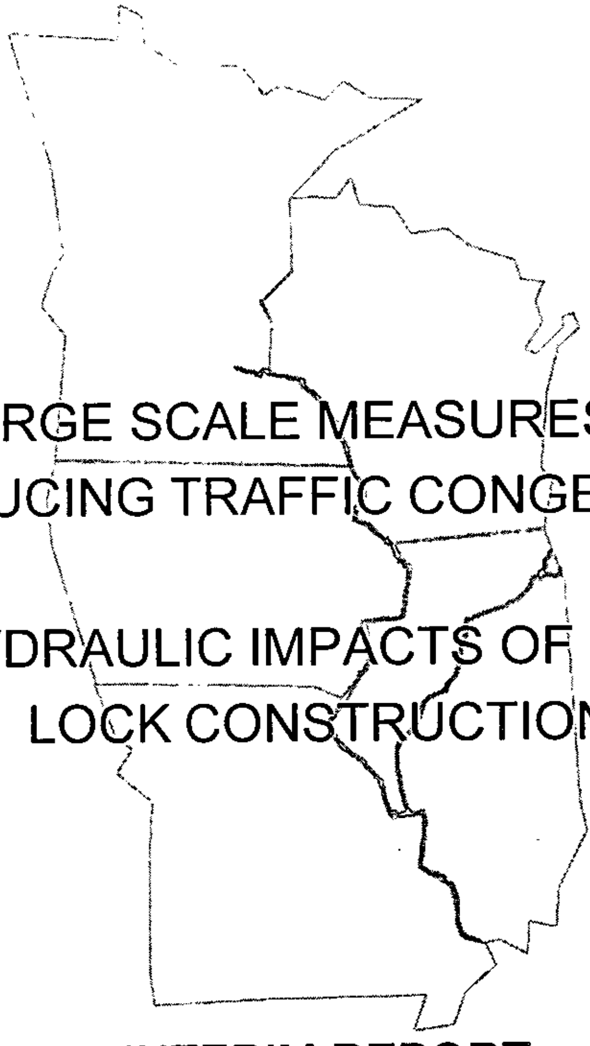
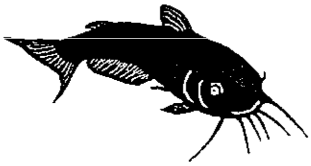
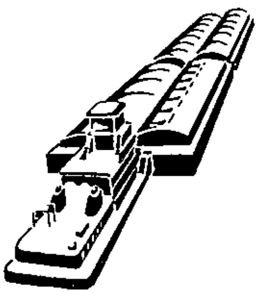
# Upper Mississippi River - Illinois Waterway System Navigation Study





## LARGE SCALE MEASURES OF REDUCING TRAFFIC CONGESTION

## HYDRAULIC IMPACTS OF NEW LOCK CONSTRUCTION



INTERIM REPORT

July 1996

US Army Corps of Engineers

Rock Island District
St. Louis District
St. Paul District

# EXECUTIVE SUMMARY

1. The objective of this report is to investigate the hydraulic impacts of new lock construction at sixteen lock and dam sites on the Upper Mississippi River and Illinois Waterway. Construction of a new lock will add additional lock capacity by providing a lock chamber with useable dimensions of either 1200 feet by 110 feet, or 600 feet by 110 feet at each site. The concern for hydraulic impacts include approach and exit conditions as well as changes in flow conditions both during and after construction. The findings contained in this report pertain to locks 1200 feet in length, although they would generally be applicable to 600 foot locks as well. Six alternative lock locations were considered in the initial phase of study. As part of the initial site screening process, this number was reduced to five. These five locations are as follows:

a. Location 1, Landward of the existing lock.
b. Location 2, Extension of the existing 600 ft lock.
c. Location 3, At the partially constructed auxillary lock.
d. Location 4, In the gated section of the dam.
e. Location 5, In the overflow section of the dam

2. Each alternative required additional features to improve lock approach and exiting conditions. All alternatives include a 1200 foot long guard/guide wall upstream and downstream of the new lock. To distinguish between a guard wall and a guide wall, the following definition, based on structure location, is provided:

Guide wall: located on the landward side of lock
Guard wall: located on the riverward side of lock

In addition, some alternatives require bank and/or channel excavation, removal or extension of existing guide walls, and additional channel training structures.

3. Extrapolation of the results of physical and numerical modeling conducted at 5 selected sites, along with mapping and aerial photography, were used to assess navigation conditions at each site and provide recommendations to improve navigation conditions as necessary. Important findings and recommendations which are common to most of the sites considered for added lock capacity are listed below.

a. From a navigability standpoint, better channel alignment and wider approach conditions make Locations 3 or 4 the preferred locations for adding lock capacity.

b. While existing bathymetry and flow characteristics at selected sites do not rule out Location 5 as a possible location for construction of a new lock, uncertainties concerning the reliability of the existing channel during the estimated 3 to 4 year period required to move the channel, seriously limit the viability of Location 5 as a plan alternative.

c. New lock construction at Location 1 is only feasible at four of the 16 sites being considered for large scale navigation improvements.

d. While ported guardwalls upstream of a lock significantly reduce outdraft and aid tows in aligning with the lock, satisfactory channel alignment must be provided in order for the ported wall to be beneficial.

e. The effective length of the upstream guard wall is measured from the end of the opposite landside lock wall. A 1200 foot wall is recommended so that tows will have protection from cross currents for their entire length.

f. A minimum approach distance of two tow lengths as measured from the end of the guide wall or guard wall, is required for good approach conditions to the lock. This is especially important for locks with ported guard walls.

g. Good access to the new 1200 foot lock from downstream is best maintained by a solid landward guide wall. However, at Location 3, access to the existing lock is hampered by a landward guide wall. Therefore, a solid riverside guard wall is the recommended structure at Location 3 if the existing lock is to remain accessible.

h. At most sites, construction of a Location 3 or 4 lock will restrict access to the existing lock. Therefore, the existing lock 600-foot lock would be dedicated primarily to recreational traffic and only used for commercial traffic if the 1200-foot lock were closed to navigation.

i. The effects of adding replacement gates in the overflow section of a dam site for a Location 4 lock are highly localized.

j. For each 60 to 80 foot tainter gate removed from service, an increase in swellhead of about 0.1 feet can be expected.

HYDRAULIC IMPACTS OF NEW LOCK CONSTRUCTION

Table of Contents

Table of Contents con't



Tables

Tables con't



Figures

Figures con't

Figures con't

## INTRODUCTION

1. The objective of this report is to investigate the hydraulic impacts of new lock construction at sixteen lock and dam sites on the Upper Mississippi River. Basically, new lock construction will add additional lock capacity by providing a lock chamber with useable dimensions of either 1200 feet by 110 feet, or 600 feet by 110 feet at each site. The concern for hydraulic impacts include approach and exit conditions as well as changes in flow conditions both during and after construction. The findings contained in this report pertain to locks 1200 feet in length, although they would generally be applicable to 600 foot locks as well. Six alternative lock locations were considered in the initial phase of study. As part of the initial site screening process, this number was reduced to five. These five locations are as follows:

a. Location 1, Landward of the existing lock.
b. Location 2, Extension of the existing 600 ft lock.
c. Location 3, At the partially constructed auxillary lock.
d. Location 4, In the gated section of the dam.
e. Location 5, In the overflow section of the dam

2. Each alternative required additional features to improve lock approach and exiting conditions. All alternatives include a 1200 foot long guard/guide wall upstream and downstream of the new lock. Any refinements in guard wall and guide wall lengths and configurations will be addressed during the site specific feasibility phase of this study, once specific sites have been identified for new lock construction. To distinguish between a guard wall and a guide wall, the following definition, based on structure location, is provided:

Guide wall: located on the landward side of lock
Guard wall: located on the riverward side of lock

In addition, some alternatives require bank and/or channel excavation, removal or extension of existing guide walls, and additional channel training structures. Features to account for ice and debris problems will also be addressed.

3. Because of secondary currents and the submerged ports of the guard wall, three-dimensional flow conditions exist. While a physical model is best suited for studying these effects, it has a high cost and does not have the flexibility of a numerical model for making quick changes in bank alignment and bathymetry. Therefore, evaluation of hydraulic impacts of new lock placement using physical models was limited to two sites which exhibit generically representative characteristicstics which allow extrapolation of results to other sites. Numerical modeling of alternatives was chosen as the tool for determining hydraulic impacts at other selected sites considered for new lock construction. Verification of the numerical models was accomplished by comparing numerical model results with results generated by the physical models at Lock and Dams 22 and 25.

4. While three-dimensional numerical models are just now becoming available (e.g. CH3D), they are time consuming to generate, difficult to calibrate, and require the use of a super computer (e.g. Cray). Therefore, a state-of-the-art, two-dimensional, depth-averaged, finite element numerical modeling procedure was selected. This consisted of using the TABS-2 system (Thomas and

McAnnally, 1985) for computing water surface elevations and flow velocities, and the software package FastTABS (Bringham Young University) for pre- and post-processing of numerical model data.

5. The TABS system has been proven to adequately model flow distribution around islands and through backwater areas. While it does account for secondary flow in the main channel, the model's ability to represent three-dimensional flow such as that occurring through the submerged ports of a guard wall are limited. To assure the adequacy of two-dimensional modeling to represent three-dimensional flow characteristics, model verification through the reproduction of measured velocity data was required. While velocity measurements for existing conditions were easily obtained from the prototype, measurements for proposed alternatives required velocity data collected in a physical model.

6. Because there are 16 sites on the Illinois Waterway and the Upper Mississippi River under consideration for new lock construction, a "generic" physical modeling plan was developed. It was determined that the diversity of flow conditions and structural foundations could be represented with two physical models. While the concept was generic model testing, a selection was made from the site list, thus allowing two models to be available for future site specific testing. Because of the diverse downbound approach conditions and the materials upon which they are founded, Lock and Dam 22 and 25 were selected for development of generic lock designs. Lock and Dam 22, represents a rather straight river channel approach with no major backwater areas, whereas Lock and Dam 25 represents a wide river condition with an extensive backwater area. Also, Lock and Dam 22 is founded on rock while Lock and Dam 25 is constructed on sand and is founded on timber piling.

7. For both of the physical models, a range of flow conditions were run for each alternative as well as base conditions. Velocity measurements made in the physical models represent the average velocity of the surface flow to a depth of 9 feet, the normal draft of a loaded barge. Therefore, velocity measurements were taken in the prototype such that a correlation between the average surface velocity of the top 9-feet of depth and the depth-averaged velocity could be made. This correlation was used to adjust depth-averaged results of the numerical models to represent the average velocity of the surface layer.

8. While Rock Island District concentrated their efforts on numerical modeling of Lock and Dams 20, 21, and 22, St. Paul District, in cooperation with St. Louis District, performed work on Lock and Dams 24 and 25. This report briefly describes the physical modeling effort, discusses the prototype data collection plan and method, presents the numerical modeling calibration to prototype data results, shows verification of the models through data collected in the physical models, presents the flow patterns for alternatives at five sites, and examines hydraulic impacts during construction. Extrapolation of the results of the physical and numerical modeling conducted at the lower 5 sites, allowed hydraulic impacts at all 16 sites considered for additional lock capacity to be assessed. A site by site assessment is provided as an appendix to this report.

## EXISTING SITE CONDITIONS

### Lock and Dam 20

9. Lock and Dam 20 is located on the right bank of the Upper Mississippi River at river mile 343.2 at Canton, Missouri. During low and normal river flows, the dam backs up water creating a pool which maintains a minimum 9 foot channel for navigation. The pool extends from the dam upstream to river mile 364.2. The dam has a total length 2,294 feet consisting of 2,144 feet of gated section which includes gates, piers, abutments and 150 feet of non-overflow earthdike. The facility was placed in operation in June of 1936.

10. The dam is constructed of concrete, with steel gates, and is founded on rock. There are 40 tainter gates that are 40 feet long by 20 feet high, six of which are submersible. There are also three non-submersible roller gates which are 60 feet long by 20 feet in diameter. The concrete pier width between the tainter gates and roller gates is 8 feet and 15 feet respectively. The main lock has useable dimensions of 600 feet by 110 feet. A partially completed auxiliary lock is located riverward and adjacent to the main lock (Figure 1).

11. For flow rates less than 110,000 cfs the navigation pool is regulated within the limits of elevation 477.0 and 481.0 feet MSL at the dam while maintaining a minimum elevation of 479.0 feet MSL at Gregory Landing (river mile 352.9). For flow rates greater than 110,000 cfs, the gates are lifted clear of the water and open river conditions exist. For receding flow rates, the gates are lowered into the water when the pool gage reads 475.5 feet MSL. The gates of the dam are then adjusted to keep the pool within specified limits. The wide band of pool limits for Lock and Dam 20 are used to dampen changes in flow created by hydropower generation upstream at Keokuk, Iowa.

12. A ported guard wall extends upstream of the riverward wall of the auxiliary lock. The wall is 470 feet long with an abrupt 15 degree riverward bend 270 feet upstream of the auxiliary lock. The wall consists of a series of cells 25 feet in diameter on 50 foot centers. Buttresses are located atop each cell. An armored wall, 18 feet in height and supported by timber piles on 5 foot centers, extends buttress to buttress over the full length of the guard wall. A sheet pile curtain wall extends 5 feet below the armored wall and is connected to the timber pile. The curtain wall extends from the nose cell to first cell upstream of the riverward lock wall. This leaves a 12 foot opening between the first cell and the lock wall for trash removal. The top of the armored wall is at the same elevation as the top of the lock wall. The bottom of the curtain wall is about 9 feet below the lower pool limit elevation.

13. The downbound approach to the lock requires flanking as tows have a tendency to be drawn into the riverbank. During high flows when the dam gates are out of the water, a helper boat is needed to assist tows approaching the lock.

## Lock and Dam 21

14. Lock and Dam 21 is located on the left bank of the Mississippi River at river mile 324.9 near Quincy, Illinois. During low and normal river flows, the dam backs up water maintaining a minimum 9 foot navigation channel upstream to river mile 343.2. The dam has a total length 2,960 feet consisting of 1,066 feet of gated section which includes gates, piers and abutments, 494 feet of non-overflow earthdike, and 1,400 feet of overflow earth dam section. The Lock and Dam was placed in operation in July of 1938.

15. Lock and Dam 21 is constructed of concrete, with steel gates, and is founded on piles in sand and gravel. There are 10 submersible tainter gates 64 feet in length by 20 feet high and 3 roller gates 100 feet wide by 20 feet in diameter. Concrete piers located between the tainter gates and roller gates are 8 feet and 15 feet respectively. The main lock has useable dimensions of 600 feet by 110 feet. A partially completed auxiliary lock is located riverward and adjacent to the main lock (Figure 2).

16. A submersible dike or overflow weir extends from the east end of the dam to high ground on the left bank and is 1,400 feet in length. The dike is protected from scour by 18 inches of riprap placed over 6 inches of crushed stone. The crown is at flat pool elevation 470 feet MSL and is 20 feet wide. Side slopes are 1V:4H on the downstream side and 1V:3H on the upstream side. Since the crest of the dike is constructed to flat pool, the dike is routinely overtopped while the pool is regulated as well as during periods of open river flow.

17. The navigation pool is regulated within the limits of elevation 469.6 and 470.1 feet MSL at the dam during low to normal flows. As flow increases, the gates are raised so as not to exceed the authorized pool limits. For flow rates greater than 130,000 cfs, the gates are lifted clear of the water and open river conditions exist. For receding flow rates, the gates are lowered into the water when the tailwater below the dam drops to 469.2 feet MSL.

18. A ported guard wall extends upstream of the riverward wall of the auxiliary lock. The wall is 470 feet long with an abrupt 15 degree riverward bend 270 feet upstream of the auxiliary lock. The wall consists of a series of cells 25 feet in diameter on 50 foot centers. Buttresses are located atop each cell. An armored wall, 18 feet in height and supported by timber piles on 5 foot centers, extends buttress to buttress over the full length of the guard wall. A sheet pile curtain wall extends 5 feet below the armored wall and is connected to the timber pile. The curtain wall extends from the nose cell to first cell upstream of the riverward lock wall. This leaves a 12 foot opening between the first cell and the lock wall for trash removal. The top of the armored wall is at the same elevation as the top of the lock wall. The bottom of the curtain wall is about 9 feet below the lower pool limit elevation.

19. Outdraft conditions at Lock and Dam 21 require flanking by downbound tows to sucessfully complete the approach to the lock. A helper boat is needed when the tailwater approaches flood stage. During high water upbound tows have often hit the lower guide wall.

## Lock and Dam 22

20. Lock and Dam 22 is located on the right bank of the Upper Mississippi River at river mile 301.2 below Saverton, Missouri. During low and normal river flows, the dam creates a pool which maintains a minimum 9 foot navigation channel upstream to river mile 324.9. The dam has a total length 3,084 feet consisting of 1,024 feet of gated section which includes gates, piers and abutments, 460 feet of non-overflow earthdike, and 1,600 feet of overflow earthen dam section constructed to elevation 459.5 feet MSL. The facility was placed in operation in July of 1938.

21. Lock and Dam 22 is constructed of concrete, with steel gates, and is founded on rock. Along the gated section of the dam there are 9 non-submersible tainter gates 60 feet long by 27 feet high, one submersible tainter gate 60 feet by 25 feet, and 3 roller gates 100 feet in length by 25 feet in diameter. The concrete pier width between the tainter gates and roller gates are 8 feet and 15 feet respectively. The main lock has useable dimensions of 600 feet by 110 feet. A partially completed auxiliary lock is located adjacent to the main lock (Figure 3).

22. An overflow dike extends from the east end of the dam to high ground on the left bank and is 1,600 feet in length. The dike is protected from scour by 18 inches of riprap placed over 6 inches of crushed stone. The crown is at flat pool elevation 459.5 feet MSL and is 20 feet wide. Side slopes are 1V:4H on the downstream side and 1V:3H on the upstream side. Since the crest of the dike is constructed to flat pool, the dike is routinely overtopped while the pool is regulated as well as during periods of open river flow.

23. The navigation pool is regulated within the limits of elevation 459.1 and 459.6 feet MSL at the dam during low to normal flows. As flow increases, the gates are raised so as not to exceed the authorized pool limits. For flow rates greater than 162,000 cfs, the gates are lifted clear of the water and open river conditions exist. For receding flow rates, the gates are lowered into the water when the tailwater below the dam drops to 458.6 feet MSL.

24. Downbound vessels must reduce speed as they approach the lock due to the presence of strong outdraft currents across the approach toward the dam. Helper boats are required to assist tows approaching the lock from upstream for flows above 100,000 cfs.

## Lock and Dam 24

25. Lock and Dam 24 is located on the right bank of the Upper Mississippi River, river mile 273.4, at Clarksville, Missouri. It backs up water from river mile 273.4 to 301.2 on the Mississippi River during low and normal river flows, thus providing a 9 foot navigation channel. The total length of the dam is 4,280 feet and includes a 1,340 foot gated section and a 2,820 foot earthen overflow dike (Figure 4).

26. Lock and Dam 24 is constructed of concrete with steel gates. The foundation of the first pier of the dam is rock, the second through fourth piers rest on piling driven into rock, and the remainder of the dam is supported by friction piling. There are 15 tainter gates, 80 feet by 25 feet,

separated by 14 concrete piers 10 feet in width. The main lock is located on the right bank and has useable dimensions of 600 feet by 110 feet. There is an adjoining auxiliary lock that is incomplete.

27. An overflow dike, 2,820 feet in length, extends from the east end of the dam to high ground. It is constructed with a core of sheet pile diaphragm cells covered with stone and slush concrete. The crown of the dike is 20 feet wide and has an elevation of 449.0 feet MSL. The dike is overtopped for a discharge of about 175,000 cfs; however, it is not overtopped while the pool is regulated.

28. The navigation pool is regulated within the limits of 445.5 and 449.0 feet MSL at the dam and a stage of 11.5 and 12.2 feet at Louisiana, Missouri (river mile 282.9) for flow rates less than 154,000 cfs. As flow increases, the gates are raised so as not to exceed the limits at Louisiana, MO. For flow rates greater than 154,000 cfs, the gates are lifted clear of the water and open river conditions exist. For receding flow rates, the gates are lowered into the water when the pool side of the dam drops to 445.5 feet MSL. The gates are then adjusted according to flow forecasts to keep the pool within the specified limits.

29. A ported guard wall extends upstream of the riverward wall of the auxiliary lock. The wall is 470 feet long with an abrupt 15 degree riverward bend 270 feet upstream of the auxiliary lock. The wall consists of a series of cells 25 feet in diameter on 50 foot centers. Buttresses are located atop each cell. An armored wall, 18 feet in height, extends buttress to buttress along the full length of the guard wall. A curtain wall, made of sheet pile, extends 5 feet below the armored wall and is supported by timber piles on 5 foot centers. The curtain wall extends from the nose cell to the first cell upstream of the riverward lock wall. This leaves a 12 foot opening between the first cell and the lock wall for trash removal. The top of the armored wall is at the same elevation as the lock wall. The bottom of the curtain wall is about 9 feet below the low control pool elevation.

30. The opening for trash removal has proved to be ineffective. Trees become pinned across the opening which in turn encourages the collection of smaller debris. As debris continues to accumulate over time, the debris gap becomes plugged. This results in more flow being forced through the series of timber piles upstream. Because the timber piles are on 5 foot centers, debris accumulates quickly. As plugging of the openings increase, the outdraft near the nose cell, due to flow crossing over to the dam, becomes more severe. Becasuse of the potential for bed scour due to these currents, riprap was placed around the cells extending about 35-feet on each side of the wall.

31. Outdraft conditions have hampered downbound tows approaching the lock. A spur dike was constructed upstream of the lock to improve approach conditions. While this has improved conditions, a helper boat is needed under moderate to high flow conditions to overcome the outdraft and align the tow with the guide wall.

## Lock and Dam 25

32. Lock and Dam 25 is located on the right bank of the Upper Mississippi River, river mile 241.4, at Cape Au Gris, Missouri. It backs up water from river mile 241.4 to 273.4 on the

Mississippi River during low and normal river flows, thus providing a 9 foot navigation channel. The structure was completed in July of 1939. The total length of the dam is 4,078 feet and includes 1,296 feet of tainter and roller gates, and 2,566 feet of earthen overflow dike (Figure 5).

33. Lock and Dam 25 is constructed of concrete, with steel gates, and is founded on wooden piles driven in sand. There are 14 tainter gates 60 feet by 25 feet and 3 roller gates 100 feet by 25 feet. Concrete piers between the tainter gates and roller gates are 8 feet and 15 feet in width respectively. The main lock is located on the right bank and has useable dimensions of 600 feet by 110 feet. There is an adjoining auxiliary lock that is incomplete.

34. An overflow dike extends from the east end of the dam to high ground on the left bank and is 2,566 feet in length. The dike is protected from scour by 18 inches of riprap placed over 6 inches of crushed stone. The crown is at elevation 434.0 feet MSL and is 20 feet wide. Side slopes are 1V:4H on the downstream side and 1V:3H on the upstream side. The dike becomes overtopped for a discharge of about 188,000 cfs; however, it is not overtopped while the pool is regulated.

35. For flow rates below 135,000 cfs, the navigation pool is regulated within the limits of elevation 429.7 and 434.0 feet MSL at the dam and 434.0 and 437.0 feet MSL at Mosier Landing (river mile 260.3). For flow rates less than 93,000 cfs the minimum pool elevation of 429.7 feet MSL is maintained at the dam. As flow increases, the gates are raised so as not to exceed the limits at Mosier Landing. When flow rates exceed 135,000 cfs, the gates are lifted clear of the water and open river conditions exist. For receding flow rates, the gates are lowered into the water when the pool side of the dam drops to 429.7 feet MSL. The gates are then adjusted according to the flow forecasts to keep the pool within the specified limits.

36. A ported guard wall extends upstream of the riverward wall of the auxiliary lock. The wall is 470 feet long with an abrupt 15 degree riverward bend 270 feet upstream of the auxiliary lock. The wall consists of a series of cells 25 feet in diameter on 50 foot centers. Buttresses are located atop each cell. An armored wall, 18 feet in height, extends buttress to buttress along the full length of the guard wall. A sheet pile curtain wall extends 5 feet below the armored wall and is supported by timber piles on 5 foot centers. The curtain wall extends from the nose cell to first cell upstream of the riverward lock wall. This leaves a 12 foot opening between the first cell and the lock wall for trash removal. The top of the armored wall is at the same elevation as the lock wall. The bottom of the curtain wall is about 9 feet below the low control pool elevation.

37. The opening for trash removal has proved to be ineffective. Trees become pinned across the opening which in turn encourages the collection of smaller debris. As debris continues to accumulate over time, the debris gap becomes plugged. This results in more flow being forced through the series of timber piles upstream. Because the timber piles are on 5 foot centers, debris accumulates quickly. As plugging of the openings increase, the outdraft near the nose cell, due to flow crossing over to the dam, becomes more severe, aggravating scour of the bed riverward of the upstream cells.

38. Severe outdraft conditions have hampered downbound tows approaching the lock. An "L" shaped spur dike was constructed upstream of the lock to improve approach conditions. While this

has improved conditions, a helper boat is often used to overcome the outdraft and align the tow with the guide wall. The presence of the guard wall hinders operation of the helper boat.

## PROTOTYPE DATA COLLECTION

### Data Collection Plan

39. Velocity data was collected in the prototype for the purpose of calibrating the numerical models for Manning's "n" values and eddy viscosities. While collection of data during high, moderate, and low flow conditions would have been ideal, a moderate flow condition was determined to be adequate for calibration purposes since model verification was to be performed through the use of the physical model results.

40. Transects for velocity data collection were located to obtain total channel discharge, flow distribution where there was divided flow, and velocity magnitudes and directions. To accomplish this, approximately seven transect lines per site were required (see Figures 6 through 10).

### Data Collection Equipment

41. Measurements for the lateral velocity profiles were made using an Acoustic Doppler Current Profiler (ADCP). The ADCP determines flow velocity by measuring the frequency shift, or Doppler effect, of sound pulses along four narrow, orthogonal beams. The ADCP transmits short acoustic pulses along the beams at a known frequency (614,400 hertz). The beams are oriented at an angle of 20 degrees from vertical and in 90 degrees azimuth increments horizontally. The ADCP receives and processes echoes from successive, discrete volumes along the four beams. The difference between transmitted and received frequencies is proportional to the velocity of water relative to the ADCP. A three dimensional velocity vector is computed using trigonometry. Any three of the four beams is sufficient to calculate the three velocity components needed. The fourth beam allows evaluation of whether the current is homogeneous among all four beams and gives an indication of data precision.

42. The ADCP uses longer acoustic pulses for tracking the river bottom than for water profiling. The longer pulses and the strong localized echo provided by the bottom allows measurement of the depth and the velocity of the ADCP relative to the bottom. The water velocity is determined as the difference between the measured water velocity and the measured velocity of the ADCP relative to the bottom. If the river bed material is moving, the ADCP will measure the downstream velocity of bed material as an upstream velocity of the boat. By using GPS to monitor movement of the boat, post-processing of the data was performed to reduce this error.

43. The ADCP can not measure the bottom 6 percent of the cross section because of echoes from the side lobes of the beams. It also loses data near the surface because processing is delayed for a short period to allow transducer ringing to subside. Velocities for the unmeasured top and bottom layers were estimated using the power law during post-processing.

44. The ADCP was used to measure the magnitude and direction of the velocity at 18 inch depth increments. The horizontal resolution of the velocity measurement depended on the speed of the boat while measurements were being made. Horizontal resolution varied between 10 to 15 feet.

## Presentation of Results

45. Data from the ADCP describing water velocity and depth, boat velocity, instrument configuration, and ADCP signal characteristics were processed through computer software that did the calculations to produce plots of depth-averaged velocities and water depths at increments of 50 feet. Examples of the data presentation are shown in Figures 11 through 15. Note that headwater and tailwater readings at the dam are given for the time data was being collected. Also the total channel discharge as measured with the ADCP is given.

46. Water surface elevations were surveyed at three locations for each site. Using bench marks at the dam, water surface elevations were determined upstream and downstream of the dam and at the most upstream and downstream transect.

Table 1
Prototype Water Surface Elevations (feet MSL) and Discharges (cfs)

| Lock& Dam | 1995 Survey Date | Approx. Discharge | Water Surface Elevations | | | |
|---|---|---|---|---|---|---|
| | | | Upstream | Headwater | Tailwater | Downstream |
| 20 | 13-14 June | 136,000 | 479.81 | 479.75 | 478.90 | 478.73 |
| 21 | 14-15 June | 134,000 | 471.45 | 470.54 | 469.12 | 468.34 |
| 22 | 16 June | 140,000 | 459.96 | 459.30 | 457.60 | 457.30 |
| 24 | 20-21 June | 120,000 | 446.32 | 446.16 | 442.72 | 442.07 |
| 25 | 22-23 June | 118,000 | 430.74 | 429.68 | 428.26 | 427.78 |

## Surface Velocities vs. Depth-Averaged Velocities

47. A later discussion shows that velocities in the physical model were measured using floats drafting at about 9 feet, whereas the numerical model produces depth-averaged velocities. Therefore, there was a concern for how surface layer velocities in the zero to 9 foot depth range differ from depth-averaged velocities for the same transect. A paper titled "Maximum and Mean Velocities and Entropy in Open-Channel Flow" (Chiu and Said, 1995) examined velocity profiles, including the Mississippi River, and found that the maximum velocity occurs at approximately one-third of the total depth below the water surface (Figure 16). WES performed a study at the Dalles Lock and Dam (The Dalles Lock and Dam, Model to Prototype Data Comparison, 1995) where flow velocities were measured through the water column, across transects, using an ADCP. A review of the velocity profiles showed the water velocities in the top layer of the column to be about 10 percent greater than the depth-averaged value in the main channel and to be about 20 percent greater outside the main channel.

48. The water depths of the two aforementioned studies are somewhat greater than the five Mississippi River sites being considered here. A quantitative analysis was required for this study. An upstream transect at each site was selected for analysis to determine a relationship between the

average velocity of the surface layer (0 to 9 foot depth) and the average velocity over the entire water column. At the selected transect, extra passes (3 to 4) across the transect were made such that data over every 50 foot horizontal increment was collected for a minimum of 40 seconds. Forty seconds is recommended by the USGS to remove the turbulence flux out of the data and provide a standard deviation about the mean of 0.2 feet per second.

49. When considering the relationship between the average flow velocity of the surface layer and the depth-averaged velocity, water depth becomes important. From Figure 16, it can be seen that the shear stresses along the bottom cause the velocity profile curve to increase at a very slow rate. With reference to Figure 16, consider the flow velocity that would be achieved by a float submerged to 2/3 of the total depth and the depth-averaged velocity that would include the lower 1/3 of the curve in its computation. Based on this, it was expected that the difference between average surface layer flow velocities and depth-averaged flow velocities would be greater in shallow water than deep water. Therefore, for the 9 foot surface layer considered here, surface velocities were expected to be somewhat greater than depth-averaged velocities in a depth range of 10 to 15 feet than depths of over 25 feet. The results of the analysis are shown in the following table:

Table 2
Average Surface Velocity vs. Depth-Averaged Velocity

| Lock | Tran- | Depth: 10'- 15' | | Depth: 15'- 20' | | Depth: 20'- 25' | | Depth: 25'plus | |
|---|---|---|---|---|---|---|---|---|---|
| & | sect | Depth | Surface | Depth | Surface | Depth | Surface | Depth | Surface |
| Dam | No. | Avg | Avg | Avg | Avg | Avg | Avg | Avg | Avg |
| 20 | 2 | 2.29 | 2.52 | 2.74 | 3.04 | 3.30 | 3.71 | 3.41 | 3.83 |
| 21 | 2 | 2.98 | 3.35 | 2.89 | 3.20 | 2.67 | 2.97 | NA | NA |
| 22 | 6 | 2.88 | 3.21 | 2.94 | 3.24 | 2.94 | 3.42 | 3.56 | 3.81 |
| 24 | 3 | 2.35 | 2.64 | 2.37 | 2.62 | 2.17 | 2.36 | 2.22 | 2.39 |
| 25 | 4 | 2.89 | 3.24 | 3.06 | 3.38 | 2.52 | 2.78 | NA | NA |

Note: Average surface velocities are for the layer depth of zero to 9 feet.

Table 3
Average Surface Velocity > Depth-Averaged Velocity (in percent)

| Lock | Tran- | Depth: 10'- 15' | | Depth: 15'- 20' | | Depth: 20'- 25' | | Depth: 25' plus | |
|---|---|---|---|---|---|---|---|---|---|
| & | sect | No. | Percent | No. | Percent | No. | Percent | No. | Percent |
| Dam | No. | Pts | Greater | Pts | Greater | Pts | Greater | Pts | Greater |
| 20 | 2 | 8 | 9.1 | 10 | 9.9 | 11 | 11.0 | 12 | 10.9 |
| 21 | 2 | 12 | 11.0 | 30 | 9.7 | 10 | 10.1 | 0 | NA |
| 22 | 6 | 20 | 10.2 | 24 | 9.2 | 2 | 14.0 | 3 | 6.6 |
| 24 | 3 | 23 | 10.9 | 20 | 9.6 | 8 | 8.0 | 4 | 7.0 |
| 25 | 4 | 31 | 10.7 | 20 | 9.4 | 2 | 9.2 | 0 | NA |

50. Table 3 indicates that a conversion factor to translate depth-averaged velocities to average velocities in the top 9 feet of the water column varies from about 1.07 to 1.14. Where float depths

were reduced to 6 feet and 3 feet in the physical model, due to shallow depths, the surface velocities would be about 11 percent greater than the depth-averaged velocities.

## NUMERICAL MODELING
## CALIBRATION AND VERIFICATION TO PROTOTYPE

### Modeling Procedure

51. A numerical model is a description of a system that uses computational methods to approximate the solution of a mathematical model. RMA2 is a numerical model that solves the two-dimensional, vertically averaged Reynolds form of the Navier Stokes equations for free surface flow. It computes water surface elevations and flow velocities at nodal points of a finite element mesh representing the river. RMA2 is the heart of the TABS system that was used for the numerical modeling effort presented here.

52. Pre- and post-processing of data was performed through the use of the software package FastTABS. FastTABS was used to generate the model grid and display model results. FastTABS can import elevations (z) located by state plane coordinates (x and y) and automatically generate a grid. Hydraulic parameters such as Manning's "n" and eddy viscosity can be easily assigned to each element. A boundary conditions file allows known water surface elevations and inflow rates to be defined. Display options provide a variety of color plots for bathymetry and flow velocities.

53. While the TABS programs can adequately model an open river with islands or man made structures such as mooring cells, accurate representation of flow through submerged ports is beyond the model's capabilities. Because the ports of the existing and proposed guard walls are submerged, a three-dimensional flow condition exists. However, if two-dimensional model results reproduce measured data, it can be assumed that the three-dimensional flow conditions can be adequately represented two-dimensionally. It is was this premise that verification of the modeling procedure was based.

54. Existing condition models for the five sites were generated and verified using velocities measured in the prototype.

### Grid Generation

55. The first step in grid generation was to select the upstream and downstream boundaries. The objective of the modeling effort was to show flow conditions that tows will encounter while approaching and exiting the lock for each alternative over a range of discharges. Therefore, the model must extend a sufficient distance upstream and downstream. A distance of about two miles upstream and downstream of the dam was deemed adequate. Two grids were generated for each study site; (1) upstream of the dam and (2) downstream of the dam.

56. The most recent hydrographic and topographic surveys were used for grid development at the five sites. Hydrographic channel surveys were used to define the river bathymetry. Detailed scour surveys taken in the vicinity of the dam were used to enhance grid definition near the dam. All

soundings were recorded to the nearest tenth of a foot. Topographic survey information was used to describe the landward and backwater areas near the river. The hydrographic channel data was digitally recorded in state plane coordinates thus providing an ASCII file of xyz data on a series of floppy discs. Scour surveys for Lock and Dams 20, 21 and 22 were recorded digitally as xyz data; however, at Lock and Dams 24 and 25, only contour plots were available, therefore an xyz file was created by digitizing (converting analog data to digital data) points along contour lines. Topographic survey data at all of the sites had to be converted in the same manner.

Table 4
Survey Information

| Lock & Dam | Hydrographic River Survey Date | Transect Spacing | Sounding Increment | Scour Survey Date | Contour Interval | Sounding Increment | Topographic Survey Date | Contour Interval |
|---|---|---|---|---|---|---|---|---|
| 20 | May 94 | 200 ft | 50 ft | Oct 94 | NA | 50 ft | Mar 94 | 2 ft |
| 21 | May 94 | 200 ft | 50 ft | Nov 94 | NA | 50 ft | Mar 94 | 2 ft |
| 22 | Oct 93 | 200 ft | 50 ft | Dec 94 | NA | 50 ft | Mar 94 | 2 ft |
| 24 | Nov 93 | 1000 ft | 50 ft | Dec 93 | 5 ft | NA | 1973 | 2 ft |
| 25 | Nov 93 | 1000 ft | 50 ft | Aug 93 | 5 ft | NA | 1973 | 2 ft |

57. The xyz files locating elevation points (nodes) within the boundary limits of each model were imported into FastTABS for grid generation of existing conditions. Because of the large number of data points, thinning of data was required. This was accomplished in two ways (1) removal of points from the data set and (2) triangulating in equilateral triangles of assigned dimensions using FastTABS. Triangulating with FastTABS produces nodal point elevations based on interpolation of the known elevations. Merging of triangles was then performed to produce quadrilateral elements. Where less definition was required, nodal points were eliminated to create larger elements. Where greater definition was required, the mesh refinement option was used.

58. A ported guard wall exists at Lock and Dams 20, 21, 24, and 25. The location of the guard wall is common to all sites. The walls extend upstream of the riverward wall of the auxiliary lock. They are 470 feet in length with an abrupt 15 degree riverward bend 270 feet upstream of the lock wall. The wall consists of a series of circular cells 25 feet in diameter on 50 foot centers. An armored wall 18 feet in height is supported by timber piles on 5 foot centers. The timber piles extend from the nose cell to the first cell upstream of the lock wall. A curtain wall made of sheet pile extends 5 feet beneath the armored wall and is supported by the timber piles. Because the TABS system is a two-dimensional model, only the circular cells could be represented. Octagonal elements were created at the cell locations and by dragging mid-side nodes, a circular element was formed.

## Calibration and Verification

59. The existing condition models were run for the discharges and appropriate tailwater elevations shown in Table 1. Typical Manning's "n" values were assigned to the main channel and backwater areas. The "n" values were then adjusted to produce similar water surface elevations measured in

the prototype. The following tables show Manning's "n" values, eddy viscosities, and the resulting water surface profiles compared to prototype values.

Table 5
Eddy Viscosities and Manning's "n" Values

| Location | L & D 20 Eddy | L & D 20 "n" | L & D 21 Eddy | L & D 21 "n" | L & D 22 Eddy | L & D 22 "n" | L & D 24 Eddy | L & D 24 "n" | L & D 25 Eddy | L & D 25 "n" |
|---|---|---|---|---|---|---|---|---|---|---|
| Upstream Model | | | | | | | | | | |
| Main Channel | 20 | 0.022 | 30 | 0.020 | 60 | 0.022 | 30 | 0.020 | 30 | 0.025 |
| Side Channels | NA | | NA | | 30 | 0.040 | 100 | 0.020 | 400 | 0.040 |
| Vegetation | NA | | 50 | 0.080 | 20 | 0.080 | 50 | 0.080 | 400 | 0.095 |
| Guard wall | 10 | 0.015 | 10 | 0.018 | NA | | 30 | 0.020 | 15 | 0.018 |
| Downstream Model | | | | | | | | | | |
| Main Channel | 20 | 0.026 | 30 | 0.020 | 60 | 0.022 | 30 | 0.020 | 30 | 0.025 |
| Side Channels | 20 | 0.026 | 30 | 0.020 | 30 | 0.040 | 100 | 0.020 | 30 | 0.025 |
| Vegetation | NA | | 50 | 0.080 | 20 | 0.080 | 50 | 0.080 | 30 | 0.085 |

Table 6
Water Surface Elevations (ft MSL)

| Lock No. | Upstream Limit Proto | Upstream Limit Model | Upstream of Dam Proto | Upstream of Dam Model | Downstream of Dam Proto | Downstream of Dam Model | Downstream Limit Proto | Downstream Limit Model |
|---|---|---|---|---|---|---|---|---|
| 20 | 479.8 | 479.7 | 479.4 | 479.4 | 478.9 | 478.9 | 478.7 | 478.6 |
| 21 | 471.4 | 471.2 | 470.5 | 470.7 | 468.5 | 468.5 | 468.3 | 468.3 |
| 22 | 460.0 | 460.1 | 459.3 | 459.4 | 457.5 | 457.5 | 457.3 | 457.3 |
| 24 | 446.3 | 446.3 | 446.2 | 446.2 | 442.7 | 442.7 | 442.1 | 442.1 |
| 25 | 430.7 | 430.7 | 429.7 | 429.9 | 428.3 | 428.2 | 427.8 | 427.9 |

60. The prototype velocities are a reflection of the June 1995 bathymetry, whereas the numerical model velocities are based on the bathymetry from October 1993 through May 1994. Therefore, water depths were included in the presentation of results to indicate changes in bathymetry which can impact the lateral velocity profile. Three transects were selected for presentation: (1) a cross section immediately upstream of the dam (2) either a mid-reach cross section upstream or a cross section immediately downstream of the dam, and (3) mid-reach cross section downstream. Prototype velocities and depths were averaged over 50 foot horizontal increments. Corresponding numerical model data points were used for verification. To reduce the quantity of data for presentation, every fifth point of the prototype data and the corresponding numerical model data point was used. Tables 7 through 11 show model verification results. Distances are in feet measured from the right bank, depths are given to the nearest foot, and velocities are given in feet per second (fps) to the nearest tenth.

Table 7
Lock and Dam 20
Verification of Models to Prototype Data

| | Upstream of Dam - Transect 3 | | | | Downstream of Dam -Transect 2 | | | | Mid Downstream Reach-Trans 6 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth | | Velocity | | Depth | | Velocity | | Depth | | Velocity | |
| Distance | Proto | Model | Proto | Model | Proto | Model | Proto | Model | Proto | Model | Proto | Model |
| 250 | 21 | 21 | 1.7 | 1.5 | 4 | 4 | 1.5 | 1.0 | 19 | 18 | 2.3 | 2.3 |
| 500 | 25 | 25 | 2.4 | 2.3 | 4 | 4 | 1.5 | 1.0 | 27 | 26 | 2.4 | 2.8 |
| 750 | 20 | 20 | 2.9 | 2.8 | 4 | 4 | 2.1 | 1.1 | 25 | 26 | 2.8 | 3.0 |
| 1000 | 17 | 17 | 3.1 | 3.1 | 4 | 4 | 1.0 | 0.9 | 25 | 25 | 3.0 | 3.1 |
| 1250 | 16 | 15 | 3.0 | 3.2 | 12 | 10 | 2.2 | 1.4 | 22 | 21 | 3.1 | 3.1 |
| 1500 | 17 | 15 | 2.9 | 3.2 | 24 | 23 | 3.1 | 2.9 | 17 | 17 | 2.9 | 3.2 |
| 1750 | 15 | 14 | 3.1 | 3.3 | 25 | 26 | 3.4 | 3.5 | 15 | 16 | 3.0 | 3.2 |
| 2000 | 15 | 16 | 3.0 | 3.3 | 27 | 26 | 3.4 | 3.8 | 16 | 16 | 3.0 | 3.1 |
| 2250 | 22 | 21 | 3.4 | 3.2 | 26 | 25 | 3.4 | 3.7 | 17 | 19 | 2.5 | 2.7 |
| 2500 | 24 | 21 | 3.5 | 2.0 | 20 | 21 | 3.1 | 3.5 | 10 | 11 | 1.8 | 2.1 |
| 2750 | | | | | 16 | 17 | 2.9 | 3.2 | | | | |
| 3000 | | | | | 13 | 13 | 2.3 | 1.9 | | | | |

Table 8
Lock and Dam 21
Verification of Models to Prototype Data

| | Upstream of Dam - Transect 4 | | | | Downstream of Dam -Transect 2 | | | | Mid Downstream Reach-Trans 7 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth | | Velocity | | Depth | | Velocity | | Depth | | Velocity | |
| Distance | Proto | Model | Proto | Model | Proto | Model | Proto | Model | Proto | Model | Proto | Model |
| 250 | 8 | 7 | 3.8 | 0.4 | 22 | 15 | 3.4 | 2.7 | 18 | 17 | 1.9 | 2.4 |
| 500 | 11 | 8 | 2.5 | 1.2 | 21 | 21 | 3.1 | 3.4 | 21 | 22 | 3.7 | 3.2 |
| 750 | 10 | 12 | 2.9 | 2.0 | 18 | 19 | 2.9 | 3.1 | 25 | 26 | 3.8 | 3.4 |
| 1000 | 14 | 16 | 3.7 | 2.7 | 14 | 16 | 2.7 | 2.9 | 26 | 28 | 4.2 | 3.7 |
| 1250 | 21 | 19 | 2.7 | 3.4 | 13 | 14 | 2.9 | 3.0 | 27 | 28 | 3.5 | 3.5 |
| 1500 | 25 | 27 | 2.8 | 3.4 | 15 | 15 | 2.9 | 3.2 | 25 | 25 | 3.0 | 3.0 |
| 1750 | 26 | 29 | 3.4 | 3.5 | 15 | 15 | 3.4 | 3.5 | 24 | 21 | 2.0 | 2.0 |
| 2000 | 25 | 26 | 3.3 | 3.7 | 16 | 16 | 3.3 | 3.5 | | | | |
| 2250 | 23 | 24 | 2.4 | 3.5 | 17 | 17 | 2.6 | 3.4 | | | | |
| 2500 | 19 | 21 | 4.6 | 2.5 | 19 | 17 | 3.0 | 2.9 | | | | |
| 2750 | | | | | 16 | 13 | 2.3 | 0.5 | | | | |

Table 9
Lock and Dam 22
Verification of Models to Prototype Data

| | Upstream of Dam - Transect 2 | | | | Mid Upstream Reach-Transect 6 | | | | Mid Downstream Reach-Trans 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth | | Velocity | | Depth | | Velocity | | Depth | | Velocity | |
| Distance | Proto | Model | Proto | Model | Proto | Model | Proto | Model | Proto | Model | Proto | Model |
| 250 | 18 | 19 | 3.4 | 3.2 | 28 | 22 | 2.8 | 2.8 | 17 | 16 | 3.6 | 2.7 |
| 500 | 24 | 24 | 4.4 | 3.4 | 16 | 16 | 3.5 | 3.6 | 20 | 20 | 6.6 | 3.5 |
| 750 | 19 | 19 | 3.4 | 3.6 | 11 | 14 | 3.2 | 3.7 | 27 | 25 | 3.0 | 4.1 |
| 1000 | 21 | 18 | 3.1 | 3.5 | 13 | 19 | 1.5 | 3.4 | 27 | 25 | 3.5 | 3.8 |
| 1250 | 22 | 20 | 3.6 | 3.6 | 14 | 16 | 2.7 | 3.4 | 27 | 23 | 3.2 | 3.8 |
| 1500 | 20 | 22 | 3.7 | 3.4 | 17 | 17 | 2.8 | 3.5 | 25 | 23 | 1.5 | 3.7 |
| 1750 | 18 | 22 | 3.1 | 2.7 | 18 | 21 | 3.6 | 3.3 | 24 | 25 | 1.9 | 2.8 |
| 2000 | 12 | 18 | 3.1 | 2.2 | 18 | 22 | 3.6 | 2.8 | | | | |
| 2250 | 9 | 10 | 2.4 | 1.5 | 17 | 20 | 3.6 | 2.2 | | | | |
| 2500 | 7 | 7 | 1.2 | 0.9 | 14 | 12 | 2.2 | 1.8 | | | | |
| 2750 | 5 | 6 | 0.7 | 0.2 | 10 | 8 | 2.6 | 0.8 | | | | |
| 3000 | 4 | 4 | 1.2 | 0.1 | 8 | 5 | 1.8 | 0.1 | | | | |

Table 10
Lock and Dam 24
Verification of Models to Prototype Data

| | Upstream of Dam - Transect 5 | | | | Mid Upstream Reach-Transect 3 | | | | Mid Downstream Reach-Trans 9 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth | | Velocity | | Depth | | Velocity | | Depth | | Velocity | |
| Distance | Proto | Model | Proto | Model | Proto | Model | Proto | Model | Proto | Model | Proto | Model |
| 250 | 20 | 17 | 2.3 | 2.1 | 14 | 14 | 1.9 | 1.9 | 17 | 15 | 2.9 | 2.3 |
| 500 | 25 | 25 | 3.0 | 2.7 | 17 | 15 | 2.3 | 2.2 | 17 | 19 | 2.4 | 2.8 |
| 750 | 26 | 28 | 3.4 | 2.7 | 16 | 15 | 2.6 | 2.3 | 19 | 23 | 2.7 | 3.0 |
| 1000 | 28 | 31 | 3.4 | 2.7 | 17 | 16 | 2.4 | 2.3 | 21 | 24 | 3.1 | 3.2 |
| 1250 | 30 | 31 | 3.0 | 2.8 | 21 | 18 | 2.1 | 2.3 | 24 | 24 | 2.4 | 3.1 |
| 1500 | 28 | 27 | 2.4 | 2.5 | 25 | 23 | 2.2 | 2.2 | 26 | 25 | 2.5 | 2.8 |
| 1750 | 16 | 16 | 1.3 | 1.7 | 26 | 26 | 1.6 | 1.9 | 26 | 23 | 2.9 | 2.4 |
| 2000 | 11 | 10 | 1.0 | 1.2 | 11 | 20 | 2.6 | 2.2 | 18 | 12 | 1.7 | 1.7 |
| 2250 | 7 | 5 | 0.8 | 0.7 | 16 | 14 | 2.5 | 2.9 | | | | |
| 2500 | 4 | 3 | 0.9 | 0.4 | 13 | 11 | 2.8 | 3.0 | | | | |
| 2750 | | | | | 10 | 10 | 2.3 | 2.9 | | | | |
| 3000 | | | | | 9 | 7 | 2.2 | 2.4 | | | | |
| 3250 | | | | | 6 | 5 | 1.8 | 2.2 | | | | |
| 3500 | | | | | 6 | 4 | 1.8 | 1.9 | | | | |
| 3750 | | | | | 6 | 4 | 1.5 | 1.6 | | | | |

Table 11
Lock and Dam 25
Verification of Models to Prototype Data

| | Upstream of Dam - Transect 1 | | | | Mid Upstream Reach-Transect 4 | | | | Mid Downstream Reach-Trans 6 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Depth | | Velocity | | Depth | | Velocity | | Depth | | Velocity | |
| Distance | Proto | Model | Proto | Model | Proto | Model | Proto | Model | Proto | Model | Proto | Model |
| 250 | 28 | 31 | 2.7 | 2.2 | 3 | 8 | 2.0 | 1.2 | 34 | 27 | 1.8 | 1.8 |
| 500 | 37 | 33 | 2.9 | 2.9 | 5 | 10 | 3.0 | 1.8 | 31 | 31 | 2.8 | 2.5 |
| 750 | 25 | 30 | 3.0 | 2.8 | 4 | 12 | 1.7 | 2.4 | 30 | 30 | 2.6 | 2.7 |
| 1000 | 26 | 27 | 2.9 | 2.9 | 6 | 17 | 2.2 | 3.0 | 25 | 30 | 2.7 | 2.7 |
| 1250 | 28 | 26 | 2.7 | 2.1 | 15 | 19 | 3.7 | 3.4 | 23 | 28 | 3.5 | 2.8 |
| 1500 | 22 | 20 | 1.2 | 1.2 | 19 | 14 | 3.4 | 3.3 | 20 | 26 | 3.0 | 2.8 |
| 1750 | 21 | 18 | 3.0 | 2.1 | 19 | 12 | 3.6 | 2.9 | 17 | 19 | 2.3 | 2.3 |
| 2000 | 35 | 28 | 2.9 | 2.3 | 15 | 11 | 1.8 | 2.8 | 9 | 13 | 1.9 | 1.6 |
| 2250 | 19 | 25 | 2.6 | 1.6 | 11 | 9 | 3.5 | 2.7 | | | | |
| 2500 | 8 | 5 | 1.4 | 1.3 | 10 | 7 | 3.4 | 2.8 | | | | |
| 2750 | | | | | 10 | 10 | 3.6 | 2.7 | | | | |
| 3000 | | | | | 11 | 11 | 2.8 | 2.7 | | | | |
| 3250 | | | | | 14 | 10 | 3.2 | 2.6 | | | | |

61. Tables 7 through 11 show good correlation between prototype and numerical model depth and vector magnitudes with few exceptions. The areas where significant variance in depth and velocity occur is explained by the following contributing factors:

a. Difficulty in precisely locating the prototype transect on the numerical grid.
b. Changes in bed configuration between data collection dates.
c. Presence of underwater features not represented in the numerical model.

An investigation of the correlation of vector direction was performed as well. Vector plots of the numerical model results were generated and compared to plots of the prototype data. In general there was very good correlation of vector direction.

62. Except for the area in the vicinity of the dam, the bathymetry of the numerical models was based on hydrographic survey transects spaced at intervals ranging from 200 to 1,000 feet. No detailed information of underwater structures, such as submerged wingdams, was available at the time of the study. Therefore, unless the hydrographic survey was taken directly over a structure, it was not represented in the grid definition. While the presence of any submerged structure would have an impact on velocities and deposition patterns, these impacts are highly localized and will not affect the "big picture".

## ALTERNATIVE PLANS

### General

63. As previously discussed, there are five potential locations for a 1200 foot lock within an existing lock and dam facility:

a. Location 1, Landward of the existing lock.
b. Location 2, Extension of the existing 600 ft lock.
c. Location 3, At the partially constructed auxiliary lock.
d. Location 4, In a gated portion of the dam.
e. Location 5, In the overflow section of the dam.

Figure 17 shows the generic site plan for Locations 1 through 4. Location 5 is not shown as it was evaluated based on existing conditions. Note that guard/guide walls are shown for each plan. There are two basic wall types, (1) ported and (2) solid, and two possible locations (1) riverward (guard wall) and (2) landward (guide wall). A brief analysis was performed to provide design criteria for selecting the best suited guard/guide wall design for each plan.

64. Upstream of the lock, an outdraft is often present in the lock approach due to flow crossing over to the dam. Because of this, a ported guard wall is the preferred guidance structure upstream of a lock. A ported guard wall consists of a series of cells with a wall attached. The wall has the same top elevation as the lock and has a bottom elevation 10 feet below the low control pool. Submerged ports allow flow to enter the lock approach, thus "pulling" the tow into the lock approach, and the flow through the ports provides a cross current to aid in aligning the tow along the wall. The need for an upstream guard wall was evaluated using both the numerical and physical models of Lock and Dam 22. An alternative to an upstream guard wall, is to utilize the full time services of a helper boat to aid tows in aligning with the lock approach.

65. Downstream of the lock, a solid guide wall is the preferred guidance structure. If a ported guard wall were to be used, flow through the ports would "push" the tow away from the wall. If a solid guard wall were used, it would restrict flow in the main channel and an eddy would be formed off the nose cell. Any guard wall design would make for a narrow entrance for upbound tows.

66. It is standard practice to provide a guard/guide walls equal in length to the usable length of the lock chamber. Consider a downbound tow along side a shorter guard wall in the upper approach. The rear of the tow would be exposed to the cross current off the nose cell causing the tow to pivot around the nose cell. Similarly, downstream of the lock, a shorter guide wall would expose the end of the tow to eddy currents that form off the nose cell.

67. In summary, the preferred guidance structures for new lock construction for guard/guide walls as they apply to the new lock locations are as follows:

a. Upstream: A ported guard wall, 1200 feet in length.
b. Downstream: A solid guide wall, 1200 feet in length.

These prefered structures were used when possible; however, because some plans allow use of the existing lock, some changes to the preferred design were required.

68. A generic guard wall design was developed for the physical model testing. It was comprised of a series of circular cells spaced to provide a port width of 20 feet. The nose cell was 50 feet in diameter, to resist direct impact loads, while all other cells were 30 feet in diameter. A curtain wall was attached to the cells. The top of the wall was the same elevation as the lock wall and the bottom of the wall was 10 feet below low control pool. In this way, the wall served two purposes: (1) flow through the ports passed beneath the tows hull to prevent "pinning" of the tow against the wall, and (2) provided a surface for attachment of an armored steel rubbing surface for tows entering and exiting the lock. As previously mentioned, this wall design was generic. New guard wall design concepts may be tested once specific sites for new lock construction have been identified.

Location 1

69. New lock construction at Location 1 consists of providing a lock, with usable dimensions of 1200 feet by 110 feet, sufficiently landward of the existing lock to allow for construction in the dry. The riverward wall of the new lock will be 75 feet landward of the existing lock. The lock entrance will be 620 feet upstream of the existing lock entrance. Access channels with a depth of 15 to 20 feet below the low control pool elevation will be required. Additional excavation of the right bank upstream and downstream of the lock will be required to provide adequate approach and exit conditions.

70. The orientation of the lock for this alternative makes the determination of the best guidance structure design difficult. In the upper approach, the new lock gates will be about 600 feet upstream of the existing lock gates. This allows the existing guide wall to remain. A ported guard wall upstream of the new lock will require a massive amount of excavation to provide an adequate approach. However, based on performance, the preferred guide structure for the new lock is a ported guard wall, 1200 feet in length. In the lower approach, the lock gates are essentially side by side. Therefore, the existing guide wall will remain for use of the existing lock and a guide wall 1200 feet in length will be provided for the new lock.

71. Navigation features for Location 1 consist of the following (see Figure 18 for generic design):

a. A ported guard wall, 1200 feet in length, upstream of the new lock.
b. A solid guide wall, 1200 feet in length, downstream of the new lock.
c. Excavation for channel access to the new lock.
d. Excavation of the right bank, upstream and downstream of lock.

## Location 2

72. New lock construction at Location 2 consists of extending the existing lock to useable dimensions of 1200 feet by 110 feet. The existing ported guard wall will be removed. There are no proposed changes to the overflow dike. Based on the preferred design for guidance features, a 1200 foot ported guard wall upstream and a 1200 foot solid guide wall downstream will be required.

73. While there is adequate room downstream for approaching and exiting tows, the upstream guard wall greatly limits the maneuvering room for tows in the lock approach. To address this, the upstream guide wall was removed and the right bank was excavated to a 1V:3H slope. The toe of slope was established at an elevation 20 feet below low control pool and 200 feet landward of the guard wall. Benching of the channel at this elevation was performed when necessary. The toe of slope runs parallel to the guard wall from the landward lock wall to a point upstream where the toe elevation intersects the natural channel.

74. When Location 2 was initially tested in the Lock and Dam 22 physical model, outdraft problems were noted in the upstream approach to the lock due to the curvature of the channel immediately upstream of the lock approach. In response, emergent channel training structures were installed and tested in the physical model to allieviate the problem.

75. Navigation features for Location 2 consist of the following (see Figure 19 for generic design):
   a. Removal of the existing ported guard wall.
   b. Construction of a ported guard wall, 1200 feet in length, upstream of the new lock.
   c. Removal of the existing downstream guide wall.
   d. Construction of a solid guide wall, 1200 feet in length, downstream of the new lock.
   e. Removal of the existing upstream guide wall.
   f. Right bank excavation upstream of the lock.
   g. Construction of channel training works which tie into the right descending bank upstream of the approach to the new lock.

## Location 3

76. New lock construction at Location 3 consists of providing a lock with usable dimensions of 1200 feet by 110 feet at the partially constructed auxiliary lock chamber, thus providing two operational locks. The existing ported guard wall will be removed. There are no proposed changes to the dam or overflow dike.

77. Because Location 3 allows the use of both the new 1200 foot lock and the existing 600 foot lock, consideration as to preferred guidance structures upstream and downstream was required. In the upper approach, a wall common to both locks would provide a guard wall for the existing lock and a guide wall for the new lock. However, flow through the wall ports would force tows approaching the 1200 foot lock away from the wall. A solid wall would have severe outdraft off the nose cell making alignment with either lock difficult. Therefore, the best upstream guidance

structure was determined to be a ported guard wall on the riverside of the new lock. Because the riverward wall of the new lock extends 250 feet upstream of the lock entrance, a ported guard wall 950 feet in length was tested in the physical model for adequacy.

78. In the downstream approach, a ported wall common to both locks would have similar disadvantages as a ported common wall in the upper approach. A solid wall in this location would make approach conditions to the existing lock difficult. A ported guard wall on the new lock would cause tows to be forced away from the wall. It was determined that the best suited guidance structures for this alternative would be a solid guard wall, 1200 feet in length, on the riverside of the new lock and an extension of the existing guide wall such that it would extend an additional 600 feet downstream.

79. Navigation features for Location 3 consist of the following (see Figure 20 for generic design):

a. Removal of the existing ported guard wall.
b. Construction of a ported guard wall, 1200 feet in length, upstream of the new lock.
c. Construction of a solid guard wall, 1200 feet in length, downstream of the new lock.
d. Extension of the existing downstream solid guide wall to a length of 1250 feet.

Location 4

80. New lock construction at Location 4 consists of providing a lock with usable dimensions of 1200 feet by 110 feet in the gated portion of the dam, adjacent to the partially constructed auxiliary lock. This plan provides two operational locks, however, because the new lock is constructed in the gated portion of the dam, two gate bays are removed from service. Four scenarios were considered to address the lost controlled flow area:

a. Construct two gate bays (typical to existing) in the overflow dike adjacent to the dam.
b. Construct two gate bays of the same size; one in the overflow dike and one between. the locks at the partially constructed auxiliary lock.
c. Construct one gate bay (typical to existing) between the locks at the auxiliary lock.
d. Do not replace the lost controlled flow area.

81. While scenario (d) would be the easiest to construct in the physical model, it was felt that by providing flow between the locks, approach conditions may improve. Therefore, scenario (c) was chosen for model testing at Lock and Dam 25. Based on the unfavorable navigation conditions produced by this scenario, scenario (c) was eliminated from model testing at Lock and Dam 22 and was replaced with scenario (d).

82. It was decided that should Location 4 be selected as the best alternative for any site, the design would be a combination of scenario (a) and (c). Two gates of the same size as those removed would be constructed in the overflow dike adjacent to the gated section of the dam. A gate operated only for passage of ice and debris would be constructed at the existing auxiliary lock location.

83. As with Location 3, this plan allows the use of both the new 1200 foot lock and the existing 600 foot lock. Based on the preferred design guidance, a 1200 foot ported guard wall will be required upstream and a 1200 foot solid guide wall will be required downstream. There is adequate space between the locks such that no changes to existing guide walls was required.

84. The riverward wall of the new lock extends 250 feet upstream of the lock entrance. This length was deducted from the required 1200 feet of guard wall. Therefore, the upstream ported guard wall, as tested, was 950 feet in length.

85. Navigation features for Location 4 consists of the following (see Figure 21 for generic design):

a. Removal of the existing ported guard wall.
b. Construction of a ported guard wall, 950 feet in length, upstream of the new lock.
c. A solid guide wall, 1200 feet in length, downstream of the new lock.

86. Navigation conditions for Location 5 were appraised using base condition bathymetry and model results. A dicussion of Location 5 appears in the Findings section of this report.

## PHYSICAL MODELING

87. Physical models of Lock and Dam 22 and 25 were constructed by the Waterways Experiment Station (WES) in Vicksburg, Mississippi. Complete reports of the physical modeling effort are presented in the CEWES technical reports, *Navigation Model Study of Lock and Dam 22* and *Navigation Model Study of Lock and Dam 25*. Because the physical model results were used to verify the numerical models, a brief description of the procedure and results is provided here.

### Physical Model Features

88. The physical models (Figures 22 and 23) were 1:120 scale reproduction of a short reach of the Mississippi River channel and adjacent backwater areas. The Lock and Dam 22 model extended about 8,000 feet upstream of the dam and about 6,000 feet downstream, whereas the Lock and Dam 25 model extended about 12,000 feet upstream and downstream of the dam. Based on experience of past model testing, these distances were considered to be adequate to model approach and exit conditions for tows 1200 feet in length.

89. The models were fixed-bed type with the channel and backwater areas molded in sand-cement mortar. Brushed concrete has proven in the past to be appropriate for representing Manning's "n". Templates were constructed along the hydrographic survey lines taken in November 1993. Each survey line transect was spaced at intervals about 1000 feet. Therefore, any underwater features, such as pre-pool wingdams, that may be located between survey transects, are not represented in the model. The backwater areas were shaped to contours taken from topographic mapping. Wire mesh folded in a zig-zag pattern was used to simulate trees and vegetation located in the backwater areas. Representation of localized scour in the vicinity of the dam was achieved by use of periodic scour survey data.

90. Portions of the model, where changes in bank alignments and channel configurations were required for different alternatives, were molded in pea gravel with a scratch coat of sand-cement mortar over the surface. The lock, dam, piers, and guide and guard walls were built from sheet metal. The dam gates were simulated with vertical sheet metal slide type gates. The existing ported guard wall for Lock and Dam 25 was constructed of sheet metal. The curtain wall and timber piles of the guard wall were not represented in the model.

91. The models were built to undistorted linear scale ratio of 1:120. This scale ratio has proven in the past to accurately reproduce velocities, cross currents, and eddies that would affect navigation. The following approximate scale ratios (Froude scaling) are of hydraulic importance:

Velocity: 1:11 Time: 1:11 Discharge: 1:158,000 Manning's n: 1:2.2

92. Inflow to the models were very accurately controlled and measured at the upper end by means of valves and venturi meters. Water surface elevations were measured by means of piezometer gages located in the model channel; 9 gages for Lock and Dam 22 and 10 gages for Lock and Dam 25 (see Figures 22 and 23 for location). For controlled river conditions, the upper stages were controlled at the dam, and for open river conditions, tailwater elevations were controlled at the lower end.

## Data Collection

93. Velocities and current direction in the model were determined by use of floats. The floats consisted of 35 mm film canisters with a flotation collar made of foam rubber for adjusting draft. The draft depth in the main channel was set at 9 feet to represent loaded barge draft. The canisters contained a battery which was wired to a bulb protruding through the canister lid. Six to 10 floats were released at a specific location and allowed to flow downstream. Access to release points was accomplished by use of a cat walk supported by two cylindrical rods at each end.

94. Cameras attached to the roof trusses at specific locations recorded the movement of the lighted floats. Recording parameters such as number of pixels the object has moved and the number of seconds between recordings are sent to the control house where post-processing of the data is performed. In seconds the results were viewed on a computer monitor where erroneous data was readily identified and eliminated from the data set. Sources of error included:

a. Floats becoming grounded on channel high spots.
b. Light sources from outside the building disrupting collection of data.
c. "Clumping" together of floats.
d. Weak light source on the float.
e. Occasional dragging of the float along the bottom.
f. Tilting of the float thus changing flow dynamics and increasing submergence.

95. Reduction in data collection errors was accomplished by rarely interfering with the floats downstream progress. When clumping occurred, a gentle nudge from a long rod was used to separate them. When grounding occurred, a gentle nudge was sometimes used; however, this float

was usually eliminated from the data set. In a location where grounding of the floats consistently occurred due to insufficient flow depth, the submergence of the floats were reduced to 6 feet and then to 3 feet when necessary.

96. Floats were released at several locations until sufficient data was obtained to define the flow pattern for the entire channel. Because of the wide channel upstream of Lock and Dam 25, it was not possible to obtain data in the backwater area.

## Base Conditions

97. A wide range of discharges and corresponding pool elevations were modeled for existing conditions as shown in the following tables. Gage locations are shown in Figures 22 and 23.

Table 12
Lock and Dam 22
Model Study Discharges and Pool Elevations (ft MSL)

| Gage | Discharge in 1,000 cfs | | | | |
|---|---|---|---|---|---|
| No. | 50 | 100 | 162 | 220 | 276 |
| 1 | 459.6 | 459.9 | 460.7 | 464.3 | 467.4 |
| 2 | 459.6 | 459.7 | 460.1 | 463.9 | 467.1 |
| 3 | 459.5 | 459.5 | 459.6 | 463.5 | 466.7 |
| 4 | **459.5** | **459.5** | **459.5** | 463.5 | 466.7 |
| 5 | 459.5 | 459.4 | 459.4 | 463.4 | 466.5 |
| 6 | 451.3 | 454.7 | 458.7 | 462.9 | 466.1 |
| 7 | **451.3** | **454.7** | 458.8 | **462.8** | **466.1** |
| 8 | 451.2 | 454.6 | 458.7 | 462.8 | 466.0 |
| 9 | 451.1 | 454.4 | 458.6 | 462.6 | 465.8 |

Table 13
Lock and Dam 25
Model Study Discharges and Pool Elevations (ft MSL)

| Gage | Discharge in 1,000 cfs | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| No. | 65 | 125 | 138 | 166 | 200 | 240 | 303 | 327 |
| 1 | 433.9 | 432.0 | 430.8 | 432.3 | 434.4 | 437.1 | 440.1 | 442.5 |
| 2 | 433.8 | 431.7 | 430.1 | 431.8 | 434.0 | 436.1 | 439.9 | 442.2 |
| 3 | 433.8 | 431.5 | 429.7 | 431.5 | 433.8 | 436.5 | 439.7 | 442.1 |
| 4 | **433.7** | **431.5** | **429.7** | **431.5** | **433.7** | **436.5** | **439.7** | **442.0** |
| 5 | 433.7 | 431.4 | 429.6 | 431.4 | 433.5 | 436.5 | 439.5 | 442.0 |
| 6 | 422.0 | 425.0 | 429.4 | 431.3 | 433.2 | 436.1 | 439.3 | 441.9 |
| 7 | **422.0** | **425.0** | 429.5 | 431.2 | 433.3 | 436.1 | 439.3 | 441.9 |
| 8 | 421.9 | 424.9 | 429.4 | 431.1 | 433.2 | 436.0 | 439.2 | 441.7 |
| 9 | 421.8 | 424.7 | 429.3 | 431.0 | 433.1 | 435.8 | 439.0 | 441.5 |
| 10 | 421.8 | 424.6 | 429.2 | 430.8 | 433.8 | 435.7 | 438.8 | 441.4 |

Note: Elevations shown in bold were controlled elevations.

## Alternatives

98. Six alternative locations for new lock construction were considered. Eliminated as part of initial site screening process was Location 6 which is on the opposite side of the channel landward of the dam. The remaining five alternative lock construction sites are as listed below.

Base Condition: Exiting Conditions - 1993 hydrographic surveys
Location 1: Landward of existing lock
Location 2: Extend existing lock
Location 3: Auxiliary (dummy) lock
Location 4: Gated portion of the dam
Location 5: Overflow section of the dam

Note: Location 5 was evaluated using Base Condition bathymetry and model results

99. The topography and nearby transportation routes precluded the implementation of a landward lock for Lock and Dam 22. The elimination of this alternative from the Lock and Dam test schedule allowed supplemental tests of other locations. Location 2 was modified to include a system of spur dikes along the upstream approach of Lock and Dam 22. For each alternative and set of base conditions, a wide range of discharges were simulated in the physical models. Plots showing vector magnitude and direction were produced for each discharge. Plots for a high, moderate, and low discharge were selected for comparison to numerical model results.

## NUMERICAL MODELING VERIFICATION TO PHYSICAL MODEL

100. Numerical models were developed to evaluate flow conditions for various plan alternatives at Lock and Dam 20, 21, 22, 24, and 25. The verification of the numerical models required an analysis to prove their ability to reproduce three-dimensional flow features, two-dimensionally. To accomplish this, numerical model results for Lock and Dam 22 and 25 were compared to respective physical model results. To reduce the number of data tables, only the results from the mid-range discharges shown in Table 14 are presented here.

101. Features such as bathymetry, topography, channel roughness, and discharge used in the physical models were similarly represented in the numerical models. The hydrographic and topographic survey data used to develop the physical model beds were used to develop the numerical model grids. As with the physical models, no additional bed definition was provided to represent submerged wing dams in the numerical model. Grid definition and model bathymetry for each of the 5 sites modeled are depicted in Figures 24 through 28 and 29 through 33 respectively.

102. It was estimated that the brushed cement mortar bed of the physical model had a roughness (Manning's "n'") between 0.010 and 0.013 which corresponds to a prototype roughness between 0.020 and 0.030. Roughness coefficients developed as part of the

numerical model calibration to prototype data were in this range; therefore, no changes were made in the Manning's "n" values shown in Table 5.

## Base Conditions

103. Essentially, the numerical models developed for prototype calibration were accepted as representative of the physical model base conditions. The existing conditions numerical model was run for the same range of discharges as the physical model. With the exception of minor grid changes due to wetting and drying problems, no changes were made to model grids. As part of the model verification, a comparison of water surface profiles was performed. Water surface elevations were obtained from the numerical model at nodes approximating the physical model gage locations (see Figures 22 and 23). The following table shows the results for three discharges; low, mid-range, and high.

Table 14
Verification of Water Surface Profile
Physical Model Elevation minus Numerical Model Elevation

| Gage | Lock and Dam 22 | | | Lock and Dam 25 | | |
|---|---|---|---|---|---|---|
| No. | 50,000 | 162,000 | 276,000 | 65,000 | 166,000 | 327,000 |
| 1 | 0.0 | +0.3 | +0.1 | +0.1 | +0.1 | +0.1 |
| 2 | 0.0 | +0.1 | +0.1 | 0.0 | 0.0 | 0.0 |
| 3 | 0.0 | -0.1 | 0.0 | 0.0 | 0.0 | -0.1 |
| 4 | 0.0 | 0.0 | +0.2 | 0.0 | 0.0 | -0.2 |
| 5 | 0.0 | -0.2 | -0.2 | 0.0 | +0.1 | 0.0 |
| 6 | 0.0 | 0.0 | +0.1 | +0.1 | +0.3 | +0.2 |
| 7 | 0.0 | +0.1 | +0.1 | 0.0 | +0.1 | 0.0 |
| 8 | 0.0 | 0.0 | 0.0 | 0.0 | +0.1 | 0.0 |
| 9 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 |
| 10 | N/A | N/A | N/A | 0.0 | 0.0 | 0.0 |

104. The depth-averaged velocity vectors produced by the numerical models were modified to represent surface layer velocities similar to the physical model. As presented in "Prototype Data Collection", the surface layer velocities will be about 10 percent greater than the corresponding depth-averaged velocity. Therefore, post-processing of the output data was performed by multiplying the magnitude of each vector by a factor of 1.1.

105. For presentation of model verification to base conditions, three transects upstream and downstream of the dam were selected for comparison. Because flow conditions in the lock approach are important, all transects were located within in reaches extending 4000 feet upstream and downstream of the dam. Transect locations for Lock and Dam 22 and 25 are given in the following table:

Table 15
Transect Locations for Comparative Analysis

| Transect Number | Upstream/ Downstream | Approximate Distance to Dam | Physical Feature |
|---|---|---|---|
| 1 | U/S | 3000-4000 ft | Spur Dike |
| 2 | U/S | 2000 ft | Lock Approach |
| 3 | U/S | 700-1200 ft | End of Guard Wall |
| 4 | D/S | 600-1200 ft | End of Lock Wall |
| 5 | D/S | 1200-2400 ft | End of Guide Wall |
| 6 | D/S | 3000-3500 ft | Lock Approach |

106. A full range of discharges were run in the physical models of Lock and Dam 22 and 25. Plots showing the magnitude and the direction of the surface velocities were generated. Numerical model results for Lock and Dam 22 and 25 were plotted for comparison to the physical model. To reduce the comparative effort of the results, numerical model plots were generated for a low, moderate, and high discharge. The following table shows the entire range of discharges run in both the physical and numerical models for all 5 sites. Velocity vector plots of numerical model results are presented for the discharges shown in bold.

Table 16
Physical and Numerical Model Discharges

| Lock & Dam | Discharges in CFS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 20 | 50,000 | 78,000 | 95,000 | **110,000** | 190,000 | 284,000 | | |
| 21 | | 50,000 | 100,000 | **134,000** | 220,000 | 280,000 | | |
| 22 | | 50,000 | 100,000 | **162,000** | 220,000 | 276,000 | | |
| 24 | 65,000 | 125,000 | 138,000 | **166,000** | 200,000 | 240,000 | 303,000 | 327,000 |
| 25 | 65,000 | 125,000 | 138,000 | **166,000** | 200,000 | 240,000 | 303,000 | 327,000 |

107. Plots of the numerical model results were made such that they encompassed the approximate area shown in the physical model plots. Through the use of FastTABS features, transects of velocity magnitudes were superimposed on the plots. Because it is difficult to control the scale of the plots, it was not possible to generate a plot that would perfectly overlay the physical model plots. Therefore, the physical model plots were enlarged through trial and error until physical features shown in the physical model plots aligned with similar features represented in the numerical model plots. For example, the length and location of guide walls, guard walls, the dam, training structures, and the general channel shape were used to get correct perspective.

108. To compare results, tables of numerical model velocities vs. physical model velocities were generated for each transect. Velocity magnitudes at 6 to 10 points of roughly equal spacing across the transect, were tabularized for comparison. With the exception of transects near the dam, the overall data sets show a fairly good comparison of results. To show the agreement as well as the exceptions, a comparison of average transect velocities was made. The following table shows how the numerical model compared to the physical model by percent difference. A positive value indicates the numerical model was greater than the physical model and vice versa for a negative value. All comparisons are based on the physical model results.

Table 17
Velocity Vector Verification - Base Conditions

| L & D # | Discharge | Transect 1 | Transect 2 | Transect 3 | Transect 4 | Transect 5 | Transect 6 |
|---|---|---|---|---|---|---|---|
| 22 | 50,000 | NA | -19% | 13% | -30% | -10% | NA |
| 22 | 162,000 | 10% | -4% | -17% | -14% | -8% | -25% |
| 22 | 276,000 | 7% | -5% | -11% | -7% | -6% | -16% |
| | | | | | | | |
| 25 | 65,000 | -8% | -8% | 3% | -16% | -10% | 10% |
| 25 | 166,000 | -5% | -14% | -12% | -30% | 3% | 1% |
| 25 | 327,000 | -2% | -1% | -2% | -4% | 5% | -7% |

109. An overall comparison shows the numerical model more often under predicted surface velocities than over predicted. This indicates that the factor used to adjust depth-averaged flow velocities to represent surface velocities may have been underestimated. The greatest difference occurs at Transect 4. It should be noted that Transect 4 is located just downstream of the dam where flow is still somewhat turbulent. Correlation of Transect 4 is best at high flows where only a swell head exists across the dam thus making flow conditions downstream of the dam less turbulent.

110. Table 17 gives an indication of how well the average transect velocities compared, but does not indicate how well individual vector points compared. To show this, the average difference between vector points was determined for each transect. The results are shown in the following table.

Table 18
Average Velocity Vector Difference (fps) - Base Conditions

| L & D # | Discharge | Transect 1 | Transect 2 | Transect 3 | Transect 4 | Transect 5 | Transect 6 |
|---|---|---|---|---|---|---|---|
| 22 | 50,000 | NA | 0.3 | 0.2 | 0.9 | 0.2 | NA |
| 22 | 162,000 | 0.4 | 0.2 | 0.9 | 0.9 | 0.4 | 1.4 |
| 22 | 276,000 | 0.3 | 0.2 | 0.6 | 0.4 | 0.3 | 0.9 |
| | | | | | | | |
| 25 | 65,000 | 0.1 | 0.2 | 0.1 | 0.2 | 0.5 | 0.2 |
| 25 | 166,000 | 0.4 | 0.7 | 0.6 | 1.0 | 0.5 | 0.2 |
| 25 | 327,000 | 0.7 | 0.1 | 0.1 | 0.8 | 0.3 | 0.4 |

111. While the magnitude of the velocity is valuable information, direction is of greater importance because this indicates the direction of force acting on the tows. Therefore, as part of the comparison, the direction of velocity vectors were examined as well. The correlation of vector direction was quite good with minor exceptions. The highly turbulent flow area just downstream of the dam was difficult to reproduce because of 3-dimensional effects. Because the numerical model represents the depth-averaged flow direction, small surface eddies that form in the physical model are not represented in the numerical model. However, examination of the plotted vectors showed correlation when strong eddies existed. Comparisons were made for all alternative lock locations.

## Plan Alternatives

112. Numerical models of the alternative plans were created by modifying the base condition grid files. The grids were refined in the vicinity of the dam to ease the creation of the lock and guidance structures. The refinement also enhanced the presentation of flow conditions in this area. Ported guard wall designs were represented in the numerical model by circular elements in the same manner as the existing guard wall was presented in the prototype calibration and base condition verification. Cell diameter and spacing was the same as the generic design used in the physical model.

113. As with the base condition comparison of numerical and physical models, a similar comparison was made for all alternative lock location plans. This included:

a. Adjust depth averaged velocities to represent surface velocities by applying a factor of 1.1.
b. Locate transects for comparison near areas of interest.
c. Generation of numerical model plots for low, mid-range, and high discharges.
d. Match numerical model plot scale to physical model plot scale for Lock and Dams 22 and 25.
e. Present average transect velocity comparison by percent difference.
f. Present average difference in velocity vectors in feet per second.

114. The basic location of transects for comparison purposes did not change from those used in the the base condition comparison. The physical features locating transect, as shown in Table 15, were the same for comparison of alternative plan results. Because a physical feature may change location with each alternative, the distance a given transect is from the dam may vary from location to location. For example, the "end of guard wall" in the upper approach was significantly different for Locations 2 and 4.

115. A review of vector plots showed a good correlation for vector direction. As with base conditions, surface eddies were not represented in the numerical models unless they were significant. The following tables show how well average transect velocities in the numerical model compared to average transect velocities in the physical model. A positive value reflects the percent the numerical model result was greater than the physical model and the opposite for negative values.

Table 19
Lock and Dam 22
Average Transect Velocity Comparison - Plan Alternatives

| Location | Discharge | Transect 1 | Transect 2 | Transect 3 | Transect 4 | Transect 5 | Transect 6 |
|---|---|---|---|---|---|---|---|
| 2 | 50,000 | 2% | -11% | -14% | -33% | -14% | -38% |
| 2 | 162,000 | 7% | -7% | -15% | -28% | -13% | -26% |
| 2 | 276,000 | 13% | 0% | 2% | -13% | 2% | -14% |
| 3 | 50,000 | -6% | -14% | -10% | -31% | -6% | -3% |
| 3 | 162,000 | 9% | -3% | 4% | -29% | -7% | -21% |
| 3 | 276,000 | 10% | -1% | -5% | -20% | -7% | -21% |
| 4 | 50,000 | % | % | % | % | % | % |
| 4 | 162,000 | % | % | % | % | % | % |
| 4 | 276,000 | % | % | % | % | % | % |

Table 20
Lock and Dam 25
Average Transect Velocity Comparison - Plan Alternatives

| Location | Discharge | Transect 1 | Transect 2 | Transect 3 | Transect 4 | Transect 5 | Transect 6 |
|---|---|---|---|---|---|---|---|
| 1 | 65,000 | -19% | -8% | 10% | -6% | 0% | -6% |
| 1 | 166,000 | -9% | -14% | -8% | -22% | -6% | -7% |
| 1 | 327,000 | -5% | 3% | 6% | -18% | 7% | 1% |
| 2 | 65,000 | -20% | -10% | 20% | 2% | -12% | -11% |
| 2 | 166,000 | -13% | -18% | -22% | 6% | -6% | -5% |
| 2 | 327,000 | -8% | 3% | -5% | 15% | 3% | -11% |
| 3 | 65,000 | 0% | -1% | -4% | 0% | -11% | -13% |
| 3 | 166,000 | -5% | -12% | -11% | 12% | -3% | -12% |
| 3 | 327,000 | -1% | 0% | 0% | 15% | 0% | -9% |
| 4 | 65,000 | 24% | -17% | -6% | -20% | -8% | -8% |
| 4 | 166,000 | -9% | -11% | -20% | -4% | -4% | -6% |
| 4 | 327,000 | -4% | -1% | -2% | -7% | -15% | -24% |

116. The above tables show fair correlation in magnitude of velocity vectors. As with the base condition comparison, it appears the factor used to adjust depth-averaged velocities to represent surface velocities may be a little low. To show the degree to which individual velocity vectors varied across the transect, the following tables were compared.

Table 21
Lock and Dam 22
Average Vector Velocity Difference (fps) - Plan Alternatives

| Location | Discharge | Transect 1 | Transect 2 | Transect 3 | Transect 4 | Transect 5 | Transect 6 |
|---|---|---|---|---|---|---|---|
| 2 | 50,000 | 0.3 | 0.2 | 0.2 | 0.9 | 0.3 | 1.2 |
| 2 | 162,000 | 0.3 | 0.3 | 0.7 | 1.7 | 0.7 | 1.6 |
| 2 | 276,000 | 0.1 | 0.0 | 0.1 | 0.8 | 0.1 | 0.9 |
| 3 | 50,000 | 0.1 | 0.2 | 0.2 | 1.0 | 0.2 | 0.8 |
| 3 | 162,000 | 0.3 | 0.1 | 0.2 | 2.1 | 0.4 | 1.3 |
| 3 | 276,000 | 0.4 | 0.1 | 0.3 | 1.3 | 0.4 | 1.4 |
| 4 | 50,000 | 0.3 | 0.1 | 0.2 | 1.2 | 1.0 | 1.0 |
| 4 | 162,000 | 0.4 | 0.3 | 1.0 | 1.4 | 1.4 | 2.1 |
| 4 | 276,000 | 0.5 | 0.3 | 1.0 | 2.1 | 2.7 | 2.7 |

Table 22
Lock and Dam 25
Average Vector Velocity Difference (fps) - Plan Alternatives

| Location | Discharge | Transect 1 | Transect 2 | Transect 3 | Transect 4 | Transect 5 | Transect 6 |
|---|---|---|---|---|---|---|---|
| 1 | 65,000 | 0.3 | 0.1 | 0.1 | 0.1 | 0.3 | 0.2 |
| 1 | 166,000 | 0.7 | 0.4 | 0.3 | 0.6 | 0.3 | 0.2 |
| 1 | 327,000 | 0.4 | 0.2 | 0.2 | 0.8 | 0.3 | 0.1 |
| 2 | 65,000 | 0.3 | 0.2 | 0.3 | 0.1 | 0.3 | 0.2 |
| 2 | 166,000 | 0.6 | 0.8 | 1.0 | 0.7 | 0.4 | 0.4 |
| 2 | 327,000 | 0.2 | 0.1 | 0.2 | 0.6 | 0.2 | 0.7 |
| 3 | 65,000 | 0.1 | 0.2 | 0.2 | 0.1 | 0.3 | 0.3 |
| 3 | 166,000 | 0.3 | 0.6 | 0.5 | 0.7 | 0.3 | 0.5 |
| 3 | 327,000 | 0.2 | 0.2 | 0.2 | 0.6 | 0.3 | 0.7 |
| 4 | 65,000 | 0.2 | 0.2 | 0.1 | 0.5 | 0.2 | 0.2 |
| 4 | 166,000 | 0.6 | 0.5 | 1.1 | 0.4 | 0.5 | 0.6 |
| 4 | 327,000 | 0.1 | 0.1 | 0.3 | 0.5 | 0.6 | 1.2 |

## HYDRAULIC IMPACTS DURING CONSTRUCTION

### Purpose

117. Each lock and dam selected as a site for new lock construction, would require the construction of a cofferdam to allow the construction area to be dewatered. Depending on the location, it may be necessary to restrict flow through a portion of the dam. Locating a new lock within the gated section of the dam may require blockage of as many as four to six dam gates during construction. This will most likely create an increase in the swellhead at the dam and effect water surface elevations for some distance upstream. Swellhead refers to the increase in water level noticed immediately upstream of the structure created by piers and other features which obstruct the flow even when the gates of the dam are out of the water and open river conditions exist. In addition to changes in water surface profiles, changes in velocity patterns may be experienced if the flow distribution through the gates is changed, possibly resulting in sedimentation or erosion.

### Method of Analysis

118. The numerical model UNET was selected to evaluate the effects of reducing the flow capacity through Dams 20, 21, 22 during construction of additional locks. UNET is a one-dimensional unsteady flow model which simulates flow through a network of open channels. It is especially well suited for modeling large river systems where the dynamic effects of levee breaches, backwater impacts, mild channel slopes and varying flow rates along the river are important.

119. Basic input data required for model execution includes channel geometry in the form of surveyed cross-sections, Manning's "n" values, stage and discharge hydrographs at model boundaries, and information describing each dam. UNET computes swellheads at each dam site using D'Aubisson's equation to estimate the headloss due to piers and abutments.

120. It was not considered necessary to analyze water surface profiles during low flows when the dams are being regulated, as the reduction in flow capacity for any one gate can be compensated for by redistributing flow through the remaining available gates. However, loss of gate capacity will require that the gates of the dam be taken out of the water earlier during high flow events to insure that authorized pool limits are not exceeded.

121. An existing calibrated model of the 1986 flood was selected to analyze swellheads and water surface profiles for open river conditions. The 1986 flood, which was approximately a 10-year event, was considered adequate to represent swellheads for a wide range of discharges when the dams are out of operation. Peak discharges among the three sites ranged from about 270,000 cfs at Lock and Dam 20 to 300,000 cfs at Lock and Dam 22. With the exception of rare flood events, once the gates of the dam are raised above the water surface, both historical data and numerical model results show that swellheads are relatively constant and independent of discharge. During the 1993 flood minor reductions in swellheads were observed. The

reductions were primarily due to greater submergence on the uncontrolled overflow sections of the dams and flow through areas that are normally not available for conveyance.

122. The effects of blocking gates at Locks and Dams 24 and 25 were evaluated using the steady flow water surface profile computation model HEC-2. Required input needed for the steady flow model is similar to that required for UNET. Two separate events were analyzed: a 10-year flood event, and the maximum flow which occurs just before the overflow section of the dams are overtopped. The discharge selected as coincident with a 10-year flood event at both locations was 290,000 cfs, based on previous studies. The maximum flow just before overtopping of the submersible overflow sections of Dams 24 and 25 were taken as 175,000 cfs, and 188,000 cfs respectively, based on data from previous flood events and subsequent model runs.

Alternatives

123. The number of gates required to be removed from service during construction will depend on the alternative selected for placement of a new lock. Construction of a new lock at Location 4 could require taking as many as four to six gates out of service during construction, depending upon the size of the gates. Alternative locations not within the gated section of the dam, may require only one or two gates to be taken out of service, or none at all. As an upper limit for the analysis of alternatives, restricting flow through the gated section of the dam by an amount equal to approximately twice the lock width was considered adequate. Because the difference in swellhead computed for blocking a single gate was rather small, gate closures at each site were modeled in two-gate increments. Alternatives were modeled by reducing the length of the gated section of the dam in the model. Table 24 lists the computed swellhead at each lock and dam site for each of the gate closure alternatives considered.

Table 23
Computed Swellhead at Dams
20, 21 and 22

| Location | Swellhead in Feet | Cumulative Difference |
|---|---|---|
| Lock and Dam 20 | | |
| All Gates open | 0.52 | NA |
| 3 - 40 ft tainter gates blocked | 0.65 | 0.13 |
| 6 - 40 foot tainter gates blocked | 0.81 | 0.29 |
| Lock and Dam 21 | | |
| All Gates open | 0.82 | NA |
| 2 - 64 ft tainter gates blocked | 0.99 | 0.17 |
| 4 - 64 ft tainter gates blocked | 1.20 | 0.38 |
| Lock and Dam 22 | | |
| All Gates open | 0.89 | NA |
| 1 - 60 ft tainter gate blocked | 1.02 | 0.13 |
| 3 - 60 ft tainter gates blocked | 1.27 | 0.38 |
| 3 - 60 ft tainters, 1 - 100 ft roller blocked | 1.52 | 0.63 |

124. A similar modeling strategy was followed at Locks and Dams 24 and 25. The resulting computed swellheads (pool minus tailwater) are shown in Table 24. As in the case of Lock and Dams 20, 21 and 22, the computed swellhead varies with the number of gates blocked. The increase in swellhead is about the same regardless of the magnitude of flow. However, any increase in swellhead would be reduced when water levels exceed the crests of the overflow dikes.

Table 24
Computed Swellhead at Dams
24 and 25

| Location | Swellhead in Feet Max Flow Before Dike Overtopping | Cum. Diff. | Swellhead in Feet 10 - Year Flood Event | Cum. Diff. |
|---|---|---|---|---|
| Lock and Dam 24 | | | | |
| All Gates open (Exist. Capacity) | 0.54 | NA | 0.66 | NA |
| 2 - 80 ft tainter gates blocked | 0.71 | 0.17 | 0.84 | 0.18 |
| 4 - 80 ft tainter gates blocked | 0.98 | 0.44 | 1.11 | 0.45 |
| Lock and Dam 25 | | | | |
| All Gates open (Exist. Capacity) | 0.78 | NA | 0.73 | NA |
| 3 - 60 ft tainter gates blocked | 0.95 | 0.17 | 0.81 | 0.08 |
| 3-60 ft tainters, 1-100 ft roller blocked | 1.12 | 0.34 | 0.88 | 0.15 |

125. In general, results were similar among the five sites analyzed. On average, a maximum increase in swellhead of about 0.1 feet can be expected for each 60 to 80 foot section of gate removed from service. Similar increases in swellhead would be anticipated at other lock and dam sites. However, some variation would be expected due to structural differences such as the length of the gated dam section and the elevation and length of overflow weirs, etc.

126. For each of the gate closure alternatives modeled, water surface profiles were also computed to evaluate the effects of an increase in swellhead upstream in the pool. Tables 25 and 26 give the number of river miles upstream of each dam where the difference in water surface elevation for each of the gate closure alternatives considered differ by less than 0.1 feet with the existing condition, all gates open. As expected the effect of an increase in swellhead at the dam diminishes with increasing distance upstream away from the dam.

Table 25
The Influence of Blocking Gate Bays on Water Surface Profiles
Lock and Dams 20, 21, and 22

| Lock and Dam No. | Number of Gates Blocked | Distance above dam to point where WSEL difference is at or less than 0.1 ft. |
|---|---|---|
| | | 270,000 CFS |
| 20 | 3 Tainters | 4.1 mi. |
| 20 | 6 Tainters | 14.9 mi. |
| | | 272,000 CFS |
| 21 | 2 Tainters | 9.1 mi |
| 21 | 4 Tainters | 17.0 mi |
| | | 300,000 CFS |
| 22 | 1 Tainter | 4.6 mi |
| 22 | 3 Tainters | 14.3 mi. |
| 22 | 3 Tainters, 1 Roller | 20.7 mi. |

Table 26
The Influence of Blocking Gate Bays on Water Surface Profiles
Lock and Dams 24 and 25

| Lock and Dam No. | Number of Gates Blocked | Distance above dam to point where WSEL difference is at or less than 0.1 ft. | |
|---|---|---|---|
| | | 175,000 CFS | 290,000 CFS |
| 24 | 2 Tainters | 6.8 mi. | 7.9 mi. |
| 24 | 4 Tainters | 17.1 mi. | 20.4 mi. |
| | | 188,000 CFS | 290,000 CFS |
| 25 | 3 Tainters | 6.7 mi. | 0.0 mi. |
| 25 | 3 Tainters, 1 Roller | 12.5 mi. | 7.7 mi. |

## Other Impacts During Construction

127. Specific sites identified for added lock capacity may require additional modeling studies to assess the impact of construction operations on navigation. This pertains primarily to extending the existing lock at Location 2, and to a lesser extent, construction of a new lock at Location 3, adjacent to the existing lock. Also, if flow through the dam is restricted, gate operation schedules will need to be developed for low to normal flows when the pools are being regulated. If necessary, these additional analyses would be accomplished during site specific feasibilty.

## FINDINGS

128. There are 16 sites on the Upper Mississippi River and Illinois Waterway under consideration for large scale lock and dam improvements. These improvements include extending the existing lock to accommodate longer tows or the construction of a new lock to operate in addition to the existing lock. The objective of this analysis was to investigate the hydraulic impacts of large scale improvements at these 16 sites. To investigate each site individually would have been beyond the scope of this study. Therefore, the following three step study plan was developed:

### Study Plan

Step 1: Study hydraulic impacts at five sites on the Upper Mississippi River utilizing physical and numerical models.
Step 2: Identify advantages and disadvantages for each of the five alternative locations considered for new lock construction.
Step 3: Assess plan alternatives for the remaining 11 un-modeled sites bases on similarities with modeled sites.

129. Step 1 is presented in detail in the main body of the report. A summary of Step 1 is presented here for review and is followed by the presentation of Steps 2 and 3.

### Step 1 (Summary)

130. The five sites selected for study were Lock and Dam 20, 21, 22, 24, and 25. Plan alternatives were obtained from the initial site screening process. Plan alternatives include large scale lock improvements at the following five locations:

Location 1: Landward of existing lock.
Location 2: Extension of existing lock.
Location 3: Auxiliary lock location.
Location 4: Gated portion of the dam.
Location 5: Overflow weir

Because of topographic limitations and land development, Location 1 was eliminated from consideration at Lock and Dam sites 20, 21, 22, and 24. An evaluation of Location 5 was made based on bathymetry and flow characteristics shown in existing conditions.

131. A generic physical model plan was developed to account for three-dimensional flow conditions, to monitor entrance and exit effects on tows, and to aid in the development of numerical models. Two sites of diverse conditions, yet generically representative, Lock and Dam 22 and 25, were selected from the five study sites for physical model tests. State-of-the-art two-dimensional computer models were generated for all five sites using the computer program TABS2. The numerical models were calibrated and verified to measured data taken in the prototype and physical models. All potential plan alternatives were tested in the physical and numerical models. Because surface velocities were recorded in the physical models, the depth-averaged numerical model velocities were adjusted to represent surface velocities for comparison of results. The comparison of results was adequate to justify the use of 2-dimensional numerical models to evaluate the performance of plan alternatives.

Step 2

132. Plots of the numerical model results were generated using the software package FastTABS. These plots focused on flow conditions in the upper and lower lock approaches for three discharges; low, mid-range, and high. By examining the magnitude and direction of velocity vectors in the upper and lower lock approaches, an evaluation of hydraulic conditions was made for each alternative plan. Because of similarities in vector plots over the range of discharges, only the mid-range discharge plots are presented here. In addition to evaluating post-project navigation conditions, hydraulic impacts during construction were also evaluated.

Location 1

133. The basic plan design for Location 1 consists of the following (see Figure 18):

a. Construct a new lock landward of the existing lock.
b. Excavate the right bank upstream and downstream of the new lock.
c. Dredge access channels to the new lock.
d. Construct a solid guide wall, 1200 feet in length, upstream of the new lock.
e. Construct a solid guide wall, 1200 feet in length, downstream of the new lock.
f. Removal of the existing ported guard wall (if present).

Of the five sites modeled, this plan design was only considered feasible for Lock and Dam 25. However, its application was evaluated for the remaining 11 sites.

134. Figures 44 and 45 show the flow conditions in the upper and lower lock approach for a mid-range discharge at Lock and Dam 25. The vector plots indicate that both downbound and upbound tows will experience acceptable approach conditions to the new lock. However, extensive bank excavation will be required both upstream and downstream to allow for an optimum two-tow length approach from the ends of the approach walls. The approach to the

existing lock from upstream will be extremely difficult due to the addition of the 1200 foot ported guard wall for the new lock directing flow across the lock entrance. Therefore, the existing lock would be dedicated to small tows and recreational traffic.

135. Hydraulic impacts during construction for this alternative are minimal. Since construction will take place on the landside of the existing lock, operation of the dam will not be impacted. Construction at this location, however, at times may hinder the approach to the existing lock.

Location 2

136. The basic plan design for Location 2 consists of the following (see Figure 19):

a. Remove the downstream guide wall.
b. Extend existing lock downstream an additional 600 feet.
c. Remove the existing upstream guide wall.
d. Grade the right bank upstream of the lock.
e. Construct a ported guard wall, 1200 feet in length, upstream of the lock.
f. Remove the downstream guide wall.
g. Construct a solid guide wall, 1200 feet in length, downstream of the lock.
c. Removal of the existing ported guard wall (if present).

137. At Lock and Dam 20, the sharp bend radius of the channel upstream of the lock will require a major realignment of the channel to provide an approach distance of 2 to 3 tow lengths so that tows will have completed maneuvering once the final approach to the lock is initiated. Straightening of the bankline and submerged dikes would also aid approaching tows significantly by directing flow parallel with the lock approach and reducing the flow concentration near the guard wall. The dikes would extend from the bankline across and perpendicular to the navigation channel, spaced at intervals of 500 feet with at least 15 feet of submergence below flat pool. Downstream of the lock, the outlet of Buck Run Creek would be re-routed at least 1200 feet downstream of its present location to allow for extension of the landside lockwall.

138. Lock and Dam 21 would require little if any channel realignment upstream or downstream. However four to five 400 foot long submerged dikes constructed in the upper lock approach similar to those at Lock and Dam 20, would aid downbound tows in their final approach to the lock. Removal of an existing spur dike upstream of the lock and excavation along the bank would provide additional manuevering room near the lock.

139. The initial tests for this plan in the Lock and Dam 22 physical model showed severe outdraft problems in the upstream lock approach as the current is deflected across the approach due to the curvature of the bankline upstream of the lock. In order to alleviate the outdraft, a series of five emergent spur dikes were constructed in the physical model to redirect flow in the approach. The spur dikes were also included in the numerical model. This plan is referred to as Location 2-MA (modified approach). Vector alignment for Location 2-MA (Lock and Dam 22) shows ideal conditions for the approach to the new lock with the emergent training structures in place.

140. Severe outdraft conditions at Lock and Dam 24 in the upstream approach, make it one of the most dangerous locks to approach in the lower reach of the Upper Mississippi River. While an emergent spur dike in the upstream approach has improved conditions somewhat, it may function better if it were shortened and an L-head were added at the upstream end. Construction of 2 to 3 additional L-head dikes spaced about 1000 feet apart with the ends parallel to the approach would further improve conditions (see discussion above). Minor excavation along the right bank would also aid tows in aligning with the lock by providing a wider approach. Downstream approach conditions were quite good with little if any channel or bank excavation anticipated.

141. Removal of the existing landside guide wall at Lock and Dam 25 and bank excavation for a distance of 600 feet upstream of the lock, will provide a 200 foot opening between the bank and the guard wall at navigation depth, aiding approaching downbound tows. Minor realignment of the upstream navigation channel would also assist tows in their approach to the lock, as the existing alignment has tows turning as they make their final approach.

142. Figures 46 through 51 show the flow conditions in the upper lock approach for a mid-range discharge at the five lock and dam sites. Implementation of the measures suggested above along with the ported guard wall, should greatly improve navigation conditions in the upstream approach for all flow conditions.

143. Figures 52 through 56 show the flow conditions in the lower approach for a mid-range discharge at the five study sites. The velocity vectors give no indication of navigation problems for upbound or downbound tows. Alignment with the guide wall is aided by forces created by a flow expansion downstream of the lock chamber.

144. As in the case of Location 1, hydraulic impacts during construction should be minor. Because the existing lock is separated from the dam by the partially constructed auxiliary lock chamber, it is unlikely that flow through the dam would be restricted. However, navigation would be interrupted during the construction period. Most likely, lock useage would be prohibited during the time of day construction operations are taking place.

145. Because of the vast improvement observed in flow conditions in the Lock and Dam 22 physical model as a result of the addition of emergent wing dikes in the upstream approach, it is recommended that these structures also be considered for Locations 3 and 4 as well. Although the addition of dikes at Lock and Dam 24 was not modeled, construction of emergent L-head wing dikes would improve navigation conditions.

Location 3

146. The basic plan design for Location 3 consists of the following (see Figure 20):

a. Construct a new lock with usable dimensions of 110x1200 feet at the location of the partially constructed auxiliary lock.
b. Remove the existing ported guard wall (if present).
c. Construct a ported guard wall, 1200 feet in length, upstream of the new lock.
d. Construct a solid riverward guard wall, 1200 feet in length, downstream of the new lock.

147. Model results showed an improved approach conditions at all five sites for a new lock constructed at Location 3 as compared to extending the existing lock at Location 2. However, some additional channel work in the approach is still recommended at a number of the sites.

148. Submerged dikes across the upstream approach channel and excavation of the bank and channel as proposed for Location 2 at Lock and Dam 20, is recommended at Location 3 as well. However, re-routing of the outlet of Buck Run Creek would not be necessary.

149. The submerged dikes noted above, would also aid downbound tows for a Location 3 lock at Lock and Dam 21.

150. Emergent L-head dikes as recommended for Lock and Dams 22 and 24 at Location 2, would also improve upstream approach conditions for Location 3 at those sites.

151. Figures 57 through 61 show the flow conditions in the upper lock approach for a mid-range discharge at the five study sites. Approach conditions for new lock construction at Location 3 was generally an improvement over conditions at Location 2 for both the existing 600 foot lock and the extended lock. Flow through the submerged ports in the ported guardwall reduces the outdraft across the approach and aids tows in aligning with the guard wall. The slight angle of the vectors reflecting flow through the submerged ports however, will make use of the existing lock difficult for tows at all five sites. Flow through the ports will tend to deflect the lead barge of an approaching tow away from the existing guide wall. The vector plots show the maximum flow velocity in the upper approach to the existing lock to be about 2 fps and decreasing to about 1 fps just upstream of the lock. This indicates that the existing lock, while possibly not suitable for use by large tows, could be dedicated to locking small tows and recreational craft.

152. Figures 62 through 66 show the flow conditions in the lower approach at Location 3 for mid-range discharges at the five study sites. At this location the guide wall for the new lock was constructed on the riverside of the new lock to avoid restricting access to the existing lock. Note that the guide wall encroaches into the channel for some distance downstream reducing the flow area in this reach. Just downstream of the wall, a significant increase in channel area occurs causing an expansion of flow. The vector plots show the impact of this increase in channel area indicating there is a slight vector force in the landward direction just downstream of the wall. This force does not appear to be of sufficient magnitude as to impact downbound tows, but may require additional maneuvering by upbound tows.

Location 4

153. The basic plan design for Location 4 consists of the following (see Figure 21):

a. Construct a new lock in the gated portion of the dam adjacent to the partially constructed auxiliary lock (loss of two gate bays).
b. Construct two gate bays in the overflow weir (replaces lost gate bays).
c. Remove existing ported guard wall (if present).
d. Construct a ported guard wall, 1200 feet in length, upstream of the new lock.
e. Construct a solid guide wall, 1200 feet in length, downstream of the new lock.
f. Construct a gate between the new lock and the existing lock for passage of ice and debris.

154. The model design for this plan evolved over time. The plan as tested in the physical model of Lock and Dam 25 allowed flow through a gate installed in the existing auxiliary lock bay between the new lock and the existing lock. The resulting high flow velocities approaching the gate made alignment of tows with either lock extremely difficult. Therefore, the gate would only be operated during periods of high flow and for passage of ice and debris. The gate would be closed when tows are approaching the lock. For this reason, the Lock and Dam 22 physical model did not incorporate gates in the auxiliary lock bay. It is recommended that lost flow capacity in the gated section of the dam be replaced by installing gates in the overflow section of the dam where applicable. The addition of gate bays in the overflow section of the dam, as presented in the recommended plan design, were not included in the physical models due to the cost of construction and the small impact to flow conditions in the lock approach.

155. Since Lock and Dam 20 does not have an overflow section, lost gate capacity would likely be compensated for by installing replacement gates in the auxiliary lock bay. These gates would only be used during high flows and would be closed when tows were approaching the lock.

156. Figures 67 through 77 show the flow conditions in the upper lock approach for a mid-range discharge at the five study sites. The vector plots show that as in the case of Location 3, flow through the ported guard wall will hamper tows entering the existing lock. However, the approach to the new 1200 foot lock is good at all of the sites. Therefore, requirements for bank excavation and channel realignment are reduced. At Lock 21, the submerged dikes recommended for Locations 2 and 3, would also improve approach conditions at Location 4. The dikes would be lengthened so they extend beyond the far edge of the navigation channel. Emergent channel training structures recommended for Locations 2 and 3 at Lock and Dam 22, while not required for Location 4, would enhance upstream approach conditions.

157. Figures 72 through 76 show flow conditions in the lower lock approach for a mid-range discharge at four of the study sites. The vector plots show that the approach to the lock from downstream is good at all sites. However, eddy currents caused by the abrupt expansion of flow downstream of the guide wall will require additional maneuvering by tows to align with the wall and proceed into the lock chamber. This effect increases with higher flows as the eddy velocities increase.

158. Construction of a new lock at Location 4 will require removing at least three gates from service during the construction period. This will create an increase in swellhead of 0.3 to 0.4 feet under open river conditions. If the gates that are to be permanently removed are replaced in the overflow section prior to initiation of construction, the increase in swellhead would be limited to 0.1 feet. Once construction is complete and the gate adjacent to the new lock can be operated, there will no increase in the swellhead over what presently exists. Since the area of construction is separated from the existing lock by the auxiliary lock chamber, there will be less interference with navigation traffic during the construction period.

Location 5

159. The basic design plan for Location 5 consists of the following:

a. Construct a new lock in the overflow weir adjacent to the dam.
b. Construct a ported guard wall, 1200 feet in length, upstream of the new lock.
c. Construct a solid guide wall, 1200 feet in length, downstream of the new lock.
d. Dredge approach channels, upstream and downstream of the new lock.

160. This plan alternative was evaluated based on existing channel conditions. Figures 29 through 33 show the bathymetry upstream and downstream of the five study sites. Channels must be dredged upstream and downstream of the new lock to provide access. The access channels should provide a depth of 20 feet at low control pool, have a minimum bottom width of 200 feet, and side slopes of 1V:10H or flatter. An examination of channel depths in the vicinity of the existing lock and the proposed new lock, give an indication of the massive amounts of dredge removal required to provide adequate entrance and exit channels for lock usage.

161. The area of the proposed access channels are presently shallow in depth, indicating that flow conditions are such that the mechanics of sedimentation have made this area shallow and will continue to maintain a shallow area. Therefore, during high flows when large quantities of sediment are moving, these channels will act as sediment traps and quickly fill. While high stages associated with high flows may allow tow traffic to continue, emergency maintenance will be required after the passage of each flood hydrograph. Also, inflow of sediments from side channel inlets upstream must be considered. The contribution of sediment to this side of the channel is likely to have a major impact on the upstream approach. Maintenance dredging of the upper and lower approach will be chronic for this plan.

162. While Lock and Dams 24 and 25 exhibited the characteristics mentioned above, bathymetry and flow characteristics at Lock and Dams 21 and 22 do not immediately rule out Location 5 as a plausible alternative. However, uncertainties concerning the reliability of the existing channel during the 3 to 4 year period estimated for channel realignment, in all likelihood remove Location 5 as a viable alternative location for construction of a new lock.

Step 3

163. Extrapolation of physical and numerical model results generated at the lower 5 sites, and examination of existing approach conditions and topographic information, provide a reasonable indication of expected navigation conditions at the remaining 11 sites being considered for additional lock capacity. Included are recommendations for channel realignment, bank excavation, and additional training structures necessary to provide the safest, most efficient approach to the lock. The results of the assessment are provided as an appendix to this report and are organized in a site by site format.

## CONCLUSIONS

164. This investigation has presented and summarized the hydraulic impacts related to new lock construction at 16 existing lock and dam sites. Recommendations which stem from these impacts are intended to provide optimal navigation conditions, reflecting both safety and efficiency. However, while locations 3 and 4 provide the best navigation conditions, economics and constructability will also influence the selection of locations and sites at which additional lock capacity will be provided.

# REFERENCES

*FastTABS, Hydrodynamic Modeling TABS Primer*, Brigam Young University and USCEWES, 1994.

Wooley, *Navigation Model Study of Lock and Dam 22, Mississippi River,* USCEWES, Vicksburg, Mississippi, February 1996.

Wooley, *Navigation Model Study of Lock and Dam 25, Mississippi River,* USCEWES, Vicksburg, Mississippi, March 1996.

Norton, *RMA-2*, Resource Management Associates, Inc., Davis California, 1973.

Thomas and Mc Nally, *TABS, Generalized Computer Program System for Open Channel Flow and Sedimentation,* USCEWES, Vicksburg, Mississippi, February 1990.

*UNET, One-Dimensional Unsteady Flow Through a Full Network of Open Channels,* Hydrologic Engineering Center, Davis California, September 1995.

# APPENDIX

## UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY HYDRAULIC IMPACTS SITE ASSESSMENT

1. In order to appraise the hydraulic impacts to navigation at all of the sites considered for added lock capacity on the Upper Mississippi River and Illinois Waterway site, results of physical and numerical modeling conducted at Lock and Dams 20 thru 25 on the Upper Mississippi River, were extrapolated to assess navigation conditions at Lock and Dams 11 thru 19, and Peoria and La Grange Lock and Dams on the Illinois Waterway. Mapping, aerial photography, and existing approach data, were also utilized, allowing a qualitative assessment of each site to be performed. As necessary, modifications to channel and bank alignment, and the addition of channel training structures, were recommended to improve approach conditions.

2. The following is a site by site description of navigation conditions and suggested modifications which would optimize approach conditions at all sites considered for expanded lock capacity. Included are maps showing the location and extent of suggested improvements for each alternative location within a site.

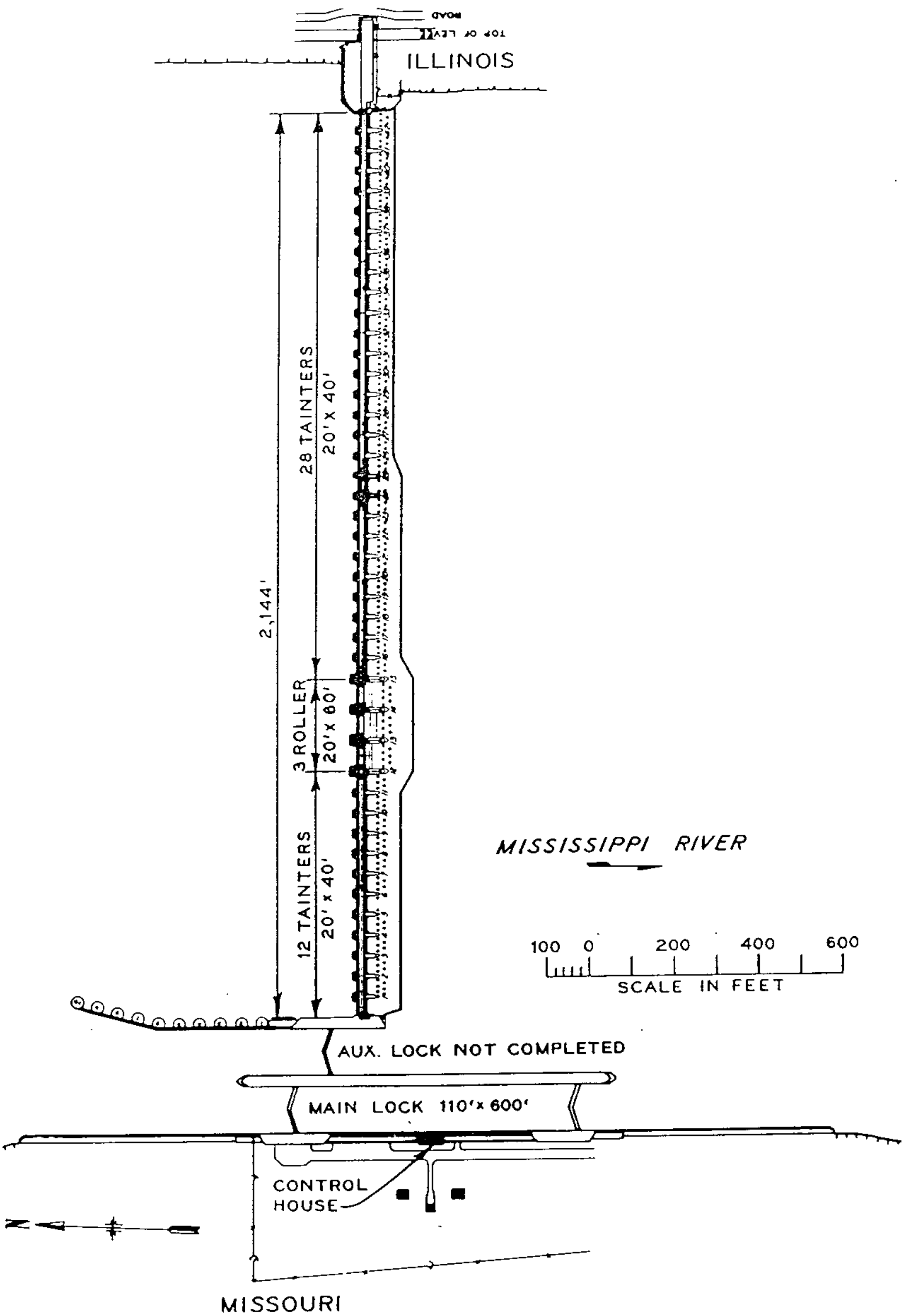



**Figure 1. Lock and Dam No. 20**

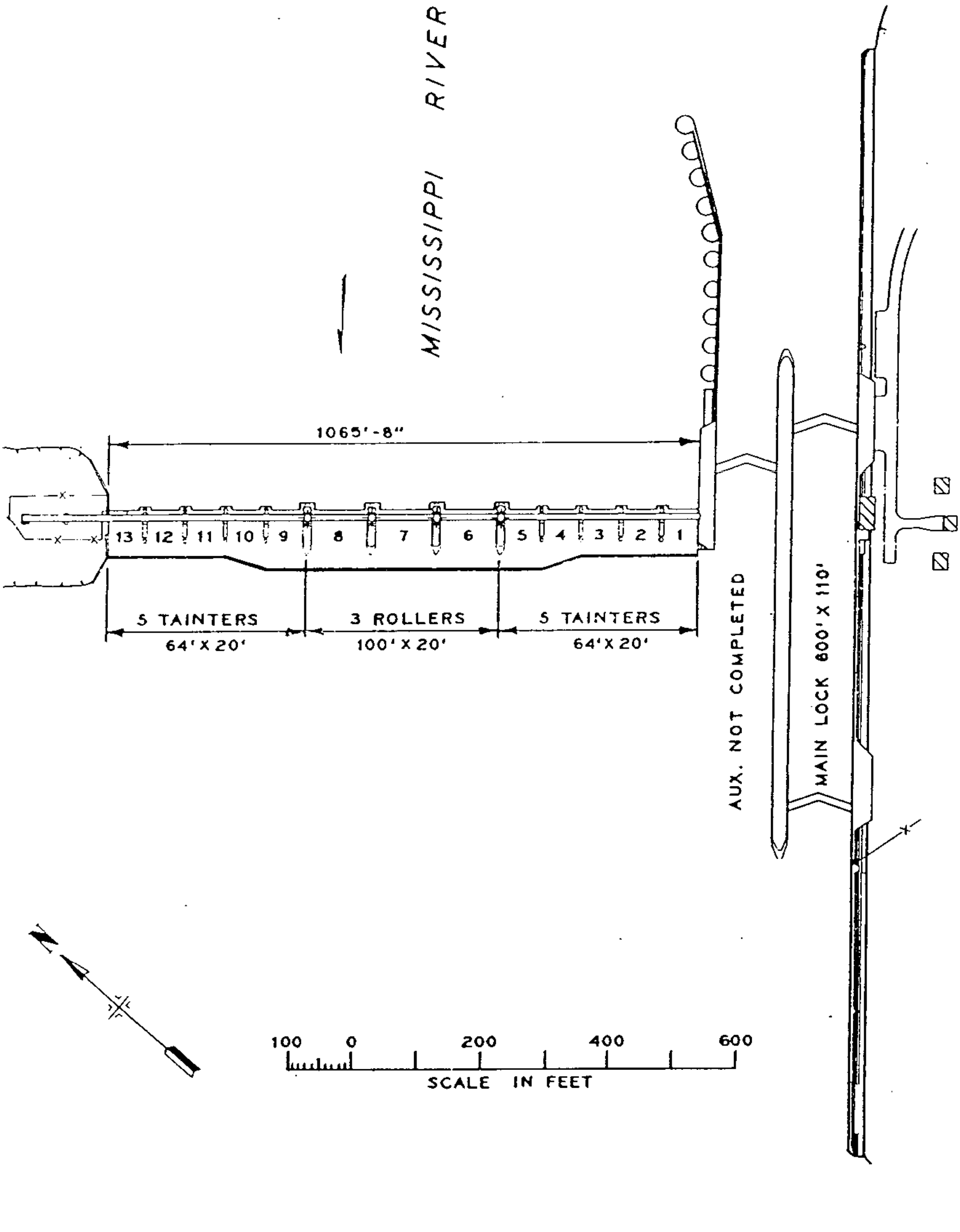



Figure 2. Lock and Dam No. 21

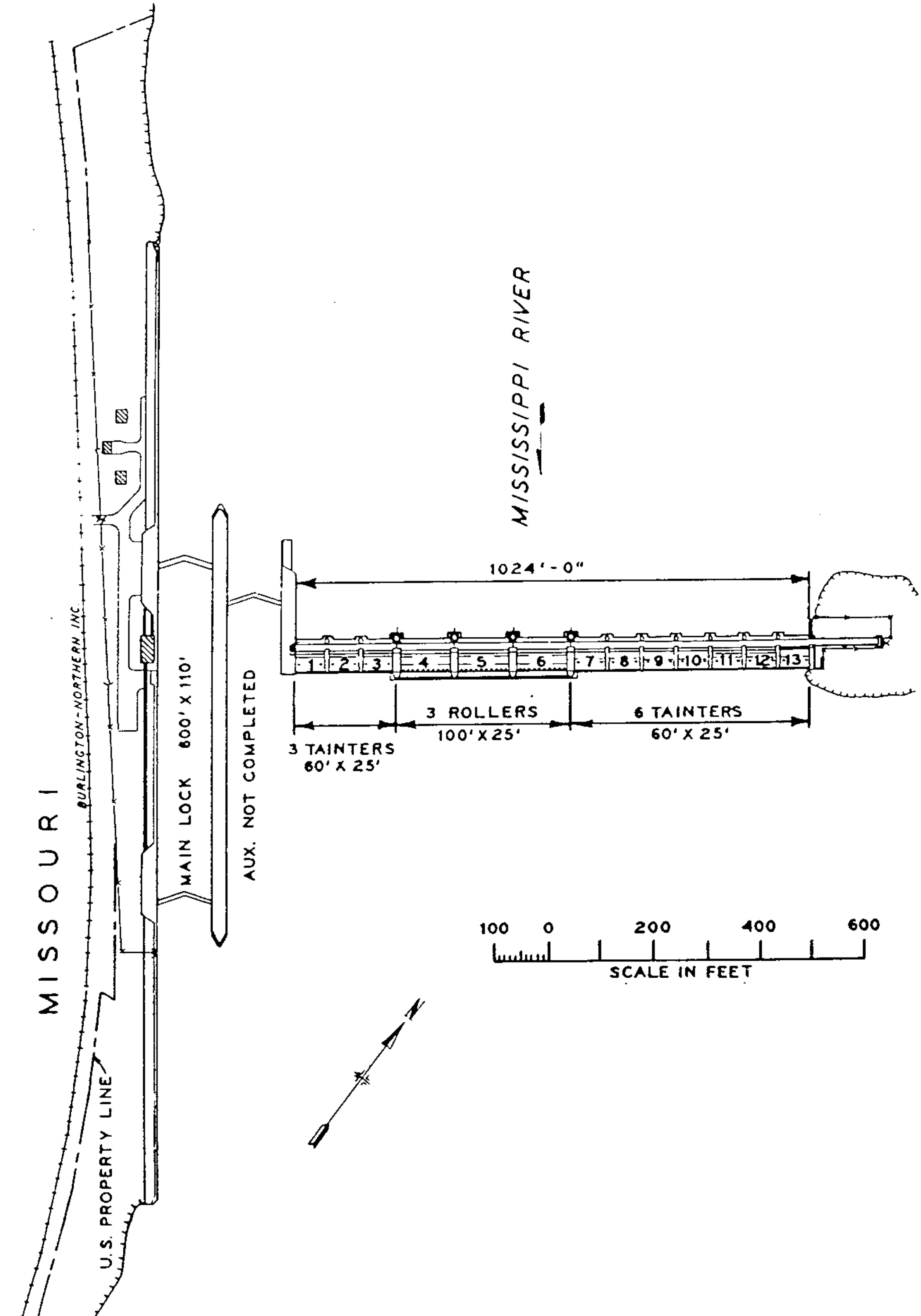



Figure 3. Lock and Dam No. 22

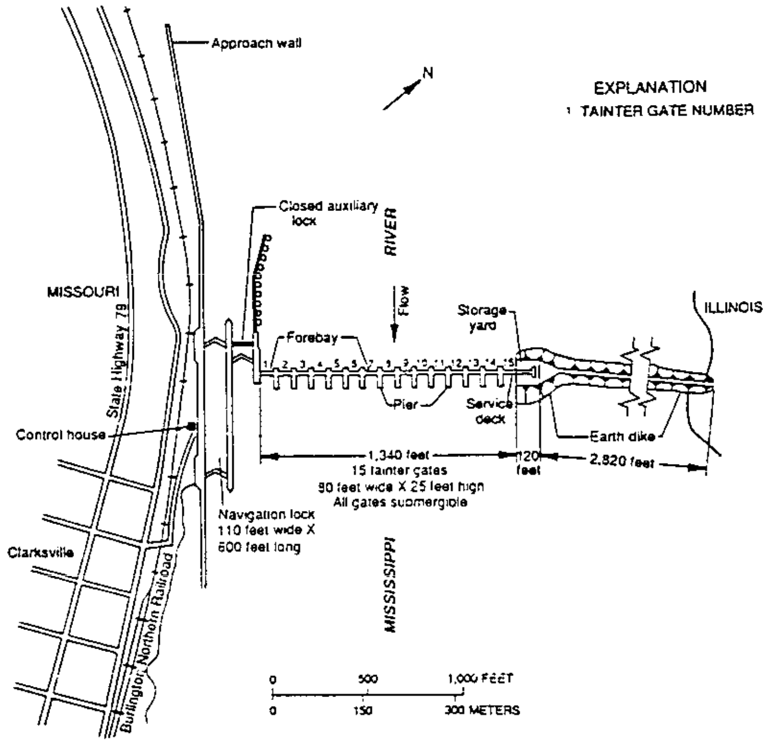



Figure 4. Lock and Dam No. 24

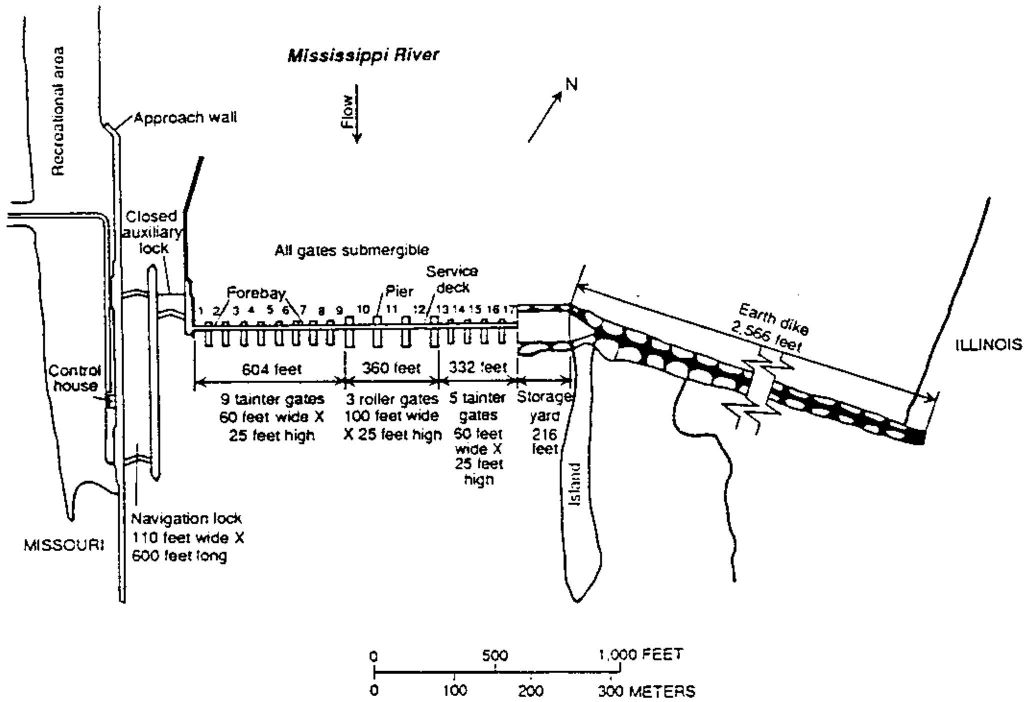



Figure 5. Lock and Dam No. 25

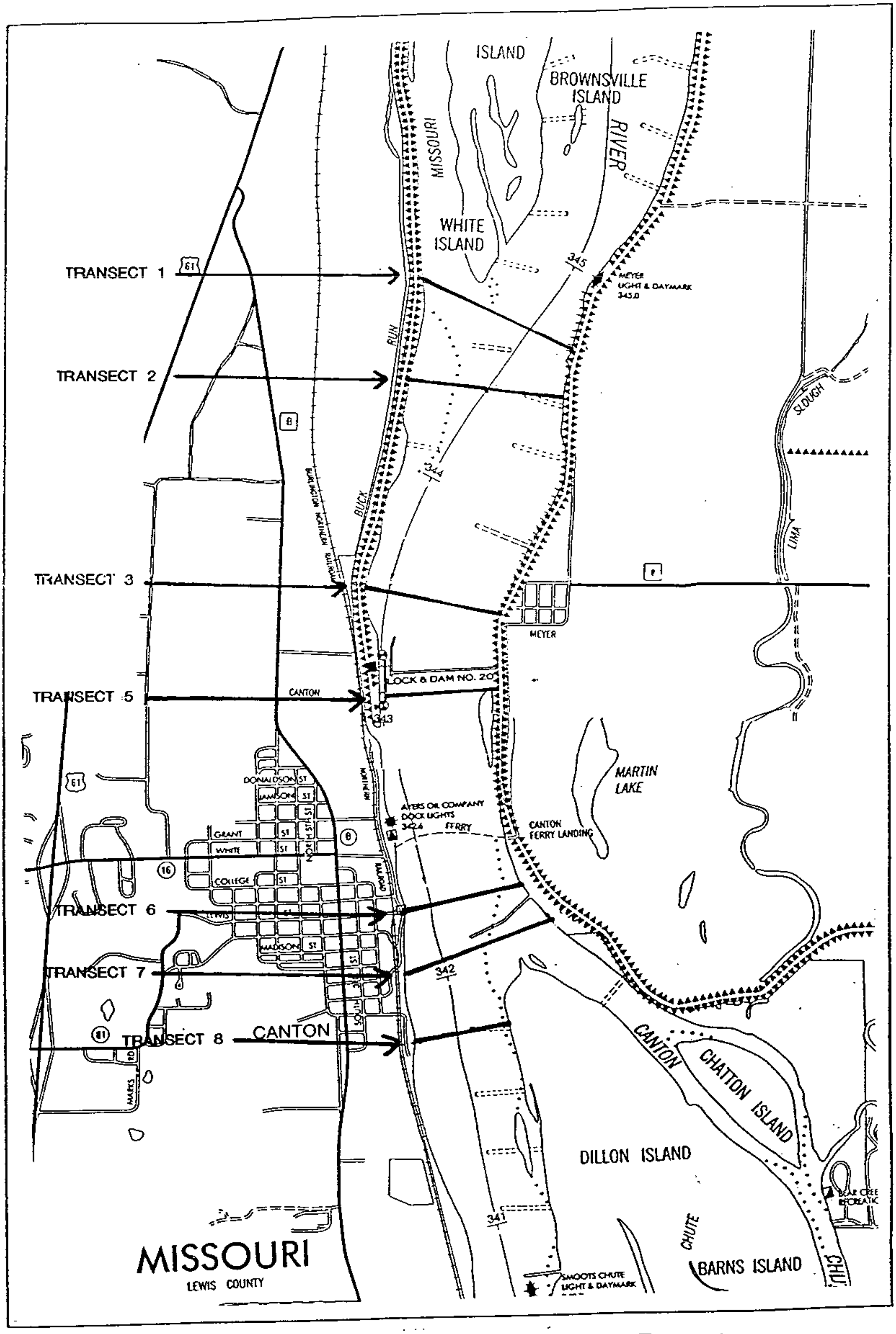



Figure 6. Lock and Dam No. 20 Data Collection Transects

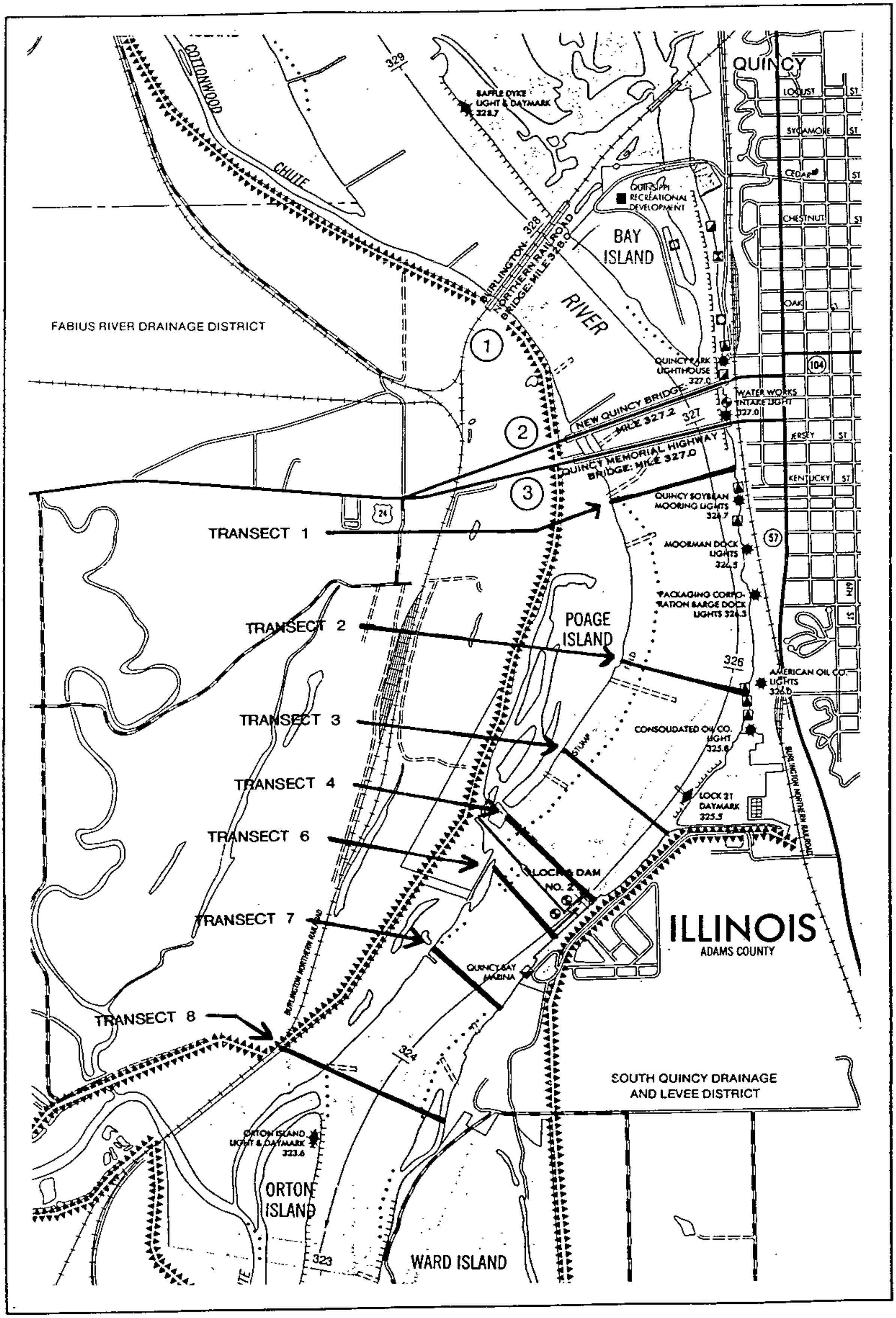



**Figure 7. Lock and Dam No. 21 Data Collection Transects**

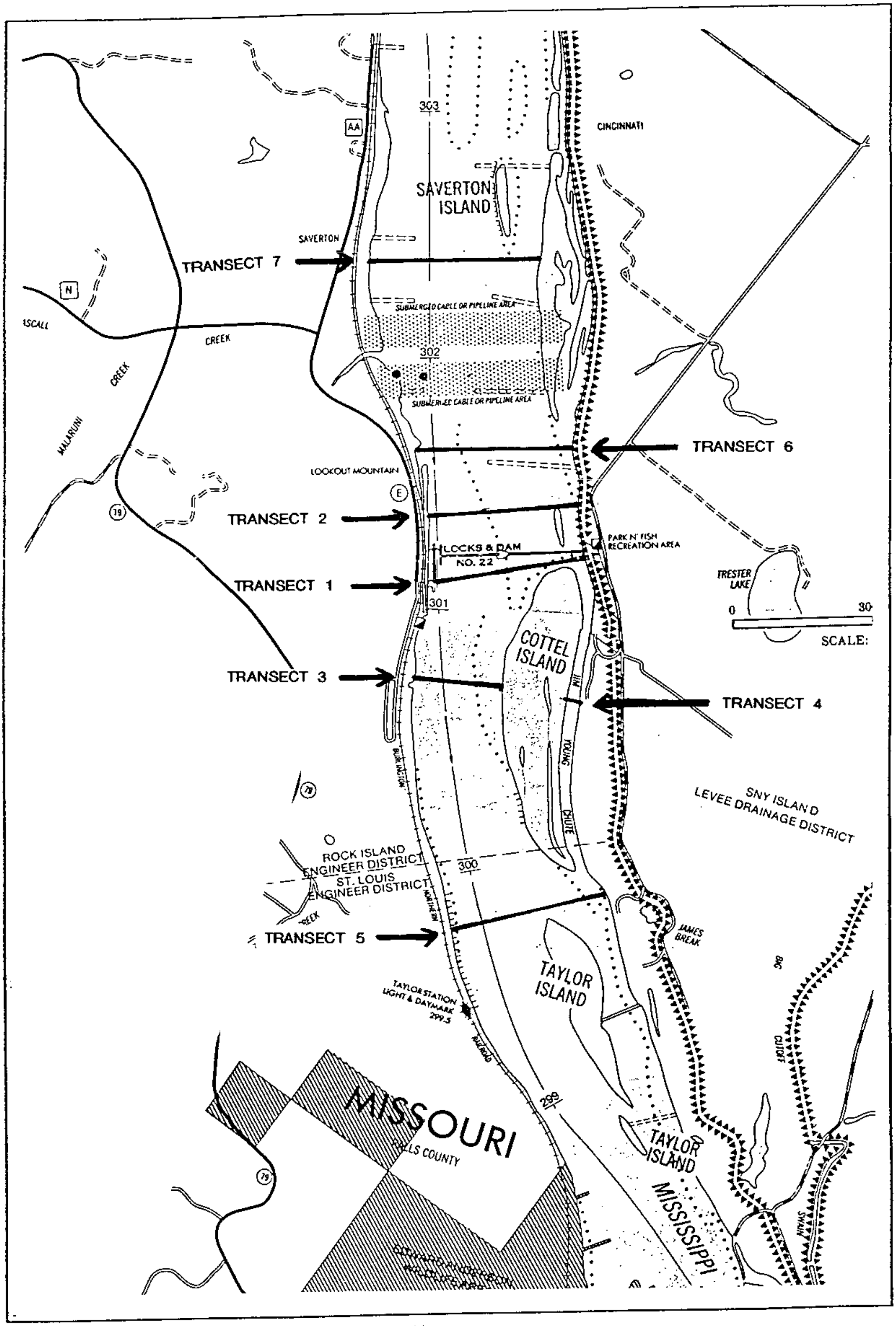



**Figure 8. Lock and Dam No. 22 Data Collection Transects**

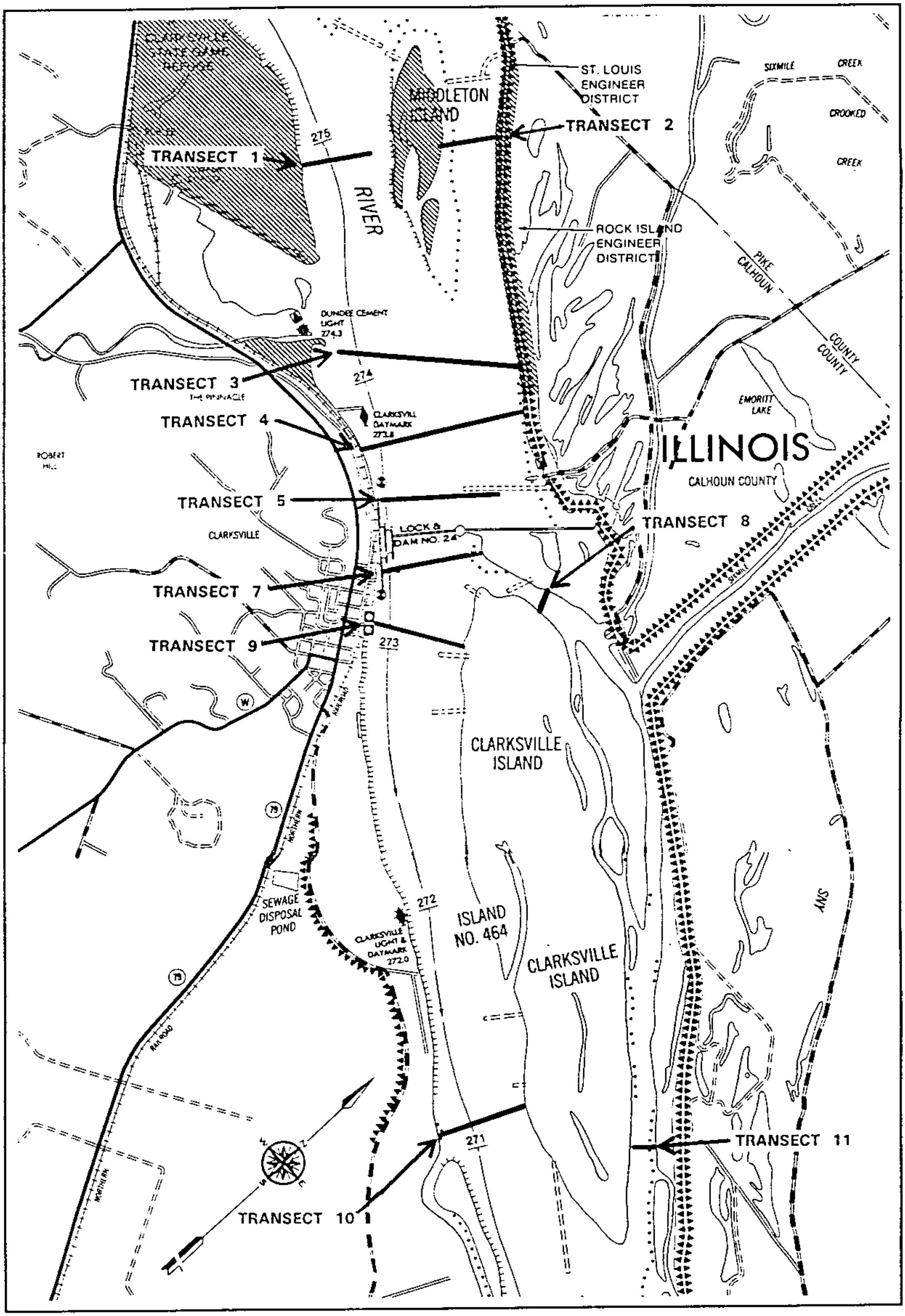



Figure 9. Lock and Dam No. 24 Data Collection Transects

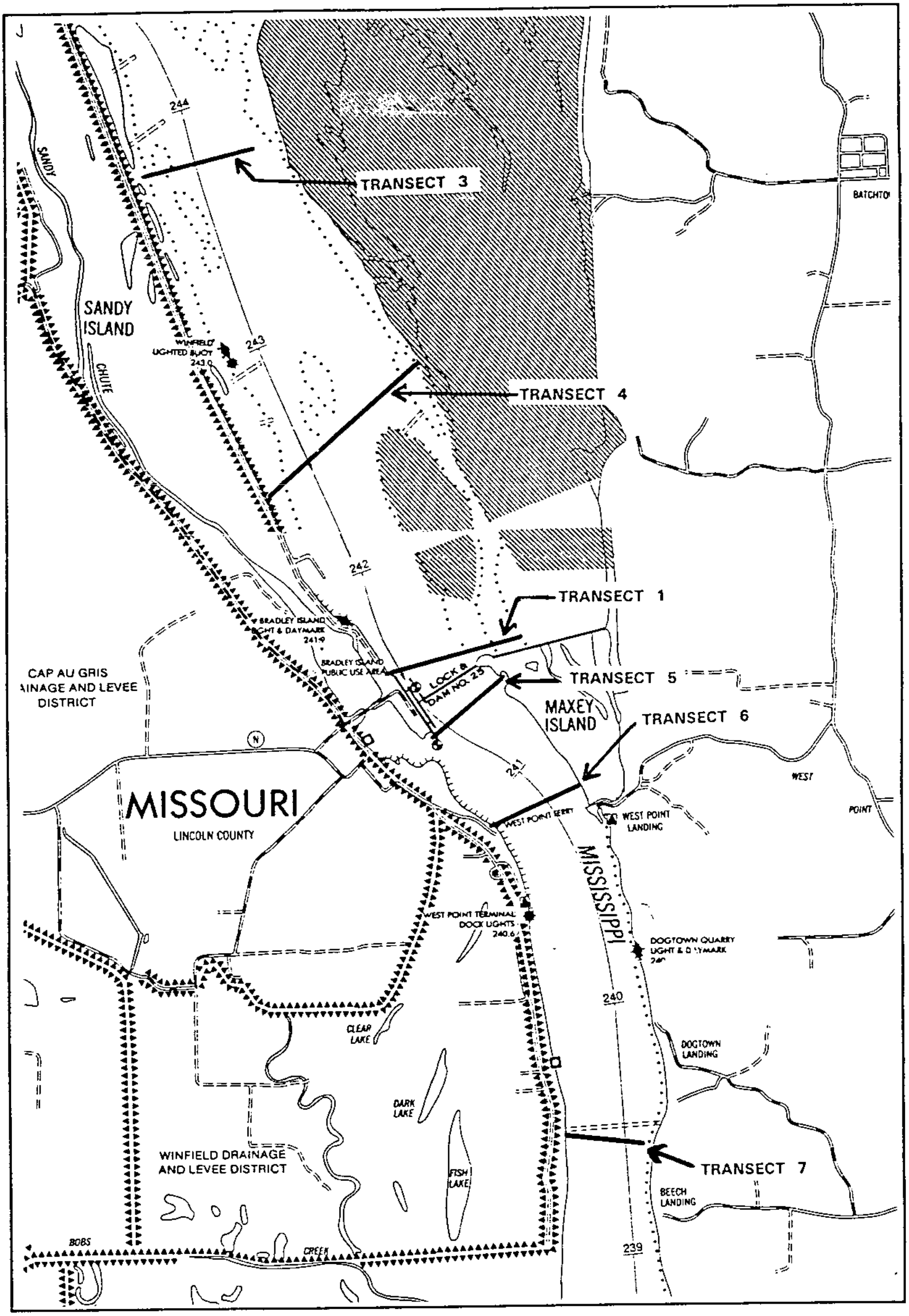



Figure 10. Lock and Dam No. 25 Data Collection Transects

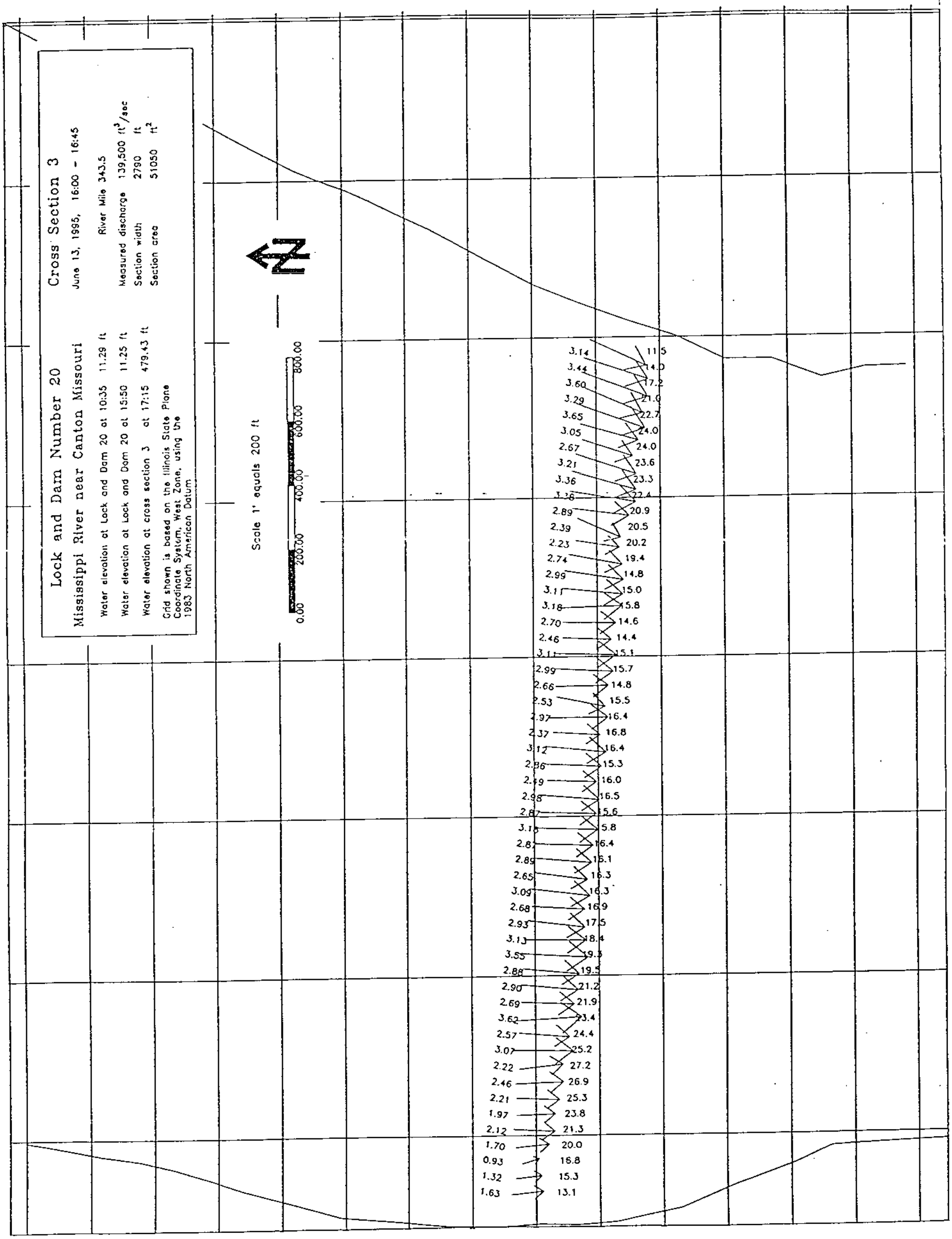



**Figure 11. Lock and Dam No. 20 - Cross Section No. 3**

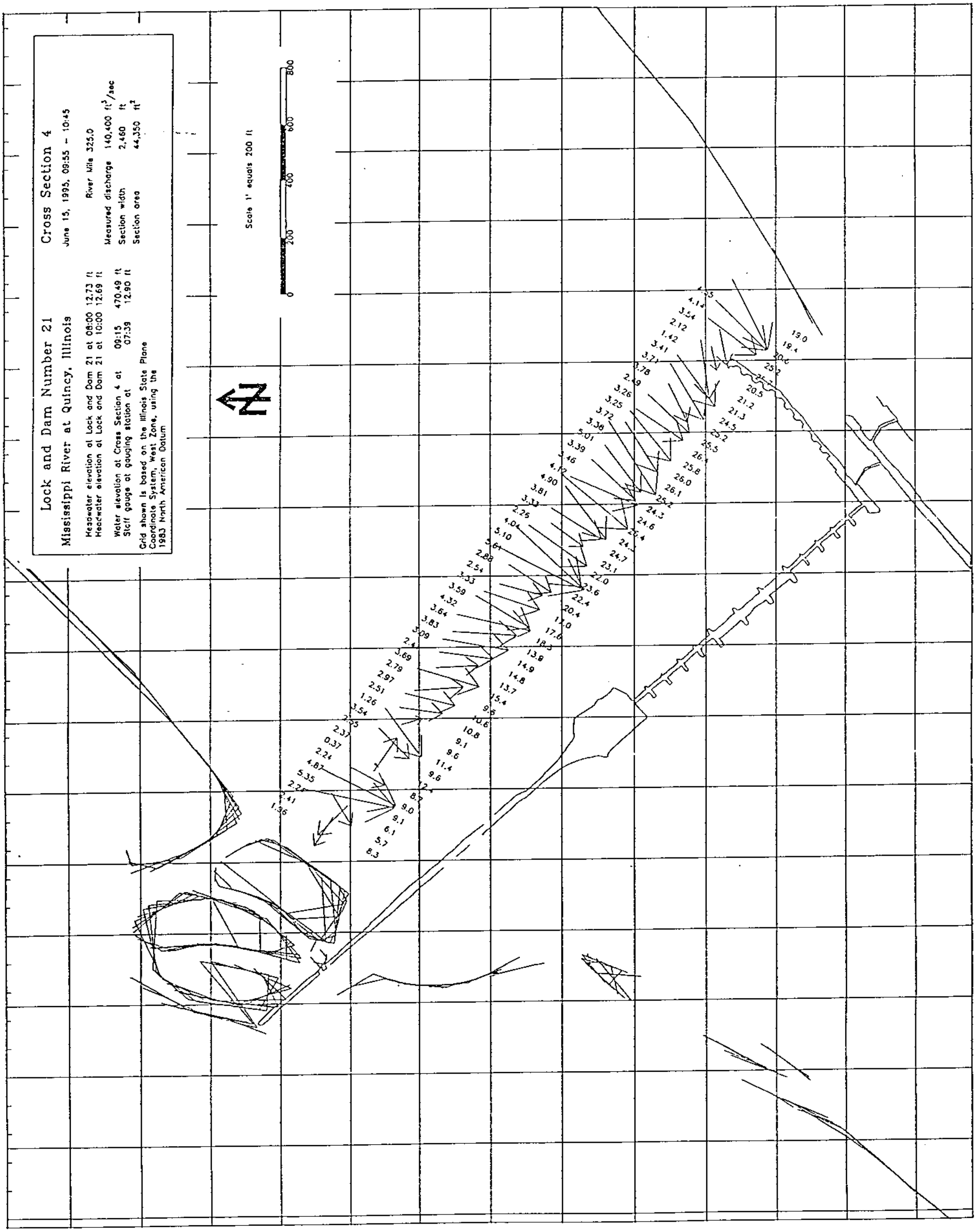



**Figure 12. Lock and Dam No. 21 - Cross Section No. 4**

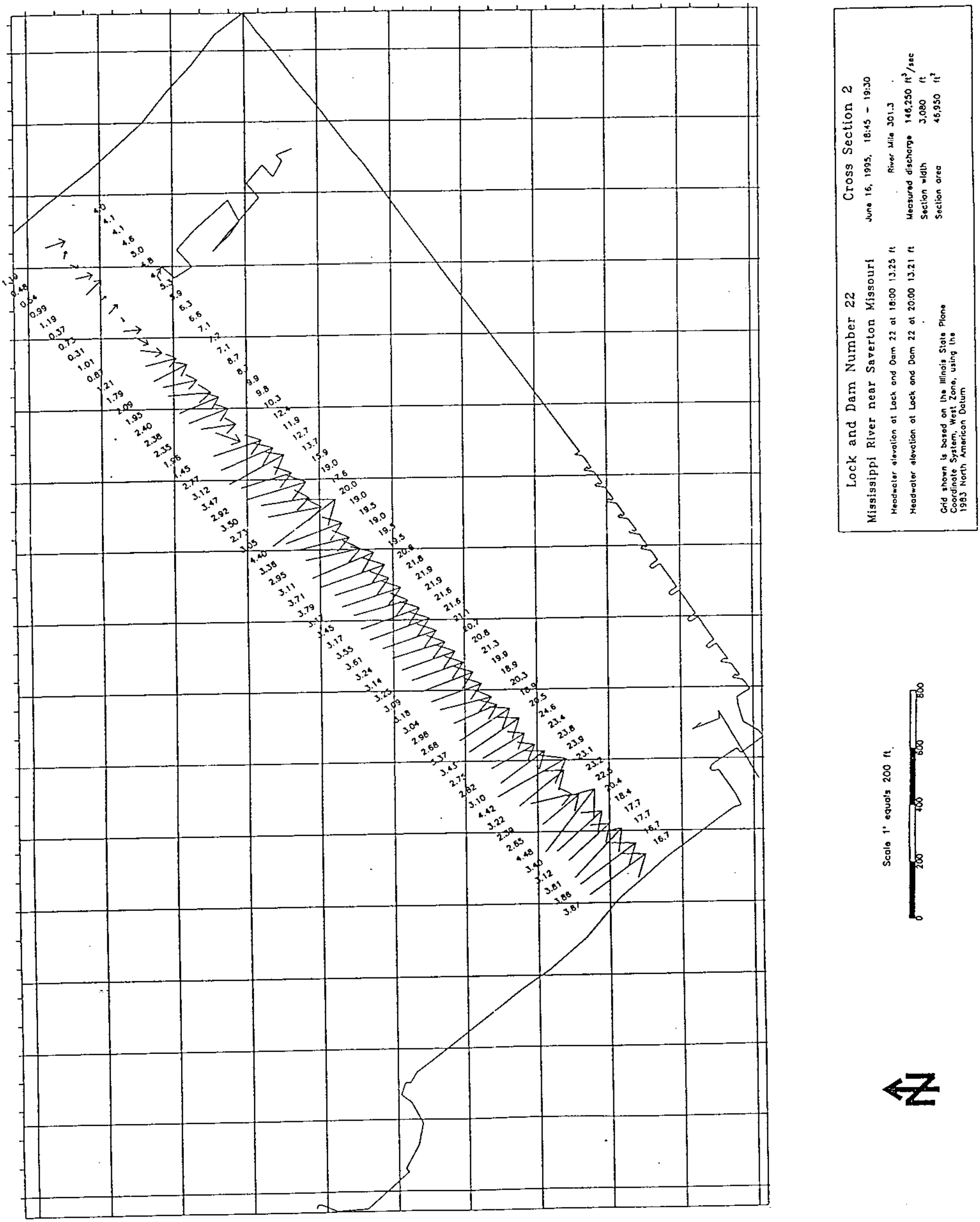



**Figure 13. Lock and Dam No. 22 - Cross Section No. 2**

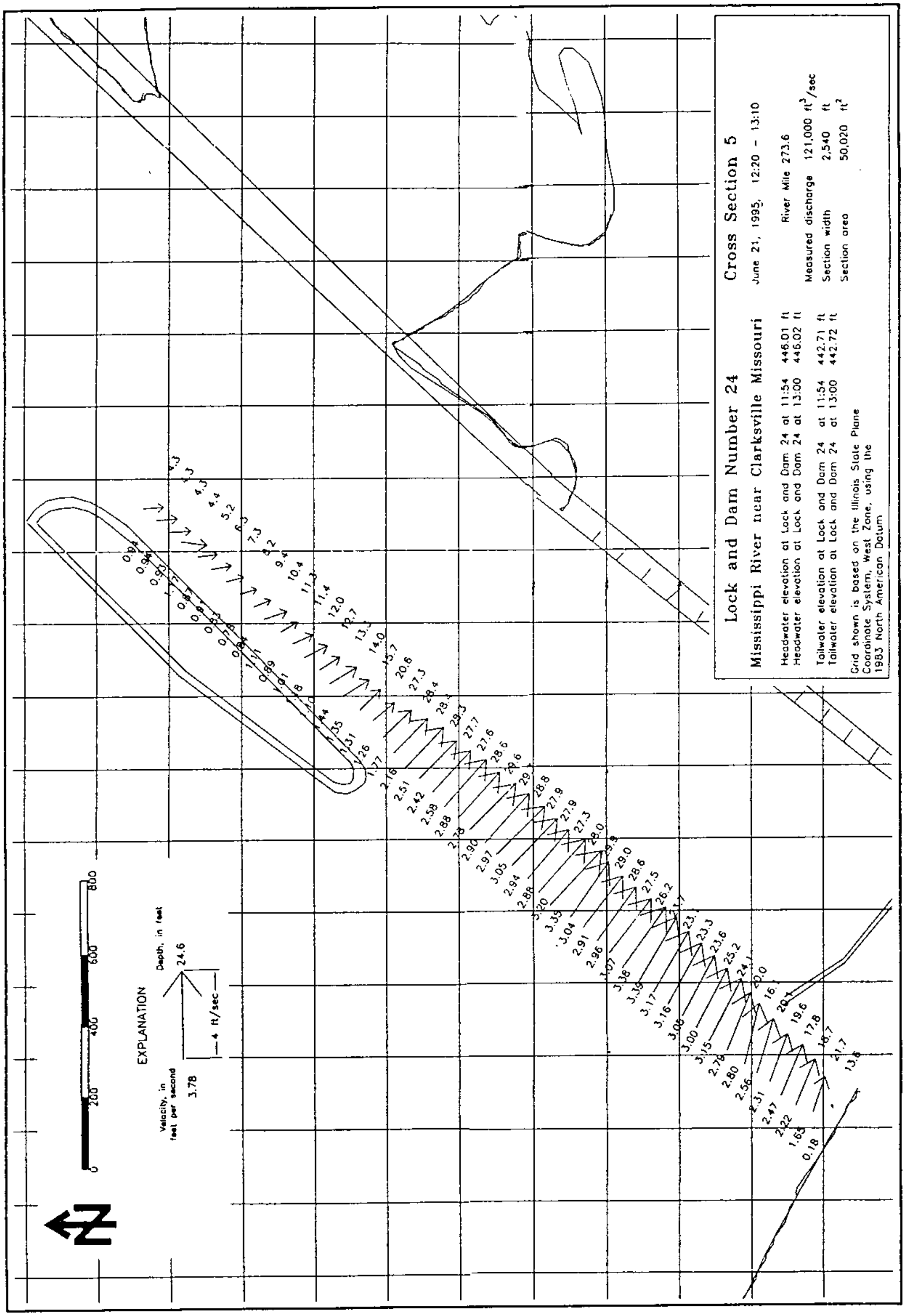



Figure 14. Lock and Dam No. 24 - Cross-Section No. 5

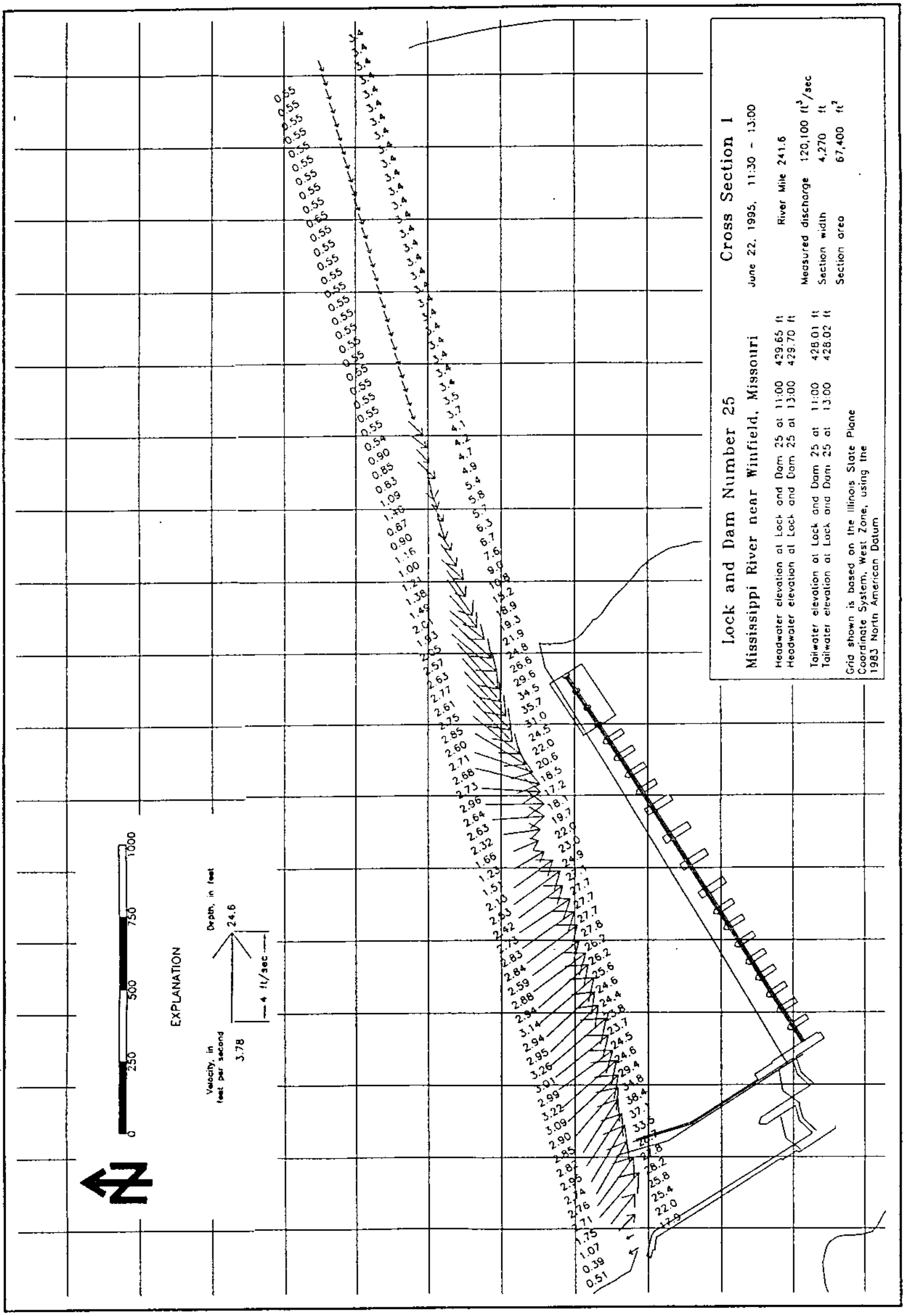



Figure 15. Lock and Dam No. 25 - Cross-Section No. 1

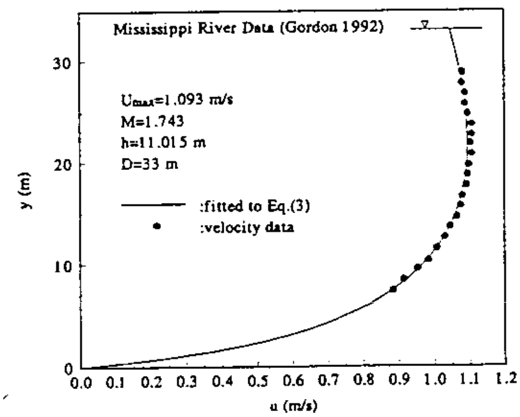



Figure 16. Velocity Profile in Mississippi River (Gordon 1992)

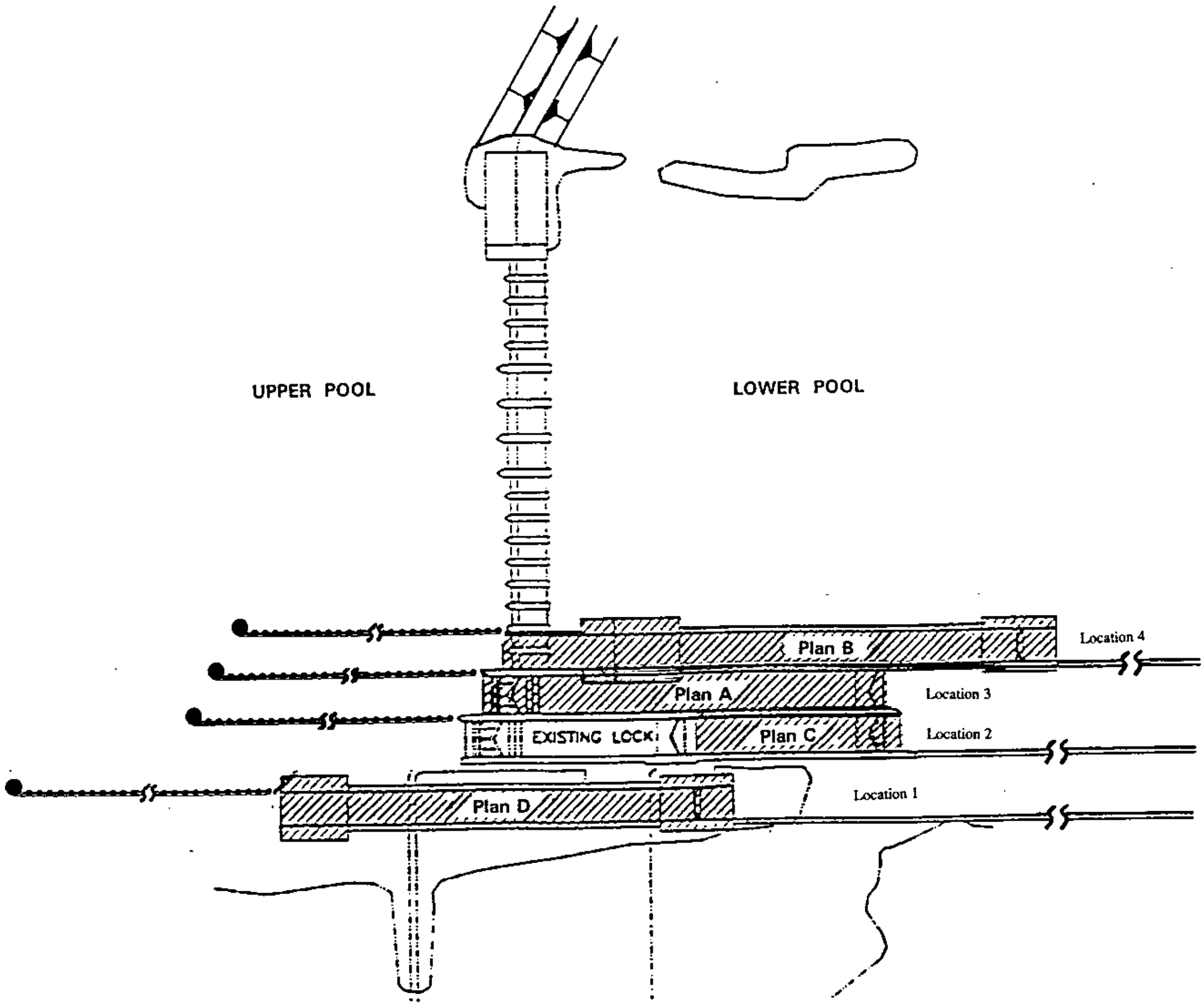



Figure 17. Generic Lock Locations

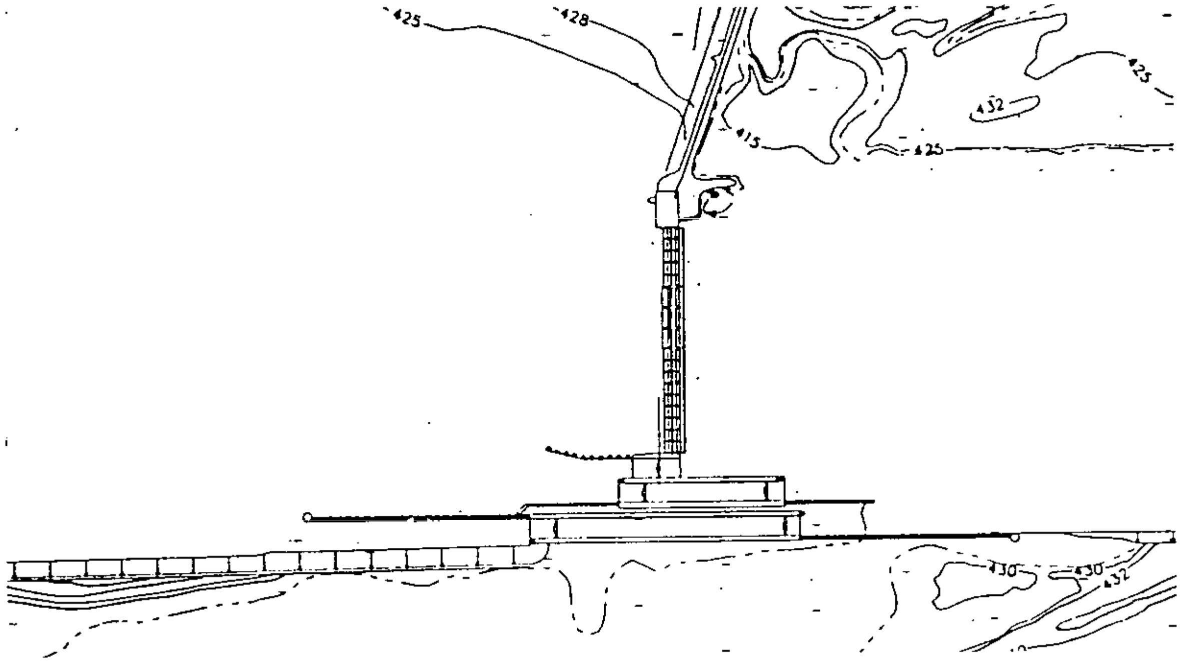



Figure 18. Location 1 - Landward of Existing Lock

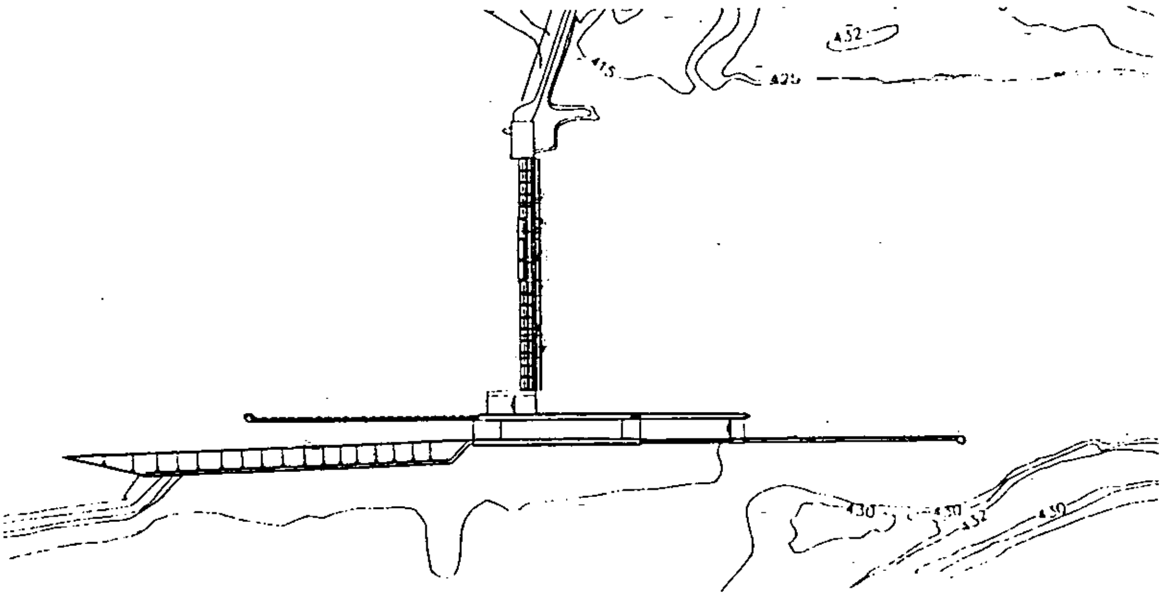



Figure 19. Location 2 - Extension of Existing Lock

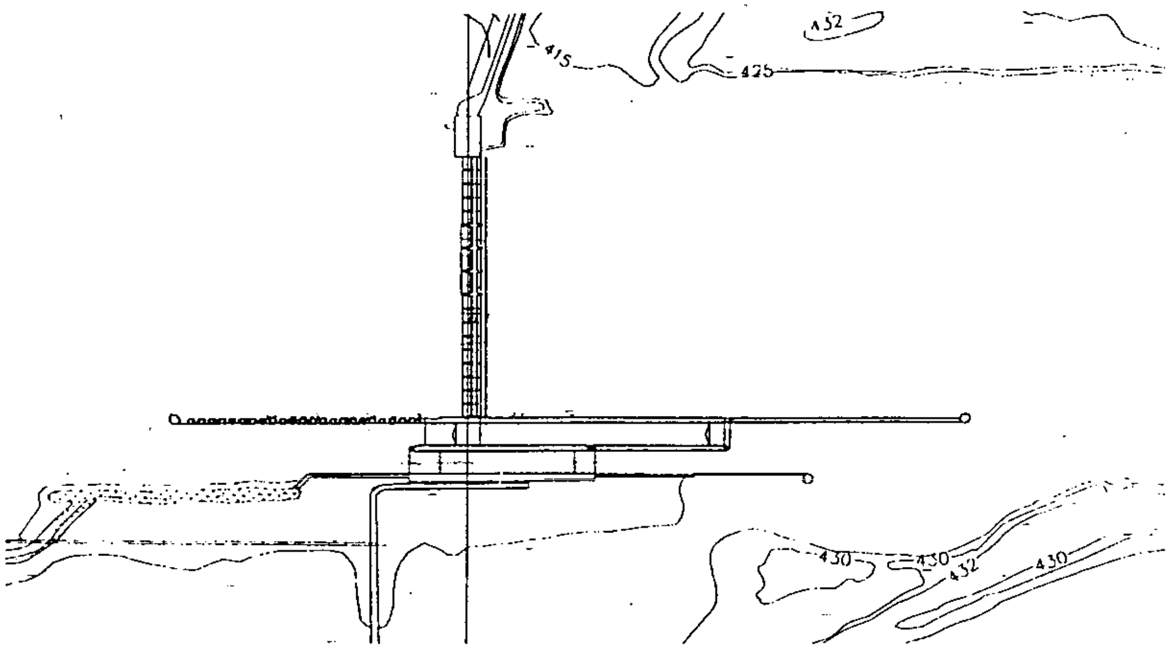



Figure 20. Location 3 - At Auxiliary Lock

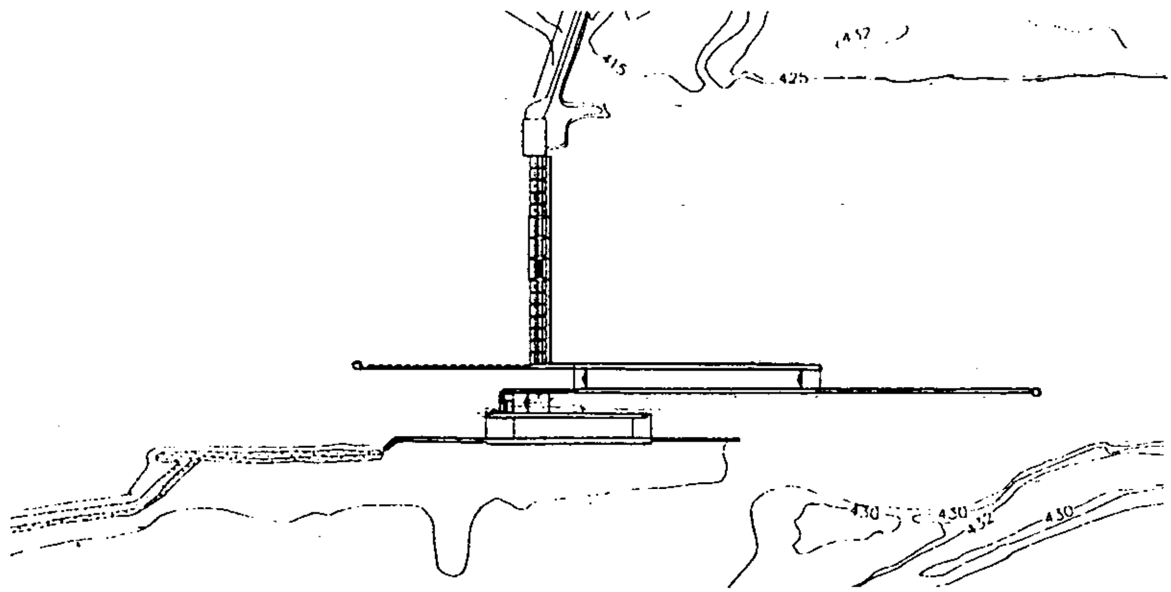



Figure 21. Location 4 - In Gated Section of Dam

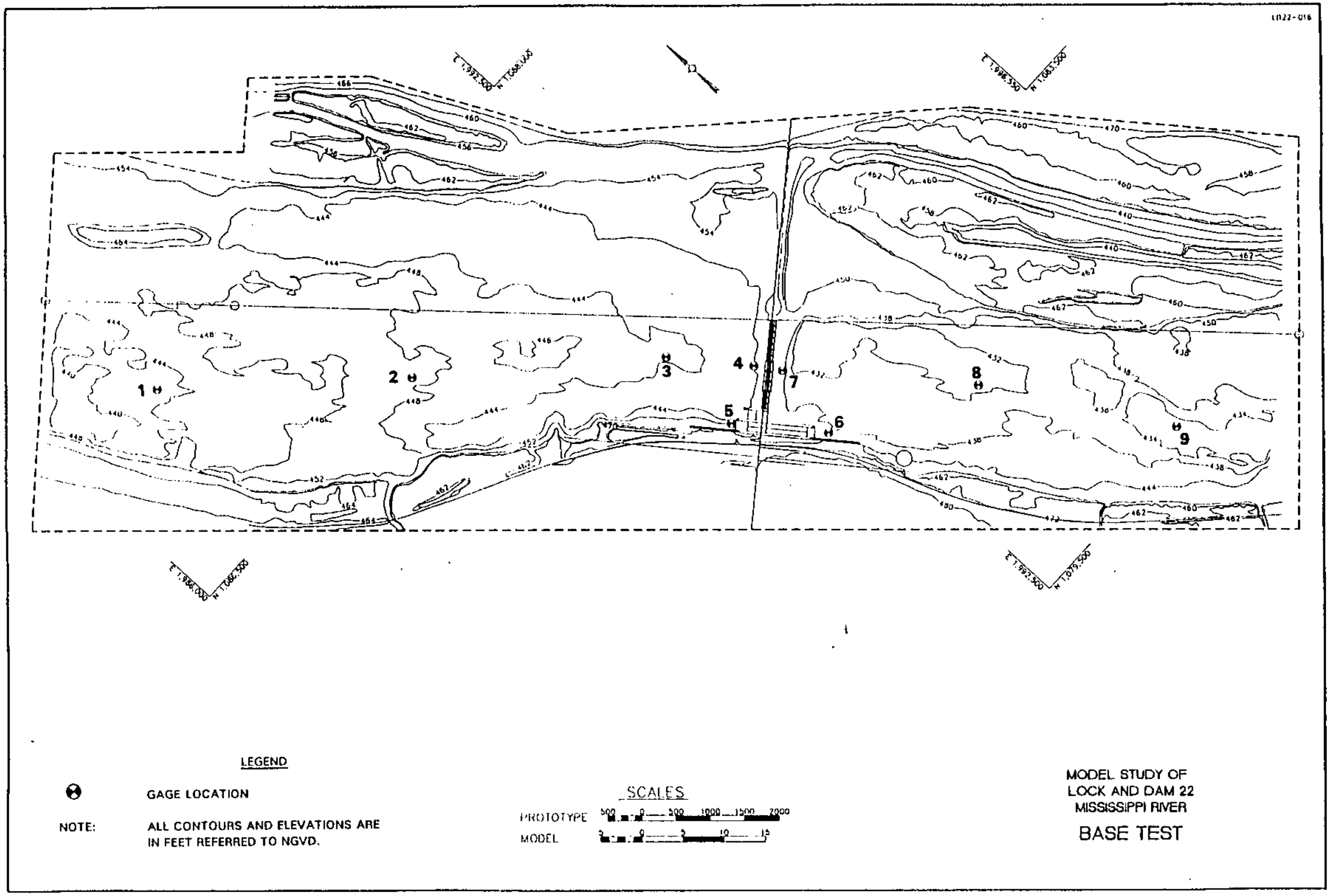



Figure 22. WES Physical Model - Lock and Dam No. 22

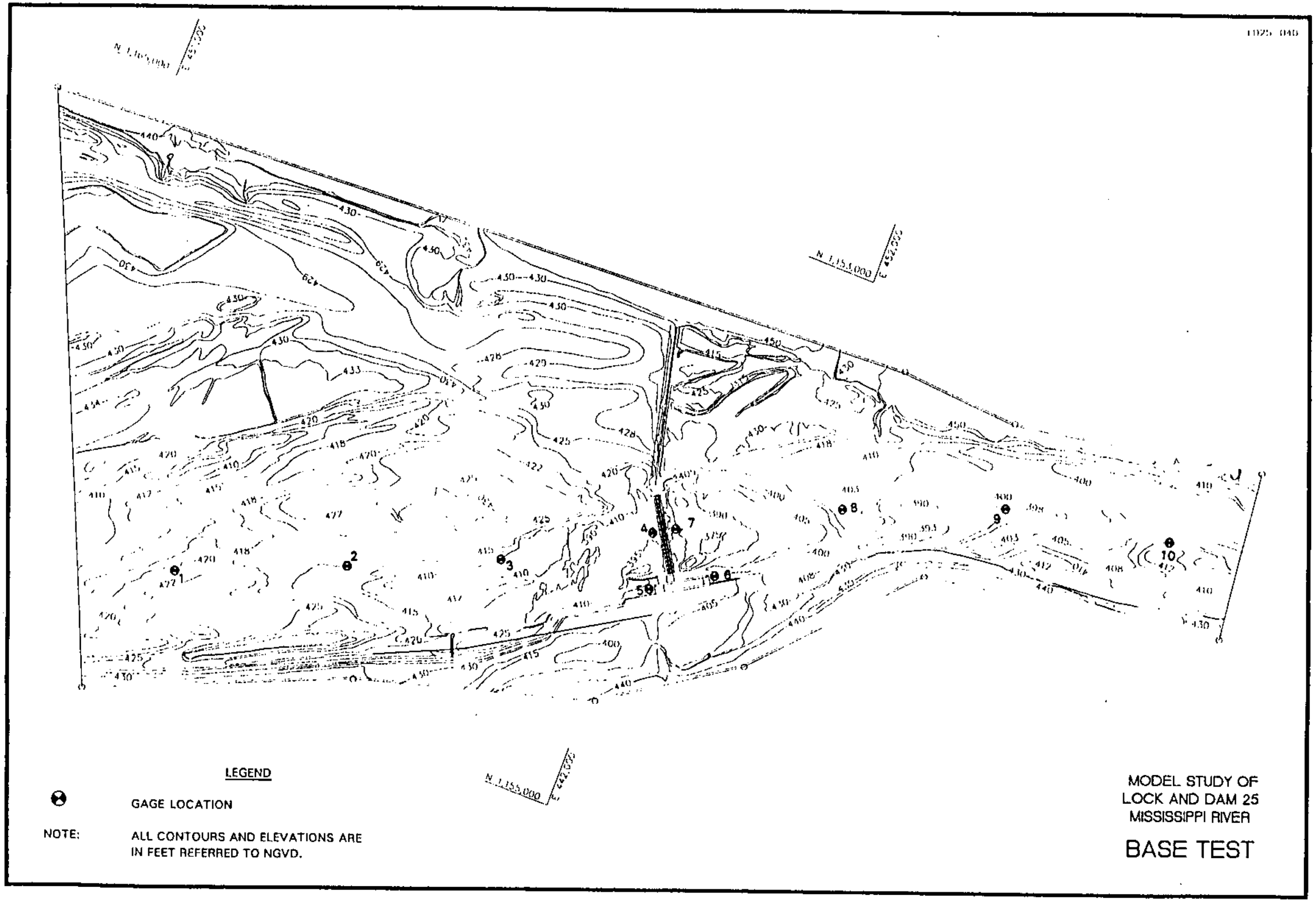



Figure 23. Wes Physical Model - Lock and Dam No. 25

# L/D 20 Numerical Model

Base Condition Grid

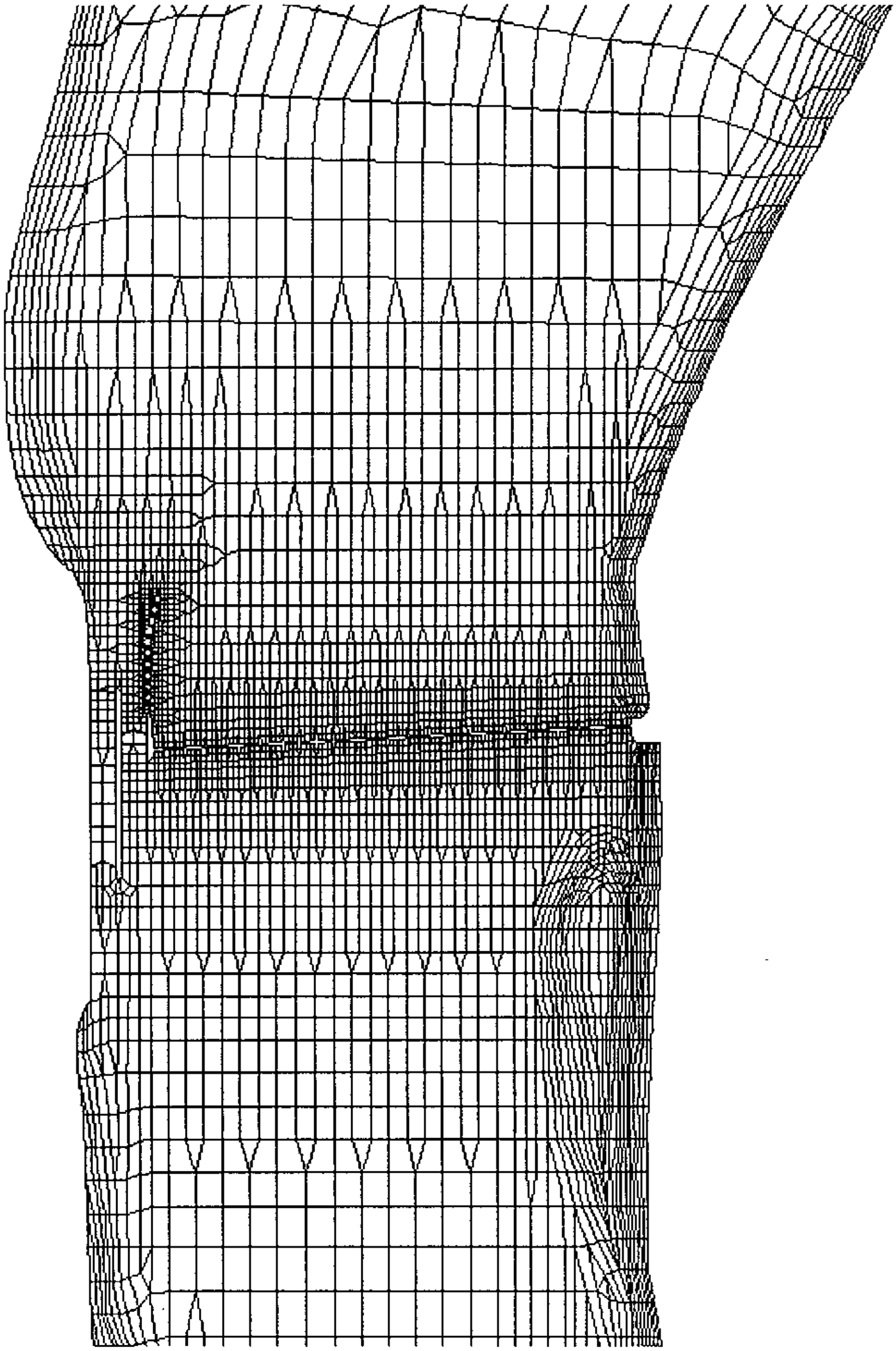


**Figure 24**

# L/D 21 Numerical Model

Base Condition: Approach Conditions
Channel Geometry Grid

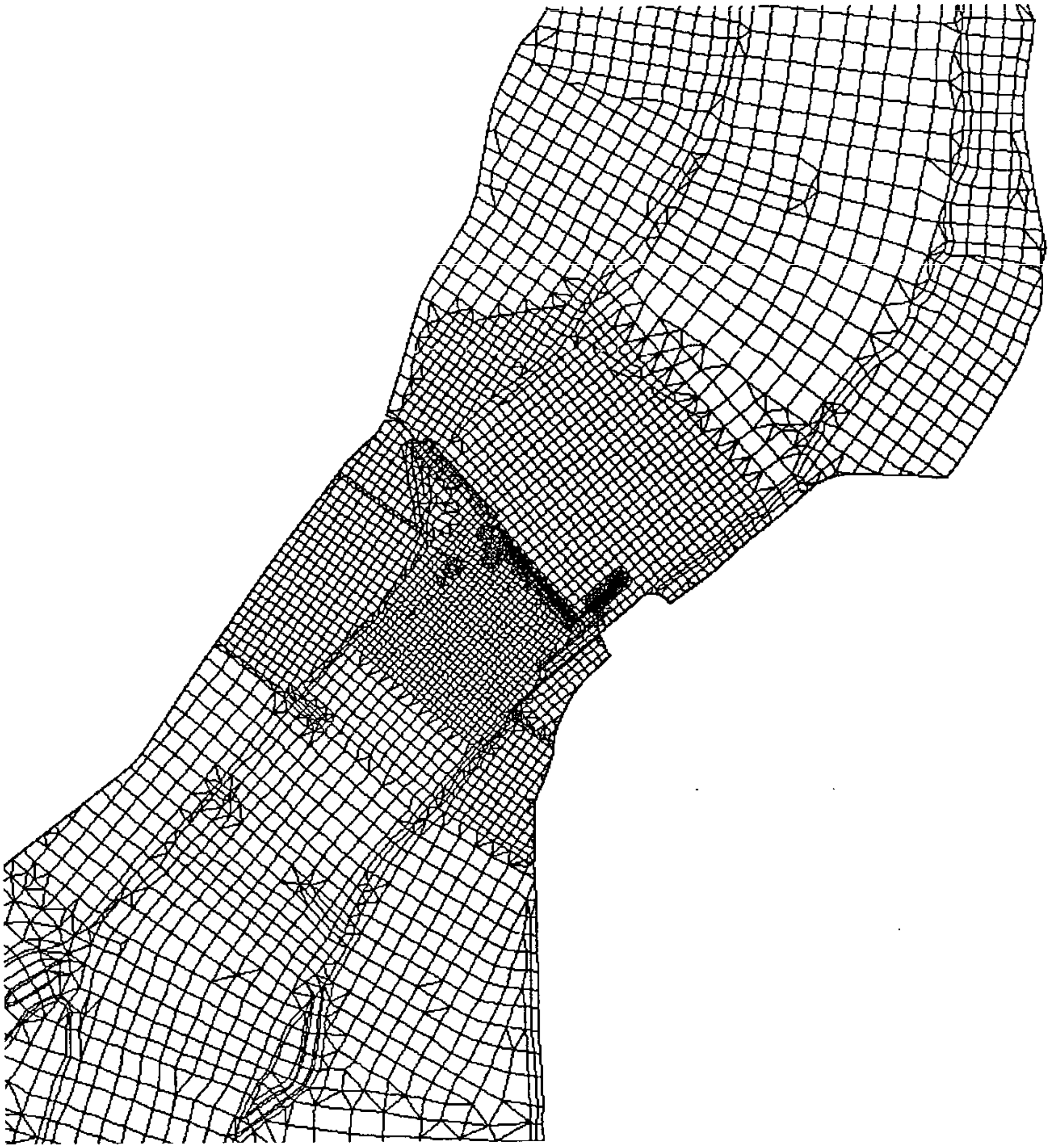


Figure 25

L/D 22 Numerical Model

Base Condition: Approach Conditions

Channel Geometry Grid

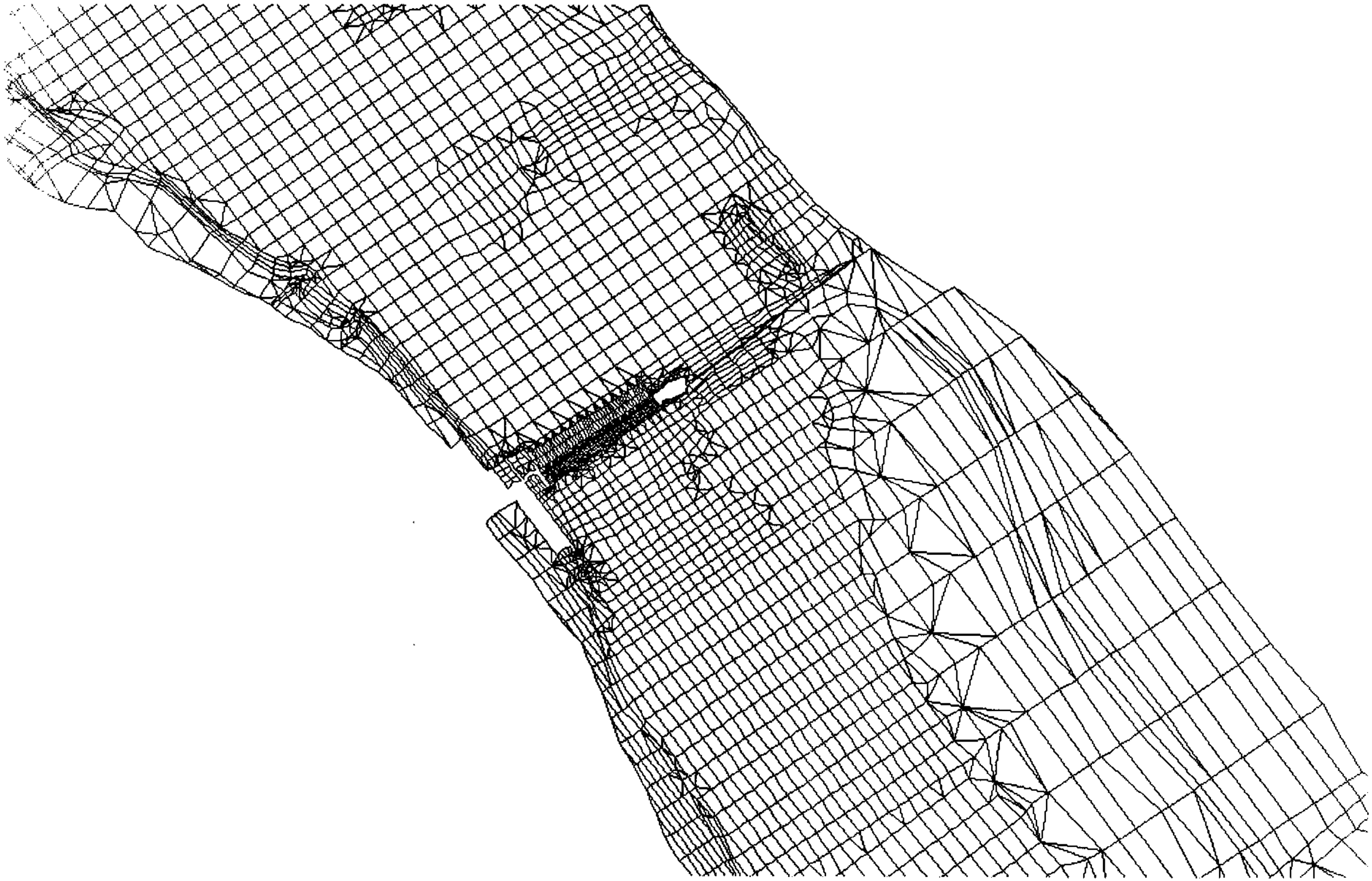


Figure 26

Lock and Dam 24 Base conditions Grid

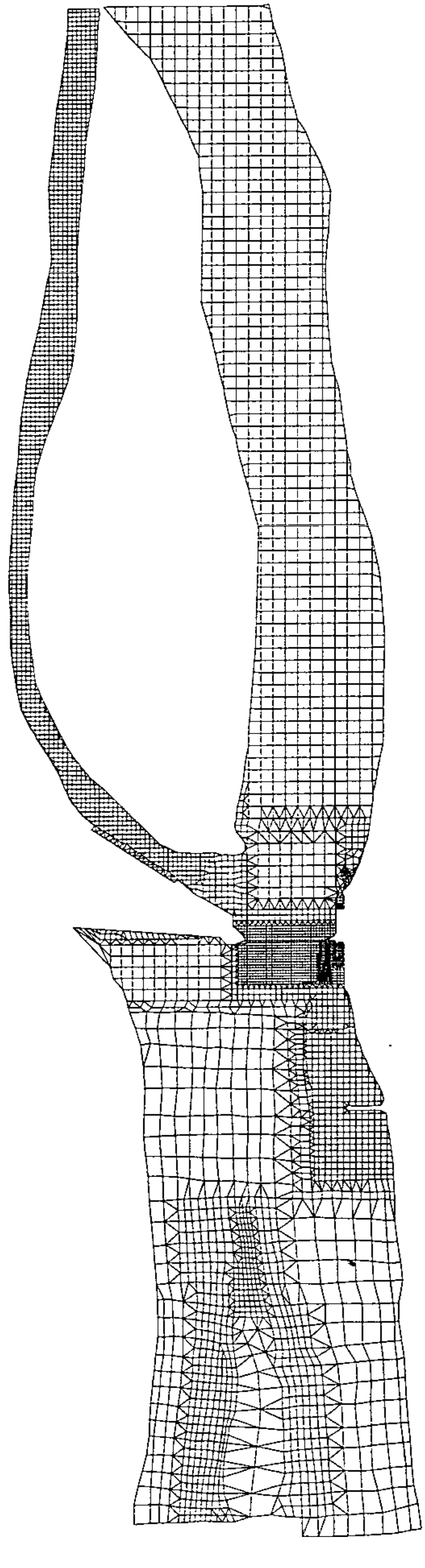


Figure 27

# Lock and Dam 25 Base Condition Grid

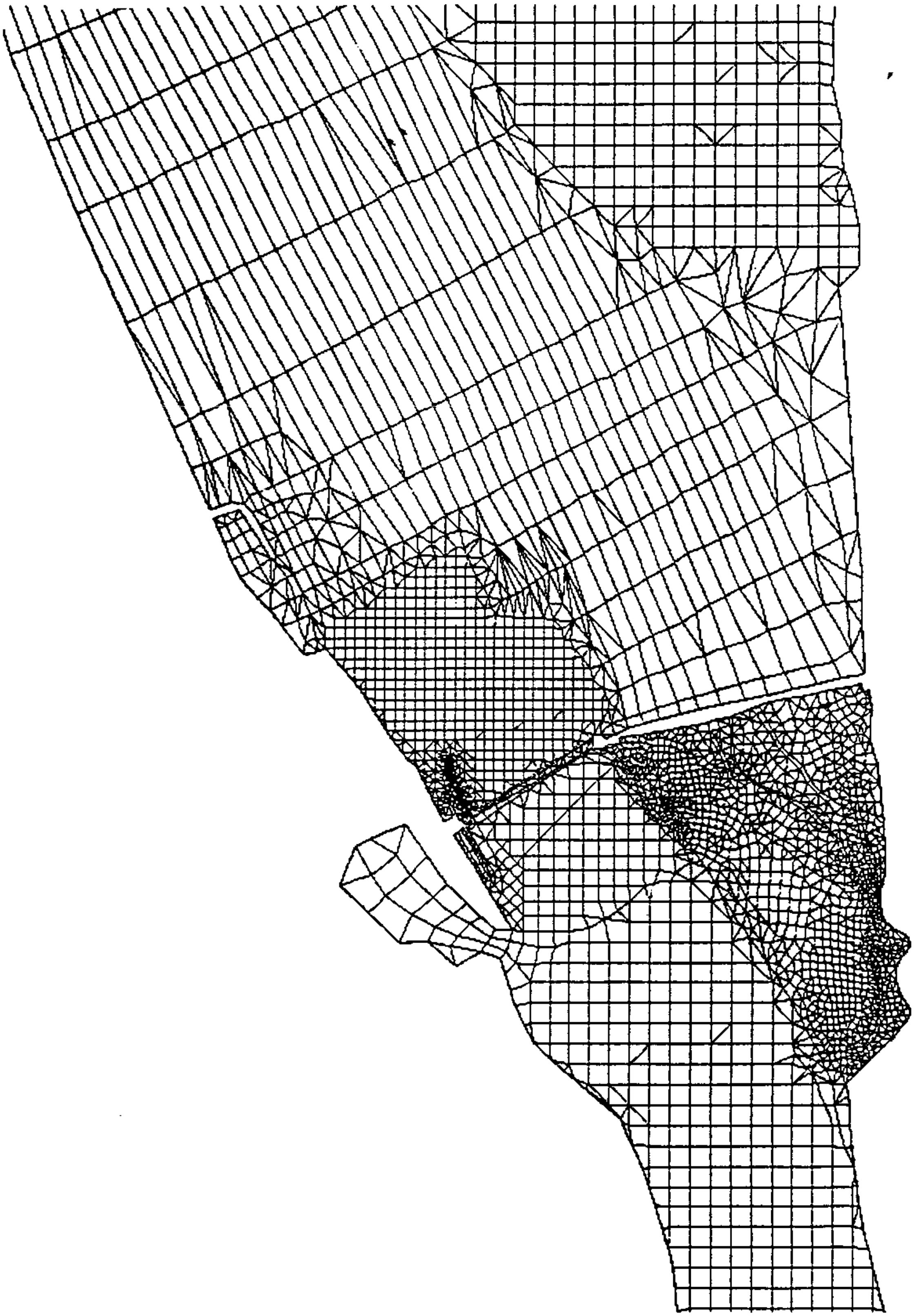
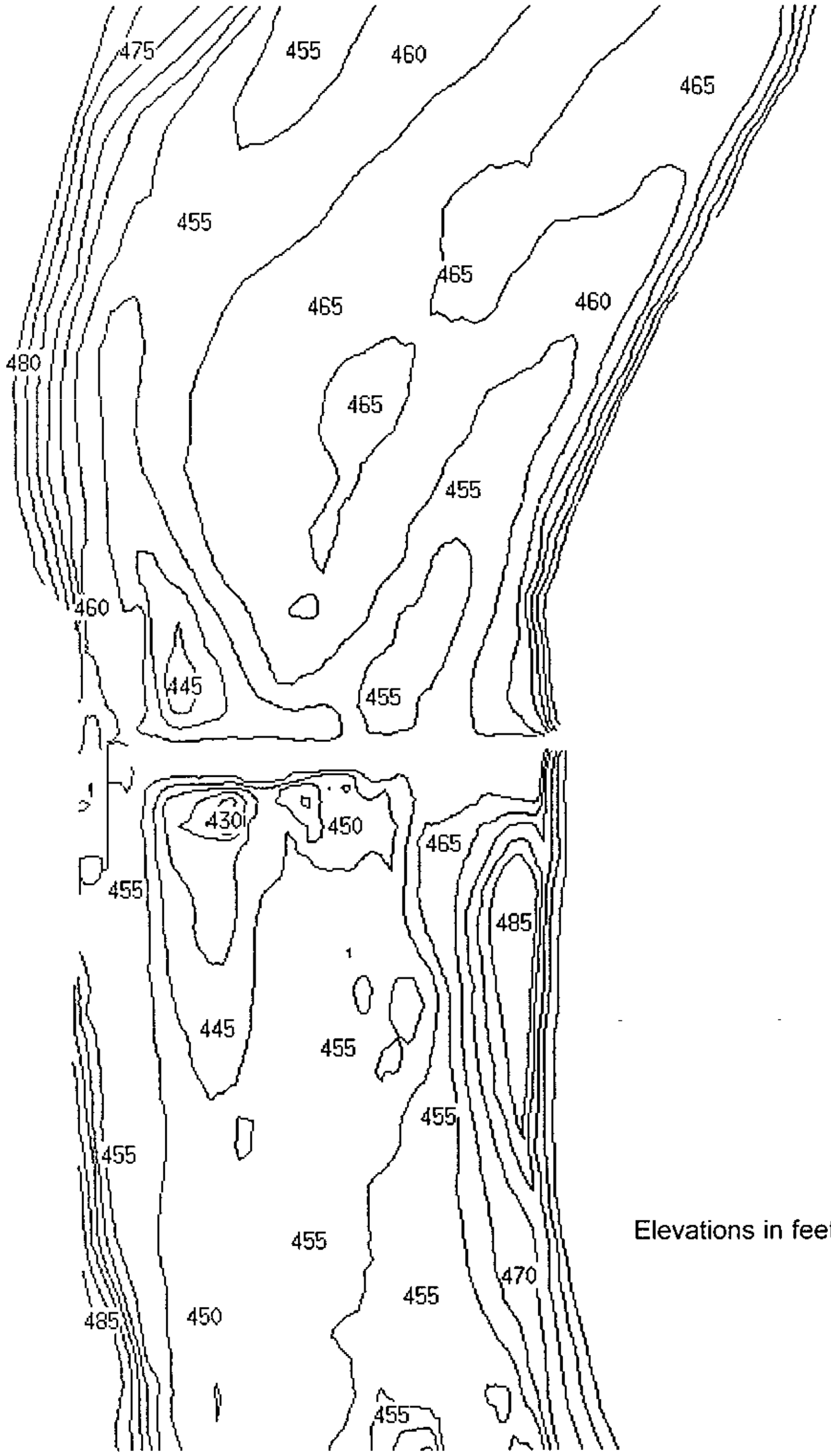


Figure 28

# L/D 20 Model

Base Condition
Bathymetry



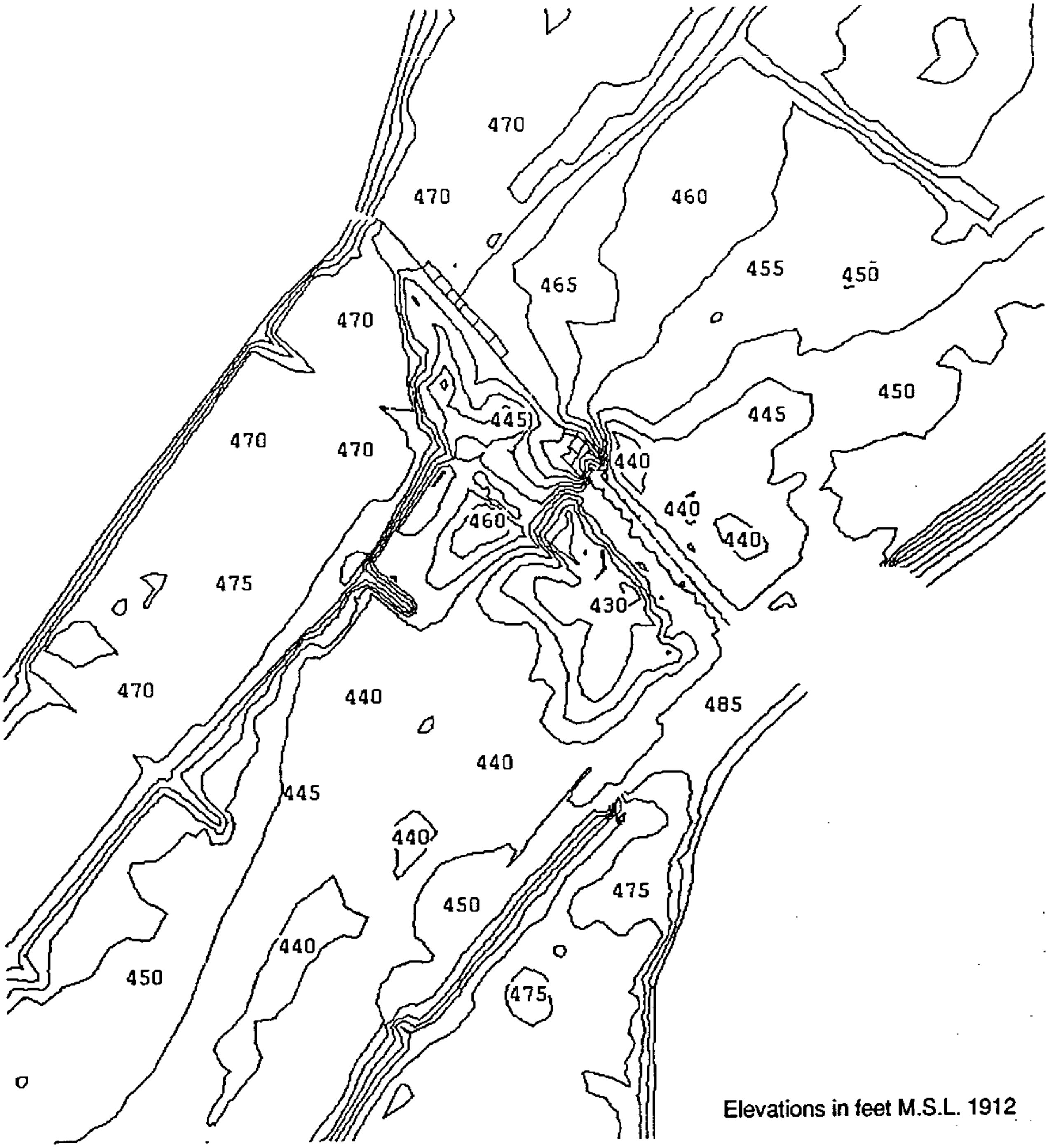

Elevations in feet M.S.L. 1912

Figure 29

# L/D 21 Model

Base Condition

Bathymetry



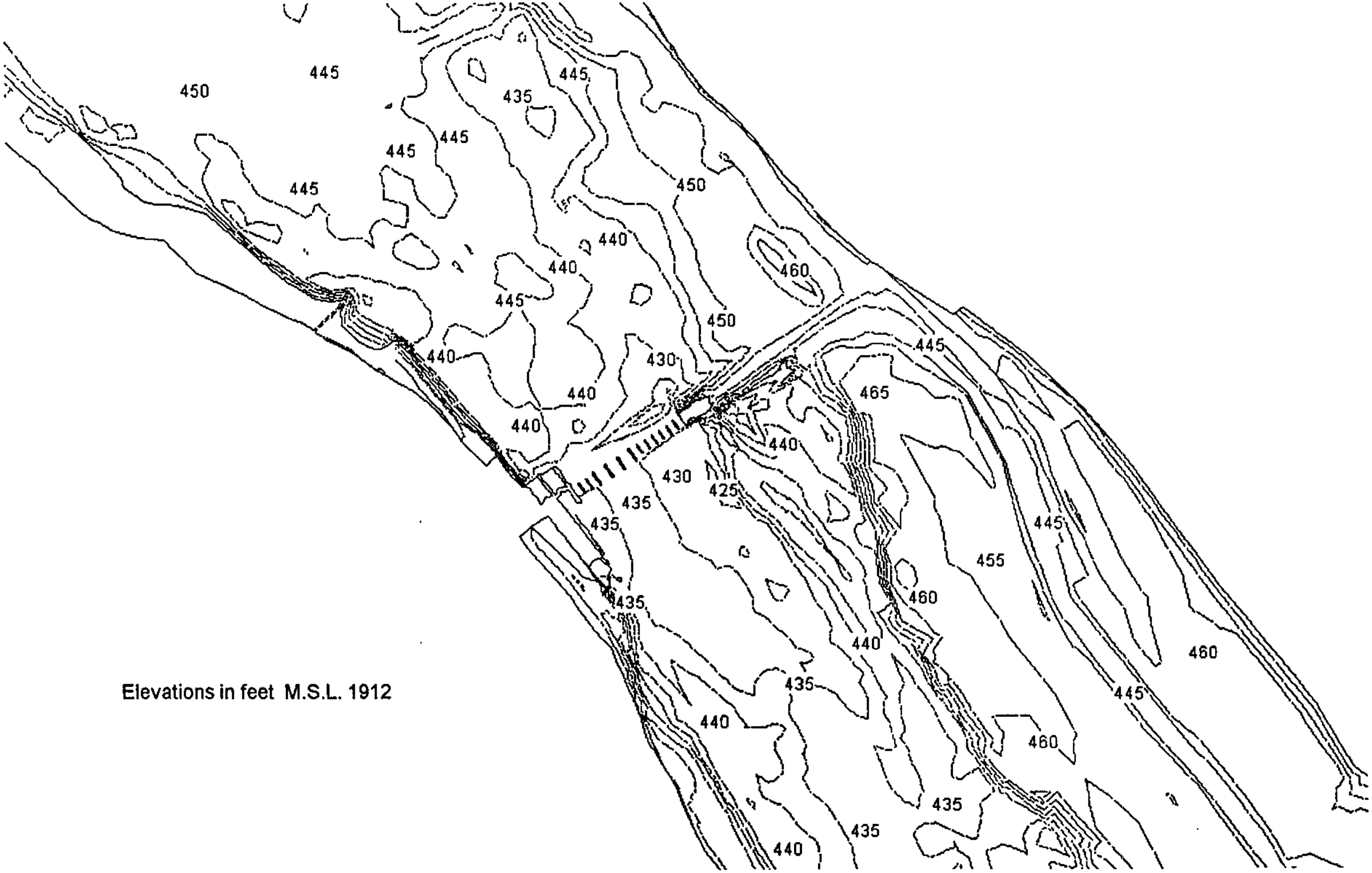

Elevations in feet M.S.L. 1912

Figure 30

# L/D 22 Model

Base Condition

Bathymetry




Elevations in feet M.S.L. 1912

Figure 31

# L/D 24 Model
## Base Condition
## Bathymetry

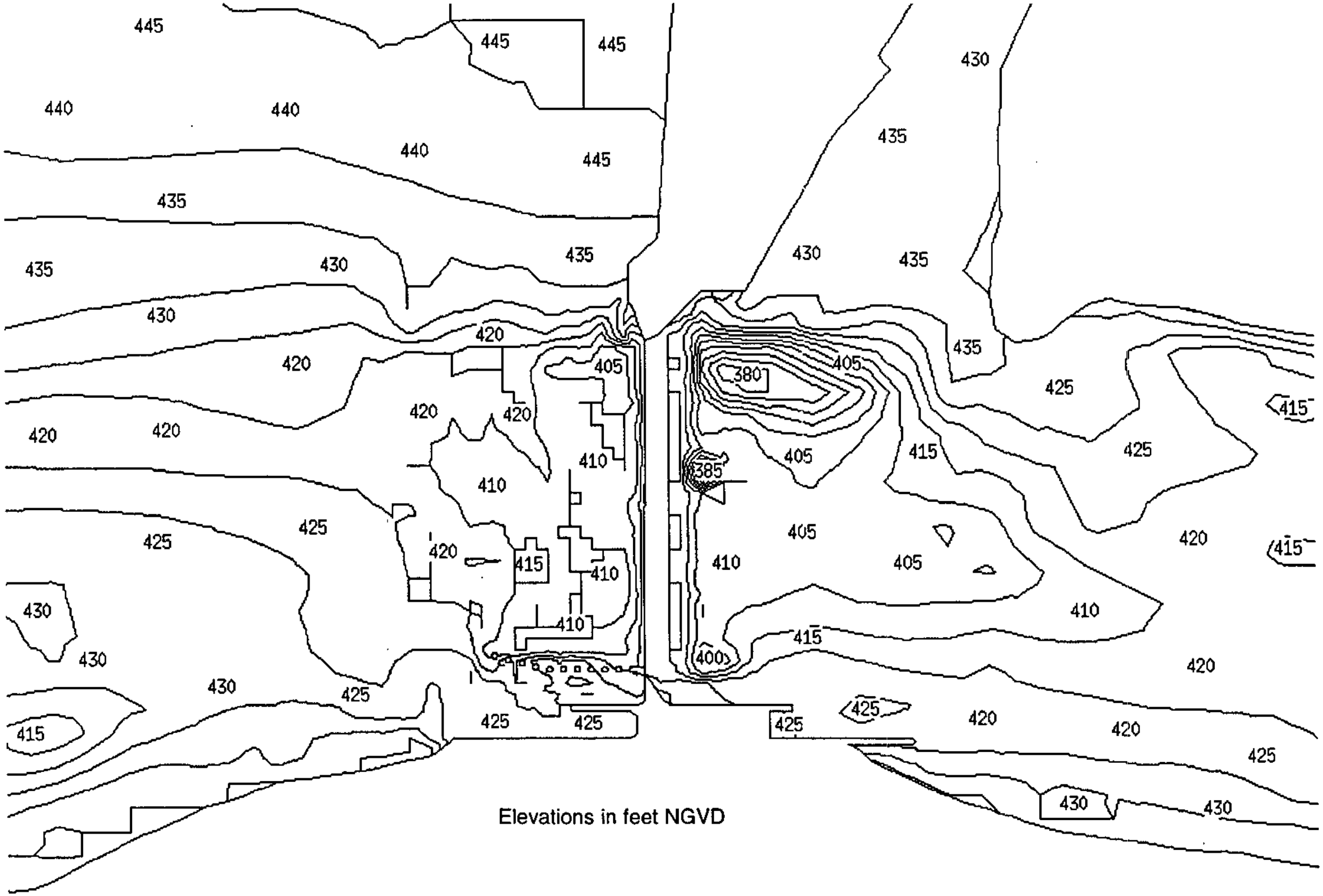



Figure 32

# L/D 25 Model

## Base Condition
## Bathymetry

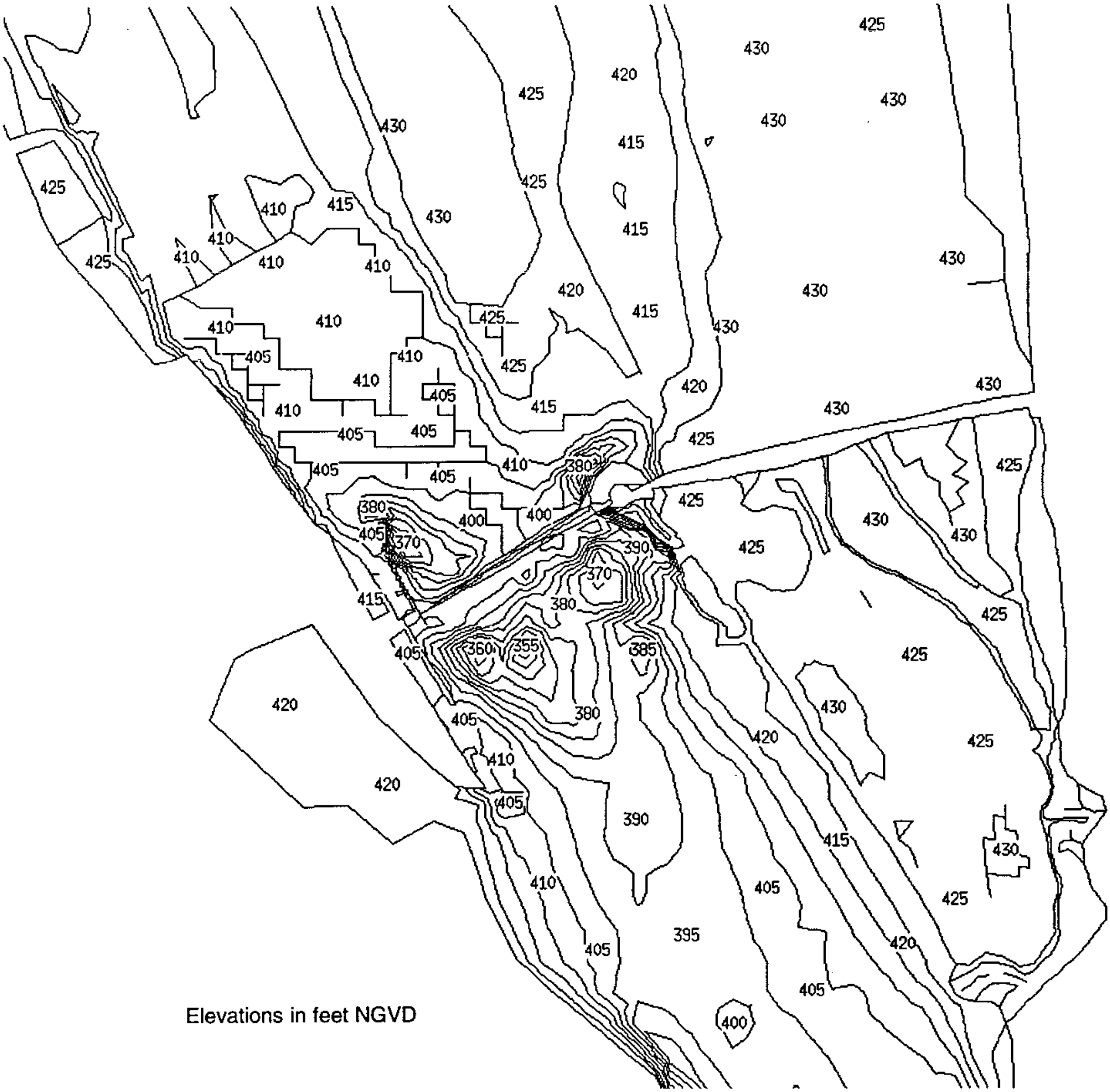
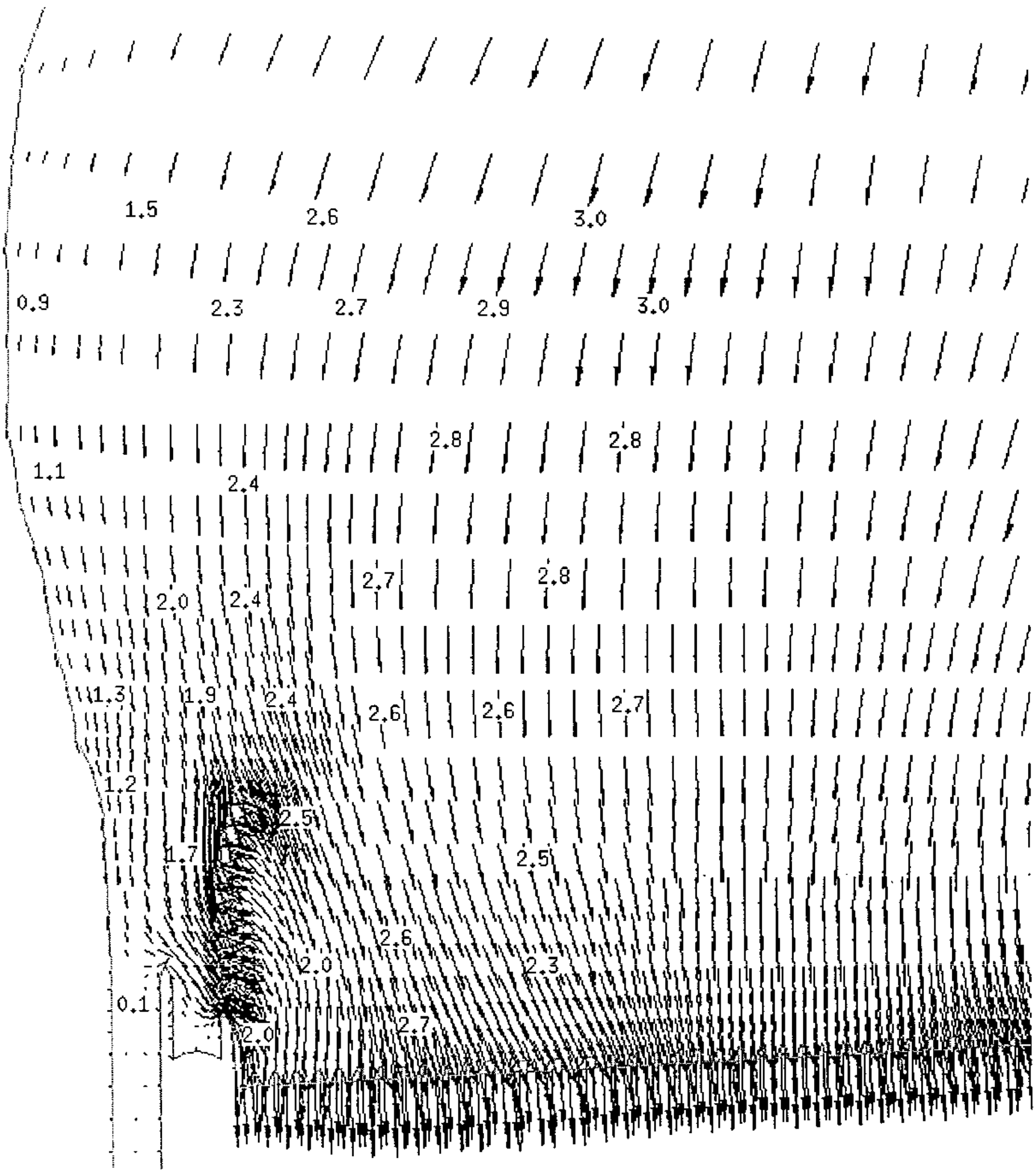



Figure 33

# L/D 20 Upstream

Base Condition

Velocity Vectors & Magnitudes (ft/s)



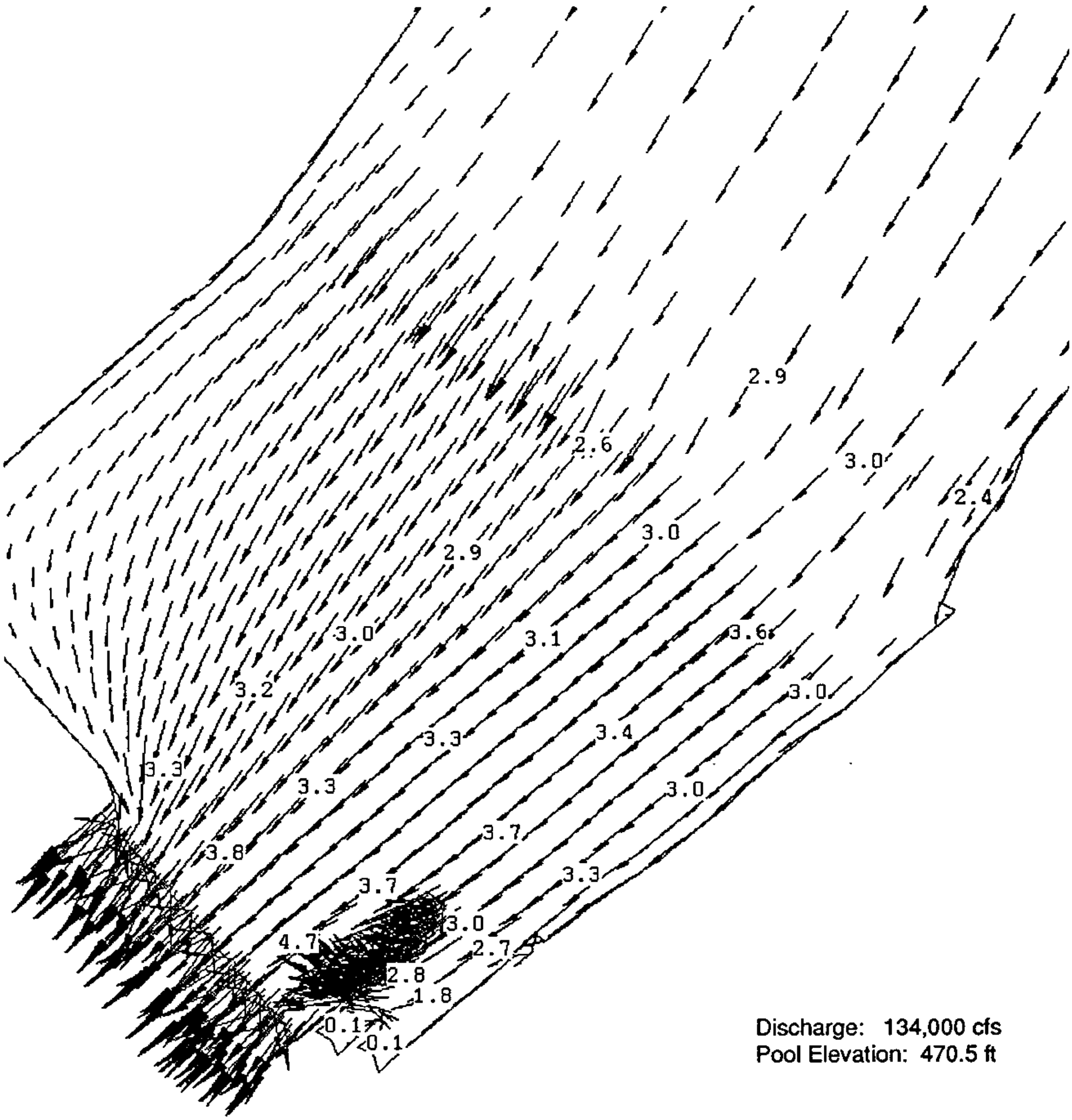

Discharge: 110,000 cfs
Pool Elevation: 476.9 ft

Figure 34

# L/D 21 Upstream

Base Condition

Velocity Vectors & Magnitudes (ft/s)



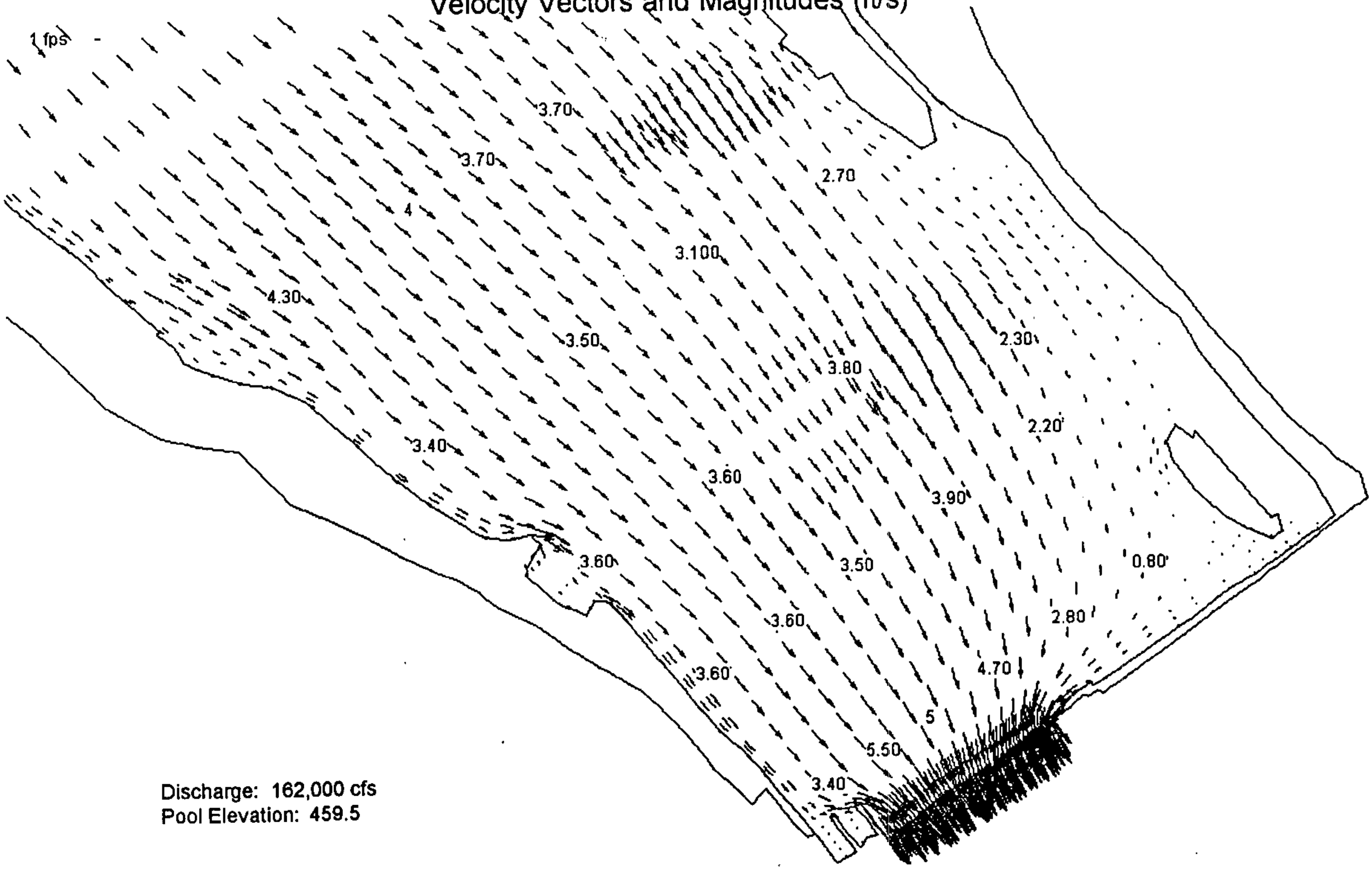

Discharge: 134,000 cfs
Pool Elevation: 470.5 ft

Figure 35

# L/D 22 Upstream

Base Condition

Velocity Vectors and Magnitudes (ft/s)




Discharge: 162,000 cfs
Pool Elevation: 459.5

Figure 36

# L/D 24 Upstream

## Base Condition

## Velocity Vectors & Magnitudes (ft/s)

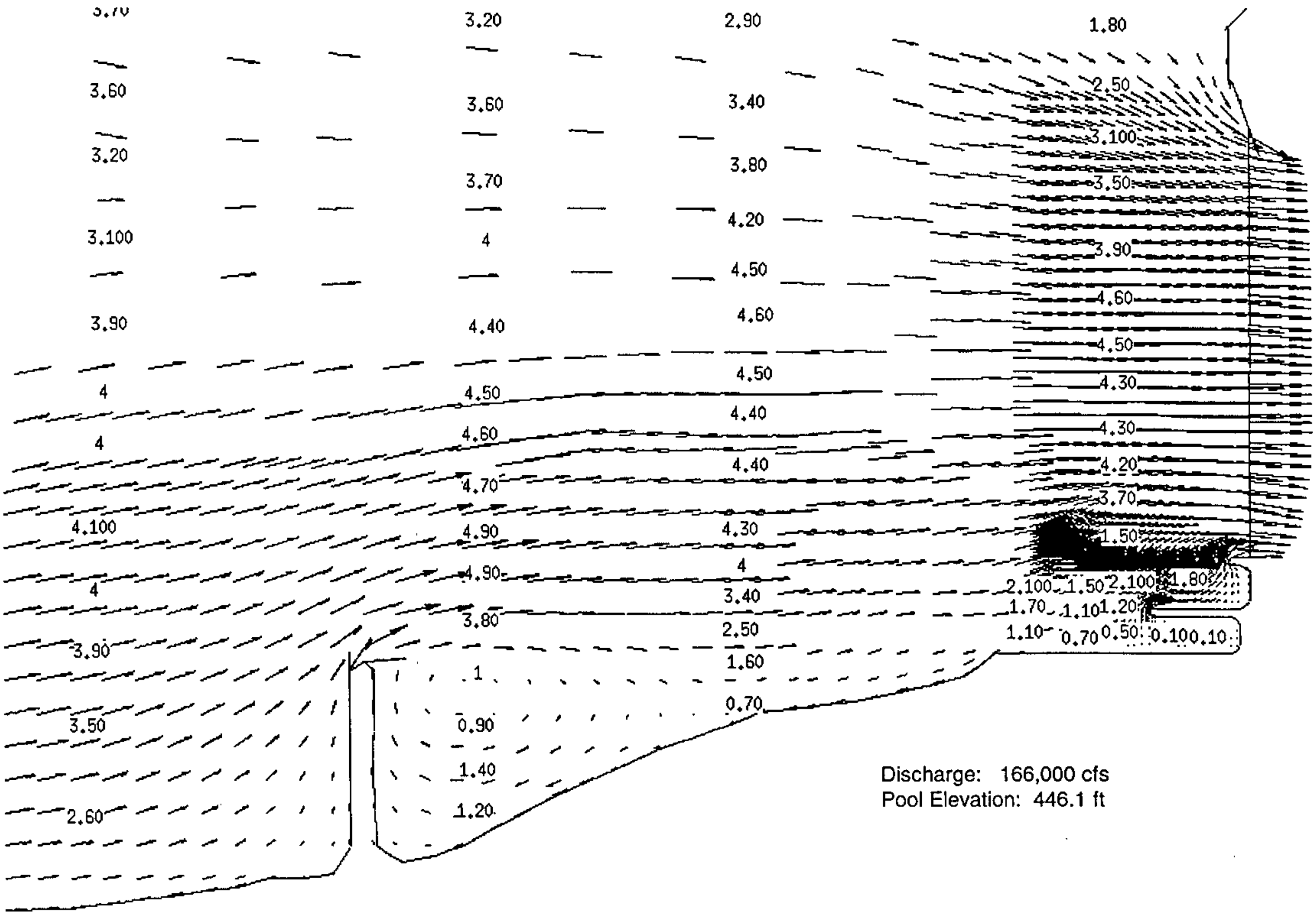
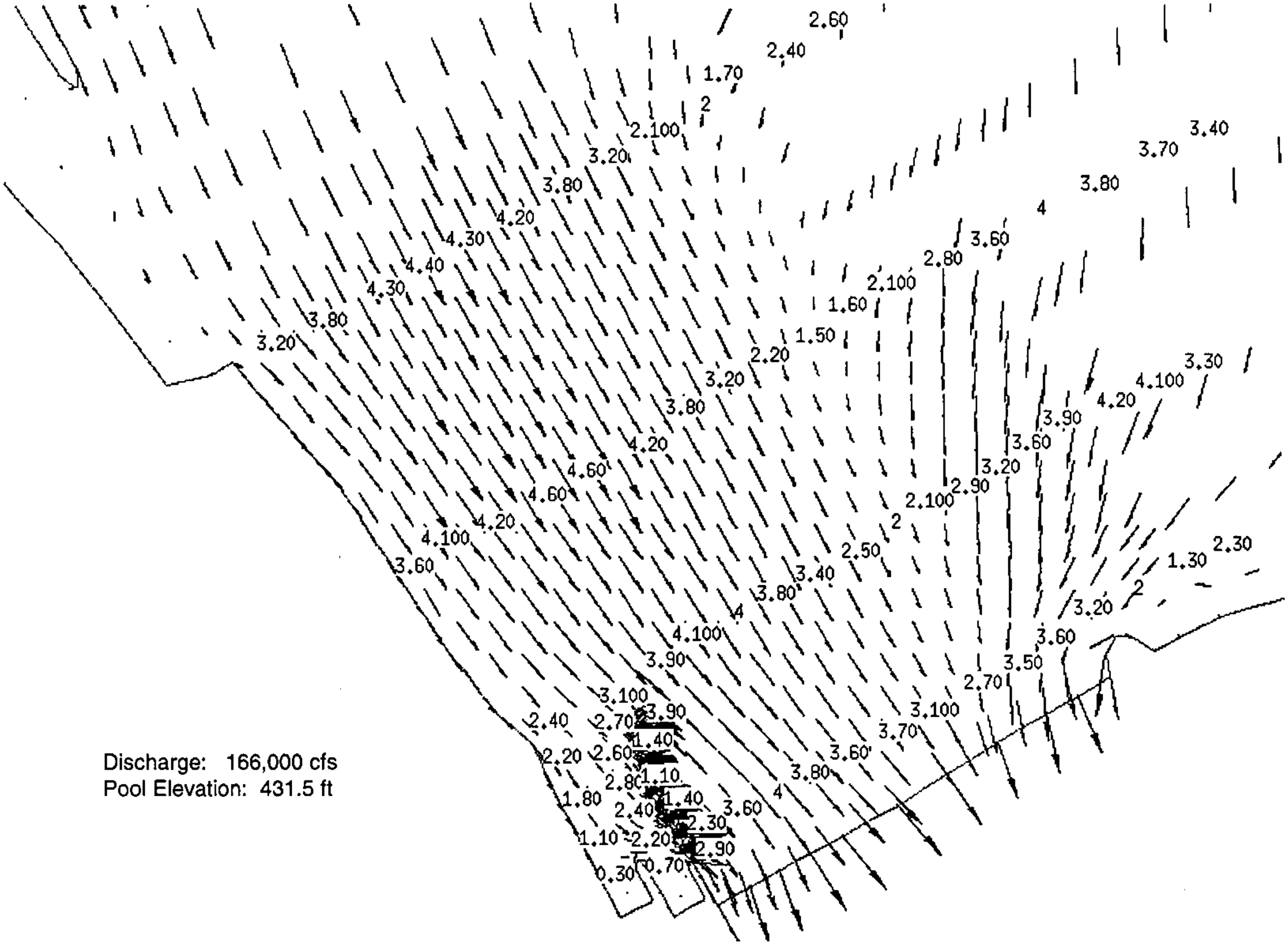



Figure 37

# L/D 25 Upstream

## Base Condition

### Velocity Vectors & Magnitudes (ft/s)



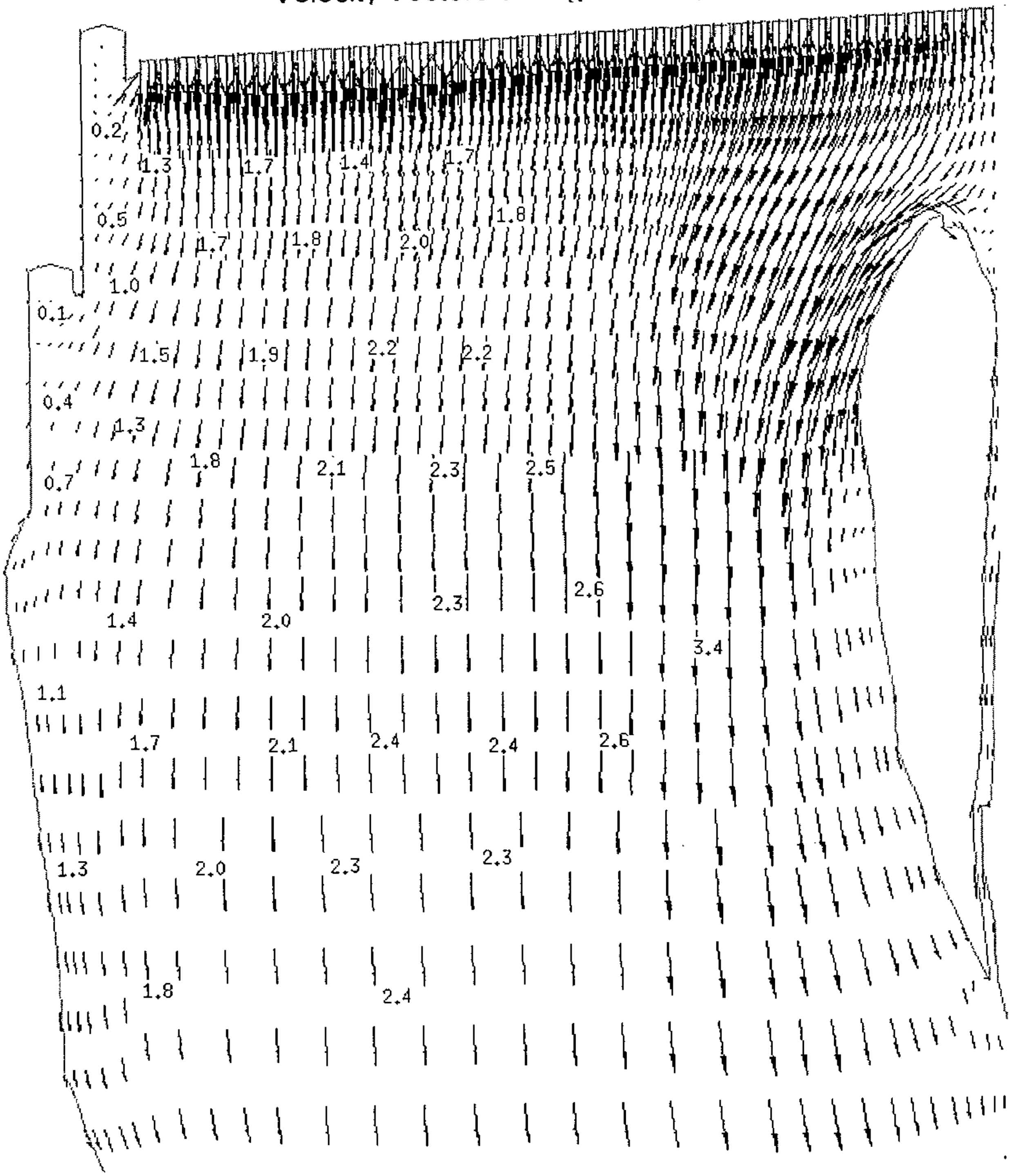
Discharge: 166,000 cfs
Pool Elevation: 431.5 ft

Figure 38

# L/D 20 Downstream

## Base Condition

Velocity Vectors & Magnitudes (ft/s)




Discharge: 110,000 cfs
Tail Elevation: 476.4 ft

Figure 39

# L/D 21 Downstream

## Base Condition

### Velocity Vectors & Magnitudes (ft/s)

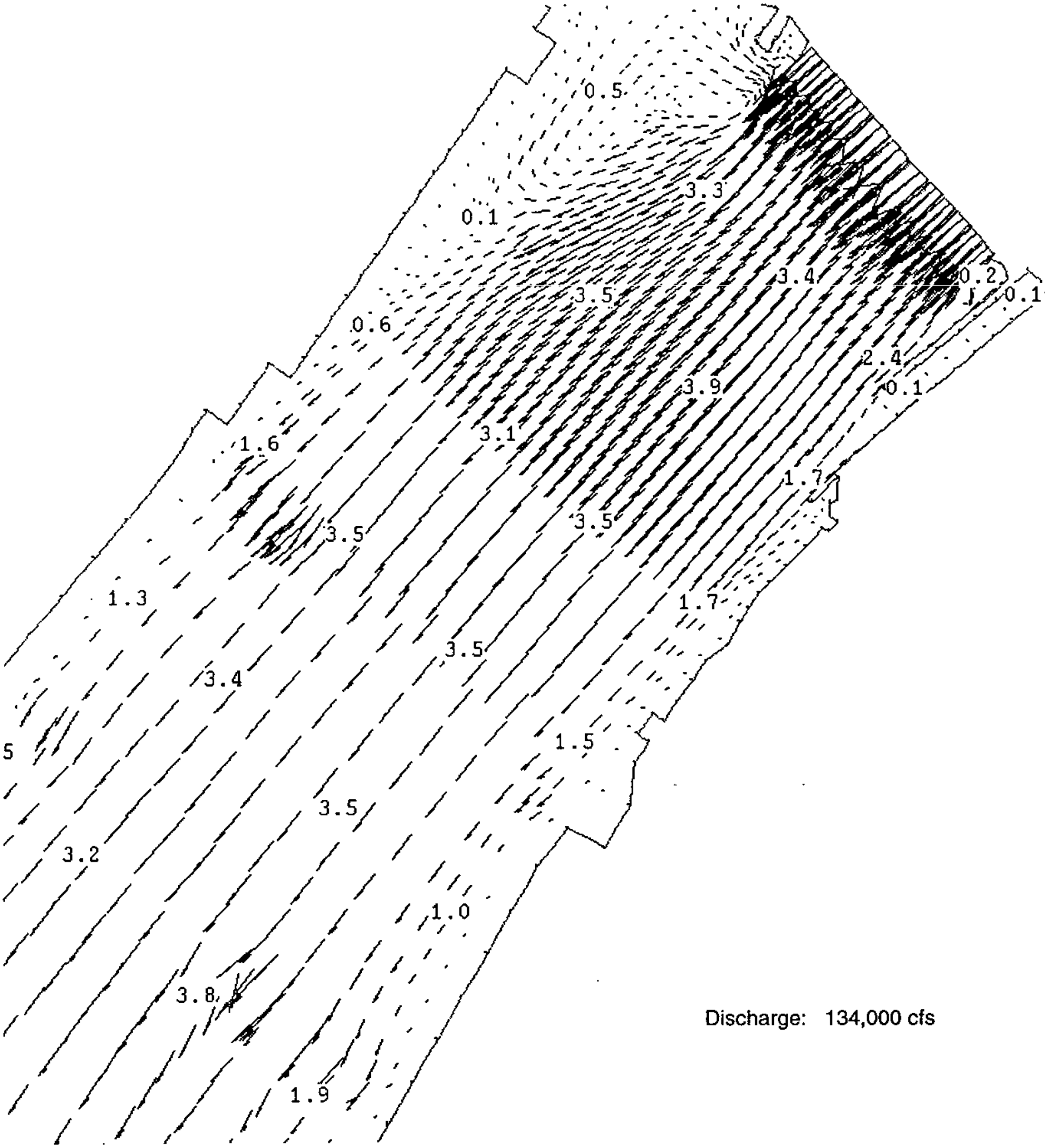
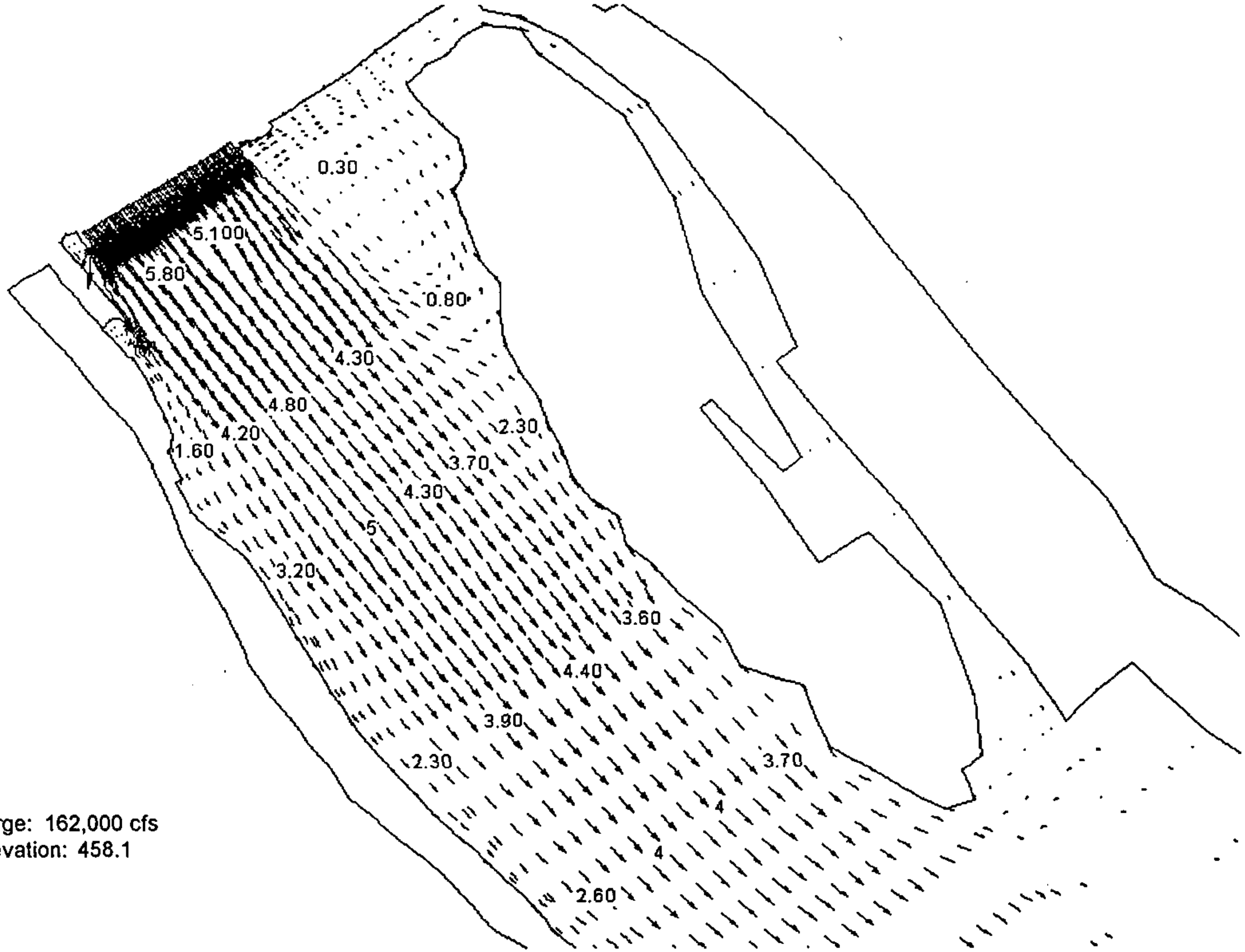



Figure 40

# L/D 22 Downstream

Base Condition: Approach Conditions

Velocity Vectors and Magnitudes (ft/s)



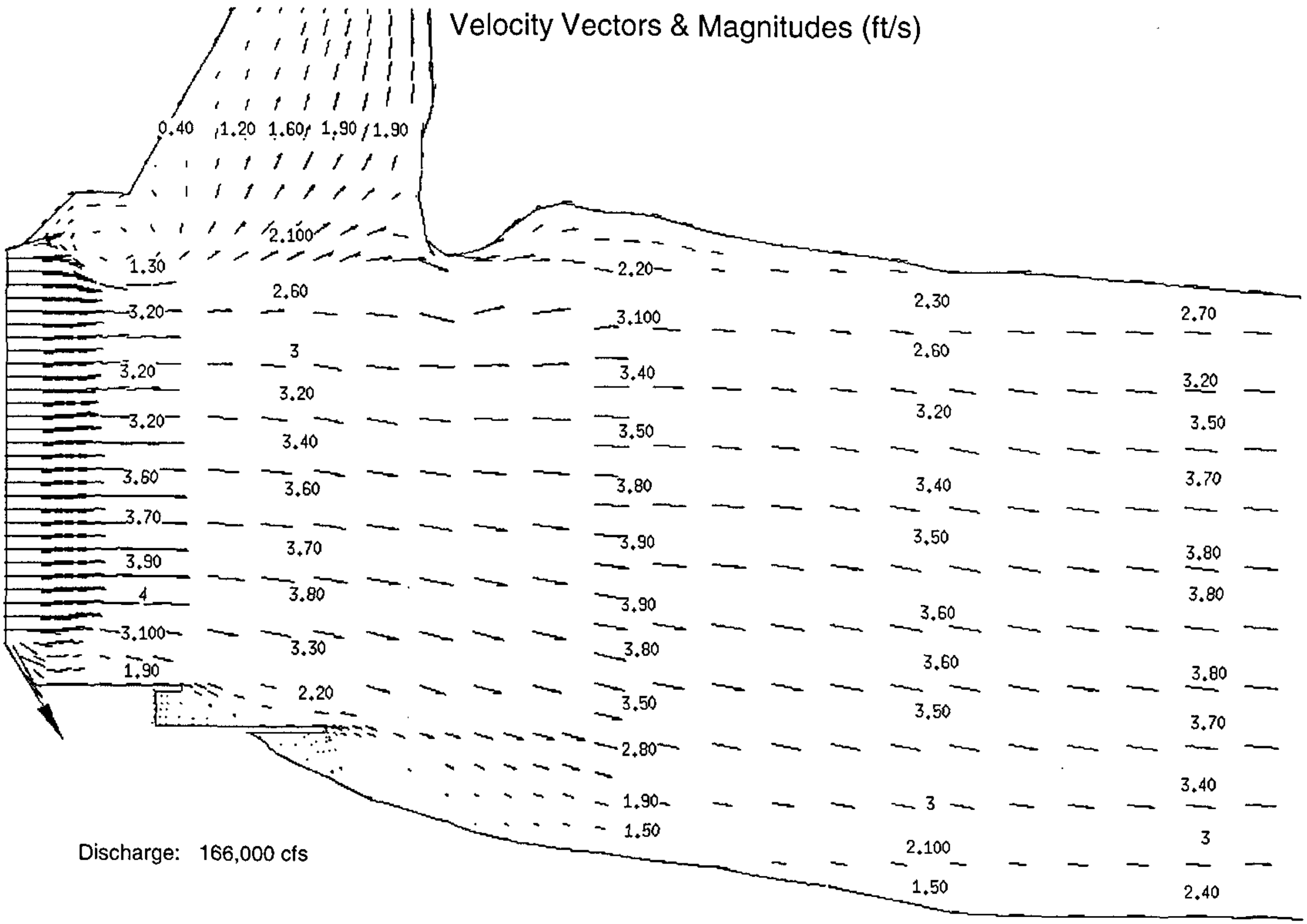

Discharge: 162,000 cfs
Tail Elevation: 458.1

Figure 41

# L/D 24 Downstream

Base Condition

Velocity Vectors & Magnitudes (ft/s)



Discharge: 166,000 cfs

Figure 42

# L/D 25 Downstream

## Base Condition
## Velocity Vectors & Magnitudes (ft/s)

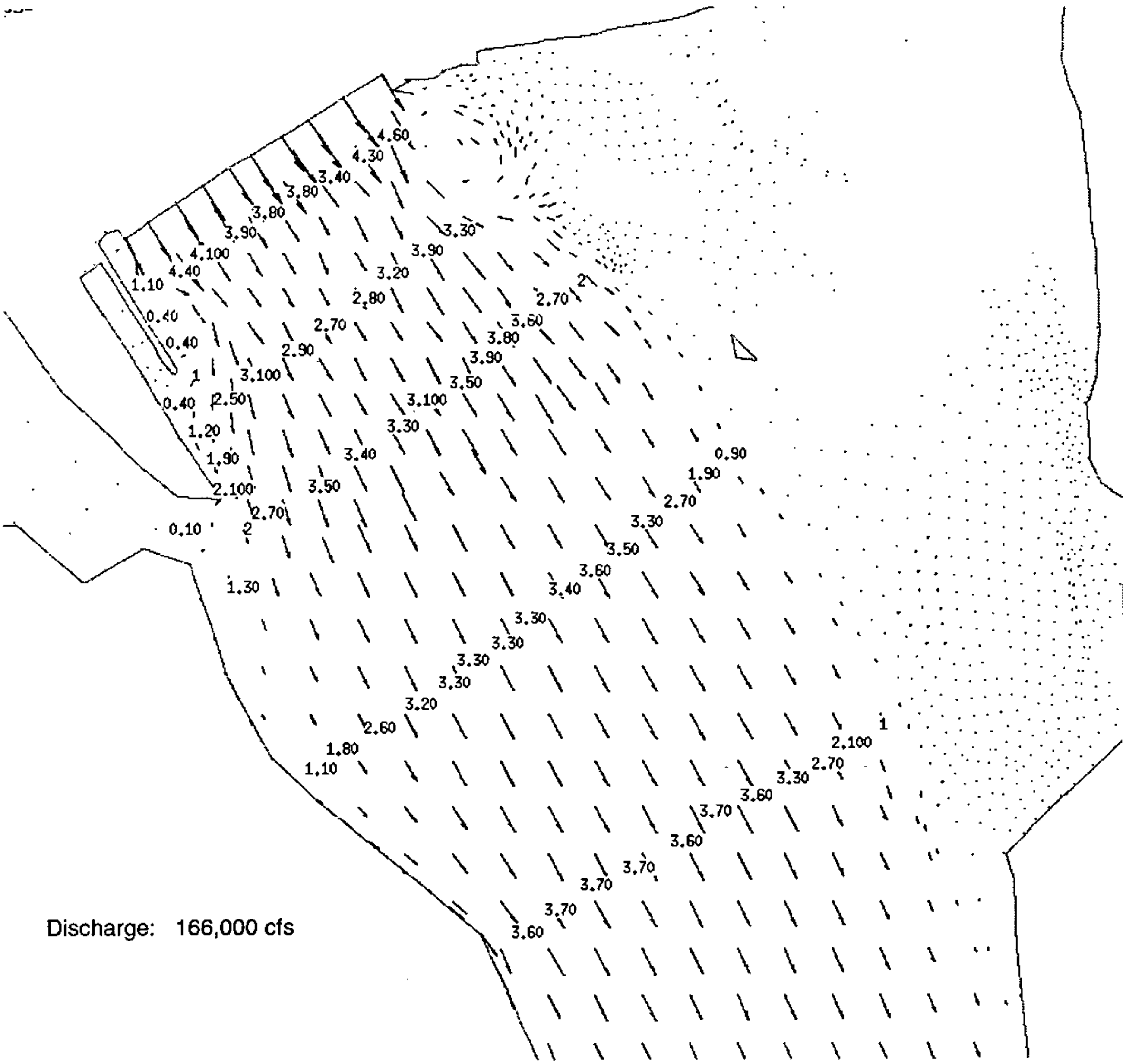



Figure 43

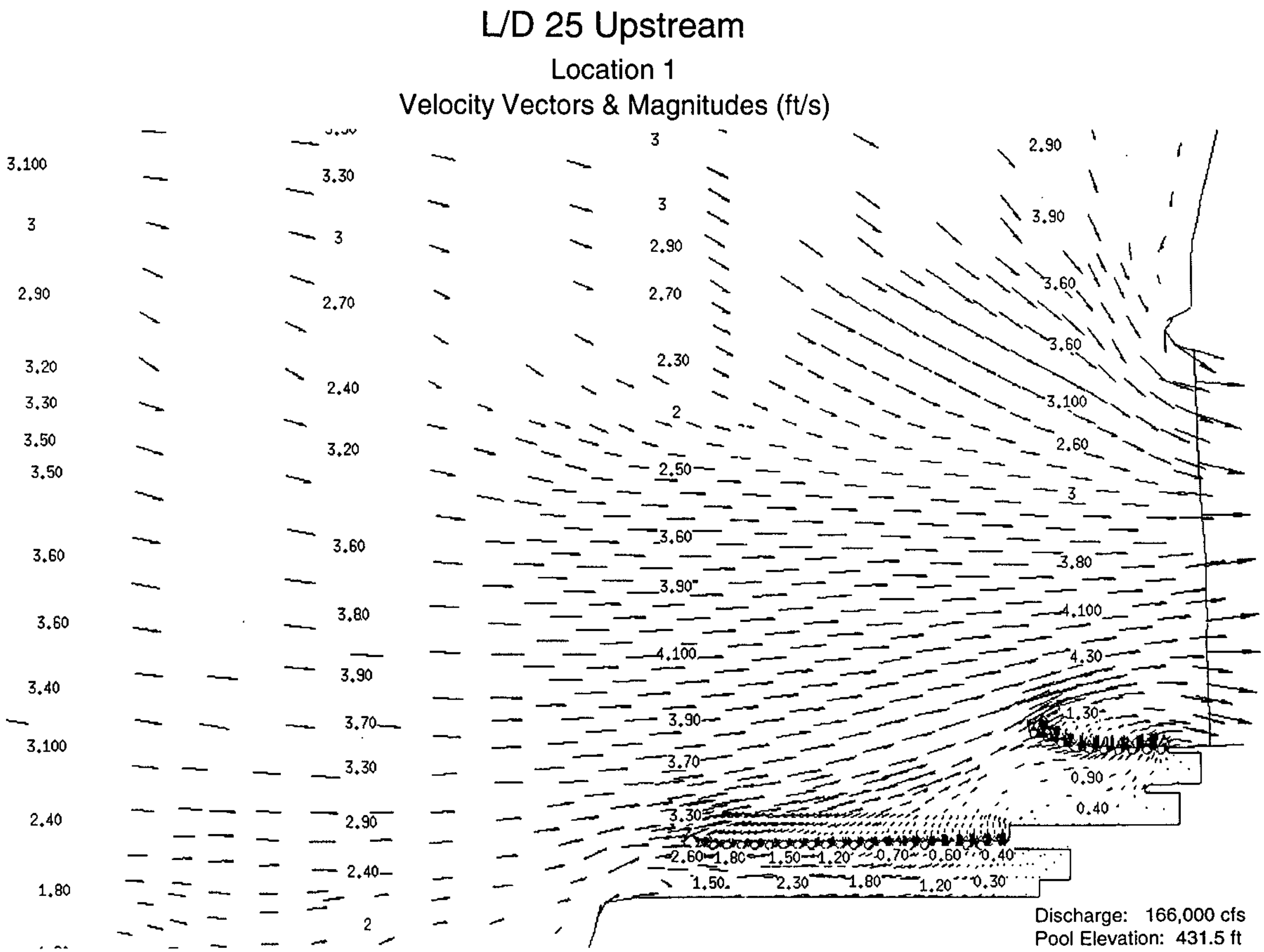
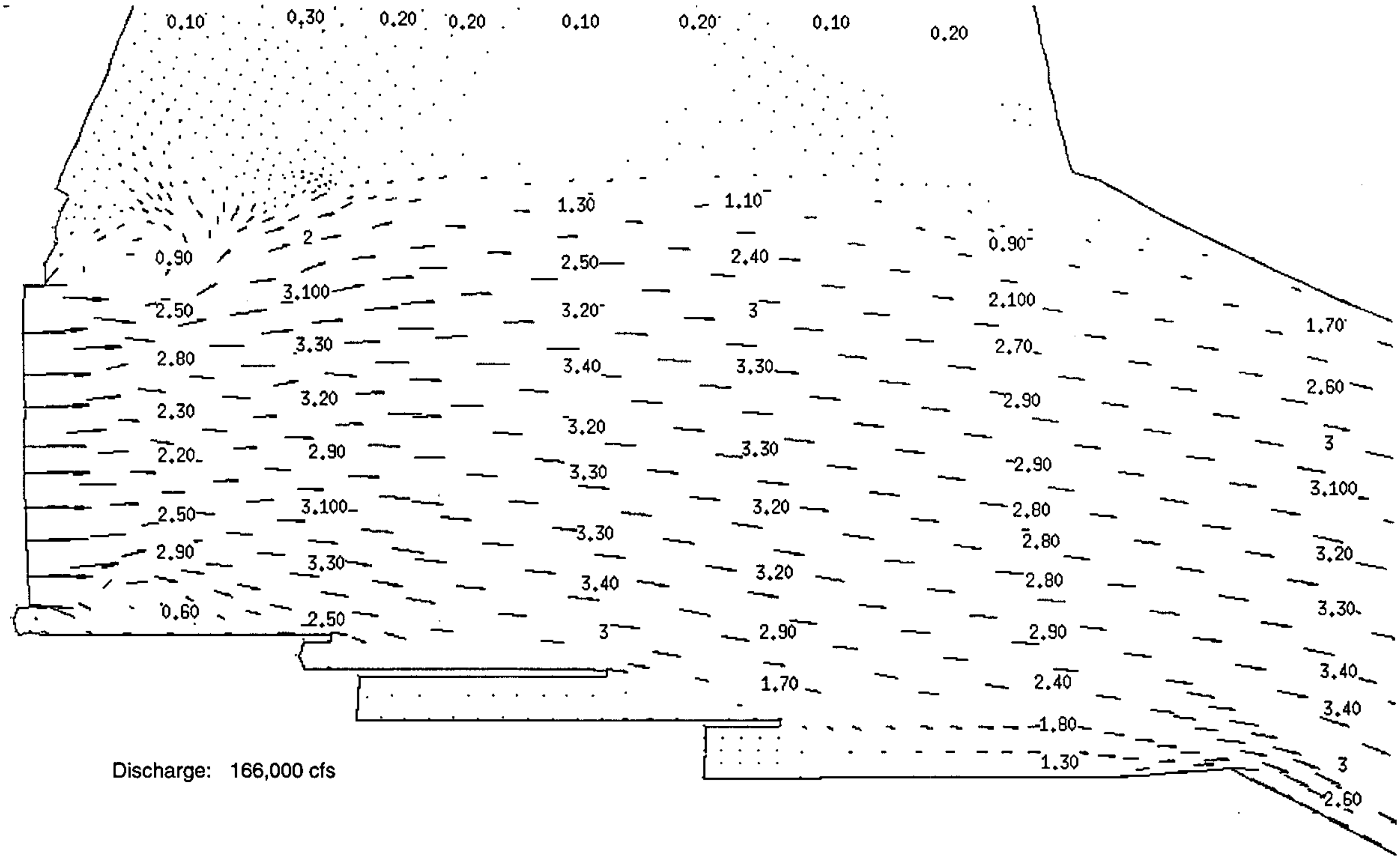

L/D 25 Upstream
Location 1
Velocity Vectors & Magnitudes (ft/s)
Discharge: 166,000 cfs
Pool Elevation: 431.5 ft

Figure 44

# L/D 25 Downstream

Location 1

Velocity Vectors & Magnitudes (ft/s)



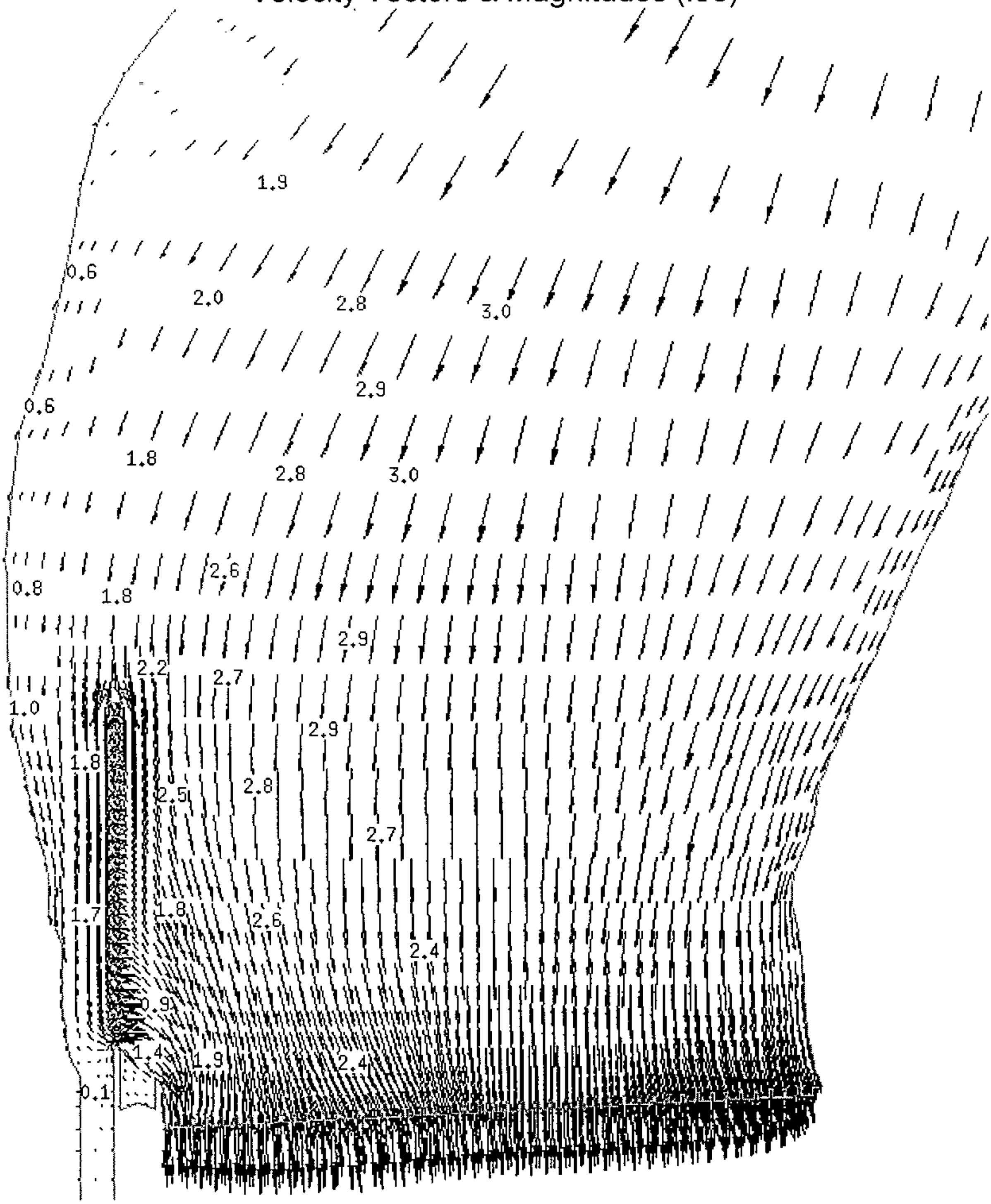

Discharge: 166,000 cfs

Figure 45

# L/D 20 Upstream

Location 2

Velocity Vectors & Magnitudes (ft/s)



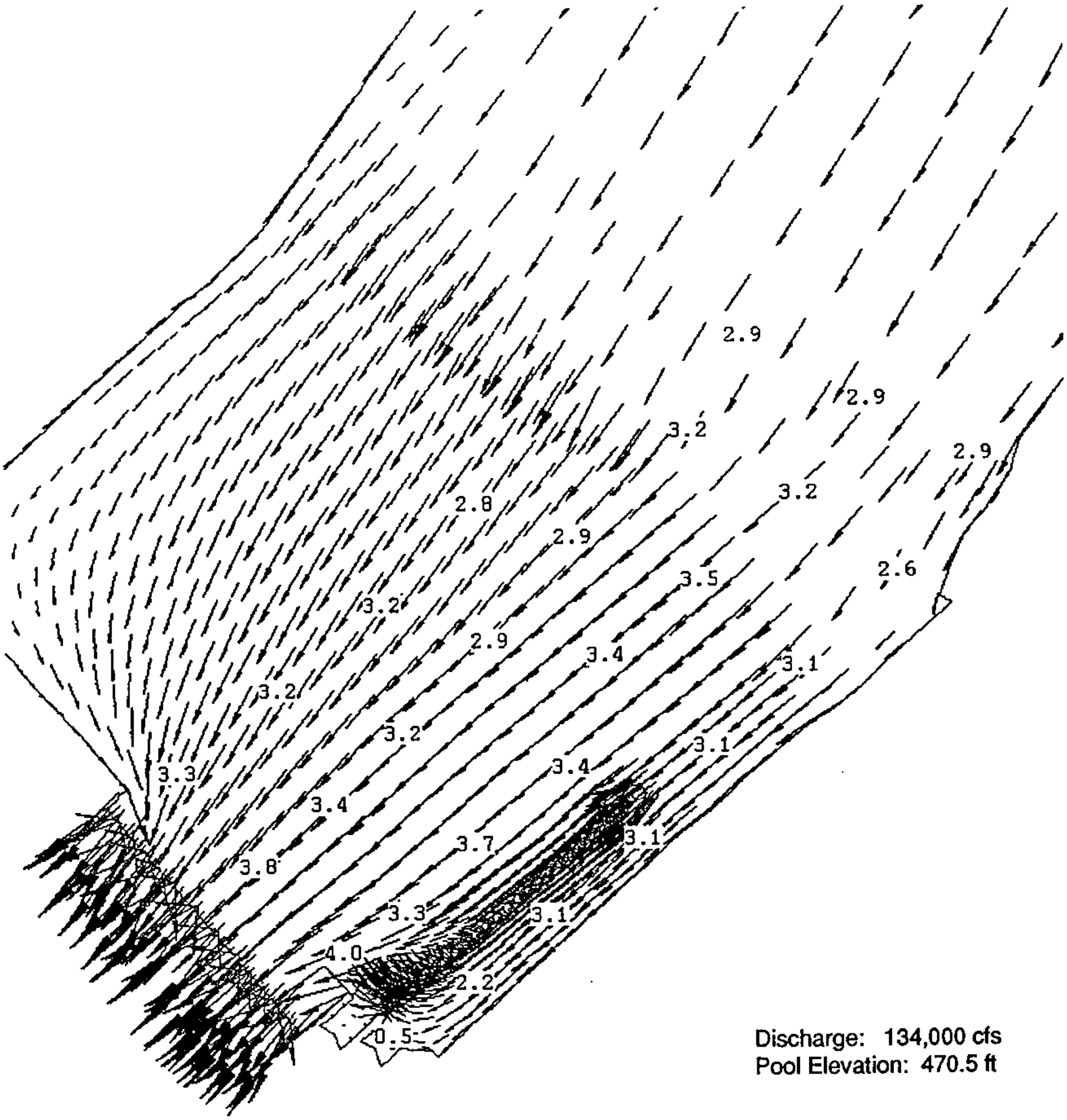

Discharge: 110,000 cfs
Pool Elevation: 476.9 ft

Figure 46

# L/D 21 Upstream

Location 2

Velocity Vectors & Magnitudes (ft/s)

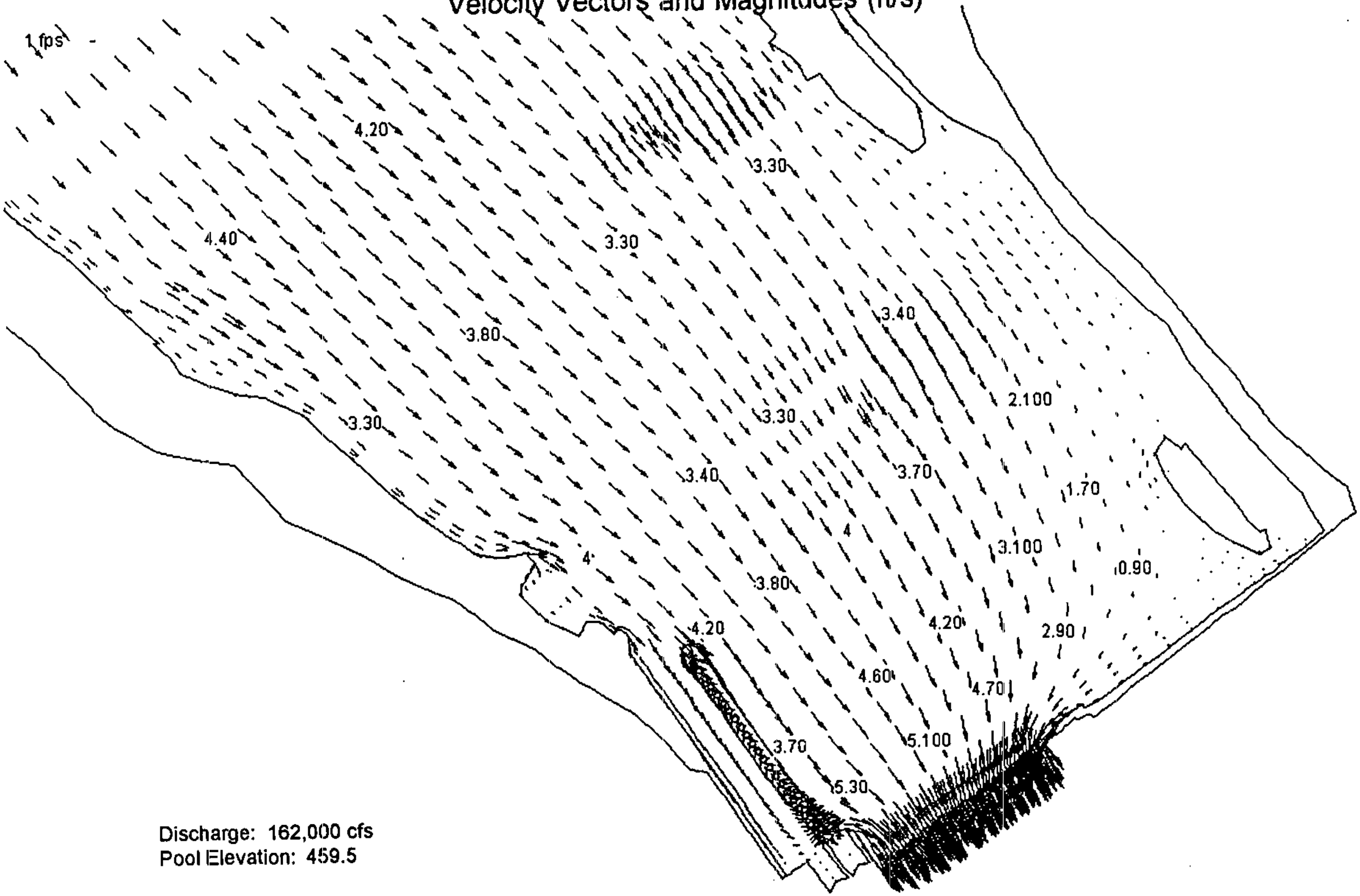



Discharge: 134,000 cfs
Pool Elevation: 470.5 ft

Figure 47

# L/D 22 Upstream

## Location 2
## Velocity Vectors and Magnitudes (ft/s)




Discharge: 162,000 cfs
Pool Elevation: 459.5

Figure 48

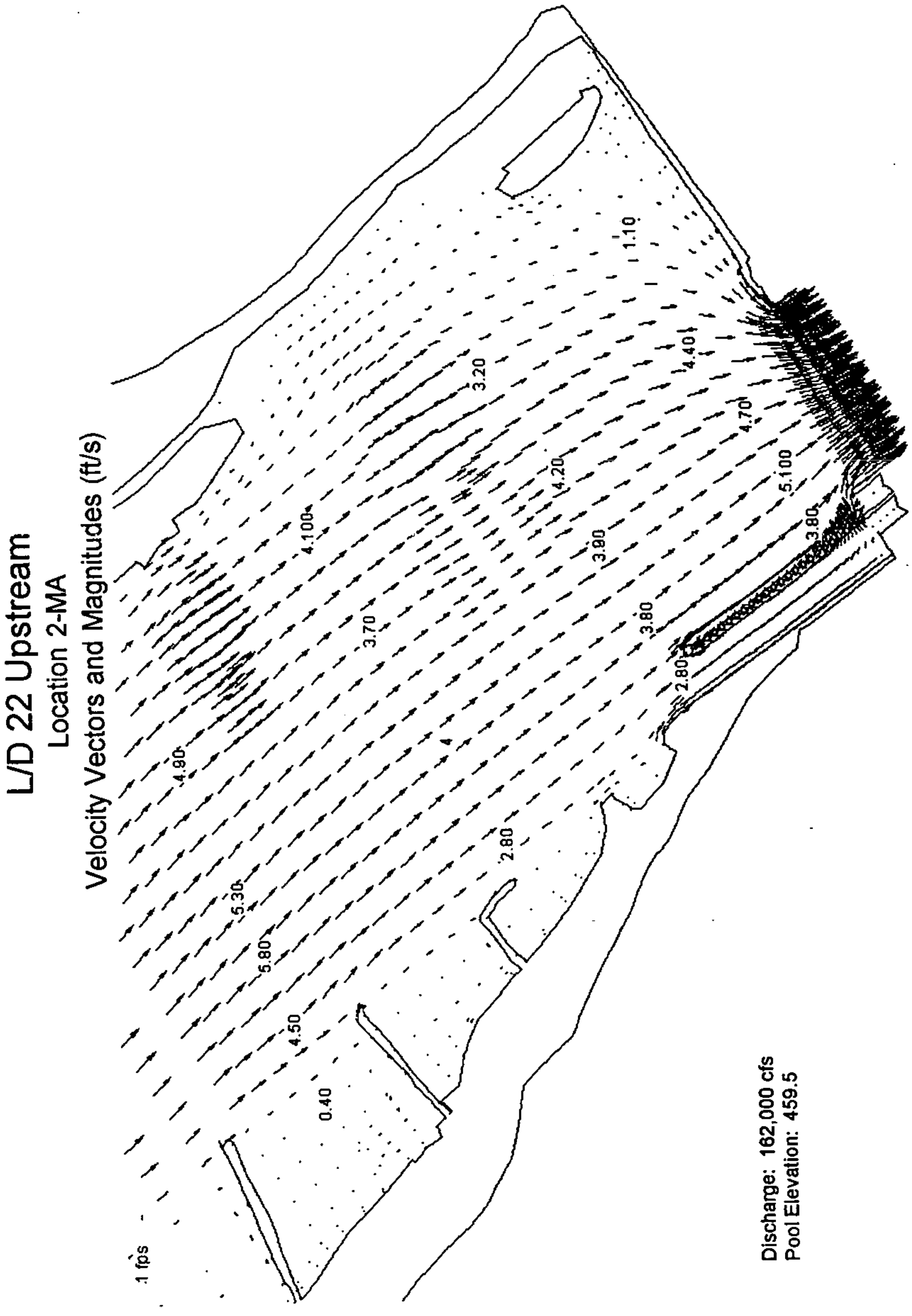
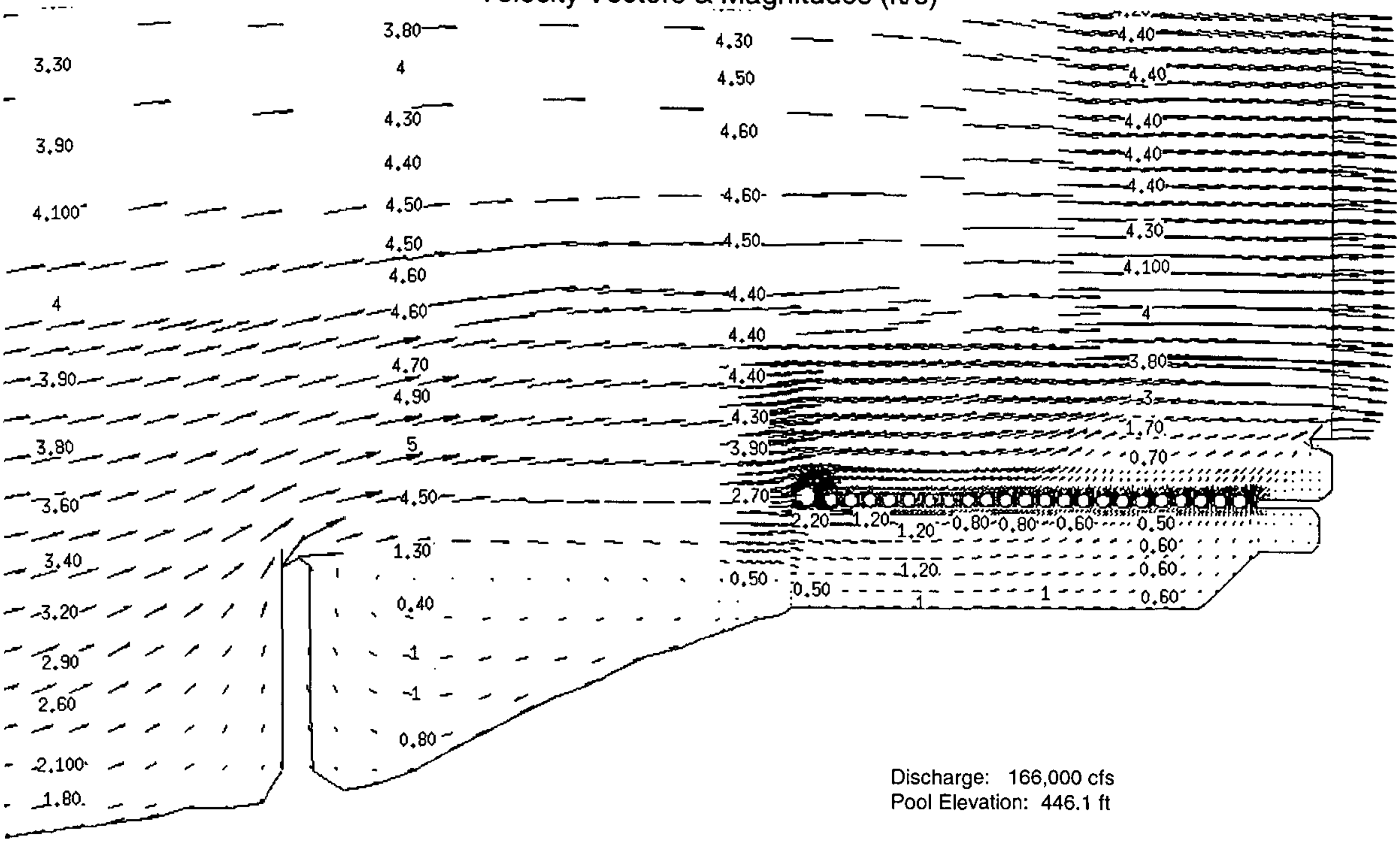

L/D 22 Upstream
Location 2-MA
Velocity Vectors and Magnitudes (ft/s)
1 fps
1.10
3.20
4.40
4.70
4.20
5.100
4.100
3.80
3.80
3.80
3.70
2.80
4.80
2.80
5.30
5.80
4.50
0.40
Discharge: 162,000 cfs
Pool Elevation: 459.5

Figure 49

# L/D 24 Upstream

## Location 2

### Velocity Vectors & Magnitudes (ft/s)



Discharge: 166,000 cfs
Pool Elevation: 446.1 ft

Figure 50

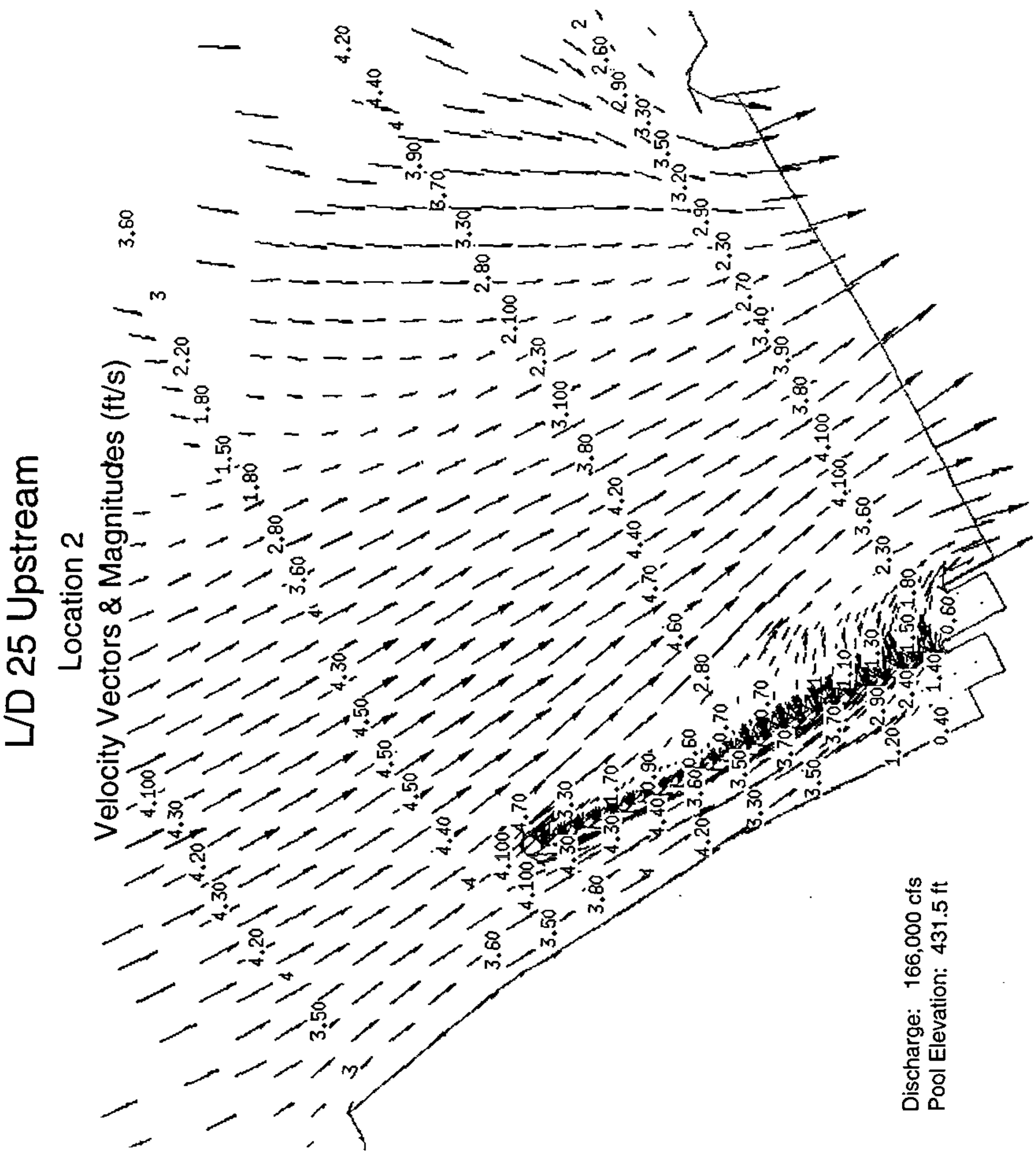
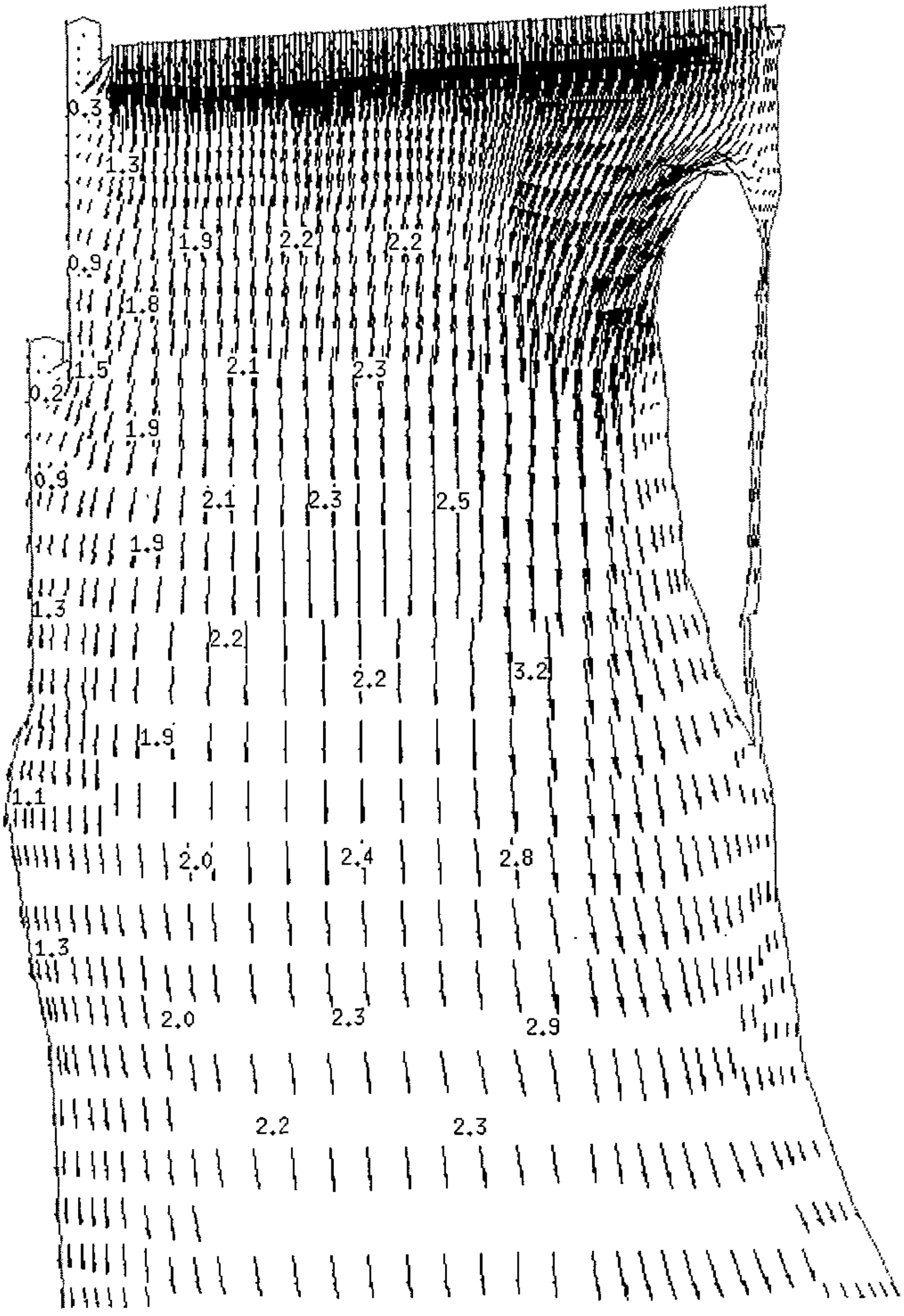

L/D 25 Upstream
Location 2
Velocity Vectors & Magnitudes (ft/s)
Discharge: 166,000 cfs
Pool Elevation: 431.5 ft

Figure 51

# L/D 20 Downstream

Location 2

Velocity Vectors & Magnitudes (ft/s)



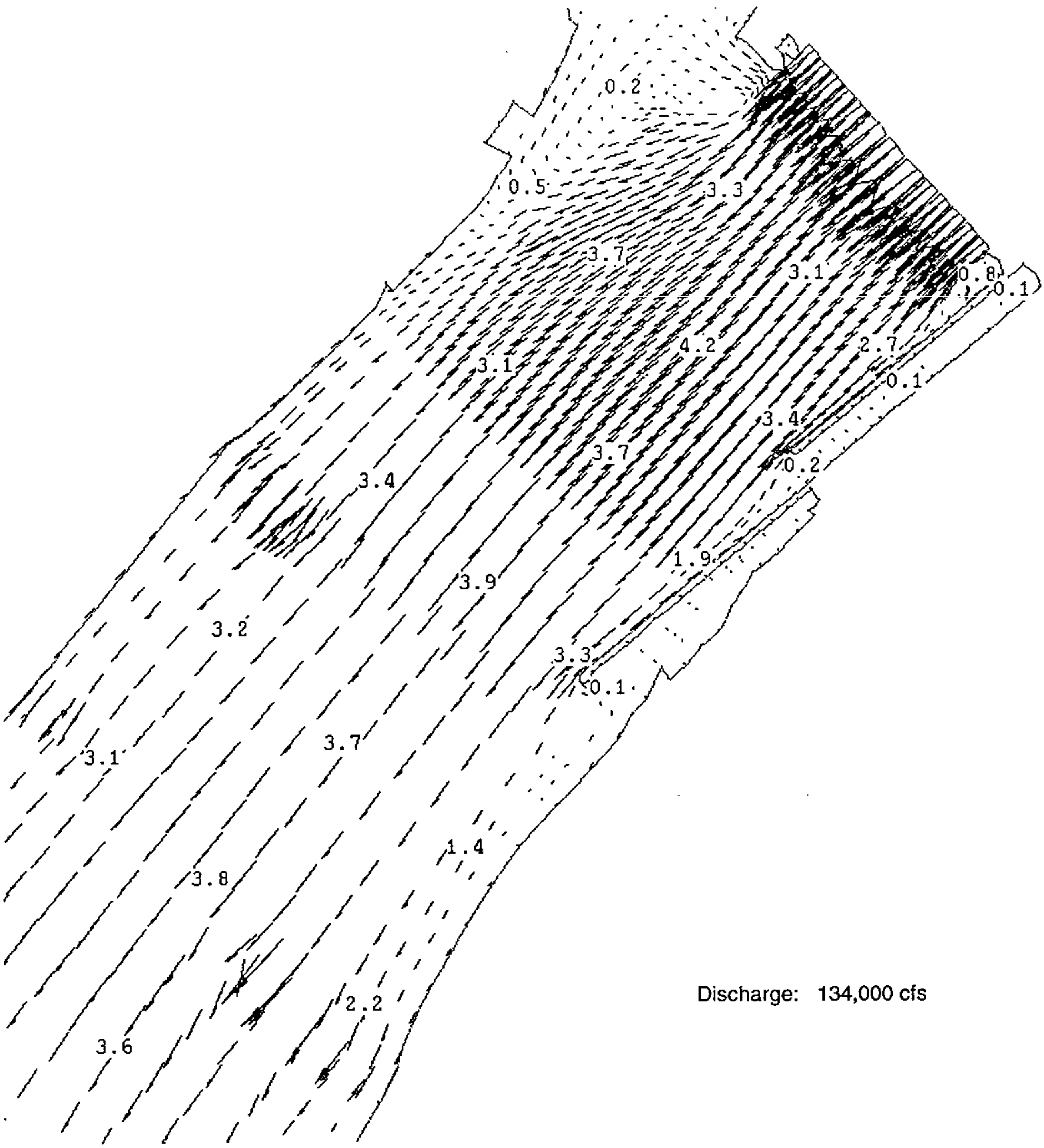

Discharge: 110,000 cfs
Tail Elevation: 476.4 ft

Figure 52

# L/D 21 Downstream

Location 2

Velocity Vectors & Magnitudes (ft/s)



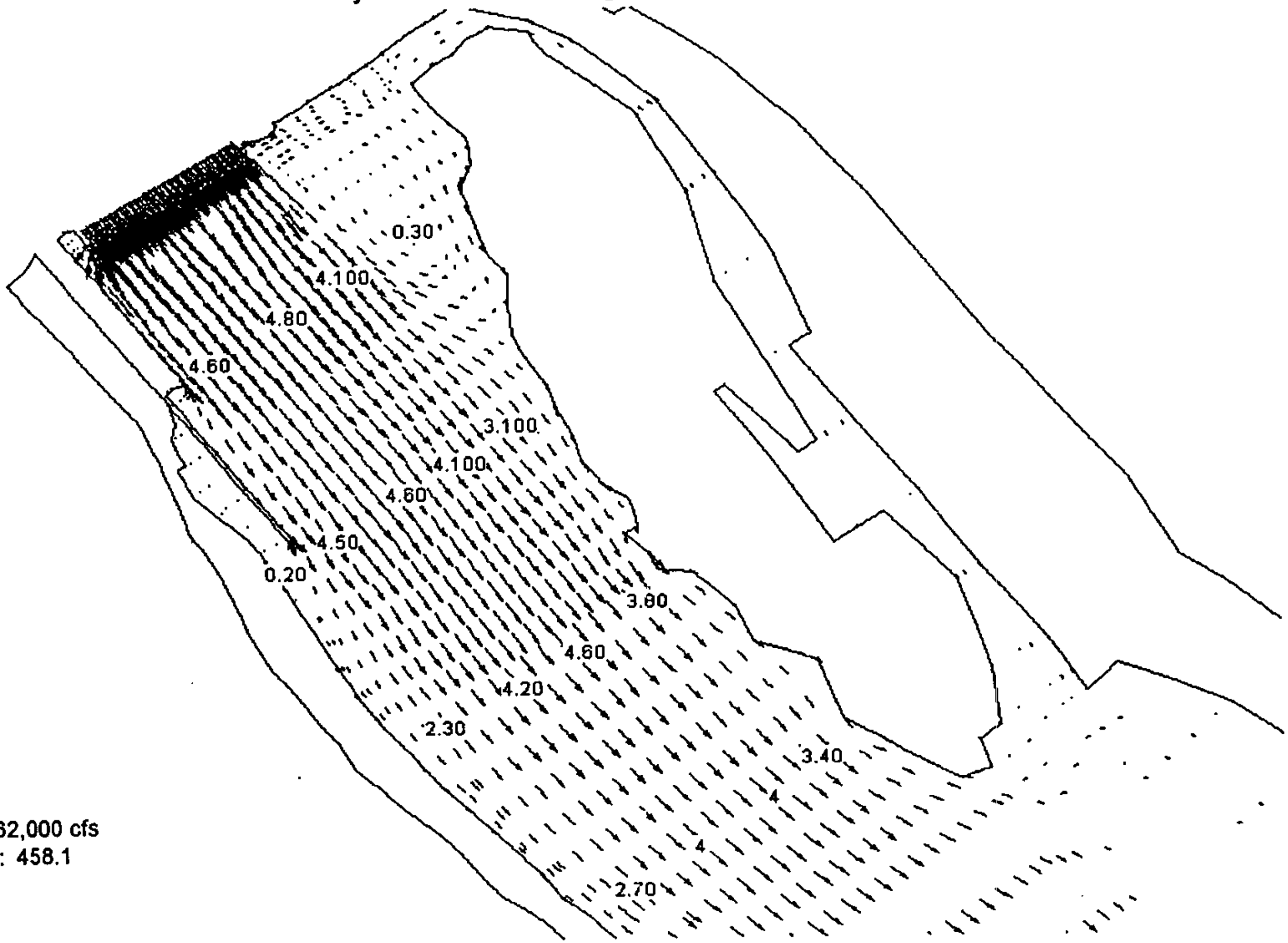

Discharge: 134,000 cfs

Figure 53

# L/D 22 Downstream

## Location 2

## Velocity Vectors and Magnitudes (ft/s)



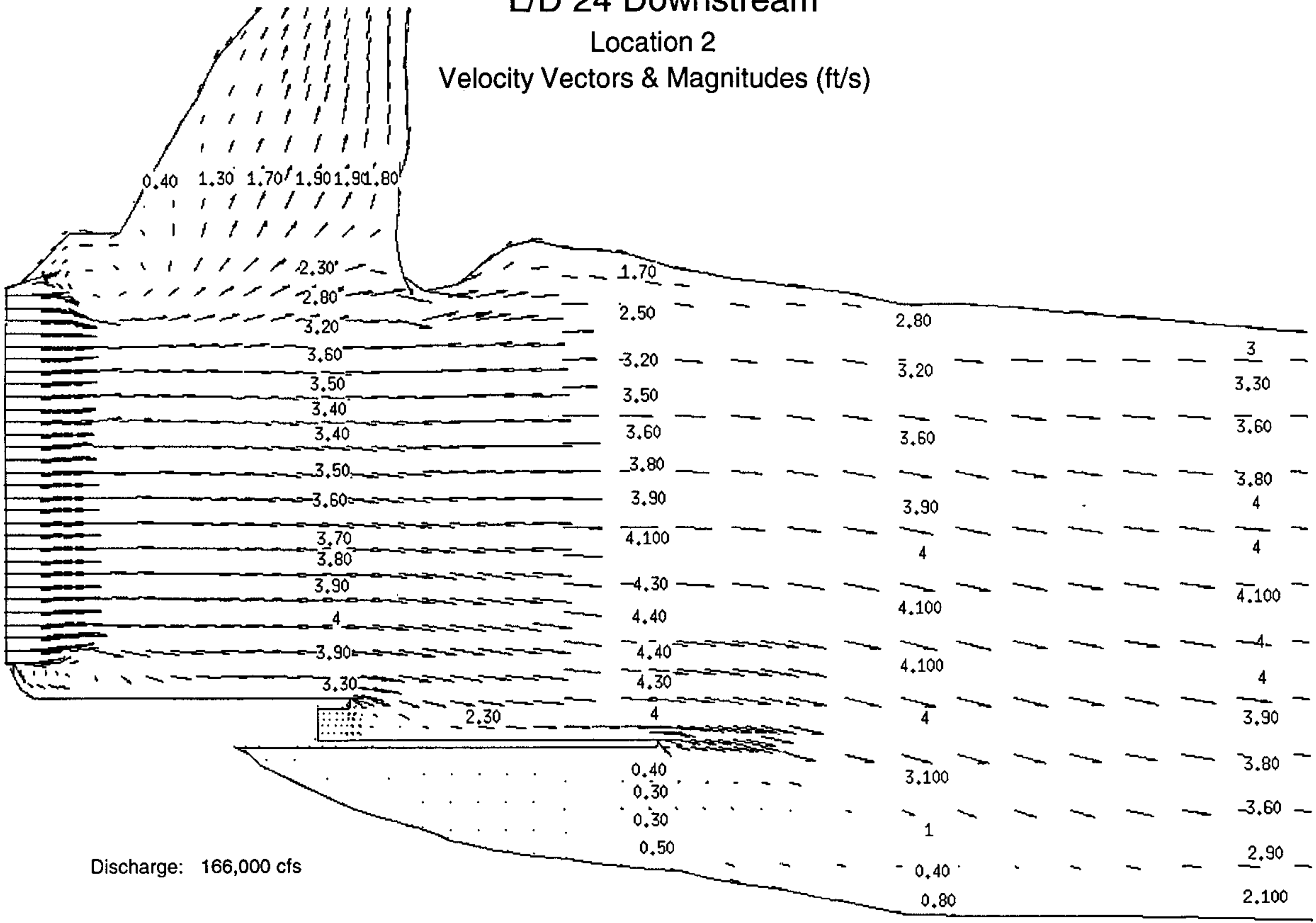

Discharge: 162,000 cfs
Tail Elevation: 458.1

Figure 54

# L/D 24 Downstream

## Location 2

## Velocity Vectors & Magnitudes (ft/s)




Discharge: 166,000 cfs

Figure 55

# L/D 25 Downstream

## Location 2

## Velocity Vectors & Magnitudes (ft/s)

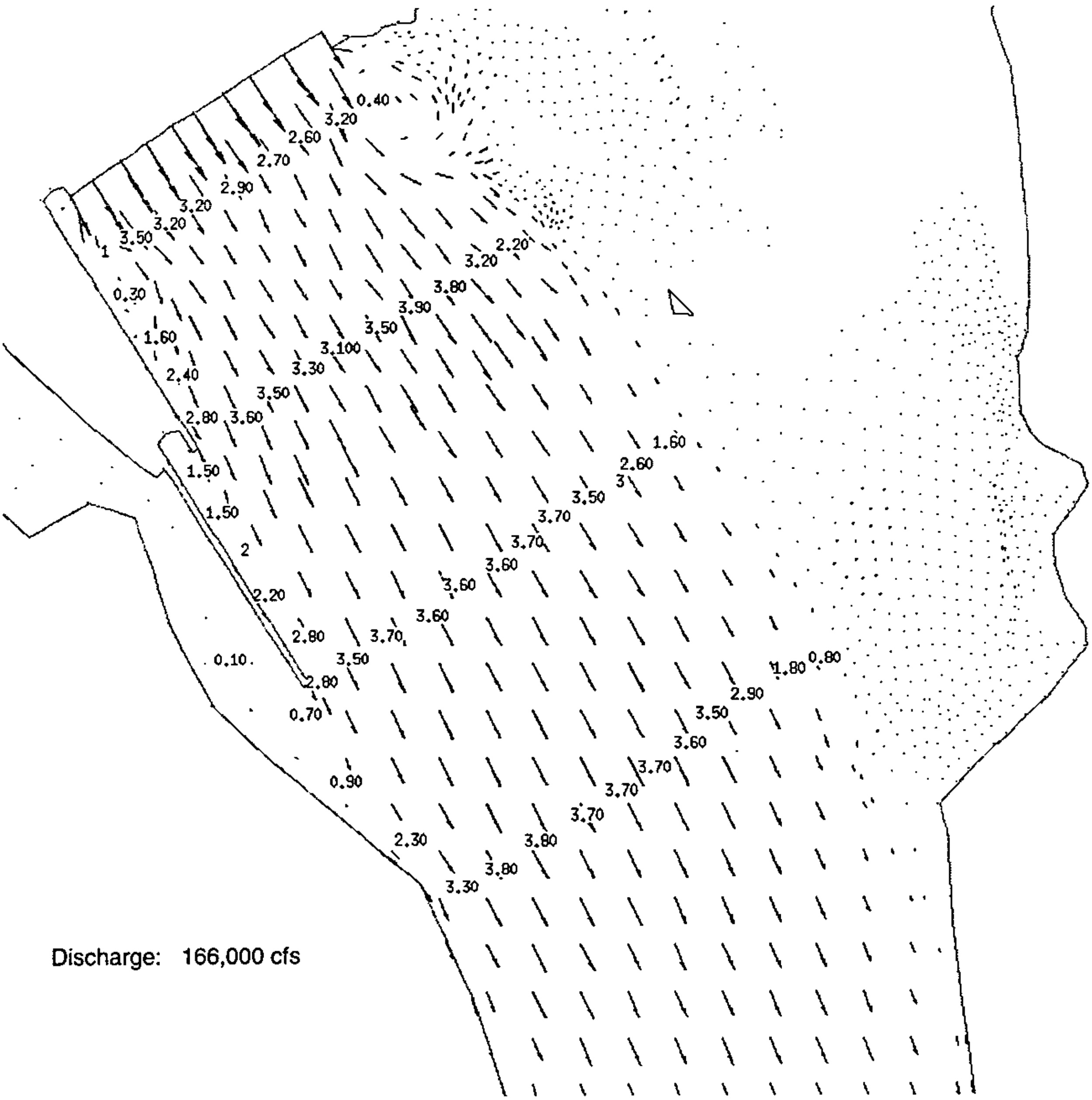
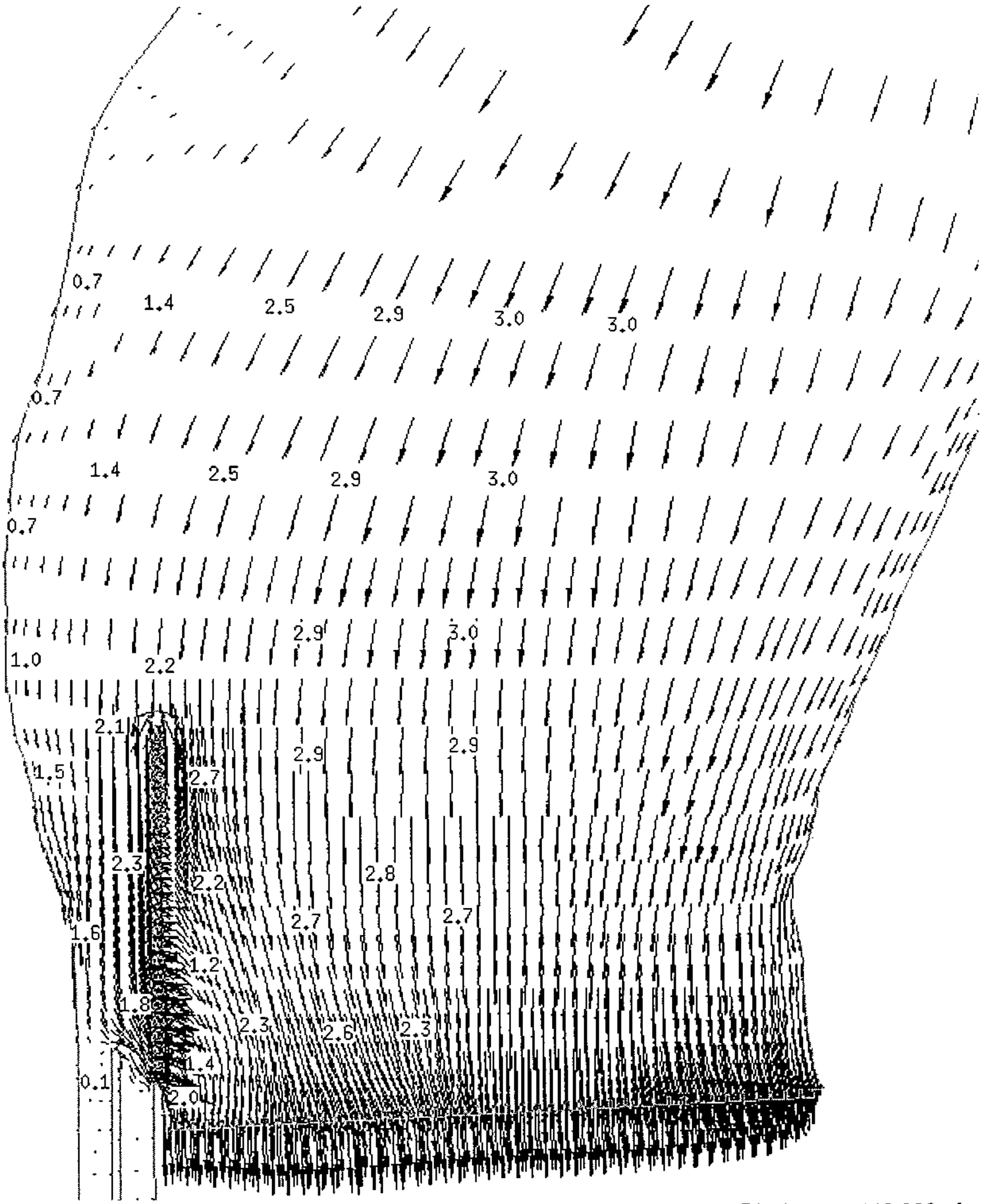



Figure 56

# L/D 20 Upstream

## Location 3

## Velocity Vectors & Magnitudes (ft/s)




Discharge: 110,000 cfs
Pool Elevation: 476.9 ft

Figure 57

# L/D 21 Upstream

Location 3

Velocity Vectors & Magnitudes (ft/s)

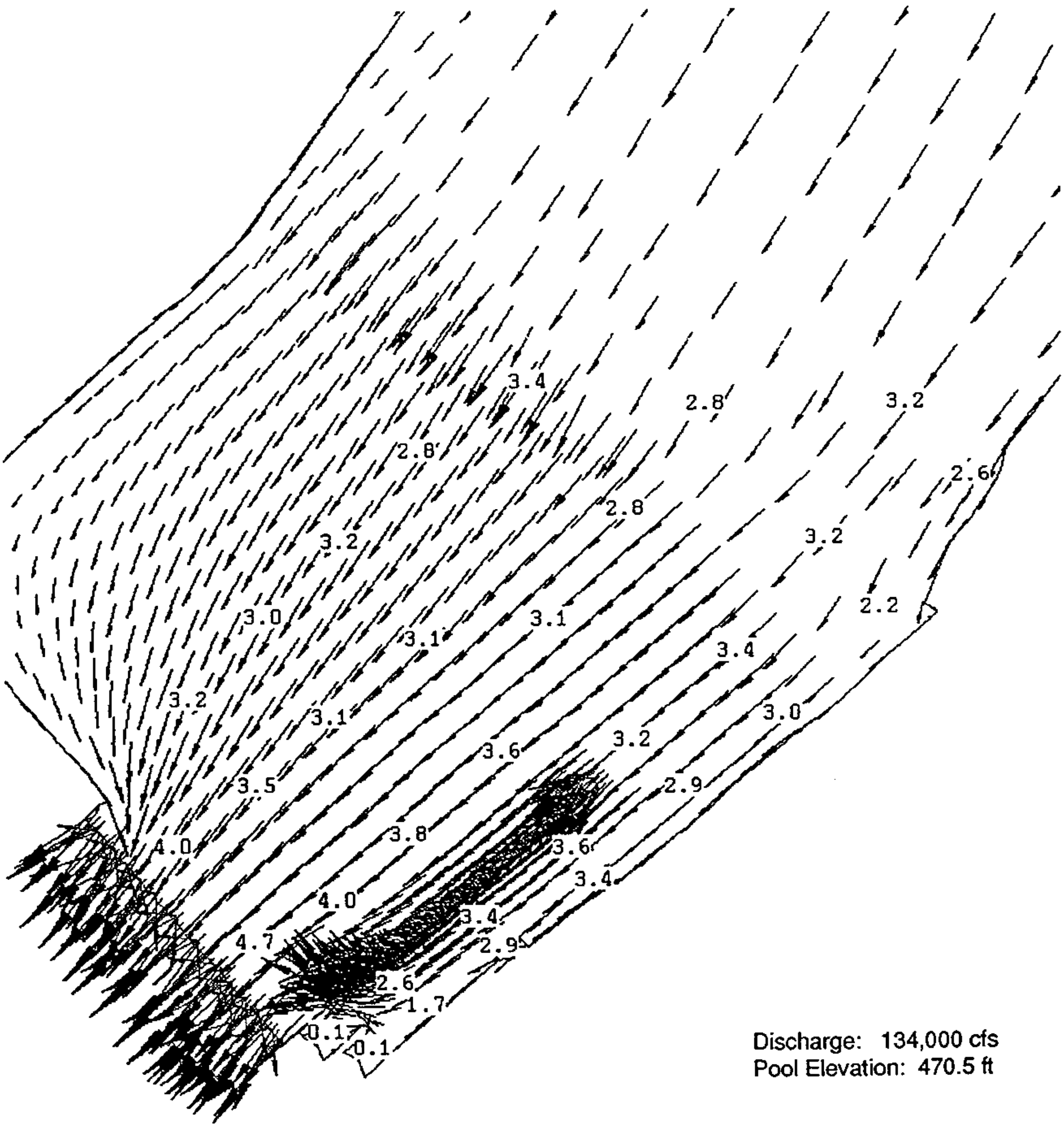
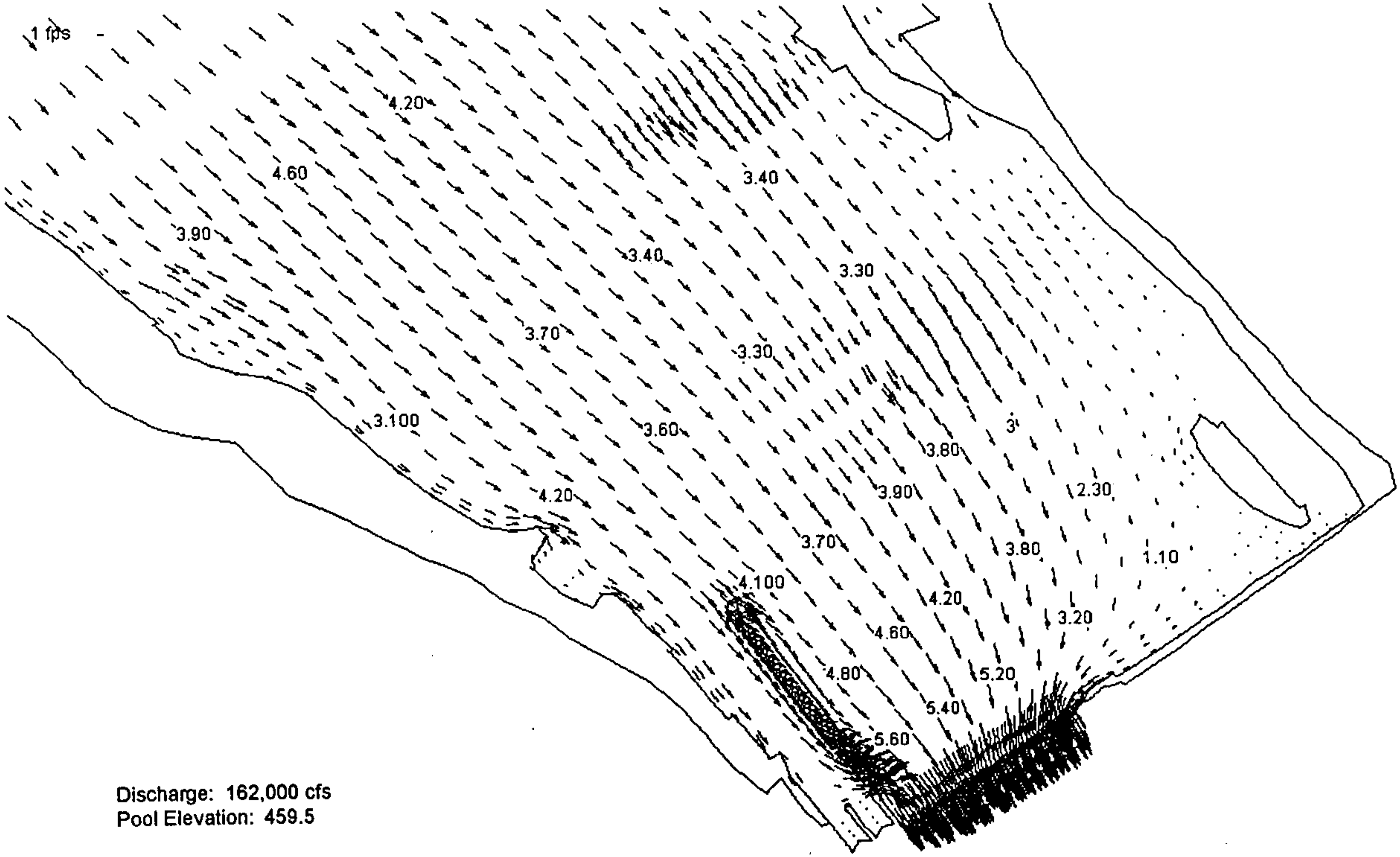



Figure 58

## L/D 22 Upstream
Location 3
Velocity Vectors and Magnitudes (ft/s)




Discharge: 162,000 cfs
Pool Elevation: 459.5

Figure 59

# L/D 24 Upstream

## Location 3

### Velocity Vectors & Magnitudes (ft/s)

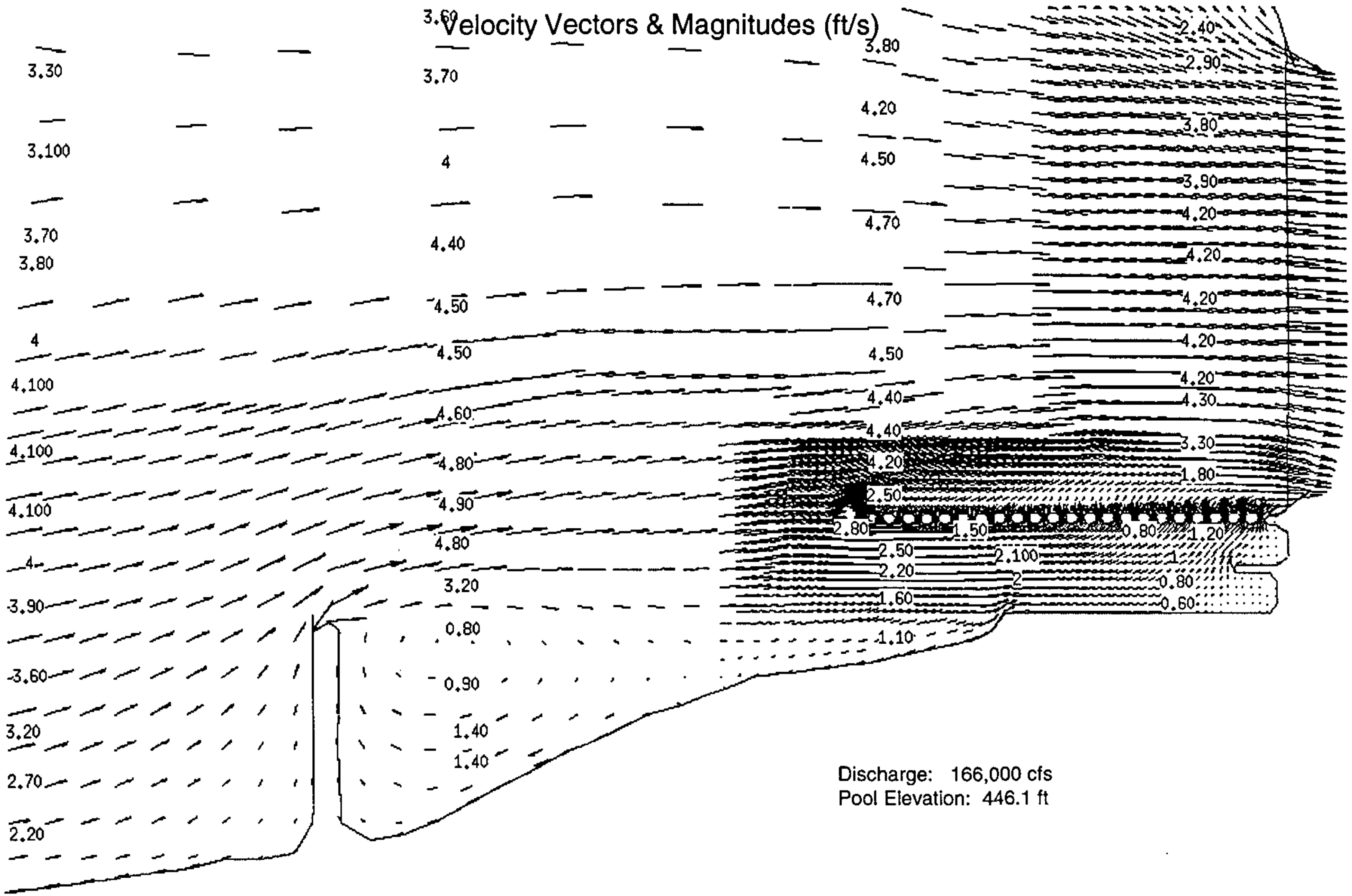
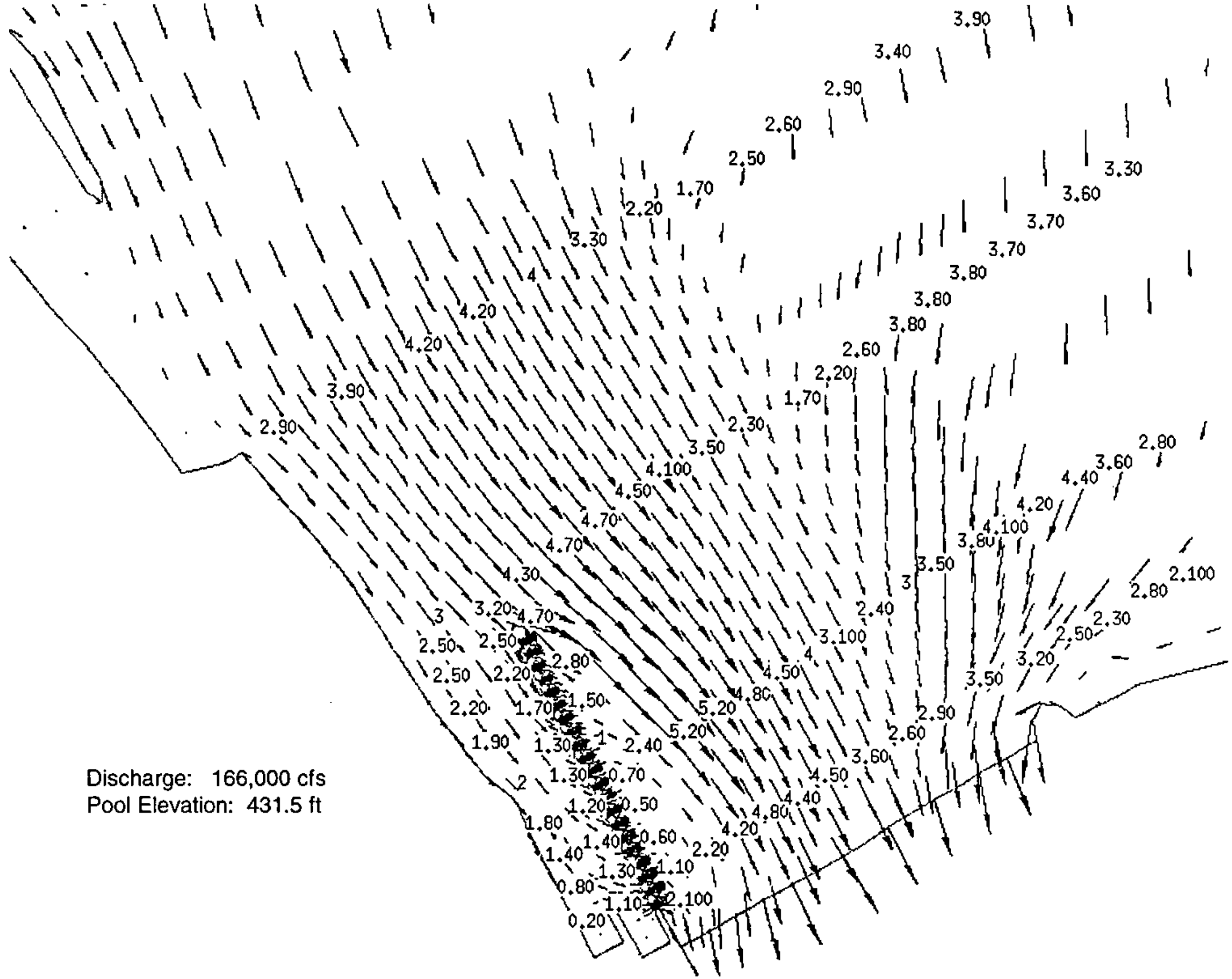



Figure 60

# L/D 25 Upstream

## Location 3

### Velocity Vectors & Magnitudes (ft/s)

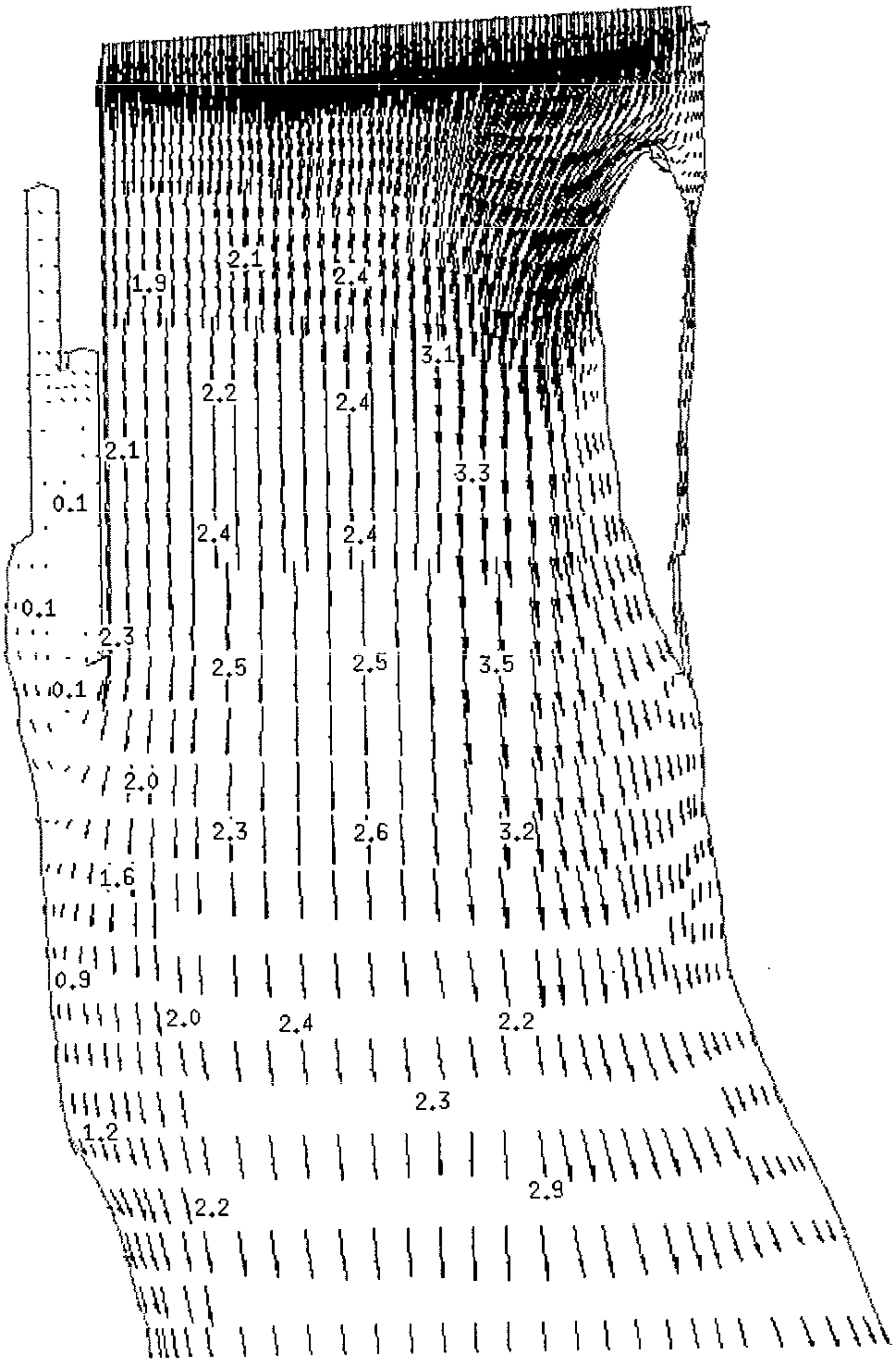


Discharge: 166,000 cfs
Pool Elevation: 431.5 ft

Figure 61

# L/D 20 Downstream

Location 3
Velocity Vectors & Magnitudes (ft/s)




Discharge: 110,000 cfs
Tail Elevation: 476.4 ft

Figure 62

# L/D 21 Downstream

Location 3

Velocity Vectors & Magnitudes (ft/s)

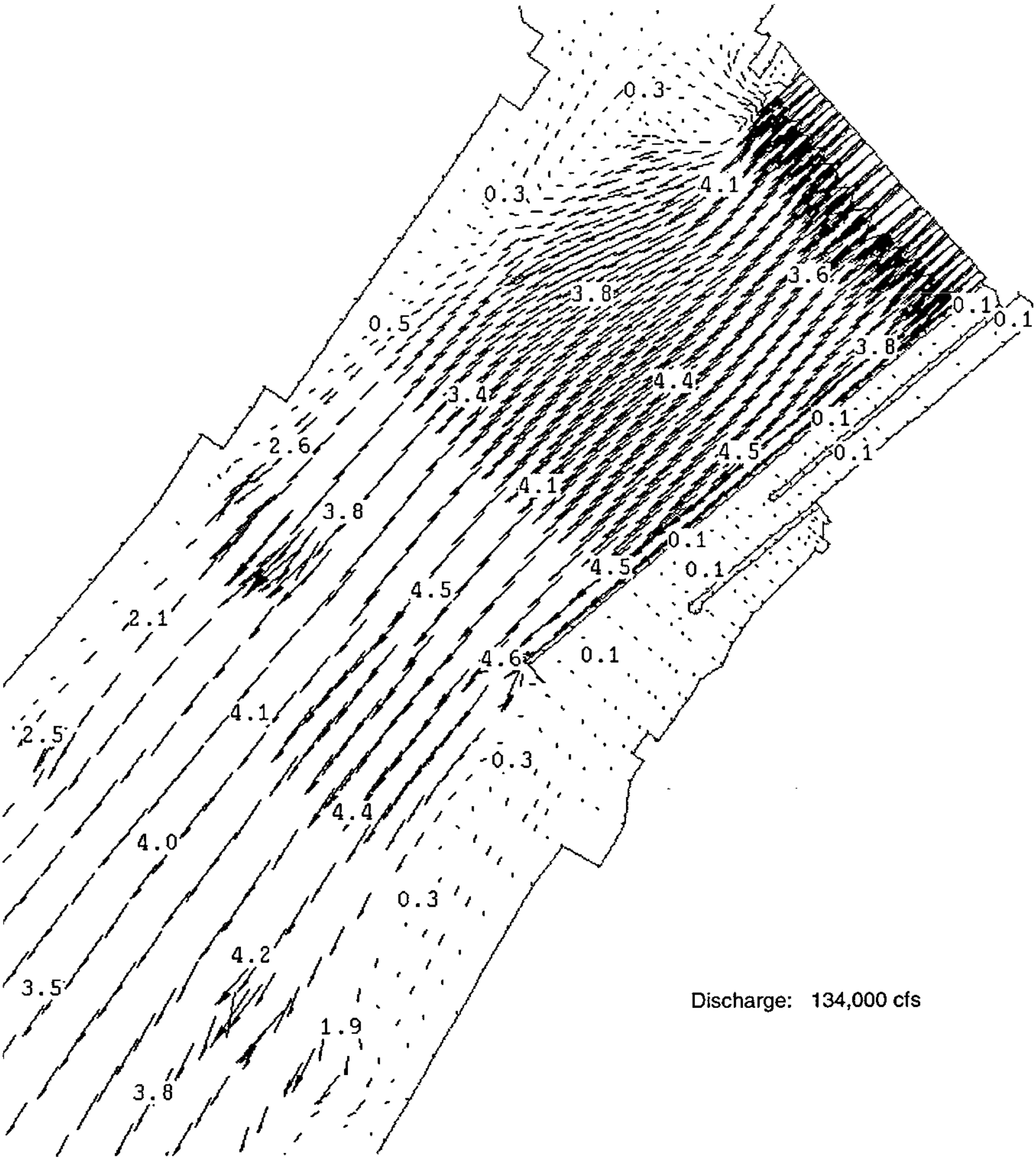
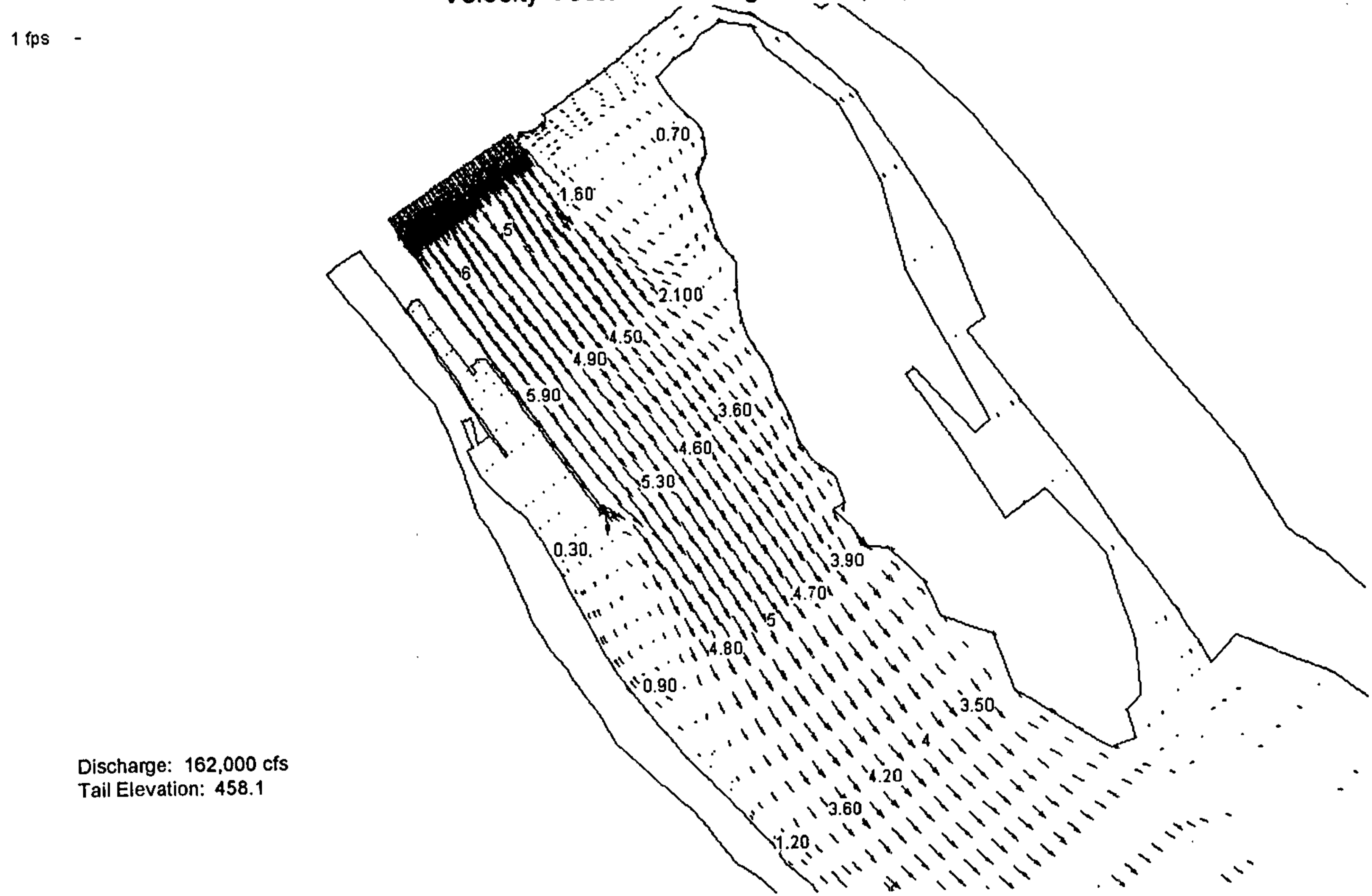



Figure 63

# L/D 22 Downstream
Location 3
Velocity Vectors and Magnitudes (ft/s)




Discharge: 162,000 cfs
Tail Elevation: 458.1

Figure 64

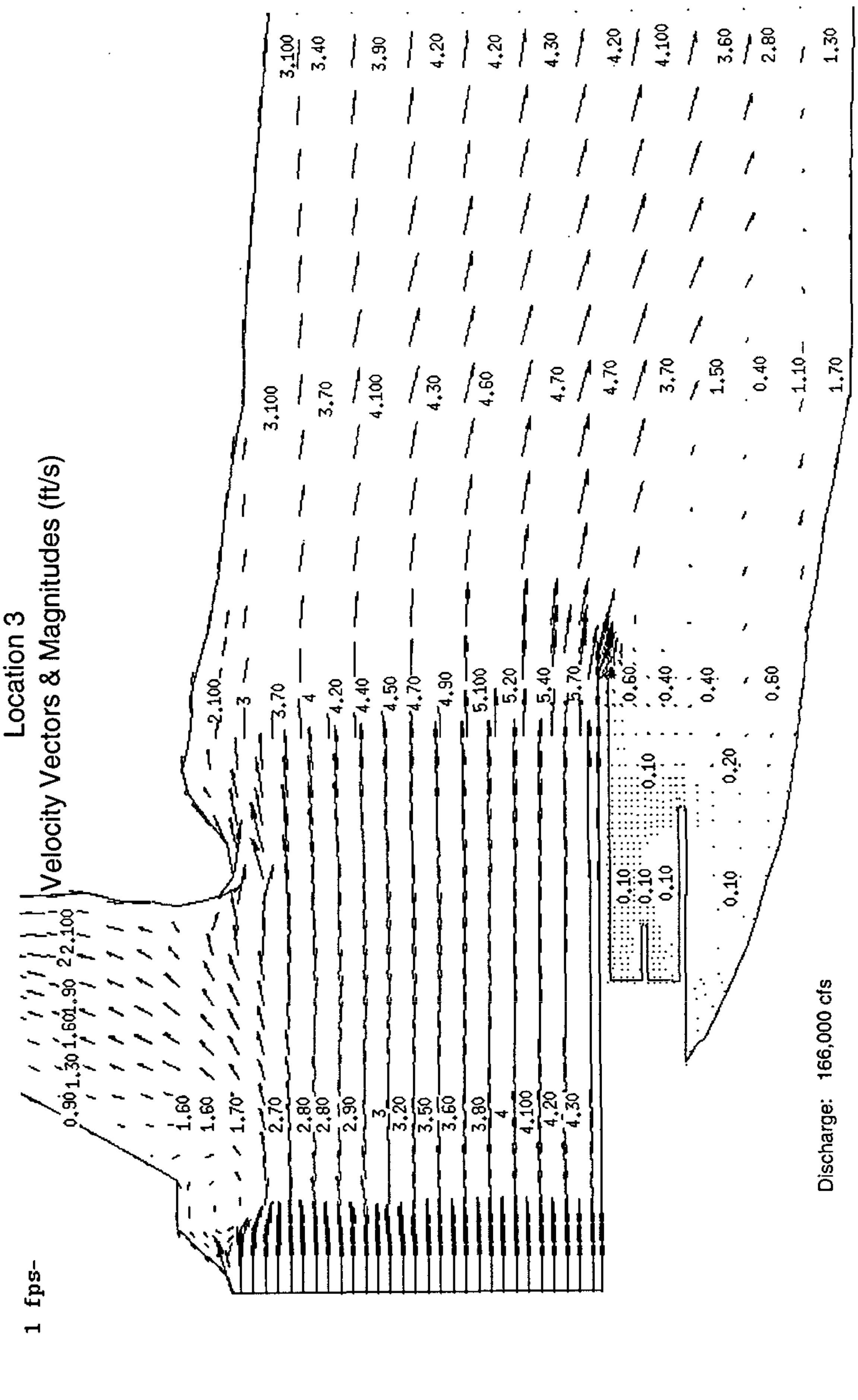

L/D 24 Downstream
Location 3
Velocity Vectors & Magnitudes (ft/s)
1 fps
Discharge: 166,000 cfs

Figure 65

# L/D 25 Downstream

## Location 3
## Velocity Vectors & Magnitudes (ft/s)

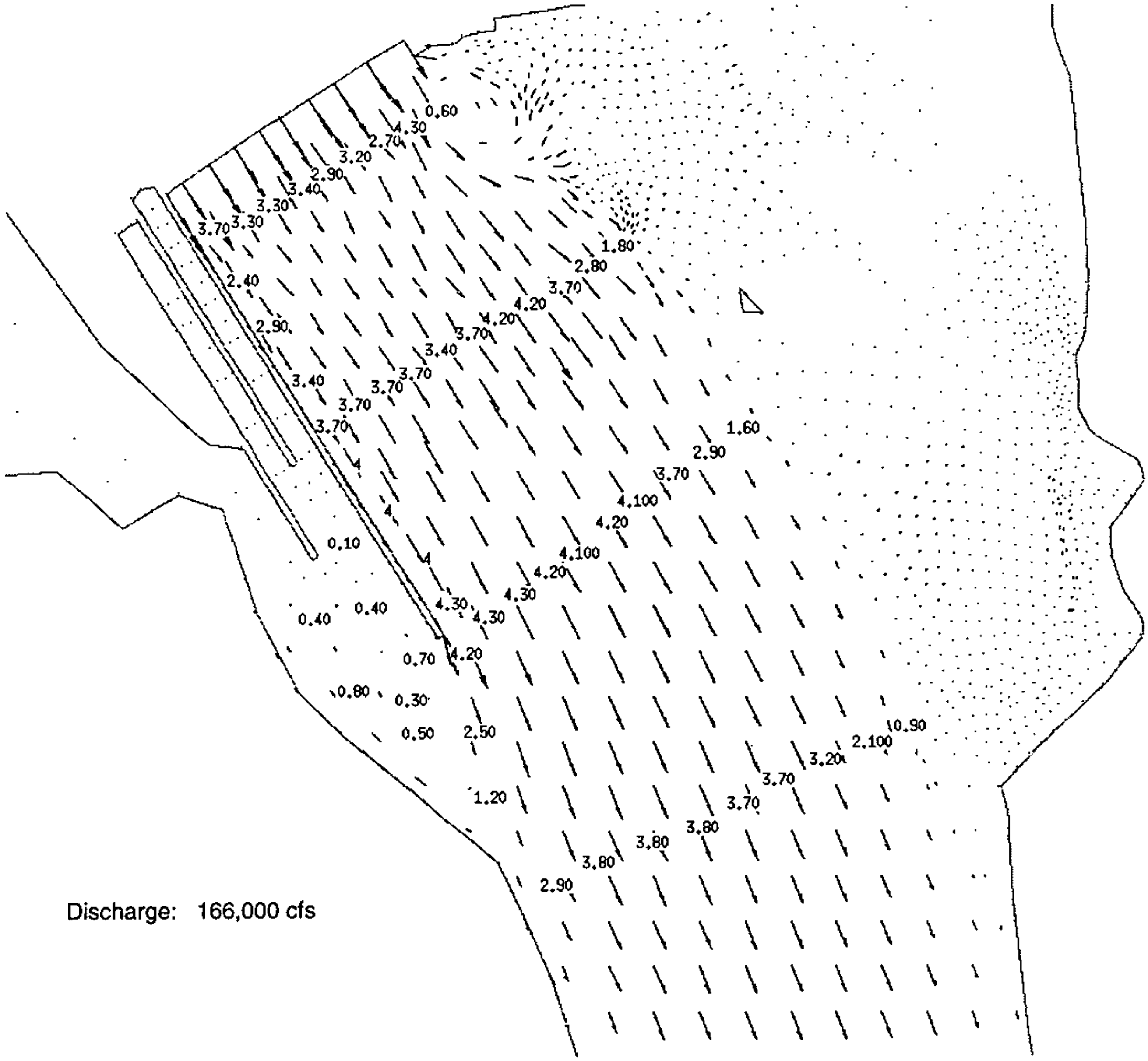
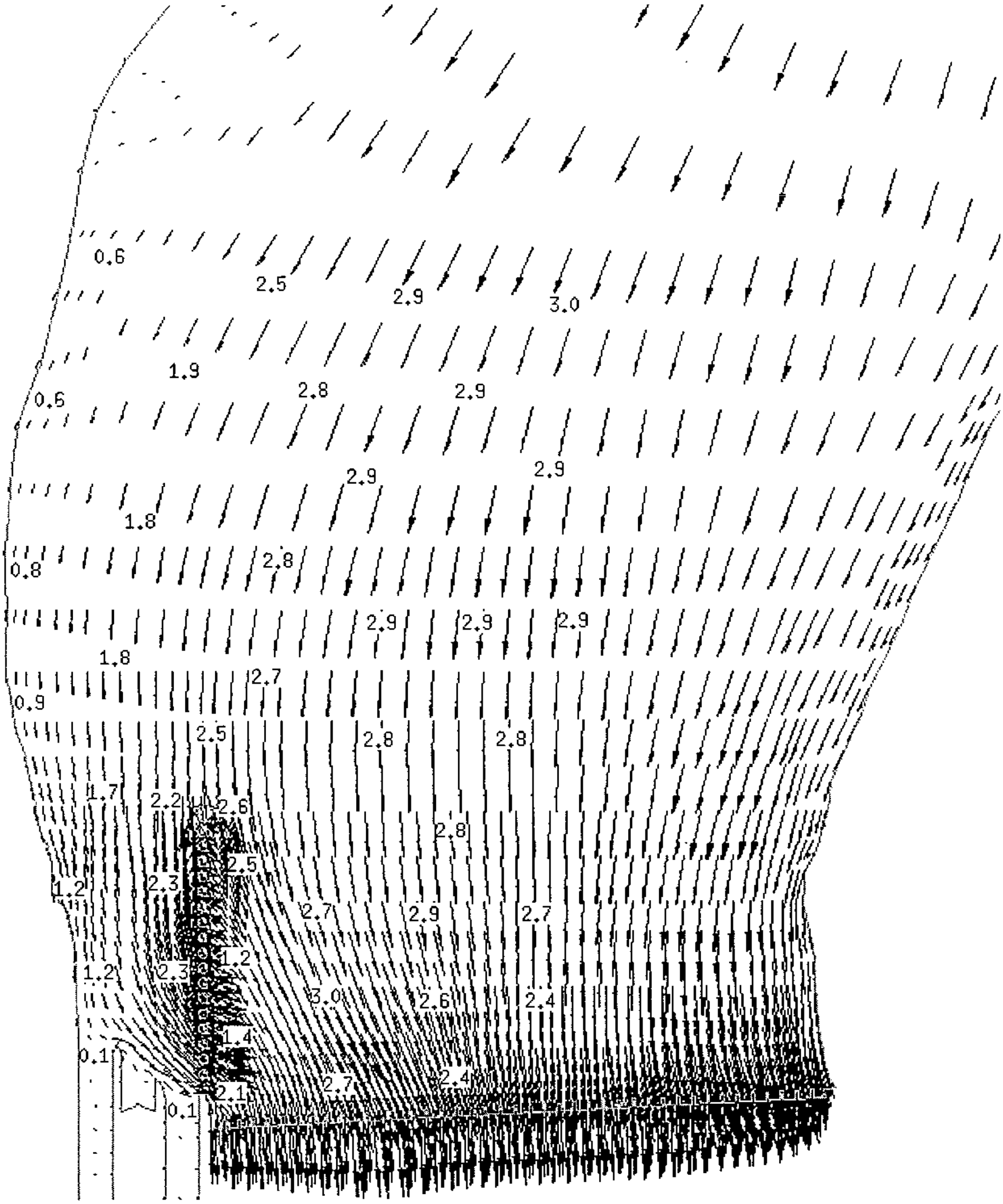



Figure 66

# L/D 20 Upstream

## Location 4

## Velocity Vectors & Magnitudes (ft/s)



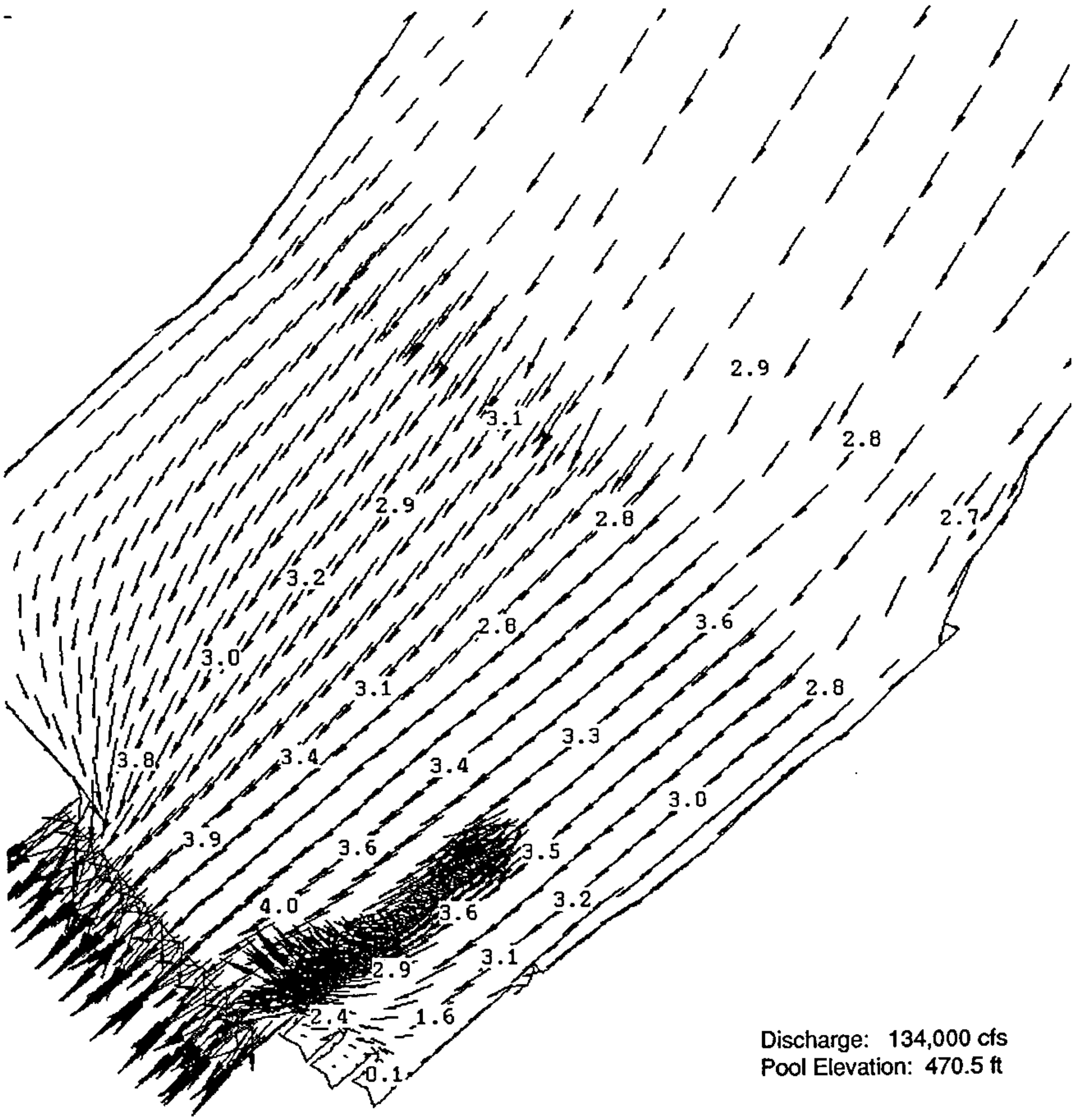

Discharge: 110,000 cfs
Pool Elevation: 476.9 ft

Figure 67

# L/D 21 Upstream

Location 4

Velocity Vectors & Magnitudes (ft/s)



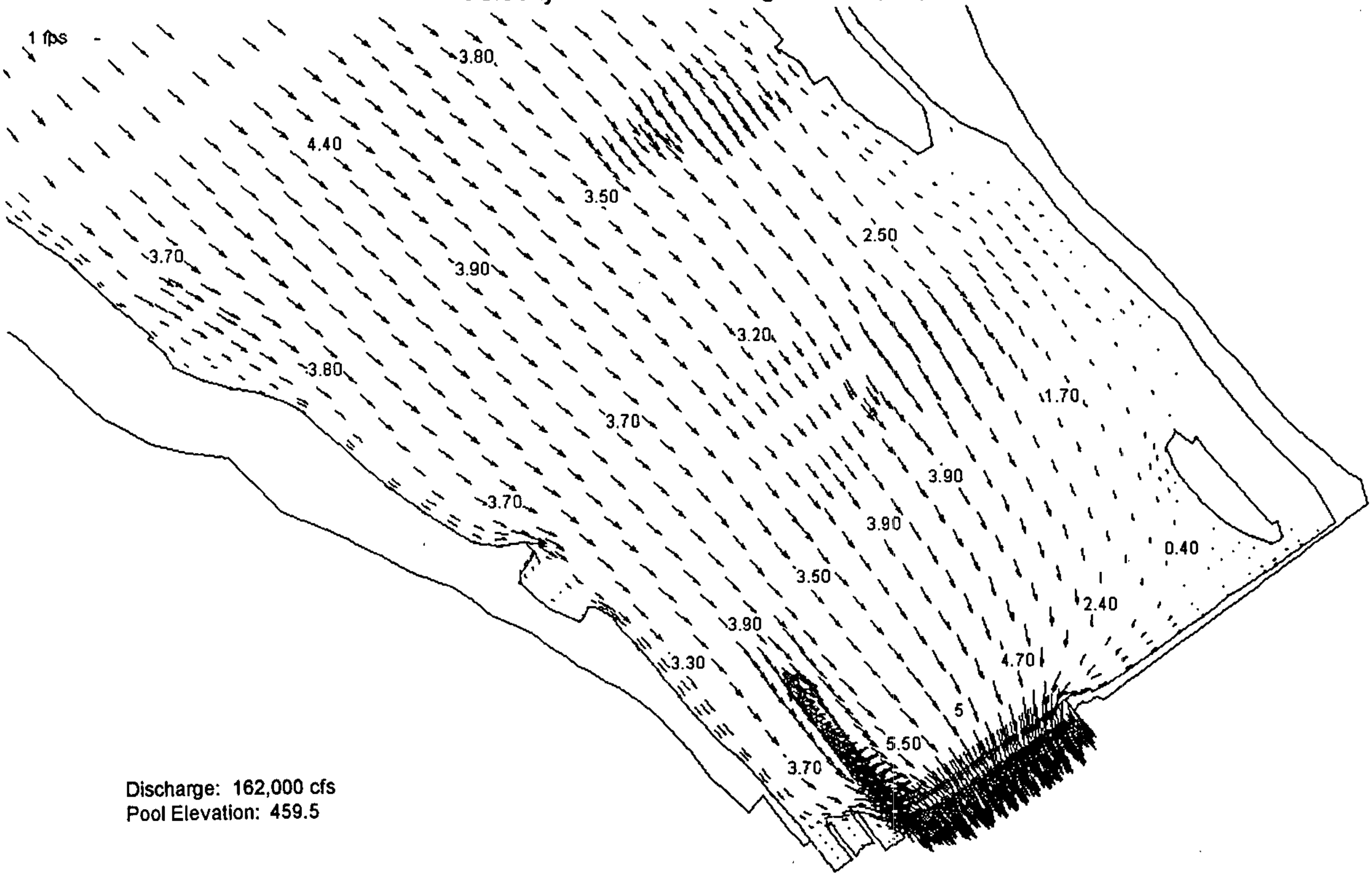

Discharge: 134,000 cfs
Pool Elevation: 470.5 ft

Figure 68

L/D 22 Upstream

Location 4

Velocity Vectors and Magnitudes (ft/s)



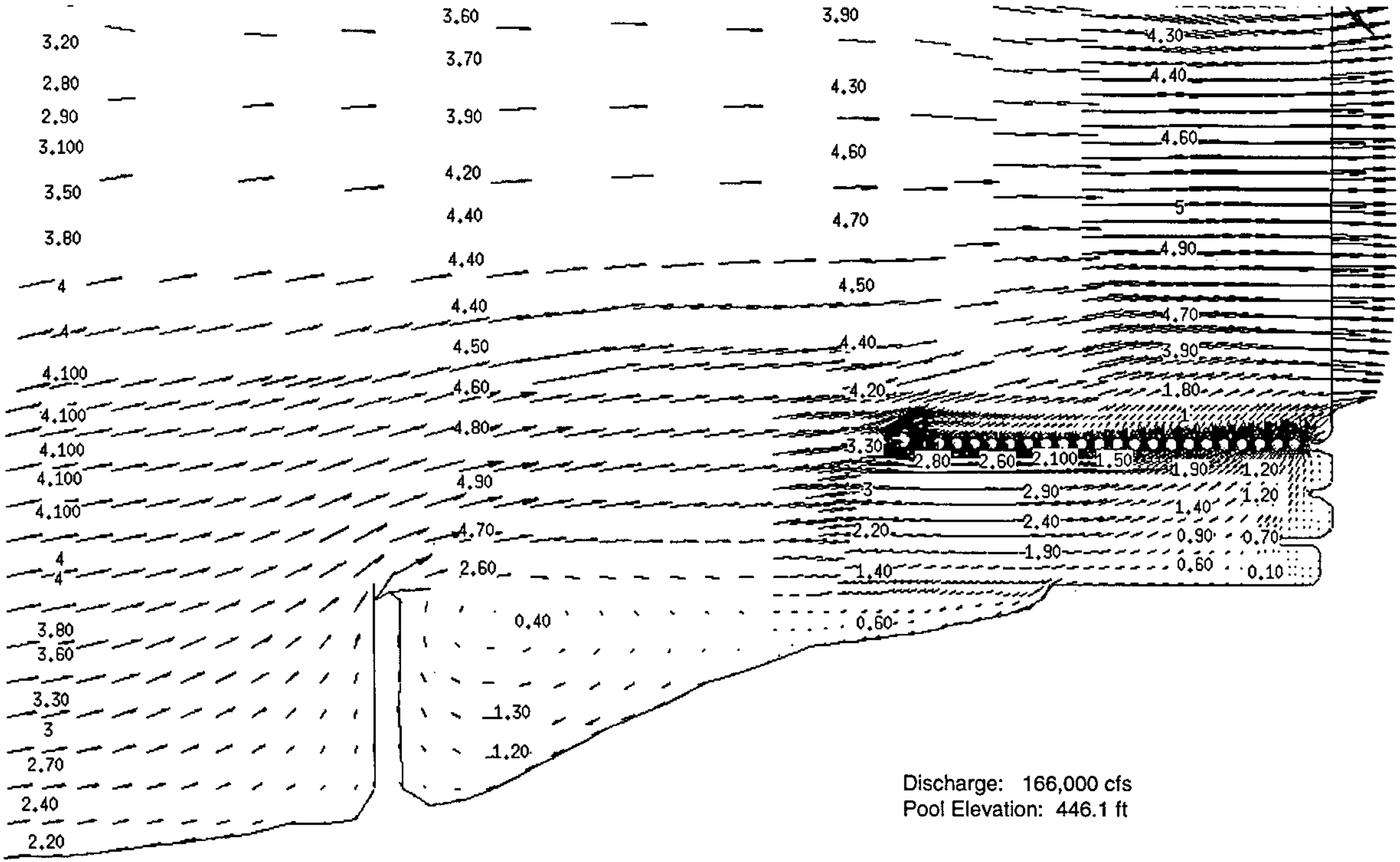

Discharge: 162,000 cfs
Pool Elevation: 459.5

Figure 69

# L/D 24 Upstream

## Location 4

## Velocity Vectors & Magnitudes (ft/s)




Discharge: 166,000 cfs
Pool Elevation: 446.1 ft

Figure 70

# L/D 25 Upstream

## Location 4

### Velocity Vectors & Magnitudes (ft/s)

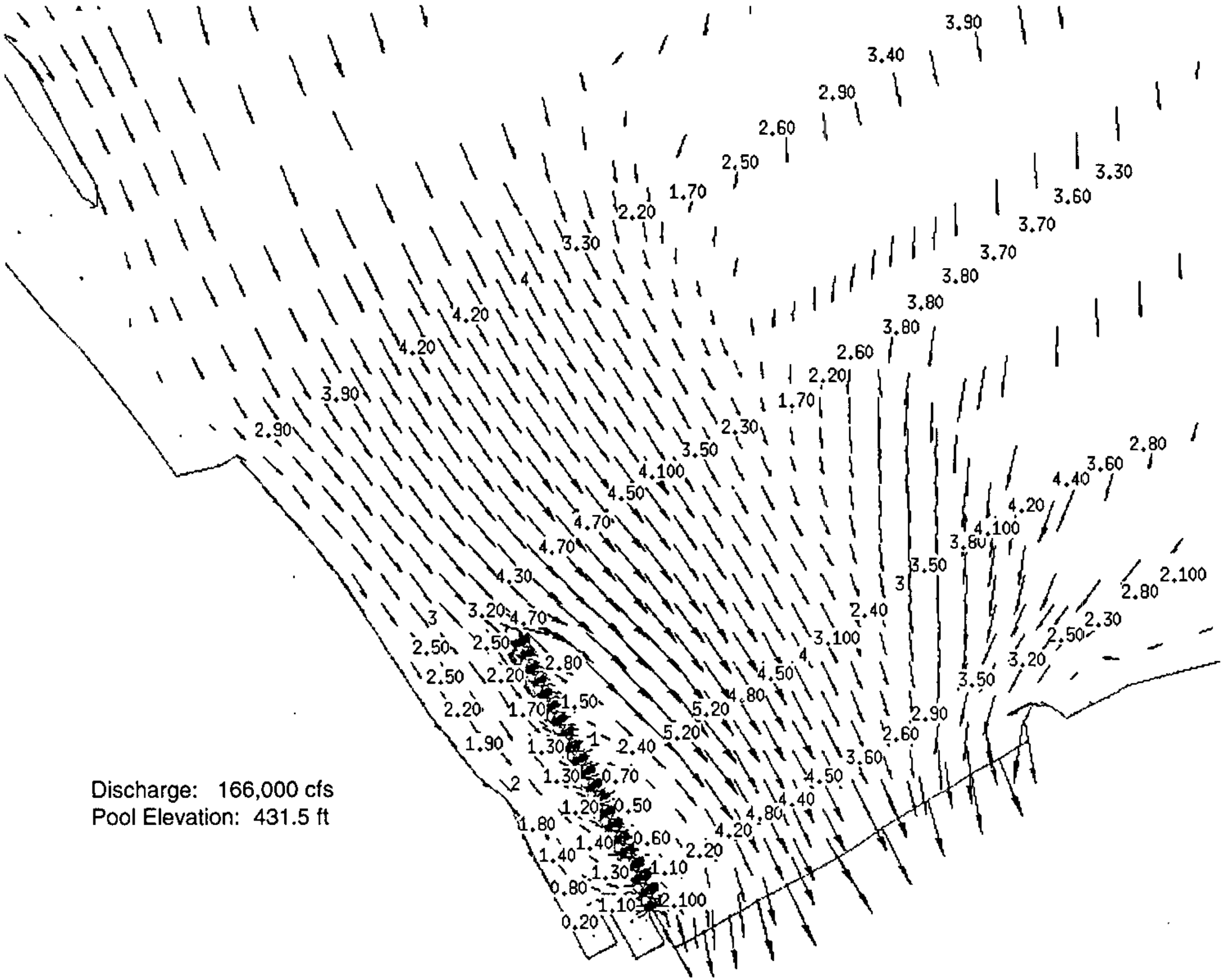
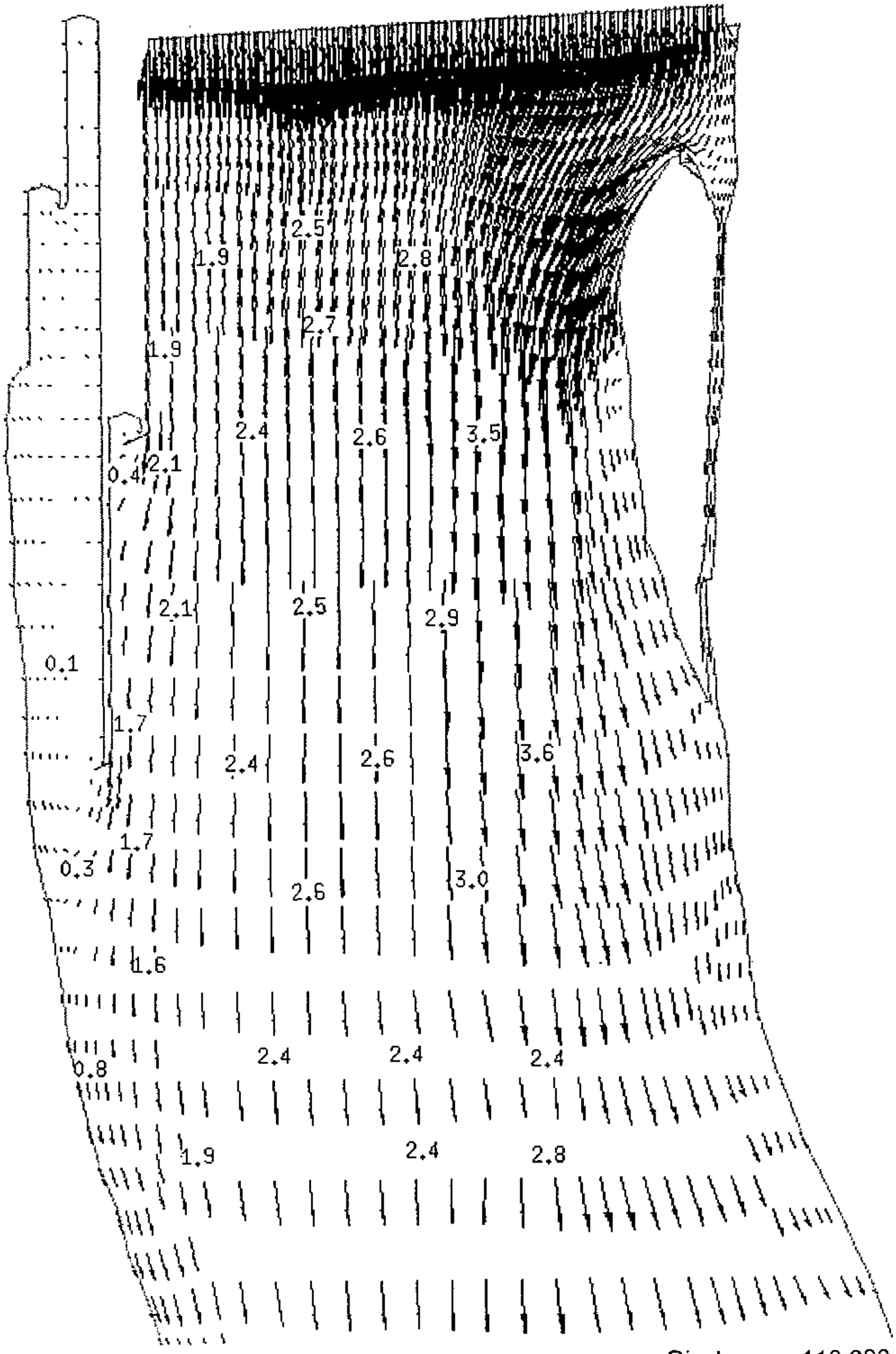



Figure 71

# L/D 20 Downstream

## Location 4

## Velocity Vectors & Magnitudes (ft/s)




Discharge: 110,000 cfs
Tail Elevation: 476.4 ft

Figure 72

# L/D 21 Downstream

Location 4

Velocity Vectors & Magnitudes (ft/s)

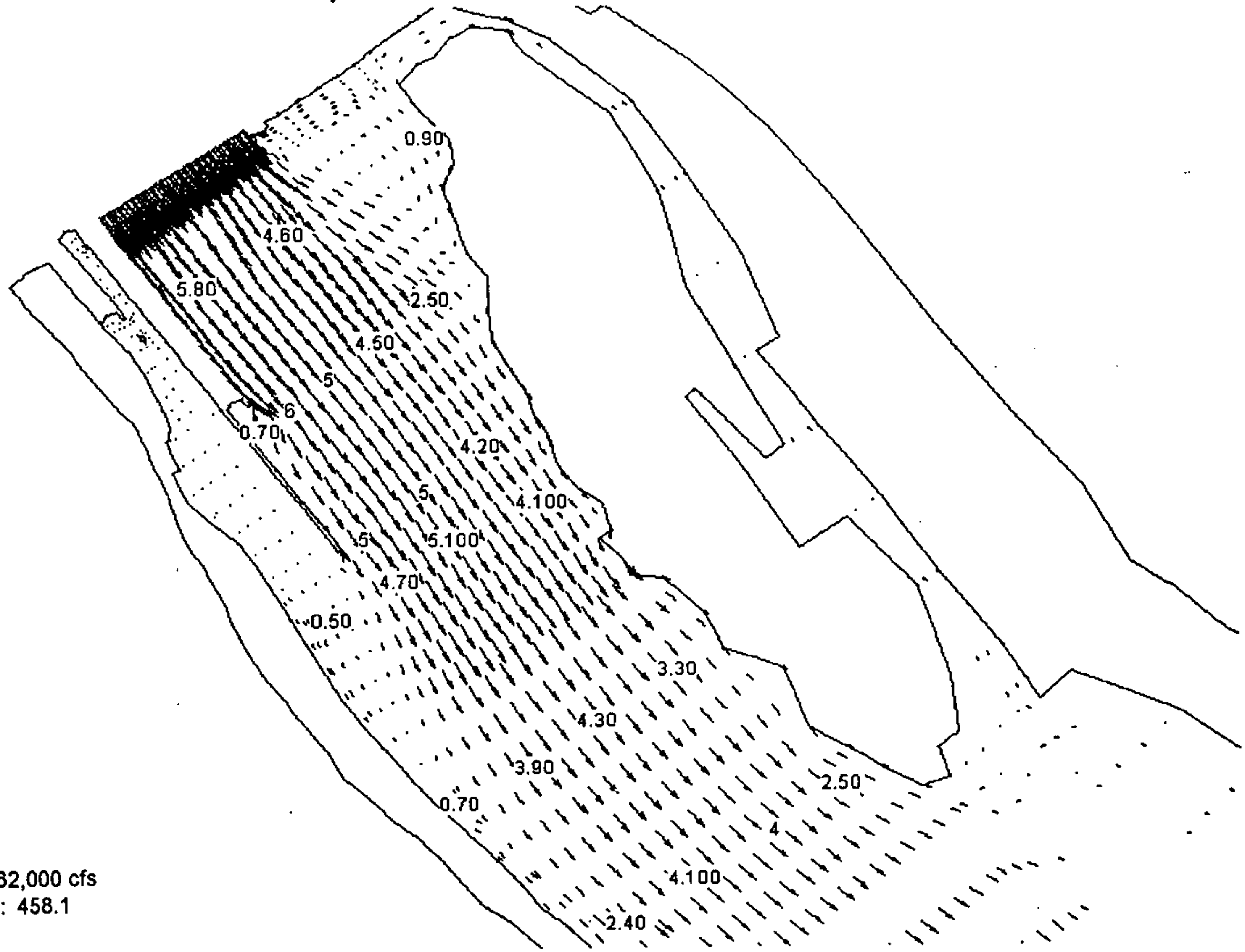

Discharge: 134,000 cfs

Figure 73

# L/D 22 Downstream

Location 4

Velocity Vectors and Magnitudes (ft/s)



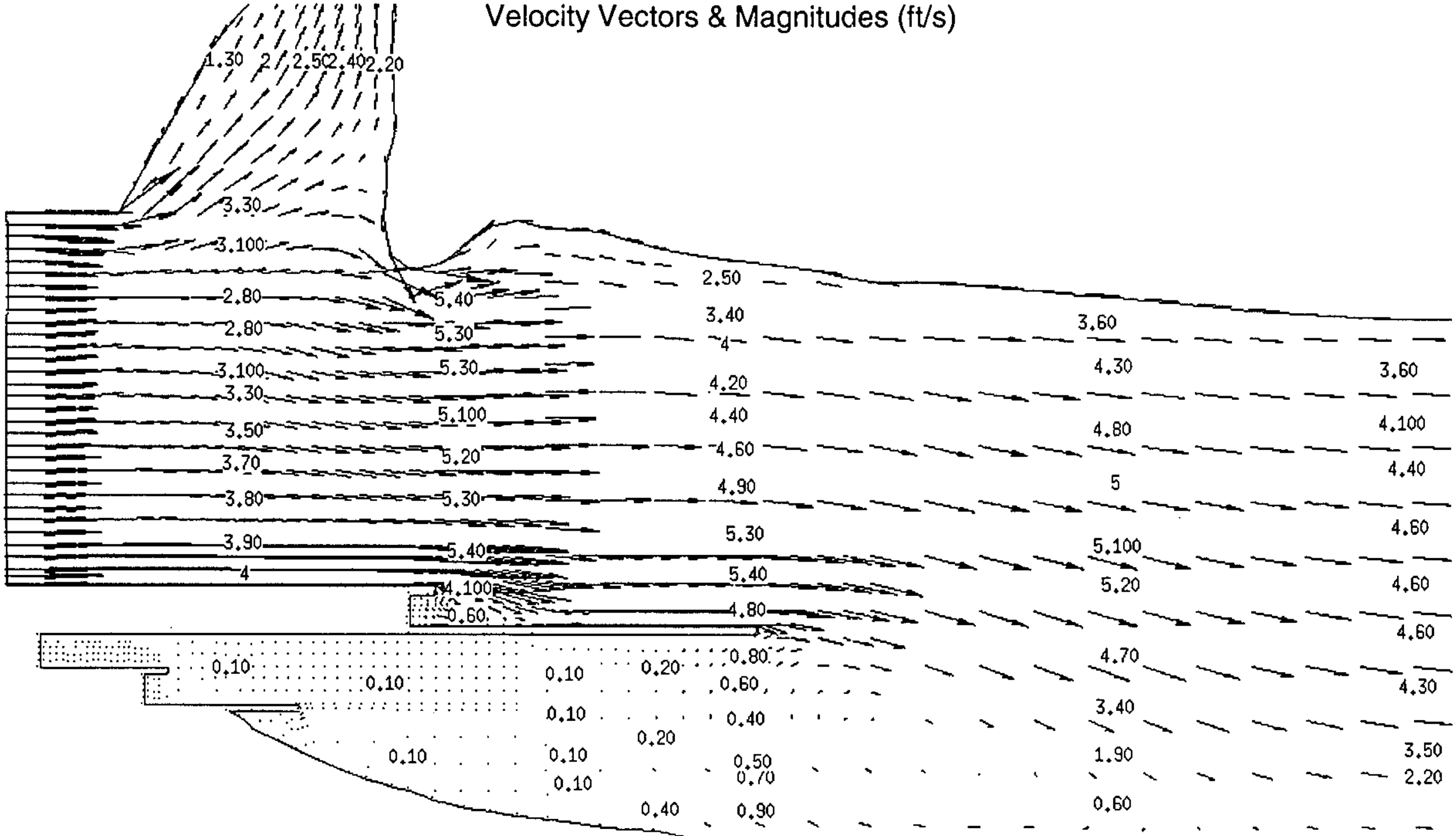

Discharge: 162,000 cfs
Tail Elevation: 458.1

Figure 74

# L/D 24 Downstream

## Location 4

### Velocity Vectors & Magnitudes (ft/s)



Discharge: 166,000 cfs

Figure 75

# L/D 25 Downstream

## Location 4

## Velocity Vectors & Magnitudes (ft/s)

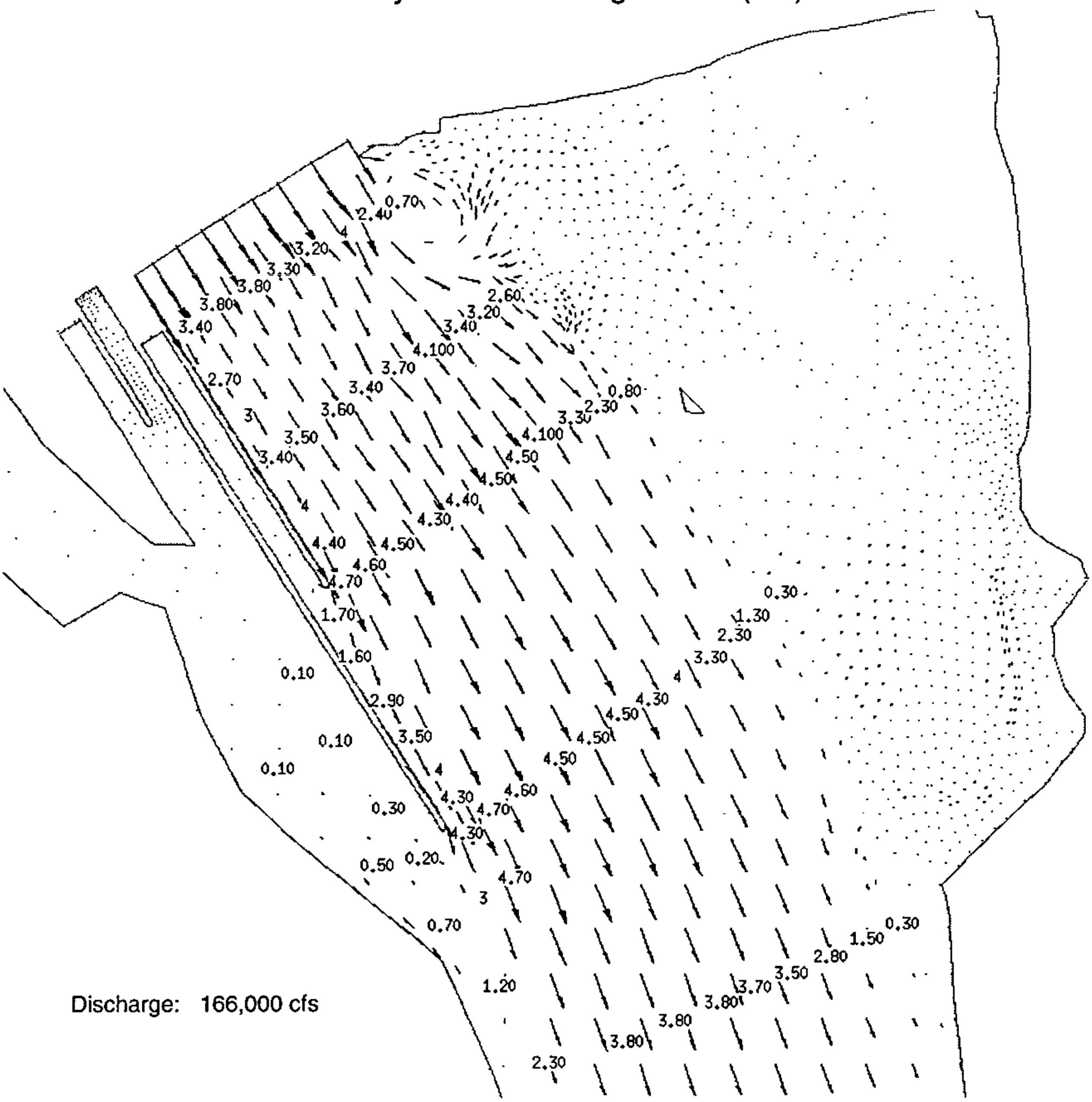



Figure 76

# APPENDIX

# UPPER MISSISSIPPI RIVER & ILLINOIS WATERWAY HYDRAULIC IMPACTS SITE ASSESSMENT

1. In order to appraise the hydraulic impacts to navigation at all of the sites considered for added lock capacity on the Upper Mississippi River and Illinois Waterway site, results of physical and numerical modeling conducted at Lock and Dams 20 thru 25 on the Upper Mississippi River, were extrapolated to assess navigation conditions at Lock and Dams 11 thru 19, and Peoria and La Grange Lock and Dams on the Illinois Waterway. Mapping, aerial photography, and existing approach data, were also utilized, allowing a qualitative assessment of each site to be performed. As necessary, modifications to channel and bank alignment, and the addition of channel training structures, were recommended to improve approach conditions.

2. The following summary is a site by site description of navigation conditions and suggested modifications which would optimize approach conditions at all sites considered for expanded lock capacity. Included are maps showing the location and extent of suggested improvements for each alternative location within a site.

LOCK AND DAM NO. 11

Existing Conditions:

Outdraft is a problem at this site as reported during the initial screening site visit. Downbound tows usually wait about 200' from the upstream end of the doglegged section of the upper guide wall. Upbound tows are able to pass downbound tows at this location. There is a marina downstream of the lock on the right descending riverbank which is a safety concern to tows as there is not a good waiting spot (mooring cell) and tows typically push into the riverbank below the dam. The Lampsillus Higgins Eye is present along the left descending riverbank below the storage yard and this area is a popular fishery. A large scour hole below the dam gates, approximately 60' to 80' deep, extends across the entire gated section of the dam and would have to be filled, at least in part, with any new lock construction at Locations 3 or 4. Small-scale measures should consider a mooring cell at R.M. 584 and another at R.M. 592 (Specht's Landing), where many tows wait. A properly placed mooring cell downstream would lessen the dangerous situation with recreation traffic in the area.

Location 2

Upstream Some channel work should improve the outdraft situation. Reconstruct the existing wing dike at R.M. 583.5 above the lock with an L-head. Add another wing dike about 1000' above the L-head dike, extending the dike from the riverbank about 1000' or where the end almost aligns with the existing lock landside guide wall. Above the last dike add a series of rock vane dikes, with a top elevation 2' below flat pool, to parallel the navigation channel shifted about 500' east. Extend the vane dikes for 3 tow lengths above the end of a new 1200' ported guard wall. Remove the existing guard wall, landside guide wall and guide wall doglegged extension.

Downstream Construct a 1200' riverside guard wall. Open up the left descending bank by shortening the existing wing dikes. An eddy may form at the end of the guard wall which can be controlled with short spur dikes extending from the right descending riverbank and built to 2' above lower pool elevation.

Location 3 (Preferred over Location 4)

Upstream Construct a new 1200' ported guard wall. Remove the existing guard wall. The existing guide wall and doglegged extension can remain. Do the same upstream channel work as for Location 2.

Downstream Construct a new 1200' riverside guard wall. The existing guide wall can remain. Open up the left descending bank by shortening the existing wing dikes. May have eddy currents in the lower lock approach which can be controlled with short spur dikes extending from the right descending riverbank constructed similar as for Location 2.

Location 4 (Really impedes the flow area downstream)

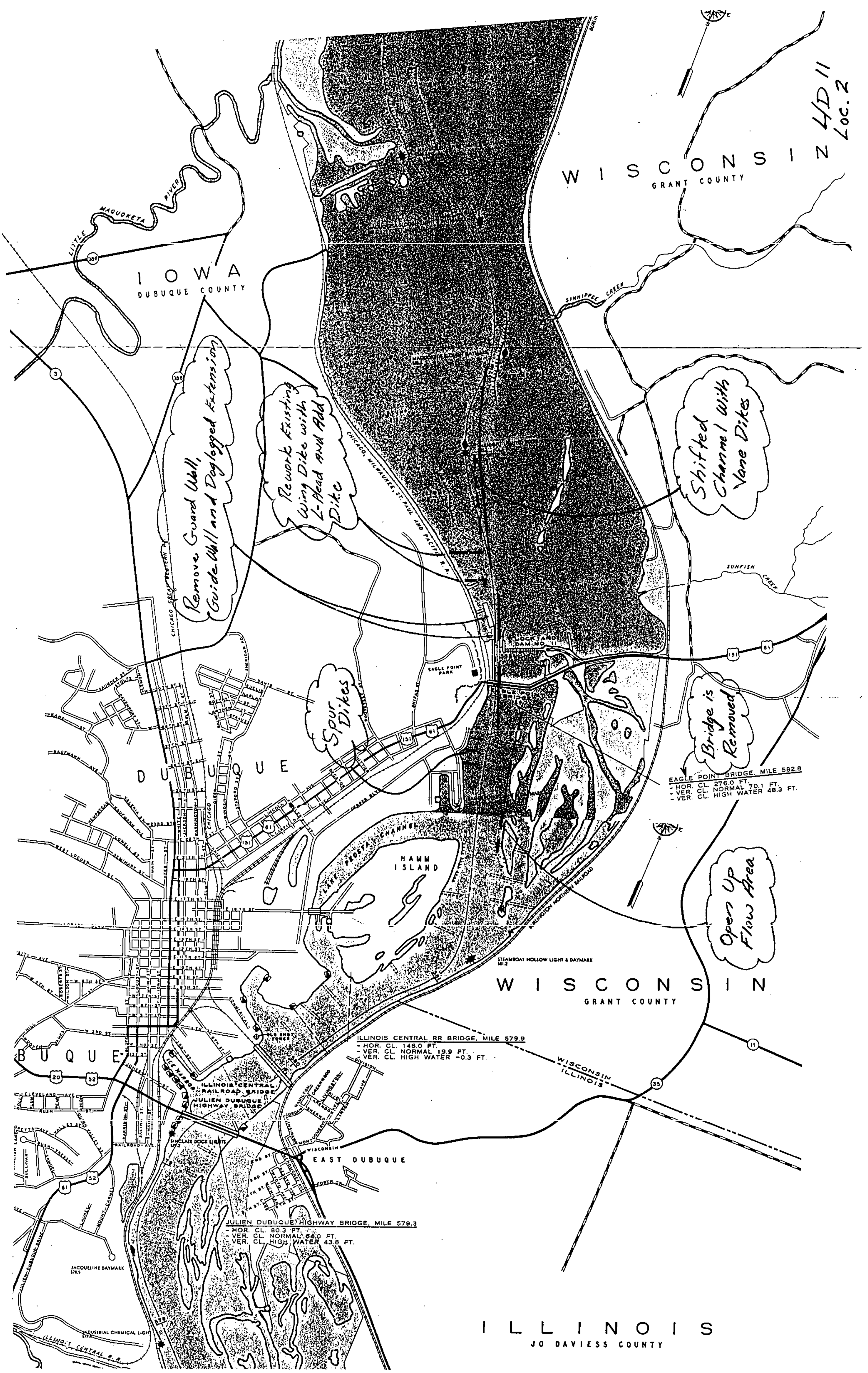
Upstream Construct a new 1200' ported guard wall. May need 400' more guard wall to control increase in outdraft with this location. Remove the existing guard wall. Need the same channel work upstream from the lock as with the other locations. But, the wing dikes become longer and more channel needs to be shifted east to be in straight alignment with the lock. The existing guide wall and doglegged extension can remain.

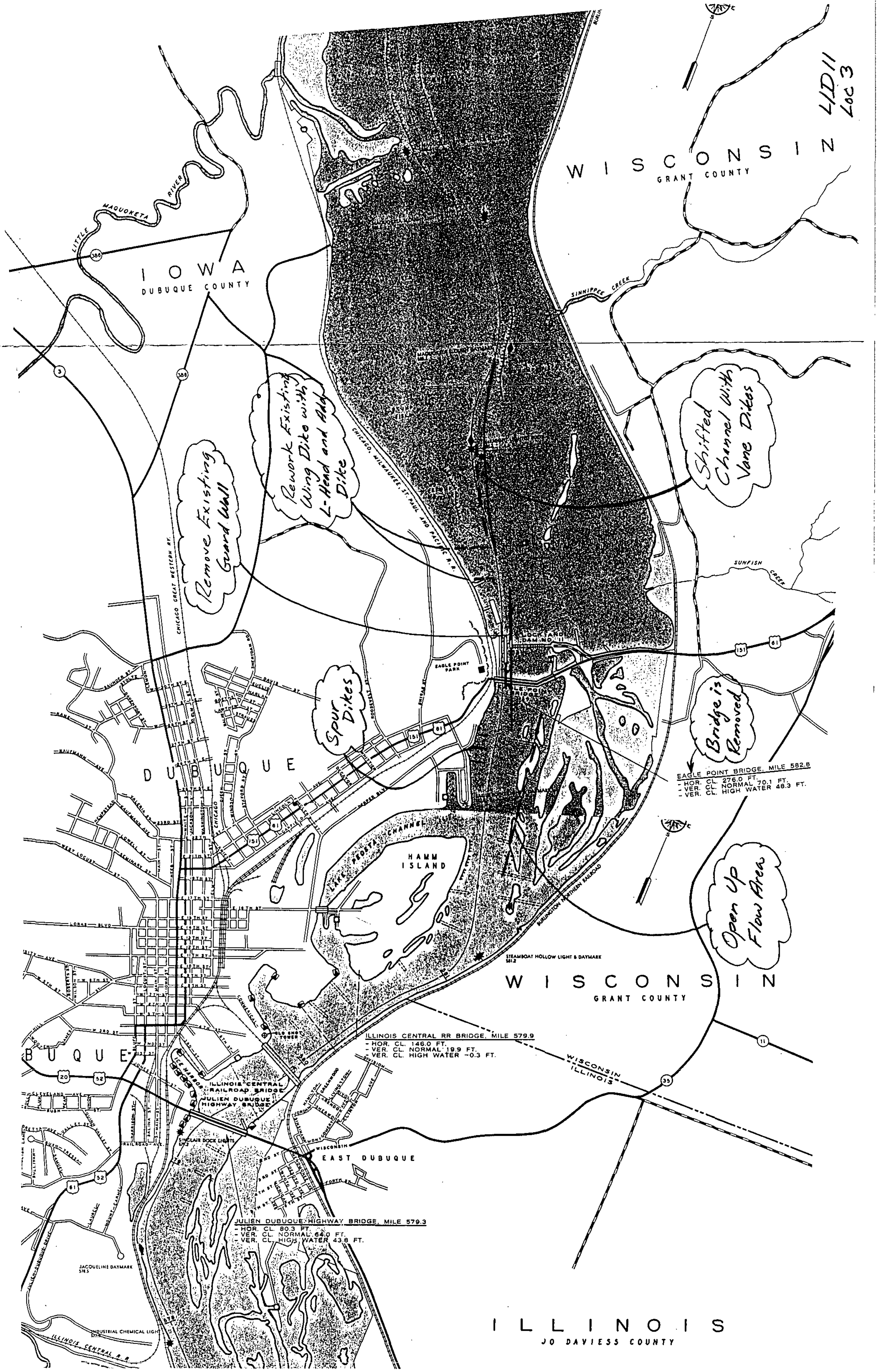
Downstream Construct a 1200' riverside guard wall. More excavation is needed along the left descending riverbank to open up the flow area below the dam. Any additional dam gates at Location 5 to replace those lost to new lock construction will necessitate this even more so. There is greater potential for eddy curents at the end of the guard wall which can be controlled with the dike field as described above for Locations 2 and 3.

Small-Scale Improvements

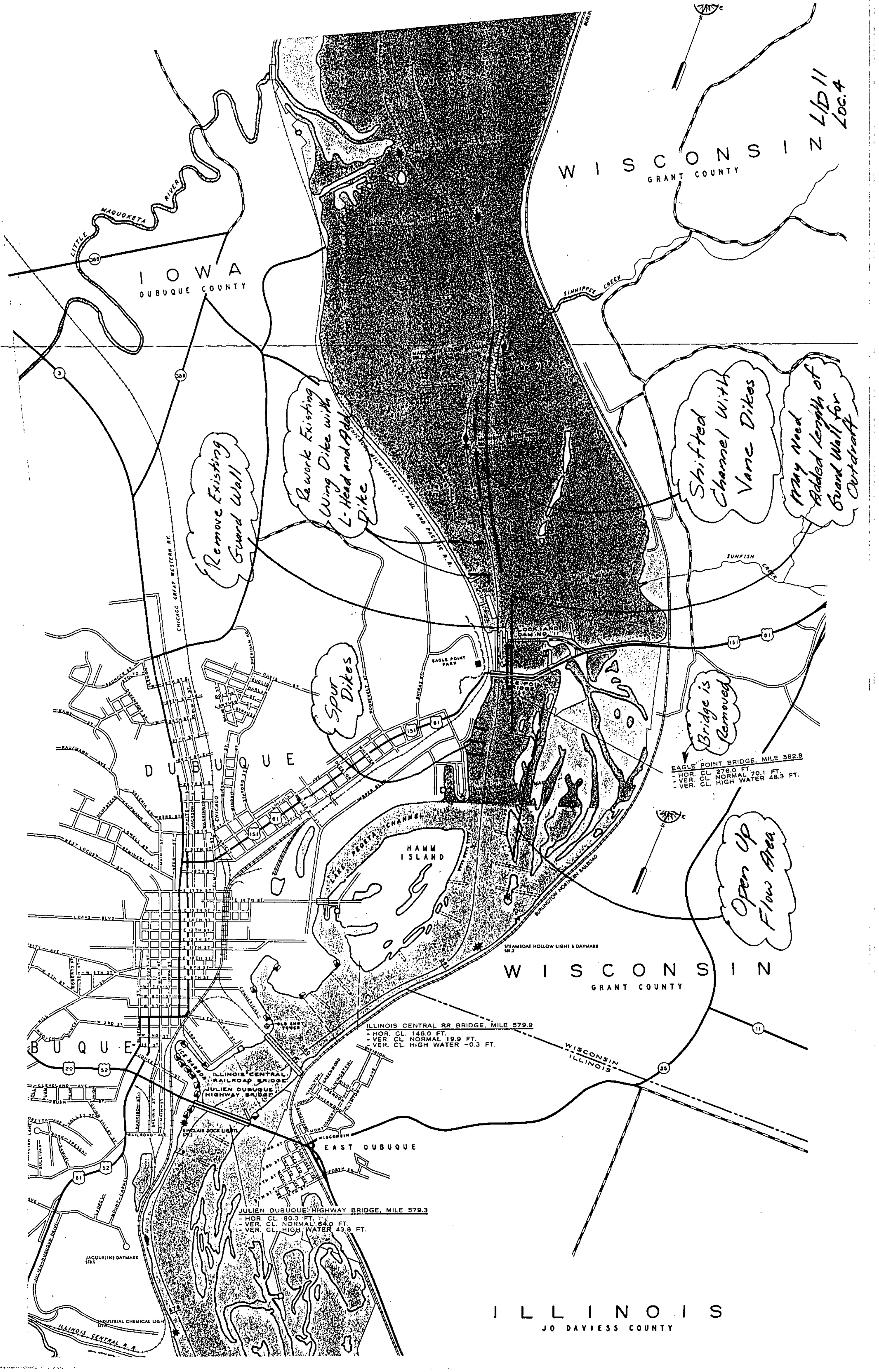
Upstream Add the two wing dikes, the vane dikes and shift the navigation channel east about 500' as described above for Location 2. Remove the existing doglegged rock dike above the guide wall and extend the guide wall to 1200'. Add a short wall angled at 45 degrees from the end of the extended guide wall or a 50' cell for a more forgiving landing area. A better improvement is a 1200' guard wall along with the channel work upstream, especially if the long-term plan is for a Location 2 lock extension. With a 1200' guard wall, the existing guard wall, guide wall and doglegged extension would be removed. The new 1200' guard wall and channel work should give a savings in approach time similar to the Lock 22 model study.

Downstream Extend the guide wall to 1200'. The spur dikes do not have to be added along the right descending riverbank.


4/D 11
Loc. 2
WISCONSIN
GRANT COUNTY
IOWA
DUBUQUE COUNTY
LITTLE MAQUOKETA RIVER
SINNIPPEE CREEK
SUNFISH CREEK
Remove Guard Wall, Guide Wall and Doglegged Extension
Rework Existing Wing Dike with L-Head and Add Dike
Shifted Channel With Vane Dikes
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC R.R.
CHICAGO GREAT WESTERN R.R.
LOCK AND DAM NO. 11
EAGLE POINT PARK
EAGLE POINT BRIDGE
Spur Dikes
Bridge is Removed
EAGLE POINT BRIDGE, MILE 582.8
- HOR. CL. 276.0 FT.
- VER. CL. NORMAL 70.1 FT.
- VER. CL. HIGH WATER 48.3 FT.
DUBUQUE
HAMM ISLAND
LAKE PEOSTA CHANNEL
BURLINGTON NORTHERN RAILROAD
Open Up Flow Area
STEAMBOAT HOLLOW LIGHT & DAYMARK 581.2
WISCONSIN
GRANT COUNTY
ILLINOIS CENTRAL RR BRIDGE, MILE 579.9
- HOR. CL. 146.0 FT.
- VER. CL. NORMAL 19.9 FT.
- VER. CL. HIGH WATER -0.3 FT.
WISCONSIN
ILLINOIS
ICE HARBOR
ILLINOIS CENTRAL RAILROAD BRIDGE
JULIEN DUBUQUE HIGHWAY BRIDGE
SINCLAIR DOCK LIGHTS
EAST DUBUQUE
JULIEN DUBUQUE HIGHWAY BRIDGE, MILE 579.3
- HOR. CL. 80.3 FT.
- VER. CL. NORMAL 64.0 FT.
- VER. CL. HIGH WATER 43.8 FT.
JACQUELINE DAYMARK 578.5
INDUSTRIAL CHEMICAL LIGHT
ILLINOIS CENTRAL R.R.
ILLINOIS
JO DAVIESS COUNTY



L/D11
Loc 3
WISCONSIN
GRANT COUNTY
IOWA
DUBUQUE COUNTY
LITTLE MAQUOKETA RIVER
SINNIPPEE CREEK
SUNFISH CREEK
Remove Existing Guard Wall
Rework Existing Wing Dike with L-Head and Add Dike
Shifted Channel With Vane Dikes
Spur Dikes
Bridge is Removed
Open Up Flow Area
CHICAGO GREAT WESTERN RY.
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC R.R.
EAGLE POINT PARK
DUBUQUE
EAGLE POINT BRIDGE, MILE 582.8
- HOR. CL. 276.0 FT.
- VER. CL. NORMAL 70.1 FT.
- VER. CL. HIGH WATER 48.3 FT.
HAMM ISLAND
LAKE PEOSTA CHANNEL
BURLINGTON NORTHERN RAILROAD
STEAMBOAT HOLLOW LIGHT & DAYMARK
WISCONSIN
GRANT COUNTY
ILLINOIS CENTRAL RR BRIDGE, MILE 579.9
- HOR. CL. 146.0 FT.
- VER. CL. NORMAL 19.9 FT.
- VER. CL. HIGH WATER -0.3 FT.
WISCONSIN
ILLINOIS
ICE HARBOR
ILLINOIS CENTRAL RAILROAD BRIDGE
JULIEN DUBUQUE HIGHWAY BRIDGE
SINCLAIR DOCK LIGHTS
EAST DUBUQUE
JULIEN DUBUQUE HIGHWAY BRIDGE, MILE 579.3
- HOR. CL. 80.3 FT.
- VER. CL. NORMAL 64.0 FT.
- VER. CL. HIGH WATER 43.8 FT.
JACQUELINE DAYMARK
INDUSTRIAL CHEMICAL LIGHT
ILLINOIS CENTRAL R.R.
ILLINOIS
JO DAVIESS COUNTY



L/D 11
Loc. 4
WISCONSIN
GRANT COUNTY
IOWA
DUBUQUE COUNTY
LITTLE MAQUOKETA RIVER
SINNIPPEE CREEK
SUNFISH CREEK
Remove Existing Guard Wall
Rework Existing Wing Dike with L-Head and Add Dike
Shifted Channel With Vane Dikes
May Need Added Length of Guard Wall for Outdraft
Spur Dikes
Bridge is Removed
Open Up Flow Area
CHICAGO GREAT WESTERN RY.
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC R.R.
LOCK AND DAM NO. 11
EAGLE POINT PARK
DUBUQUE
EAGLE POINT BRIDGE, MILE 582.8
- HOR. CL. 276.0 FT.
- VER. CL. NORMAL 70.1 FT.
- VER. CL. HIGH WATER 48.3 FT.
LAKE PEOSTA CHANNEL
HAMM ISLAND
BURLINGTON NORTHERN RAILROAD
STEAMBOAT HOLLOW LIGHT & DAYMARK
WISCONSIN
GRANT COUNTY
ILLINOIS CENTRAL RR BRIDGE, MILE 579.9
- HOR. CL. 146.0 FT.
- VER. CL. NORMAL 19.9 FT.
- VER. CL. HIGH WATER -0.3 FT.
WISCONSIN
ILLINOIS
ICE HARBOR
ILLINOIS CENTRAL RAILROAD BRIDGE
JULIEN DUBUQUE HIGHWAY BRIDGE
SINCLAIR DOCK LIGHTS
EAST DUBUQUE
JULIEN DUBUQUE HIGHWAY BRIDGE, MILE 579.3
- HOR. CL. 80.3 FT.
- VER. CL. NORMAL 64.0 FT.
- VER. CL. HIGH WATER 43.8 FT.
JACQUELINE DAYMARK
INDUSTRIAL CHEMICAL LIGHT
ILLINOIS CENTRAL R.R.
ILLINOIS
JO DAVIESS COUNTY

## LOCK AND DAM NO. 12

Existing Conditions:

Outdraft is a problem at this site as reported during the initial screening site visit. In addition there is a poor exit condition going downstream. As tows leave the lock, they have to "flank out" to get away from the wall and avoid a wing dam just below Mill Creek. Downstream there is some interference with recreation traffic as there is a city dock just downstream of the lock. With a downstream extension of the existing lock access to the dock could be partially or completely shut off and tows would have a difficult time making it back to the channel exiting 600' downstream of their present exit. For Location 2, only an upstream extension was thought possible. Lock personnel thought the upstream outdraft problem could be solved with a 1000' solid extension of the landside guide wall. It was also thought that because of the downstream approach/exit conditions tows may have difficulty making it back to the channel with a downstream extension of a Location 3 lock. A downstream extension at Location 3 would limit the use of the existing lock to smaller vessels. A large scour hole below the dam gates, approximately 90' deep, extends across the entire gated section of the dam and would have to be filled, at least in part, with any new lock construction at Locations 3 or 4. The existing mooring cell upstream of the lock at R.M. 557.4 is well placed for the existing lock usage.

Location 2 (Upstream Lock Extension)

Upstream Construct a new 1200' ported guard wall. Consider removing the mooring cell at R.M. 557.4 and placing a new cell upstream. May have to do some bank shaping upstream to provide 150' opening at navigation depth at the start of the guard wall. Also may have to shift channel landward to provide a straight approach of 2 tow lengths above the guard wall.

Downstream Extend the landside guide wall. May require some channel work extending 2 tow lengths downstream to improve downstream exit condition. Open up the channel along the left descending riverbank by removing 200' to 400' from the ends of the wing dikes for a distance of about 5000' below the dam.

Location 2 (Downstream Lock Extension)

Upstream Construct a new 1200' ported guard wall. Remove the existing guide wall and slope the riverbank to provide 150' opening at navigation depth at start of guard wall. Angle a wing wall from the end of the landside lock wall to the newly sloped bankline. Leave the bankline where it is upstream of the existing guide wall and excavate the bank upstream of the new ported guard wall to provide a straight approach of 2 tow lengths above the guard wall. Consider removing the mooring cell at R.M. 557.4 and placing a new cell upstream.

Downstream Construct a 1200' landside guide wall. Channel work extending 2 tow lengths downstream may be required to improve the downstream exit condition. Open up the channel along the left descending riverbank to parallel the right bank by removing 200' to 400' from the ends of the wing dikes for a distance of about 5000' below the dam. Remove the wing dike below Mill Creek. May have to excavate the riverbank at the end of the new guide wall for access to the public docking facilities. The new guide wall will offer some protection to the public docking facility but also cut-off its view.

Location 3 (Upstream Extension)

Upstream Construct a new 1200' ported guard wall. Add a rubbing surface on a part of the new lock wall for tows to land on when using the existing lock. Consider removing the mooring cell at R.M. 557.4 and placing a new cell upstream. May have to do some channel widening for access to the existing lock and to provide a straight approach of 2 tow lengths above the guard wall.

Downstream A landside guide wall will present problems as tows will be too close to the flow from the dam gates. Construct a 1200' riverside wall. Remove the wing dike below Mill Creek and do some channel widening for 2 tow lengths below the new riverside wall to improve and make room for the downbound exit and upbound approach. Open up the channel along the left descending riverbank to parallel the right bank by removing about 200' to 400' from the ends of the wing dikes for a distance of 5000' below the dam.

Location 3 (Downstream Extension) **PROBABLY THE BEST PLAN**

Upstream Construct a 1200'ported guard wall. Leave the existing guide wall in place and fill in the bankline above the guide wall with rock fill, tapering back to the existing riverbank about 0.4 mile above the end of the guide wall. Consider removing the mooring cell at R.M. 557.4 to open up the channel and placing a new cell upstream.

Downstream Construct a new 1200' landside guide wall. Try to keep water velocity to a maximum of 5 to 6fps under navigation conditions so downbound tows can move off the wall and are not pinned by side currents. Remove the wing dike below Mill Creek. Open up the channel along the left descending riverbank to parallel the right bank by removing about 200' to 400' from the ends of the wing dikes for a distance of 5000' below the dam. This locaction limits the use of the existing lock to smaller tows and recreation traffic.

Location 4 (Downstream Extension)

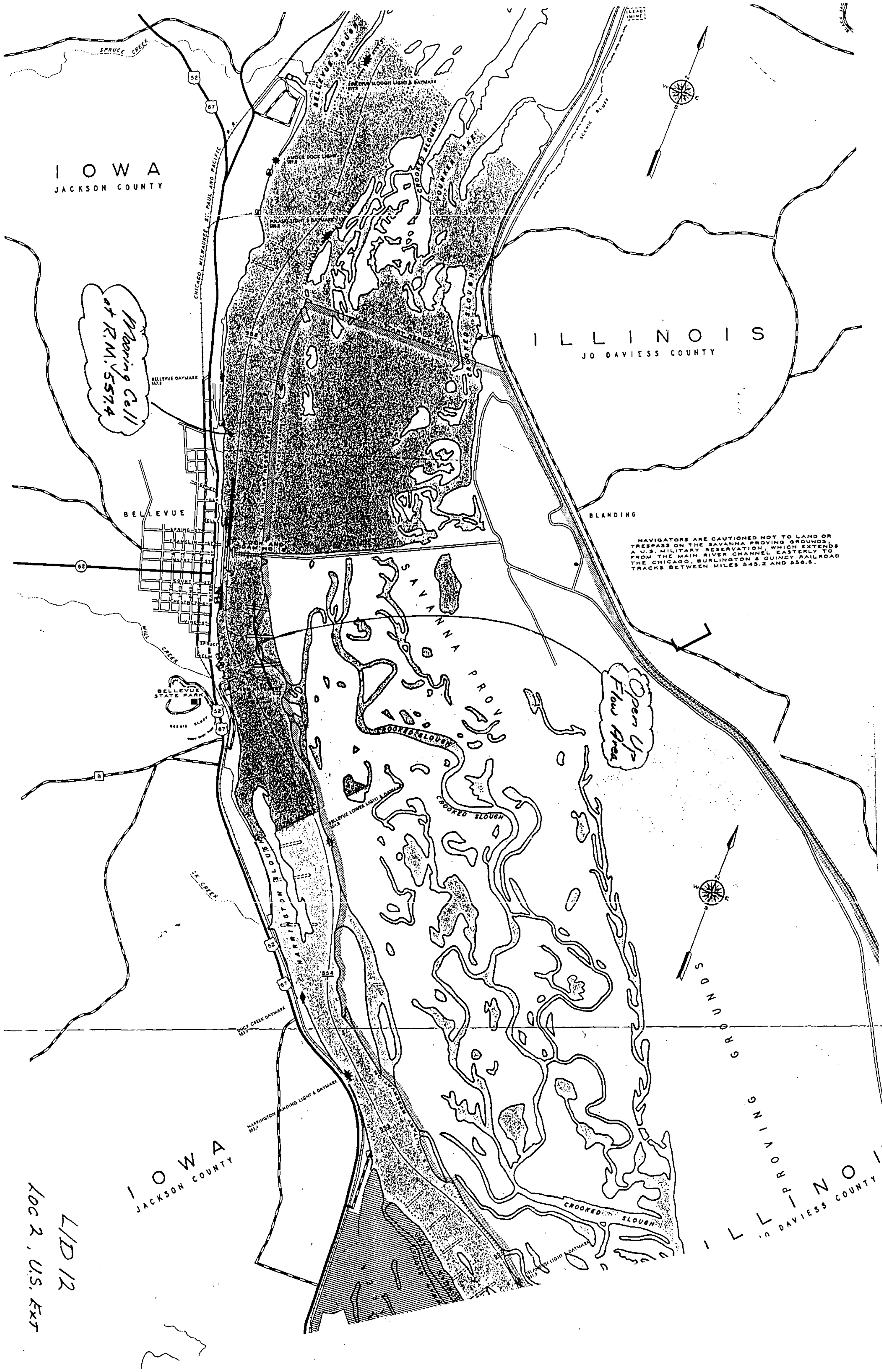
Upstream Construct a 1200' guard wall. Leave the existing guide wall in place and fill in the bankline above the guide wall with rock fill, tapering back to the existing riverbank about 0.4 mile above the end of the guide wall.

Downstream For navigation, a 1200' guard wall is preferred. Could use a 1200' landside guide wall and lessen the downstream channel work along the right descending bank. Should keep the maximum flow velocity to 5 to 6fps so downbound tows are not pinned to the wall by side currents. Open the channel along the left descending riverbank by removing about 200' to 400' from the ends of the wing dikes for a distance of 5000' below the dam. Any additional dam gates at Location 5 to replace those gates lost to new lock construction will necessitate opening the flow area even more so.

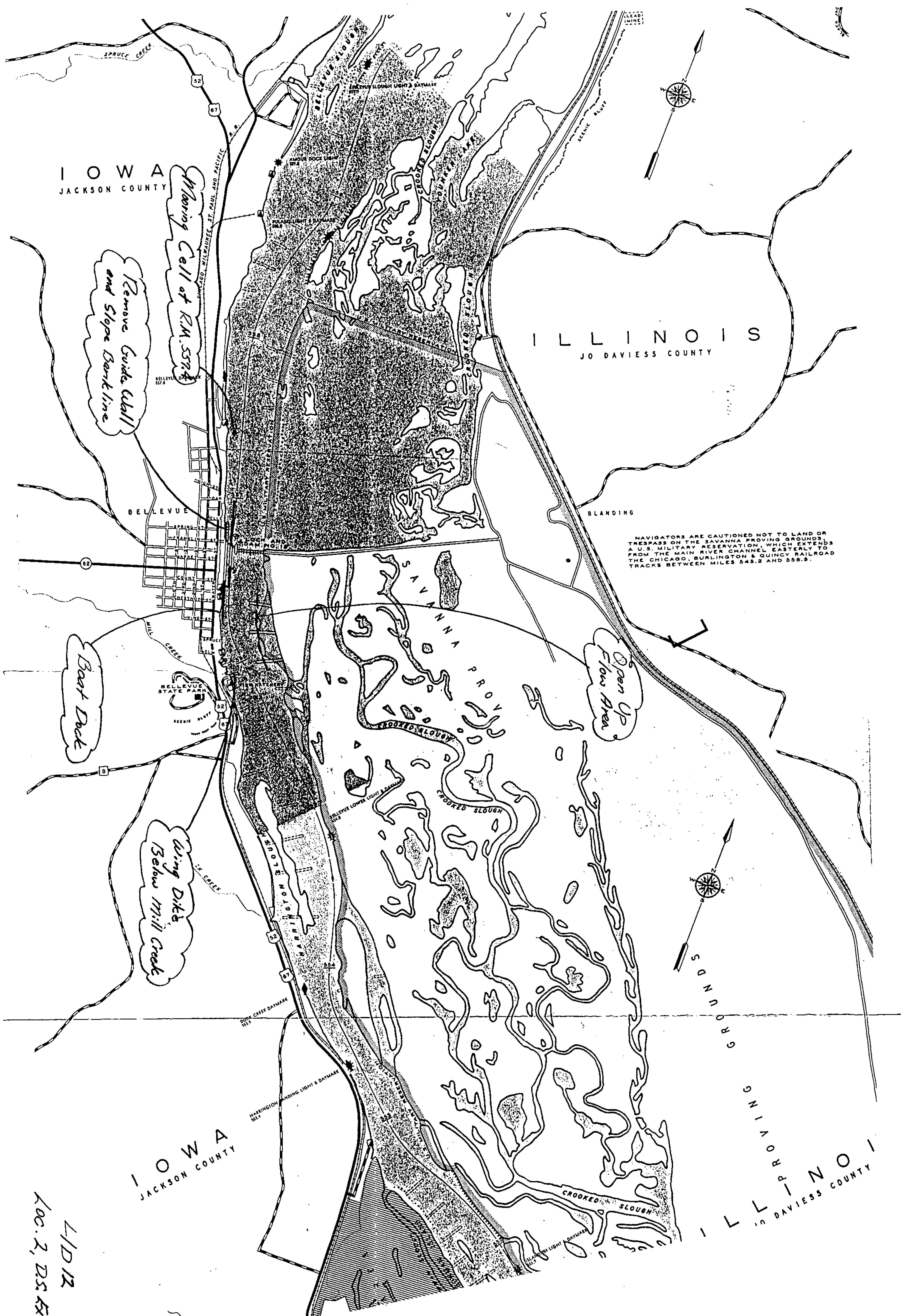
Small-Scale Improvements

Upstream Add a 1200' guard wall, remove the existing guide wall and slope the riverbank to give a 150' opening at navigation depth at the end of the guard wall OR extend the existing guide wall to 1200' and fill in the bankline above the extended guide wall with rock fill. The outdraft condition will still exist but should be improved.

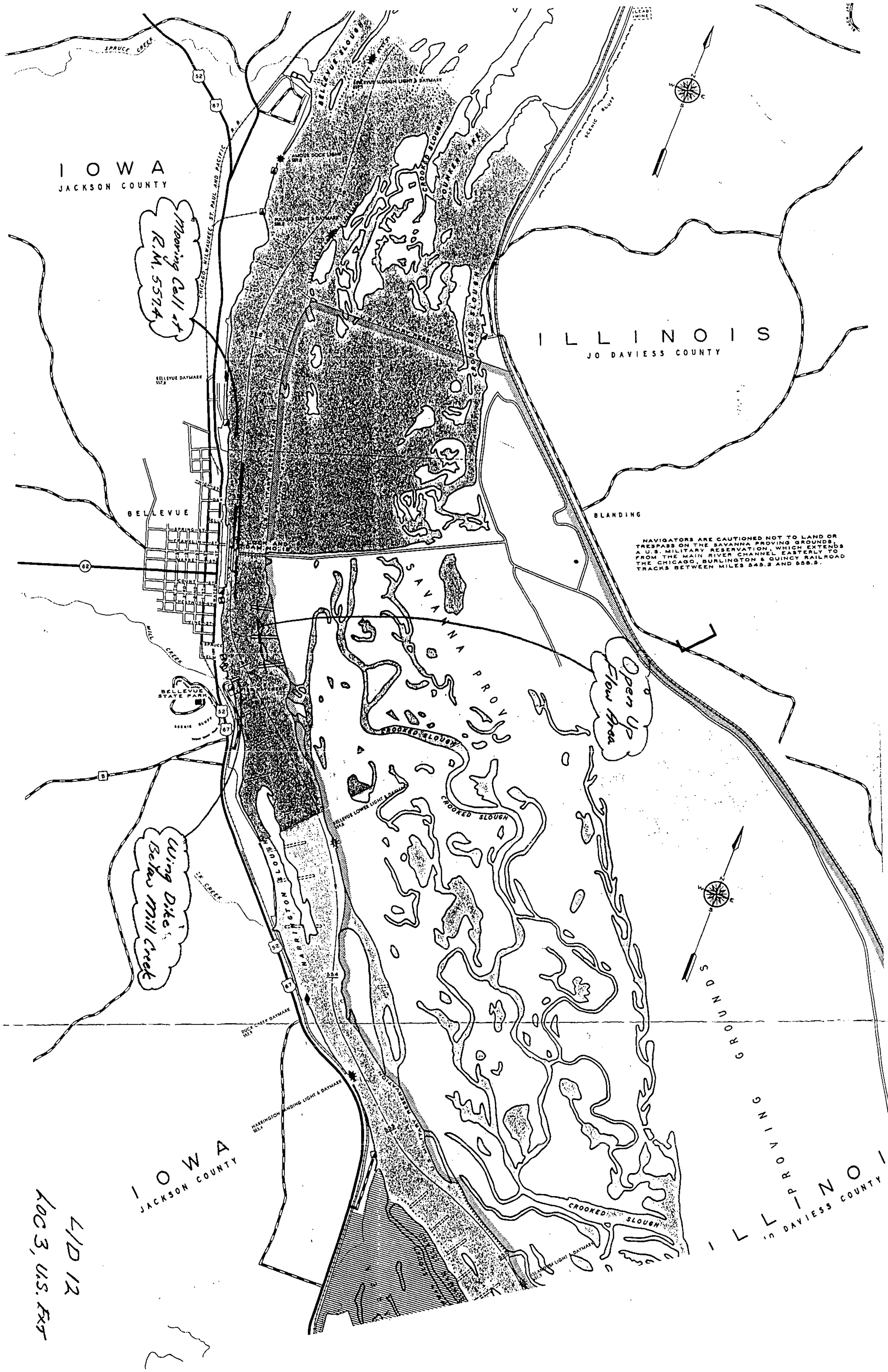
Downstream Extend the landside guide wall to 1200'. Open up the flow area along the left descending riverbank to parallel the right bank by removing about 200' to 400' from the ends of the wing dikes for a distance of 5000' below the dam. (This may require a study before implementing) Remove the wing dike below Mill Creek.

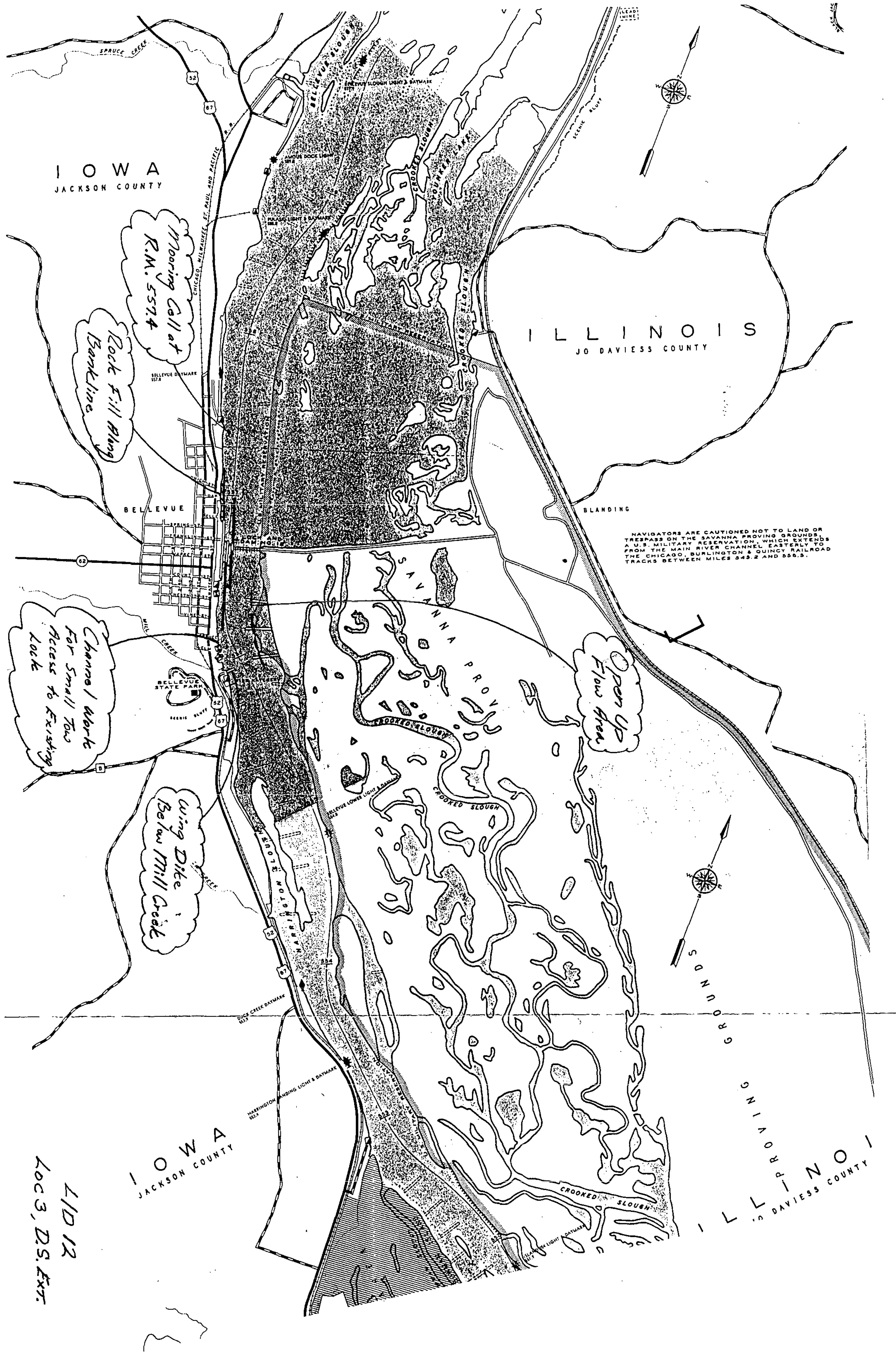


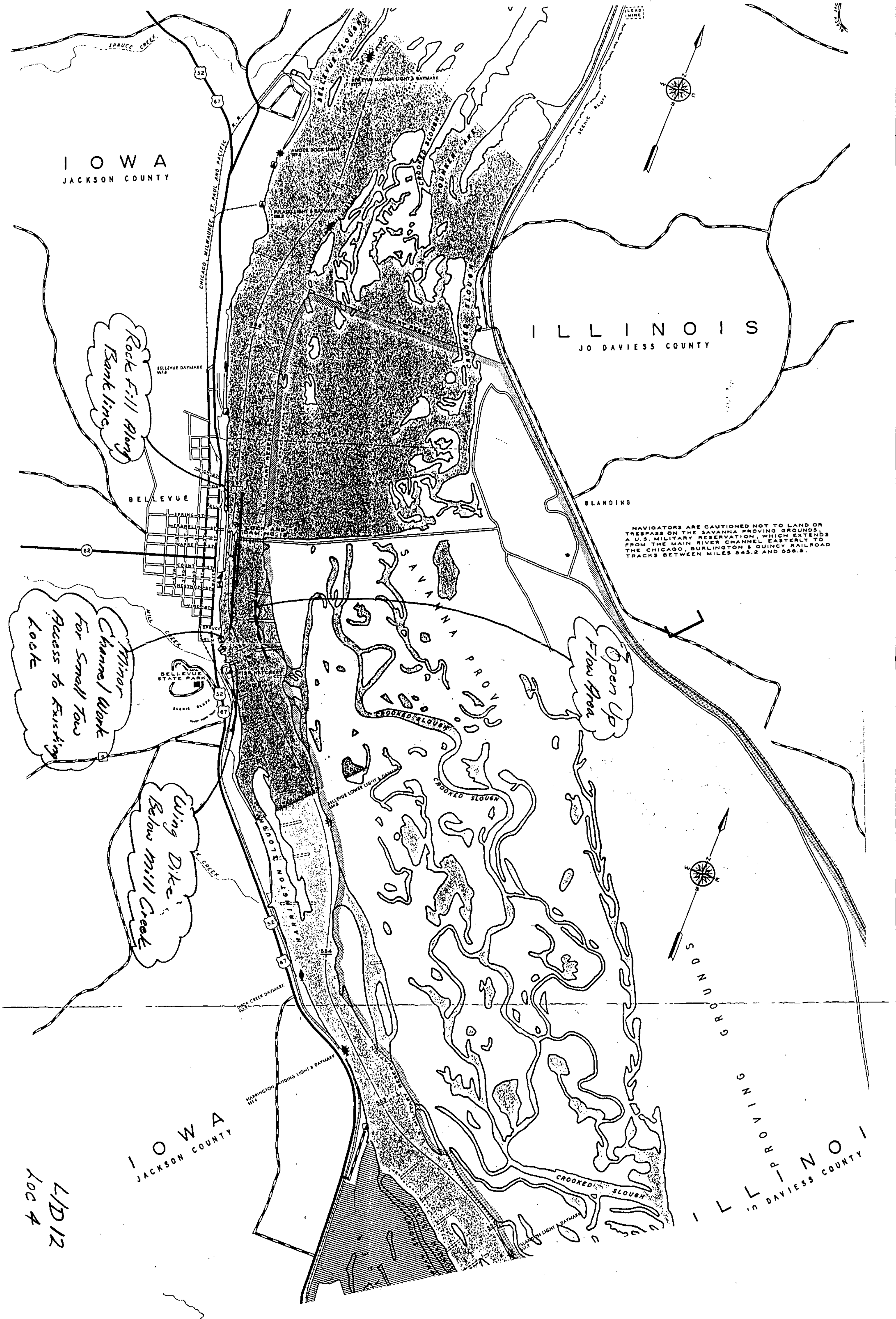
IOWA
JACKSON COUNTY
ILLINOIS
JO DAVIESS COUNTY
SPRUCE CREEK
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC R.R.
BELLEVUE SLOUGH
BELLEVUE SLOUGH LIGHT & DAYMARK
CROOKED SLOUGH
BELLEVUE DAYMARK 557.8
Mooring Cell at R.M. 557.4
BELLEVUE
MILL CREEK
BELLEVUE STATE PARK
SCENIC BLUFF
BLANDING
NAVIGATORS ARE CAUTIONED NOT TO LAND OR TRESPASS ON THE SAVANNA PROVING GROUNDS, A U.S. MILITARY RESERVATION, WHICH EXTENDS FROM THE MAIN RIVER CHANNEL EASTERLY TO THE CHICAGO, BURLINGTON & QUINCY RAILROAD TRACKS BETWEEN MILES 545.2 AND 558.5.
SAVANNA PROVING GROUNDS
Open Up Flow Area
BELLEVUE LOWER LIGHT & DAYMARK
HARRINGTON SLOUGH
DUCK CREEK DAYMARK
HARRINGTON LANDING LIGHT & DAYMARK
L/D 12
Loc 2, U.S. Ext




L/D 12
Loc. 2, D.S. Ext.


IOWA
JACKSON COUNTY
ILLINOIS
JO DAVIESS COUNTY
BELLEVUE
BELLEVUE STATE PARK
BLANDING
SPRUCE CREEK
MILL CREEK
BELLEVUE SLOUGH
CROOKED SLOUGH
HARRINGTON SLOUGH
SAVANNA PROV
GROUNDS
PROVING
BELLEVUE DAYMARK 557.8
DUCK CREEK DAYMARK
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC
NAVIGATORS ARE CAUTIONED NOT TO LAND OR TRESPASS ON THE SAVANNA PROVING GROUNDS, A U.S. MILITARY RESERVATION, WHICH EXTENDS FROM THE MAIN RIVER CHANNEL EASTERLY TO THE CHICAGO, BURLINGTON & QUINCY RAILROAD TRACKS BETWEEN MILES 545.2 AND 556.5.
Mooring Cell at R.M. 557.4
Open Up Flow Area
Wing Dike; Below Mill Creek
L/D 12
Loc 3, U.S. Ext


IOWA
JACKSON COUNTY
ILLINOIS
JO DAVIESS COUNTY
BELLEVUE
BELLEVUE STATE PARK
BLANDING
SPRUCE CREEK
MILL CREEK
BELLEVUE SLOUGH
CROOKED SLOUGH
HARRINGTON SLOUGH
SAVANNA PROVING GROUNDS
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC R.R.
BELLEVUE DAYMARK 557.8
BELLEVUE LOWER LIGHT & DAYMARK
DEEP CREEK DAYMARK
HARRINGTON LANDING LIGHT & DAYMARK
NAVIGATORS ARE CAUTIONED NOT TO LAND OR TRESPASS ON THE SAVANNA PROVING GROUNDS, A U.S. MILITARY RESERVATION, WHICH EXTENDS FROM THE MAIN RIVER CHANNEL EASTERLY TO THE CHICAGO, BURLINGTON & QUINCY RAILROAD TRACKS BETWEEN MILES 543.2 AND 556.3.
Mooring Cell at R.M. 557.4
Rock Fill Along Bankline
Channel Work For Small Tow Access to Existing Lock
Wing Dike Below Mill Creek
Open Up Flow Area
L/D 12
Loc 3, D.S. Ext.


IOWA
JACKSON COUNTY
ILLINOIS
JO DAVIESS COUNTY
SPRUCE CREEK
BELLEVUE
BLANDING
BELLEVUE STATE PARK
BELLEVUE DAYMARK 557.8
CROOKED SLOUGH
HARRINGTON SLOUGH
SAVANNA PROVING GROUNDS
NAVIGATORS ARE CAUTIONED NOT TO LAND OR TRESPASS ON THE SAVANNA PROVING GROUNDS, A U.S. MILITARY RESERVATION, WHICH EXTENDS FROM THE MAIN RIVER CHANNEL EASTERLY TO THE CHICAGO, BURLINGTON & QUINCY RAILROAD TRACKS BETWEEN MILES 545.2 AND 556.5.
Rock Fill Along Bankline
Minor Channel Work For Small Tow Access to Existing Lock
Wing Dike's Below Mill Creek
Open Up Flow Area
L/D12
Loc 4

## LOCK AND DAM NO. 13

Existing Conditions:

Outdraft is not a problem at this site. The pool is very wide and wind can be a problem for tows to navigate against especially when pushing empty barges. The prevailing winds from the west can help downbound tows approach the lock by pushing them against the upper guide wall but the winds also accumulate ice around the upper lock gates. The lock is very makeable and the mooring cell upstream of the lock is in a good location. Lock personnel feel that conditions could be improved by placing a guide cell 300' above the intermediate wall.

Location 2

Upstream Extend the guide wall to 1200'. The existing dike above the guide wall is the reason why there is no outdraft problem now and the dike should be left in place beyond the end of the extended guide wall. No upstream channel work is needed.

Downstream Extend the guide wall to 1200'. Should have little or no channel work.

Location 3

Upstream Construct a new 1200' ported guard wall. Leave the existing guide wall and dike above it in place. May have to extend the dike another 1000' upstream to get added protection from outdraft for a distance of 3 tow lengths above the lock. Outdraft potential increases with a Location 3 lock.

Downstream Construct a 1200' riverside guard wall. Additional channel work or bank excavation is required to provide a 200'+/- wide canal for a distance of about 1 1/2 tow lengths below the riverside wall for smaller vessels and recreation traffic using the existing lock.

Location 4 (As close as possible to the auxiliary bay)

Upstream Construct a new 1200' ported guard wall. Leave the existing guide wall and dike above it in place. Will have to extend the dike another 1000' or so upstream to get added protection from outdraft for a distance of 3 tow lengths above the lock.

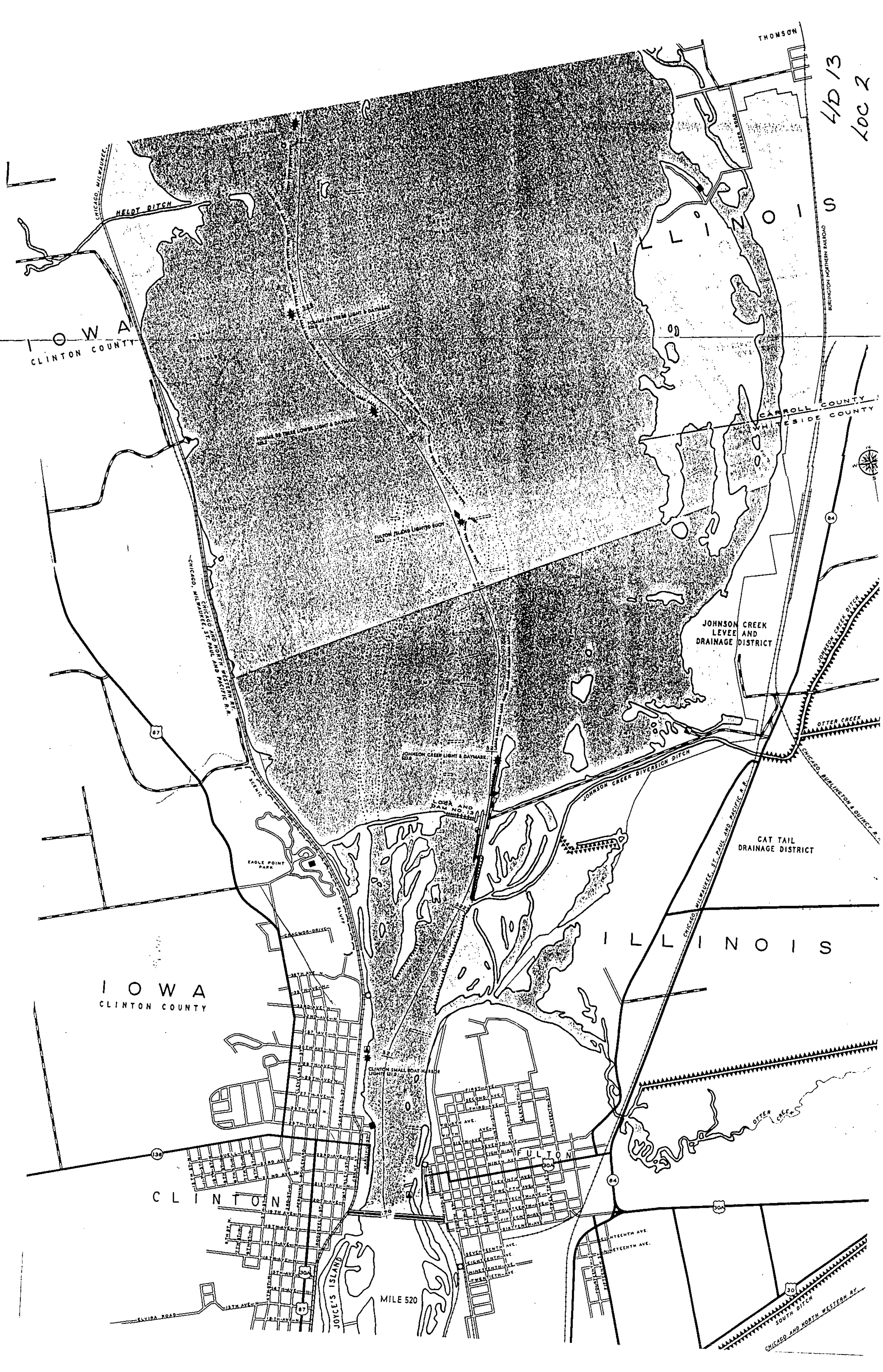
Downstream Construct a 1200' riverside guard wall. May require a little bank excavation or shaping at the end of the wall for smaller vessels and recreation traffic to access the existing 600' lock.

This location will restrict the flow area downstream of the dam. Should open up the right descending bank by removing wing dikes and bankline below the dam. This is also needed to accommodate any replacement dam gates located in the storage yard area to makeup for dam gates lost to new lock construction.

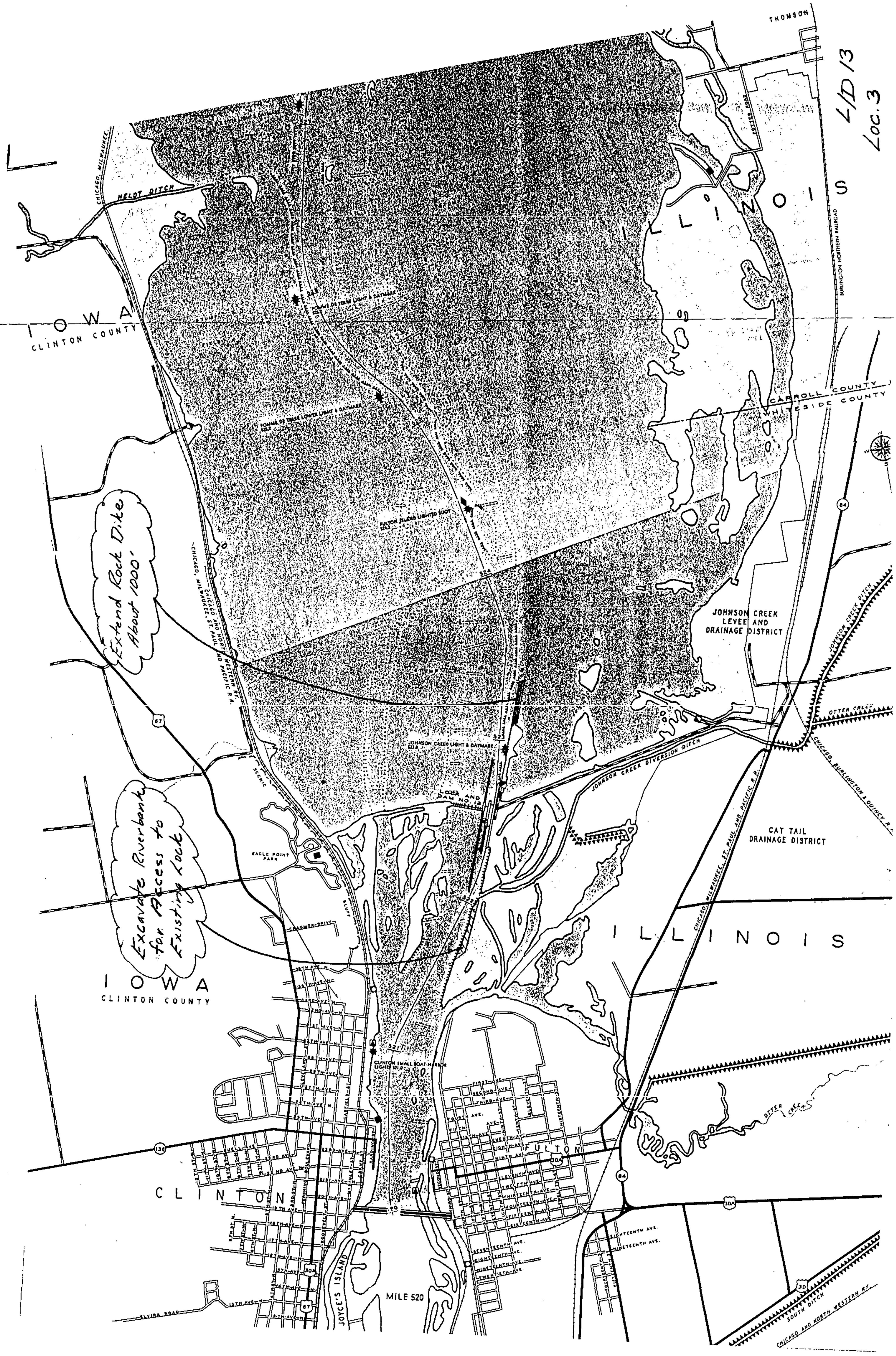
Small-Scale Improvements

Upstream Extend the guide wall and leave remaining dike in place above the extended wall. Approach time is not significantly improved. May want to consider short stub wall 50' to 75' long angled at 5 to 10 degrees at the end of the intermediate wall in lieu of a guide cell as exisiting conditions suggest. Don't want to do anything to diminish the existing transit time through the lock under existing conditions.

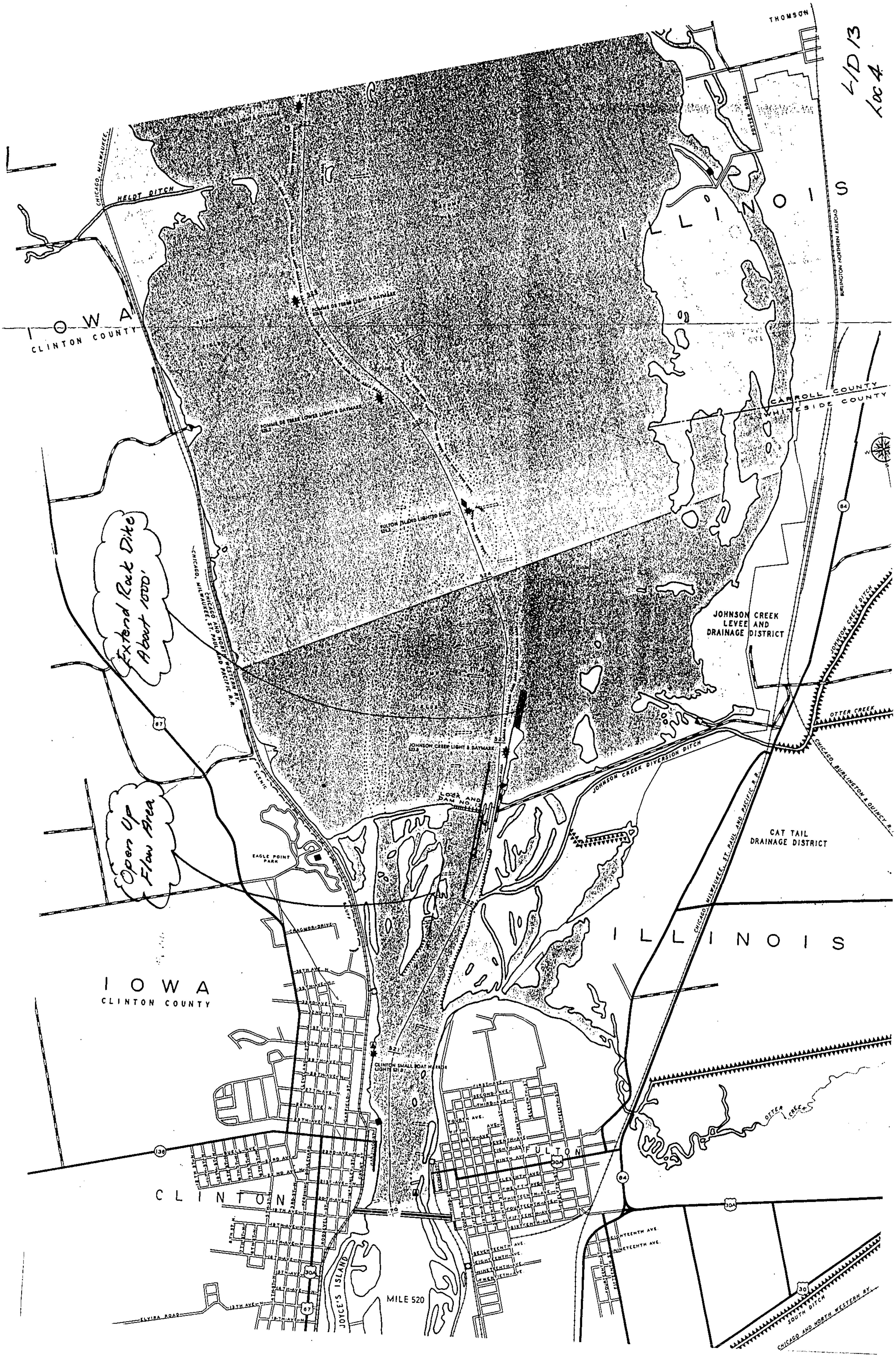
Downstream Extend the landside guide wall.



THOMSON
4D 13
Loc 2
HELDT DITCH
CHICAGO, MILWAUKEE
IOWA
CLINTON COUNTY
ILLINOIS
BURLINGTON NORTHERN RAILROAD
POTTERS ROAD
CARROLL COUNTY
WHITESIDE COUNTY
84
JOHNSON CREEK LEVEE AND DRAINAGE DISTRICT
JOHNSON CREEK DITCH
OTTER CREEK
CHICAGO, BURLINGTON & QUINCY R.R.
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC R.R.
CHICAGO AND NORTH WESTERN RY.
JOHNSON CREEK DIVERSION DITCH
JOHNSON CREEK LIGHT & DAYMARK
FULTON ISLAND LIGHTED BUOY
POMME DE TERRE LOWER LIGHT & DAYMARK
POMME DE TERRE LIGHT & DAYMARK
LOCK AND DAM NO. 13
67
EAGLE POINT PARK
SCENIC
BLUFF
CRAGMOR DRIVE
CAT TAIL DRAINAGE DISTRICT
IOWA
CLINTON COUNTY
ILLINOIS
CLINTON SMALL BOAT HARBOR LIGHTS 521.8
136
CLINTON
FULTON
30A
84
30
JOYCE'S ISLAND
MILE 520
ELVIRA ROAD
SOUTH DITCH
OTTER CREEK



L/D 13
Loc. 3
THOMSON
ILLINOIS
IOWA
CLINTON COUNTY
CARROLL COUNTY
WHITESIDE COUNTY
HELDT DITCH
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC R.R.
CHICAGO AND NORTH WESTERN RY.
BURLINGTON NORTHERN RAILROAD
POTTER ROAD
Extend Rock Dike About 1000'
Excavate Riverbank for Access to Existing Lock
JOHNSON CREEK LEVEE AND DRAINAGE DISTRICT
JOHNSON CREEK DITCH
JOHNSON CREEK DIVERSION DITCH
JOHNSON CREEK LIGHT & DAYMARK
FULTON ISLAND LIGHTED BUOY
POMME DE TERRE LOWER LIGHT & DAYMARK
POMME DE TERRE LIGHT & DAYMARK
LOCK AND DAM NO. 13
OTTER CREEK
CHICAGO, BURLINGTON & QUINCY R.R.
CAT TAIL DRAINAGE DISTRICT
EAGLE POINT PARK
SCENIC
CRAGMOR DRIVE
CLINTON SMALL BOAT HARBOR LIGHT
CLINTON
FULTON
JOYCE'S ISLAND
MILE 520
ELVIRA ROAD
SOUTH DITCH
67
136
30A
84
30



4/D13
Loc 4
THOMSON
ILLINOIS
IOWA
CLINTON COUNTY
CARROLL COUNTY
WHITESIDE COUNTY
HELDT DITCH
Extend Rock Dike About 1000'
Open Up Flow Area
CHICAGO AND NORTH WESTERN R.R.
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC R.R.
JOHNSON CREEK LEVEE AND DRAINAGE DISTRICT
JOHNSON CREEK DIVERSION DITCH
JOHNSON CREEK DITCH
OTTER CREEK
CHICAGO, BURLINGTON & QUINCY R.R.
CAT TAIL DRAINAGE DISTRICT
LOCK AND DAM NO. 13
EAGLE POINT PARK
SCENIC
BURLINGTON NORTHERN RAILROAD
POTTER ROAD
JOHNSON CREEK LIGHT & DAYMARK
ILLINOIS
IOWA
CLINTON COUNTY
CLINTON
FULTON
JOYCE'S ISLAND
MILE 520
ELVIRA ROAD
CHICAGO AND NORTH WESTERN RY.
SOUTH DITCH

## LOCK AND DAM NO. 14

Existing Conditions:

Downbound tows leave the main channel with its stronger current and angle into the slower moving water above the lock. Then they stop, pull the stern eastward to line up with the lock, and continue downstream. Upbound tows cross the main channel with its stronger current as they approach the lock. Once they cross the main channel a secondary current pushes them west toward the downstream guide wall. This aligns the tow for the lockage. This same current requires downbound tows to start turning east after they exit the lock to avoid being pushed aground downstream of the lock. There are no waiting areas near the lock for upbound or downbound tows to wait. During the site visit it was mentioned that a mooring cell downstream in the "wide spot" just upstream of the Campbell's Light and Day Mark should be a No. 1 priority. Downbound tows would benefit with cells at R.M. 493.5 and 494.5. The 80' by 320' auxiliary lock landward of the main lock is used mainly on weekends for recreation traffic. This smaller lock outlets the environmentally and historically sensitive Old Le Claire Canal which is about 5.5 feet deep. The initial site screening for new lock construction screened out Locations 3 (the smaller lock), 5, and 6.

Location 1 This location is directly landward of the existing 600' lock, between it and the smaller 320' lock. After reviewing the needed channel relocation work to accommodate this location including 1.4 million cubic yards of excavation, most of which is rock, this location was also screened out.

Location 2

Upstream The criteria for having a straight distance of two tow lengths above the end of the guide wall for the downbound approach can be relaxed somewhat because of the lower flow velocities above the lock. In general velocities in excess of 3 fps start to create problems for the approach. However, even for one tow length there is significant channel work required which impacts the properties and recreation harbor above the lock. A 1200' ported guard wall is preferred if tows can get landside of the wall with the needed channel work. The existing guard wall would be removed as well as the guide wall and the bankline sloped back to give an opening of 150' at navigation depth at the end of the new guard wall If the channel work impacts the area too much, extension of the existing guide wall to 1200' would suffice but the approach would be the same as it is now with little improvement.

Downstream A 1200' landside guide wall. No channel improvement should be needed to keep the smaller lock open to smaller vessels including recreation traffic.

Location 4

Recommend no dam gates between the new lock and the existing lock. Can possibly handle one dam gate. If the final arrangement has the lock moved farther out into the dam, may need protection cells above the dam gates between the new lock and the existing lock. This location offers a better opportunity to get tows on the landside of a new ported guard wall.

Upstream Remove the existing guard wall. Construct a new 1200' ported guard wall. Location 2 may be preferred if more than one dam gate is needed between the new and the existing lock.

Downstream A 1200' landside wall is preferred from a navigation standpoint but this would require channel work and bank excavation along the right descending riverbank for smaller tows to use the existing lock. This work is in a known bald eagle roosting area. A 1200' riverside guard wall will lessen the channel and bankline work needed.

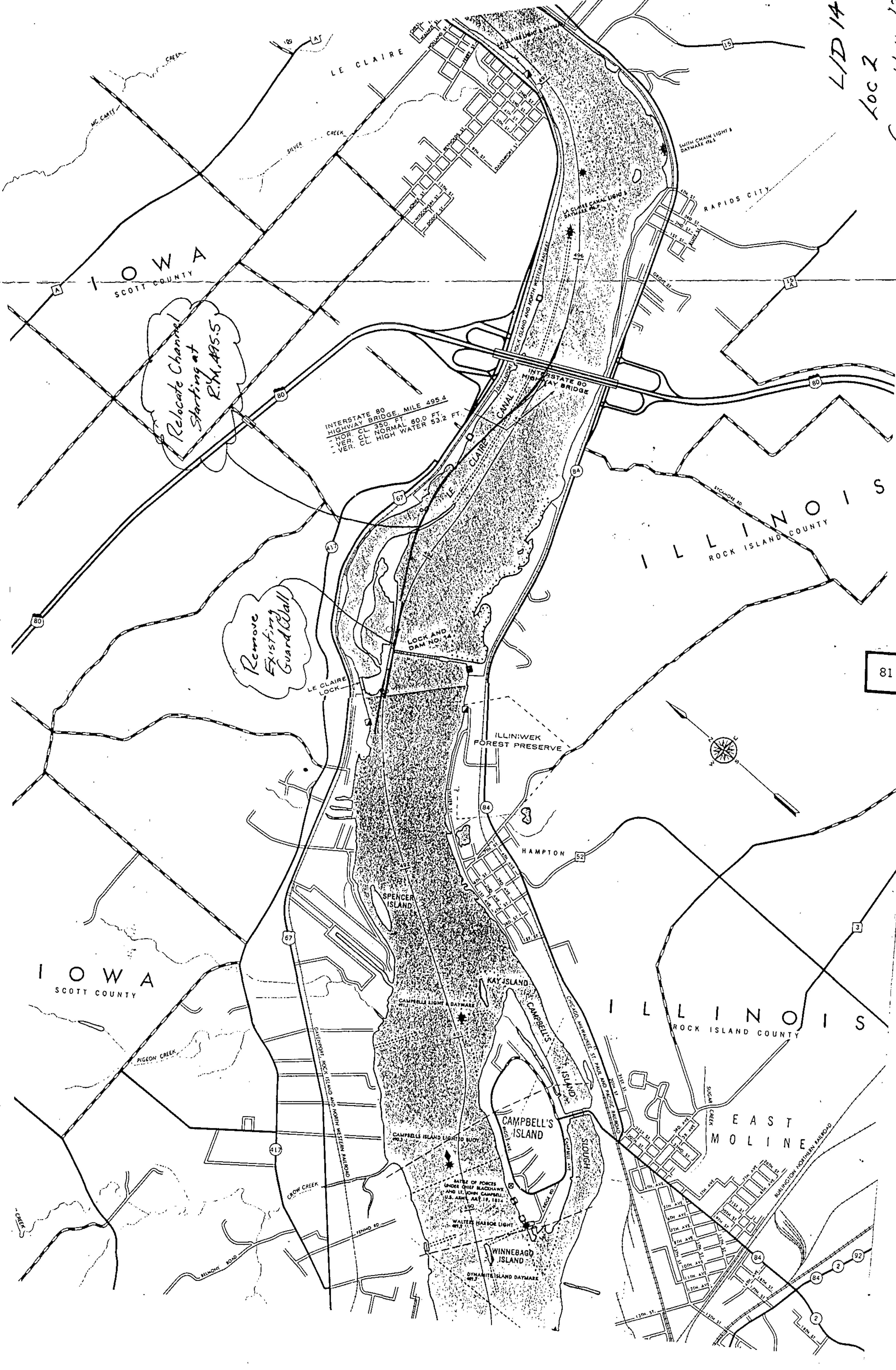
Given the above considerations, it may be best to locate a new lock out into the dam with protection cells above the dam gates between the new and existing locks. Channel rock excavation is required for a Location 4 lock and for replacement gates located in the non-overflow section of the dam.

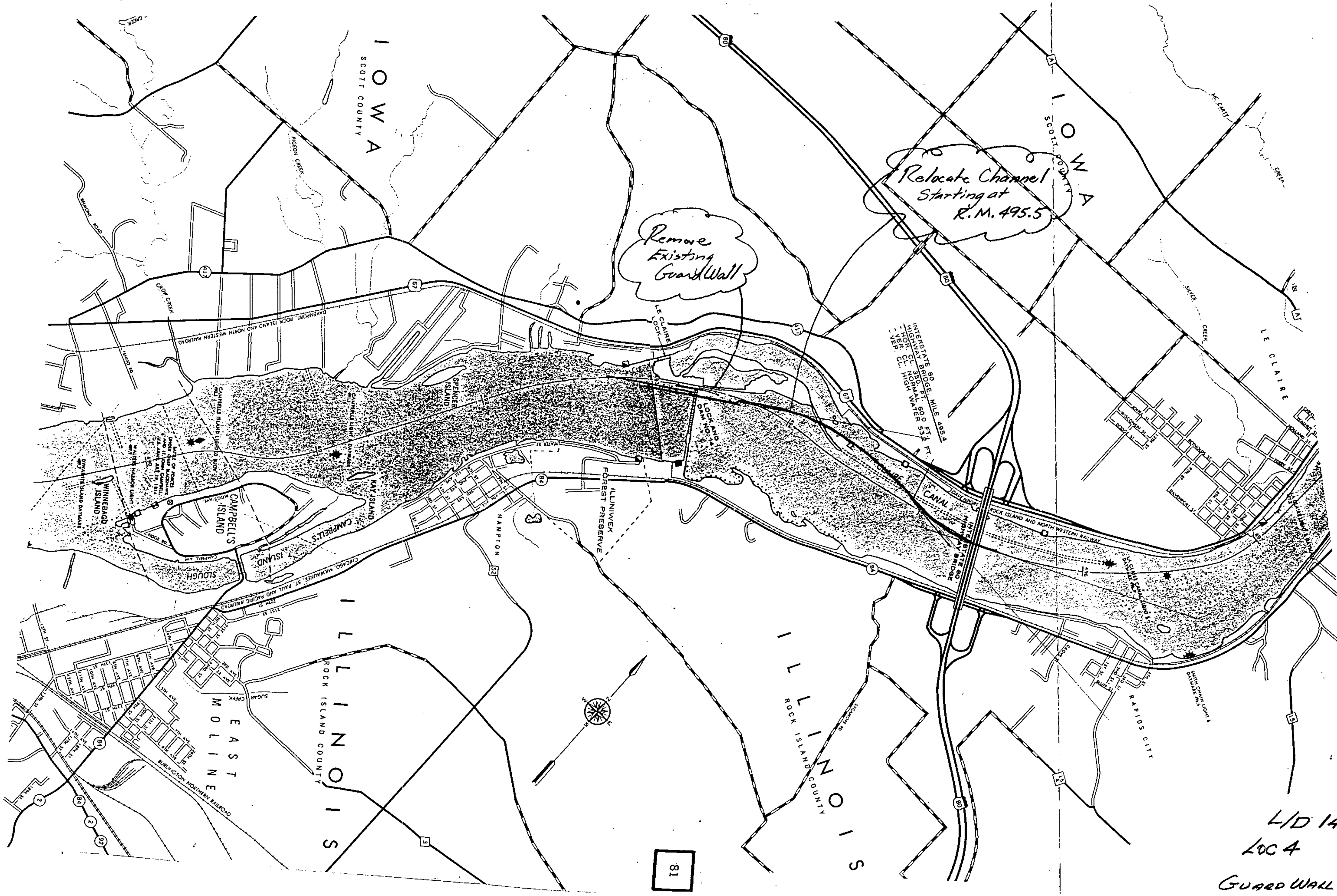
Small-Scale Improvements

Upstream A modified channel would improve the approach time. An extended ported guard wall can not be constructed unless the channel work is done. Extending the guide wall will benefit lockage transit time but will not make the approach more efficient.

Downstream Extended landside guide wall.

L/D 14
Loc 2
Guard Wall / Tow L.






L/D 14
Loc 4
Guard Wall 1 Tow L.

## LOCK AND DAM NO. 15

Existing Conditions:

From the initial screening site visit it was found that outdraft can be severe at this site and the reach of river from Lock 15 to Lock 14 can be the most congested area on the Upper Mississippi River. Presently, tows are pushed away from the downstream guide wall by eddy currents and Sylvan Slough currents. Options for proposed new lock construction are limited by the existing urban development in the area and site geography. The initial screening eliminated all locations except Locations 2 and 3. At both of these two locations, only an upstream extension of the existing lock, Location 2, or the 360' auxiliary lock, Location 3 is proposed. Downstream extensions at either location were not considered because of the interference with the government bridge traffic (the swingspan would remain open during the entire locking process) and more importantly because of the limited/tight downstream approach/exit from a downstrem extension and the flow impact from Sylvan Slough.

Location 2 (Upstream Lock Extension)

Upstream Construct a 1200' ported guard wall. Remove and shape about 400' of riverbank at the upper end of the guard wall to provide a 150' wide opening at navigation depth for entrance. Starting at the end of the guard wall, place 4 submerged dikes (groins) spaced at 500' apart, extending from the bankline to a little beyond the far edge of the navigation channel. They are constructed of rock to a height of 15' to 20' below flat pool. (20' is preferred) The dikes reduce the magnitude of the outdraft making it easier to maneuver to the protected area behind the wall.

Downstream Extend the existing landside guide wall to 1200' measured from the end of the intermediate wall. Construct a 600'+/- long rock dike at the end of Sylvan Slough to deflect the slough current away from the navigable approach. Build to a height of 3' to 4' below the lower pool level where operation would cease.

Location 3 (Upstream Lock Extension)

Upstream Construct a 1200' ported guard wall. Remove and shape the bankline as described above for better access to the existing lock. Construct 4 submerged dikes as described above starting at the end of the new ported guard wall and extend to beyond the far edge of the navigation channel.

Downstream Construct a 1200' landside guide wall. This limits the use of the existing lock to smaller tows and recreation traffic. Extend the deflection dike at the end of Sylvan Slough farther out. Consider a short stub wall angled downstream from the end of the dam wall to deflect flow from the dam gates.

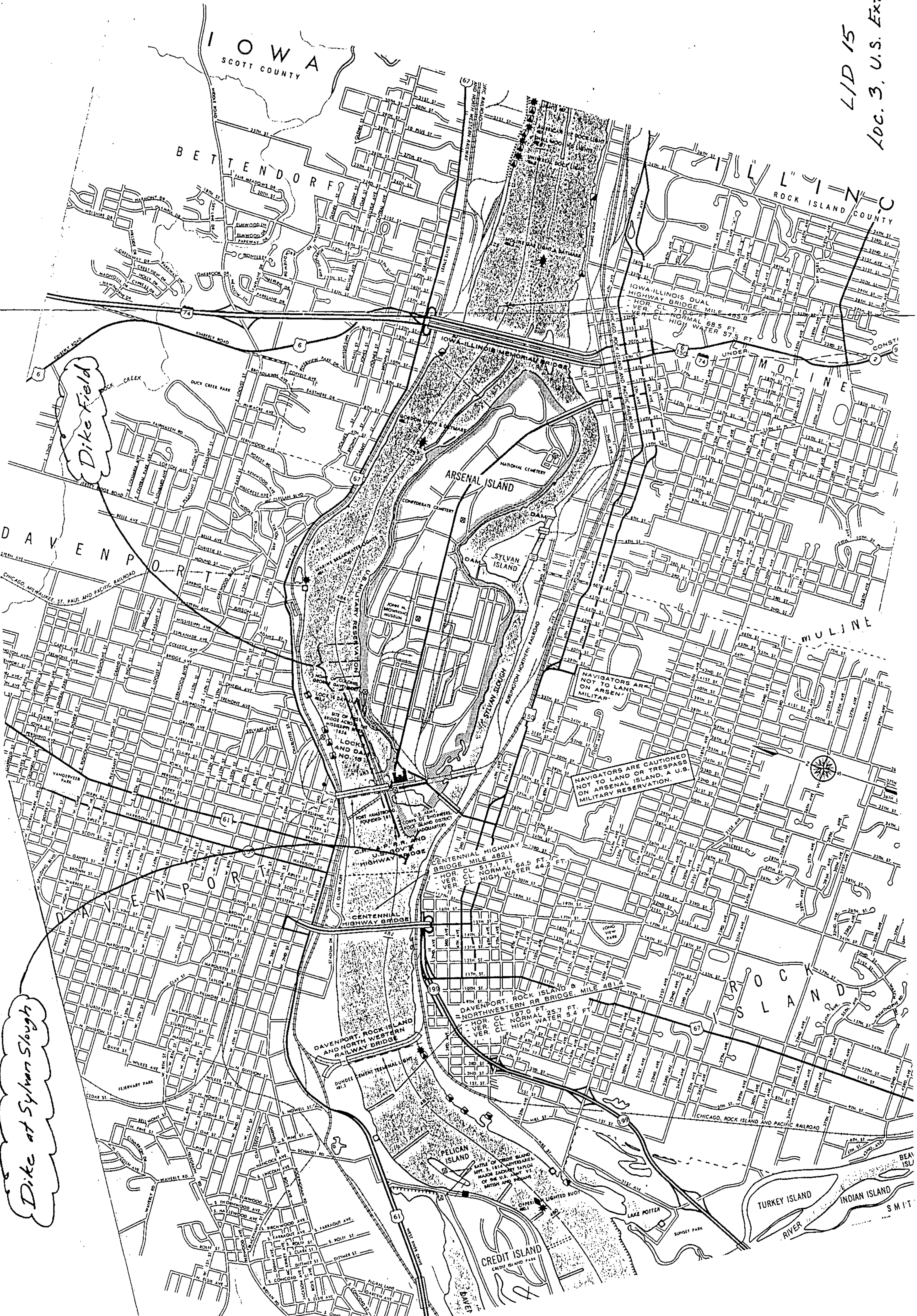
Small-Scale Improvements

Upstream The greatest efficiency from a navigation standpoint would be achieved with a ported 1200' guard wall, excavation of about 400' of bankline to provide adequate opening at the end of the guard wall, and the submerged dike system to improve maneuverability above the guard wall. This would allow continued access to the small harbor area landward of the lock but tow haulage, as now exists, would be on alternating walls.

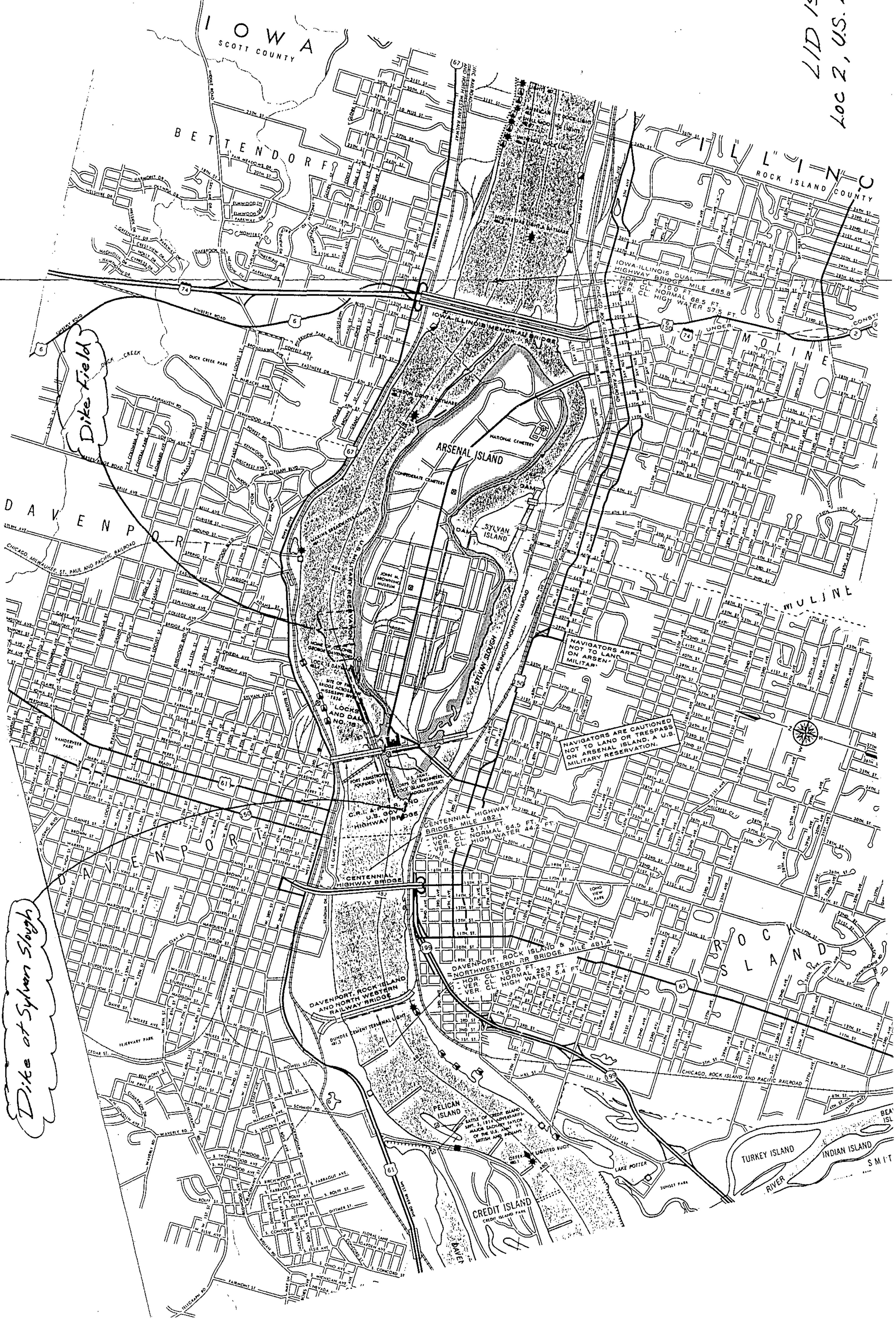
An alternative arrangement would be to excavate and reshape the bankline, install the dike field and extend the existing landside guide wall. This would keep all the tow haulage on the landside walls but may cutoff access to the harbor unless another canal is excavated to it. Or, to maintain access to the harbor, the guide wall could be extended short of 1200' and a 50' cell installed upstream on which tows could pivot and align with the lock. This would allow small craft access to the harbor but limit full use of the tow haulage system.

Downstream Extend the guide wall to 1200'. Construct a 600'+/- rock dike at the end of Sylvan Slough to deflect the slough current. Build to a height of 3' to 4' below the lower pool level where operation would cease.

L/D 15
Loc. 3, U.S. Ext.



LID 15
Loc 2, U.S. Ext.



## LOCK AND DAM NO. 16

Existing Conditions:

Downbound traffic can take an hour or so longer to get to the lock than it takes to lock through The traffic crosses the current and heads to the upper lock gate. Then tows stop and backup toward the wing dike above the lock at R.M. 457.7 to align better with the lock and then enter the lock. The wing dike reduces the the current and makes it easier to enter the lock. When leaving the lock, some downbound tows start turning before they clear the lock and have damaged the lower miter gate by brushing them. This may be due inpart because tows must then cross toward the Iowa side of the river to align with the channel span of the Muscatine highway bridge about a mile downstream. During recent rehab work it was noted that closing the first two tainter gates caused an eddy current which pulled tows off the guide wall.

Channel realignment is a must especially upstream of the lock to improve the locking efficiency at this site. This pertains to any proposed new lock construction as well as small-scale improvements.

Location 2 (Upstream Lock Extension)

If an upstream lock extension is made to retain the existing distance downstream for crossing to the Muscatine bridge channel span, the following is recommended:

Upstream The navigation channel should be relocated starting at R.M. 460 and be aligned so the channel is straight for a minimum distance of 2400' at a 5 to 10 degree angle landward from the end of a new 1200' ported guard wall. This gives downbound tows an approach from behind the guard wall and a more efficient course to steer through the crossing current resulting from the left descending bankline turning landward above the lock. The existing guard wall can remain at the auxiliary bay. The existing landside guide wall would be removed as part of the new lock construction and the bankline flared back from the end of the new lock wall. Wing dikes along the left descending riverbank at R.M. 457.7 and 457.9 will have to be removed.

Downstream Extend the existing guide wall to 1200'. This would give added protection from eddy currents moving tows off the wall. This may be what is happening now causing it to appear like the tows are turning to soon before they clear the lock.

Location 2 (Downstream Lock Extension)

Upstream The navigation channel would be relocated upstream as before to provide an approach at a 5 to 10 degree angle from behind a new 1200' ported guard wall. Remove the existing guard wall. Remove the existing guide wall and slope the riverbank to provide a

150' wide opening at navigation depth at the upper end of the new guard wall. Remove the wing dikes above the lock as needed.

Downstream Construct a 1200' landside guide wall. May have to add a 50' long wall angled at 45 degrees from the end of the riverside lock wall or a 50' cell since the turn will be a little more difficult and this would give added protection to the lock wall and the tow.

With a downstream extension at Location 2, there is still adequate distance for tows to maneuver to/from the channel span at the downstream Muscatine highway bridge. Therefore, only construction on the downstream side of the dam should be considered for any new proposed lock construction, since it is usually more economical to construct in the lower pool.

Location 3

Upstream The navigation channel would be relocated starting at about R.M. 460 similar to Location 2 so that tows approach at a 5 to 10 degree angle from behind a new 1200' ported guard wall. Remove the existing guard wall. Since this location is a little farther from the riverbank, outdraft becomes more of a problem. Starting at the end of the new ported guard wall, place five submerged dikes (groins), spaced 500' apart, extending from the riverbank to a little beyond the far edge of the new 300' navigation channel. They are constructed of rock to a height of 15' to 20' below flat pool. (20' is preferred) These reduce the magnitude of the outdraft above the guard wall making it easier to maneuver to the protected area behind the wall.

Downstream Construct a 1200' landside guide wall. This wall will limit the existing lock to smaller tows and recreation traffic. May have to protect against an eddy current along the left bank and do some bank excavation to open up the access to the existing lock. The guide wall may have to have a rubbing surface on both sides.

Location 4 (Close to the auxiliary bay, not out into dam)

Upstream The navigation channel would be relocated similar to Location 3 so that the downbound approach is made at a 5 to 10 degree angle from behind a new 1200' ported guard wall. Remove the existing guard wall. Place the five submerged dikes above the lock as for Location 3 and extend them beyond the far edge of the 300' navigation channel.

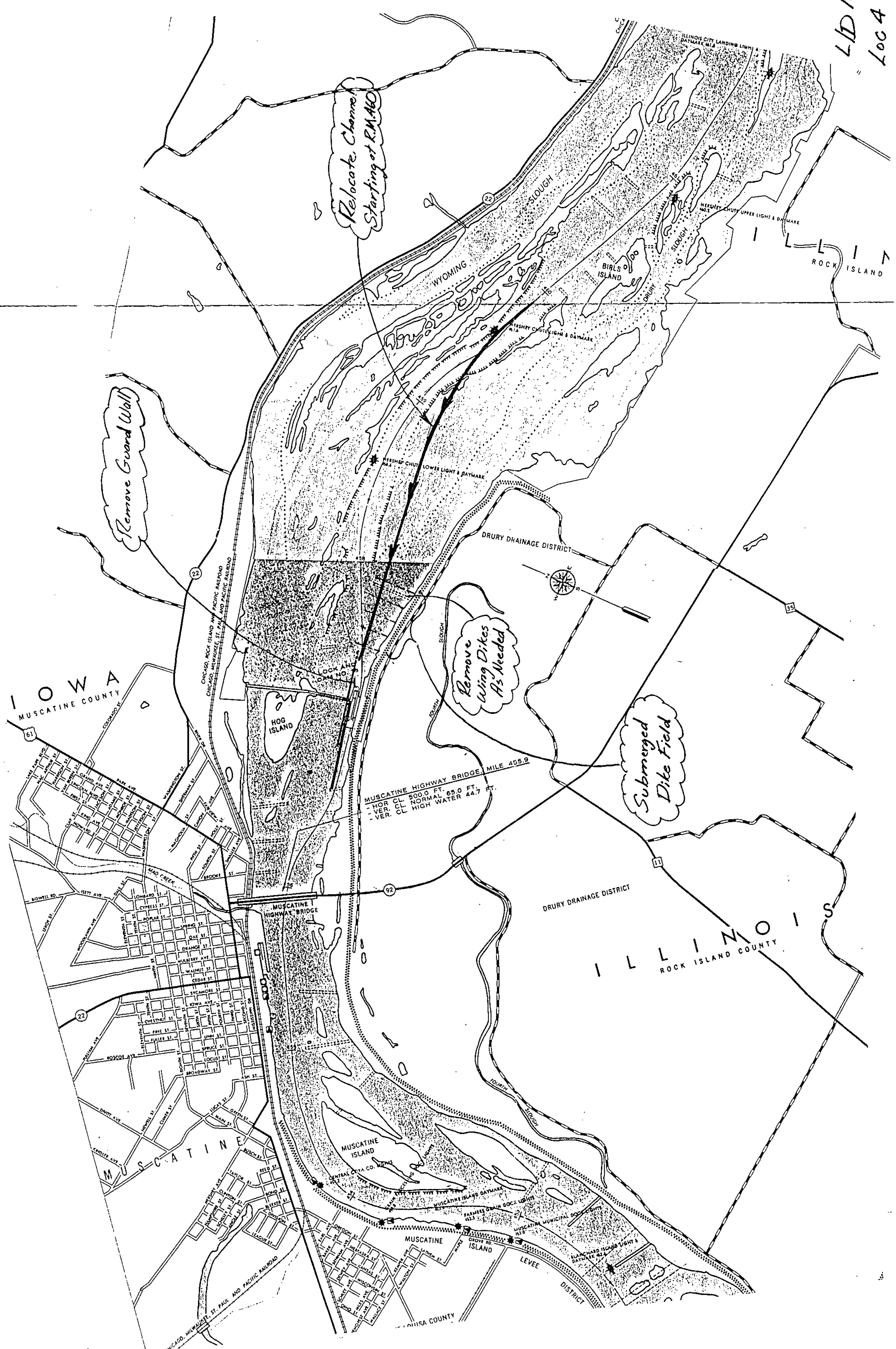
Downstream Construct a 1200' landside guide wall. May have to add an additional 200' +/- of wall to protect against potential eddy currents along the left descending riverbank. The existing lock will be limited to smaller tows/ vessels. Additional dam gates at the storage yard area to replace dam gates lost to new lock construction may require some dredging to open up the flow area along the right descending riverbank below the storage yard.

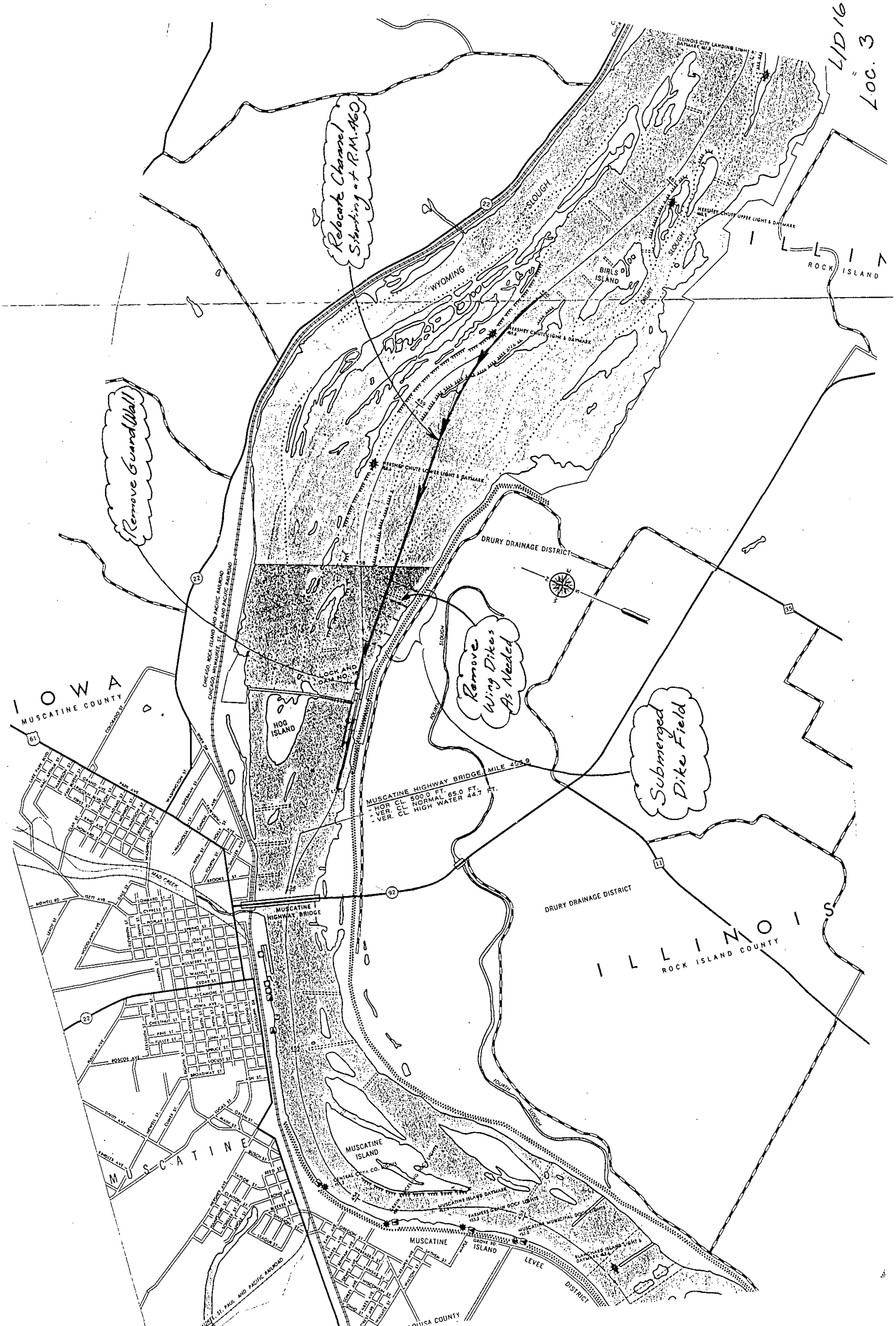
A Location 5 lock was initially screened out. But, a lock located at the existing storage yard presents the best alignment for a navigation channel upstream of the Muscatine bridge. After being informed about the massive dredging needed to establish such a channel and the maintenance dredging associated with maintaining two separate channels, discussion stopped.

Small-Scale Improvements

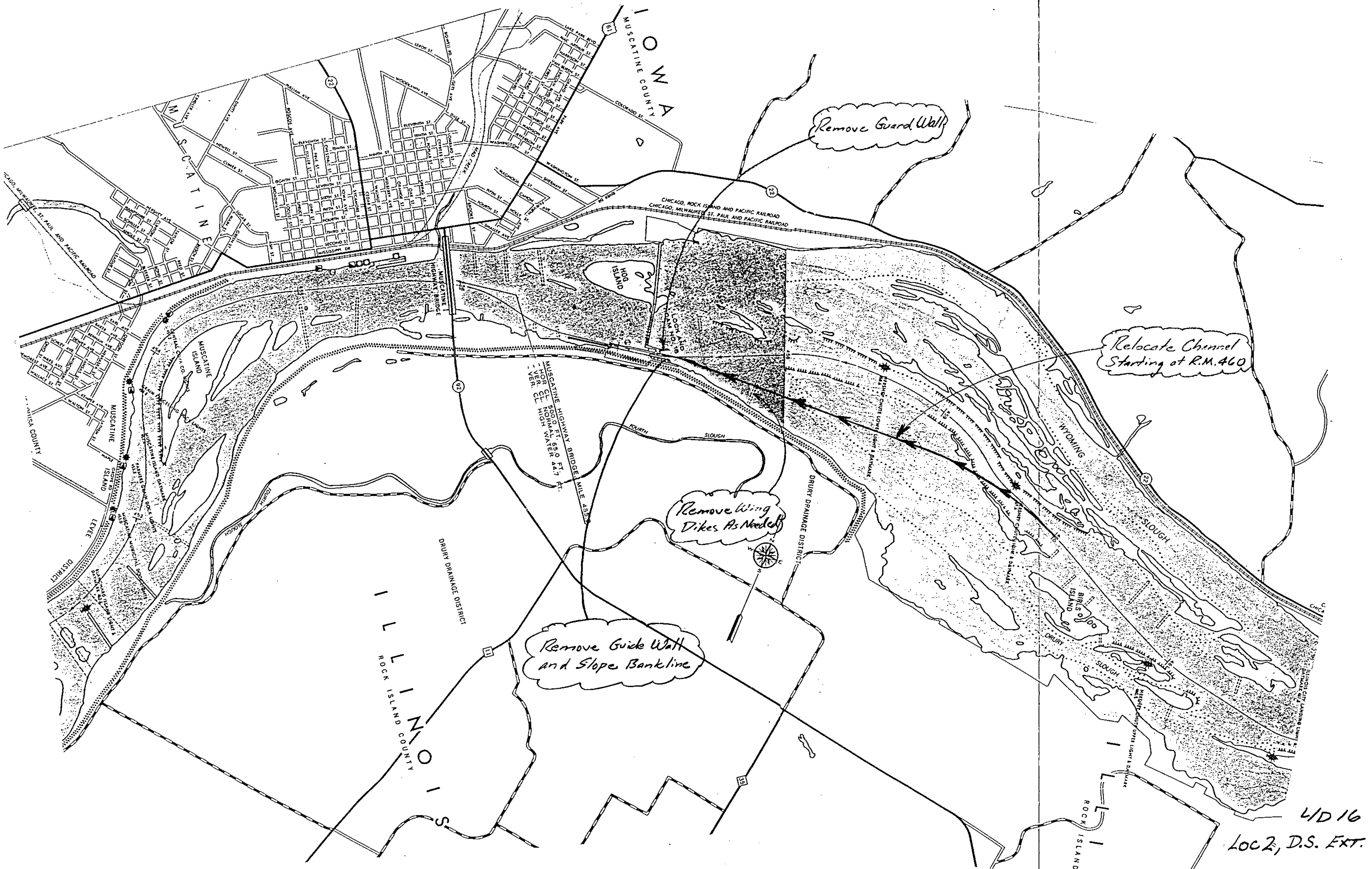
Upstream Could extend the existing guide wall 600' and the savings in approach time would be the 600' of flanking time. The most efficient improvement would be the channel work described for Location 2 along with a 1200' ported guard wall. Should not do the channel work alone without a new 1200' ported guard wall. Remove the existing guard wall. Remove the guide wall and slope the bankline to provide a 150' wide opening at navigation depth at the start of the guard wall. Do not need the submerged dikes above the lock.

Downstream An extended guide wall would reduce the eddy action on a tow since the tow would be out of the lock chamber an additional 600'.

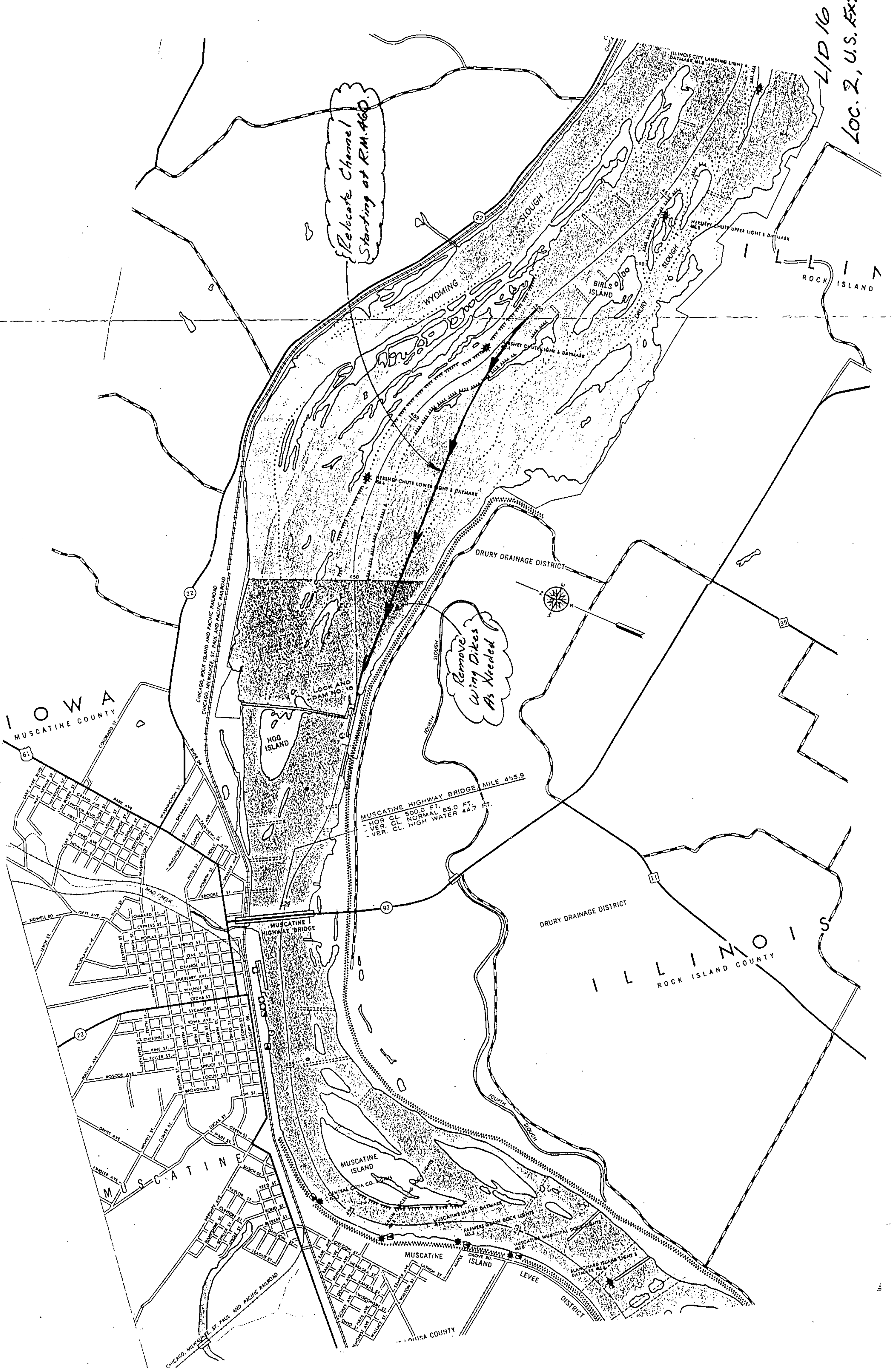

LD 16
Loc 4
Relocate Channel Starting at R.M. 460
Remove Guard Wall
Remove Wing Dikes As Needed
Submerged Dike Field
IOWA
MUSCATINE COUNTY
MUSCATINE
ILLINOIS
ROCK ISLAND COUNTY
DRURY DRAINAGE DISTRICT
WYOMING
SLOUGH
BIRLS ISLAND
DRURY
HOG ISLAND
LOCK AND DAM NO. 16
MUSCATINE HIGHWAY BRIDGE, MILE 455.9
- HOR. CL. 500.0 FT.
- VER. CL. NORMAL 65.0 FT.
- VER. CL. HIGH WATER 44.7 FT.
MUSCATINE HIGHWAY BRIDGE
MUSCATINE ISLAND
FOURTH SLOUGH
MUSCATINE ISLAND LEVEE DISTRICT
LOUISA COUNTY
MAD CREEK
CHICAGO, ROCK ISLAND AND PACIFIC RAILROAD
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD
HERSHEY CHUTE LOWER LIGHT & DAYMARK
HERSHEY CHUTE UPPER LIGHT & DAYMARK
ILLINOIS CITY LANDING LIGHT & DAYMARK



LID 16
Loc. 3
Relocate Channel Starting at R.M. 460
Remove Guard Wall
Remove Wing Dikes As Needed
Submerged Dike Field
IOWA
MUSCATINE COUNTY
ILLINOIS
ROCK ISLAND COUNTY
ROCK ISLAND
WYOMING SLOUGH
DRURY SLOUGH
BIRLS ISLAND
HOG ISLAND
LOCK AND DAM NO. 16
DRURY DRAINAGE DISTRICT
FOURTH SLOUGH
MUSCATINE HIGHWAY BRIDGE, MILE 455.9
- HOR. CL. 500.0 FT.
- VER. CL. NORMAL 65.0 FT.
- VER. CL. HIGH WATER 44.7 FT.
MUSCATINE HIGHWAY BRIDGE
MUSCATINE ISLAND
MUSCATINE
MUSCATINE ISLAND LEVEE DISTRICT
GROVE RD
LOUISA COUNTY
MAD CREEK
CHICAGO, ROCK ISLAND AND PACIFIC RAILROAD
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD
HERSHEY CHUTE UPPER LIGHT & DAYMARK
HERSHEY CHUTE LIGHT & DAYMARK
HERSHEY CHUTE LOWER LIGHT & DAYMARK
ILLINOIS CITY LANDING LIGHT & DAYMARK
MUSCATINE ISLAND DAYMARK
MUSCATINE MUNICIPAL DOCK LIGHTS
BLANCHARD ISLAND LIGHT & DAYMARK



IOWA
MUSCATINE COUNTY
MUSCATINE
Remove Guard Wall
Relocate Channel Starting at R.M. 460
Remove Wing Dikes As Needed
Remove Guide Wall and Slope Bankline
CHICAGO, ROCK ISLAND AND PACIFIC RAILROAD
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD
HOG ISLAND
LOCK AND DAM NO. 16
MUSCATINE HIGHWAY BRIDGE
MUSCATINE HIGHWAY BRIDGE, MILE 455.
- HOR. CL. 500.0 FT.
- VER. CL. NORMAL 65.0 FT.
- VER. CL. HIGH WATER 44.7 FT.
WYOMING SLOUGH
BIRLS ISLAND
DRURY SLOUGH
FOURTH SLOUGH
DRURY DRAINAGE DISTRICT
MUSCATINE ISLAND
MUSCATINE ISLAND
LEVEE DISTRICT
LOUISA COUNTY
ILLINOIS
ROCK ISLAND COUNTY
MAD CREEK
L/D 16
Loc 2, D.S. Ext.



L/D 16
Loc. 2, U.S. Ext.
Relocate Channel Starting at R.M. 460
Remove Wing Dikes As Needed
IOWA
MUSCATINE COUNTY
ILLINOIS
ROCK ISLAND COUNTY
ROCK ISLAND
WYOMING SLOUGH
BIRLS ISLAND
DRURY SLOUGH
HERSHEY CHUTE UPPER LIGHT & DAYMARK
HERSHEY CHUTE LIGHT & DAYMARK
HERSHEY CHUTE LOWER LIGHT & DAYMARK
DRURY DRAINAGE DISTRICT
LOCK AND DAM NO. 16
HOG ISLAND
FOURTH SLOUGH
MUSCATINE HIGHWAY BRIDGE, MILE 455.9
- HOR. CL. 500.0 FT.
- VER. CL. NORMAL 65.0 FT.
- VER. CL. HIGH WATER 44.7 FT.
MUSCATINE HIGHWAY BRIDGE
CHICAGO, ROCK ISLAND AND PACIFIC RAILROAD
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD
MAD CREEK
MUSCATINE
MUSCATINE ISLAND
MUSCATINE ISLAND LEVEE DISTRICT
LOUISA COUNTY

## LOCK AND DAM NO. 17

Existing Conditions:

During the initial site screening visit, it was reported that usually there is always an outdraft requiring downbound traffic to flank their approach to the lock. A helper boat is generally used when the tailwater reaches 7 or 8 feet. From a navigation standpoint, it is best to locate a new lock as close as possible to the left descending bank to lessen the outdraft.

Location 1

Upstream Flare the bank excavation upstream to the approach which could be 300' wide. Construct a 1200' ported riverside guard wall. Should have little if any upstream channel excavation other than bank excavation. This location will require a setback of the agricultural levee.

Downstream There will be "much excavation" and a setback of the agricultural levee. Use a 1200' landside guide wall. Extend the new bankline straight for a distance of 600' downstream from the end of the guide wall before curving back to the channel at a 15 degree maximum angle.

Location 2

Upstream Construct a 1200' ported guard wall. Flare the upstream bank excavation to the approach channel. (An upstream extension of the lock would reduce the upstream and downstream bank excavation)

Downstream Use a 1200' landside guide wall. Extend the new bankline straight for a distance of 600' downstream from the end of the guide wall before curving back to the channel at a 15 degree maximum angle.

Location 3

Upstream There should be little if any channel work. Construct a 1200' ported riverside guard wall. Leave the existing guide wall in place. Add spur dikes above the guide wall to reduce the outdraft. Space the dikes at 1000', extending them from the existing riverbank to the edge of the "bankline" extended upstream from the existing guide wall. Use an L-head at the last dike just above the lock. May need to shorten the wing dikes along the right bank to maintain an adequate flow area.

Downstream Use a 1200' guide wall. Remove the existing guide wall for the existing 600' lock and excavate the bank to open up the area for lockage through the existing lock by smaller vessels which have to go landward of the new 1200' guide wall for the 1200' lock. May need a rubbing surface on both sides of the new 1200' guide wall. May want to consider an upstream extension to reduce the channel excavation. (It appears that a lock constructed in the upper pool may be the better solution for any location at this lock site).

Location 4

Upstream Use a 1200' ported guard wall. Have no bank excavation. Install the spur dikes above the lock as described for Location 3. Reduce the length of the right bank wing dams.

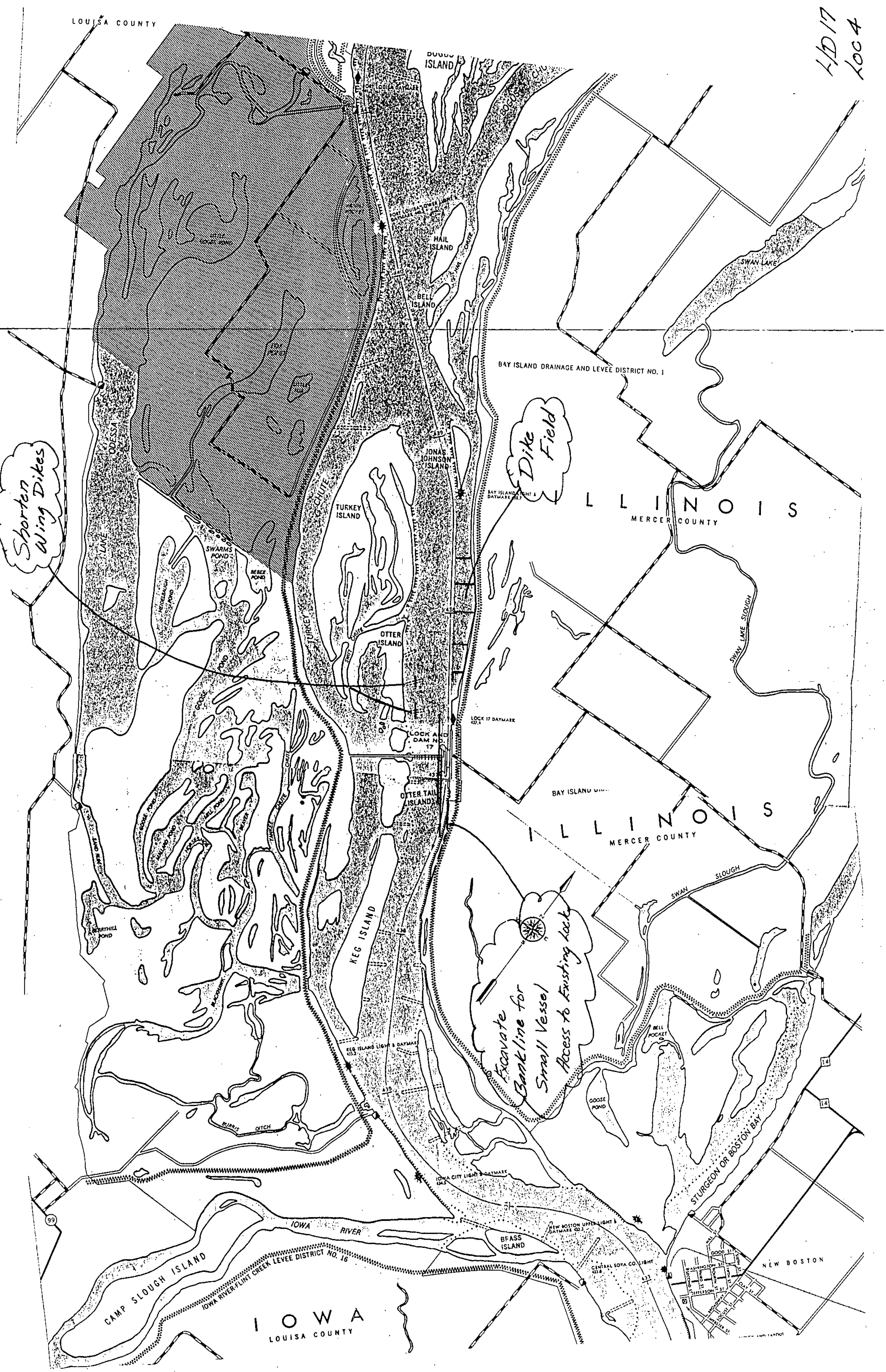
Downstream Construct a 1200' landside guide wall. Open up the river access to the existing 600' lock but leave the existing guide wall in place. May need some bank excavation if 1200' tows are to use the 600' lock also. (Need to decide if 1200' tows are to use the 600' lock or limit the 600' lock to 600' tows and/or smaller vessels) Make up the flow loss by adding dam gates at Location 3 or in the right bank channel area, Location 5.

Small-Scale Improvements

Upstream From a navigation standpoint it is best to add a 1200' ported guard wall and flare the left bank, removing the existing guide wall. Add a dike field upstream of the lock as discussed above to reduce the outdraft. Use 5 or 6 dikes spaced 1000' apart starting about a mile above the lock. (The dike field should be modeled to verify its benefit) Adding the dike field will impact the existing left bank tow waiting areas. One or two mooring cells may have to be added to replace the lost waiting areas. Also, the wing dams along the right bank may need to be shortened to maintain the flow area. Extending the existing guide wall to 1200' (a rock dike is there now) is a less desirable option to a ported guard wall but an extension could have merit along with the dike field.

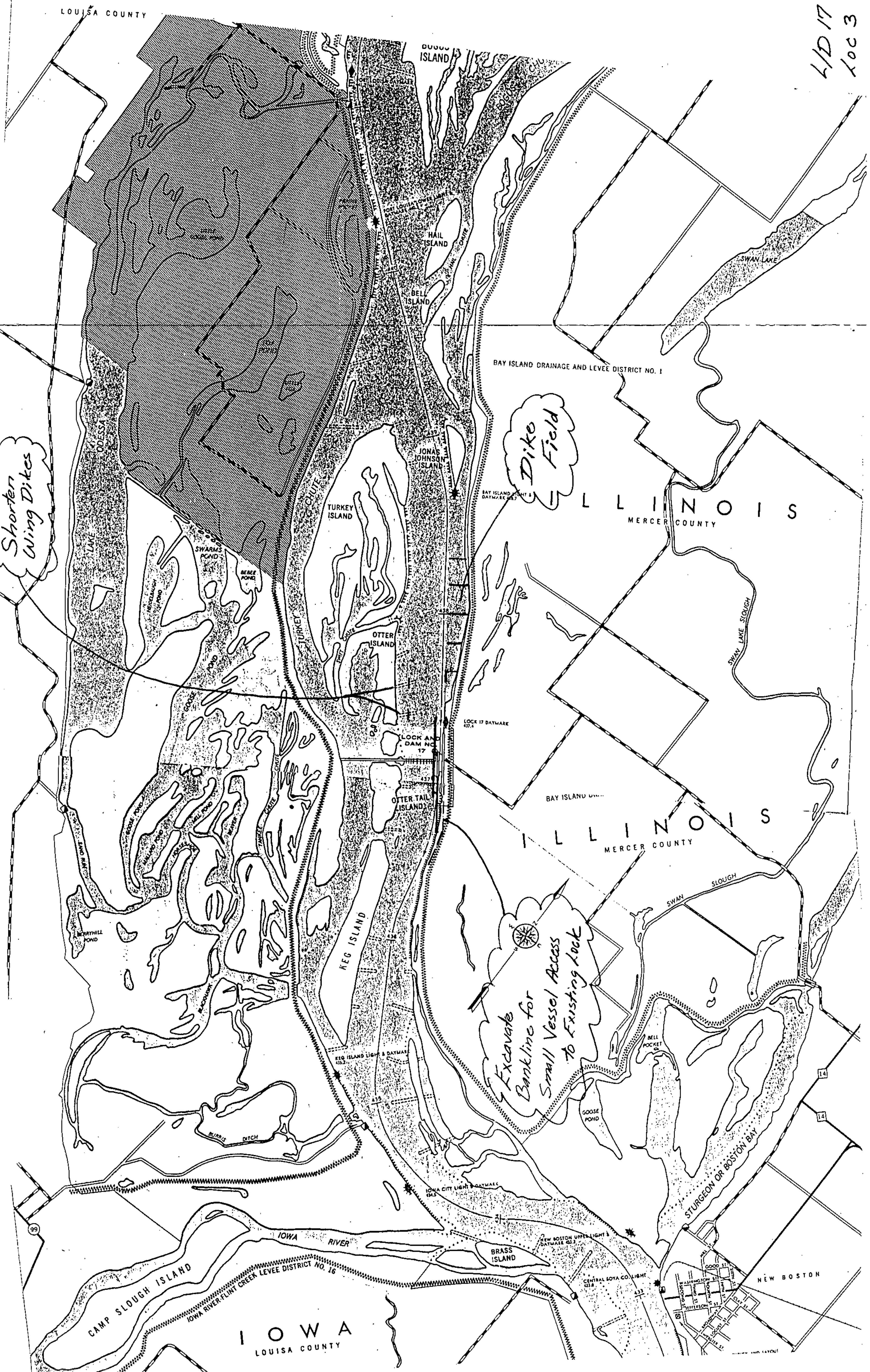
Downstream Extend the guide wall to 1200' with some bank excavation downstream of the extended wall to avoid pinching exiting tows. Extend the new bankline straight for a distance of 600' downstream from the end of the guide wall before curving back to the channel at a 15 degree maximum angle.

Navigable Pass Through the Dam Dam 17 has a low flow capacity relative to other dams on the Upper Mississippi River. Consequently, Lock 17 is usually one of the first locks to go out of operation during higher than normal flows when the lock gates become inoperable because of high water. A navigable pass situation allows tows to pass through a section of the dam after gates in the dam are lowered when the head differential between the upper and lower pools approaches zero. By-passing the locking process in this way saves transit time and is beneficial to navigation. A navigable pass condition would exist an estimated 30 percent of the time at this site. A minimum pass width of 350' is needed in the dam and can be attained by incorporating wicket gates in the dam structure. The wicket gate sill should be at least 15' below flat pool and the end walls curved to train flow smoothly through the pass opening. The channel approach to the pass area requires the removal of the right bank wing dikes and the filling in of the openings along the right bank to create a solid bankline to eliminate potential cross currents during high water which hinder steering in the pass area.



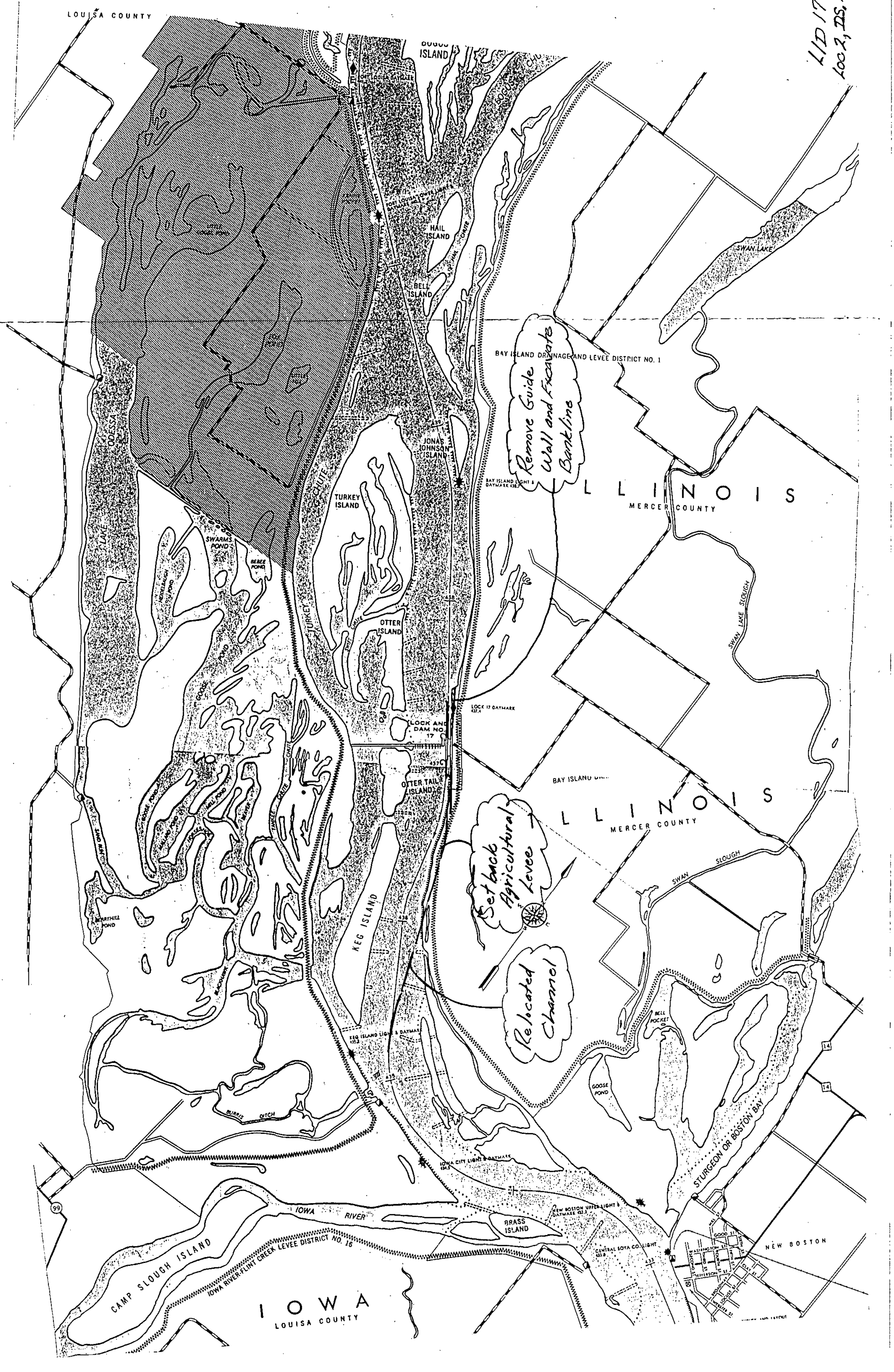
4D17
Loc 4
LOUISA COUNTY
BOGUS ISLAND
HAIL ISLAND
BELL ISLAND
SWAN LAKE
BAY ISLAND DRAINAGE AND LEVEE DISTRICT NO. 1
Dike Field
JONAS JOHNSON ISLAND
ILLINOIS
MERCER COUNTY
Shorten Wing Dikes
ODESSA
LAKE
TURKEY CHUTE
TURKEY ISLAND
SWARMS POND
BEBEE POND
OTTER ISLAND
SWAN LAKE SLOUGH
LOCK 17 DAYMARK
LOCK AND DAM NO. 17
OTTER TAIL ISLAND
BAY ISLAND
ILLINOIS
MERCER COUNTY
SWAN SLOUGH
Excavate Bankline for Small Vessel Access to Existing Lock
KEG ISLAND
BERRYHILL POND
BELL POCKET
GOOSE POND
STURGEON OR BOSTON BAY
BURRIS DITCH
IOWA CITY LIGHT & DAYMARK
IOWA RIVER
BRASS ISLAND
CAMP SLOUGH ISLAND
IOWA RIVER-FLINT CREEK LEVEE DISTRICT NO. 16
NEW BOSTON
IOWA
LOUISA COUNTY

L/D 17
Loc 3

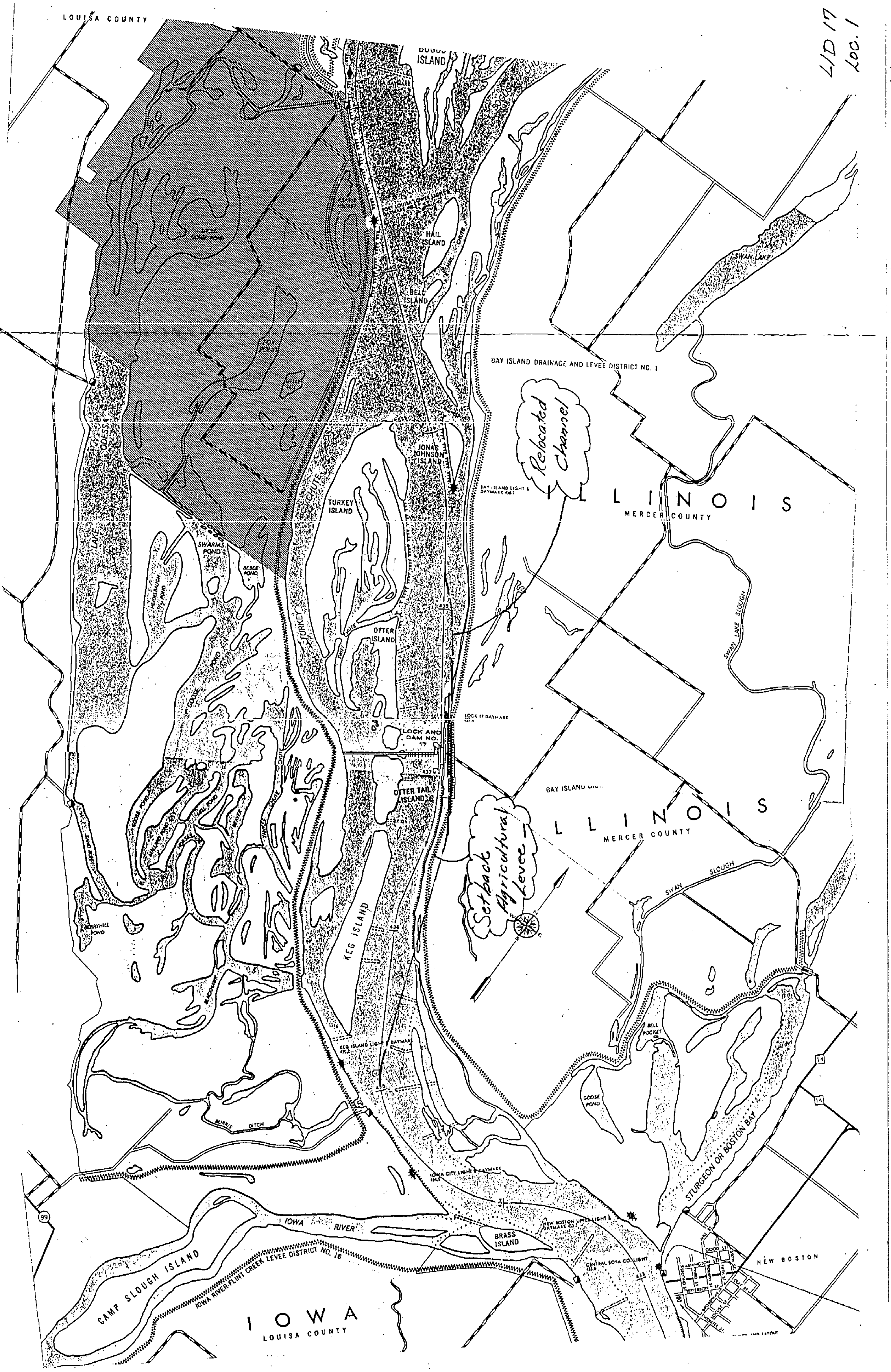


LOUISA COUNTY
BOGUS ISLAND
HAIL ISLAND
BELL ISLAND
BAY ISLAND DRAINAGE AND LEVEE DISTRICT NO. 1
SWAN LAKE
Dike Field
JONAS JOHNSON ISLAND
BAY ISLAND LIGHT & DAYMARK
ILLINOIS
MERCER COUNTY
TURKEY ISLAND
TURKEY CHUTE
OTTER ISLAND
SWAN LAKE SLOUGH
Shorten Wing Dikes
ODESSA
LAKE
SWARMS POND
BEBEE POND
GOOSE POND
LOCK 17 DAYMARK
LOCK AND DAM NO. 17
OTTER TAIL ISLAND
BAY ISLAND
ILLINOIS
MERCER COUNTY
SWAN SLOUGH
YANKEE CHUTE
KEG ISLAND
BERRYHILL POND
Excavate Bankline for Small Vessel Access to Existing Lock
KEG ISLAND LIGHT & DAYMARK
BELL POCKET
GOOSE POND
BURRIS DITCH
IOWA CITY LIGHT & DAYMARK
STURGEON OR BOSTON BAY
IOWA RIVER
BRASS ISLAND
NEW BOSTON UPPER LIGHT & DAYMARK
CAMP SLOUGH ISLAND
IOWA RIVER-FLINT CREEK LEVEE DISTRICT NO. 16
CENTRAL SOYA CO. LIGHT
NEW BOSTON
IOWA
LOUISA COUNTY

LID 17
Loc 2, DS, Ext.



LID 17
Loc. 1


LOUISA COUNTY
BOGUS ISLAND
HAIL ISLAND
BELL ISLAND
SWAN LAKE
BAY ISLAND DRAINAGE AND LEVEE DISTRICT NO. 1
Relocated Channel
JONAS JOHNSON ISLAND
BAY ISLAND LIGHT & DAYMARK 438.7
ILLINOIS
MERCER COUNTY
ODESSA
LAKE
TURKEY ISLAND
TURKEY CHUTE
SWARMS POND
BEBEE POND
GOOSE POND
OTTER ISLAND
LOCK 17 DAYMARK 437.4
LOCK AND DAM NO. 17
OTTER TAIL ISLAND
BAY ISLAND
ILLINOIS
MERCER COUNTY
Setback Agricultural Levee
SWAN LAKE SLOUGH
SWAN SLOUGH
KEG ISLAND
BERRYHILL POND
BELL POCKET
GOOSE POND
KEG ISLAND LIGHT & DAYMARK
BURRIS DITCH
IOWA CITY LIGHT & DAYMARK
STURGEON OR BOSTON BAY
IOWA RIVER
BRASS ISLAND
NEW BOSTON UPPER LIGHT & DAYMARK
CENTRAL SOYA CO. LIGHT
NEW BOSTON
CAMP SLOUGH ISLAND
IOWA RIVER-FLINT CREEK LEVEE DISTRICT NO. 16
IOWA
LOUISA COUNTY

**LOCK AND DAM NO. 18**

Existing Conditions:

An initial site visit to Lock and Dam 18 revealed that approach conditions to the existing lock are good. Tows make a zigzag approach/exit upstream of the lock, but the maneuvering required could be considered relatively insignificant compared to other sites. Outdraft is not a problem at this site, although wind effects tows in their upstream approach to the lock.

Location 2

Upstream A 1200 foot ported riverside guard wall will be constructed. The existing 600 foot guard wall will be removed. Channel realignment may be needed upstream for a distance of as much as 2 miles. However, the magnitude of the channel work required should not be significant.

Downstream Very little if any channel improvements should be required. The existing 600 foot landward guide wall would be extended to 1200 feet.

Location 3

Upstream The existing 600 foot ported guard wall will be removed and replaced with a 1200 foot ported riverside guard wall. Channel realignment similar to Location 2 would be required.

Downstream As with a Location 2 Lock, very little if any channel improvements should be required. A 1200 foot landward guide wall would be constructed. Use of the existing lock would be restricted to small vessels and recreational craft.

Location 4

Upstream Construction of a 1200 foot ported riverward guard wall will be required. The existing guard wall will be removed. Minimal channel work would be required at this location.

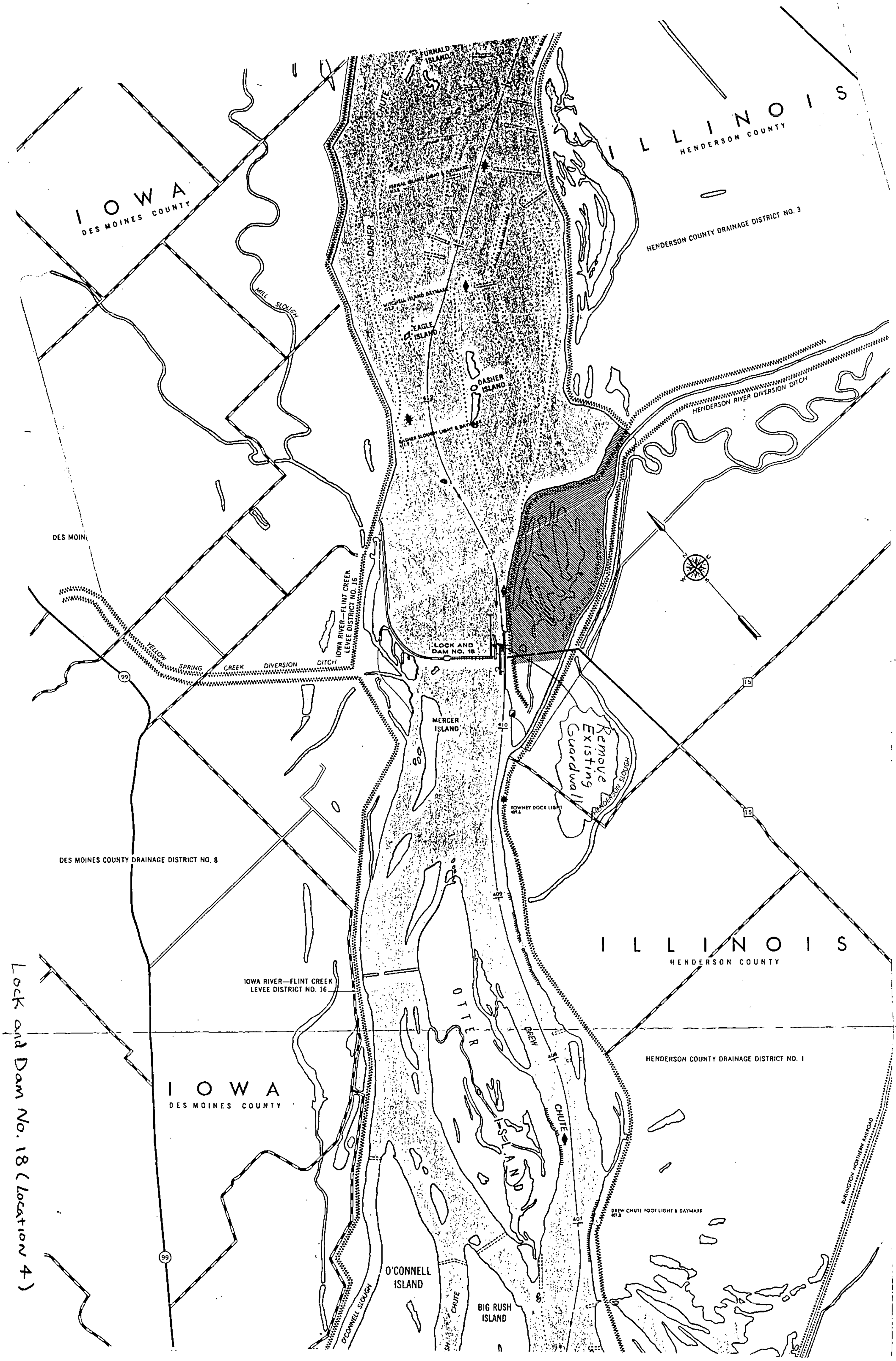
Downstream No channel improvements should be required. A 1200 foot landward guide wall would be constructed.

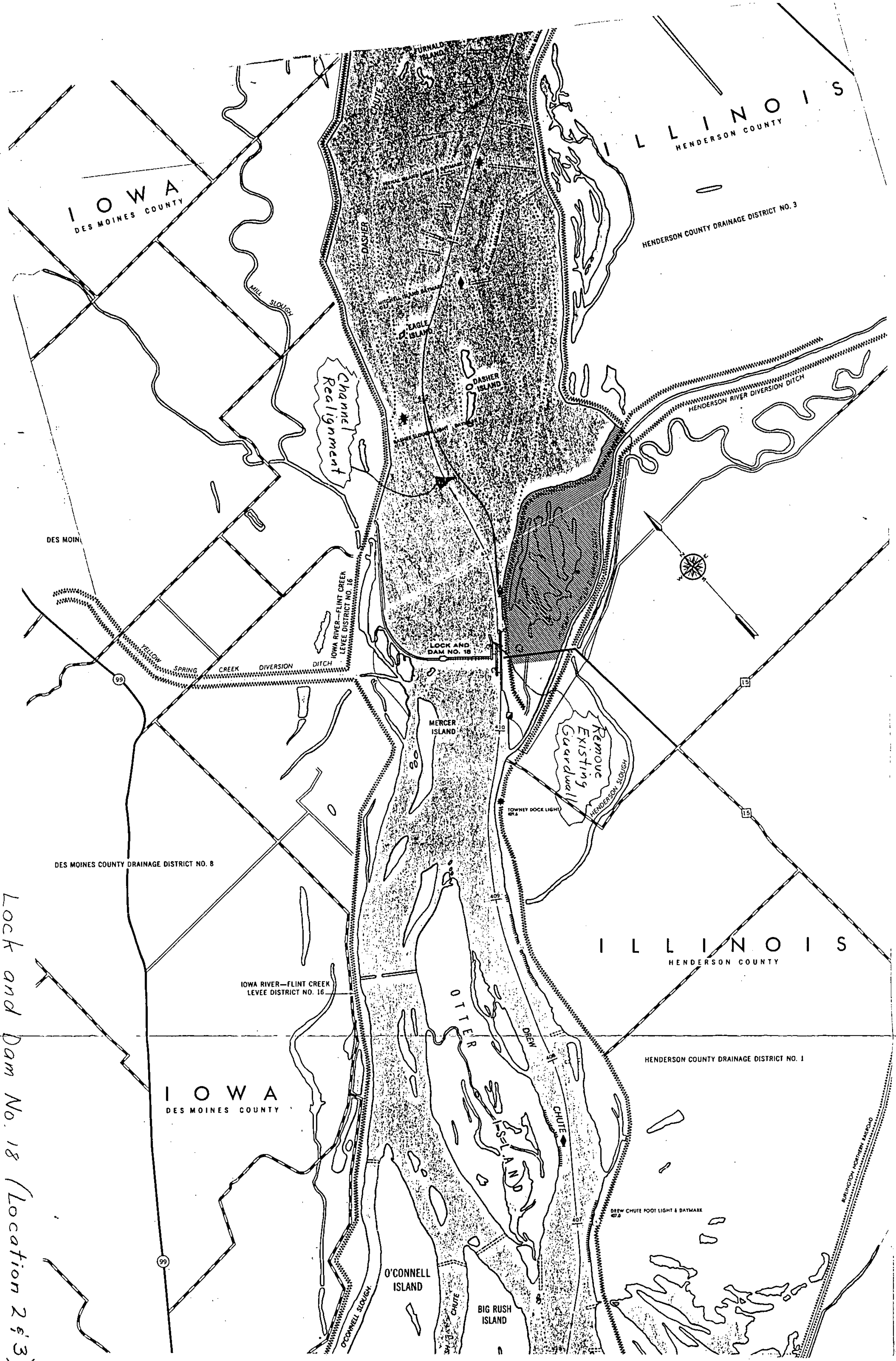
Small-Scale Improvements

Upstream The most effective small scale improvement would be to extend the existing 600 foot landward guide wall to 1200 feet with some minimal channel realignment.
Placement of a mooring cells between river miles 411 and 412 would be beneficial to downbound tows. A guide cell 50 to

75 feet upstream of the bullnose of the intermediate wall would also aid tows in their approach to the lock.

<u>Downstream</u> Very little if any improvements should be required. Extension of the existing guide wall from 600 feet to 1200 feet would provide some additional benefit to tows approaching the lock from downstream. Mooring cells between river miles 410.2 and 409 would aid upbound tows waiting to approach the lock.


IOWA
DES MOINES COUNTY
ILLINOIS
HENDERSON COUNTY
HENDERSON COUNTY DRAINAGE DISTRICT NO. 3
FURNALD ISLAND
CHUTE
DASHER
MILL SLOUGH
EAGLE ISLAND
DASHER ISLAND
412
HENDERSON RIVER DIVERSION DITCH
DES MOIN
IOWA RIVER—FLINT CREEK LEVEE DISTRICT NO. 16
YELLOW SPRING CREEK DIVERSION DITCH
LOCK AND DAM NO. 18
99
15
MERCER ISLAND
410
Remove Existing Guardwall
HENDERSON SLOUGH
TOWHEY DOCK LIGHT 409.6
DES MOINES COUNTY DRAINAGE DISTRICT NO. 8
409
ILLINOIS
HENDERSON COUNTY
IOWA RIVER—FLINT CREEK LEVEE DISTRICT NO. 16
OTTER ISLAND
DREW CHUTE
408
HENDERSON COUNTY DRAINAGE DISTRICT NO. 1
IOWA
DES MOINES COUNTY
DREW CHUTE FOOT LIGHT & DAYMARK 407.8
407
BURLINGTON NORTHERN RAILROAD
O'CONNELL ISLAND
O'CONNELL SLOUGH
BIG RUSH ISLAND
Lock and Dam No. 18 (Location 4)




Lock and Dam No. 18 (Location 2 & 3)

## lOCK AND DAM NO. 19

Existing Conditions:

There is an existing 1200' lock at this site. Any additional new lock construction such as a supplemental 600' lock would be at Location 3 where the old abandoned dry dock and lock are located. A previous model study was completed by WES addressing potential small-scale improvements for the approach area above the 1200' lock.

Location 3 (600' or 1200' lock)

Upstream Locate a new lock as close as possible to the existing 1200' lock with the upstream miter gates aligned even with the upstream miter gates of the existing 1200' lock. Construct a ported guard wall at least 1200' long riverward of the new lock. Check the recommended wall length in the above mentioned model study report. The ported guard wall should be designed to pass ice. That portion of the existing upstream ice deflection wall which projects landward above the new guard wall will have to be removed. Will need to study the flow requirements through the new ported guard wall for power generation. Flow distribution is critical.

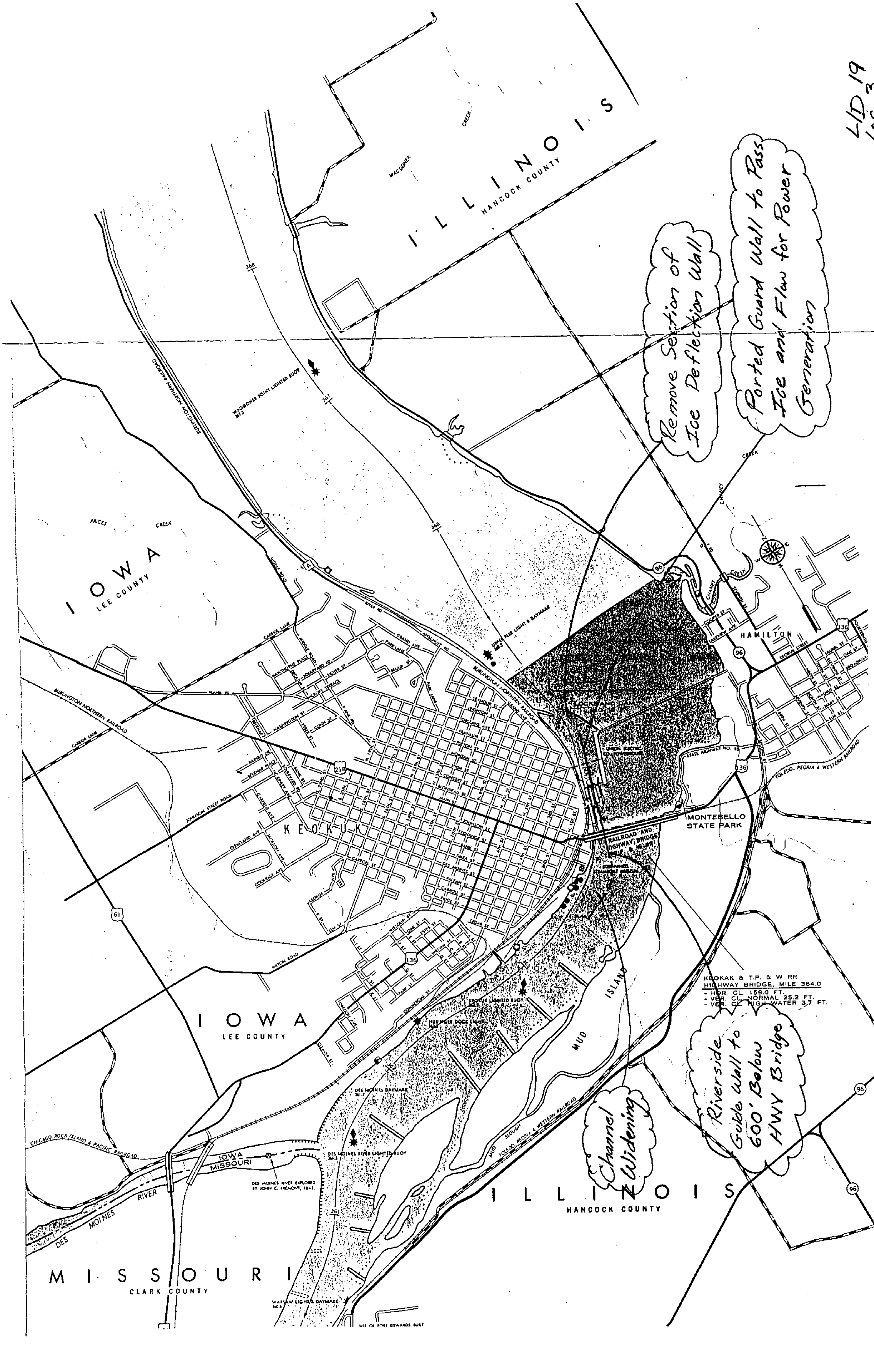
Downstream Need a riverside wall extending 600' downstream of the highway bridge. May need a total wall length of 1200' for a 1200' tow locking through a new 600' lock. Rock excavation will be required to widen the channel below the lock.

Small-Scale Improvements

Upstream Review the completed model study which addressed small-scale improvements for the approach area above the existing 1200' lock. Addressed improvements included; a ported riverside guard wall, adding a landside guide wall, a submerged dike system upstream to direct flow to the dam, and removal of part of the upstream ice deflector wall. Also, NCR is currently preparing a report addressing the addition of an ice chute to improve locking efficiency.

Downstream Channel widening (rock excavation) to provide a passing zone closer to the lock would reduce the upbound approach time. Some extension of the riverside guide wall/guard wall may help to protect tows if downstream currents are a problem.

LD 19
Loc. 3


ILLINOIS
HANCOCK COUNTY
IOWA
LEE COUNTY
KEOKUK
HAMILTON
MONTEBELLO STATE PARK
MUD ISLAND
MISSOURI
CLARK COUNTY
DES MOINES RIVER
BURLINGTON NORTHERN RAILROAD
TOLEDO, PEORIA & WESTERN RAILROAD
CHICAGO, ROCK ISLAND & PACIFIC RAILROAD
RAILROAD AND HIGHWAY BRIDGE
KEOKAK & T.P. & W RR
HIGHWAY BRIDGE, MILE 364.0
- HOR. CL. 156.0 FT.
- VER. CL. NORMAL 25.2 FT.
- VER. CL. HIGH WATER 3.7 FT.
Remove Section of Ice Deflection Wall
Ported Guard Wall to Pass Ice and Flow for Power Generation
Channel Widening
Riverside Guide Wall to 600' Below HWY Bridge

**LOCK AND DAM NO. 20**

Existing Conditions

Discussions with the lockmaster and tow pilots during an initial site visit revealed the downbound approach to the lock requires flanking during the approach. Tows have a tendency to be drawn into the riverbank. During high flows when the dam gates are out of the water, a helper boat is needed to assist tows making their final approach to the lock from upstream. This can occur frequently since the dam is one of the first to go out operation during high water. The upbound approach to the lock can take as long as 45 minutes after a downbound lockage due to the distance downstream tows must wait before making the approach.

Location 1

Additional excavation beyond that already identified along with required relocations in the town of Canton could eliminate this location from further consideration.

Location 2

Upstream A 1200 foot ported riverside guard wall would be constructed requiring removal of the existing ported wall. Major channel modifications will be required upstream. The sharp bend radius of the channel would probably require an approach distance equal to 3 tow lengths so that tows will have completed manuvering once the final approach to the lock is initiated. Straigtening of the bankline and submerged dikes upstream of the lock would aid approaching tows significantly. The dikes should extend from the bankline to the channel and be spaced at intervals of about 500 feet with at least 15 feet of submergence at flat pool. A 1200 foot ported riverside guard wall would be constructed requiring removal of the existing ported wall. Bank excavation opposite the wall would be required to provide a 200 foot entrance width.

Downstream The landside guide wall would be extended by 600 feet. The extension would require the wall to be backfilled so that it could be tied into the bankline. The outlet of Buck Run Creek is immediately downstream of the end existing guide wall. Guide wall extension would require the creek and its outlet to be re-routed downstream at least 600 feet. Also, the tip of a shoal under the water should be removed to improve the approach to the lock.

Location 3

Upstream A 1200 foot ported riverside guard wall would be constructed requiring removal of the existing ported wall.

Major channel excavation and bankline work similar to Location 2 would still be required.

Downstream A solid 1200 foot landside guide wall constructed between the existing lock and the new lock would provide a rubbing surface for both locks. Although bankline excavation/realignment would be required to provide small vessels access to the existing lock, the amount of excavation required would be far less than the channel excavation required if a riverside guide wall were to be constructed. The landside guide wall for the existing 600 foot lock could be left in place without any extension. As a result, Buck Run Creek would probably not need to be re-routed. However, the tip of the shoal should be removed to improve the approach to the existing lock.

Location 4

Upstream A 1200 foot ported riverside guard wall would be constructed requiring removal of the existing ported wall. Although channel work upstream would still be required, it would not be as extensive as that required for Locations 2 and 3. The new lock should be located as close to the existing lock as possible with lost gates being replaced in the existing partially constructed auxillary lock bay.

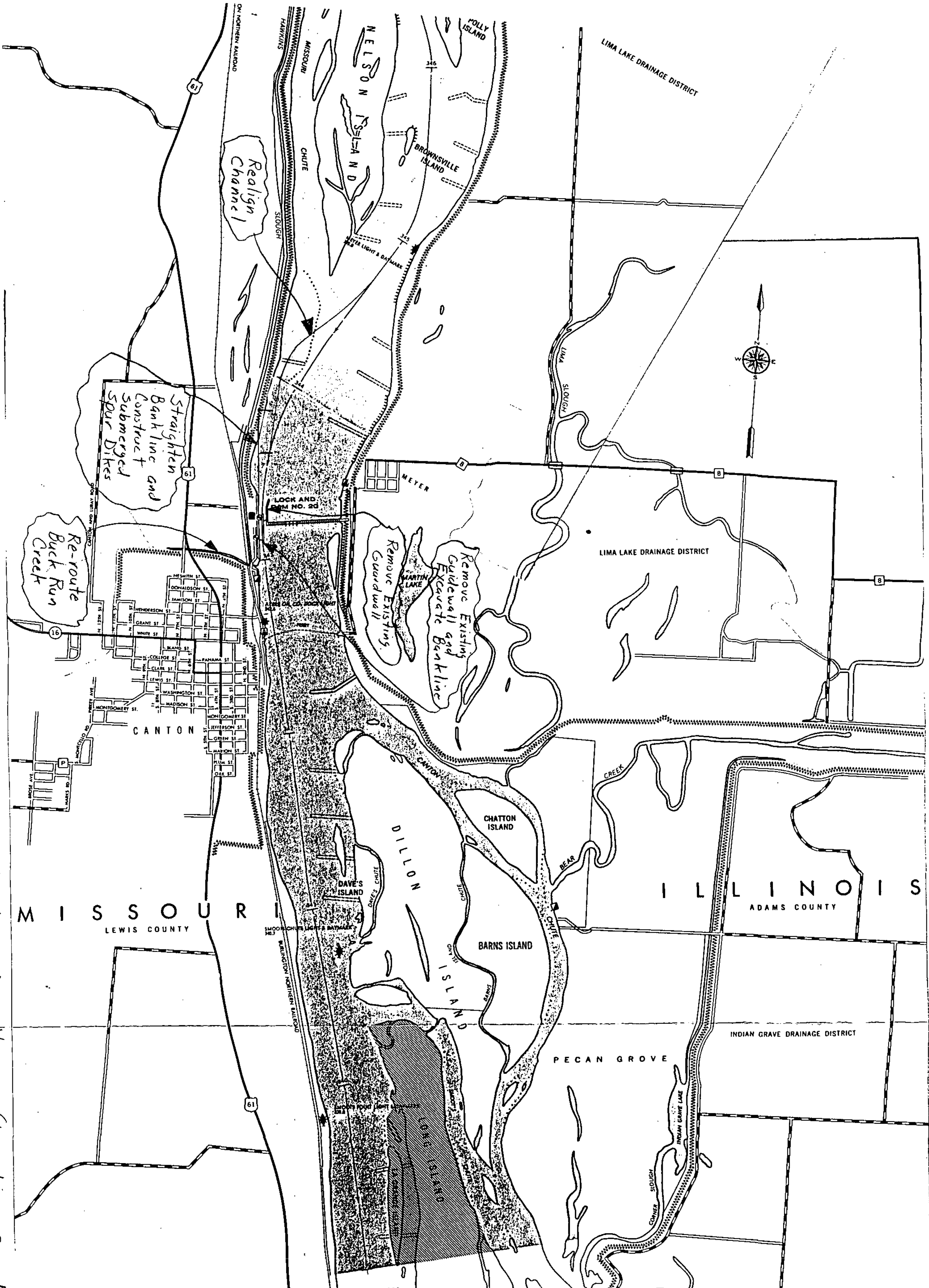
Downstream A solid 1200 foot landside guide wall would be constructed. Channel excavation and removal of the tip of the shoal would be required to enhance access to the existing lock. However, no channel work for the 1200 foot lock should be required.

Small Scale Improvement

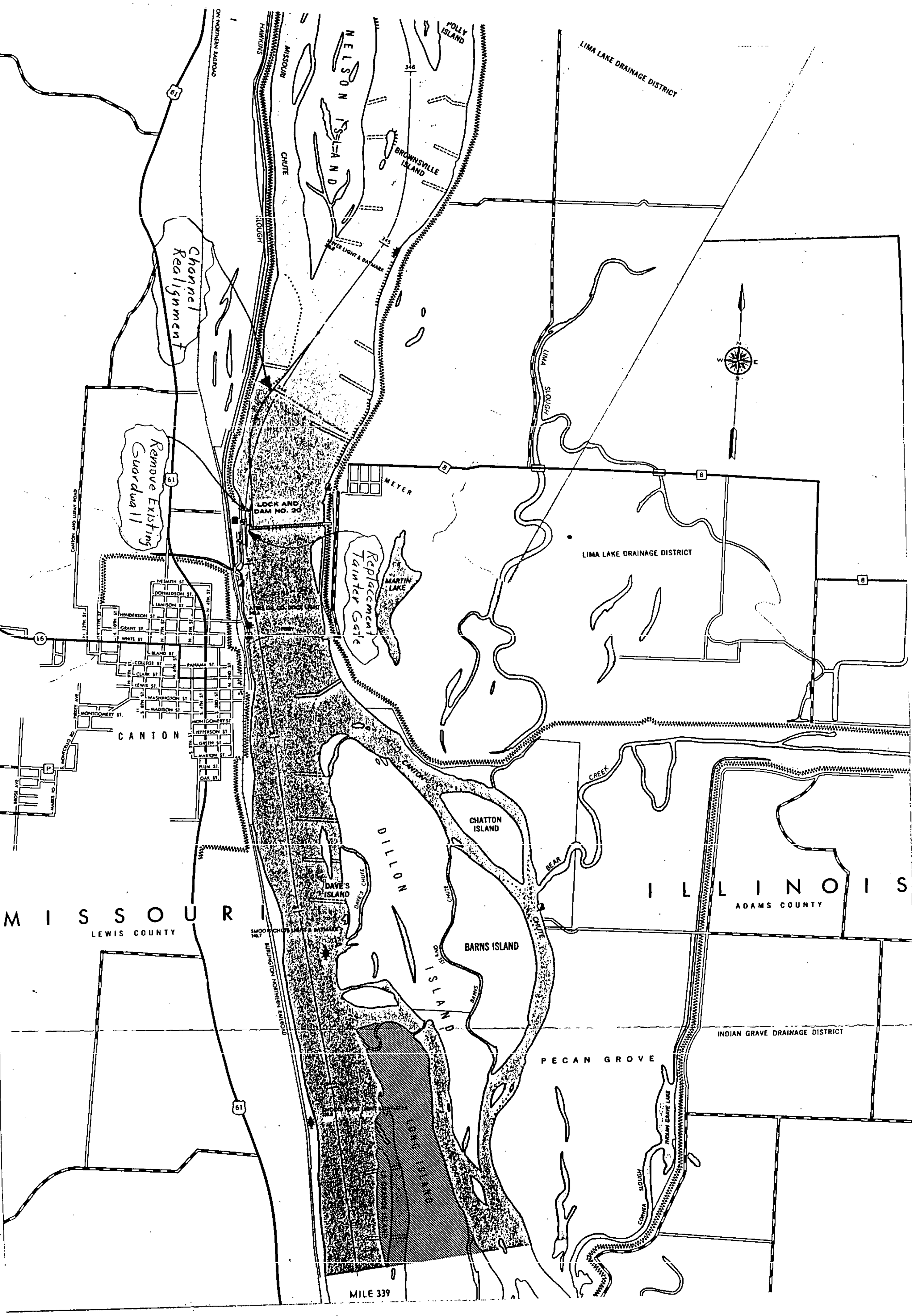
Upstream Small scale improvements upstream are limited as upstream channel work which provides significant improvement in approach conditions, is also beyond the scope of what could be considered small scale improvements. However, straigtening of the bankline upstream of the lock as discussed above would be of some benefit.

Downstream Re-routing of Buck Run Creek and extending the existing landside guide wall with some realignment of the channel would be the most beneficial improvement. The wall could be tied into the bankline by either backfilling or construction of a rock dike between wall and the bankline. A mooring cell properly located downstream of the lock would aid upbound tows waiting to approach the lock and would divert tows away from the present fleeting area along the west bank which is a known mussel sanctuary.

Navigable Pass Through the Dam Lock 20 is usually one of the first locks to go out of operation during higher than normal flows when the lock gates become inoperable because of high water. A navigable pass situation allows tows to pass through a section of the dam after gates in the dam are lowered as the head differential between the upper and lower pools approaches zero. By-passing the locking process in this way saves transit time and is beneficial to navigation. A navigable pass condition would exist an estimated 30 percent of the time at this site. A minimum pass width of 480' is needed in the dam and can be attained by incorporating wicket gates in the dam structure. The water depth over the sill would be at least 16.5' and the end walls curved to maintain an even flow through the opening. The approach channel above and below the opening would be 300' wide.




Lock and Dam No. 20 (Locations 2 and 3)




Lock and Dam No. 20 (Location 4)

**LOCK AND DAM NO. 21**

Existing Conditions

Downbound tows use a flanking approach to the lock and fight an outdraft off the end of the intermediate lock wall. High tailwaters approaching flood stage require use of a helper boat to assist tows approaching the lock.

Location 2

Upstream The existing 600 foot ported guard wall would be removed. A 1200 foot ported riverside guard wall would be constructed. In order to reduce the flow concentration in the vicinity of the guard wall, five to six 400 foot long submerged dikes spaced about 500 feet apart would be constructed. The dikes would be submerged a minimum of 15 feet below flat pool allowing tows clear passage and would extend from the bankline to the far edge of the navigation channel. Removal of an existing spur dike upstream of the lock and extensive excavation along the bank will be required to provide good approach conditions to the lock.

Downstream Extension of the existing 600 foot landward guide wall to 1200 feet would give tows protection from breaking currents for their entire length. Minimal channel work would be required.

Location 3

Upstream The existing 600 foot ported riverside guard wall would be removed and replaced with a 1200 foot ported guard wall. Submerged dikes similar to those described above would also be required for this location.

Downstream A 1200 foot riverward guide wall would be constructed. Minimal channel work would be required. Eddy currents and sediment deposition could be a problem immediately downstream of the wall.

Location 4

Upstream The existing 600 foot ported guard wall would be removed. A 1200 foot ported riverward guard wall would be constructed. Bank realignment would be less extensive at this location. However, longer submerged spur dikes would be required extending from the shoreline to beyond the end of the channel.

Downstream A 1200 foot riverward guide wall would be constructed. Minimal channel work would be required. Eddy currents and sediment deposition could be a problem immediately downstream of the wall as noted for Location 3. An alternative would be to construct landward guide wall.

However, there may be a tendency for tows to be pushed out into high velocity currents.

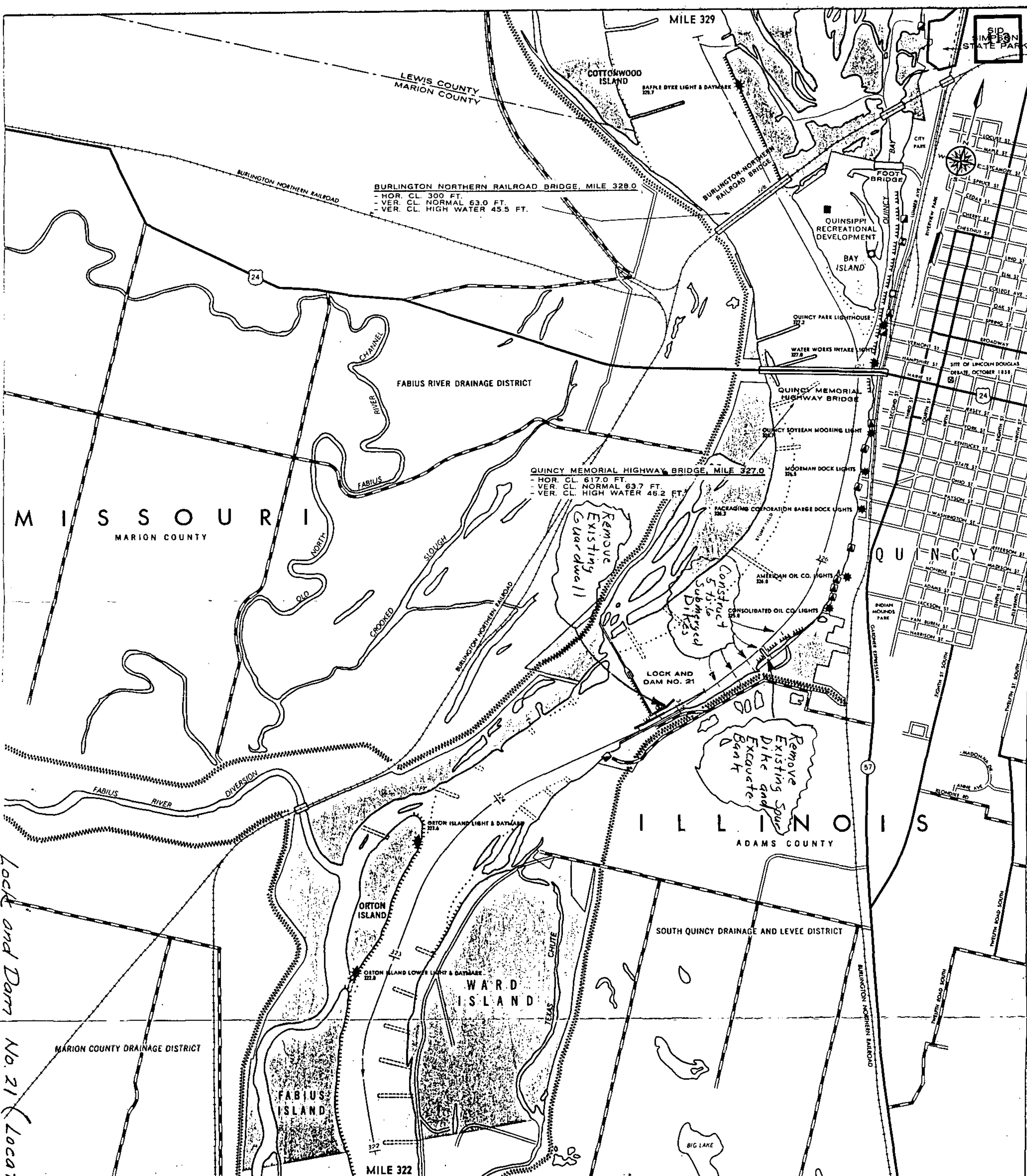
Location 5

Although bathymetry data suggest that a lock constructed at Location 5 would not be out of the question and may have some advantages over the other locations investigated, maintaining access to the existing lock during the 3 to 4 year period required to develop a channel to the new lock could be extremely difficult. The probabilty of severe impacts on existing traffic render this alternative infeasible.

Small Scale Improvements

Upstream Extension of the existing 600 foot ported guard wall could provide a major improvement in approach time for downbound tows. However, construction would be contingent upon knowing if and at which location large scale improvements would be instituted at a later date. Upstream bank alignment, submerged dikes, and a guide cell located off the intermediate wall would also provide improved approach conditions.

Downstream Extension of the existing 600 foot downstream guidewall to 1200 feet would improve approach times for upbound tows.




Lock and Dam No. 21 (Locations 2, 3 and 4)

## LOCK AND DAM NO. 22

Existing Conditions

As downbound vessels reduce speed to make the approach to the lock, they must fight a strong outdraft. Helper boats are required to assist at tailwater stages above 8 feet. The channel upstream of the lock is narrow. A mooring cell located 3500 feet upstream of the lock is rarely used because it is hard to access. Therefore, downbound traffic waits approximately 3 miles upstream to allow upbound traffic to pass.

Location 2

Upstream Construct a 1200 foot ported riverside guard wall. Excavate the bankline to provide a 200 foot wide approach to the lock. A system of 5 emergent spur dikes spaced approximately 1000 feet apart constructed to an elevation of 2 feet above flat pool would significantly improve approach conditions at any of the locations considered for added lock capacity. The dikes would extend from the bank to the near edge of the navigation channel with their length being dependent on lock location.

Downstream The existing 600 foot landside guide wall would be extended by 600 feet.

Location 3

Upstream Construct a 1200 foot ported riverside guard wall with the dike system described for Location 2. Bankline excavation would not be required at this location.

Downstream A 1200 foot riverside guide wall would allow full access to the existing lock. A landside wall would provide a better approach to the 1200 foot lock as well as a rubbing surface for both locks. However, the wall thickness would need to be increased and access to the existing lock would be limited by the narrow entrance.

Location 4

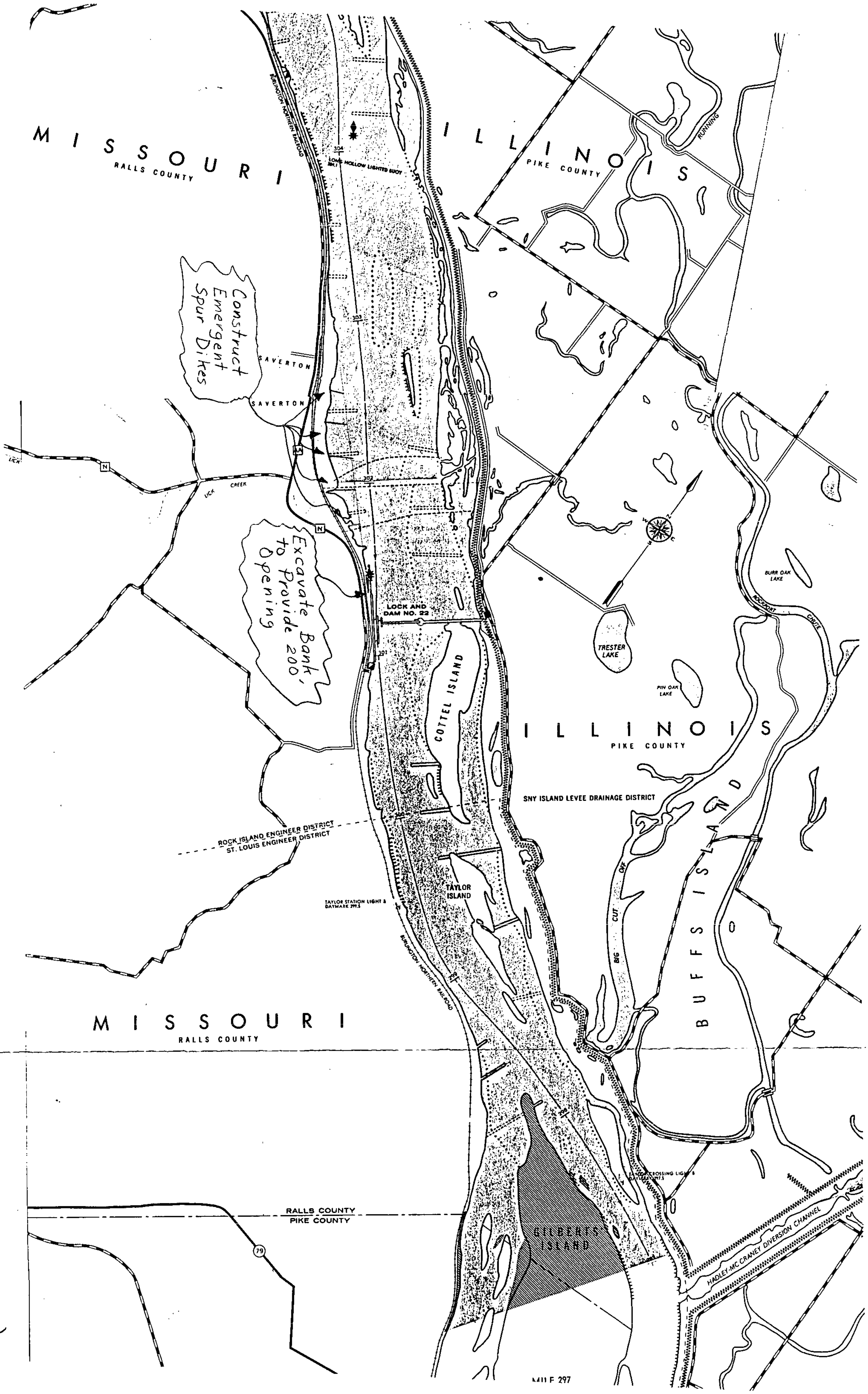
Upstream Construct a 1200 foot ported riverside guard wall with the dike system described for Location 2. Although the dikes would not be necessary for low flow conditions, they would still be very beneficial when flows exceed 160,000 cfs. Bankline excavation would not be required at this location.

Downstream A 1200 foot riverside guide wall performed satifactorily in the physical model study of Lock 22. However a landside wall may perform as well if not better. The landside guide wall for the existing lock should be extended from 600 to 1200 feet.

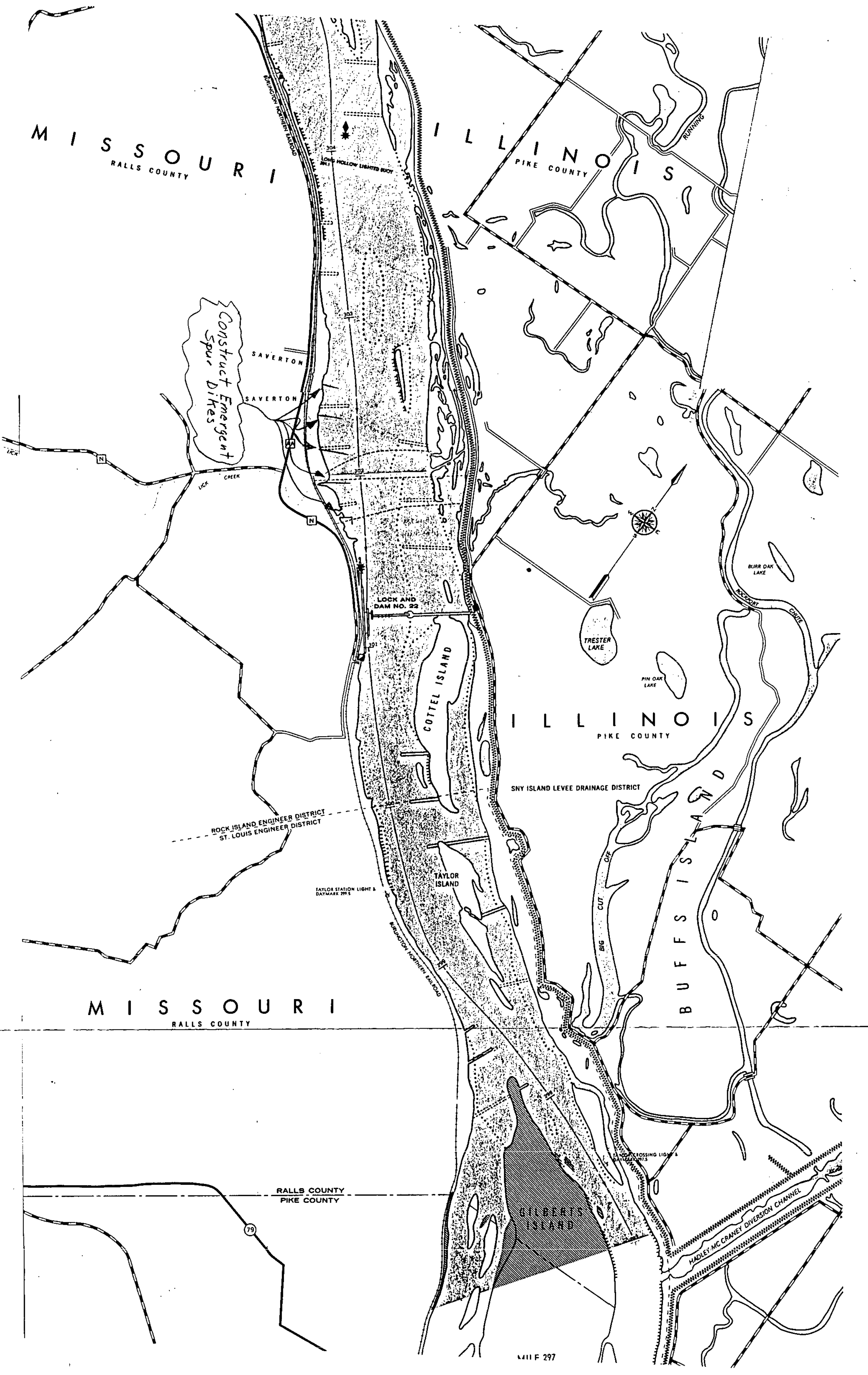
Small Scale Improvements

Upstream Construction of a dike system upstream as described above and channel excavation to provide a wider entrance to the lock, would provide the greatest improvement in approach conditions. The dike system will also make the existing mooring cell upstream more accessible. A 1200 riverside ported guard wall would provide additional improvements. However, unlike the dike system, its placement would be location dependent. Future construction of a 1200 foot lock at Location 3 or 4 would require its removal.

Downstream Since existing downstream approach conditions are quite good, few if any improvements downstream would shorten approach times significantly. Extending the existing guide wall to 1200' would not improve the approach time but together with improved tow haulage would improve the lock transit time for some lockages since the reconnect of extracted cuts would be made outside the lock chamber.




Lock and Dam No. 22 (Location 2)




Lock and Dam No. 22 (Locations 3 and 4)

**LOCK AND DAM NO. 24**

Existing Conditions

Severe outdraft conditions in the upstream approach to the lock give Lock and Dam No. 24 the distinction of being one of the most dangerous locks to approach in the lower reach of the Upper Mississippi River. While construction of a spur dike in the upstream approach has improved the situation, a helper boat is still needed much of the time to aid tows in their approach to the lock.

Location 2

Upstream Remove existing ported guard wall and construct 1200 foot ported riverward guard wall. Excavation with removal of the existing guide wall along the right bank would be required to widen the approach. This may in turn require relocation of the railroad line which is loacted very near the shoreline. The possibility exists that a boat harbor upstream may be impacted as well by increased sedimentation.

The existing upstream spur dike may function better if it were shortened and an L-head were added at the riverward end. Construction of 2 to 3 additional dikes spaced at a maximum distance of 1000 feet with the ends parallel to the approach would improve the approach at all locations.

Downstream Extending the existing landside guide wall to 1200 feet would be the only improvement required downstream.

Location 3

Upstream Remove the existing 600 foot ported riverward guard wall and replace with a 1200 foot ported riverward guard wall. Construction of the dike system described above would be required. However, excavation to widen the approach should not be necessary.

Downstream Construct a 1200 foot riverside guide wall.

Location 4

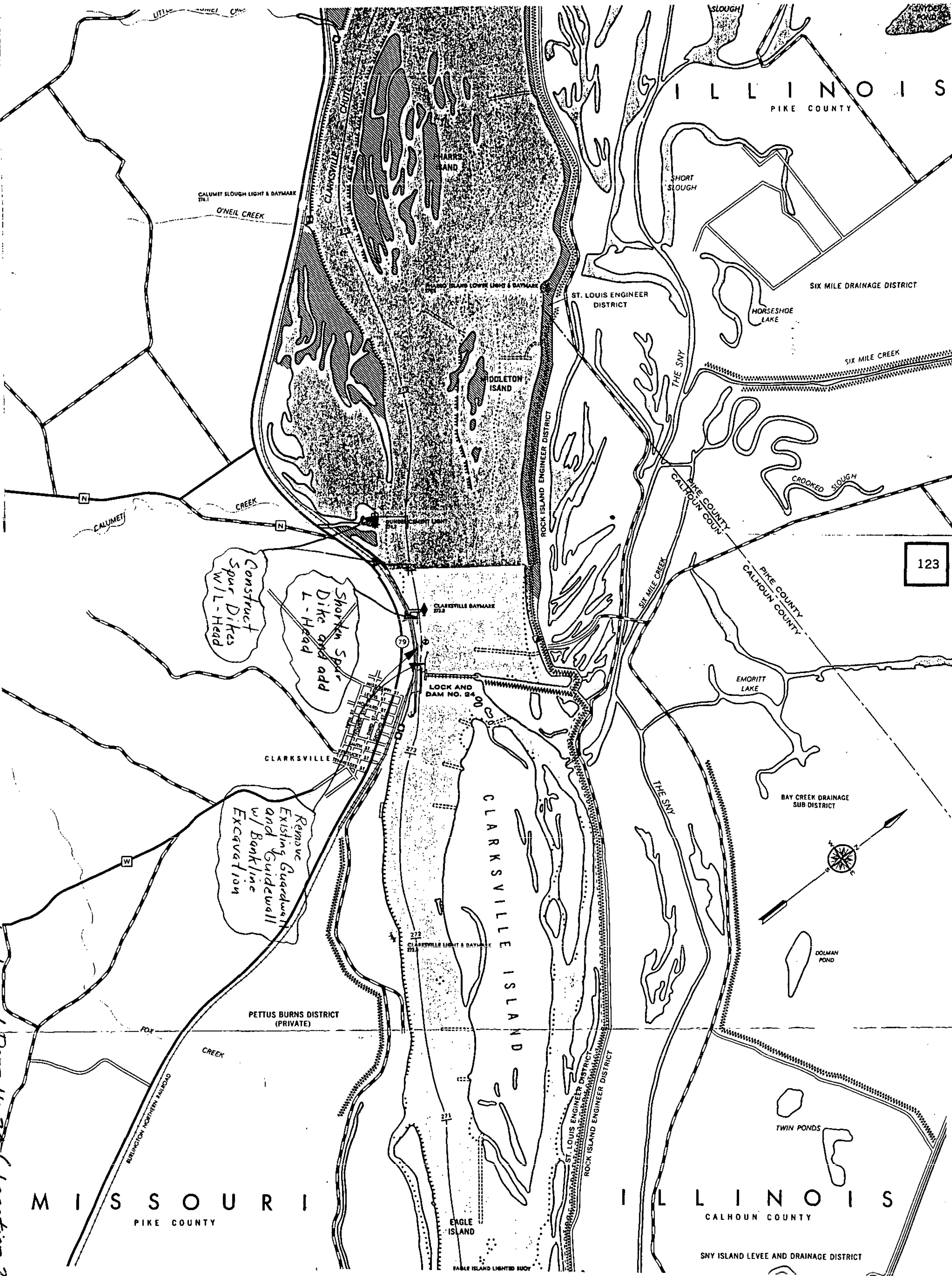
Upstream Remove the existing ported guard wall and construct a 1200 foot ported riverside guard wall. Construction of spur dikes may not be necessary at this location.

Downstream Construct a 1200 foot landside guide wall.

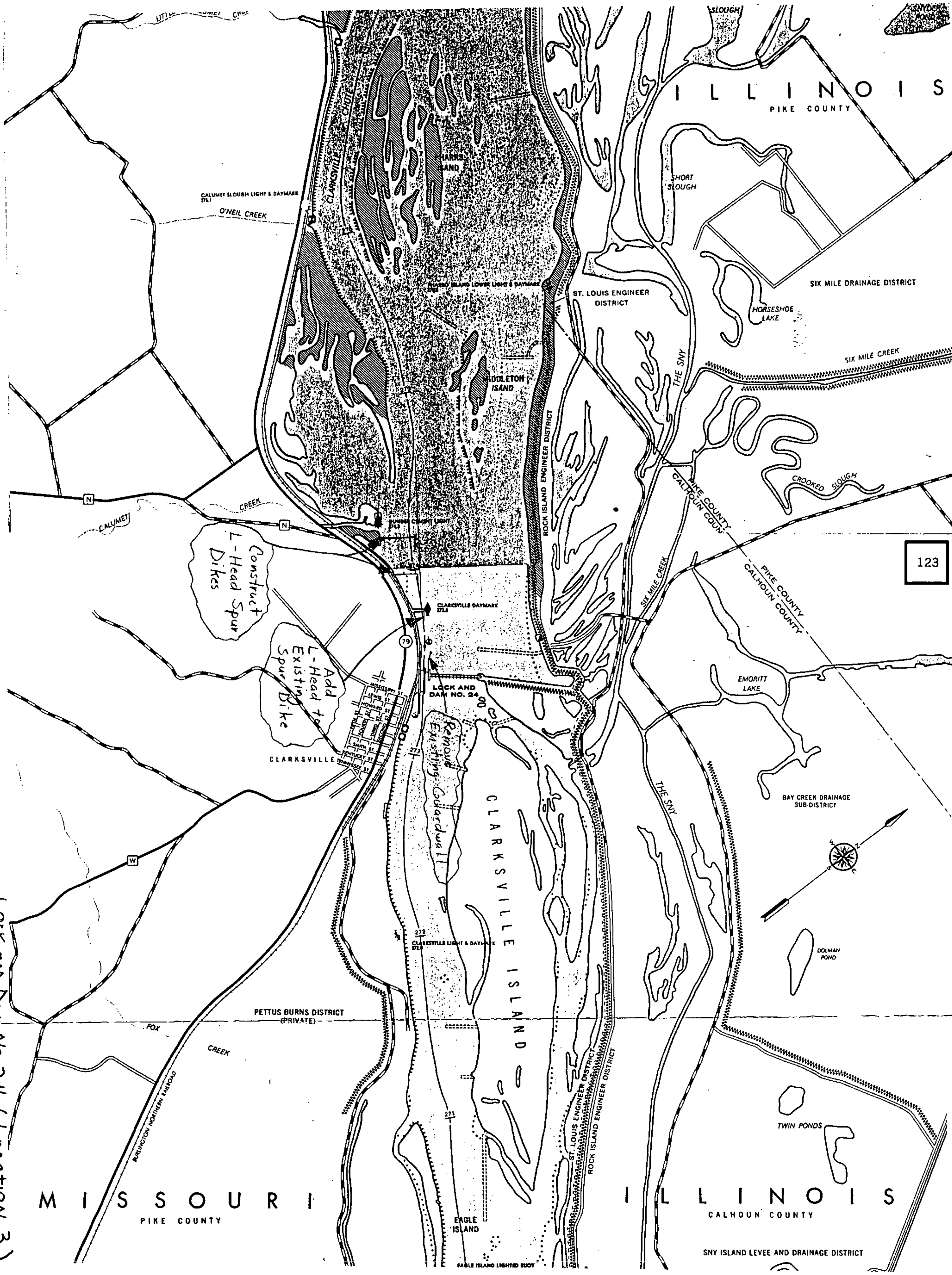
Small Scale Improvements

Upstream Construction of the dike field upstream of the lock as described above would improve approach conditions significantly. An upstream 1200 foot ported riverside guard wall with excavation along the right bank would also be of benefit but would be dependent upon the location future large scale improvements.

Downstream There are no small scale improvements which would provide significant benefits at this site.




Lock and Dam No 24 (Location 2)




Lock and Dam No. 24 (Location 3)


Lock and Dam No. 24 (Location 4)

## LOCK AND DAM NO. 25

Existing Conditions

Severe outdraft conditions hamper downbound tows approaching the lock. While construction of a spur dike in the upstream approach has improved the situation, a helper boat is still needed much of the time to aid tows in their approach to the lock. The ported guard wall creates some interference with the helper boat. Additionally, the trash removal opening in the ported guard wall has proven to be ineffective as trees become pinned across the opening which in turn encourages the collection of smaller debris. As debris continues to accumulate over time, the debris gap becomes plugged. This results in more flow being forced through the series of timber piles upstream. Because the timber piles are on 5 foot centers, debris accumulates quickly. As plugging of the openings increase, the outdraft near the nose cell, due to flow crossing over to the dam, becomes more severe, aggravating scour of the bed riverward of the upstream cells as well as hampering navigation.

Location 1

Upstream A 1200 foot ported riverward guard wall would be constructed and would extend from the riverside wall of the new lock. Extensive excavation would be required along the right descending bank both upstream and downstream of the lock. Extensive channel work would also be required to allow tows to align with the lock a minimum of two tow lengths upstream of the guard wall. Locating the lock downstream of the dam would reduce excavation. However, foundation and structural concerns limit its practicality.

Under this alternative, the approach to the existing lock would be extremely difficult as outdraft would increase due to the addition of the 1200 foot ported guard wall located upstream and landward of the existing lock. Therefore, use of the existing lock would probably be limited to small tows and recreational craft.

Downstream Excavation along the right bank with construction of a 1200 foot landward guide wall would be required.

Location 2

Upstream The existing ported guard wall would be removed and replaced with a 1200 foot ported riverside guard wall. The existing landward guide wall would be removed allowing the bankline to be excavated 600 feet upstream to provide a 200 foot opening between the bank and guard wall at navigation depth. Although channel realignment upstream would not be a requirement for safe approach to the lock, realignment would significantly improve the approach as the existing alignment has tows turning as they make their approach.

Downstream The existing 600 foot landward guide wall would be extended by 600 feet. No excavation is required. However, limited excavation would improve the entrance. Without any excavation, tows leaving the lock will be required to stay on the wall longer.

Location 3

Upstream This location best fits the normal design criteria that is proven in the field. The existing 600 foot ported guard wall would be removed and replaced with a 1200 foot ported riverside guard wall. Neither bank excavation or channel realignment should be required although limited channel realignment would aid tows in getting in the protection of the guard wall sooner as at Location 2.

Downstream A 1200 foot solid landside guide wall would be the preferred configuration for entrance to the new lock. However, entrance to the existing lock would be severely restricted. Removal of the exsiting landside guide wall with bank excavation would provide sufficient opening to the existing lock. The intermediate wall would provide a rubbing surface for both locks.

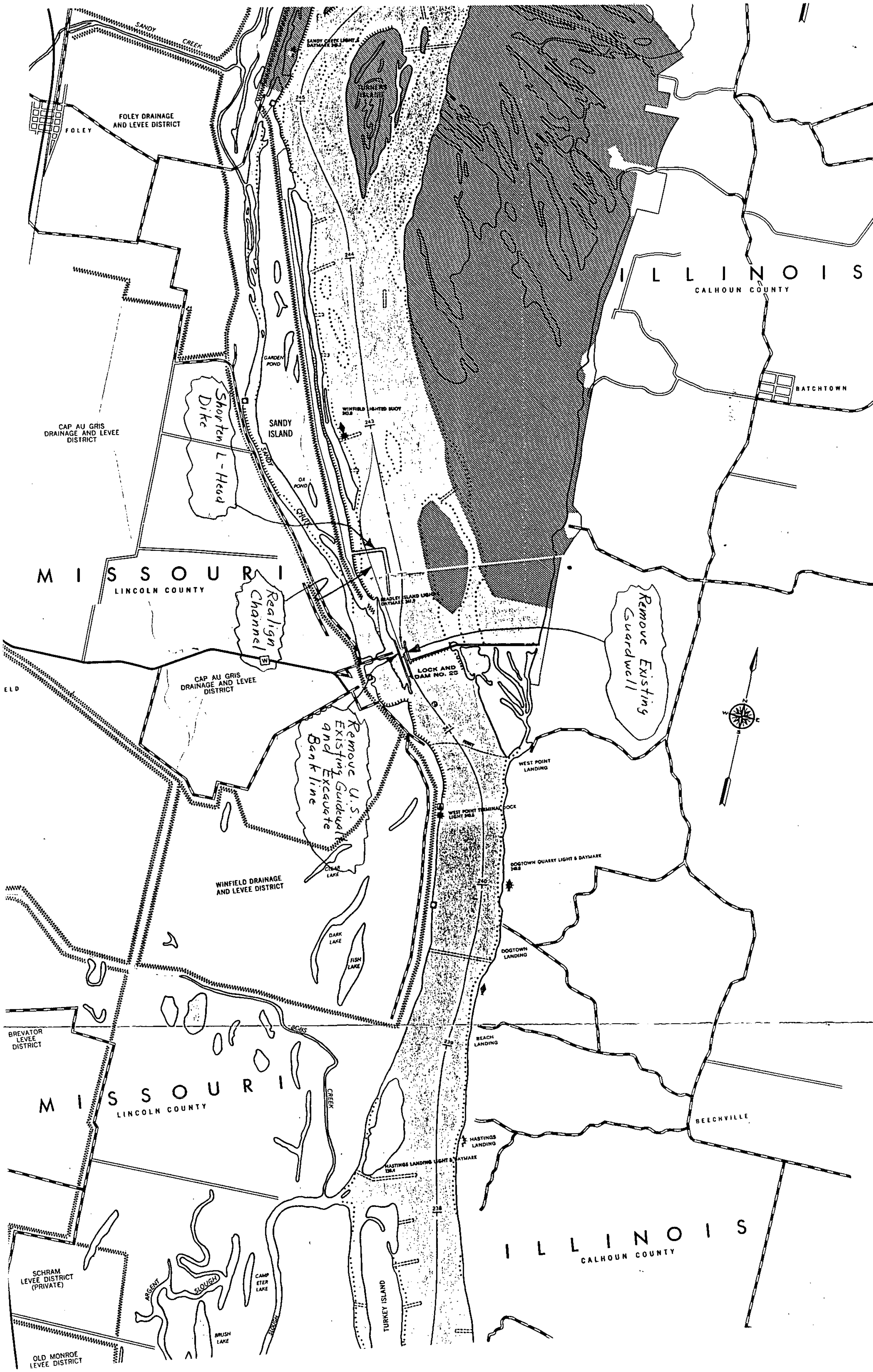
Location 4

Upstream The existing 600 foot guard wall would be removed and replaced with a 1200 foot ported riverside guard wall. The present upstream channel alignment is adequate for this location. Therefore, no bankline or channel excavation would be required. Lost tainter gate capacity would be compensated for by placing a tainter gate in the partially constructed auxillary lock chamber between the new lock and the existing lock. This gate would be operated according to flow conditions.

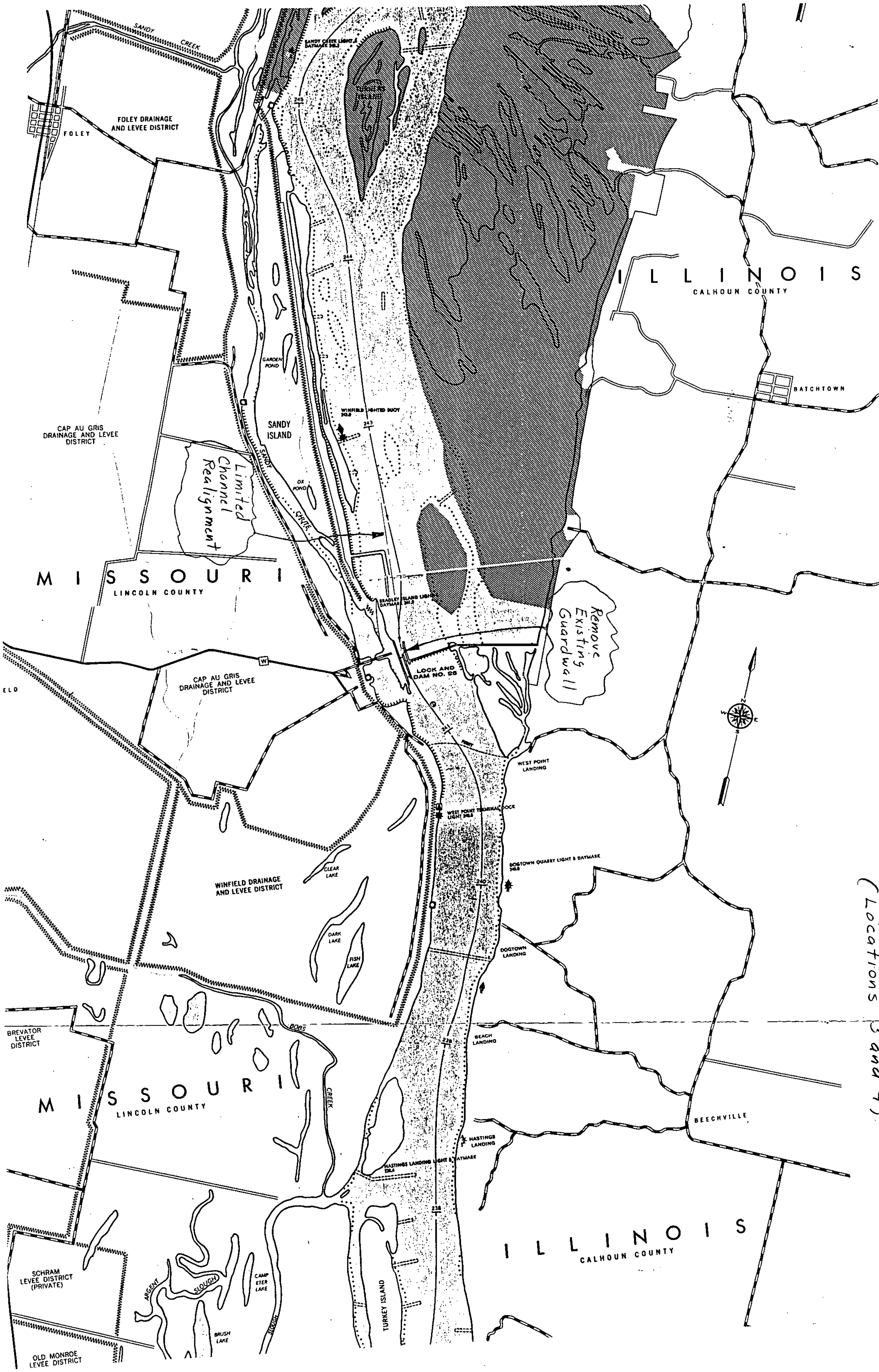
Downstream A 1200 foot landside guide wall would be constructed. No additional excavation is required.

Small Scale Improvements

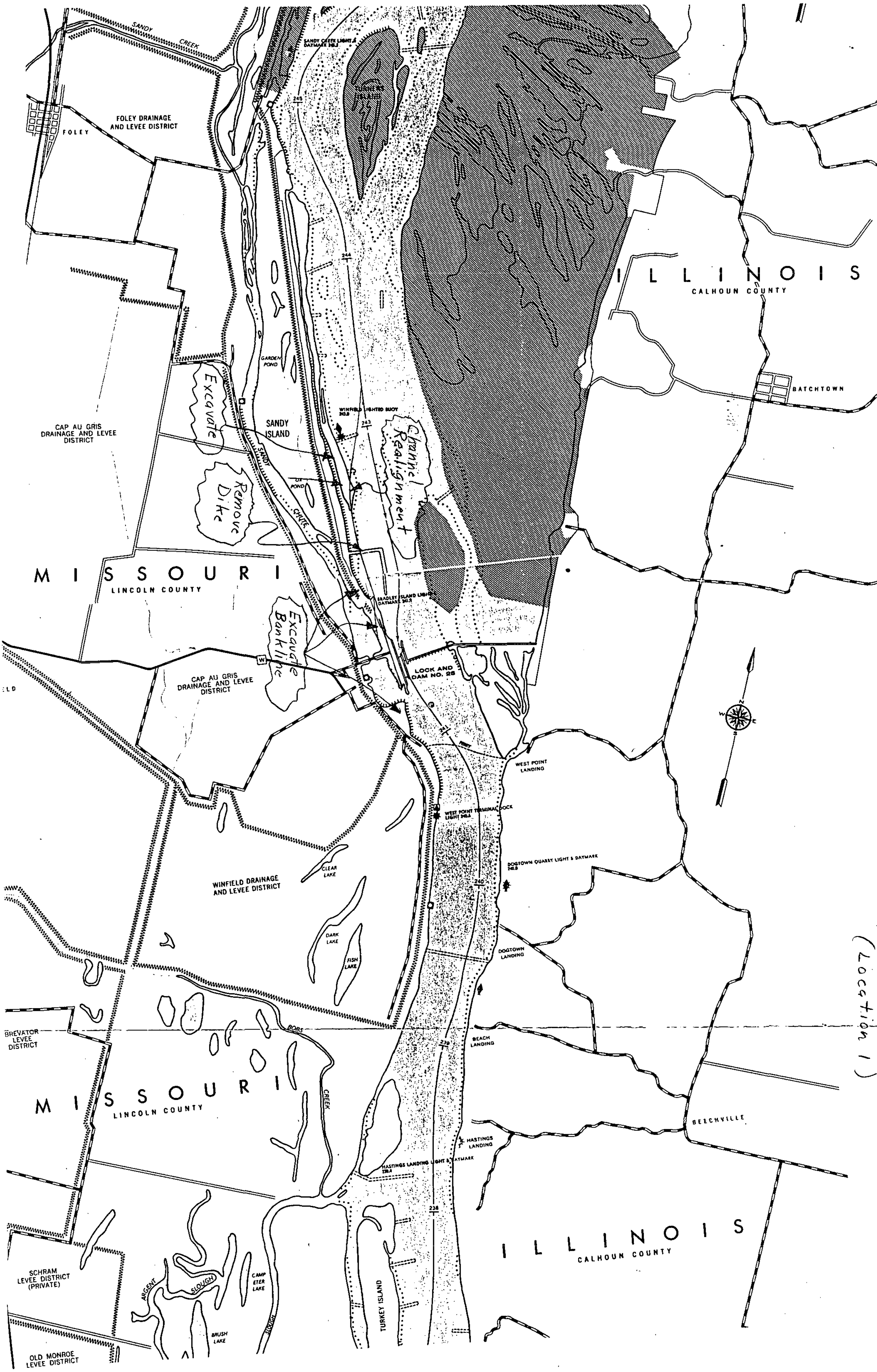
Channel realignment both upstream and downstream would improve overall transit time with upstream improvements providing the greatest benefit. Extension of guard walls and guide walls would not improve approach times significantly.




Lock and Dam No. 25 (Location 2)




Lock and Dam No. 25 (Locations 3 and 4)




Lock and Dam No. 25 (Location 1)

**PEORIA LOCK AND DAM**

Existing Conditions:

The dam consist of an 80' wide tainter gate and 108 wicket gates 4' wide. Open pass exist about 40 percent of the time. The I-474 bridge about 1000 feet upstream impacts all the locations for potential new lock construction. New construction must provide 60' of clearance from flat pool to low steel of the bridge. Presently there is about 64' of clearance at the channel span. The end anchor spans slope down and the bridge profile will have to be checked for adequate clearance for a Location 1 lock. The criteria of providing a straight downbound approach of two tow lengths (2400') above the upper guide/guard wall may be relaxed because of the lower flow velocities common when the lock is in use. The lower velocities allow easier manuevering by tows above the lock.

Location 1

Upstream Extend a 1200'ported guard wall 400' upstream of the I-474 bridge pier. This locates the upper miter gates for a 1200' lock about 800' downstream from the bridge. With this arrangement there is a slight turn in the downbound approach (0 tow lengths above the end of the guard wall) but with some minor bank excavation a 200' wide opening is possible at the guard wall upper entrance. Some added protection/reinforcement may be required for the I-474 bridge piers landward of the excavated canal to the upper lock gates. The canal should be a minimum of 150'-175' wide at navigation depth down to the lock. The guard wall can be solid at the bridge pier but should be ported upstream and downstream of the pier. The commercial dock upstream will have to be relocated.

Downstream A 1200' landside guide wall and channel excavation are required. The commercial dock downstream will have to be relocated.

Location 2 (Upstream extension) Best H&H location

Upstream Incorporate the I-474 bridge piers into a short landside wall. Extend a 1200' ported guard wall from the end of the short landside wall at the bridge piers. Gives good open pass conditions. It may be possible to reduce the ported wall length to less than 1200' because of low flow velocities.

Downstream Extend the guide wall to 1200'. If outdraft from the flow through the tainter gate is a problem for the upbound approach, a wingwall (short wall) could be added to the riverside wall to deflect the flow from the tainter gate.

Location 4 (At the tainter gate location)

Upstream This involves construction of a new lock at the 80' wide submergible tainter gate location and moving the tainter gate to the existing 600' lock bay. There should be little if any channel excavation needed. Align the uppper end of a new lock with the upper end of the existing lock or shift the upper end of the new lock upstream a couple hundred feet at most. The upstream channel will be narrowed to about 200' wide and the channel span at the I-474 bridge will be narrowed to about 250' wide. Protection cells may be needed for the I-474 channel span west bridge piers. Extending the lock downstream maintains a more suitable channel for the open pass situation . Use a 1200' landside ported guard wall.

Downstream Construct a 1200' landside guide wall.

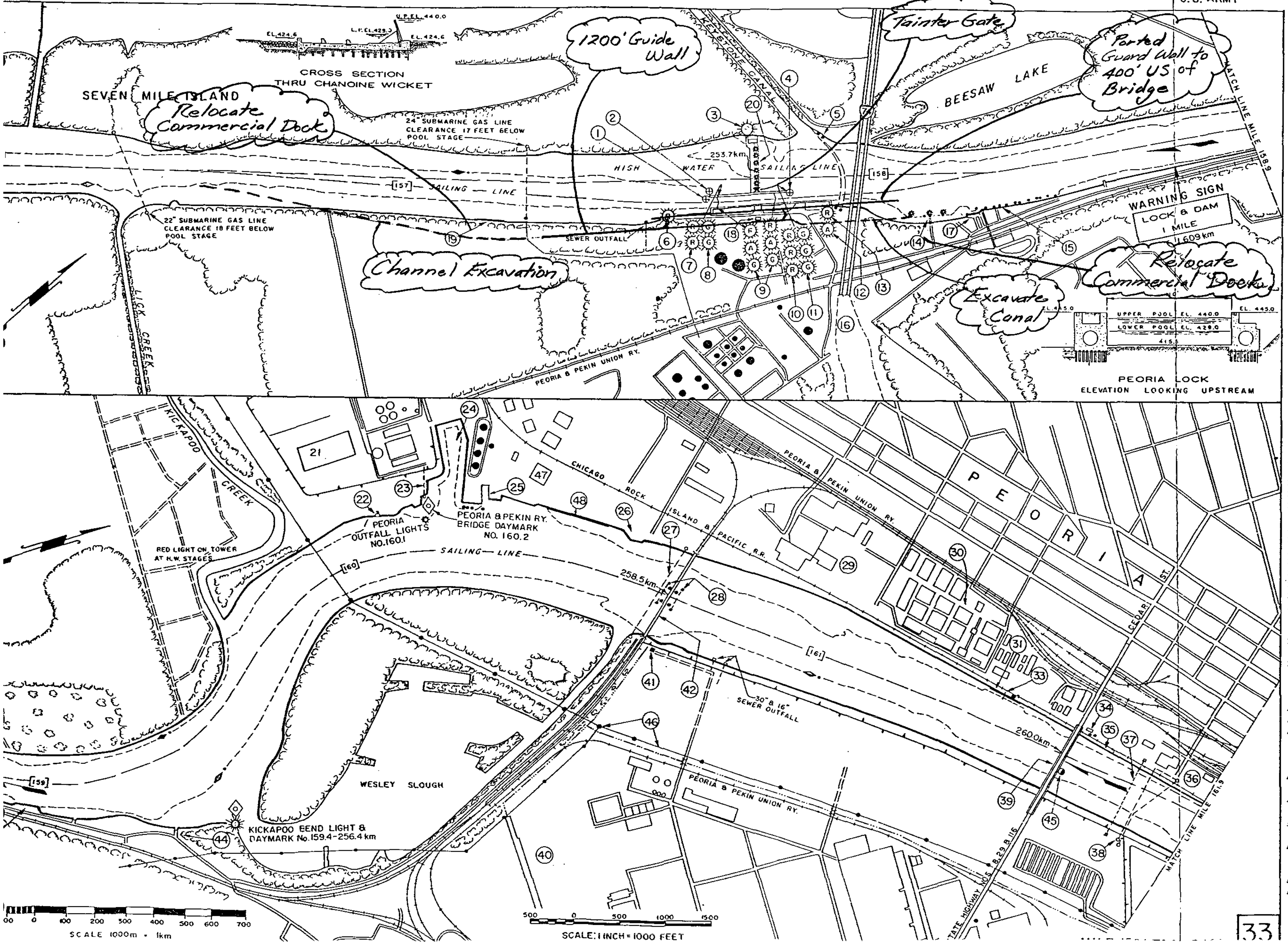
Small-Scale Improvements

Upstream Extend the guide wall to 1200' encasing the I-474 bridge piers into the wall. Add a dike system or reconfigure the bankline just upstream of the wall to keep flow from getting landward of the wall and sweeping across the approach.

Downstream Extend the guide wall to 1200'. If needed, construct a short wall (100' long at a 15 degree angle) at the end of the riverside wall to divert the tainter gate flow away from the upbound approach.

CORPS OF ENGINEERS

U.S. ARMY



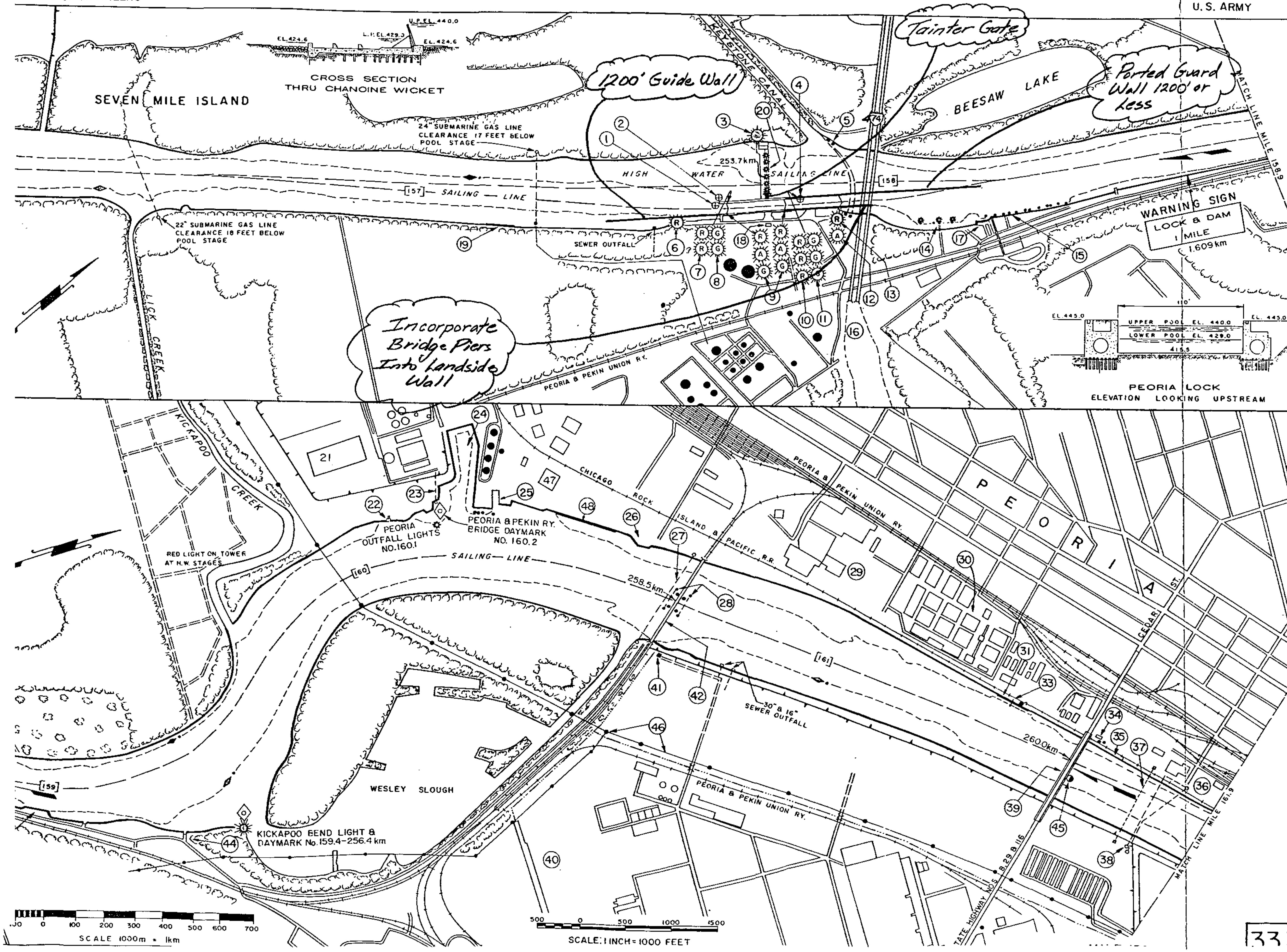

33

**LEGEND**

1. PEORIA LOCK GAGE, LOWER (U.S. GAGE) EL. OF ZERO = 417.0 M.S.L. '29
2. PEORIA LK. GAGE, LOWER AUX.(U.S. GAGE) EL. OF ZERO = 424.6
3. ONE RED LIGHT ON DAM WEIR WALL
4. LAUNCHING RAMPS AVAIL. FOR USE TO AVOID LOCKING - PEORIA LOCK GAGE UPPER EL. OF ZERO - 424.5 M.S.L. '29
5. SUBMARINE PIPE LINE CROSSING PANHANDLE EASTERN P.L.C.O. - CLEAR 16.0 FT BELOW POOL STAGE
6. ONE RED LIGHT
7. 2 RED LIGHTS ARRANGED IN A VERT. LINE, SHOWN WHEN THERE IS A NAVIGABLE PASS THROUGH THE DAM
8. 2 GREEN LIGHTS ARRANGED IN A VERT LINE, SHOWN WHEN THERE IS NO NAVIGABLE PASS THROUGH THE DAM
9. LOCK SIGNAL LIGHTS
10. 3 RED LIGHTS ARRANGED IN A VERT LINE, SHOWN WHEN THERE IS A NAVIGABLE PASS THROUGH THE DAM
11. 3 GREEN LIGHTS ARRANGED IN A VERT LINE, SHOWN WHEN THERE IS NO NAVIGABLE PASS THROUGH THE DAM
12. 1 AMBER LIGHT SHOWN WHEN ANY WICKETS OF THE DAM ARE OPEN WHICH MAY CAUSE A SET IN THE CURRENT CONDITION IN THE UPPER LOCK APPROACH
13. 1 RED LIGHT 5 FT ABOVE AMBER LIGHT
14. STANDARD OIL CO. DOCK
15. CENTRAL ILLINOIS DOCK CO
16. ROAD AND BRIDGE CONSTRUCTION AREA
17. UNITED GRAIN CO
18. CONTROL STATION
19. AGRICO CHEM. CO. DOCK
20. AMBER FLASHER LIGHTS ON DAM WHEN RAISED FROM MAY 1 TO SEPT 30
21. PEORIA SEWAGE DISPOSAL PLANT
22. COMMERCIAL SOLVENTS DOCK
23. SEWER OUTLET
24. COMMERCIAL SOLVENTS CORP HARBOR
25. MARTIN OIL SERV. INC.
26. PURTSCHER READY-MIX CONCRETE DOCK
27. SUB. CABLE CL. 17 FT BELOW POOL STAGE
28. SUB. CABLE CL. 19 FT BELOW POOL STAGE
29. PACKING PLANTS
30. HIRAM WALKER & SONS, INC
31. HIRAM WALKER DOCK
33. PUMP INTAKE FOR HIRAM WALKER
34. STATE OF ILL. WATER SURVEY DIV
35. INFILTRATION PITS
36. GAS WORKS
37. TRANSMISSION LINE - VERT. CL. 87 FT. ABOVE POOL STAGE - VERT. CL. 71 FT ABOVE HIGH WATER
38. SUB. GAS PIPE LINES - CL. 16 FT BELOW POOL STAGE
39. CEDAR ST. HWY. BR., FIXED SPAN - HOR. CL. 280.0 FT - VERT. CL. 78.5 FT ABOVE POOL STAGE - VERT. CL. 62.0 FT. ABOVE HIGH WATER FOR 210 FT WIDTH
40. EAST PEORIA DRAINAGE & LEVEE DISTRICT
41. E. PEORIA D. & L. DIST (PUMP HOUSE)
42. P. & P.U. RY. BRIDGE, BASCULE-HOR. CL. 140 FT - VERT. CL. CLOSED 21.3 FT ABOVE POOL STAGE - VERT. CL. CLOSED 4.9 FT. ABOVE HIGH WATER
43. BAILEY'S BOATYARD (GASOLINE) LAUNCHING RAMP
44. HARBOR LIGHT PIER (GASOLINE) LAUNCHING RAMP
45. GAGE INDICATING CLEARANCE FOR FRANKLIN ST. BRIDGE
46. TRANSMISSION LINE - VERT. CL. 87 FT ABOVE POOL STAGE - VERT. CL. 71 FT ABOVE HIGH WATER
47. READY MIX CONCRETE CO
48. PEORIA BARGE TERMINAL

Peoria 4D
Loc 1

CORPS OF ENGINEERS — U.S. ARMY




## LEGEND

1 PEORIA LOCK GAGE. LOWER (U S GAGE) EL OF ZERO = 417.0 M S.L. '29
2 PEORIA LK GAGE. LOWER AUX.(U.S GAGE) EL. OF ZERO = 424 6
3 ONE RED LIGHT ON DAM WEIR WALL
4 LAUNCHING RAMPS AVAIL FOR USE TO AVOID LOCKING - PEORIA LOCK GAGE UPPER EL. OF ZERO - 424 5 M.S L '29
5 SUBMARINE PIPE LINE CROSSING PANHANDLE EASTERN P.L C.O. - CLEAR 16.0 FT BELOW POOL STAGE
6 ONE RED LIGHT
7 2 RED LIGHTS ARRANGED IN A VERT LINE, SHOWN WHEN THERE IS A NAVIGABLE PASS THROUGH THE DAM
8 2 GREEN LIGHTS ARRANGED IN A VERT LINE, SHOWN WHEN THERE IS NO NAVIGABLE PASS THROUGH THE DAM
9 LOCK SIGNAL LIGHTS
10 3 RED LIGHTS ARRANGED IN A VERT LINE, SHOWN WHEN THERE IS A NAVIGABLE PASS THROUGH THE DAM
11 3 GREEN LIGHTS ARRANGED IN A VERT LINE, SHOWN WHEN THERE IS NO NAVIGADLE PASS THROUGH THE DAM
12 1 AMBER LIGHT SHOWN WHEN ANY WICKETS OF THE DAM ARE OPEN WHICH MAY CAUSE A SET IN THE CURRENT CONDITION IN THE UPPER LOCK APPROACH
13 1 RED LIGHT 5 FT ABOVE AMBER LIGHT
14 STANDARD OIL CO DOCK
15 CENTRAL ILLINOIS DOCK CO
16 ROAD AND BRIDGE CONSTRUCTION AREA
17 UNITED GRAIN CO
18 CONTROL STATION
19 AGRICO CHEM. CO DOCK
20 AMBER FLASHER LIGHTS ON DAM WHEN RAISED FROM MAY 1 TO SEPT 30
21 PEORIA SEWAGE DISPOSAL PLANT
22 COMMERCIAL SOLVENTS DOCK
23 SEWER OUTLET
24 COMMERCIAL SOLVENTS CORP HARBOR
25 MARTIN OIL SERV. INC.
26 PURTSCHER READY-MIX CONCRETE DOCK
27 SUB CABLE CL. 17 FT BELOW POOL STAGE
28 SUB CABLE CL 19 FT BELOW POOL STAGE
29 PACKING PLANTS
30 HIRAM WALKER & SONS. INC
31 HIRAM WALKER DOCK
33 PUMP INTAKE FOR HIRAM WALKER
34 STATE OF ILL WATER SURVEY DIV
35 INFILTRATION PITS
36 GAS WORKS
37 TRANSMISSION LINE - VERT CL 87 FT. ABOVE POOL STAGE - VERT CL. 71 FT ABOVE HIGH WATER
38 SUB. GAS PIPE LINES - CL 16 FT BELOW POOL STAGE
39 CEDAR ST HWY. BR , FIXED SPAN - HOR. CL 280 0 FT - VERT. CL 78 5 FT ABOVE POOL STAGE - VERT. CL. 62 0 FT. ABOVE HIGH WATER FOR 210 FT WIDTH
40 EAST PEORIA DRAINAGE & LEVEE DISTRICT
41 E PEORIA D. & L. DIST.(PUMP HOUSE)
42 P. & P.U RY. BRIDGE. BASCULE-HOR CL 140 FT - VERT. CL CLOSED 21 3 FT ABOVE POOL STAGE - VERT CL CLOSED 4.9 FT. ABOVE HIGH WATER
43 BAILEY'S BOATYARD (GASOLINE) LAUNCHING RAMP
44 HARBOR LIGHT PIER (GASOLINE) LAUNCHING RAMP
45 GAGE INDICATING CLEARANCE FOR FRANKLIN ST BRIDGE
46 TRANSMISSION LINE - VERT CL 87 FT ABOVE POOL STAGE - VERT CL 71 FT. ABOVE HIGH WATER
47 READY MIX CONCRETE CO
48 PEORIA BARGE TERMINAL

Peoria L/D
Loc 2, US Ext.

LA GRANGE LOCK AND DAM

Existing Conditions:

The dam consist of an 80' wide tainter gate and 104 wicket gates 4' wide. Open pass exist about 50 percent of the time. The tainter gate has helped to lessen the magnitude of the outdraft. Lower flow velocities (1-2 fps) allow easier maneuvering for tows on their downbound approach as they tuck into the pocket of water above the lock. The criteria of providing a straight approach for two tow lengths (2400') above the guide/guard wall may be relaxed because of the lower flow velocities. The lock is located on the outside of a bend in the river and the natural flow "pins" tows to the right descending bank.

Location 1

Upstream Requires a great amount of channel excavation but the approach can probably be designed, using a relaxed two tow length criteria, to be within the estimated assumed needed rights-of-way for this location. The required channel excavation would be less if a new 1200' lock were shifted downstream with respect to the existing 600' lock so that the upper miter gates align closer to the lower gates of the existing lock. Excavate a 200' wide canal to the lock. Examine the lock filling to avoid problems with tows and smaller recreation craft. An upstream guard wall may not have to be ported or may only have to be ported for 500' or so depending on how far the lock is shifted downstream. About 5 river training dikes each 200' long with a top elevation 2' above flat pool would be needed along the left descending bank above the dam.

Downstream Channel widening is needed with a 1200' guide wall.

Location 2

Upstream With a 1200' guard wall and relaxed two tow length criteria there is still an appreciable amount of channel widening needed but not to the extent as for Location 1. Will need the 5 wing dikes as described for Location 1. There is some concern that the required channel excavation/widening for both Locations 1 and 2 will result in a reach of river too wide with some yet to be determined adverse impacts.

Downstream Extend the landside guide wall to 1200'.

Location 4 (At the tainter gate location)

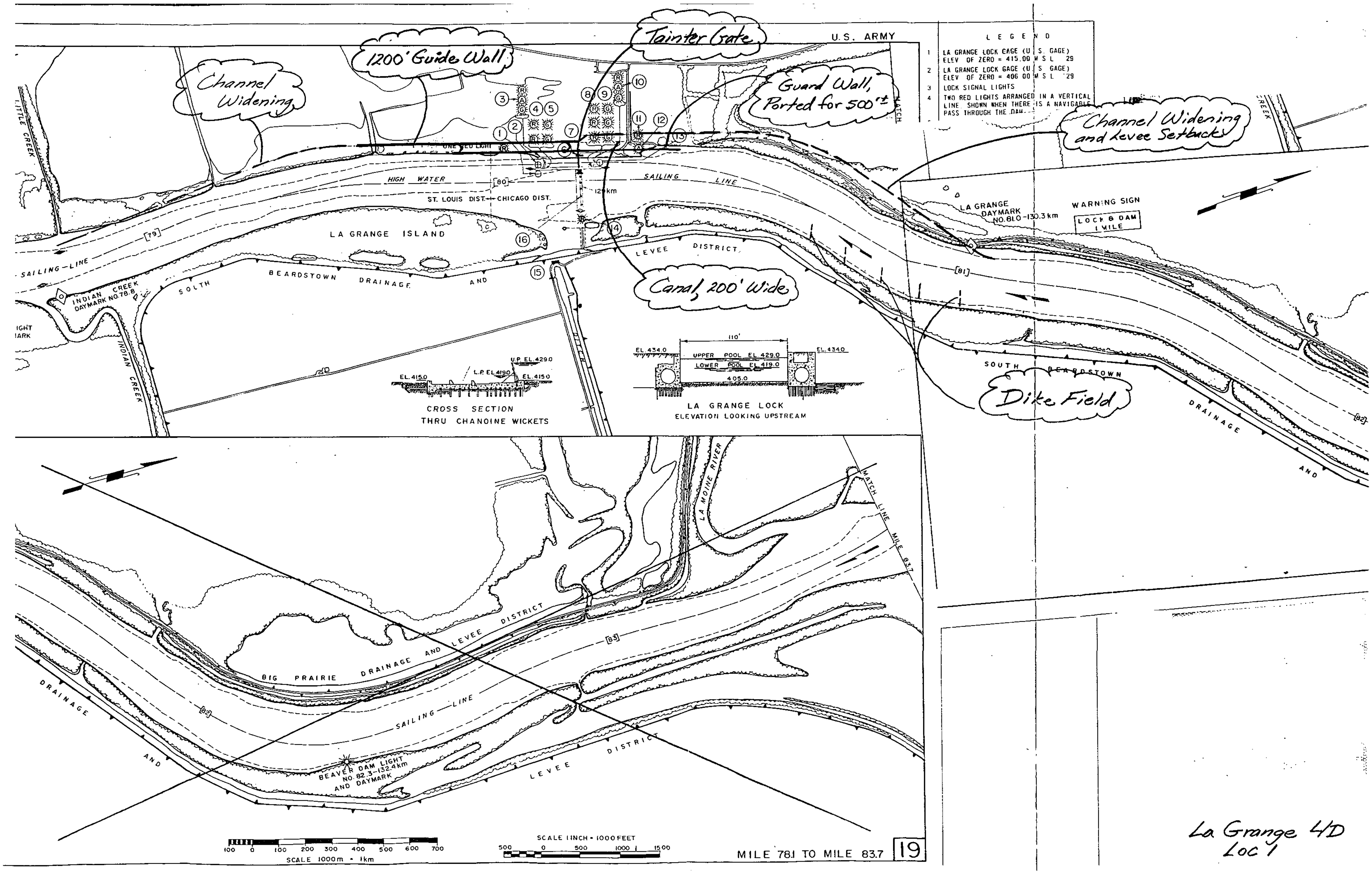
Upstream This involves construction of a new lock at the 80' wide submergible tainter gate location and moving the tainter gate to the existing 600' lock bay. There would be little if any channel excavation. Construct the lock in the tailwater with an upstream landside ported guard wall. Could have flow on both sides of the lock which could draw the tow away from the ported wall. Would need to study this.

Downstream Construct a 1200' solid landside wall. May need some downstream channel dredging near the end of the guide wall along the left bank, 200' wide by 2000' long for the open pass situation.

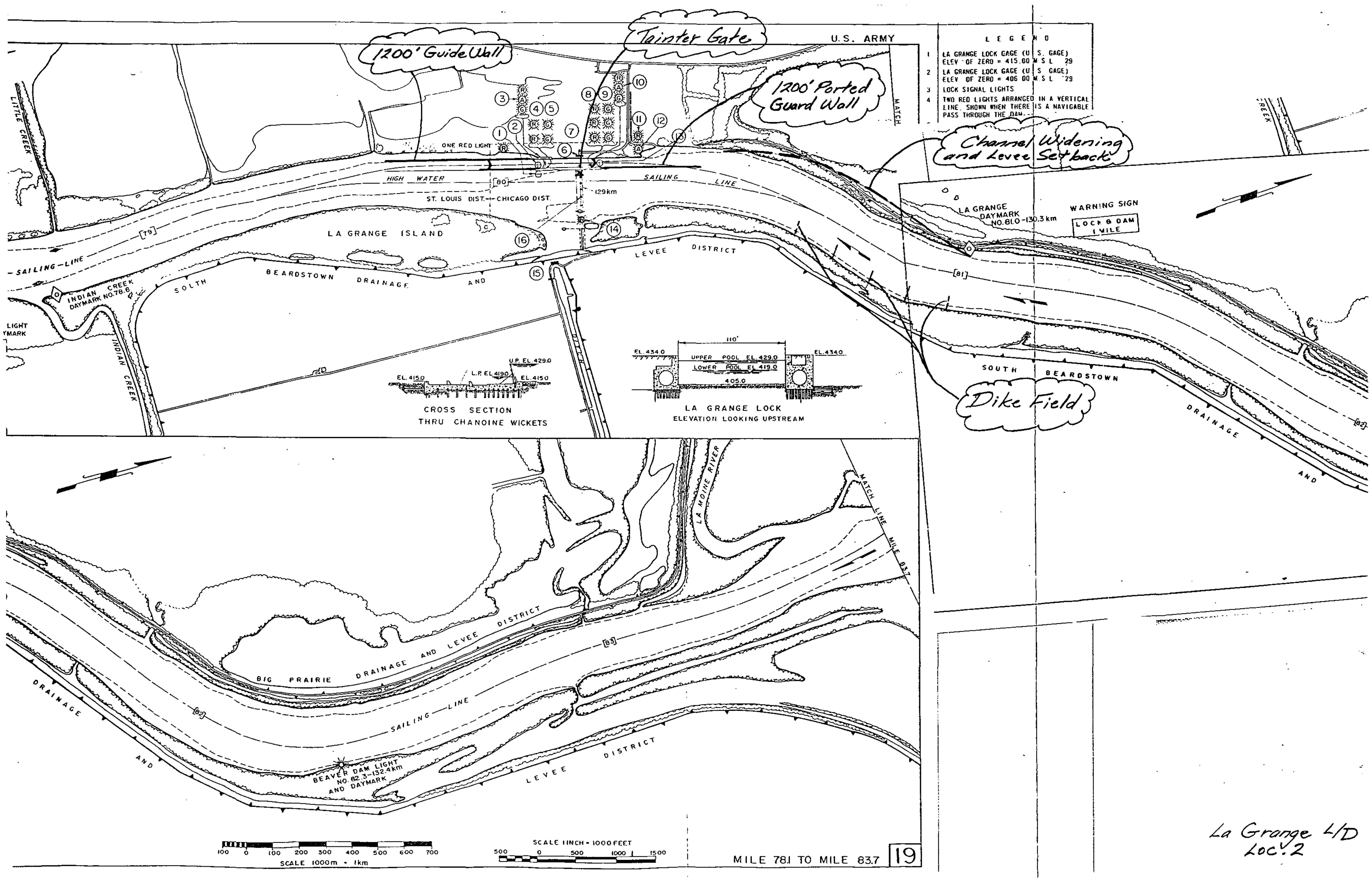
Small-Scale Improvements

Upstream Extend the guide wall 600' upstream and fill-in the bankline from the end of the extended wall to blend into the natural bank. With a ported guard wall, need upstream bank and channel excavation and the 5 wing dikes along the left riverbank as discussed above.

Downstream Extend the guide wall 600'.




La Grange 4D
Loc 1




La Grange L/D
Loc. 2