	STD. PEN.	DESCRIPTION
175.5		GROUND SURFACE.
175.4		CONCRETE WALK.
174.2	6-7-8	BROWN GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, (FILL), MOIST MEDIUM STIFF TO STIFF, (WC 21.7%).
171.9	18-34-60	BROWN AND GREY VERY SOFT TO SOFT WEATHERED SHALE WITH THIN LIMESTONE LAYERS, (WC 17.6).
171.3	28-35	GREY SOFT SHALE, (WC 11.0%).
170.7		GREY SHALE, THIN BEDDED, HARD, CALCAREOUS.
169.8		GREY SHALE, THIN BEDDED, HARD, CALCAREOUS, OXIDIZED ZONE AT 5.0m.

WELL # 83-7 LOCATION 411N 1435E ELEVATION 176.4m

ELEVATION	STD. PEN.	DESCRIPTION
176.4		GROUND SURFACE.
176.3		CONCRETE WALK.
173.3	3-4-5	BROWN GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, TRACE OF ORGANICS, (FILL), MOIST, STIFF.
171.8	17-20-41	GREY BROWN SOFT WEATHERED SHALE.
171.6	27-50	BROWN SOFT WEATHERED SHALE WITH LIMESTONE LAYERS.
169.8		GREY SHALE, THIN BEDDED, CLAYEY, CALCAREOUS, SOFT TO MEDIUM HARD, OXIDIZED.
168.4		GREY SHALE, THIN BEDDED, MEDIUM HARD TO HARD, LIMESTONE LAYERS AT 7.46m.

WELL # 83-8 LOCATION 412N 1436E ELEVATION 178.2m

ELEVATION	STD. PEN.	DESCRIPTION
178.2		GROUND SURFACE.
177.9		CONCRETE WALK.

176.7		BROWN GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, (FILL) MOIST, STIFF.
175.1	10-11-17	BROWN VERY SOFT WEATHERED SHALE WITH LIMESTONE FRAGMENTS, (FILL), MOIST, STIFF, (WC 21.1%).
173.7	16-50	BROWN WEATHERED SHALE WITH LIMESTONE LAYERS, (WC 16.7%).
173.4	27-60	BROWN AND GREY SOFT WEATHERED SHALE, (WC 14.5%).
170.3		GREY SHALE, THIN BEDDED, MEDIUM HARD TO HARD, 3.5cm LIMESTONE LAYERS AT 5.5m.

WELL # 83-9 LOCATION 412N 1436E ELEVATION 180.0m

ELEVATION	STD. PEN.	DESCRIPTION
180.0		GROUND SURFACE.
179.7		CONCRETE WALK.
177.4	10-6-25	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS TOPSOIL, (FILL), MOIST STIFF, (WC 23.3%).
177.0	-8-8	BROWN GREY VERY SOFT WEATHERED SHALE, (WC 17.7%).
175.5	16-35-41	BROWN SOFT WEATHERED SHALE WITH LIMESTONE FRAGMENTS.
173.5		BROWN SHALE, SOFT TO MEDIUM HARD, THIN BEDDED, WEATHERED WITH THIN LIMESTONE BEDS.
172.7		GREY SHALE MEDIUM HARD, SILTY, CALCAREOUS.

WELL # 83-10 LOCATION 412N 1436E ELEVATION 180.9m

ELEVATION	STD. PEN.	DESCRIPTION
180.9		GROUND SURFACE.
180.8		CONCRETE WALK.
180.2	1-2-2	BROWN AND GREY SILTY CLAY, MOIST, STIFF, (A 1%, CS 8% FS 4%, ST 43%, CL 44%, LL 36, PI 16, WC 19.4%).
178.8	3-15-7	GREY BROWN SILTY CLAY WITH LIMESTONE, MOIST, STIFF.
177.3	17-25-50	BROWN VERY SOFT WEATHERED SHALE, (WC 15.3%).
176.8	25-30-38	BROWN WEATHERED SHALE, JOINTED.

176.5		GREY SOFT SHALE, (WC 9.1%).
175.9	-60-	GREY BROWN SHALE, THIN BEDDED, SOFT TO MEDIUM HARD WEATHERED, CALCAREOUS.
173.5		GREY SHALE, THIN BEDDED, SOFT TO MEDIUM HARD, SILTY WITH 10.2cm LIMESTONE BEDS NEAR THE MIDDLE.

WELL # 83-12 LOCATION 412N 1436E ELEVATION 182.6m

ELEVATION	STD. PEN.	ELEVATION
182.6		GROUND SURFACE.
182.5		TOPSOIL.
180.4	4-4-5	BROWN GREY SILTY CLAY WITH LIMESTONE AND SHALE FRAGMENTS, (FILL), (A 4%, CS 5%, FS 4%, ST 40%, CL 39%, LL 39, PI 21).
179.6	18-12-20	BROWN GREY VERY SOFT WEATHERED SHALE WITH THIN LIMESTONE LAYERS, (WC 19.8%).
176.6	12-16-20	BROWN GREY VERY SOFT WEATHERED SHALE WITH THIN LIMESTONE LAYERS, (WC 14.6%).
176.1	-75-	GREY SOFT SHALE, (WC 7.8%).

WELL # 83-13 LOCATION 412N 1436E ELEVATION 183.3m

ELEVATION	STD. PEN.	DESCRIPTION
183.3		GROUND SURFACE.
183.2		TOPSOIL.
181.1	4-4-5	BROWN AND GREY SILTY CLAY WITH LIMESTONE AND SHALE FRAGMENTS, TRACE OF ORGANICS, (FILL), MOIST STIFF TO MEDIUM STIFF, (WC 16.8%).
180.0	4-5-6	GREY AND BROWN SILTY CLAY WITH LIMESTONE AND BRICK FRAGMENTS, TRACE OF ORGANICS, (FILL), MOIST MEDIUM STIFF, (WC 24.3%).
179.5	-10-	BROWN AND GREY VERY SOFT WEATHERED SHALE, (WC 19.5%).
177.4	18-32-54	GREY VERY SOFT TO SOFT SHALE WITH THIN LIMESTONE LAYERS.

WELL # 83-14 LOCATION 412N 1436E ELEVATION 185.8m

ELEVATION	STD. PEN.	DESCRIPTION
185.8		GROUND SURFACE.
184.2	5-5-6	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, (FILL), MOIST, STIFF, (WC 16.9%).
183.6	5-6-7	BROWN GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, (FILL), MOIST, STIFF.
181.6	16-25-31	BROWN GREY VERY SOFT WEATHERED SHALE, (WC 15%).

WELL # 83-16 LOCATION 413N 1437E ELEVATION 189.5m

ELEVATION	STD. PEN.	DESCRIPTION
189.5		GROUND SURFACE.
187.9	4-5-6	DARK BROWN SANDY SILTY CLAY WITH CINDERS AND ROCK FRAGMENTS, (FILL), SLIGHTLY MOIST, VERY STIFF, (WC 11.9%).
186.4	14-23-32	BROWN GREY SOFT WEATHERED SHALE WITH THIN LIMESTONE, (WC 14.2%).

WELL # 83-17 LOCATION 413N 1437E ELEVATION 188.4m

ELEVATION	STD. PEN.	DESCRIPTION
188.4		GROUND SURFACE.
186.9	5-6-6	GREY AND BROWN SILTY CLAY WITH CINDERS AND ROCK FRAGMENTS, MOIST, STIFF.
185.4	16-26-36	BROWN SOFT WEATHERED SHALE.
183.9	24-36-50	BROWN AND GREY SOFT WEATHERED SHALE WITH THIN LIMESTONE LAYERS.
182.2	48-108	GREY SOFT SHALE.

WELL # 83-18 LOCATION 413N 1473E ELEVATION 186.6m

ELEVATION	STD. PEN.	DESCRIPTION
186.6		GROUND SURFACE.
186.3	4-5	DARK BROWN SILTY CLAY WITH ROOTS, (FILL), MOIST,

		MEDIUM STIFF, (WC 27.9%).
183.3	16-27-38	BROWN AND GREY SILTY WEATHERED SHALE WITH THIN LIMESTONE LAYERS, MOIST, STIFF, (11.7%).
181.9	42-78-80	GREY SOFT WEATHERED SHALE WITH THIN LIMESTONE LAYERS, (WC 7.8%).

WELL # 83-19 LOCATION 413N 1437E ELEVATION 186.0m

ELEVATION	STD. PEN.	DESCRIPTION
186.0		GROUND SURFACE.
185.3	6-5-5	DARK BROWN AND GREY SILTY CLAY WITH CINDERS AND ROCK FRAGMENTS, (FILL), MOIST, MEDIUM STIFF.
184.2	4-6-5	BROWN AND GREY SILTY TO SANDY CLAY WITH SHALE, BRICK AND LIMESTONE FRAGMENTS, (FILL), MOIST, MEDIUM STIFF.
183.0	10-14-19	BROWN SOFT WEATHERED SHALE WITH THIN LIMESTONE.
181.5	49-81	GREY SOFT SHALE WITH THIN LIMESTONE LAYERS.

WELL # 83-20 LOCATION 413N 1437E ELEVATION 186.6m

ELEVATION	STD. PEN.	DESCRIPTION
186.6		GROUND SURFACE.
184.1	7-8-7	GREY SILTY CLAY WITH ROCK FRAGMENTS, TRACE OF ORGANICS, (FILL), MOIST, STIFF, (WC 19.2%).
182.3	16-24-26	BROWN AND GREY VERY SOFT TO SOFT WEATHERED SHALE WITH THIN LIMESTONE LAYERS, (WC 14.7%).
181.1	80-100	GREY SOFT SHALE WITH THIN LIMESTONE LAYERS, (WC 11.3%).

WELL # 83-21 LOCATION 414N 1437E ELEVATION 184.3m

ELEVATION	STD. PEN.	DESCRIPTION
184.3		GROUND SURFACE.
184.0		TOPSOIL.
183.4	-14-	BROWN SILTY CLAY, SLIGHTLY MOIST.
182.0	5-5-6	DARK BROWN AND GREY SILTY CLAY WITH LIMESTONE AND SHALE

		FRAGMENTS, (FILL), MOIST, STIFF, (WC 20.1%).
181.2	5-6-6	BROWN AND GREY SILTY CLAY WITH SHALE FRAGMENTS, (FILL), MOIST, STIFF (WC 21.4%).
179.7	4-5-8	GREY SOFT SHALE FRAGMENTS, (FILL).
178.1	8-7-4	BROWN AND GREY SILTY CLAY WITH SHALE FRAGMENTS, (FILL) MOIST, STIFF.
177.9	3-4	DARK BROWN AND GREY SILTY CLAY WITH SHALE FRAGMENTS (FILL), WET, SOFT, (A 16%. CS 18%, FS 16%, ST 26%, CL 24%, LL 31, PI 12, WC 25.8%).
176.5	4-6-9	BROWN AND GREY CLAY WITH LIMESTONE AND SHALE FRAGMENTS, (FILL), MOIST, VERY STIFF, (WC 18.7%).
170.6	15-20-26	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS MOIST, VERY STIFF, (WC 19.1%).
169.4	-80-	BROWN AND GREY SOFT WEATHERED SHALE WITH ROCK FRAGMENTS, (WC 6.6%).
168.1		GREY AND BROWN SHALE, THIN BEDDED, MEDIUM HARD, 5-10cm LIMESTONE BEDS NEAR THE TOP AND BOTTOM.
163.6		GREY SHALE, THIN BEDDED, MEDIUM HARD, CALCAREOUS, SILTY, THIN LIMESTONE BEDS 10.2cm.

WELL # 83-22 LOCATION 414N 1438E ELEVATION 184.8m

ELEVATION	STD. PEN.	DESCRIPTION
184.8		GROUND SURFACE.
182.5	4-7-8	GREY AND BROWN SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, VERY STIFF.
181.2	7-7-10	GREY AND BROWN CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, STIFF TO VERY STIFF.
178.7	5-8-13	GREY AND BROWN SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, STIFF.
177.2	33-90	GREY SOFT SHALE.
174.2		GREY SHALE, MEDIUM HARD TO HARD, SILTY, CALCAREOUS, WITH 12.7cm LIMESTONE BEDS, JOINTED ZONE AT 8-8.8m.

WELL # 83-23 LOCATION 414N 1438E ELEVATION 182.5m

ELEVATION	STD. PEN.	DESCRIPTION
182.5		GROUND SURFACE.
181.8	10-30	BLACK CINDERS, SAND AND BLACKTOP, (FILL), MOIST, STIFF.
180.2	1-1-1	BLACK CINDERS, (FILL), MOIST, VERY LOOSE.
179.5	1-1-3	GREY AND BROWN SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), VERY MOIST, SOFT (WC 28.8%).
178.7	5-10-12	GREY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, TRACE OF ORGANICS, (FILL), MOIST, STIFF.
177.8	5-9-12	BROWN AND GREY SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, MOIST, VERY STIFF (WC 19.1%).
174.9	9-14-28	BROWN SOFT WEATHERED SHALE, TRACES OF ROCK FRAGMENTS, (WC 16.1%).
174.1	33-65	BROWN AND GREY SOFT WEATHERED SHALE WITH LIMESTONE FRAGMENTS, (WC 17.2%).
172.6	25-70	GREY SOFT SHALE WITH A TRACE OF ROCK FRAGMENTS, (WC 7.2%).
172.2		GREY LIMESTONE.
169.6		GREY SHALE, SILTY, HARD, CALCAREOUS, 5-15cm JOINTED BEDS, OF LIMESTONE.

WELL # 83-24 LOCATION 414N 1438E ELEVATION 181.5m

ELEVATION	STD. PEN.	DESCRIPTION
181.5		GROUND SURFACE
180.9		BLACKTOP, (FILL).
180.0	3-7-3	BLACK CINDERS, (FILL), MOIST, LOOSE.
177.7	4-6-5	GREY AND BROWN SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, STIFF TO MEDIUM STIFF.
176.9	4-5-6	GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, STIFF.
176.0	-8-	BROWN SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, STIFF.
175.4	21-26-50	BROWN VERY SOFT WEATHERED SHALE, TRACE OF ROCK

		FRAGMENTS.
173.0	26-50	BROWN AND GREY SOFT WEATHERED SHALE, TRACE OF ROCK FRAGMENTS.
170.0		GREY SHALE, MEDIUM HARD TO HARD, CALCAREOUS, FOSSILIFEROUS, WITH THIN BEDS OF LIMESTONE.

WELL # 83-36 LOCATION 415N 1440E ELEVATION 181.8m

ELEVATION	STD.PEN.	DESCRIPTION
181.8		GROUND SURFACE.
181.2	3-4-5	GREY AND BROWN SILTY CLAY WITH CINDERS, SHALE AND ROCK FRAGMENTS, (FILL), MOIST, STIFF.
179.7	4-6-8	BROWN AND GREY SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, TRACE OF ORGANICS, (FILL), MOIST, STIFF.
178.2	9-11-13	BROWN AND GREY SILTY CLAY WITH TRACE OF LIMESTONE, (A 8%, CS 5%, FS 3%, ST 39%, CL 45%, LL 35, PI 19, WC 20.2%).
176.7	13-30-51	BROWN AND GREY SOFT WEATHERED SHALE.
175.9	-71-	GREY AND BROWN SOFT SHALE 75% AND LIMESTONE 15% SHALE- HARD, FOSSILIFEROUS, LIMESTONE- FINE GRAINED THIN BEDDED 15cm.
172.9		INTERBEDDED GREY SHALE 85% AND LIMESTONE 15%, SHALE- HARD, FOSSILIFEROUS, LIMESTONE- FINE GRAINED, THIN BEDDED 15cm.

WELL # 83-38 LOCATION 415N 1440E ELEVATION 179.2m

ELEVATION	STD. PEN.	DESCRIPTION
179.2		GROUND SURFACE.
179.1	-7-	CINDERS, (FILL), MOIST, VERY LOOSE.
176.9	5-3-5	BROWN AND GREY SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, STIFF.
176.2	4-4-6	GREY SILTY CLAY WITH SHALE FRAGMENTS, TRACE OF ORGANICS, (FILL), MOIST, MEDIUM STIFF.
175.4	5-9-11	BROWN AND GREY SILTY CLAY WITH LIMESTONE AND SHALE FRAGMENTS, (FILL), MOIST, STIFF.

172.7	19-32-40	BROWN AND GREY VERY SOFT WEATHERED SHALE WITH THIN LIMESTONE LAYERS.
172.2	-85-	GREY SOFT SHALE WITH LIMESTONE LAYERS.

WELL # 83-40 LOCATION 415N 1440E ELEVATION 177.0m

ELEVATION	STD. PEN.	DESCRIPTION
177.0		GROUND SURFACE.
175.5	7-15-14	GREY AND BROWN SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, VERY STIFF, (WC 15.9%).
171.7	15-26-50	BROWN AND GREY SOFT WEATHERED SHALE WITH LIMESTONE LAYERS, (WC 16.0%).
170.9	28-62	GREY AND BROWN SOFT SHALE.
170.0	-85-	GREY SOFT SHALE.

WELL # 83-43 LOCATION 415N 1441E ELEVATION 176.9m

ELEVATION	STD. PEN.	DESCRIPTION
176.9		GROUND SURFACE.
176.8	-3-	BLACK CINDERS, (FILL), MOIST, LOOSE.
175.5	4-6-8	GREY AND BROWN SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, STIFF.
172.3	12-20-31	BROWN AND GREY SOFT TO VERY SOFT WEATHERED SHALE WITH LIMESTONE LAYERS. (LL 37.0, PI 18.0).
172.0	-65-	GREY SOFT SHALE.

WELL # 83-45 LOCATION 415N 1441E ELEVATION 180.4m

ELEVATION	STD. PEN.	DESCRIPTION
180.4		GROUND SURFACE.
180.0	3-4	DARK BROWN SILTY CLAY WITH CINDERS.
179.6	-6-	BROWN AND GREY VERY SOFT WEATHERED SHALE, MOIST, STIFF.
177.3	16-20-33	BROWN SOFT WEATHERED SHALE.
175.1	-55-	BROWN AND GREY SOFT WEATHERED SHALE WITH THIN LIMESTONE

		LAYERS.
174.3	-93-	GREY SOFT SHALE.

WELL # 83-48 LOCATION 415N 1441E ELEVATION 180.2m

ELEVATION	STD. PEN.	DESCRIPTION
180.2		GROUND SURFACE.
179.9	3-3	BLACK CINDERS, (FILL), MOIST, LOOSE.
177.9	5-6-7	BROWN AND GREY SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, STIFF, (A 3%, CS 6%, FS 6%, ST 50, CL 35%, LL 37, PI 17, WC 18%).
177.1	4-6-9	GREY SILTY CLAY WITH SHALE FRAGMENTS, (FILL), MOIST, STIFF.
176.4	9-13-17	BROWN VERY SOFT WEATHERED SHALE.
173.9	31-44	BROWN SOFT WEATHERED SHALE WITH THIN LIMESTONE BEDS, (WC 15.7%).
173.6	-54-	GREY AND BROWN SOFT SHALE.

WELL # 83-51 LOCATION 415N 1442E ELEVATION 173.3m

ELEVATION	STD. PEN.	DESCRIPTION
173.3		GROUND SURFACE.
172.7	4-34	DARK BROWN SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, CINDERS, (FILL), MOIST, MEDIUM STIFF.
171.0	59-19-49	BROWN AND GREY SOFT WEATHERED SHALE WITH LIMESTONE LAYERS.
170.1	28-40	GREY SOFT SHALE WITH LIMESTONE LAYERS.

WELL # 83-57 LOCATION 411N 1435E ELEVATION 164.1m

ELEVATION	STD. PEN.	DESCRIPTION
164.1		GROUND SURFACE.
164.0		BLACKTOP AND CONCRETE.
163.8		BLACK CINDERS, (FILL), MOIST, LOOSE.

163.5	12-14-15	BROWN AND GREY VERY SOFT HIGHLY WEATHERED SHALE WITH LIMESTONE FRAGMENTS, (FILL).
163.4		BROWN AND GREY SOFT WEATHERED SHALE.
162.0	26-40-50	GREY SOFT SHALE WITH LIMESTONE LAYERS.

WELL # 83-58 LOCATION 413N 1436E ELEVATION 187.8m

ELEVATION	STD. PEN.	DESCRIPTION
187.8		GROUND SURFACE.
187.5		CONCRETE AND BLACKTOP.
186.3	3-3-14	GREY AND BROWN SILTY CLAY WITH LIMESTONE AND SHALE FRAGMENTS, (FILL), MOIST, MEDIUM STIFF.
184.7	4-5-3	GREY AND BROWN SILTY CLAY WITH CINDERS, ASPHALT, LIMESTONE AND SHALE FRAGMENTS, (FILL), MOIST, MEDIUM STIFF.
180.2	3-3-5	BROWN AND GREY SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, MEDIUM STIFF.
179.3	4-3-6	GREY SILT CLAY WITH TRACES OF SHALE AND LIMESTONE FRAGMENTS, MOIST, STIFF.
175.6	-80-	GREY VERY SOFT SHALE WITH LIMESTONE LAYERS.

WELL # 83-59 LOCATION 413N 1436E ELEVATION 186.3m

ELEVATION	STD. PEN.	DESCRIPTION
186.3		GROUND SURFACE.
182.2	3-4-6	TOPSOIL.
185.0	8-9-12	BROWN SILTY CLAY WITH GRAVEL, LIMESTONE AND SHALE FRAGMENTS, (FILL), MOIST, STIFF.
184.5		CONCRETE FOOTER.
181.8	15-12-13	BROWN AND GREY SILTY CLAY WITH LIMESTONE AND SHALE FRAGMENTS. (FILL), MOIST, VERY STIFF.
178.4	50-116	BROWN AND GREY SOFT WEATHERED SHALE WITH LIMESTONE LAYERS.

WELL # 1-67 LOCATION 411N 1435E ELEVATION 165.3m

ELEVATION	STD. PEN.	DESCRIPTION
165.3		GROUND SURFACE.
163.8	7-6-7	BROWN AND GREY SILTY CLAY AND WEATHERED SHALE WITH ROCK FRAGMENTS, (FILL), MOIST, STIFF.
162.9	5-5-6	BROWN AND GREY SILTY CLAY WITH ROCK FRAGMENTS, (FILL), MOIST, MEDIUM STIFF.
162.2	6-7-8	BROWN WEATHERED SHALE AND SILTY CLAY (PROBABLE FILL), MOIST.
160.7	20-24-33	BROWN WEATHERED SHALE WITH LIMESTONE FRAGMENTS.
159.2	41-61-84	BROWN AND GREY WEATHERED SHALE 10.2cm LIMESTONE LAYERS AT 159.6m.
158.0	94-65	BROWN AND GREY WEATHERED SHALE WITH LIMESTONE FRAGMENTS.
157.4		GREY WEATHERED SHALE WITH LIMESTONE FRAGMENTS.

WELL # 2-67 LOCATION 411N 1435E ELEVATION 158.4m

ELEVATION	STD. PEN.	DESCRIPTION
158.4		GROUND SURFACE.
156.5	1-2-1	TOPSOIL, SAND, CINDERS, ASHES, BRICK, LIMESTONE FRAGMENTS AND SILTY CLAY, (FILL), MOIST, STIFF TO LOOSE.
153.4		VOID.
155.0	6-8-11	BRICK AND LIMESTONE FRAGMENTS, (FILL), MOIST MEDIUM DENSE.
150.8	10-28-14	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS MOIST, MEDIUM STIFF TO STIFF.

WELL # 3-67 LOCATION 411N 1435E ELEVATION 170.1m

ELEVATION	STD. PEN.	DESCRIPTION
170.1		GROUND SURFACE.
168.6	3-17-16	BROWN AND GREY SILTY CLAY, BRICK AND ROCK FRAGMENTS,

		(FILL), MOIST, STIFF.
164.8	19-43-36	BROWN SILTY CLAY AND WEATHERED SHALE, 1.5 TO 2.5cm LIMESTONE LAYERS, MOIST, VERY STIFF.
162.0	35-56-125	GREY BROWN WEATHERED SHALE, 2.5-5cm LIMESTONE LAYERS, DRY, HARD.

WELL # 5-67 LOCATION 411N 1435E ELEVATION 162.6m

ELEVATION	STD. PEN.	DESCRIPTION
162.6		GROUND SURFACE.
162.1	2-2-3	TOPSOIL, CLAY, GRAVEL AND BRICK, (FILL), MOIST, STIFF.
161.4	6-6-8	BROWN SILTY CLAY, MOIST, STIFF.
157.6	6-8-11	BROWN SILTY CLAY, WEATHERED SHALE AND LIMESTONE FRAGMENTS, DRY TO MOIST, HARD.
155.8	32-32-40	BROWN AND GREY WEATHERED SHALE, MOIST TO DRY, HARD.
155.0	-130-	GREY WEATHERED SHALE AND LIMESTONE FRAGMENTS, WET TO DRY, HARD.

WELL # 7-67 LOCATION 411N 1435E ELEVATION 156.9m

ELEVATION	STD. PEN.	DESCRIPTION
156.9		GROUND SURFACE.
155.7	2-11-16	BROWN AND GREY SILTY CLAY, BROKEN ROCK AND BRICK, (FILL), MOIST, STIFF.
150.8	14-15-17	BROWN AND GREY SILTY CLAY AND LIMESTONE FRAGMENTS, MOIST, STIFF.
149.3	19-27-34	BROWN AND GREY WEATHERED SHALE AND LIMESTONE FRAGMENTS, MOIST, HARD.

WELL # 9-67 LOCATION 412N 1436E ELEVATION 169.1m

ELEVATION	STD. PEN.	DESCRIPTION
169.1		GROUND SURFACE.
167.8	2-3-3	CINDERS, BRICK, CLAY, (FILL), LOOSE TO MEDIUM STIFF.
163.7	112-12-10	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS,

		MOIST, STIFF.
163.0	16-12-16	BROWN WEATHERED SHALE, MOIST, STIFF.
161.5	40-60-100	GREY WEATHERED SHALE, MOIST, STIFF.

WELL # 13-67 LOCATION 412N 1436E ELEVATION 171.0m

ELEVATION	STD. PEN.	DESCRIPTION
171.0		GROUND SURFACE.
170.9	10-10-14	TOPSOIL, DRY, LOOSE.
170.3		BROWN SILTY CLAY WITH LIMESTONE FRAGMENTS, LIMESTONE LAYERS, ROOTS AND WOOD, (FILL), DRY, STIFF.
168.8	9-9-10	BROWN SILTY CLAY WITH TRACES OF GREY CLAY, ROOTS, COAL FRAGMENTS, LIMESTONE FRAGMENTS AND LAYERS, (FILL), SLIGHTLY MOIST, STIFF.
166.5	11-15-30	BROWN AND GREY WEATHERED SHALE WITH LIMESTONE LAYERS, SLIGHTLY MOIST, STIFF TO VERY STIFF.
164.6	24-24-30	LAYERED GREY AND BROWN SHALE AND LIMESTONE, DRY, HARD.

WELL # 14-67 LOCATION 413N 1437E ELEVATION 180.0m

ELEVATION	STD. PEN.	DESCRIPTION
180.0		GROUND SURFACE.
179.4	1-2-3	TOPSOIL, CINDERS, CLAY AND BRICK, (FILL), MOIST, SOFT.
178.7	4-4-5	BROWN SILTY CLAY, WEATHERED SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, MEDIUM STIFF.
171.3	3-6-8	BROWN AND GREY SILTY CLAY, WEATHERED SHALE AND LIMESTONE FRAGMENTS, (FILL), MOIST, MEDIUM STIFF.
168.1	32-22-22	BROWN SILTY CLAY, WEATHERED SHALE AND LIMESTONE FRAGMENTS, MOIST, HARD.
167.7		BROWN AND GREY WEATHERED SHALE, MOIST, HARD.
167.1		LAYERED GREY SHALE AND LIMESTONE.

WELL # 15-67 LOCATION 413N 1437E ELEVATION 171.9m

ELEVATION	STD. PEN.	DESCRIPTION
171.9		GROUND SURFACE.
165.9	5-6-8	BROWN AND GREY SILTY CLAY, WEATHERED SHALE WITH LIMESTONE FLOAT AND FRAGMENTS, (FILL), MOIST, MEDIUM STIFF.
161.1	40-20-12	BROWN SILTY CLAY WITH LIMESTONE FLOAT AND FRAGMENTS, (FILL), MOIST, STIFF.
159.6		LAYERED BROWN AND GREY SHALE AND LIMESTONE.
158.0		LAYERED GREY SHALE, WEATHERED SHALE AND LIMESTONE.
155.0		LAYERED GREY SHALE AND LIMESTONE.

WELL # 19-67 LOCATION 413N 1437E ELEVATION 179.7m

ELEVATION	STD. PEN.	DESCRIPTION
179.7		GROUND SURFACE.
179.7	2-2-2	ASHES, ROOTS, GRASS, (FILL), MOIST, VERY LOOSE.
178.7		BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, STIFF.
176.7	7-5-6	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, STIFF.
176.2	15-20-25	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS WEATHERED BROWN SHALE, MOIST, STIFF.
172.3	40-80-65	GREY WEATHERED SHALE, MOIST, MEDIUM STIFF.

WELL # 23-67 LOCATION 414N 1438E ELEVATION 179.6m

ELEVATION	STD. PEN.	DESCRIPTION
179.6		GROUND SURFACE.
176.6	2-3-3	CINDERS, ASHES, (FILL), LOOSE, MOIST TO WET.
173.5	10-12-16	BROWN AND GREY SILTY CLAY WITH BROWN AND GREY WEATHERED SHALE, MOIST, STIFF.
171.9	100	GREY SHALE, MOIST, HARD.

170.0		LAYERED GREY SHALE AND LIMESTONE.

WELL # 25-67 LOCATION 414N 1438E ELEVATION 169.5m

ELEVATION	STD. PEN.	DESCRIPTION
169.5		GROUND SURFACE.
166.8	6-7-7	BROWN AND GREY SILTY CLAY, LIMESTONE FRAGMENTS, CINDERS, (FILL), MOIST, MEDIUM STIFF.
164.9	10-12-16	BROWN AND GREY SILTY CLAY, LIMESTONE FRAGMENTS, MOIST, STIFF.
164.5	20-20-26	GREY AND BROWN WEATHERED SHALE, MOIST, HARD.
163.2	15-30-45	GREY SHALE, MOIST, LOOSE.
154.7		LAYERED GREY SHALE AND LIMESTONE.

WELL # 27-67 LOCATION 414N 1438E ELEVATION 154.2m

ELEVATION	STD. PEN.	DESCRIPTION
154.2		GROUND SURFACE.
152.7	12-16-18	BROWN SANDY CLAY, CINDERS AND LIMESTONE FRAGMENTS, (FILL), MOIST, STIFF.
140.5	32-29-42	BROWN AND GREY SILTY CLAY AND LIMESTONE FRAGMENTS, WITH 1.5 TO 7.5cm LIMESTONE LAYERS, MOIST, VERY STIFF TO HARD.

WELL # 30-67 LOCATION 414N 1438E ELEVATION 171.6m

ELEVATION	STD. PEN.	DESCRIPTION
171.6		GROUND SURFACE.
170.9	6-8-6	BROWN SILTY CLAY, LIMESTONE FRAGMENTS AND TOPSOIL, (FILL), MOIST, STIFF.
170.1	8-8-5	BROWN SILTY CLAY AND LIMESTONE FRAGMENTS,MOIST, STIFF.
166.6	13-20-22	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, STIFF.
158.0		LAYERED BROWN AND GREY SHALE AND LIMESTONE.

WELL # 32-67 LOCATION 414N 1439E ELEVATION 169.7m

ELEVATION	STD. PEN.	DESCRIPTION
169.7		GROUND SURFACE.
166.1	4-4-7	TOPSOIL, CLAY, CINDERS, WOOD AND BRICK, (FILL), WET, SOFT.
164.7	4-8-11	GREY AND BROWN SILTY CLAY, SOFT TO STIFF, MOIST.
164.1	16-50-30	BROWN SILTY CLAY WITH SHALE AND LIMESTONE FRAGMENTS, MOIST, HARD.
162.9		LAYERED BROWN AND GREY WEATHERED SHALE.
161.9		LAYERED BROWN AND GREY LIMESTONE.

WELL # 33-67 LOCATION 414N 1439E ELEVATION 163.6m

ELEVATION	STD. PEN.	DESCRIPTION
163.6		GROUND SURFACE.
162.1	4-5-6	TOPSOIL, CLAY, CINDERS AND BRICK, (FILL), MOIST MEDIUM DENSE.
155.7	49-16-8	BROWN SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, VERY STIFF.

WELL # 35-67 LOCATION 414N 1439E ELEVATION 172.6m

ELEVATION	STD. PEN.	DESCRIPTION
172.6		GROUND SURFACE.
171.9	3-3-3	BROWN AND GREY SILTY CLAY, TOPSOIL, ROOTS, GRASS AND WEEDS, (FILL), MOIST, MEDIUM STIFF.
167.3	8-10-14	BROWN AND GREY SILTY CLAY AND LIMESTOE FRAGMENTS, MOIST, STIFF.
164.6	40-63	BROWN AND GREY SILTY CLAY WITH SEAMS OF LIMESTONE AND GREY WEATHERED SHALE, MOIST, STIFF.

WELL # 36-37 LOCATION 414N 1439E ELEVATION 163.0m

ELEVATION	STD. PEN.	DESCRIPTION
163.0		GROUND SURFACE.
162.2	3-2-2	BROWN SILTY CLAY, ROOTS, LIMESTONE FRAGMENTS AND TOPSOIL, (FILL), MOIST, MEDIUM STIFF.
161.5	6-8-6	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, (FILL), MOIST, MEDIUM STIFF.
155.5	10-20-18	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, STIFF.

WELL # 39-67 LOCATION 415N 1440E ELEVATION 173.7m

ELEVATION	STD. PEN.	DESCRIPTION
173.7		GROUND SURFACE.
172.9	2-4-8	BROWN SILTY CLAY, ROOTS, BARK, LEAVES, GRASS AND TOPSOIL, (FILL), MOIST, LOOSE TO STIFF.
170.7	11-16-16	BROWN SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, STIFF.
165.2	14-25-22	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, MEDIUM STIFF TO STIFF.
164.7		GREY WEATHERED SHALE, MOIST, HARD.

WELL # 41-67 LOCATION 415N 1440E ELEVATION 167.1m

ELEVATION	STD. PEN.	DESCRIPTION
167.1		GROUND SURFACE.
166.9	4-2-4	SAND AND ROOTS, (FILL), MOIST, LOOSE.
164.0	12-16-22	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, STIFF.
162.5	20-22-40	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, STIFF TO HARD.
161.0	20-30-30	BROWN AND GREY WEATHERED SHALE, MOIST, STIFF TO HARD.
159.5	40-35-70	BROWN AND GREY WEATHERED SHALE, MOIST, HARD.

WELL # 43-67 LOCATION 415N 1441E ELEVATION 171.4m

ELEVATION	STD. PEN.	DESCRIPTION
171.4		GROUND SURFACE.
170.8	1-1-2	TOPSOIL.
170.2	4-3-4	BROWN SILTY CLAY, LIMESTONE FRAGMENTS, MOIST, STIFF.
166.2	14-18-25	BROWN SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, VERY STIFF.
165.2		LAYERED BROWN AND GREY WEATHERED SHALE.
163.2		LAYERED BROWN AND GREY WEATHERED SHALE AND LIMESTONE.
161.7		LAYERED BROWN AND GREY WEATHERED SHALE, CLAY AND LIMESTONE.

WELL # 44-67 LOCATION 415N 1441E ELEVATION 163.2m

ELEVATION	STD.PEN.	DESCRIPTION
163.2		GROUND SURFACE.
161.9	25-19-12	GREY FINE TO COARSE GRAVEL, CINDERS, (FILL), DRY DENSE.
161.0	7-5-8	GREY SILTY CLAY, CINDERS, (FILL), MOIST, STIFF.
155.6	9-11-15	BROWN AND GREY SILTY CLAY WITH 1.5 TO 2.5cm LIMESTONE LIMESTONE LAYERS, MOIST, STIFF.
154.0	34-57-68	GREY WEATHERED SHALE, DRY, HARD.

WELL # 47-67 LOCATION 415N 1442E ELEVATION 168.6m

ELEVATION	STD. PEN.	DESCRIPTION
168.6		GROUND SURFACE.
168.4	4-4-6	TOPSOIL, SAND AND ROOTS, MOIST, LOOSE TO MEDIUM STIFF.
167.0	10-8-7	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS (FILL), MOIST, MEDIUM STIFF TO STIFF.
162.5	10-20-30	BROWN AND GREY SILT CLAY WITH LIMESTONE FRAGMENTS, MOIST, MEDIUM STIFF TO VERY STIFF.
161.4		BROWN GREY WEATHERED SHALE, MOIST, HARD.

161.0		LAYERED BROWN AND GREY SHALE AND LIMESTONE, VERY HARD.

WELL # 48-67 LOCATION 415N 1443E ELEVATION 173.0m

ELEVATION	STD. PEN.	DESCRIPTION
173.0		GROUND SURFACE.
170.7	2-6-7	BROWN AND GREY SILTY CLAY, (FILL), MOIST, MEDIUM STIFF.
167.7	8-8-11	BROWN AND GREY SILTY CLAY AND LIMESTONE FRAGMENTS, MOIST, STIFF.
165.1	21-23-33	BROWN AND GREY WEATHERED SHALE, DRY, HARD.
163.6		LAYERED GREY SHALE AND LIMESTONE LAYERS, 20% LIMESTONE IN 1-15.2cm LAYERS.

WELL # 49-67 LOCATION 415N 1443E ELEVATION 163.6m

ELEVATION	STD. PEN.	DESCRIPTION
163.6		GROUND SURFACE.
163.1	3-14-4	TOPSOIL, CLAY, CINDERS, BRICK AND STONE, (FILL), MOIST DENSE.
161.6	4-9-6	BROWN SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, STIFF.
159.9	25-32-50	BROWN SILTY CLAY, WEATHERED SHALE AND LIMESTONE FRAGMENTS, MOIST, HARD.
158.7		LAYERED BROWN AND GREY WEATHERED SHALE AND LIMESTONE.
153.1		LAYERED GREY AND BROWN SHALE AND LIMESTONE.

WELL # 50-67 LOCATION 415N 1443E ELEVATION 151.6m

ELEVATION	STD. PEN.	DESCRIPTION
151.6		GROUND SURFACE.
151.5		CONCRETE WALK.
147.2	6-10-7	BROWN AND GREY CLAY AND LIMESTONE FRAGMENTS, (FILL), MOIST, MEDIUM STIFF.
144.9	11-27-13	BROWN AND GREY SILTY CLAY AND LIMESTONE FRAGMENTS,

		MOIST, STIFF.
143.0	24-18-33	BROWN AND GREY WEATHERED SHALE AND LIMESTONE FRAGMENTS, MOIST, VERY STIFF.
141.6		LAYERED GREY SHALE AND LIMESTONE, 5% LIMESTONE IN 1 TO 2.5cm LAYERS.

WELL # 51-67 LOCATION 415N 1443E ELEVATION 179.5m

ELEVATION	STD. PEN.	DESCRIPTION
179.5		GROUND SURFACE.
178.7	7-8-8	BROWN SANDY CLAY WITH ROCK FRAGMENTS, (FILL), MOIST, STIFF.
177.2	3-4-5	BROWN SILTY AND SANDY CLAY WITH ROCK FRAGMENTS, (FILL), MOIST, MEDIUM STIFF.
176.4	4-6-7	BROWN AND GREY SILTY CLAY, MOIST, MEDIUM STIFF.
173.2	38-50	BROWN AND GREY WEATHERED SHALE.
171.9		LAYERED SHALE AND LIMESTONE.

WELL # 52-67 LOCATION 415N 1443E ELEVATION 170.2m

ELEVATION	STD. PEN.	DESCRIPTION
170.2		GROUND SURFACE.
170.1	4-5-5	BROWN AND GREY SILTY CLAY, TOPSOIL, (FILL), MOIST, STIFF.
168.7	6-8-8	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, ROOTS, WEEDS, (FILL), MOIST, MEDIUM STIFF.
164.9	12-15-22	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, STIFF TO VERY STIFF.
163.5		GREY AND BROWN SHALE.
162.0		LAYERED GREY SHALE AND LIMESTONE.

WELL # B-1-1 LOCATION 407N 1433E ELEVATION 149.6m

ELEVATION	STD. PEN.	DESCRIPTION
149.6		GROUND SURFACE.

149.3		COBBLESTONES AND GRAVEL, (FILL).
148.4	2-11-16	CINDERS AND GRAVEL, (FILL), MOIST, MEDIUM DENSE, (WC 20%).
147.7	5-6-7	BROWN SILTY CLAY, (FILL), MOIST, MEDIUM STIFF, (WC 20%).
145.8	7-7-8	BROWN SILTY CLAY, MOIST, STIFF, (WC 20%).
145.1	6-5-6	BROWN SILTY CLAY, MOIST, MEDIUM STIFF, (WC 23%).
144.3	4-5-6	BROWN SANDY SILTY CLAY, VERY MOIST, SOFT, (WC 25%).
143.5	5-5-5	BROWN CLAYEY SILT, VERY MOIST, SOFT, (WC 23%).
143.1	4-5-7	BROWN FINE TO COARSE SAND, MOIST, MEDIUM DENSE, (WC 7%).
141.3	5-6-8	BROWN SILTY SAND, MOIST, LOOSE, (WC 9%).
140.5	7-7-6	BROWN FINE TO COARSE SAND, MOIST, MEDIUM DENSE, (WC 6%).
139.0	7-8-10	BROWN FINE TO COARSE SAND WITH SILT SEAMS, MOIST, MEDIUM DENSE, (WC 10%).
137.5	9-11-14	BROWN FINE TO COARSE SAND, MOIST, MEDIUM DENSE, (WC 21%).
134.4	3-3-4	GREY SILTY CLAY, (VARVED), VERY MOIST, MEDIUM STIFF, (WC 28%).
129.8	3-4-5	GREY SILTY CLAY, VERY MOIST, SOFT, (WC 33%).
128.3	4-4-5	GREY SILTY CLAY, (VARVED), VERY MOIST, MEDIUM STIFF, (WC 32%).
122.2	7-8-8	GREY FINE TO COARSE SAND WITH CLAY SEAMS, (WC 19%).
121.6	40-85	GREY GRAVELLY SAND, WET, VERY DENSE, (WC 10%).
120.7		GREY SHALE AND LIMESTONE, 80% SHALE, 20% LIMESTONE, LIMESTONE 5 TO 9cm LAYERS.

WELL # B-1-2   LOCATION 407N 1433E   ELEVATION 150.7m

ELEVATION	STD. PEN.	DESCRIPTION
150.7		GROUND SURFACE.

147.1	3-4-2	CINDERS AND GRAVEL, SOME CLAY, RUBBLE, (FILL), MOIST, DENSE.
146.4	1-2-5	BROWN SANDY CLAYEY SILT WITH ORGANICS, VERY MOIST, SOFT, (WC 46%).
145.6	2-2-2	BROWN AND GREY SANDY SILT WITH ORGANICS, VERY MOIST LOOSE, (WC 27%).
144.9	4-3-4	GREY SANDY SILT, WET, LOOSE, (WC 23%).
144.1	7-10-9	BROWN AND GREY SANDY SILT, MOIST, MEDIUM DENSE, (WC 17%).
143.3	4-12-15	BROWN AND GREY SILTY SAND, WET, MEDIUM DENSE, (WC 21%).
141.8	9-16-12	BROWN AND GREY SANDY CLAYEY GRAVEL, ROCK FRAGMENTS, MOIST, MEDIUM DENSE.
139.8	4-5-7	GREY SILTY CLAY, MOIST, STIFF, (WC 26%).
129.6	2-4-5	GREY SILTY CLAY, (VARVED), VERY MOIST, MEDIUM STIFF (WC 35%).
128.1	3-5-4	GREY SANDY SILT, WET, LOOSE, (WC 32%).
126.4	2-3-5	GREY FINE TO COARSE SAND, WET, LOOSE, (WC 27%).
125.1	9-12-16	GREY SILTY SAND WITH CLAY LAYERS, WET, MEDIUM DENSE.
123.5	6-10-12	GREY SILTY CLAY, (VARVED), MOIST, STIFF, (WC 25%).
122.0	29-53-52	GREY SANDY SILTY CLAY, (VARVED), ROCK FRAGMENTS, MOIST, VERY DENSE, (WC 27%).
120.5		GREY SHALE AND LIMESTONE, 80% SHALE, 20% LIMESTONE, LIMESTONE 4.4 TO 9.5cm LAYERS.

WELL # B-1-3 LOCATION 407N 1432E ELEVATION 150.7m

ELEVATION	STD. PEN.	DESCRIPTION
150.7		GROUND SURFACE.
150.5		CONCRETE.
149.2	7-12-10	CINDERS AND GRAVEL AND SAND, (FILL), MOIST, MEDIUM DENSE.
148.5	3-4-6	BROWN SANDY SILT, MOIST, LOOSE, (WC 14%).

147.7	6-6-6	BROWN SILTY FINE SAND, MOIST, MEDIUM STIFF, (WC 11%).
145.5	5-6-6	BROWN AND GREY SANDY SILT WITH CLAY LAYERS, MOIST, MEDIUM DENSE, (WC 20%).
144.7	7-7-8	GREY SANDY SILT, VERY MOIST, MEDIUM DENSE, (WC 20%).
143.3	9-10-12	BROWN GRAVELLY SAND WITH ROCK FRAGMENTS, MOIST, MEDIUM DENSE, (WC 22%).
142.4	3-3-3	BROWN AND GREY SILTY CLAY, MOIST, MEDIUM STIFF, (WC 29%).
140.1	3-4-5	GREY SILTY CLAY, VERY MOIST, MEDIUM STIFF, (WC 28%).
183.6	4-3-3	GREY SILTY CLAY, MOIST, MEDIUM STIFF, (WC 24%).
137.1	2-2-2	GREY SILTY CLAY, (VARVED), VERY MOIST, SOFT, (WC 31%).
132.5	3-3-3	GREY SILTY CLAY, (VARVED), VERY MOIST, MEDIUM STIFF, (WC 31%).
134.0	2-4-5	GREY SILTY CLAY, (VARVED), MOIST, MEDIUM STIFF, (WC 28%).
129.5	3-4-3	GREY SILTY CLAY, (VARVED), MOIST, STIFF.
126.4	4-6-6	GREY SILTY CLAY, (VARVED), SAND LENSES, VERY MOIST, SOFT, (WC 31%).
123.4	8-11-9	GREY FINE TO MEDIUM SAND, WET, MEDIUM DENSE, (WC 22%).
121.9	29-47-68	GREY SILTY SAND AND LIMESTONE FRAGMENTS, WET, DENSE, (WC 10%).
120.3		GREY SHALE AND LIMESTONE, 85% SHALE, 15% LIMESTONE, 3 TO 6.5cm LIMESTONE LAYERS.

WELL # B-1-4   LOCATION 407N 1432E   ELEVATION 151.6m

ELEVATION	STD. PEN.	DESCRIPTION
151.5		GROUND SURFACE.
148.5	6-4-3	CINDERS, SAND AND BRICK FRAGMENTS, (FILL), MOIST, MEDIUM DENSE.
147.0	6-7-8	BROWN AND GREY SILTY CLAY, MOIST, STIFF, (WC 26%).
141.7	3-4-5	GREY SILTY CLAY, MOIST, MEDIUM STIFF, (WC 25%).
139.4	4-4-3	GREY SILTY CLAY, (VARVED), MOIST, MEDIUM STIFF,

		(WC 30%).
136.4	2-2-4	GREY SILTY CLAY, (VARVED), VERY MOIST, SOFT, (WC 34%).
134.8	4-4-5	GREY SILTY CLAY, (VARVED), VERY MOIST, MEDIUM STIFF, (WC 31%).
133.3	4-5-6	GREY SILTY CLAY, (VARVED), VERY MOIST, SOFT, (WC 34%).
131.8	2-4-5	GREY SILTY CLAY, (VARVED), VERY MOIST, SOFT, (WC 30%).
128.7	5-6-6	GREY SILTY CLAY, (VARVED), MOIST, MEDIUM STIFF, (WC 32%).
127.2	6-5-7	GREY SILTY CLAY, (VARVED), MOIST, MEDIUM STIFF, (WC 33%).
125.7	8-10-10	LIGHT GREY FINE SAND, WET, LOOSE, (WC 25%).
124.2	5-7-8	GREY SILTY CLAY WITH SAND LAYERS, VERY MOIST, SOFT, (WC 35%).
123.7	10-17-25	GREY SILTY SAND, WET, DENSE, (WC 27%).
122.5		GREY SILTY CLAY AND STONE FRAGMENTS, MOIST, VERY DENSE.
120.5		INTERBEDDED GREY SHALE AND LIMESTONE, 60% SHALE, 40% LIMESTONE, 3 TO 16cm LIMESTONE LAYERS.

WELL # B-1-5 LOCATION 407N 1432E ELEVATION 151.0m

ELEVATION	STD. PEN.	DESCRIPTION
151.0		GROUND SURFACE.
147.2	4-9-7	CINDERS, BRICK, WOOD AND CLAY LAYERS, (FILL), MOIST, MEDIUM STIFF.
146.5	4-2-7	GREY SANDY SILT WITH CLAY LAYERS, CINDERS, (FILL), MOIST, SOFT, (WC 27%).
145.1	5-6-5	BROWN AND GREY SANDY CLAYEY SILT, VERY MOIST, SOFT, (WC 22%).
143.4	5-7-7	MOTTLED BROWN AND GREY SILTY CLAY, MOIST, SOFT, (WC 26%).
142.7	3-6-8	BROWN AND GREY SILTY CLAY, MOIST, STIFF, (WC 26%).
141.9	5-6-8	BROWN AND GREY SILTY CLAY WITH SILT PACKETS, MOIST, MEDIUM STIFF, (WC 29%).

140.4	3-2-4	GREY SILTY CLAY, TRACE OF ORGANICS, VERY MOIST, MEDIUM STIFF, (WC 28%).
138.9	3-3-2	GREY SILTY CLAY, (VARVED), MOIST, MEDIUM STIFF, (WC 28%).
134.3	2-4-4	GREY SILTY CLAY, (VARVED), VERY MOIST, SOFT, (WC 34%).
132.8	4-5-8	GREY SILTY CLAY, (VARVED), VERY MOIST, SOFT.
129.7	4-4-6	GREY SILTY CLAY, (VARVED), VERY MOIST, MEDIUM STIFF, (WC 30%).
128.2	3-7-10	GREY SILTY SAND WITH CLAY, WET, MEDIUM DENSE, (WC 31%).
126.7	7-7-9	GREY FINE TO MEDIUM SAND, WET, MEDIUM DENSE, (WC 26%).
125.1	9-10-13	GREY SILTY CLAY, (VARVED), MOIST, STIFF, (WC 21%).
123.6	2-8-10	GREY FINE SAND, WET, MEDIUM DENSE, (WC 25%).
122.1	6-10-35	GREY SILTY CLAY, (VARVED), TRACE OF FINE GRAVEL, MOIST, STIFF, (WC 30%).
120.6		GREY SHALE AND LIMESTONE, 85% SHALE, 15% LIMESTONE, 2 TO 7.6cm LIMESTONE LAYERS.

WELL # R-7-1 LOCATION 408N 1431E ELEVATION 169.0m

ELEVATION	STD. PEN.	DESCRIPTION
169.0		GROUND SURFACE.
168.8		CONCRETE AND GRAVEL BASE.
168.7	1	CINDERS, (FILL), MOIST, LOOSE.
167.5	2-2	BROWN AND GREY SILTY CLAY, MOIST, MEDIUM STIFF, (WC 25%).
165.9	3-3-2	BROWN AND GREY SANDY SILT, MOIST, LOOSE, (WC 20%).
164.4	2-2-3	BROWN SANDY SILT, WET, LOOSE, (WC 27%).
163.7	3-4-5	GREY SILT, MOIST, LOOSE, (WC 25%).
161.4	3-4-4	GREY CLAYEY SILT WITH TRACE OF ORGANICS, VERY MOIST, SOFT, (WC 29%).
160.6	4-5-6	GREY SILTY CLAY, MOIST, MEDIUM STIFF, (WC 25%).
159.9	4-4-4	GREENISH GREY SILTY CLAY, MOIST, STIFF, (WC 25%).

158.3	5-5-6	BLUISH GREY SILTY CLAY, MOIST, MEDIUM STIFF, (WC 24%).
157.6	6-9-12	GREENISH AND BLUISH GREY SILTY CLAY, MOIST, VERY STIFF, (WC 18%).
156.8	13-19-23	GREY SILTY CLAY, MOIST, HARD, (WC 17%).
155.9	29-38-67	GREY SHALE.
154.4		GREY SHALE AND LIMESTONE, 90% SHALE, 10% LIMESTONE.

WELL # R-7-2 LOCATION 408N 1432E ELEVATION 169.6m

ELEVATION	STD. PEN.	DESCRIPTION
169.6		GROUND SURFACE.
168.0	9-11-10	BROWN AND GREY CLAYEY SILT WITH SAND AND BRICK FRAGMENTS, (FILL), MOIST, MEDIUM DENSE, (WC 18%).
166.6	6	GREY SILTY SAND WITH GRAVEL AND ROCK FRAGMENTS AND CONCRETE, (FILL), MOIST, DENSE, (WC 29%).
165.0	2-5-6	MOTTLED BROWN AND GREY SILTY CLAY, MOIST, STIFF, (WC 25%).
163.5	3-4-6	GREENISH GREY SILTY CLAY, MOIST, MEDIUM STIFF, (WC 26%).
162.0	6-9-11	BLUISH GREY SILTY CLAY, MOIST, STIFF, (WC 26%).
159.7	7-19-15	GREENISH AND BLUISH GREY SILTY CLAY, MOIST, STIFF, (WC 24%).
158.9	7-12-19	BROWN AND GREY SILTY CLAY, MOIST, VERY STIFF, (WC 23%).
158.2	6-13-18	BROWN AND GREY SILTY CLAY, MOIST, VERY STIFF, (WC 24%).
157.4	12-15-17	BROWN AND GREY CLAYEY SILT, MOIST, HARD, (WC 18%).
155.9	10-16-20	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, HARD, (WC 20%).
154.4	9-14-19	BROWN AND GREYSILTY CLAY, MOIST, HARD, (WC 20%).
152.9	12-18-21	GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, HARD, (WC 16%).
151.3	19-25-35	GREY SHALE.

WELL # R-16-1 LOCATION 408N 1431E ELEVATION 156.1m

ELEVATION	STD. PEN.	DESCRIPTION
156.1		GROUND SURFACE.
154.6	6-9-15	BROWN AND GREY SANDY CLAY, (FILL), MOIST, STIFF, (WC 20%).
153.1	11-12-18	BROWN AND GREY SILTY SAND AND ROCK FRAGMENTS, (FILL), MOIST, DENSE, (WC 14%).
151.6	9-4	ROCK FRAGMENTS AND CONCRETE AND CINDERS, (FILL), MOIST, VERY DENSE, (WC 14%).
150.8	10-7-5	BROWN GRAVELLY CLAYEY SAND, (FILL), MOIST, MEDIUM DENSE, (WC 21%).
150.1	2-3-2	GREY AND BROWN SANDY SILTY CLAY WITH CINDERS, (FILL), VERY MOIST, SOFT, (WC 22%).
149.3	4-2-2	BROWN AND GREY GRAVELLY CLAYEY SAND, (FILL), VERY MOIST, VERY LOOSE, (WC 19%).
148.5	3-3-2	GREY GRAVELLY CLAYEY SAND, (FILL), WET, LOOSE, (WC 22%).
147.8	1-2-2	DARK BROWN CLAYEY SAND, (FILL), VERY MOIST, VERY LOOSE, (WC 25%).
147.0	2-3-2	BROWN CLAYEY SANDY AND GRAVEL, (FILL), VERY MOIST, LOOSE, (WC 19%).
145.5	2-2-2	GREY SILTY SAND, (FILL), WET, VERY LOOSE, (WC 19%).
143.9	4-5-5	DARK GREY AND BROWN CLAYEY SAND AND GRAVEL, (FILL), VERY MOIST, MEDIUM DENSE, (WC 22%).
142.4	4-5-6	GREY CLAYEY SAND AND GRAVEL, WET, MEDIUM DENSE, (WC 18%).
140.9	3-4-5	BROWN AND GREY SILTY CLAY, MOIST, STIFF, (WC 27%).
139.4	4-4-6	GREY CLAYEY SILT, VERY MOIST, MEDIUM STIFF, (WC 28%).
137.6	6-7-7	GREY SILTY CLAY, VERY MOIST, MEDIUM STIFF, (WC 31%).
133.3	4-5-7	GREY FINE SAND, WET, MEDIUM DENSE, (WC 23%).
131.8	6-5-9	GREY GRAVELLY SILTY SAND, WET, MEDIUM DENSE, (WC 14%).
130.3	5-6-8	GREY FINE SAND, WET, MEDIUM DENSE, (WC 21%).

128.7	6-9-10	GREY CLAYEY SILT WITH SAND LAYERS, VERY MOIST, VERY STIFF, (WC 29%).
122.7	10-15-14	GREY SILTY CLAY WITH SAND LAYERS, VERY MOIST, VERY STIFF, (WC 21%).
122.5	94	GREY LIMESTONE.
121.0		GREY SHALE AND LIMESTONE, 70% SHALE, 30% LIMESTONE, 2.5 TO 5cm LIMESTONE LAYERS.

WELL # B-11-1 LOCATION 410N 1431E ELEVATION 181.4m

ELEVATION	STD. PEN.	DESCRIPTION
181.4		GROUND SURFACE.
177.6	9-11-7	CINDERS, BRICK AND GRAVEL, (FILL), MOIST, MEDIUM DENSE.
176.8	3-7-6	BROWN AND GREY SILTY CLAY WITH RUBBLE, (FILL), MOIST, VERY STIFF, (WC 17%).
176.1	10-6-12	GREY SILTY CLAY, TRACE OF BRICK FRAGMENTS, (FILL), MOIST, STIFF, (WC 25%).
175.3	4-7-8	GREY SILTY CLAY WITH CINDERS, COAL AND BRICK FRAGMENTS, (FILL), MOIST, STIFF, (WC 20%).
173.8	3-4-4	BROWN AND GREY SILTY CLAY WITH ROCK FRAGMENTS, (FILL), MOIST, STIFF, (WC 20%).
173.0	6-5-3	GREY AND BROWN SILTY CLAY, TRACE OF BRICK FRAGMENTS, (FILL), MOIST, MEDIUM DENSE.
160.1	7-3-6	CINDERS, BRICK FRAGMENTS, GRAVEL AND CLAY, (RUBBLE FILL), MOIST, LOOSE.
157.0	8-70-70	GREY SILTY CLAY, TRACE OF WOOD AND CINDERS, MOIST, STIFF, (WC 29%).
156.7	30-70	GREY SANDY CLAY, GRAVEL AND ROCK FRAGMENTS, WET, VERY DENSE.
155.2		GREY SHALE AND LIMESTONE, 80% SHALE, 20% LIMESTONE, 1.2 TO 5cm LIMESTONE LAYERS.

WELL # B-11-2 LOCATION 410N 1431E ELEVATION 171.8m

ELEVATION	STD. PEN.	DESCRIPTION
171.8		GROUND SURFACE.
170.2	1	TOPSOIL AND CINDERS, (FILL), MOIST, VERY LOOSE.
168.7	1-1-2	CINDERS, (RUBBLE FILL), MOIST, VERY LOOSE.
165.7	2-2-1	CINDERS, CLAY, SAND, ROCK AND BRICK FRAGMENTS, (RUBBLE FILL), MOIST, LOOSE.
164.9	2-2-2	BROWN AND GREY SANDY LEAN CLAY, TRACE OF WOOD AND BRICK FRAGMENTS, MOIST, MEDIUM STIFF, (WC 24%).
163.4	5-4-4	SAND, CINDERS, CLAY, SHALE AND ROCK FRAGMENTS, (RUBBLE FILL), MOIST, LOOSE.
156.5	4-3-3	CINDERS, SAND CLAY, ROCK AND BRICK FRAGMENTS, (RUBBLE FILL), MOIST, LOOSE.
155.0	10-27-33	BROWN AND GREY SILTY CLAY AND BRICK FRAGMENTS, MOIST, STIFF, (WC 20%).
153.5	8-7-8	GREY SILTY CLAY, VERY MOIST, MEDIUM STIFF, (WC 31%).
152.0	22-24-27	GREY AND GREENISH GREY LEAN CLAY, TRACE OF LIMESTONE FRAGMENTS, MOIST, VERY STIFF, (WC 19%).
151.7	37-62	GREY SHALE.
150.1		LAYERED GREY SHALE AND LIMESTONE.

WELL # B-11-4 LOCATION 410N 1431E ELEVATION 172.9m

ELEVATION	STD. PEN.	DESCRIPTION
172.9		GROUND SURFACE.
172.7		CONCRETE.
172.3	2-7-15	ROCK FRAGMENTS, (FILL), MOIST, DENSE.
170.6	9-11-9	BROWN AND GREY SANDY SILTY CLAY WITH GRAVEL AND ROCK FRAGMENTS, (FILL), MOIST, STIFF, (WC 18%).
169.1	10-10-11	CINDERS, CLAY AND BRICK FRAGMENTS, (FILL), MOIST, VERY DENSE.
168.3	9-10-8	BROWN AND GREY SANDY SILTY CLAY WITH ROCK FRAGMENTS, (FILL), MOIST, VERY STIFF, (WC 19%).

164.8	10-9-14	DARK BROWN CLAY, CINDERS, BRICK AND ROCK FRAGMENTS, (FILL), MOIST, DENSE.
159.2	2-2-2	CINDERS, CLAY AND BRICK FRAGMENTS, (RUBBLE FILL), MOIST, LOOSE.
157.6	10-11-19	BROWN AND GREY SLTY CLAY, MOIST, VERY STIFF.
156.1	9-12-16	BROWN SILTY CLAY, MOIST, VERY STIFF.
154.6	17-20-25	BROWN SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, HARD.
154.3	40-69	GREY SHALE.
152.8		GREY SHALE AND LIMESTONE, 90% SHALE, 10% LIMESTONE.

WELL # B-11-5 LOCATION 410N 1431E ELEVATION 170.8m

ELEVATION	STD. PEN.	DESCRIPTION
170.8		GROUND SURFACE.
169.3	4-5-6	CINDERS, BRICK FRAGMENTS, COBBLES WITH CLAY, (RUBBLE FILL), MOIST, STIFF.
168.1	5-6-7	BROWN AND GREY SILTY CLAY WITH GRAVEL AND ROCK FRAGMENTS, (FILL), MOIST, STIFF.
163.2	2-2-4	CINDERS, BRICK FRAGMENTS, COBBLES, WOOD WITH CLAY, (RUBBLE FILL), MOIST, DENSE, (WC 19%).
162.8	3-4-7	GREY SILTY CLAY WITH SHALE FRAGMENTS, (FILL), MOIST, STIFF, (WC 22%).
162.1	2-4-1	BROWN AND GREY SILTY CLAY, TRACE OF BRICK FRAGMENTS, (FILL), MOIST, STIFF, (WC 23%).
158.9	5-6-8	BROWN AND GREY SILTY CLAY, MOIST, STIFF, (WC 20%).
156.1	6-10-12	BROWN SILTY CLAY, MOIST, VERY STIFF, (WC 19%).
155.4	30-30-75	GREY SHALE.
153.9		GREY SHALE AND LIMESTONE, 90% SHALE, 10% LIMESTONE, 5 TO 10cm LIMESTONE LAYERS.

WELL # B-11-8 LOCATION 410N 1431E ELEVATION 168.0m

ELEVATION	STD. PEN.	DESCRIPTION
168.0		GROUND SURFACE.
167.7	9-10	BROWN SAND AND GRAVEL, (FILL), DRY, MEDIUM DENSE.
166.5	11	BROWN LEAN CLAY, (FILL), MOIST, STIFF, (WC 13%).
163.5	4-4-4	CINDERS, BRICK AND GRAVEL, (RUBBLE FILL), MOIST, MEDIUM DENSE.
161.9	3-4-4	BROWN SILTY SAND, (FILL), MOIST, LOOSE, (WC 20%).
161.2	3-4-6	BROWN SILTY CLAY, (FILL), MOIST, STIFF, (WC 23%).
158.9	5-8-10	CLAY, CINDERS, BRICK AND ROCK FRAGMENTS, (RUBBLE FILL), MOIST, MEDIUM DENSE.
157.5	3-4-7	BROWN AND GREY CLAYEY SILT, MOIST, MEDIUM STIFF, (WC 23%).
156.9	10-20-60	BROWN AND GREY SILTY CLAY, (HIGHLY WEATHERED SHALE), WITH LIMESTONE FRAGMENTS, MOIST, HARD.
155.4		LAYERED GREY SHALE AND LIMESTONE, 75% SHALE, 25% LIMESTONE, 2.5 TO 15cm LIMESTONE LAYERS.

WELL # R-9-3 LOCATION 409N 1431E ELEVATION 180.9m

ELEVATION	STD. PEN.	DESCRIPTION
180.9		GROUND SURFACE.
179.4	7-10-12	BROWN CLAYEY SAND WITH ROCK FRAGMENTS, (FILL), MOIST, MEDIUM DENSE, (WC 8%).
177.8	9-11-10	GREY AND BROWN SILTY CLAY, (HIGHLY WEATHERED SHALE), MOIST, HARD, (WC 16%).
177.5	45-100	GREY SHALE.
168.4		GREY SHALE AND LIMESTONE, 90% SHALE, 10% LIMESTONE, 2.5 TO 19cm LIMESTONE LAYERS.

WELL # B-3-1 LOCATION 408N 1432E ELEVATION 170.0m

ELEVATION	STD. PEN.	DESCRIPTION
170.0		GROUND SURFACE.
168.4	2-2-3	BROWN AND GREY SILTY CLAY, TRACE OF TOPSOIL AND ROCK FRAGMENTS, (FILL), MOIST, STIFF, (WC 23%).
157.0	11-14-19	BROWN AND GREY SILTY CLAY, MOIST, VERY STIFF, (WC 18%).
156.2	11-14-20	BROWN AND GREY SILTY CLAY WITH LIMESTONE FRAGMENTS, MOIST, VERY STIFF, (WC 16%).
155.4		GREY SHALE.
150.9		INTERBEDDED GREY SHALE AND LIMESTONE, 3.5cm LIMESTONE LAYERS.

WELL # B-9-1 LOCATION 408N 1430E ELEVATION 163.5m

ELEVATION	STD. PEN	DESCRIPTION
163.5		GROUND SURFACE.
163.3		CONCRETE.
162.0	7-6-5	BROWN GRAVELLY CLAYEY SAND, (FILL), VERY MOIST, MEDIUM DENSE, (WC 16%).
156.7	38-47-55	BROWN FINE TO COARSE SAND AND GRAVEL, MOIST, VERY DENSE, (WC 3%).
155.9	12-17-18	BROWN GRAVELLY SAND WITH CLAY AND SILT LAYERS, MOIST, DENSE, (WC 8%).
154.4	4-17-17	BROWN FINE TO COARSE SAND, MOIST, DENSE, (WC 3%).
153.6	9-12-19	BROWN FINE TO MEDIUM SAND, MOIST, DENSE, (WC 7%).
152.9	8-15-16	BROWN SILTY SAND WITH CLAY LAYERS, WET DENSE, (WC 19%).
152.1	8-15-15	BROWN CLAYEY SILT, WET, MEDIUM DENSE, (WC 28%).
151.3	7-16-17	BROWN SILTY CLAY SITH SILT SEAMS, VERY MOIST, STIFF, (WC 29%).
149.8	6-9-22	BROWN SILTY SAND WITH CLAY SEAMS, WET, DENSE, (WC 19%).
148.7	5-15-17	BROWN AND GREY SILTY CLAY, MOIST, STIFF, (WC 20%).
148.3	10-77-19	GREY SILTY CLAY MOIST, STIFF, (WC 20%).

WELL # B-9-4 LOCATION 408N 1431E ELEVATION 159.6m

ELEVATION	STD. PEN.	DESCRIPTION
159.6		GROUND SURFACE.
155.0	4-7-5	BROWN SANDY CLAY, CINDERS, GRAVEL AND BRICK, (FILL), MOIST, STIFF.
154.2	2-3-3	BROWN AND GREY SANDY SILTY CLAY, (FILL), VERY MOIST, SOFT, (WC 22%).
153.5	4-3-3	BROWN AND GREY SANDY CLAYEY SILT, (FILL), VERY MOIST, SOFT, (WC 19%).
152.7	3-4-3	BROWN SILTY SAND, (FILL), MOIST, LOOSE, (WC 20%).
151.9	5-5-5	BROWN GRAVELLY SILTY SAND, (FILL), TRACE OF BRICK AND CINDERS, MOIST, LOOSE, (WC 18%).
151.2	3-3-3	BROWN AND GREY GRAVELLY SILTY SAND, (FILL), CINDERS, BRICK, VERY MOIST, SOFT, (WC 18%).
150.4	4-3-4	BROWN AND GREY GRAVELLY SILTY SAND, (FILL), MOIST, SOFT, (WC 20%).
149.7	4-5-5	DARK GREY SANDY SILTY GRAVEL, (FILL), WET, MEDIUM DENSE, (WC 24%).
145.9	7-8-10	BROWN FINE TO COARSE SAND, WET, MEDIUM DENSE, (WC 14%).
137.9	2-4-3	GREY SILTY CLAY, (VARVED), VERY MOIST, SOFT, (WC 26%).
136.7	16	GREY SILTY SAND, WET, MEDIUM DENSE, (WC 23%).
124.5	4-6-8	GREY SILTY CLAY SITH SAND LENSES, VERY MOIST, STIFF (WC 28%).
124.2	18-21	GREY GRAVELLY SILTY CLAY WITH FINE SAND SEAMS, MOIST, MEDIUM STIFF, (WC 33%).
122.7		GREY SHALE AND LIMESTONE, 80% SHALE, 20% LIMESTONE, 2.5 TO 11.5cm LIMESTONE LAYERS.

WELL # B-9-5 LOCATION 408N 1431E ELEVATION 158.0m

ELEVATION	STD. PEN.	DESCRIPTION
158.0		GROUND SURFACE.
157.9		CONCRETE.

155.0	3-3-3	BROWN SILTY SAND, (FILL), MOIST, LOOSE, (WC 15%).
153.5	1-2-2	CINDERS, TRACE OF CLAY, (FILL), MOIST, LOOSE.
152.7	2-3-2	DARK GREY CLAYEY SAND WITH CINDERS AND BRICK FRAGMENTS, (FILL), VERY MOIST, SOFT, (WC 23%).
151.9	3-1-3	DARK GREY GRAVELLY CLAYEY SAND, TRACE OF CINDERS, (FILL), VERY MOIST, SOFT, (WC 25%).
150.4	2-3-3	GREY AND BROWN SILTY CLAY, FILL, MOIST, MEDIUM STIFF, (WC 30%).
149.7	4-5-5	GREY SILTY CLAY, MOIST, STIFF, (WC 26%).
148.9	5-6-5	BROWN AND GREY SILTY CLAY, MOIST, STIFF, (WC 28%).
127.6	4-3-5	GREY SILTY CLAY, (VARVED), VERY MOIST, SOFT.
126.4	17-30-34	GREY SILTY CLAY WITH ROCK FRAGMENTS, VERY MOIST, SOFT.
124.8		GREY SHALE AND LIMESTONE, 80% SHALE, 20% LIMESTONE, 4 TO 8.25cm LIMESTONE LAYERS.

WELL # B-9-6 LOCATION 408N 1431E ELEVATION 157.7m

ELEVATION	STD. PEN.	DESCRIPTION
157.7		GROUND SURFACE.
157.4		CONCRETE WALK.
154.7	1-2-3	BROWN SANDY CLAY, CINDERS SAND GRAVEL AND BRICK, (FILL), MOIST, LOOSE.
153.2	2-1-2	BROWN SILTY CLAY, (FILL), VERY MOIST, SOFT, (WC 25%).
152.4	1-2-2	DARK BROWN CLAYEY SILT, TRACE OF GLASS AND ORGANICS, (FILL), VERY MOIST, SOFT, (WC 27%).
151.6	2-3-4	BROWN CLAYEY SILT, (FILL), VERY MOIST, SOFT, (WC 22%).
150.9	2-3-3	BROWN LEAN CLAY, MOIST, MEDIUM STIFF, (WC 22%).
148.6	3-3-2	BROWN SANDY LEAN CLAY, MOIST, STIFF, (WC 17%).
147.1	3-3-4	GREY SILTY CLAY, (VARVED), VERY MOIST, SOFT, (WC 33%).
146.3	3-3-3	GREY SILTY CLAY, VERY MOIST, SOFT, (WC 36%).
141.0	3-2-4	GREY SILTY CLAY, (VARVED), VERY MOIST, SOFT.

137.9	4-5-4	GREY SILTY CLAY, VERY MOIST, SOFT, (WC 36%).
136.4	5-6-6	GREY SILTY CLAY, (VARVED), MOIST, SOFT, (WC 29%).
134.9	3-4-4	GREY SILTY CLAY, VERY MOIST, SOFT, (WC 33%).
131.8	9-10-18	GREY SILTY CLAY, (VARVED), VERY MOIST, SOFT, (WC 32%).
130.3	10-17-20	GREY SILTY CLAY, VERY MOIST, SOFT, (WC 32%).
127.9	18-32-41	GREENISH GREY SILTY CLAY, TRACE OF LIMESTONE FRAGMENTS, MOIST, HARD, (WC 18%).
126.4		GREY SHALE AND LIMESTONE, 70% SHALE, 30% LIMESTONE, 2.5 TO 15cm LIMESTONE LAYERS.

WELL # B-9-11 LOCATION 408N 1431E ELEVATION 171.7m

ELEVATION	STD. PEN.	DESCRIPTION
171.7		GROUND SURFACE.
171.6		CONCRETE.
170.2	2-4-3	BROWN CLAY, CINDERS, ASH AND BRICK FRAGMENTS, (FILL), MOIST, LOOSE.
168.7	3-4-4	BROWN CLAYEY SILT, MOIST, SOFT, (WC 23%).
167.2	4-5-6	MOTTLED BROWN AND GREY SILTY CLAY, MOIST, STIFF, (WC 23%).
165.6	5-6-8	MOTTLED BROWN AND GREY FAT CLAY, MOIST STIFF, (WC 29%).
164.1	7-8-9	MOTTLED BROWN AND GREY SILTY CLAY, MOIST, STIFF, (WC 24%).
162.6	8-9-11	MOTTLED BROWN AND GREY SILTY CLAY, TRACE OF FOSSILS, MOIST, VERY STIFF, (WC 22%).
159.6	9-10-11	MOTTLED BROWN AND GREY LEAN CLAY, MOIST, VERY STIFF, (WC 20%).
158.8	15-17-22	BROWN AND GREY LEAN CLAY, WITH LIMESTONE FRAGMENTS, MOIST, VERY STIFF, (WC 25%).
157.7	8-14-34	BROWN AND GREY SANDY LEAN CLAY WITH LIMESTONE FRAGMENTS, MOIST, VERY STIFF, (WC 19%).
154.7		GREY SHALE AND LIMESTONE.

WELL # B-11-8 LOCATION 410N 1431E ELEVATION 168.0m

ELEVATION	STD. PEN.	DESCRIPTION
168.0		GROUND SURFACE.
167.7	9-10	BROWN SAND AND GRAVEL, (FILL), DRY, MEDIUM DENSE.
166.5	11	BROWN LEAN CLAY, (FILL), MOIST, STIFF, (WC 13%).
163.5	4-4-4	CINDERS, BRICK AND GRAVEL, (RUBBLE FILL), MOIST, MEDIUM DENSE.
161.9	3-4-4	BROWN SILTY SAND, (FILL), MOIST, LOOSE, (WC 20%).
161.2	3-4-6	BROWN SILTY CLAY, (FILL), MOIST, STIFF, (WC 23%).
158.9	5-8-10	CLAY, CINDERS, BRICK AND ROCK FRAGMENTS, (RUBBLE FILL), MOIST, MEDIUM DENSE.
157.5	3-4-7	BROWN AND GREY CLAYEY SILT, MOIST, MEDIUM STIFF, (WC 23%).
156.9	10-20-60	BROWN AND GREY SILTY CLAY, (HIGHLY WEATHERED SHALE) WITH LIMESTONE FRAGMENTS, MOIST, HARD.
155.4		LAYERED GREY SHALE AND LIMESTONE, 75% SHALE, 25% LIMESTONE, 2.5 TO 12.5cm LIMESTONE LAYERS.

WELL # B-15-3 LOCATION 410N 1431E ELEVATION 176.8m

ELEVATION	STD. PEN.	DESCRIPTION
176.8		GROUND SURFACE.
173.2	10-21-30	BROWN SANDY CLAY AND COBBLES, (RUBBLE FILL), MOIST, HARD.
170.1	7-11-5	BROWN SILTY CLAY, BRICK FRAGMENTS AND CINDRERS, (RUBBLE FILL), MOIST, STIFF.
168.4	12-27-65	BROWN SANDY CLAY, CINDERS AND COBBLES, (RUBBLE FILL), MOIST, HARD.
166.8	80	CINDERS, BRICK AND ROCK FRAGMENTS, (RUBBLE FILL), DRY, VERY DENSE, (WC 25%).
165.9	3-4	DARK BROWN SILT, MOIST, MEDIUM STIFF, (WC 28%).
163.1	11-14-16	BROWN AND GREY SILTY CLAY, TRACE OF LIMESTONE FRAGMENTS, (HIGHLY WEATHERED SHALE), MOIST, HARD, (WC 19%).

160.4		LAYERED GREY SHALE AND LIMESTONE, 80% SHALE, 20% LIMESTONE, 2.5 TO 10cm LIMESTONE LAYERS.

WELL # B-3-2 LOCATION 408N 1432E ELEVATION 167.8m

ELEVATION	STD. PEN.	DESCRIPTION
167.8		GROUND SURFACE.
166.3	5-3-4	BROWN SANDY SILTY CLAY, (FILL), MOIST, STIFF, (WC 16%).
163.3	8-10-11	BROWN SILTY CLAY, MOIST, STIFF, (WC 21%).
157.2	16-14-19	BROWN AND GREY SILTY CLAY, MOIST, VERY STIFF.
156.4	18-20-27	GREY AND BROWN SANDY SILTY CLAY, MOIST, HARD.
154.9	15-21-24	GREY AND BROWN SILTY CLAY, MOIST, VERY STIFF.
152.6	28-19-24	GREY SILTY CLAY, MOIST, VERY STIFF.
150.6	17-21-28	GREY CLAYEY GRAVEL WITH LIMESTONE FRAGMENTS, MOIST, STIFF.

WELL # R-17-1 LOCATION 408N 1433E ELEVATION 180.6m

ELEVATION	STD. PEN.	DESCRIPTION
180.6		GROUND SURFACE.
179.0	12-12-10	CINDERS, BRICK FRAGMENTS, GRAVEL, ROCK FRAGMENTS, BROWN AND GREY CLAY, (FILL), MOIST, MEDIUM DENSE.
178.3	8-10-12	BROWN AND GREY CLAY WITH BRICK AND ROCK FRAGMENTS, (FILL), MOIST, VERY STIFF.
177.5	9-12-13	GREY AND BROWN WEATHERED SHALE WITH FINE ROCK FRAGMENTS, MOIST, VERY STIFF.
175.5	17-25-50	GREY AND BROWN WEATHERED SHALE, MOIST, VERY STIFF TO VERY HARD.
174.0		GREY WEATHERED SHALE, MOIST TO DRY, VERY HARD.
172.5		GREY WEATHERED SHALE AND LIMESTONE, MOIST TO DRY, VERY HARD.

WELL # R-17-2 LOCATION 408N 1433E ELEVATION 179.6m

ELEVATION	STD. PEN.	DESCRIPTION
179.6		GROUND SURFACE.
178.9	6-9-12	CLAY, ROCK FRAGMENTS, (FILL), MOIST, VERY STIFF.
176.6	14-15-15	BROWN WEATHERED SHALE WITH THIN ROCK LAYERS AND FRAGMENTS, MOIST, HARD.
175.1	25-36-47	BROWN AND GREY WEATHERED SHALE WITH THIN LIMESTONE LAYERS, MOIST, HARD TO VERY HARD.
173.4	25-45	GREY SHALE, DRY, VERY HARD.
170.3		LAYERED GREY SHALE AND LIMESTONE, DRY, VERY HARD.

WELL # 1 LOCATION 408N 1433E ELEVATION 168.4m

ELEVATION	STD. PEN.	DESCRIPTION
168.4		GROUND SURFACE.
168.0	4	BROWN AND GREY LEAN CLAY WITH GRAVEL AND ROCK FRAGMENTS, (FILL), MOIST-STIFF.
165.4	16-10-120	GREY SOFT SHALE WITH THIN LIMESTONE LAYERS.

WELL # 3 LOCATION 408N 1433E ELEVATION 174.7m

ELEVATION	STD. PEN.	DESCRIPTION
174.7		GROUND SURFACE.
174.0	7	BROWN LEAN CLAY WITH SAND, GRAVEL AND BRICK FRAGMENTS, (FILL), MOIST, STIFF.
173.2	32-64	GREY AND SOFT SHALE WITH THIN LIMESONE LAYERS.

WELL # 4 LOCATION 408N 1433E ELEVATION 177.1m

ELEVATION	STD. PEN.	DESCRIPTION
177.1		GROUND SURFACE.
174.0	3-13-50	BROWN LEAN CLAY WITH SAND, GRAVEL, ROCK AND BRICK FRAGMENTS, (FILL), MOIST, MEDIUM STIFF TO STIFF.
172.5	89-116	GREYISH BROWN HIGHLY WEATHERED SHALE WITH THIN

LIMESTONE LAYERS.

WELL # 5 LOCATION: ONE LYTLE PLACE ELEVATION 152.2m

ELEVATION	STD. PEN.	DESCRIPTION
152.2		GROUND SURFACE.
149.5	4-5-4	SAND, GRAVEL, ROCK, BRICK AND CONCRETE FRAGMENTS, (FILL), MOIST, LOOSE.
147.7	4-5-6	LAYERED BROWN SANDY SILT AND FINE SAND, MOIST, STIFF.
144.6	4-6-7	BROWN CLAY WITH SAND LAYERS, MOIST, STIFF.
139.4	5-5-6	DARK GREY SILTY CLAY WITH FINE SAND LAYERS, VERY MOIST, VERY DENSE.
132.3	6-8-11	GREENISH GREY AND GREY SILTY CLAY, MOIST, STIFF.
132.0		GREY SANDY CLAYEY SILT, VERY MOIST, MEDIUM DENSE.
123.7		SOUNDING TO ROCK.
122.2		LAYERED GREY SHALE AND DARK GREY LIMESTONE, 55% SHALE, 45% LIMESTONE, SHALE - SILTY, CALCAREOUS SOFT TO HARD, LIMESTONE - 1 TO 11.5cm BEDS, CRYSTALLINE, FOSSILIFEROUS, HARD.

WELL # 7 LOCATION 408N 1433E ELEVATION 157.9m

ELEVATION	STD. PEN.	DESCRIPTION
157.9		GROUND SURFACE.
157.2		CONCRETE.
156.3	3-4-5	BROWN AND GREY SANDY LEAN CLAYWITH GRAVEL AND ROCK FRAGMENTS, (FILL), MOIST, MEDIUM STIFF TO STIFF.
154.7	16-92-125	SHALE WITH THIN LIMESTONE LAYERS.

WELL # 9 LOCATION 408N 1433E ELEVATION 157.9m

ELEVATION	STD. PEN.	DESCRIPTION
157.9		GROUND SURFACE.
157.1	3-4-6	DARK LEAN CLAY WITH SAND, GRAVEL, ROCK FRAGMENTS, TRACE OF BRICK FRAGMENTS, (FILL), MOIST, STIFF.

154.8	3-7-9	BROWN CLAY WITH ROCK FRAGMENTS, MOIST, STIFF TO VERY STIFF.
151.7	8-50-78	BROWN VERY HIGHLY WEATHERED SHALE WITH THIN LIMESTONE LAYERS.
150.9	36-78	GREY AND BROWN HIGHLY WEATHERED SHALE WITH THIN LIMESTONE LAYERS, MOIST, HARD.
145.5	75-132	GREY SOFT SHALE WITH THIN LIMESTONE LAYERS.

WELL # 12 LOCATION 408N 1433E ELEVATION 162.1m

ELEVATION	STD. PEN.	DESCRIPTION
162.1		GROUND SURFACE.
160.6	3-4-5	BROWN SANDY LEAN CLAY, TRACE OF GRAVEL, ROCK AND BRICK FRAGMENTS, (FILL), MOIST, STIFF.
159.8	4-5-6	BROWN LEAN CLAY, (FILL), MOIST, STIFF.
157.6	5-9-12	BROWN CLAY, MOIST, STIFF TO VERY STIFF.
156.0	25-60-100	BROWN HIGHLY WEATHERED SHALE WITH THIN LIMESTONE LAYERS.
152.7	85-112-128	GREY SOFT SHALE WITH THIN LIMESTONE LAYERS.

WELL # 13 LOCATION 408N 1433E ELEVATION 166.0m

ELEVATION	STD. PEN.	DESCRIPTION
166.0		GROUND SURFACE.
165.0	3-3-4	BROWN SILT, ROCK FRAGMENTS, (FILL), MEDIUM DENSE.
163.7	6-5-5	DARK BROWN SANDY LEAN CLAY WITH GRAVEL AND ROCK FRAGMENTS, MOIST, MEDIUM STIFF TO STIFF.
163.5	5	DARK BROWN CLAY, TRACE OF ROCK FRAGMENTS, MOIST, MEDIUM STIFF TO STIFF.
158.4	14-52-70	BROWN HIGHLY WEATHERED SHALE WITH THIN LIMESTONE LAYERS.
156.7	112-122	GREY SOFT SHALE SITH THIN LIMESTONE LAYERS.

WELL # 14 LOCATION 408N 1433E ELEVATION 165.5m

ELEVATION	STD. PEN.	DESCRIPTION
165.5		GROUND SURFACE.
166.8	4-6-7	DARK BROWN AND BLACK SANDY SILTY CLAY WITH GRAVEL, ROCK AND BRICK FRAGMENTS, (FILL), MOIST, STIFF.
166.0	5-6-8	BROWN CLAY NOTED SHALE FRAGMENTS, MOIST, STIFF.
164.5	1-16-20	BROWN SOFT HIGHLY WEATHERED SHALE.
162.2	22-36-50	BROWN HIGHLY WEATHERED SHALE WITH THIN LIMESTONE LAYERS.
156.7	36-94-115	GREY SOFT SHALE WITH THIN LIMESTONE LAYERS.

WELL # 15 LOCATION 407N 1433E ELEVATION 145.1m

ELEVATION	STD. PEN.	DESCRIPTION
145.1		GROUND SURFACE.
143.6	5-10-18	BROWN SANDY SILT AND SANDY CLAYEY SILT WITH ROCK FRAGMENTS, GRAVEL AND LEAN CLAY SEAMS, TRACE OF ASPHALT FRAGMENTS, (FILL), MOIST, MEDIUM DENSE TO DENSE.
142.0	5-6-6	DARK BROWN SILTY SAND WITH CINDERS, CONCRETE FRAGMENTS, AND GRAVEL, TRACE OF SPARK PLUG FRAGMENTS, (FILL), MOIST, MEDIUM DENSE.
141.3	5-5-6	BROWN SAND AND GRAVEL WITH BRICK AND CONCRETE FRAGMENTS, (FILL), MOIST, MEDIUM DENSE.
141.0	50	CONCRETE, (FILL).
139.2	3-3-4	BRICK, CONCRETE AND MORTAR FRAGMENTS WITH SLAG, (FILL), MOIST, LOOSE.
137.5	2-4-6	BROWN SAND WITH BRICK FRAGMENTS, (FILL), WET, LOOSE.
137.2	5-4	BROWN SANDY SILTY CLAY WITH LENSES, TRACE OR ROCK AND BRICK FRAGMENTS, (FILL), WET, SOFT.
136.0	3	GREY LEAN CLAY, NOTED ORGANIC MATTER, MOIST, SOFT TO MEDIUM STIFF.
134.4	8-8-8	BROWN AND GREY SANDY LEAN CLAY WITH SHALE FRAGMENTS AND SAND LENSES, TRACE OF FINE BRICK FRAGMENTS, MOIST, STIFF.

131.1	6-7-13	GREY AND BROWN LEAN CLAY WITH SHALE FRAGMENTS, NOTED ROCK FRAGMENTS, MOIST TO VERY MOIST, STIFF TO MEDIUM STIFF.
130.9	90	GREY SOFT SHALE.

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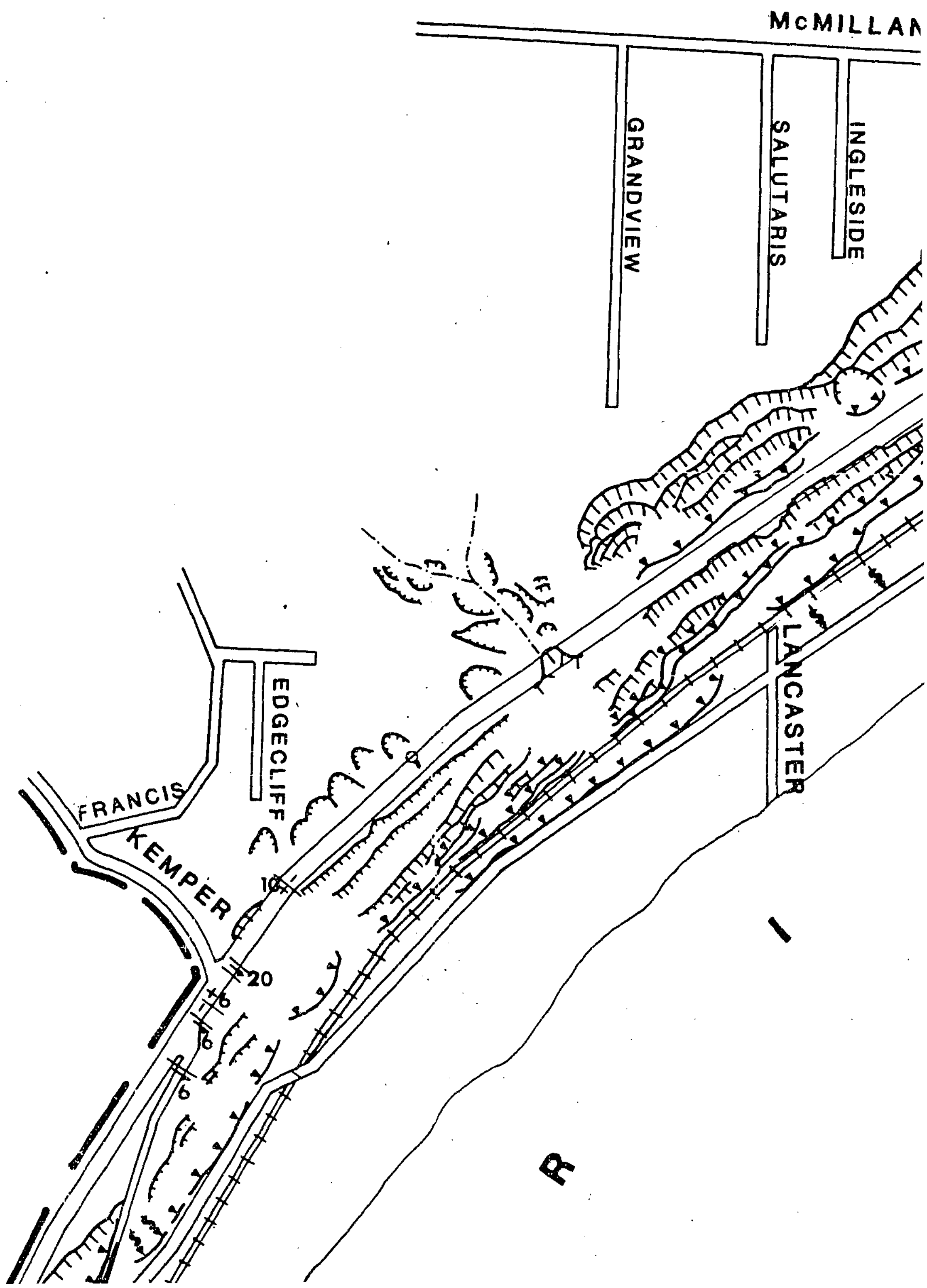
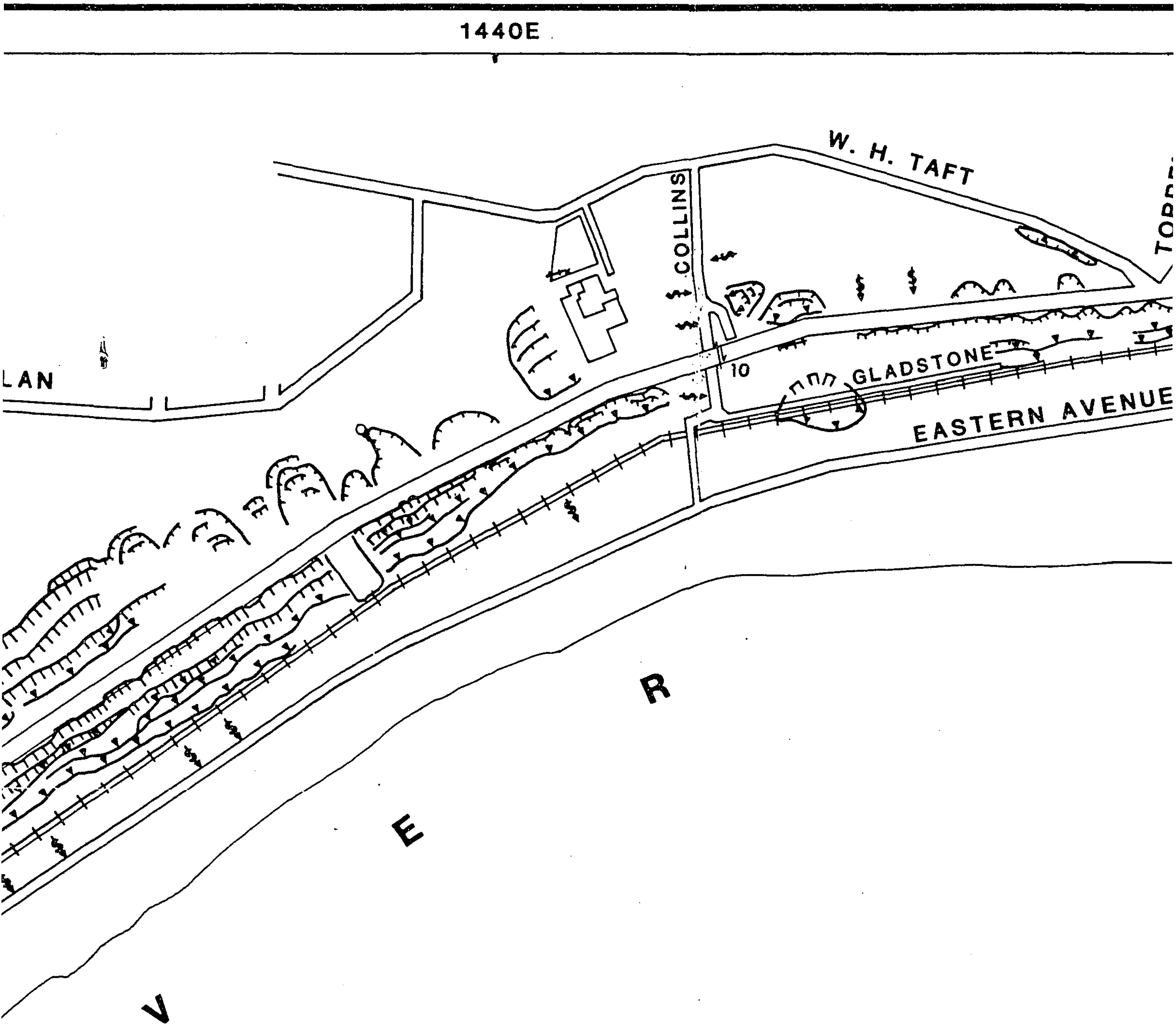
AP OF
EASTERN AVENUE

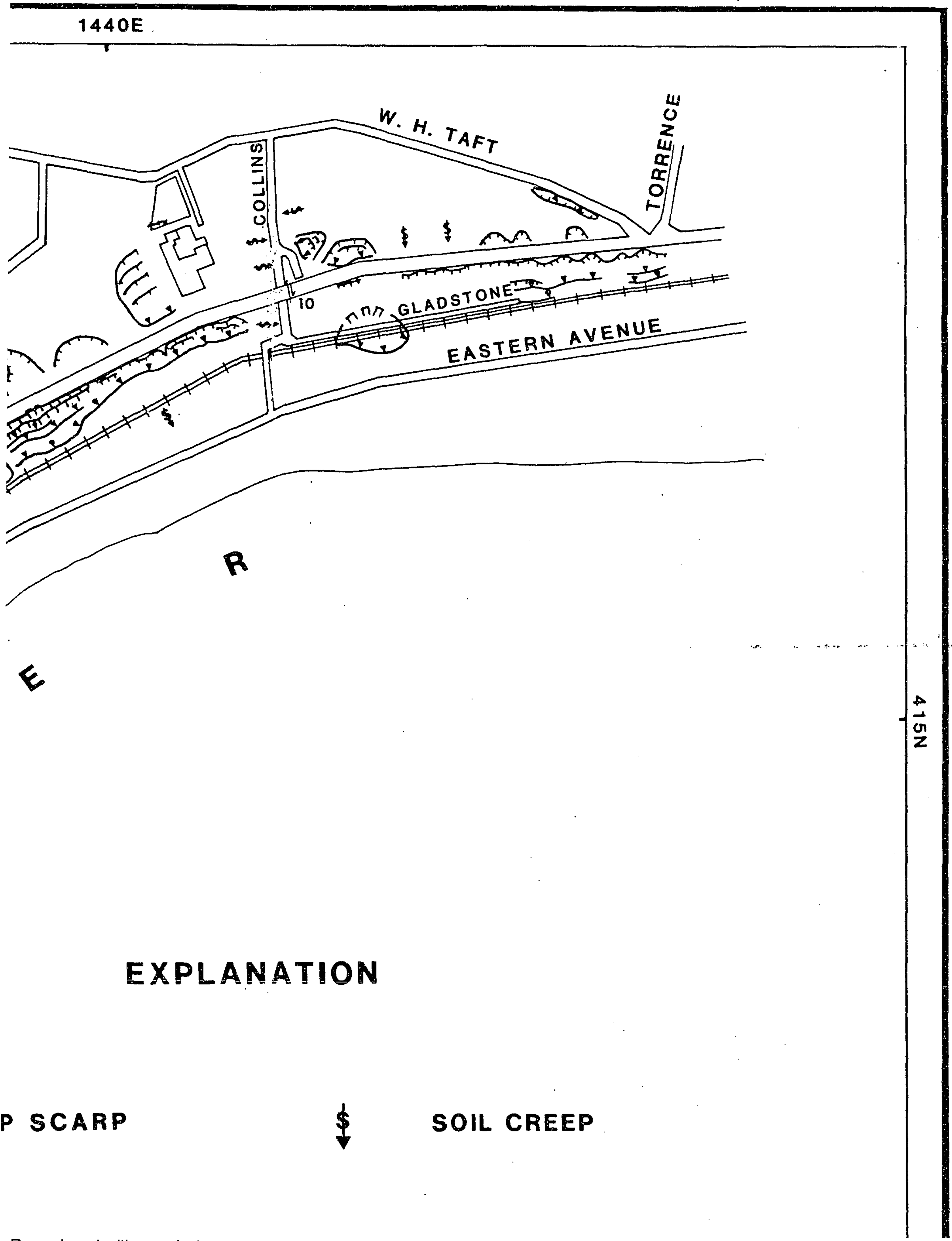




EXPLANATION

DEEP SCARP

SOIL CREEP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EXPLANATION
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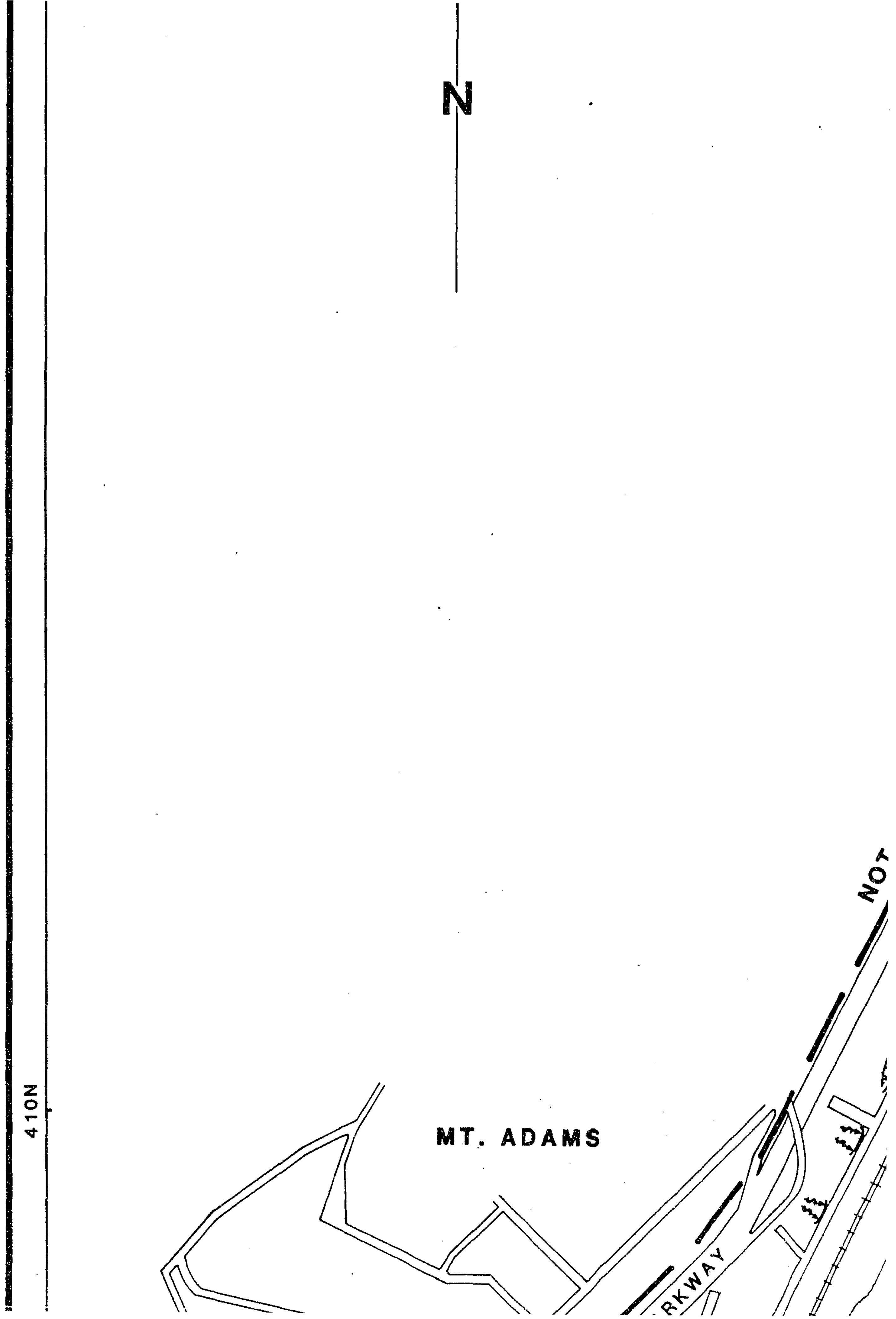
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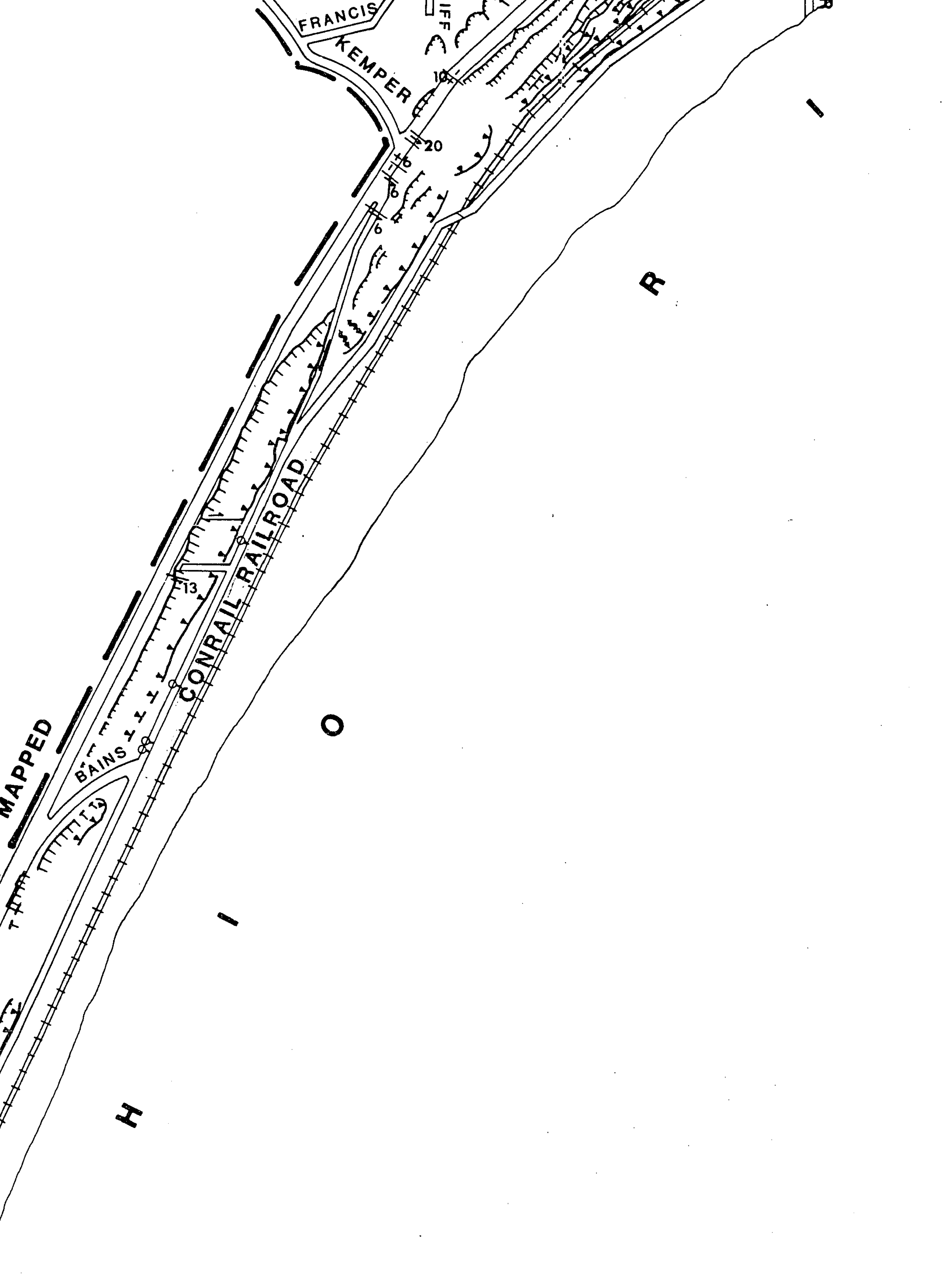
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EXPLANATION

DEEP SCARP

SOIL CREEP

SHALLOW SCARP

SEEPAGE

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RAILROAD TRACK

LATERAL DISPLACEMENT IN CENTIMETRES

VERTICAL DISPLACEMENT IN CENTIMETRES

EXPLANATION

SCARP

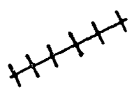
SOIL CREEP

.OW SCARP

SEEPAGE

RED SCARP

INTERMITTENT STREAM



TENSIONAL CRACK

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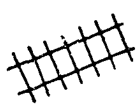

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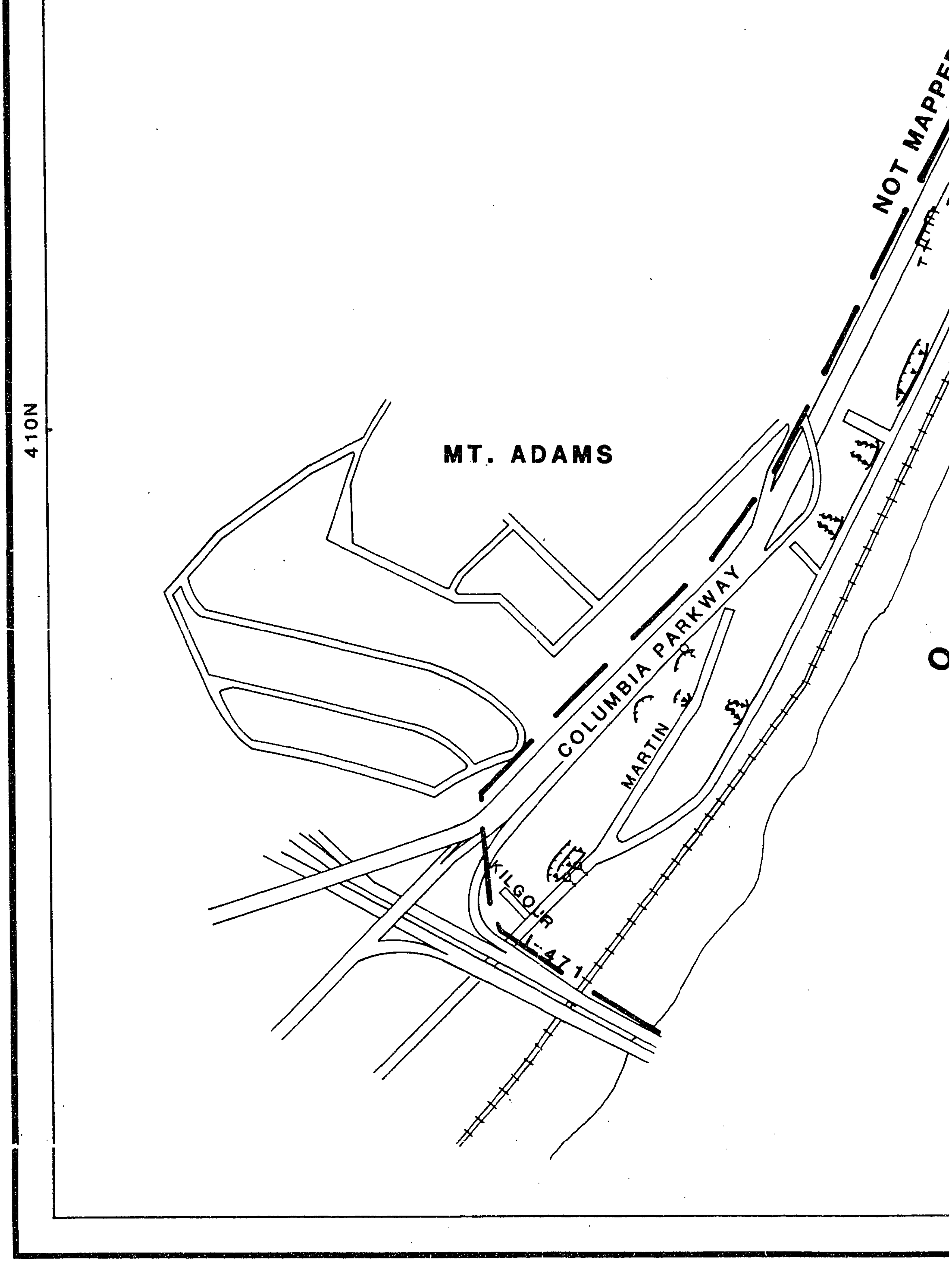
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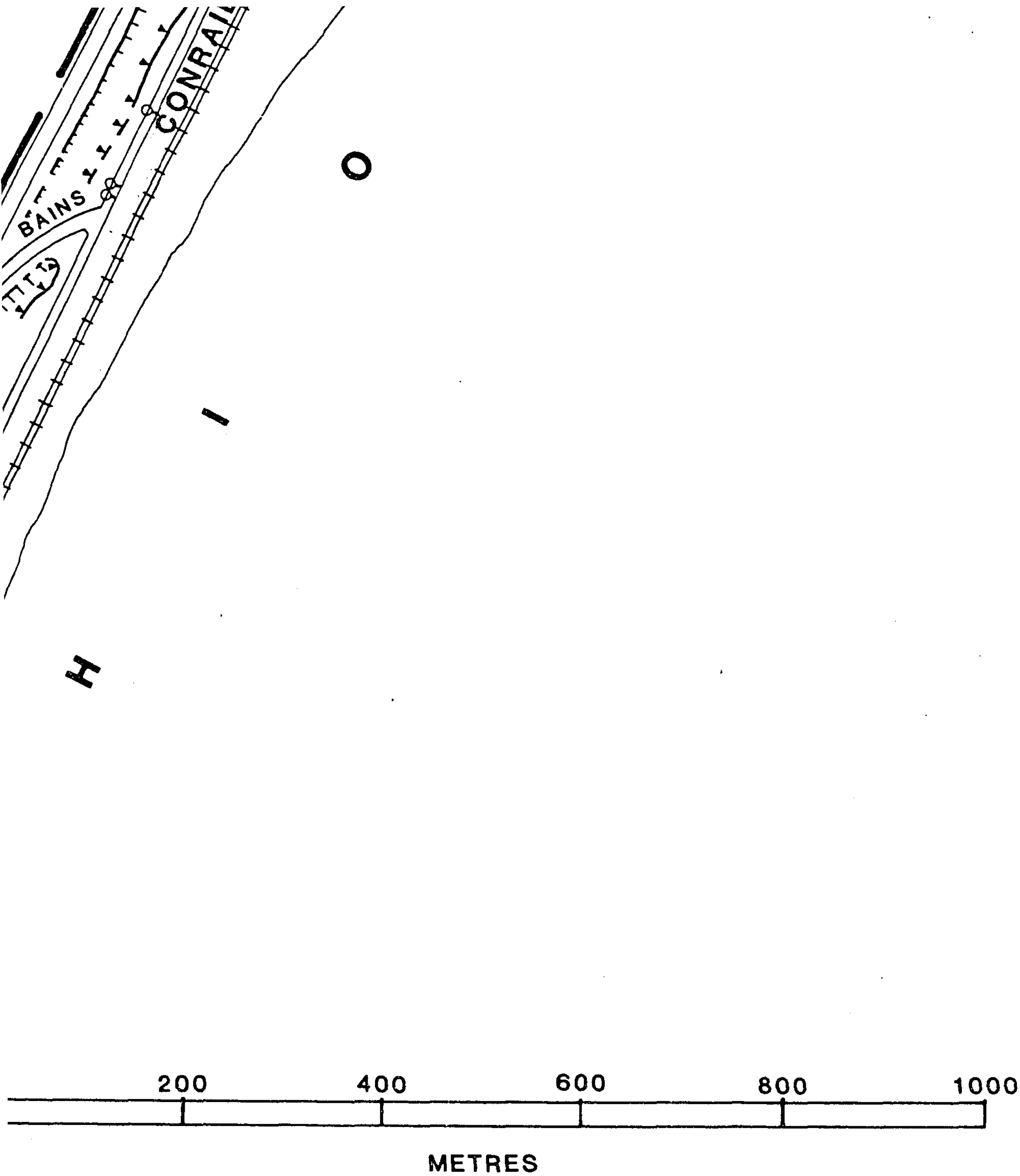

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6

LATERAL DISPLACEMENT IN CENTIMETRES

8

VERTICAL DISPLACEMENT IN CENTIMETRES

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TENSIONAL CRACK

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RAILROAD TRACKS

DISPLACEMENT IN CENTIMETRES

DISPLACEMENT IN CENTIMETRES

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RELATIVE STABILITY MAP OF
COLUMBIA PARKWAY AND EAS
CINCINNATI, OHIO

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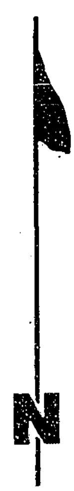

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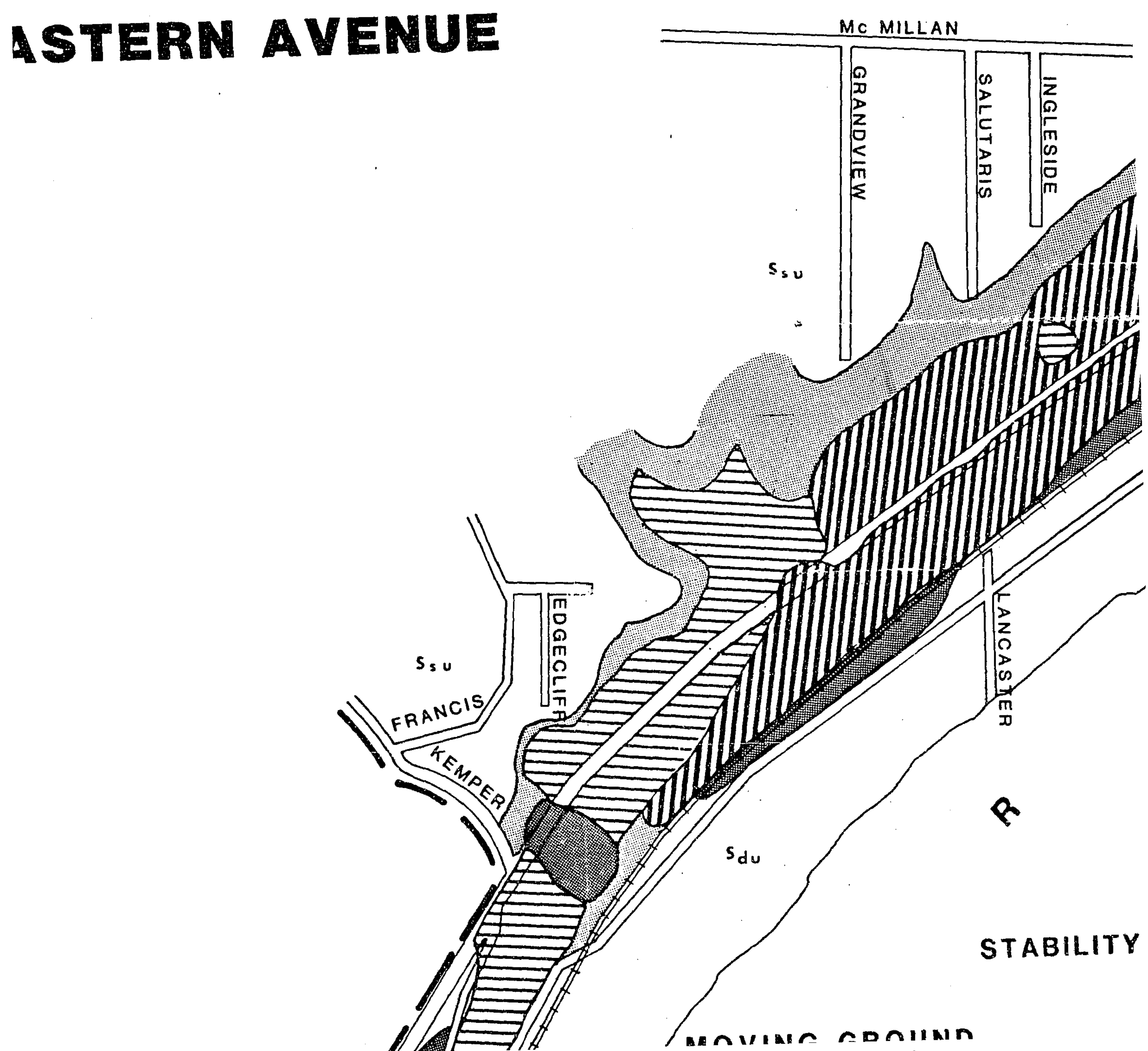
ASTERN AVENUE
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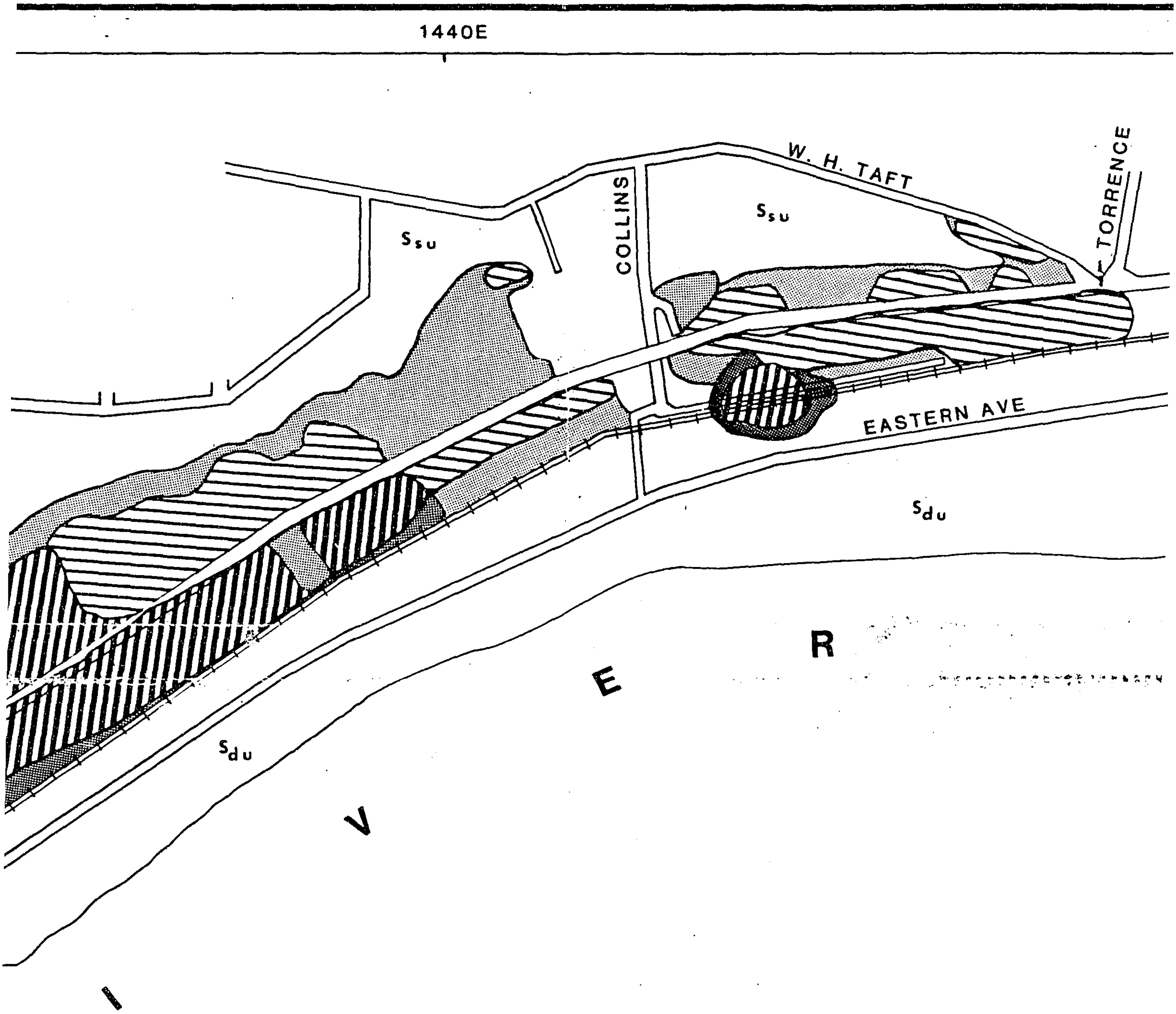

EXPLANATION

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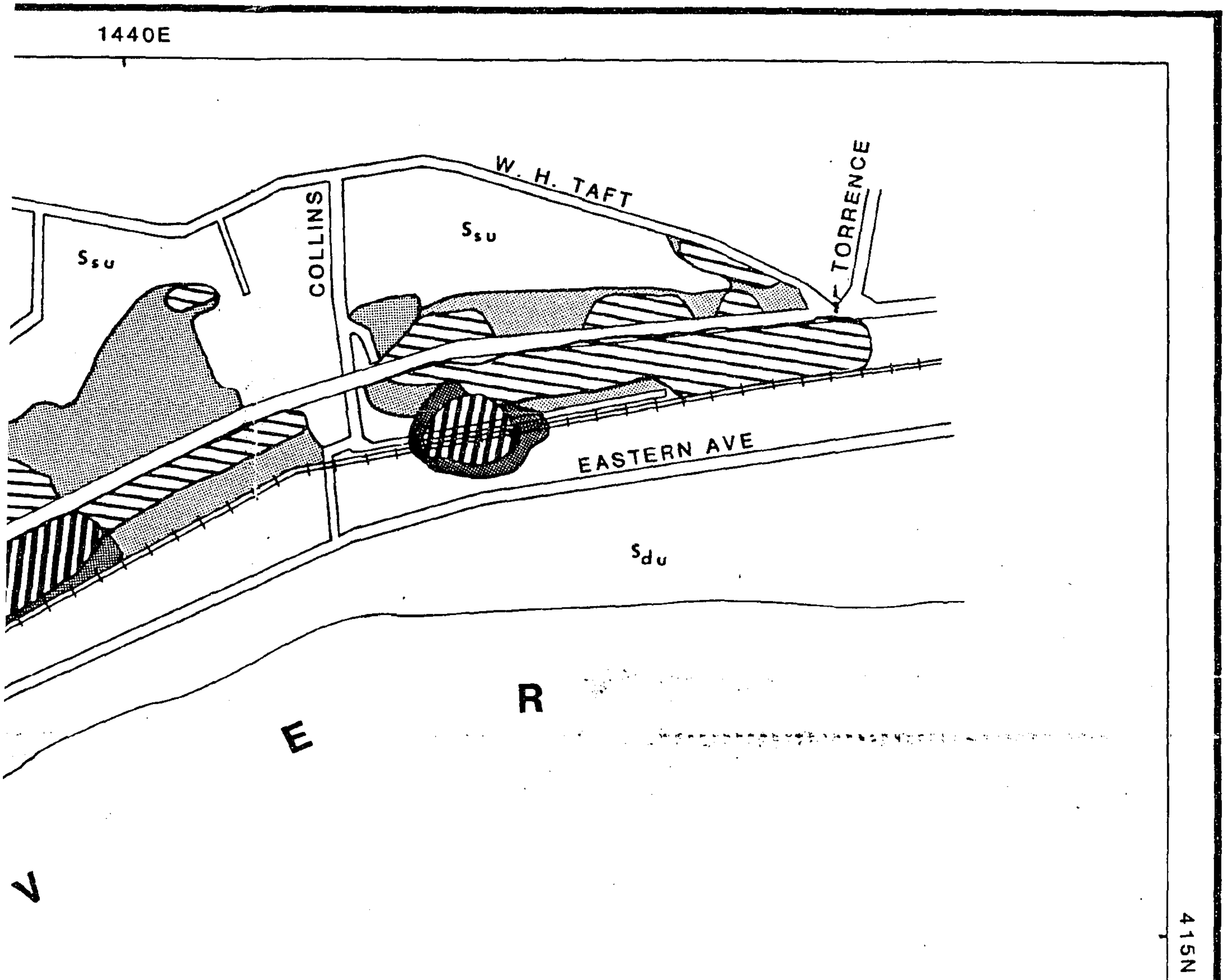
FURTHER INVESTIGATION



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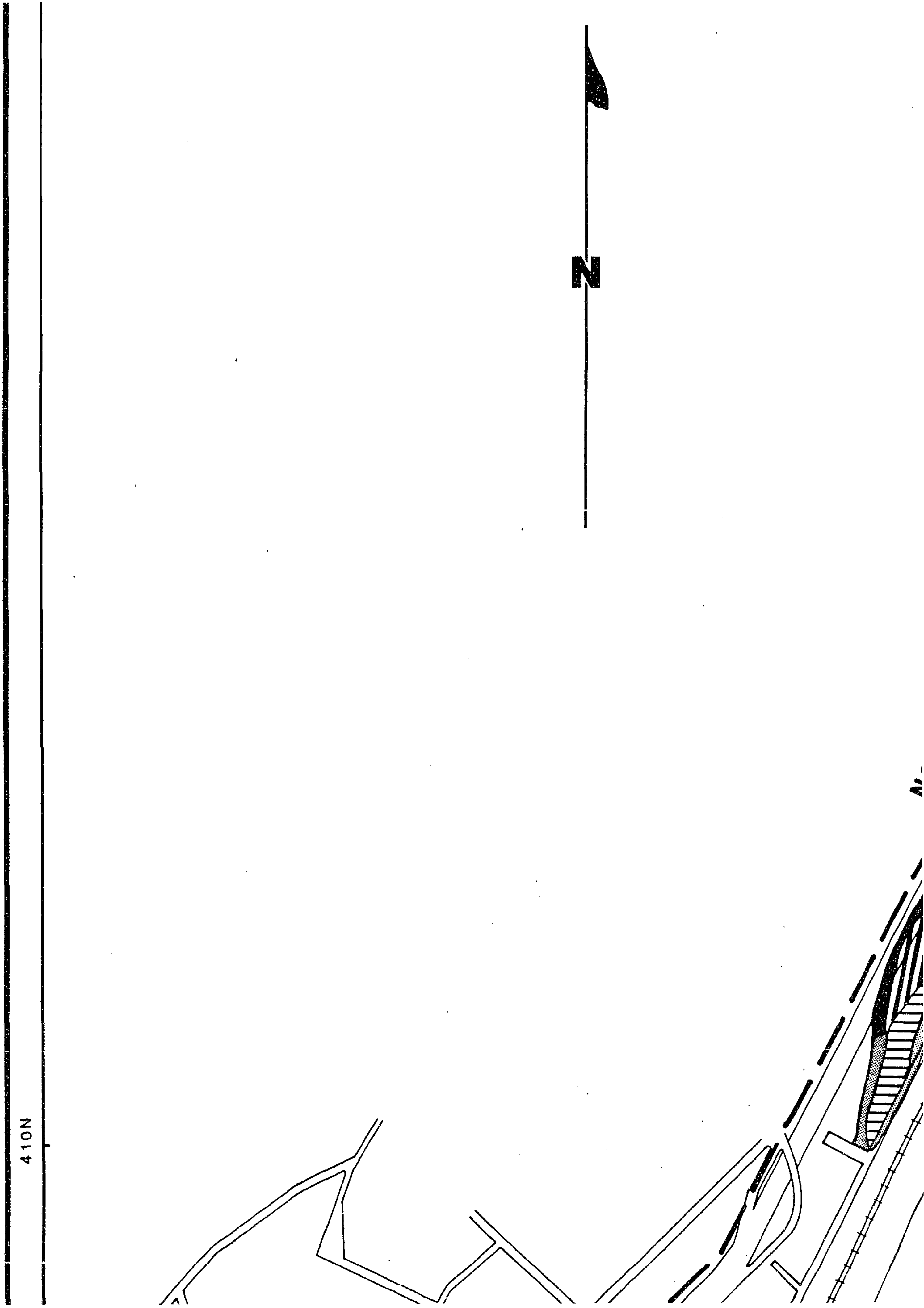
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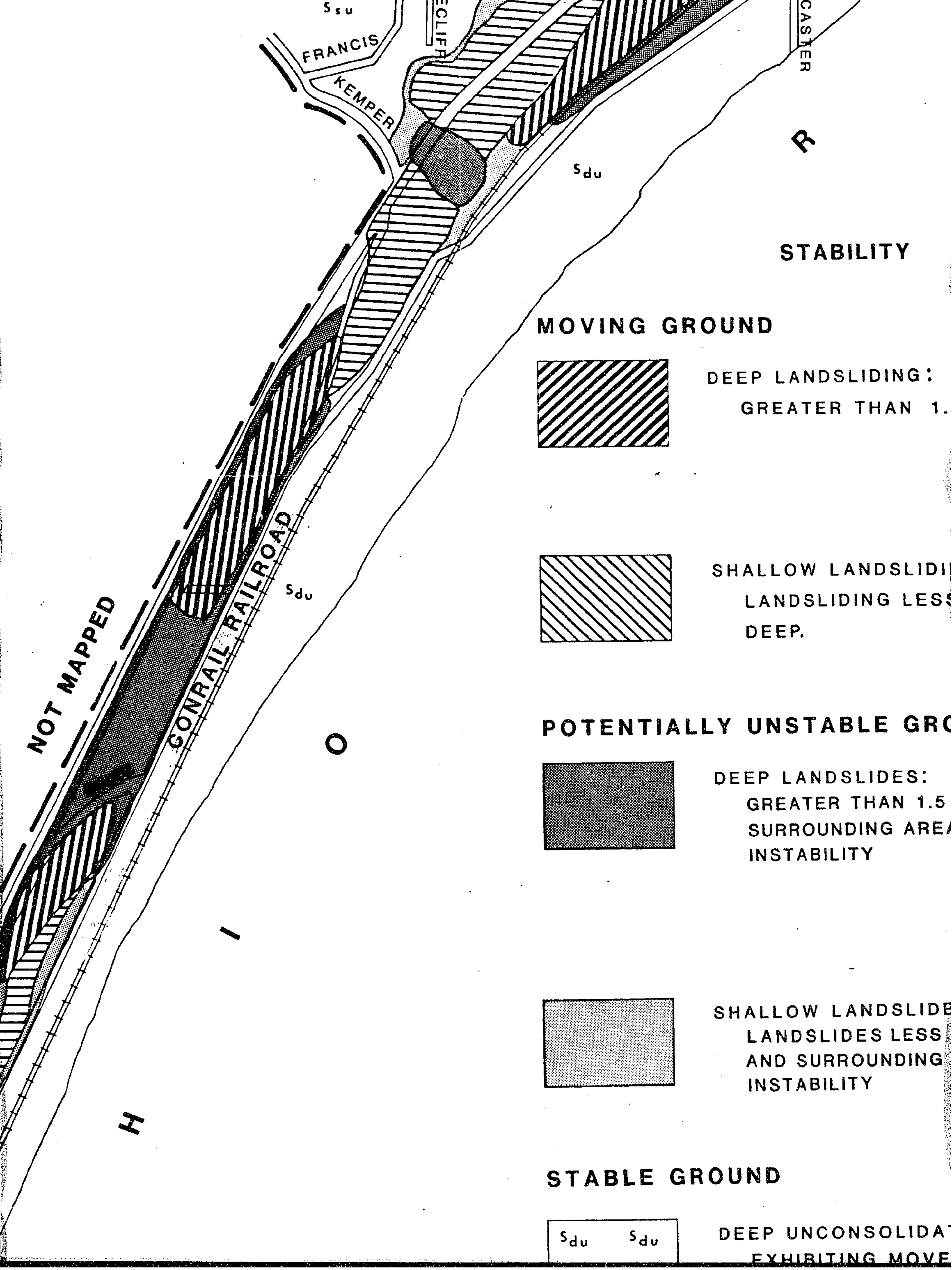
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MOVING GROUND
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AND SURROUNDING
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STABLE GROUND
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EXHIBITING MOVE

EXPLANATION

FURTHER INVESTIGATION

ACTIVE LANDSLIDING
.5 METRES DEEP.

1. IS THE LANDSLIDE ACTIVE?
   (MONITOR WITH INCLINOMETERS FOR SEVERAL MONTH
2. WHAT ARE THE DEPTH AND LATERAL BOUNDARIES OF L
   (MONITOR WITH INCLINOMETERS FOR SEVERAL MONT
3. WHAT ARE THE PORE-WATER PRESSURES?
   (MONITOR WITH PIEZOMETERS FOR SEVERAL MONTHS
4. HOW WOULD PROPOSED DEVELOPMENT STABILIZE THE

ING: ACTIVE
SS THAN 1.5 METRES

1. WHATARETHE DEPTH AND LATERAL EXTENT OF THE LANDS
   (TRENCH THE AREA)
2. HOW WOULD THE GROUND BE STABILIZED AS A RESULT
   DEVELOPMENT?

OUND

DORMANT LANDSLIDES
5 METERS DEEP AND
EAS OF POSSIBLE DEEP

1. WHAT ARE THE DEPTH AND LATERAL BOUNDARIES OF POT
   LANDSLIDES?
   (EXPLORE WITH BORINGS AND TRENCHES)
2. WHAT ARE THE PORE-WATER PRESSURES?
   (MONITOR WITH PIEZOMETERS FOR SEVERAL MONTHS
3. IS THERE ACTIVE LANDSLIDING?
   (MONITOR WITH INCLINOMETERS FOR SEVERAL MONTI
4. WHAT IS THE FACTOR OF SAFTEY AGAINST SLIDING?
5. HOW WILL STABILITY BE MAINTAINED?

DES: DORMANT
S THAN 1.5 METRES THICK
G AREAS OF SHALLOW

1. WHATARETHE DEPTH AND LATERAL EXTENT OF POTENT
   LANDSLIDES?
   (EXPLORE WITH TRENCHES AND BORINGS)
2. HOW WILL STABILITY BE MAINTAINED?

ATED: AREAS NOT

1. WHAT ARE THE MATERIALS, THEIR DISTRIBUTION AND EN

ANATION

FURTHER INVESTIGATION

IG

1. IS THE LANDSLIDE ACTIVE?
   (MONITOR WITH INCLINOMETERS FOR SEVERAL MONTHS)
2. WHAT ARE THE DEPTH AND LATERAL BOUNDARIES OF LANDSLIDING?
   (MONITOR WITH INCLINOMETERS FOR SEVERAL MONTHS)
3. WHAT ARE THE PORE-WATER PRESSURES?
   (MONITOR WITH PIEZOMETERS FOR SEVERAL MONTHS)
4. HOW WOULD PROPOSED DEVELOPMENT STABILIZE THE GROUND?

1. WHATARETHE DEPTH AND LATERAL EXTENT OF THE LANDSLIDE?
   (TRENCH THE AREA)
2. HOW WOULD THE GROUND BE STABILIZED AS A RESULT OF DEVELOPMENT?

DES

1. WHAT ARE THE DEPTH AND LATERAL BOUNDARIES OF POTENTIAL LANDSLIDES?
   (EXPLORE WITH BORINGS AND TRENCHES)
2. WHAT ARE THE PORE-WATER PRESSURES?
   (MONITOR WITH PIEZOMETERS FOR SEVERAL MONTHS)
3. IS THERE ACTIVE LANDSLIDING?
   (MONITOR WITH INCLINOMETERS FOR SEVERAL MONTHS)
4. WHAT IS THE FACTOR OF SAFTEY AGAINST SLIDING?
5. HOW WILL STABILITY BE MAINTAINED?

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1. WHATARETHE DEPTH AND LATERAL EXTENT OF POTENTIAL LANDSLIDES?
   (EXPLORE WITH TRENCHES AND BORINGS)
2. HOW WILL STABILITY BE MAINTAINED?

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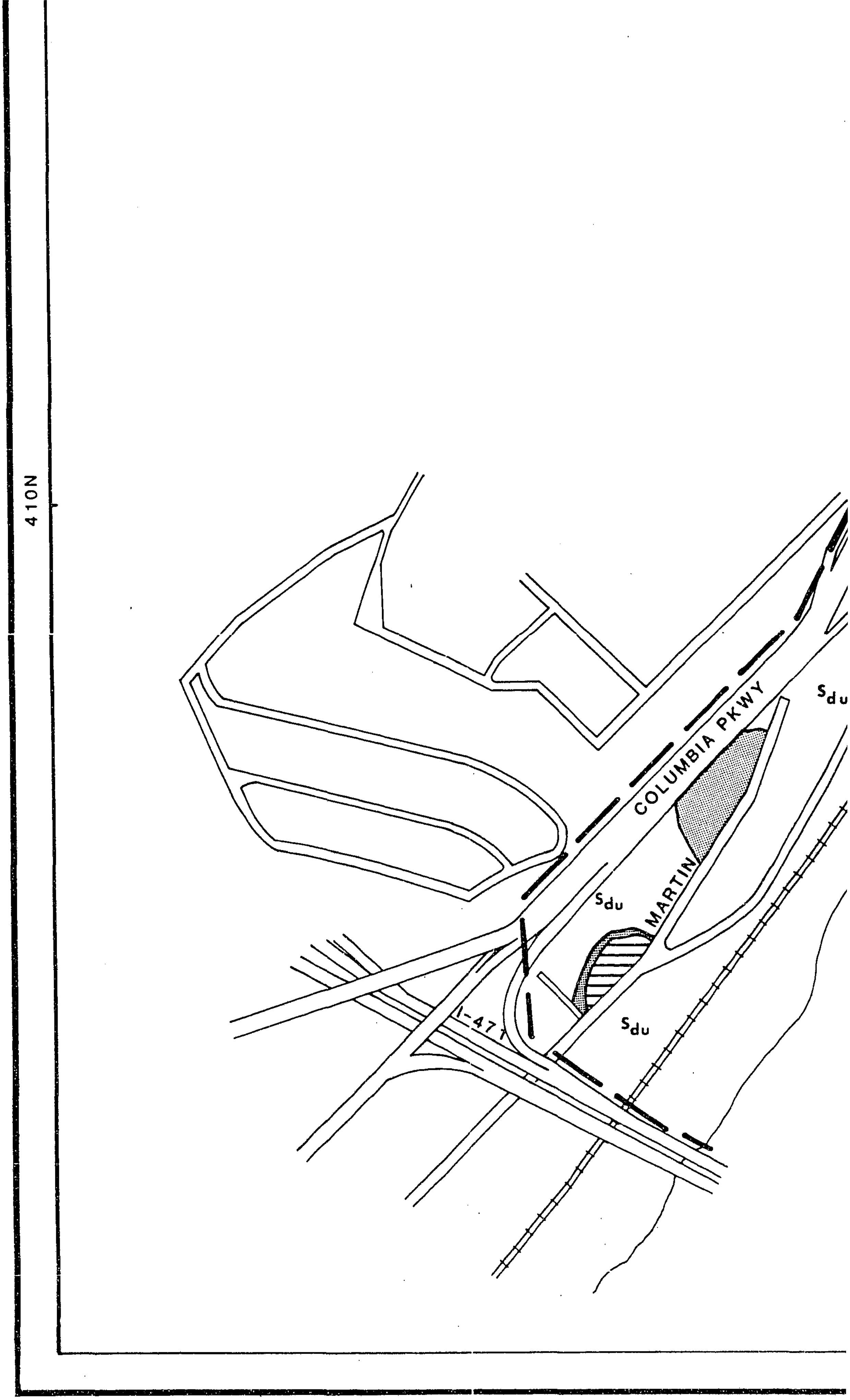
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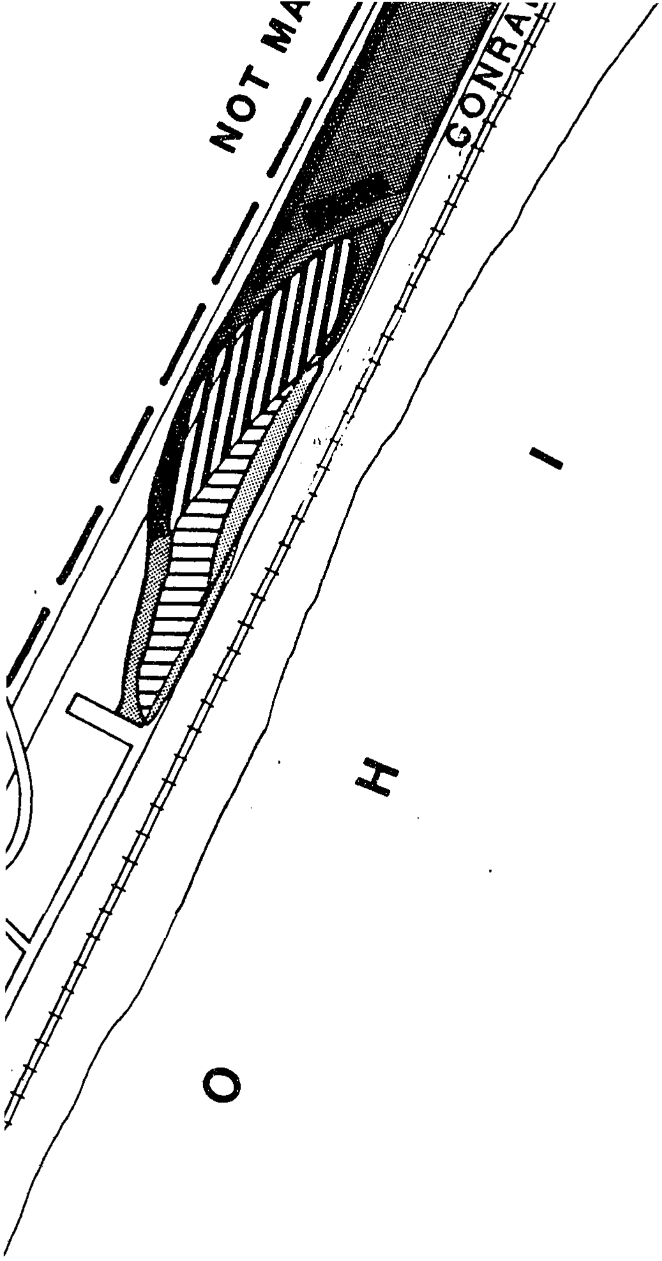

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DEEP.

DEVELOPMENT?

UNSTABLE GROUND

EP LANDSLIDES: DORMANT LANDSLIDES GREATER THAN 1.5 METERS DEEP AND SURROUNDING AREAS OF POSSIBLE DEEP INSTABILITY	1. WHAT ARE THE DEPTH AND LATERAL LANDSLIDES? (EXPLORE WITH BORINGS AND TR 2. WHAT ARE THE PORE-WATER PRES (MONITOR WITH PIEZOMETERS FO 3. IS THERE ACTIVE LANDSLIDING? (MONITOR WITH INCLINOMETERS F 4. WHAT IS THE FACTOR OF SAFTEY 5. HOW WILL STABILITY BE MAINTAINE
ALLOW LANDSLIDES: DORMANT LANDSLIDES LESS THAN 1.5 METRES THICK AND SURROUNDING AREAS OF SHALLOW INSTABILITY	1. WHATARETHE DEPTH AND LATERAL LANDSLIDES? (EXPLORE WITH TRENCHES AND E 2. HOW WILL STABILITY BE MAINTAIN

ND

EP UNCONSOLIDATED: AREAS NOT EXHIBITING MOVEMENT. DOMINATED BY DEEP DEPOSITS OF ALLUVIUM, COLLUVIUM AND FILL	1. WHAT ARE THE MATERIALS, THEIR D PROPERTIES? (EXPLORE WITH BORINGS, TEST PI 2. WHERE IS THE GROUNDWATER TABL (MONITOR WITH BORINGS) 3. HOW MUCH SETTLEMENT WILL OCCU (CALCULATE USING INFORMATION F 4. HOW COULD INSTABILITY BE INTROD
ALLOW UNCONSOLIDATED: AREAS NOT EXHIBITING MOVEMENT DOMINATED BY THIN DEPOSITS OF COLLUVIUM AND FILL.	1. FOUND STRUCTURES ON BEDROCK.

0 200 400 600 800 1000

METRES

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DEVELOPMENT?

IDES

P

1. WHAT ARE THE DEPTH AND LATERAL BOUNDARIES OF POTENTIAL LANDSLIDES?
   (EXPLORE WITH BORINGS AND TRENCHES)
2. WHAT ARE THE PORE-WATER PRESSURES?
   (MONITOR WITH PIEZOMETERS FOR SEVERAL MONTHS)
3. IS THERE ACTIVE LANDSLIDING?
   (MONITOR WITH INCLINOMETERS FOR SEVERAL MONTHS)
4. WHAT IS THE FACTOR OF SAFTEY AGAINST SLIDING?
5. HOW WILL STABILITY BE MAINTAINED?

ICK

1. WHATARETHE DEPTH AND LATERAL EXTENT OF POTENTIAL LANDSLIDES?
   (EXPLORE WITH TRENCHES AND BORINGS)
2. HOW WILL STABILITY BE MAINTAINED?

BY
VIUM

1. WHAT ARE THE MATERIALS, THEIR DISTRIBUTION AND ENGINEERING PROPERTIES?
   (EXPLORE WITH BORINGS, TEST PITS AND SOIL TESTS)
2. WHERE IS THE GROUNDWATER TABLE?
   (MONITOR WITH BORINGS)
3. HOW MUCH SETTLEMENT WILL OCCUR AS A RESULT OF DEVELOPMENT?
   (CALCULATE USING INFORMATION FROM BORINGS AND SOIL TESTS)
4. HOW COULD INSTABILITY BE INTRODUCED BY PROPOSED DEVELOPMENT?

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FILL.

1. FOUND STRUCTURES ON BEDROCK.

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METRES

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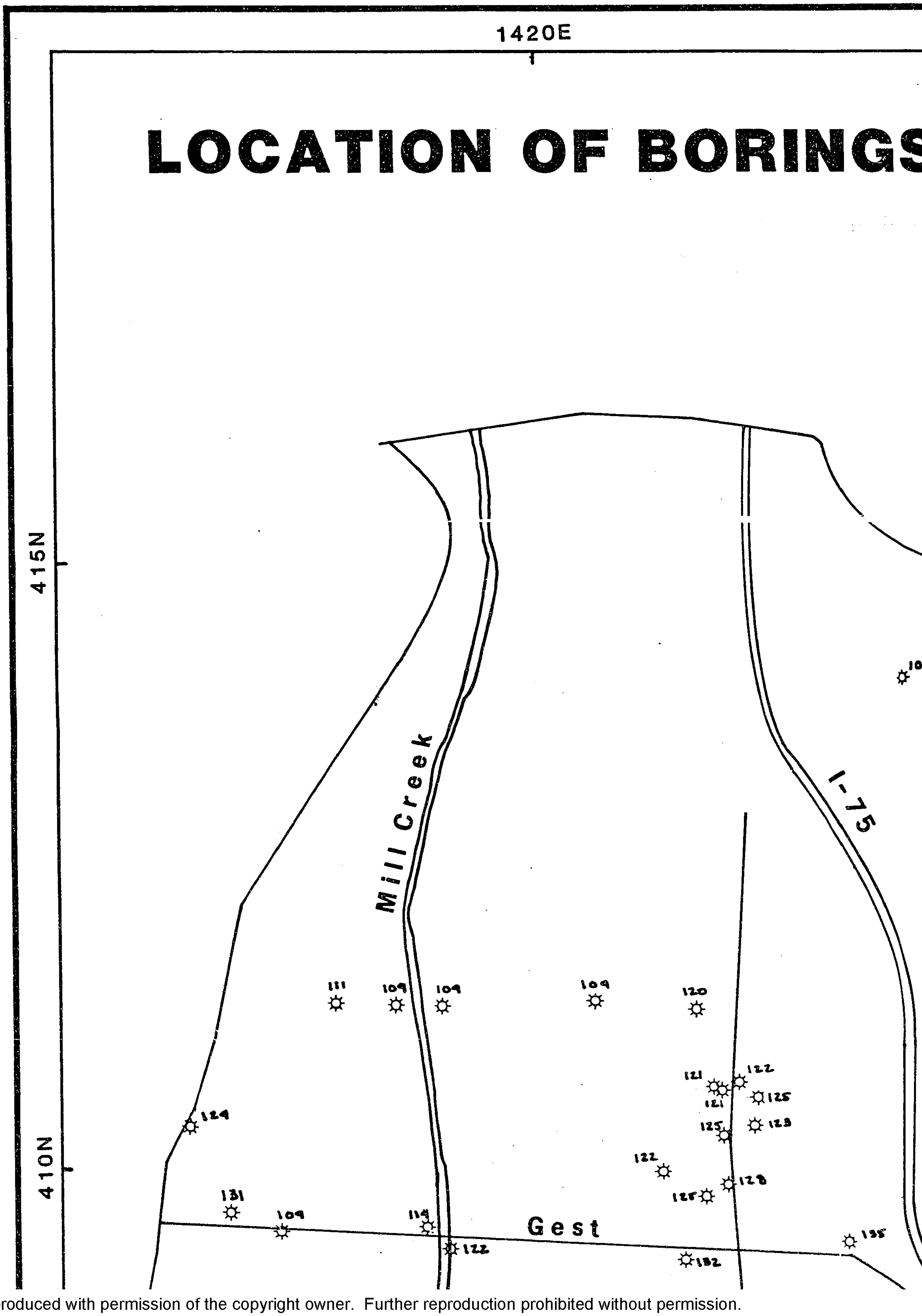
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LOCATION OF BORINGS
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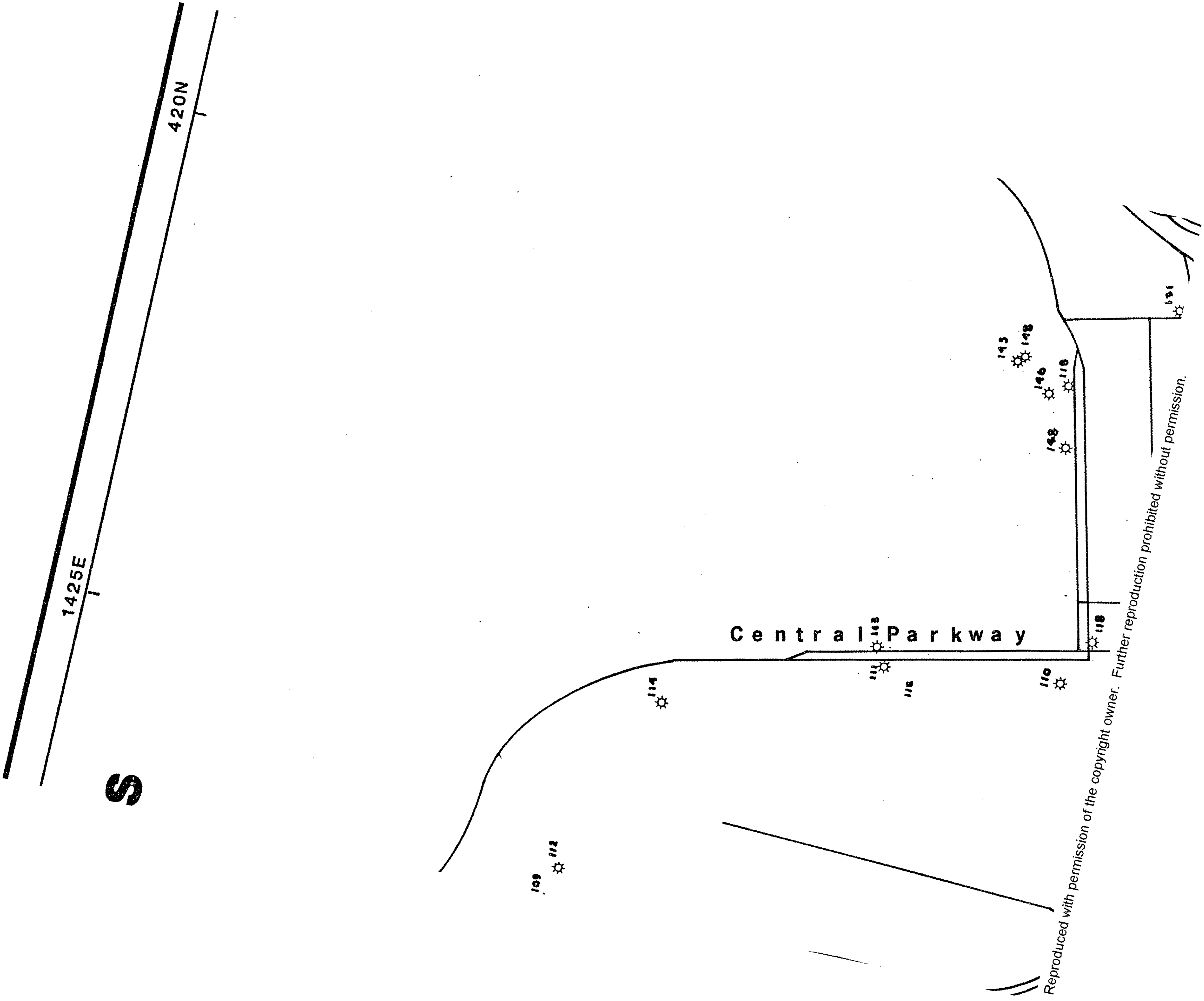
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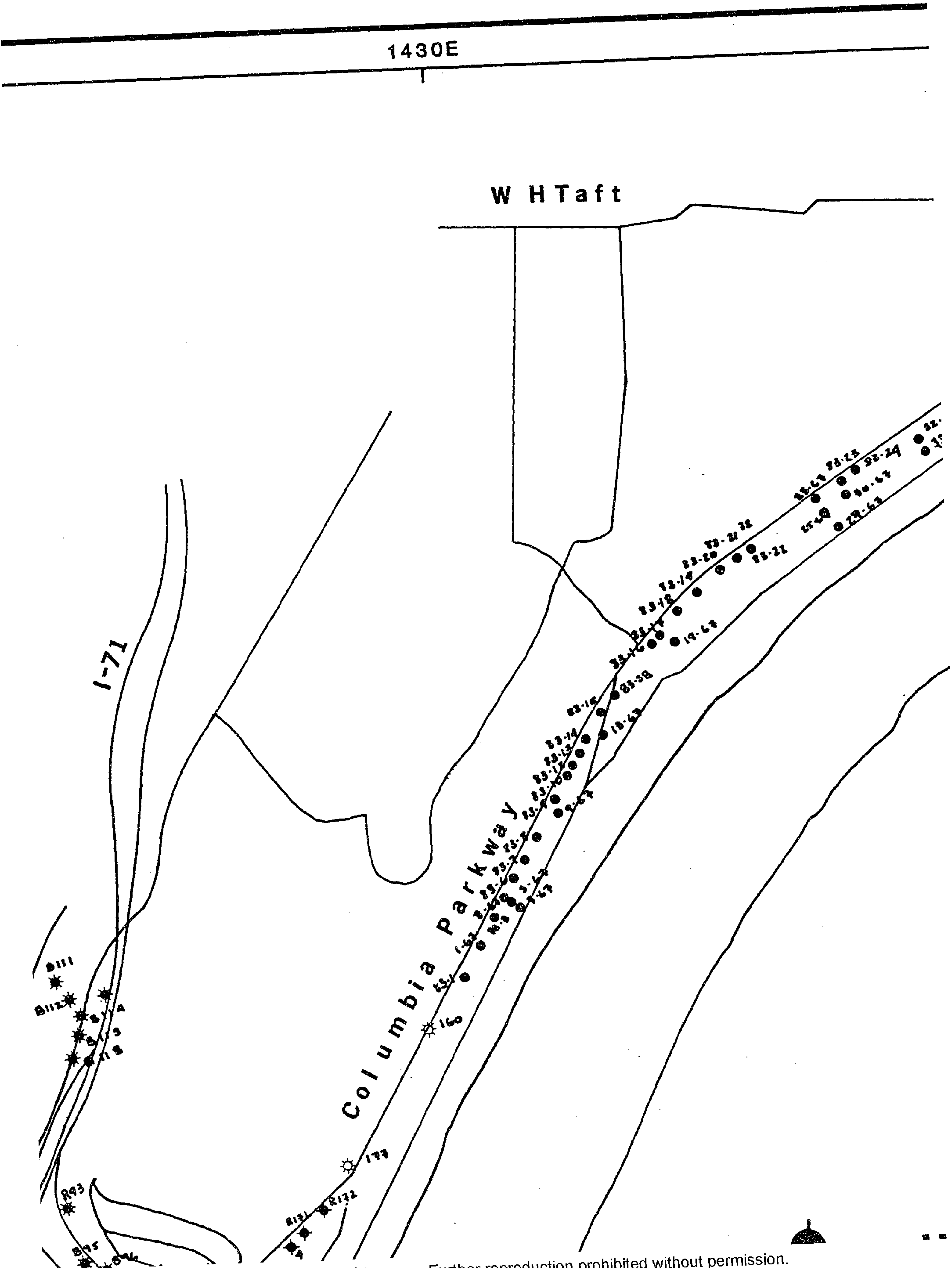
Central Parkway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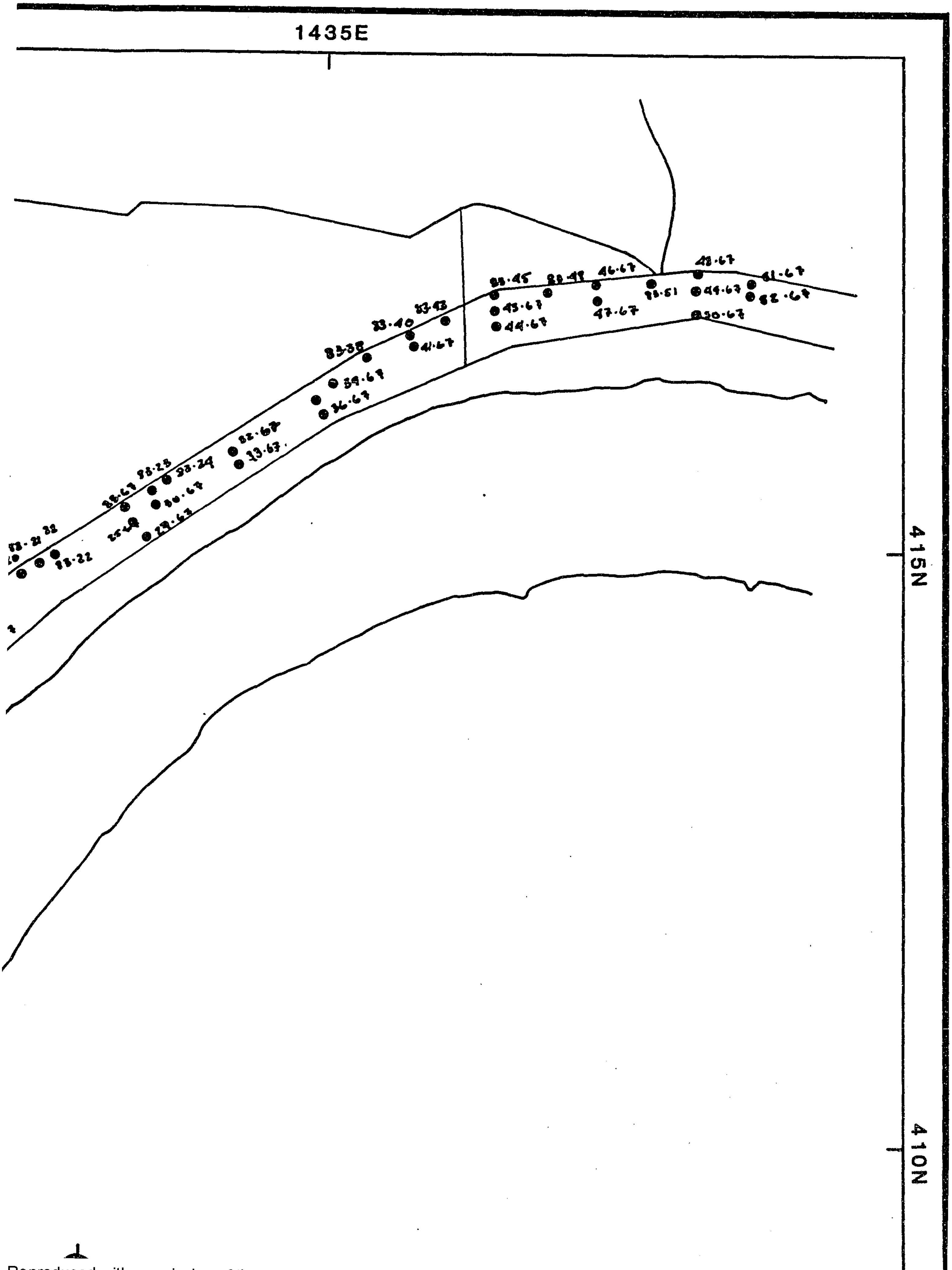
Columbia Parkway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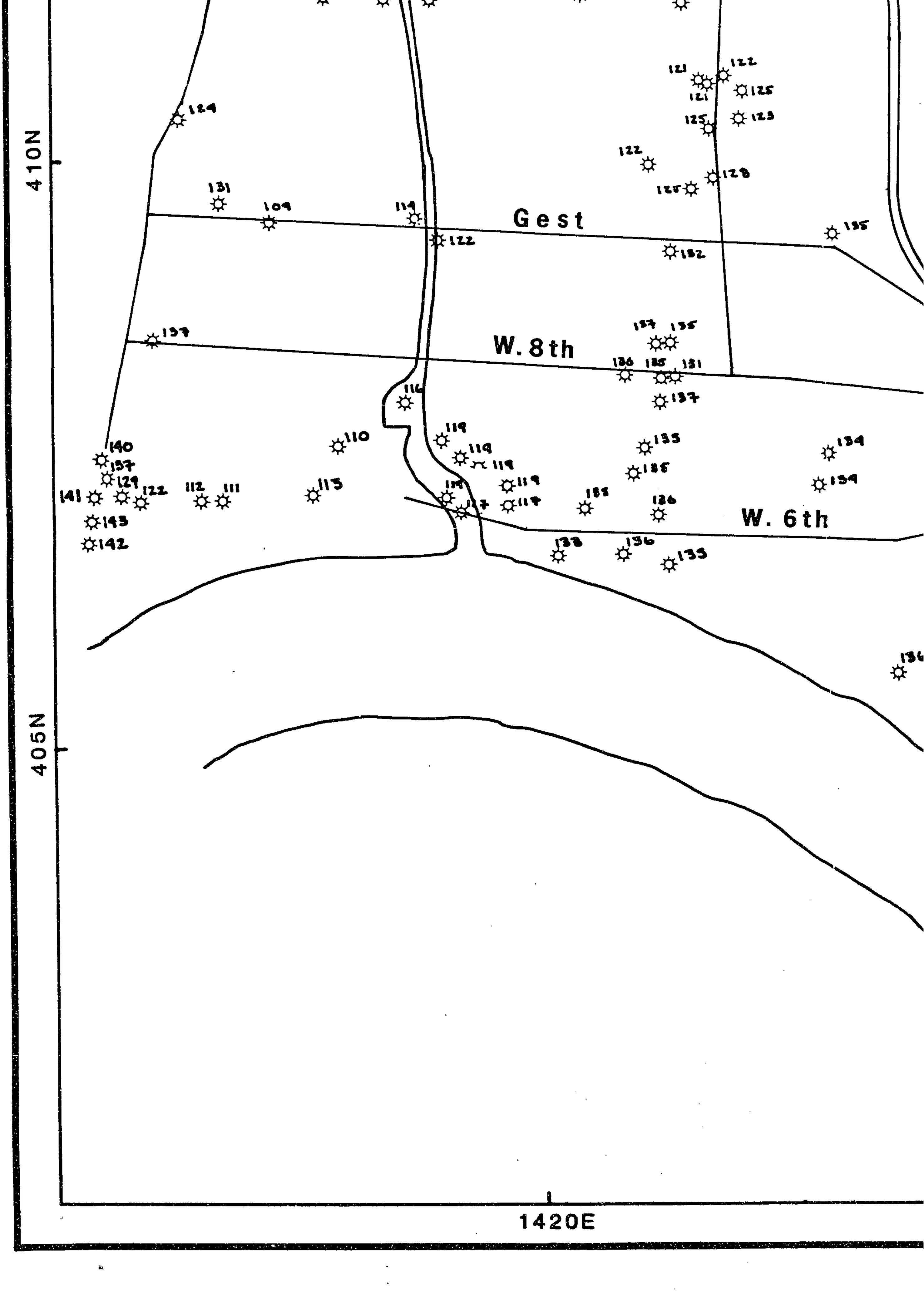
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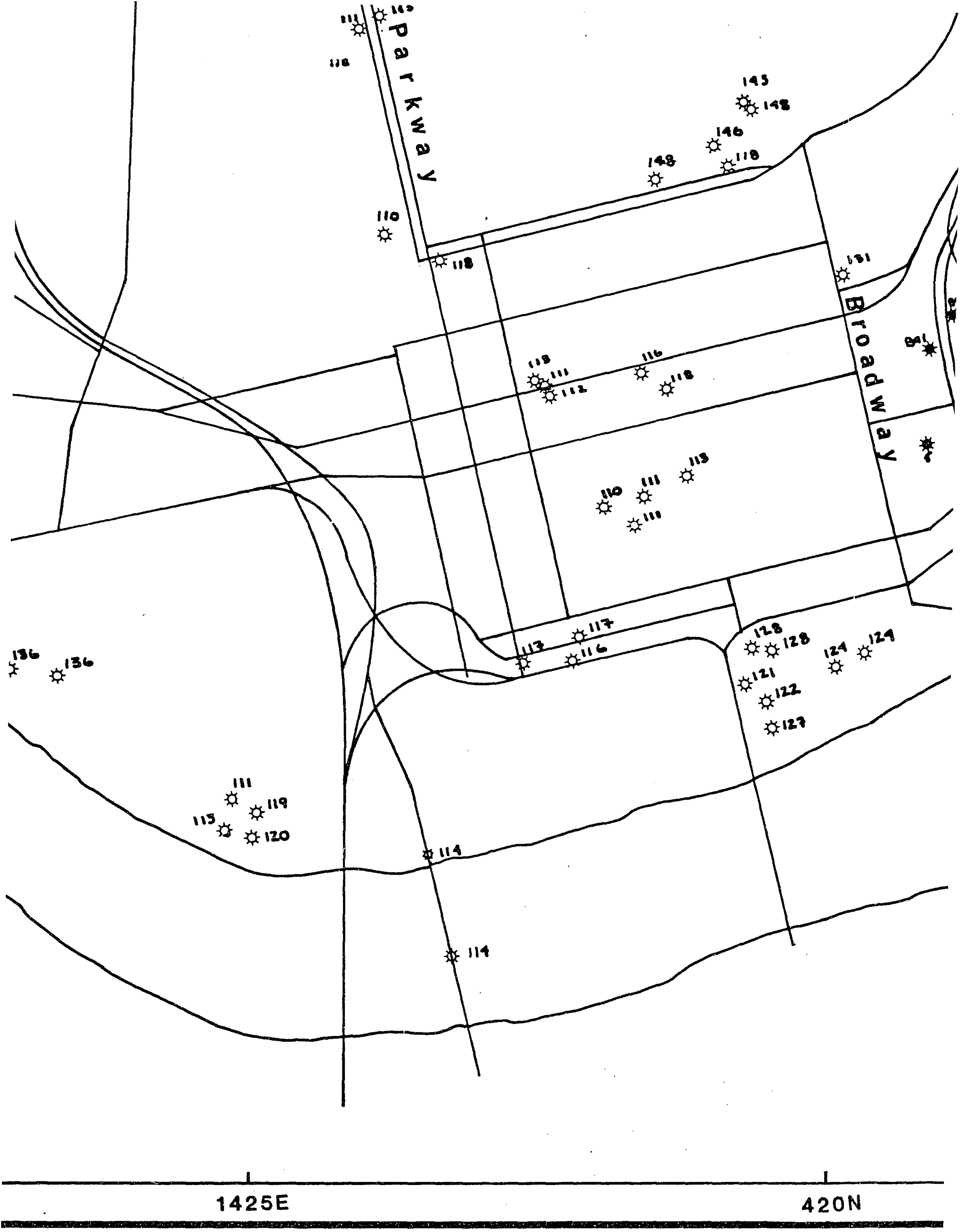
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Broadway
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R. H. DURRELL 1961

BOREHOLE LOGS IN APPENDIX B

ALTITUDE OF TOP OF BEDROCK
IN METRES

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