A Highlight of Engineering Geologic Issues in Fargo, North Dakota

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Introduction

Geology is the study of the Earth. It is the field of scientific endeavor that seeks to understand and describe our physical environment. There are many sub-disciplines within the science of geology. There are the pure research disciplines such as experimental mineralogy and petrology and modern global seismology, and the applied disciplines such as hydrogeology, petroleum geology and engineering geology. The applied science aspects of geology result in the application of basic earth science data to the current problems of the day. In this short overview I would like to highlight some of the more interesting aspects of the applied geology of our state, particularly in the Fargo area, by way of looking through the engineering geologist's site level, so to speak.

The concept that the natural conditions existing within our environment could bear unfavorable impacts on the construction of engineered works has been around for a considerable amount of time but probably was not fully realized in this country until the occurrence of the Industrial Revolution (1750-1900). It was during this time that the need arose for a basic understanding of the geological conditions of areas that were likely to be used as locations for engineered works such as bridges, buildings or subsurface excavations constructed to serve as storage areas or as conveyance for materials or fluids.

Engineering Geology

The application of geology to the supporting factors of engineered works is the sub-discipline of geology known as Engineering Geology. Engineering Geology is an applied facet of the science of geology. The engineering geologist seeks to investigate, understand, predict, and communicate the relationships between particular geological aspects of an area, region, or site, that bear consideration on the construction of engineered works such as roads, bridges, foundations, and buildings (Figure 1).

The Association of Engineering Geologists (AEG) defines the role of the Engineering Geologist as:

"the discipline of applying geologic data, techniques, and principles to the study both of a) naturally occurring rock and soil materials, and surface and subsurface fluids, and b) the interaction of introduced materials and processes with the geologic environment, so that geologic factors affecting the planning, design, construction, operation, and maintenance of engineering structures (fixed works) and the development, protection, and remediation of ground-water resources, are adequately recognized, interpreted, and presented for use in engineering and related practice. The Engineering Geologist utilizes specialized geologic training and experience to provide quantitative geologic information and recommendations based on it, as well as judgmental recommendations."

Figure 1. Failure of engineered fill soils on the eastern ramp of the Business Hwy 94 overpass just west of the City of West Fargo. Failure occurred after recent heavy rainfall in the area during the fall of 2004 (Photo by Anderson).

Engineering geologists in some form or fashion have most likely been around since ancient times as evidenced by the general observation that if one is to look back in history at many of the engineered and constructed works of the ancient world, it is surprising how many are located on generally good natural sites and appear to take into consideration their local geologic conditions. Some of the earliest types of works likely to have been studied by engineering geologists include the construction of tunnels for water transport and the construction of the Roman highway (Kiersch, 1991).

Today, most engineering geologists are well versed in soil and rock mechanics, issues relating to slope stability, aggregate resource exploration and characterization, and groundwater resource identification, development, and protection. The field is very diverse and amassed with many interesting challenges that affect today's, as well as many, historically engineered works.

We will briefly examine some of the more prevalent issues, both historical and recent, encountered in the Fargo area, North Dakota. It should be mentioned that this discussion is not intended to be the last word on the geology of Fargo, it is simply a brief discussion of some of the more visible and contemporary issues that many in the Fargo area deal with on a daily basis.

Surficial Geologic Overview of the Fargo Area

The surficial geology (defined here as the near surface sediments most encountered during the construction of engineered works) in the Fargo area is characterized by a relatively uniform blanket of glacial lake sediments deposited during the onset of Glacial Lake Agassiz around 11,000 years before present (b.p). The sediments that underlie the Fargo area consist dominantly of glacial lake silts, sands, and clays (and gradational combinations of each) that reach depths of up to 150 feet below the land surface (bls).

The Red River of the North incises this *relatively* featureless plain and periodically delivers a healthy amount of overbank fines to the area during seasonal flooding events (Figure 2).

Figure 2. View to the north along North Elm Street in Fargo. High water levels in the Red River encroaching upon local transportation routes (Photo by Anderson).

Formally, the sediments underlying the Fargo area that are arguably of greatest concern consist of glaciolacustrine silts, clays, and silty clays of the Sherack and Brenna Formations (Harris, et al, 1974). In the Fargo area these sediments are generally found to depths slightly greater than 100 ft. The generalized stratigraphy of these units is somewhat regular with approximately 20 feet of yellow-brown laminated silty clays of the Sherack Formation underlain by approximately 80 feet of gray, fat clays of the Brenna Formation (Schwert, 2003). Due to the fact that these glaciolacustrine sediments contain high amounts of swelling clays in their overall mineralogy these sediments present many difficulties when structural loads are applied.

Examples of Engineering Geologic Issues in the Fargo Area

For the most part, the engineering geologic problems that exist in the Fargo area are the result of the interaction between constructed engineered works and the underlying "load bearing" sediments. The presence or absence of water within these sediments serves to create two major engineering geologic issues within the valley: soil stability issues related to the construction of surface engineered works and slope stability issues along the Red River of the North along the North Dakota border with Minnesota.

Previous workers (Moran, 1972 and1974, Arndt, 1977, and Schwert 1997, 2003) have documented several significant engineering geologic conditions that exist throughout the Red River Valley. Some examples are the elastic deformation of clayey glaciolacustrine soils, shrink-swell properties, inadequate bearing capacity, and mass movements.

Elastic deformation of clay-rich soils has been documented throughout the Red River Valley. It has been shown that under certain cases of loading and unloading, such as in the construction, use, and subsequent failure of the Fargo grain elevator in 1955 (Figure 3), soils beneath the structure have been shown to deform in response to the increased load upon them, deforming as a consequence and resulting in an adverse structural effect. Upon removal of the load, these materials have been shown to restore to their previous condition.

Volumetric expansion of clay-rich soils under differing moisture conditions has also been documented. During significantly wet periods, subsurface soils have been shown to increase their capacity to accept water into their mineralogical framework, with a resultant loss of bearing capacity. Conversely, during periods of drought the opposite has been noted, resulting in overall volumetric reduction of material. Taken in concert these changes in soil volume over time have the cumulative effect of destroying the underlying foundation stability of many engineered structures.

Many structural failures have occurred due to the inherent weakness of clay-rich soils in the Red River Valley and their inability to accept uniform or differential loads. Three significant failures noted include the Transcona Elevator in Winnipeg, Manitoba, the Fargo Grain Elevator in 1955 and the failure of the NP railroad grade best chronicled by Schwert (1997).

These types of failures have occurred simply by the overloading of unstable foundation soils in the subsurface, which deformed through compaction under increasing loads with further expansion of materials around the structures (much like placing a brick in a box of mud).

Mass movements of unstable soils within the Fargo area have also been extensively documented by Harris, (2003) and Schwert, (2003). It has been noted that failures of materials along the banks of the Red River are persistent and common and are related to the inherent instability of underlying Brenna Formation sediments undergoing plastic deformation in the subsurface with the resultant block failure of overlying Sherack and recent alluvial sediments (Figures 4 & 5).

Figure 3. View of the collapsed Fargo Grain Elevator after subsurface soil failure in 1955. (Photo from the Institute for Regional Studies, NDSU, Fargo).

It is important to consider that if we choose to ignore the surrounding geology in the construction of engineered works, then the surrounding geology will most certainly assert its influence on our engineered structures.

Current Investigations

The common factors in the majority of the engineering geologic problems that are encountered in the Fargo area are the result of the inherent physical properties of the glacial Lake Agassiz offshore sediments and the underlying stratigraphic relationships of these materials. The best way to deal with these conditions is to identify problem areas prior to utilization and look for other areas with more favorable geologic conditions.

Currently, the NDGS is conducting detailed geologic mapping studies in the Fargo and Grand Forks areas at a

Figure 4. View to the south along the eastern bank of the Red River depicting earthflow, soil slumping, and bank failure near residential developments in north Fargo. Note the subvertical orientation of trees and presence of developing scarps in the foreground (Photo by Anderson).

Figure 5. View to the north of failed cutbank along a meander of the Red River in north Fargo. Note the presence of a well defined failure scarp and the subvertical orientation of nearby trees (Photo by Anderson).

scale of 1:24,000. These detailed maps, and their derivative products, will provide for an enhanced understanding of existing geologic conditions in the Fargo area and serve as the primary database for virtually all applied and basic earth science investigations in the future.

We have a good understanding of the engineering geologic nature of the glaciolacustrine deposits of the Sherack and Brenna Formations in the vicinity of the Fargo area. We also have a generally good understanding of their physical and engineering properties and stratigraphic relationships. How these materials vary spatially, both in two and three dimensions, could reveal previously unknown engineering geologic conditions and provide solutions to engineering geologic problems yet to be encountered. There is much work yet to be done!

Select References

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Moran, S.R., 1972, Subsurface Geology and Foundation Conditions in Grand Forks, North Dakota; North Dakota Geological Survey, Miscellaneous Series No. 44, 18 p.

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Schwert, D.P., 2003, A geologist's perspective on the Red River of the North: history, geography, and planning/management issues, *in* Proceedings, 1st International Water Conference, Red River Basin Institute, Moorhead, MN, 16 p.

Web Sites of Interest

Geologic Issues in the Fargo area:
www.ndsu.nodak.edu/fargo_geology
www.state.nd.us/ndgs/

General overview of mass movement
http://www.fiu.edu/~longoria/natural/mass/mmain.htm

Association of Engineering Geologists
www.aegweb.org

The City of Fargo
www.ci.fargo.nd.us

The City of West Fargo
www.westfargo.org