Technical Report M11

SEDIMENTATION STUDY OF THE UPPER MISSISSIPPI RIVER AT BOLTERS BAR / IOWA ISLAND, RIVER MILES 230 TO 223

HYDRAULIC MICRO MODEL INVESTIGATION

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INTRODUCTION

A sedimentation improvement study of the Bolters Bar / Iowa Island reach of the Upper Mississippi River was initiated by the Potamology Section of the St. Louis District and sponsored by the Avoid and Minimize Program. The purpose of the study was to evaluate a number of design alternatives and/or modifications to alleviate channel maintenance dredging between Mississippi River Miles 228 and 225.

Personnel from the St. Louis District directly in charge of the study oversight included: Mr. Claude Strauser, Chief, Potamology Section; Mr. Steve Redington, Chief, River Engineering Unit; and Mr. Ron Yarbrough, Avoid and Minimize Program Manager.

The study was conducted between June 1998 and December 1998, using a physical hydraulic micro model at the St. Louis District Applied River Engineering Center in St. Louis, Missouri. The model study was performed by Mr. David Gordon, Hydraulic Engineer, under direct supervision of Mr. Robert Davinroy, District Potamologist for the St. Louis District.

Personnel from the Missouri Department of Conservation involved in the study included Mrs. Jenny Frasier, Mr. Bob Hrabik, Mr. Mike Peterson, Mr. David Herzog, Mr. Mark Boone, Ms. Lesly Conaway, Mr. Mark Haas, Mr. Gordon Farabee, Mr. Ken Brumett, and Mr. Ken Dalrymple. Personnel from other agencies also involved in the study included Mr. Butch Atwood from the Illinois Department of Natural Resources, and Mr. Bob Clevenstine and Ms. Joyce Collins from the U.S Fish and Wildlife Service.

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BACKGROUND

This report details the investigation of a sedimentation study of the Upper Mississippi River using a physical hydraulic micro model. Micro model methodology was used to evaluate the current sediment transport conditions in the Mississippi River at the Bolters Bar / Iowa Island reach. The model was also used to evaluate the sediment transport trends that could be expected to occur in the river from various applied channel improvement design alternatives. These alternatives were conceptualized and submitted by members of a study team representing the St. Louis District, the Missouri Department of Conservation, the Illinois Department of Natural Resources, and the U.S. Fish and Wildlife Service. The primary goal was to evaluate the impacts of these measures on the resultant bed configuration, or sediment transport response, within the study reach.

1. Study Reach

The Bolters Bar / Iowa Island reach is located approximately 25 miles northwest of Downtown St. Louis, Missouri. The reach is located within the navigation pool established by Locks and Dam 26 at Mile 201 near Alton, Illinois. Plate 1 is a vicinity map and USGS quad sheet of the study reach depicting the characteristics, configuration and nomenclature of the Upper Mississippi River through the study reach. Oblique aerial photographs of the area are shown on Plate 2.

The beginning of the study reach was located upstream of Two Branch Island at Mile 232. The navigation channel was positioned on the southwestern or Missouri side of the island with an equally sized side channel on the northeastern or Illinois side. The study focal point began near the downstream end of Two Branch Island at Mile 230. Downstream of Two Branch Island, the navigation channel followed the bluff line on the north and Illinois side of the river throughout the study reach. This reach consisted of several side channels on the south and

southeast, or the Missouri side of the river. The first side channel began near Mile 228.5 and extended behind Dardenne Island. This chute shall be named Dardenne Chute for the purpose of this report. The second chute began near Mile 227.3, extended behind Bolter Island, and converged with Dardenne Chute near Mile 226.0. This chute shall be named Bolter Chute for the purpose of this report. The third chute started at the head of Iowa Island near Mile 225.0, extended behind Iowa and Enterprise Islands, and converged with Bolter Chute near Mile 224.0. A small side channel separated Iowa and Enterprise Islands and returned to the main channel. The large, main chute shall be named Iowa Chute for the purpose of this report. This single side channel eventually merged with the main channel at the tail of Island No. 521 near Mile 221.5, which was at the end of the study reach. The actual end of the focused study reach was near Mile 223 or just downstream of Iowa Island.

The main channel, side channels, and all the banklines in this reach are used by thousands of recreational boaters. Numerous marinas for recreational boats are located within the side channels and on the floodplain along the Missouri banks. These boaters travel in the side channels and use their links to the main channel. Additionally, many homes are located within the rock bluffs along the Illinois bank throughout the study reach. Some of the property owners have reported problems boating along their banks due to shallow conditions. Those located within the dike field between Miles 226.0 and 225.2 have requested Corps assistance in maintaining their access to the river. These recreational interests combined with increasing environmental awareness about side channels and those concerns of the navigation industry make this reach extremely sensitive to change. Therefore, consideration must given to all these interests when designing remedial measures in the navigation channel to minimize the affect on people and the environment.

2. Dredging Analysis

In terms of dredging frequency and groundings, the reach has been one of the most troublesome within the three navigation pools in the St. Louis District. Plate 3 shows the dredge cut locations and disposal sites between Miles 228 and 224 for the dredging that occurred between 1979 and 1996. The two most frequent and costly areas were located near the head of Bolter Island at Mile 227 and upstream the head of Iowa Island between Miles 226 and 225. Other areas of less frequent dredging included sites downstream of Mile 224. Plate 4 shows a graph of the yearly dredging totals from 1979 to 1996 between Miles 227.6 and 224.8. Within this three-mile reach, 3,911,647 cubic yards of material was dredged at a cost of $5,162,689 over a period of 18 years. That translated into a yearly average of 217,000 cubic yards of material at a cost of $286,000. The area between Miles 226.0 to 224.8, just upstream of Iowa Island, accounted for over 77% of the total volume and costs. Data before 1978 was not analyzed because dredging records were not accurately kept before this time.

Dredging in this area has not only been repetitive and costly, but also troublesome. The Corps has had difficultly locating viable dredge spoil placement areas that will not negatively affect recreation, homeowners, or the environment. The normal disposal method of dredge material is open water placement without confinement. Areas to place this material within the reach are very limited. Therefore, in 1996, under the Avoid and Minimize Environmental Impacts Program, placement of this material in deep portions of the channel thalweg was initiated. Physical and biological monitoring showed no adverse effects to the environment but the deep portion of channel can only handle a small portion of the overall volume dredged from the reach. Furthermore, this material eventually will be naturally transported from these deep areas and may be deposited in other problem areas downstream that already experience repetitive channel maintenance dredging. Therefore, a means must be found to reduce the shoaling problem and then utilize the remaining dredge material in a beneficial manner.

3. Flow Split Analysis

It has been concluded that the main cause of repetitive dredging through the reach was due to the loss of flow in the main channel to the side channels. Historical discharge measurements have revealed steady decreases in flow within the main channel. Plate 5 displays flow split measurements collected at Miles 227.3 and 224.6 between 1988 and 1997. Each colored bar shows the percent of the total discharge handled by each channel throughout the years.

At Mile 227.3, the data shows that the main channel had normally carried more than 60% of the total flow from 1988 to 1995. By 1996 and 1997 the flow in the main channel had dropped to below 50% of the total. The decrease in flow in the main channel correlates with increased flow in both Bolter and Dardenne Chutes.

At Mile 224.6, the data shows the main channel carried nearly 50% of the total flow from 1988 to 1994. From 1995 to 1997, the flow in the main channel dropped to about 40% of the total flow. This decrease is also attributed to increased flows in Bolter Chute. A flow increase in Iowa Chute was not shown. The increased flows through Bolter Chute appeared to be the main cause for the reduction of flow in the main channel.

Repetitive dredging has been a problem through this reach due to the decreased flows in the main channel as well as the alignment of the main channel with the islands and side channels. The location of the head of Bolter Island caused the river to form a sharp bend in this area. This bend caused a point bar to encroach from the Illinois or left descending bank. This alignment coupled with the low flows in the main channel, has caused the dredging problem near Mile 227. The rehabilitation of a closure structure in Bolter Chute located at Mile 226.3 was designed before this micro model study was initiated. This measure was designed as a means to prevent the flows through Bolter Chute from continuing to increase and to recapture the eroding bankline near the closure. The closure was constructed in 2000 after the completion of this study. The design included

raising the crown elevation of the current structure to an elevation of +4 feet minimum pool while leaving a notch 200 feet wide with an invert elevation of –9 feet minimum pool.

The alignment of the main channel at the head of Iowa Island forced the direction of flow towards the head of island. The increased width of the main channel between Miles 226 and 225 enabled lower velocities that allowed more sediment deposition, which therefore attributed to the shoaling problems in the area. The combination of poor alignment, increased width in the main channel, and the loss of flow to Iowa and Bolter Chutes were responsible for the repetitive dredging between Miles 226 and 225.

4. Study Purpose and Goals

The purpose of this study was to assess the sediment transport conditions of the Mississippi River and to examine the interaction between the main channel and the side channel complex.

The primary goal was to evaluate design alternatives that would provide improvements to the repetitive channel maintenance dredging situation. A conventional solution to the problems would be the construction of closure structures across the mouths of each of the chutes. This measure would increase the flow rates in the main channel, which would increase sediment transport, decrease deposition, and deepen the main channel. Environmental and recreational interests for the side channels eliminated this type of solution. Recreational boat owners consistently use the side channels to enter the main channel, while closing the side channels may adversely effect the river environment and habitat.

Therefore, an innovative and creative solution was needed to reach the goal of reducing or eliminating dredging while allowing the side channels to remain

relatively unchanged. This included examining methods of increasing velocities in the main channel and improving the navigation channel alignment without closing off the chutes. The use of dikes, chevrons, and other structures in the main channel were considered. Assessments of these alternatives included the examination of the ultimate effects to sedimentation patterns within the main channel, at the entrances to the side channels, and within each side channel.

MICRO MODEL DESCRIPTION

1. Scales and Bed Materials

Plate 6 is a photograph of the Bolters Bar hydraulic micro model used in this study. The model insert encompassed the Mississippi River channel between Miles 232.5 and 221.5. After entrance and exit conditions in the model were adjusted, the actual study reach was located between Miles 230.0 and 223.0. The scales of the model were 1 inch = 800 feet, or 1:9600 horizontal, and 1 inch = 50 feet, or 1:600 vertical, for a 16 to 1 distortion ratio. This distortion supplied the necessary forces required for the simulation of sediment transport conditions similar to those of the prototype. The bed material used was granular plastic urea, Type II, with a specific gravity of 1.40.

2. Appurtenances

The micro model insert was constructed according to 1994 high-resolution aerial photography of the study reach shown on Plate 7. The insert was then mounted in a standard micro model hydraulic flume. The riverbanks of the insert were constructed from dense polystyrene foam. Rotational jacks located within the hydraulic flume controlled the slope of the model. River training structures in the model were made of galvanized steel mesh.

Flow into the model was regulated by customized computer hardware and software interfaced with an electronic control valve and submersible pump. This interface was used to automatically simulate repeatable discharge hydrographs in the model. Discharge was monitored by a magnetic flow meter interfaced with the customized computer program. Water stages were manually checked with a mechanical three-dimensional point digitizer. A three-dimensional laser digitizer was used to measure and record the resultant bed configurations in the model.

MICRO MODEL TESTS

1. Model Calibration

The calibration of the micro model involved the adjustment of water discharge, sediment volume, hydrograph time scale, model slope, and entrance conditions of the model. These parameters were refined until the measured bed response of the model was similar to that of the prototype. (Note: all elevations described in this report are referenced to the Minimum Pool (MP) Elevation for Locks and Dam 26)

A. Design Hydrograph

In all model tests, the effective discharge hydrograph was simulated in the micro model. This hydrograph served as the average design flow response. Because of the constant variation experienced in the prototype, a design hydrograph was used to theoretically analyze the average expected sediment response. Each hydrograph simulated a discharge range between extreme low flow to high "within-channel" flow. The most important factors during the modeling process are the establishment of an equilibrium condition of sediment transport and the simulation of high and low energy conditions. High flow in the model simulated an average energy condition representative of the river's bed forming flow and sediment transport potential at bankfull stage. The time increment or duration of each hydrograph cycle (peak to peak) was three minutes.

B. Prototype Data

Several prototype hydrographic surveys were used to determine the general bed characteristics and sediment transport trends that have existed in the prototype. Plate 7 also shows an 1880-bankline survey of the study reach overlaid on the 1994 aerial photograph. The map shows that minimal changes in the bankline configuration have occurred over a 100-year time period. This suggests that

bedrock, clay deposits, and other non-erodable material may be predominant in this area. Hydrographic surveys of the Mississippi River main channel from 1993, 1995, and 1997 are shown on Plates 8, 9, and 10, respectively. All of the modern day surveys show almost identical bathymetric trends although the 1993 survey shows very shallow depths throughout the entire reach. These depths may have been a temporary result of the Flood of 1993.

The general trends of the prototype as observed in the hydrographic surveys are described as follows:

- The thalweg entered the study reach along the right descending bank near Mile 229.0. A scour hole pattern with depths below –50 feet MP was located within the dike field upstream and downstream of the entrance to Dardenne Chute. These deep scour holes were probably the result of dredging that occurred previously to construct a new highway embankment. Historical surveys do not show that these scour holes have ever reached these depths.
- The navigation channel narrowed near the head of Bolter Island at Mile 227.3. A point bar extended from the left descending bank near Mile 227.0.
- A narrow but deep channel with depths below –20 feet MP was located on the right descending bank between Miles 227.2 and 226.0.
- Between Miles 226.0 and 225.0, the main channel was shallow with depths between –10 and –20 feet MP as the width widened with a crossing toward the head of Iowa Island. Depths in this reach have been artificially maintained by dredging. Therefore, natural depths between 0 and –10 feet MP would be expected under conditions without dredging.
- A small area of scour with depths below –20 feet MP was located near the head of Iowa Island on the right descending bank near Mile 225.0.
- The main channel then made a quick, shallow crossing to the left descending bank between Miles 225.0 and 224.3. A small scour hole with depths below –20 feet MP was located on the bank near Mile 224.3.
- The main channel then began another crossing back to the right descending bank between Miles 244.0 and 223.0.

Plate 10 is also a 1998 prototype survey of the side channel complex. The prototype surveys showed the following trends:

- Depths at the entrance to Dardenne Chute were above -10 feet MP.
- Depths in the remaining portions of Dardenne Chute were variable between 0 and –20 feet MP.
- A deep thalweg was located at the entrance to Bolter Chute with depths near –30 feet MP.
- Depths decreased near Closure Dike 226.3. Depths beyond the closure varied but generally remained below –10 feet MP.
- After Dardenne Chute merged with Bolter Chute, depths were between –10 and –20 feet MP to Mile 225.3.
- A scour hole with depths over –20 feet MP was located along the right descending bank between Miles 225.3 to 224.7 as the chute bends toward the main channel. A crossing was located where this channel merged with Iowa Chute.
- Depths at the entrance to Iowa Chute and throughout the channel were generally between 0 and –10 feet MP. Depths through the small chute between Iowa and Enterprise Islands were also between 0 and –10 feet MP.
- At the confluence of Iowa Chute with Bolter Chute, a thalweg with depths below –20 feet MP was located on the left descending bank between Miles 224.0 to 223.0.

Depths within Bolter Chute and the main side channel appeared to have average depths comparable to, or deeper than those within the main navigation channel.

2. Base Test

Model calibration was achieved once a favorable qualitative comparison of the prototype surveys was made to several surveys of the model. The resultant bathymetry of this bed response served as the base test of the micro model.

Plate 11 shows the resultant bed configuration of the micro model base test. The base test was developed from the simulation of successive repeatable design hydrographs until bed stability was reached and a similar bed response was achieved as compared with prototype surveys. This survey then served as the comparative bathymetry for all design alternative tests.

Results of the micro model base test bathymetry and a comparison to the prototype surveys indicated the following trends:

- The thalweg of the main channel entered the study reach on the right descending bank with depths approaching –30 feet MP. The thalweg became shallower as it approached the entrance of Dardenne Chute. Scour holes with depths over –20 feet MP were formed off the ends of Dikes 228.8R, 228.4R and 228.1R. The depths of these scour holes in the prototype were much greater, although as previously mentioned, it is suspected that they were artificially deepened by dredging.
- The thalweg became shallow between Miles 227.9 and 227.4. Depths along the left descending bank were below –10 feet MP through this reach. These trends resembled those of the prototype surveys.
- A thalweg with depths below –20 feet MP was located on the right descending bank, beginning at the head of Bolter Island at Mile 227.3 and extending to Mile 226.0. A point bar with depths between 0 and –10 feet MP was formed on the left descending bank near Mile 227.0. These trends also resembled those of the prototype surveys.
- Shoaling conditions began near Mile 226.0 as the channel began its crossing toward the head of Iowa Island. While depths through this crossing were above –10 feet MP, the depths along the left descending bank were just below –10 feet MP. Depths were above –10 feet MP along the right descending bank approaching the entrance of Iowa Chute. The shallow depths and shoaling in the main channel represent possible natural conditions if dredging in the reach was discontinued. The area on the left descending bank, along Dikes 226.0L to 225.2L, has traditionally been a dredge disposal

area. Therefore, depths shown in the prototype surveys were generally higher than those in the base test. Plate 12 shows the bathymetry of the base test with an artificial dredge cut and material placement. A shallow crossing was artificially created between Miles 226.0 and 225.0 with the disposal placed in the dike field on the left descending bank. This artificial dredge cut and material placement resembled the bathymetry shown in the prototype surveys.

- A scour hole with a depth of –30 feet MP was formed near the head of Iowa Island on the right descending bank. The channel made a short, shallow crossing to the left descending bank where another scour hole formed with depths below –30 feet near Mile 224.2. The channel again became shallow before another area of scour hole was formed on the left descending bank. These trends, while slightly deeper, resembled those of the prototype surveys.

Results of the base test within the side channel complex showed slight differences as compared to the prototype. Overall elevations were slightly higher in the base test as compared to the prototype. The base test indicated the following bathymetric trends in the side channels.

- Dardenne Chute had depths mainly between 0 and –10 feet MP. These elevations were slightly higher in some areas than shown in prototype surveys.
- The upper end of Bolter Chute to Closure Dike 226.3R had depths below –10 feet MP. Depths downstream of the dike to Mile 225.2 were generally between 0 and –10 feet MP. A scour hole with depths below –30 feet MP was formed on the right descending bank between Miles 225.2 and 224.7. A crossing was then located just downstream of this area. Although the trends were consistent with the prototype surveys, the elevations were slight higher.
- Iowa Chute had depths between 0 and –10 feet MP before its confluence with Bolter Chute. Downstream of this area, depths were below –20 feet MP while depths further downstream were between –10 and –20 feet MP.

Generally, the overall bathymetric trends established in the micro model base test were similar to those trends observed in the prototype surveys.

3. Design Alternative Tests

Nine design alternative plans were modeled tested to examine methods of improving the sedimentation conditions between miles 228.0 and 225.0. The effectiveness of each design was evaluated by comparing the resultant bed configuration to that of the base condition. Impacts or changes of each alternative were evaluated by the sediment response of the model. A qualitative evaluation of the ramifications to the main channel and all the side channels was made during team participation meetings at the Applied River Engineering Center in St. Louis, Missouri. Personnel from the St. Louis District Corps of Engineers, Missouri Department of Conservation, Illinois Department of Natural Resources, and the U.S. Fish and Wildlife Service carefully examined and discussed each alternative.

Alternative A:

- *Bull Nose, at +2 feet MP, added at the head of Bolter Island, Mile 227.4*
- *Three Chevrons, at +2 feet MP, added upstream of Iowa Island along the right descending bank at Miles 225.3, 225.2, and 225.1*

Plate 13 is a plan view map of the resultant bed configuration of Alternative A. Test results indicated that the bull nose reduced the width of the point bar on the left descending bank and widened the navigation channel along the right descending bank at Mile 227.0. The three chevrons increased depths slightly in the main channel but their overall effect was negligible. There were negligible changes to the bathymetry within the side channels.

Alternative B:

- *Raised Dikes 227.9L, 227.6L, and 227.4L to +2 feet MP*

- *Bull Nose, at +2 feet MP, added at the head of Bolter Island, Mile 227.4*
- *Six Chevrons, at +2 feet MP, added upstream of Iowa Island along the right descending bank at Miles 225.7, 225.6, 225.5, 225.4, 225.2, and 225.1*

Plate 14 is a plan view map of the resultant bed configuration of Alternative B. Test results indicated that the raised dikes on the left descending bank increased the height of deposition within the dike field and formed a scour pattern off the ends of the dikes. These dikes and the bull nose reduced the width of the point bar at Mile 227.0. The six chevrons increased depths in the main channel between Miles 225.7 and 225.0. Increased deposition was evident along the left descending bank between Miles 226.0 and 225.2. There were negligible changes to the bathymetry within the side channels.

Alternative C:

- *Raised Dikes 227.9L, 227.6L, and 227.4L to +2 feet MP*
- *Bull Nose, at +2 feet MP, added at the Head of Bolter Island, Mile 227.4*
- *Three Dikes, at +2 feet MP, added on the left descending bank at Miles 227.2, 226.3, and 226.1*
- *Six Chevrons, at +2 feet MP, added upstream of Iowa Island along the right descending bank at Miles 225.7, 225.6, 225.5, 225.4, 225.2, and 225.1*

Plate 15 is a plan view map of the resultant bed configuration of Alternative C. Test results indicated that the raised dikes and the bull nose reduced the width of the point bar at Mile 227.0. The dikes added at Miles 226.3L and 226.1L increased deposition on the left descending bank within the dike field between Miles 226.0 and 225.2. The row of chevrons formed a scour pattern with depths below –20 feet MP in navigation channel. Navigable depths and widths were maintained through the entire reach. The channel crossing between Miles 225 and 224.3 was deepened to below –20 feet MP. There were negligible changes to the bathymetry within the side channels.

Alternative D:

- *Raised Dikes 227.9L, 227.6L, and 227.4L to +2 feet MP*
- *Three Dikes, at +2 feet MP, added on the left descending bank at Miles 227.2, 226.3, and 226.1*
- *Four Dikes, at +2 feet MP, added on the right descending bank at Miles 225.8, 225.7, 225.6, and 225.4*
- *Two Chevrons, at +2 feet MP, added upstream of Iowa Island along the right descending bank at Miles 225.2 and 225.1*

Plate 16 is a plan view map of the resultant bed configuration of Alternative D. Test results indicated that the width of the point bar at Mile 227.0 was reduced. The main channel between Miles 226 and 225.5 was deepened significantly. The dikes added at Miles 226.3L and 226.1L increased deposition on the left descending bank within the dike field between Miles 226.0 and 225.2. Navigable depths and widths were maintained through the entire reach. The scour hole at the head of Iowa Island was deepened and widened significantly. There were negligible changes to the bathymetry within the side channels.

Alternative E:

- *Raised Dikes 227.9L, 227.6L, and 227.4L to +2 feet MP*
- *Three Dikes, at +2 feet MP, added on the left descending bank at Miles 227.2, 226.3, and 226.1*
- *Raised and Lengthened Dikes 226.0L, 225.8L, 225.6L, and 225.4L to +2 feet MP*
- *Five Chevrons, at +2 feet MP, added upstream of Iowa Island along the right descending bank at Miles 225.8, 225.6, 225.4, 225.2, and 225.1*

Plate 17 is a plan view map of the resultant bed configuration of Alternative E. Test results indicated that the width of the point bar at Mile 227.0 was reduced. The additional and raised dikes increased deposition on the left descending bank within the dike field between Miles 226.3 and 225.2. A scour pattern with depths below –20 feet MP formed off the ends of the raised dikes. The channel crossed to the left descending bank between Chevron 225.8 and Dike 225.8. Navigable

depths and widths were maintained through the entire reach. The scour hole at the head of Iowa Island was deepened and widened significantly. There were negligible changes to the bathymetry within the side channels.

<u>Alternative F:</u>

- *Raised Dikes 227.9L, 227.6L, and 227.4L to +2 feet MP*
- *Three Dikes, at +2 feet MP, added on the left descending bank at Miles 227.2, 226.3, and 226.1*
- *Removed Dikes 226.0L, 225.8L, 225.6L, and 225.4L*
- *Four Chevrons, at +2 feet MP, added upstream of Iowa Island along the left descending bank at Miles 226.0, 225.8, 225.6, and 225.4 (in the locations where the dikes were removed)*
- *Five Chevrons, at +2 feet MP, added upstream of Iowa Island along the right descending bank at Miles 225.8, 225.6, 225.4, 225.2, and 225.1*
- *Closure Dike 226.3R, in Bolter Chute, raised to +4 feet MP with a 100 foot wide notch with an invert elevation of –5 feet MP*

Plate 18 is a plan view map of the resultant bed configuration of Alternative F. Test results indicated that the width of the point bar at Mile 227.0 was reduced. The rehabilitation of Closure Dike 226.3R created a scour hole with depths below –20 feet MP on the downstream side. The additional dikes and chevrons on the both banks increased deposition although small deeper channels were evident in between each structure. Navigable depths and widths were maintained through the entire reach. The scour hole at the head of Iowa Island was deepened and widened significantly. There were negligible changes to the bathymetry within the side channels.

<u>Alternative G:</u>

- *Raised Dikes 227.9L, 227.6L, and 227.4L to +2 feet MP*
- *Realigned and extended the longitudinal trail on Dike 227.5R*
- *1200 foot longitudinal dike, at +2 feet MP, added on the right descending bank at Mile 226.2*

- *Removed Dikes 226.0L, 225.8L, 225.6, and 225.4L*
- *Five Chevrons, at +2 feet MP, added upstream of Iowa Island along the right descending bank at Miles 225.7, 225.5, 225.4, 225.2, and 225.1*
- *Closure Dike 226.3R, in Bolter Chute, raised to +4 feet MP with a 100 foot wide notch with an invert elevation of –5 feet MP*

Plate 19 is a plan view map of the resultant bed configuration of Alternative G. Test results indicated that the width of the point bar at Mile 227.0 was reduced. The rehabilitation of Closure Dike 226.3R created a scour hole with depths below –30 feet MP on the downstream side. The new longitudinal dike at Mile 226.2 formed a scour pattern with depths below –20 feet MP. Deposition increased within the chevron field where depths were between 0 to –10 feet MP although small deeper channels were evident in between each structure. Navigable depths and widths were maintained through the entire reach. There were negligible changes to the bathymetry within the side channels.

Alternative H:

- *Raised Dikes 227.9L, 227.6L, and 227.4L to +2 feet MP*
- *Realigned and extended the trail on Dike 227.5R*
- *1200 foot longitudinal dike, at +2 feet MP, added on the right descending bank at Mile 226.2*
- *Removed Dikes 226.0L, 225.8L, 225.6, and 225.4L*
- *Three Chevrons, at +2 feet MP, added upstream of Iowa Island along the right descending bank at Miles 225.6, 225.4, and 225.1*
- *Closure Dike 226.3R, in Bolter Chute, raised to +4 feet MP with a 100 foot wide notch with an invert elevation of –5 feet MP*

Plate 20 is a plan view map of the resultant bed configuration of Alternative H. Test results indicated that the width of the point bar at Mile 227.0 was reduced. The rehabilitation of Closure Dike 226.3R created a scour hole with depths below –30 feet MP on the downstream side. The new longitudinal dike at Mile 226.2 formed a scour pattern with depths below –20 feet MP. Deposition increased within the chevron field where depths were between 0 to –10 feet MP although

small deeper channels were evident in between each structure. Navigable depths and widths were scarcely maintained through the entire reach. There were negligible changes to the bathymetry within the side channels.

<u>Alternative I:</u>

- *1200 foot longitudinal dike, at +2 feet MP, added on the right descending bank at Mile 226.2*
- *Removed Dikes 226.0L, 225.8L, 225.6, and 225.4L*
- *Four Chevrons, at +2 feet MP, added upstream of Iowa Island along the right descending bank at Miles 225.7, 225.5, 225.3 and 225.1*
- *Closure Dike 226.3R, in Bolter Chute, raised to +4 feet MP with a 100 foot wide notch with an invert elevation of –5 feet MP*

Plate 21is a plan view map of the resultant bed configuration of Alternative I. Test results indicated that the width of the point bar at Mile 227.0 was reduced slightly. The rehabilitation of Closure Dike 226.3R created a scour hole with depths below –20 feet MP on the downstream side. Deposition increased within the chevron field where depths were between 0 to –10 feet MP although small deeper channels were evident in between each structure. Navigable depths and widths were maintained through the entire reach. There were negligible changes to the bathymetry within the side channels.

CONCLUSIONS

1. Evaluation and Summary of the Model Tests

Most of the structural designs tested in the micro model improved the bed and sediment transport conditions of the study reach. The goal was to consider multiple alternatives and then examine which designs would provide the greatest benefit in the most cost effective and environmentally sensitive manner. Although the reduction of dredging was the focus of this study, it was also very important to consider the impacts to recreation and habitat. The impacts on deposition within the side channels, at the entrance to the side channels and along the left descending bank between Miles 226 and 225 were carefully evaluated. The following is an evaluation and summary of the findings of the model tests:

Several designs were used as a means to reduce the point bar located on the left descending bank near mile 227.0. The addition of a bull nose at the head of Bolter Island in Alternatives A, B, and C and the realignment and extension of the longitudinal trail on Dike 227.5 in Alternatives G and H proved most effective. Both of these structural modifications widened the navigation channel and reduced the width of the point bar. The raised Dikes 227.9L, 227.6L, and 227.4L and the addition of Dike 227.2L in Alternatives B, C, D, E, F, G, and H provided limited benefits to the reduction in width of the point bar. The rehabilitation of Closure Dike 226.3R also showed a slight improvement in the main channel.

All the designs with the exception of Alternative A showed various improvements to depths within the navigation channel between Miles 226 and 225. Some designs improved conditions more considerably than others. Therefore, the remedial designs for this reach were evaluated based on three criteria:

1. The effect on depths and alignment within the navigation channel.
2. The effect on depths at the entrance to Iowa Chute.
3. The effect on depths along the left descending bank in this reach.

Fortunately, none of the designs effected depths at the entrance to Iowa Chute or the depths within the side channels. However, differing effects to depth were noted along the left descending bank. The following summarizes the effects of the chevrons and other modifications within this reach.

- The chevrons in Alternative A proved ineffective at increasing depths in the navigation channel due to their location and the number of structures.
- The chevrons in Alternative B proved effective at increasing depths in the navigation channel although some shoaling was still evident in their upstream location. Significant deposition occurred adjacent to the structures along the left descending bank.
- In Alternative C, the chevrons from Alternative B were implemented with additional dikes placed upstream on the left descending bank. This design proved extremely beneficial at increasing depths in the navigation channel although significant shoaling occurred along the left descending bank.
- In Alternative D, the additional dikes from Alternative C were implemented with 2 chevrons and short dikes along the right descending bank. This design also proved beneficial at increasing depths in the navigation channel although shoaling again occurred along the left descending bank.
- The structures designed in Alternative E were very effective at increasing depths in the navigation channel. Some shoaling occurred again along the left descending bank.
- In Alternative F, Dikes 226.0L through 225.4L were replaced with 4 chevrons. Five more chevrons were implemented along the right descending bank. This design also proved effective at increasing depths in the navigation channel but shoaling occurred again along the left descending bank. Small channels with greater depths were located within the shoaled area and around the chevrons along the left descending bank.
- In Alternative G, a longitudinal, deflector dike was implemented near Mile 226.2R along with five chevrons along the right descending bank. Dikes 226.0L through 225.4 were removed. This configuration was also effective at

increasing depths in the navigation channel. Additional deposition was not incurred along the left descending bank.

- Alternative H implemented only three of the chevrons from the Alternative G design. These results were similar to Alternative G although not as effective at increasing depths in the navigation channel. Minimal deposition was incurred along the left descending bank.
- Alternative I implemented four of the chevrons from the Alternative G. This configuration resulted in navigation channel depths almost identical to those in Alternative G. Depths were increased in the navigation channel and additional deposition was not incurred along the left descending bank.

2. Recommendations

The St. Louis District, acting upon suggestions from the Dredge Material Disposal Review Team, recommended that blunt nosed chevron dikes be tested in the micro model to help solve the problem. These structures act as upstream protection for dredge material artificially placed in their downstream shadow. They create roughness in the channel, and when placed properly, may take the place of a traditional dike field.

The first three chevron structures were constructed in Pool 24 in 1993 near Mile 289.5. Dredge material was subsequently placed inside and adjacent to the structures. Much of the material placed on the outside of the chevrons was transported downstream by the river while most of the material placed within the shadow of the structure remained. The structures have formed a scour hole immediately downstream of the head of the dike while a large, isolated sand bar extends downstream. Each chevron provides aquatic habitat at variable depths with a diverse mosaic of shallow sandbar, deep slack water, and off-channel areas as well as increased wetted perimeter. At least 53 species of fish, and a highly diverse group of macro invertebrates have been collected during biological monitoring of the complex. Vegetation colonization and wading bird use of the

islands has also been documented. In addition to a multitude of environmental benefits, the sandbars that each chevron provides create many recreational opportunities. Placement of chevrons in the Bolters Bar study reach is expected to result in the same diverse group of habitat type and species benefits as the complex in Pool 24. Therefore, many of the micro model tests involved chevron designs to eliminate dredging.

Chevrons model tested along the right descending bank proved most effective at providing beneficial sediment transport conditions between Miles 226 and 225. Through a number of model tests, the most beneficial alignments and locations were designed while other structural modifications enhanced the benefits of the chevrons.

The most beneficial and cost effective chevron configuration is shown in Alternative I. The resulting bathymetry formed by these structures met the three criteria mentioned previously. This design increased depths in the main channel and induced deposition within the chevron field and along the right descending bank. Within this deposition were several small deeper channels around the structures. This alternative also showed that additional shoaling was not induced at the entrance to Iowa Chute or within any of the other side channels. The location of the longitudinal dike and the four chevrons also created an improved alignment for towboats navigating downstream toward the head of Iowa Island. Under the existing configuration, tow pilots must navigate directly toward the head of Iowa Island before turning left to avoid grounding on the island.

Additional deposition was not incurred along the left descending bank due to the removal of the four dikes along the bank. The existing dikes in the other designs created a catchment area for deposition. The length of these dikes may also inhibit navigation if the chevrons are implemented.

The rehabilitation of Closure Dike 226.3R had a slight effect at reducing the width of the point bar at Mile 227.0. The realignment and extension of the trail on Dike 227.5R may further reduce the width of the point bar and widen the navigation channel. None of these structural modifications recommended showed any adverse effects to depths or the diversity in any of the side channels or their entrances.

Therefore, it is recommended that the four chevrons and the deflector dike from Alternative I be constructed along with an extension of the trail on Dike 227.5R. After this construction, the depositional area and existing dikes along the left descending bank should be monitored to determine if the removal of these structures would accelerate the natural removal of sediments from this area. The condition, length and height of these structures are not documented. They were probably built of wooden piles and are currently buried in the sediment. The option to remove these structures should be determined after construction and monitoring of the Alternative I design is complete.

3. Interpretation of Model Test Results

In the interpretation and evaluation of the results of the tests conducted, it should be remembered that the results of these model tests were qualitative in nature. Any hydraulic model, whether physical or numerical, is subject to biases introduced as a result of the inherent complexities that exist in the prototype. Anomalies in actual hydrographic events, such as prolonged periods of high or low flows are not reflected in these results, nor are complex physical phenomena, such as the existence of underlying rock formations or other non-erodable variables. Flood flows were not simulated in this study.

This model study was intended to serve as a tool for the river engineer to guide in assessing the general trends that could be expected to occur in the actual river from a variety of imposed design alternatives. Measures for the final design may

be modified based upon engineering knowledge and experience, real estate and construction considerations, economic and environmental impacts, or any other special requirements.

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4. “Section 204 – Fact Sheet, Unpublished Report”, US Army Corps of Engineers, St. Louis District - Avoid and Minimize Program, July 1997.

FOR MORE INFORMATION

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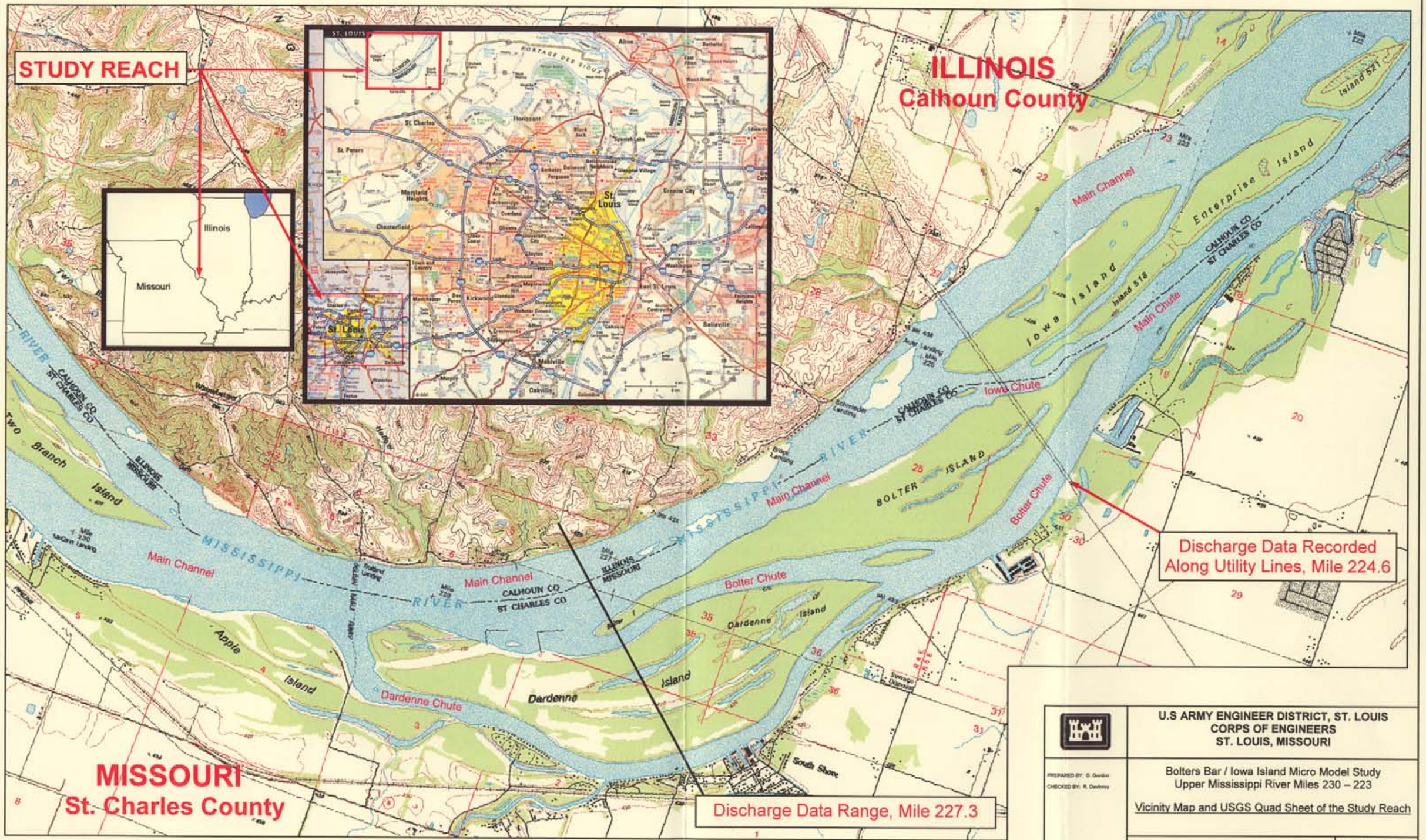
Or you can visit us on the World Wide Web at:

http://www.mvs.usace.army.mil/engr/river/river.htm

APPENDIX OF PLATES

Plate Numbers 1 through 21 follow:

1. Vicinity Map and USGS Quad Sheet of the Study Reach
2. Photographs of the Bolters Bar / Iowa Island Reach
3. Dredge Cut and Disposal Sites, 1979 to 1996, River Miles 228 to 225
4. Yearly Dredging Totals and Costs, 1979 to 1996, River Miles 227.6 to 224.8
5. Yearly Flow Split Measurements, 1988 to 1997, At River Miles 227.3 & 224.6
6. Bolters Bar / Iowa Island Micro Model
7. 1880 Bankline Survey
8. 1993 Prototype Survey
9. 1995 Prototype Survey
10. 1997 Main Channel and 1998 Side Channel Prototype Surveys
11. Base Test
12. Base Test, Dredged Between River Miles 226 & 225
13. Alternative A
14. Alternative B
15. Alternative C
16. Alternative D
17. Alternative E
18. Alternative F
19. Alternative G
20. Alternative H
21. Alternative I



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Bolters Bar / Iowa Island Micro Model Study
Upper Mississippi River Miles 230 – 223

Vicinity Map and USGS Quad Sheet of the Study Reach

PLATE NO. 1

TOP PHOTO: Looking Downstream from River Mile 227.6

BOTTOM PHOTO: Looking Upstream from River Mile 224.0

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PREPARED BY: D. Gordon CHECKED BY: R. Davinney	Bolters Bar / Iowa Island Micro Model Study Upper Mississippi River Miles 230 – 223 Photographs of the Bolters Bar / Iowa Island Reach
	PLATE NO. 2

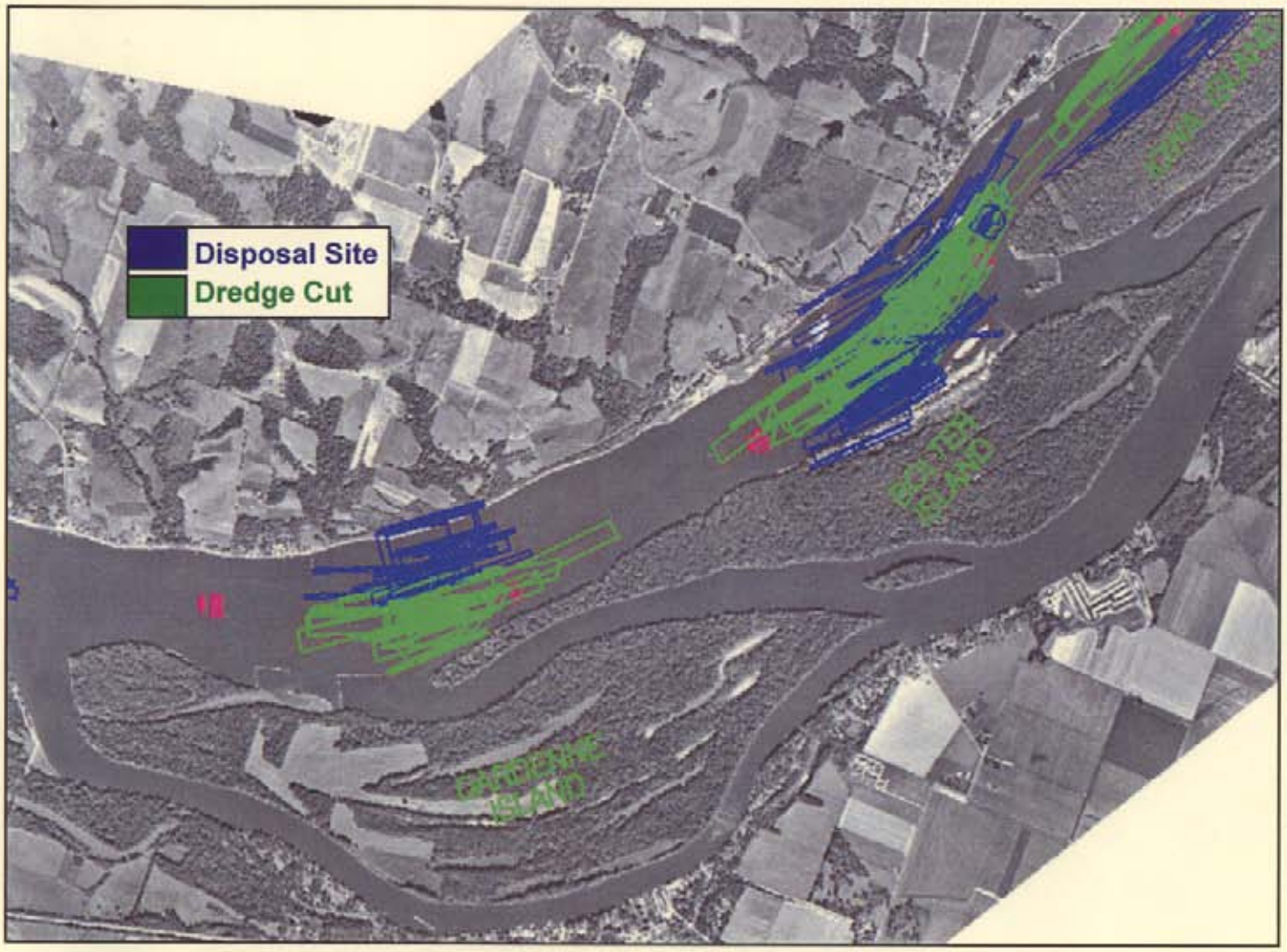

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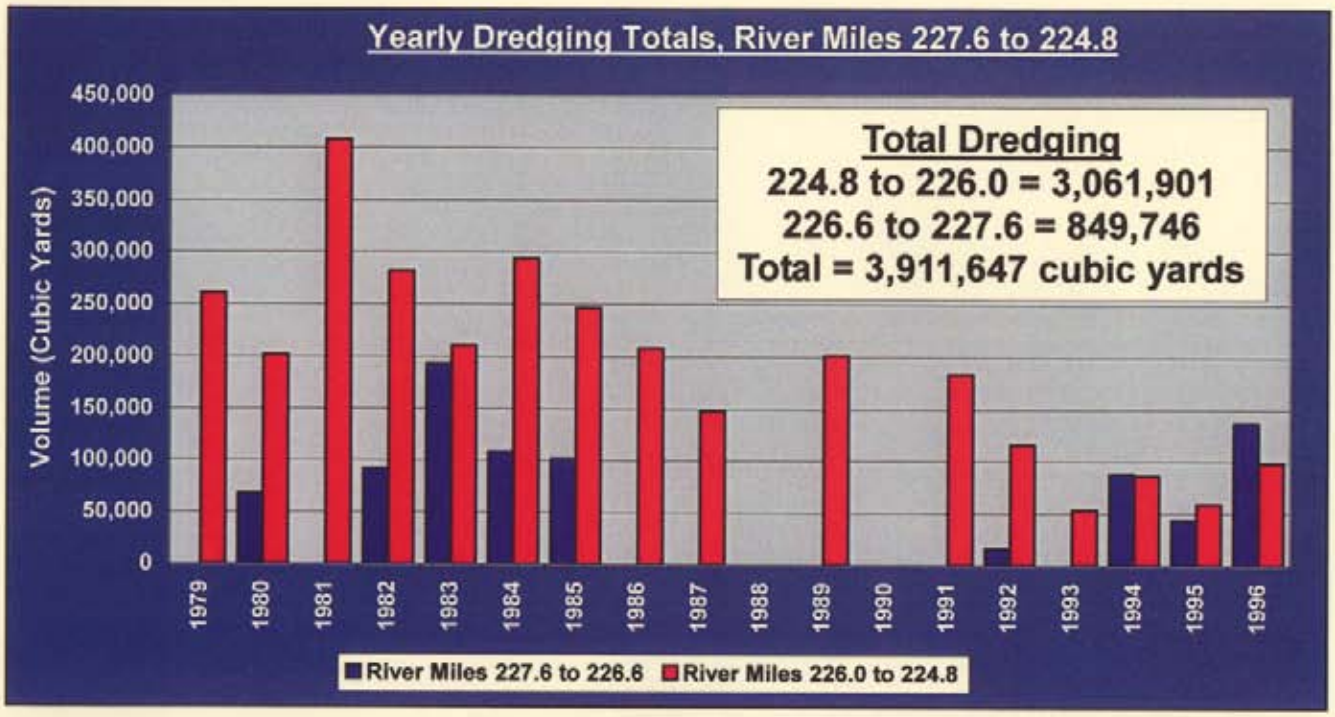
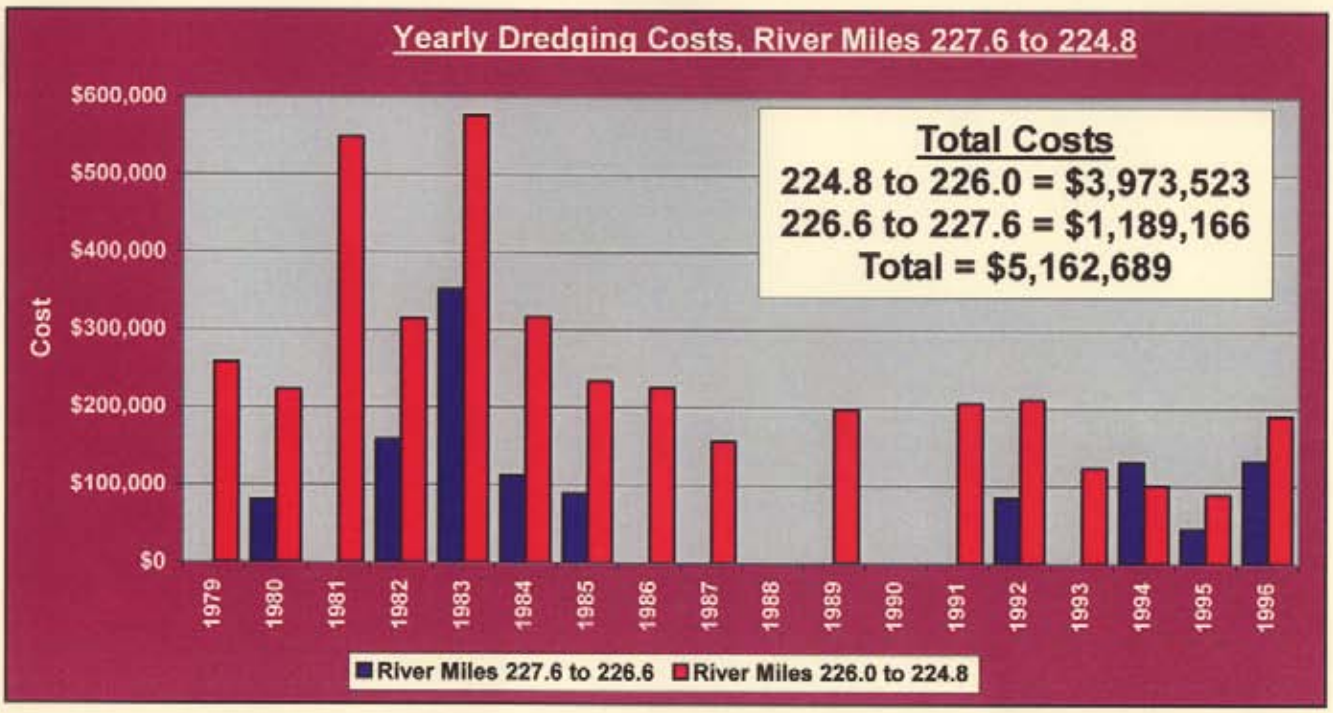
	PLATE NO. 3





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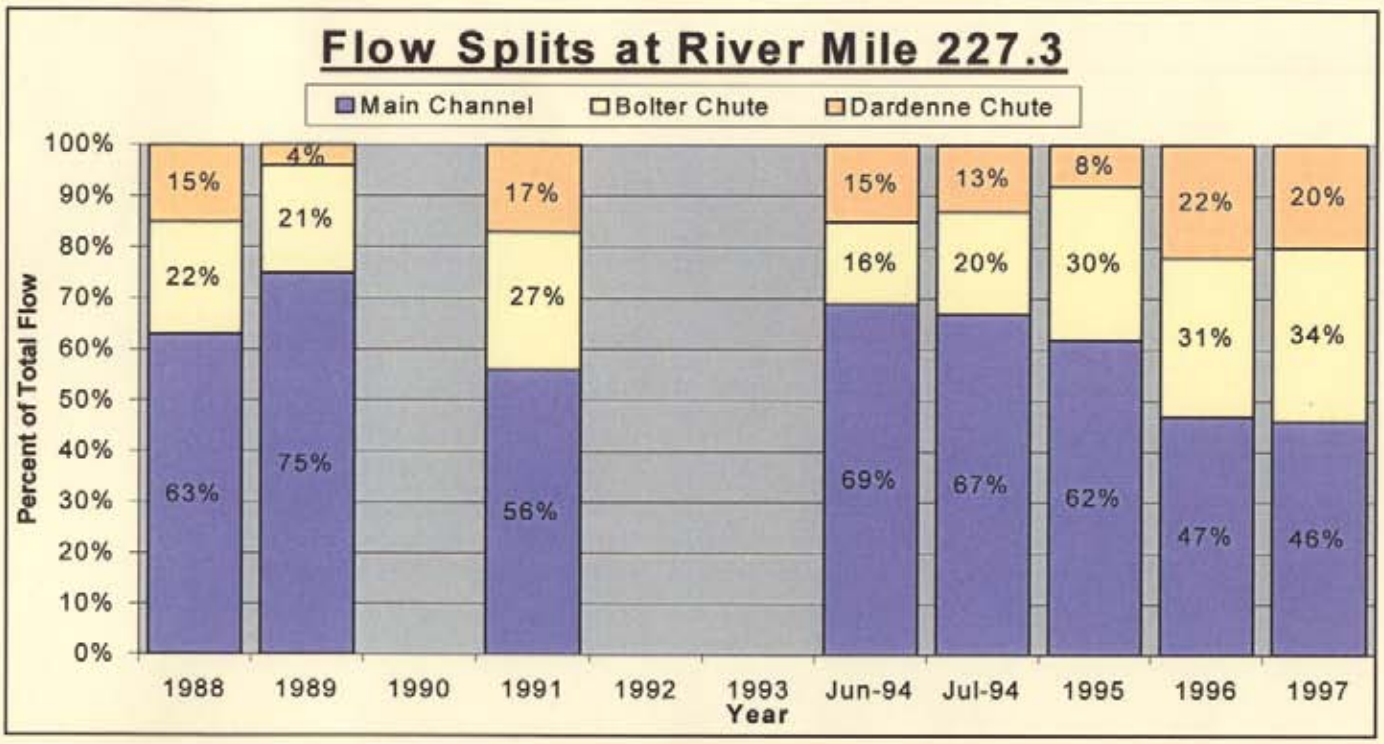
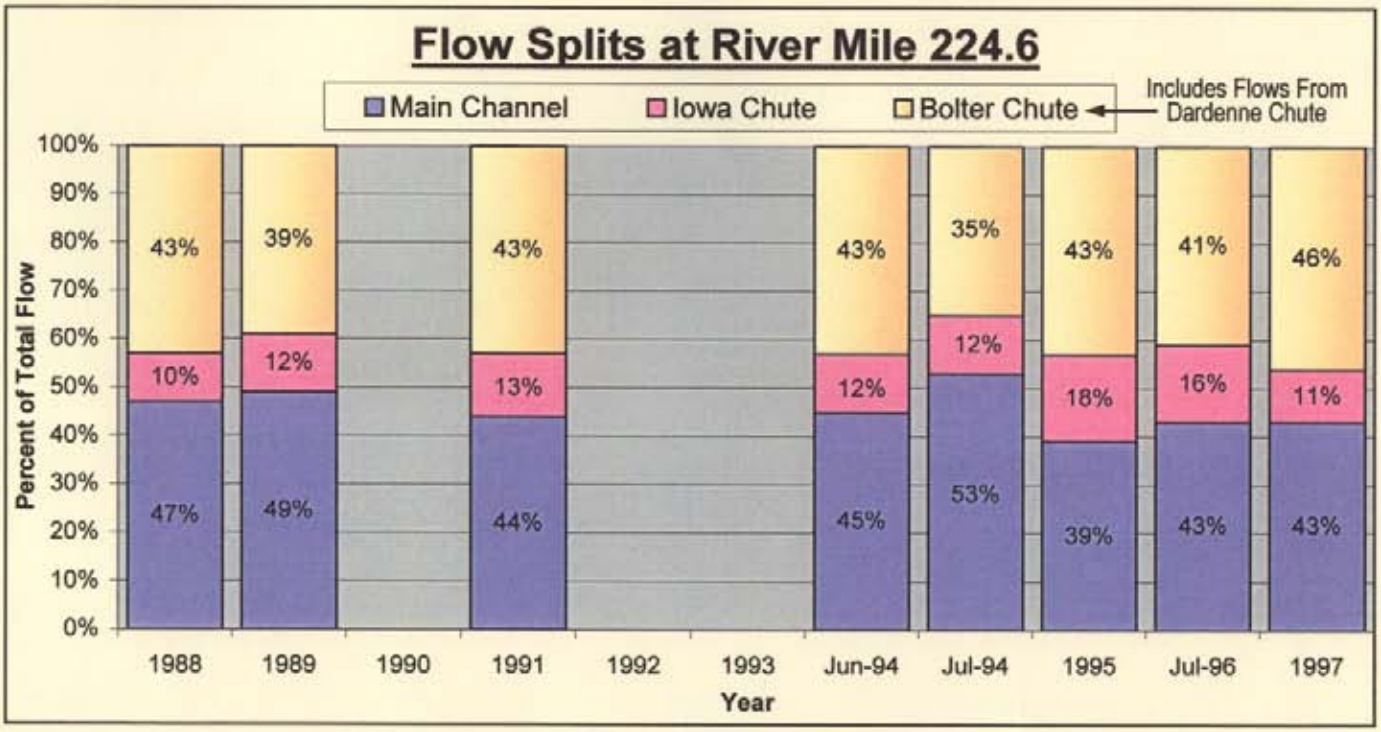
Bolters Bar / Iowa Island Micro Model Study
Upper Mississippi River Miles 230 – 223

Yearly Dredging Totals and Costs, 1979 to 1996
River Miles 227.6 to 224.8

PLATE NO.
4





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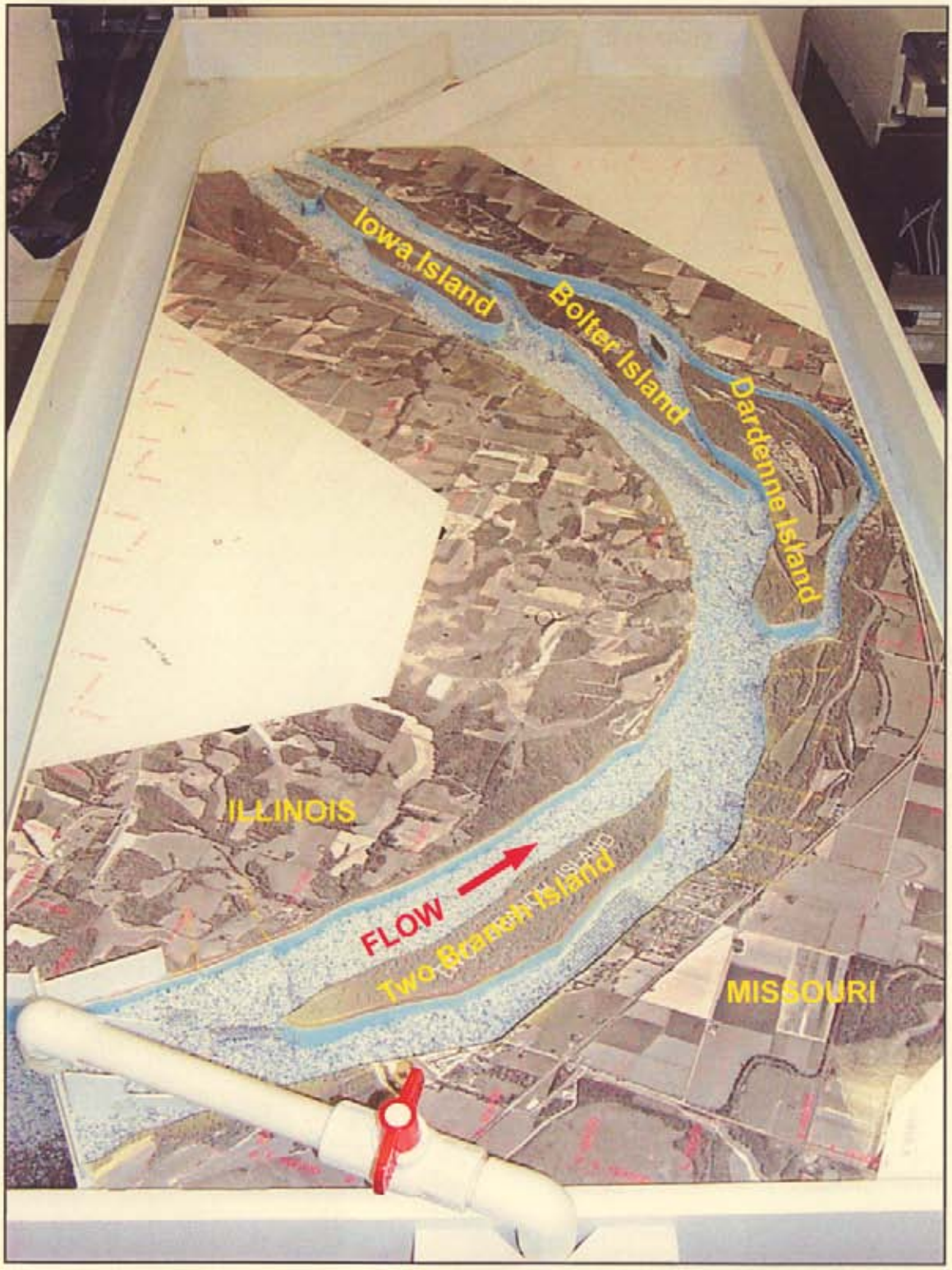
Bolters Bar / Iowa Island Micro Model Study
Upper Mississippi River Miles 230 – 223

Yearly Flow Split Measurements, 1988 to 1997
At River Miles 227.3 and 224.6

PLATE NO. 5



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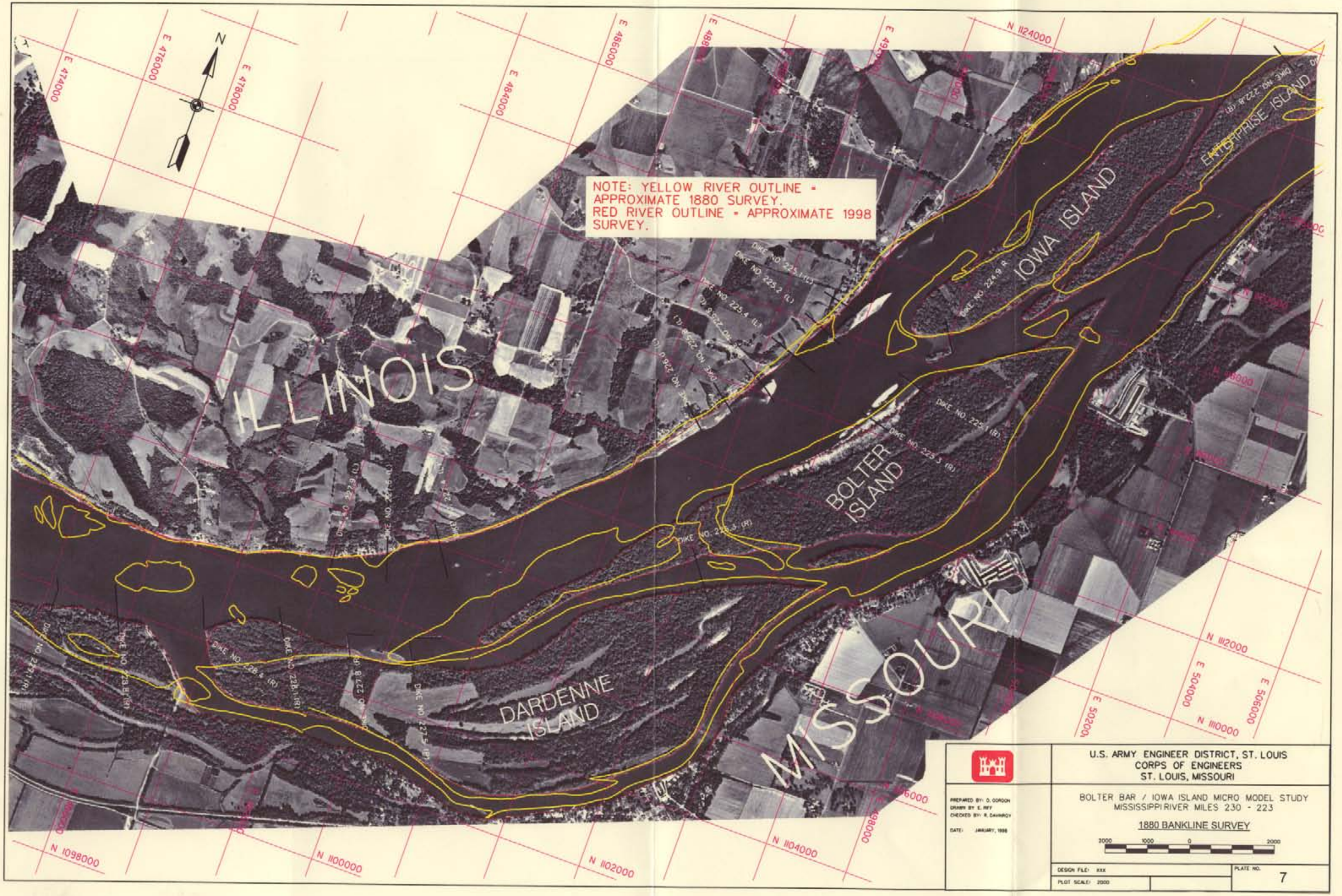
Bolters Bar / Iowa Island Micro Model Study
Upper Mississippi River Miles 230 – 223

Bolters Bar / Iowa Island Micro Model

PLATE NO. 6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DRAWN BY: E. IRY
CHECKED BY: R. DAVINROY
DATE: JANUARY, 1998
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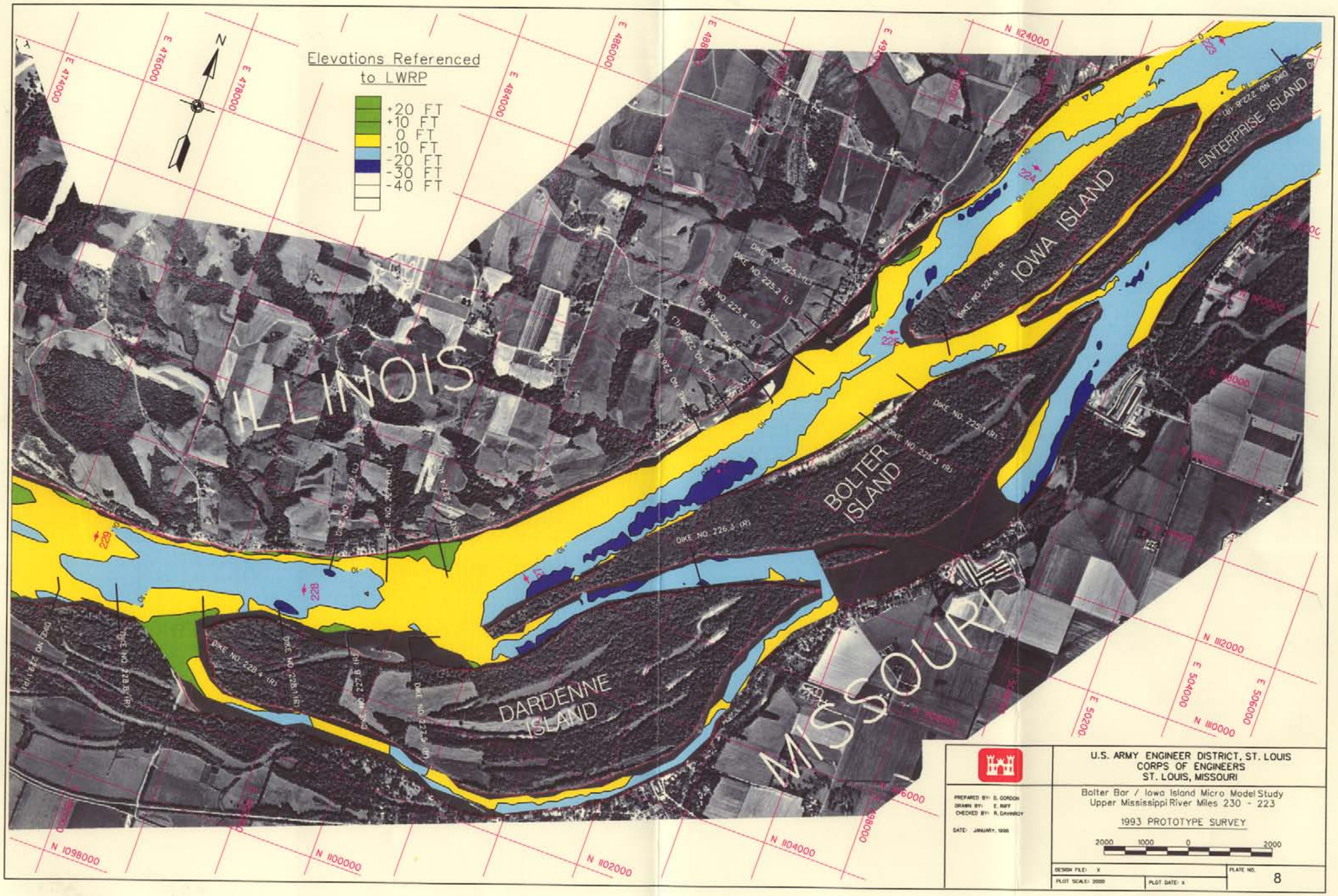
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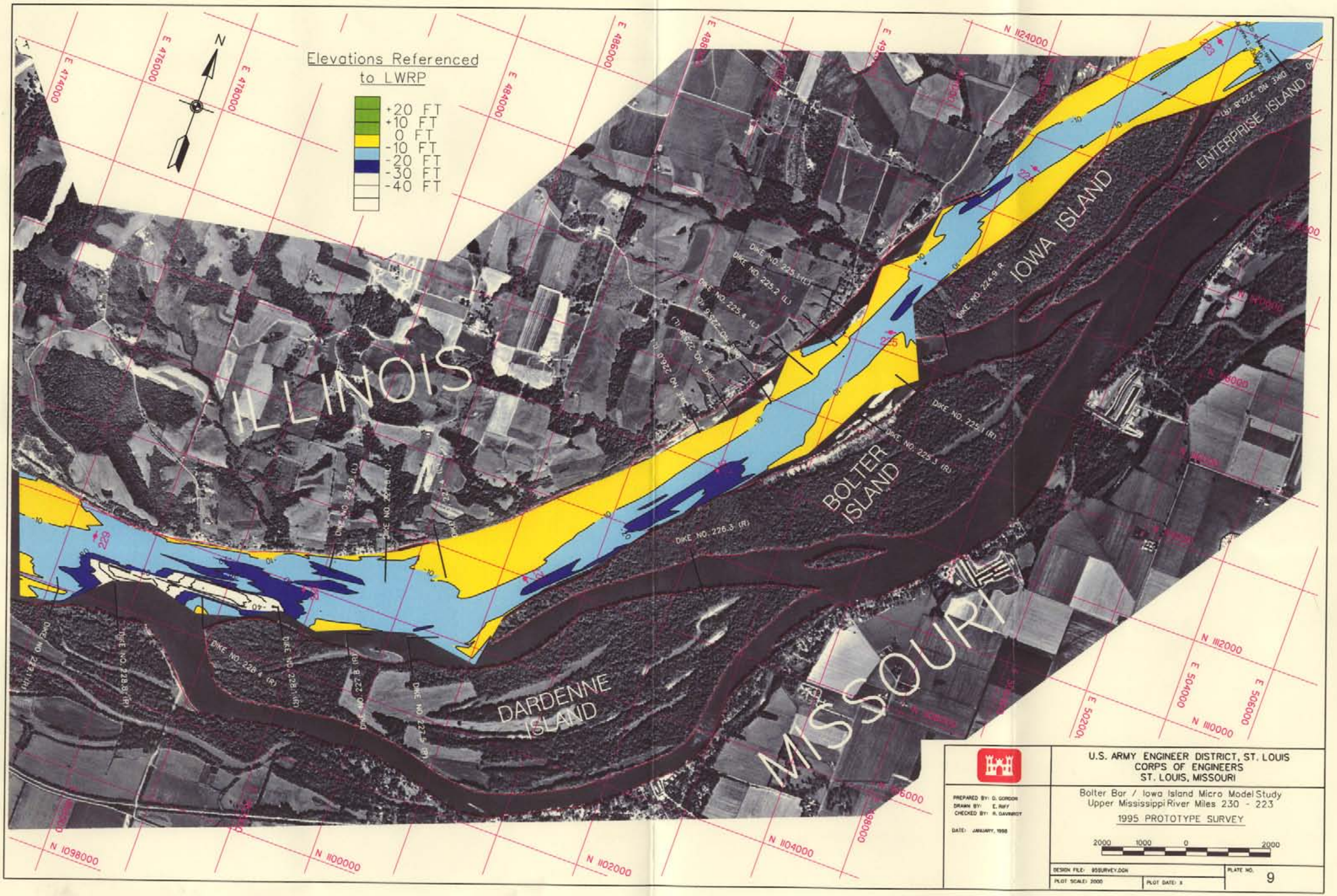
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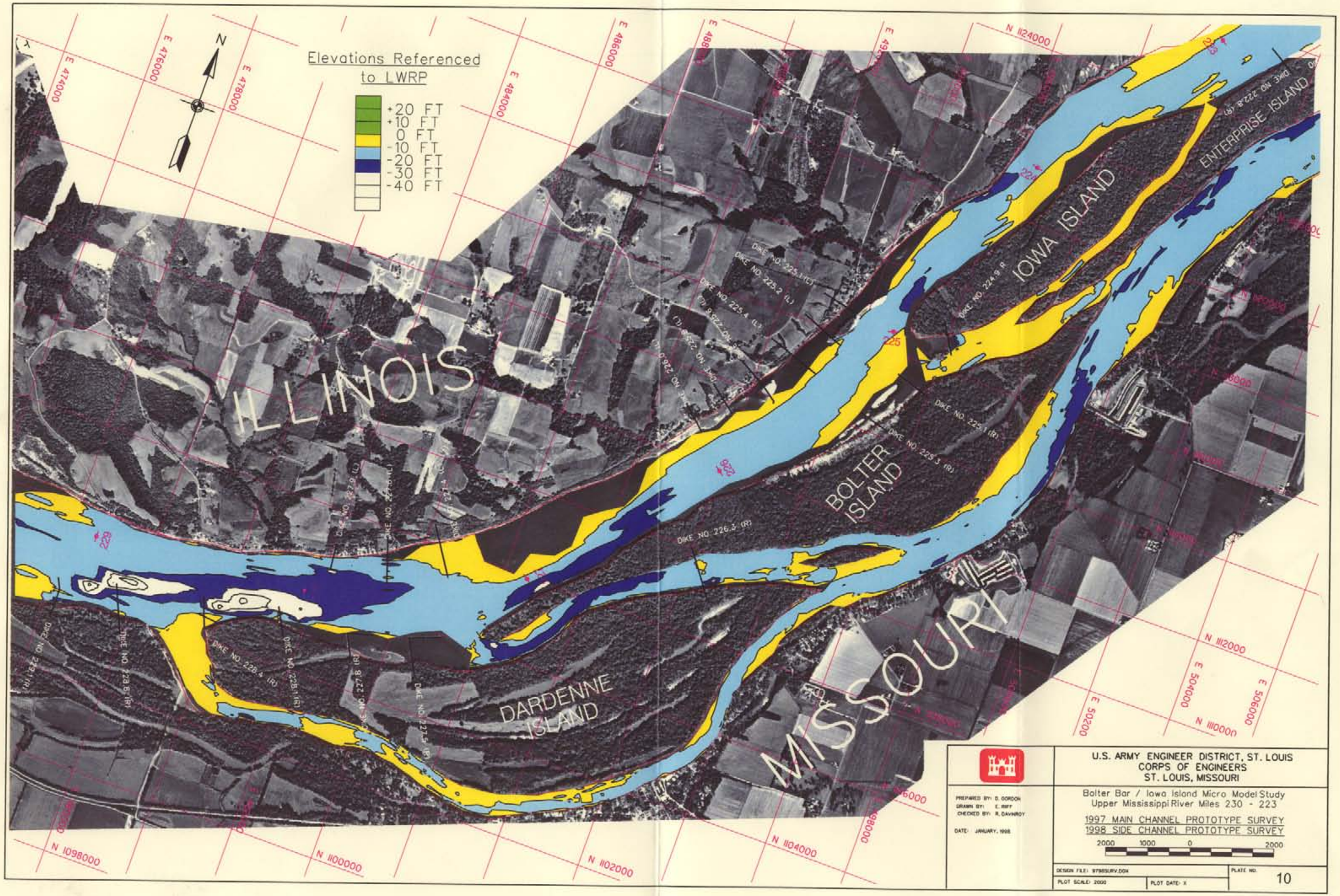

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Upper Mississippi River Miles 230 - 223

1997 MAIN CHANNEL PROTOTYPE SURVEY
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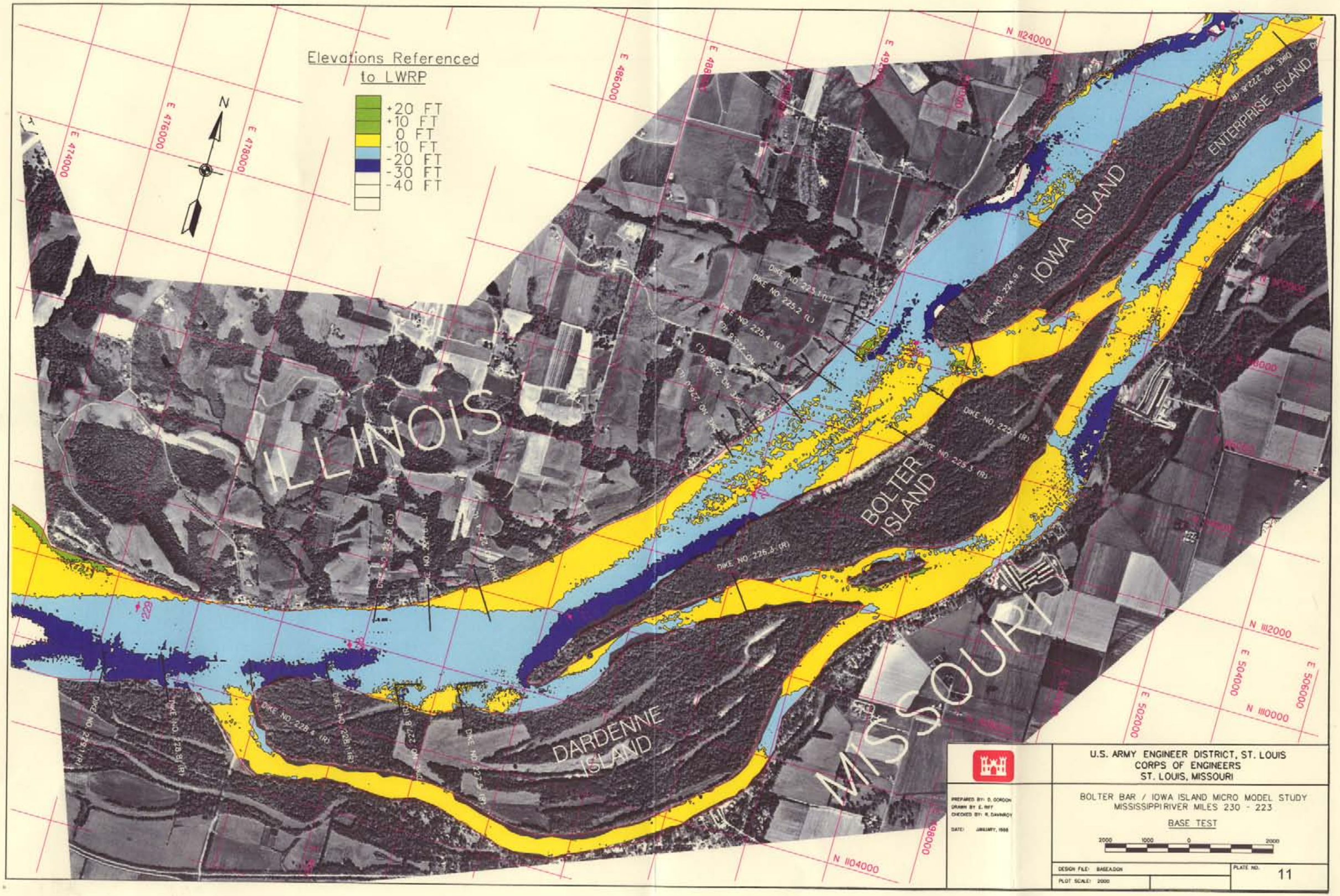
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BOLTER BAR / IOWA ISLAND MICRO MODEL STUDY
MISSISSIPPI RIVER MILES 230 - 223
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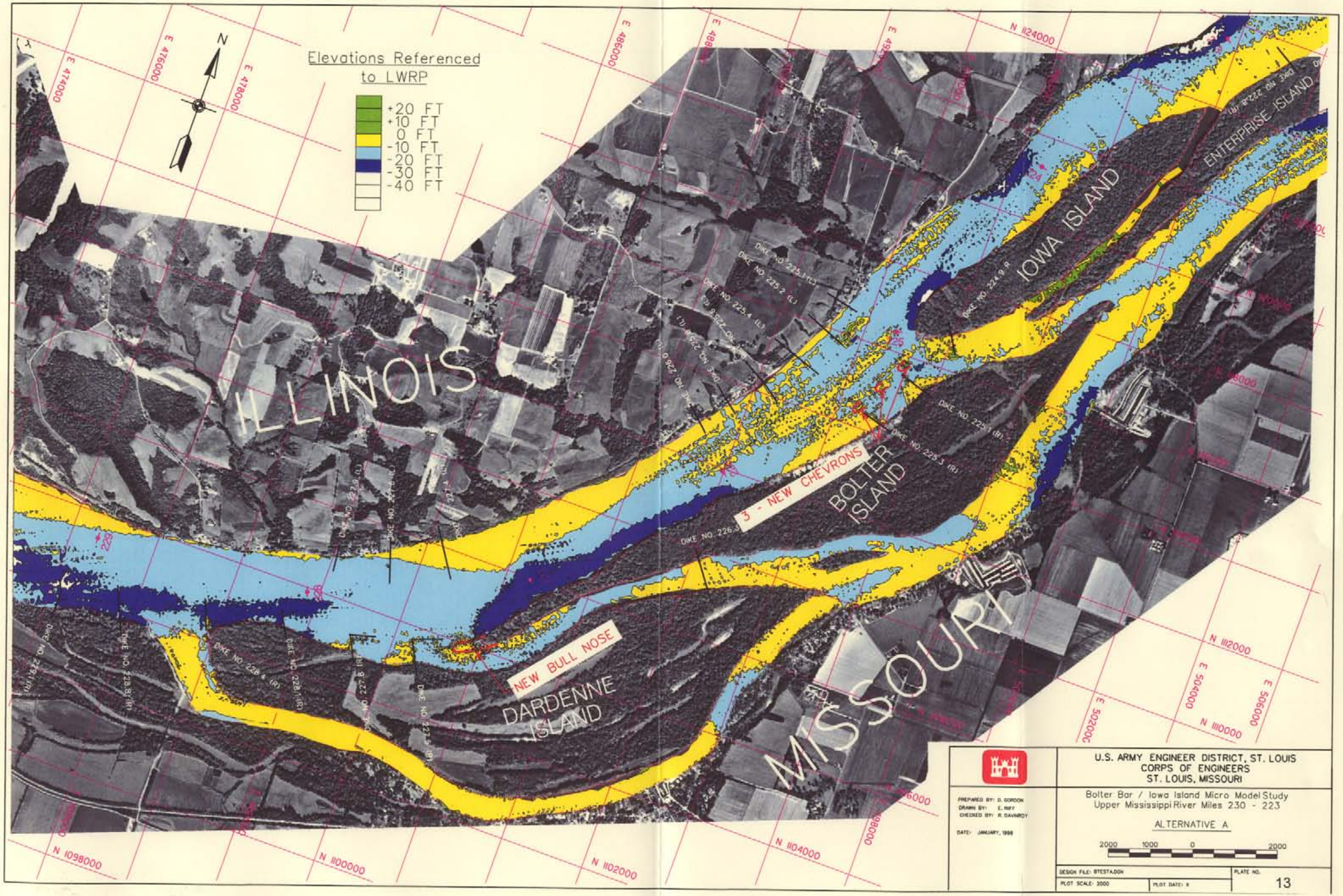

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Bolter Bar / Iowa Island Micro Model Study
Upper Mississippi River Miles 230 - 223

ALTERNATIVE A

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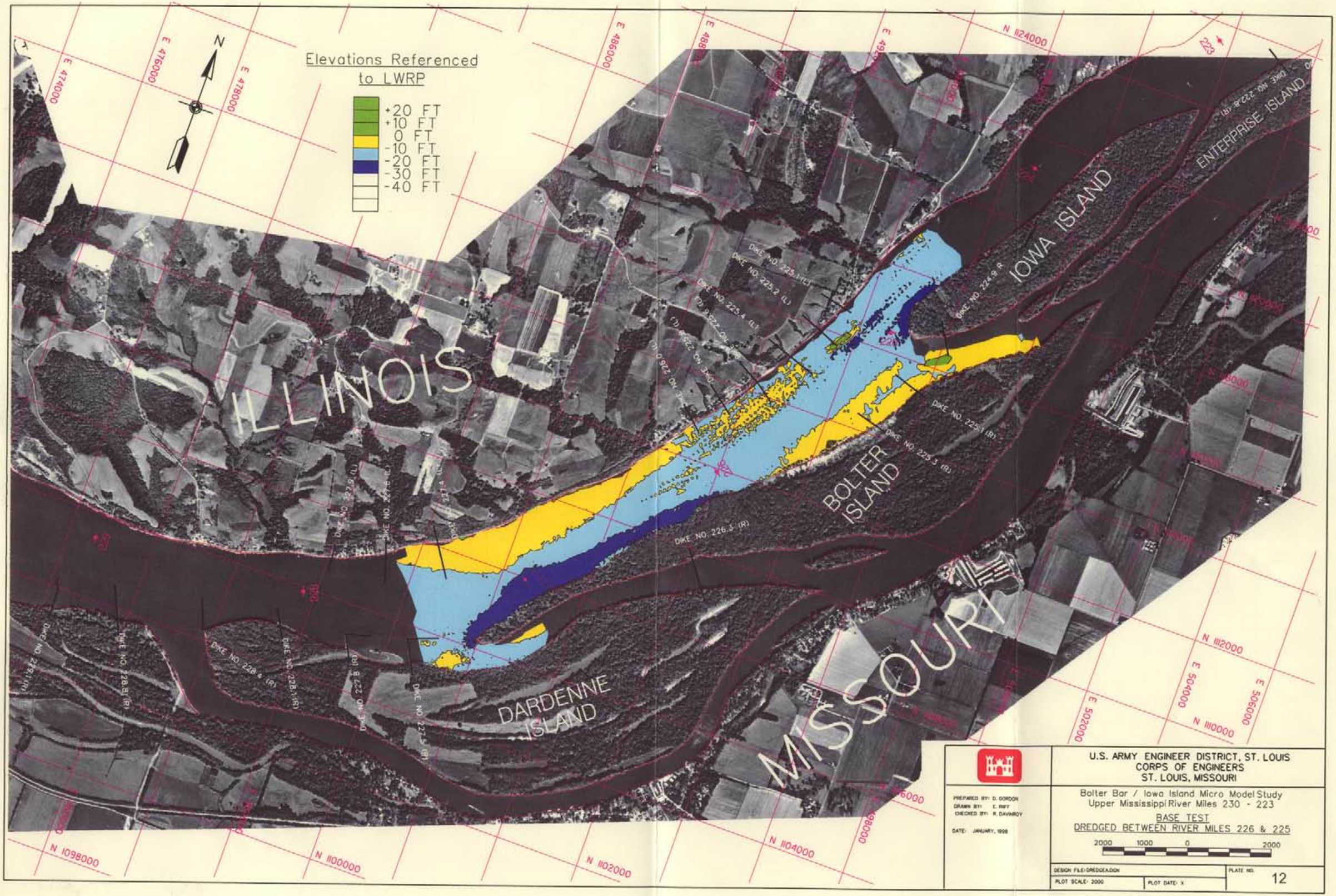
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CHECKED BY: R. DAVINROY
DATE: JANUARY, 1998
Bolter Bar / Iowa Island Micro Model Study
Upper Mississippi River Miles 230 - 223
BASE TEST
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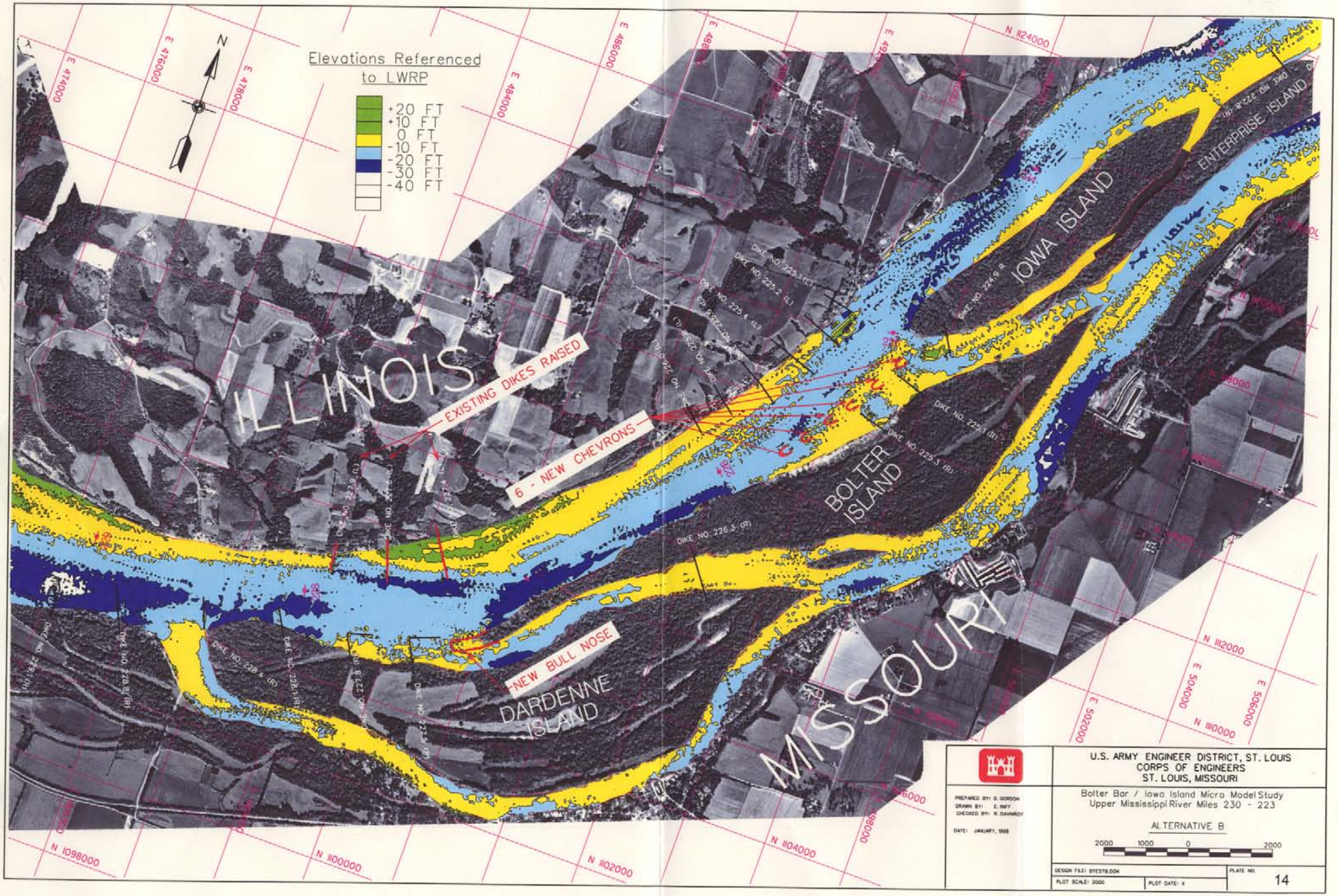

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PREPARED BY: D. GORDON
DRAWN BY: E. RIFF
CHECKED BY: R. DAVIMROY
DATE: JANUARY, 1998

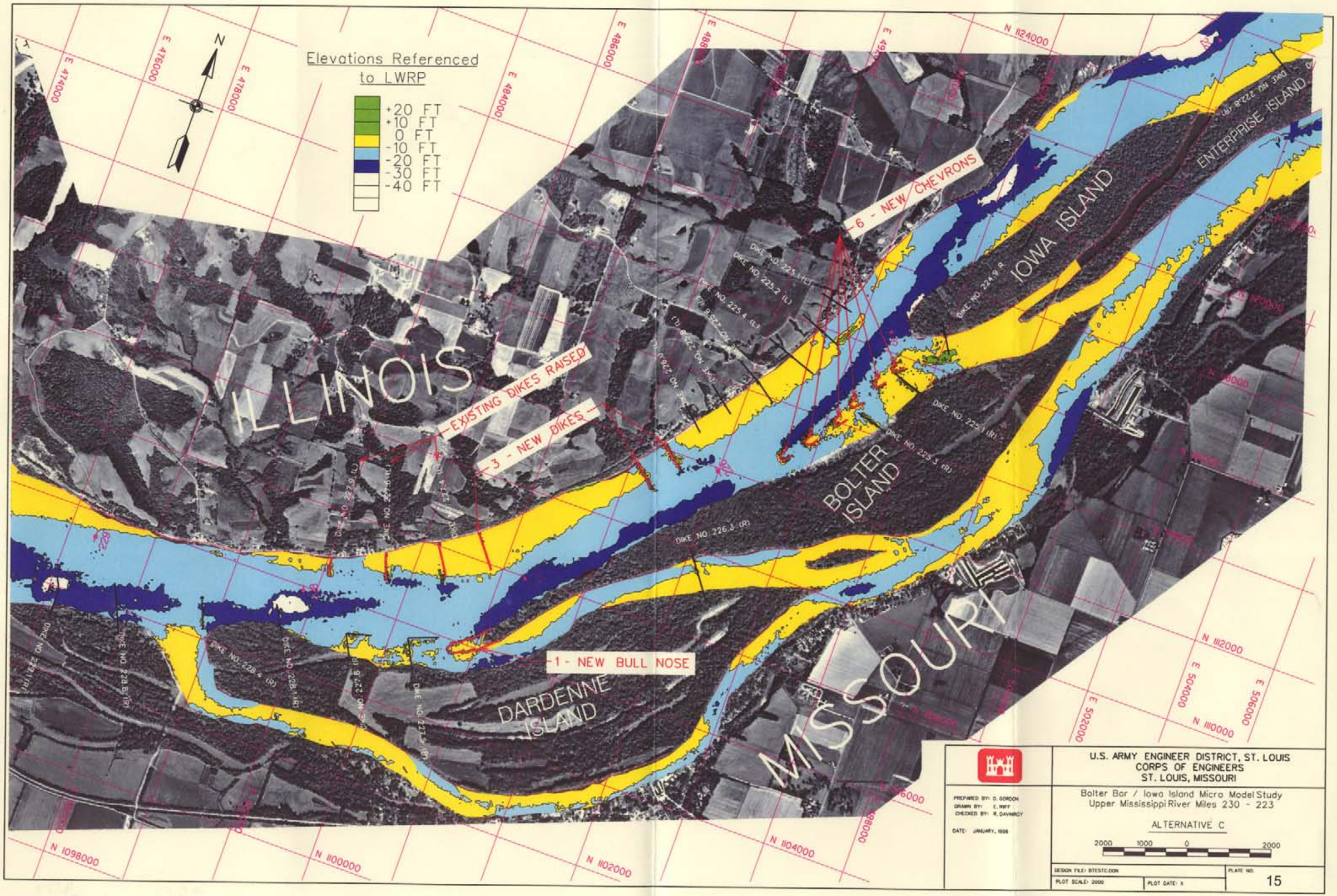
Bolter Bar / Iowa Island Micro Model Study
Upper Mississippi River Miles 230 - 223

ALTERNATIVE B

2000 1000 0 2000

DESIGN FILE: BTESTB.DGN
PLOT SCALE: 2000
PLOT DATE: X

PLATE NO. 14



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Upper Mississippi River Miles 230 - 223

ALTERNATIVE C

2000 1000 0 2000

DESIGN FILE: BTESTC.DGN
PLOT SCALE: 2000
PLOT DATE: X

PLATE NO. 15

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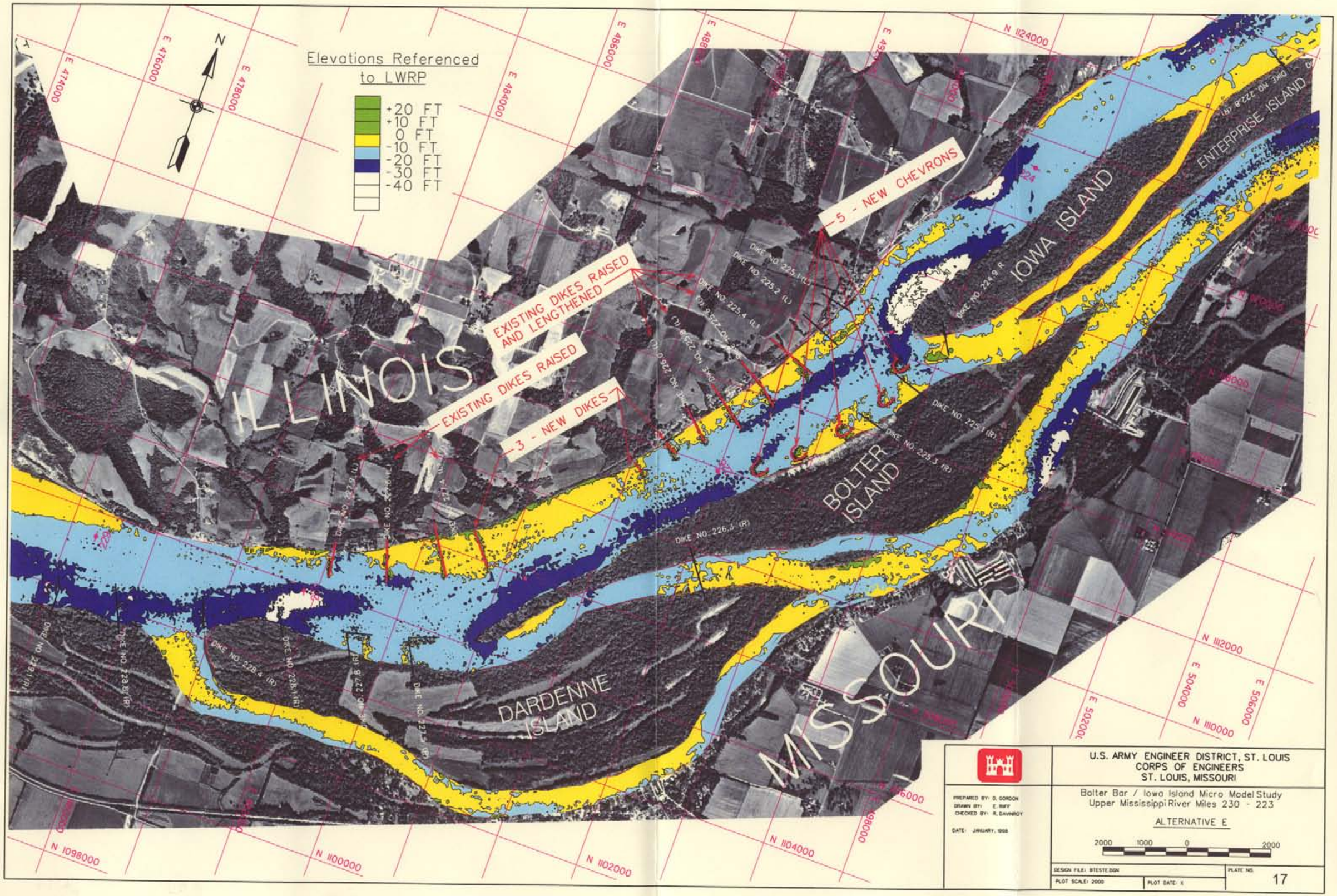
Bolter Bar / Iowa Island Micro Model Study
Upper Mississippi River Miles 230 - 223

ALTERNATIVE D

2000 1000 0 2000

DESIGN FILE: BTEST0.DGN
PLOT SCALE: 2000
PLOT DATE: X

PLATE NO. 16



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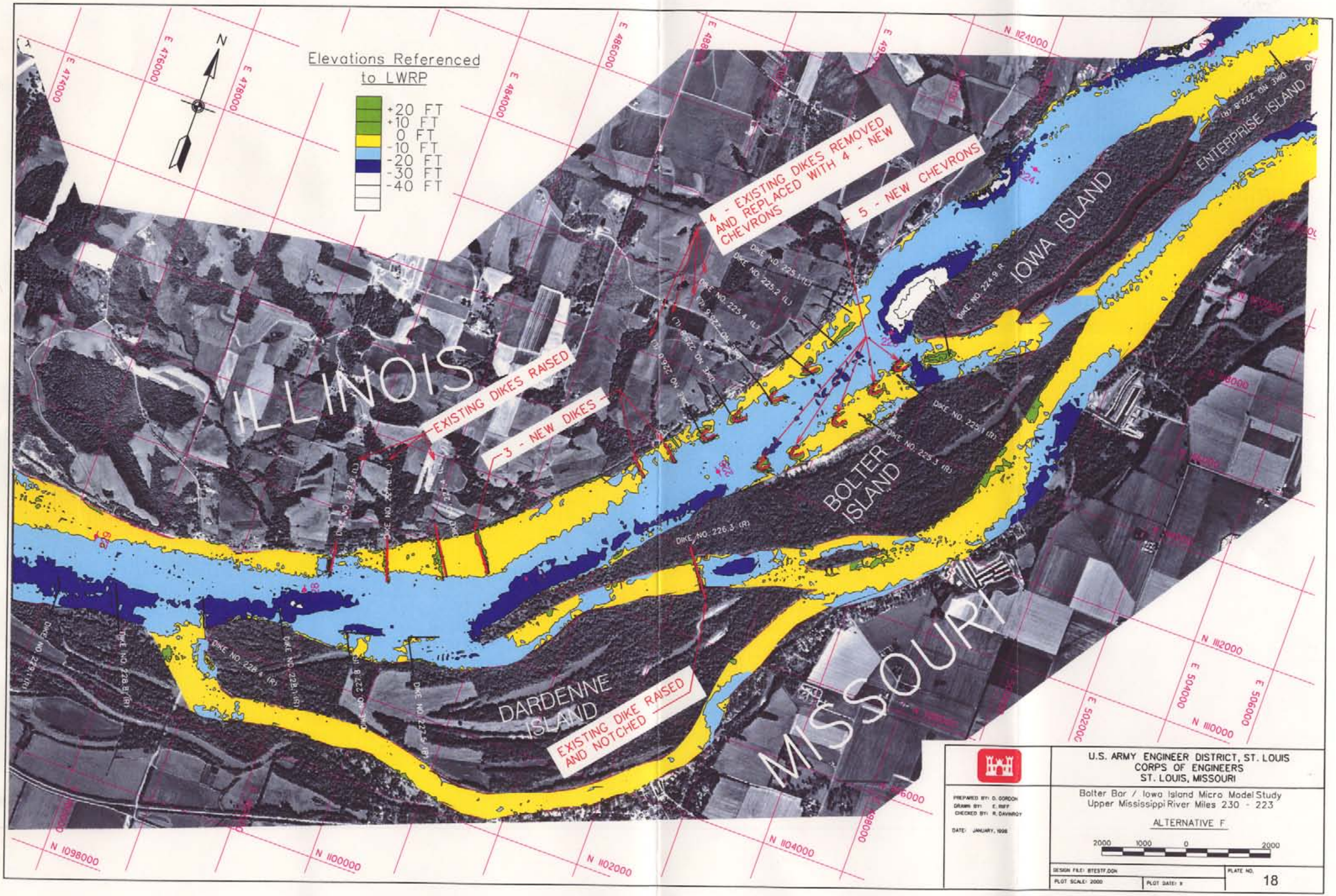
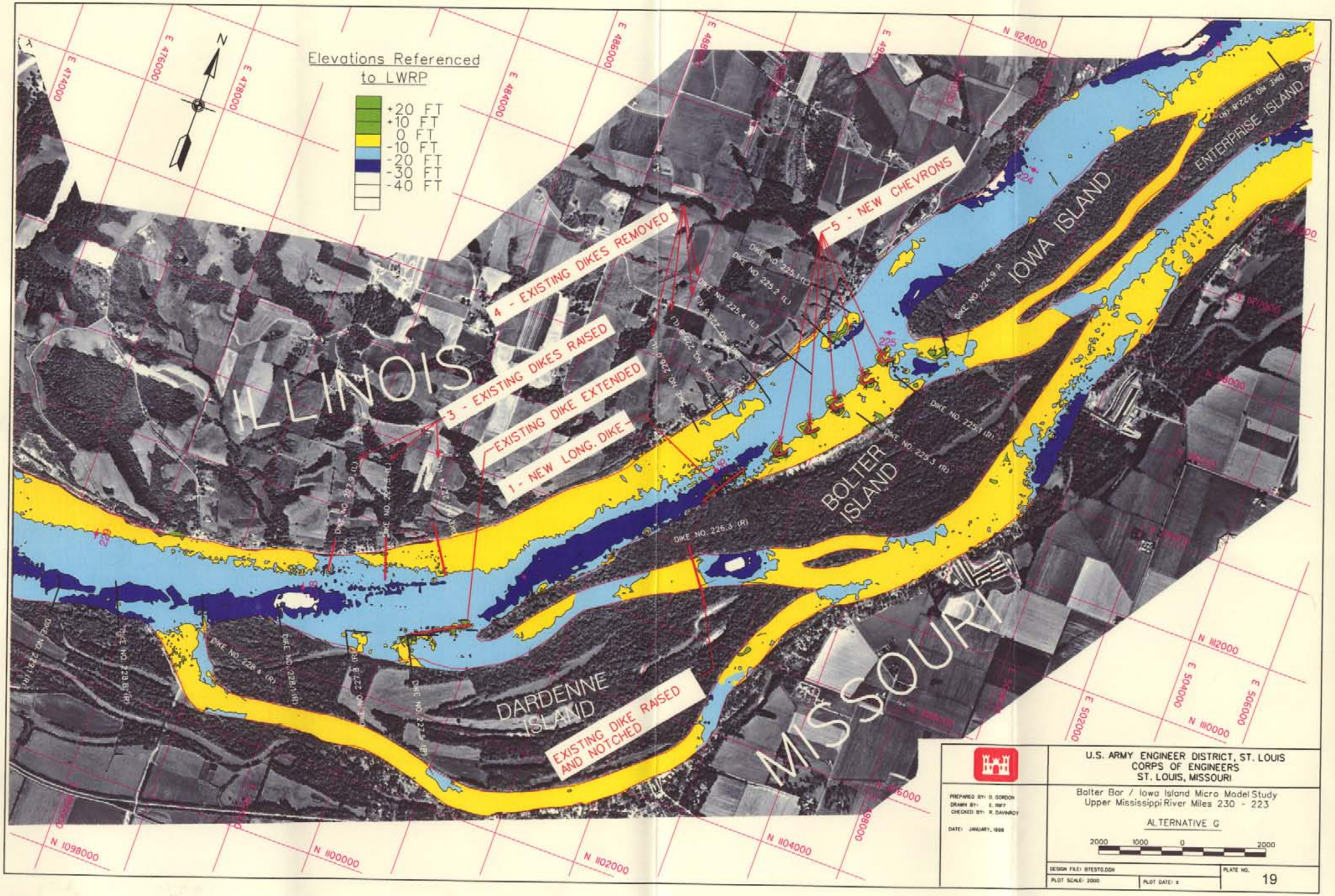
Bolter Bar / Iowa Island Micro Model Study
Upper Mississippi River Miles 230 - 223

ALTERNATIVE E

2000 1000 0 2000

DESIGN FILE: BTESTE.DGN
PLOT SCALE: 2000
PLOT DATE: X
PLATE NO. 17


Elevations Referenced to LWRP
+20 FT
+10 FT
0 FT
-10 FT
-20 FT
-30 FT
-40 FT
N
ILLINOIS
MISSOURI
IOWA ISLAND
ENTERPRISE ISLAND
BOLTER ISLAND
DARDENNE ISLAND
EXISTING DIKES RAISED
3 - NEW DIKES
4 - EXISTING DIKES REMOVED AND REPLACED WITH 4 - NEW CHEVRONS
5 - NEW CHEVRONS
EXISTING DIKE RAISED AND NOTCHED
DIKE NO. 226.3 (R)
DIKE NO. 224.9 R
DIKE NO. 225.1 (R)
DIKE NO. 225.3 (R)
DIKE NO. 225.4 (L)
DIKE NO. 225.2 (L)
DIKE NO. 228.6 (R)
DIKE NO. 228.1 (R)
DIKE NO. 227.8 (R)
DIKE NO. 227.5 (R)
DIKE NO. 229.1 (R)
DIKE NO. 228.8 (R)
DIKE NO. 228.0 (L)
DIKE NO. 228.9 (L)
DIKE NO. 228.8 (R)
N 1098000
N 1100000
N 1102000
N 1104000
N 1112000
N 1110000
N 1124000
E 474000
E 476000
E 478000
E 484000
E 486000
E 492000
E 502000
E 504000
E 506000
PREPARED BY: D. GORDON
DRAWN BY: E. RIFF
CHECKED BY: R. DAVINROY
DATE: JANUARY, 1998
U.S. ARMY ENGINEER DISTRICT, ST. LOUIS
CORPS OF ENGINEERS
ST. LOUIS, MISSOURI
Bolter Bar / Iowa Island Micro Model Study
Upper Mississippi River Miles 230 - 223
ALTERNATIVE F
2000 1000 0 2000
DESIGN FILE: BTESTF.DGN
PLOT SCALE: 2000
PLOT DATE:
PLATE NO.
18



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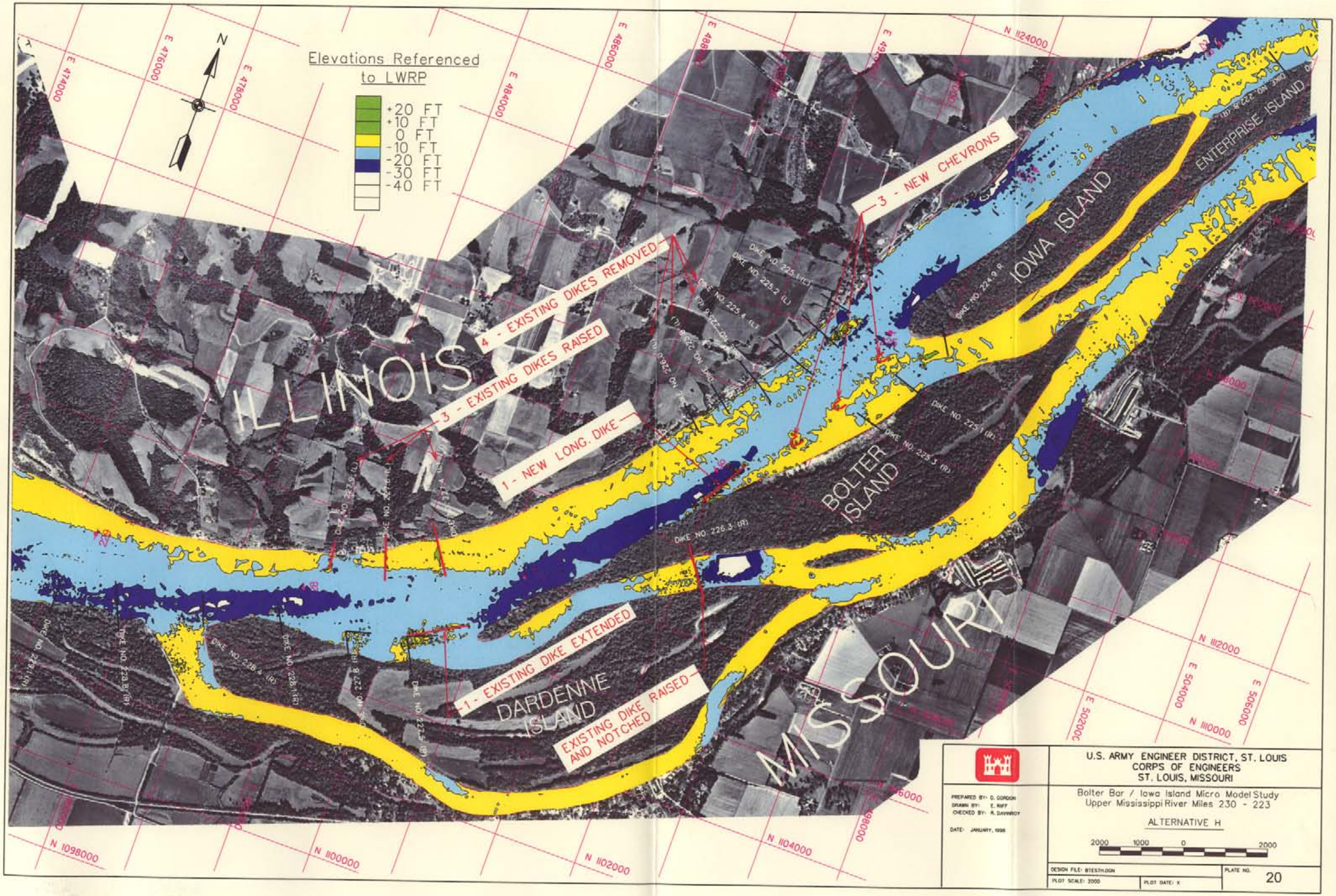
Bolter Bar / Iowa Island Micro Model Study
Upper Mississippi River Miles 230 - 223

ALTERNATIVE G

2000 1000 0 2000

DESIGN FILE: BTEST0.DGN
PLOT SCALE: 2000
PLOT DATE: X

PLATE NO. 19



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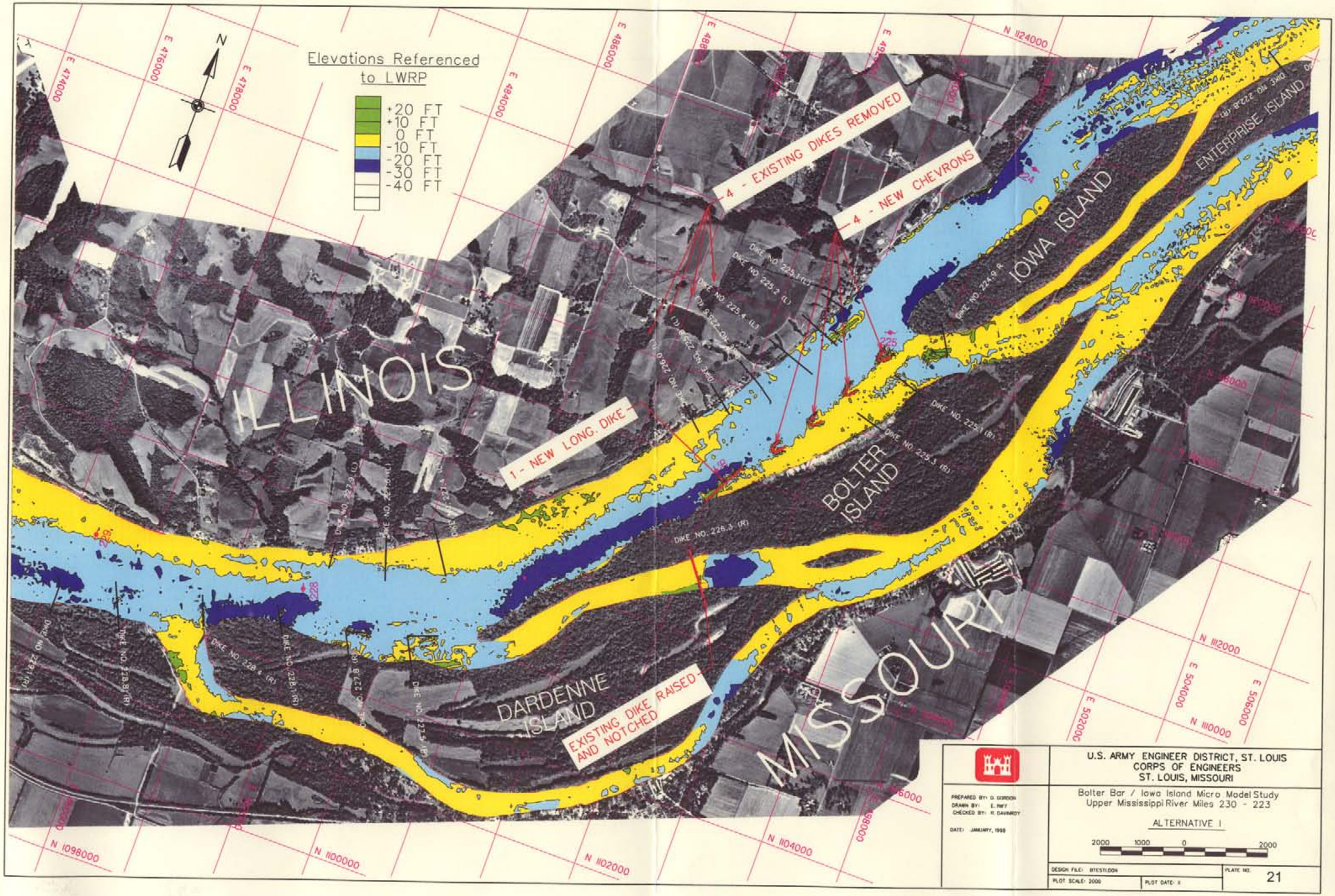
Bolter Bar / Iowa Island Micro Model Study
Upper Mississippi River Miles 230 - 223

ALTERNATIVE H

2000 1000 0 2000

DESIGN FILE: BTESTH.DGN
PLOT SCALE: 2000
PLOT DATE: X

PLATE NO. 20



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Bolter Bar / Iowa Island Micro Model Study
Upper Mississippi River Miles 230 - 223

ALTERNATIVE I

2000 1000 0 2000

DESIGN FILE: BTESTLOON
PLOT SCALE: 2000
PLOT DATE: X

PLATE NO. 21