Appendix J:

Geotechnical Evaluation

Lower Pool 2 Channel Management Study:
Boulanger Bend to Lock and Dam No. 2

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1. PURPOSE

The purpose of this project is to provide safe, reliable, and efficient navigation through the Boulanger Bend area (RM 817.0 to 821.0). In recent years, The U.S. Army Corps of Engineers has been unable to maintain this stretch of channel to authorized dimensions due to increasing amounts of sedimentation. The reduced channel dimensions have subsequently led to reduced towboat sizes, towboat groundings, and difficulty in maintaining the U.S. Coast Guard's Aids-to-Navigation. The reduced channel dimensions were established in the mid-1990's as a result of a limited Operation and Maintenance budgets and in efforts to extend the life of the temporary dredged material placement sites in Lower Pool 2 (Pine Bend, Upper Boulanger and Lower Boulanger islands). Restoring this section of channel to the full dimensions, as authorized (plus bend width), would be costly, and past experience suggests that sedimentation of the area can occur very quickly following dredging, leading to wasted effort. Therefore, the U.S. Army Corps of Engineers determined that studying potential options for optimizing channel maintenance practices in the area would be prudent.

2. LOCATION

The Boulanger Bend to Lock & Dam No. 2 Study Area is located on the Mississippi River in Lower Pool 2 between river miles 815.2 and 821.0. The site lies within the Minneapolis-St. Paul metropolitan area near Cottage Grove, MN (Figure 1).

This segment of the nine foot navigation channel has experienced changing sedimentation patterns that have exceeded the U.S. Army Corps of Engineers' (USACE) ability to maintain the channel. The degraded channel has adversely affected commercial navigation and is more costly for the U.S. Coast Guard's to delineate and maintain safe conditions for all users.

3. PROJECT FEATURES

The recommended plan is to excavate/maintain a wider channel that is still within authorized dimensions and place two new training structures (rock sills) one on the right descending bank from River Mile 819.5 to 819.8 and one on the left descending bank from River Mile 818.4 to 818.9. These minor changes would improve navigability, safety and reduce channel maintenance requirements. The proposed channel improvement is depicted in Figure 1.

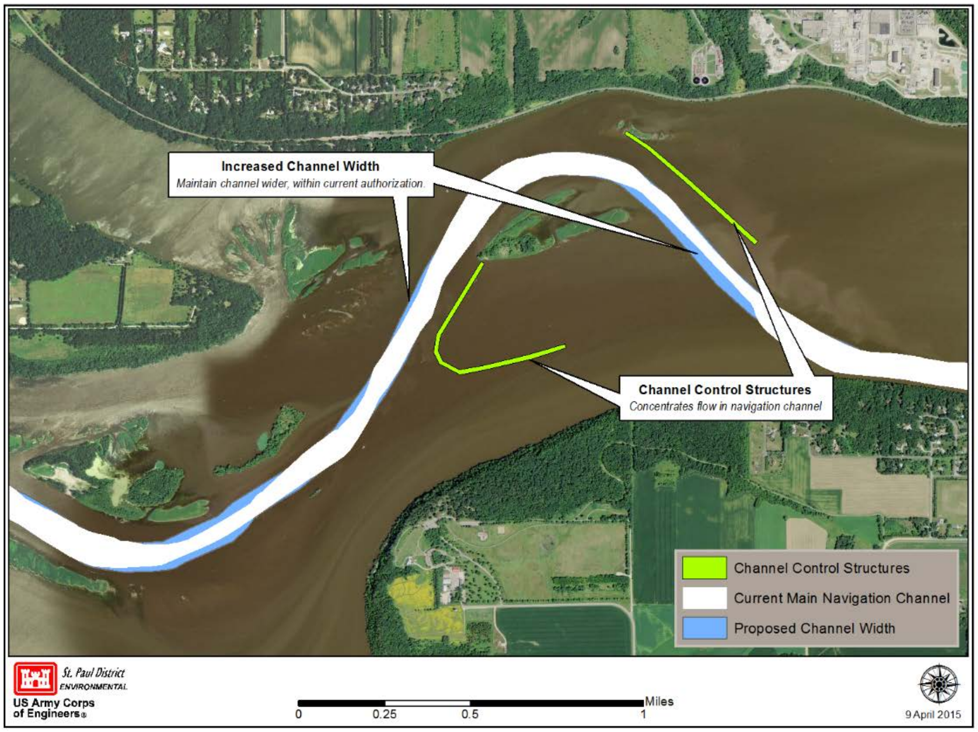

Figure 1 – Proposed Project Features

4. GEOLOGY AND PHYSIOGRAPHY

The landscape of the Project Area is the result of complex interaction of glaciations and bedrock geology. The Project Area is located at the transition between the Eastern St. Croix Moraine and Rochester Till Plain physiographic areas. The area is underlain by Paleozoic era sedimentary rocks that formed in marine environments of the Hollandale Embayment. Exposed outcrops include, in descending order, Galena formation dolomitic limestone, Decorah shale, Platteville limestone, Glenwood shale and St. Peter Sandstone.

Overlying the bedrock is glacial drift and glaciofluvial deposits of various thicknesses. The till is largely from the Superior and Des Moines lobes deposited during the late Wisconsin glaciation (ca. 30,000 to 12,000 years before present) although drift from earlier glacial episodes may be present (e.g., Wright 1972b). The Superior lobe ice margin (St. Croix Moraine), just north of the Project Area, buried previous Glacial Mississippi River channels during its advance that culminated ca. 15,500 before present (BP). The Des Moines lobe margin (Bemis Moraine), a few miles west of the Project Area, reached its furthest extent ca. 14,000 BP. Melt water from the retreating Superior and Des Moines lobes created large outwash plains north and south of the Project Area and partially excavating fill of ancestral Mississippi River channels. Subsequently, the Grantsburg sublobe, an offshoot of the Des Moines Lobe, overrode the St. Croix Moraine ca. 13,500 BP blocking southward drainage with flows diverted to the St. Croix River. With retreat of the Grantsburg sublobe, lower outlets were uncovered, establishing the modern course of the UMR. A series of downcutting events ensued that excavated previous valley fills with sustained high magnitude discharges of sediment free melt water that formed a series of terraces. The lowest terrace (e.g., Lower Grey Cloud Island) was established during the drainage of Glacial Lake Agassiz through catastrophic flooding down its outlet stream Glacial River Warren (modern Minnesota River) between ca. 12,000 and 9,400 BP. As glacial ice receded, diminished flows with increased sediments resulted in alluviation of the deeply incised upper Mississippi River (UMR). In some areas, massive alluvial fans accumulated at tributary mouths, forming dams that produced a series of river lakes (e.g., Lake Pepin). Sediment cores indicate a sequence of riverine lakes (i.e., Vermillion, Cannon, Pepin) occupied Pool 2 that were subsequently filled with sediments of the UMR delta, prograding past Hastings ca. 6,000 BP. Additional Holocene environmental changes (e.g., vegetation, climate) deposited a veneer of loess over the till and contributed to remobilization of colluvial and alluvial sediments that influenced floodplain geomorphology and fluvial activity, such as lateral channel migration and Paleoflood events.

Before 1875, when construction of river training structures ensued, the lower Pool 2 locality contained a diverse floodplain geomorphology characteristic of an anastimosed (ie. multiple channel) river. The area included outwash terraces (Grey Cloud Island), side channels (e.g., Grey Cloud, Boulanger, Nininger sloughs), islands (Islands 17 and 18), lakes (Balden, Baldwin, King, Spring), ponds, point bars, natural levees and marsh complexes.

More recently, beginning in the mid-Nineteenth Century, widespread areas of vegetation (i.e., prairie and forests) were removed for grazing and cropland causing erosion and the establishment of basin-wide artificial drainage networks which have accelerated sediment deposition in the floodplain (e.g., Knox 2001). These activities, combined with construction and operation of the lock and dam system have significantly affected the geomorphic processes occurring in Lower Pool 2. Submergence of the natural levees and backwaters, combined with the shift in vegetation communities, has decreased flow resistance in the backwaters causing secondary channel formation and expansion, and leading to increased backwater conveyance over time. Under existing conditions, Baldwin Lake and Spring Lake - the two largest backwaters in Lower Pool 2 – convey significant portions of the total river discharge (approximately 18-percent and 23 percent of the flow at a total river discharge of 20,600). Downstream of Spring Lake, flow is spread out over the completely submerged floodplain, which causes a decrease in stream power in the main channel resulting in sediment deposition.

Several recent geomorphologic changes have impacted the navigation channel. The channel at Freeborn Bend has been migrating downstream. The channel between River Miles 818 and 820 is moving east. Most of the wing dams in this area have been buried due to sedimentation, and a significant portion of the revetment below river mile 819 has been inundated. Each of these factors contributes to allowing significant flows to break out of the main channel and reduce the sediment capacity of the river in the project area.

The channel excavation and rock-sill structure construction will occur in the river. Channel bottom material has not been characterized by the NRCS. The west rock-sill structure will tie into an existing island which has been characterized as Algansee Sandy Loam. The east rock-sill structure will tie into a much smaller existing island which has not been characterized by the NRCS.

5. SUBSURFACE EXPLORATION

The Saint Paul District completed fifteen soil borings for the Lower Pool 2 Boulanger Cutoff project. The locations for the borings taken are shown in Attachment J-1.

At the rock sill structure locations, the borings show a layer of greenish gray to gray, soft, fine-grained material (varying in thickness from 10 ft to over 30 ft thick) soil followed by a layer of sand mixed with fine-grained material. The clay layer is generally fat clay (CH) with Standard Penetration Test N-Values taken near the proposed rock sill structures ranging from 0 to 1 at the top of the layer and values from 3 to 8 at the bottom.

Existing borings have not been tested. More borings will be advanced, and testing will be completed for the next phase of design.

Since existing borings have not been tested, consolidation test data from soil boring 87-24M at Lock and Dam 2 were used in the settlement analysis. Boring 87-24M was initiated for the foundation investigation for construction of the Central Control Station for Lock and Dam 2, which is just upstream of the Boulanger Bend project. The upper thirty feet of the boring was characterized as soft, wet, and gray lean and fat clay. Standard Penetration Test N-values for the Lock and Dam 2 sample are similar to those recorded at the Boulanger Bend project and range from 1 to 2 at the top of the clay layer and 3 to 4 at the bottom.

6. GEOTECHNICAL DESIGN

The design approach consisted of evaluating selected alternatives. The primary features of this alterative include channel excavation and construction of two new training structures. This plan will include action to excavate/maintain a wider channel that is still within authorized dimensions and place two new training structures (rock sills) one on the right descending bank from River Mile 819.5 to 819.8 and one on the left descending bank from River Mile 818.4 to 818.9. These features will improve navigability, safety and reduce channel maintenance requirements. The proposed designs were analyzed to meet the following criteria:

(i) The proposed designs must be stable and must not develop objectionable deformations under all conditions of construction and operation.

No geotechnical analyses were performed on the proposed channel excavation.

A consolidation settlement analysis was performed to determine a reasonable range of expected settlement of the rock sill structures on top of the existing clay foundation. Beneath the alignment of the proposed structures, the clay layer ranges from 10 feet to 30 feet thick. The change in stress after construction of the rock sill structures were computed using surface loads on a semi-infinite mass. The change in stress is based on the additional load that the foundation would experience with the construction of the rock sill structures. Computations for settlement can be found in Attachment L-2.

Because consolidation test data are unavailable at the project site and the clay layer thicknesses vary from 10 to 30 feet, there is a high level of uncertainty in the estimated range of expected settlement. Once additional borings are advanced and more consolidation tests are performed, the settlement analysis will be updated.

Beneath the clay layer, there is a free-draining sand layer that will compress during construction. Consolidation settlement was not considered within this layer.

6.1 CONSOLIDATION SETTLEMENT METHODOLOGY

Consolidation settlement calculations were performed using one-dimesional consolidation theory as described in EM 1110-1-1904, Settlement Analysis (30 September 1990). This theory is combined with elastic solutions for change in vertical stress (developed by Poulos and Davis, 1974) to calculate settlement at any location due to an applied distributed load. These solutions will assume a two-dimensional surface load applied to a semi-infinite mass. To determine a settlement range, calculations were computed at both the thinnest and thickest clay cross-sections identified in the borings.

Settlement was computed using consolidation parameters and the calculated change in vertical stress within the clay later (see Attachment L-2). The layer was broken into one-foot sub-layers where change in vertical stress was calculated at the sub-layer mid-point. Settlement within each sub-layer was then computed to the depth of the bottom of the boring. Cumulative settlement was then determined by summing the settlement from each sub-layer. Settlement was calculated through the centerline of the distributed load at the location of maximum fill height. Calculations assumed groundwater level equal to the channel bed elevation (i.e., depth of groundwater is zero). Since the water elevation will be significantly higher on the structures, the effective unit weight of the rock was used during computations.

6.2 CONSOLIDATION SETTLEMENT RESULTS AND REMARKS

Settlement calculations reveal that roughly 7 to 12 inches of settlement can be expected over the lifetime of the project. Observable settlement is expected to take several years. Typically, settlement has been taken into account by overbuilding the structure, but the impact on the one-percent flood profile is particularly important to the Minnesota Department of Natural Resources. While the excavation of the channel increases conveyance and drops the water surface about 0.05 feet, the construction of the rock sill training structures decreases conveyance-subsequently raising the water surface. Stage increases higher than 0.005 feet are unacceptable. To avoid increased flood stages, the rock sill structure top elevation should not exceed 0.4 feet above low control pool. This constraint prevents overbuilding of the rock sill structures to mitigate consolidation settlement.

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Attachment J-1

Soil Exploration

Attachment J-2

Settlement Calculations