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WHOOPING CRANE ROOSTING HABITAT SIMULATION MODEL FOR THE PLATTE RIVER IN NEBRASKA

Biology Workgroup
Platte River Management Joint Study

Prepared by the
Whooping Crane Model Subcommittee

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INTRODUCTION

This report provides documentation for a whooping crane (Grus americana) roost habitat simulation model developed for the Platte River in Nebraska. The purpose of the model is to characterize the relationship between river discharge and roosting habitat. The relationship is based on physical habitat parameters within the channel which are related to flow. Habitat suitability criteria are used in conjunction with hydraulic simulations of the Instream Flow Incremental Methodology (IFIM). The model is applied to an 89 mile reach of the central Platte River between Lexington and Chapman, Nebraska.

IFIM (Bovee 1982) is a state of the art modeling tool that consists of a collection of computer models and analytical procedures. It is designed to predict changes in aquatic habitats or aquatic resources, in relation to river discharge. Physical habitat simulation of IFIM is based on physical features of roosting habitat that are related to discharge; it is not an ecological model.

Physical habitat simulation is comprised of two components, a hydraulic model and a species model. Habitat suitability criteria used in the whooping crane model were developed by consensus of whooping crane experts and the Biology Workgroup of the Platte River Joint Management Study. Hydraulic modeling was conducted under the direction of the U.S. Bureau of Reclamation and conform with the IFIM guidelines described by Bovee (1982).

This report describes whooping crane use of riverine habitats for roosting, the development and application of habitat criteria in the physical habitat simulation using IFIM, and modeling output. The report is organized into five sections:

I. The study area

II. Hydraulic modeling and simulation procedures

III. Whooping crane roosting habitat suitability criteria

IV. Application of the whooping crane criteria and hydraulic models using IFIM

V. Results of the model application

This study was conducted for the Platte River Management Joint Study. The study has involved the U.S. Fish and Wildlife Service (Service) and the U.S. Bureau of Reclamation (Bureau) in cooperation with a number of other federal, state, and private resource management and interest groups. The study covered a seven year period from 1983 to 1989. The authors of this report are David Carlson of the US Fish and Wildlife Service, Del Holz and Duane Woodward of the US Bureau of Reclamation, and Jerry Ziewitz of the Platte River Whooping Crane Habitat Maintenance Trust.

I. THE STUDY AREA

The study area is an 89 mile reach of the central Platte River between Lexington and Chapman, Nebraska (Shenk and Armbruster 1986, USFWS 1987). A 56 mile segment within the reach has been designated as critical habitat for whooping cranes (Federal Register 43[94]: 20938-20942). The study area and its location in Nebraska is shown in Figure 1.

Channel widths in the study area vary considerably. In some river segments, particularly in upper reaches of the study area, anabranching channels have replaced the former wide, braided channel. The average width of individual channels in highly anabranched segments of the river is approximately 200 feet. Channel widths are generally greater in the lower (eastern) end of the study area. Some of these channels have widths of 1200 feet or more.

The bed material of the central Platte River is an unconsolidated alluvium of sand and gravel. The river overlies an aquifer and high water table. The channel gradient is approximately 6.0 feet per mile, and varies from 5.0 to 7.0 feet per mile.

Islands of various sizes have developed within the channel and are common in the study area. However, two major island complexes that result from splits in the channel are morphologically significant. These are the Fort Farm/Killgore islands between Kearney and Gibbon, and the Shoemaker/Indian Island/Mormon Island complex that extends from Wood River to three miles east of Grand Island.

Large forested areas have developed on stabilized islands and accreted areas within the former river channel. Predominant woody shrubs are sandbar willow, indigo bush, rough-leaf dogwood and red-osier dogwood. The predominant trees are cottonwood, and red cedar (USFWS 1981). Much of the river valley has been converted to cropland with the predominant crop being irrigated corn. Wetland meadows and native grasslands still exist in some lowland areas in the river valley. These low lying grasslands have soil moisture regimes that are hydraulically related to the river stage (Hurr 1983).

No major inflows occur in the study area. One major diversion, the Kearney Canal, diverts water near Elm Creek. Flow is returned to the river approximately 6.0 miles east of Kearney. The diversion operates during most ice-free days of the year.

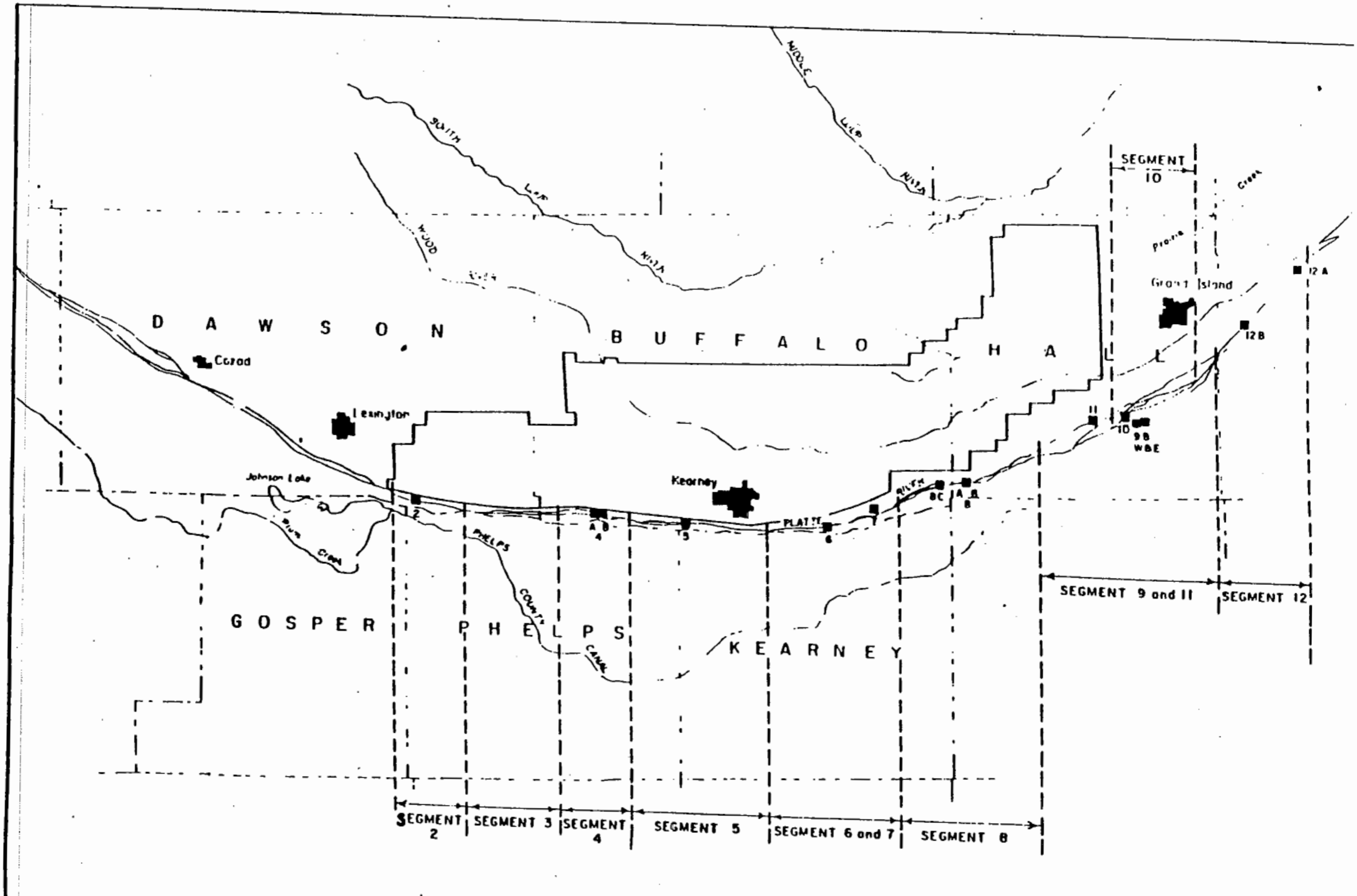
II. HYDRAULIC SIMULATION

The procedures used for IFIM study design and modeling physical channel features followed the guidelines described by Bovee (1982). An interagency team (U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, and Nebraska Game and Parks Commission) of hydrologists and biologists familiar with IFIM and the study area participated in study site selection. The 89 mile reach was first divided into 12 segments based on the channel morphology and flow regime. One or more representative reaches (study sites) were selected in each segment to represent physical features of the segment. A total of 16 study sites were established in the study area (Figure 1).

Segments and study sites were sequentially numbered from Lexington downstream to Chapman (Figure 1). River segments 3 and 5 have similar channel morphology and flow regimes and study site 5 was used to represent both of these segments. Some segments have variable characteristics. These are represented by specific sub-segments which were modeled separately. For example, river segment 8 contains three sub-segments designated 8A, 8B, and 8C. Sub-segment 8A further is composed of a north and south channel and the two study sites located in these channels are designated 8AN and 8AS, respectively.

The length of individual study sites ranged from 766 to 6871 feet. Between three and nine permanent transects were established at each site; a total of 85 transects were established at the 16 study sites. Transects were weighted to describe the length, and the longitudinal characteristics of the channel represented by each transect.

Field measurements were collected between March 1983 and April 1988. Between two and nine measurements, or sets of hydraulic data, were collected at each study site. River profiles, water velocities, and the occurrence and location of woody perennial vegetation were recorded for each transect. Information about the location, measurements, and



PLATTE RIVER HABITAT
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length of river represented by each study site is shown in Table A-1 of Appendix A.

Both Water Surface Profile (WSP) and IFG-4 models (Milhous et al. 1984) were used to model channel hydraulics. Discharge relationships were simulated for flows between 0.4 and 2.5 times the measured discharge. The Bureau (USBR 1989) has described further details of procedures used for field data collection and hydraulic simulation. IFG-4 hydraulic simulation files were prepared, and simulations of various hydraulic parameters have been reported (USBR 1987).

Assumptions upon which IFIM evaluations are predicated pertain to this model. Among the assumptions is that the channel is either stable or in dynamic equilibrium (Milhous et al. 1984). Channel changes may occur on both a short term and long term basis.

Changes in the bed of alluvial streams which result in short term variations in hydraulic parameters are often related to the preceding flow regime (Milhous and Bovee 1978). More intensive IFIM sampling and study design may often be required to understand the hydraulic relationships associated with this variation (C. Stalnaker pers. comm.). Several sights have been repeatedly sampled by the Bureau and Service in order to discern these short-term variations. A consensus of professional opinion has formed that the hydraulic measurements and simulations can be used to accurately portray the present conditions of the river (USFWS 1987a). The hydraulic measurements conducted by the Joint Study, and hydraulic and habitat simulations made using these measurements are referred to as "present conditions".

Long-term changes in channel morphology can occur that are related to fluvial dynamics including sediment transport, flow duration, and channel geometry (Hydrology Workgroup 1989). The validity with which the modeling simulations can be used to predict long-term trends under various future scenarios is not known. The approach of the Joint Study is to treat the database as the present condition while continuing to monitor possible changes in channel hydraulics (USBR 1987, Hydrology Workgroup 1989). Habitat versus flow relationships can be reconstructed if hydraulic or morphologic conditions of the channel change. In addition, hydraulic modeling techniques are being examined and developed that could be used to predict possible changes of alluvial dynamics (USBR pers. comm.).

III. WHOOPING CRANE USE OF RIVERINE ROOSTING HABITATS

Shallow river channels represent one of several types of habitat used for roosting by whooping cranes. Whooping crane biologists generally agree whooping cranes select roost sites based on the security offered by the site(s). The following characteristics have been used to describe riverine roost sites (Biology Workgroup 1988):

1) Presence of water: Whooping cranes roost in water. The availability of water is an inherent requirement of whooping crane behavior.

2) Wide horizontal visibility: Whooping cranes select roost sites free of visual obstructions or with an unobstructed view, presumably to allow them to see approaching terrestrial predators. Visibility at riverine sites includes both a broad, unobstructed channel width and upstream and downstream visibility.

3) Depth of water: Whooping cranes stand in shallow water to roost. Deeper water is often present in the channel adjacent to the roost sites. In braided alluvial rivers such as the Platte, a mixture of deeper thalwegs and shallowly submerged sandbars occur. Biologists have hypothesized that deep water surrounding riverine roost sites form a deterrent to terrestrial predators.

4) Water width: In addition to simply being present and having adequate depths, the expanse of water surrounding the roost site must be sufficiently wide to provide a sense of isolation and security.

The US Fish and Wildlife Service (1981) reported whooping cranes generally preferred to roost in wide river channels which have low, exposed, bare sandbars, relatively shallow water, slow rates of flow, and isolation from human disturbance. The following characteristics were described based on 10 riverine sites used by whooping cranes, including four sites on the Platte River:

1) wide channel, with 9 of 10 sites being between 155 and 365 meters (170 and 400 yards);

2) slow flow, i.e. approximately 0.4-1.8 meters per second (1-4 mph) although water in the main channel may be flowing faster;

3) shallow water except in the main channel (all sites evaluated were less than 30 centimeters (12 inches) deep and six of nine sites were 5-15 centimeters (2-6 inches) deep);

4) unvegetated;

5) fine substrate, usually sand;

6) good horizontal visibility unobstructed from river bank to river bank and at least a few hundred yards upstream and downstream (or to a bend in the river) at all sites;

7) good overhead visibility without tall trees, tall and dense shrubbage or high banks near the roost;

8) close proximity (usually less than 1.6 kilometer or 1 mile) to suitable feeding sites;

9) isolation (0.4 kilometer or 0.25 mile) from roads, houses, and railroad tracks; and,

10) sandbars in the vicinity of the roost that usually sloped gradually into the water (often less than 1-2 degrees), had low topographic relief (often less than 0.3 meters (1 foot)), no banks over several cm high, and had little or no vegetation.

Additional measurements of physical parameters has been systematically collected at whooping crane roost sites used in the Platte River study area from 1983 to 1989 (Appendix B). Based on measurements at 21 roost sites the following parameters have been described:

1) Active channel widths of 172 to 1365 feet;

2) Water width within the channel ranging from 172 to 1207 feet;

3) The percentage of the active channel that was water-filled ranges from 59 to 100 percent (mean = 93.3 percent);

4) Profiles of the river channels ranging from barren sandbars as high as one foot above the water, to channels greater than 3.5 feet deep.

Roosting Habitat Criteria

Habitat suitability criteria are designed to implement habitat parameters in the model. The habitat criteria were originally developed by consensus of whooping crane and modeling experts in two workshops which were conducted under the supervision of the Service's National Ecology Research Center. The habitat-use information and suitability criteria of the workshops have been described in two reports (Shenk and Armbruster 1986, USFWS 1987b). An alternate depth criterion was subsequently developed for the Biology Workgroup by the whooping crane model subcommittee (1988), and the suitability index curves were refined to include data collected at roost sites used through the 1989 spring migration.

Four habitat parameters are used to describe the principal qualities of roost sites on the Platte River which are compatible with IFIM simulation. These parameters are the channel width, wetted area within the channel, the distribution of depths in the wetted area, and lack of disturbance.

Two of the parameters, wetted area and water depth, vary with flow. The other two parameters, areas subject to disturbance and channel width, do not; these parameters characterize factors that are constant and specific within each river segment. The "freedom from disturbance" criterion functions as a binary criterion in the model and is used to eliminate areas of the river subject to disturbance from further consideration. The channel width, in combination with the longitudinal characteristics of the river, describe both the visibility characteristics within the channel and the open areas of channel available to cranes. Suitability criteria and index curves have been developed to describe the discharge dependant parameters.

The standard used to define the criteria and structure suitability curves is "habitat-use". Habitat-use data documents the whooping cranes use of or preference for habitat with particular characteristics. It is assumed that (1) the species will select and use areas that are best able to satisfy its life requirements; and (2) as a result, greater use will occur in higher quality habitat (Schamberger and O'Neil 1986).

Suitability is defined in terms of the assumed relationship between optimum conditions and the opposite extreme of no resource available. Suitability index curves were produced for each habitat criteria, with values ranging from 0.0 to 1.0. The index values represent an interpretation of the biological significance of a measure of the habitat criterion. In some cases, conditions identified as optimum (suitability index equal to 1.0) represent a compromise between biological and management considerations. For example, a number of whooping crane sightings have been made on rivers with wetted widths greater than 1000 feet. The channel of the Platte River was historically several thousand feet wide throughout much of the study area. Today, however, only a few relatively short reaches have channels widths greater than 1000 feet. From a practical standpoint, a water width of 1000 feet was judged to be sufficient to provide a desirable management condition. The suitability index curve was constructed accordingly.

The information used to develop the criteria are from confirmed sightings and direct observations of roost sites made on the Platte River by professional biologists. A nocturnal roost is defined as the location occupied by a single or group of whooping cranes in the late evening as it became dark or when the cranes were first observed in the early morning, between first light and shortly (15 minutes) after sunrise.

The data that were used to develop the suitability criteria have been collected on the Platte River system since 1966. Physical habitat features have been systematically measured at roost sites on the Platte River since the 1983 fall migration. The suitability index curves are derived from, and applicable to, roosting habitat on the Platte River system under the "present conditions" (i.e., the physical, morphological and hydraulic conditions that currently prevail).

a. Disturbance and Excluded areas

Whooping cranes usually avoid areas within one-quarter mile of certain types of disturbance (USFWS 1981). Disturbances that were identified during the IFIM study design were county roads, railroad tracks, and bridges. Reaches of the river within one-quarter mile of these disturbances were excluded from representation.

Other reaches of river are excluded because of power line crossings. Power lines pose a flight hazard to cranes attempting to locate roosting areas. River reaches in the immediate vicinity of power lines were determined to be undesirable for modeling, and a one-quarter mile length of river upstream and downstream of power line crossings was excluded. The lengths of river represented by each study site that are given in

Appendix A, Table A-1, have been adjusted to exclude lengths of river influenced by disturbances and power lines.

b. Active Channel Width

Whooping cranes roosting on the Platte River have demonstrated a preference for sites with broad channels, free of woody vegetation, and with good horizontal and overhead visibility (USFWS 1981). The active channel width criterion is used to describe these features. Other factors being equal, broad, active channels with wide unobstructed views have greater value than narrow channels. The active channel width criterion includes the characteristics of "unobstructed view" described by Shenk and Armbruster (1986), and is synonymous with "unobstructed channel width" criterion described by the USFWS (1987b).

Table 1. Bank to bank, unobstructed channel widths reported at 40 riverine whooping crane roost sites, ranked from largest to smallest for sightings on the Platte River system and other Great Plains rivers.

	Unobstructed channel width (ft)	
rank	Platte River	Other rivers
1	1365	2050
2	1207	1837
3	1152	1640
4	1087	1575
5	1048	1476
6	1019	1276
7	986	1247
8	975	1230
9	881	1230
10	856	1201
11	850	1050
12	831	899
13	827	810
14	755	600
15	699	512
16	696	489
17	600	
18	570	
19	552	
20	507	
21	495	
22	475	
23	373	
24	172	

Channels of the Platte River that normally carry flow (active channels) are bounded by woody, perennial vegetation. The banks and vegetation form visual obstructions to cranes standing in the river. The location of river banks and perennial woody vegetation greater than three feet in height (USFWS 1987b) is coded in the hydraulic data files for each IFIM transect, and the width of the active channel is measured as the distance between obstructions along a transect.

Channel widths used by whooping cranes on the Platte River are given in Table 1. Channel widths have ranged from 172 to 1365 feet. Of 24 roost sites evaluated on the Platte River, 20 have been in channels greater than 500 feet wide, and two other sites were in channels 495 and 474 feet wide. In contrast, the availability of channels greater than 500 feet on the central Platte River is limited (USFWS 1981). Use of channels with widths generally greater than 500 feet is substantiated by observations made at a number of other riverine roost sights (R. Lock pers. comm.). The suitability index curve originally developed to describe the unobstructed channel width is shown in Appendix C.

The whooping crane's requirement for a wide unobstructed view includes upstream and downstream visibility (Faanes, in press). Characteristics of upstream and downstream visibility at roosts on the Platte River are reported in Appendix B. Upstream and downstream visibility are not directly measured by the model, however, aspects of the field design (i.e., transect placement and transect weighting) are used to represent the longitudinal characteristics of the river channel at each site. The active channel width criterion in combination with the longitudinal characteristics describe the "active channel area". The implementation is described in Section IV of this report. Channels having widths less than 170 feet, the narrowest channel used by whooping cranes, are excluded from the model.

c. Water Width

This criterion characterizes the expanse of water that normally occurs in the channel at roost sites. An expanse of water apparently provide cranes a sense of isolation and security (Shenk and Armbruster 1986, USFWS 1987b). The water width is computed as the sum of the wetted widths within the channel (USFWS 1987b).

Table 2. Width of water within the unobstructed channels reported at 35 riverine roost locations used by whooping cranes. Total water widths are ranked from largest to smallest for Platte River sightings and for other Great Plains rivers.

	Water Width (ft)	
rank	Platte River	Other Rivers
1	1207	1640
2	1087	1575
3	1048	1230
4	963	1230
5	948	1230
6	861	1115
7	843	1050
8	831	984
9	827	810
10	826	787
11	804	489
12	755	
13	748	
14	696	
15	646	
16	600	
17	562	
18	520	
19	507	
20	495	
21	475	
22	356	
23	172	
24	121	

The water width in channels used by whooping cranes shown in the Platte River and other Great Plains rivers are shown in Table 2. The greatest observed water width used by whooping cranes on the Platte River is 1207 feet. Water widths greater than 1207 feet have been reported at a number of roost sites on other rivers in the migration corridor. The narrowest water width in the channel at sites used by whooping cranes on the Platte River is 121 feet (Johnson unpubl. data, presented in Shenk and Armbruster 1986).

The suitability index curve constructed for this criterion has a value of 0.0 for widths less than 120 feet. A suitability value of 0.9 is assigned to wetted widths of 850 feet and a suitability value of 1.0 is assigned to wetted widths of 1000 feet or greater (Figure 2).

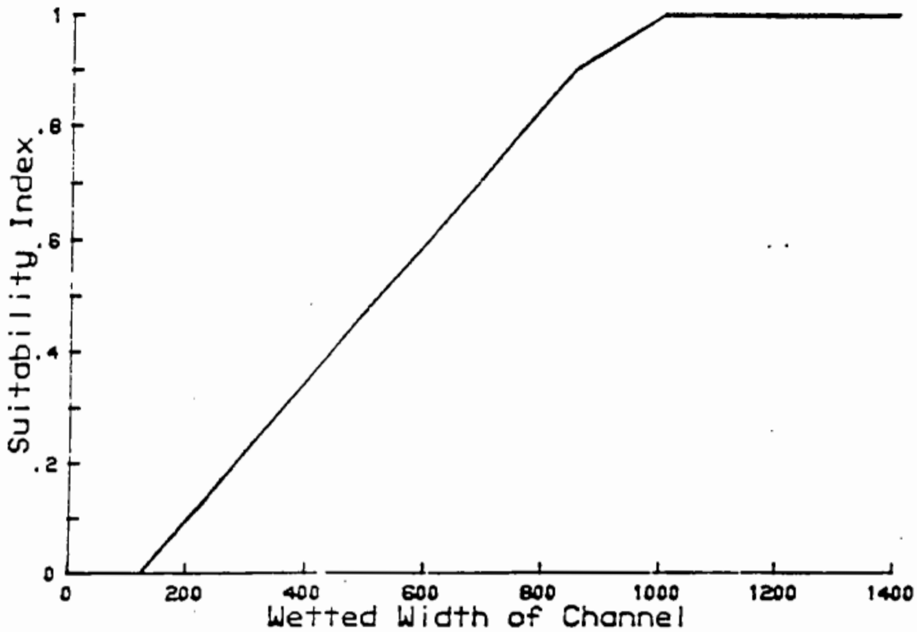


Figure 2. Suitability index curve for the Wetted Width criterion used in the whooping crane roosting habitat simulation model.

d. Depth

Whooping cranes using the Platte River often roost on shallowly submerged sandbars at a distance from the edge of water and visual obstructions. Deeper water has bounded the submerged sandbar or specific location where cranes stood. The actual depths of water whooping cranes stand in can vary within certain limits if the over-all suitability at the site is sufficiently met. Because of natural variation in the alluvial channel bed, a suitable roosting site will have a variety of water depths: submerged sandbars that are braided by a number of deeper channels or thalwegs within the main channel.

The depth criterion was empirically developed based on the variation of depths measured at roost locations. Channel profiles were collected at 21 locations used by whooping cranes on the Platte River (Figure 3). Measurements of water depths were collected by placing a transect across the channel at the roost site shortly after cranes had left. Each transect was placed perpendicular to the channel and between the banks or points of visual obstruction. Measurements of water depth were taken at intervals along it.

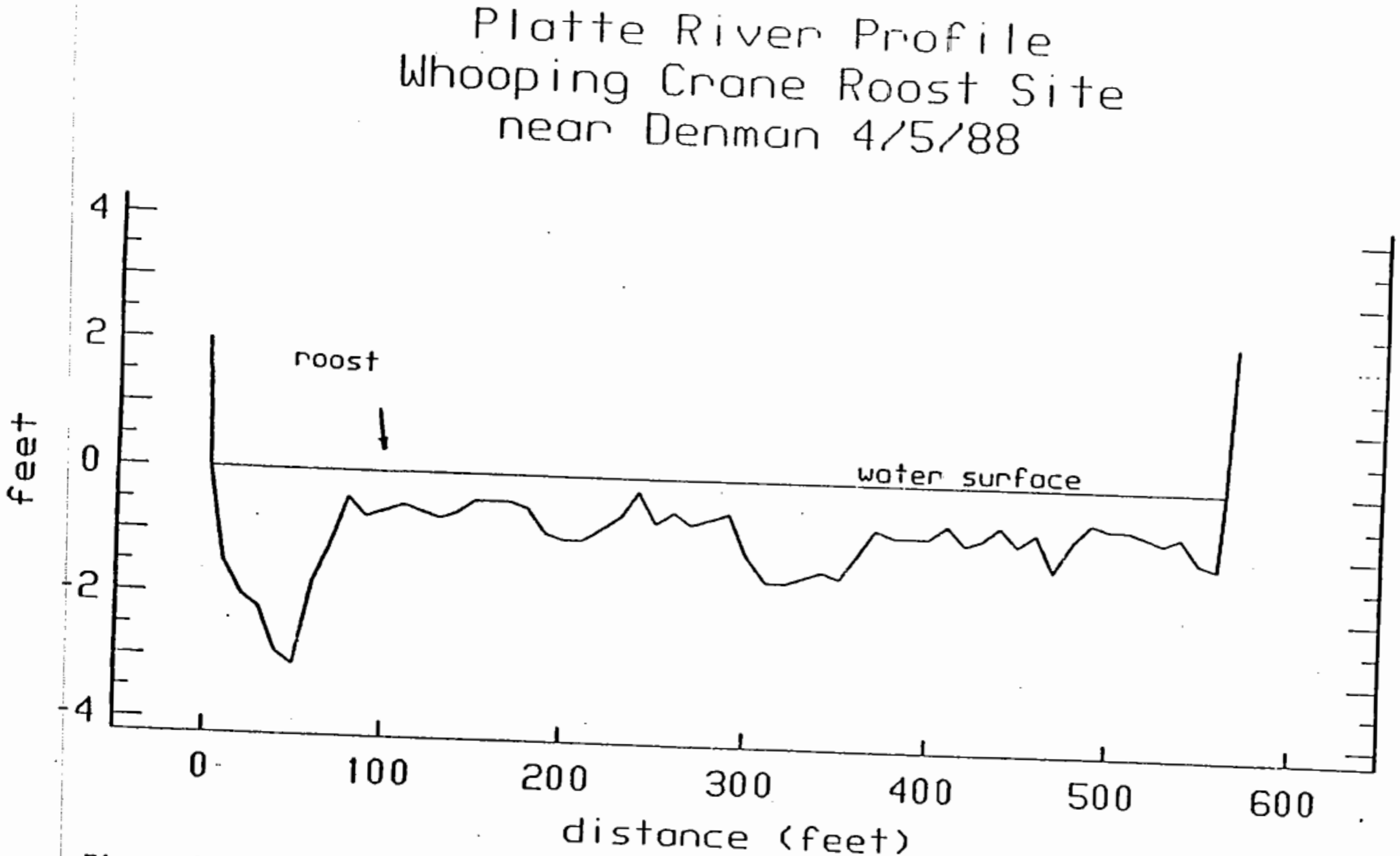


Figure 3. Profile of a Platte River channel near Denman. This is an example of 21 profiles measured at whooping crane roost sites.

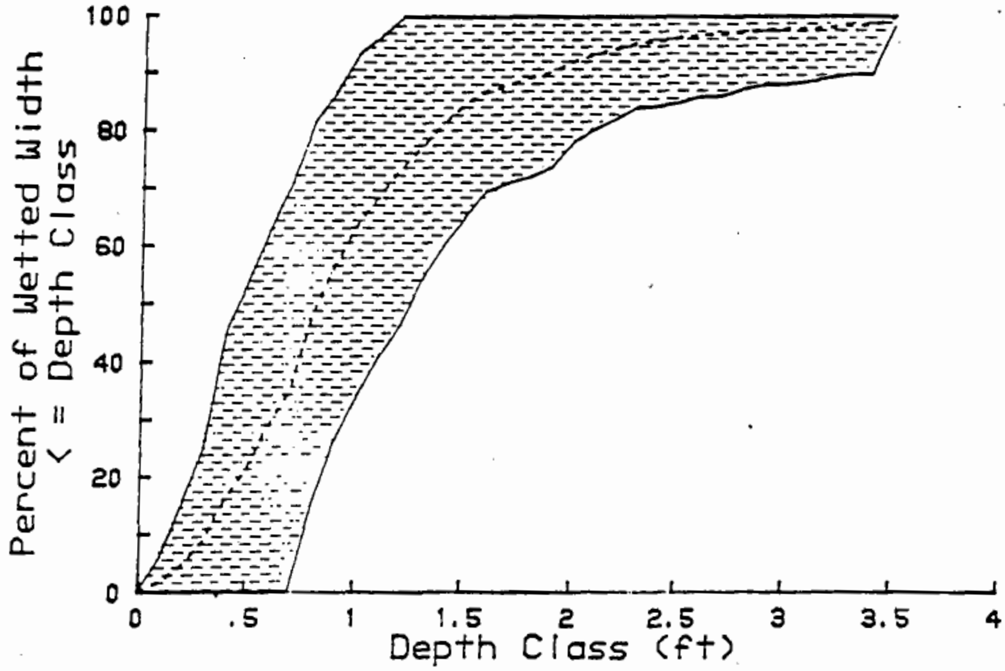


Figure 4. Cumulative depth distribution curve for whooping crane roost sites on the Platte River. The curve is the mean plus and minus 2 standard deviations of the cumulative distribution functions for 21 roosts sites. This range (shaded area) is the suitable zone used in the whooping crane model.

The proportion of the wetted width was computed for each 0.1 foot increment in depth, and a cumulative distribution function (cdf) was developed for each roost site to describe the statistical distribution of depths at the site. A range of suitable depths was calculated by averaging the cdf curves of all 21 roosts sites (Figure 4). The suitable range was defined as the mean cdf curve, plus and minus two standard deviations.

The suitability index of transects at the IFIM study sites is determined by how well the cumulative distribution function (cdf) for the transect at a given flow conforms with the cdf computed for whooping crane roost sites. The suitability index of the transect is calculated as the proportion of the points on its cdf curve that fall within the suitable range. This calculation is repeated for each transect segment for each flow that is simulated. A detailed description of the depth criterion was provided in a report prepared for the Biology Workgroup (Carlson et al. 1988).

IV. IMPLEMENTATION OF HABITAT VARIABLES

The habitat suitability criteria are applied to the central Platte River study area using hydraulic simulation and a physical habitat simulation program. The physical habitat simulation is implemented by a computer program originally developed by Ziewitz (1987) and modified by Woodward.

Physical roosting habitat used in this model is considered by convention to be a function of habitat quality (suitability) and the quantity (area) of available habitat. This approach is based on a similar concept often used with HSI models when they are applied in Habitat Evaluation Procedures (HEP) and IFIM system models. The channel area within the study area is a constant, and incremental changes in river flow result in incremental changes in the quality of habitat within the study area.

An IFIM transect represents the profile of one or more channels, depending on channel morphology. Individual channels represented by a transect are referred to as "transect segments" (Figure 5a). A transect segment represents the active portion of the river; that portion which conducts flow and is bounded either by stable banks or permanently vegetated islands. The channel may carry the total Platte River discharge or a portion of it.

Transect segments are the sampling unit of the model and certain physical characteristics of each transect segment are fixed. These characteristics include the location of banks and tall woody vegetation, the number and location of channels, and the length of river it represents. The information is coded into hydraulic input files (IFG-4 files) and does not change during hydraulic or habitat simulation.

Habitat value is computed as a product of the active channel area and suitability indices. The active channel area is first computed by multiplying the unobstructed channel width of each transect segment by the length of river the transect segment represents. This implementation serves two purposes. Operationally, the habitat/discharge relationship that is generated at a site is a composite for all channels that are available, provided they meet or exceed the minimum suitability for channel width. Secondly, greater weight is given to channels that are wider and have greater suitability.

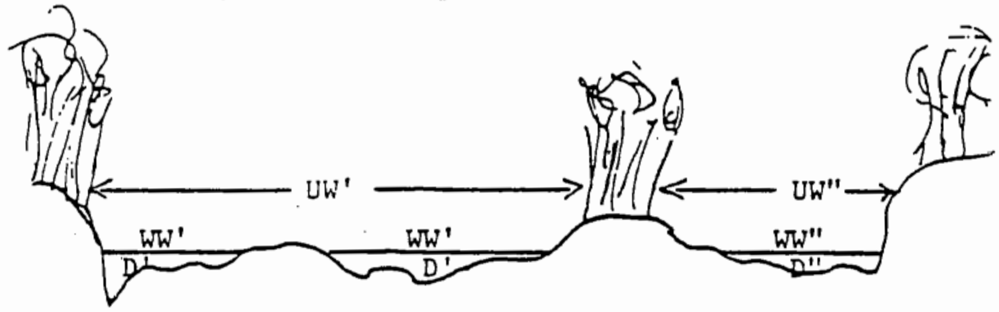
Suitability indices are computed for the flow dependant criteria (depth and water width) for each transect segment, and the channel area represented by the transect segment is "weighted", or multiplied, by the suitability indices. A habitat function termed "weighted habitat area"

(WHA) is produced for the portion of river channel represented by the segment. The simple equation that expresses this relationship is:

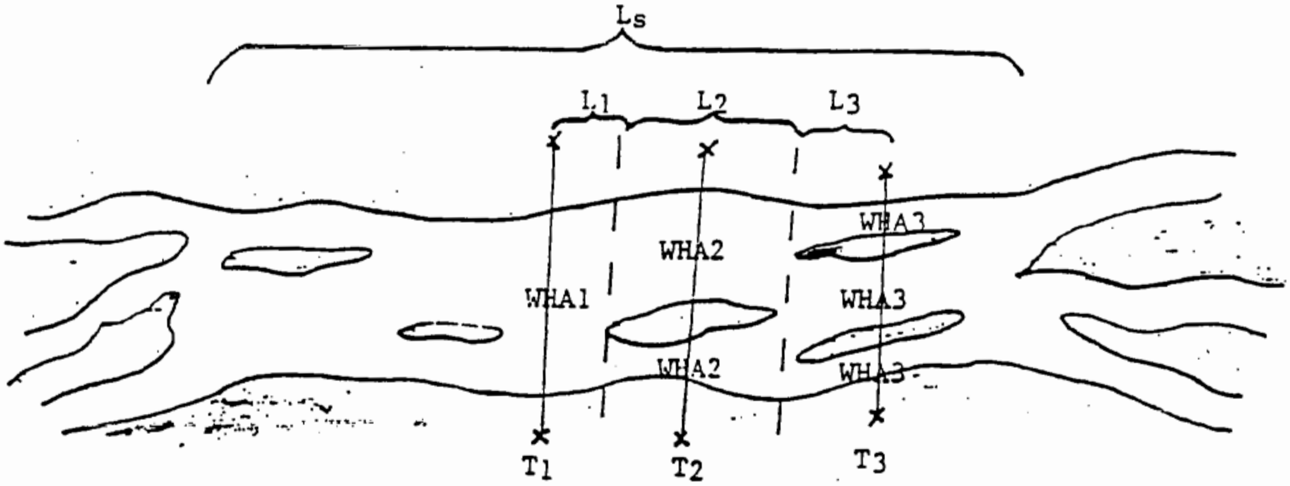
Weighted Habitat Area = (CW x L) (SIww x SId)

where: WHA = Weighted Habitat Area for a transect segment
CW = Width of the active channel
L = Length of river represented by the transect
SIww = Suitability index for water width
SId = Suitability index for water depth

The habitat values of the transect segments are added together to derive the WHA for the study site (Figure 5b). The habitat value is expressed in terms of the WHA value per 1000 linear feet of river for each river segment. WHA is an composite index of the relative quality and quantity of roost habitat, absolute magnitudes are not meaningful.



(a) Representation of a transect cross-section



(b) Representation of a study site

$$WHA/1000\ ft = \sum_{3}^{t=1}\left[(\sum WHA)_t\right] \div \sum_{3}^{t=1} L_t \quad \times 1000$$

Figure 5. Channel width and indices for water width and water depth are computed for each transect segment (a). Weighted habitat area per unit length of river is computed by summing WHA for all transect segments at the site and dividing by the total length of the study site (b). T = transect; L = length of river represented by individual transects (L_t) and the study site (L_s).

V. RESULTS OF PHYSICAL HABITAT SIMULATION

The preliminary results of flow versus habitat relationships generated by the model are given in Figures D-1 through D-15, and in Appendix D. When more than one measurement was made at a site, slight shifts in the hydraulic and habitat versus flow simulations are sometimes observed. These are believed to be due to shifts in the channel bed that occurs between measurements. The model treats the channel bed as static for the hydraulic and habitat simulations of each data set. The flow versus habitat curves presented in this report were combined using a mathematical algorithm developed by the Bureau of Reclamation (in prep.). Irregularities that appear in the resulting habitat/discharge curves of individual sites are dampened when the relationships are combined for the entire study area.

To produce a flow versus habitat relationship for the study area, the WHA relationships for each site were first multiplied by the length of the river segment represented by the site to obtain WHA for the river segment. The WHA for the river segments were then added together. The physical habitat versus flow relationship for the study area is given in Figure 6 (preliminary).

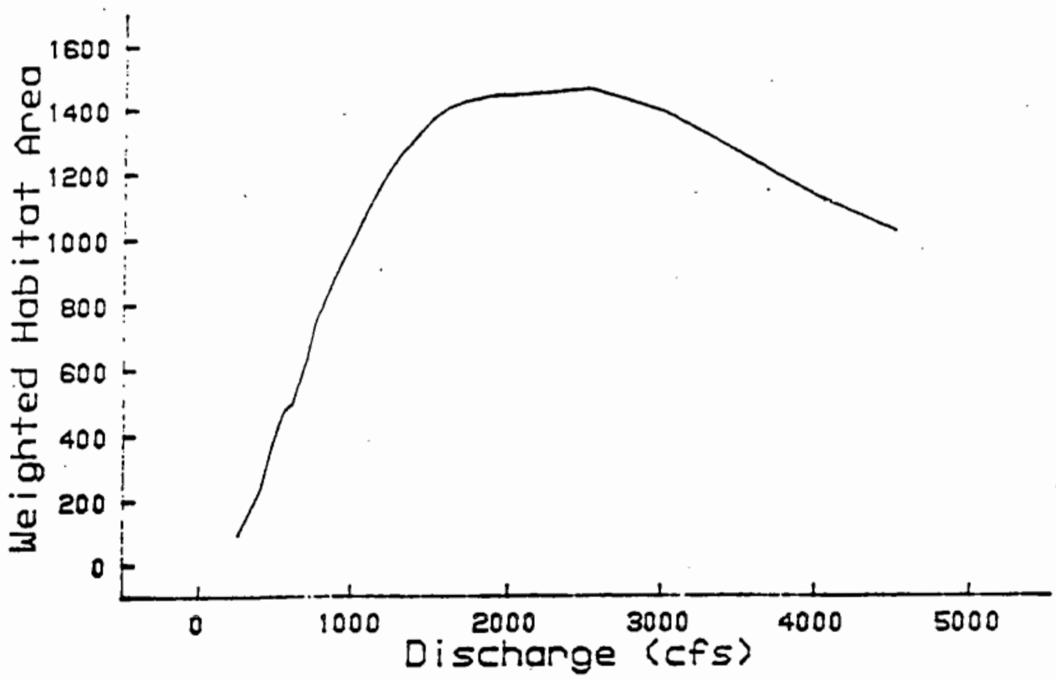


Figure 6. Habitat versus discharge relationship simulated for whooping crane roosting habitat for the central Platte River study area.

VI. ASSUMPTIONS AND LIMITATIONS

The model is based on physical features of roosting habitat which are discharge related; it is not an ecological model. Several issues important to maintaining the ecological value of whooping crane migratory and roost habitat on the Platte River are beyond the scope of the model. These issues include, but are not necessarily limited to the hydrology of wet meadows, the importance of feeding in riverine habitat, the maintenance of river channel morphology, and the juxtaposition of land use and habitat types.

The model is applicable to roost habitat characteristics within the banks of the river channel proper. Occasionally, roosting opportunities occur in the riverine setting but outside of the channel due to bank overflow, or when lowlands adjacent to the channel fill with groundwater. Though these events can be related to river discharge, the model does not address the value of these potential roosting areas.

The model represents the relationship of whooping crane habitat to discharge in the existing setting; it does not address whooping crane response to change in relationships among the habitat variables beyond those that presently occur. The hydraulic measurements and subsequent simulations represent the "present conditions" of the river. The hydraulic conditions that are likely to prevail under various long-term scenarios of river or flow management are not known. Though channel features available to whooping cranes under the present conditions vary considerably, the sighting information on channel and water-related features used limit the channel changes that can be modeled.

Several inter-relationships among these and other habitat criteria have been examined which could bear further consideration in habitat management and recovery decisions. Further investigation and interpretation of these relationships will depend upon identifying specific uses of the model, as well as formulation of specific management objectives for the recovery of roosting habitat.

VERIFICATION AND VALIDATION

Verification and validation are ongoing processes of model development and refinement. Verification is conducted to assure the model is internally consistent, that it operates properly, and that the logic and mathematical operations are performed in the manner they are intended. Validation, on the other hand, tests the model's accuracy. Validation is designed to determine if assumptions of the model are sound, if criteria accurately portray biological relationships, and if the model's output is accurate or consistent with the observed response of the organism. Methods used to test a model have been described by O'Neil and Schamberger (1986) and by Terrell (1988).

Several forms of verification have been undertaken periodically throughout the development of the model through sensitivity analysis, input from species authorities and modeling experts, and professional review. Methods of validating the habitat versus flow relationship have not been developed. However, river flows during recent whooping sightings on the Platte River appear, are at a minimum grossly consistent with high habitat values simulated for those flows. Further validation will rely upon additional sighting information, use of additional information with the analytical methodology described above, or the future development of other analytical methods.

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Table A-1. Information about the IFIM study sites used in the simulation of the whooping crane roosting habitat versus discharge relationship.

Site number & approximate location	River segment number and segment length site represents [a]		Measurement number & date		Measured discharge (cfs)	Range of discharges simulated (cfs)	IFG4 data file
Site 2 Jeffreys Island	2	3.9 miles	1	10/10/84	2030	825-5155	IF0021W
			2	04/10/85	2290	916-5725	IF0022W
			3	07/22/85	640	250-1600	IF0023W
Site 4A Elm Creek	4	3.0 miles	2	03/26/85	1871	800-4700	IF04A2W
			3	07/08/85	227	090-0570	IF04A3W
Site 4B Odessa	4	5.0 miles	2	03/27/85	1716	686-4290	IF04B2W
			3	07/09/85	215	086-0538	IF04B3W
Site 5[b] Kearney	3	8.0 miles	~~1~~ 2	05/06/85	2063	825-5158	IF0052W
	5	10.7 miles	~~2~~ 3	07/23/85	520	208-1300	IF0053W
Site 6 Audubon Sanctuary	6	7.6 miles	1	10/03/84	1430[c]	600-3500	IF0061W
			2	04/03/85	1977	800-4900	IF0062W
			3	07/17/85	290	120-0750	IF0063W
			4	06/09/86	549	220-1372	IF0064W
Site 7 Gibbon	7	11.2 miles	1	10/09/84	893	357-2233	IF0071W
			2	04/22/85	335	134-0838	IF0072W
			3	07/15/85	209	083-0522	IF0073W
Sites 8AN Denman	8	7.3 miles	2	03/20/85	1525[d]	614-3843	IF8AN2W
			3	07/24/85	177	070-0442	IF8AN3W
Site 8AS Denman	8	7.3 miles	2	03/20/85	1746[d]	700-2600	IF8AS2W
			3	07/30/85	360	150-0900	IF8AS3W
Site 8B Denman	8	2.3 miles	2	03/21/85	3336	1350-5000	IF08B2W
			3	07/12/85	415	166-1038	IF08B3W
			4	05/21/86	1802	721-4500	IF08B4W

Table A-1. (continued)

Site 8C Denman	8	3.0 miles	1	10/15/84	4270	1708-5000	IF08C1W
			2	04/18/85	1372	550-3430	IF08C2W
			3	07/19/85	540	216-1350	IF08C3W
Site 9BW [e] Mormon Island Crane Meadows	9	16.3 miles	4	04/02/85	1299 [f]	780-3200	IF9BW4W
			5	07/10/85	110	066-0275	IF9BW5W
			6	10/02/85	858	500-2150	IF9BW6W
			7	04/03/86	1113	4[illegible]0-2800	IF9BW7W
			8	06/12/86	604	250-1500	IF9BW8W
			9	03/22/88	1120	450-2800	IF9BW9W
Site 9BE [e] Mormon Island Crane Meadows	9	16.3 miles	2	04/01/85	1305 [f]	522-3263	IF9BE2W
			3	07/11/85	96	038-0240	IF9BE3W
			4	10/03/85	950	380-2350	IF9BE4W
			6	06/11/86	530	212-1325	IF9BE6W
			7	03/24/88	1140	456-2850	IF9BE7W
Site 10 Mormon Island Crane Meadows	10	8.2 miles	1	10/01/84	464 [g]	186-1160	IF0101W
			2	04/04/85	380	152-0950	IF0102W
			4	03/23/88	564	225-1410	IF0104W
Site 11 Mormon Island Crane Meadows	11	16.5 miles	1	10/04/84	758 [g]	300-2000	IF0111W
			2	04/12/85	885	350-2200	IF0112W
			3	07/20/85	350	150-0850	IF0113W
Site 12A Chapman	12	5.4 miles	1	10/12/84	2225	890-4500	IF12A1W
			2	04/15/85	1837	600-3900	IF12A2W
			3	07/16/85	215	090-0550	IF12A3W
			4	06/13/86	1068	427-2670	IF12A4W
Site 12B Phillips	12	4.4 miles	2	04/16/85	1857	743-4643	IF12B2W
			3	07/25/85	600	239-1495	IF12B3W

a. The segment lengths that are reported have been adjusted (reduced) to account for reaches subject to disturbances, such as roads and bridges.

b. Site 5 represents two river segments, Segment 3 and Segment 5.

c. Site 6 does not represent all river channels; reported discharges are approximately 68 percent of the total river flow.

Table A-1. (continued)

d. Site 8A is a split channel; 8AS carries 60 percent of the total flow and 8AN carries 40 percent.

e. Sites 9BW and 9BE represent the same river segment.

f. Flow at Sites 9BW and 9BE relate to the total flow as: Total flow (cfs) = (Reported flow x 1.81) + 354 cfs.

g. Site 10 flow relates to total flow as: Total flow (cfs) = (Reported flow x 7.35) + 266 cfs.

h. Site 11 flow relates to total flow as: Total flow (cfs) = (Reported flow x 2.64) - 144 cfs.

Table B-1. Measurements of physical habitat variables collected at 21 whooping crane roost sites on the central Platte River.

DATE	CHANNEL WIDTH (ft)	WATER WIDTH (ft)	PERCENT OF CHANNEL WETTED	MEDIAN WATER DEPTH (ft)	UPSTREAM VISIBILITY (est miles)	DOWNSTREAM VISIBILITY (est miles)
10/28/83	1152	748	65	.74	0.2	0.2
10/21/85	1019	826	81	.74	0.2	0.3
11/05/86	699	646	92	.71	0.2	0.3
03/22/87	1207	1207	100	.89	1.0+	1.0+
04/08/87	1087	1087	100	1.10	1.0+	1.0+
04/10/87	975	948	97	.72	1.0+	1.0+
04/11/87	1048	1048	100	1.03	0.2	0.2
04/12/87	881	861	98	.97	1.0+	1.0+
10/22/87	986	963	98	.64	0.8	0.4
03/24/88	373	356	95	.93	0.5	0.8
03/25/88	831	831	100	.83	0.3	0.6
03/28/88	552	520	94	.90	---	---
03/30/88	172	172	100	.39	---	---
04/01/88	495	495	100	.81	---	---
04/03/88	1365	804	59	.90	0.5	1.8
04/04/88	475	475	100	.95	---	---
04/04/88	850	843	99	.92	1.0+	1.0+
04/05/88	570	562	99	.75	1.0+	1.0+
04/06/88	507	507	100	1.37	---	---
03/30/89	709	~~266~~ 677	95	.43	0.5	1.0+
04/16/89	678	589	87	.68	0.3	0.5

"---" not available

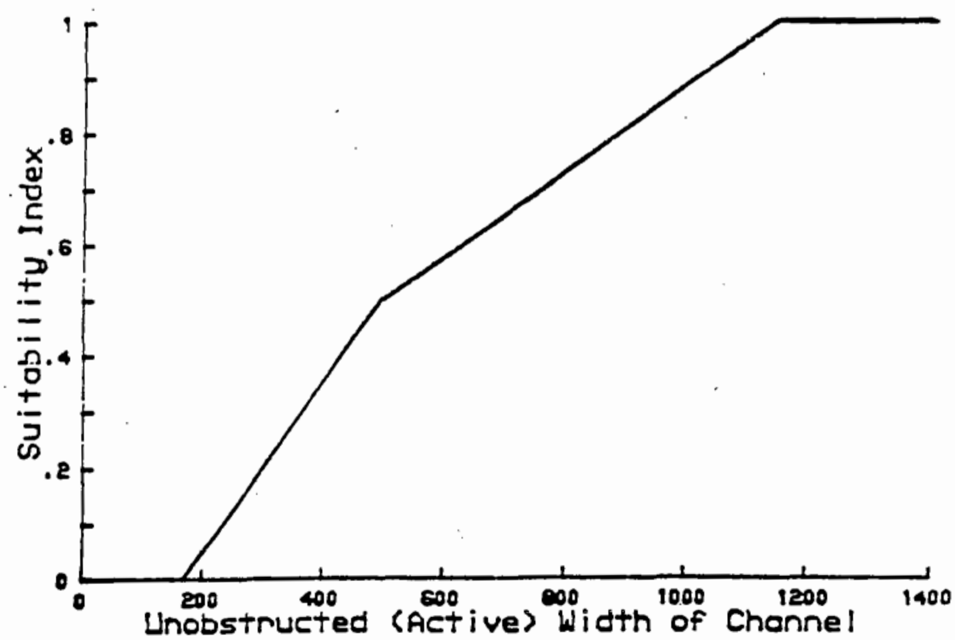
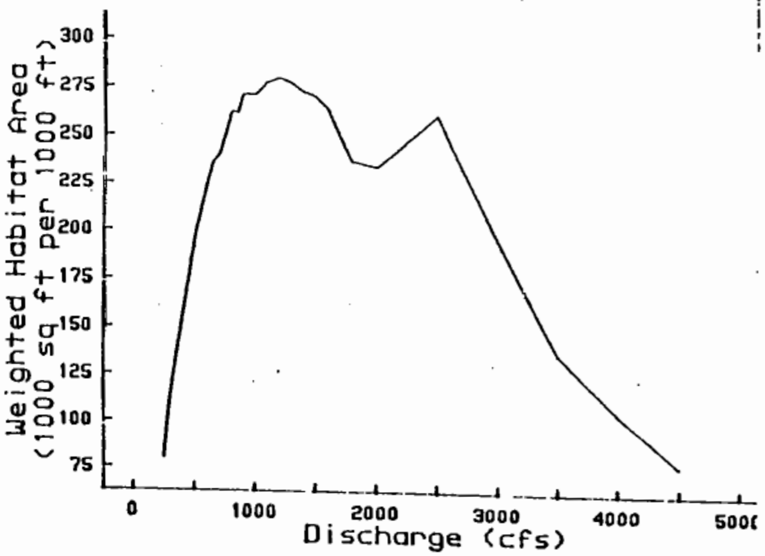


Figure C-1. Suitability index curve for the Unobstructed Channel Width criterion.

Appendix D

Site 2



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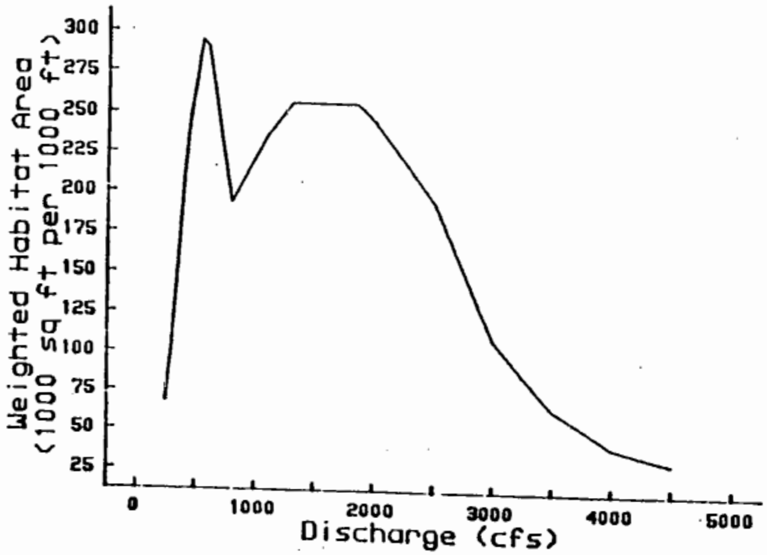
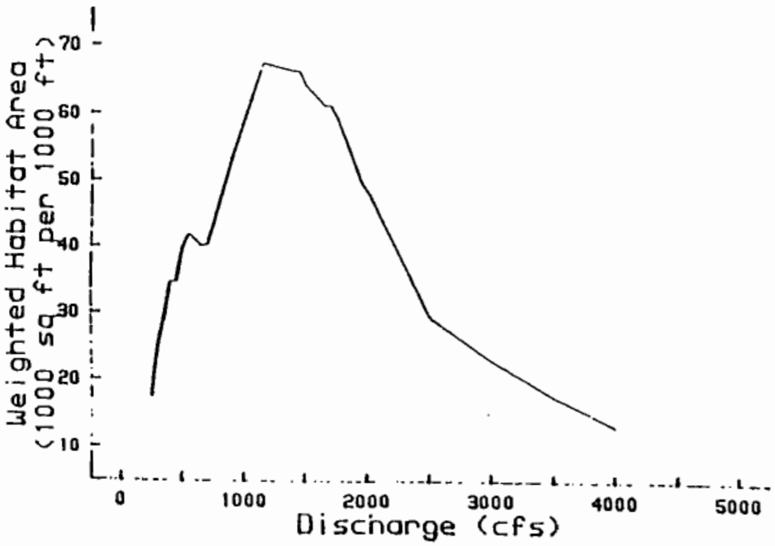
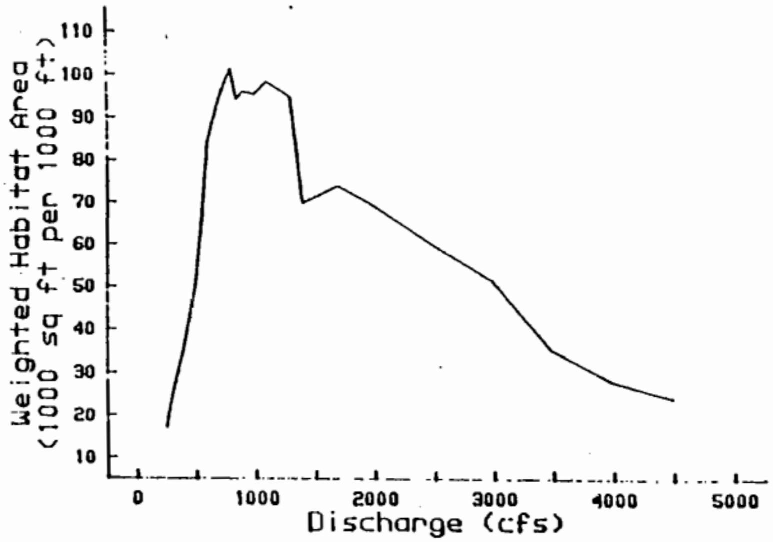


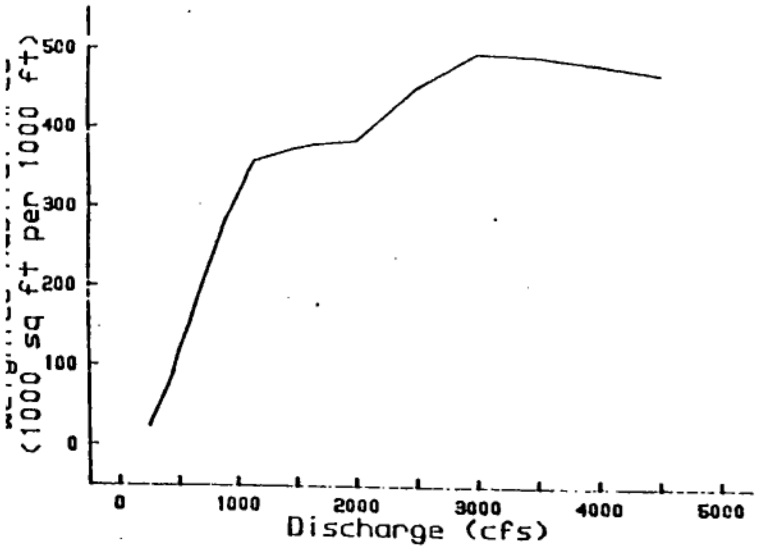
Site 4b



Site 5



Site 6



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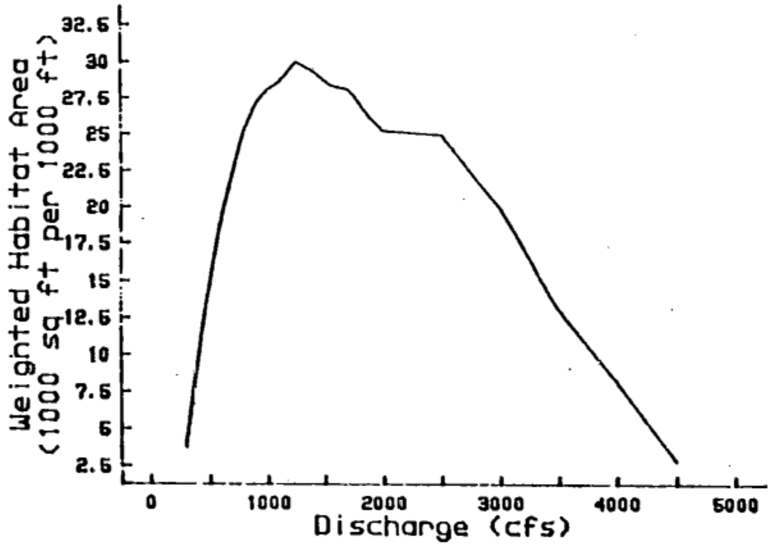
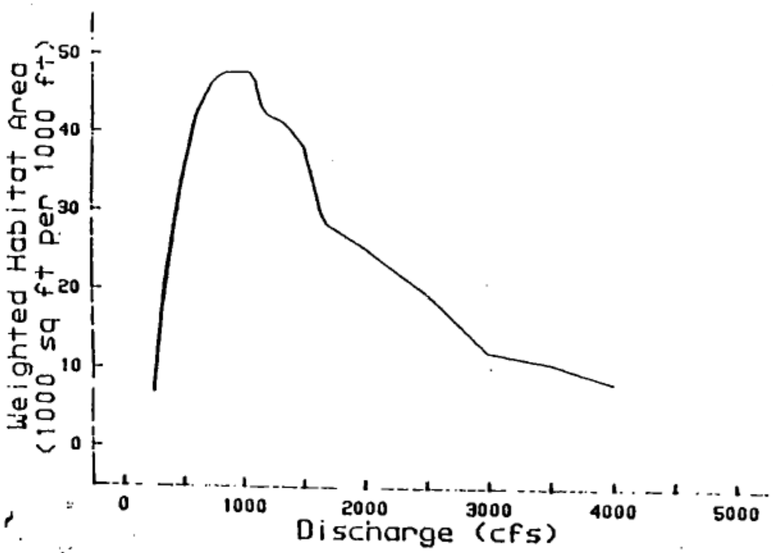
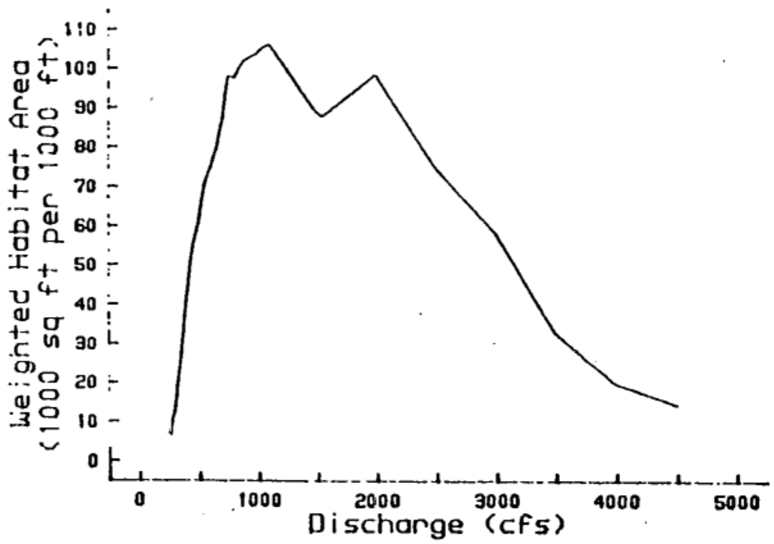


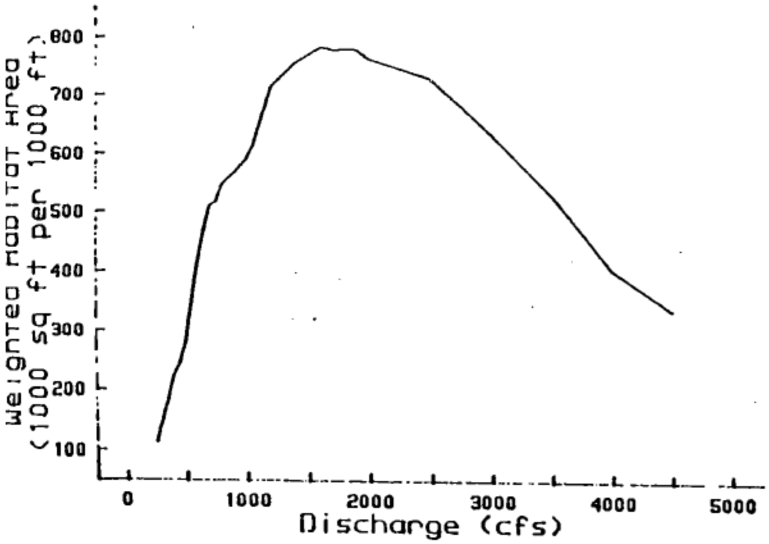
Site 8as



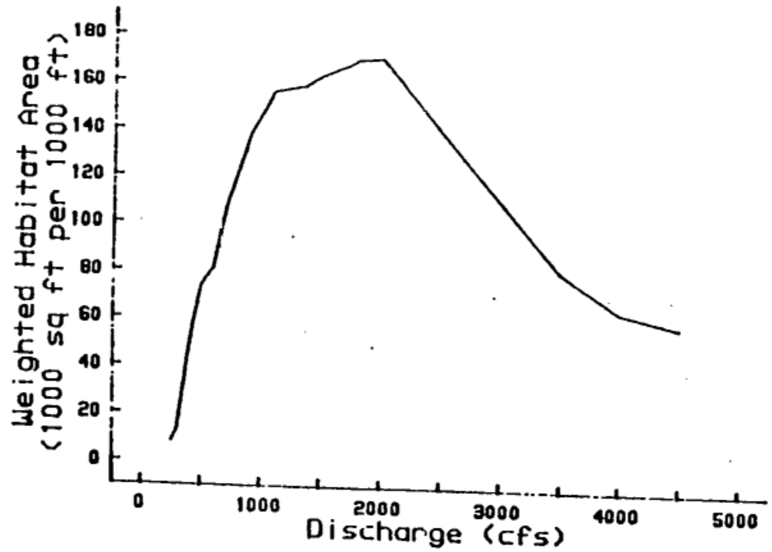
Site 8an



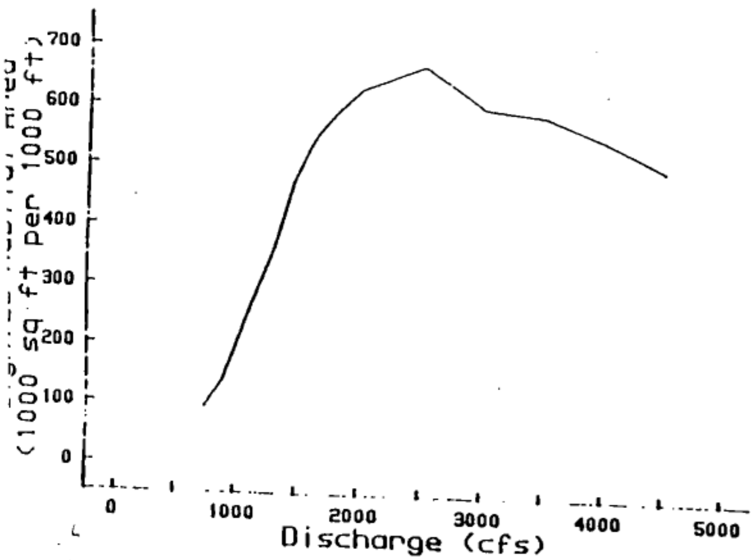
Site 8b



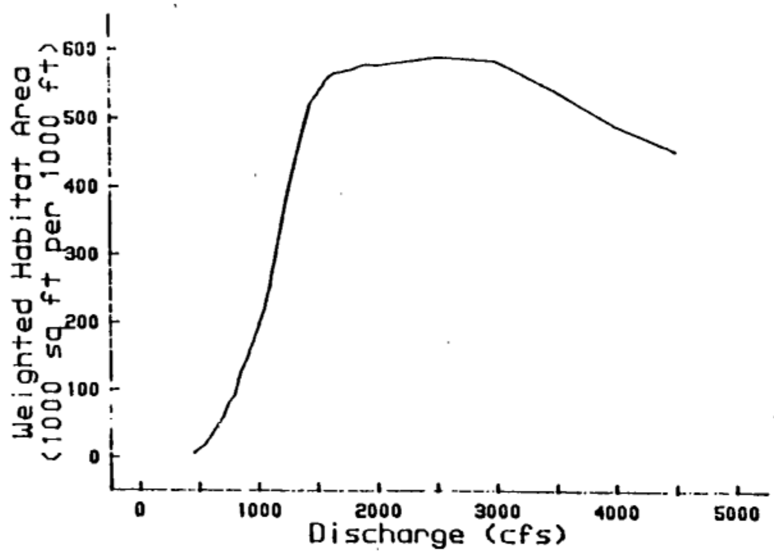
Site 8c



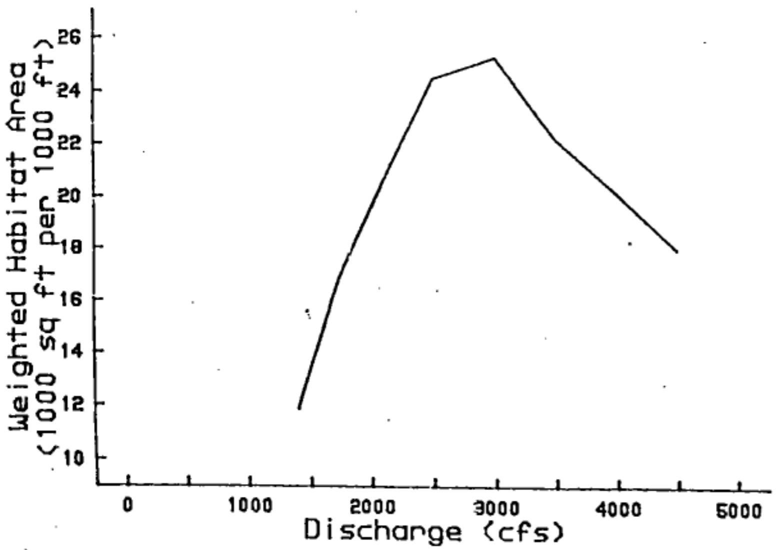
Site 9be



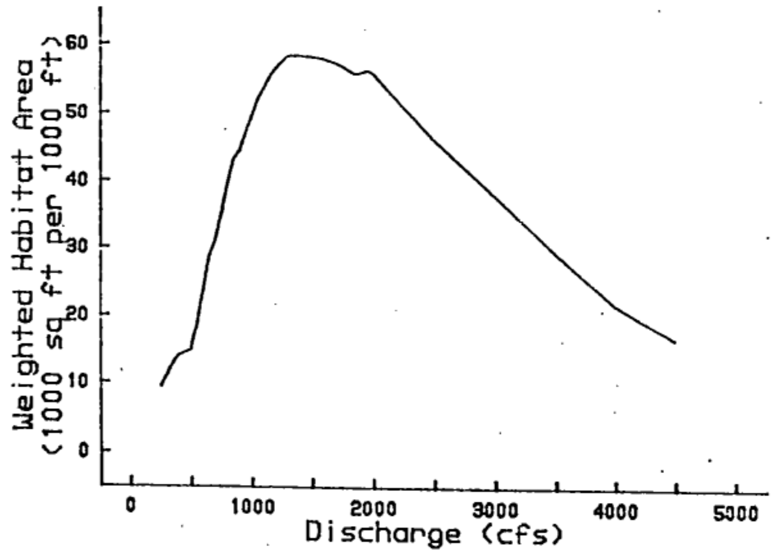
Site 9bw



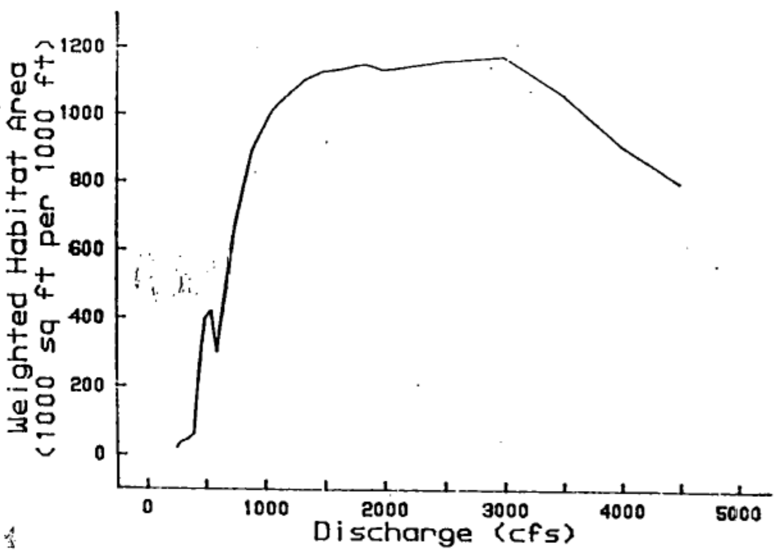
Site 10



Site 11



Site 12a



Site 12b