Habitat Assessment, Missouri River at Hermann, Missouri

By Robert B. Jacobson, Mark S. Laustrup, and Joanna M. Reuter

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Abstract

This report documents methods and results of aquatic habitat assessment in the Missouri River near Hermann, Missouri. The assessment is intended to improve understanding of spatial and temporal variability of aquatic habitat, including habitats thought to be critical for the endangered pallid sturgeon (*Scaphirhynchus albus*). Physical aquatic habitat – depth, velocity, and substrate – was assessed around 9 wing dikes and adjacent to the U.S. Route 19 bridge, at discharges varying from 44,000 cubic feet per second (cfs) to 146, 000 cfs during August 2000 – May, 2001. For the river as a whole, velocities are bi-modally distributed with distinct peaks relating to navigation channel and wing-dike environments. Velocities predictably showed an increasing trend with increasing discharge. Substrate within wing dikes was dominated by mud at low discharges, whereas the navigation channel had patches of transporting sand, rippled sand, and coarse sand. Discharges that overtopped the wing dikes (about 93,000 cfs, March 2001) were associated with increases of patchy sand, rippled sand, and coarse sand within the wing dikes. When flows were substantially over the wing dikes (146,000 cfs, May 2001) substrates within most wing dikes showed substantial reorganization and coarsening.

The habitat assessment provides a geospatial database that can be used to query wing dikes for distributions of depth, velocity, and substrate for comparison with fish samples collected by US Fish and Wildlife Service biologists (Grady and others, 2001). In addition, the assessment documented spatial and temporal variation in habitat within the Hermann reach and over a range of discharges. Measurable geomorphic change – alteration of substrate conditions plus substantial erosion and deposition – was associated with flows equaled or exceeded 12-40% of the time (40-140 days per year). Documented geomorphic change associated with high-frequency flows underscores the natural temporal variability of physical habitat in the Lower Missouri River.

Introduction

This study of aquatic habitat near Hermann, Missouri was developed in cooperation with the Missouri Department of Transportation (MoDOT) in order to assess habitat availability and variability near a proposed bridge replacement (fig. 1). The U.S. Route 19 bridge over the Missouri River at Hermann, Missouri is scheduled for replacement, probably starting in 2003 (MoDOT annual report, p. 14). Concerns that construction activities could adversely affect endangered pallid sturgeon (*Scaphirhynchus albus*) prompted the Missouri Department of Transportation and the U.S. Fish and Wildlife Service (USFWS) to seek additional information on this endangered species in the vicinity of the new bridge. MoDOT and USFWS agreed that more information was needed on a) the distribution and abundance of pallid sturgeon in the general vicinity of the existing bridge structure, b) the seasonal use of river habitat in the immediate vicinity of the existing bridge structure, and c) the physical characteristics of river habitat (substrate type, bottom contours, and other aquatic habitat features) that could be impacted potentially during construction of the new bridge and the subsequent removal of the existing structure. This study addresses only physical habitat assessment in the Hermann reach.

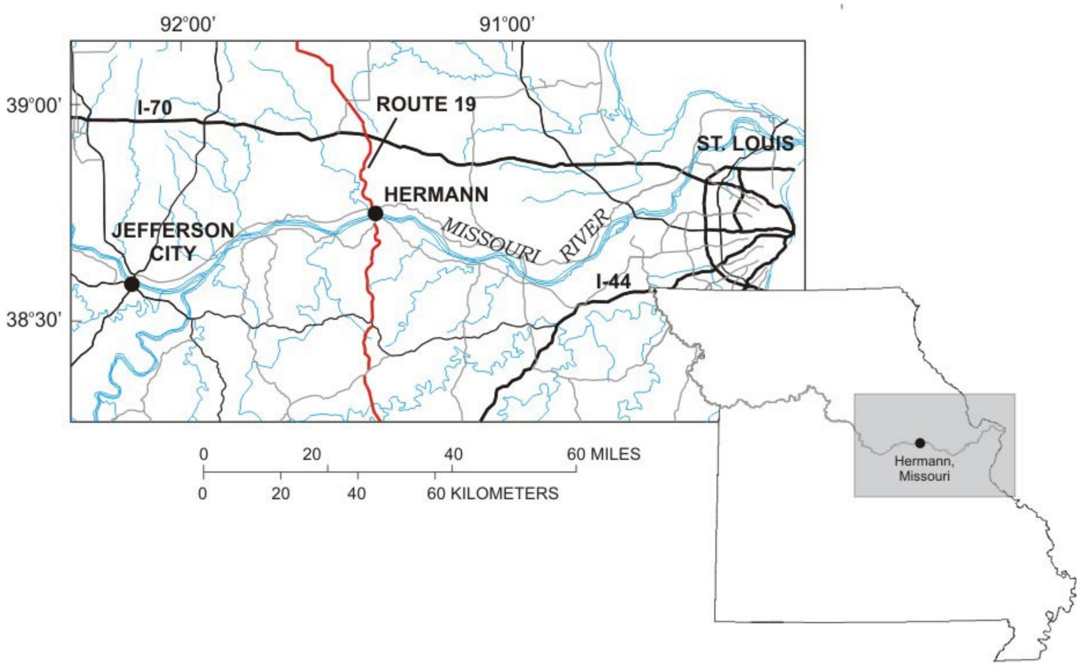


Figure 1. Location of Hermann, Missouri and the Route 19 crossing of the Missouri River

Physical aquatic habitat is generally defined as the combination of depth, velocity, and substrate that make up the space in which aquatic organisms live. Physical habitat varies spatially within a river channel and over time. Spatial variation in the Missouri River is particularly great because of the hydraulic influence of wing dikes and other navigation structures. Habitat varies over time in two ways: At discharges below sediment transport thresholds, depths and velocities vary as discharge varies. At discharges above sediment transport thresholds, channel geometry also can be altered, resulting in new combinations of depth, velocity, and substrate for a given discharge. The high spatial and temporal variation of physical habitat expected in the Missouri River present specific challenges to assessment of habitat and especially to assessment of habitat change. High spatial variability requires detailed mapping of physical characteristics at spatial scales relevant to fish use of habitat. Such detailed data are generally unavailable on the Missouri River. Assessment of change after an event like bridge construction requires an understanding of background variation for comparison. A key question is whether background variation in habitat because of sediment-transporting events is so great that the effects of bridge construction would not be detected.

Purpose and Scope

This report documents methods and results of aquatic habitat assessment in the Missouri River near Hermann, Missouri. Only recently have studies addressed physical aquatic habitat – depth, velocity, and substrate – on the lower Missouri River (Jacobson and Laustrup, 2000). Very little is understood or quantified about how habitats vary at the scale of river reaches and navigation structures, and how the habitats may change on annual timescales. This study involves spatially intensive assessments of habitats associated with wing dikes (channel training structures), quantified over a range of discharges. The resulting data provide an unprecedented level of detail of habitat complexity around engineered structures and provide critical contextual information to support fish sampling efforts.

The study addresses two objectives.

1. The first objective is development of baseline information to assess the direct effects of bridge construction (and destruction) on physical habitat in areas adjacent to the Route 19 bridge (fig. 2). This objective requires detailed mapping of habitat characteristics with sufficient repetitions to characterize temporal variations.
2. The second objective is characterization of habitats immediately upstream and downstream of the bridge (fig. 2) and to develop associations with presence or absence of pallid sturgeon, in coordination with US Fish and Wildlife. The degree of association will illustrate the extent to which physical habitat controls pallid sturgeon seasonal distributions, and hence whether changes in physical habitat as a result of bridge construction would be expected to impair pallid sturgeon populations. This objective would provide results transferable to other bridge construction projects along the Lower Missouri River. This report is intended to illustrate the scope and utility of the digital, georeferenced physical habitat data and indicate its applicability to investigating biological associations. Copies of the geospatial database can be obtained by contacting the authors. Investigation of the links between physical habitat and biological associations is beyond the scope of the present report and will be evaluated in a subsequent report.

Aquatic habitat was assessed around 9 wing dikes and adjacent to the U.S. Route 19 bridge along the lower Missouri River near Hermann, Missouri (fig. 2; table 1). Habitat assessments were performed from August 2000 to May 2001, four times at discharges ranging from 44,000 cubic feet per second (cfs) to 163,000 cfs (fig. 3, table 2). Coordinated fish sampling by US Fish and Wildlife resulted in pallid sturgeon or hybrid sturgeon captures at 6 of the 9 dikes (table 1; Grady and others, 2001).

Table 1. Information for individual wing dikes within assessment area

Dike Number	River Mile	Sturgeon Capture (Grady and others, 2001)	Note
104.4	98.6	Pallid, hybrid	Spur dike, left
104.05	98.3	Hybrid	L-head dike, right
104	98.3	Hybrid	L-head dike, left
103.76	98	Hybrid	L-head dike, left
103.74	98	Hybrid	Spur dike, right
103.5	97.8	Hybrid	L-head dike, left
103.2	97.5		L-head dike, left
102.9	97.2		L-head dike, left
102.5	96.8		Spur dike, right

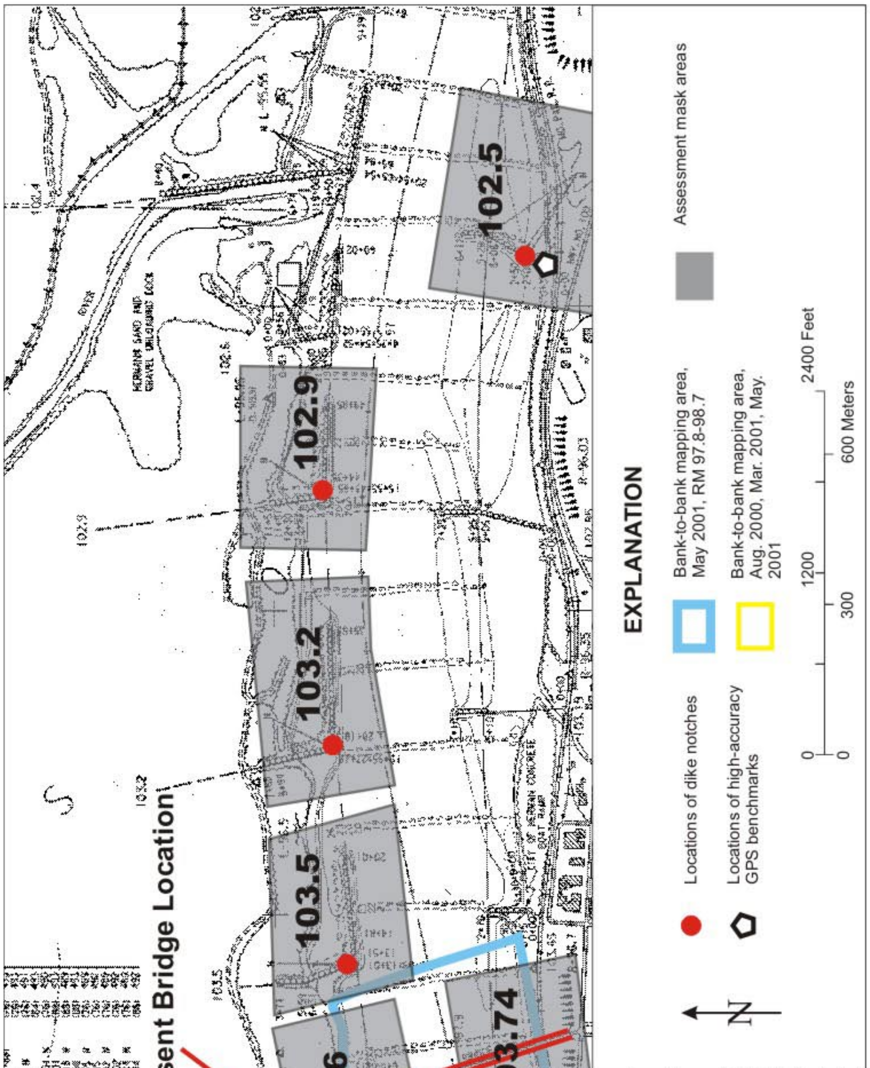
Right and left refer to direction facing downstream

For the purposes of this study, we defined wing-dike habitat as the area extending downstream of a wing dike to the next wing dike or to a distance of 250 m, whichever is shorter, and extending laterally to the bank, and laterally approximately 50 m into the navigation channel, usually to the navigation line (fig. 2). The habitat survey included all parts of the area that were approximately 1 m or greater in depth and that could be accessed safely by boat at the prevailing river stage. These areas encompass the main physical habitat systems related to wing dikes, including the slow-velocity areas upstream of the wing dike, the deep scour holes associated with dike tips, the deep scour holes that typically occur where the dike is keyed into the bank, and the bar and secondary channels typically associated with flow separation downstream and shoreward of the wing dike. In addition, the survey area includes substantial areas of the navigation channel, thereby allowing direct comparisons between habitats in these two diverse environments.

Table 2. Dates, discharge, and stage during four habitat assessment periods.
[cfs, cubic feet per second; ft, feet]

Date		Discharge, cfs			Stage, ft		Percent of time daily mean flow is equal to or more than value	
Start	End	Mean During Assessment	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
8/22/2000	8/24/2000	60,000	48,700	70,300	6.4	10.0	83%	56%
11/27/2000	11/29/2000	44,000	44,100	44,700	5.5	5.6	86%	86%
3/7/2001	3/9/2001	93,000	89,000	97,000	11.9	12.8	39%	34%
5/9/2001	5/11/2001	146,000	128,500	163,400	15.9	18.9	21%	12%

Discharge and stage data are provisional hourly, real-time hydrologic data, subject to change.
Mean is average of hourly measurements. Daily mean is average of hourly measurements for each day.



Basemap: U.S. Army Corps of Engineers, 1994, Missouri River Hydrographic Survey, Plate 38.

Figure 2. Nine wing dikes selected for habitat characterization in the vicinity of the Route 19 bridge, Hermann, Missouri.

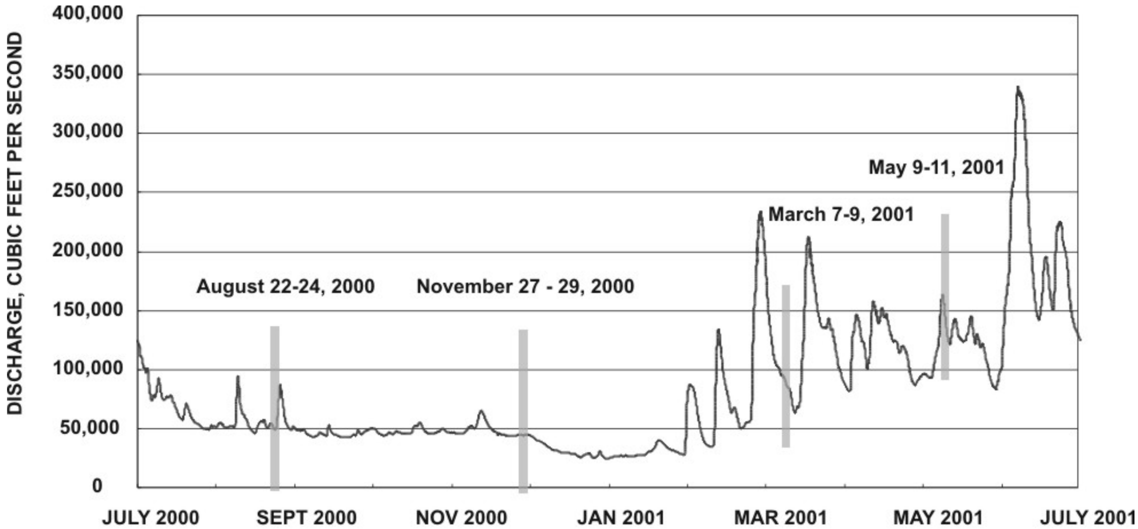


Figure 3. Hourly discharge, Missouri River at Hermann, Missouri, July 2000 to July 2001, and timing of habitat assessments.

Habitat assessment included the following:

1. Mapping bathymetry of the dike areas to produce maps with 2-foot contour interval.
2. Mapping substrate using an acoustic classification system, yielding maps of classified substrate material.
3. Collection of velocity data using acoustic Doppler velocimetry.

Methods

Data were collected and processed using protocols currently under development by CERC. A collection and processing schematic is shown in figure 4.

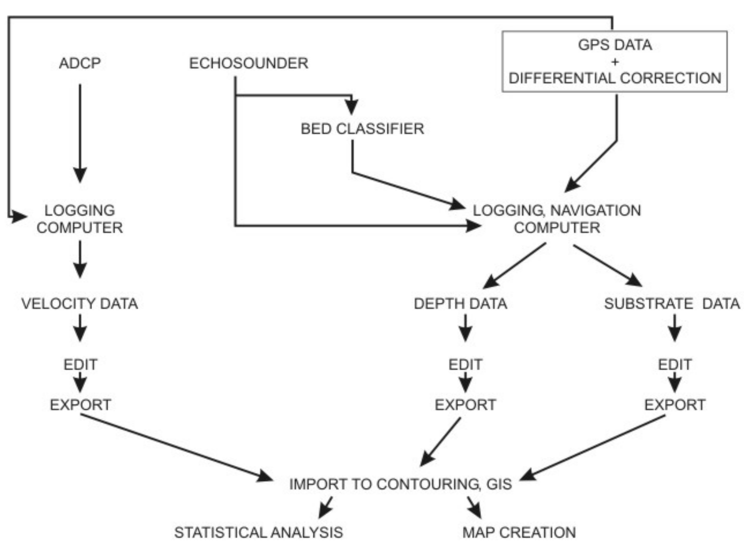


Figure 4. Schematic diagram of habitat assessment data collection and processing. ADCP, acoustic Doppler current profiler; GPS, global positioning system; GIS, geographic information system.

A Note on Units

A mixture of measurement units is used in this report in order to communicate effectively to the broad range of potential users. Locations along the river are given in river miles (RM) rather than kilometers, because these are the customary units used along the Missouri River to indicate location. River miles begin with 0 at the junction of the Missouri River with the Mississippi River at St. Louis, and increase in the upstream direction. Similarly, discharges are given in cubic feet per second (cfs) because the English units are customary and accepted. We use feet for elevation and depth because topographic and engineering design data sets generally use feet. The elevations are referenced to feet above mean sea level, NAVD 88 vertical datum. Most of the users of current velocity data, however, use metric units, usually centimeters per second (cm/s). For planimetric coordinates we use meters in a universal transverse Mercator grid (utm zone 15) and we discuss relative planimetric distances in meters. Reference to left and right bank locations relate to direction while facing downstream.

Data Collection

Navigation base maps were compiled from digital U.S. Army Corps of Engineers Missouri River navigation charts for 1994. These maps were simplified and projected from state-plane coordinates to UTM coordinates, WGS84 datum, for concurrence with global positioning data. The digital maps were exported from a geographic information system (GIS) as georeferenced DXF files that could be imported into navigation software.

The digital maps were used as base maps for transect design and real-time navigation using HyPack Lite (Coastal Oceanographics, Middlefield, Connecticut) navigation software. Because the navigation base maps included all wing dikes used in this study, sampling transects could be constructed to cover all areas of interest using transect layout routines in HyPack. Transects were spaced 20 m and extended beyond the area of interest defined for each wing dike (fig. 5). The orientation of transects was determined by constructing a line along the length of the wing dike, or in the case of curved wing dikes, from the intersection of the wing dike with the shore to the curved tip. Lateral transect lines were then generated at 20 m intervals upstream and downstream of the wing dike. The 20-m spacing was used to provide sufficient spatial coverage for creating continuous surface maps of depth and substrate data.

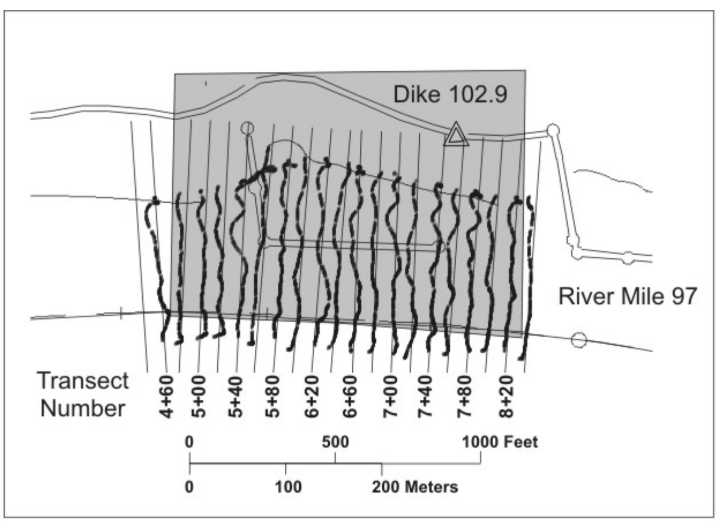


Figure 5. Typical arrangement of 20-m sampling transects at dike 102.9, with postings of bathymetric data collected May 2001.

All data were georeferenced in the field by a real-time, 12-channel differential global positioning system (DGPS) to sub-meter accuracy. Differential corrections were provided in real time by the

Omnistar ((Omnistar Inc., Houston, Texas) satellite-based system, except for areas under the Route 19 bridge where we used the St. Louis Coast Guard beacon for differential corrections. The beacon and satellite based corrections were found to have similar positional accuracies at this site, both estimated at 0.6 – 1.0 m, 1 SD error. The DGPS data were collected at 200 millisecond (ms) intervals, resulting in positions approximately every 0.3 – 3.0 m along each transect at typical boat speeds of 2 – 8 knots (1-4 meters per second, m/s) during data collection. Boat speeds were maintained at 5 knots or less most of the time.

Bathymetric data were collected with an Innerspace 449DF echo sounder (Innerspace Technology, Inc., Waldwick, New Jersey) equipped with a 208 kHz, 8^o transducer mounted in the center of the boat hull, directly below the DGPS antenna during the first three dates (fig. 6). During the May 2001 collection, we used an over-the-side transducer and calculated positions with appropriate offsets. The echo sounder was calibrated by patch test to account for boat draft, blanking distance, and environmental conditions that could affect the speed of sound in water. The patch test is a calibration procedure based on suspending a steel plate at known depths below the transducer. Pitch and heave were not compensated; however these corrections are thought to be minor given typical calm-water working conditions. The precision of the echosounder data is 0.03 m. Patch test results indicate that, under favorable bottom conditions, the depth accuracy is approximately 0.07 m.

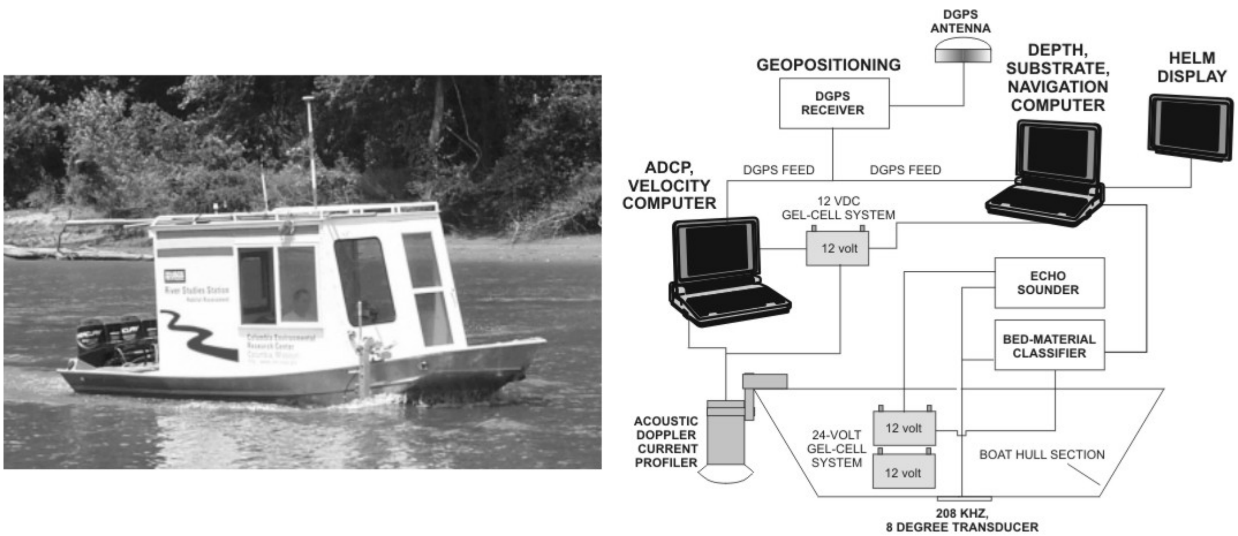


Figure 6. USGS habitat assessment boat system schematic. DGPS, differential global positioning system; ADCP, acoustic Doppler current profiler.

Bed material was classified into substrate classes using a RoxAnn system[1] (Stenmar Microsystems, Aberdeen, Scotland), which uses the transducer output from the Innerspace system. The RoxAnn analyzes the shape of the acoustic signal returned from the river bottom to calculate two parameters related to roughness and hardness (e_1 and e_2) (see, for example, Rukavina, 1997). Values of e_1 and e_2 collected over substrates of known composition were used to develop a classification matrix specific to the echo sounder/transducer system and to the bottom conditions of the Missouri River (fig. 7). Deep, turbid water prevented calibration sampling of some substrates; hence, confidence in assigned classes varies. For example, calibration is good for sand, coarse sand, and gravelly sand classes because these substrate classes are based on first-hand observations. In contrast, classes like sand with dunes and very soft/very rough could not be observed directly and their classification is therefore inferred. Mud and transporting sand tend to have the same e_1 and e_2 characteristics and are combined in one unit. Depth, bed-material classification, and DGPS positions were logged into standardized HyPack files.

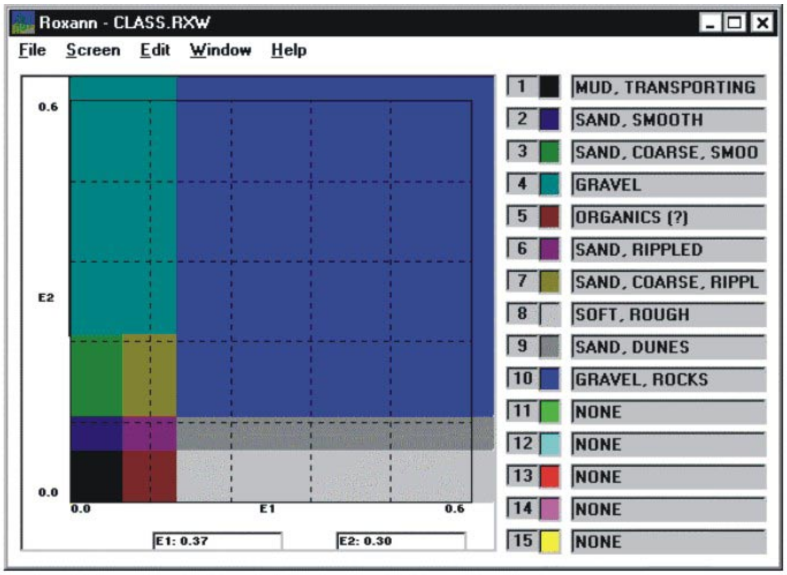


Figure 7. Graphical representation of RoxAnn substrate classification model used in this report, showing ranges of e_1 and e_2 values used to define substrate classes.

Velocity data were collected with a Workhorse Rio Grande Model 600[1] kHz acoustic Doppler current profiler (ADCP), and logged in WinRiver[1] software (RD Instruments, San Diego, California). These data were also georeferenced with DGPS data, but were collected on a separate laptop computer (fig. 6) running the WinRiver ADCP acquisition program. The ADCP was set up to collect 3-dimensional water velocity data in 0.35-m deep bins from the surface to the bottom following generally accepted setup and operation procedures (Morlock, 1996). A column of bins (called an ensemble) was collected nominally every 2.5 seconds, resulting in an ensemble spacing that varied from approximately 2.5 – 10 m at typical boat speeds. For ADCP data collection, boat speeds were maintained below 5 knots, resulting in a maximum ensemble spacing of about 3.8 m. The ADCP was internally calibrated for measured water temperature and compensates automatically for pitch and roll. Typical velocity profile transects are illustrated in figure 8.

Data Processing

Bathymetry

Several pre-processing steps were required prior to generating continuous surfaces for the bathymetric datasets. Depth data were edited using a routine included with HyPack. Typically, editing is required to remove spurious reflections from water-column turbulence or fish and to correct for places where bottom conditions prevented a good digitization (fig. 9). Also, the DGPS signal occasionally dropped out where high banks or trees interfered with satellite reception, thereby creating incorrect GPS positions. The high data input rates allowed spurious depths to be deleted without affecting the representation of bottom contours. In some places, substantial areas of spurious depths could be corrected by reference to depths digitized by the RoxAnn unit, to depths from the ADCP, or to the echo sounder paper trace. Positioning errors due to DGPS dropout could often be corrected in HyPack by linearly interpolating positions relative to adjacent correct positions. Following editing for accuracy and content, the datasets were exported as comma-delimited XYZ text files.

Depths were converted to actual elevations by comparison to water-surface elevations. Elevation benchmarks were established by high-accuracy differential GPS upstream (at wing dike 104.4) and downstream (at wing dike 102.5). Water surface elevations were measured twice a day during habitat assessment. Mean daily water-surface elevations were established along the Hermann reach by creating a surface of constant slope from upstream to downstream using a custom script in ArcView[1] geographic information system software. This surface was then used as a datum from which depths were subtracted to calculate bottom elevations. Elevation data were subsequently exported from ArcView for import into a contouring software package.

Elevation data from ArcView[1] (ESRI, Redlands, California) dbf files were saved as text files and imported into Surfer 7[1] software (Golden Software, Golden, California). Break lines and a blanking file were digitized on the computer screen. Break lines and blanking files aid in the surfacing process by limiting areas where data can be interpolated.

Surfaces were interpolated using kriging, a standard surface interpolation method. A four quadrant elliptical search with a radii of 50 x 30 meters was used against the 20-meter spacing of transects. An anisotropy ratio of 2.0 was applied to all datasets to compensate for high data density

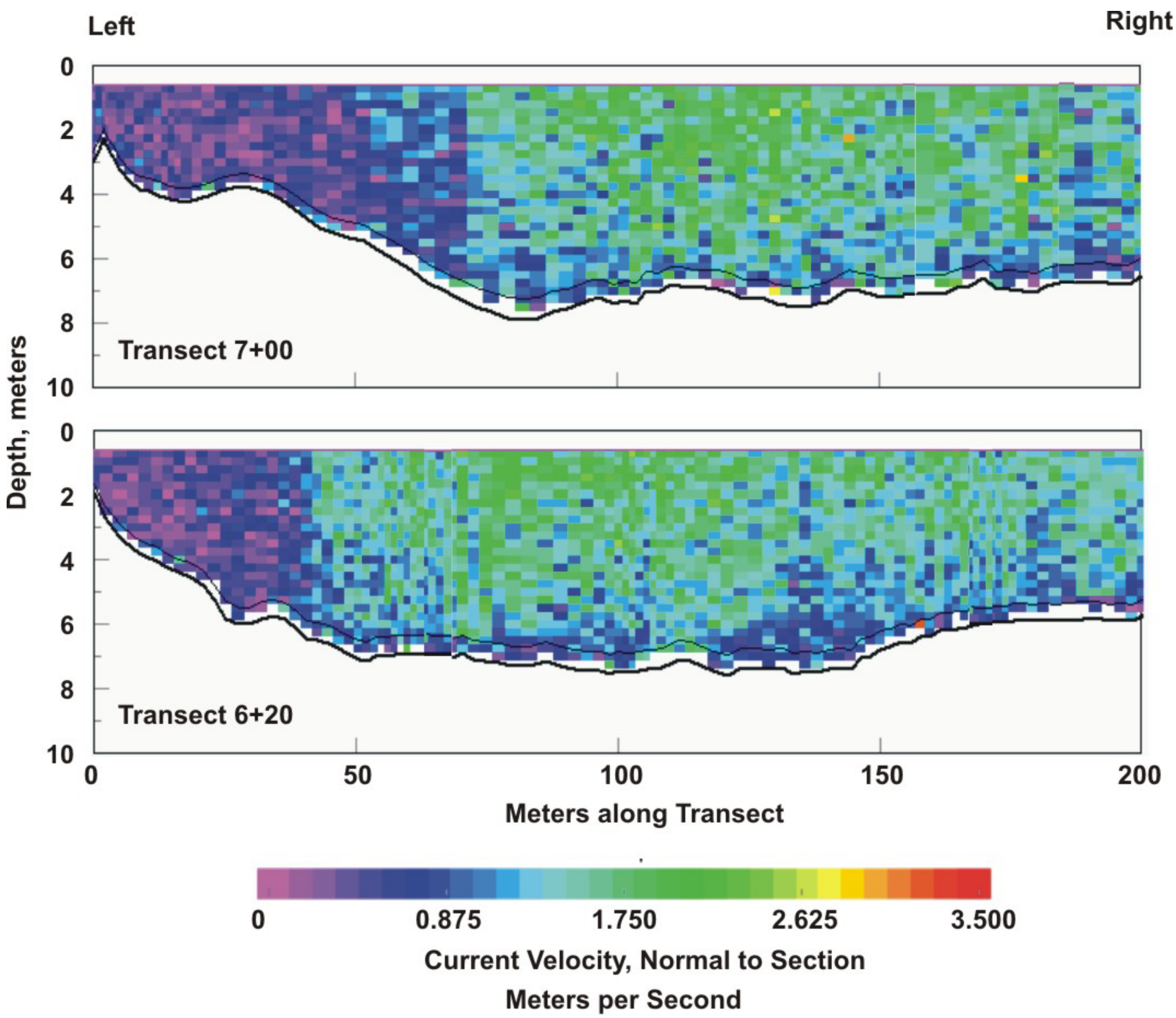


Figure 8. Examples of ADCP transects showing distribution of current velocities in vertical plane, from May 2001 assessment, dike 102.9. Transects are viewed looking downstream. Current velocities are total magnitude in meters per second.

along the transects. The anisotropy angle was set perpendicular to each set of transect lines. Break lines at elevations greater than the maximum elevation in the dataset were used along the shorelines and wing dikes to constrain interpolation to the mapped areas. Spurious data points were eliminated from consideration and the output grid resolution was set to 1-meter. A blanking file was then used to clip the interpolated grid to the extent of the input data set.

The Surfer 7 grids were exported as ASCII files and then added to an ArcView project as a table. Each table was added to a view as a point event theme and converted to a 1-m grid.

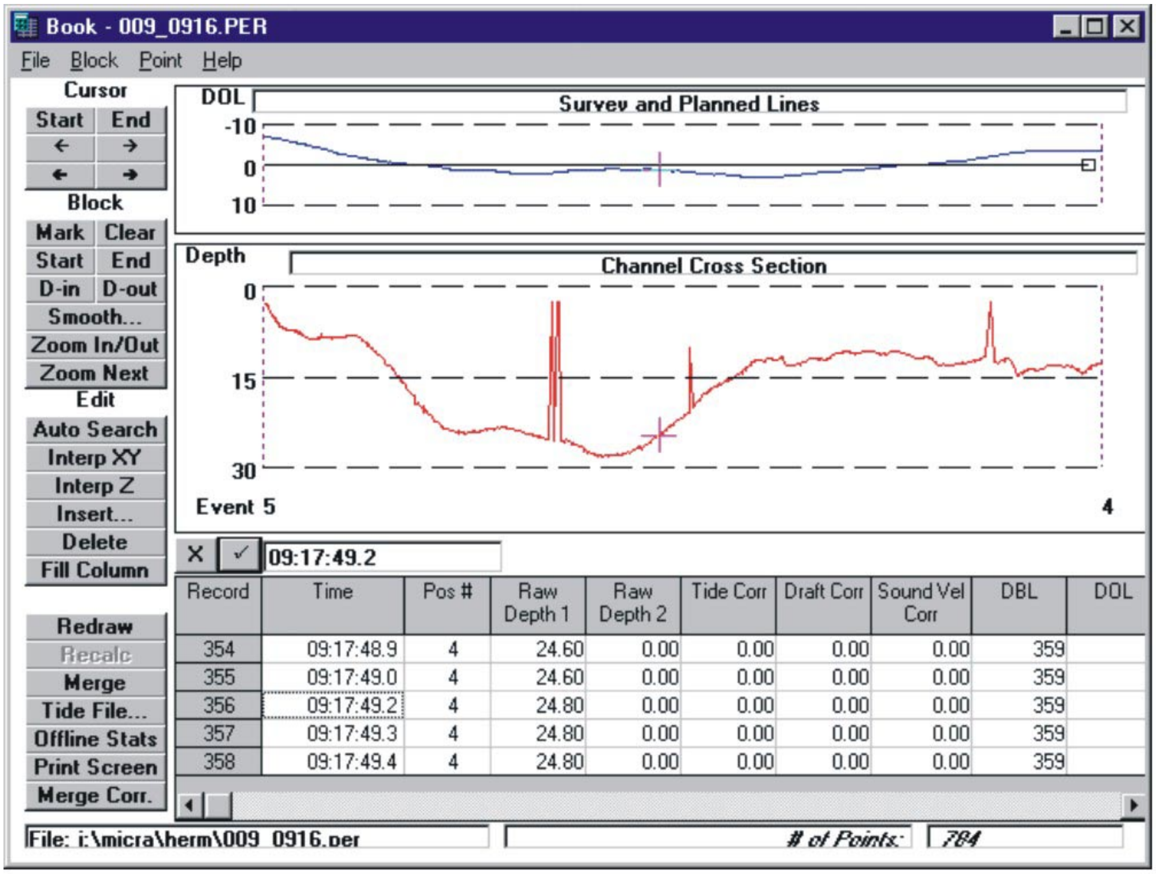


Figure 9. Edit screen from HyPack showing typical digitized depth transect. The blue line shows boat position relative to planned transect. The red line is the digitized depth trace. Spurious depth spikes are deleted and depths interpolated.

Substrate Data

Substrate data were exported from HyPack as ASCII files, imported into Surfer 7, gridded, contoured, and exported as text files. Because of instrumental drift during the 8 months of the project, the substrate data needed to be recalibrated. This recalibration was calculated by comparing e_1 and e_2 values collected over the same area during all four assessments. The area selected was composed of coarse rock above and along the wing dike at RM 104.05; it is highly unlikely that the substrate at the calibration site varied during this time. The values for November 2000, March 2001, and May 2001 were recalibrated by multiplying the gridded data by ratios to the August 2000 dataset.

The recalibration was accomplished with a Perl[1] script (Practical extraction and report language, ActiveState Corporation, Vancouver, British Columbia), which read the roughness (e_1) and hardness (e_2) files from Surfer 7, applied the correction factors, classified substrate according to the classification scheme (fig. 7), and wrote the coordinates and classified substrate to a text file. Each text file of classified substrate was added to ArcView as an event theme and converted to a 1-m grid.

ADCP Data

ADCP data were exported from WinRiver as ASCII-formatted files and reformatted with a Perl script for import into ArcView. The velocity magnitude, horizontal velocity direction, vertical velocity component, and position (easting, northing, and depth) were extracted for each individual bin during this reformatting step. For each ensemble (vertical collection of data), the mean velocity magnitude was also calculated.

These data were subsequently imported into ArcView for 2D and 3D visualization. ADCP velocities and directions are displayed on maps as surface velocities, with arrow symbols rotated in the direction of flow and attributed with length and color according to water velocity magnitude. Velocity data are also displayed as vertical mean velocity of each ADCP ensemble, with magnitude indicated by color and size.

Calculation of Habitat Change

Erosion and deposition between subsequent bathymetric surveys was calculated by subtracting one bathymetric surface from another to show net change. Cumulative errors in the collection, elevation calculation, gridding, and contouring processes limit estimated accuracy of individual elevation maps to +/- 1.0 ft. Consequently, erosion and deposition are summarized in broad categories of less than 2.0 ft. change, 2-6 ft. change, 6-10 ft. change, and greater than 10 ft. change. Change calculations are particularly sensitive to the spatial distribution of data points near areas of high slope along wing dikes where difficulties in maneuvering the boat limit the ability to stay on transect. Anomalously high values of erosion and deposition adjacent to wing dikes should be ignored.

Results

Results of the four habitat assessments are shown in maps in Appendix 1, arranged by wing dike number and date. In addition, a bank-to-bank map of channel elevation from RM 97.8 (downstream of the Route 19 bridge) to RM 98.7 (upstream of dike 104.4) is presented in Appendix 2. Depths and velocities by wing dike are summarized in table 3. Assessment masks (fig. 2) provide the basis for comparison among wing dikes and among dates. The masks are used to clip depth, velocity, and substrate data to set consistent areas for maps and statistical analyses. The mask size and shape were selected to sample conditions within the wing dike and in adjacent areas of the navigation channel and upstream and downstream of the dike structure. The masks were designed to characterize wing-dike habitats in a broad sense. The georeferenced habitat data collected in this project are amenable to additional sub sampling with smaller masks to address specific habitat questions.

Depth and Elevation

The maps in Appendix 1 show elevations of the river bottom in the wing dikes for the 4 assessment periods. Because the emphasis in this report is on geomorphic change, the maps show elevations rather than depths. The associated ranges of depths represented in the wing-dike complexes are summarized in table 3. Depths vary from 0 to the maximum of 58 ft in a deep hole in at wing dike 104.4.

The elevation data illustrate the broad range of physical habitat conditions among wing dikes, but they also indicate systematic variation of elevations. Typically, wing dikes have deep scour holes offshore and downstream from their tips. Spur dikes (for example 102.5) tend to have deep and extensive scours off the tips whereas L-head dikes generally have smaller, shallower scours at the intersection of the L (for example, 102.9, 103.2). The tip scours are associated with convergent flow, which is evident even at low discharge (for example, see the velocity plots for dike 102.9, 103.2). Presumably, the velocities are even more intense at higher flows. Water velocities over the tip scours are

Table 3. Means, ranges, and standard deviations of vertically averaged current velocities and depths, summarized by dike number and assessment date.
[cm, centimeters; Min., minimum; Max., maximum; Std. Dev., standard deviation]

	August 2000								November 2000							
	Current Velocity, cm per second				Depth, feet				Current Velocity, cm per second				Depth, feet			
Dike Number	Mean	Min.	Max.	Std. Dev.	Mean	Min.	Max.	Std. Dev.	Mean	Min.	Max.	Std. Dev.	Mean	Min.	Max.	Std. Dev.
102.5	71.6	8.7	242.0	31.6	10.8	0.0	31.3	6.0	72.0	4.9	217.7	34.4	10.6	0.0	31.7	5.6
102.9	89.6	4.5	540.9	42.1	12.6	0.0	23.3	4.8	90.5	11.9	199.9	41.0	13.6	0.0	25.0	4.7
103.2	92.9	2.6	169.7	37.1	13.7	0.0	25.9	5.6	95.3	10.8	183.0	43.9	14.0	0.0	26.6	5.6
103.5	89.5	9.8	169.4	32.5	15.5	0.0	26.0	7.3	98.7	13.9	192.1	39.5	14.7	0.0	26.7	5.5
103.74	114.6	24.9	582.6	95.9	11.0	0.0	24.2	4.3	80.3	12.8	230.6	31.6	10.3	0.0	22.1	3.8
103.76	89.1	7.6	403.2	43.9	14.9	0.0	28.0	7.4	82.8	7.9	223.4	35.9	14.5	0.0	28.0	5.6
104	76.9	11.2	213.3	29.3	14.5	0.0	32.3	6.2	71.3	2.9	156.6	32.3	13.0	0.0	29.3	5.6
104.05	83.9	10.2	369.4	34.8	13.5	0.0	20.7	4.4	88.0	23.1	168.8	35.2	13.4	0.0	20.9	4.7
104.4	72.6	20.9	190.4	28.2	15.6	0.0	49.5	9.0	68.9	9.5	169.1	32.8	15.2	0.0	50.9	9.1

	March 2001								May 2001							
	Current Velocity, cm per second				Depth, feet				Current Velocity, cm per second				Depth, feet			
Dike Number	Mean	Min.	Max.	Std. Dev.	Mean	Min.	Max.	Std. Dev.	Mean	Min.	Max.	Std. Dev.	Mean	Min.	Max.	Std. Dev.
102.5	80.3	23.6	204.6	38.5	16.2	0.0	35.1	5.4	90.2	16.1	277.9	33.0	20.5	0.0	36.9	5.4
102.9	109.3	13.7	226.6	56.6	19.6	0.0	31.5	6.6	133.1	21.2	240.6	56.6	22.3	0.0	36.1	7.2
103.2	109.1	24.0	228.1	55.2	19.8	0.0	33.2	7.3	127.7	11.6	267.2	60.0	22.3	0.0	37.6	8.2
103.5	111.9	20.9	820.5	54.2	21.3	0.0	34.4	7.0	140.7	22.1	264.3	58.6	23.3	0.0	36.8	8.0
103.74	99.1	20.1	599.7	43.1	18.0	0.0	36.1	4.9	118.9	32.0	214.5	39.8	23.1	0.0	40.0	5.4
103.76	95.7	10.5	204.9	49.0	20.5	0.0	34.9	7.0	111.2	15.9	213.8	49.3	24.0	0.0	39.5	7.8
104	90.5	9.1	236.8	46.6	19.1	0.0	41.4	7.0	105.2	21.6	221.2	45.3	23.0	0.0	43.5	7.5
104.05	109.6	3.6	212.3	44.9	18.2	0.0	28.4	5.0	129.7	27.9	424.1	40.4	21.5	0.0	31.0	5.2
104.4	91.2	23.5	192.1	37.7	21.9	0.0	56.7	9.1	117.9	28.3	255.4	49.4	24.9	0.0	58.1	8.5

spatially highly variable because they include downstream-directed velocities as high as 200 cm/s and much smaller magnitude upstream-directed velocities in the recirculating eddy.

Many wing dikes have deep and large scour holes downstream of where the dike intersects with the shoreline (for example, see dikes 104.4, 103.2). The shoreline scours often are associated with embayments eroded laterally into the shoreline. Water velocities measured over the shoreline scours during the four assessments were uniformly low (vertically averaged velocities of less than 100 cm per second) and highly variable in direction. We therefore infer that these scour holes are being maintained by flood events of considerably higher discharge than those measured. They may be remnant scours from the "Great Flood" of 1993, which was approximately 750,000 cfs in this reach. The common presence of large-woody debris accumulations at these sites indicates that large woody debris may also contribute to flow convergence and scour during large floods.

Some relatively small scours are associated with wing-dike notches (for example, the shallow, smaller scour at dike 103.2). The notch in 102.5 is associated with a persistent channel that extends from the notch to the bank side of the downstream bar.

Flow separation downstream from spur-dike tips can cause deposition of a sand bar (eddy bar or reattachment bar) because of lowered velocities and recirculation of water in eddies. A good example of a dike-field sand bar is shown at dike 102.5. Similar dike-related sandbars exist at the other spur dikes; the dike geometry of L-head dikes prevents generation except at very high discharges.

The bank-to-bank map shown in Appendix 2 illustrates the wide variation of elevations and depths in a typical Lower Missouri River channel. Over the range of discharges mapped, at least one half of the channel area is dominated by scour holes and bars adjacent to the deep navigation channel. The distribution of depths for the bank-to-bank mapping area assessed during August 2000, March 2001, and May 2001is shown in figure 10. The distributions have single peaks indicative of the dominant navigation channel, but the wide variation reflects the extremes of shallow and deep water that occur along the channel margin and associated with wing dikes. Mean depth and the standard deviation of depths both increase with increasing discharge, but at a decreasing rate (fig. 11).

In general, wing dikes with large scours had the greatest mean depths over the range of discharges (for example, 104.4, fig. 12). Spur dikes with eddy bars had some of the smallest mean depths.

Velocity

The general range of velocities in the dataset is 0 – 300 cm/sec (table 3). Some values as high as 800 cm/sec were recorded in high-velocity zones around bridge piers or in dike notches, but these represent small areas of habitat. Velocities are strongest and oriented downstream in the navigation channel. Within wing dikes, velocities are considerably slower at all discharges and become more variable in direction, reflecting complex eddying flow. Concentrations of high flow velocity are apparent in wing-dike notches, for example, dike 102.5 during May 2001.

ADCP data were collected bank-to-bank from approximately RM 98.1-98.7 for August 2000, March 2001, and May 2001 assessments (fig. 2). These data allow a comprehensive analysis of velocities within the channel including wing dikes and the navigation channel. Histograms of vertically averaged velocities for the three time periods show distinct bimodal distributions according to whether the data were collected within or on the navigation side of the wing dikes (fig. 13). The mean of the vertically averaged velocities and the standard deviation increase with discharge, although at a decreasing rate (fig. 14).

Means of vertically averaged velocities in individual wing dikes also increase with discharge (fig. 15). In general, wing dikes at greater distances from the thalweg (navigation line) had lower mean velocities than those closer to the thalweg. Wing dikes that are far from the thalweg are on the inside (concave side) of bends whereas those near the thalweg are on the outside where flow converges. Because these datasets include areas within and adjacent to the structure, the mean velocities include

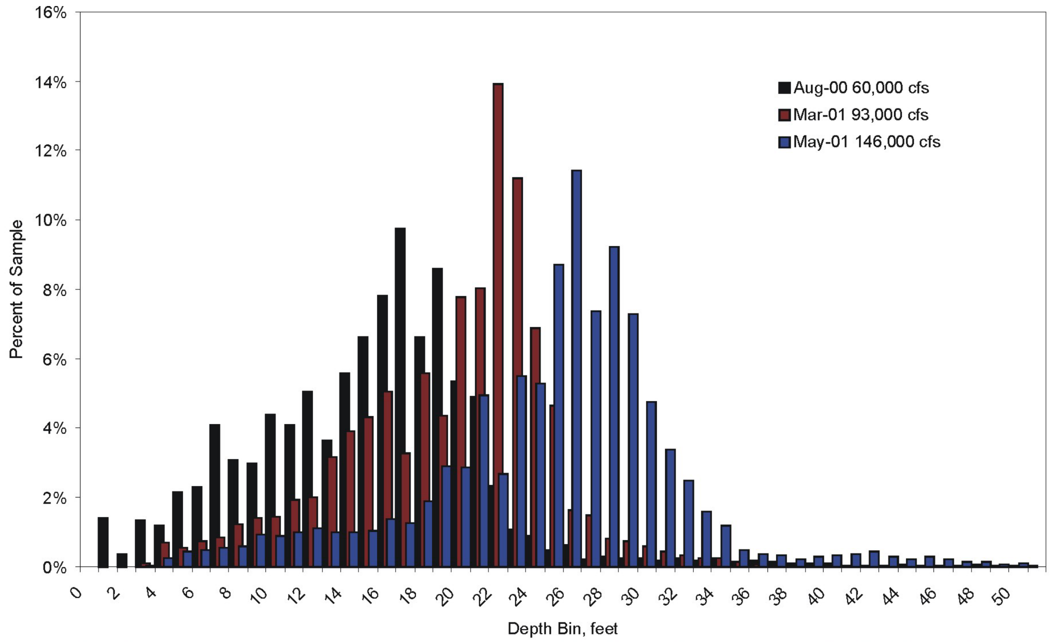


Figure 10. Histograms of depths, bank-to-bank RM 98.1 - 98.7, August 2000, March 2001, and May 2001.

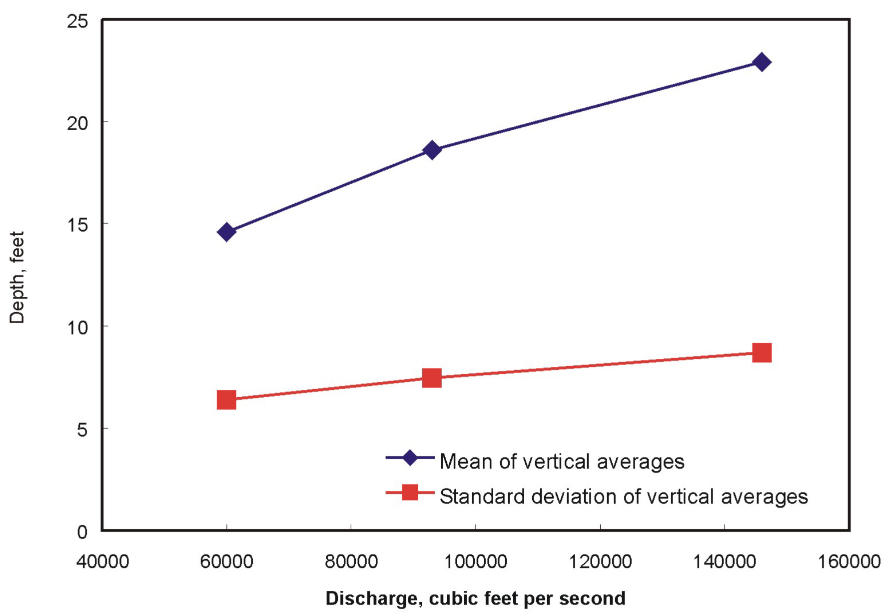


Figure 11. Relation between discharge, mean, and standard deviation of the populations of depths shown in fig. 10. Mean depth and standard deviation increase with increasing discharge but at a slowing rate.

part of the navigation channel with substantially higher current velocities. Some datasets also include anomalously high velocities associated with specific structures. For example, the high mean velocities for dike 103.74 resulted from high velocities that were measured close to the Route 19 bridge piling in August 2000. During other assessments water conditions did not permit the boat to sample as close to the piling, so mean velocities are biased toward lower numbers.

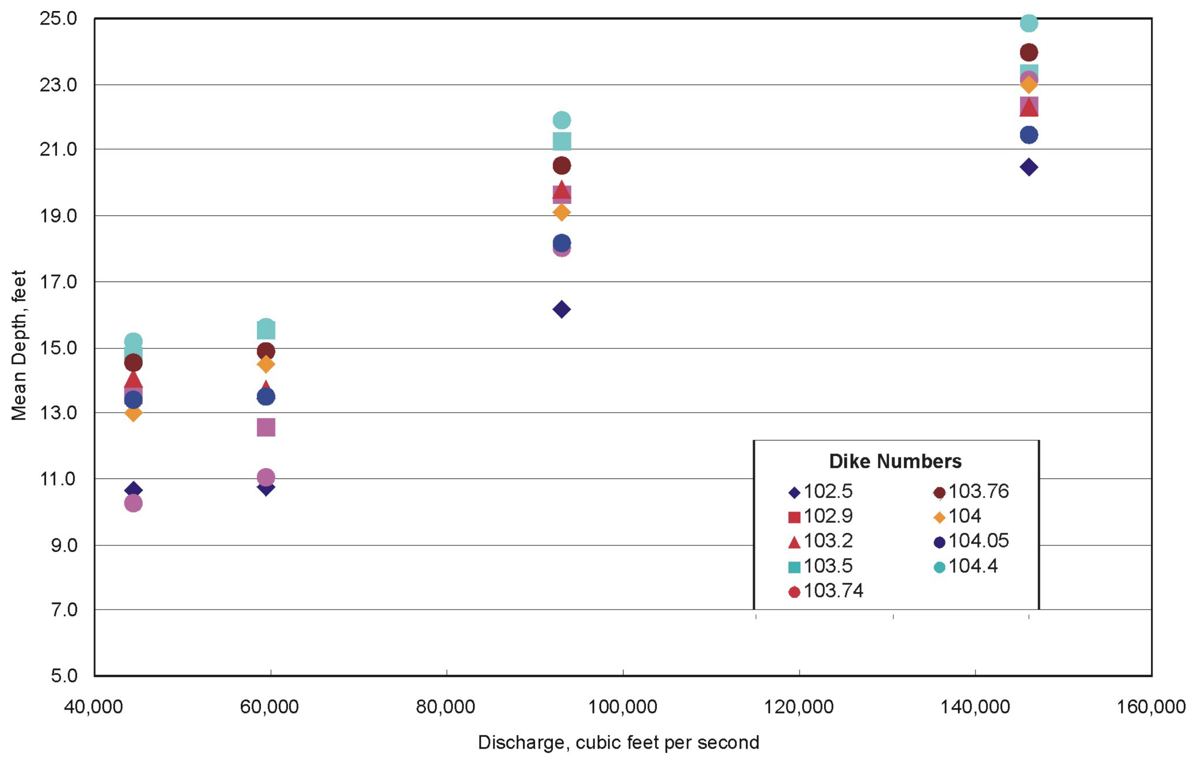


Figure 12. Relations between discharge and mean depth, by wing dike.

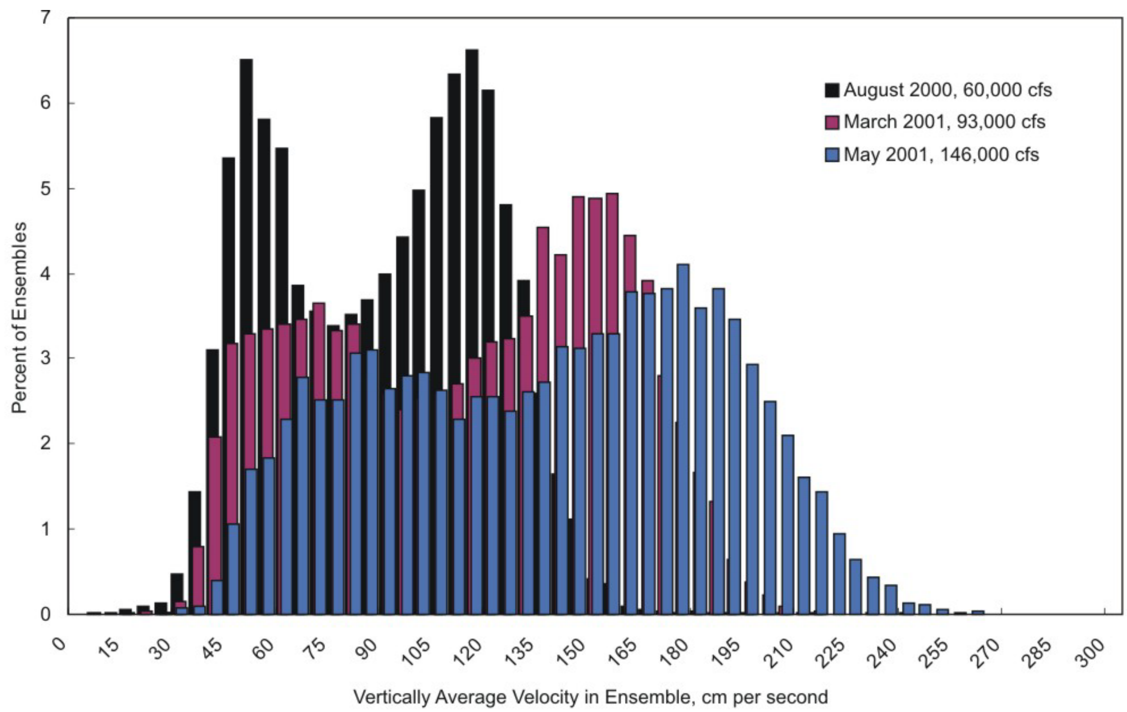


Figure 13. Histograms of vertically averaged current velocities, bank-to-bank RM 98.1 - 98.7, August 2000, March 2001, and May 2001.

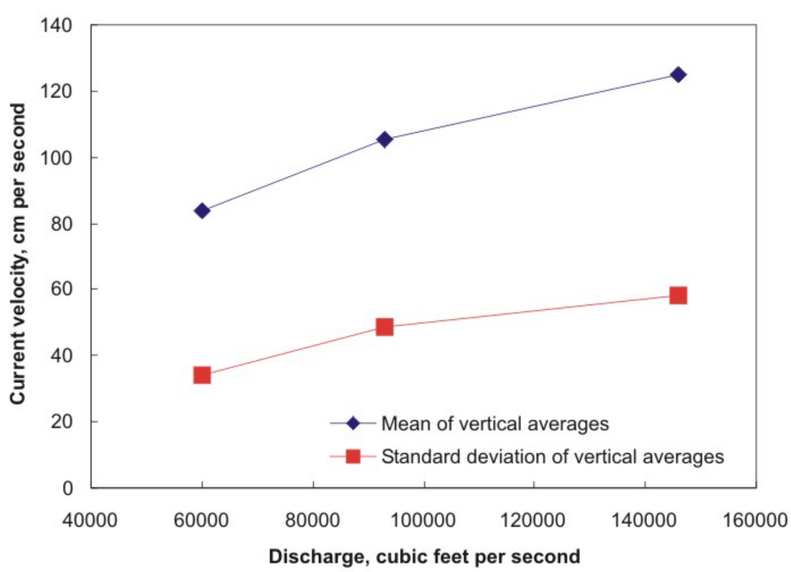


Figure 14. Relation between discharge, mean, and standard deviation of the populations of vertically averaged current velocities shown in fig. 10. Mean current velocity and standard deviation increase with increasing discharge but at a slowing rate.

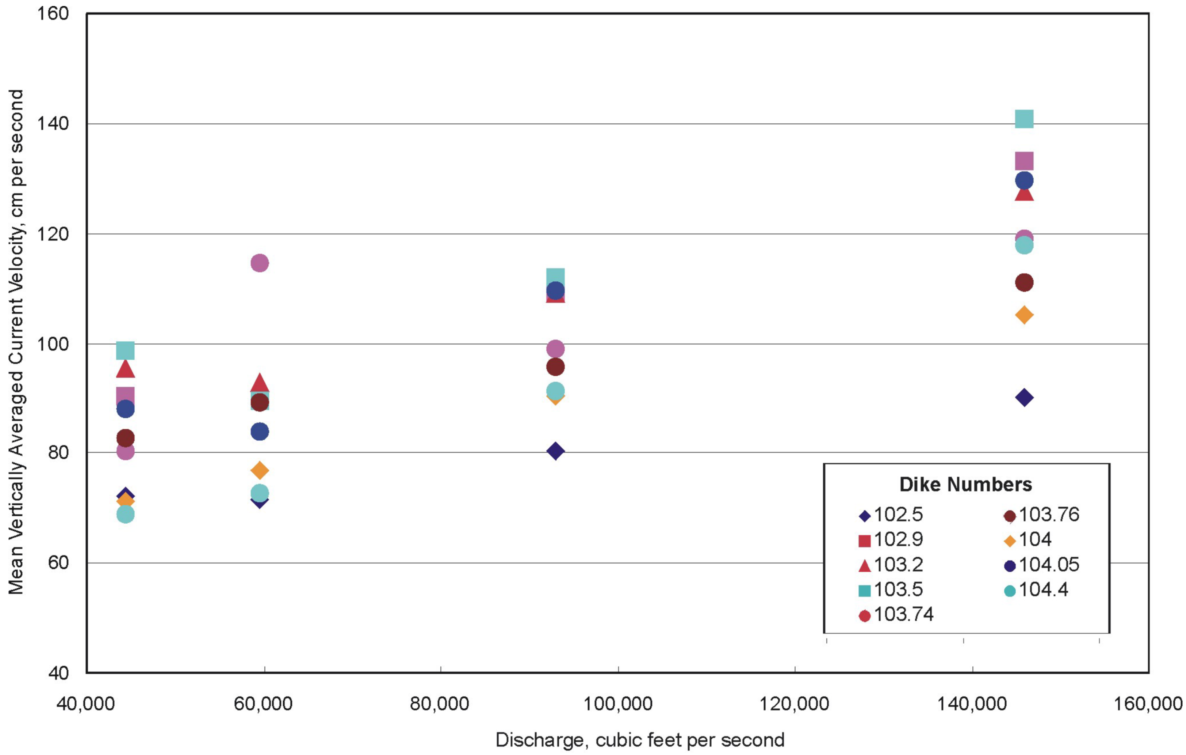


Figure 15. Relations between discharge and mean vertically averaged velocity, by wing dike.

Substrate

Although most of the substrate categories assigned to combinations of roughness (e_1) and hardness (e_2) variables have been calibrated with field observations, interpretation of substrate results is complicated by some specific uncertainties.

- Soft, smooth, muddy sediment shares the same range of roughness and hardness as transporting sand, the carpet of saltation load in transit over the riverbed. Therefore, the 'Mud, transporting sand' unit is mapped in low-velocity zones within the wing dikes as well as in the center of the navigation channel.

- Areas of clear accumulation of particular organic matter (leaves, twigs) have the same soft, moderately rough signature as rippled sand. Therefore, some areas mapped as "Organics (?), rippled sand" occur in low velocity zones within wing dikes as well as in the navigation channel where ripples and suspended sediment near the bed result in the same soft, rough characteristics.

- Small amounts of fine sediment deposited on rock associated with wing dikes and revetments result in a dampening of the hardness signature. As a result, these moderately rough areas frequently classify as rippled sand and coarse sand rather than rock.

Notwithstanding these complications, the substrate data provide a unique source of quantified information about the riverbed and its stability. One of the very clear relations seen in the substrate maps (Appendix 1) is the sharp boundary between mud and sand along the channel-parallel portion of the L-head dikes (102.9, 103.2, 103.5, 103.76, 104, 104.05). Up to discharges where the dike is overtopped (about 93,000 cfs) the area within the dike is dominated by mud and the area outside is dominated by sand, coarse sand, and rippled sand. In contrast, the boundary between channel sand and mud is more diffuse downstream of the end of the spur dikes (102.5, 103.74, 104.4).

The downstream one third of 103.74 has patches of coarse sand, sand, gravel and rock that are evident over a range of discharges. This coarse material may be associated with old structures near the city boat ramp. The coarse texture of substrate in this area is notable and unique among the areas assessed at Hermann.

With increasing discharge – comparing low flows in August and November 2000, moderate flow in March 2001, and relatively high flow over the wing dikes in May – several patterns of change become evident. All the wing dikes showed progressive changes in substrate characteristics and spatial pattern. Two spur dikes (102.5 and 103.74) were characterized by extensive mud deposits downstream during low discharges (August and November 2000). As discharge increased, the mud area contracted toward the bank and the area downstream became more heterogeneous, including patches of sand, coarse sand, and rippled sand at 93,000 cfs in March 2001. The 93,000 cfs (just over the wing dikes) followed a flood peak of about 230,000 cfs about a week prior on February 28 (fig. 3); the coarse, patchy substrate distribution may have been adjusted to the 93,000 cfs flow or it may have been a remnant from the earlier flood. At 146,000 cfs in May 2001, the substrate associated with both these spur dikes was characterized by patches of rippled sand, coarse sand, and gravel.

The L-head dikes and 104.4 had a consistent distribution of mud within the wing dike and sand outside during the August and November flows. Areas upstream of the L-heads tended to be more diverse with more patches of sand and rippled sand. In most of the L-heads, the March 2001 assessment included substantial patches of sand and rippled sand within the dike, possibly resulting from the large flood in late February. Areas in the adjacent navigation channel were characterized by extensive areas of soft, smooth sediment (presumably transporting sand) with patches of sand and rippled sand. At 146,000 cfs in May 2001, areas within the L-head wing dams showed more diversity of substrate than areas outside. This is especially true for dikes 103.2 and 104.05 where the interiors of the wing dikes where characterized by coarse sand, rippled sand, coarse rippled sand, gravel, and rock. The navigation channel adjacent to most L-head wing dikes mapped as homogeneous soft, smooth sediment (for example, 103.5, 104), presumably reflecting the large quantities of sand in active transport at this discharge.

Geomorphic Change

Geomorphic change was assessed in each mapped wing dike by calculating net erosion and deposition between elevation maps for each pair of assessment dates, and overall for the period August 2000 – May 2001. The elevation-change maps (Appendix 1) produced should be interpreted with care; the calculations are susceptible to large error on the edges of the data collection area and along wing dikes. Areas of erosion or deposition with linear orientations adjacent to wing dikes or the shore should be ignored.

Several broad trends are apparent within these data. In general, the spur dikes were more geomorphically active than the L-head dikes. Predictably, the first time period (August – November 2000), which was dominated by low flow, was characterized by little geomorphic change. Most of the change was 2-6 feet of erosion mapped in the navigation channel or to the channel side of spur dikes. This observation indicates that even during periods of low flow, significant sediment transport occurs within the navigation channel, and can result in altered main-channel habitats.

Greater amounts of erosion and deposition are associated with the period November 2000 – March 2001. Although the prevailing discharge during the March 2001 assessment was 93,000 cfs, the channel had experienced as much as 230,000 cfs the week before. The sandbar associated with dike 102.9 experienced substantial erosion; the tip scour of dike 103.74 expanded downstream; the navigation channel adjacent to L-head dike 104 experienced substantial deposition; and a broad area of the eddy bar at dike 104.4 was eroded laterally with some areas eroding more than 10 ft vertically.

For some dikes, the period March 2001 – May 2001 had the most geomorphic change. Dike 102.5 had extensive erosion of the eddy bar during this time period, and the eroded area downstream of dike 103.74 also increase substantially. L-head dikes 102.9 and 103.76 experienced measurable amounts of deposition within the dike.

Because sediment transport can lag and can be limited by supply, geomorphic change measured as the net erosion or deposition can be lagged in time after sediment-transporting flows. Hence, the large amount of geomorphic change from November 2000 – March 2001 may have resulted from a large flood peak of 230,000 cfs that preceded the March 2001 assessment (fig. 3). Between the March 2001 and May 2001 assessments, another flood of approximately 215,000 cfs occurred followed by three weeks of moderate flows (100,000 – 150,000 cfs). The geomorphic change measured may have resulted from the largest of these flows, or from the sequence of events, and may possibly have been mitigated by variation in sediment availability. While these factors complicate identification of the cause/effect links between discharge and geomorphic change, it is clear that discharges of 100,000 – 230,000 cfs are capable of substantial alteration of habitats in this reach of the Missouri River; this conclusion is supported independently by the substrate data which showed substantial changes associated with the same flows.

Conclusions

The objectives of this study were to develop baseline habitat data to aid evaluation of the direct effects of bridge construction and to characterize habitats in the vicinity of the bridge to facilitate understanding of associations between habitat and habitat use by endangered pallid sturgeon. The four habitat assessments over a range of discharges during a nine-month period documented the spatial and temporal distributions of habitat within and adjacent to wing dikes in the Hermann reach. The mapped data established what the area looked like during the assessments and documented the degree of change associated with a normal range of flows. On a broad scale, habitats were stable or resilient: the same deep scours that existed in August 2000 were mapped in May 2001. The same eddy bars associated with spur dikes that were mapped in August 2000 existed in May 2001 in the same places. The assessment data show that erosion and deposition modified these features, but they persisted. Some features, like scour holes off spur dike tips and eddy bars, may be persistent because of the hydraulic effects of the navigation structures that ensure that they are reformed after altering flows. Other habitat features, like the deep, embayed scours adjacent to the banks may be essentially static features that are remnant from large floods in the 1990's.

On a finer scale, the substrate and geomorphic change data documented that the moderate flows experienced during the assessment period were effective in altering key habitat elements. The March 2001 and May 2001 assessments documented erosion of wing-dike eddy bars and deposition within some L-head wing dikes. The substrate maps documented redistribution of sediments and overall coarsening of sediments with increasing discharge. These results document the type and magnitude of habitat alteration that can be expected under naturally fluctuating flow conditions, and thereby set a standard against which to evaluate construction-induced habitat changes.

The second objective was to characterize habitats immediately upstream and downstream of the bridge to develop associations with presence or absence of pallid sturgeon. This report documents the large spatial and temporal variation in habitat that exists in the Hermann reach. The digital, georeferenced physical habitat data developed in the course of these assessments is available for additional analysis and linkage with fish sampling data. In general, the data indicate that the habitats that are thought to be critical for pallid sturgeon over wintering – deep scours associated with wing dikes (Grady and others, 2001)– are stable, persistent habitat features in the Hermann reach. However, the habitat features that are thought to be important feeding and living areas for pallid sturgeon during the warm season – outside edges and downstream ends of sand bars (Sheehan and others, 2000; Snook, 2001) -- are shown to be susceptible to alteration by moderate flows.

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