BOLTON & MENK

Real People. Real Solutions.

Engineer's Report for

Proposed Levee Repairs

Drainage District No. 2

Subdrainage District No. 3

Pottawattamie County, Iowa

2018

Submitted by:
Bolton & Menk, Inc.
300 W Mckinley St
Jefferson, IA 50129
P: 507-625-4171

Certification

Engineer's Report

for

Proposed Levee Repairs

Drainage District No. 2
Subdrainage District No. 3
Pottawattamie County, Iowa
P12.111254

2018

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision, and that I am a duly Licensed Professional Engineer under the laws of the State of Iowa. My renewal date is December 31, 2018.

By: Jonathan P. Rosengren

Jonathan P. Rosengren, P.E.
License No. 21661

Date: June 13, 2018

Table of Contents

I. Introduction 1
A. Scope of Work 1
B. Location 1
C. History – DD2 Sub 2 Levee 1
D. History – DD 2 Sub 3 Levee 2
II. Investigation 3
A. Private Levees Serving to Protect the District 4
B. Historic Protection Level 5
C. Revised Protection 5
D. District Right-of-Way 7
III. Other Regulatory Requirements 7
A. State of Iowa Flood Plain Permit 7
B. Clean Water Act Compliance 7
IV. Proposed Work 7
A. Subdrainage District No. 3 Levee 8
B. Mayne Private Levee 9
C. I-680 Realigned Levee 9
D. Paxton Private Levee 9
E. Fill Material 10
F. Right-of-Way Acquisition 11
G. Work Limits 12
H. Utilities 12
V. Assessment Schedule Review 12
VI. Discussions & Recommendations 12
VII. References 13

Tables

Levee Datum Elevation Calculation 4
1962 Annual Exceedance Probabilities – Missouri River at Omaha Gage 5
2002 Annual Exceedance Probabilities – Missouri River at Omaha Gage 6
Summary of Estimated Construction Costs 10

Appendix

Appendix A: Letter to Iowa DOT

Appendix B: Determination of Flood Frequency of the Missouri River Below Gavins Point Dam

Appendix C: Missouri River Levee System

Appendix D: Rights-of-Way Tabulation

Appendix E: 2018 Annexation and Benefited Lands Maps

Appendix F: Engineer's Opinion of Probable Costs

Proposed Plans

I. INTRODUCTION

A. Scope of Work

In the fall of 2016, Bolton & Menk, Inc. was appointed engineer to review the Levee systems in Drainage District No. 2, Subdrainage District Nos. 2 & 3 and to reclassify the lands for benefits derived from the same. Upon review of the existing system, records in the office of the County Auditor and discussions with the Board of Trustees, the scope has been modfied to include re-establishment of the repair elevation and cross section of the levee and acquisistion of right-of-way for two private levees.

B. Location

Drainage District No. 2, Subdrainage District Nos. 2 & 3 have historically protected an area of Missouri River flood plain starting approximately even with Omaha's Eppley Airfield on the south and extending to near the Sac Ditch to the north along the Missouri River. The alignment of these two levees generally followed the historic river bank at the time the subdrainage districts were established.

On April 6, 2018 the Board of Trustees approved annexation of approximately 8,300 acres of land into Subdrainage District No. 3 to bring the total area assessed in the district to 11,341 acres. This annexation included the area originally protected by the Subdrainage District No. 2 Levee. Maps showing the lands annexed at that hearing and the benefit classifications assigned to all parcels in the district are included in Appendix E of this report.

C. History – DD2 Sub 2 Levee

October 6, 1917 – Petition to Establish Subdistrict – Requesting construction of open ditches in Sections 16 and 21, and taking over of private levees

Unknown Date – Engineer's Report – Recommends construction of a Main Ditch and Lateral Ditch as well as improvement of private levees.

March 7, 1918 – Hearing on Report – Board directed engineer to amend his report to provide a less expensive plan

Unknown Date – Amended Engineer's Report – Modifies recommended open ditches

March 20, 1918 – Hearing on Amended Report – Recommended improvements approved as amended

April 10, 1918 – 2nd Amended Engineer's Report – Recommended levee as only sub district improvement

April 10, 1918 – Hearing on Second Amended Report – Board approves changes and disallows damages for open ditch.

September 7, 1918 – Engineer's Report – Recommends taking over privately constructed levees in Sections 16 and 21. Top width is 12' with 3:1 slopes on the river side and 1.5:1 slopes on the land side. Right-of-way recommended is 120 feet.

January 6, 1919 – Report of Commissioners

August 24, 1951 – Meeting–

Letters from the MB Pitts Estate requesting a tube be constructed through the Paxton Levee.

Discussion regarding ownership of the levee was held. USACE had made some repairs the previous year, possibly at the request of DD 2 Trustees

Drainage Attorney for the district stated his "opinion that even if all had been done as inferred, there had been no adoption of the levee as a part of the drainage district's improvements; that to take over such an improvement there should first be an investigation and a report by a competent engineer that it was to the advantage and gain of the district to do so, coupled with a transfer of the improvement to the district by the private owners, waivers of compensation claims for damages and for the value of right-of-way so that the improvement could safely be adopted by the district and recorded as such."

Trustees for DD 2 suggested they lend a currently unused 36" tube with flood gate to the landowners to install at their expense in the private levee.

D. History – DD 2 Sub 3 Levee

May 1920 – Petition for Levee

1920 – Engineer's Report – Recommends construction of a levee connecting to the Sub 2 Levee in Section 28-76-44 then running west to 130th St then south to the Missouri River then west to the ICRR in Section 11-75-44

Height was to match DDS2 levee at their intersection then have "practically uniform height corresponding with the water level of the Missouri River."

Right-of-Way width is 100 feet. Top width was 20 feet with 3:1 slopes on the river side and 2:1 on the land side.

A levee was built on either side of the Pigeon DD 2 outlet channel from the DD S3 Levee north to the Mayne Bridge in Section 3-75-44 where the DD 2 levees end.

Right-of-way is 100 feet for each levee. Top matched DD S3 levee elevation Top width was 10 feet with 3:1 slopes ditch side and 2:1 land side.

Two flood gates were added. One in the west levee along Pigeon DD 2 at the location of a depression. The second in the main levee near station 351+00

October 12, 1951 – Meeting with Mormon Pioneer Memorial Bridge members

Discussions on plan to replace portions of DDS3 with road bed of new Mormon Trail Road.

New road would be 1 to 2 feet lower than the DDS3 Levee at its junction with the Paxton Private Levee in Section 32-76-44. "Nevertheless the roadway provided more protection because there was no danger of the waters going through it, and that it would only go over the roadway if there was a flood such as had not been anticipated."

The Trustees strongly objected to the planned lowering of the district levee. Trustee Rief agreed to donate dirt from his land north of the highway to raise the elevation another 1 to 2 feet. Also agreed that if raising the top caused the road bed to extend beyond the right-of-way he would waive any damage claim for said right-of-way taken.

c. 1970's I-680 Road Plans

Plans show old Mormon Trail Road along DD2S3 Levee in Sections 29 and 32. Old road was raised by agreement of October 12, 1951 to match

DD2S3 Levee top.

Old road elevation from plans: 993.0

I-680 road elevation from plans: 991.0

Datum Equation: Plan Elevation 993.33 = 994.00 NAD 1983 Iowa State Plane South elevation

Jun - Aug 2011 – Missouri River Flood

During the summer of 2011, severe river flooding led to the overtopping of the district levees resulting in several reaches of damage, including destruction of the I-680 roadway which historically served as part of the DD 2 Sub 3 Levee.

October 31, 2011 – Reconstruction of Destroyed I-680 roadway completed at a cost of $19.1M

2012 – Repairs made by the USACE and drainage district to Sub 3 Levee and private Paxton and Mayne Levees. Repair costs assessed to the district in 2018.

II. INVESTIGATION

Survey of the DD 2 Sub 3 Levee was completed in December of 2017. This survey included cross sections and top of levee elevations over the full length of the district and private river levees which combined provide flood protection to the district. The survey also gathered information regarding the restored elevation of the the I-680 roadway near the county road 130th St overpass.

The district records at the county auditor's office were reviewed, however, no record of the levee elevations or grades were found. Fortunately, review of the I-680 and Mormon Pioneer Memorial Bridge roadplans revealed good datum ties to the original levee elevations.

In 1951, the Mormon Pioneer Memorial Bridge commission planned to construct a two lane highway through the district and for a short distance very near and parallel to the district levee. The road plans show the existing levee along with a note stating the levee would be used as borrow to supply the necessary earthfill to construct the roadway proposed. The proposed road elevation was 991.0 based on the state datum at that time.

At a meeting in October of that year, the commission met with the trustees of Subdrainage District No. 3 to discuss the proposed work. At that meeting the trustees objected to the planned elevation, stating the road elevation would be lower than the historic elevation of the facility. After review of the levee with the commission and district engineers, it was agreed the proper elevation of the levee was 2 feet higher at 993.0. Trustee Rief offered to supply the necessary borrow to raise the roadway back to the historic levee height. The minutes of this meeting and selected road plan sheets are included in Appendix A of this report

In the mid-1970's plans were developed to turn the Mormon Bridge Road into a four lane interstate highway. The plans for this improvement show the road elevation of the Mormon Trail Road at 993.0 as was agreed between the trustees and the state in 1951. The plans also show cutting this road bed down to 991.0 to supply the necessary earthfill to construct the two road grades proposed. This set of plans is the only place we have been able to determine a true elevation for the Sub 3 Levee Top. Using benchmark data correlated to the road plans for I-29, the historic levee top at the south line of Section 29-76-44 is calculated as follows:

Levee Datum Elevation Calculation			
Plan Benchmark Elev	**Less Plan Levee Elev**	**Plus Measured Benchmark Elev**	**Equals Calculated Levee Elev**
993.33	993.0	994.00	993.67

Selected plan sheets are included in Appendix A of this report.

The 1920 Engineer's Report states the grade of the levee generally follows the water elevation in the river. Using Lidar data gathered by the state of Iowa and resources available online, we have estimated the river grade at approximately 1.0 foot of fall per mile. We have projected this grade to the alignments shown in the included planset to set the repair grade of the district levee.

Our survey reveals that large portions of the levee system are below grade with some portions as much as 5 feet below grade particularly in the southeast corner of the district. The system as a whole averages approximately 2 feet below the repair grade elevation. Several acres of trees will need to be cleared from the levee in the southeast corner of the district in order for repairs to be made and to extend the funtional life of the levee.

A. Private Levees Serving to Protect the District

1. Mayne Levee

The west end of the Sub 3 Levee was designed to run north along the west line of Section 32-76-44. County road 130th St was constructed on top of the levee for approximately 1 mile. A private levee was constructed at some point after Sub 3 was built yet prior to 1936 and connected to Sub 3 at the south end of 130th St. This levee, known historically as the Mayne Levee continued west and north along the bank of the river to near the center of Section 30-76-44.

The portion of this levee south of I-680 renders the reach of Sub 3 beneath 130th St unnecessary as no flood waters would reach 130th St which would not also overtop Sub 3. A sanitary landfill built adjacent to the levee in Section 31-76-44 disguises a large reach of this levee. The fill from this landfill prevents overflow from the river and requires only a portion of the Mayne Levee be maintained to provide the necessary protection.

Our survey has found the top of the levee, which was repaired as part of the work in 2012, to be very uneven, ranging between 1 foot and 5 feet below grade. This levee was found to be generally free of trees.

2. Paxton Levee

Prior to 1936, a private levee known historically as Paxton Levee was constructed intersecting the Sub 3 Levee at approximately the SE corner of the SW ¼ of Section 29-76-44. The Paxton Levee lies west of the DD 2 Sub 2 Levee. This levee now connects to the north slope of the road embankment of I-680 then runs generally north to the river then follows the river bank north to the Sac Ditch. At the intersection with the Sac Ditch, the levee continues north under the jurisdiction of the Honey Creek Levee System.

There are no records of the grade, elevation or cross section of the Paxton Levee when it was originally built. There are indications that the same private landowner built the Paxton Levee as built the original private Levee which was acquired by DD 2 Sub 2 in 1917. When Sub 2 acquired the levee, there is no mention in the Engineer's Report of needing to raise the elevation. When the Sub 3 Levee was built in 1920, the top elevation was set to match the earlier Sub 2 Levee.

Using these pieces of circumstantial evidence, it is reasonable to assume that the Paxton Levee also matched the elevation of the Sub 3 Levee at the intersection point in Section 29. Matching these elevations and using the general river grade projected to the alignment, we find the appropriate repair grade to be 0.01% with a top width of 12 feet and sides slopes of 3:1.

Our survey has found the majority of this levee to be between 1.5 and 3 feet below the repair grade, with one reach between stations 23 and 59 averageing approximatley 4 to 5 feet below grade. The majority of this levee was found to be free from trees, though in one short reach, trees are beginning to regrow in what will become the district right-of-way. These trees should be removed to prevent regrowth of trees on the levee itself.

B. Historic Protection Level

Included in Appendix B is a study conducted in 2002 by Roger Kay of the Army Corps of Engineers. His work was to update the exceedance probablity curves for the Missouri River downstream of Gavins Point Dam in South Dakota. A summary table of the exceedance probablilities, river flows and river stages from the 1962 review follows.

1962 Annual Exceedance Probabilities – Missouri River at Omaha Gage			
Prob (%)	**Return Period (years)**	**Flow (cfs)**	**Stage (feet)**
50	2	74000	25.26
20	5	103000*	29.65*
10	10	125000	31.57
5	20	142500*	32.70*
4	25	150000*	33.15*
2	50	170000	34.20
1	100	190000	35.17

**Estimated from available data points*

We have reviewed the river grades in the area along with the elevations of the river gage at the I-480 bridge south of the district in Omaha. In the area of the Sub 3 and Paxton Levees, the natural river bank elevation matches a river gage stage of approximately 24.5' above the river bottom. The repaired top of levee for this system is approximately 32.5' above the river bottom.

Using the 1962 data, the levees have historically protected from river flows in the range of Q20. Due to flood damage, settlement, tree growth, several low spots and general lack of routine maintenance of the district and private levees the current level of protection provided by the levees is a river stage of approximately 29.5' south of I-680 and 29.0' north of I-680. This is a reduction of approximately 3' to 3.5' of protective elevation.

C. Revised Protection

As stated above, the annual exceedance probabilities were recalculated by the Army Corps in 2002. The results of that recalculation resulted in reduced elevations for each event threshold. Thus the protection level provided by the repaired levees today would slightly exceed the Q25 flow. The table below shows the revised annual exceedance probability numbers, along with local effects at several river stages as listed on the USGS website for the Omaha river gage.

2002 Annual Exceedance Probabilities – Missouri River at Omaha Gage					
From Kay Paper				From USGS Website	
Prob (%)	**Return (years)**	**Flow (cfs)**	**Stage (feet)**	**Stage (feet)**	**Flood Impacts at Stage**
				19	At this level, the City of Council Bluffs begins to close drainage gates that discharge into the river.
				21	At this level the City of Council Bluffs begins closing flood gates.
50	2	64100	23.46	25	A casino parking lot begins to flood along the Iowa side of the river. In addition, Haworth Park located in Bellevue begins to flood.
20	5	85200	27.18	27	NP Dodge Park, Freedom Park, Tom Hanafan Park and Fontenelle Forest begin to flood.
				28	At this level most of the flood gates for the city of Council Bluffs are closed.
				29	At this level water nears the base of the Council Bluffs levee. Significant lowland flooding occurs in NP Dodge Park, Freedom Park, Tom Hanafan Park, Fontenelle Forest and Haworth Park.
10	10	123500	31.47		
5	20	129400	31.85		
4	25	132500*	32.05*	32	Interstate 680 West between the Mormon bridge and Interstate 29 begins to flood. Also, Interstate 29 between Crescent and Council Bluffs begins to flood.
2	50	148000	33.04		
1	100	174900	34.46	34.26	This level represents a flood that has a 1-percent chance of being equaled or exceeded in any given year.
.2	200	207700	35.79	36	Water reaches the bottom of flood wall just north of Interstate 480. Low lying roads are also affected just east of Riverfront Drive north of the pedestrian bridge.
.5	500	248200	37.15	38.26	This level represents a flood that has a 0.2-percent chance of being equaled or exceeded in any given year.
				40	At this level the water nears the top of the federal levee

**Estimated from available data points*

D. District Right-of-Way

The Engineer's Reports for both Subdrainage District No. 2 and Subdrainage District No. 3 record the acres of land taken for district rights-of-way for both facilities. The recorded width of the Sub 2 Levee rights-of-way is 120 feet, for Sub 3 the width is 100 feet.

There is currently no right-of-way for the Mayne and Paxton Levees. Approriate right-of-way should be acquired for both levees within which to maintain these facilites into the future. The existing acres of right-of-way are listed in Appendix D of this report.

III. OTHER REGULATORY REQUIREMENTS

A. State of Iowa Flood Plain Permit

The Iowa DNR, Flood Plain Management Program will have jurisdiction to review the proposed levee repairs described in this report. According to the IDNR rules for agricultural levees, the protection levels of the structures should not exceed Q25. At the time the levees were constructed, the protection level would have been in the neighborhood of Q15-Q20 which would be acceptable. Because the recurrence interval was revised in 2002, the protection level today is slightly higher than a Q25, which could potentially be a sticking point with the IDNR.

We do not believe this will prevent the necessary approvals from the IDNR for several reasons:

- The proposed work is the repair of existing levees on the existing alignments.
- The levees only exceed the Q25 threshold by 0.5' and could receive a variance.
- The other levees in the area which may be impacted are significantly higher than the Sub 3 Levee. If flood waters overtop the nearby levees, the area of Pigeon Creek will have already long since been inundated, providing significant storage for flood waters and flood reduction.
- The protection of the I-680 and I-29 Interstates provides a significant value to these levees which would warrant a variance to prevent extreme losses to the State of Iowa from future floods.

This permit will be applied for once it is clear that the project will move forward to construction.

B. Clean Water Act Compliance

The work proposed in this report is the repair of existing agricultural levees on their existing alignment. Under the requirements of the Clean Water Act Section 404, this work should be exempt from USACE regulation. We have requested a review by the Omaha District of the USACE to confirm this exemption to allow the project to continue moving forward.

As of the date of this report that has been no response from the USACE to any of our inquiries.

IV. PROPOSED WORK

The investigation has confirmed the need for repairs within the district. In order to restore the original flood protection, it is necessary to remove trees within the right-of-way and repair the levee cross section.

The original Engineer's Report for the district recommended two surface water pipes with flood gates be placed in the Sub 3 Levee. Both pipes were located during our survey and are shown on

the included plans. However, we have not reviewed the condition of these pipes or whether they will be long enough following repair of the levee. The condition and situation of each pipe will be reviewed during construction after repair of the levee, to determine if further work may be necessary.

A significant number of trees have been allowed to grow up on and near the existing levees. Many were cleared as part of the 2012 repair work, yet many still remain. We recommend that all trees within the work limits of the project be cleared to prevent damage to the levees. We recommend that after the trees are removed, a regular spray plan be implemented to prevent the return of trees and brush.

We recommend that special effort be made to establish a strong stand protective brome cover on the newly restored levees. This work will include fertilizer, mulch and nurse crops to aid the quick establishment of a weed and tree free vegetative cover.

Where the levees are repaired, we recommend stripping the existing levee surface, fill the levee with appropriate earth material and replacing the strippings as topsoil with the intention to quickly re-establish a vegetative cover on the levees.

A. Subdrainage District No. 3 Levee

We recommend the full repair of the Subdrainage District No. 3 Levee between I-29 and 130th St parallel to the river. The repair cross section of the Sub 3 in the original Engineer's Report appears excessive for the needs of the district. We recommend narrowing the Sub 3 Levee top width to 12 feet with 3:1 sideslopes to match the repair sections of the private levee systems in the area. Any repairs will only add material to the existing levee, we are not recommending any portion be reduced in size from the existing condition. The proposed 12 foot top width will still allow access along the entire length of the levee for maintenance while reducing the cost of the repair.

The east end of the repair would intersect the I-29 roadway near the bluff. A short reach of levee between the interstate and the foot of the bluff would be left unrepaired as the interstate road surface at this location would limit the protection provided by this short reach of levee. The I-29 roadway at this location is approximately 1 foot below the repair elevation of the levee.

It is generally accepted that the top 1 foot of an earthen levee provides significantly less resistance to flood waters than the remaining levee. However, we also believe that if this foot of elevation is missing, there is no opportunity for this 1 foot freeboard to provide protection. The protection provided by this 1 foot gap does not warrant the modification of I-29 or construction of replacement levees at this time. We instead recommend an agreement with the Iowa DOT be made such that when I-29 is reconstructed at a future date, the Iowa DOT will raise the roadbed at this location to restore the protective elevation. The only portion of the district placed at slightly greaterrisk by this lower elevation is approximately 200 acres lying between Pigeon Creek and bluff.

We have identified one location on the East Pigeon Outlet Levee where the Main Open Ditch of Pigeon Creek Drainage District has undermined the stability of the existing levee. We recommend at this location that the levee be deconstructed and moved away from the Main Open Ditch channel. We also recommend that riprap armor be placed on the stabilized ditch bank to prevent further erosion and undermining of the confining levee.

A large reach of the Sub 3 Levee has become unnecessary. The function of the reach of levee from the south end 130th St, running under the county road, north to the south line of Section 29, then running east to its' intersection with the Sub 2 Levee in the NW NE of Section 28-76-44 has been replaced by the private levees lying to the west of this line. We recommend that this reach of levee be abandoned as a district facility and the rights-of-way of this reach be abanonded back to the use of the landowners. The right-of-way to be abanonded is shown

in Appendix C of this report.

B. Mayne Private Levee

We recommend right-of-way containing the private Mayne Levee be acquired and repairs made to the structure between 130th St, west to the landfill property by Subdrainage District No. 3 as a district levee. This levee will be repaired using the same repair cross section as the Sub 3 levee to the east, using a 12 foot top with 3:1 sideslopes.

C. I-680 Realigned Levee

As described in the Investigation Section of this report, a large reach of the Sub 3 Levee has been lowered by the construction of the I-680 roadway. The cost and logistics to raise the levee and the roadway on its' original alignment would be prohibitive. Rather, we recommend construction of a new earthen levee parallel to I-680 from the river, east to the intersection with the Paxton Levee. This work also includes a small levee south of the interstate to provide continuous protection to the district.

The drainage of the north and south road ditches will require care be taken during the work to ensure that drainage is no lost by this work. The drainage pipes from the road ditches to the river will be reviewed during construction and necessary modifications made to ensure continued function.

This levee for approximately half of its' length would have a top width of 12 feet and sideslopes of 3:1. At station 141, we recommend the new levee be constructred beneath the existing county road 145th St. The work would raise the roadway approximately 5 feet and provide significant protection to both the county road and I-680.

This work is intended to fix issues caused by the Iowa DOT roadway and it is expected that the costs associated with this portion of the work will be assessed directly to the Iowa DOT. We have submitted our information to the department including survey data. As of the date of this report, we have not had any additional response.

D. Paxton Private Levee

We recommend right-of-way containing the private Paxton Levee be acquired and repairs made to the structure from the north side of I-680 north to its' intersection with the Sac Ditch in the N ½ of Section 17-76-44 by Subdrainage District No. 3 as a district levee. The levee will be repaired using the apparent repair section of the existing levee using a 12 foot top with 3:1 sideslpes. Included in this repair is several acres of tree clearing out to the work limits of the project.

Acquisistion of this levee as a district facility will render the Subdrainage District No. 2 Levee of little value to the lands which it once protected. We find that the cost to repair the Sub 2 Levee exceeds the benefits imparted to the lands in the district. We therefore recommend that the Subdrainage District No. 2 Levee be abandoned as a district facility and the right-of-way returned to the landowners to do with as they please. A tabulation of the abandoned right-of-way acres of the Sub 2 Levee is included in Appendix D of this report.

For the purposes of understanding the costs of repair, we have broken the estimated costs into four zones. A description of each zone and a summary of the estimated construction costs to repair each zone is shown below.

Summary of Estimated Construction Costs			
Name	**Description**	**Estimated Construction Costs**	**Average Cost Per Station**
Zone 1	Sub 3 Levee from I-29 on the east to the East Pigeon Creek Outlet Levee North to the Mayne Bridge	$174,000	$3,645
Zone 2	From Mayne Bridge south to Sub 3 Levee parallel to the river, west to and including the Mayne Levee south of the landfill	$457,000	$2,420
Zone 3	Work parallel on both north and south side of I-680 to restore protection lost by construction of I-680	$1,568,000	$14,792
Zone 4	Paxton Levee from I-680 north to Sac Ditch	$708,000	$4,544

Please note that the repairs described above will be subject to US Army Corps of Engineers and Iowa DNR review and permitting requirements.

E. Fill Material

There are two options for sourcing the fill material used to restore the levees described below. The first and recommended option is to excavate fill material from the river side toe of the levees. The second, and more expensive option is to import fill material from a borrow site in the bluffs near the district.

1. Non-Local Borrow Material

Sourcing and transporting material from the bluffs is attractive due to the large quantity of uniform material within sight of the levees. However, the cost to truck the material from several potential sites, to the several different reaches of levee drastically increase the cost of the material. The estimated cost per cubic yard of material ranges between $11 and $15, with the least expensive being the borrow for the re-aligned I-680 levee. This option would not require land be purchased for right-of-way to contain the borrow pit.

A possible solution to reduce the cost of this material is to allow the contractor to transport the material during the winter slow period. The material would then be graded and shaped the following spring. This would also reduce the damages associated with compaction as the ground would be frozen solid. Using material from the bluff for fill in the levee will add approximately $2,400,000 in assessable costs to the district compared with the recommended plan.

2. Local Borrow Material

A less expensive option for sourcing material to repair the levees is to use the local soils on the riverside toe of the levee. This material is less uniform than the loess soils from the bluff, but research has shown that the actual fill material of a levee, has little actual effect on the ability of the structure to prevent flooding.

The major downside to this option is the necessity to strip approximately 2.5 feet of soil off of an area of approximately 100 acres over the length of the levee system, including much farmland. If this method is used to source fill material, the area of the borrow pits should be taken as district right-of-way and a land value somewhere near full market value should be considered for the land.

A way to reduce the impact of this option for borrow material is to use multiple larger borrow pits located throughout the project to consolidate impacts to areas of less impact to farming operations. This could allow for a less expensive cost of fill material. Using local fill material will save the district an estimated 50% of the total estimated project costs.

We recommend a combination of these two borrow plans. We believe the hill borrow would be best suited for use on the I-680 realignment for three reasons.

1. Fill material for this site is likely the least expensive due to the easy access to the intersate highway.
2. The south side of the highway is a sanitary landfill. Rather than strip material off the top of the capped landfill, fill material must be imported to prevent pollution of the site.
3. Construction of the new levee would require taking a portion of farmland out of production, to add to this another several acres of farmland removed for borrow, it may be difficult to attain cooperation with the landowner.

For the remaining levee work, we recommend using local borrow to reduce costs. The cost estimate included in this report assumes the borrow is taken from a uniform strip along the riverside toe of the levee, however these costs could be reduced further by creating specific borrow sites throughout the project.

Two cost estimates are included in Appendix F of this report, the first is the recommended repair using local borrow for the majority of the proposed work and borrow from the nearby bluffs for the realigned levee along I-680. The second estimate is using the non-local borrow material for all proposed repairs.

F. Right-of-Way Acquisition

In this report, we have recommended acquisition of right-of-way for all or portions of two existing private levees. Subdrainage District No. 3 currently holds no right-of-way on these facilities within which to maintain the facilities. We therefore recommend appropriate right-of-way be purchased along these levees as part of the acquisistion process.

We recommend a right-of-way of 100 feet in width centered on both the Paxton and Mayne Levees as described in this report. We also recommend acquisistion of right-of-way on the existing borrow pits which are unfarmable along the west side of the Paxton Levee, a width of approximately 150 feet from the proposed right-of-way line in Section 20-76-44.

Construction of the new levee along I-680 will require some additional right-of-way along the north edge of the existing IDOT right-of-way. The authorities of the district in acquiring this right-of-way are more streamlined than those the IDOT relies upon. Because of this, we recommend the right-of-way for this reach of levee be acquired by the district, through Iowa Code 468, with reimbursement by the IDOT for those acres of land at the end of the project.

We also recommend adjustment of the existing rights-of-way along the remaining length of the Sub 3 Levee. The existing levee through this reach has been relocated several times during the history of the district due to flooding. Due to these relocations, the existing right-of-way does not follow the levee over long reaches. To remedy this situation, we recommend reallocating existing right-of-way acres within contiguous farm units to properly recenter the levee in the district right-of-way.

If the borrow used to repair the levees is taken from the adjacent farmland, we recommend those new borrow areas also be included in the right-of-way acquisistion completed with this project.

Appendix D contains a right-of-way tabulation showing the above proposed right-of-way acquisistions. We recommend the acquisistion of approximately 70.5 acres of right-of-way affecting 68 parcels within which to maintain the levees. If the district opts to use dirt from the local area for borrow material, the recommended acres of right-of-way to aquire will increase to 172.7 acres.

If right-of-way is to be acquired, an appraisal commission, made up of two landowners from the county and the engineer, are appointed to recommend fair payment. The right-of-way appraiser's report is considered at a continued or separate public hearing prior to adoption. Drainage district rights-of-ways are exempt from real estate taxes and drainage district assessments.

G. Work Limits

The permanent right-of-way is not intended to be wide enough to accommodate construction activities associated with major repairs. The district will need a larger area within which to clear and grub trees, strip and stockpile topsoil and compact the levee fill. The extent of the work limits on the Levee will be finalized when the final construction plans are developed, but it will typically be out to 100 feet from the levee centerline on the side or sides in which work will be done. Landowners will also be entitled to compensation for damages in the work area outside the right-of-way. Within the permanent right-of-way, construction-related damages will not be compensated. It is recommended that whenever possible, a landowner not crop the work area and instead accept fair rent for the land. Compensation for use of and damages within the temporary work area is normally determined at the project completion hearing.

H. Utilities

Overhead power lines and other utility lines likely parallel or cross the levees at various locations. Extra care will need to be taken when working under or near these utility lines. The contractor will be responsible to use Iowa OneCall to notify utility companies and to cooperate in the locating, marking, and protection of these facilities.

V. ASSESSMENT SCHEDULE REVIEW

Subdrainage District No. 3 completed the process of annexing benefiting lands and reclassifiying all lands within the district in April of 2018. There is no annexation or reclassification required at this time.

VI. DISCUSSIONS & RECOMMENDATIONS

This report confirms the need for repairs to the Drainage District No. 2, Subdrainage District No. 3 Levee System. The work described in this report can accomplish this need.

Right-of-Way Acquisistion and Levee Repairs Recommended. We recommend the repair of the Subdrainage District No. 3 Levee, relocation of the levee along I-680 and acquisition of the Mayne and Paxton private levees as district facilities as decribed in this report. The Engineer's Opinion of Probable Cost for this work of Drainage District No. 2 Subdrainage District No. 3 as proposed is $2,201,000. We find that the proposed improvement project will be practicable, feasible, and beneficial to the public.

Installment Payments. Iowa drainage district law provides that large improvements assessments may be spread over not less than ten nor more than twenty annual installments at the discretion of

the Board of Trustees. Typically the board would spread assessments of the magnitude contemplated in this report over twenty years. If we assume that the board will allow twenty annual installments at 5% interest, repair costs for lands in the district would be about $15 per acre per year.

Crop Insurance Savings. With the advent of federal crop insurance with the last Farm Bill, there is a belief among some that levees have become obsolete. While it is true that the loss of revenue from a flood is reduced because of insurance, the system is based upon a ten year rolling average.

One year of lost crop can reduce the average yield by 20% which is then reduced a further 15-20% depending on the insurance threshold chosen. This means a farm that would average 200 bushels per acre would only receive payment for 128 bushels, or 64% of the average yield.

Assuming the levee is fully abandoned so that no protection is provided, areas of the district could flood as frequently as every 3-6 years. If the repaired levees can limit flooding to once every 25 years, the increased return on insurance during the 20 year installment period would be $33.50. This assumes the 10 year county average yield of 180 bushels per acre and a flat $3 per bushel price over the duration of the installment period.

If we consider the levees in the current state of disrepair and the proposed repair, assuming the same yield and price as above, the return on insurance is $17.30. While this is lower than comparing with the no levee situation, it does show that there is still significant value to be gained by maintaining the levees even with federal crop insurance. If the crop insurance program were to end, that value would be even greater.

The above calculation is only meant to illustrate the financial return of the proposed levees and is not intended to be specific to any farm or situation. The landowners alone possess sufficient knowledge of their farming operation to correctly judge the value of the levee for their property.

It is recommended that the Board of Trustees for Drainage District No. 2, Subdrainage District No. 3, take appropriate action, with legal guidance, to accomplish the following:

- Tentatively approve this engineer's report.
- Pursue agreement by the Iowa DOT of a workable plan to fix the levee damaged by the construction I-680 Interstate
- Conduct a public hearing on the proposed repairs.
- Adopt the proposed repair plan, modified as deemed appropriate to satisfy the needs of the district.
- Appoint rights-of-way appraisers and continue hearing.
- Approve rights-of-way compensation.
- Direct the engineer to apply for and acquire the permits and regulatory approvals necessary to complete the project as approved by the Board of Trustees.
- Direct the engineer to prepare the necessary plans and specifications and to proceed toward a bid letting.

Respectfully submitted,

Bolton & Menk, Inc.

VII. REFERENCES

Kay, Roger. (2002). Determination of Flood Frequency of the Missouri River Below Gavins Point Dam.

Appendix A: Letter to Iowa DOT

BOLTON & MENK
Real People. Real Solutions.

1519 Baltimore Drive
Ames, IA 50010-8783

Ph: (515) 233-6100
Fax: (515) 233-4430
Bolton-Menk.com

April 6, 2018

Iowa Department of Transportation

RE: Drainage District Levee
I-680 from I-29 to the Mormon Bridge
Pigeon Creek Drainage & Levee District
Pottawattamie County, Iowa
Project No.: P12.111254

Dear Sir or Madame:

Bolton & Menk, Inc. has been appointed as the engineer to review the condition of and recommend necessary repairs to the existing levees in Drainage District No. 2 otherwise known as Pigeon Creek Drainage & Levee District (DD 2). The district's levees consist of levees lying along the district's Main Open Ditch and two levees along the Missouri River. A part of the levees on the river has long included the highway grade.

In the course of our investigation, we have found strong evidence that the district's levee has been inadvertently, though quite substantially lowered by the initial construction and subsequent reconstruction of the I-680 road grade in the reach where it is also the district's levee. Our investigation to date indicates that the actions of the Iowa Department of Transportation (IDOT) since the construction of I-680 in the late 1970's has resulted in the lowering of the district's levee by approximately three (3) vertical feet. This lowering has been detrimental for the owners of the lands intended to be protected by the historic levees and also the highway.

The intent of this letter is to provide details of the history of the district and subsequent road improvements in the area as well as a proposal for a potential solution to the issue which does not require raising of the existing I-680 roadway.

With this letter we have included pages from multiple documents which support our preliminary finding that the lands of the district have been placed at greater flooding risk by the actions of the IDOT. Each included document will be reviewed and the significance explained in the sections which follow.

We invite the IDOT to review the information, including surveyed elevations and either concur with our proposed solution or provide an alternate solution to restore the level of protection to the district lands which was available prior to the construction of I-680.

DD 2 Sub 2 and Sub 3 Levees – Records in Pottawattamie County Auditor's Office

Included with this letter is a map of the several district and private facilities in the subject area. The district facility alignments are drawn as defined in the engineer's reports on file in the Auditor's office. The private facilities have been sketched from historical aerial photographs.

DD 2 Sub 2 was originally a privately constructed levee, largely owned by a man named James Paxton and taken over and improved as the DD 2 Sub 2 Levee in 1917. The levee was taken over and widened, though did not require additional height (Engineer's Report – Undated – c. Dec 1917).

DD 2 Sub 3 was petitioned for in May of 1920 and approved later that same year. The top elevation of the levee is defined as matching the Sub 2 Levee elevation at the north end of Sub 3, having "practically uniform height corresponding with the water level of the Missouri River" throughout its' length. Review of the river grade indicates that a grade of 0.02% or 1.06 feet per mile of length is appropriate for the grade of the levee top (Engineer's Report – Undated – c. 1920).

Both levees were constructed and maintained by the district, including purchasing and maintaining a permanent right-of-way. Review of the district files to date has failed to turn up any record plans for elevation from which to repair either levee. As part of a pending report, we will recommend a repair grade based off the several sources of data found during this investigation.

Paxton Levee – Private Levee

The Paxton Levee is a private levee built sometime prior to the 1930's aerial photo available from the Iowa DNR and after the construction of the Sub 3 Levee described above. This aerial was flown between January 1, 1936 and December 31, 1941 covering the full state of Iowa. There is no record of repair elevation or grade for this levee, however, it appears the primary owner of the levee is the same James Paxton who owned large portions of the privately built DD 2 Sub 2 Levee. It is logical to assume that Paxton matched the top elevation of the Sub 3 Levee where the two met near the current I-680 roadway.

Missouri River Bridge Plans – North Omaha Bridge Commission – c. 1950

We have included with this letter, the cover sheet and sheets A.6 through A.9 showing the planned grade of the highway. From the report the design elevation of the road surface near the current county road overpass is 991.0 as shown on sheet A.7 of the included plan sheets.

No elevation of the existing levee is given on the plans, however a note directs to "Use existing levee for part of borrow". A second levee is shown running north from the road, this is the Paxton Levee discussed above.

Meeting with Mormon Pioneer Memorial Bridge Commission – October 12, 1951

At a meeting between the road commission and the trustees for DD2, it was made clear that the new roadway was intended to replace the existing Sub 3 Levee in Section 32-76-44. The minutes of this meeting are attached to this letter.

During that meeting it was stated that both the existing Sub 3 Levee and Paxton Levee were in disrepair and approximately 2 feet lower than their historic repair elevations. At that meeting Mr. Rief, Trustee for DD 2 volunteered to supply the borrow material to restore the finished road grade to the repair elevation of the historic levee.

I-680 Road Plans – c. 1978

In the 1970's the IDOT pursued improvement of the Mormon Trail Road to a four lane divided highway to serve as an interstate highway. The as-built plans provided by the IDOT shows the planned grade of the new I-680 roadway and the existing Mormon Trail Road. Review of the plan elevations shows that both plan sets used the same elevation datum.

These profiles show the existing Mormon Trail Road elevation east of the point where it intersected the Sub 3 Levee to be 991.0 as originally planned in 1950. Where the Mormon Trail Road grade intersected the Sub 3 Levee, the elevation rose quickly to elevation 993.0, two feet higher than planned. This confirms that the modifications recommended in the October 12, 1951 meeting were carried out during construction of the Mormon Trail Road.

The road plans for I-680, both in the plan and profile sheets of the interstate and the profile of the county road crossing show the existing Mormon Trail Road embankment being cut down from 993.0, the historic levee elevation, to 991.0. This work lowered the district's levee top elevation by two feet from the design elevation.

Bolton & Menk, Inc. Benchmark Survey

The confirmation of the 1951 proposed modification now gives us a known elevation for one location on the Sub 3 Levee. Unfortunately, we have been unable to find any elevation benchmark on either of the road plans sets. With no elevation benchmark, we proceeded to check that this datum matched the plans for the I-29 interstate to which I-680 connects.

This match was confirmed by roadway elevations at the I-680/I-29 interchange near Crescent. With this confirmed datum match, we were able to seek out the several listed benchmarks on the 1964 as-built plans of the I-29 roadway. Ten benchmarks are described on the plans, we were able to locate only one, all others have either been destroyed or covered by new structures. The single found benchmark is USGS monument #138. The report for this monument is included with this letter.

In the late 1950's when I-29 was constructed, the defined sea level elevation of Monument #138 was 993.58. However a local elevation of 993.33 was defined and used on Monument #138by the IDOT as part of the datum for all three plan sets discussed in this letter. In June 1991, the elevation of USGS Monument #138 was redefined by the USGS at elevation 994.00 (NAVD 88).

Based on the Mormon Trail Road Commission and IDOT plans, the top of the Sub 3 Levee and Paxton Levee at the interstate in Section 32-76-44 is defined as 993.0 based on the recorded benchmark on the I-29 plans. Stated another way, it is 0.33' lower than the elevation of the established physical USGS #138 benchmark marker. Using the current sea level survey datum NAVD 88 the top of the levee should then be 993.67.

2011 Missouri River Flood

The 2011 Missouri River Flood resulted in the second highest river stage recorded at Omaha since that data has been gathered. This flood was large enough to overtop the interstate and cause extreme damage to the roadway. The IDOT issued an emergency contract to rebuild the destroyed I-680 roadway to the 1978 as-built condition. The reconstruction of 2.63 miles of I-680 was bid September 14th and was open to traffic November 2nd 2011.

2018 I-680 Roadway Elevation

As part of the project survey, we have gathered cross section and profile data of the several levees in this area, including elevations on the existing road surface of I-680 and the county road overpass. After reviewing the survey and comparison with the overpass elevation, we believe the rebuilt interstate road surface is in fact now 2.67 feet lower than the top elevation of the levee it is intended to replace. Below are tables to illustrate these findings:

I-680 Road Surface Relative to USGS Monument #138			
Original Plan Elevations		**Adjusted Benchmark Elevations**	
Plan Elevation	991.0	**Expected Elevation**	991.67
NGVD 29 Bench (mod)	993.33	**NAVD 88 Bench**	994.0
Difference	2.33	**Difference**	2.33

County Road Overpass Relative to USGS Monument #138			
Original Plan Elevations		**Adjusted Benchmark Elevations**	
Plan Elevation	1013.35	**Plan Elevation**	1014.02
NGVD 29 Bench (mod)	993.33	**NGVD 29 Bench (mod)**	994.00
Difference	20.02	**Difference**	20.02

Comparison of Design vs Survey		
Location	**1978 Adjusted Plan**	**2018 Survey**
Top of Overpass Abutment	1013.13	1013.13
I-680 Road Bed	991.67	991.0
Difference	**21.46**	**22.13**
Variance	**-0.67**	

Possible Explanation for Elevation Error

When our staff setup the survey equipment and measured the USGS Monument #138 elevation using the RTN network, the measured elevation was 994.0. When the I-680 roadway elevation was measured at the county road overpass using the same equipment, the roadway elevation was 991.0, a difference of 3.0'.

We theorize that the rebuilt roadway relied solely upon the assumption that the State Plane elevation matched the reported elevations of the road profile in the 1978 as-built plans. We postulate that the different elevation datum used by the IDOT in the 1950's, 1960's and 1970's was simply missed.

Proposed Solution

Regardless of the current road surface elevation, it is clear that the original construction of the I-680 Interstate lowered the DD 2 Sub 3 Levee. We believe it is the IDOT's responsibility to restore the Sub 3 Levee damaged by the work of the IDOT to the historic levee top elevation. With the understanding that raising the existing roadway presents an extreme expense, we propose an alternate less costly project to accomplish the same.

We recommend that a new levee parallel the west bound lanes of I-680 at the north right-of-way line. This levee will have a top elevation of 993.67 and run from the intersection of the Paxton Levee and I-680 west to the Missouri River bank where the levee will tie into the existing bridge abutment. For a portion of this distance the proposed levee would run beneath the county gravel road on the north side of I-680. The remaining distance would traverse portions of a farm field and the I-680 road ditch.

We propose that this work, including acquisition of rights-of-way upon which to maintain the newly constructed levee, be undertaken by the drainage district, of which the IDOT will be part. The costs of this work would then be assessed to the IDOT as a unique special benefit assessment.

This proposed plan would avoid the expensive raising and reconstruction of new I-680 and prevent the IDOT from directly having to manage the project. It would be contingent upon IDOT cooperation in and support of the issuance of permits needed to do the work.

We look forward to working with your staff to find a solution to this problem which all parties can accept and which can be speedily accomplished.

Sincerely,

Bolton & Menk, Inc.

Jonathan P. Rosengren, P.E.
Senior Project Engineer

Cc: Trustees of Pigeon DD 2
James C. Hudson, Attorney

Encl: DD 2 Facilities Map
DD 2 Sub 2 Engineer's Report
DD 2 Sub 3 Engineer's Report
Mormon Trail Road Plans
DD 2 Sub 3 Meeting Minutes
1964 I-29 As-Builts Benchmark Information
USGS Monument #138 Record
I-680 Road Plans
BMI Plan & Profiles of Interstate Survey

DD 2 Facilities Map

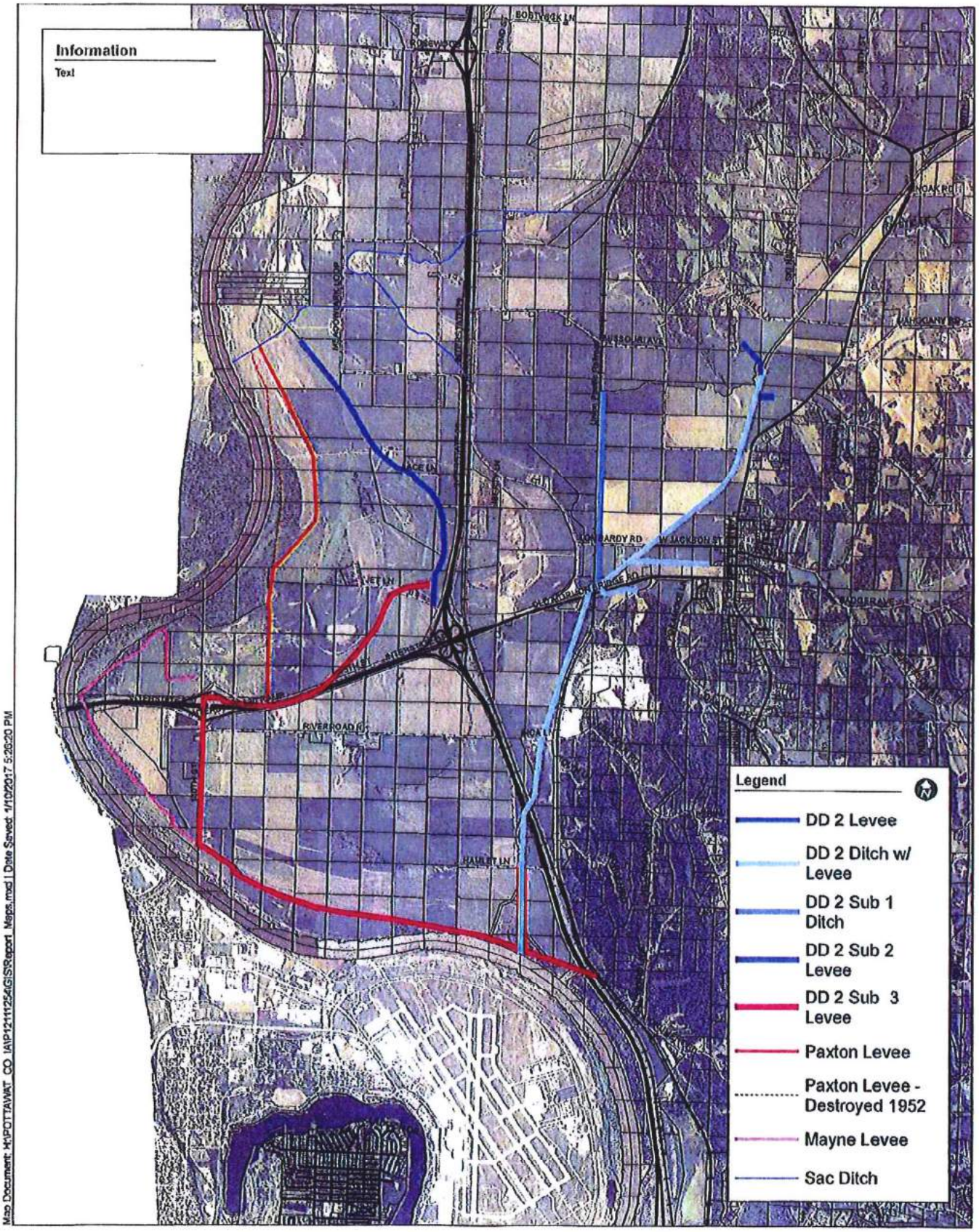
Pigeon Creek

Pigeon DD 2

2013 Aerial

January, 2017

BOLTON & MENK
Real People. Real Solutions.



Map Document: H:\PDT\AWAT_GO_IA\P\121112540\GIS\SReport_Maps.mxd | Date Saved: 1/10/2017 5:26:20 PM

DD 2 SUB 2 Levee
Engineer's Report

In re Petition of A. M. Hiatt and others.

The said levee to have the same heighth at its upper end as that of the levee along Sub-District No. 2 of said Pigeon Creek Drainage District at its point of contact with the levee, and from that point to its terminus the top to have practically uniform heigth corresponding with the water level of the Missouri River. The ground to be appropriated for the right of way for said levee to have a width of 100 feet, the foot of the levee on the outside of r river side to be built twenty five (25) feet from the outside line of said right of way, and from there to its terminus to be built fifty (50) feet from the outside line of the right of way. Said levee to have a width of twenty (20) feet on top with side slope of 3 to 1 on the outer or river side and 2 to 1 on the inner side. (Not however to be built across Pigeon Creek Ditch.)

2- An earth levee along the west side of the main ditch of said Pigeon Creek Drainage District No. 2 connecting with the main levee above described at what is marked on the plat Station 320 plus 64 and running thence north for a distance of 3264 feet. Said levee to have a heighth corresponding with said main levee, to have a width on top of 10 feet with side slopes of 3 to 1 on the ditch side and 2 to 1 on the land side. The same to be built upon the center line of a right of way to be acquired for that purpose which will have a width of one hundred (100) feet from the bank of the ditch on the west side thereof.

3- An earth levee along the east side of the main ditch of said Pigeon Creek Drainage District No. 2 connecting with the main levee above described at what is marked on the plat Station 322 plus 76 and running thence north for a distance of 3308 feet. Said levee to have a heighth corresponding with said main levee, to have a width on top of ten (10) feet with side slopes of 3 to 1 on the ditch side and 2 to 1 on the land side. The same to built upon the center line of a right of way adquired for that purpose which will have a width of one hundred (100) feet from the bank of the ditch on the east side thereof.

Two floodgates, one inthe levee on the west side of Pigeon Creek Ditch at a point where there is a depression in the ground, to permit the surface water to flow into the ditch and protect from overflow water from the ditch side; the other in the main levee at a depression in the ground near Station 351 to permit surface water to flow through towards the river at the south end and to protect against overflow water from the river.

I recommend the establishment of a sub-district within said Pigeon Creek Drainage District No. 2 which will include therein all lands within the follpwing boundary line, to-wit:

Commencing at the intersection of the northerly line of the right of way for the main levee as herein described with the easterly line extended of Government Lot 2 in Section 28-76-44, said point being 2149 feet north from the SE corner of said lot and following the outer or river side of the right of way for the main levee as described above to its intersection with the main line of the Illinois Central Railroad at a point near the NW corner of Section 11-75-44, thence following the center of said Railroad northwesterly to the government meander line on the north side of Section 27-76-44, thence following the said meander line westerly to the east line of Government Lot 2 in Section 28-76-44, thence north along said east line extended to the point of beginning;

The construction of the above levees and improvements will protect the lands from overflow water from the Missouri River, reclaim the same, render them fit for cultivation, and be a public benefit and utility and conducive to the public health and welfare.

The proposed sub-district above described includes all lands that will be benefitted or otherwise affected by the levees and the improvements above described, and there is attached hereto a list of the owners of said lands as shown on the transfer books in the County Auditor's office. Also there is attached hereto a list giving the different parcels of land required for right of way, the owners of the same, a description and the acreage required for each separate tract. Also an estimate of the cost of construction of said sub-district, of the levee, and of the improvements recommended for the same, Which list of land owners of right of way and estimate of cost are made a part of this report.

Respectfully,

(Signed) E. F. Cook
Engineer

At Council Bluffs, Iowa.
Sept. 7th-1920

of lands in Sub-District No. 3 Pigeon No. 2 together with the owners appears on the transfer books in the County Auditors office and the areas of the different tracts:

1 of 1

landa f-- such levee--
locate such levee-- purpose of ---
complish the pr̶u̶pose of the County Auditor --
in writing to the County Auditor

ATTEST *Edw. ... Holland* Clerk

[signature] Chairman

DD2 SUB3 Levee
Engineer's Report

To the Board of Supervisors of
Pottawattamie County, Iowa.

Gentlemen:-

Pursuant to your direction I have made an examination of the lands referred to in the petition of A. M. Hiatt for a levee and drainage district as a sub-district of Pigeon Creek Drainage District No. 2, this county and I find that they are to a very great extent subject to overflow from the Missouri River which makes the drainage of a great deal of that territory in its present condition very bad and renders a great acreage of land unfit for cultivation and impossible to reclaim without a levee such as I recommend herein.

I have made a survey of such lands and all in that locality which would be benifitted by the levee and improvements herein recommended and file herewith and as a part of this report a plat and profile showing the proposed district and the levees and improvements recommended. They show also the course and length of said levee through each tract of land and the number of acres to be appropiated therefrom as a right of way for the construction of the levee and the elevations of deep depressions therein.

I recommend the Construction of the following levee and improvements, to-wit:

1 An earth levee along the following line, said line being the toe of the levee embankment on the outside or river line of the same, to-wit:

Commencing at a point on the east line extended of Government Lot 2, in Section 28, Township 76 N, Range 44 W, 5th. P. M. which point is 2,124 feet north from the S. E. corner of said lot, call this point station Oand by bearing and distance as follo[ws]

		11 plus 20
S 82° 30' W	to station	15 " 00
S68 ° 00' W	" "	18 " 00
S 66° 00' W	" "	22 " 00
S 27° 45' W	" "	32 " 50
S 18° 45' W	" "	37 " 00
S 35° 45' W	" "	45 " 00
S 36° 45' W	" "	52 " 00
S 34° 50' W	" "	60 " 00
S 43° 45' W	" "	66 " 00
S 49° 30' W	" "	70 " 00
S 58° 40' W	" "	73 " 00
S 63° 30' W	" "	81 " 00
S 67° 45' W	" "	87 " 65
S 78° 00' W	" "	95 " 37.5
S 88° 00' W	" "	105 " 37.5
N 88° 45' W	" "	108 " 30
N 45° 00' W	" "	

(Note: Station 108 plus 30 equals station 114 plus 21)

West To station 122 plus 00 which is the Northwest corner of Section 32-76-44, thence on Section line and Section line extended south to station 181 plus 00

S 64° 00' E	to station	184 plus 00
S 54° 00' E	" "	189 " 00
S 62° 30' E	" "	197 " 32
S 50° 30' E	at station 197 plus 46 cross east line of Lot 4, Auditors Sub. of Government Lots 1 and 2, Section 5-75-44 at a point 1458 feet south of the NE corner of said lot 4..	

S 61° 40' E	to station	199 plus 50
S 66° 00' E	" "	202 plus 00
S 69° 10' E	" "	214 plus 00
S 71° 50' E	" "	220 " 00
S 79° 50' E	" "	235 " 00
S 83° 50' E	" "	249 " 00
S.79° 40' E	" "	237 " 00
S 86° 40' E	" "	300 " 00
S 72° 45' E	" "	305 " 00
	" "	354 plus 17

which point is the center of the main line of the Illinois Central Railroad. This point is 450 feet east and 2[illegible]1 feet south from the NW corner of Section 11-75-44.

DD 2 SUB 3 Levee
Engineer's Report

In re Petition of A. M. Hiatt and others.

The said levee to have the same heigth at its upper end as that of the levee along Sub-District No. 2 of said Pigeon Creek Drainage District at its point of contact with the levee, and from that point to its terminus the top to have practically uniform heigth corresponding with the water level of the Missouri River. The ground to be appropriated for the right of way for said levee to have a width of 100 feet, the foot of the levee on the outside or river side to be built twenty five (25) feet from the outside line of said right of way, and from there to its terminus to be built fifty (50) feet from the outside line of the right of way. Said levee to have a width of twenty (20) feet on top with side slope of 3 to 1 on the outer or river side and 2 to 1 on the inner side. (Not however to be built across Pigeon Creek Ditch.)

2- An earth levee along the west side of the main ditch of said Pigeon Creek Drainage District No. 2 connecting with the main levee above described at what is marked on the plat Station 320 plus 64 and running thence north for a distance of 3264 feet. Said levee to have a heighth corresponding with said main levee, to have a width on top of 10 feet with side slopes of 3 to 1 on the ditch side and 2 to 1 on the land side. The same to be built upon the center line of a right of way to be acquired for that purpose which will have a width of one hundred (100) feet from the bank of the ditch on the west side thereof.

3- An earth levee along the east side of the main ditch of said Pigeon Creek Drainage District No. 2 connecting with the main levee above described at what is marked on the plat Station 322 plus 76 and running thence north for a distance of 3308 feet. Said levee to have a heighth corresponding with said main levee, to have a width on top of ten (10) feet with side slopes of 3 to 1 on the ditch side and 2 to 1 on the land side. The same to built upon the center line of a right of way adquired for that purpose which will have a width of one hundred (100) feet from the bank of the ditch on the east side thereof.

Two floodgates, one inthe levee on the west side of Pigeon Creek Ditch at a point where there is a depression in the ground, to permit the surface water to flow into the ditch and protect from overflow water from the ditch side; the other in the main levee at a depression in the ground near Station 351 to permit surface water to flow through towards the river at the south end and to protect against overflow water from the river.

I recommend the establishment of a sub-district within said Pigeon Creek Drainage District No. 2 which will include therein all lands within the follpwing boundary line, to-wit:

Commencing at the intersection of the northerly line of the right of way for the main levee as herein described with the easterly line extended of Governement Lot 2 in Section 28-76-44, said point being 2149 feet north from the SE corner of said lot and following the outer or river side of the right of way for the main levee as described above to its intersection with the main line of the Illinois Central Railroad at a point near the NW corner of Section 11-75-44, thence following the center of said Railroad northwesterly to the government meander line on the north side of Section 27-76-44, thence following the said meander line westerly to the east line of Government Lot 2 in Section 28-76-44, thence north along said east line extended to the point of beginning;

The construction of the above levees and improvements will protect the lands from overflow water from the Missouri River, reclaim the same, render them fit for cultivation, and be a public benefit and utility and conducive to the public health and welfare.

The proposed sub-district above described includes all lands that will be benefitted or otherwise affected by the levees and the improvements above described, and there is attached hereto a list of the owners of said lands as shown on the transfer books in the County Auditor's office. Also there is attached hereto a list giving the different parcels of land required for right of way, the owners of the same, a description and the acreage required for each separate tract. Also an estimate of the cost of construction of said sub-district, of the levee, and of the improvements recommended for the same, Which list of land owners of right of way and estimate of cost are made a part of this report.

Respectfully,

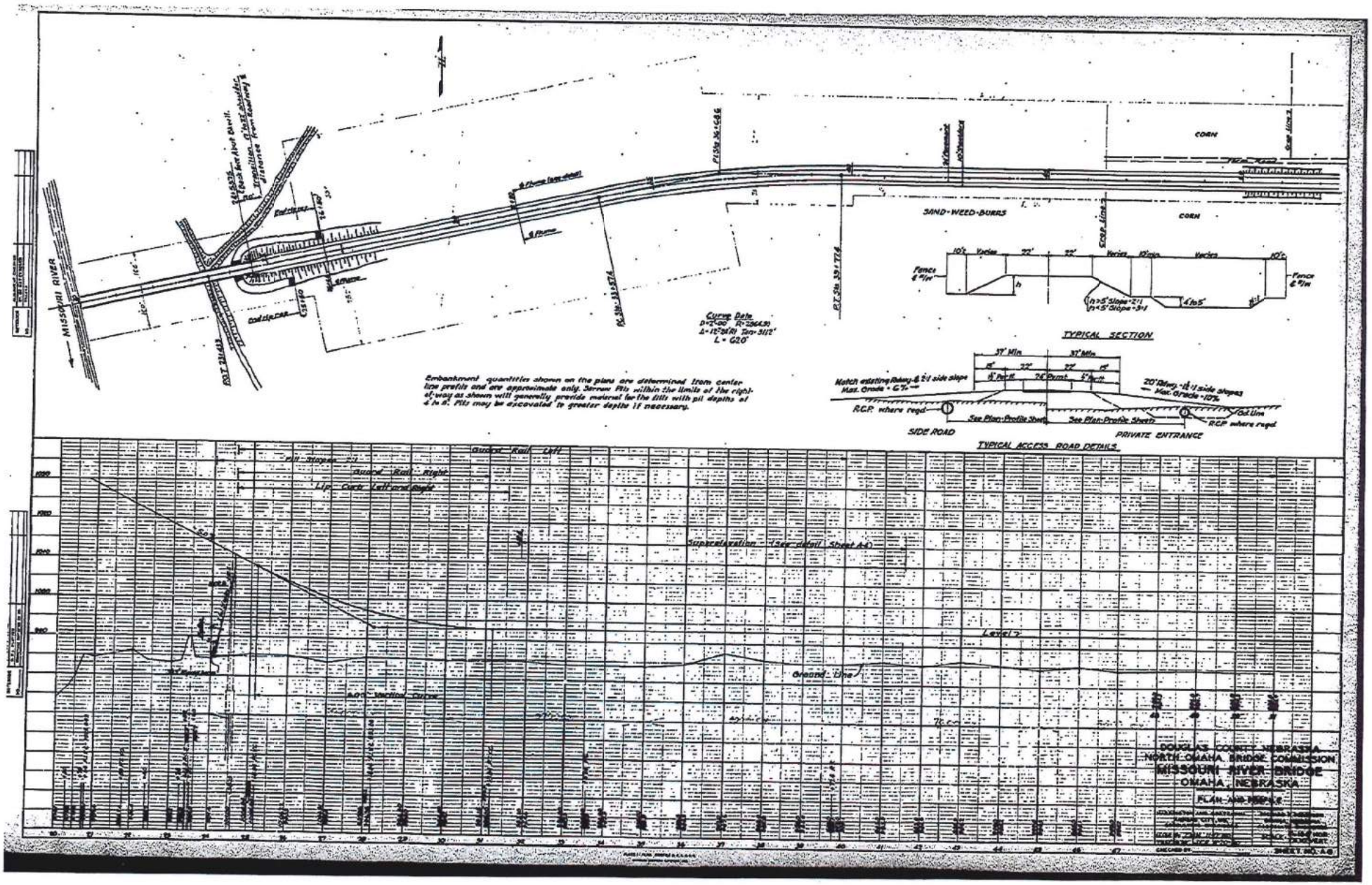
(Signed) E. E. Cook
Engineer

Dated At Council Bluffs, Iowa.
Sept. 7th-1920

[illegible] of lands in Sub-District No. 3 Pigeon No. 2 together with the owners [illegible] appears on the transfer books in the County Auditors office and the [illegible] areas of the different tracts:

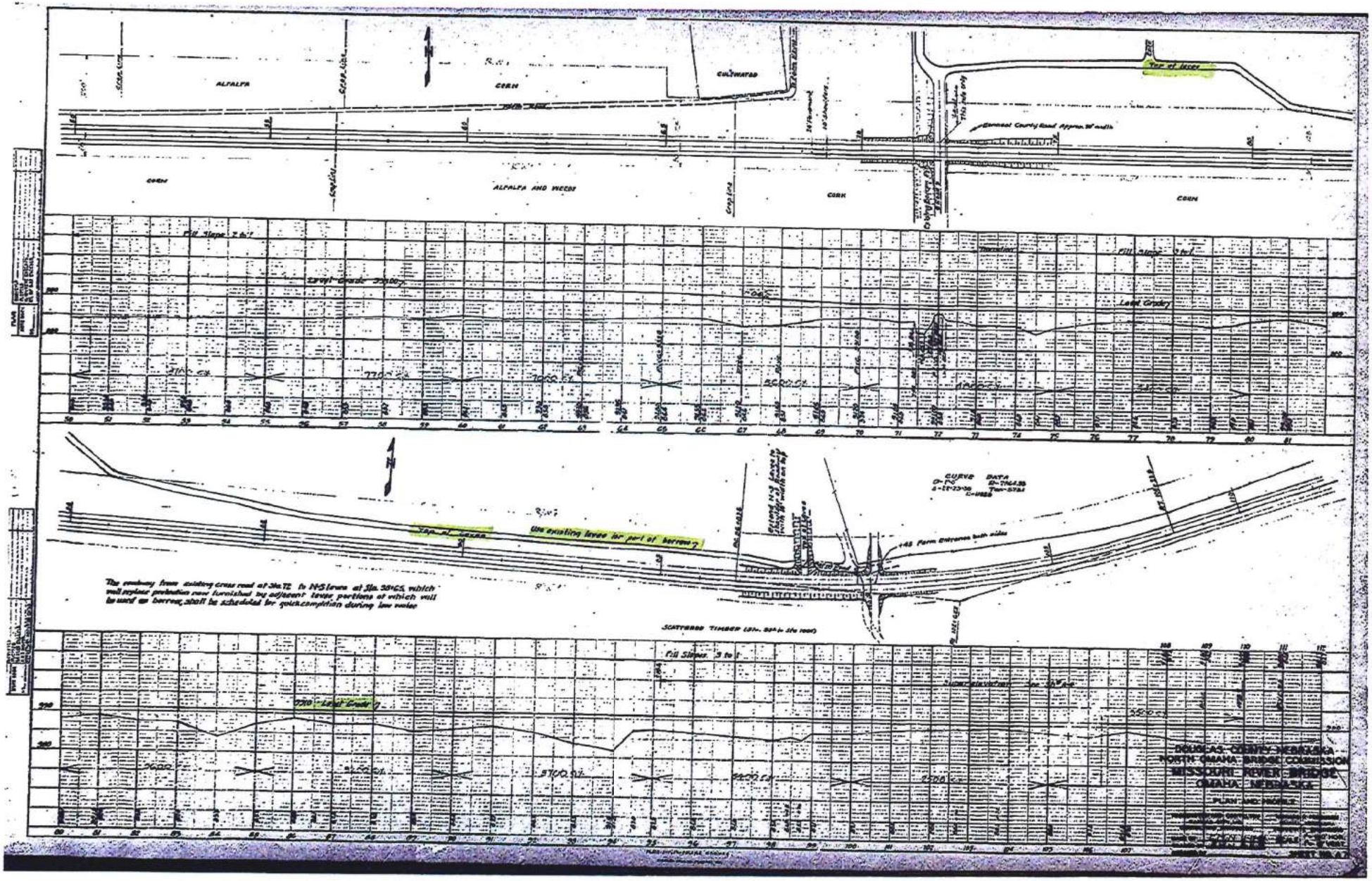
2 of 2

Mormon Trail Road



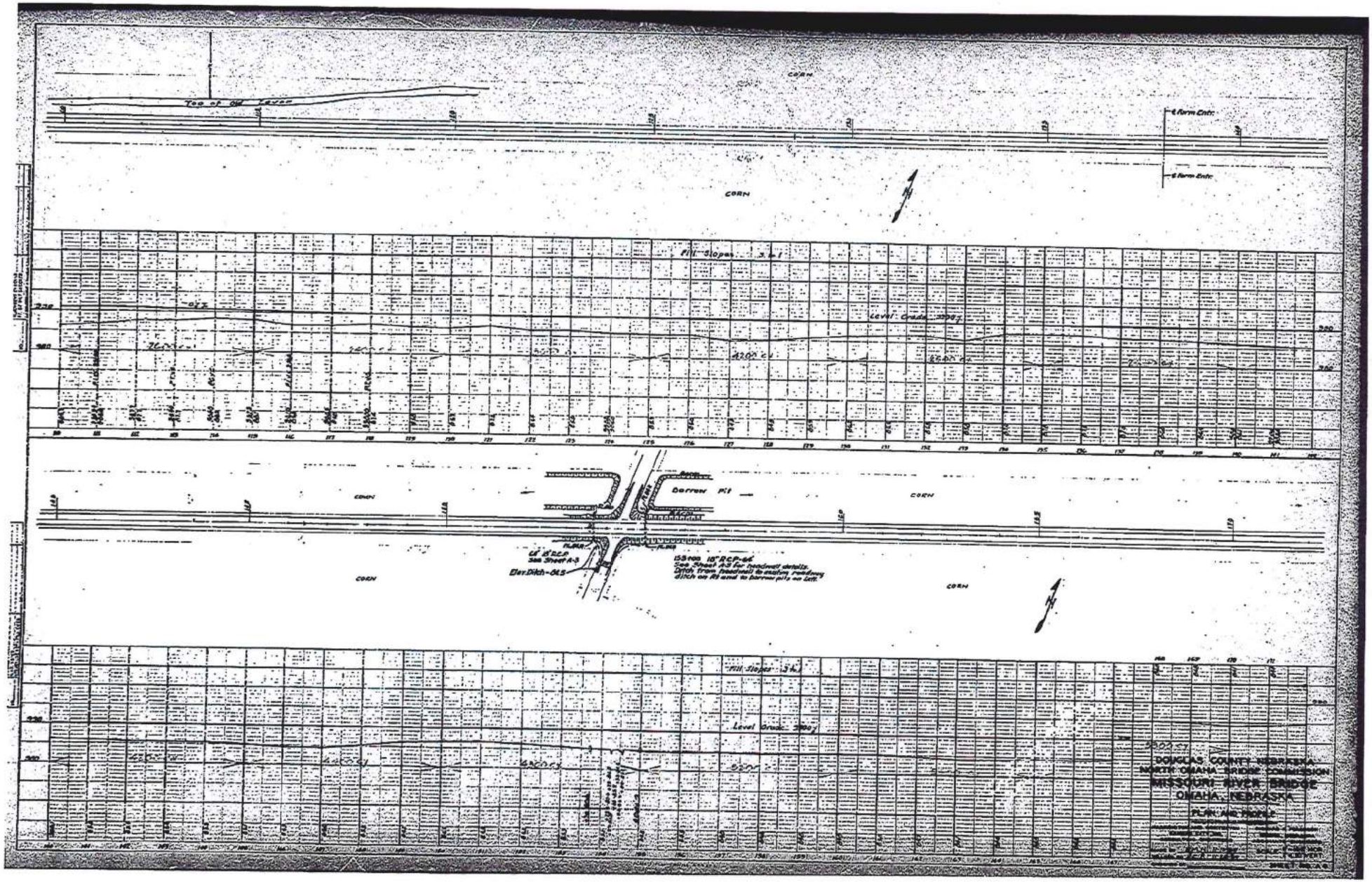
1 of 4

Mormon Trail Road



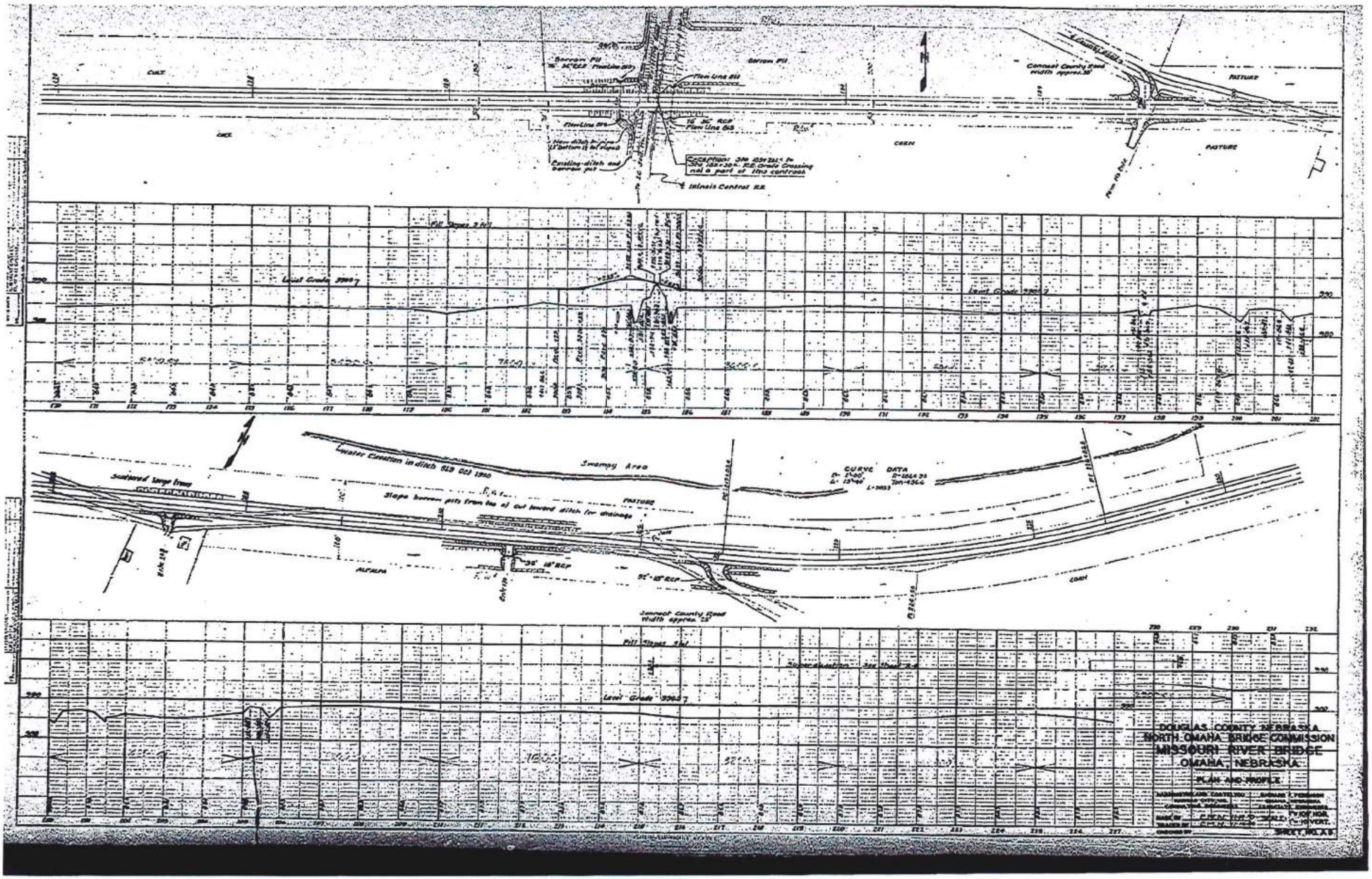
2 3/4 of 4

Mormon Trail Road



3 of 4

Mormon Trail Road



DD2 SUB3 Meeting Minutes

Attest: Ute Collins
Clerk

October 12,1951

The board met at 11:30 a.m., pursuant to a call from the Chairman with all members present and Chairman Moran presiding.

Minutes of the last meeting in this district were read and, on motion, approved.

In attendance at the meeting, in addition to the District's Engineer and Attorney, Arnold O.Christensen and DeVere Watson, respectively, were the members of the Mormon Pioneer Memorial Bridge Commission, with their attorneys and engineers. They were in attendance in response to the board's demand for a proper showing that the Commission's roadbed thru Sec.32-76-44, which was constructed to take the place of a section of the main levee of Sub-district No.3, afforded as much protection to the lands of this sub-district as they enjoyed from the section of the levee to be supplanted. The Commission's engineer explained how they had planned a grade, to be covered by concrete slab, which would protect against any flood that could be expected - and in line with the thinking and conclusions of the U.S.Engineers on this subject in this locality. He stated that while the sub-district's levee near it's junction with the north and south Paxton private levee was perhaps a foot or two higher than the roadway would be, nevertheless the roadway provided more protection because there was no danger of the waters going thru it, and that it would only go over the roadway if there was a flood such as had not been anticipated. He also explained that the Paxton private levee run down to a lower grade to the north, and that the sub-district's levee run down lower to the west - in fact, lower than the roadway plan, so that merely because it might have been a foot or two higher at one point or two did not mean that the lands had protection up to that heighth. He also offered the further information, which, he stated, was recognized in all engineering circles, that the last foot or two of the average dirt top levee of the width of the sub-district's levee was of little or no resistance to the pressure of a head of water, whereas the top of the concreted roadway would be its strongest point for stability.

Engineer Christensen told the board that he agreed quite generally with the above conclusions, and that from his examination of the plans, data and information furnished by the Commission, and from his own knowledge of both the physical facts involved and engineering experience, that the district would enjoy as great or greater security from the roadway than it did from the levee, with cost of repairs, maintenance and supervision being eliminated.

Trustee Rief stated that it was his belief that the plans for the roadway did not give the district the same protection it had with the levee. He stated he had lived in that vicinity all of his life and had seen water higher than the roadway. He urged the road be raised another foot or two to be sure, agreeing to donate the dirt from his land to the north, and agreeing that if putting the extra top on the road caused the fill to get out of the right of way that he would waive any claim for damages or for said additional right of way taken.

1 of 2

DD 2 SUB 3
Meeting Minutes

. . . After some discussion and consideration of the matters presented, the board members requested the engineers for both the Commission and the drainage district to study the matter further, to be sure that the drainage district's protection was equal to or exceeded that formerly enjoyed, and to report back to the board and the Bridge Commission any findings, recommendations and suggestions that they might make in addition to what had been offered at this meeting - and in the light of the obvious situation where the district and the Commission desired to be absolutely sure that there was the same or more protection in order to better secure both the roadway, bridge and farm lands, to make as sure of their recommendations as feasible and practicable.

On motion the board voted to adjourn - to meet again at a call from the Chairman.

Leo P Moran
Chairman

Attest:
Hunter Hunt
Clerk

April 3, 1953

Board in session at call of chairman Moran. All present. Minutes read and approved.

Following bills audited, allowed and certified for payment:

Clarence Jackson, seeding - 633.00
rent of seeder 12.00

Adjourned to call from chairman.

Attest:
Hunter Hunt
Clerk

Leo P Moran
Chairman

April 6, 1953

All members present. Minutes read and approved.

Following bills audited, allowed and certified to Auditor for payment:

Joe Moran, brome - 451 lbs. @ 20¢ 19.00
7½ hrs. rental of seeder 7.50

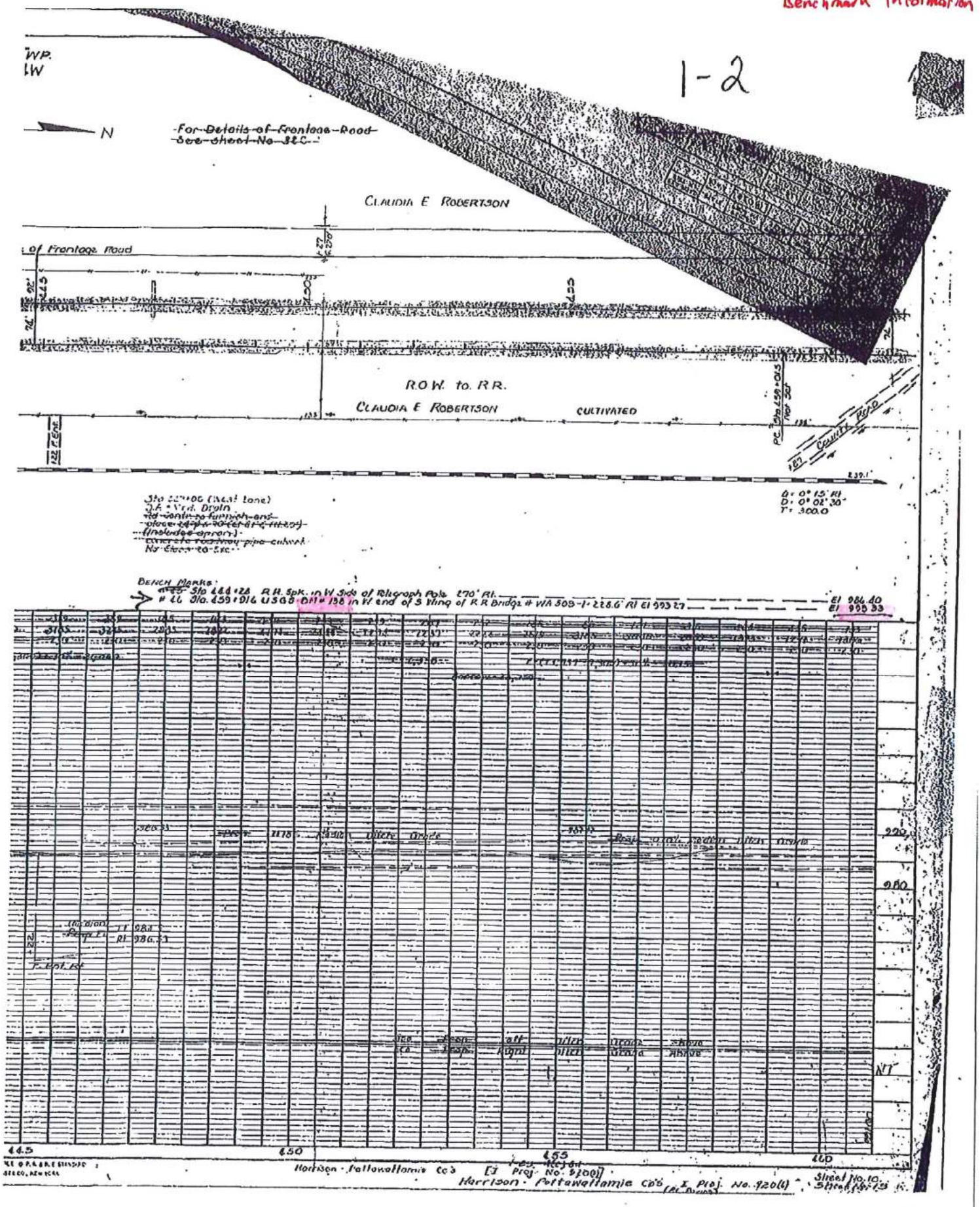
Adjourned to call from chairman.

Attest:
Hunter Hunt

Leo P Moran

2 of 2

1964 I-29 As-builts
Benchmark information



1 of 1

USGS Monument #138 Records

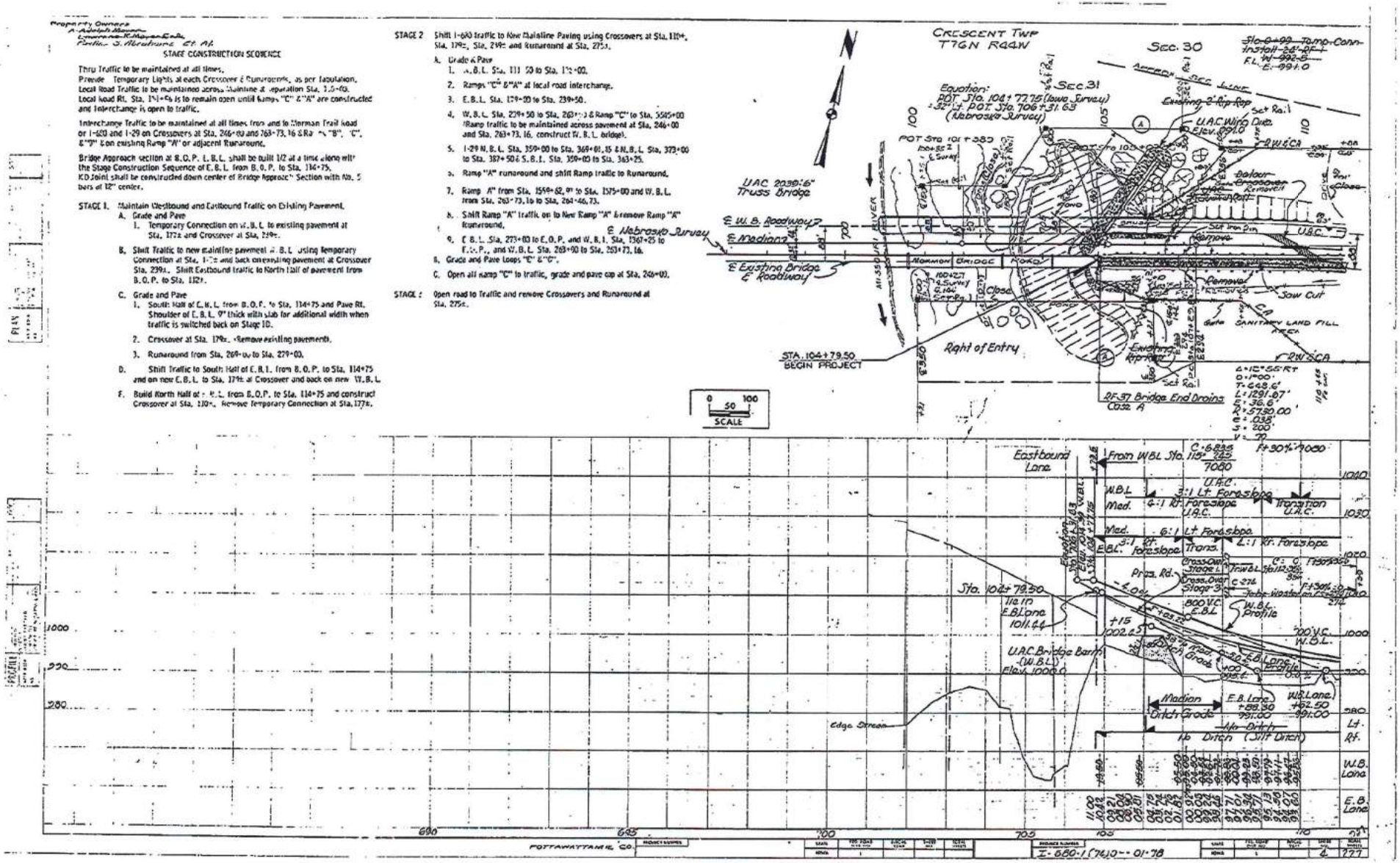
The NGS Data Sheet

See file dsdata.pdf for more information about the datasheet.

```
PROGRAM = datasheet95, VERSION = 8.12.2
1         National Geodetic Survey,   Retrieval Date = AUGUST 28, 2017
 MJ0731 ***********************************************************************
 MJ0731  DESIGNATION -  V 138
 MJ0731  PID         -  MJ0731
 MJ0731  STATE/COUNTY-  IA/POTTAWATTAMIE
 MJ0731  COUNTRY     -  US
 MJ0731  USGS QUAD   -  LOVELAND (1994)
 MJ0731
 MJ0731                          *CURRENT SURVEY CONTROL
 MJ0731 ______________________________________________________________________
 MJ0731* NAD 83(1986) POSITION- 41 22 57.      (N) 095 53 54.      (W)   SCALED
 MJ0731* NAVD 88 ORTHO HEIGHT =    302.972 (meters)       994.00  (feet) ADJUSTED
 MJ0731 ______________________________________________________________________
 MJ0731  GEOID HEIGHT    -        -28.209 (meters)                       GEOID12B
 MJ0731  DYNAMIC HEIGHT  -        302.839 (meters)       993.56  (feet) COMP
 MJ0731  MODELED GRAVITY -    980,174.7   (mgal)                         NAVD 88
 MJ0731
 MJ0731  VERT ORDER      -  FIRST     CLASS II
 MJ0731
 MJ0731.The horizontal coordinates were scaled from a topographic map and have
 MJ0731.an estimated accuracy of +/- 6 seconds.
 MJ0731.
 MJ0731.The orthometric height was determined by differential leveling and
 MJ0731.adjusted by the NATIONAL GEODETIC SURVEY
 MJ0731.in June 1991.
 MJ0731
 MJ0731.Significant digits in the geoid height do not necessarily reflect accuracy.
 MJ0731.GEOID12B height accuracy estimate available here.
 MJ0731
 MJ0731.The dynamic height is computed by dividing the NAVD 88
 MJ0731.geopotential number by the normal gravity value computed on the
 MJ0731.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 MJ0731.degrees latitude (g = 980.6199 gals.).
 MJ0731
 MJ0731.The modeled gravity was interpolated from observed gravity values.
 MJ0731
 MJ0731;                    North         East     Units  Estimated Accuracy
 MJ0731;SPC IA S      -   156,290.      299,420.     MT  (+/- 180 meters Scaled)
 MJ0731
 MJ0731_U.S. NATIONAL GRID SPATIAL ADDRESS: 15TTF576852(NAD 83)
 MJ0731
 MJ0731                              SUPERSEDED SURVEY CONTROL
 MJ0731
 MJ0731  NGVD 29    (??/??/92)  302.845  (m)            993.58  (f) ADJ UNCH    1 2
 MJ0731
 MJ0731.Superseded values are not recommended for survey control.
 MJ0731
 MJ0731.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 MJ0731.See file dsdata.pdf to determine how the superseded data were derived.
 MJ0731
 MJ0731_MARKER: DB = BENCH MARK DISK
 MJ0731_SETTING: 38 = SET IN THE ABUTMENT OR PIER OF A LARGE BRIDGE
 MJ0731_SP_SET: ABUTMENT
 MJ0731_STAMPING: V 138 1948
 MJ0731_MARK LOGO: CGS
 MJ0731_STABILITY: B = PROBABLY HOLD POSITION/ELEVATION WELL
 MJ0731_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
```

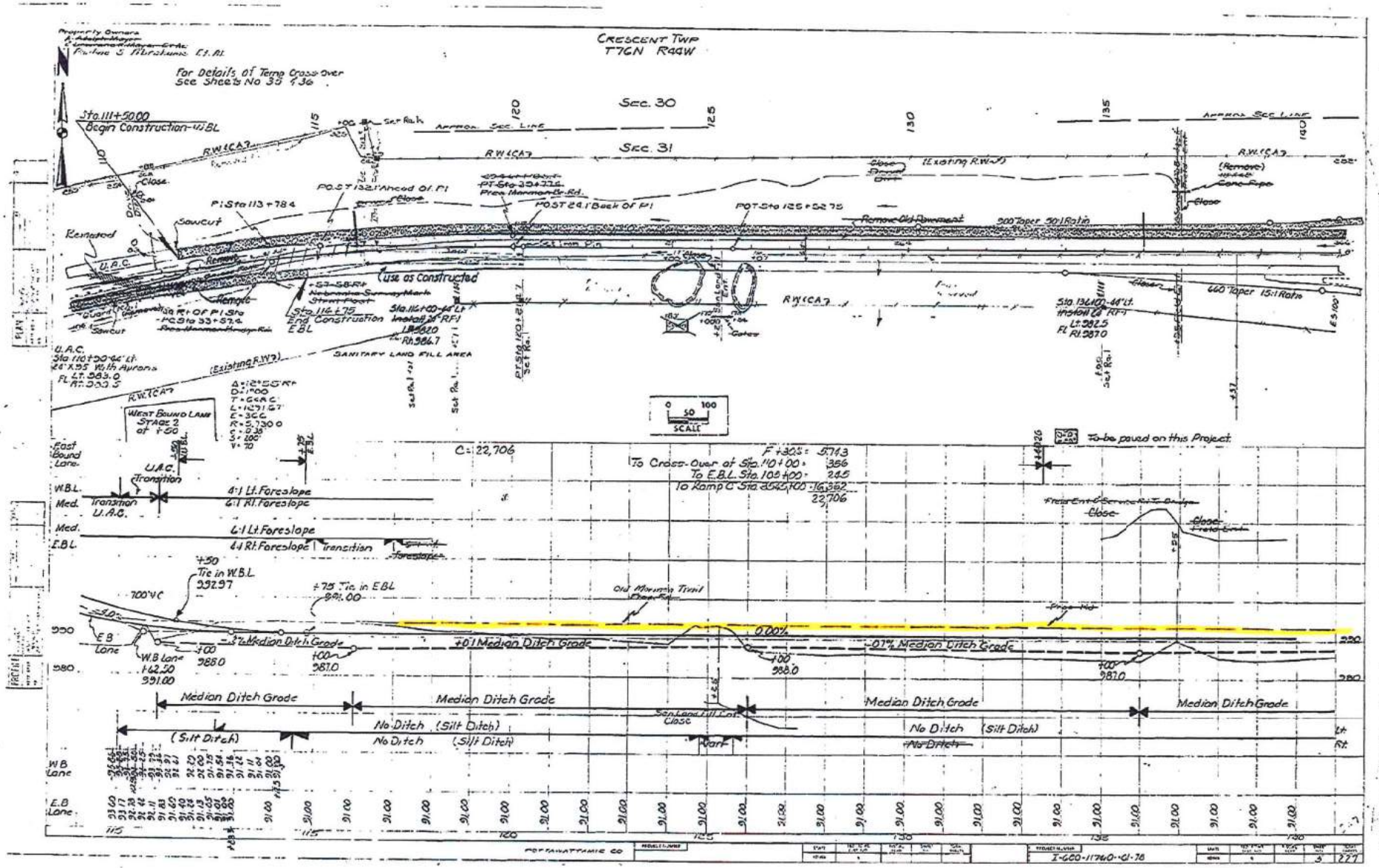
1 of 1

I-680 Plans



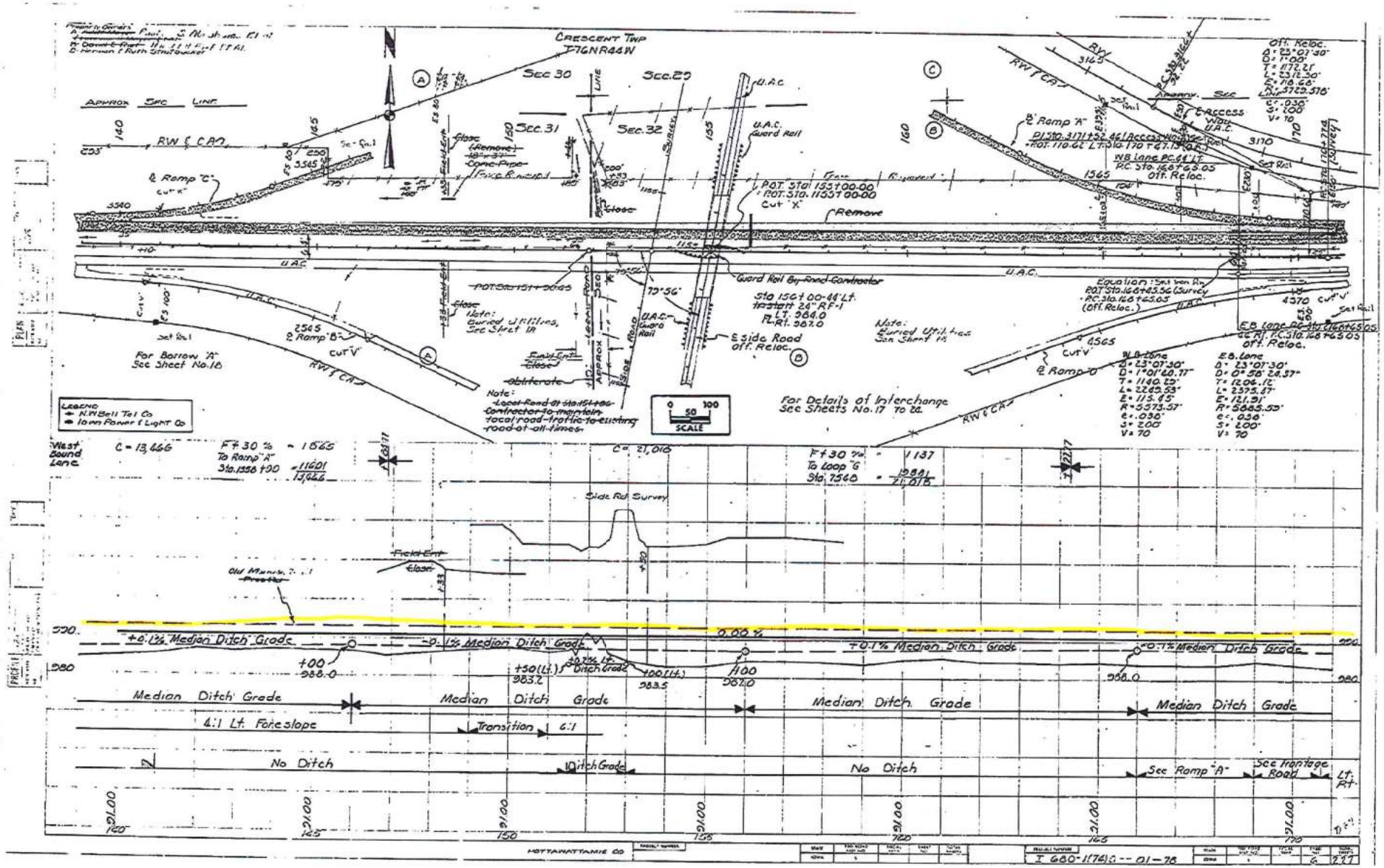
1 of 5

I-680 Plans



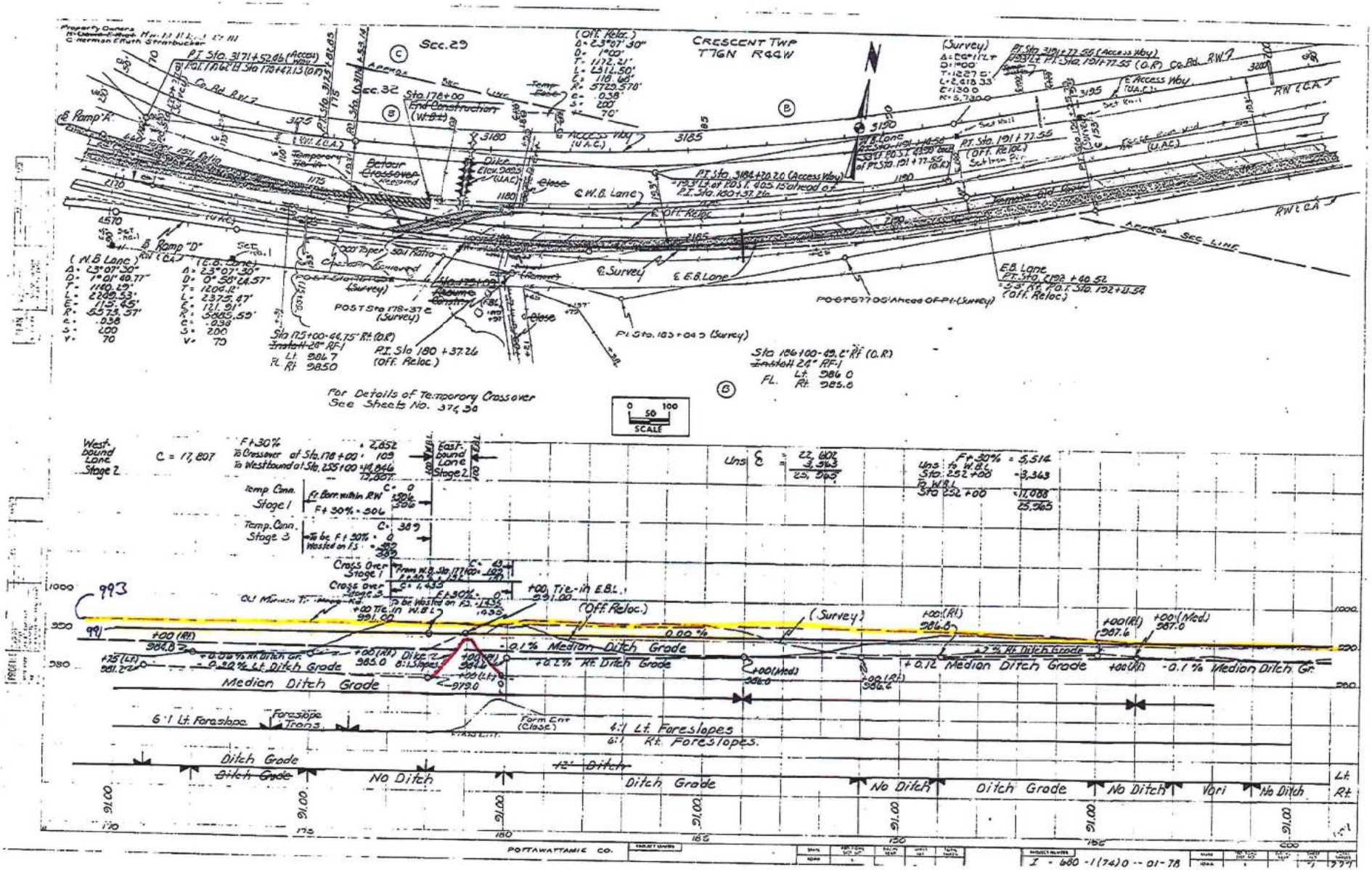
2 of 5

I-680 Plans

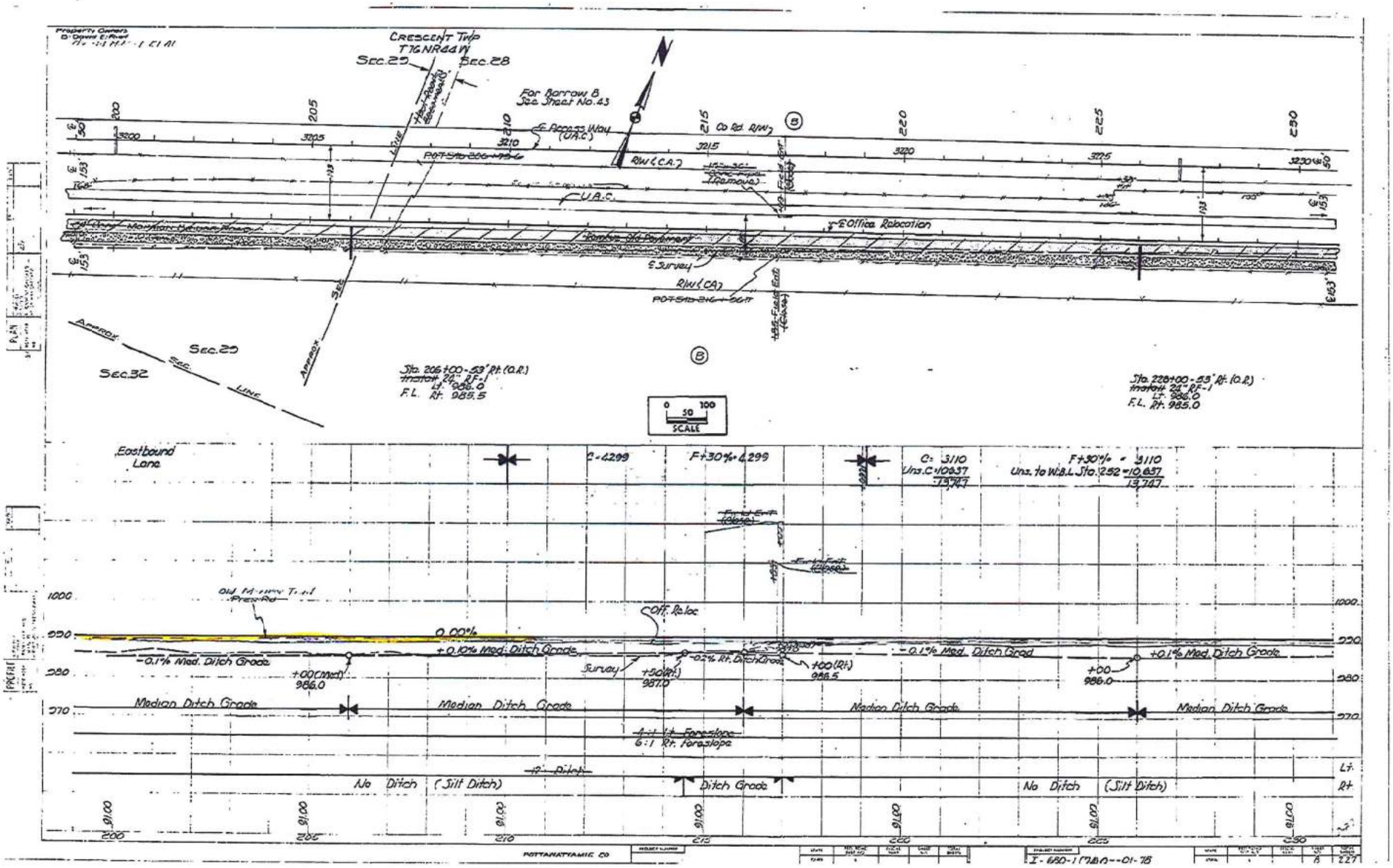


3 of 5

I-680 Plans

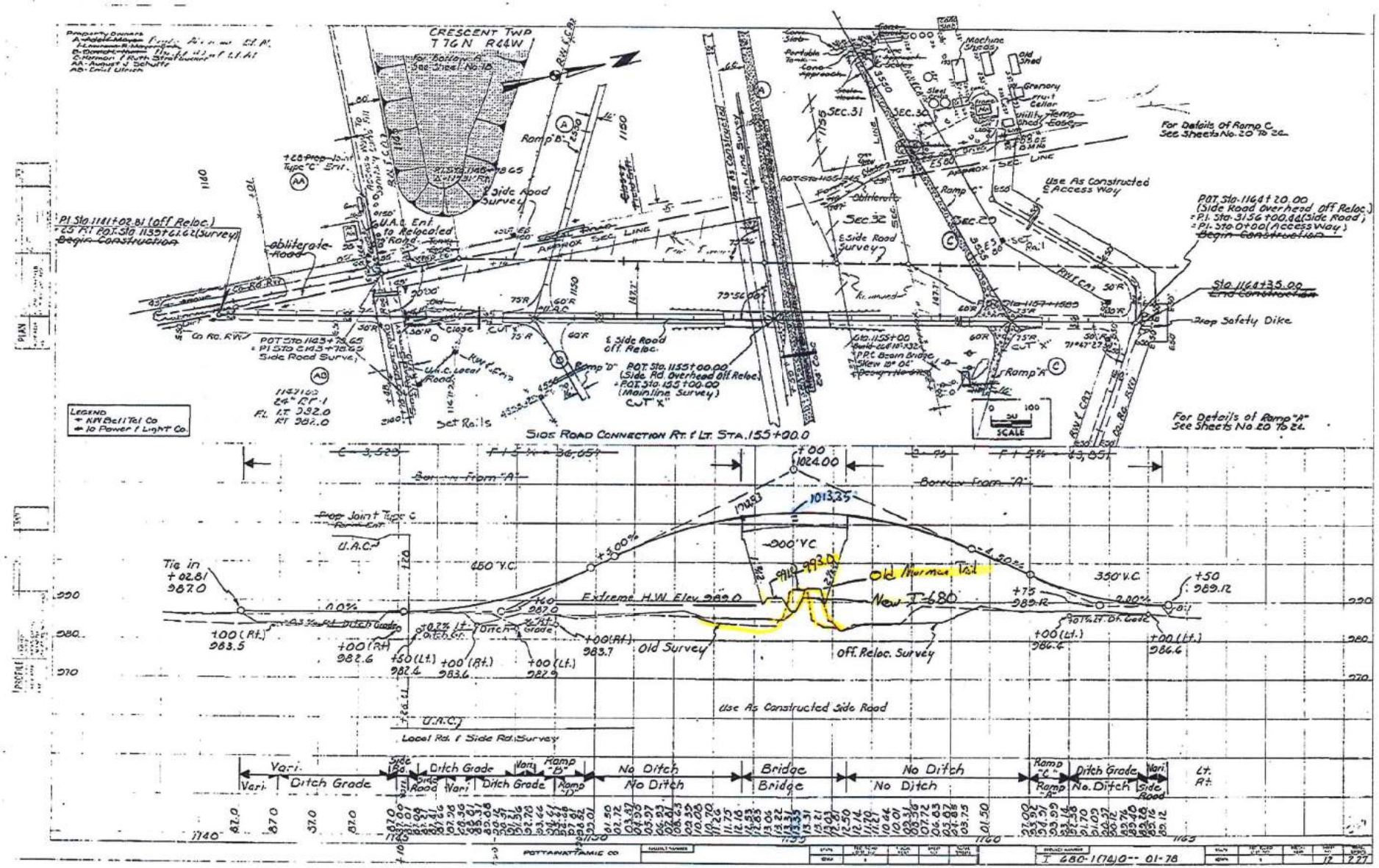

CRESCENT TWP
T 76N R 46W
Sec. 29
Sec. 32
Co. Rd. RW 7
E. Ramp "A"
B Ramp "D"
E.B. Lane
W.B. Lane
E. Survey
E. Off. Reloc.
Temporary Crossover
Access Way (U.A.C.)
Dike Elev. 900.5
Sta. 178+00 End Construction (W.B.L.)
Sta. 175+00-44.75' Rt. (O.R.) Install 24" RF-1
P.I. Sta. 180+37.26 (Off. Reloc.)
P.I. Sta. 191+77.55 (Off. Reloc.)
P.I. Sta. 192+40.52 (Off. Reloc.)
P.I. Sta. 183+04.5 (Survey)
Sta. 186+00-49.6' Rt. (O.R.) Install 24" RF-1
For Details of Temporary Crossover See Sheets No. 37 & 38
SCALE 0 50 100
Westbound Lane Stage 2
Eastbound Lane Stage 2
Temp. Conn. Stage 1
Temp. Conn. Stage 3
Cross over Stage 1
Cross over Stage 3
+00 Tie-in E.B.L. 991.00
+00 Tie-in W.B.L. 991.00
(Off. Reloc.)
(Survey)
-0.1% Median Ditch Grade
+0.2% Rt. Ditch Grade
+0.12 Median Ditch Grade
-0.1% Median Ditch Gr.
6:1 Lt. Foreslope
Foreslope Trans.
4:1 Lt. Foreslopes
6:1 Rt. Foreslopes.
Ditch Grade
No Ditch
42" Ditch
Vari
POTTAWATTAMIE CO.
I - 680 - 1(174)0 -- 01 - 78

I-680 Plans

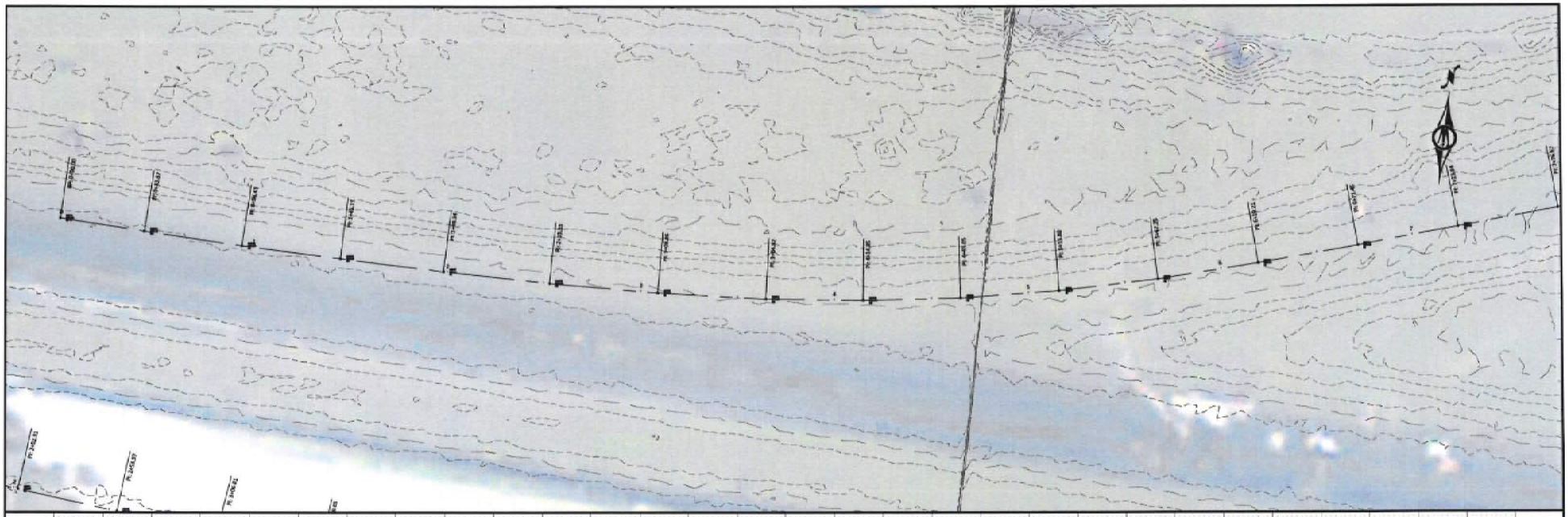


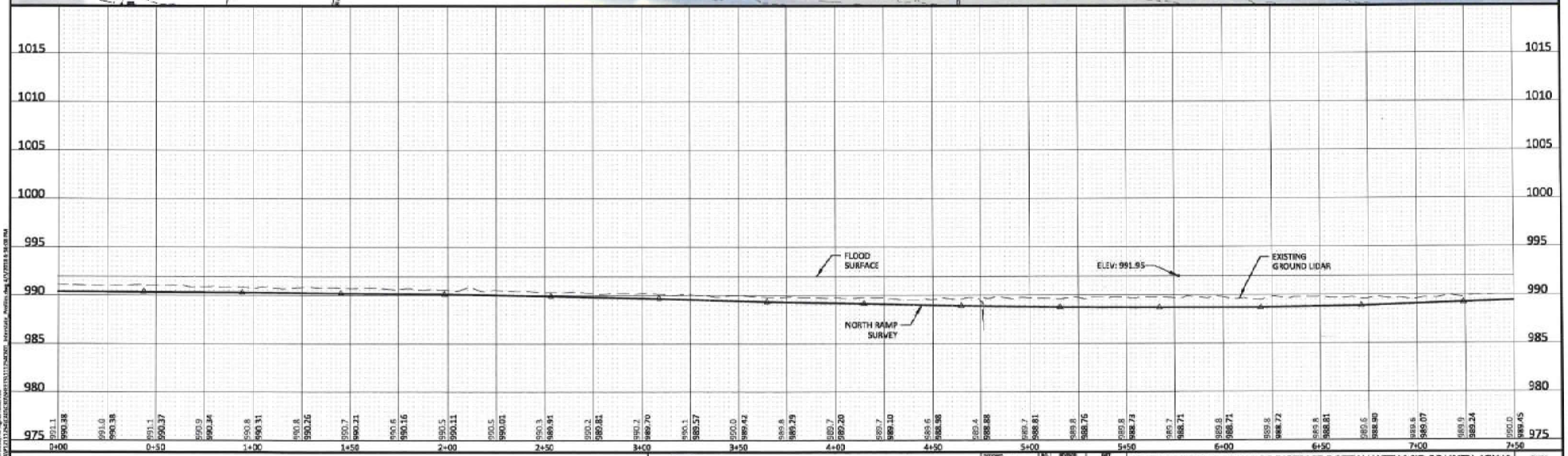
5 of 5

County Road Overpass



1 of 1





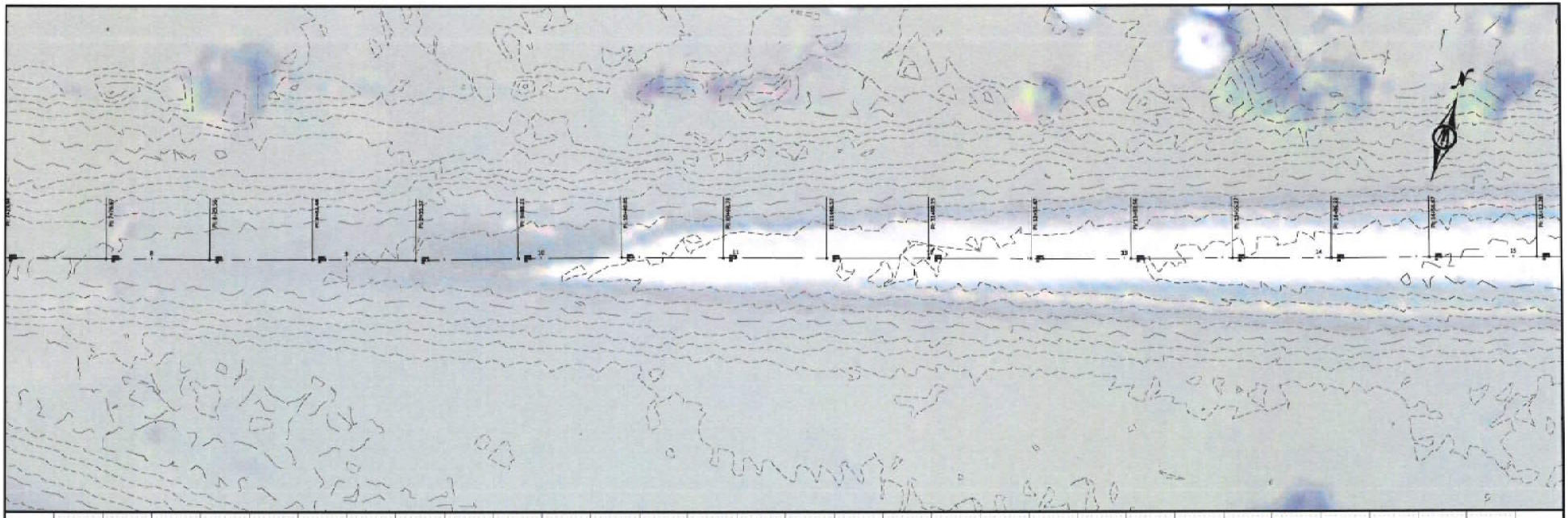
BOLTON & MENK
300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50125
Phone: (515) 386-4101
Email: jefferson@bolton-menk.com
www.bolton-menk.com

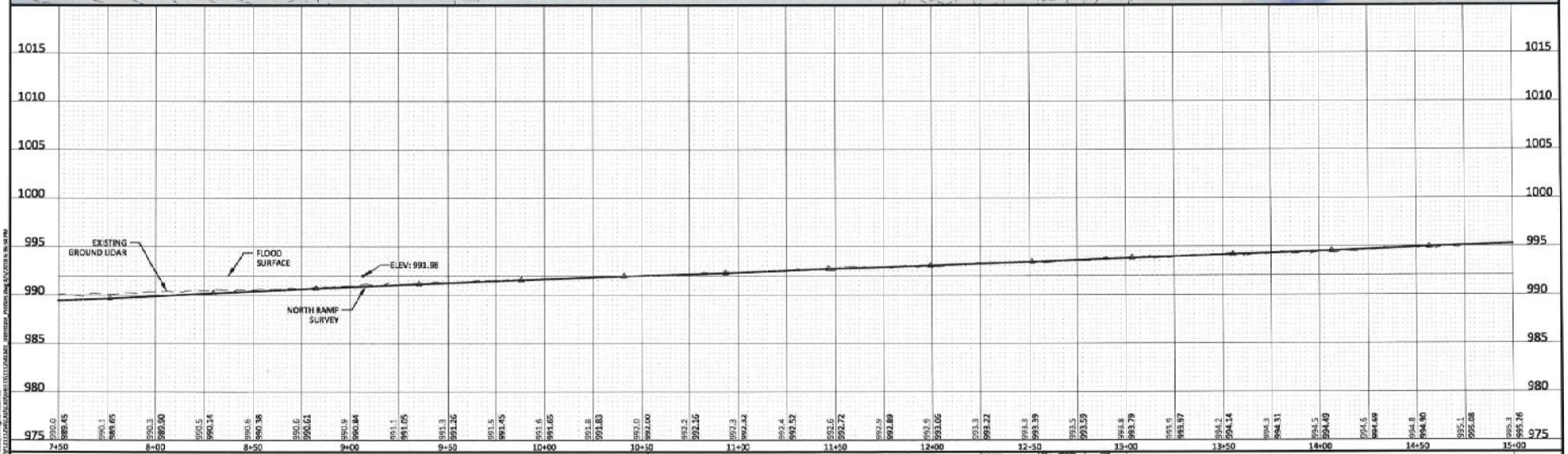
DESIGNED JPR
DRAWN JPR
CHECKED DDE
QUALITY REG. NO. XXXXXXXXXX

NO.	REVISION	DATE

PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA
SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS
PLAN & PROFILE - NORTH RAMP

SHEET 1 OF 15



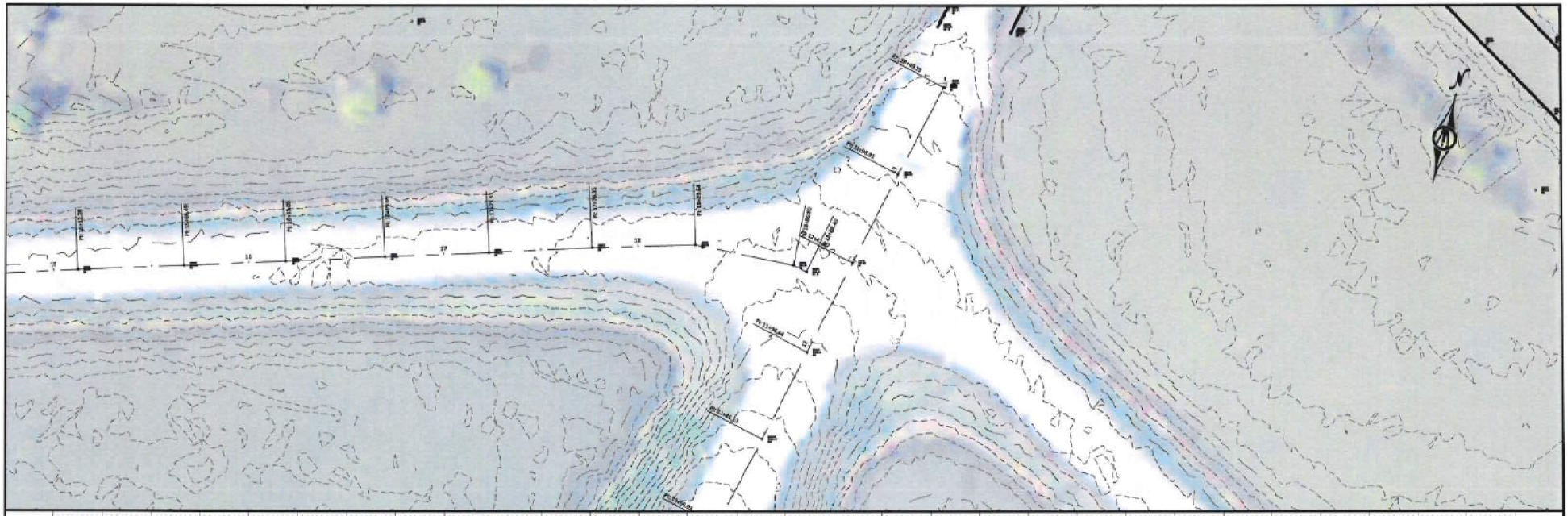


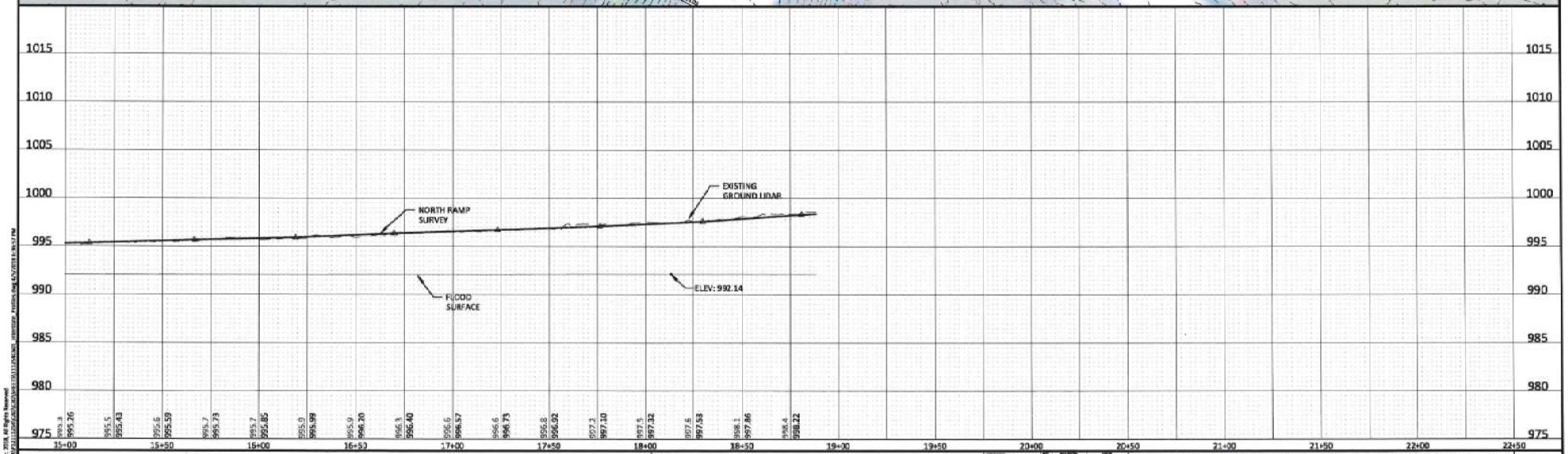
BOLTON & MENK
300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50125
Phone: (515) 386-4101
Email: Jefferson@bolton-menk.com
www.bolton-menk.com

DESIGNED JPR
DRAWN JPR
CHECKED DDE
COUNTY PROJ. NO. 0000000000

PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA
SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS
PLAN & PROFILE - NORTH RAMP

SHEET 2 OF 15



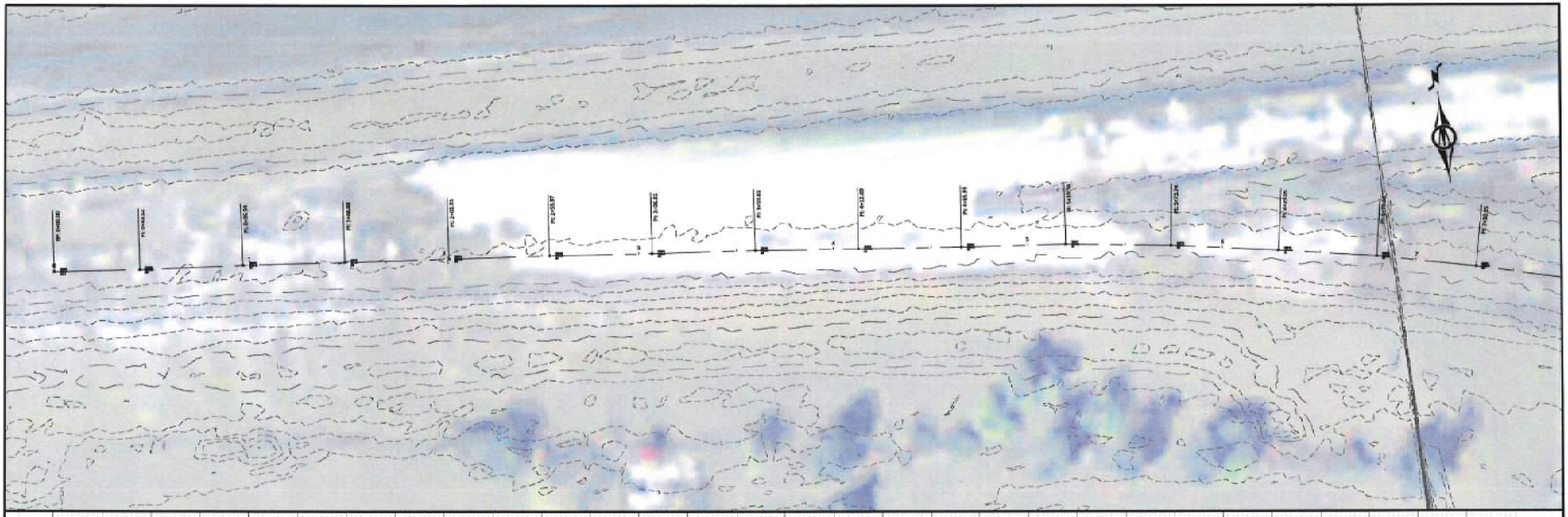


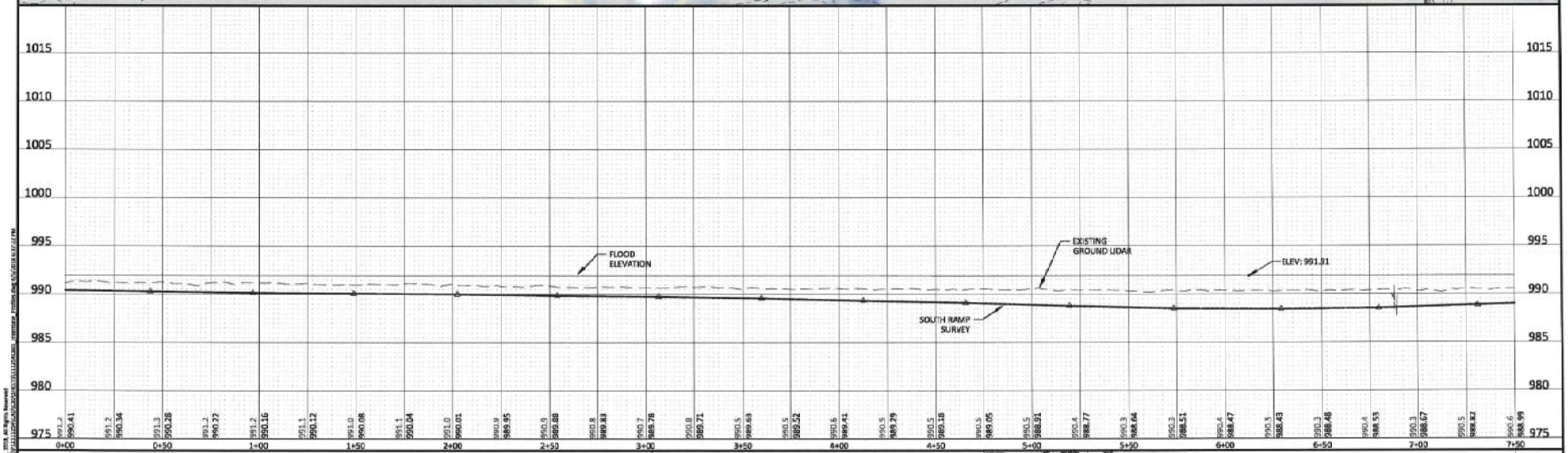
BOLTON & MENK
300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50129
Phone: (515) 386-4101
Email: Jefferson@bolton-menk.com
www.bolton-menk.com

DESIGNED JPR
DRAWN JPR
CHECKED DDE
CLIENT PROJ NO. XXXXXXXXXX

PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA
SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS
PLAN & PROFILE - NORTH RAMP

SHEET 3 OF 15





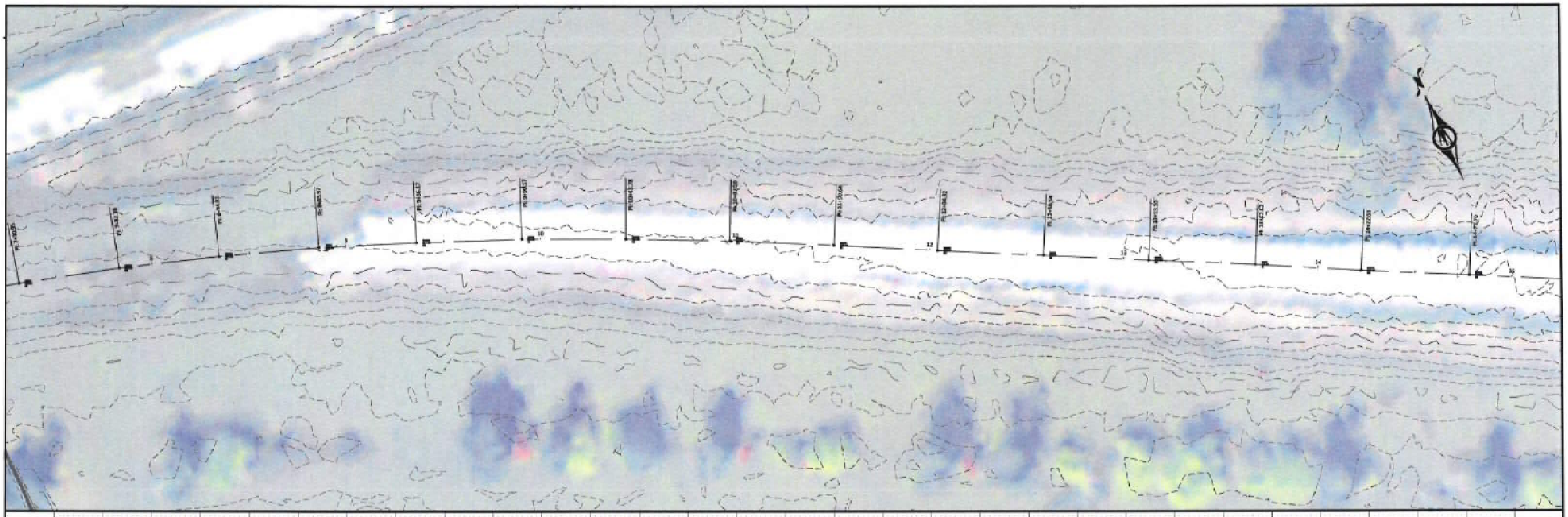
BOLTON & MENK
300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50129
Phone: (515) 386-4101
Email: jefferson@bolton-menk.com
www.bolton-menk.com

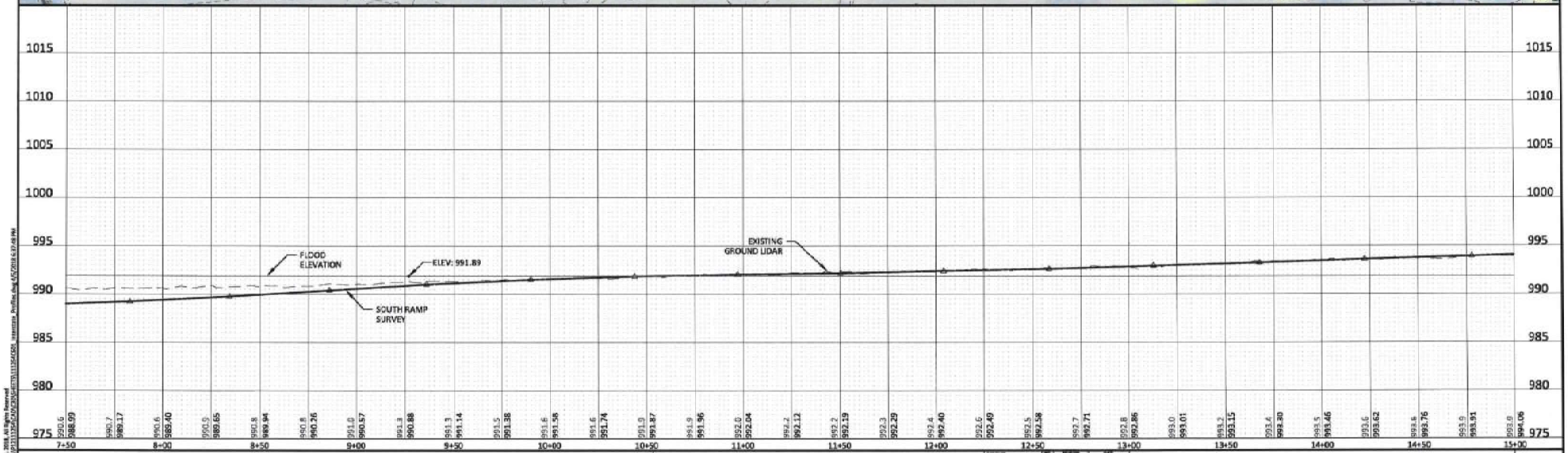
DESIGNED JPR
DRAWN JPR
CHECKED DCE
CLIENT PROJ. NO. XXXXXXXXXX

NO.	REVISION	DATE

PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA
SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS
PLAN & PROFILE - SOUTH RAMP

SHEET 4 of 15





BOLTON & MENK

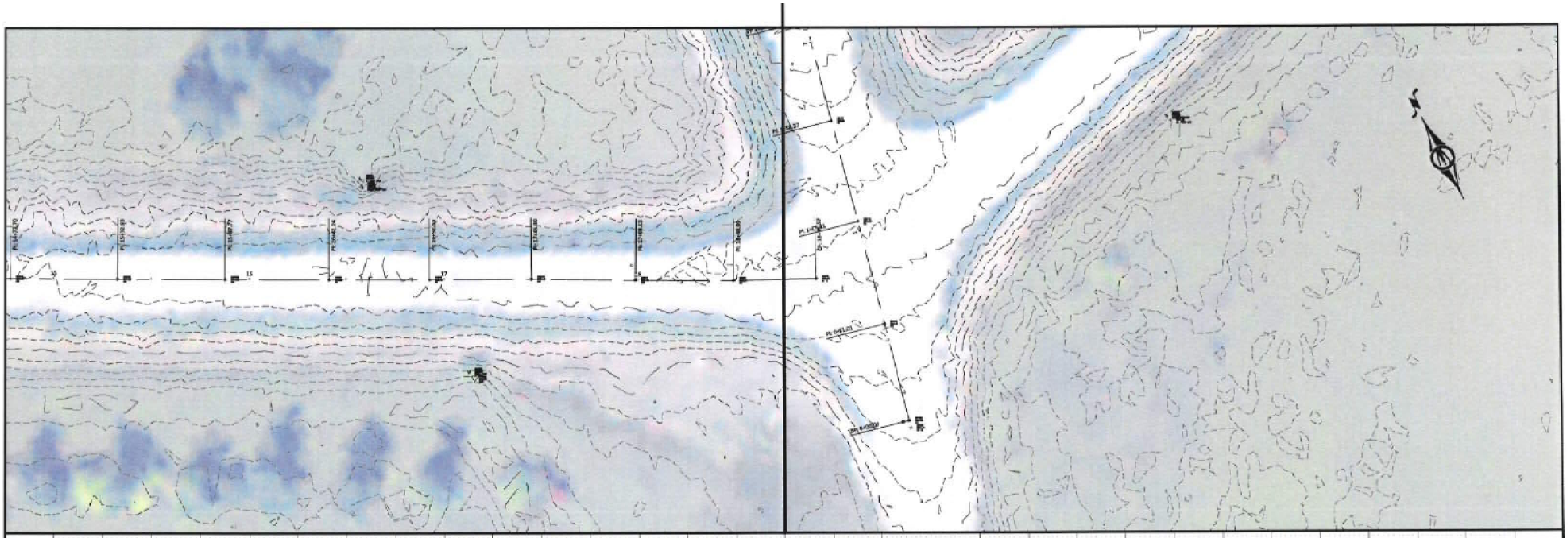
300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50129
Phone: (515) 386-4101
Email: Jefferson@bolton-menk.com
www.bolton-menk.com

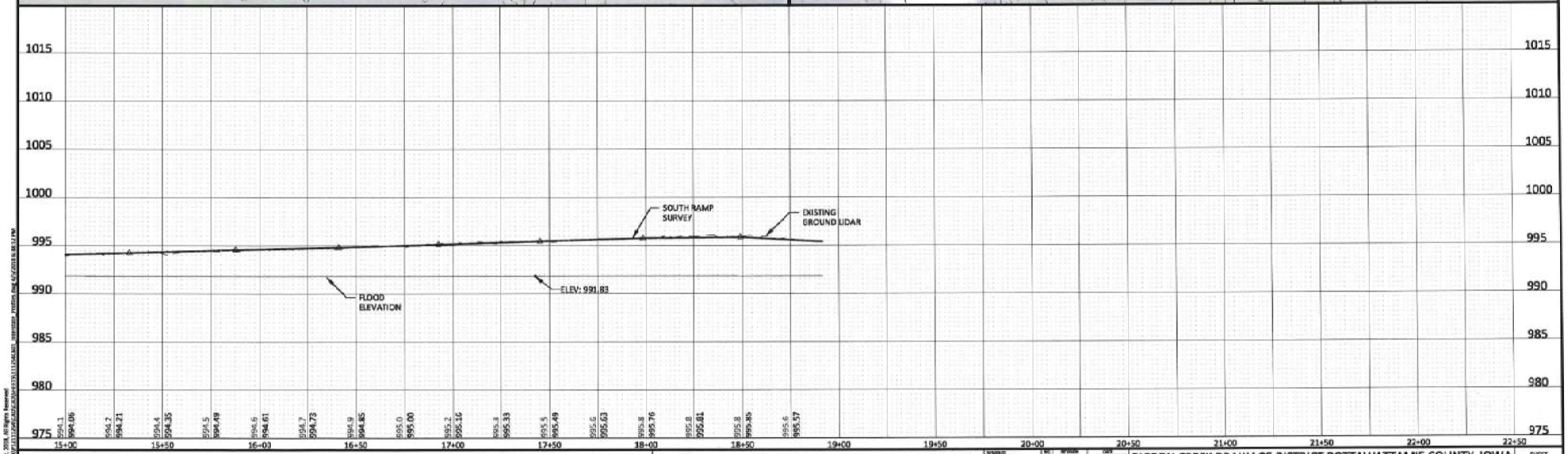
DESIGNED JFR
DRAWN JFR
CHECKED DDE
CLIENT PROJ. NO. XXXXXXXXXX

NO.	REVISION	DATE

PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA
SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS
PLAN & PROFILE - SOUTH RAMP

SHEET 5 OF 15



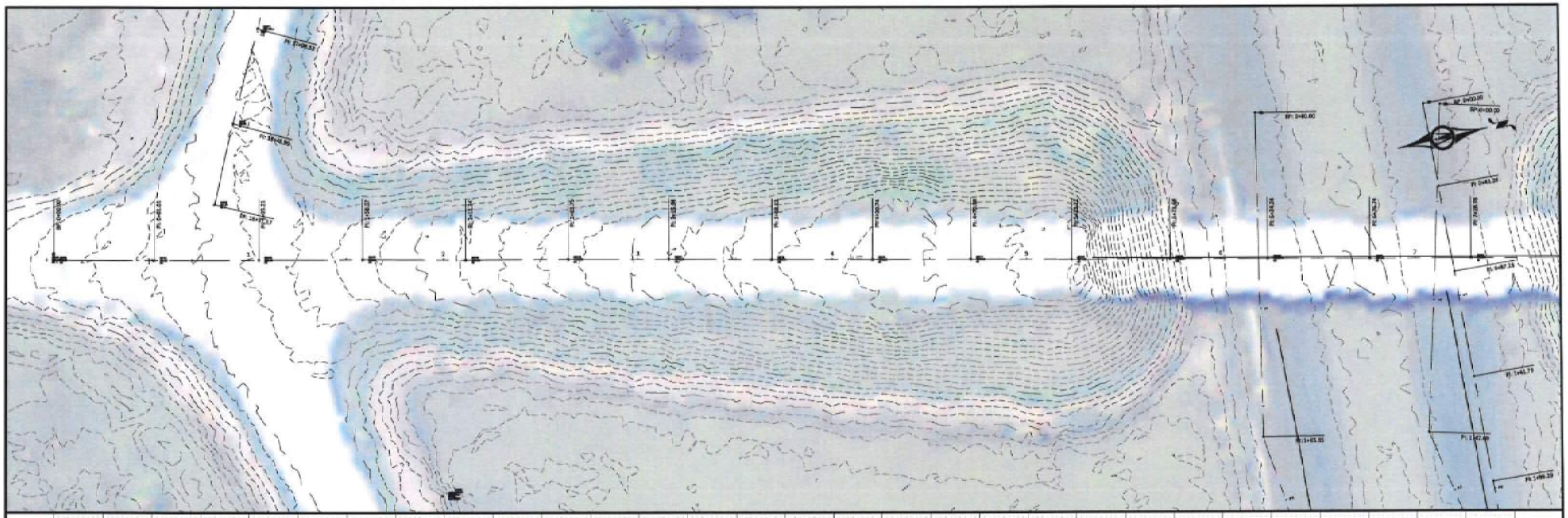


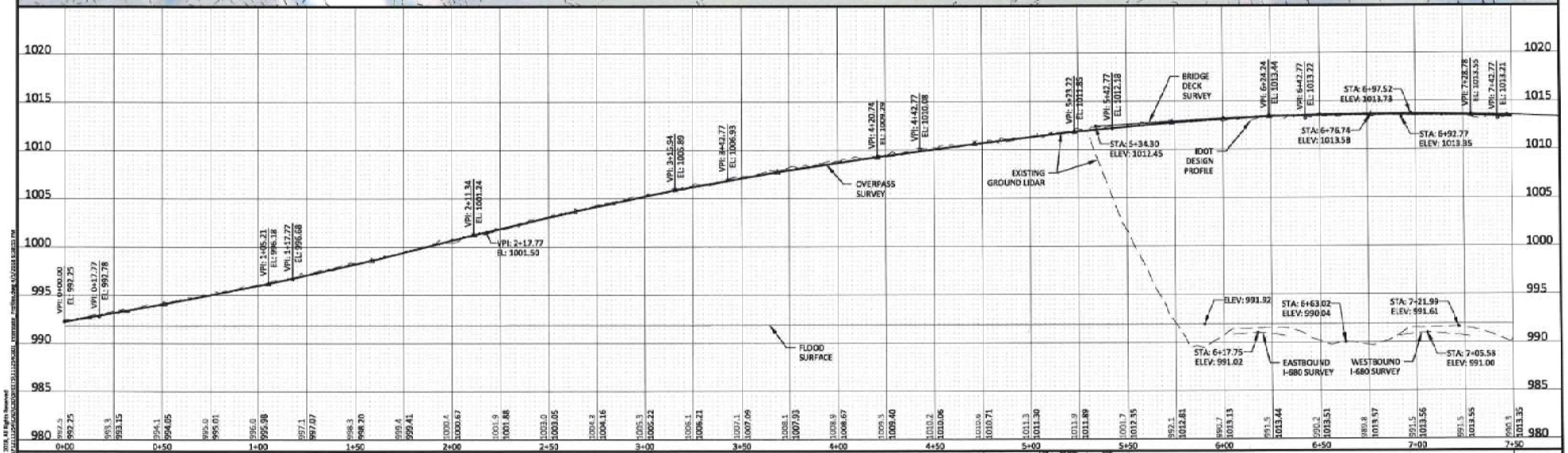
BOLTON & MENK
300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50129
Phone: (515) 386-4101
Email: Jefferson@bolton-menk.com
www.bolton-menk.com

DESIGNED	JFR
DRAWN	JFR
CHECKED	DDE
CLIENT PROJ. NO.	0000000000

PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA
SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS
PLAN & PROFILE - SOUTH RAMP

SHEET 6 OF 15



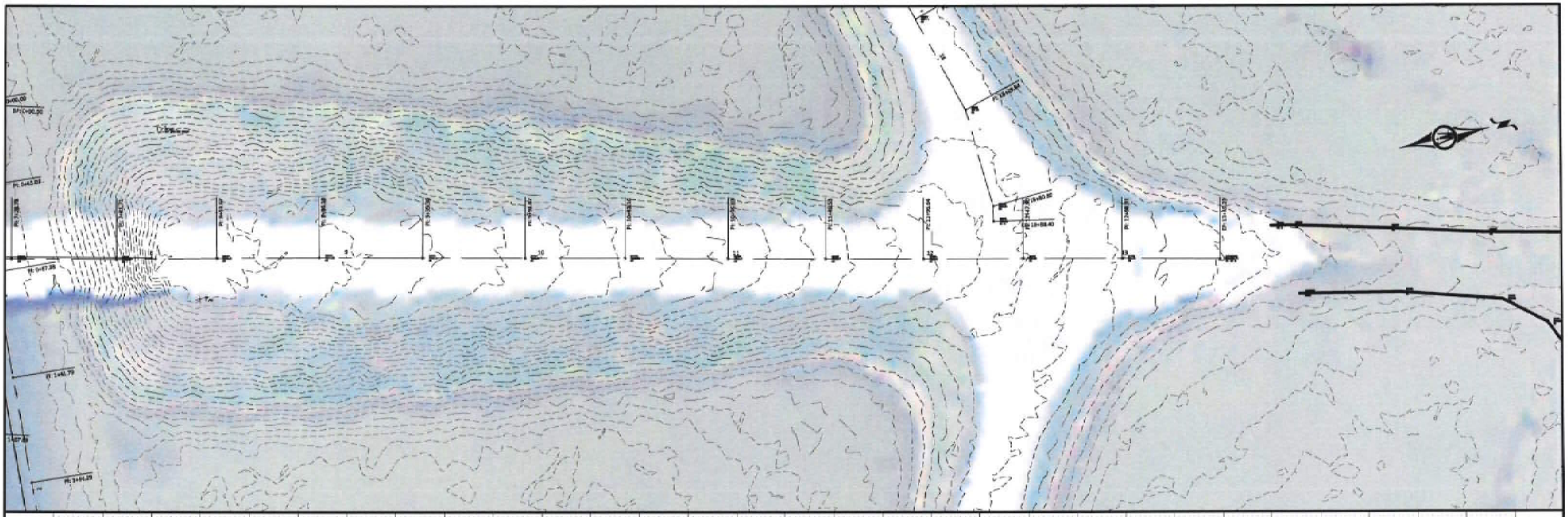


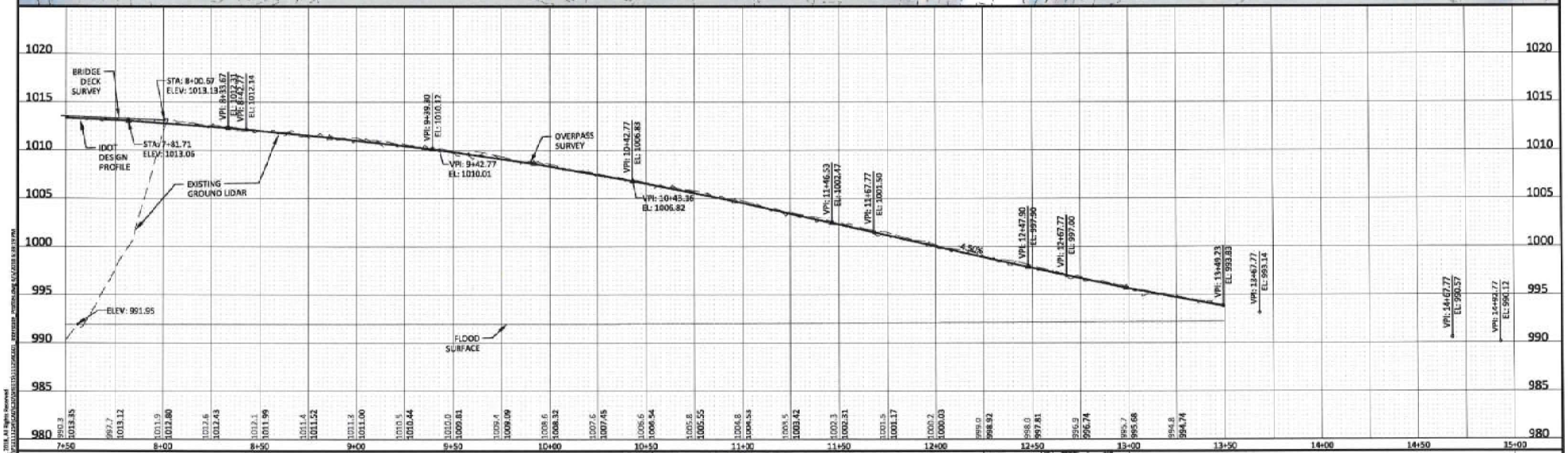
BOLTON & MENK
300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50129
Phone: (515) 386-4101
Email: Jefferson@bolton-menk.com
www.bolton-menk.com

DESIGNED JPR
DRAWN JPR
CHECKED DDE
CLIENT PROJ. NO. XXXXXXXXXX

PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA
SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS
PLAN & PROFILE - OVERPASS

SHEET 7 OF 15

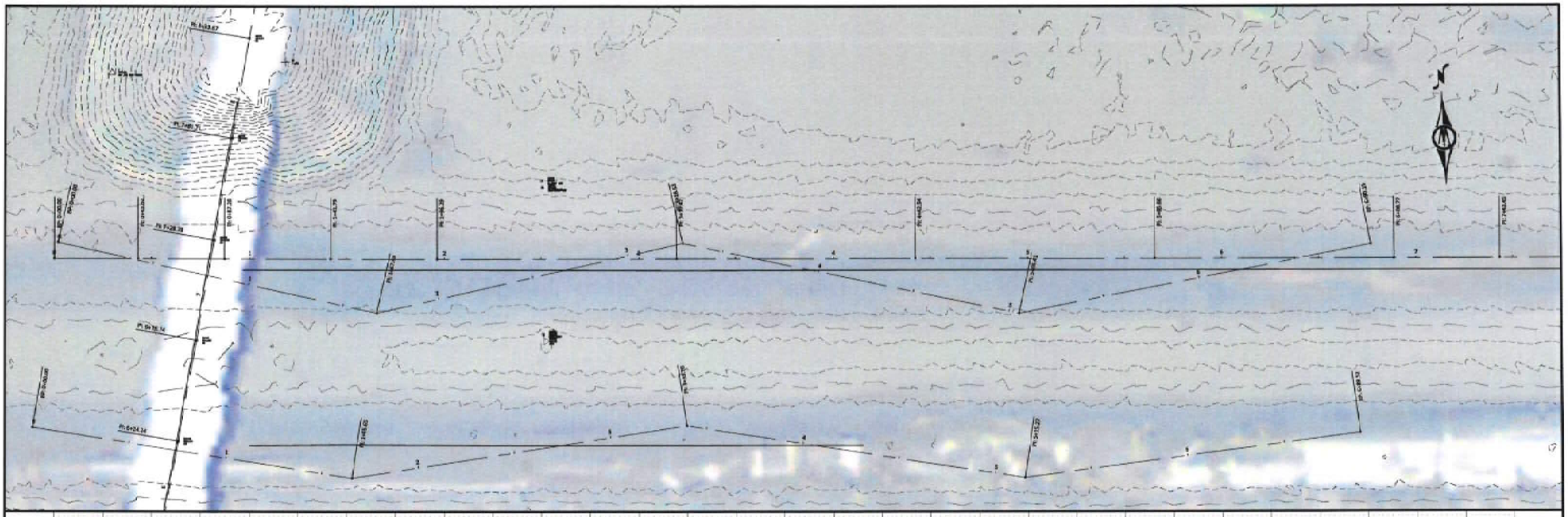


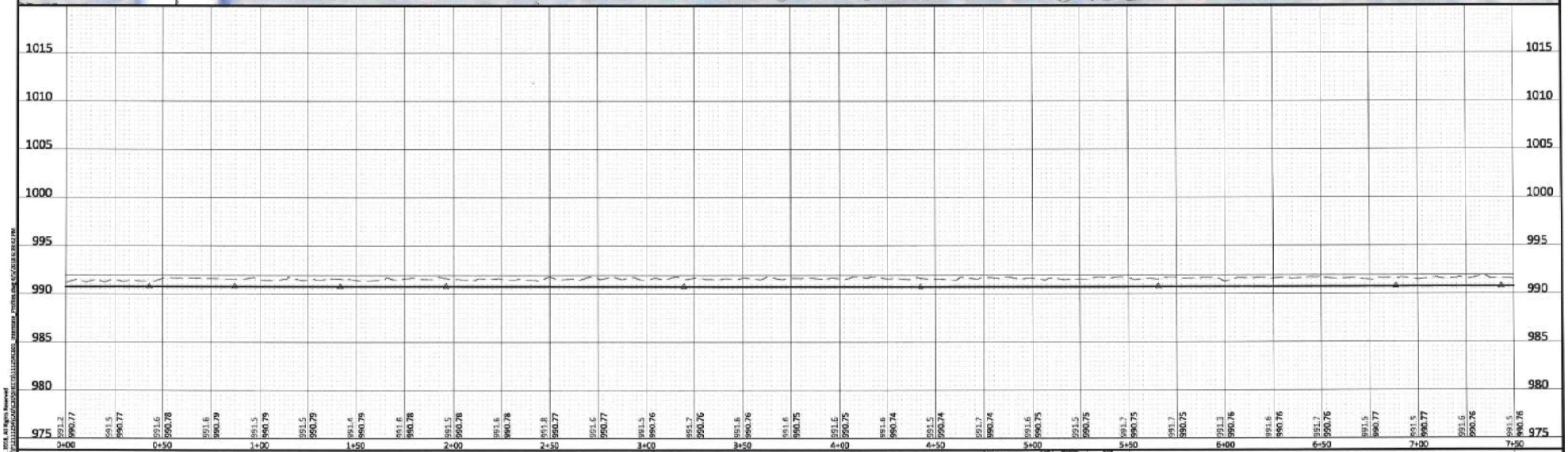


BOLTON & MENK
300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50129
Phone: (515) 386-4101
Email: Jefferson@bolton-menk.com
www.bolton-menk.com

PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA
SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS
PLAN & PROFILE - OVERPASS

SHEET 8 OF 15





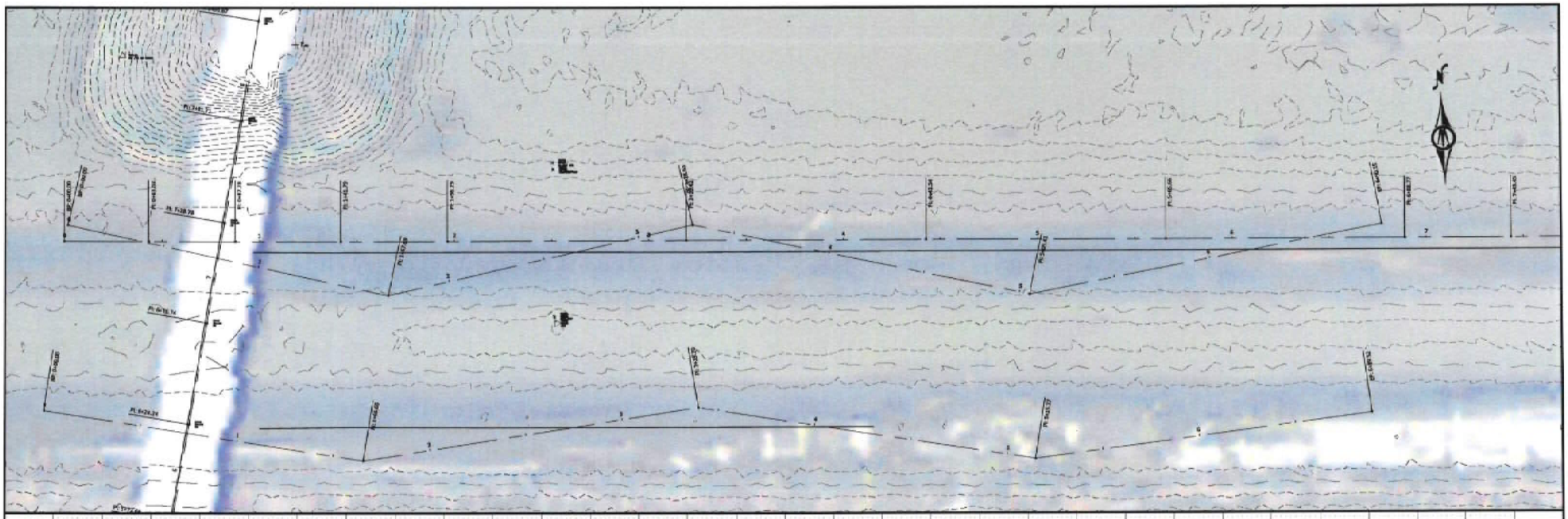
BOLTON & MENK
300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50129
Phone: (515) 386-4101
Email: Jefferson@bolton-menk.com
www.bolton-menk.com

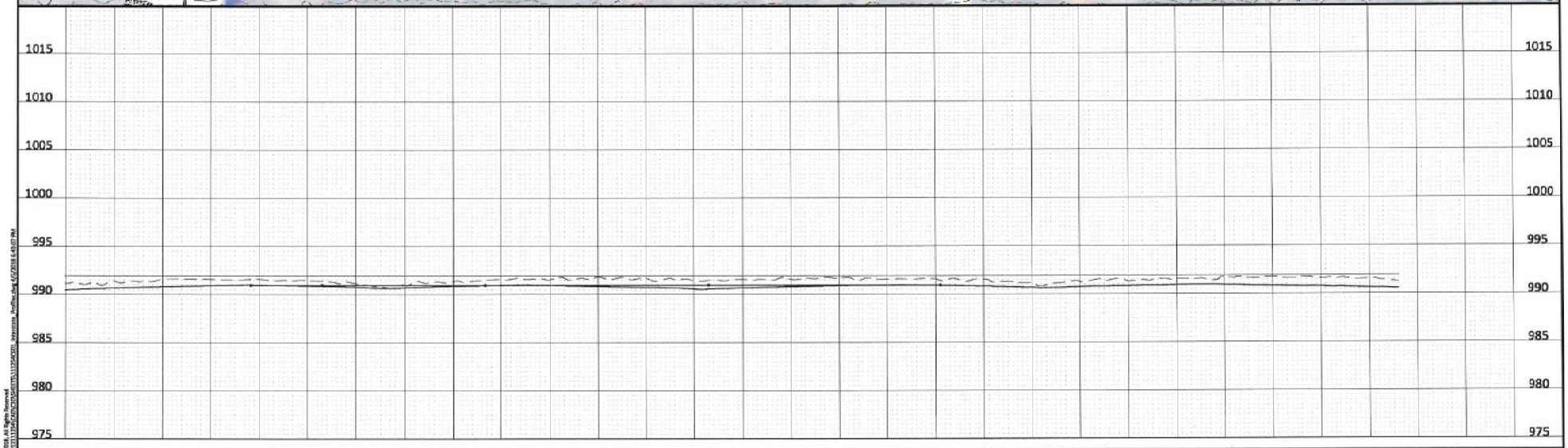
DESIGNED JPR
DRAWN JPR
CHECKED DBE
COUNTY PROJ. NO. XXXXXXXXXX

NO. REVISION DATE

PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA
SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS
PLAN & PROFILE - WEST BOUND I-680

SHEET 9 OF 15



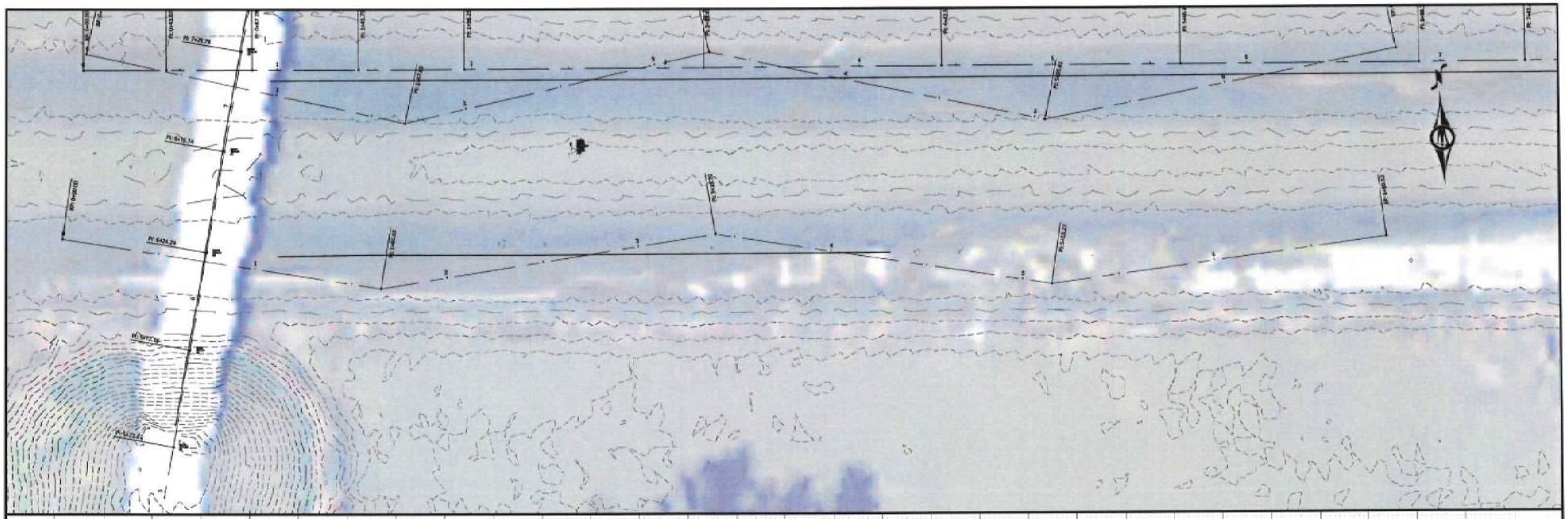


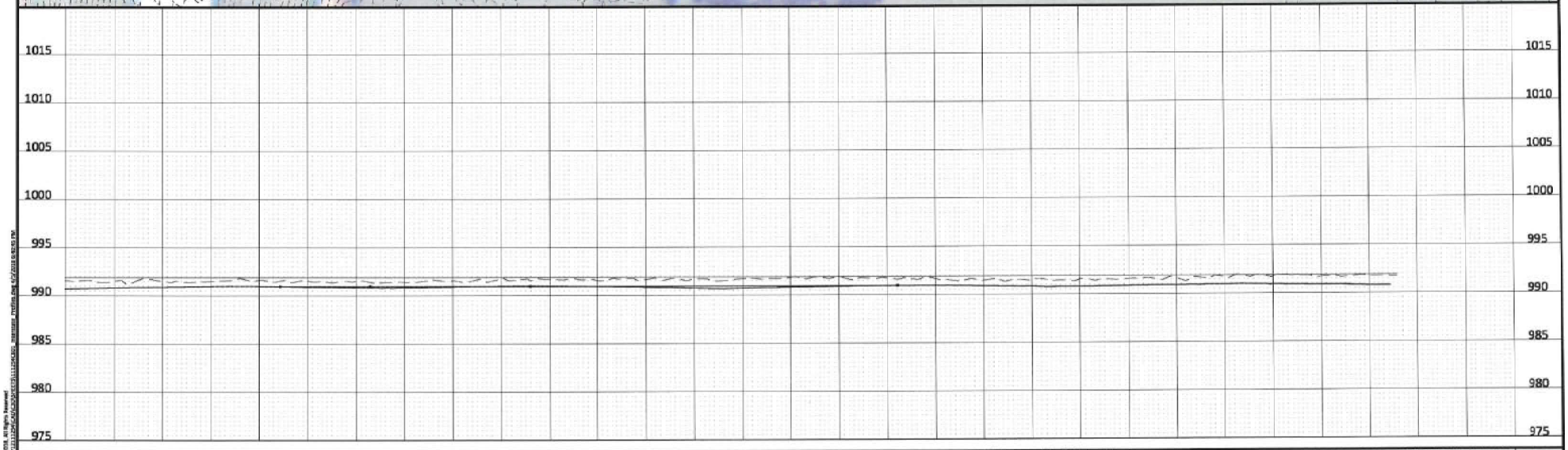
BOLTON & MENK
300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50129
Phone: (515) 386-4101
Email: jefferson@bolton-menk.com
www.bolton-menk.com

DESIGNED	JFR		
DRAWN	JFR		
CHECKED	DDE		
CLIENT PROJ. NO.	XXXXXXXXXX		

PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA
SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS
WEST BOUND LANE CHECKS

SHEET 10 OF 15



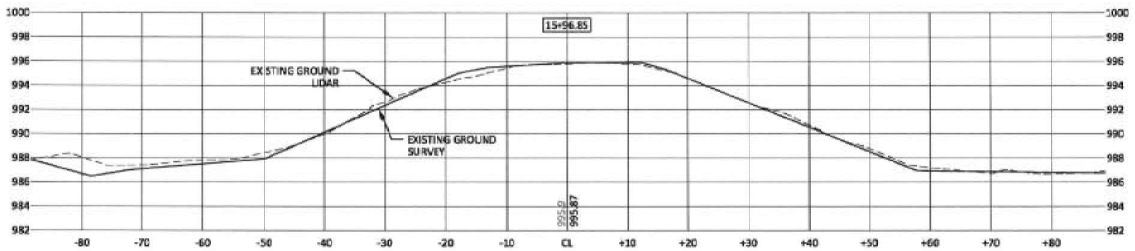


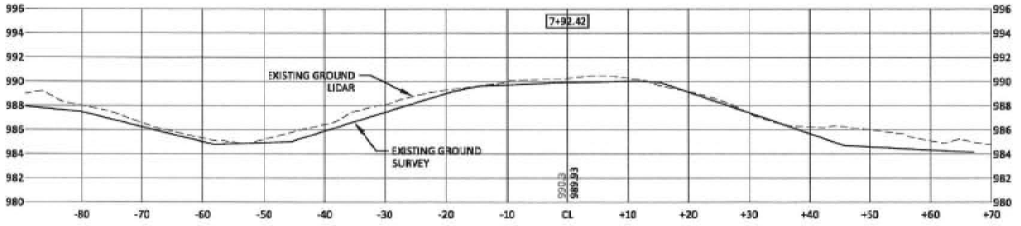
BOLTON & MENK
300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50125
Phone: (515)386-4101
Email: jefferson@bolton-menk.com
www.bolton-menk.com

DESIGNED	JPR	NO.	REVISION
DRAWN	JPR		
CHECKED	CDE		
COUNTY PROJ. NO.	0000000000		

PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA
SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS
EAST BOUND LANE CHECKS

SHEET 11 OF 15





BOLTON & MENK

800 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50129
Phone: (515) 386-4101
Email: Jefferson@bolton-menk.com
www.bolton-menk.com

DESIGNED	JPR
DRAWN	JPR
CHECKED	CDE
DIRECT PROJ. NO.	0000000000

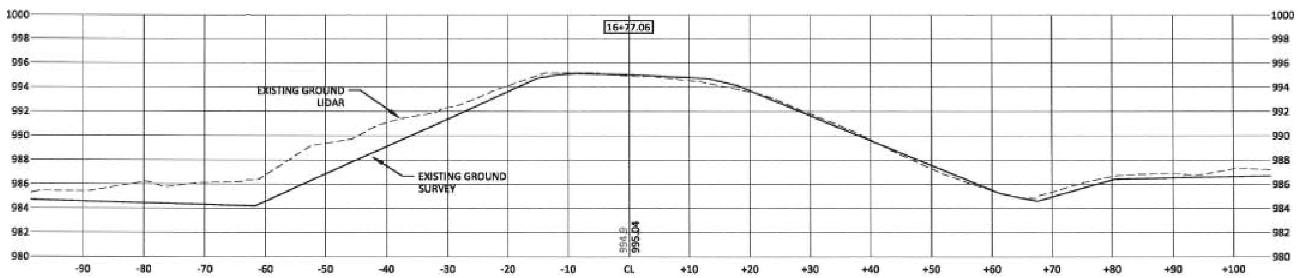
NO.	REVISION	DATE

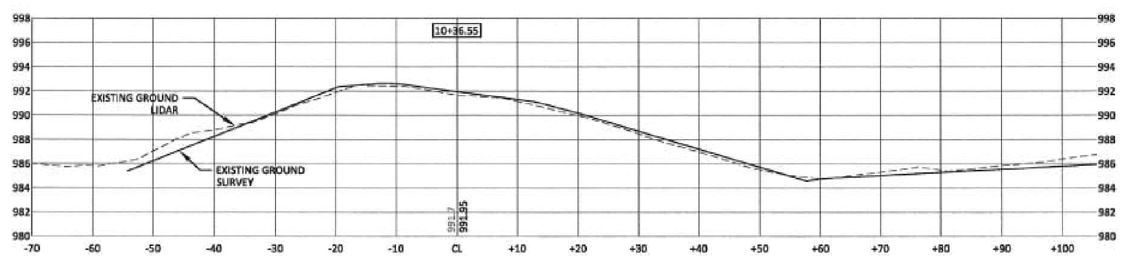
PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA

SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS

CROSS SECTIONS - NORTH RAMP

SHEET 12 OF 15





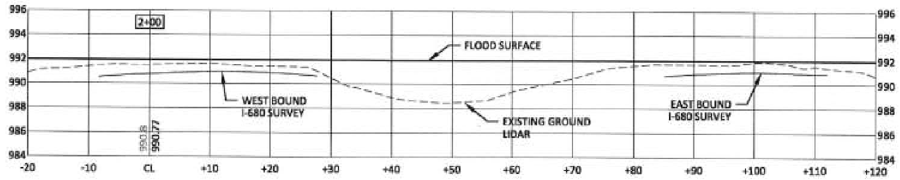
BOLTON & MENK

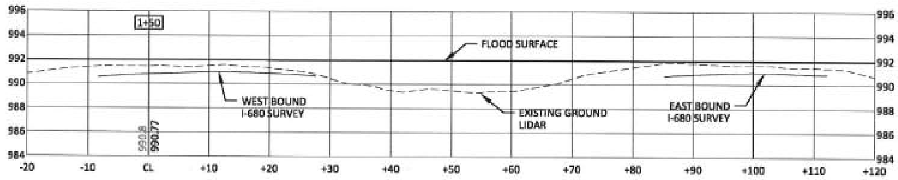
300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50129
Phone: (515) 386-4101
Email: Jefferson@bolton-menk.com
www.bolton-menk.com

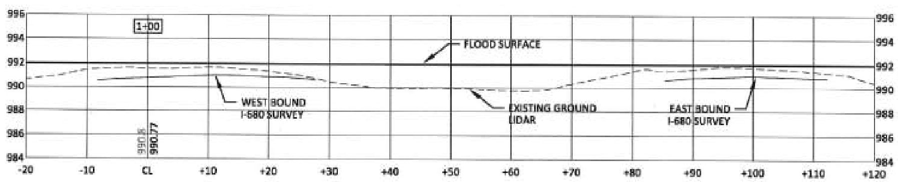
DESIGNED JPR
DRAWN JPR
CHECKED DDE
CLIENT PROJ. NO. XXXXXXXXXX

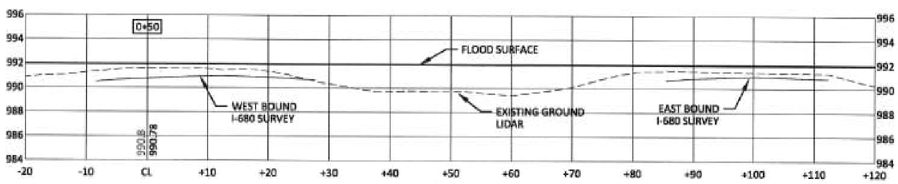
NO.	REVISION	DATE

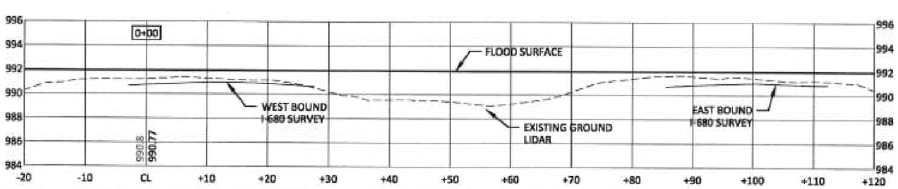
PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA
SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS
CROSS SECTIONS - SOUTH RAMP

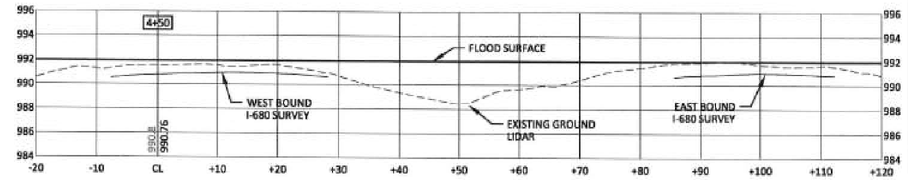


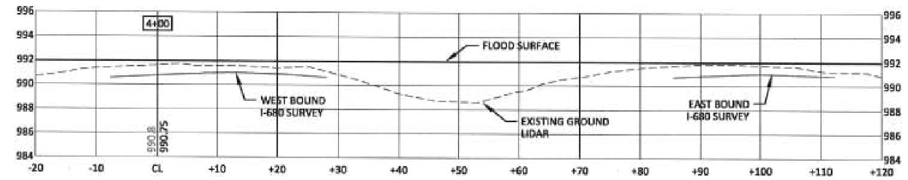


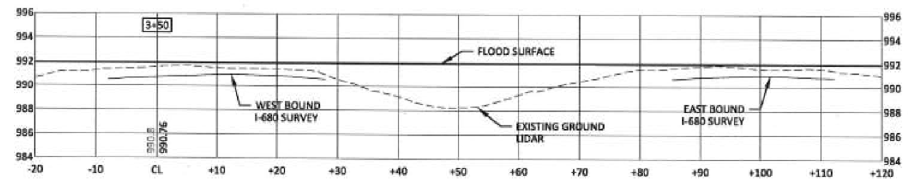


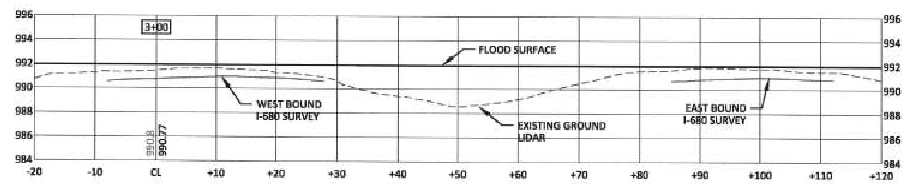


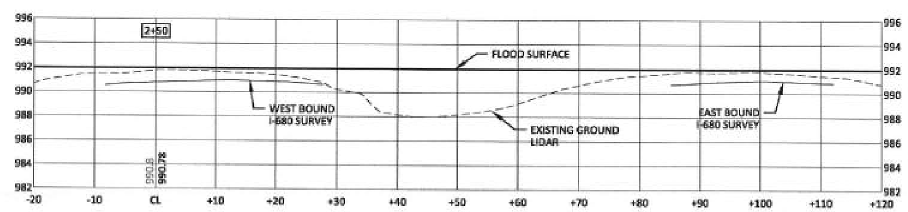












BOLTON & MENK
300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50129
Phone: (515) 386-4101
Email: Jefferson@bolton-menk.com
www.bolton-menk.com

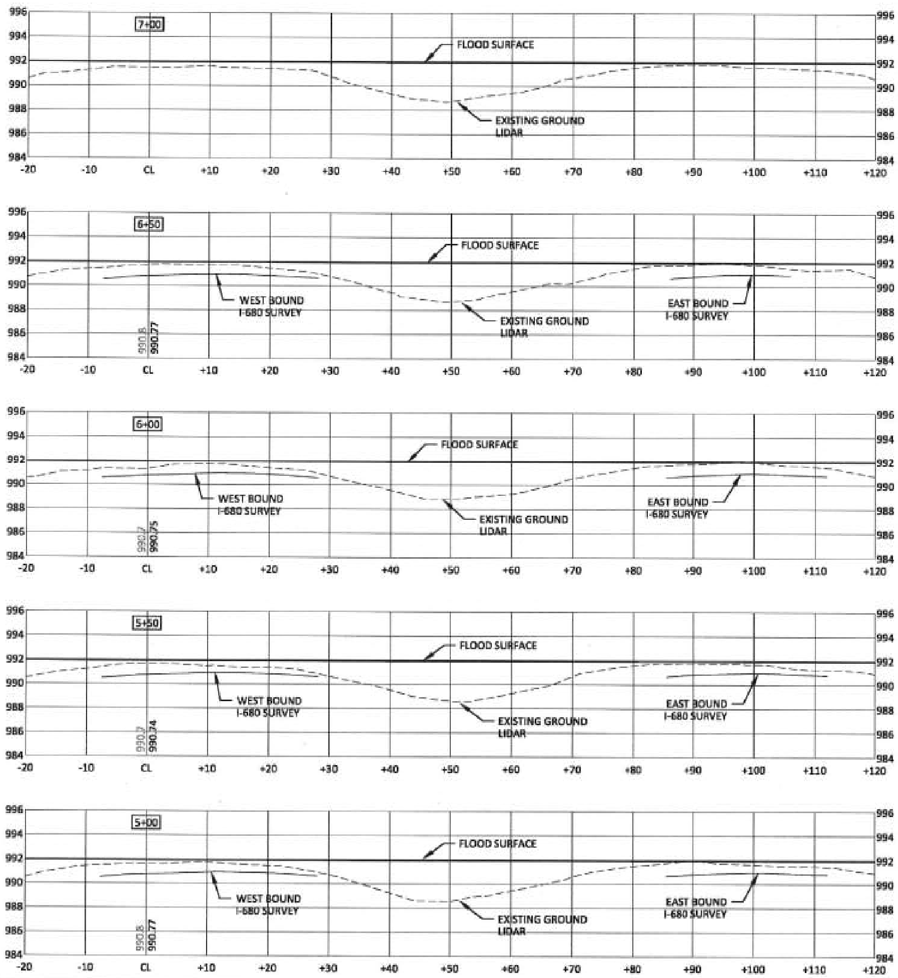
DESIGNED JPR
DRAWN JPR
CHECKED DDE
CLIENT PROJ. NO. XXXXXXXXXX

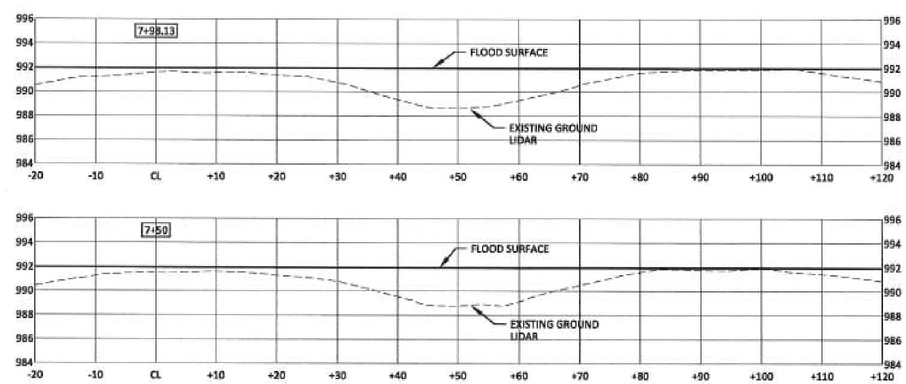
PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA

SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS

CROSS SECTIONS - WEST BOUND I-680

SHEET 14 OF 15





BOLTON & MENK

300 WEST MCKINLEY ST, P.O. BOX 68
JEFFERSON, IOWA 50129
Phone: (515) 386-4101
Email: Jefferson@bolton-menk.com
www.bolton-menk.com

DESIGNED JPR
DRAWN JPR
CHECKED CJDE
CLIENT PROJ. NO. XXXXXXXXXX

PIGEON CREEK DRAINAGE DISTRICT POTTAWATTAMIE COUNTY, IOWA
SUBDRAINAGE DISTRICT NO. 3 LEVEE REPAIRS
CROSS SECTIONS - WEST BOUND I-680

SHEET 15 OF 15

Appendix B: Determination of Flood Frequency of the Missouri River Below Gavins Point Dam

Determination of Flood Frequency of the Missouri River Below Gavins Point Dam

Conference Paper · July 2002

CITATIONS
0

READS
12

1 author:

Roger Kay
US Army Corps of Engineers
10 PUBLICATIONS **29** CITATIONS

SEE PROFILE

DETERMINATION OF FLOOD FREQUENCY OF THE MISSOURI RIVER BELOW GAVINS POINT DAM

Roger L. Kay, P.E., Hydraulic Engineer, U.S. Army Corps of Engineers, Omaha District, Omaha, NE

106 S. 15 St, CENWO-ED-HE, Omaha, NE 68102, Phone: (402) 221-3150, Fax: (402) 221-3005, E-mail: Roger.L.Kay@usace.army.mil

INTRODUCTION

Prior to this study, the discharge frequency relationships established for the Missouri River are those that were developed in 1962 and published in the Missouri River Agricultural Levee Restudy Program Hydrology Report (USACE, 1962). This hydrology information was used for the water surface profiles and flood inundation areas that were developed for the Missouri River Flood Plain Study during the mid to late 1970's. Almost 40 years of additional streamflow data were available since the Missouri River Hydrology was last updated. Development of unregulated flows and regulated flows for a long term period of record was a monumental task for the Missouri River because of the extensive water development that has occurred in the basin. Daily flow hydrographs were developed through computer model studies for both unregulated and regulated flow conditions. Estimates of historical and current level depletions were developed by the US Bureau of Reclamation and incorporated into the analysis. Regulated flow conditions include the current level of water resources development and flood control regulation on the tributaries in addition to the regulation provided by the Missouri River Mainstem Reservoir system. A Technical Advisory Group, consisting of hydrology experts in government, education and private practice, approved the methods used in the discharge frequency analysis.

Previous Studies Several studies have been undertaken in the past to define the flow frequency relationship of the Missouri River for various purposes pertaining to flood control measures. Past studies include the 308 Report (U.S. Secretary of War), the Flood Control Act of 1944 (U.S. Congress, 1944), Missouri River Levees, Definite Project Report (USACE, 1946), the Main Stem Flood Control Benefits Re-evaluation (USACE, 1956), and the Missouri River Agricultural Levee Restudy Program (USACE, 1962). Hydrologic data developed as part of the 1962 study included flow hydrographs, annual peak discharge probability curves, stage-discharge rating curves, evaluation of levee confinement effects, and effects of reservoir control. The discharge frequency relationships derived from this study are shown in Table 1.

Table 1. 1962 Missouri River Discharge-Frequency

LOCATION	50 %	10 %	2%	1%
Sioux City	44,000	65,000	82,000	90,000
Omaha	74,000	125,000	170,000	190,000
Nebraska City	108,000	160,000	200,000	220,000
Rulo	117,000	170,000	220,000	241,000

Basin Description The Missouri River rises along the Continental Divide in the northern Rocky Mountains and flows generally easterly and southeasterly to join the Mississippi River near St. Louis Missouri. The river drains nearly 530,000 square miles in Canada and 10 states, or an area equal to one-sixth of

the contiguous United States. Its headwaters begin near Three Forks, Montana where the Madison River, the Jefferson River and the Gallatin River join to form the Missouri River. From there it travels 2,315 square miles to its confluence, making it the longest river in the United States. Major Missouri River tributaries are the Yellowstone River, which drains an area of 70,000 square miles, the Platte River with a 90,000 square mile drainage area; and the Kansas River, which drains an area of approximately 60,000 square miles

Average annual precipitation varies from over 40 inches in parts of the Rocky Mountains and southeastern parts of the basin, to less than 10 inches immediately east of the Rocky Mountains. Temperature extremes range from winter lows of –60ºF in Montana to summer highs of up to 120ºF in Nebraska, Kansas, and Missouri. The broad range in latitude, longitude, and elevation of the Missouri River basin and its location near the geographical center of the North American Continent results in a wide variation in climatic conditions, from season to season and from year to year. Because of these extreme variations in climatic conditions, extensive development of water resources has occurred.

Water Resources Development Water resources development in the Missouri River basin has been dramatic over the past 150 years. Significant periods of development were prior to 1910 and since 1949. Early water resource developments were oriented largely towards single-purpose improvements to meet specific needs without substantial regard for other potential functions. However, as the region's demand for water resources grew, and technology improved, multi-purpose programs became more prevalent.

Flood Control Reservoirs Numerous reservoirs and impoundments constructed by different interests for flood control, irrigation, power production, recreation, water supply, and fish and wildlife are located throughout the basin. The U.S. Bureau of Reclamation (USBR) and the U.S. Army Corps of Engineers (USACE) have constructed the largest of these structures. Six mainstem dams constructed by the Corps are the most significant authorized flood control projects within the basin, providing a combined capacity in excess of 73.5 million acre-feet, of which more than 16 million acre-feet is for flood control. In addition to the six main stem projects operated by the Corps, 65 tributary reservoirs operated by USBR and USACE provide over 15 million acre-feet of flood control storage.

Irrigation Development Irrigation first appeared in the Missouri Basin about 1650 by the Taos Indians along Ladder Creek in northern Scott County, Kansas. 'Modern' irrigation appeared in the basin in the late 1850s and early 1860s, and water use for irrigation and other uses grew rapidly through the remainder of the 19th century and into the early 20th century, especially in the more arid western plains. According to USBR estimates, irrigation and other depletions have reached 13.5 million acre-feet annually above Rulo, Nebraska.

Navigation Channel The Missouri River has served as a form of transportation for centuries. The first river navigation development work consisted of snagging and clearing to remove obstructions that hindered early steamboat traffic. In 1912, Congress authorized a 6-foot channel between Kansas City and the mouth. In 1927, Congress authorized the extension of the navigation channel to Sioux City, as well as a study to determine the feasibility of a nine-foot channel. In 1945, Congress authorized the nine-foot channel to be constructed to Sioux City. In

1981, the navigation channel project was officially declared finished, with the terminus of the project at River Mile 734 at Sioux City.

Levees After floods of the early 1900s, States in the Missouri River basin authorized local drainage districts to construct flood protection works, and some of the drainage districts came to the Corps of Engineers for assistance in their flood control efforts. The Missouri River levee system was authorized by the Flood Control Acts of 1941 and 1944 to provide protection to agricultural lands and communities from Sioux City, Iowa to the mouth at St. Louis, Missouri. However, development of a Federal levee system has not occurred between Sioux City and Omaha, Nebraska. Following construction of the Federal levee system, farming of the lands riverward of the Federal levees became more extensive. Private levees have also been built in those areas where Federal levees were not built.

HYDROLOGIC ANALYSIS

The hydrologic analysis performed for this study was composed of many steps. In order to provide a homogenous data set from which frequency analysis can be performed, effects of historic reservoir regulation and stream depletions had to be removed from the observed stream flow record. This produced the data set referred to as the "unregulated flow" data set. A homogeneous "regulated flow" data set was then developed by extrapolating reservoir and stream depletions to current use level over the period of record. A relationship between the annual unregulated and regulated flow peaks was established in order to determine the regulated flow frequency at various points.

Methodology The following is a brief description of the work performed to estimate the flow frequency for points along the Missouri River.

1) The existing stream flow data for mainstem gaging stations were extended by converting stage records to discharge through use of old rating curve information at each gage prior to the establishment of USGS gaging records. This extended the period of record for the study back to 1898.
2) Estimates of historic and current level irrigation water use and other consumptive uses (otherwise referred to as depletions, in sum) were developed by the USBR. The historic level depletions were utilized in estimating the unregulated flow data set, while the current level depletions were used in developing the regulated flow data set.
3) Historic evaporation and precipitation records were researched and compiled for inclusion in the input data set to the unregulated flow model.
4) Reservoir regulation data were compiled for inclusion in the input data set to the unregulated flow model.
5) The unregulated flow computer model was run, using data developed by both Omaha and Kansas City Districts, to determine a daily record of unregulated flows from Yankton, South Dakota to Hermann, Missouri covering the period from January 1, 1898 to December 31, 1997.
6) Flow frequency analyses were performed on the annual peaks using procedures found in Bulletin #17b (reference). The results indicated the use of a mixed distribution of spring and summer peaks above the Kansas River and the use of annual peaks downstream of the Kansas River.

7) The regulated flow computer model was run, using data developed by both Omaha and Kansas City Districts, to determine a daily record of regulated flows from Gavins Point Dam to Hermann, Missouri covering the period from January 1, 1898 to December 31, 1997.
8) Annual peaks from the regulated flow data set were determined at each station. The annual peaks from the regulated and unregulated data sets were then paired against each other in descending order. A relationship between regulated and unregulated flow frequencies could then be established at each station.

Database An extensive database of information was compiled in order to determine homogeneous unregulated and regulated data sets. Information collected included streamflow and stage records, meteorological records, hydrologic data associated with reservoirs and estimates of irrigation and other basin depletions.

Stream Flow Records The first river stage station on the Missouri River was established on January 1, 1872 at Fort Leavenworth, Kansas. Within the current boundaries of the Omaha District, the first stage gage on the Missouri River was established on April 10, 1872 at Omaha, Nebraska. Other river stage gages were established at Plattsmouth, Nebraska on April 19, 1873; at Nebraska City on August 1, 1878; and at Sioux City, Iowa on September 2, 1878. Mean daily discharge records were compiled from the USGS (USGS, 1928-1997). Since daily discharge records were not available for the entire study period, discharge values were estimated from stage records prior to about 1928. Rating curves were developed by using information from the discharge measurements of the late 19th and early 20th centuries. These rating curves were applied to the stage data collected by USACE and U.S. Weather Bureau (USDA, 1895-1928) to develop daily values of discharge. For those periods during which the river was noted as ice covered, a constant was applied to the rating curve that reduced flows to account for the increased hydraulic radius. Missing records at Sioux City were estimated based on comparison of the USGS monthly estimates of flows and eye fitting the missing discharge hydrograph to preserve the monthly volumes. Missing records at Omaha and Nebraska City were estimated by routing upstream flows to these gages.

Meteorological Records Meteorological records such as precipitation and evaporation were needed for determining unregulated flows, as precipitation and evaporation affect the amount of water in reservoir storage. Evaporation from large flood control reservoirs is a major loss of water from the basin and must be accounted for in determining unregulated flows. Precipitation on reservoir surfaces must also be accounted for, as direct runoff is increased.

Precipitation and evaporation records were drawn from National Weather Service records available on CD-ROM. Records were drawn from the closest and/or most reliable nearby precipitation and/or evaporation station for each reservoir project. Missing precipitation records were filled in with the average monthly precipitation computed from available records. For each day with a missing precipitation record, the average monthly values were divided by the number of days in the month and used to replace the missing record. Several reservoirs antecede evaporation records, so the daily average from the period of record at each station was used to estimate evaporation records at these reservoirs prior to the period of record. Additionally, some stations do not report evaporation records during winter months, so monthly average values,

taken from NWS 34 (NWS, 1982b), were used at these stations. The evaporation records were adjusted using pan evaporation coefficients from NWS 33 (NWS, 1982a) and USACE (1973a).

Area-Capacity Relationships Area-capacity relationships at each reservoir are important for determining how much water is lost to evaporation and how much is gained from precipitation at each reservoir. Survey data was gathered for each reservoir modeled in the UFDM. Even though each reservoir has suffered from sedimentation, the area-capacity relationship has remained relatively stable over time, so a single relationship was used at each reservoir.

Reservoir Hydrologic Data In order to accurately estimate how each flood control reservoir is affecting flows through holdouts, it is necessary to have accurate records of reservoir inflow and outflow and/or reservoir storage. Data for inflow, outflow and storage are available from the USBR, USACE and USGS for nearly all reservoirs, although some data had to be collected for the privately owned reservoirs from the reservoir owners. Reservoir data were obtained for the following dams: Clark Canyon, Hebgen, Canyon Ferry, Gibson, Tiber, Fort Peck, Fresno, Bull Lake, Boysen, Buffalo Bill, Yellowtail, Garrison, Heart Butte, Bowman-Haley, Shadehill, Keyhole, Pactola, Angostura, Oahe, Big Bend, Fort Randall, Gavins Point, Pipestem, and Jamestown.

Depletion Estimates In order to properly develop unregulated and regulated flows, an accurate accounting of streamflow depletions by irrigation, reservoir holdouts, and other consumptive uses was needed. The USBR was contracted with to provide estimates of streamflow depletions for the period 1898-1996 for the Missouri River upstream of Hermann, Missouri. The values provided by the USBR were by month, and included historic (actual) level of depletions and current-use level depletions.

Unregulated Flow Unregulated flow can be defined as removing the effects of all consumptive uses of water (reservoir holdouts, irrigation, etc.) from the observed flow record; in other words the unregulated flow approximates the natural flow of the river. The unregulated flow data set was developed through use of the Unregulated Flow Development Model (UFDM), utilizing data sets for discharge, reservoir inflow and outflow or storage change, evaporation, precipitation, area-storage relationships, depletion data, and routing parameters, as well as observed flow at each gage.

Hydrologic Model Description (UFDM) Reliable runoff or flow data are a continuing need for purposes of efficient utilization of the available water supply in the Missouri Basin. With these data the nature and distribution of the supply becomes apparent, long term normals are defined more precisely, effects of basin water resources development can be estimated, and reservoir regulation effects on downstream flood flows or low water conditions may be developed. The UFDM is a computer model developed by the U.S. Army Corps of Engineers Reservoir Control Center at the Missouri River Region Office to determine unregulated flows for a base level of water resource development in the basin. The model is used to assist in determining flood control benefits for the mainstem reservoir system as well as to determine the amount of runoff from the upper Missouri River basin. In basic terms, the model determines reservoir holdouts and adds these holdouts to irrigation and other water-use depletions to obtain total holdouts in each mainstem reservoir reach. The total holdouts are routed through the system of reservoirs

and then downstream to each gage, with the holdouts added to observed flow at each gage to determine unregulated flow. A more detailed description of the UFDM modeling philosophy may be found in USACE (1973b).

Once all input data were compiled, the model was run, covering the period of January 1, 1898 to December 31, 1997. Annual peaks and various other data were extracted from the output data.

Model Verification Traditionally, hydrologic computer models are calibrated to observed events to obtain some degree of confidence in the model parameters. Of great concern is validating flows for the period 1898-1928, which were derived by use of stage readings converted to flow estimates. One means to verify the accuracy of the model output is to compare it to various hydrologic and climatological data. Comparison of mean annual flows and an annual basin-weighted drought index supported the mean annual flows as reasonable for the period 1898-1928. An analysis of observed annual stream flows tends to further support this position. Although the 1898-1928 estimated flows are higher than any other period during the historical record, they are reasonable when considering the effects of droughts, depletions, and reservoirs. Results indicate that the estimates of annual discharges for the period of 1898-1928 prepared for this study may be overestimated by as much as 1 to 2 million acre-feet per year. Because the discharges were estimated by use of rating curves derived from measurements made primarily during the summer months, it is believed that the majority of the overestimation would occur during late fall and winter periods, when flows were at their lowest. Consequently, comparison of monthly unregulated flow volumes showed that for the periods 1898-1928 and 1967-1997, differences in monthly flow volumes were not statistically significant except in the months of August-January. Therefore, it is concluded that high flows and peak flows estimated for the period 1898-1928 are reasonable and adequate for peak flow frequency and high flow volume investigations. (Interestingly, monthly flow volumes from 1929-1966 are significantly lower from monthly flow volumes in either 1898-1928 or 1967-1997.)

Regulated Flow Regulated flows are defined as those flows over a period of record, assuming a constant level of development, in other words the historic period is modeled as if all current reservoirs and irrigation depletions had been in place over the period of record. The regulated flow data set was developed through use of the Daily Routing Model (DRM), utilizing data sets for discharge, reservoir inflow and outflow, and depletions.

Hydrologic Model Description (DRM) The DRM was originally developed for use in the Missouri River Master Water Control Manual Update Study to evaluate flood control, interior drainage, and groundwater levels along the Missouri River and navigation contributions to the Mississippi River. The DRM contains 20 nodes including the six mainstem reservoirs and 14 gaging stations. The model utilizes two sets of input data. The first set of input files contains historic reach inflow and streamflow depletion data in yearly files, and the second contains the various constants and variable parameters that define regulation decisions on the basis of flood control, navigation and other authorized purposes. Each yearly file contains 14 months of data – December of the previous year through January of the following year. More detailed information on the background and use of the DRM can be found in USACE (1998).

Input Data Development Virtually all input data required for the DRM was previously developed for the unregulated flow analysis or developed for previous studies utilizing the DRM. Input data at gaging stations includes incremental reach inflow, observed gage flow data, and incremental reach depletion data. Input for the six mainstem reservoirs includes reservoir inflow, reservoir outflow, incremental reach inflow, evaporation, and storage. The remaining data sets are the rule curves that dictate the operation of the reservoirs given various parameters. The DRM uses depletion data by adjusting historic flows to present day consumptive water uses.

Model Verification The output for the DRM can be compared to observed data for a relatively good check on the validity of model results. The mainstem reservoir system reached operational volume in 1967, so results from 1968 to 1997 can be compared to see how well the model reproduces the observed hydrograph. The modeled peaks were 2,000-4,000 cfs higher on average, depending on station. However, for the highest flow year (1997), the simulated and observed peaks are nearly identical.

Some difference can be expected between observed and simulated, as the actual and current level of depletion differ somewhat; therefore it can be expected that the simulated values are higher than the observed. By comparing computed and observed end of month mainstem storage from 1967 to 1990, nearly all the difference can be explained due to depletions that were increasing at a rate of about 82,000 acre-feet per year. The final calibration check is to compare the computed daily discharge versus observed daily discharge at Gavins Point Dam. Daily release patterns and values match well throughout the observed period since 1967. In several years, however, there are significant differences at various times of the year; most often this is due to the model being unable to more accurately forecast future inflows in order to step up or step down releases.

FREQUENCY ANALYSIS

A frequency analysis was performed on the unregulated flow data set at each gaging station. A relationship between regulated and unregulated peak annual flows was then developed at each station. The regulated-unregulated relationship was then used to derive the regulated flow frequency at each station.

Unregulated Flow Frequency Frequency analysis was performed on peak annual unregulated flows at each gage, using Bulletin 17B procedures. Outliers were examined, and historical flood information was considered for increasing the reliability of estimates of less frequent floods. A mixed distribution was evaluated for applicability to the flow data. In order to obtain regionally consistent frequency profiles, skew values were regionalized for final frequency estimates.

Methodology The Technical Advisory Group/Interagency Advisory Group (TAG/IAG) recommended using Bulletin 17B procedures after investigating various distribution methodologies and their applicability to the study area. Hence, analyses were performed on the annual peak unregulated flow series at each gage. However, it became apparent that this procedure did not adequately describe the upper end of the frequency curve for this portion of the Missouri River, based on the 1952 flood of record and on historical flood information prior to 1898. Further analyses would go to show that the snowmelt season and rainfall season events have different distributions, and should therefore be treated as a mixed population.

Mixed Population Analysis Downstream of the Yellowstone River, the Missouri River has historically been subject to two main annual flood events - a spring plains snowmelt period, and a summer mountain snowmelt and plains rainfall period. Each series of floods was examined to see if they differed significantly and if the two flood periods could be combined to better describe the flow frequency at each gage. For purposes of analysis, the calendar year was divided into two seasons: spring (January 1 - April 30) and summer (May 1 - December 31). The majority of large floods above the Platte River result from plains snowmelt floods, while between the Platte and Kansas Rivers, plains snowmelt floods constitute the majority of top 5 floods.

USACE (1993) suggests the use of mixed population analysis when there are two or more different, but independent, causative conditions, as exists on the upper Missouri basin. The plains snowmelt and mountain snowmelt can be considered independent, or very nearly so, as plains snowpack typically peaks from February to early-April, and is almost non-existent by the end of April, while the mountain snowpack typically continues to accumulate until mid-May or later. Rainfall sometimes augments a plains snowmelt and sometimes a very late snowfall may occur in May over much of the upper basin. However, runoff characteristics differ greatly from early spring to late spring, with mostly frozen soil early in the spring resulting in much greater runoff than occurs later in the spring from the same volume of precipitation.

Regionalization of Statistics In order to obtain regionally consistent frequency curves at each gage, it is necessary to regionalize the results of the flow frequency analysis. However, there is no guidance for regionalizing computed flow statistics in a mixed distribution, other than USACE (1993) stating, "*If annual flood peaks have been separated by causative factors, a generalized skew must be derived for each separate series to apply the log-Pearson Type III distribution as recommended by Bulletin 17B.*"

An examination of the station statistics shows a break in computed values of skew between Omaha and Nebraska City. Therefore, it was decided to regionalize skew for the gages above the Platte River and for those between the Platte and Kansas Rivers, and this was done by averaging the skew between stations in each reach. Use of the regional skew values results in the following frequency relationships at each gage (see Table 2).

Table 2. Regional Frequency Relations for Mixed Distribution, Yankton to Rulo, Unregulated Flow

Percent Chance Exceedance	Yankton	Sioux City	Decatur	Omaha	Nebraska City	Rulo
99	80500	83700	84000	86800	116700	115700
95	100100	103400	103700	107400	138700	138600
90	111800	115200	115600	119700	152000	152600
80	127600	130800	131100	136200	169800	171400
50	162200	165100	165300	172100	210100	214200
20	205300	207500	207400	216200	260900	268400
10	234600	236300	235300	245200	293900	303000
5	272100	273200	270100	280200	329100	340400
2	330300	330200	324400	334400	374100	386200
1	385600	383800	376000	386700	417600	429300
0.5	450000	446000	436100	447700	473600	485200
0.2	526400	519500	507100	519600	548700	557900

The regionally computed values show a slight decrease in discharge from Yankton to Decatur for the less frequent events. This can be attributed to the fact that the floodplain broadens tremendously downstream of Yankton and large flood waves are attenuated through this valley storage, and there is not much

lateral inflow from Yankton to Omaha.

Regulated-Unregulated Relationships Frequency analysis of a regulated data set should generally not be done by normal analytical methods. In order to determine an accurate regulated frequency relationship, it is necessary to determine the unregulated frequency relationship at the gage, and determine a relationship between regulated and unregulated peaks. The regulated-unregulated relationship is then applied to the unregulated frequency curve to determine the final regulated flow frequency relation.

Methodology The regulated-unregulated relationship is determined by pairing regulated and unregulated peak values with one another, and determining the relationship that best describes that pairing. Since the unregulated analysis relied upon a mixed distribution analysis, it was thought that perhaps the regulated-unregulated relationship could be derived by pairing the spring regulated and unregulated peaks and the summer regulated and unregulated peaks, determining the relationship for the spring and summer data, and combine the curves using the probability of union. However, this method proved unsatisfactory, as the spring and summer regulated values were not wholly independent, making the combination of the curves extremely cumbersome. Thus, it was decided to determine the regulated-unregulated relationship using annual peaks from the regulated and unregulated data sets. Data were first paired by year (year-ordered pairs), but this resulted in a great deal of scatter. Each data set was then ordered by magnitude of flood, and then paired (rank-ordered pair). This pairing resulted in a relationship that plotted through the median of the year-ordered pair data. In order to develop a regulated-unregulated relationship with a greater degree of confidence for the less frequent events, it was necessary to develop some "design" storms to synthesize data points to extrapolate the regulated-unregulated relationship. Several large floods that had roughly the same exceedance probability at 5 or more of the gages from Yankton to St. Joseph were chosen as representative in terms of timing as well as areal distribution. Those design floods that did not reasonably preserve the consistency of the volume-duration curve of the baseline flood were not used for extending the regulated-unregulated relationships. The remaining floods were then plotted with the year-ordered pairs and rank-ordered pairs to ensure they fell within the scatter of points. A 2nd-degree polynomial was derived that best fit the upper half of the data points, and an ocular fit for each relationship was then determined over the entire range of data points. Below is an example of the regulated-unregulated relationship at Nebraska City.

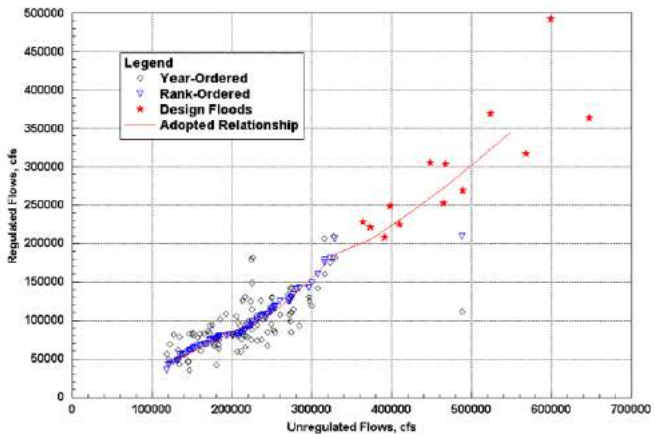


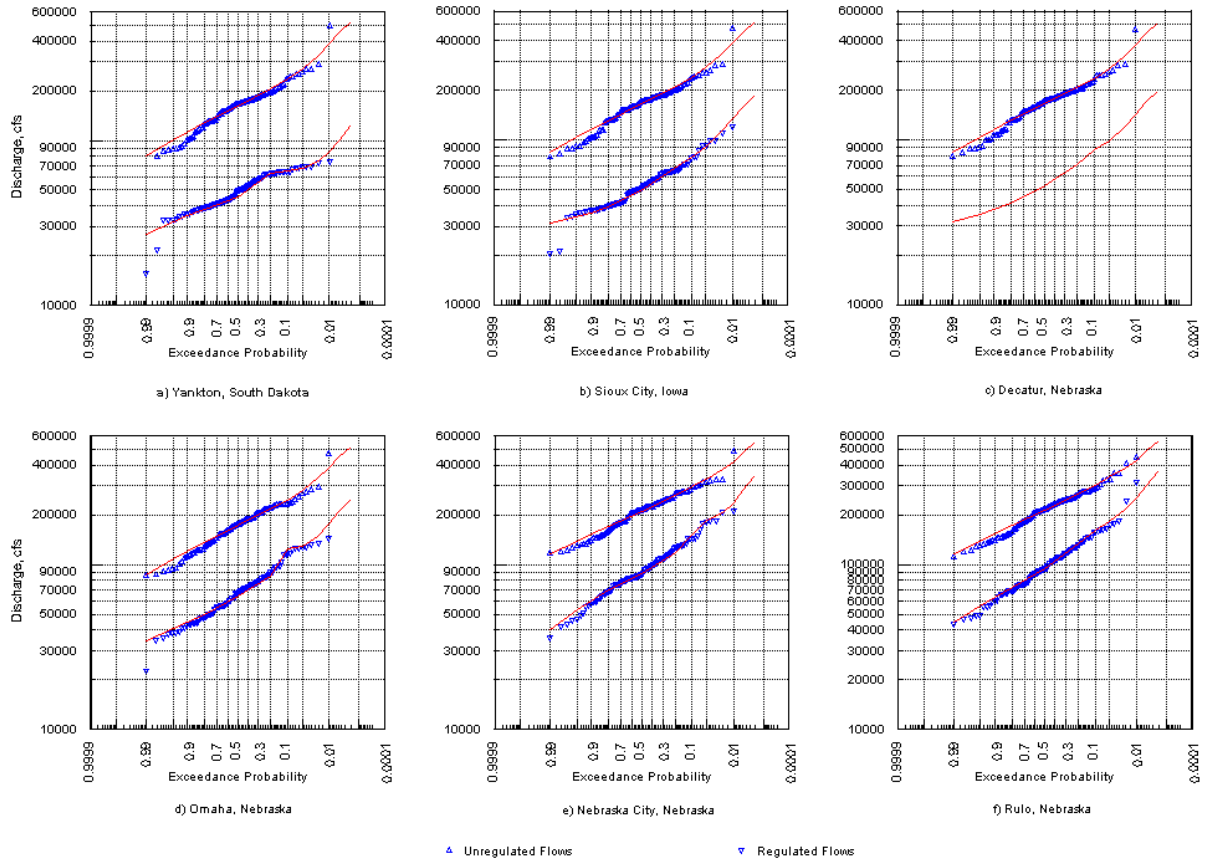
Figure 1. Regulated-Unregulated Relationship at Nebraska City

Regulated Flow Frequency In order to determine the final regulated flow frequency relationship at each gage, the regulated-unregulated relationship is applied to the unregulated frequency curves. This results in the regulated flow frequency relationships found in the table below. All values are relatively consistent with results of the previous study, with the exception of flows at Sioux City, where the 100-year flood value has increased by almost 50%.

Table 3. Regulated Frequency Curves, Yankton to Rulo

Percent Chance Exceedance	Yankton	Sioux City	Omaha	Nebraska City	Rulo
99	27000	31200	34600	40600	44900
95	32100	34000	40700	53500	55800
90	34800	36100	44800	60500	62800
80	38300	39100	49900	70500	72600
50	45200	49500	64100	88000	94800
20	63000	66800	85200	118500	132400
10	65000	78300	123500	149500	160600
5	68000	89900	129400	186000	181700
2	74700	113900	148000	206000	216800
1	84900	133700	174900	236500	252100
0.5	99400	157100	207700	278900	301200
0.2	123500	185400	248200	345400	370700

Plots comparing the unregulated and regulated flow frequency relationships are shown below (Figures 2a-f) for the gages from Yankton, South Dakota to Rulo, Nebraska. As can be seen, the effectiveness of flood protection afforded by the mainstem dams decreases as one moves downstream.



Figures 2a-f. Flow Frequency Relationships for Regulated and Unregulated Flow Conditions

FLOW REGIMES FOR UNREGULATED AND REGULATED CONDITIONS

Daily flows from both the regulated and unregulated flow data sets were averaged over the period of record, and mean values of flow were derived for each day of the year. Additionally, upper and lower quartiles and deciles were derived from the data sets. The results show that for most years, the spring rise is relatively insignificant compared to the summer rise. The results

also show that regulation has effectively removed both the spring and summer rises, and flows do not decline for several months later compared to the unregulated condition. Sample results are shown in Figure 3 for Sioux City and Nebraska City gages.

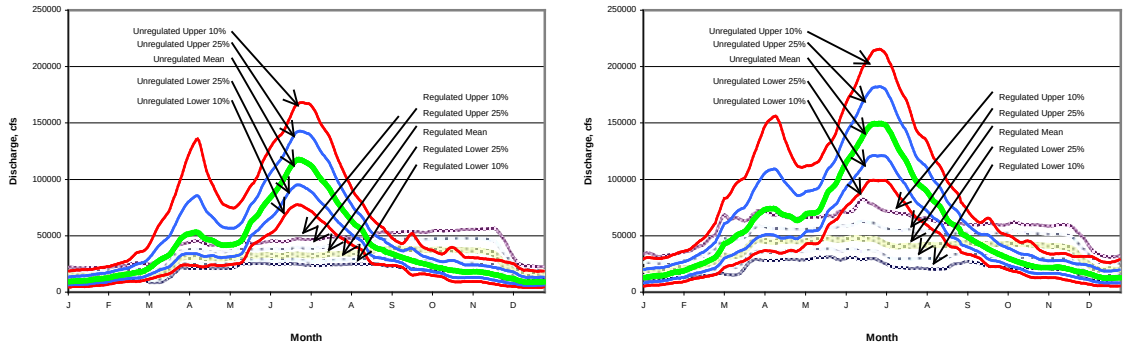


Figure 3. Upper and Lower Quartiles and Deciles and Mean Annual Regulated and Unregulated Flow, Sioux City and Nebraska City

Depletions have a significant impact on annual flow volume, but relatively little impact on flow frequencies. Average maximum streamflow depletions are 35,000 cfs at Sioux City and over 50,000 cfs at Rulo in mid-summer. However, since spring flows have a much greater impact on the upper portion of the frequency curves, and depletions are negligible in the spring, ignoring the impacts of depletions has only about a 1% impact on the computed 1% flood. However, depletions are important to consider, as they comprise slightly over 25% of the mean annual natural flow between Yankton and Rulo. If depletions are ignored, the unregulated flow hydrograph changes so that the summer rise peak is not nearly as prominent relative to the spring rise, and the mean annual hydrograph does not steadily decrease from July through December. Additionally, losses of water through reservoir regulation, mainly through evaporation, account for nearly 10% of the mean annual natural flow at Sioux City.

CONCLUSIONS

The frequency of flooding along the Missouri River has been greatly reduced by operation of the six Missouri River mainstem dams above the Kansas River, although the effectiveness of regulation decreases as one moves downstream. The natural hydrograph of the Missouri River between the Yellowstone and Kansas Rivers is dominated by two main flood periods, spring and summer, that necessitate use of a mixed distribution analysis to compute flow frequencies for the unregulated condition. Flow frequencies for regulated conditions are best determined using a regulated-unregulated relationship applied to the unregulated flow frequencies. Accounting for all consumptive uses of water in the basin, including reservoir regulation and irrigation depletions, leads to a more homogeneous data set. Use of these data sets should lead to a better understanding of the relationship between the natural and current conditions flows on the Missouri River. The unregulated and regulated flow data sets will also be useful for other future studies of the Missouri River.

REFERENCES

U.S. Geological Survey, 1928-1997, USGS Water Resources Data (for various states). U.S. Geological Survey Water-Data Report *or* Surface Water Supply of the United States.

U.S. Army Corps of Engineers,1946, Missouri River Levees – Definite Project Report, Appendix I – Hydrology. Missouri River Division, Omaha, Nebraska.

U.S. Army Corps of Engineers, 1956, Missouri River, Re-evaluation of Main Stem Flood Control Benefits. Missouri River Division, Omaha, Nebraska.

U.S. Army Corps of Engineers, 1962, Missouri River Agricultural Levee Restudy Program, Hydrology Report. Missouri River Division, Omaha, Nebraska.

U.S. Army Corps of Engineers, 1973(a), MRD-RCC Technical Report JE-73, Mainstem Reservoir System Reservoir Evaporation Estimates. Missouri River Division, Omaha, Nebraska.

U.S. Army Corps of Engineers, 1973(b), MRD-RCC Technical Study S-73, Upper Missouri River, Unregulated Flow Development. Missouri River Division, Omaha, Nebraska.

U.S. Army Corps of Engineers, 1993, Hydrologic Frequency Analysis. EM 1110-2-1415, Headquarters, Washington, D.C.

U.S. Army Corps of Engineers, 1998, Volume 2A: Reservoir Regulation Studies, Daily Routing Model Studies, Missouri River Master Water Control Manual Review and Update Study. Missouri River Region, Northwestern Division, Omaha, Nebraska.

U.S. Congress, 78th Session, 1944, Flood Control Act of 1944. P.L. 78-534, Washington, D.C.

U.S. Department of Agriculture, 1895-1928, Daily River Stages at River Gage Stations of the Principal Rivers of the United States. Parts VI through XXVI, Weather Bureau, Washington, D.C.

U.S. Department of Commerce, 1982(a), Evaporation Atlas for the Contiguous 48 United States. NOAA Technical Report NWS 33, National Weather Service, Washington, D.C.

U.S. Department of Commerce, 1982(b), Mean Monthly, Seasonal, and Annual Pan Evaporation for the United States. NOAA Technical Report NWS 34, National Weather Service, Washington, D.C.

U.S. Secretary of War, 1934, Missouri River. House Document No. 238, Government Printing Office, Washington, D.C.

Appendix C: Missouri River Levee System

MISSOURI RIVER LEVEE SYSTEM
SIOUX CITY, IOWA, TO MOUTH
(SIOUX CITY, IOWA, TO RULO, NEBRASKA)

CONDITION OF IMPROVEMENT - 30 SEPTEMBER 1983

PROJECT

The project was authorized by the Flood Control Acts of August 1941 and December 1944, and that portion of the project applicable to the Omaha District provides for a series of levee units and appurtenant works along both banks of the Missouri River from Sioux City, Iowa, to Rulo, Nebraska, for the protection of agricultural lands and small communities against floods. The levees will be constructed of pervious random fill with an impervious blanket on the riverward side, riprap on the riverward side at critical locations, and pressure-relief wells, as required, on the landward side.

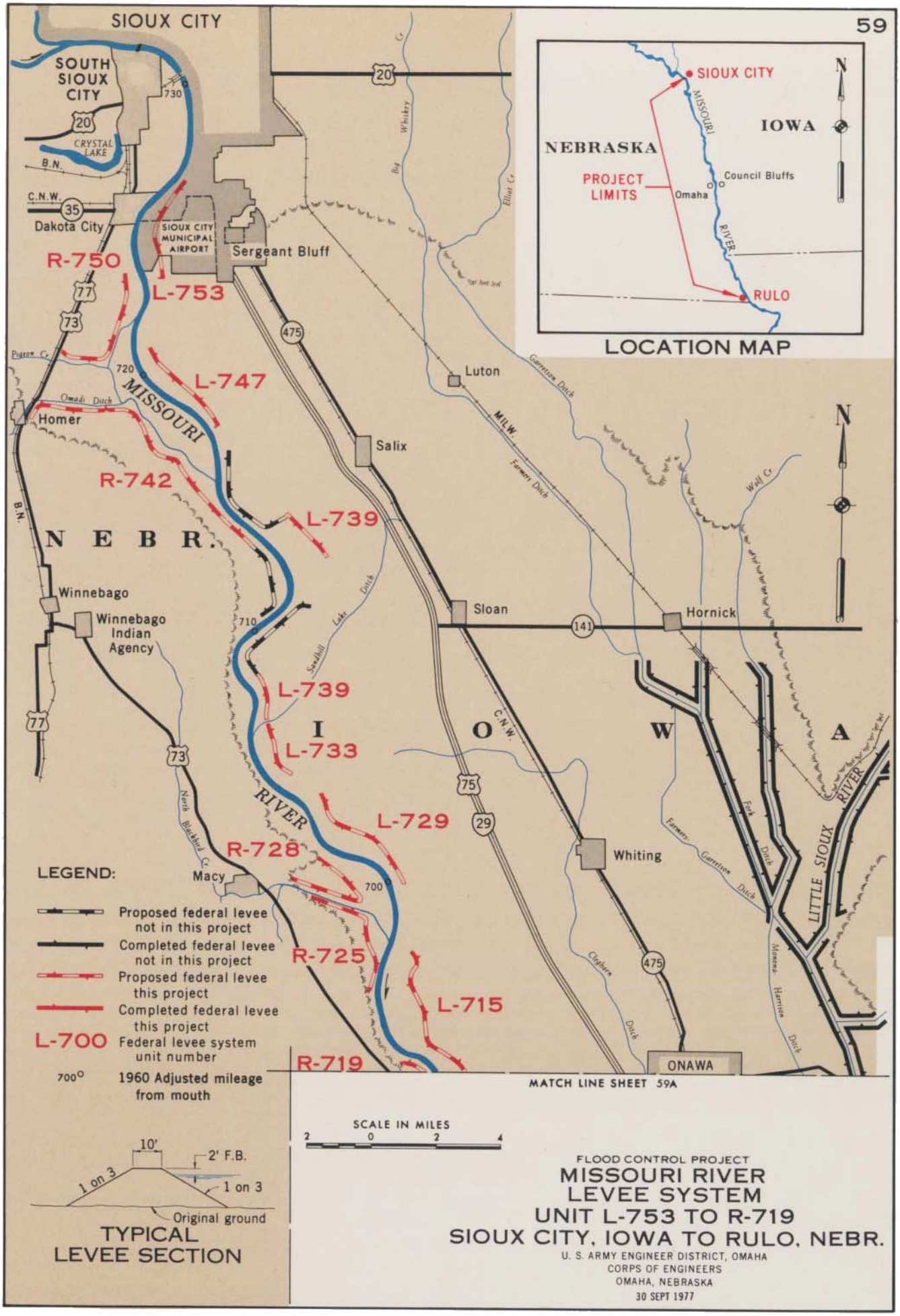
Length of Levees	225 miles
Average Height	12.6 feet
Volume of Embankment	52,000,000 cubic yards
Crown Width	10 feet
Side Slopes	1 on 3

PROGRESS OF WORK

Construction is complete on the following units authorized for construction: R520, L536, R548, L550-561, R562, R573, L575, R580, L594, L601, L672-624, and R613. The active portion of the project is 85 percent complete. Construction of Unit L611-614 Stages 1 and 2 levees are complete. Stage 3 levee construction was awarded on 23 June 1982 and is 41 percent complete. A contract for construction of Unit R616 was awarded on 5 May 1983 and is 40 percent complete. All remaining uncompleted units have been classified "inactive."

ESTIMATED COST

	Active Program (Oct 1983)	Inactive Program (Jul 1964)
Federal	$36,800,000	$27,525,000
Non-Federal	4,600,000	3,182,000
Total	$41,400,000	$30,707,000



LOCATION MAP

LEGEND:

- Proposed federal levee not in this project
- Completed federal levee not in this project
- Proposed federal levee this project
- Completed federal levee this project
- L-700 Federal levee system unit number
- 700 1960 Adjusted mileage from mouth

MATCH LINE SHEET 59A

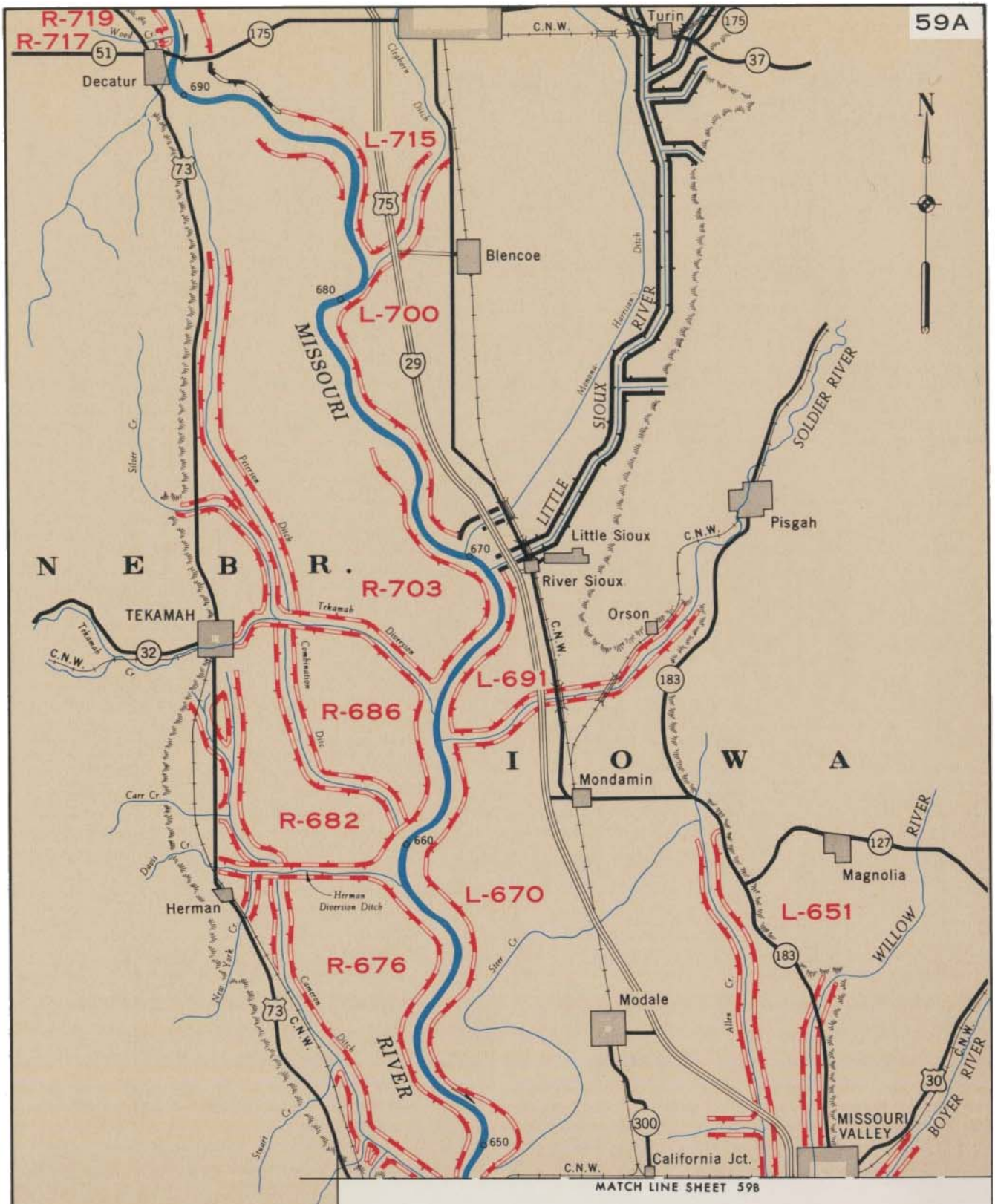
SCALE IN MILES
2 0 2 4

TYPICAL LEVEE SECTION

FLOOD CONTROL PROJECT

MISSOURI RIVER LEVEE SYSTEM
UNIT L-753 TO R-719
SIOUX CITY, IOWA TO RULO, NEBR.

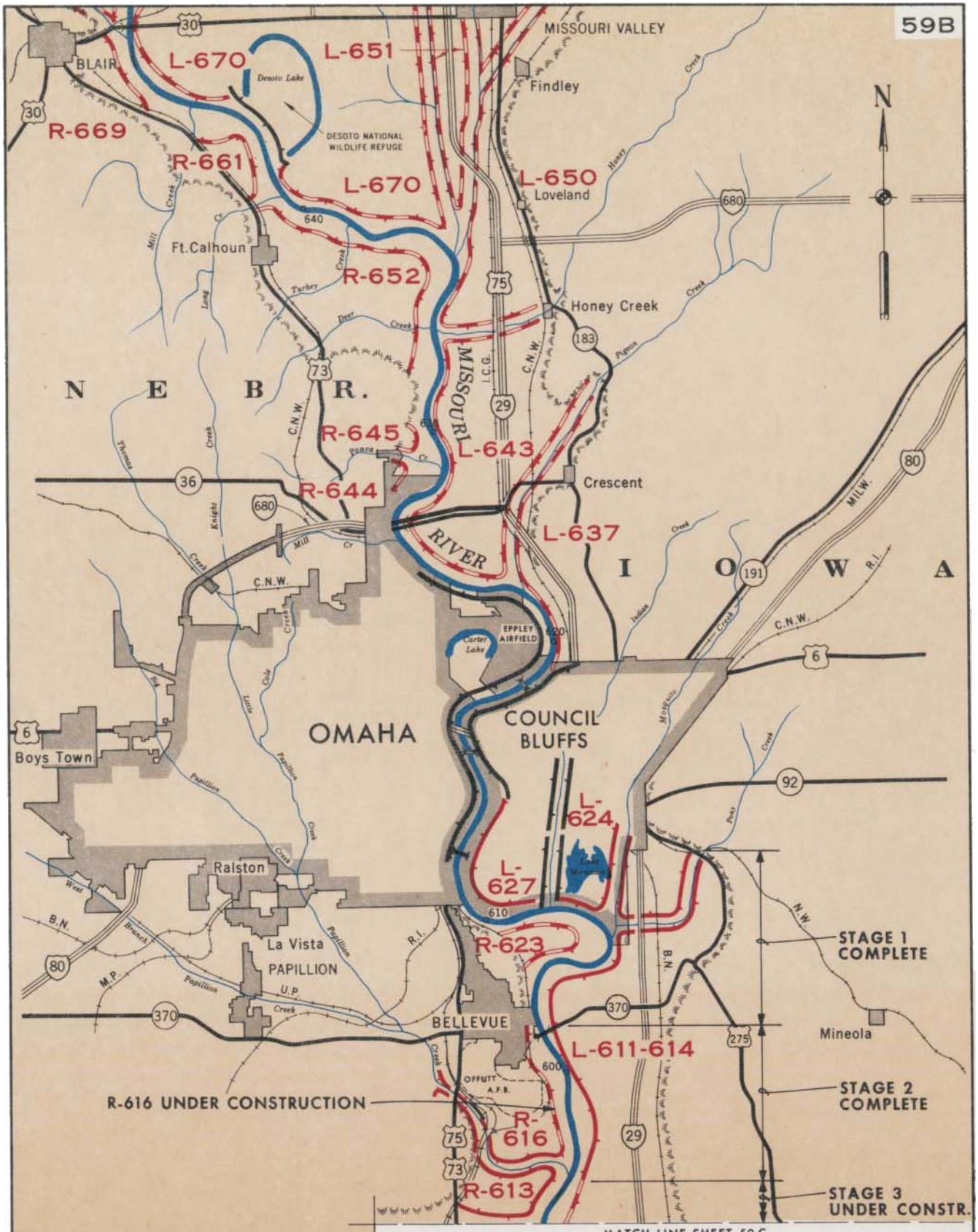
U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA
30 SEPT 1977



FLOOD CONTROL PROJECT

MISSOURI RIVER LEVEE SYSTEM UNIT R-719 TO L-670 SIOUX CITY, IOWA TO RULO, NEBR.

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA
30 SEPT 1977

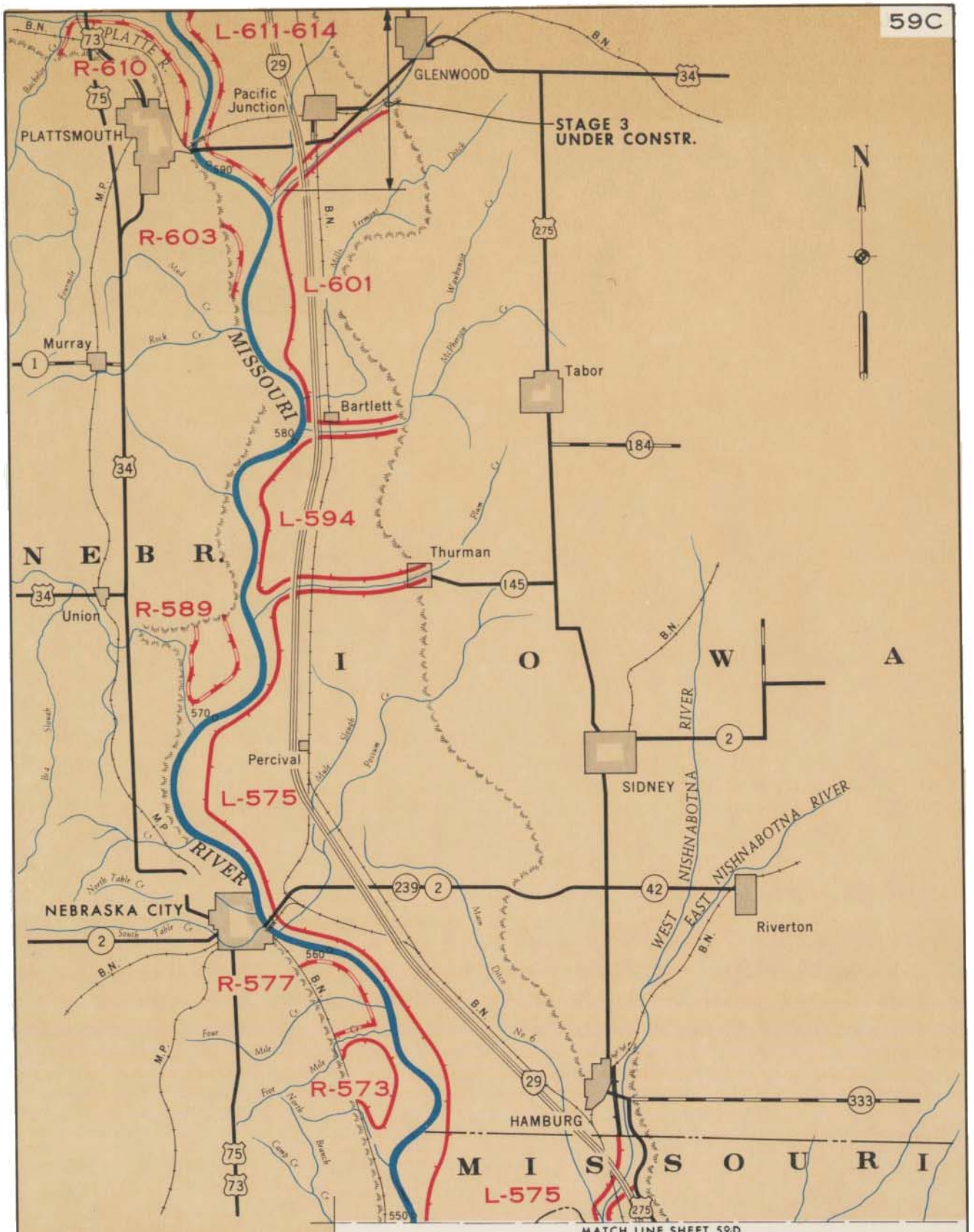


MATCH LINE SHEET 59 C

FLOOD CONTROL PROJECT

MISSOURI RIVER LEVEE SYSTEM
UNIT L-670 TO L-611-614
SIOUX CITY, IOWA TO RULO, NEBR.

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA
30 SEPT. 1983



FLOOD CONTROL PROJECT

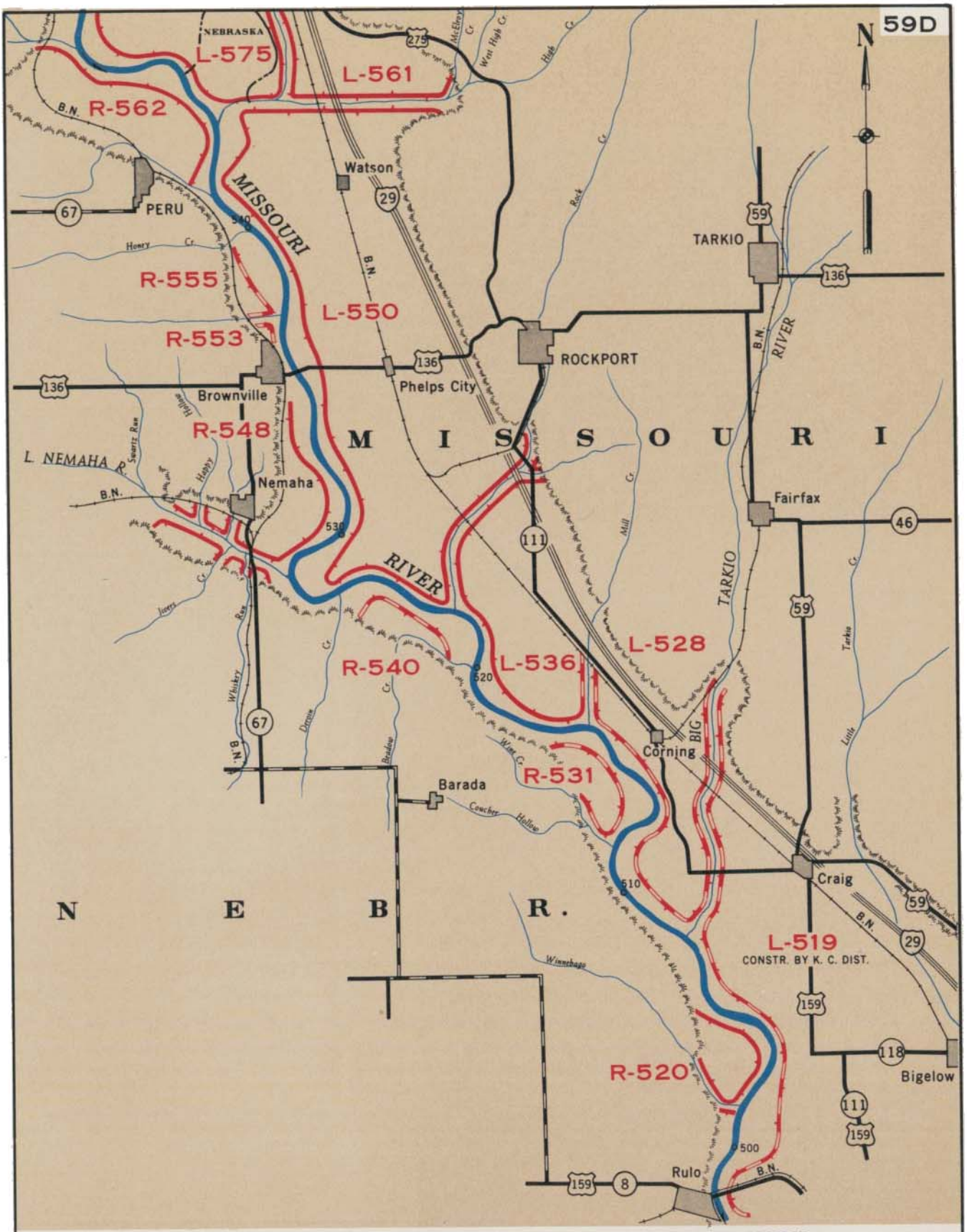
MISSOURI RIVER LEVEE SYSTEM

UNIT L-611-614 TO L-575

SIOUX CITY, IOWA TO RULO, NEBR.

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA

30 SEPT. 1982



FLOOD CONTROL PROJECT

MISSOURI RIVER LEVEE SYSTEM UNIT L-575 TO R-520 SIOUX CITY, IOWA TO RULO, NEBR.

U. S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA
30 SEPT 1977

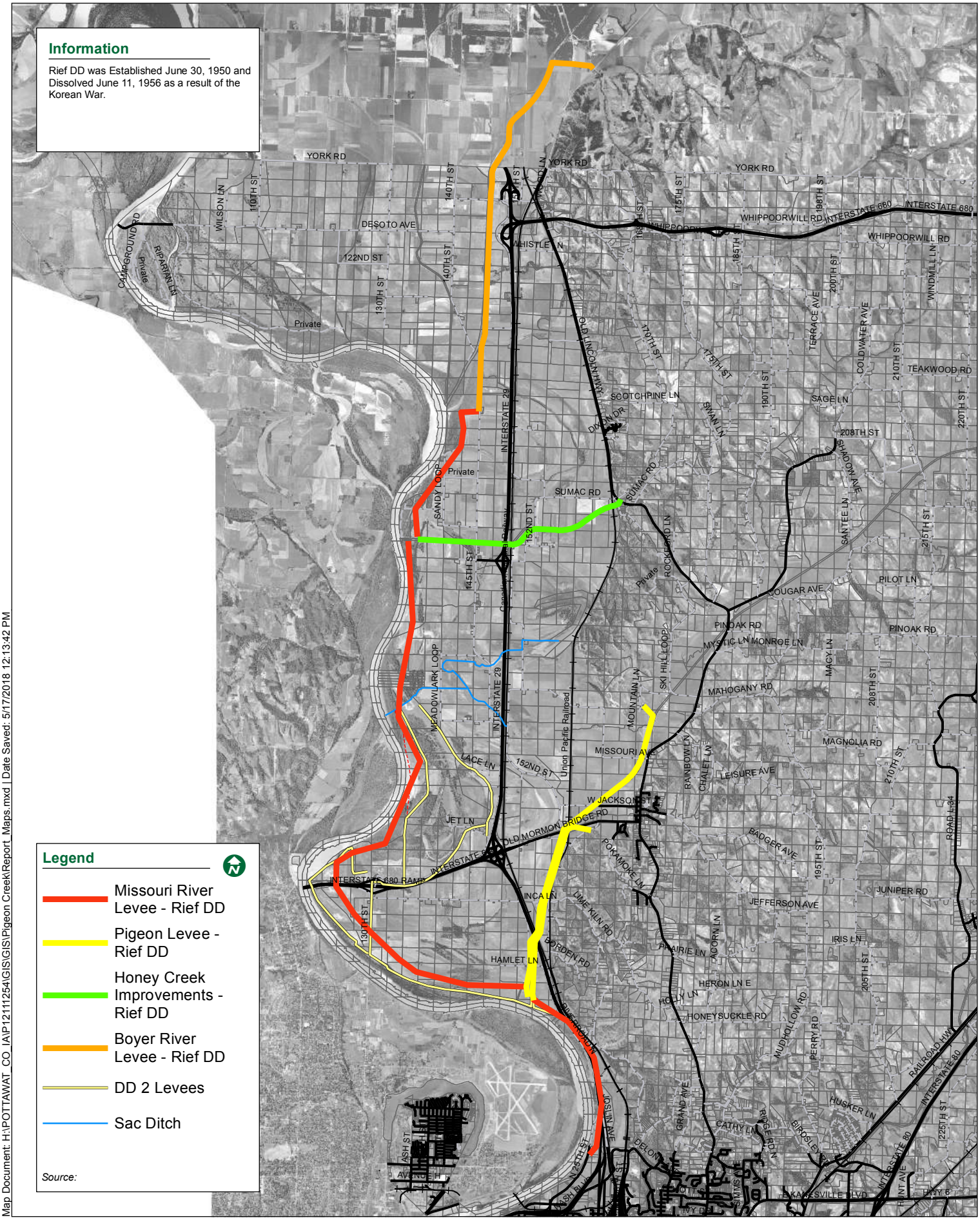
Rief Levee District

DD 2 Sub 3 Levees

Proposed Facilities - No Improvements Built

May, 2018

BOLTON & MENK
Real People. Real Solutions.



V. RIEF LEVEE DISTRICT NO. 33

A. Petition for Levee District – October 1948

Requests levee along Missouri River beginning at the north end of Council Bluffs Flood Control Unit One and running upstream to the outlet of the Boyer River and also the levee bank along the Boyer River, Honey Creek and Pigeon Creek.

This district generally coincides with the district boundaries of the USACE Units L-637, L-643 and L-650.

B. Engineer's Report – May 27, 1949

Notes the existence of levees along the Missouri River, Boyer River, Honey Creek and Pigeon Creek. "If the levees along the Missouri River did not exist, these land would have been flooded by the Missouri River about 12 times in the last twenty years. These present levees do offer some protection, but are inadequate for Missouri River Floods of the magnitude of the floods of 1943 and 1947."

States levees along the tributary ditches are inadequate and result in broken levees and flooding.

Cross section will be 10 foot top with 3:1 sideslopes.

Levees will be built by the USACE. Designed with a free board of 2 feet above the design 50 year flood on the tributary watershed. This elevation is 4 feet higher than the 1943 flood.

"If these improvements are to be constructed by the United States Corps of Engineers with federal funds, it is necessary that a levee district be established to assure local cooperation and to provide the necessary right-of-way."

"The federal Government constructs all of the levees, the drainage structures through the levee, and alters the railroad bridges. The cost of raising or lengthening primary or secondary road bridges will be borne by the state or county respectively."

Estimated cost to the district is $180,000 borne by approximately 18,000 acres.

C. Hearing on Establishment – September 7, 1949

D. Hearing on Report of Appraisers – October 25, 1949

E. Continued Hearing – November 10, 1949

Board desired to meet with Us Congressman and USACE to discuss financial aid for County to reconstruct bridges.

F. Continued Hearing – December 10, 1949

G. Continued Hearing – March 15, 1950

H. Continued Hearing – June 7, 1950

Remonstrance filed – Unsuccessful

I. Continued Hearing – June 26, 1950

J. Continued Hearing – June 26, 1950

K. District Established – June 30, 1950

Following motion to establish, representatives from the USACE in attendance announced that "as soon as the board signed up the necessary documents agreeing to furnish the required right-of-way and holding the Corps free of damage claims, that work would be begun that would relieve all of these districts and governmental units from any cost for the actual construction work – effecting a savings in the whole unit of approximately $2,700,000."

L. Engineer's Supplemental Report – August 30, 1950

Report modifies alignment and right-of-way as result of negotiations with J.H. Mayne

M. Agreement signed with J.H. Mayne for Right-of-Way – September 1, 1950

N. Engineer's Report – December 26, 1950

Informs the board that the Corps has stopped work on the project, and it is unpredictable when or if the USACE would proceed with the task of construction

Board would take no action to publish the work by private contract

Board moved that no warrants for right-of-way would be issued until a contract for the work was let.

O. Order to Classify – January 28, 1954

It was clear that no funding would be forthcoming from the USACE and that a schedule should be created to reimburse the county for the expenses of establishment.

P. Petition for dissolution of Rief Levee District No. 33

Q. District dissolved – June 11, 1956

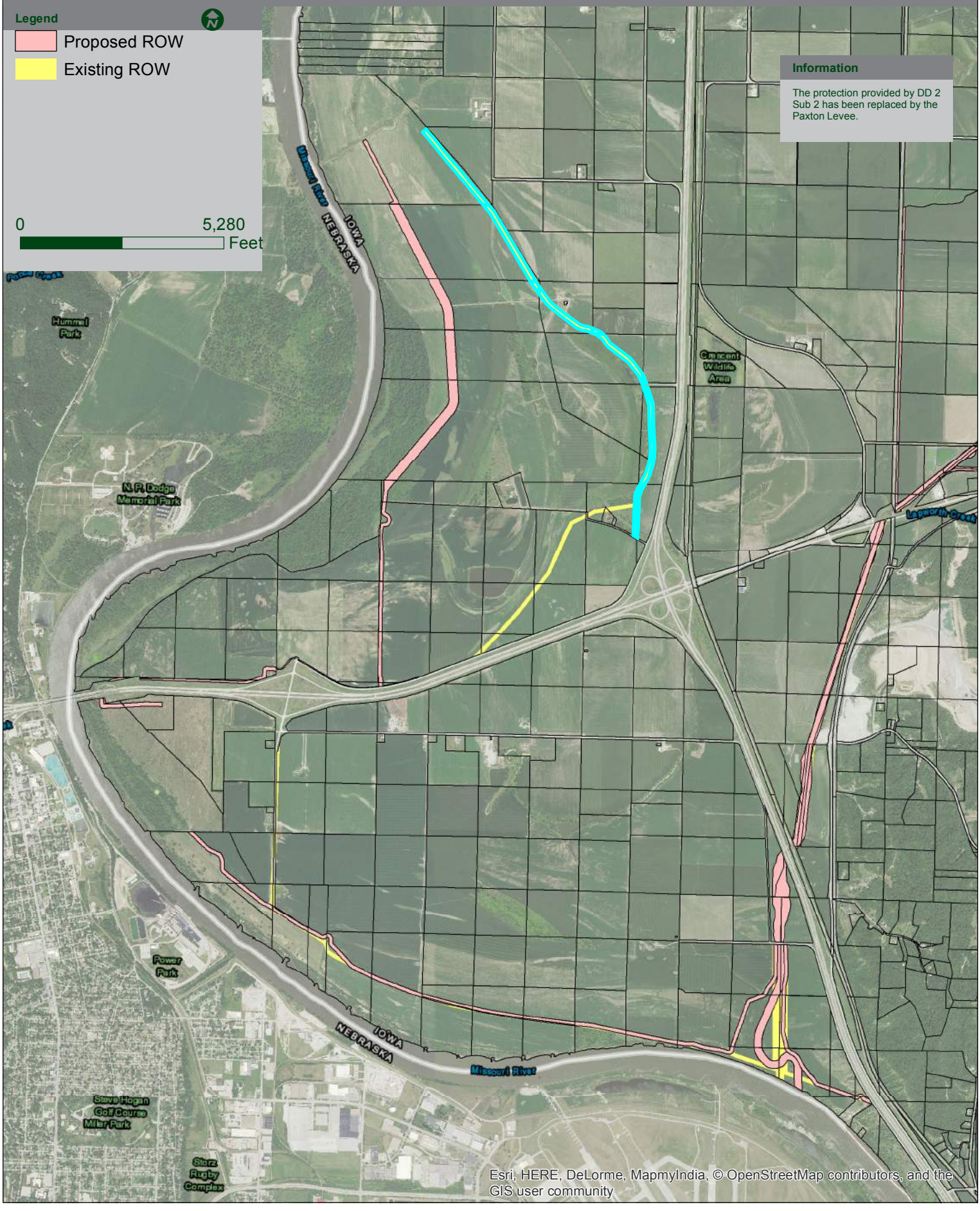
Appendix D: Rights-of-Way Tabulation

Proposed Levee Repairs

DD 2 Sub 2 Right-of-Way to Abandon

DD 2 Sub 3 Pottawattamie County, Iowa

May, 2018



Map Document:
Date Saved: never never

Rights-of-Way Tabulation
Proposed Levee Repairs
Rights-of-Way to be Abandoned
Drainage District No. 2
Subdrainage District No. 2
Pottawattamie County, Iowa
2018

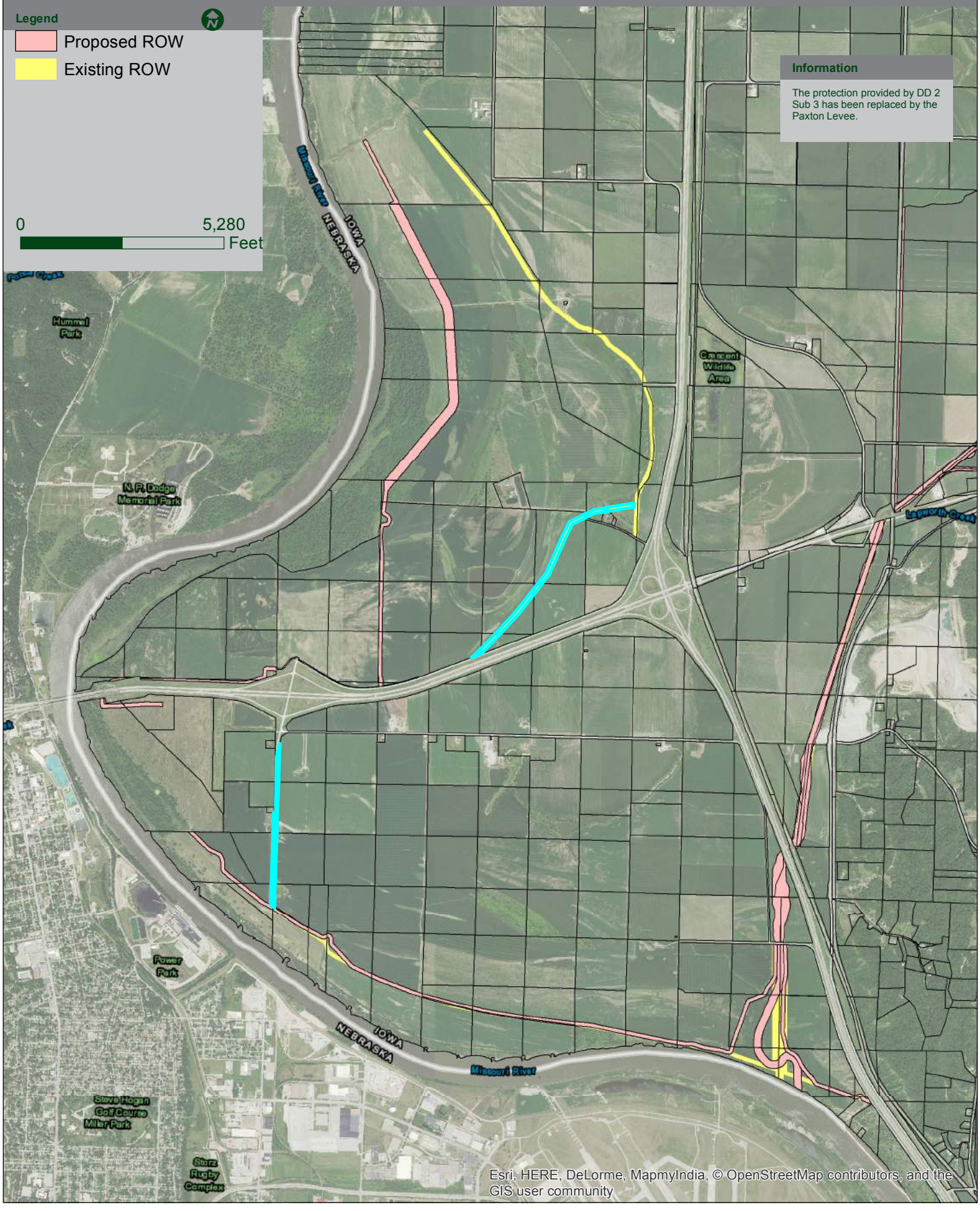
Landowner	S-T-R	Legal	Parcel ID	Right-of-Way Existing
GENERAL SALES-INVESTMENT PTSP	21-76-44	G/L 1 N1/2 NW EXC COMM 491.9'S 660.72'W NE COR NE NW TH W94.02' S86.28'E61.48' N31.27'E31.99' N54.58' TOPOB	764421100004	4.91
GENERAL SALES-INVESTMENT PTSP	21-76-44	G/L 2 SW NE & SE NW	764421200003	4.57
RESPELIERS, JOE SR-MARGARET E TRUST	21-76-44	G/L 4 & ACCRE W OF I-29 & E OF LEVEE E1/2 SE	764421400003	1.52
RESPELIERS, JOE SR-MARGARET E TRUST	28-76-44	ACCRE G/L 1 E1/2 NE W OF RR EXC I-29	764428200004	1.33
VALLIER, LORANE A-MARY LOU	21-76-44	S1/2 NW NE	764421200002	0.5
VALLIER, LORANE A-MARY LOU	28-76-44	NE NE W OF DIKE & PT SW SE W OF LEVEE 21-76-44	764421400002	1.97
VALLIER, LORANE A-MARY LOU	21-76-44	PT G/L 4 E1/2 SE W OF LEVEE (WETLANDS) FOR 1991 ASSESSMENT	764421400005	4.06
WILLIAMS, RANDY J	21-76-44	SE NE W OF I-29	764421200005	0.31
SONDGEROTH, THEODORE-JOAN	28-76-44	ACCRE G/L 2 W1/2 NE COMM NW COR NW NE TH E1333.08' S1406.9' TO C/L RD NWLY668.47' NE233.62' NW434.97' SW440.85' NW389.21' N948.12' TO POB	764428200001	2.13
			Total Acres Abandoned - Sub 2 Levee	**21.3**

Proposed Levee Repairs

DD 2 Sub 3 Right-of-Way to Abandon

DD 2 Sub 3 Pottawattamie County, Iowa

May, 2018



Map Document:
Date Saved: never never

Rights-of-Way Tabulation
Proposed Levee Repairs
Rights-of-Way to be Abandoned
Drainage District No. 2
Subdrainage District No. 3
Pottawattamie County, Iowa
2018

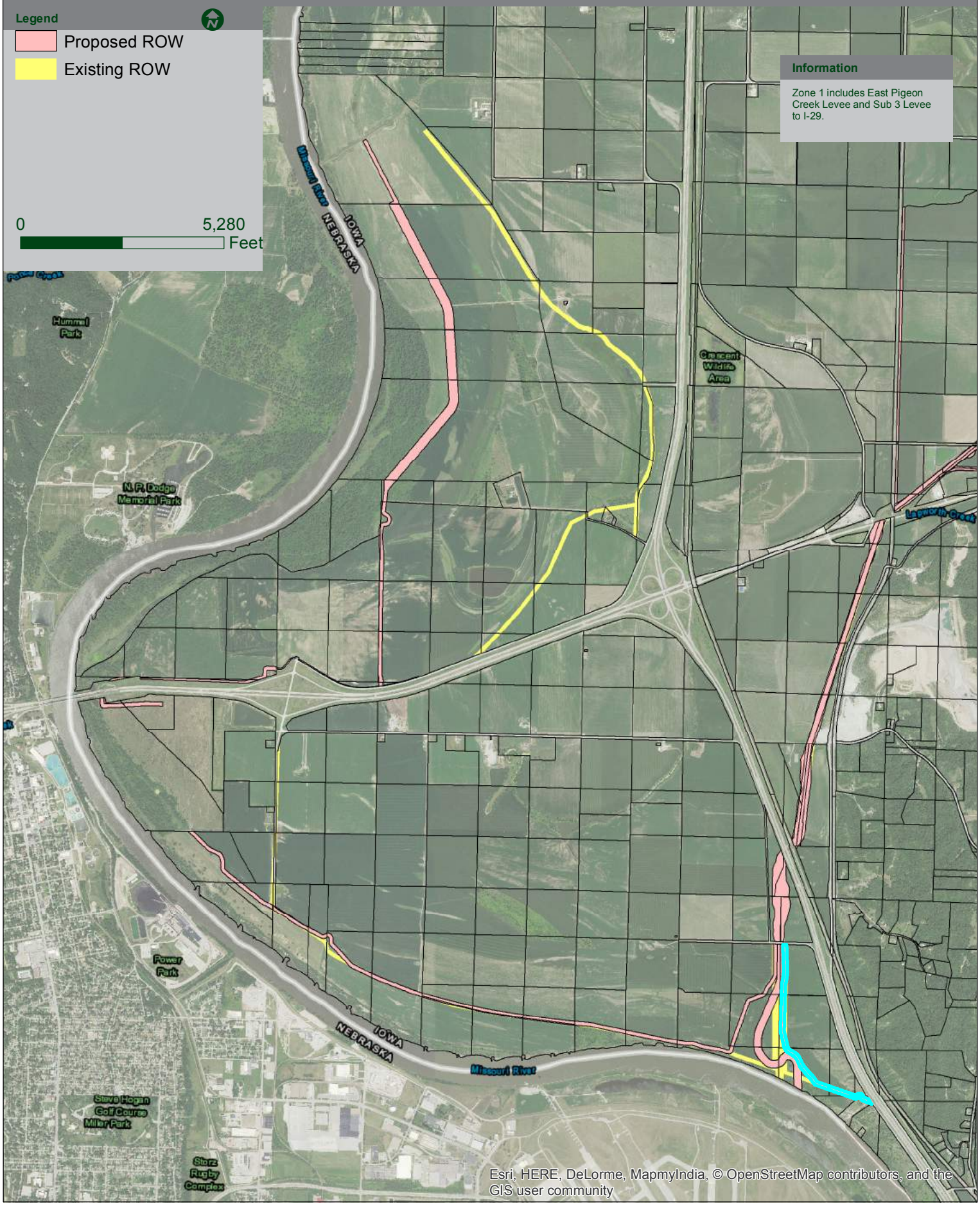
Landowner	S-T-R	Legal	Parcel ID	Right-of-Way Existing
SONDGEROTH, THEODORE-JOAN	28-76-44	ACCRE G/L 2 W1/2 NE COMM NW COR NW NE TH E1333.08' S1406.9' TO C/L RD NWLY668.47' NE233.62' NW434.97' SW440.85' NW389.21' N948.12' TO POB	764428200001	2.68
DILTS BROTHERS LLC	31-76-44	G/L 3 & ACCRE NE SE EXC N660' E660' & EXC N135' E226' S660'	764431400005	0.14
POTTAWATTAMIE COUNTY	10-75-44	PT GOVT LTS 1 & 2 COMM 337.87'S NE COR SECT 10 TH S1094.6' TO RIVER BANK NWLY TO C/L DRAINAGE DITCH NELY ALONG DITCH 890.64' TO SWLY ROW INTERSTATE SE TO POB EXC .723 AC ADJ RIVER	754410200003	0.01
POTTAWATTAMIE COUNTY	31-76-44	PT G/L 3 & ACCRE NE SE N135' E226' S660' (PARCEL A)	764431400006	0.02
REID, RUTH	28-76-44	PT G/L 2 NW NE COMM 1672.57'N 392.18'SE SW COR NE1/4 TH NE421' SE351.66'SW242.61' NW289.47'TO POB (PARCEL A)	764428200006	0.19
RIEF, RONALD E	28-76-44	SE NW & S578' G/L 3 & ACCRE	764428100004	5.07
RIEF, RONALD E	28-76-44	NW SW	764428300001	3.3
RIEF, RONALD E	28-76-44	NE SW N OF I-680	764428300002	0.6
RIEF, RONALD E	28-76-44	SW SW EXC I-680	764428300003	1.46
RIEF, RONALD E	29-76-44	SE SE EXC I-680	764429400004	0.36
ULRICH, LARRY	31-76-44	G/L 4 SE SE	764431400004	0.82
ULRICH, LARRY	32-76-44	SW NW	764432100002	1.24
ULRICH, LARRY	32-76-44	NW SW	764432300001	1.38
ULRICH, LARRY	32-76-44	SW SW	764432300003	0.69
			Total Acres Abandoned - Sub 3 Levee	**17.96**

Proposed Levee Repairs

DD 2 Sub 3 Zone 1 Right-of-Way

DD 2 Sub 3 Pottawattamie County, Iowa

May, 2018



Map Document:
Date Saved: never never

Rights-of-Way Tabulation
Proposed Levee Repairs
Drainage District No. 2
Subdrainage District No. 3
Zone 1 - East Pigeon Creek Levee and East End of Sub 3 Levee
Pottawattamie County, Iowa
2018

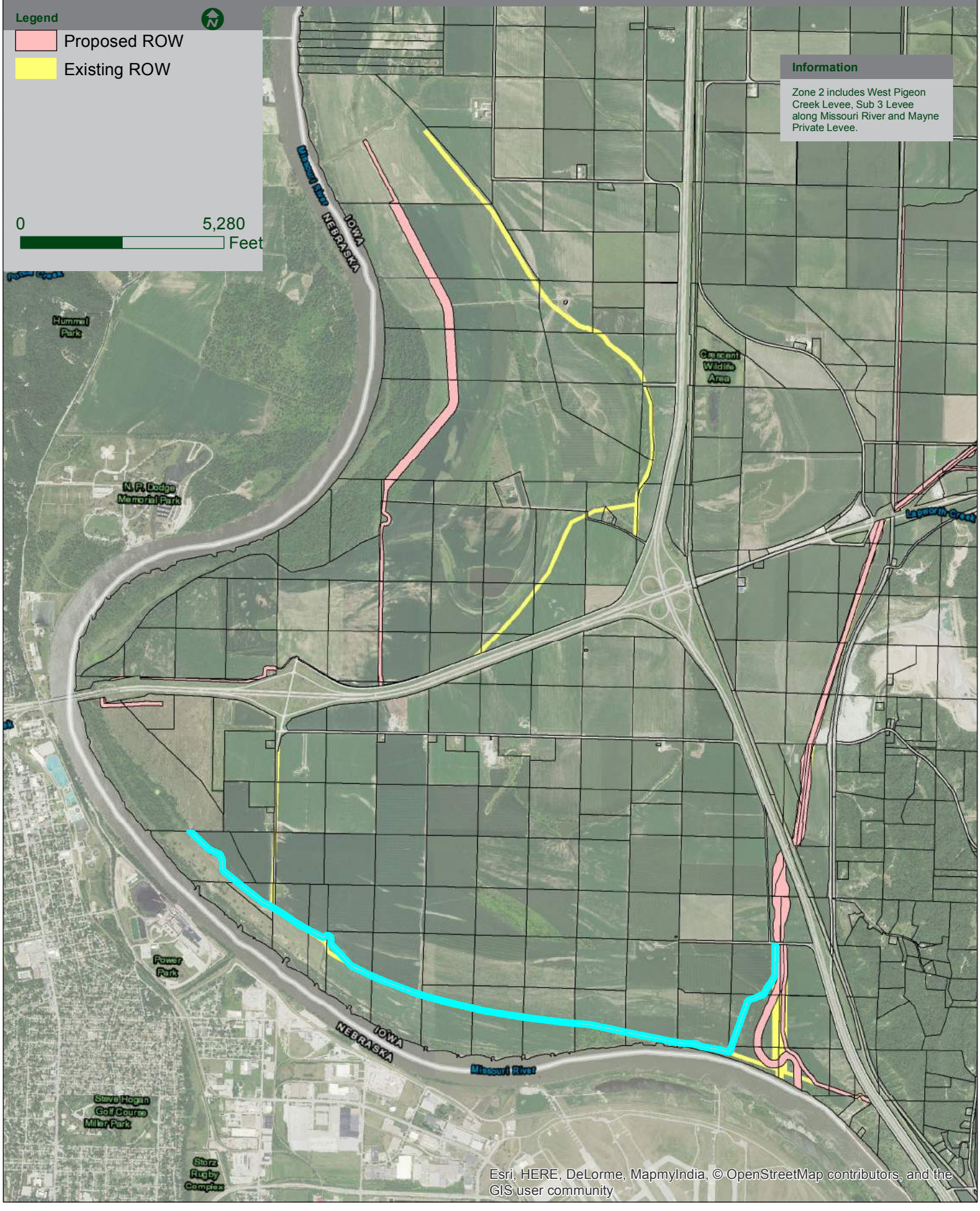
Landowner	S-T-R	Legal	Parcel ID	Right-of-Way Existing	Right-of-Way Required	Right-of-Way Acquired
BRABEC, FRANK	10-75-44 & 3-75-44	PT SE SE, & PT G/L 1 SE1/4 SECTION 3 & PT G/L 1 NE1/4 SECTION 10 COMM660'W NE COR SECTION10 TH SW545.16'NW807.21' E1040.3' S117.96' TO POB(PARCEL A)	754410200001	0.08	0.12	**0.04**
DILTS, CLIFFORD D TRUST	3-75-44	W OF I-29 SW NE	754403251002	2.99	3	0.01
DILTS, CLIFFORD D TRUST	3-75-44	NW SE EXC I-29	754403400001	3.14	3.17	0.03
DILTS, CLIFFORD D TRUST	3-75-44	GOVT LT 1 SW SE EXC S117.96'	754403400005	4.22	3.63	-0.59
DILTS, CLIFFORD D TRUST	3-75-44	W1/2 SE SE EXC I-29 & EXC S117.96'	754403400007	1.52	1.48	-0.04
					Adjusted =	**-0.59**
GIRAMONTI, MARIE	10-75-44 & 3-75-44	PT SE SE SECTION 3 & PT G/L 1 NE1/4 SECTION 10 COMM 256.1'W NE CORSECTION 10 THSE81.48' SW607.34'SLY230.26' NW391.54' NE545.16' N117.96'E322.4' SE147.41' TOPOB (PARCEL B)	754410200002	0.9	0.8	**-0.1**
SPARCK, JERRY V	3-75-44	COMM 256.10'W OF SE COR SE SE TH W405' N663' SELY778' TO POB EXC SELY147.41' OFW322.40' W OF I-29	754403400008	0.1	0.31	**0.21**
					Net Acres to be Acquired - Zone 1	**0.25**

Proposed Levee Repairs

DD 2 Sub 3 Zone 2 Right-of-Way

DD 2 Sub 3 Pottawattamie County, Iowa

May, 2018



Map Document:
Date Saved: never never

Rights-of-Way Tabulation
Proposed Levee Repairs
Drainage District No. 2
Subdrainage District No. 3
Zone 2 - West Pigeon Creek Levee, Sub 3 Levee and Mayne Levee
Pottawattamie County, Iowa
2018

Landowner	S-T-R	Legal	Parcel ID	Right-of-Way Existing	Right-of-Way Required	Right-of-Way Acquired
DILTS, CLIFFORD D TRUST	3-75-44	SE NW	754403100005	2.99	3.18	0.19
DILTS, CLIFFORD D TRUST	3-75-44	ACCRE TO GOVT LT 2 & LT 3 W1/2 SW & SE SW	754403300001	7.25	3.56	-3.69
DILTS, CLIFFORD D TRUST	3-75-44	GOVT LT 2 NE SW	754403300003	3.14	3.86	0.72
					Adjusted =	**-2.78**
RESPELIERS, JOE SR-MARGARET E TRUST	4-75-44	G/L 1 SE NE & ACCRE TO G/L 1 NE SE	754404200004	3.12	3.12	0
RESPELIERS, JOE SR-MARGARET E TRUST	4-75-44	ACCRE TO G/L 2 W1/2 SE	754404400001	3.09	3.09	0
					Adjusted =	**0**
RIVER LAND BEEF-PORK	4-75-44	PT LT 6 SUB OF GOVT LT 4 NW SW & ACCRE GOVT LT 4 SW SW COMM NW COR TH S494.2' SELY1314.9' N691.68' W1303.1' TO POB (PARCEL A)	754404300004	1.91	2.37	0.46
RIVER LAND BEEF-PORK	4-75-44	PT LT 5 SUB OF GOVT LT 3 NE SW & ACCRE GOVT LT 3 SE SW COMM NE COR TH S825.66' NWLY1336.76' N691.68' E1305.47' TO POB (PARCEL A)	754404300006	2.32	2.21	-0.11
RIVER LAND BEEF-PORK	5-75-44	PT LT 8 SUB GOVT LTS 1 & 2 NE SE & ACCRE TO LT 8 E1/2 SE1/4 COMM NW COR TH E1315.22' S494.2' NWLY1350.26' N189.75' TO POB (PARCEL A)	754405400003	1.32	2.1	0.78
					Adjusted =	**1.13**

Rights-of-Way Tabulation
Proposed Levee Repairs
Drainage District No. 2
Subdrainage District No. 3
Zone 2 - West Pigeon Creek Levee, Sub 3 Levee and Mayne Levee
Pottawattamie County, Iowa
2018

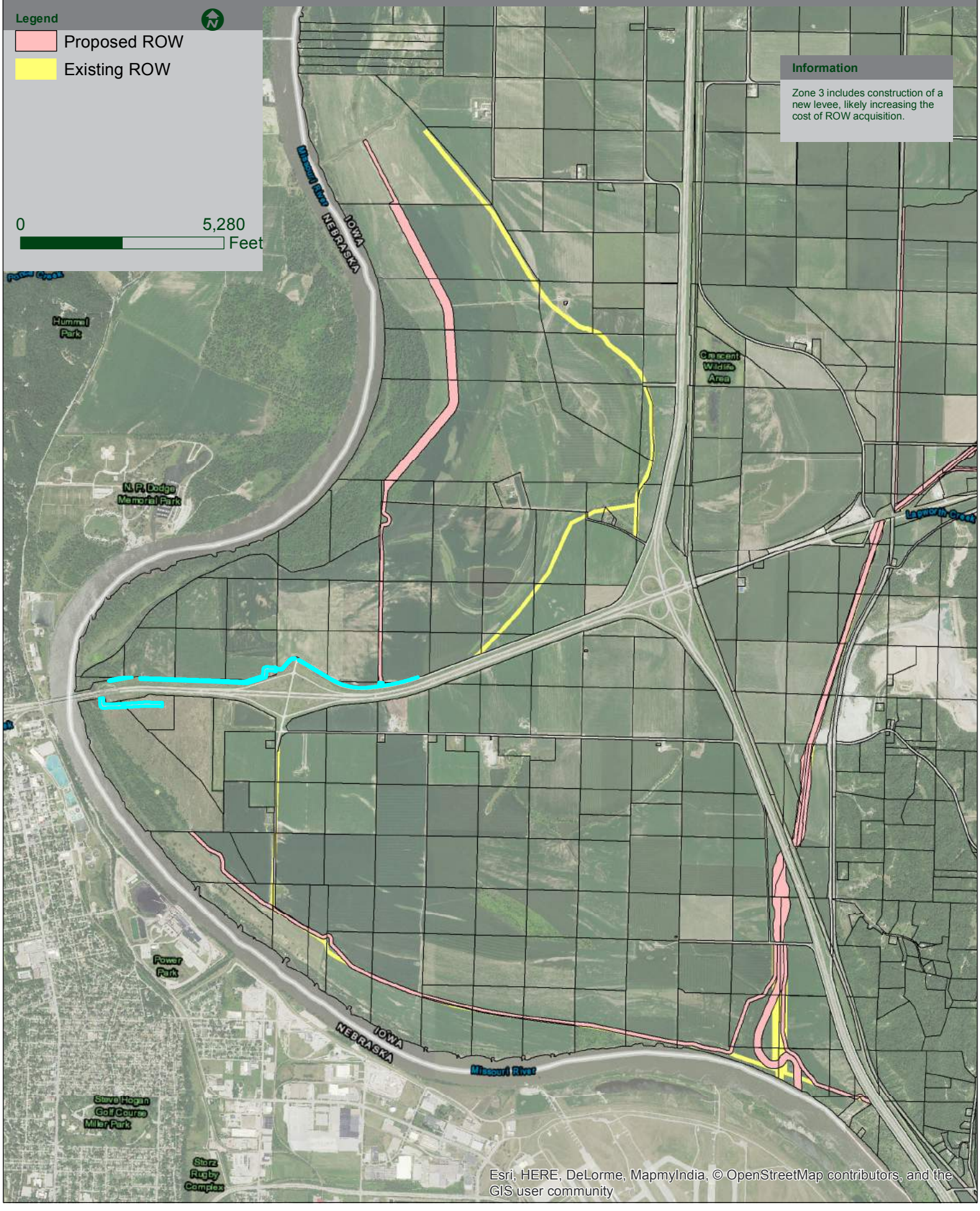
Landowner	S-T-R	Legal	Parcel ID	Right-of-Way Existing	Right-of-Way Required	Right-of-Way Acquired
SCHULTZ FARMS INC	4-75-44	LT 6 SUB OF GOVT LT 4 NW SW & ACCRE GOVT LT 4 SW SW EXC COMM NW COR TH S494.2' SELY1314.9' N691.68' W1303.1' TO POB	754404300005	1.15	0.7	-0.45
SCHULTZ FARMS INC	4-75-44	LT 5 SUB OF GOVT LT 3 NE SW & ACCRE GOVT LT 3 SE SW EXC COMM NE COR TH S825.66' NWLY1336.76' N691.68' E1305.47' TO POB	754404300007	0.77	0.88	0.11
SCHULTZ FARMS INC	5-75-44	LT 5 SUB GOVT LTS 1 & 2 SE NW & ACCRE LT 5 SE NW & NE SW	754405100005	3.28	3.8	0.52
SCHULTZ FARMS INC	5-75-44	LT 6 SUB GOVT LTS 1 & 2 SW NE & ACCRE LT 6 SW NE & W1/2 SE1/4	754405200004	3.22	3.21	-0.01
SCHULTZ FARMS INC	5-75-44	LT 8 SUB GOVT LTS 1 & 2 NE SE & ACCRE TO LT 8 E1/2 SE1/4 EXC COMM NW COR TH E1315.22' S494.2' NWLY1350.26' N189.75' TO POB	754405400004	1.81	1	-0.81
					Adjusted =	**-0.64**
ULRICH, EMIL-MARTHA	6-75-43	NE NE GOVT LT 1	754406200002	0.71	2.53	**1.82**
ULRICH, LARRY	5-75-44	W213' LT 4 SUB GOVT LTS 1 & 2 NW NW	754405100001	0.11	0.39	0.28
ULRICH, LARRY	5-75-44	ACCRE TO W2/3 LT 4 SUB GOVT LTS 1 & 2 W1/2 NW	754405100002	3.23	2.13	-1.1
ULRICH, LARRY	5-75-44	E1/3 LT 4 SUB OF GOVT LTS 1 & 2 NW NW & ACCRE TO E1/3 LT 4 SW NW	754405100003	1.45	1.22	-0.23
ULRICH, LARRY	31-76-44	ACCRE G/L 4 S1/2 SE & SE SW	764431400003	0	4.39	4.39
					Adjusted =	**3.34**
					Net Acres to be Acquired - Zone 2	**6.29**

Proposed Levee Repairs

DD 2 Sub 3 Zone 3 Right-of-Way

DD 2 Sub 3 Pottawattamie County, Iowa

May, 2018



Map Document:
Date Saved: never never

Rights-of-Way Tabulation
Proposed Levee Repairs
Drainage District No. 2
Subdrainage District No. 3
Zone 3 - Realigned Levee Parallel to I-680
Pottawattamie County, Iowa
2018

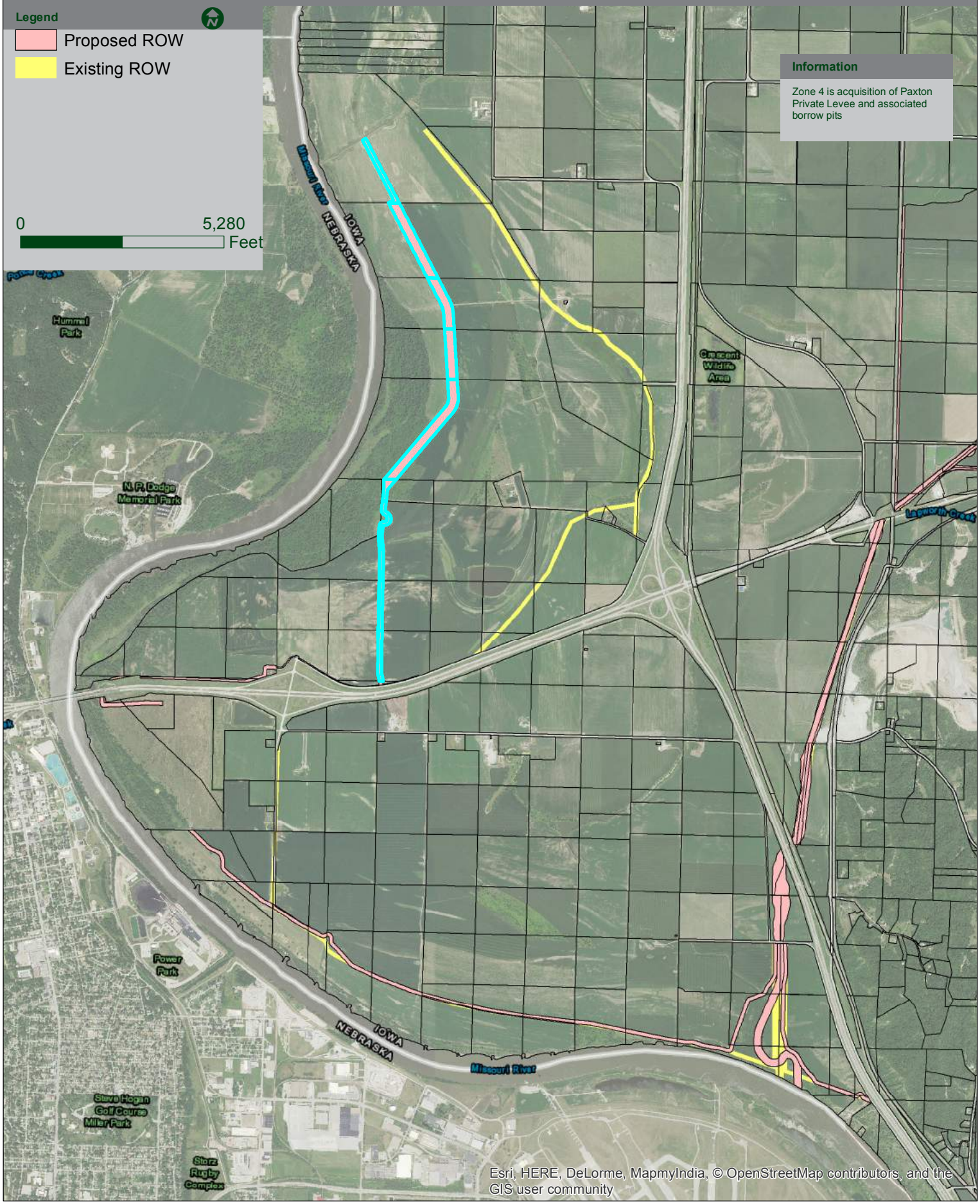
Landowner	S-T-R	Legal	Parcel ID	Right-of-Way Existing	Right-of-Way Required	Right-of-Way Acquired
MAK FARM CO LLC	30-76-44	SE SW EXC ST OF IOWA	764430300004	0	0.11	0.11
MAK FARM CO LLC	30-76-44	SE SE EXC I-80	764430400004	0	1.62	1.62
MAK FARM CO LLC	31-76-44	G/L 1 S OF I-680 N1/2 NW	764431100001	0	2.29	2.29
MAK FARM CO LLC	31-76-44	ACCRE TO GOVT LTS 1,2 & 3 LYING S OF I-680	764431100002	0	1.76	1.76
MAK FARM CO LLC	31-76-44	PT N1/2 NE, NE NW & G/L 1 & ACCRE NW NW LYING N OF I-680	764431200001	0	3.91	3.91
					Adjusted =	**9.58**
RIEF, RONALD E	32-76-44	NW NE & NE NW LYING N OF I-680	764432100003	0	0.66	**0.66**
STRATBUCKER, ROBERT A	29-76-44	SW SW EXC I-680	764429300003	0	0.88	0.88
STRATBUCKER, ROBERT A	29-76-44	SE SW EXC I-680	764429300004	0	0.13	0.13
					Adjusted =	**1.67**
					Net Acres to be Acquired - Zone 3	**15.4**

Proposed Levee Repairs

DD 2 Sub 3 Zone 4 Right-of-Way

DD 2 Sub 3 Pottawattamie County, Iowa

May, 2018



Map Document:
Date Saved: never never

Rights-of-Way Tabulation
Proposed Levee Repairs
Drainage District No. 2
Subdrainage District No. 3
Zone 4 - Paxton Levee from I-680 to Sac Ditch
Pottawattamie County, Iowa
2018

Landowner	S-T-R	Legal	Parcel ID	Right-of-Way Existing	Right-of-Way Required	Right-of-Way Acquired
FROST, GARY TRUST	17-76-44	ACCRE TO G/L 1 & 2	764417100001	6.9	4.48	**-2.42**
GENERAL SALES-INVESTMENT PTSP	16-76-44	ACCRE TO GOVT LTS 1 & 2	764417400001	6.43	12.56	6.13
GENERAL SALES-INVESTMENT PTSP	21-76-44	ACCRE TO GOVT LT 1	764421100001	0.75	8.1	7.35
GENERAL SALES-INVESTMENT PTSP	21-76-44	ACCRE TO GOVT LT 2	764421100003		7.54	7.54
GENERAL SALES-INVESTMENT PTSP	21-76-44	ACCRE TO GOVT LT 3	764421300001		18.26	18.26
GENERAL SALES-INVESTMENT PTSP	29-76-44	ACCRE G/L 3 E1/2 NW N OF CRK	764429100003		0.23	0.23
GENERAL SALES-INVESTMENT PTSP	29-76-44	ACCRE G/L 2 NW NE EXC S2040'	764429200001		1.99	1.99
					Adjusted =	**41.5**
RIEF, RONALD E	29-76-44	GOVT LT 2 & ACCRE S2040' W1/2 NE	764429200002		4.6	4.6
RIEF, RONALD E	29-76-44	NW SE	764429400001		2.91	2.91
RIEF, RONALD E	29-76-44	SW SE EXC I-680	764429400003		3.17	3.17
					Adjusted =	**10.68**
STRATBUCKER, ROBERT A	29-76-44	LT 3 SE NW & SW NW LYING S OF CRK	764429100001		0.34	0.34
STRATBUCKER, ROBERT A	29-76-44	NE SW	764429300002		0.1	0.1
					Adjusted =	**0.44**
					Net Acres to be Acquired - Zone 4	**54.51**

Appendix E: 2018 Annexation and Benefited Lands Maps

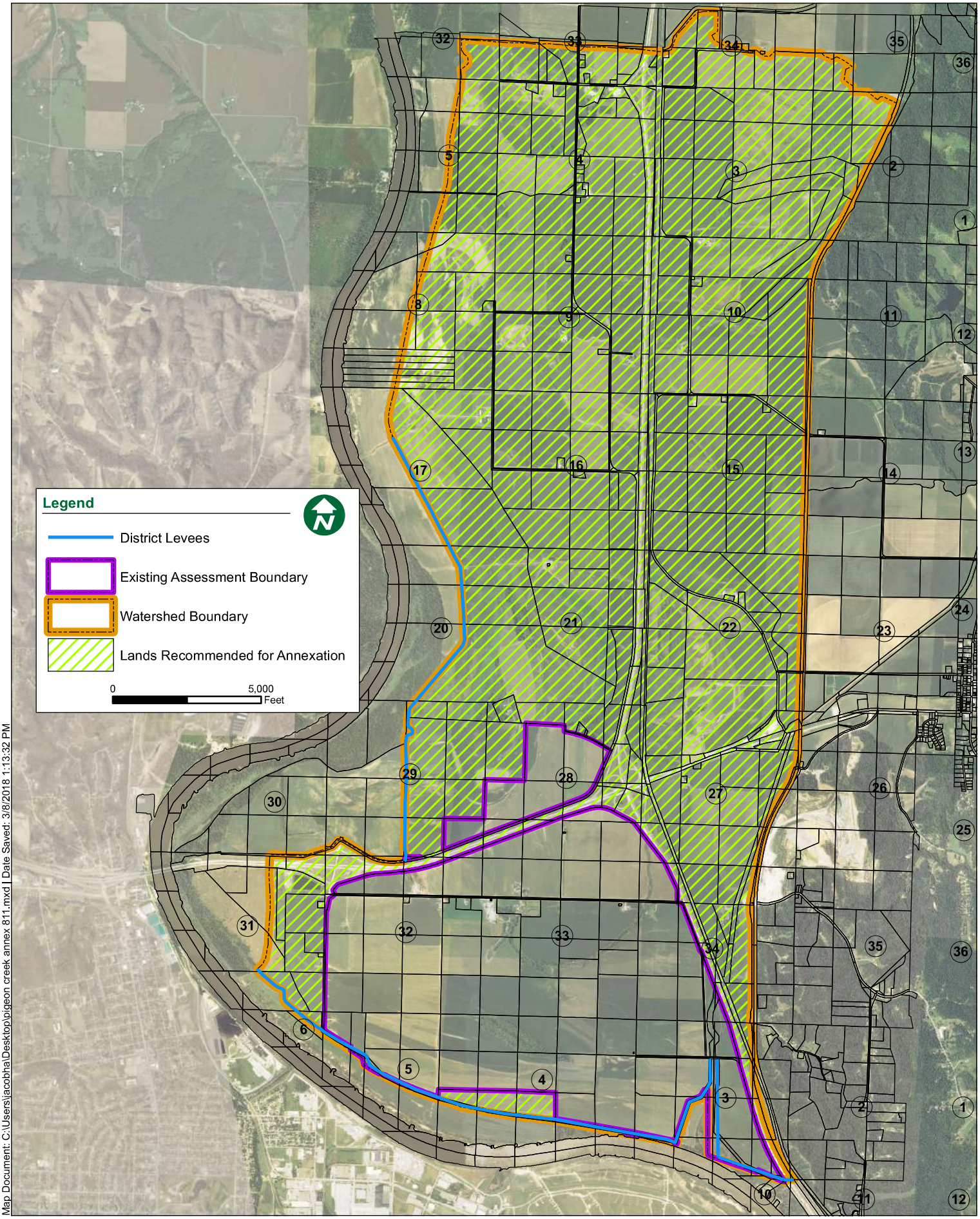
Lands Recommeded for Annexation

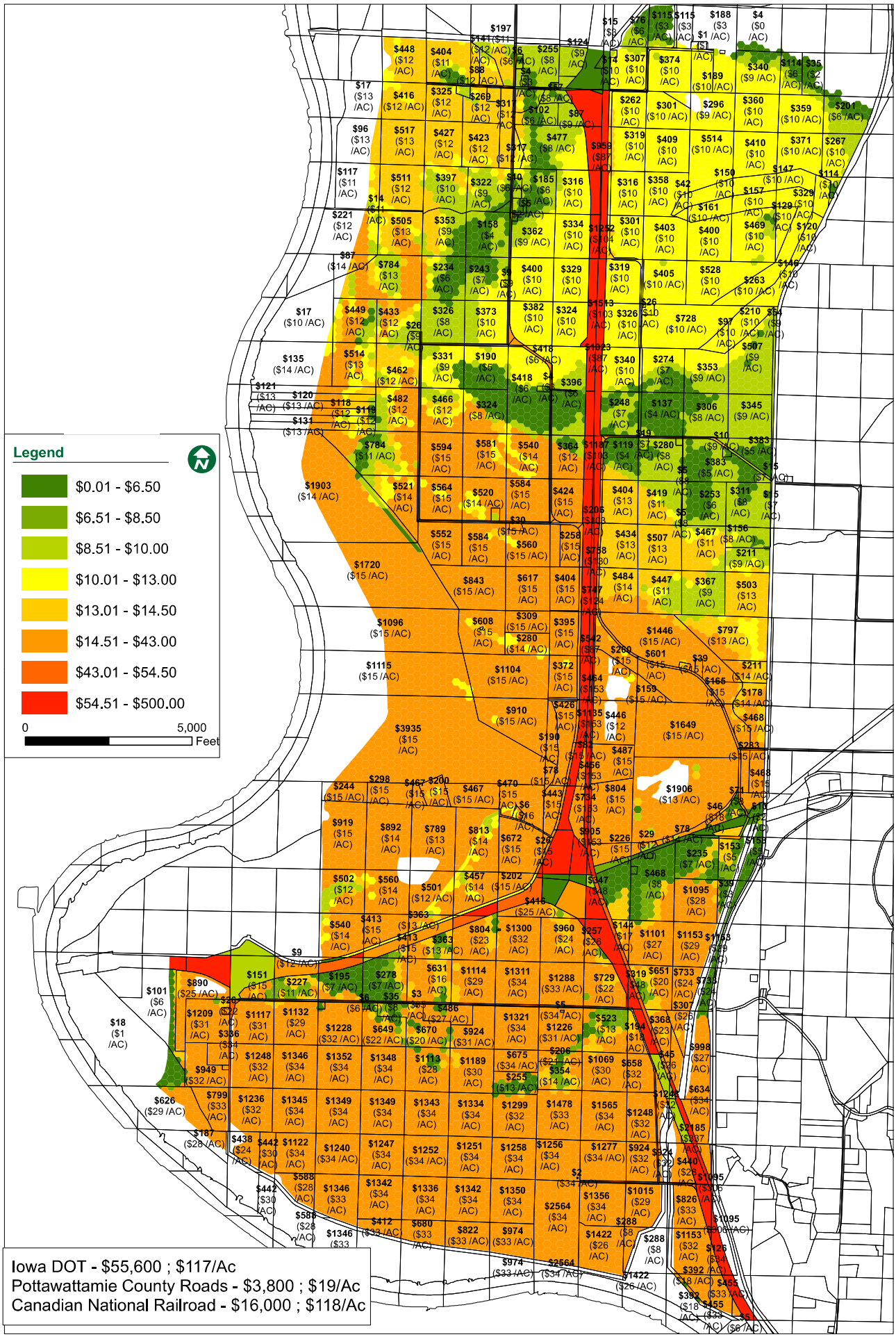
Pottawattamie County

Drainage District No. 2 Subdrainage District No.3

March, 2018

BOLTON & MENK
Real People. Real Solutions.




Legend
$0.01 - $6.50
$6.51 - $8.50
$8.51 - $10.00
$10.01 - $13.00
$13.01 - $14.50
$14.51 - $43.00
$43.01 - $54.50
$54.51 - $500.00
0
5,000
Feet
Iowa DOT - $55,600 ; $117/Ac
Pottawattamie County Roads - $3,800 ; $19/Ac
Canadian National Railroad - $16,000 ; $118/Ac

Appendix F: Engineer's Opinion of Probable Costs

Engineer's Opinion of Probable Cost
Proposed Levee Repairs
Borrow Taken from Riverside Levee Toe
Drainage District No. 2
Subdrainage District No. 3
Pottawattamie County, Iowa
2018

Construction Division 1--Zone 1 Levee

Item	Description	Unit	Quantity	Unit Price	Total
101	Strip Stockpile Topsoil	CY	4,189	$4	$14,662
102	Respread Topsoil	CY	6,208	$2	$12,416
103	Levee Fill	CY	30,525	$4	$122,100
104	Clearing & Grubbing	AC	4.0	$2,000	$8,000
105	Seed & Fertilize Levee	AC	5.1	$500	$2,550
106	Administration of Erosion Management Plan	LS			$250
107	Seeding of Temporary Stabilization	AC	5.5	$800	$4,400
108	Silt Fence Install and Review	LF	500	$3	$1,500
109	Mobilization	LS	1	$8,300	$8,300
				Estimated Division 2 Subtotal	**$174,000**

Construction Division 2--Zone 2 Levee

Item	Description	Unit	Quantity	Unit Price	Total
101	Strip Stockpile Topsoil	CY	23,151	$4	$81,029
102	Respread Topsoil	CY	18,474	$2	$36,948
103	Levee Fill	CY	73,417	$4	$293,668
104	Clearing & Grubbing	AC	1.7	$2,000	$3,400
105	Seed & Fertilize Levee	AC	15.3	$500	$7,635
106	Administration of Erosion Management Plan	LS			$500
107	Seeding of Temporary Stabilization	AC	11.0	$800	$8,800
108	Silt Fence Install and Review	LF	1,000	$3	$3,000
109	Mobilization	LS	1	$21,700	$21,700
				Estimated Division 2 Subtotal	**$457,000**

Construction Division 3--Zone 3 Levee -- Paid by IDOT

Item	Description	Unit	Quantity	Unit Price	Total
101	Strip Stockpile Topsoil	CY	15,246	$4	$53,361
102	Respread Topsoil	CY	12,258	$2	$24,516
103	Levee Fill	CY	124,429	$11	$1,368,719
104	Clearing & Grubbing	AC	2.0	$2,000	$4,000
105	Seed & Fertilize Levee	AC	12.6	$500	$6,300
106	Administration of Erosion Management Plan	LS			$2,000
107	Seeding of Temporary Stabilization	AC	24.0	$800	$19,200
108	Silt Fence Install and Review	LF	5,000	$3	$15,000
109	Mobilization	LS	1	$74,700	$74,700
				Estimated Division 2 Subtotal	**$1,568,000**

Engineer's Opinion of Probable Cost
Proposed Levee Repairs
Borrow Taken from Riverside Levee Toe
Drainage District No. 2
Subdrainage District No. 3
Pottawattamie County, Iowa
2018
Construction Division 4--Zone 4 Levee

Item	Description	Unit	Quantity	Unit Price	Total
101	Strip Stockpile Topsoil	CY	28,081	$4	$98,284
102	Respread Topsoil	CY	25,640	$2	$51,280
103	Levee Fill	CY	124,844	$4	$499,376
104	Clearing & Grubbing	AC	3.7	$2,000	$7,400
105	Seed & Fertilize Levee	AC	12.9	$500	$6,450
106	Administration of Erosion Management Plan	LS			$1,000
107	Seeding of Temporary Stabilization	AC	9.0	$800	$7,200
108	Silt Fence Install and Review	LF	1,000	$3	$3,000
109	Mobilization	LS	1	$33,700	$33,700
				Estimated Division 2 Subtotal	**$708,000**

Engineer's Opinion of Probable Cost
Proposed Levee Repairs
Borrow Taken from Riverside Levee Toe
Drainage District No. 2
Subdrainage District No. 3
Pottawattamie County, Iowa
2018

	Subtotal of Construction Divisions 1 through 3	**$2,907,000**
	Construction Contingency	**$145,400**
	Total Estimated Construction Cost	**$3,052,400**
	Less Estimated Construction Costs Paid by Others	**$1,568,000**
	Total Estimated Assessable Construction Cost	**$1,484,400**
Levee Right-of-Way Acquisition		
Zone 1	0.25 Acres	$110
Zone 2	6.29 Acres	$2,830
Zone 3	15.4 Acres	$69,300
Zone 4	54.51 Acres	$24,530
Less Costs Reimbursed By IDOT		-$69,300
Borrow Right-of-Way Acquisition		
Zone 1	8.22 Acres	$36,990
Zone 2	21.67 Acres	$97,560
Zone 3	0 Acres	$0
Zone 4	35.77 Acres	$160,965
Less Costs Reimbursed By IDOT		$0
Construction Related Damages		
Work Area Rental (114.4 ac)		$28,600
Other Damages		$76,000
Basic Engineering Services		
Survey, Study & Report. Meetings & Hearing		$25,000
Regulatory Permit Administration		$40,000
Construction Plans, Specifications, & Bid Letting		$35,000
Construction Engineering Services		$100,000
Less IDOT Reimbursed Engineering Costs		-$40,000
Legal Services, Publications, Mailings, Etc..		$5,000
Farmed Wetland Mitigation Assistance (3.0 ac X $7,500/ac)		$21,000
Finance, Interest & Contingency		$103,800
	Total Estimated Assessable Project Cost	**$2,202,000**
	Estimated Average Cost Per Currently Assessed Acre (11,341 ac)	$194
	Estimated Average Cost Per Acre Per Year (10 years)	$25
	Estimated Average Cost Per Acre Per Year (20 years)	$15
	Total Estimated Project Cost for IDOT	**$1,677,300**

Engineer's Opinion of Probable Cost
Proposed Levee Repairs
Borrow Supplied from Land Outside District
Drainage District No. 2
Subdrainage District No. 3
Pottawattamie County, Iowa
2018

Construction Division 1--Zone 1 Levee

Item	Description	Unit	Quantity	Unit Price	Total
101	Strip Stockpile Topsoil	CY	4,189	$4	$14,662
102	Respread Topsoil	CY	6,208	$2	$12,416
103	Levee Fill	CY	30,525	$13	$396,825
104	Clearing & Grubbing	AC	4.0	$2,000	$8,000
105	Seed & Fertilize Levee	AC	5.1	$500	$2,550
106	Administration of Erosion Management Plan	LS			$250
107	Seeding of Temporary Stabilization	AC	5.5	$800	$4,400
108	Silt Fence Install and Review	LF	500	$3	$1,500
109	Mobilization	LS	1	$22,000	$22,000
				Estimated Division 2 Subtotal	**$463,000**

Construction Division 2--Zone 2 Levee

Item	Description	Unit	Quantity	Unit Price	Total
101	Strip Stockpile Topsoil	CY	23,151	$4	$81,029
102	Respread Topsoil	CY	18,474	$2	$36,948
103	Levee Fill	CY	73,417	$15	$1,101,255
104	Clearing & Grubbing	AC	1.7	$2,000	$3,400
105	Seed & Fertilize Levee	AC	15.3	$500	$7,635
106	Administration of Erosion Management Plan	LS			$500
107	Seeding of Temporary Stabilization	AC	11.0	$800	$8,800
108	Silt Fence Install and Review	LF	1,000	$3	$3,000
109	Mobilization	LS	1	$62,100	$62,100
				Estimated Division 2 Subtotal	**$1,305,000**

Construction Division 3--Zone 3 Levee -- Paid by IDOT

Item	Description	Unit	Quantity	Unit Price	Total
101	Strip Stockpile Topsoil	CY	15,246	$4	$53,361
102	Respread Topsoil	CY	12,258	$2	$24,516
103	Levee Fill	CY	124,429	$11	$1,368,719
104	Clearing & Grubbing	AC	2.0	$2,000	$4,000
105	Seed & Fertilize Levee	AC	12.6	$500	$6,300
106	Administration of Erosion Management Plan	LS			$2,000
107	Seeding of Temporary Stabilization	AC	24.0	$800	$19,200
108	Silt Fence Install and Review	LF	5,000	$3	$15,000
109	Mobilization	LS	1	$74,700	$74,700
				Estimated Division 2 Subtotal	**$1,568,000**

Engineer's Opinion of Probable Cost
Proposed Levee Repairs
Borrow Supplied from Land Outside District
Drainage District No. 2
Subdrainage District No. 3
Pottawattamie County, Iowa
2018
Construction Division 4--Zone 4 Levee

Item	Description	Unit	Quantity	Unit Price	Total
101	Strip Stockpile Topsoil	CY	28,081	$4	$98,284
102	Respread Topsoil	CY	25,640	$2	$51,280
103	Levee Fill	CY	124,844	$14	$1,747,816
104	Clearing & Grubbing	AC	3.7	$2,000	$7,400
105	Seed & Fertilize Levee	AC	12.9	$500	$6,450
106	Administration of Erosion Management Plan	LS			$1,000
107	Seeding of Temporary Stabilization	AC	9.0	$800	$7,200
108	Silt Fence Install and Review	LF	1,000	$3	$3,000
109	Mobilization	LS	1	$96,100	$96,100
				Estimated Division 2 Subtotal	**$2,019,000**

Engineer's Opinion of Probable Cost
Proposed Levee Repairs
Borrow Supplied from Land Outside District
Drainage District No. 2
Subdrainage District No. 3
Pottawattamie County, Iowa
2018

Subtotal of Construction Divisions 1 through 3	**$5,355,000**
Construction Contingency	**$267,800**
Total Estimated Construction Cost	**$5,622,800**
Less Estimated Construction Costs Paid by Others	**$1,568,000**
Total Estimated Assessable Construction Cost	**$4,054,800**
Right-of-Way Acquisition	
Zone 1 0.25 Acres	$110
Zone 2 6.29 Acres	$2,830
Zone 3 15.4 Acres	$69,300
Zone 4 54.51 Acres	$24,530
Less Costs Reimbursed By IDOT	-$69,300
Construction Related Damages	
Work Area Rental (114.4 ac)	$28,600
Other Damages	$141,000
Basic Engineering Services	
Survey, Study & Report. Meetings & Hearing	$25,000
Regulatory Permit Administration	$40,000
Construction Plans, Specifications, & Bid Letting	$35,000
Construction Engineering Services	$150,000
Less IDOT Reimbursed Engineering Costs	-$40,000
Legal Services, Publications, Mailings, Etc..	$5,000
Farmed Wetland Mitigation Assistance (3.0 ac X $7,500/ac)	$21,000
Finance, Interest & Contingency	$223,300
Total Estimated Assessable Project Cost	**$4,711,000**
Estimated Average Cost Per Currently Assessed Acre (11,341 ac)	$415
Estimated Average Cost Per Acre Per Year (10 years)	$53
Estimated Average Cost Per Acre Per Year (20 years)	$32
Total Estimated Project Cost for IDOT	**$1,677,300**

Proposed Plans