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US Army Corps of Engineers
St. Louis District

THEBES STONE DIKE REVETMENT HYDRAULIC SEDIMENT RESPONSE MODEL STUDY UPPER MISSISSIPPI RIVER MILES

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ST. LOUIS DISTRICT
HYDROLOGIC AND HYDRAULICS BRANCH
APPLIED RIVER ENGINEERING CENTER
FOOT OF ARSENAL STREET
ST. LOUIS, MISSOURI 63118

Sponsored by and Prepared for:
U. S. Army Corps of Engineers—St. Louis District,
Regulating Works Stone Dike Alteration Program

In Cooperation With:
Illinois Department of Natural Resources
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U.S. Fish and Wildlife Service

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INTRODUCTION

The U.S. Army Corps of Engineers, St. Louis District initiated a study of the Upper Mississippi River between Miles 43.0 and 35.0, approximately nine miles downstream of Cape Girardeau, Missouri. The study's main purpose was to evaluate design alternatives to the existing stone dike configurations in this reach of the river with intent to improve environmental habitat.

Ms. Mary M. Miles, P.E., hydraulic engineer and Mr. Edward H. Riff, engineering technician, under direct supervision of, Mr. David C. Gordon, P.E., hydraulic engineer and Mr. Robert D. Davinroy, P.E., Chief of River Engineering, conducted the study between March 2007 and December 2009. Other personnel also involved with the study included: Mr. Leonard Hopkins, P.E., Chief of Hydraulics and Hydrology Section, June Jeffries, P.E., Project Manager for Regulation Works, Mr. Brian Johnson and Mr. Ken Cook from the Environmental Branch of the Planning, Programs, and Project Management Division, Mr. Lance Engle, Dredging Project Manager. Personnel from other agencies involved in the study included: Mr. Butch Atwood from the Illinois Department of Natural Resources, and Ms. Joyce Collins from the U.S. Fish and Wildlife Service, and Mr. David Ostendorf from the Missouri Department of Conservation.

TABLE OF CONTENTS

LIST OF TABLES

BACKGROUND

Hydraulic Sediment Response (HSR) modeling methodology was used to evaluate sediment transport conditions and the impact associated with the incorporation of future design alternatives along a reach of the Upper Mississippi River between River Miles (RM) 43.0 to 35.0. The study was funded by the Regulation Works Project as part of the Stone Dike Alteration Program of the U. S. Army Corps of Engineers, St. Louis District.

The goal of this study was to diversify aquatic habitat in this reach of the Upper Mississippi River by modifying existing dike structures, and developing new side channels and bar formations while maintaining the integrity of the navigation channel.

1. Study Reach

The study reach was located approximately nine miles downstream of Cape Girardeau, Missouri. The reach modeled was approximately eights miles of the Upper Mississippi River, between RM 43.0 and 35.0. The model included calibrated stretches from RM 41.5 to approximately 37.0 (including the side channel portions of the model). Plate 1 is a location and vicinity map of the study reach. The study area was located in Scott County, Missouri and Alexander County in Illinois. Both the Missouri and Illinois sides of the river were studied for environmental improvements.

Plate 5 is a 2006 aerial photograph illustrating the planform and nomenclature of the Upper Mississippi River between RM 43.0 and 35.0. The left descending bank (LDB) was composed of a series of islands, developing islands, and side channels. The right descending bank (RDB) was composed of a series of river training structures and rock outcroppings. New and old growth of cottonwoods and willows were prevalent on both the RDB and LDB.

At the time of this study, the entire study reach had a total of 60 dikes. Dikes 40.4L, 40.0L, and 39.6L act as closure structures on the LDB. Six dikes are longitudinal dikes, nine dikes act as hardpoints in Santa Fe Chute and six dikes are remnant wood pilings. At the time of this study, construction plans were scheduled for five chevrons, one dike and one weir in the main channel of the study area. Table 1 lists all the existing river training structures in the study reach and approximate dike descriptions obtained from an April 2000 helicopter field visit. The dike fields are shown on Plate 5.

Table 1: Existing River Training Structures

Structure Name	Length from Bank (feet)	Approximate Top Elevation (feet) Taken From Aerial Photos	Approximate Height Above LWRP (Nearest half foot)	Date of Readings
MAIN CHANNEL STRUCTURES				
DIKE NO. 42.8 L	720	315.0	11.0	April 6, 2000
LONGITUDINAL DIKE NO. 42.8 L		315.0	11.0	April 6, 2000
DIKE NO. 42.5 L	980	Underwater		April 6, 2000
DIKE NO. 42.3 L		-	-	April 6, 2000
DIKE NO. 42.1 R	280	310.5	6.5	April 6, 2000
DIKE NO. 41.9 R		-	-	April 6, 2000
DIKE NO. 41.7 R	350	311.5	8.0	
DIKE NO. 41.7 L	1140	311.5	8.0	April 6, 2000
LONGITUDINAL DIKE 41.7 L		311.5	8.0	April 6, 2000
LONGITUDINAL DIKE 41.7 L		311.5	8.0	April 6, 2000
DIKE NO. 41.6 L	370	311.5	8.0	April 6, 2000
DIKE NO. 41.4 R	130	Underwater		April 6, 2000
LONGITUDINAL DIKE NO. 41.4 R		Underwater		April 6, 2000
DIKE NO. 41.4 L	1470	312.0	8.5	April 6, 2000
DIKE NO. 41.0 R		-	-	April 6, 2000
DIKE NO. 40.8 R	350	Underwater		April 6, 2000
DIKE NO. 40.6 R		-	-	April 6, 2000
DIKE NO. 40.6 L	1180	312.0	9.0	April 6, 2000
DIKE NO. 40.4 L	900	312.0	9.0	April 6, 2000
DIKE NO. 40.2 R	440	311.5	9.0	April 6, 2000
DIKE NO. 40.0 R	300	311.5	9.0	April 6, 2000
DIKE NO. 40.0 L		-	-	April 6, 2000
DIKE NO. 39.7 R	320	311.5	9.0	April 6, 2000
DIKE NO. 39.6 L	1020	311.5	9.5	April 6, 2000
LONGITUDINAL DIKE NO. 39.6 L		311.5	9.5	April 6, 2000
DIKE NO. 39.4 R	250	311.5	9.5	April 6, 2000
DIKE NO. 39.1 R	300	312.0	10.0	April 6, 2000
DIKE NO. 38.9 R	340	312.0	9.5	April 6, 2000

Table 1: Existing River Training Structures (continued)

DIKE NO. 38.6 R	450	Underwater		April 6, 2000
DIKE NO. 38.4 R	550	311.0	10.0	April 6, 2000
DIKE NO. 38.3 L	220	312.0	11.0	April 6, 2000
DIKE NO. 38.2 R	360	311.0	10.0	April 6, 2000
DIKE NO. 38.0 R	230	312.0	11.0	April 6, 2000
DIKE NO. 38.0 L	480	312.0	11.0	April 6, 2000
DIKE NO. 37.8 R	420	310.5	9.5	April 6, 2000
DIKE NO. 37.7 L	Remnant Wood Piling			August 15, 2007
DIKE NO. 37.6 R	270	311.5	11.0	April 6, 2000
DIKE NO. 37.5 L	420	311.5	11.0	April 6, 2000
DIKE NO. 37.4 L	Remnant Wood Piling			August 15, 2007
DIKE NO. 37.2 L	500	310.5	10.0	April 6, 2000
DIKE NO. 37.1 L	Remnant Wood Piling			August 15, 2007
DIKE NO. 36.7 L	450	310.0	10.0	April 6, 2000
DIKE NO. 36.5 L	500	310.0	10.0	April 6, 2000
DIKE NO. 36.2 L	430	Underwater		April 6, 2000
DIKE NO. 35.9 L	450	311.0	11.5	April 6, 2000
DIKE NO. 35.7 L	Remnant Wood Piling			August 15, 2007
DIKE NO. 35.5 L	350	311.75	13.0	April 6, 2000
DIKE NO. 35.2 L	Remnant Wood Piling			August 15, 2007
DIKE NO. 35.1 R	380	310.59	12.0	April 6, 2000
LONGITUDINAL DIKE NO. 35.1 R		310.59	12.0	April 6, 2000
Side Channel Structures				
DIKE NO. 41.4 L (CLOSURE STURCTURE)		Not Measured		Not Applicable
DIKE NO. 40.0 L (CLOSURE STRUCTURE)	Remnant Wood Piling			August 15, 2007
DIKE NO. 39.6 L (CLOSURE STRUCTURE)		Not Measured		Not Applicable
DIKE NO. 35.0 L	1000	310.55	12.0	April 6, 2000
DIKE NO. 38.7 L (HARD POINT)	300	-	-	-
DIKE NO. 38.4 L (HARD POINT)	300	-	-	-
DIKE NO. 38.1 L (HARD POINT)	300	-	-	-
DIKE NO. 37.7 L (HARD POINT)	300	-	-	-
DIKE NO. 37.5L (HARD POINT)	300	-	-	-
DIKE NO. 37.3 L (HARD POINT)	300	-	-	-
DIKE NO. 37.15 L (HARD POINT)	300	-	-	-
DIKE NO. 37.05 L (HARD POINT)	300	-	-	-
DIKE NO. 39.6 L (HARD POINT)	300	-	-	-

2. Study Goal

The Stone Dike Alteration Program was initiated by the St. Louis District to improve environmental habitat in reaches of the Middle Mississippi River with flow patterns that have been established by stone dikes. Reaches of the Mississippi River and priorities of those reaches were agreed upon by the St. Louis District Corps of

Engineers, the U. S. Fish and Wildlife Agency, Missouri Department of Conservation and the Illinois Department of Natural Resources. The primary goal of this study was to investigate alterations, additions or subtractions to the existing dike configurations in the Thebes reach that will provide increased environmental diversification while not negatively impacting the navigation channel.

3. History

The construction of river training structures has caused the river channel study reach to change over time.

1928 aerial photos (Plate 2) of the project area showed no river training structures in the study reach. Thebes Bridge, located just upstream of the study reach, was constructed between 1902 and 1905. Differences between the 1928 and 2006 aerial photos can be seen on Plates 2 & 5. The main differences existed in the island structures along the LDB and the constriction of the main channel along the entire study reach of the main channel.

1956 sounding maps (Plate 3) showed that most of today's structures were already in place. Differences between the 1956 sounding maps and 2006 aerial photos can be seen on Plates 3 & 5. Again, the main differences existed in the island structures along the LDB and the constriction of the main channel along the entire study reach of the main channel. Islands were starting to develop due to the construction of the dike fields along the LDB.

1970 aerial photos (Plate 4) of the project area showed a channel configuration very similar to that shown in the 2006 aerial photos (Plate 5).

Table 2 lists the variation in main channel width between the aerial photos and sounding maps listed above.

Table 2: Main Channel Width take from Aerial Photography by Year and River Mile (RM) as Designated in 2006

Year	RM 43	RM 42	RM 41	RM 40	RM 39	RM 38	RM 37	RM 36	RM 35	AVG.
1928	2300 ft	3500 ft	3300 ft	3500 ft	3000 ft	2600 ft	3900 ft	2000 ft	2000 ft	2900 ft
1956/ 1957	-	2500 ft	2600 ft	2300 ft	1200 ft	2000 ft	2100 ft	2000 ft	2100 ft	2100 ft*
1970	2000 ft	2400 ft	3000 ft	2300 ft	2000 ft	2000 ft	1700 ft	2000 ft	2200 ft	2200 ft
2006	1700 ft	3000 ft	3200 ft (Island on LDB)	2100 ft (Island on LDB)	1800 ft	1700 ft	1600 ft	1850 ft	2000 ft	2100 ft
AVG.	2000 ft*	2850 ft	3025 ft	2550 ft	2000 ft	2075 ft	2325 ft	1950 ft	2075 ft	

*1956/1957 not included in average

Dredging totals for two mile reaches of the river are shown in Table 3

Table 3: Dredging Totals

Total (1995-2006)	RM 44-42	RM 42-44	RM 40-38	RM 38-68
Occurrences	3	3	8	1
Cubic Yards x (100)	7,333	6,147	20,217	1,275

4. Field Observations

Personnel from the Applied River Engineering Center inspected the study reach. These reconnaissance missions allowed the site to be photographed and studied. The site visits are described below.

August 15 and 16, 2007:

The Thebes, Illinois gage (RM 43.7) was at a stage of 15.1 ft / +10.1 ft LWRP on August 15 and 14.1 ft / +9.1 ft LWRP on August 16.

Velocity data was taken on this site visit. The results are as follows.

Table 4: Field Visit Velocity and Depth Readings

River Mile	Channel Location	Depth (ft)	Velocity (ft/s)
43	Downstream of Thebes Bridge, Mid-channel	50	5.7
41.2	Side-channel, Upstream of Santa Fe Chute	22	2.4
37	Mid-channel	29.5	3.5
35	Illinois Side, Main-channel side of Santa Fe Chute	18	3.6
35	Mid-channel	23	3.2

The shore lines had abundant vegetation, mostly in the form of willows varying in height. Some vegetation was observed on existing river training structures.

Santa Fe Chute had gravel bars just downstream of closure structure 39.6L. Depth was available in Santa Fe Chute for jon boat access to existing sandbar (one-third the way up side-channel).

HYDRAULIC SEDIMENT RESPONSE (HSR) MODEL DESCRIPTION

1. Scales and Bed Materials

A physical HSR model was designed and constructed to investigate the sediment transport conditions described previously. Plate 6 is a photograph of the HSR model used in this study. The zero reference plane of the prototype was assumed to be at the LWRP (Low Water Reference Plane) condition. The model employed a horizontal scale of 1 inch = 500 ft, or 1:6000, and a vertical scale of 1 inch = 55 ft, or 1:660, for a 9.1 to 1 distortion ratio of linear scales. 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 HSR model insert was constructed according to 2006 aerial photography of the study reach. The insert was then mounted in a standard HSR flume. The riverbanks of the model were constructed from dense polystyrene foam. Rotational jacks located within the hydraulic flume controlled the slope of the model. The measured slope of the insert and flume was approximately 0.01 inch/ inch. 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 control the flow of water and sediment into the model. Discharge was monitored by a magnetic flow meter interfaced with the customized computer software. Water stages were manually checked with a mechanical three-dimensional point digitizer. Resultant bed configurations were measured and recorded with a three-dimensional laser digitizer.

HSR MODEL TESTS

1. Model Calibration

The calibration of the HSR model involved the adjustment of water discharge, sediment volume, model slope, and entrance and exit conditions of the model. These parameters were refined until the measured bed response of the model was similar to that of the prototype.

A. HSR Model Operation

In all model tests, a steady state flow was simulated in the Upper Mississippi River channel. This served as the average design energy response for the river. This steady state was used to theoretically analyze the ultimate expected sediment response. The flow was held steady at a constant flow rate of approximately 1.8 gallons per minute (GPM) during model calibration and for all design alternative tests. The most important factor during the modeling process is the establishment of an equilibrium condition of sediment. The steady flow in the model simulated an average energy condition representative of the river's channel forming flow and sediment transport potential at bankfull stages.

B. Prototype Data and Observations

To determine the general bathymetric characteristics and sediment response trends that existed in the prototype, several present and historic hydrographic surveys were examined. Comprehensive hydrographic surveys were taken in 1970, 1989, 1995, 1998, 2000, 2001, and 2005 (Plates 7, 8, 9, 10, 11, 12, and 13). A 2001 detailed channel and side channel sweep survey of the study reach, between approximately River Miles 40.4L and 35.0L is shown on Plate 12. All of the comprehensive surveys listed above had similar bathymetric trends to each other and were used to calibrate the hydraulic sediment response model. The trends of the river in the 1989 survey were similar to the other years, but the depths were shallower due to drought conditions.

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

- At the entrance of the study reach, the thalweg was located along the LDB near RM 43.0 with depths up to approximately -30 ft LWRP.
- A rock outcropping existed on both the LDB (entrance of model to RM 43.4) and RDB (RM 43.6 to 42.9).
- Scour holes of various sizes existed off the tips of all dikes within the reach. A large scour hole existed between RM 40.7 and 40.5 on the RDB and reached depths of -40 to -50 ft LWRP. Another large scour hole was observed off the tip of Dike 39.6L and reached depths of -40 to -50 ft LWRP.
- A channel crossing from the LDB to the RDB began at RM 43.0 and ended at RM 42.0. A dredging problem existed within this crossing with some depths surveyed as shallow as -6 to -10 ft LWRP.
- The channel remained along the RDB from RM 42.0 to 40.0 with depths ranging between -15 ft to -30 ft LWRP.
- A channel crossing from the RDB to the LDB began at RM 40.0 and ended at RM 38.5. Dike No. 39.6R forced the thalweg back over to the LDB. A dredging area existed in the crossing between river mile 40.0 and 38.4 with depths as shallow as -5 ft LWRP.
- The channel remained along the RDB from RM 38.5 to 35.0 with depths ranging between -15 ft to -30 ft LWRP. Shoaling existed along the LDB between RM 35.0 to the end of the study reach.

C. Scheduled Construction

At the time of the study several river training structures were scheduled to be constructed in this reach of river. These scheduled construction projects were placed in the model after the model was calibrated with current river structures. Structure dimensions were taken from construction plans. Future, scheduled river structures are shown on Plate 14. A list of structures scheduled for construction is shown on Table 5.

Table 5: Planned Construction of River Training Structures

River Mile	Construction Date	Status	Elevation (LWRP)
DIKE NO. 40.4 L	Fiscal Year 2010	200 ft Dike Extension	Elev. 318 ft
DIKE NO. 40.4 L	Fiscal Year 2010	100 ft Notch	Elev. 305 ft
WEIR NO. 39.6 L	Fiscal Year 2010	Existing Dike Attachment	Elev. 287 ft
DIKE NO. 36.7 L	Fiscal Year 2010	150' Partial Dike Removal	Existing Grade
CHEVRON 36.7 L	Fiscal Year 2010	New	Elev. 316 ft
DIKE NO. 36.5 L	Fiscal Year 2010	220' Partial Dike Removal	Existing Grade
CHEVRON 36.5 L	Fiscal Year 2010	New	Elev. 316 ft
DIKE NO. 36.2 L	Fiscal Year 2010	57' Partial Dike Removal	Existing Grade
CHEVRON 36.2 L	Fiscal Year 2010	New	Elev. 315 ft
DIKE NO. 35.9 L	Fiscal Year 2010	235' Partial Dike Removal	Existing Grade
CHEVRON 35.9 L	Fiscal Year 2010	New	Elev. 315 ft

2. Base Test

Model calibration was achieved after it was determined through qualitative comparisons that the base test surveys were similar to several prototype surveys of the river. The resultant bathymetry of the base test is shown on Plate 15. The base test was developed from the simulation of successive repeatable steady state flow tests until bed stability was reached and a similar bed response was achieved as compared with prototype surveys. After the base test was achieved, the river training structures scheduled to be constructed and altered were added to the model. This base test survey (including the river training structures to be constructed and altered) served as the comparative bathymetry for all design alternative tests (Plate 16). Results of the HSR base test bathymetry (without river training structures to be constructed) and a comparison to the prototype surveys indicated the following trends:

- At the entrance of the study reach the thalweg was located along the LDB near RM 43.0 with depths up to approximately -30 ft LWRP.
- A rock outcropping was placed on both the LDB (entrance of model to RM 43.4) and RDB (RM 43.6 to 42.9).

- A channel crossing from the LDB to the RDB began at RM 43.0 and ended at RM 42.0. Shoaling existed in the crossing between RM 43.0 and 41.6. This section of the model was part of the entrance conditions.
- The channel remained along the RDB from RM 42.0 to 40.0 with depths ranging between -15 ft to -30 ft LWRP.
- A channel crossing from the RDB to the LDB began at RM 40.0 and ended at RM 39.0. Dike No. 39.6L forced the thalweg back over to the RDB.
- A shoaling area existed along the RDB between RM 40.5 and 39.0 with depths shallowing to -2 ft LWRP. A shallowing in the crossing between RM 40.0 and 38.0 exists with depths to -8 ft LWRP.
- The channel remained along the RDB from RM 38.0 to 35.0 with depths ranging between -10 ft to -30 ft LWRP. A shoaling existed along the LDB between RM 38.0 to the exit conditions of the model. The shoaling extending across the entire channel width starting at RM 36.5. This was due to exit conditions and the area is not considered as part of the calibrated model.
- Santa Fe Chute was not considered as part of the calibrated model. Sediment conditions were maintained in equilibrium throughout the modeling process but were not studied.

The main differences between the model (without river training structures to be constructed) and prototype surveys are:

- Entrance and exit conditions did not coincide with the prototype. The model was generally considered calibrated between RM 41.5 and 37.0. Areas outside of these locations were not used in the modeling process.
- Scour hole formations off the tips of most of the dikes were not as definite within the reach with the exception of Dike 39.6L.
- The scour hole surrounding Dike 39.6L was much larger than in the prototype due to constraints of the model and non-permeable surfaces used to mimic the restriction of water from the main channel into the side channel.

- Santa Fe Chute was not considered as part of the calibrated model. Sediment conditions were maintained in equilibrium throughout the modeling process but were not studied.

Results of the HSR base test bathymetry (including the river training structures to be constructed and altered) differed slightly from the base test. The differences are as follows:

- The crossing from RDB to LDB occurred a half mile upstream of that of the prototype. The crossing started at RM 40 in the prototype and at RM 39.5 in the model with construction. This early crossing was most likely caused by scheduled construction to existing Dikes 40.4L and 39.6L.
- The shallowing at the crossing starting at RM 39.0 was reduced due to scheduled construction.

In general, the overall bathymetric trends established in the HSR model base test were similar to those trends observed in the prototype. The main differences were the shallow depth or lack of scour holes behind most of the dikes in this stretch of the Upper Mississippi River. The depth of the scour holes shown in the prototype were most likely formed during high flow events. Since this model study simulated average design energy the scour holes were shallower in the base test.

3. Design Alternative Tests

All design alternatives studied in the HSR model utilized the existing dike configurations in the prototype surveys. All proposed construction as listed in Table 5 were utilized. Eleven design alternative plans were model tested to examine methods of modifying the sediment transport response trends that would foremost create greater environmental diversity in the study reach while not negatively impacting the navigation channel. The effectiveness of each design was evaluated by comparing the resultant bed configuration to that of the base test. Impacts or changes induced by each alternative were evaluated by observing the sediment response of the model.

Alternatives were considered successful if noticeable, increased environmental bed diversity occurred while not producing negative impacts to the navigation channel. Because of this loose criteria, an alternatives success was more subjective then when an alternative is used to find a decrease in sedimentations. Examples of alternatives that could be considered successful would produce secondary side channels, increase scour hole patterns, or increased flow to an existing side channel. Table 6 outlines the different alternatives that were run, defines if an alternative was successful or not, and shows brief comments about that alternative.

Table 6: HSR Model Alternatives and Evaluations

Alternative Number	Structure	Type of Structure	Dimension/Height (ft)	Alternative Successful	Comments
1 (Plate 17)	42.4L	Install Chevron	300 x 300/ +18 LWRP	No	This alternative was tested because it is part of future Master Plan designs. It showed what may be general trends from the structures, but was outside the range of the calibration of the model.
	42.2L	Install Chevron	301 x 300/ +18 LWRP		
	42.0L	Install Chevron	302 x 300/ +18 LWRP		
	41.8L	Install Chevron	303 x 300/ +18 LWRP		
	41.6L	Install Chevron	304 x 300/ +18 LWRP		
	41.4L	Install Chevron	305 x 300/ +18 LWRP		
2 (Plate 18)	41.0R	Remove Dike Section	200 / -15 LWRP	No	This alternative did not create additional diversity in the area. In addition, the changes could adversely affect planned construction work to Weir 39.6L.
	40.8R	Remove Dike Section	201 / -15 LWRP		
	40.6R	Remove Dike Section	202 / -15 LWRP		
	40.2R	Remove Dike Section	203 / -15 LWRP		
	40.0R	Remove Dike Section	204 / -15 LWRP		
3 (Plate 19)	41.0R	Notch Existing Dike	200/ +5 Grade	No	This alternative did not create additional diversity in the area. In addition, the changes could adversely affect planned construction work to Weir 39.6L.
	40.8R	Notch Existing Dike	200/ +5 Grade		
	40.6R	Remove Dike Section	200/ -15 LWRP		
	40.2R	Remove Dike Section	200/ -15 LWRP		
	40.0R	Remove Dike Section	200/ -15 LWRP		
4 (Plate 20)	41.0R	Notch Existing Dike	200/ +5 Grade	No	This alternative did not create additional diversity in the area. In addition, the changes could adversely affect planned construction work to Weir 39.6L. This alternative may be feasible in the future if dredging issues around RM 39.0 persist.
	40.8R	Notch Existing Dike	200/ +5 Grade		
	40.6R	Remove Dike Section	200/ -15 LWRP		
	40.2R	Remove Dike Section	200/ -15 LWRP		
	40.0R	Remove Dike Section	200/ -15 LWRP		
	39.8L	Install Dike	500/ +18 LWRP		
5 (Plate 21)	39.4R	Install Rootless Dike	200/ +18 LWRP	No	This alternative created a secondary flow split around the structures. Additional sedimentation occurred around the structures on the RDB.
	39.1R	Install Rootless Dike	200/ +18 LWRP		
	38.9R	Install Rootless Dike	200/ +18 LWRP		
	38.6R	Install Rootless Dike	200/ +18 LWRP		

Alternative Number	Structure	Type of Structure	Dimension/Height (ft)	Alternative Successful	Comments
6 (Plate 22)	40.0L	Install Rootless Dikes	200/ +18 LWRP	Yes	This alternative created a secondary flow split around the structures. Additional sedimentation occurred around the structures on the RDB but the navigation channel is along the LDB. Dike 40.4L may cause interference with weir 39.6L. Recommend construction at a later date if necessary.
	39.4R	Install Rootless Dikes	200/ +18 LWRP		
	39.1R	Install Rootless Dikes	200/ +18 LWRP		
	38.9R	Install Rootless Dikes	200/ +18 LWRP		
	38.6R	Install Rootless Dikes	200/ +18 LWRP		
7 (Plate 23)	41.0R	Notch Existing Dike	200/ +5 Grade	No	This alternative created some split flow conditions but not a continuous split flow along the lower structures on the RDB.
	40.8R	Notch Existing Dike	200/ +5 Grade		
	40.6R	Remove Dike Section	200/ -15 LWRP		
	40.2R	Remove Dike Section	200/ -15 LWRP		
	40.0R	Remove Dike Section	200/ -15 LWRP		
	40.0L	Install Rootless Dikes	200/ +18 LWRP		
	40.0R	Remove Dike Section	200/ -15 LWRP		
	39.1R	Install Rootless Dikes	200/ +18 LWRP		
	38.9R	Install Rootless Dikes	200/ +18 LWRP		
	38.6R	Install Rootless Dikes	200/ +18 LWRP		
8 (Plate 24)	41.7L	Notch Existing Dike	100/ +5 Grade	No	This alternative increased the size of scour holes around 41.7L and 40.6L but did not allow for a continuous channel through 41.4L. In addition side channel modeling in is not conclusive due to uncalibrated conditions at the entrance and exit of the side channel.
	41.4L	Remove Closure Structure	+5 Grade		
	40.6L	Notch Existing Dike	100/ +5 Grade		
9 (Plate 25)	39.8L	Install Dike	500/ +18 LWRP	No	This alternative did not increase environmental diversity. It may be an option if dredging problems persist downstream after the installation of Weir 39.6L.

Alternative Number	Structure	Type of Structure	Dimension/Height (ft)	Alternative Successful	Comments
10 (Plate 26)	38.0L	Notch Existing Dike	200/ +5 Grade	No	This alternative did not create environmental diversity in the area. In addition it would be inprudent to install in structures so close to the new chevrons scheduled for FY10 construction.
	37.5L	Notch Existing Dike	201/ +5 Grade		
	37.2L	Notch Existing Dike	202/ +5 Grade		
11 (Plate 27)	38.6R	Notch Existing Dike	150/ +5 Grade	No	This alternative did not create environmental diversity in the area.
	38.4R	Notch Existing Dike	150/ +5 Grade		
	38.2R	Notch Existing Dike	150/ +5 Grade		

CONCLUSIONS

1. Summary

Several alternative design tests were conducted for this HSR model study. The primary intention of each alternative tested was increasing environmental diversity in this stretch of river. Alternative 1 was the only exception to this and was tested to show the results of a current plan under consideration to relieve persistent dredging conditions. Secondary negative impacts to the navigation channel were also monitored in these alternative tests.

Table 7: Evaluation of Model Tests for Primary and Secondary Purposes

Test	Substantial Increased Environmental Diversity	Negative Impacts to Main Navigation Channel	Possible Negative Impacts to Schedule FY10 Construction
Alternative 1			
Alternative 2			X
Alternative 3			X
Alternative 4			X
Alternative 5	X		
Alternative 6	X		X
Alternative 7			X
Alternative 8	X		
Alternative 9			X
Alternative 10			
Alternative 11			X

2. Recommendations

Alternatives 5 and 8 both provided increased environmental diversity in the model. Alternative 5 created a split flow pattern around the tested structures in the model. The split flow did create a small side channel but did not offer a great difference in depth through the side channel. Sedimentation along the RDB outside the main navigation channel was also created from this alternative. The small increase in split flow diversity from these structures would not create a great benefit for the construction costs and sedimentation that is caused.

Alternative 8 consisted of changes to the side channel. This design showed increased flow in the side channel but no significant depth reduction around the area of closure structure 41.4L. Future high flow events of this area may cause the area to scour further and provide for increased flow through the side channel year round. However, the full extent of Alternative 8 could not be tested in this model due to entrance and exit conditions of the side channel being outside of the model extents. Alternative 8 is recommended for further study but cannot be conclusively recommended from this study.

It is recommended that neither Alternative 5 nor 8 be constructed at this time. Future construction plans from this model may be merited after monitoring of the new river training structures (to be completed FY10) has been done. In the future, if it is warranted and issues from sedimentation are along the RDB caused by Alternative 5 are still non-intrusive to the main Navigation Channel, then Alternative 5 may be a viable option for increased diversity. If further alleviation from dredging is needed around RM 39 after the construction of Weir 39.6L then the rootless dike extension off Dike 40.0L from Alternative 6 and Dike 39.8L from Alternative 9 may be viable options. Both of these alternatives may cause negative impacts to Weir 39.6L by filling in the scour hole in the area around the weir.

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 unknown underlying rock formations or other non-erodible 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.

FOR MORE INFORMATION

For more information about HSR modeling or the Applied River Engineering Center, please contact Mr. Robert Davinroy, P.E. at:

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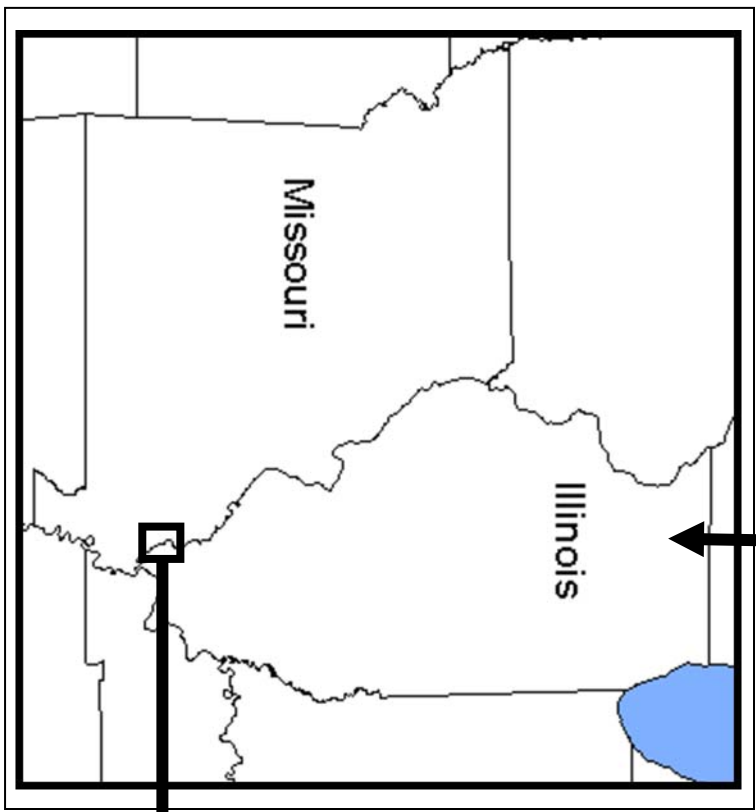
Hydrologic and Hydraulics Branch
Foot of Arsenal Street
St. Louis, Missouri 63118

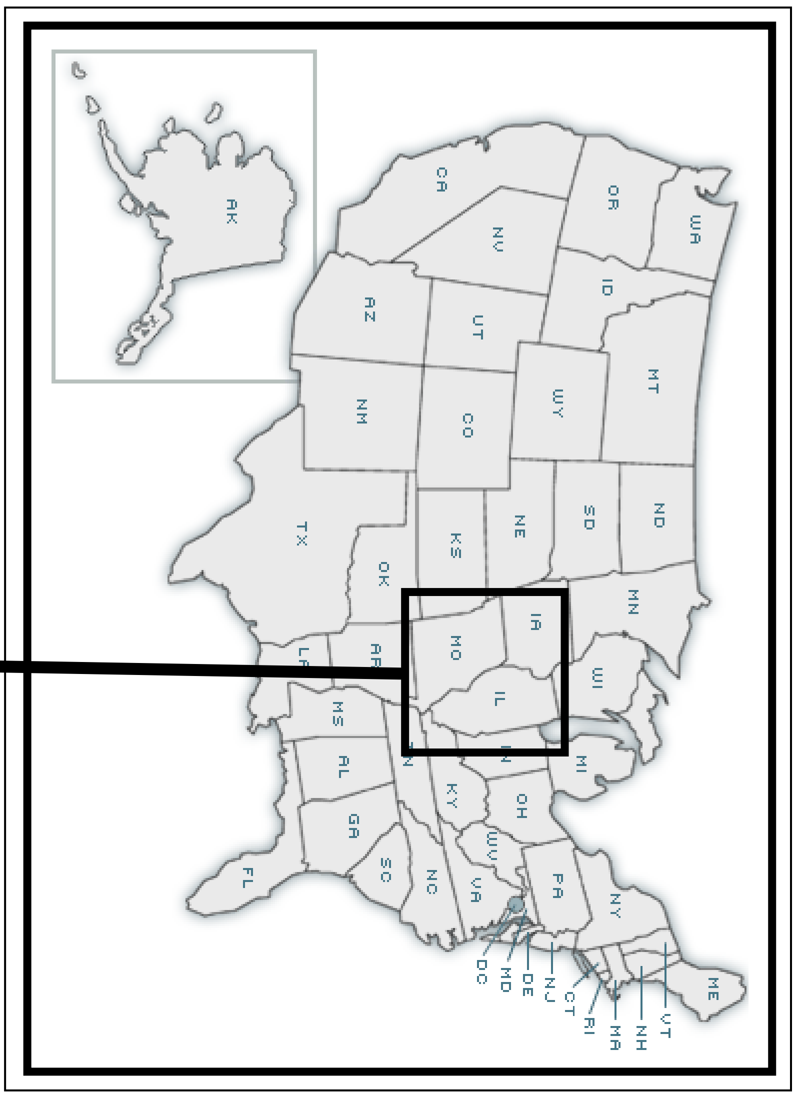
Phone: (314) 865-6326
Fax: (314) 865-6352

E-mail:
Robert.D.Davinroy@usace.army.mil

Or you can visit us on the World Wide Web at:
http://www.mvs.usace.army.mil/eng-con/expertise/arec/index.html

APPENDIX OF PLATES





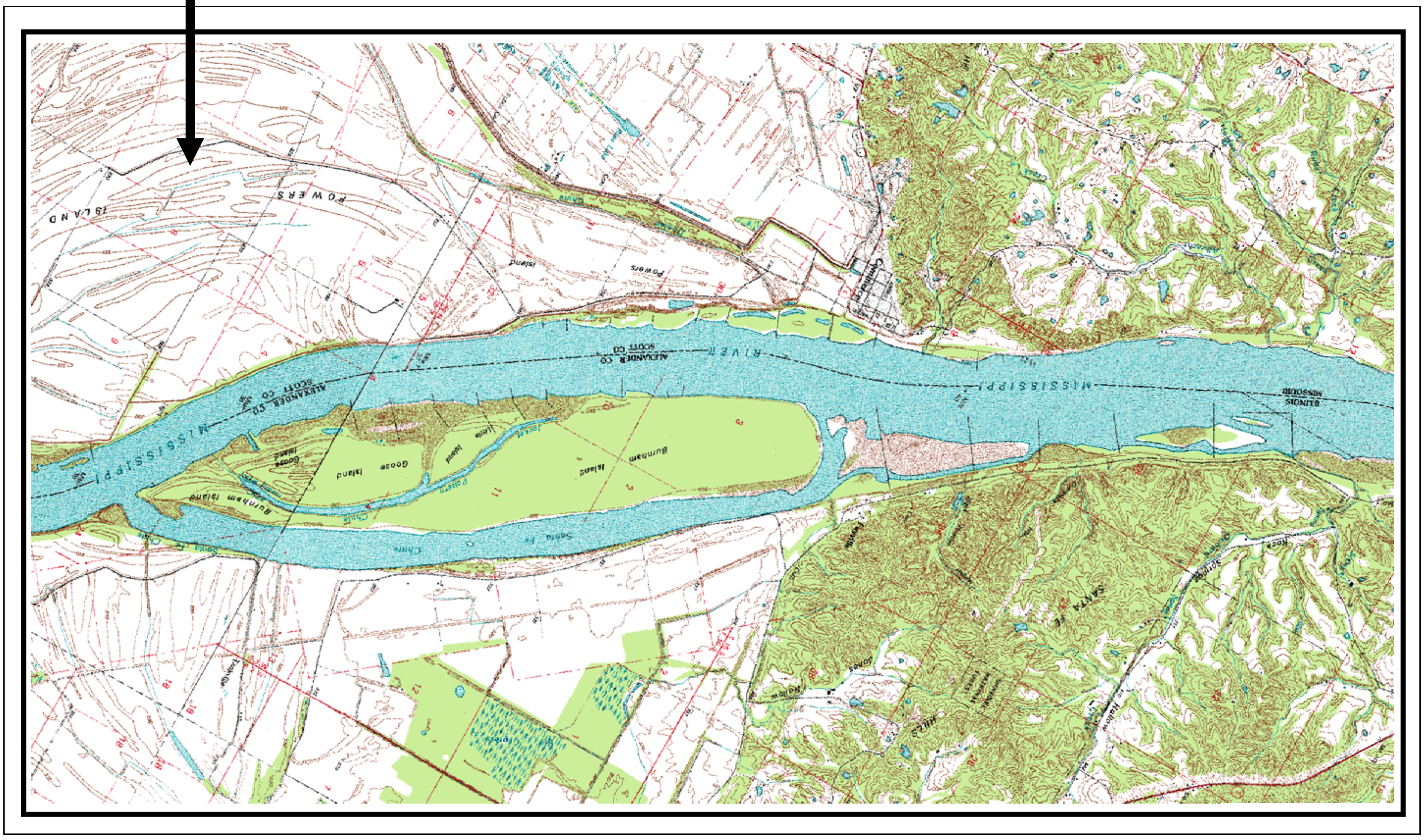


PLATE NUMBER 1

Location and Vicinity Map

U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT	PLOT DATE April 13, 2010	
	PREPARED BY M. Miles, P.E.	DRAWN BY M. Miles, P.E.
UPPER MISSISSIPPI RIVER BASIN Thebes HSR Model River Miles 44 - 35	CHECKED BY R. Davinroy, P.E.	
	FILE NAME ...ARC/THEBES	

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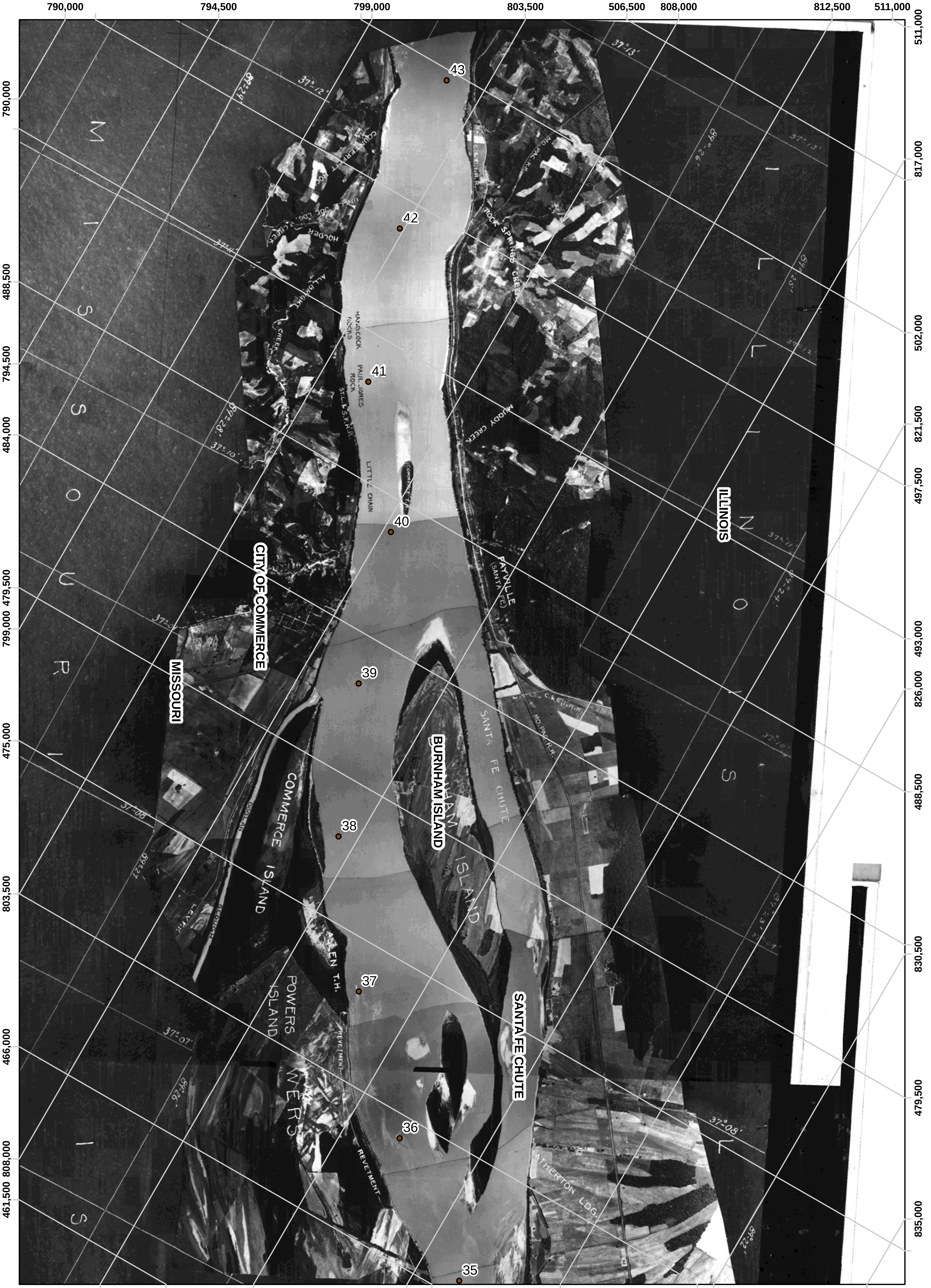

PLATE NUMBER
2

0 1,500 3,000 6,000

Feet

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1928 Aerial Photograph

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 44 - 35

PLOT DATE: April 13, 2010	
PREPARED BY: M. Miles, P.E.	DRAWN BY: M. Miles, P.E.
CHECKED BY: R. Davinroy, P.E.	
FILE NAME: ...ARC/THEBES	

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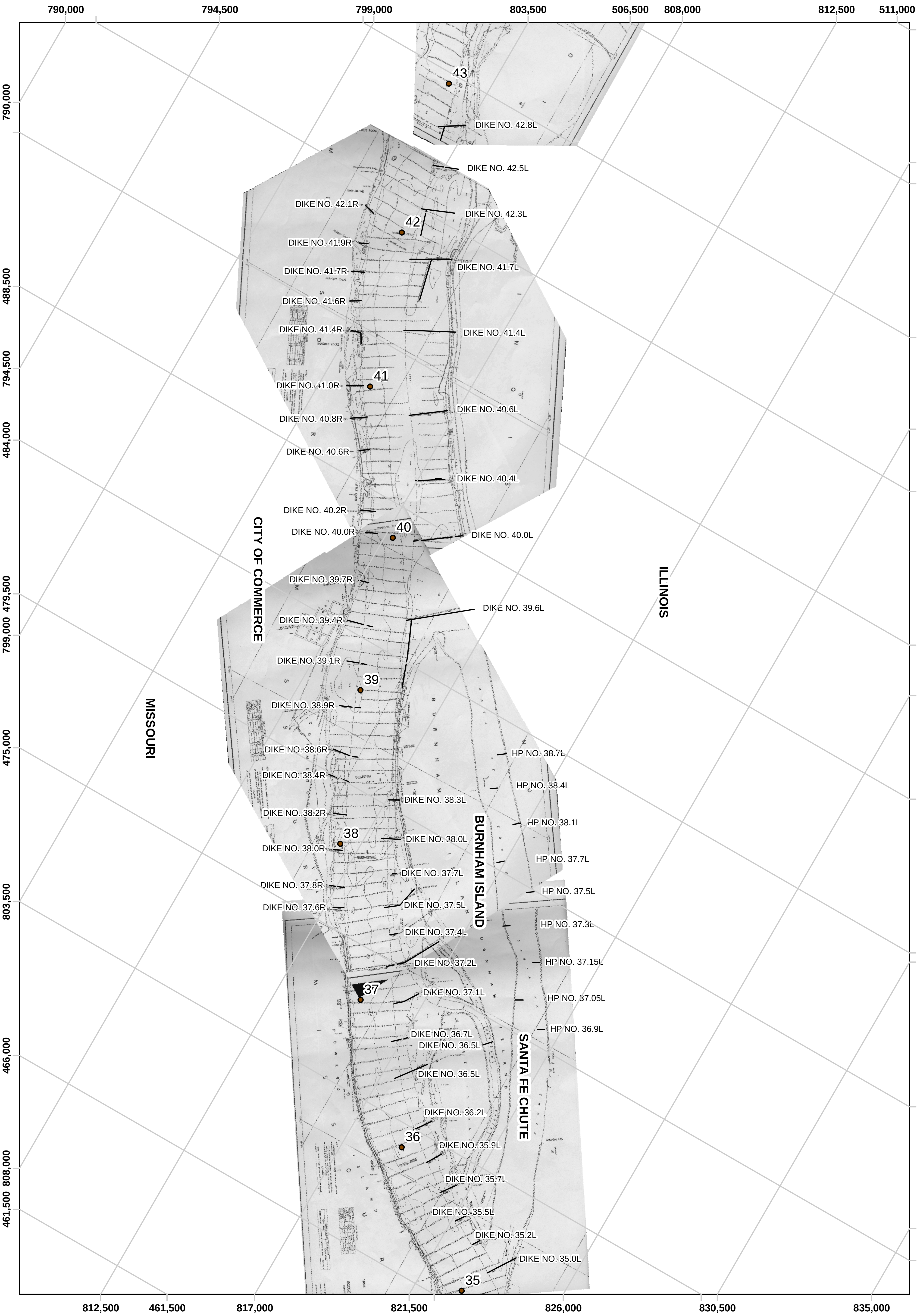

PLATE NUMBER 3	0 1,500 3,000 6,000 Feet THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME 1956 Aerial Photograph	U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT UPPER MISSISSIPPI RIVER BASIN Thebes HSR Model River Miles 44 - 35	PLOT DATE: April 13, 2010 PREPARED BY: M. Miles, P.E. DRAWN BY: M. Miles, P.E. CHECKED BY: R. Davinroy, P.E. FILE NAME: ...ARC/THEBES

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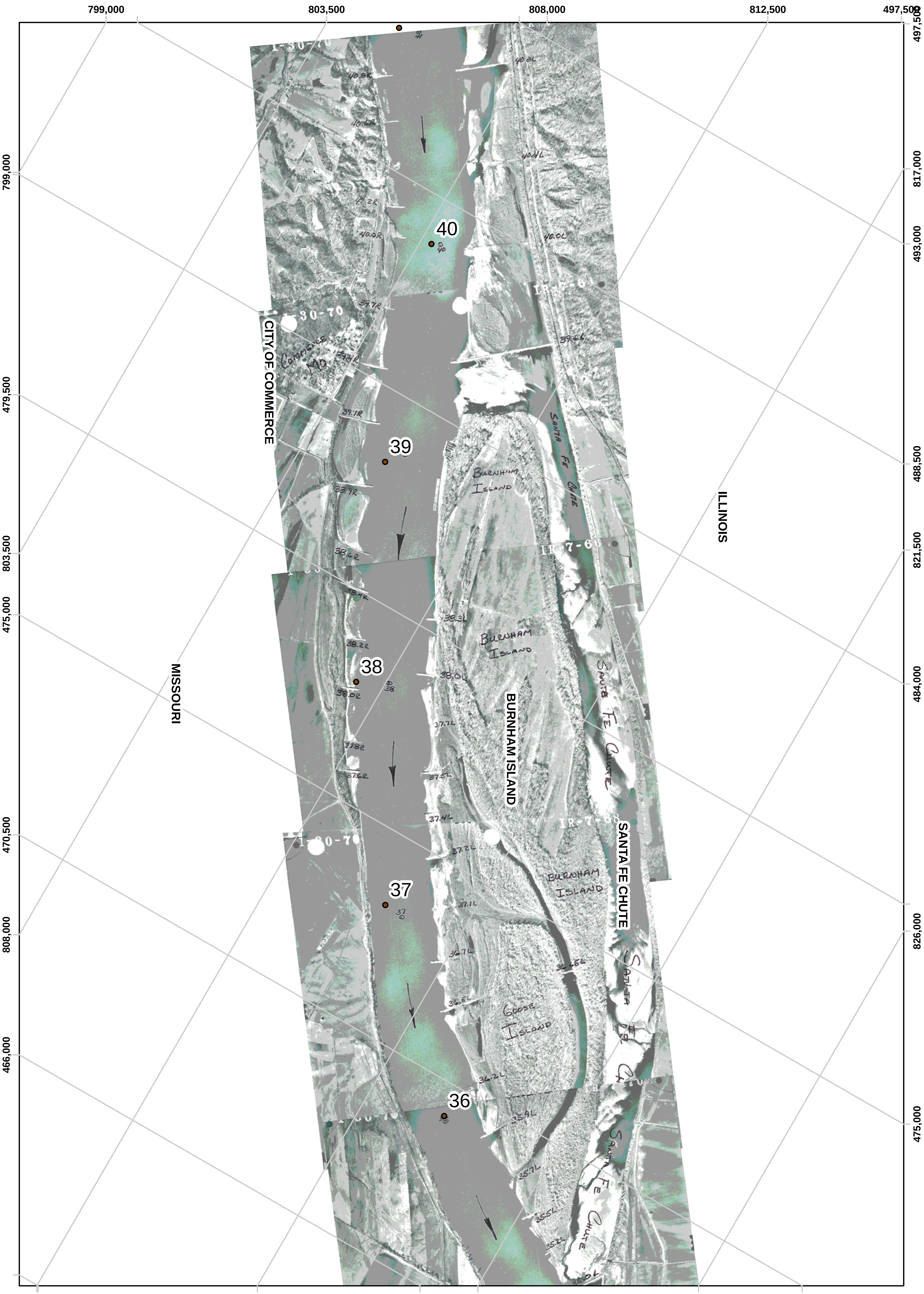

0 1,000 2,000 4,000
Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

PLATE NUMBER 4

1970 Aerial Photograph

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 41 - 35

PLOT DATE: April 13, 2010	
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PLATE NUMBER 5

0 1,500 3,000 6,000
Feet

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2006 Aerial Photograph

2007 Floodplain Aerial Photo

U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT	PLOT DATE: April 13, 2010	
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UPPER MISSISSIPPI RIVER BASIN Thebes HSR Model River Miles 44 - 35	CHECKED BY: R. Davinroy, P.E.	
	FILE NAME: ...ARC/THEBES	

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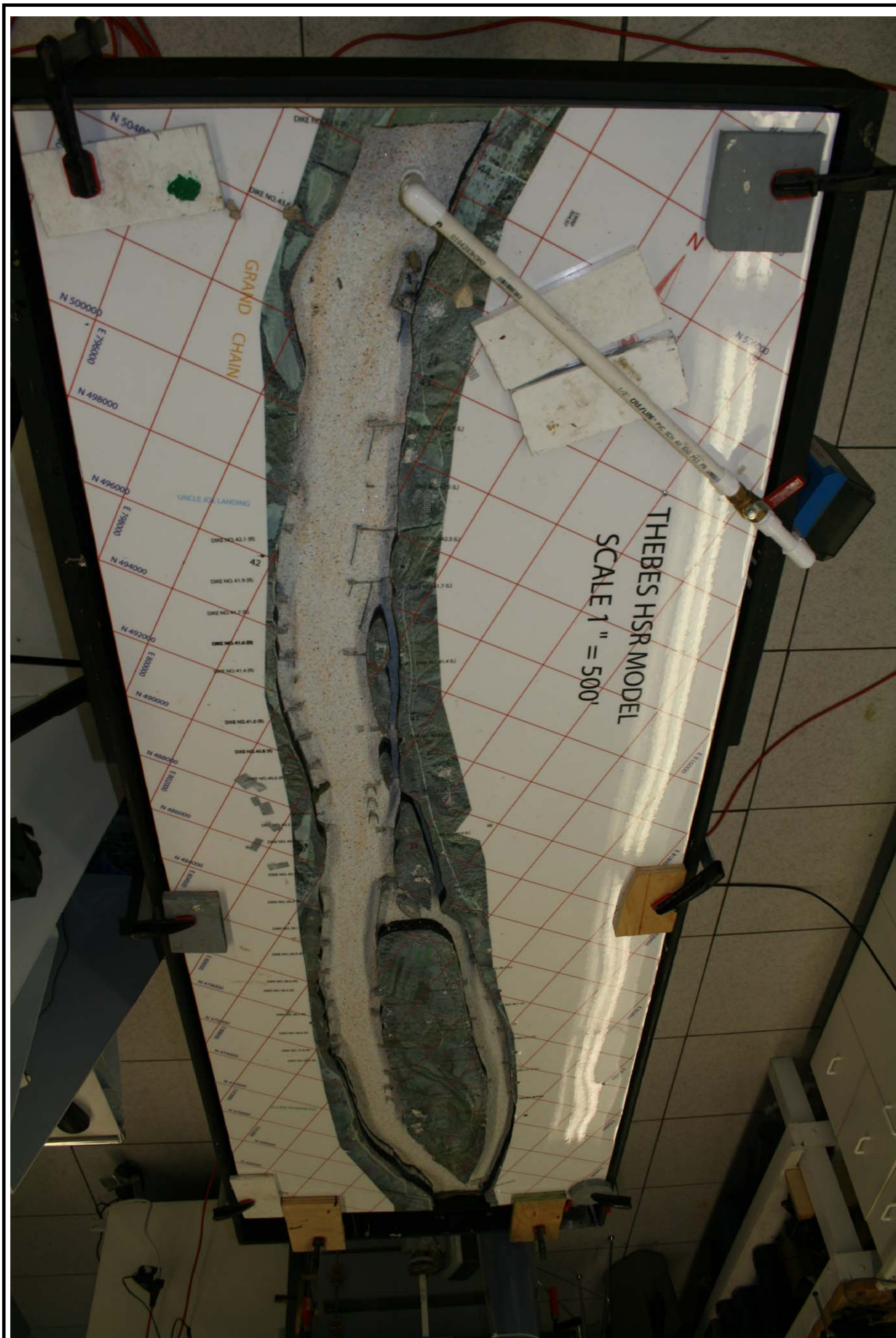

PLATE NUMBER
6

Thebes HSR Model

U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT	PLOT DATE April 13, 2010	
	PREPARED BY M. Miles, P.E.	DRAWN BY M. Miles, P.E.
UPPER MISSISSIPPI RIVER BASIN Thebes HSR Model River Miles 44 - 35	CHECKED BY R. Davinroy, P.E.	
	FILE NAME ...ARC/THEBES	

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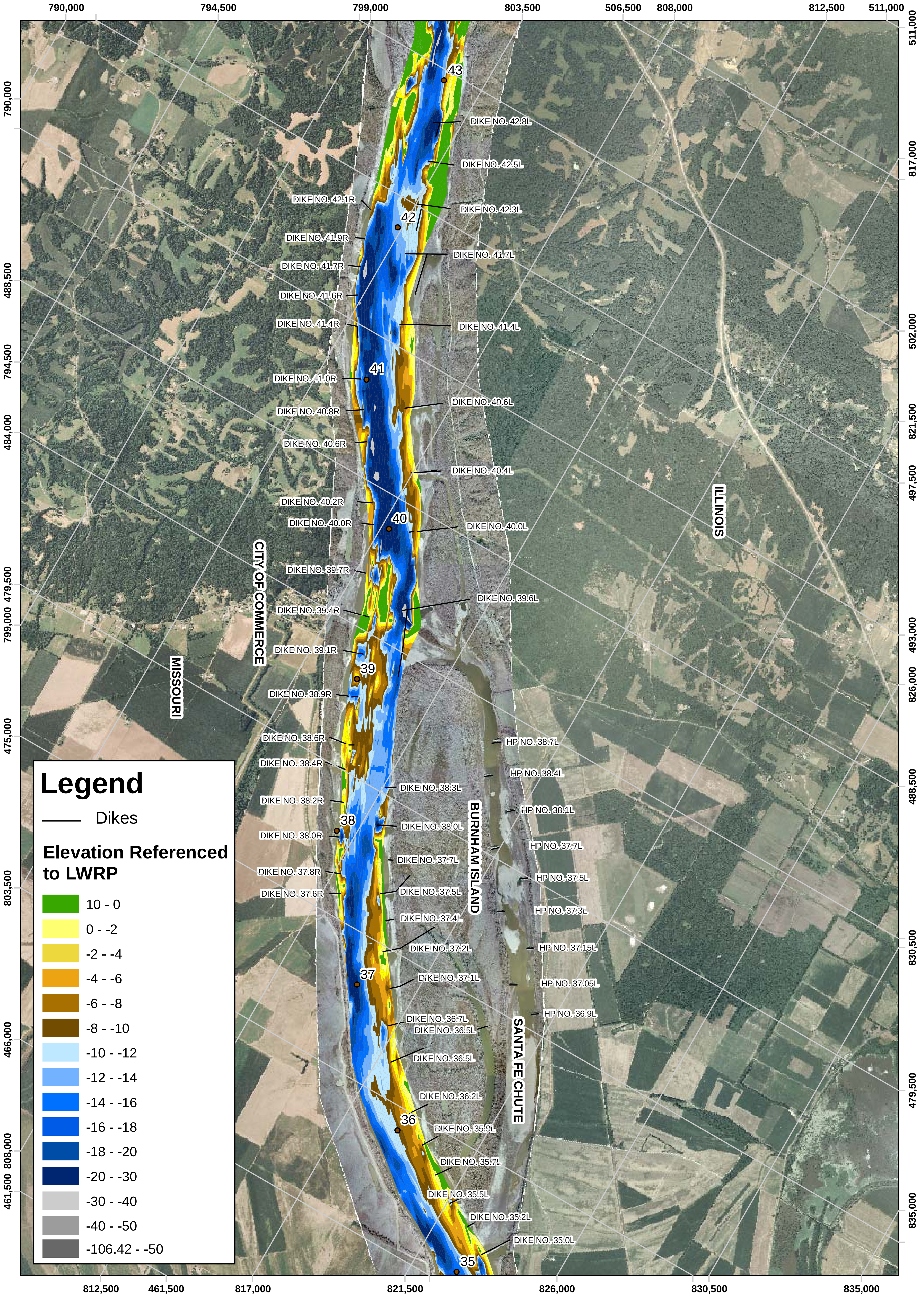

PLATE NUMBER 7

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Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

1970 Hydrographic Survey

2006/2007 Aerial Photo

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UPPER MISSISSIPPI RIVER BASIN Thebes HSR Model River Miles 44 - 35	CHECKED BY: R. Davinroy, P.E.
	FILE NAME: ...ARC/THEBES

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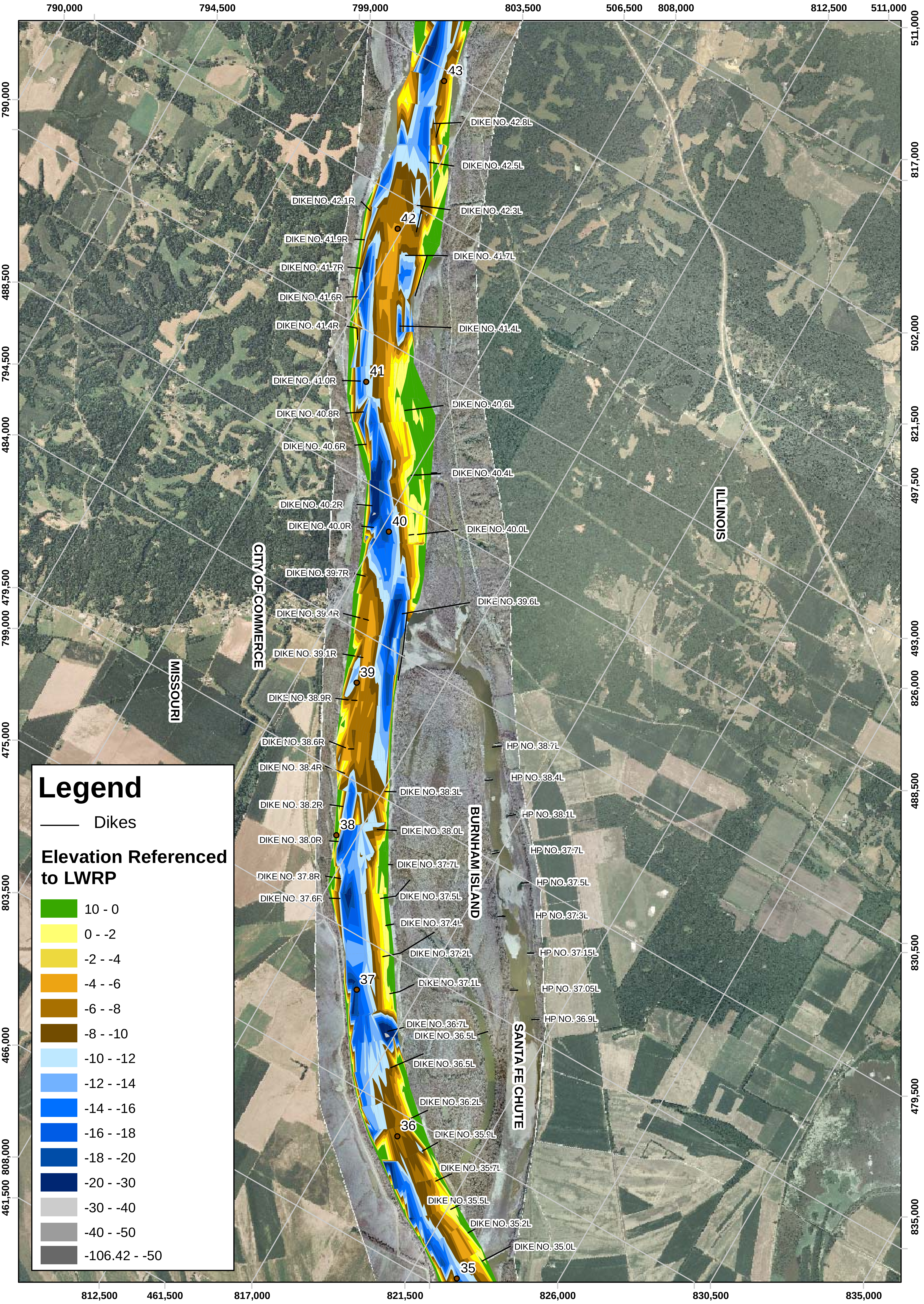

PLATE NUMBER 8

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Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

1989 Hydrographic Survey

2006/2007 Aerial Photo

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ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 44 - 35

PLOT DATE: April 13, 2010	
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CHECKED BY: R. Davinroy, P.E.	
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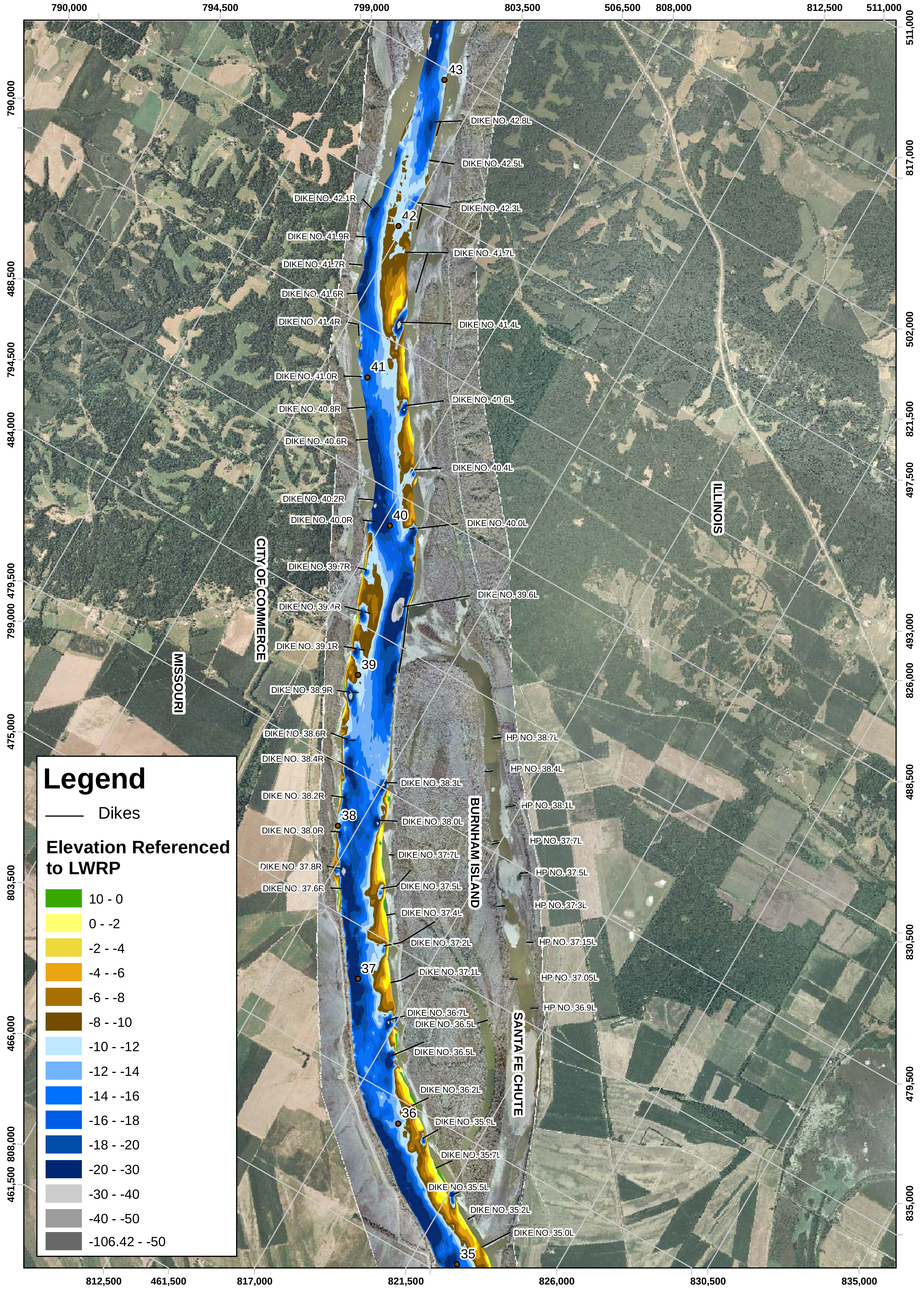

PLATE NUMBER
9

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Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

1995 Hydrographic Survey

2006/2007 Aerial Photo

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ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 44 - 35

PLOT DATE: April 13, 2010	
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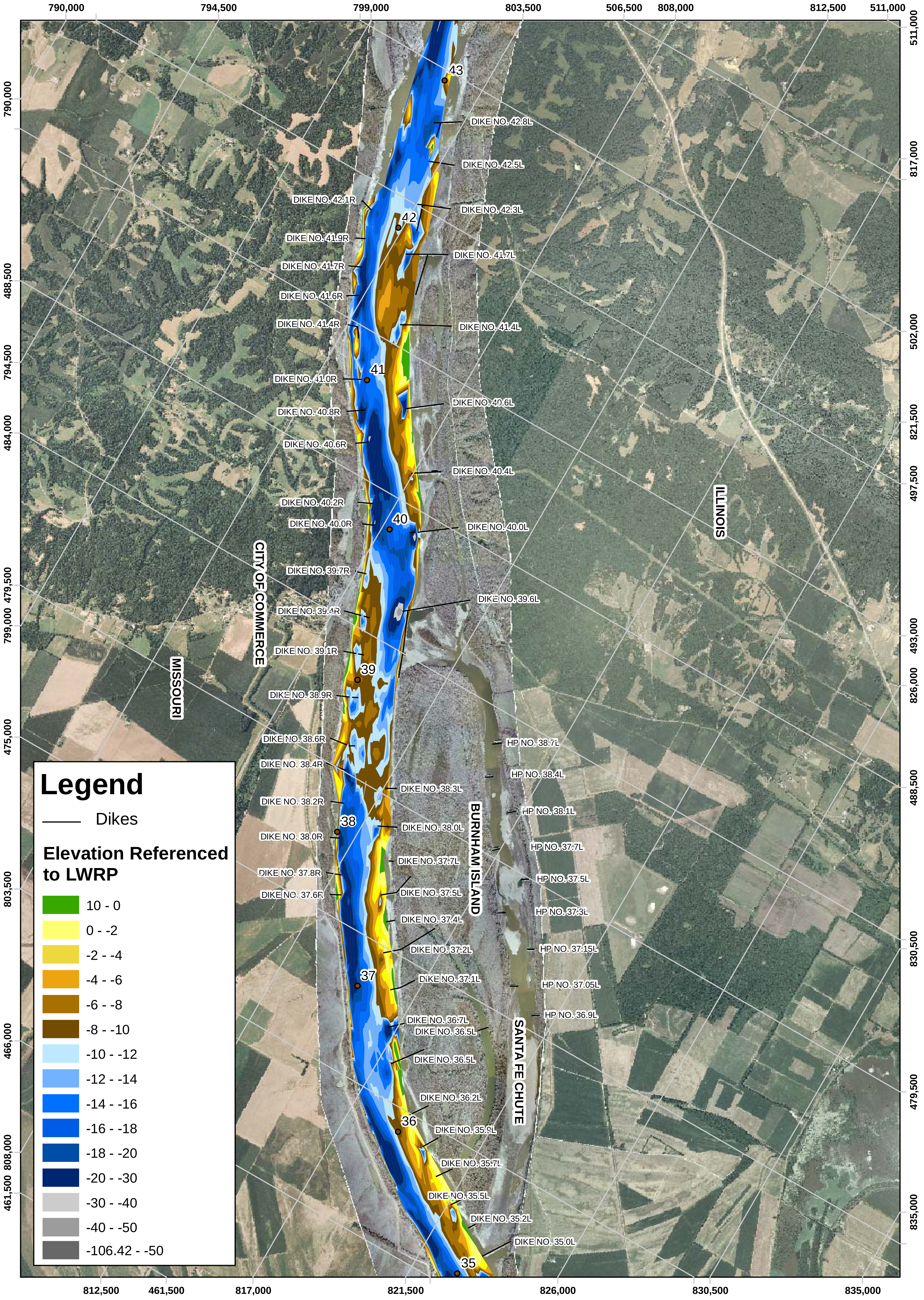

PLATE NUMBER
10

0 1,500 3,000 6,000
Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

1998 Hydrographic Survey
2006/2007 Aerial Photo

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ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 44 - 35

PLOT DATE: April 13, 2010
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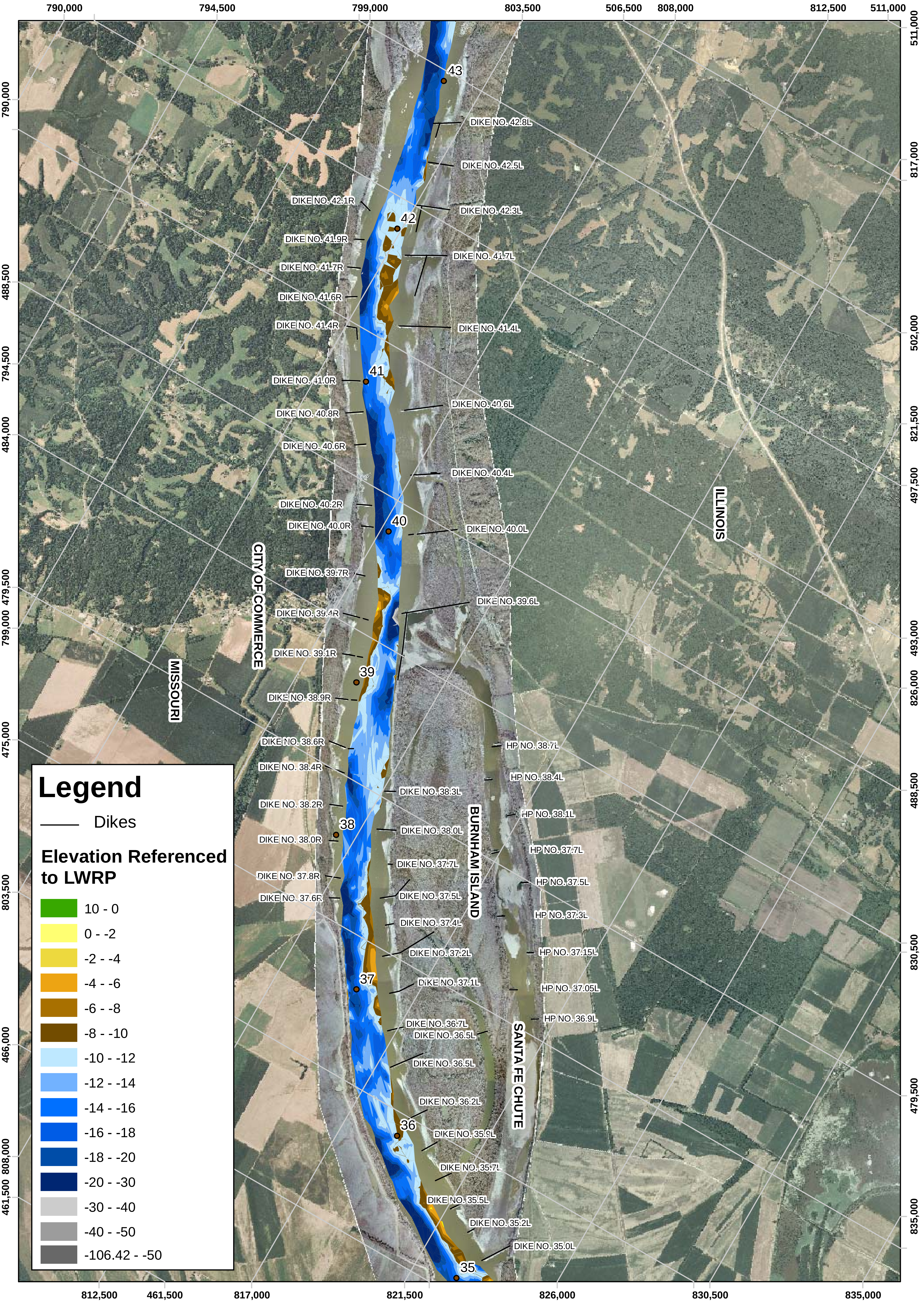

PLATE NUMBER 11

0 1,500 3,000 6,000
Feet

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2000 Hydrographic Survey
2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 44 - 35

PLOT DATE: April 13, 2010	
PREPARED BY: M. Miles, P.E.	DRAWN BY: M. Miles, P.E.
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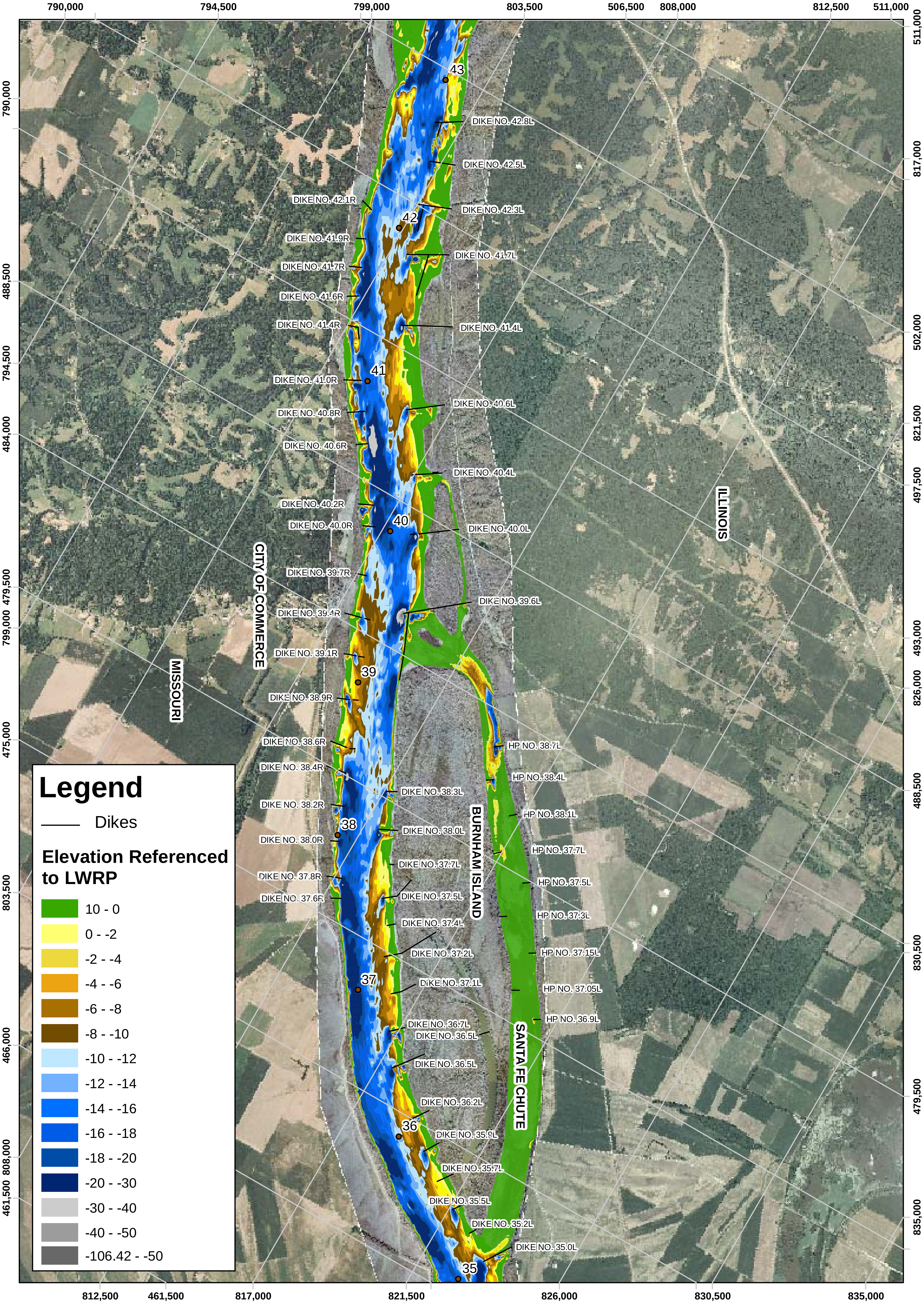

PLATE NUMBER 12

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Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

2001 Hydrographic Survey
2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 44 - 35

PLOT DATE: April 13, 2010	
PREPARED BY: M. Miles, P.E.	DRAWN BY: M. Miles, P.E.
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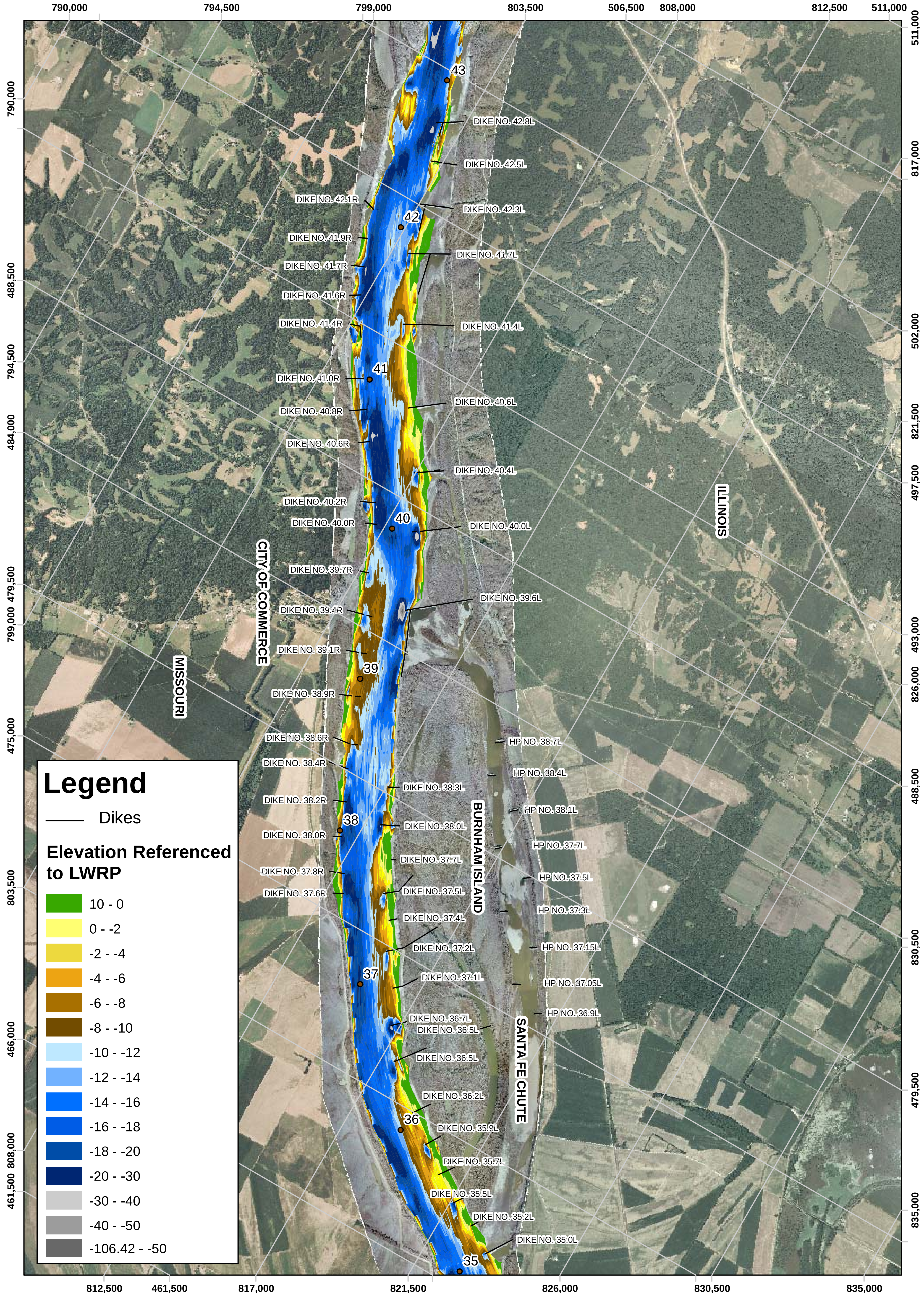

PLATE NUMBER 13

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Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

2005 Hydrographic Survey
2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 44 - 35

PLOT DATE: April 13, 2010	
PREPARED BY: M. Miles, P.E.	DRAWN BY: M. Miles, P.E.
CHECKED BY: R. Davinroy, P.E.	
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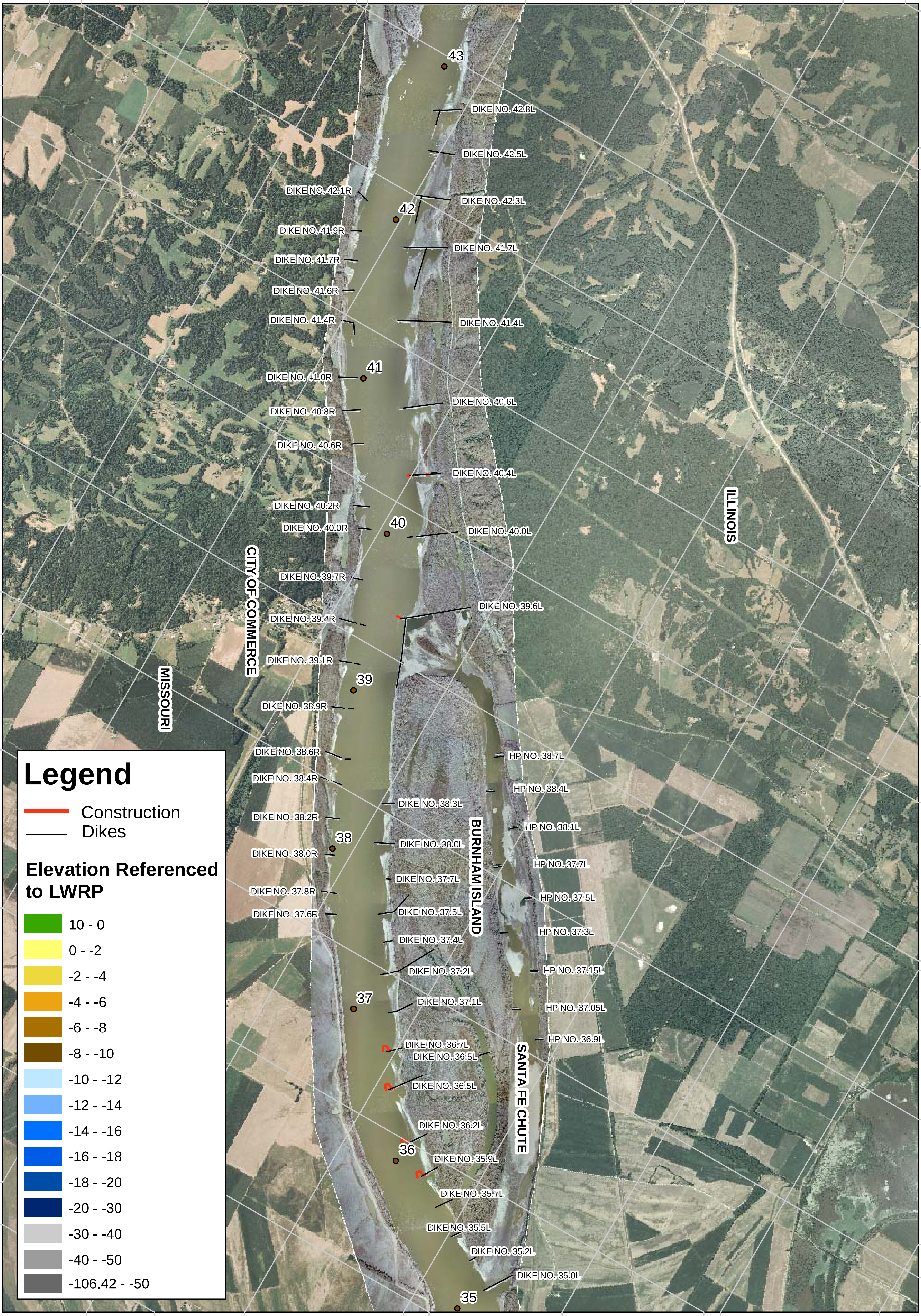

PLATE NUMBER 14	0 1,500 3,000 6,000 Feet THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME Scheduled Construction in Study Reach 2006/2007 Aerial Photo	U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT UPPER MISSISSIPPI RIVER BASIN Thebes HSR Model River Miles 44 - 35	PLOT DATE: April 13, 2010 PREPARED BY: M. Miles, P.E. DRAWN BY: M. Miles, P.E. CHECKED BY: R. Davinroy, P.E. FILE NAME: ...ARC/THEBES

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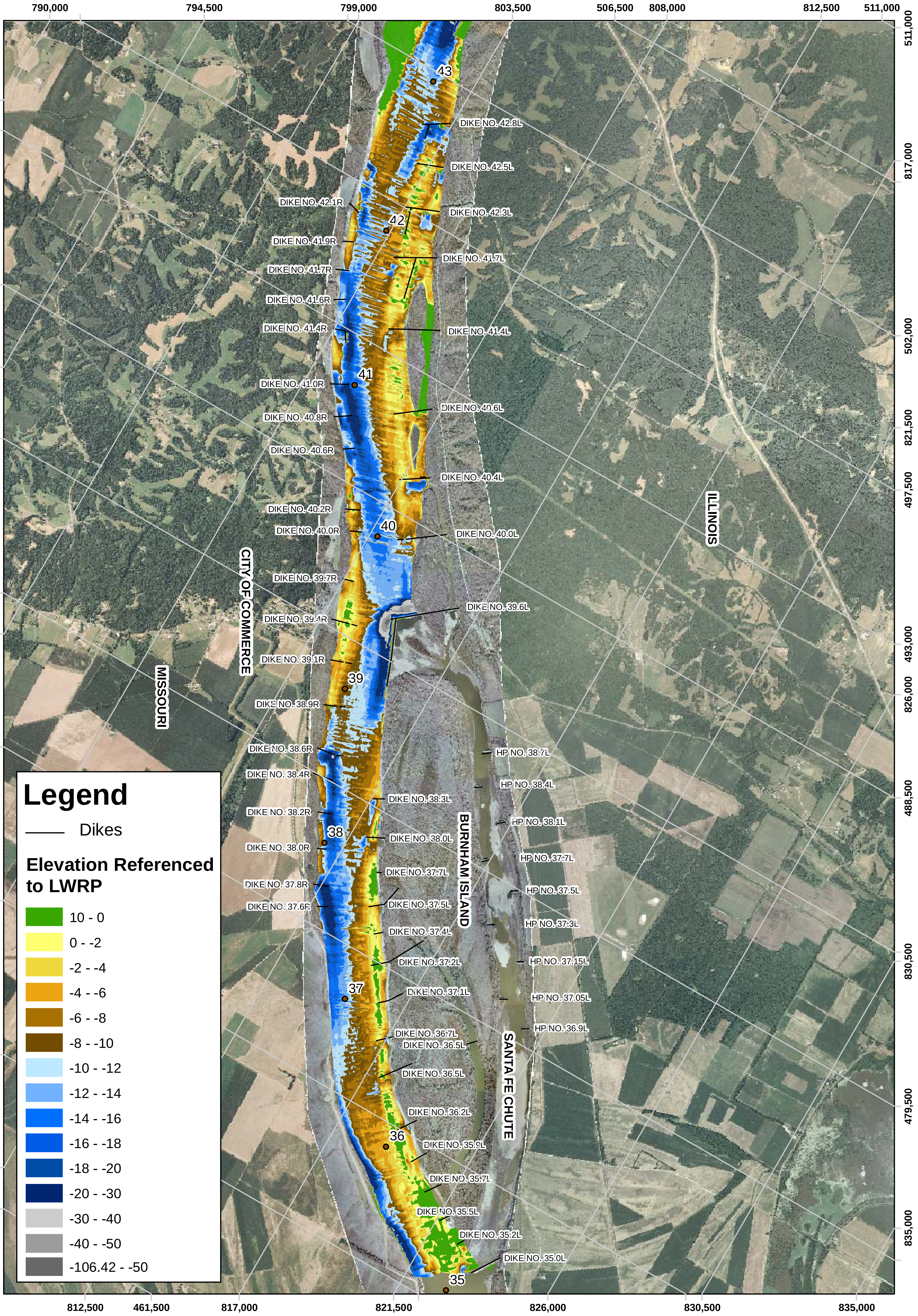

PLATE NUMBER 15

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Feet

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Base Test

2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 44 - 35

PLOT DATE: April 13, 2010	
PREPARED BY: M. Miles, P.E.	DRAWN BY: M. Miles, P.E.
CHECKED BY: R. Davinroy, P.E.	
FILE NAME: ...ARC/THEBES	

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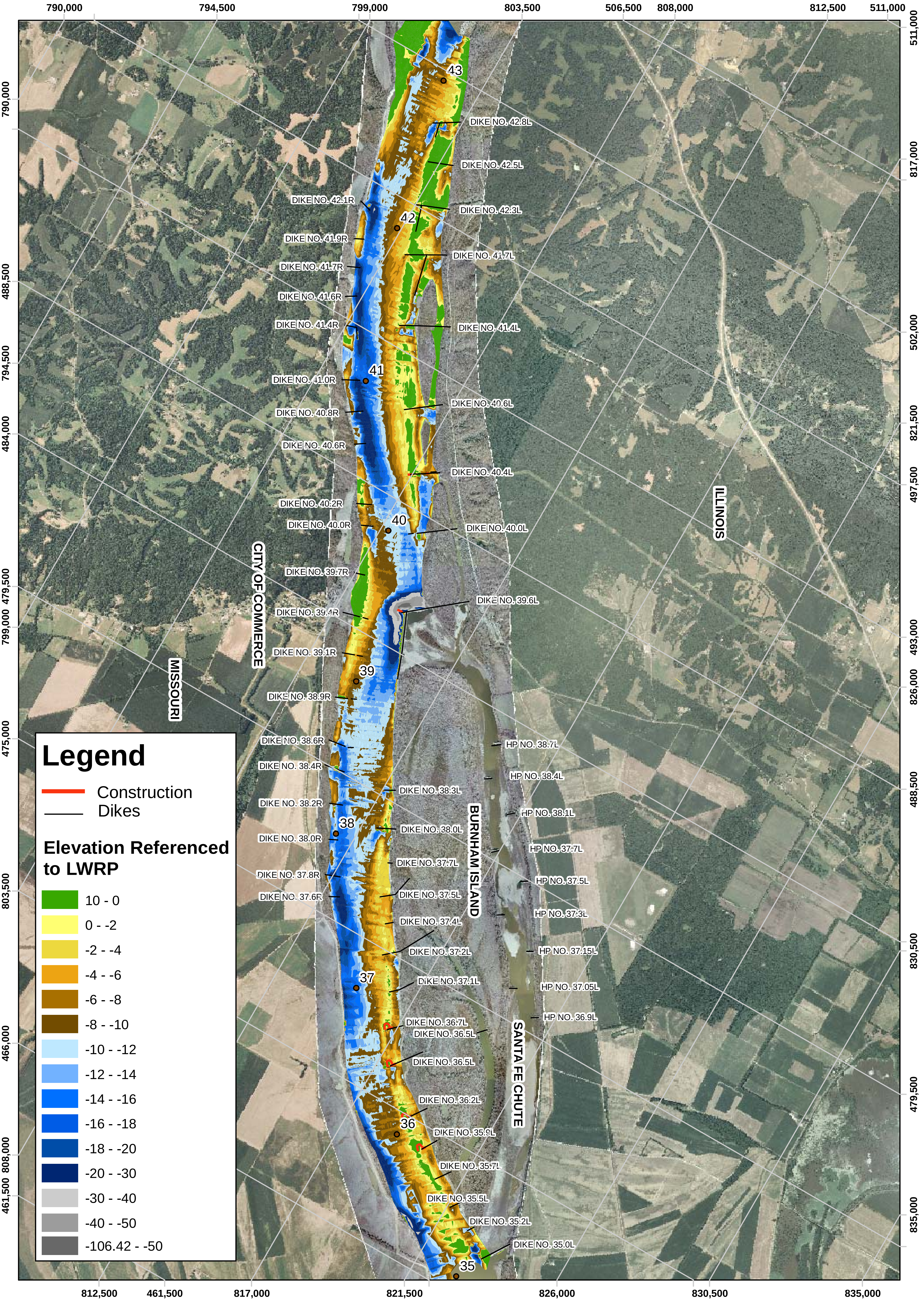

PLATE NUMBER 16

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Feet

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Base Test with Scheduled Construction
2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT	PLOT DATE: April 13, 2010 PREPARED BY: M. Miles, P.E. — DRAWN BY: M. Miles, P.E.
UPPER MISSISSIPPI RIVER BASIN Thebes HSR Model River Miles 44 - 35	CHECKED BY: R. Davinroy, P.E. FILE NAME: ...ARC/THEBES

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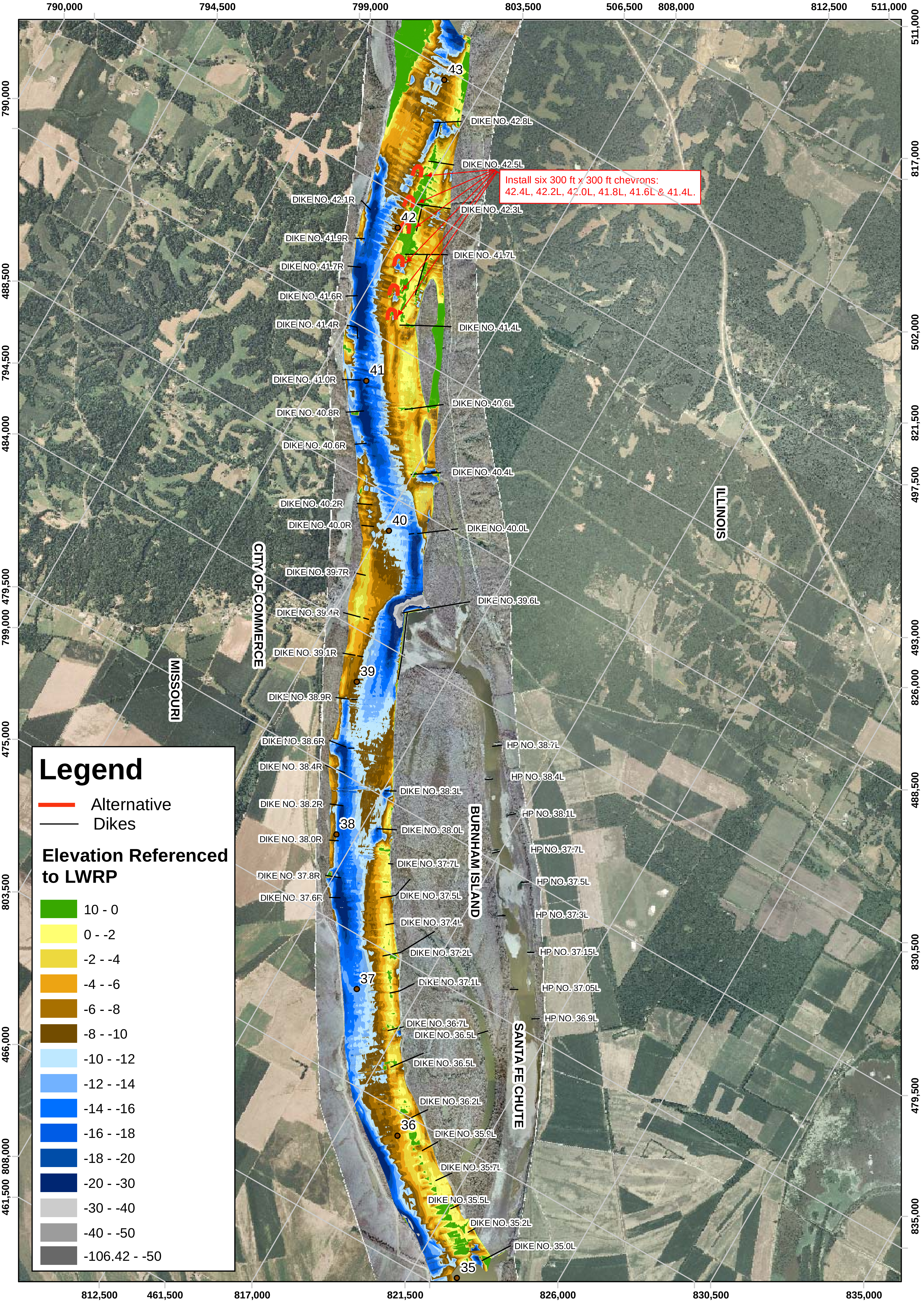

PLATE NUMBER 17

0 1,500 3,000 6,000

Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

Alternative 1

2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT	PLOT DATE: April 13, 2010
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UPPER MISSISSIPPI RIVER BASIN Thebes HSR Model River Miles 44 - 35	CHECKED BY: R. Davinroy, P.E.
	FILE NAME: ...ARC/THEBES

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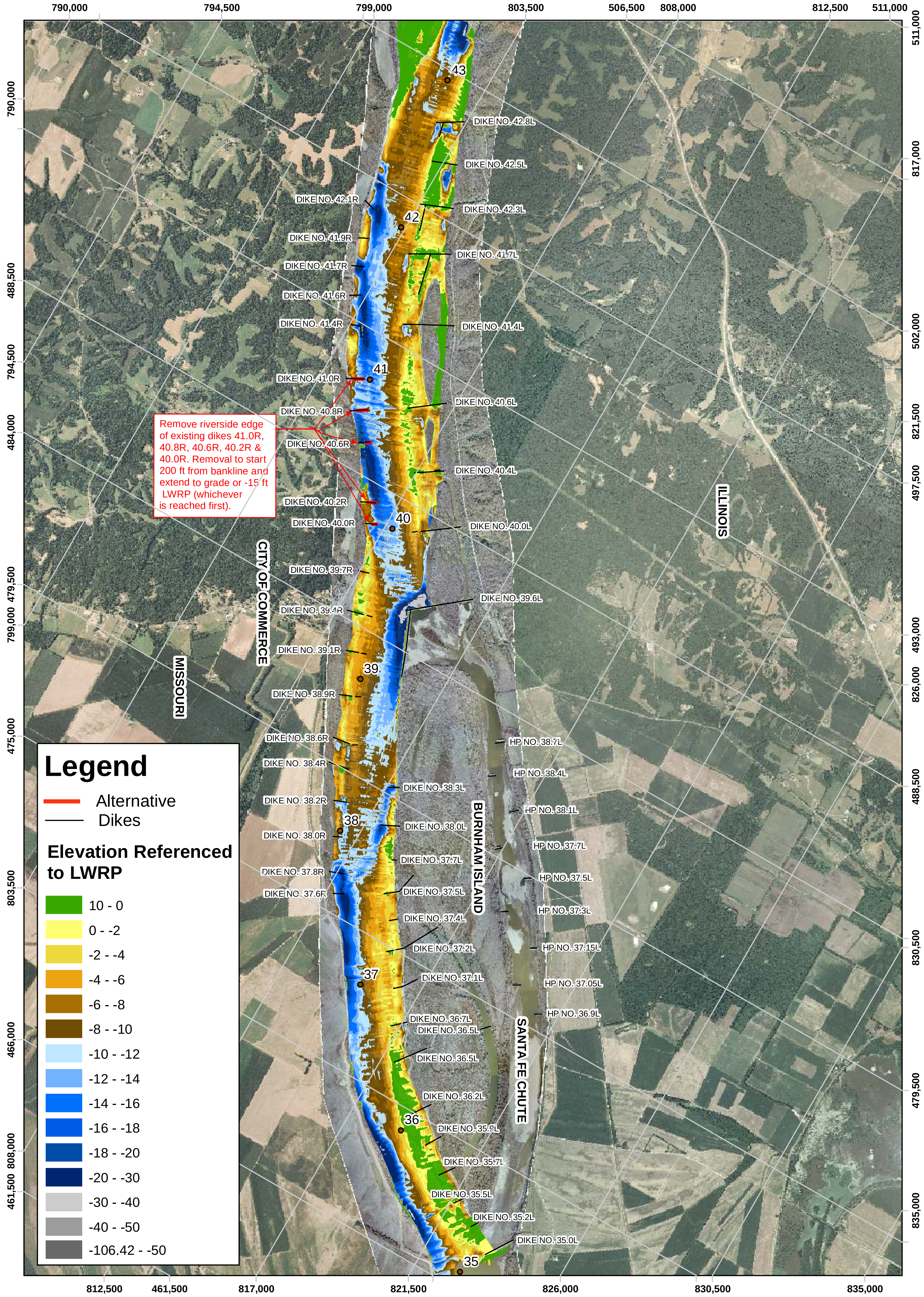

PLATE NUMBER 18

0 1,500 3,000 6,000
Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

Alternative 2
2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 44 - 35

PLOT DATE: April 13, 2010	
PREPARED BY: M. Miles, P.E.	DRAWN BY: M. Miles, P.E.
CHECKED BY: R. Davinroy, P.E.	
FILE NAME: ...ARC/THEBES	

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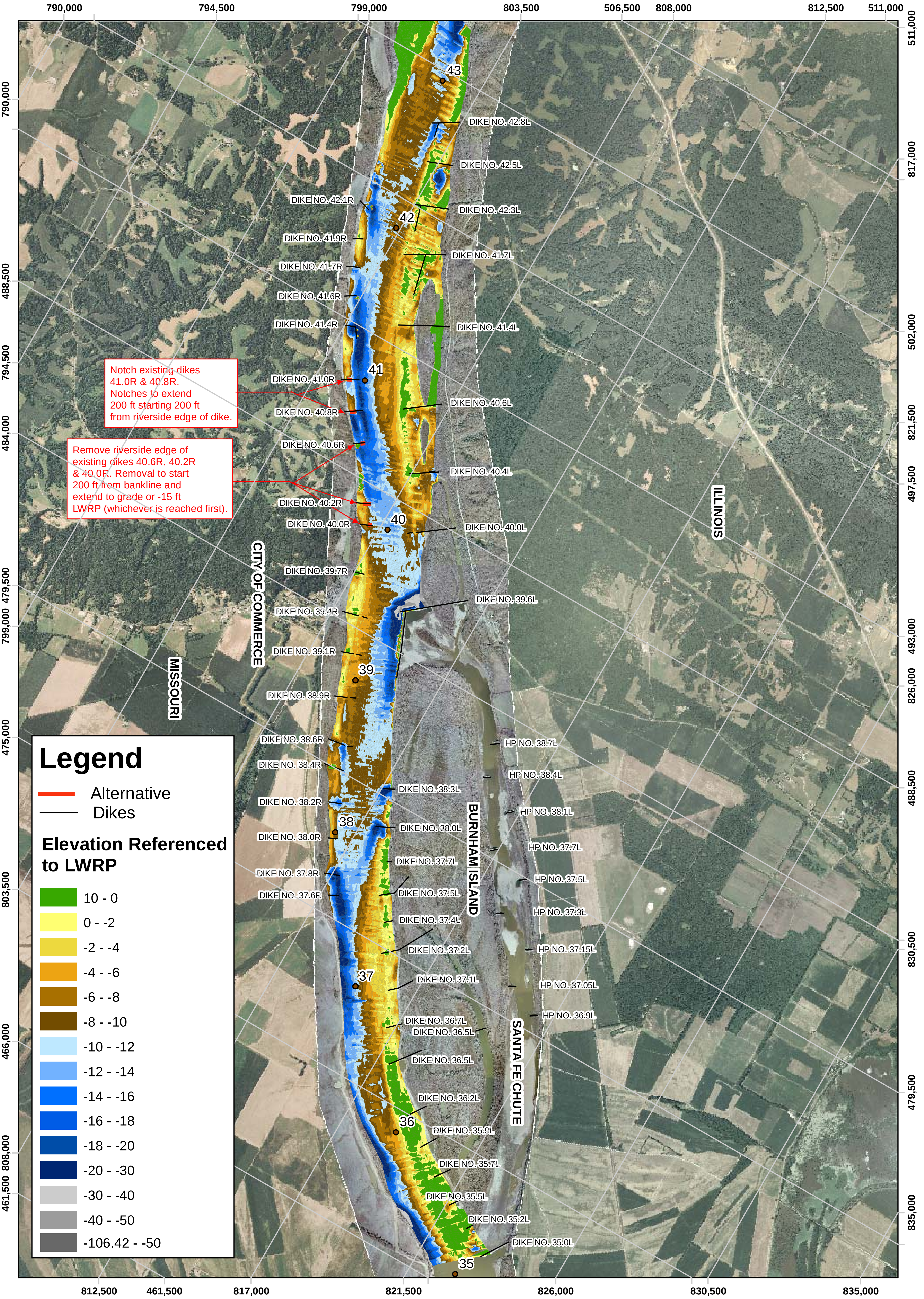

PLATE NUMBER	
19	

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Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

Alternative 3

2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT	PLOT DATE: April 13, 2010	
	PREPARED BY: M. Miles, P.E.	DRAWN BY: M. Miles, P.E.
UPPER MISSISSIPPI RIVER BASIN Thebes HSR Model River Miles 44 - 35	CHECKED BY: R. Davinroy, P.E.	
	FILE NAME: ...ARC/THEBES	

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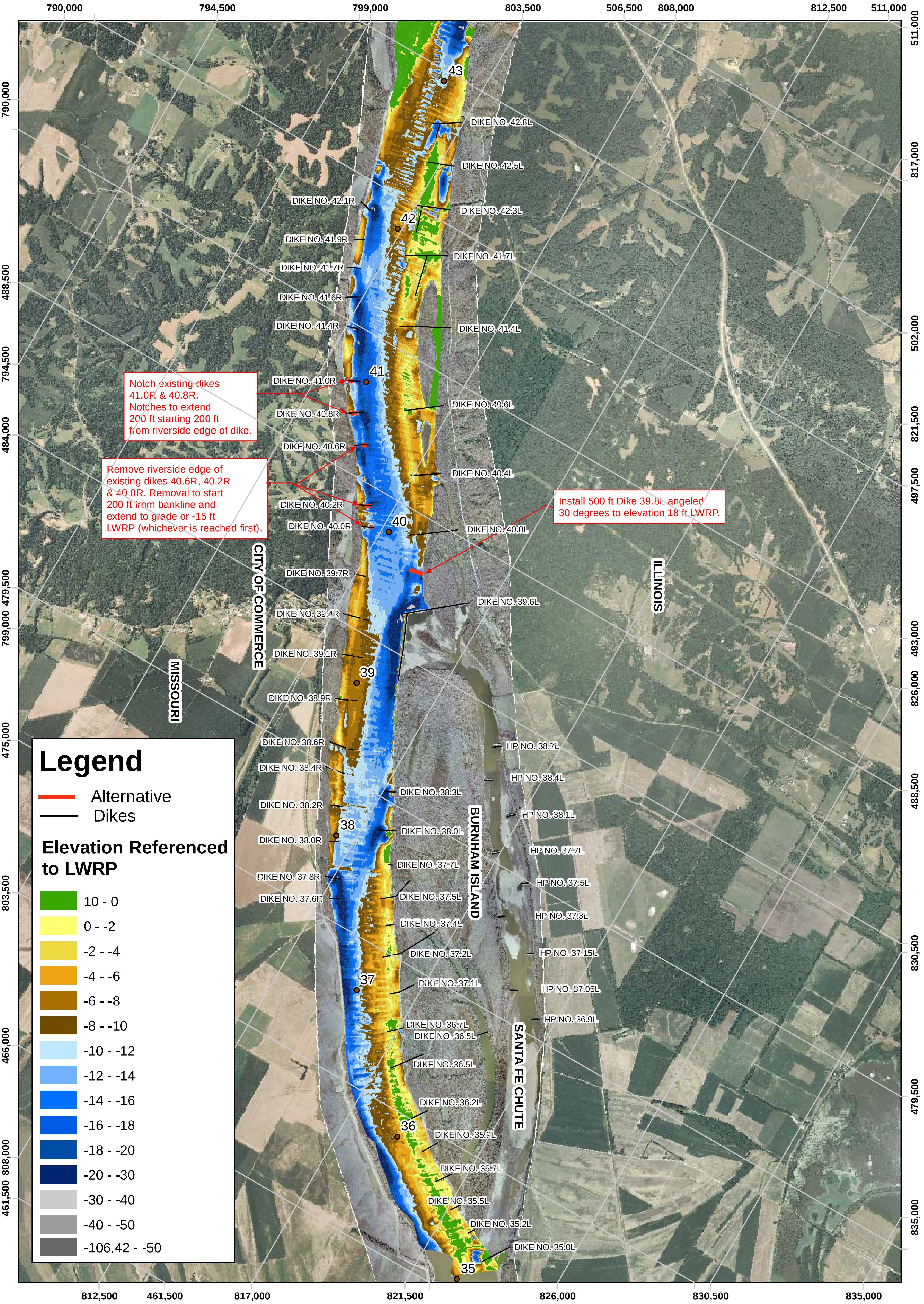

PLATE NUMBER 20

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Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

Alternative 4

2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT	PLOT DATE: April 13, 2010 PREPARED BY: M. Miles, P.E. DRAWN BY: M. Miles, P.E.
UPPER MISSISSIPPI RIVER BASIN Thebes HSR Model River Miles 44 - 35	CHECKED BY: R. Davinroy, P.E. FILE NAME: ...ARC/THEBES

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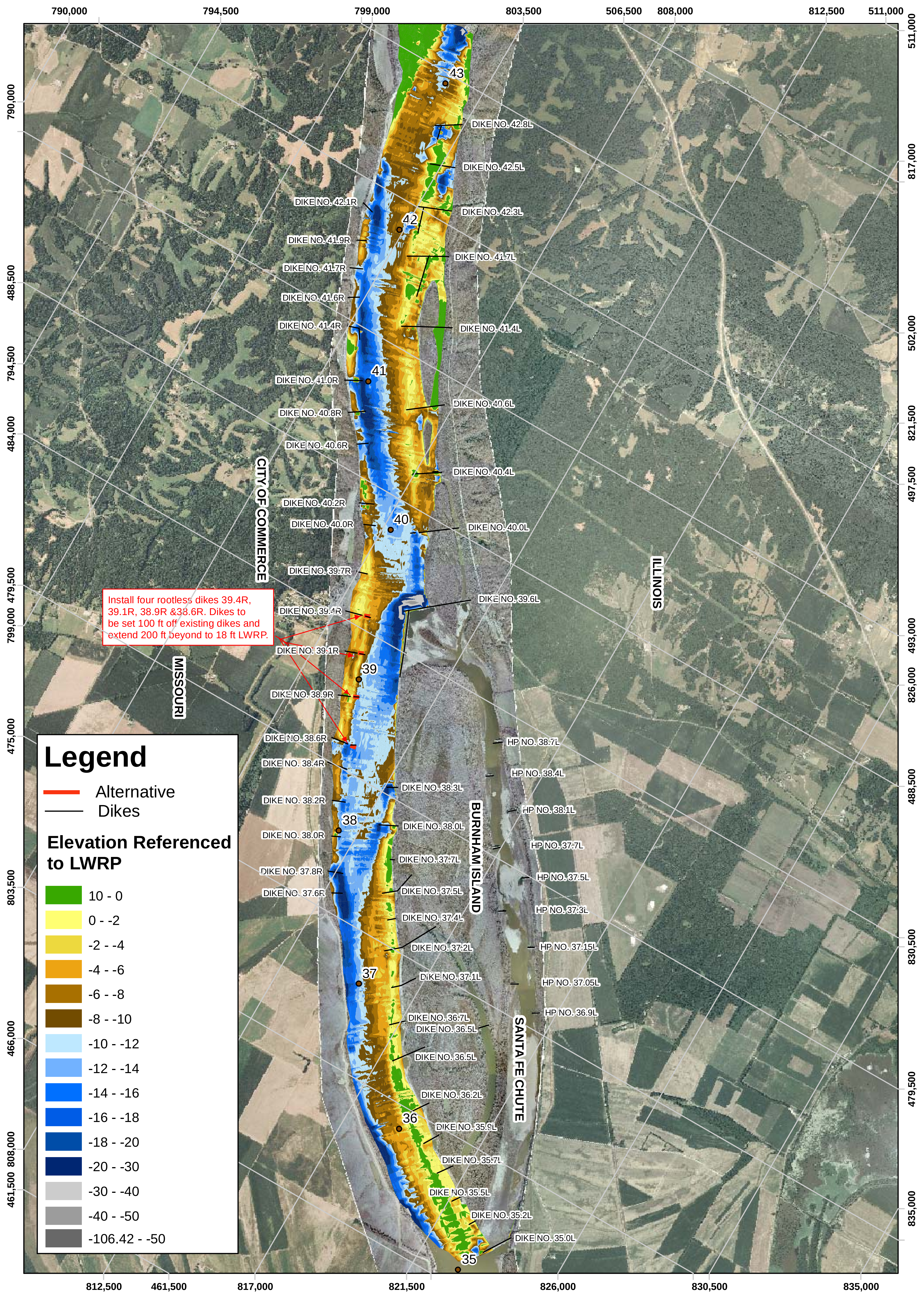

PLATE NUMBER 21

0 1,500 3,000 6,000
Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

Alternative 5

2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 44 - 35

PLOT DATE: April 13, 2010	
PREPARED BY: M. Miles, P.E.	DRAWN BY: M. Miles, P.E.
CHECKED BY: R. Davinroy, P.E.	
FILE NAME: ...ARC/THEBES	

N W E S

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers St. Louis District®

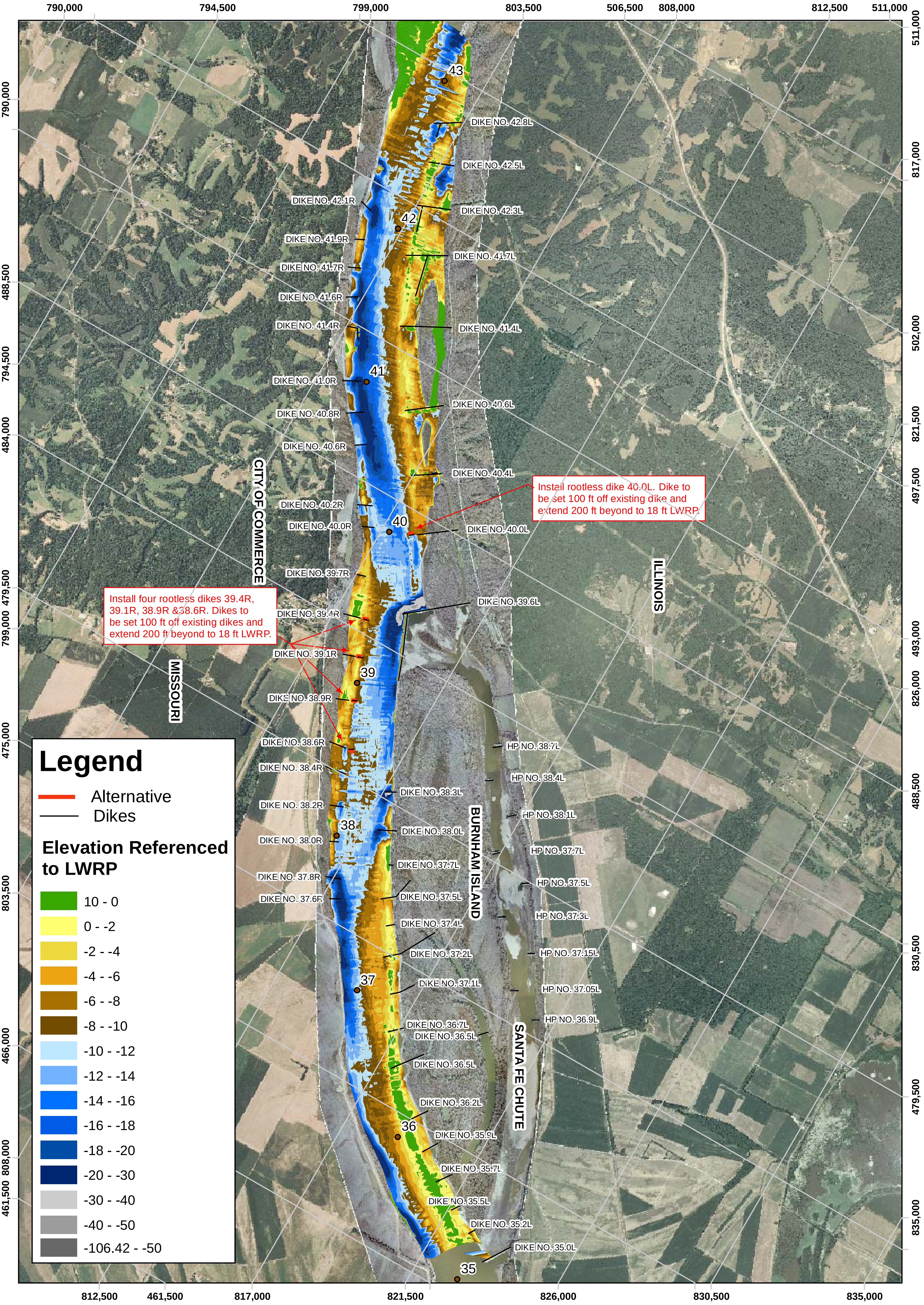

PLATE NUMBER 22

0 1,500 3,000 6,000

Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

Alternative 6

2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT	PLOT DATE: April 13, 2010
	PREPARED BY: M. Miles, P.E. / DRAWN BY: M. Miles, P.E.
UPPER MISSISSIPPI RIVER BASIN Thebes HSR Model River Miles 44 - 35	CHECKED BY: R. Davinroy, P.E.
	FILE NAME: ...ARC/THEBES

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers St. Louis District®

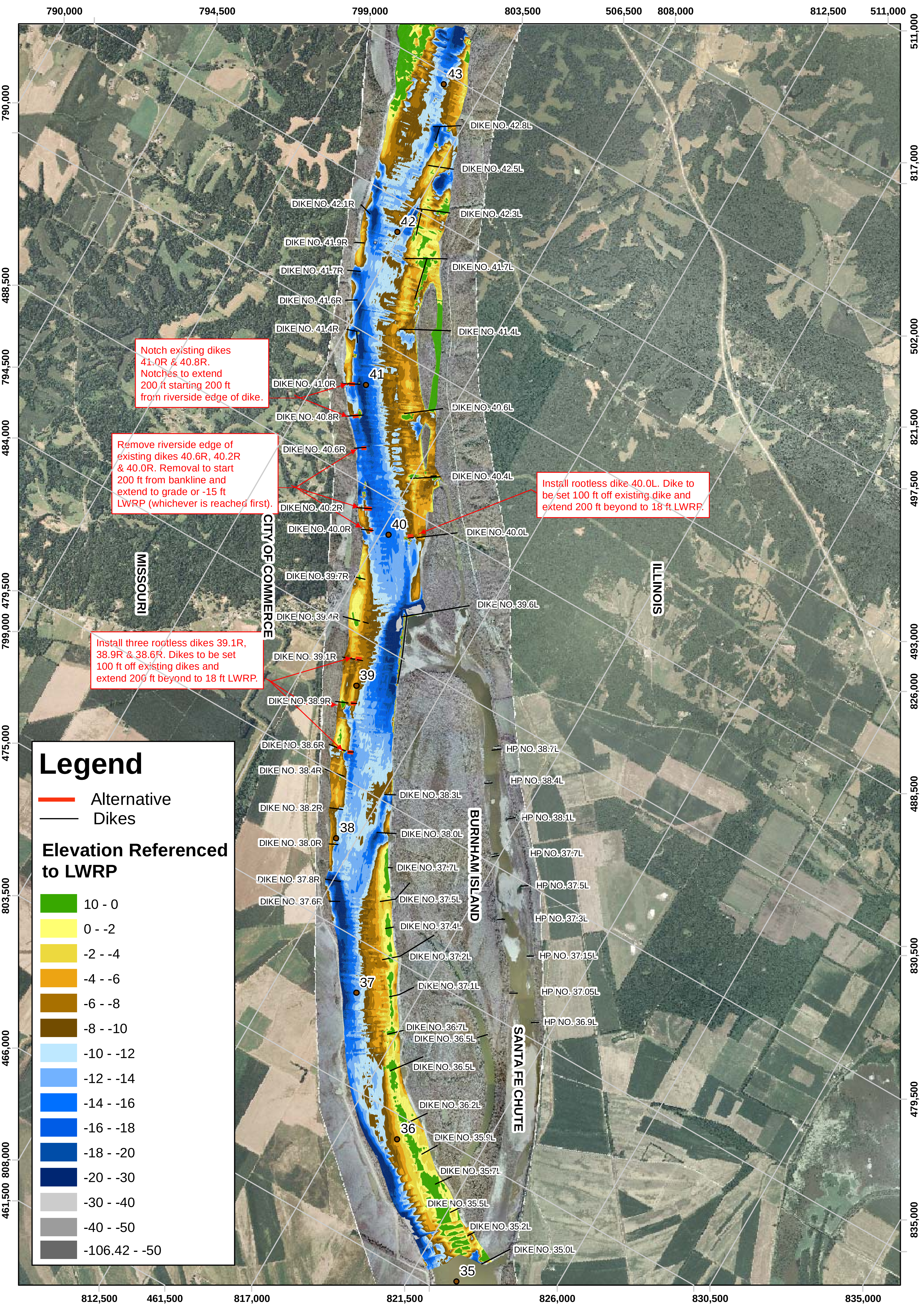

PLATE NUMBER 23

0 1,500 3,000 6,000 Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

Alternative 7

2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 44 - 35

PLOT DATE: April 13, 2010	
PREPARED BY: M. Miles, P.E.	DRAWN BY: M. Miles, P.E.
CHECKED BY: R. Davinroy, P.E.	
FILE NAME: ...ARC/THEBES	

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District®

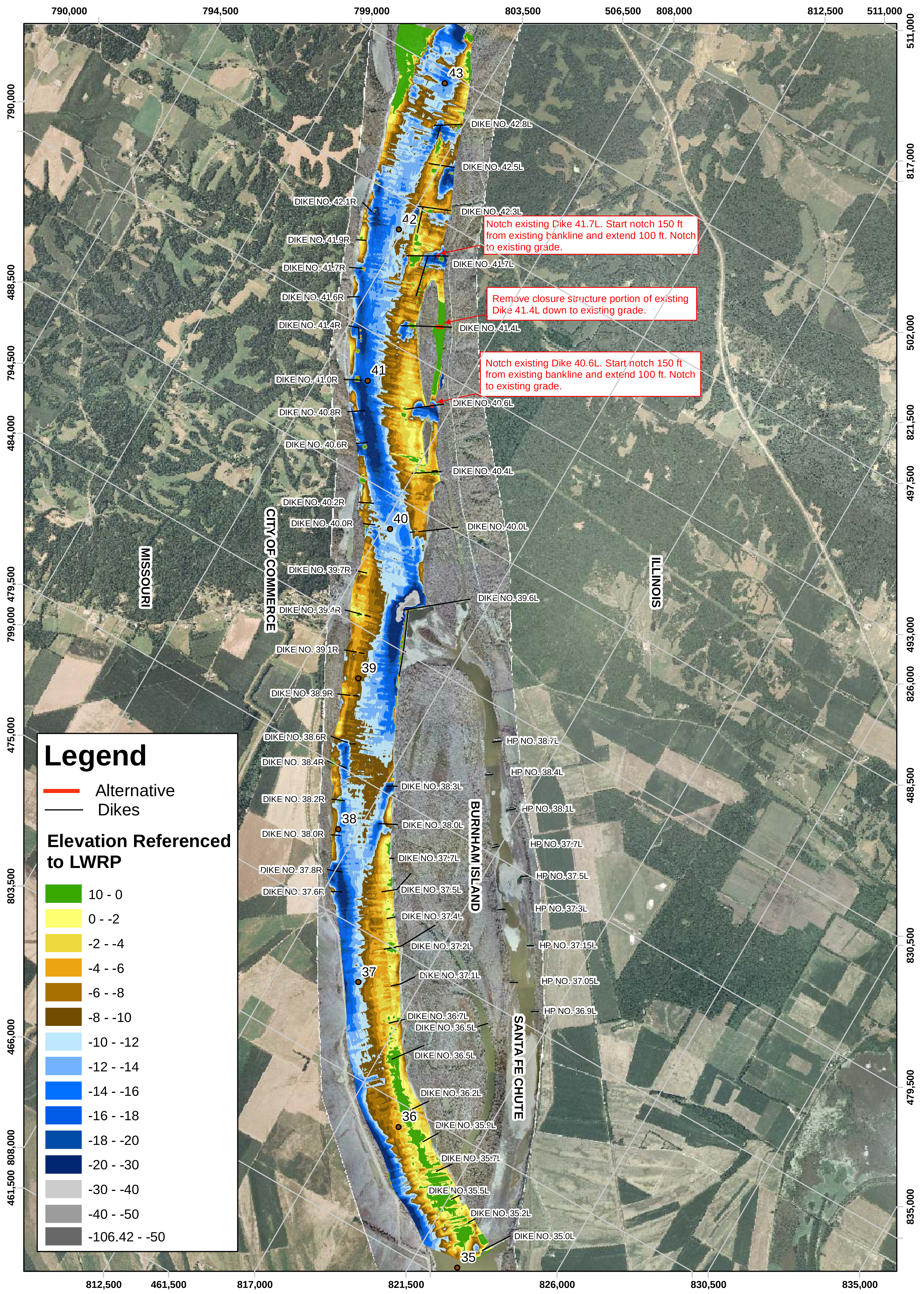

PLATE NUMBER 24

0 1,500 3,000 6,000
Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

Alternative 8
2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT	PLOT DATE: April 13, 2010	
	PREPARED BY: M. Miles, P.E.	DRAWN BY: M. Miles, P.E.
UPPER MISSISSIPPI RIVER BASIN Thebes HSR Model River Miles 44 - 35	CHECKED BY: R. Davinroy, P.E.	
	FILE NAME: ...ARC/THEBES	

N E S W

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers St. Louis District®

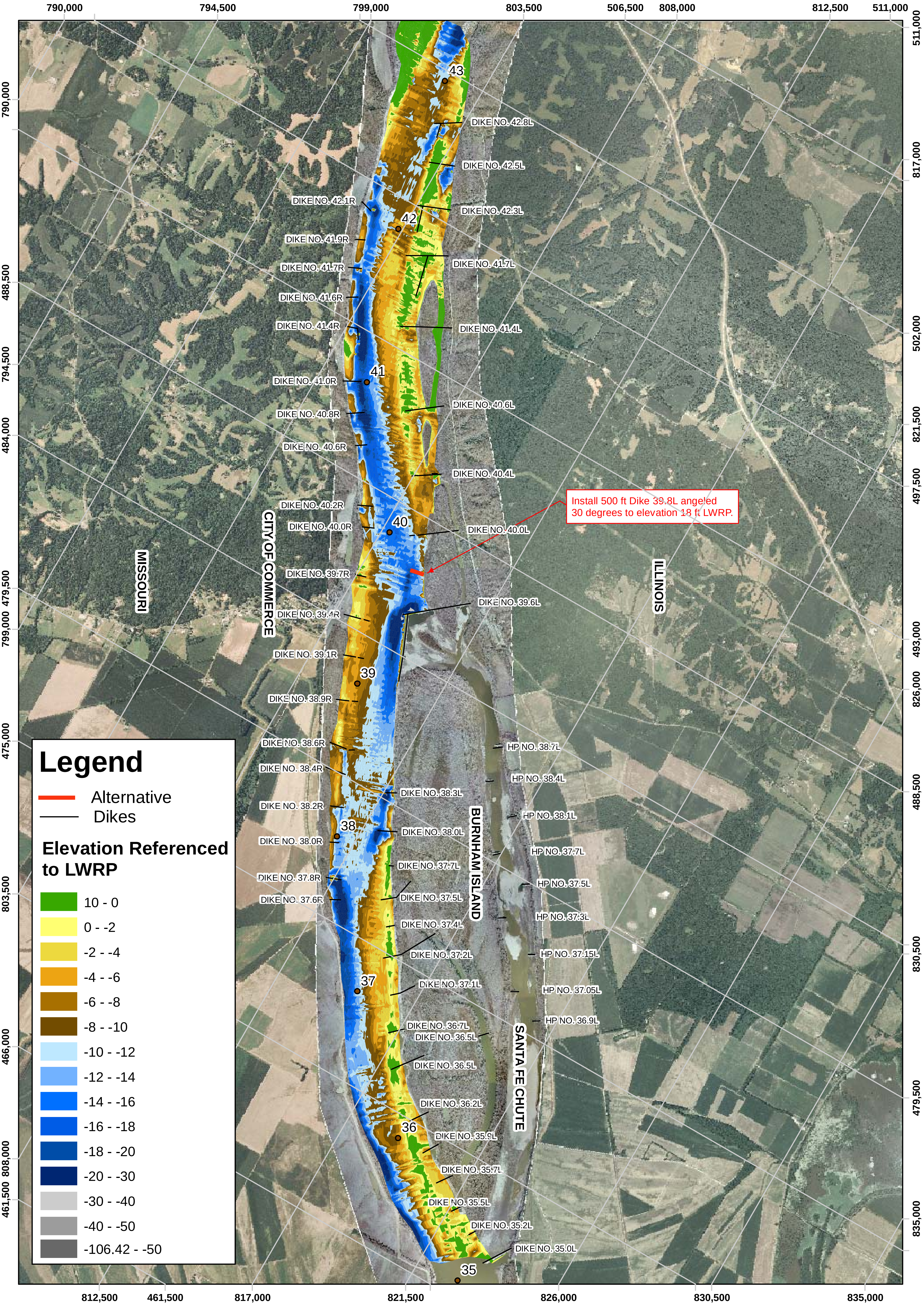

PLATE NUMBER 25	0 1,500 3,000 6,000 Feet THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME Alternative 9 2006/2007 Aerial Photo	U.S. ARMY CORPS OF ENGINEERS ST. LOUIS, DISTRICT UPPER MISSISSIPPI RIVER BASIN Thebes HSR Model River Miles 44 - 35	PLOT DATE: April 13, 2010 PREPARED BY: M. Miles, P.E. DRAWN BY: M. Miles, P.E. CHECKED BY: R. Davinroy, P.E. FILE NAME: ...ARC/THEBES

N E S W

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District®

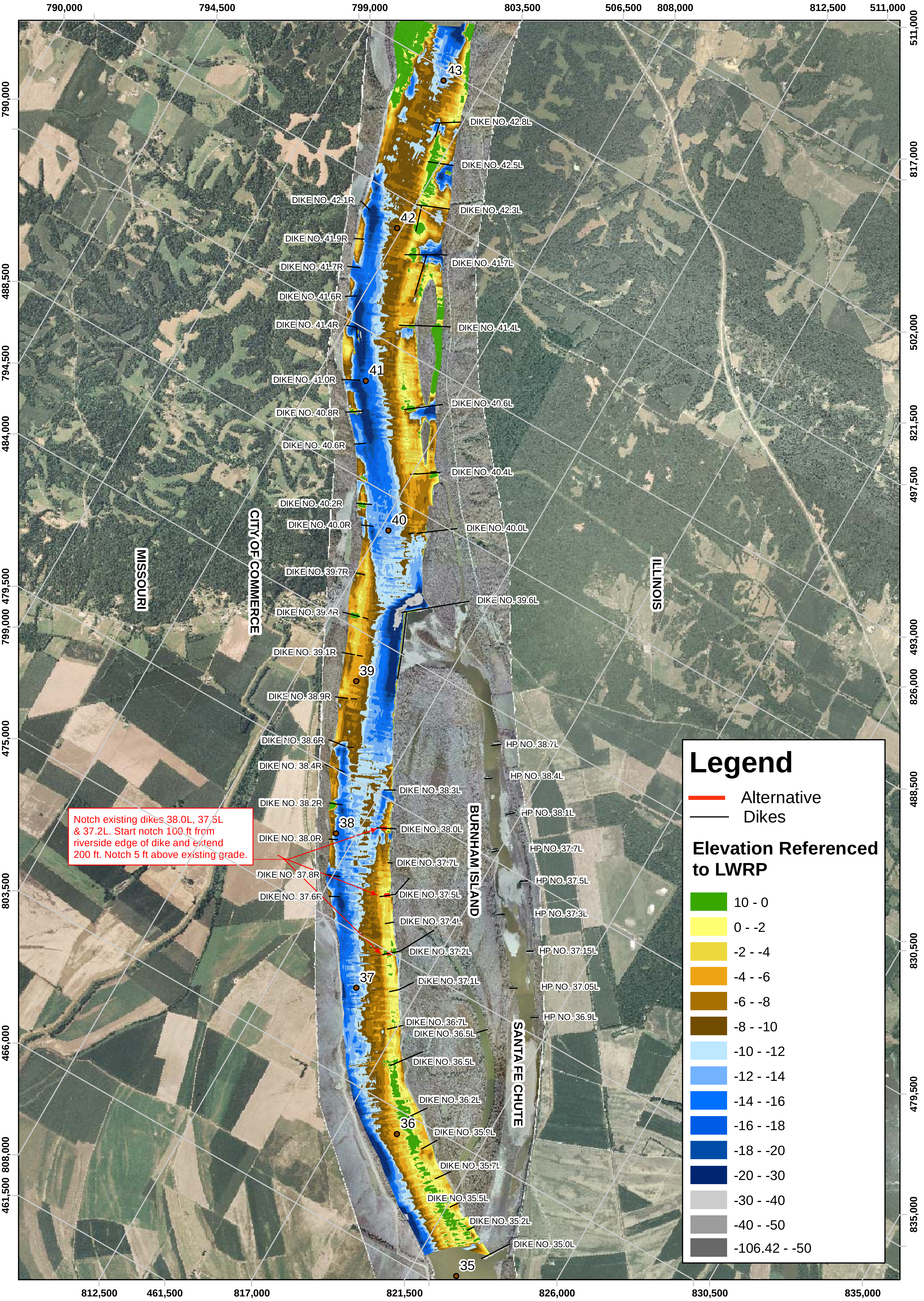

PLATE NUMBER 26

0 1,500 3,000 6,000
Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

Alternative 10
2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 44 - 35

PLOT DATE: April 13, 2010
PREPARED BY: M. Miles, P.E.
DRAWN BY: M. Miles, P.E.
CHECKED BY: R. Davinroy, P.E.
FILE NAME: ...ARC/THEBES

APPLIED RIVER ENGINEERING CENTER

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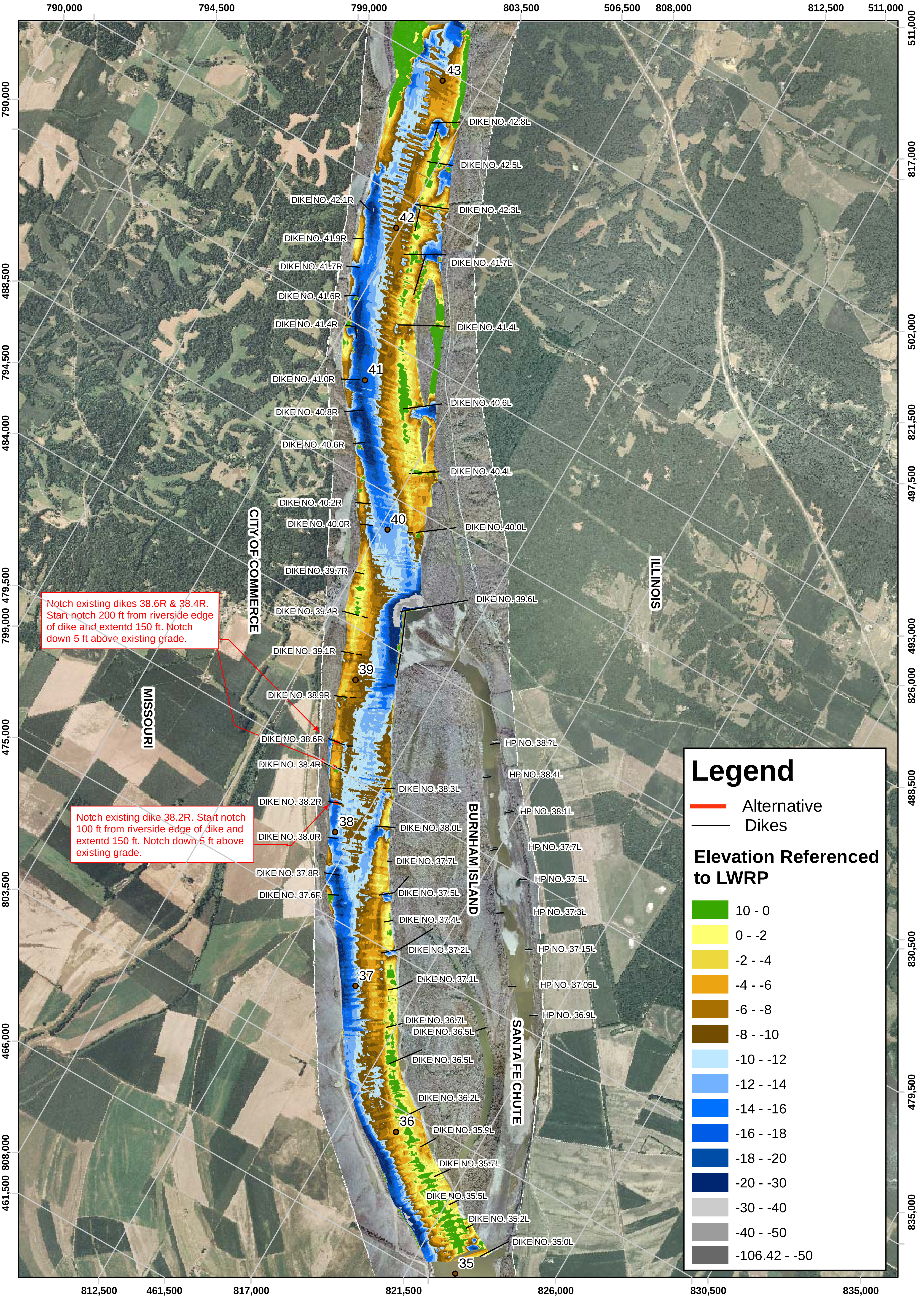

PLATE NUMBER 27

0 1,500 3,000 6,000
Feet

THE INFORMATION DEPICTED ON THIS MAP REPRESENTS THE RESULTS OF SURVEYS MADE ON THE DATES INDICATED AND CAN ONLY BE CONSIDERED AS INDICATING THE GENERAL CONDITIONS EXISTING AT THAT TIME

Alternative 11

2006/2007 Aerial Photo

U.S. ARMY CORPS OF ENGINEERS
ST. LOUIS, DISTRICT

UPPER MISSISSIPPI RIVER BASIN
Thebes HSR Model
River Miles 44 - 35

PLOT DATE: April 13, 2010	
PREPARED BY: M. Miles, P.E.	DRAWN BY: M. Miles, P.E.
CHECKED BY: R. Davinroy, P.E.	
FILE NAME: ...ARC/THEBES	

APPLIED RIVER ENGINEERING CENTER

US Army Corps of Engineers
St. Louis District