Appendix J
Geotechnical Engineering

Table of Contents

List of Figures

List of Tables

1 Purpose

This Appendix presents more detailed information regarding the geotechnical aspects of the Yorkinut Slough Habitat Rehabilitation and Enhancement Project (Project). It contains all other relevant geotechnical and subsurface information necessary for a detailed and thorough understanding and review of work that was not included within the main report.

2 Location

The work is located at the Two Rivers National Wildlife Refuge (Refuge) administered by the U.S. Fish and Wildlife Service (USFWS). It lies on the right descending bank of the Illinois River, between River Miles (RM) 5 and 11 in Calhoun County, Illinois. The area is bounded by the Illinois River to the North, Swan Lake to the North-West, Calhoun Point to the East, and adjacent landowners to the South. It is near the city of Brussels, Il; some 2 to 3 miles East of the city. Chapter 1 Section C of the main report contains more information.

3 Project Features

The study team considered four alternatives. All of these require some form of earthwork construction. The Tentatively Selected Plan (TSP) is Alternative 3 Intermediate B (see Chapter 6 of the main report). A brief overview of the geotechnical work required by each alternative is summarized below:

- Alternative 1 – Minimum: Incorporates measures to remediate the seepage issue of the Pump Station Moist Soil Unit (MSU). Berm raise is considered along the berm between Swan Lake and Yorkinut Slough. The combination of four different MSUs into two requires the degrade/removal of the separating berms between them. The construction of two new wells will be performed by Ducks Unlimited.
- Alternative 2 – Intermediate A: Multiple MSU reconfigurations require the degrade/removal of separating berms. The berm between Swan Lake and Yorkinut Slough will be raised with shallower slopes. A new berm will go across Swan Lake, and two new wells will be built by Ducks Unlimited.
- Alternative 3 – Intermediate B: Multiple MSU reconfigurations require the degrade/removal of separating berms. The berm between Swan Lake and Yorkinut Slough will be raised with shallower slopes. A new berm will go across Swan Lake with a different proposed alignment as Alternative Intermediate A, and four new wells will be built, two by Ducks Unlimited, and two by the U.S. Army Corps of Engineers (USACE).
- Alternative 4 – Maximum: Multiple MSU reconfigurations require the degrade/removal of separating berms. The berm between Swan Lake and Yorkinut Slough will be raised with shallower slopes. A new berm will go across Swan Lake with the same proposed alignment as Alternative Intermediate B, and four new wells will be built, two by Ducks Unlimited, and two by USACE. Channel improvements and modifications may require some earthwork.

4 Subsurface Exploration

A total of 12 borings were performed as part of this feasibility study. Ducks Unlimited also drilled 4 borings as part of their test well operations on March 16, 2022. At that time, they only described the soils by depth and performed pump tests but took no samples. Their borings are also included as part of this appendix as a reference. The borings were used to understand the general soil stratigraphy throughout the site and to confirm clay cap presence and thickness. Borings taken at proposed well locations were also intended to

locate the aquifer depths to inform well designs. Boring designations include the year ("22"), "YS" for Yorkinut Slough, and "AD" for auger drive. Table 1 summarizes general information about the borings.

Table 1. General Boring Information.

Boring	Date	Easting (ft)	Northing (ft)	Boring Depth (ft)	Driller
DU #1	3/16/2021	2190785.929	826552.193	100	Grosch
DU #2	3/16/2021	2196141.442	822451.807	120	Grosch
DU #3	3/16/2021	2198633.935	826426.265	120	Grosch
DU #4	3/16/2021	2199003.551	829109.868	115	Grosch
22-YS-AD-01	3/31/2022	2197997.879	831756.022	31.5	USACE NWK
22-YS-AD-02	3/30/2022	2198483.476	830514.789	31.5	USACE NWK
22-YS-AD-03	3/29/2022	2198082.206	829174.943	31.5	USACE NWK
22-YS-AD-04	10/14/2022	2195743.6	826023.3	30.0	Hurst-Rosche
22-YS-AD-05	10/10/2022	2195321.9	826637.3	30.0	Hurst-Rosche
22-YS-AD-06	10/7/2022	2194847.9	827158.3	30.0	Hurst-Rosche
22-YS-AD-07	10/17/2022	2194602.8	825234.5	30.0	Hurst-Rosche
22-YS-AD-08	10/7/2022	2192737.6	826265	30.0	Hurst-Rosche
22-YS-AD-09	4/4/2022	2191189.859	826741.108	33.6	USACE NWK
22-YS-AD-10	10/19/2022	2194978.072	827445.657	30.0	Terracon
22-YS-AD-11	10/12/2022	2198641.792	826422.714	120	Terracon
22-YS-AD-12	10/14/2022	2198991.116	829072.078	116.1	Terracon

*Easting and Northing correspond to State Plane Coordinate System IL WEST and were obtained by hand-held GPS.
** USACE NWK – USACE Kansas City District.

Soil samples were collected during completion of Standard Penetration Tests (SPT) in accordance with ASTM D1586. SPT samples for borings 04, 05, 06, 07, 08, and 10 were collected on 2.5-foot centers to a termination depth of 30 ft. SPT samples were collected for borings 01, 02, 03, and 09 on 5-foot centers to a termination depth of 30 ft. SPT samples were collected for borings 11 and 12 on 2.5-foot centers to a depth of 60 ft, then on 5-foot centers to a depth of 120 ft or refusal. Materials were classified according to ASTM D1587 Test Method for Description and Identification of Soils (Visual-Manual Procedures). Boring locations are shown in Figure 5. Boring logs are presented at the end of this appendix.

4.1 Drilling Timeline

Ducks Unlimited (DU) had originally proposed installing a total of four new wells to replace some of the older wells in the Refuge. These wells were dubbed the Office Well, Deer Plain Well, Yorkinut Well, and Calhoun Point Well. In March of 2021, Grosch Irrigation Co. Inc. drilled and installed four test wells for them at the proposed well locations and performed pump tests. When DU sought estimates to construct the wells, they came back higher than expected. DU determined they would only be able to build one, or two at most. It was determined they would surely build the Office well, and if funds permitted, Deer Plain well as well. During this time, USACE awarded the USACE Kansas City District (NWK) a drilling task order for borings 01 to 09. The NWK drilling crew was onsite between March 28th to April 5th, 2022, but due to unfavorable site conditions from heavy rainfall prior to their arrival were only able to complete borings 01, 02, 03, and 09. A second task order was

drafted during the late Spring/early Summer to complete the remaining drilling as well as drill in the well locations. At the time of drafting said task order, DU had not confirmed whether they could build the Deer Plain well, so the task order assumed USACE would construct the Deer Plain, Yorkinut, and Calhoun Point wells. Boring 10 was originally proposed at the Deer Plain well location. When DU confirmed they would also build Deer Plain well, a modification to the task order was issued to change boring 10 from the proposed Deer Plain well location to the Pump Station MSU to explore the drainage issues there. This task order was awarded to Hurst-Rosche who drilled the shallow borings and subcontracted the deep borings out to Terracon. Although boring 10 reached only a shallow depth (30 ft), Terracon drilled it because Hurst-Rosche had contracted it out to them before the modification was issued. This modification changed the location, bottom of hole depth, and the rate of testing for the boring. This slew of drilling took place from October 7 to 19, 2022.

4.2 Pump Station MSU

Figure 1. Pump Station ("Leaky") MSU shown with NRCS soil classification as mostly Beaucoup.

One of the geotechnical objectives of this Project was to determine the cause for the Pump Station MSU's inability to hold water (see Figure 1). This currently impacts the Sponsor's ability to manage the unit as intended or desired without incurring into additional pumping costs, further impacting their ability to provide refuge to migrating waterfowl. Observations from the Refuge staff indicate that it takes about a week of pumping to flood the MSU. As soon as the pumps are turned off, it takes roughly the same amount of time for the water to completely drain out.

Borings 04, 05, 06, and 10 were taken within the MSU boundaries (see Figure 5) to characterize the subsurface profile of the unit and discover any clues as to the drainage

issue. The study team conducted a site visit on July 27, 2022. At the time, the Refuge Manager stated that the ditch that runs alongside the Western edge of the MSU is not thought to have been designed whenever it was dug, and that it appears the MSU drains slower whenever the ditch is full. This observation points to the possibility of a sand lens being cut or a sand layer being exposed to surface. The drainage path would be through the sand lens into the ditch. A review of NRCS soils data from the Web Soil Survey (https://websoilsurvey.nrcs.usda.gov) (Figure 2) appeared to back this hypothesis up. The survey shows Beaucoup soils, the main constituent of the MSU, tend to experience a sharp increase in sand content from around 10% to 17% at a depth of 3.5 ft to 4ft. This jump in sand content translates to greater amounts of coarser material being present at that depth and would increase soil permeability, aiding seepage. Likewise, we see a decline in clay content. At that same depth, the clay percentage drops down from 30% to 23%. A soil needs a clay content of about 27% or 28% before it is able to start consistently ponding water, and here we see it decrease past that threshold. The study team visited the site a second time to perform soil probes. The intent was to verify the presence/depth of a sand layer consistent with the hypothesis that the water was draining through it. The visit took place on September 15, 2022. The 36-inch probes taken at the MSU all retrieved silt and clay soils. No sand samples were encountered within the MSU during this site visit. A control sample taken at an adjacent MSU did find a sand lens, however that MSU does not experience seepage issues. The findings at the time were inconclusive. The locations of the soil probes can be seen in Figure 3.

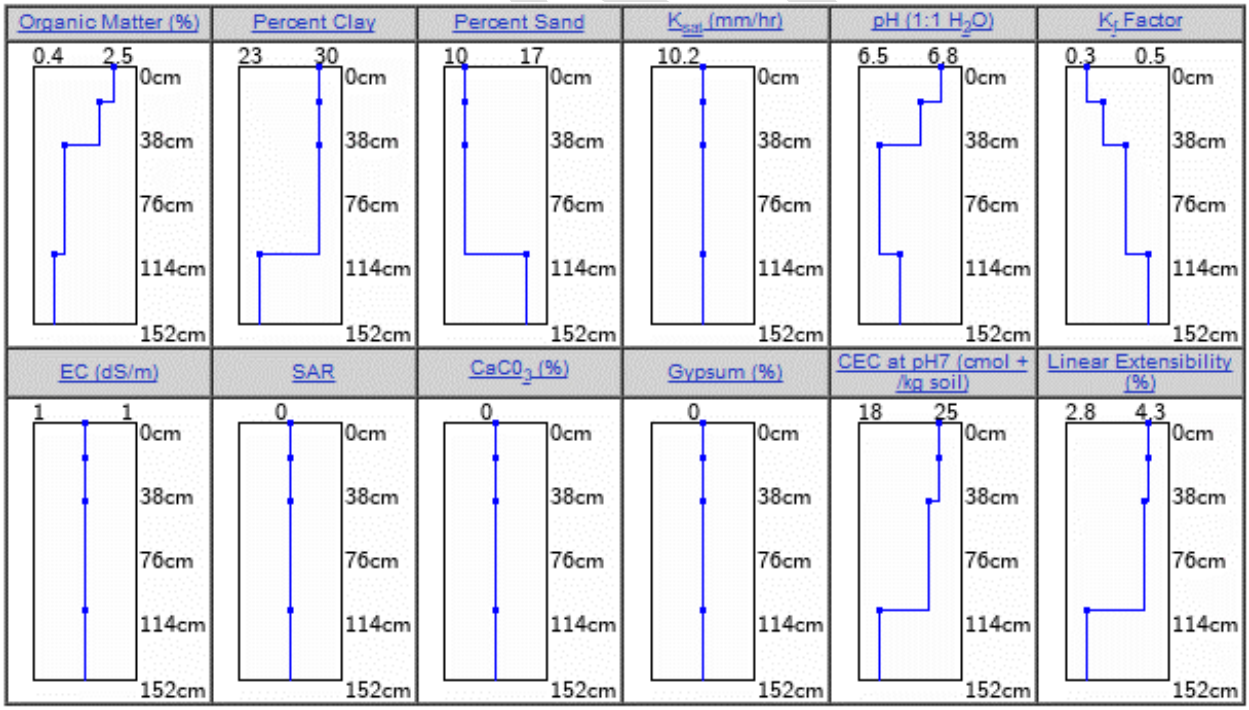

Figure 2. NRCS data for the Beaucoup soil series at the Pump Station MSU.

During the visit, the Refuge wildlife biologist reported her observation that the last place the Leaky MSU holds water is at the north-west corner in an “L” shape, where the north and west berms meet. Topography indicates water drains in the MSU from the south-

east to the north-west. The south-east corner is not considered to be the main problem area because drainage persists even when water is off the high ground located there. The observation suggests the north-west corner might be involved in the drainage issue since water continues to escape even when only present at this location. Subsequent review of borings 06 and 10 did not reveal anything concerning in this area.

Figure 3: Soil Probe Locations

Review of historical aerial imagery and the boring logs later revealed another possibility. Borings 04, 06, and 10 had clay caps at the ground surface some 9 to 10 feet thick underlain by sands. Boring 05 only had 5.5 feet of clay cap, also underlain by sands. Historical aerial images show that close to boring 05 is an area that is consistently wet and lacking vegetation. This could indicate a sandy outcrop at or near the surface where the water is draining from the MSU at low stages in Swan Lake and could possibly seep in during higher stages. The lack of vegetation can also be indicative of sand outcrops since vegetation does not grow easily in sands. Two of these possible outcrops are shown in Figure 4.

Figure 4. Historical images showing possible areas of shallow sand at Pump Station MSU.

The Refuge Manager also believes there is a possibility for clay drainage tiles to be present in the field. Some of the USFWS Refuge personnel have looked at historical aerial imagery of the area but have not come upon a definitive conclusion yet. The study team has considered the use of different geophysical methods to determine the presence of the clay drainage tiles and of a sandy layer close to the ground surface, and of cutting a shallow trench along the western ditch to try to unearth some clay drainage tiles, if present. None of these two avenues have been pursued at the time of writing this report.

4.3 Boring Results

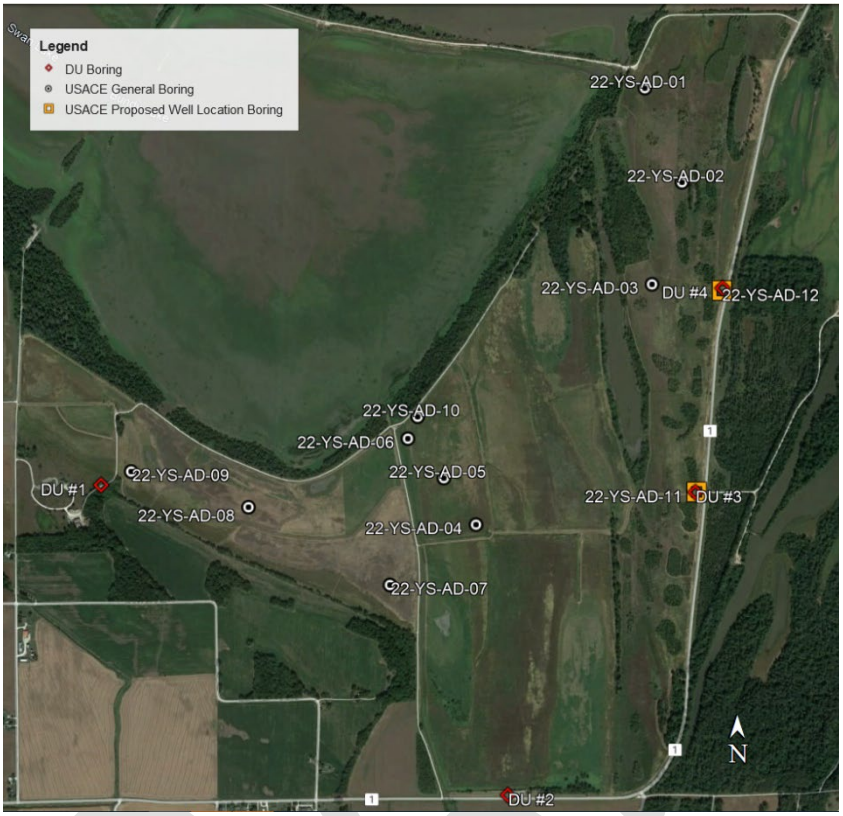

Figure 5. Boring locations.

The study area stratigraphy generally consists of a clay cap at the ground surface underlain by sands. The clay cap is generally some 9 to 10 ft thick. Clay lenses are also present deeper down. Borings 02 and 03 had an additional clay layer about 20 to 25 ft down. A clay cap of only 5.5 ft was observed at borings 05 and 08. Although, the clay cap in boring 05 is thought to be associated with the drainage issue of the Pump Station MSU, it is not considered to be an issue in boring 08 since the Lower Calhoun MSU holds water. Boring 09 shows 25 ft of clays and clayey sands before transitioning to sands. Borings 11 and 12 encounter the aquifer at a depth of 13 and 20.5 ft, respectively, and boring 12 hit rock at 108.5 ft of depth while boring 11 never encountered rock. The water table ranges from 6.6 ft deep to 16.8 ft deep throughout all the borings drilled. At the Calhoun Point Well location (22-YS-AD-12), the water table is 13 ft below ground surface, while at the Yorkinut Well location (22-YS-AD-11) it is 16.8 ft below ground surface.

4.4 Borrow

Borrow would come from within the study area. Berm degrades may also provide suitable material for construction. Site investigations revealed a generally thick clay cap at the ground surface. Some of the clay cap may be used as borrow while still leaving enough thickness in place to avoid seepage problems. However, due to the high variability of soils withing a floodplain, the thickness of the clay cap should be confirmed in the locations borrow may be taken. The clay cap soils and any other borrow source should be tested to confirm suitable properties for the application before use.

5 Laboratory Testing

All the samples retrieved were disturbed and were collected by means of a splitspoon sampler. The lab data is included at the end of this appendix. The analyses performed on the soil samples were:

- Water Content (w%) (ASTM D2216)
- USCS classification (ASTM D2487)
- Atterberg Limits (ASTM D4318)
- Gradation Curves (ASTM C117 AND C136)
- Visual classification of the fines (ASTM D2487)

6 Well Design

During March 2022, Grosch Irrigation Co. Inc. drilled borings at Ducks Unlimited well sites #3 (Yorkinut Well), and #4 (Calhoun Pt. Well). The test holes were logged for soil type, and then a temporary well was installed and tested. The test pumping wells were constructed with 50 ft of 6" SDR 26 PVC casing, and 40 ft of 6" saw slot PVC screen with .032" slot width. Site #3 had a static water level of 13 ft, reported a drawdown of 22.5 ft at a pumping rate of 225 GPM, and a drawdown of 19 ft at a pumping rate of 155 GPM. Site #4 had a static water level of 20 ft, reported a drawdown of 20 ft at a pumping rate of 230 GPM, and a drawdown of 17 ft at a pumping rate of 160 GPM. Well design recommendations were developed based on the results of the pumping tests and lithology. Table 2 depicts the well design recommendations provided by Grosch.

Table 2. Well design recommendations.

Well	Depth (ft)	Screen Length (ft)	Casing Length (ft)	Stainless Steel Screen Slot Size	Filter Pack	Well Diameter (in)	Well Riser Thickness (in)
Yorkinut Well	100 - 120	30	70 - 90	70	RF #2	24	0.375
Calhoun Point Well	100 - 120	30	70 - 90	70	RF #2	24	0.375

7 Recommendations

The level of subsurface investigation performed as part of this study was unable to determine the cause of the Pump Station MSU's drainage problems. Insight for future investigations might be gained from proposed activities that will not be incorporated into this report. These activities are contingent on time and funding. As part of these, a trench will be dug along the ditch berm in an effort to locate the suspected clay drainage tiles. Separately, a Frequency Domain Electromagnetic (FDEM) survey is planned to look at areas of interest to detect any anomalies that might indicate the source or path of drainage. It is recommended the FDEM take a look at the two locations identified in Figure 4. The trench should be at least 20 ft away from the berm toe, no more than 3 ft deep, and the excavated material should be placed back and compacted as best as possible. If no further investigation will be pursued, or if the cause of the drainage cannot be determined, the

MSU should not be combined with other units. Alternate management strategies should, thus, be pursued.

Additional subsurface exploration will need to be obtained during PED. The additional exploration should consist of Standard Penetration Test (SPT), auger borings with undisturbed samplings, and laboratory testing to characterize the subsurface conditions at the site. The subsurface investigation is needed for the design of proposed measures to be constructed. If the Project includes the construction of a new pump station and a berm along Swan Lake, borings at the proposed pump station location and along the berm alignment are recommended to inform the construction and design.

The locations of the borings will be finalized in PED when structure and berm locations are finalized. It is assumed that a minimum of one boring will be needed per structure for the pump station, gate structure(s), and other structures with significant loading. Testing will vary for each structure, but at a minimum testing will include soil classifications (sieve and Atterberg limits), moisture contents, as well as UU triaxial strength testing and consolidation testing under the pump station. All testing will follow the appropriate ASTMs. Borrow soils should also be tested to ensure their properties are appropriate for the intended use. The thickness of the clay cap should be confirmed at proposed borrow pit locations to avoid exposing the sands below.

8 Boring Logs

9 Laboratory Test Results

10 Ducks Unlimited Drilling Logs