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AN EXAMINATION OF THE POTENTIAL TO REDUCE THE COST
OF AN UNDERGROUND LRT ALIGNMENT THROUGH
GEOLOGIC PLANNING AND TECHNOLOGICAL INNOVATION

PHASE 1

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By

AMERICAN UNDERGROUND-SPACE ASSOCIATION
511 11th Avenue South Box 320
Minneapolis, MN 55415

(612) 339-5403

Susan Nelson, Executive Director

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Technical input was received from AUA members:

Russell K. McFarland
Vice President, Operations
UTD, Incorporated
8220 Russell Road
Alexandria, VA 22309

Charles R. Nelson
Vice President, Engineering
CNA Consulting Engineers
2800 University Avenue S.E.
Minneapolis, MN 55414

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INTRODUCTION

The question of whether Twin Cities Metropolitan Region transportation needs should be served by fixed rail transit has been debated for many years. It appears that the issue may be approaching resolution as a result of the formation of the Regional Transit Board (RTB) and recent activity on the part of Hennepin County in forming a Regional Rail Authority and moving ahead with planning activity.

Some important questions about light rail (LRT), such as the capacity of the system, are being answered, but others are not resolved. One of these is whether to site portions of a light rail system underground. While many decisionmakers endorse the worth of an underground alignment in at least the most densely developed urban areas, the cost versus benefit to construct underground versus a surface alignment has been an important factor.

The benefits of an underground transit alignment are many. Primary among them are the benefits associated with any grade-separated or dedicated right-of-way, namely reliability. By avoiding direct interaction with other vehicles, and associated congestion on busy streets, riders are assured of predictable, on-time transportation. An underground alignment also avoids the visual impairment of an elevated alignment, such as the "El" in Chicago, in areas where no other dedicated right-of-way exists.

Minnesota's severe winters offer another excellent reason to consider the protection of a subsurface alignment. The effect of a few inches of snow on vehicular traffic is all too familiar to Twin Cities residents. An underground alignment, particularly in

the most congested urban centers, would assure mobility and transportation in the worst weather.

The purpose of the AUA Transit Study is to determine whether the cost of providing an underground alignment in the Metropolitan Region can be reduced, rendering such an underground alignment more attractive. Recognizing the importance of a favorable geology to underground construction cost, Phase I of the study examines surficial and bedrock geology of the Metropolitan Region, and identifies areas believed to be favorable for an underground alignment. In addition, innovations are occurring in tunneling technology and underground space utilization which may be applicable to transit in this area. Phase II of the study will examine innovation which may reduce the cost of tunneling in the Metropolitan Region.

While the Study is generally regional in scope, particular attention has been given to Minneapolis in this Phase I report. This is due to LRT planning activity by Hennepin County and the imminence of decisions regarding LRT alignments in Minneapolis's downtown.

Geologic data in this report are based on the most current maps published by the Minnesota Geologic Survey. While the information in this report is suitable for a large scale assessment of the physical potential for an underground alignment, detailed geotechnical investigation is necessary to confirm the suitability of proposed underground alignments.

UNDERGROUND CONSTRUCTION METHODS

There are two basic ways to construct space in the subsurface; cut and cover construction, and mining or tunneling techniques.

Cut and Cover Construction is a method whereby a trench is opened at the surface, the desired space is created, then covered with soil on completion. This type of construction is commonly used at shallow depths or in situations where surrounding soils or rock are not competent to safely accommodate the size of the space desired if created by mining or tunneling techniques.

Cut and Cover construction is usually disruptive to surface activity in urbanized areas. It involves rerouting or diverting traffic, limiting or eliminating access to commercial activities, and relocation of underground utilities.

Mining and/or Tunneling Methods involve gaining access to the strata to be excavated and performing most of the construction underground. These techniques generally have the benefit of avoiding disruption to surface activity and the large-scale relocation of services which accompanies cut and cover construction. Tunneling can be performed in either soils or bedrock. Because ground conditions cannot be observed before construction, thorough geologic investigation is necessary to minimize potential problems and construction delay resulting from unforeseen geologic conditions for any type of underground construction.

Three scenarios for an underground alignment and/or transit stations in the Twin Cities have been suggested in previous reports: 1) cut and cover; 2) shallow tunnel; 3) deep tunnel.

Cut and cover construction would take place at shallow depths. These Alignments are confined to street rights-of-way or open space due to the presence of surface structures such as buildings and building foundations.

Shallow tunnels have been proposed in glacial soils at a depth of approximately 40 feet. Again, due to the presence of surface structures such as building foundations and sub-basements, a shallow tunnel alignment will be confined to the street system or open space. Stations in this strata would be constructed by the cut and cover method.

Deep tunnels have been proposed for the St. Peter sandstone, at a depth of approximately 100 to 120 feet. Tunneling at this depth is not confined to the street system since construction would occur beneath all existing structures. A deep tunnel alignment therefore allows maximum flexibility in transit routing. Stations at this elevation would be constructed by mining or tunneling techniques.

THE IMPORTANCE OF GEOLOGY TO THE COST OF UNDERGROUND PROJECTS

There are several significant cost elements in the provision of underground transit alignments, and most of them relate to the geology in which construction will occur. Therefore, it is extremely important to gather pertinent geologic data in the early planning stages of a project to assure that development is as cost-effective as possible.

The major cost elements of an underground transit alignment are:

- o type of rock or soil
- o local experience base
- o construction equipment expense
- o advance or production rates
- o presence or absence of existing underground structures
- o portal opportunities and scenarios
- o tunnel lining and/or support required
- o depth of the alignment and stations, i.e. cost of vertical access
- o length of system

The geology in which a project will occur is basic to all other costs. Whether construction occurs in soil or rock, homogeneous or mixed materials, horizontal beds or vertical ones, hard or soft rock, water-laden or dry materials, all influence construction cost. The ideal situation is where construction occurs in homogeneous, flat-bedded, dry, workable materials. However, underground projects have been built under all types of conditions through necessity. For instance, a coal mine operates in inclined beds at 10,500 feet in the Rockies - a very difficult

and unpredictable situation - but worthwhile because the coal is valuable. An expansion of the Washington, D.C., Metro is taking place beneath the Anacostia River in materials which vary from lenses of fine sands to clays to soils - again very unpredictable, but necessary to provide desired transit service.

Geology determines the type of equipment necessary to construct the space. Tunnel Boring Machines and other types of tunneling equipment are being used successfully in soils and rock to create the type and shape of space necessary. The type and hardness of soil or rock determines the equipment to be used and the production rates achievable.

Drill and blast techniques, where rock is broken by explosives and then removed, is generally used in medium to hard bedrock, but recent advances in tunneling technology have encouraged more extensive use of tunneling machines as production rates in even the hardest rocks have shown dramatic increase.

An important cost factor in underground transit is the cost to move riders between station level and the surface. Depth of alignment can be influenced by geologic as well as other factors. If more favorable tunneling conditions are found in deeper strata, a judgment must be made whether the savings to be realized offset the cost of providing more extensive vertical conveyance.

As our cities have evolved, more and more of their supporting infrastructure has been sited in the subsurface at various depths. It is most common to find sanitary and storm sewer at the greatest depths, with services such as electrical

and gas utilities nearer the surface. It is advisable to avoid relocating such services when siting an underground alignment when possible, due to the expense incurred.

Grade changes and portal opportunities are also a function of geology or topography, as well as existing surface and underground uses. The ideal portal situation for an underground alignment is to enter the strata to be excavated horizontally. This is possible in areas where the topography consists of bluffs, hills or escarpments. In flat areas, the subsurface must be entered by creating an inclined access to the desired depth. The difficulty and cost of such an access depend on the depth of the proposed alignment and the material which must be excavated.

The amount of structural support required to assure the safety and reliability of underground construction also depends on the geology of the surrounding material. In very hard rock, large spans can be created with little structural support. Weaker rock may require rock reinforcement, or may require the use of tunnel linings, or other support. Tunnels in soils require the use of strong linings, both to finish the space, but also to offset the pressure of surrounding soils and to maintain the safety of the tunnel.

The total cost of an underground alignment is directly related to the length of the segment and the ease or difficulty of construction. Economies of scale can be realized in several ways. First, equipment, mobilization and training can be written off over more work. Second, different technology can be developed for long term projects than for short ones. A steady stream of work over several years is most efficient.

THE IMPORTANCE OF PLANNING

Planning for underground projects can save time and money. Planning relies on good data, but often information necessary for planning underground projects is either unavailable or located in several agencies.

As mentioned in the previous section, geology is critical to the cost of an underground project. Planning for an underground alignment should begin with an investigation of the geology of alternative alignments to identify favorable areas as well as those which should be avoided. Choosing alignments to maximize favorable geology can reduce the cost of a project by avoiding difficult geologic situations and the cost to mitigate them.

Knowledge of the nature and location of existing structures in the subsurface may also influence route selection. Avoidance of existing structures, to the maximum extent possible, reduces project cost.

GEOLOGY OF THE TWIN CITIES METROPOLITAN REGION

The Twin Cities Metropolitan Region is underlain by essentially flat-bedded sedimentary rocks, deposited by ancient seas over millions of years, forming the Twin Cities Structural and Hydrologic basin. These rocks have eroded and are covered by unconsolidated soils left by retreating glaciers in more recent geologic time. The stratigraphy of Regional soils and bedrock is shown in the geologic column in figure 1.

The strata at the upper levels of the column are of greatest importance when considering underground construction in the Metropolitan Region. These layers are the Glacial drift, Decorah shale, Platteville limestone, Glenwood shale and St. Peter sandstone.

Surficial Geology

Glacial drift is composed of unconsolidated soils and ranges from an average depth of 50 feet near the Minneapolis CBD to a depth of several hundred feet in outlying areas. While the soils are a complex mix of lenses of varied deposits, a review of their engineering properties indicates that underground construction is generally possible in some of these soils either by the cut and cover method or by shallow tunneling.

The Minnesota Geological Survey has identified 26 categories of soils in the Metropolitan Region. They are glacial and post-glacial deposits and fall into four major groups: Superior Lobe deposits, Des Moines Lobe deposits, Terrace deposits and Postglacial deposits. For the purposes of this study, the

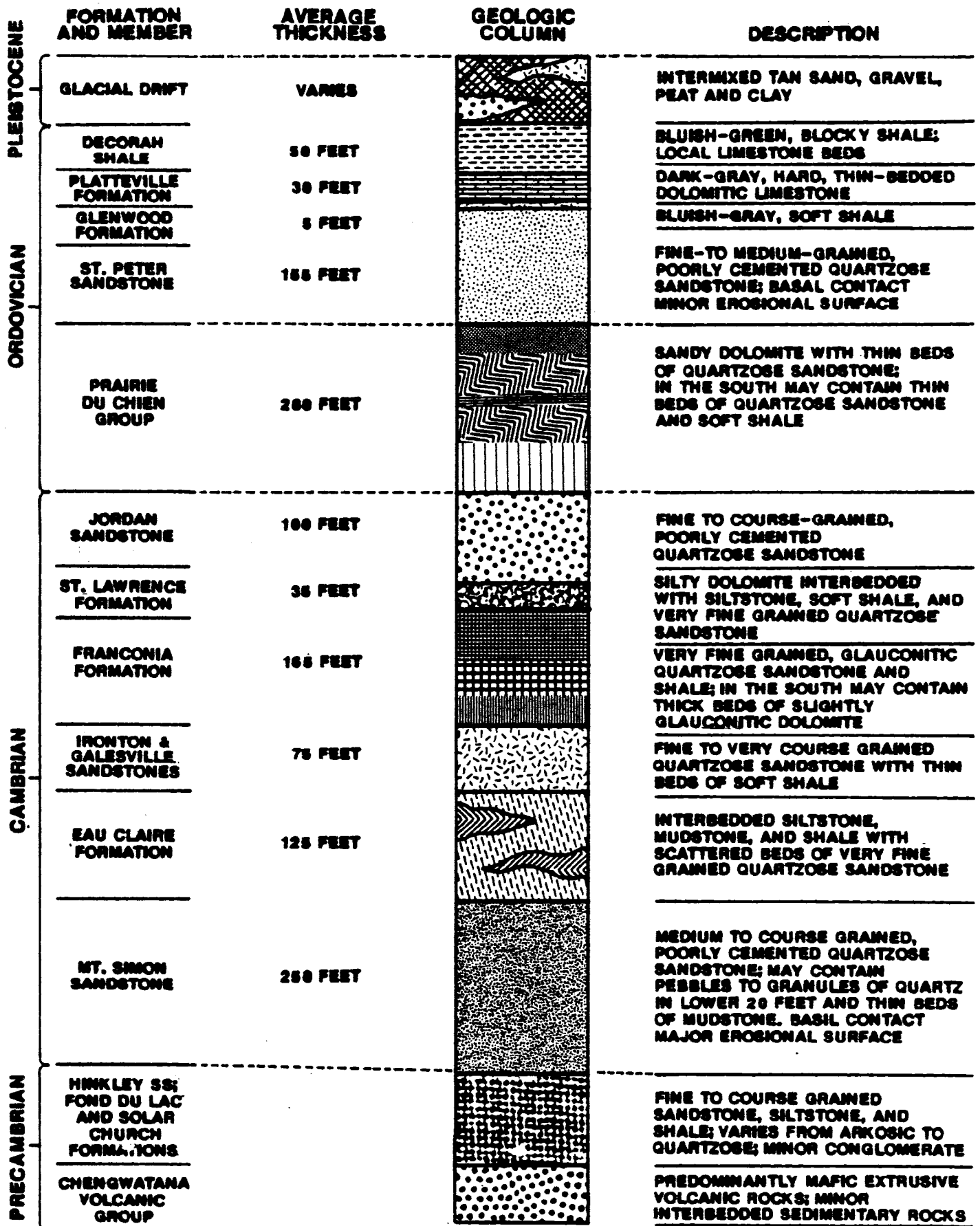


Figure 1
Geologic Column

SOURCES
Liesch, S.A. 1961, Geohydrology of the Jordan Aquifers, Minneapolis-St. Paul Metropolitan Area.
Minnesota Department of Conservation, Division of Water, Technical Paper No. 2, 24 PP Jirsa, Mark A. Olsen, Bruce M. Bloomgren, Bruce A. 1966

Bedrock Geologic Map of the Seven County Twin Cities Metropolitan Area, Minnesota By Jirsa, Mark A. Olsen, Bruce M. and Bloomgren, Bruce A.
Minnesota Geologic Survey

engineering properties of each of the 26 soils types were rated in terms of their suitability for shallow tunneling. Four ratings categories were established - good, fair, poor and very poor.

The soils types rated "good" are glacial tills of the Des Moines and Superior lobe deposits. These soils are clay loams, loams, loams with inclusions of silty loam and silty sand, tills, sandy loams, ice-contact sand and silty sand.

"Fair" soils types for shallow tunneling are found in the Terrace deposits and Des Moines lobe deposits groups. These soils are sand, silty sand, gray and red tills, clay loam, loam, sandy clay loam, sandy loam, sand and gravel.

Soils in the "poor" category are found in all major soils groups and include sandy deposits with boulder zones, fine sands and silt, silty clay, outwash deposits of sand and gravel and undifferentiated valley fill.

"Very poor" soils are again found in each of the major groups and include post-glacial deposits such as artificial fill, organic deposits such as peat and organic silt and clay, middle terrace deposits which contain many boulders and large limestone blocks, and ice contact deposits which also contain many boulders and cobbles.

Soils were assessed and mapped in terms of their suitability for a shallow tunnel LRT alignment. Only those soils in the "good" and "fair" categories are shown in figure 2, for the Greater Minneapolis-St. Paul urban areas, the most extensive area within the Metropolitan Region for which published

information is available from the Minnesota Geological Survey.

As shown in figure 2, areas with soils in the "good" rating category are found primarily in communities outside the downtowns of Minneapolis and St. Paul, with the exception of an area within the extreme northwest corner of Minneapolis and areas east and southeast of downtown St. Paul. Large areas with "good" soils exist to the northeast and west of Minneapolis and in communities east and south of St. Paul.

Areas which possess "fair" soils for shallow tunneling are centered in Minneapolis, and extend to communities to the north and northwest, south to Richfield, Bloomington and the Minneapolis - St. Paul International Airport, portions of West St. Paul, downtown St. Paul and South St. Paul.

Bedrock Geology

The first bedrock strata which occurs in the Region is the Decorah Shale. The Decorah shale, where present, directly underlies the glacial drift. The Decorah shale generally occurs in thin layers over the Platteville limestone, but is known to reach thicknesses of up to 70 feet in certain locations in the Region. The significance of the Decorah shale is 1) where it occurs, the Platteville limestone beneath it exists in its full thickness and is generally in good condition; and 2) in areas where vertical access to transit is necessary, the Decorah shale represents a second rock which strata must be penetrated by a vertical shaft.

The Platteville limestone is the next bedrock strata. Where the Decorah shale is present, the Platteville limestone has not

been eroded and is approximately 40-45 feet thick. In areas where the Decorah shale has eroded, the top of the Platteville limestone is an erosion surface of variable thickness with an average maximum thickness of 30' in the metropolitan area. It is generally believed that in those areas where the limestone is not eroded or exists in layers of 15 feet or more thickness, it is capable of forming self-supporting spans over large openings.

The Glenwood shale is a 3' to 5' strata which consists of thin beds of soft shales. The Glenwood is a weak rock which weakens further when exposed to air and humidity. For this reason, the Glenwood shale is often removed when constructing space beneath the Platteville limestone.

The St. Peter sandstone is a soft, easily excavated layer of bedrock which underlies the Platteville limestone. Extensive construction has taken place in the St. Peter sandstone in the Metropolitan region over the last hundred years, generally to accomodate sanitary and storm sewers, because the material is very easy to work with. Construction has generally occurred in the upper layers of the 150 foot thick strata.

The juxtaposition of the hard Platteville limestone and the soft, easily excavated St. Peter sandstone, offers relatively inexpensive tunneling conditions. Minimal structural support, if any, is required for spans of 40 to 50 feet in width.

Figure 3 shows the areas in the seven-county Metropolitan Region where the Platteville limestone and the St. Peter sandstone are found. Wherever the Platteville limestone is present, it is underlain by the St. Peter sandstone. As shown in figure 3, these limestone and sandstone layers are concentrated

in the center of the Twin Cities Metropolitan Region.

Hydrogeology

Water can occur in both soils and bedrock, and can be an important factor in construction costs. The prime determinants of the location of water tables are the presence of impermeable materials which confine the water in some manner.

The Twin Cities hydrologic basin can be viewed as being similar to a layer cake whose rock layers slope greatly upward and outwards from a central point nearly 1000 feet below the surface. The Twin Cities basin consists of a series of "aquifers", layers that are permeable and transmit water readily, and "aquicludes", layers that are impermeable. The St. Peter sandstone is an aquifer, and exhibits both "water table" conditions, in which water is not under pressure and drains into nearby river valleys, and "artesian" conditions in which the water has no place to drain and is therefore under pressure.

Water can also occur in lenses in soils and bedrock, where an impermeable layer prevents drainage in the material above. Perched water tables are more difficult to predict due to their random nature. They can cause support problems when tunnels are driven through the saturated area. It may be less difficult to tunnel beneath these impervious clay layers than to construct tunnels at the shallower elevation. Lenses of relatively impermeable siltstones occur regularly in the lower 60 feet of the 150 foot St. Peter sandstone, and less commonly in the upper layers. Underground construction for transit is not anticipated at these lower depths.

Geologic Hazards

Geologic Hazards are features which can lead to unexpected added costs during construction of civil engineering works or to the failure of the works to provide their designed purpose efficiently. Potential problems for a deep underground alignment include caves or voids in the sandstone, and buried river valleys.

The caves which have been discovered within the metropolitan area are openings within the sandstone. Although they usually occur as openings or voids just below the overlying limestone layer, a few are located at a lower elevation within the sandstone itself. Caves have occurred naturally and as a result of man's activities, such as mining out of the sandstone. The locations of mine openings are usually known and have been recorded on various maps. Caves that resulted from natural geologic processes or voids which were a side effect of man's activities, may be present in a number of places in the Metropolitan Region. Where they are encountered unexpectedly they constitute a hazard. If the existence of a cave is confirmed during site investigation studies, then proper engineering procedures can be designed to remedy the problem during the construction phase.

The known natural caves in the metro area occur primarily along the river bluffs. Water entering joints or fractures in the limestone migrated down through fractures in the Glenwood shale into the sandstone and moved toward the region's rivers,

which were at lower elevations. Much of the sandstone is friable so that moving water can loosen and erode individual grains. Where the disaggregated sand grains escaped at a bluff face, openings formed and gradually widened and extended toward the water sources. The possibility of natural caves should be anticipated not only beneath the limestone layer near the river bluffs, but also near the edges of the buried river valleys.

Man-made caves can occur in two ways: first, as a result of the mining of sandstone; secondly, as a side effect of other activities, such as where leakage of water along and outside of pipes or tunnel linings has caused the sandstone to break down. Where the sand has escaped, voids have formed, some of substantial size.

An important geologic feature in the Metropolitan Region is the existence of a number of "buried valleys". These are river valleys cut through the Platteville limestone and the St. Peter sandstone into the Prairie du Chien bedrock formation prior to and during the ice age. Later as drainage was blocked and changed by advances and retreat of glaciers, these were filled and buried by water-laid deposits and glacial debris. Commonly there is little or no surface evidence of their existence. One example is the chain of lakes in Minneapolis which occur as a series of depressions along a major buried valley. Whenever underground construction is considered near the edges of buried valleys, careful site investigation is necessary prior to final site selection and design.

Potential soils-related hazards include a high groundwater table, the presence of large boulders in the glacial drift, and

polluted soils and groundwaters. A problem is likely to stem from a high groundwater table, requiring construction dewatering and more extensive drainage and/or waterproofing techniques for those structures which extend below the groundwater tables. Groundwater tables can be subject to both seasonal and long term changes in elevation. Blocking of groundwater flow patterns by construction, or an increase in the recharge of groundwater, will cause water levels to rise. Drainage and dewatering around underground constructions may cause a drop in the area groundwater table depending on how the drainage water is disposed of. Caution must be exercised close to areas of water-sensitive soils which change in volume with changes in the ground moisture content. A lowering of the groundwater table can cause settlement, or subsidence, in such soils. Anticipation of such situations allows for preventative measures and more stringent construction techniques.

Other difficulties which may be encountered during construction in otherwise generally favorable soil areas relate to manmade construction or conditions. Pollution of the ground water is quite likely within surficial deposits. This pollution can include chemical wastes from industry as well as leads, spills and the general absorption of untreated and polluted surface waters. This should only present a problem for subsurface construction if the groundwater has become corrosive or explosive.

The surficial geology of the Metropolitan Region is much more complex than the bedrock geology. This raises two major

concerns when considering a shallow tunnel alignment in the Metropolitan Region. First, while a soils type may appear to be generally suitable for underground construction, the deposits are uneven within themselves. It is difficult, if not impossible, to anticipate when tunneling machinery will move from one type of material to another. This uncertainty can cause project delay as techniques or even equipment must be altered to meet the new condition.

A second major concern is that soils deposits in the Region consist in most cases of shallow lenses of different types of materials. A soils type which falls in the "good" or "fair" ratings category, may be shallow and may be underlain by deposits which are much less suitable for tunneling. This type of situation could halt construction altogether if a deposit which contains both boulders and flowing ground is encountered unexpectedly. Figure 4 is a cross-section which illustrates the complexity of the Region's surficial geology.

Local experts estimate the cost of shallow tunneling under the best conditions in this geology to exceed the cost of tunneling in the St. Peter sandstone. This is due to the complexity and unpredictability of surficial geology in contrast with the homogeneity of the St. Peter sandstone. Table 1 shows the estimated cost ratio of tunneling in the four soils rating categories vs. the cost of tunneling in the St. Peter sandstone.

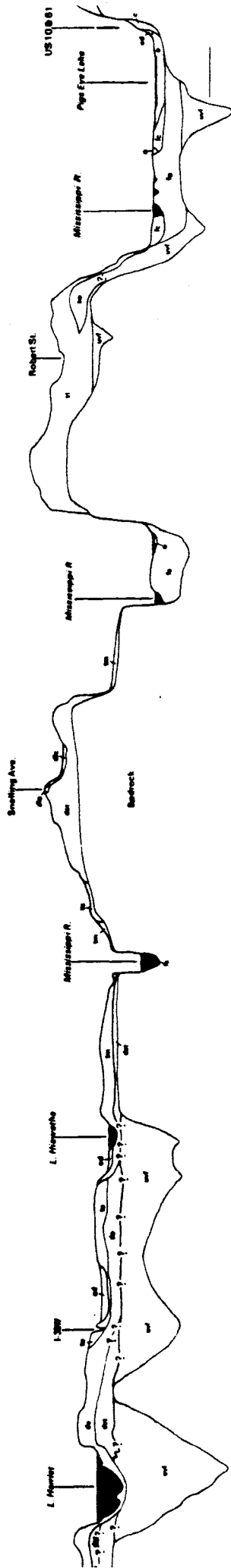


Figure 4
Cross-Section of Surficial Geology,
Lake Harriet to U.S. 10 & 61

SOURCE
 Secondary Geologic Map of the
 Minneapolis - St. Paul Urban Area
 by Meyer, Gary H.
 Minnesota Geologic Survey

Table 1

Soils Rating Category	Cost Ratio *
Good	1.5
Fair	2.0
Poor	2.5
Very Poor	3.0

*Tunneling in St. Peter sandstone = 1.0

Existing Structures

The presence of existing structures, both underground and on the surface, has an important impact on potential underground routes, the cost to develop them and, in some cases, their viability.

In heavily urbanized areas, it is common to find myriad utilities near the surface. Cut and cover and shallow tunnel construction may necessitate moving these services. The cost to do so is a function of the number and size of such services in a given area.

In the Twin Cities Metropolitan Region, the primary existing structures in bedrock are storm and sanitary sewer lines. When constructed in bedrock, these lines are found in the upper portions of the St. Peter sandstone strata. Other underground

structures in bedrock are district heating lines, abandoned water power structures, abandoned street car power structures and manmade and natural caves.

Existing facilities in soils include primarily communications and utility lines such as telephone cables, gas mains, electric service, water pipes, steam mains, pedestrian tunnels and building foundations. Most of the conduits, mains and cables are located beneath or adjacent to the streets.

MINNEAPOLIS DATA

Geology

Minneapolis **bedrock geology** is shown in figure 5. As shown, most of the downtown area and the southern parts of the city are underlain by the strata necessary for a deep tunnel alignment - the St. Peter sandstone overlain by the Platteville limestone.

The surficial geology of Minneapolis is shown in figure 6. As shown, soils in the city are generally considered fair to very poor for shallow tunneling. This is due to the engineering properties of the soils, the complexity and unpredictability of the deposits, and in cases, insufficient soils depths to accomodate tunneling activity.

Existing Structures in Bedrock

Existing structures in bedrock include sanitary and storm sewers, water mains, district heating facilities, caves, abandoned water power structures, and abandoned streetcar power tunnels. The location of sanitary and storm sewers, water mains, historic structures along the riverfront and the University of Minnesota district heating tunnels are shown in figure 7.

Sanitary sewer lines in bedrock are generally large interceptor lines. They are up to 12 feet in diameter and are located an average of 11 feet below the bottom of the Platteville limestone layer. The deepest location is 28 feet below the bottom of the limestone layer near the intersection of Nicollet Avenue at 3rd Street.

Figure 5
Minneapolis Bedrock Geology

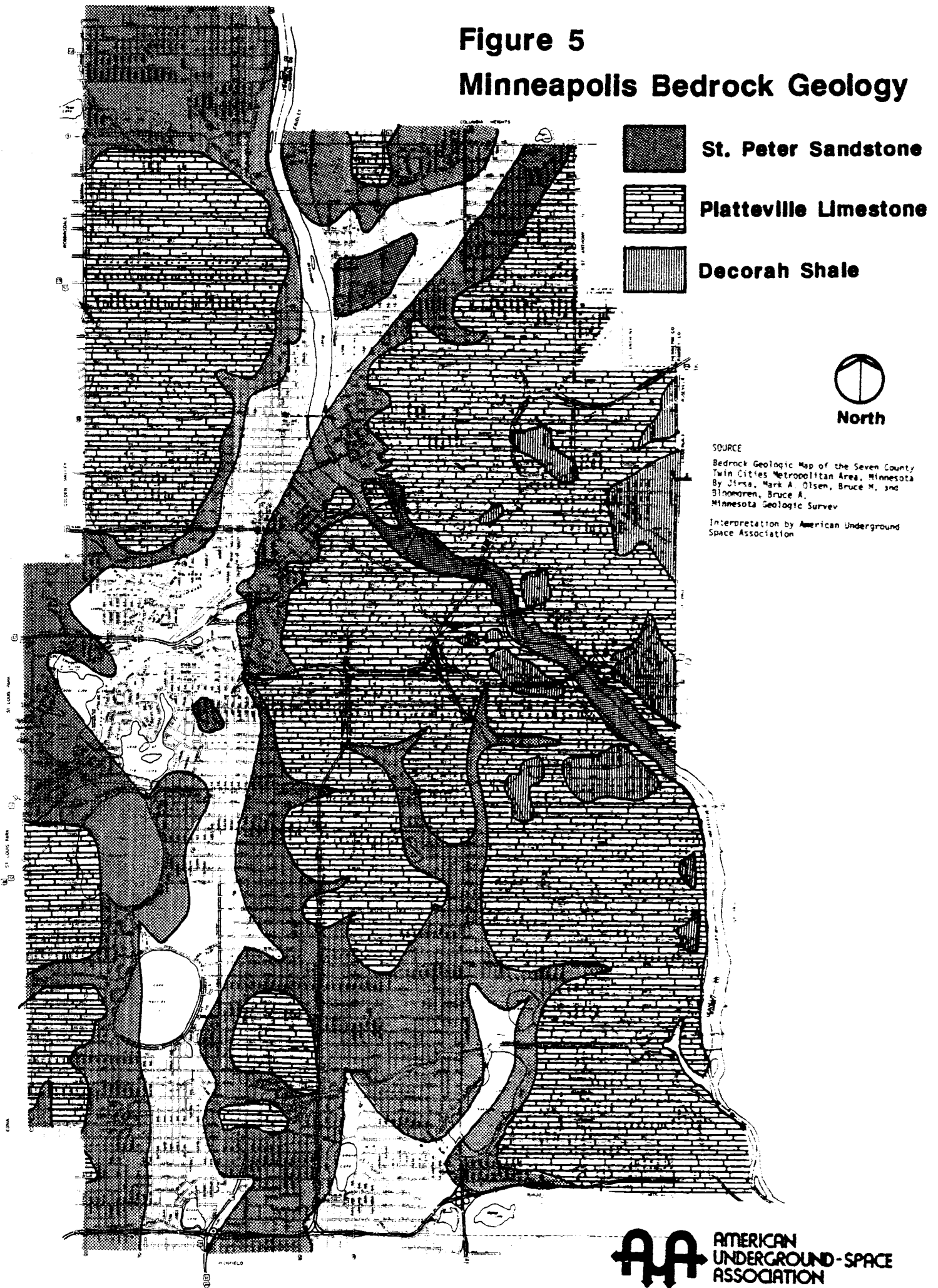





Figure 6 Minneapolis Surficial Geology

-  **Good Soils**
-  **Fair Soils**
-  **Fair but Shallow Soils**

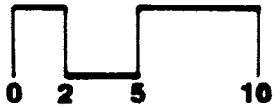


SOURCE
Quaternary Geologic Map of the
Minneapolis - St. Paul Urban Area
By Meyer, Gary N.
Minnesota Geologic Survey

Interpretation by American Underground-Space
Space Association

Figure 7

**Existing Structures
In St. Peter Sandstone,
Minneapolis, Minnesota**



Feet in Thousands

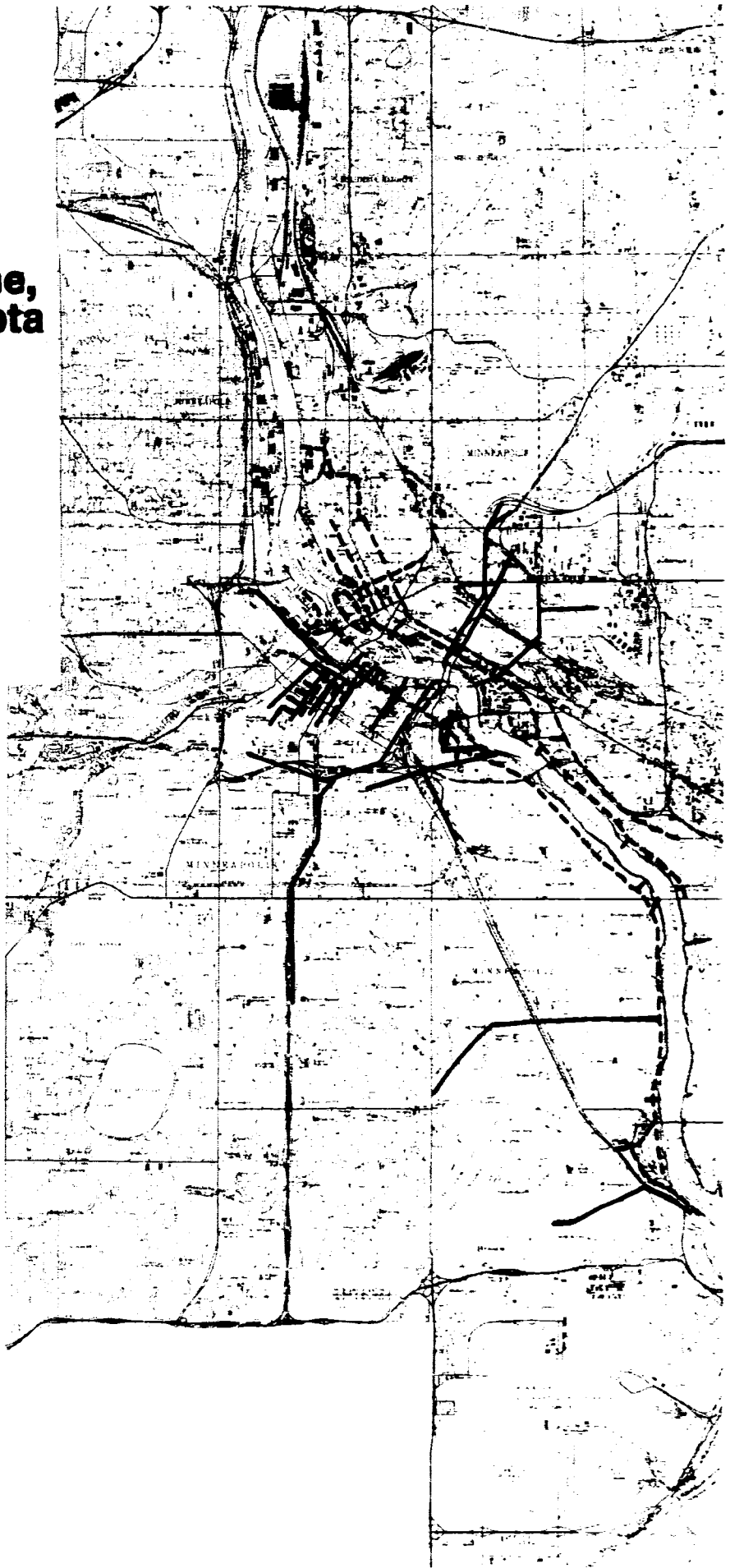
----- Sanitary Sewer Tunnels

———— Storm Drain Tunnels

SOURCE
Minneapolis Public Works Dept.
August, 1981

NOTES
This Map is Prepared for Planning Purposes
and Should Not be Used Where Accurate
Measurements Are Required

Courtesy of Underground Space Center,
University of Minnesota



Storm sewer tunnels reach a size of up to 14 feet in diameter. Most of them are sited at a depth of 10 to 20 feet beneath the bottom of the limestone layer, but some extend to a depth of nearly 40 feet.

Abandoned water power structures - canals and raceways - were built by early industrialists to provide power for the industries located in the St. Anthony Falls area. There are also several abandoned tunnels in the area. The deepest of these tunnels has an invert nearly 17 feet below the bottom of the limestone while the shallowest extends approximately 10 feet below the bottom of the limestone. The tunnels are approximately 16 feet wide. Because there are so many abandoned structures in the area, it is generally recommended that tunneling be approached with caution there.

Water mains in Minneapolis are usually found in soils. However, the mains which serve Nicollet Island are located in bedrock. The tunnels which contain the mains are 3 by 5 feet and are sited an average of 17 to 18 feet beneath the surface. The overlying limestone is approximately 9 feet thick. Because an underground alignment is unlikely on Nicollet Island, the precise location of these water mains is not shown in this report.

The University of Minnesota operates an extensive system of district heating tunnels on both the east and west banks of the Minneapolis campus. The tunnels are located from 5 to 20 feet below the bottom of the limestone layer. The heating tunnels also carry telephone cable in the area.

Several caves are located in the City. Most of them are located along the Mississippi River between St. Anthony Falls and

Fort Snelling. The caves were formed by erosion or were manmade. Of importance to a potential underground transit alignment are the large caves located beneath downtown Minneapolis. A major one is located beneath Shiek's Restaurant, adjacent to 4th Street between Marquette and 2nd Avenue S. It is located approximately 70 to 75 feet below street level. The height of the cave ranges from 3 to 6 feet. The ceiling is formed by the Platteville limestone. This cave is believed to have been formed by the hydraulic action of an artesian well that flowed out of control. The cave was later enlarged by backflooding into sewer tunnels.

The second known cave in the downtown area is located adjacent to Nicollet Mall, between Seventh and Eighth streets. It is triangular in shape, with the longest side 65 feet in length. The maximum width of the cave is 22 feet. It is located just beneath the Platteville limestone and is approximately 5 feet high at its highest point. This cave was discovered during excavation for sanitary sewer lines in the early 1900's.

Existing Structures in Soils

Most of the communications and utility infrastructure which serves the city is located in glacial drift. The presence, location and magnitude of these services may have an important impact on the cost of cut and cover construction or shallow tunneling, depending on whether or not their presence conflicts with proposed construction activity.

Most of the underground services in soils are found beneath the streets, and it can be safely assumed that each street in the City contains at least one service. In the more densely

developed areas, several services will be present.

In addition to the cables, conduits, pipes and mains, the presence of building foundations will affect the location, feasibility and cost of shallow underground construction. Improper design or construction could endanger adjacent or nearby building foundations. This is a greater problem when underground construction is proposed near a structure with a shallow foundation than when a foundation extends to bedrock.

Existing structures in soil in Minneapolis include steam mains for district heating, telephone cable, gas mains, electric service, pedestrian tunnels, and cable television service.

Minnegasco currently operates approximately 1.7 miles of district heating steam lines in downtown Minneapolis. All steam mains are found within the perimeter of 10th Avenue South, West 14th Street, Hennepin Avenue, and the Mississippi River.

The conduits are usually 20 inches in diameter, but may reach 24 inches in diameter. Conduits are located approximately 5 feet beneath the sidewalks. At locations where conduit crosses a street, the conduit is generally at a depth of 12 to 15 feet below the surface, although in some locations the conduit is as deep as 36 feet and constructed in tunnel. The deeper locations are necessary due to the competition for space with utilities located near the surface. The location of the district heating system is shown in figure 8.

Northwestern Bell Telephone company serves a large part of the city via underground cables, located beneath the streets. The cables are encased in concrete conduits which vary in size

from 2x2 feet or 3x3 feet. The conduits are at an average depth of 6 feet, unless there is competition for space with other utilities. The cables are maintained via manholes in the street, located between each conduit. The manholes reach a depth of 9 or 10 feet.

Due to the sensitive nature of communications functions, the location of underground telephone cables are not shown in this report. A map of existing telephone cable locations is available for review at Northwestern Bell's main office.

All of the gas mains in Minneapolis are located beneath the streets, at a depth of from 3 to 9 feet. The depth again varies with competition for space with other utilities.

The average size of the downtown mains varies from 16 to 24 inches, although some 30 inch mains are in use. The size of the main varies due to the amount of pressure in the main and the size of the building it serves.

Gas mains outside the downtown are located nearer to the surface, from a depth of one to five feet. Those mains range in size from 2 to 5 inches in diameter, depending on the area served. Major gas mains in the city are shown in figure 9.

Northern States Power Company provides electrical power to Minneapolis's downtown and the more densely populated communities in the city via underground lines. The location of major underground electrical lines in the city is shown in figure 10.

All facilities within the perimeter of the Mississippi River, Portland Avenue, Grant Street and 3rd Avenue North are located underground. The lines are found on either side of the



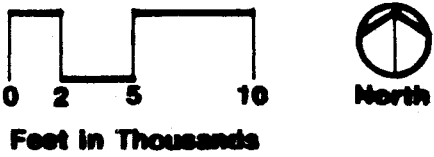
SOURCE:
 Minneegasco, September 1981
 Courtesy of Underground Space Center,
 University of Minnesota

●●●●● Distribution Line

Figure 8
District Heating System:
Downtown Minneapolis



Figure 9
Major Gas Lines



- 14-18 inch Diameter
- 20-24 inch Diameter

SOURCE:
Minnegasco, January 1981
Courtesy of Underground Space Center,
University of Minnesota

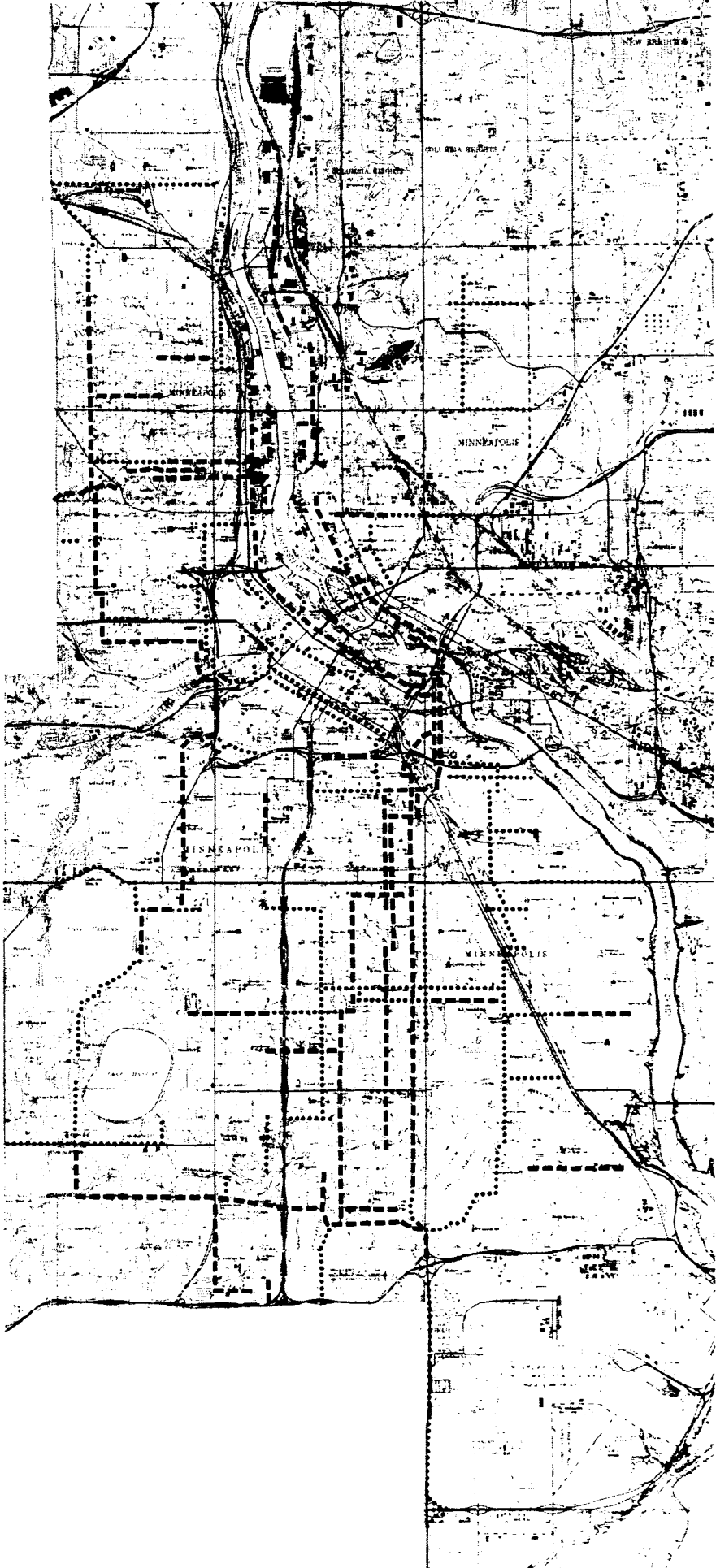
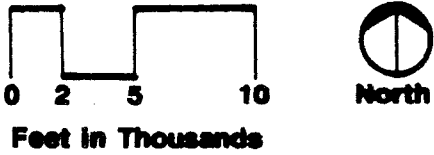
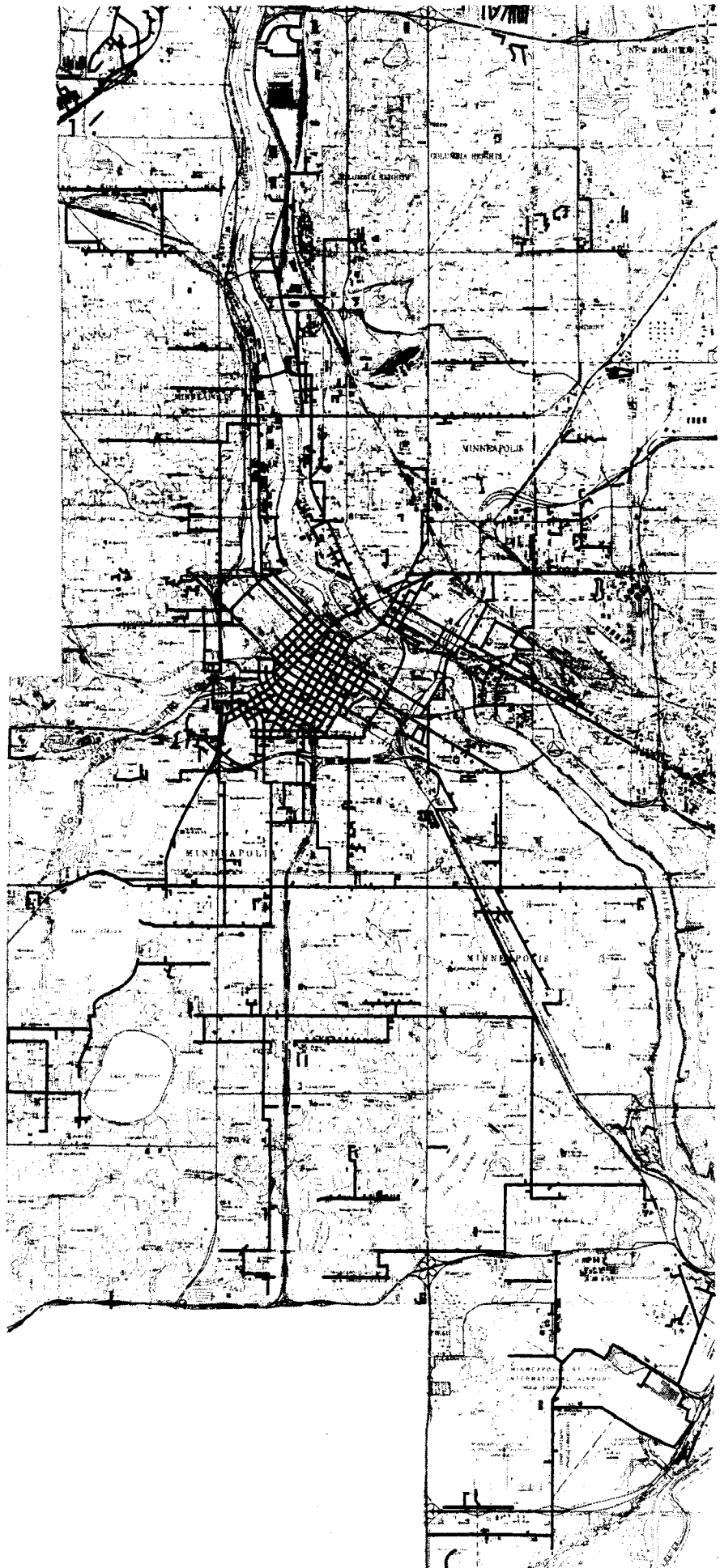


Figure 10 Electrical Service



———— Underground Electrical Lines

SOURCE:
Northern States Power Company, 1981
Courtesy of Underground Space Center,
University of Minnesota



street, depending on space demands of other utilities. The lines are contained within concrete-covered pipes located at an average depth of 5 1/2 feet.

Transformer vaults are located beneath sidewalks in the downtown area. Generally, there is one vault per city block, although each large building in the central business district has its own vault. The vaults are from 12 to 15 feet in height and 35 to 100 feet in length. A 12 inch thick concrete slab forms the roof of the vaults and this in turn is covered by the 4-inch-thick sidewalk.

Underground service outside the downtown area is provided in lines encased in pipe which is 3 1/2 to 5 inches in diameter, located from 2 to 3 feet below the surface.

There are several pedestrian tunnels located in shallow underground space in the city. They generally connect buildings in the downtown area, although some are located outside the central business district. The location of most of these tunnels is unknown, and will have to be determined if an underground LRT alignment is selected.

Except for the water mains on Nicollet Island, all water mains in the city are located in glacial drift. The mains follow street alignments except for the area surrounding Theodore Wirth Park. The mains are of varying size, ranging from 6 inches to 48 inches in diameter. The smaller mains, up to 16 inches in diameter, are generally covered by 8 feet of soil, which prevents freezing in the winter. Since there is a greater volume of water in the larger mains, some of these pipes have only 2 to 3 feet of

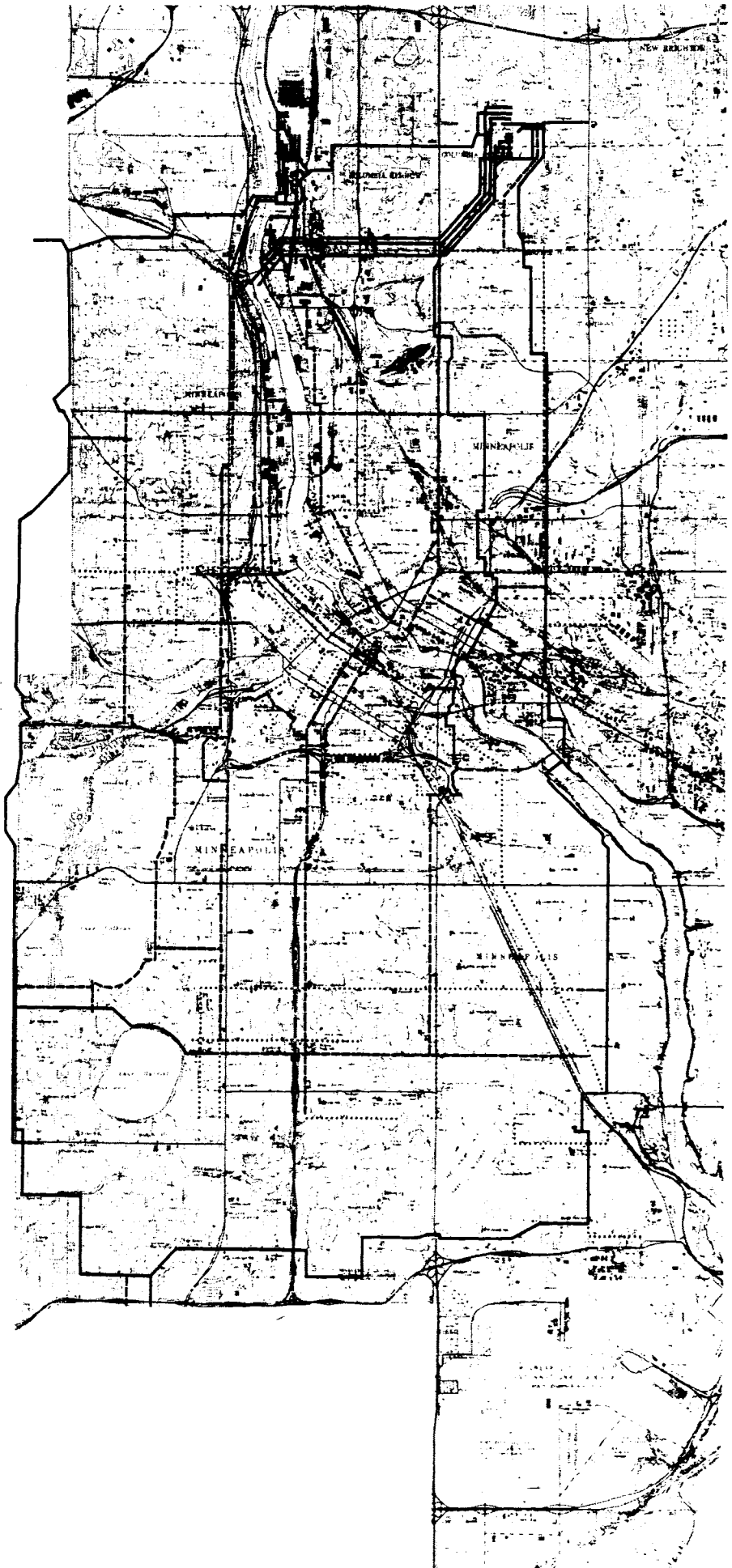
Figure 11
Major Water Mains



Feet in Thousands

- 16-20 inch Diameter
- - - - 24-36 inch Diameter
- 40-96 inch Diameter

SOURCE:
 Minneapolis Water Works, March 1961
 Courtesy of Underground Space Center,
 University of Minnesota



cover. The depth of water mains in the City is affected by the presence of other structures. In some areas the mains are located at a depth of more than 8 feet.

Some of the water mains in the city are encased in concrete. This includes those mains which are located at a depth greater than 8 feet, and mains which pass under railroad tracks, for example. The major water mains in Minneapolis are shown in figure 11.

SUITABILITY OF PROPOSED TRANSIT ROUTES FOR AN UNDERGROUND ALIGNMENT

Potential LRT alignments identified in the report, "Light Rail Transit Implementation Planning Program" April 1985, are shown as they relate to Regional Geology in Figure 2 and Figure 3. While serious consideration of underground alignments has been given only to congested urban areas, it is still useful to assess underground potential in the broadest geographic areas. Therefore the potential for each alignment has been assessed for shallow and deep tunnel alignments. Because the selection of transit alignments through Minneapolis depends on several factors in addition to the physical suitability of a route, no attempt was made to assess the impact of existing structures on either a shallow or deep tunnel alignment.

As shown in Figure 2, the areas with potential for shallow tunnel are within downtown Minneapolis, to the University of Minnesota East Bank campus, and the Hiawatha Corridor route to the Minneapolis - St. Paul airport. It should be noted however, that soils along these alignments are in the "fair" ratings category which means that tunneling conditions will be difficult.

A shallow tunnel could be constructed along a northwest alignment, depending on destination, in "fair" to "good" soils conditions with initial segments constructed in "poor" to "very poor" soils.

A shallow tunnel would not be suitable for the southwest alignment due to "poor" or "very poor" soils conditions. Similarly, a shallow tunnel would be inadvisable between the

University of Minnesota campus and downtown St. Paul due to "poor" or "very poor" soils conditions.

As shown in Figure 3, bedrock geology appears to be suitable for a deep tunnel alignment through downtown Minneapolis, to the University of Minnesota, and between the downtowns of Minneapolis and St. Paul. A deep tunnel alignment also is possible for the Hiawatha corridor between Minneapolis and the airport.

While the St. Peter sandstone is present northwest of Minneapolis, the Platteville limestone is eroded. A deep tunnel along a Northwest alignment may be possible. Tunnelling conditions in the homogeneous St. Peter sandstone would appear to be good, and perhaps this bears further analysis.

As shown, once an area of deep soils and no bedrock is traversed at the western edge of Minneapolis downtown, it would be possible to construct most of the southwest corridor in a deep tunnel alignment.

