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Environmental Impact Research Program

Low-Flow Habitat Rehabilitation-Evaluation, RCHARC Methodology, Rapid Creek, South Dakota

by Mitchell R. Peters, Steven R. Abt, Chester C. Watson,
Colorado State University

J. Craig Fischenich, WES

Prepared for Headquarters, U.S. Army Corps of Engineers

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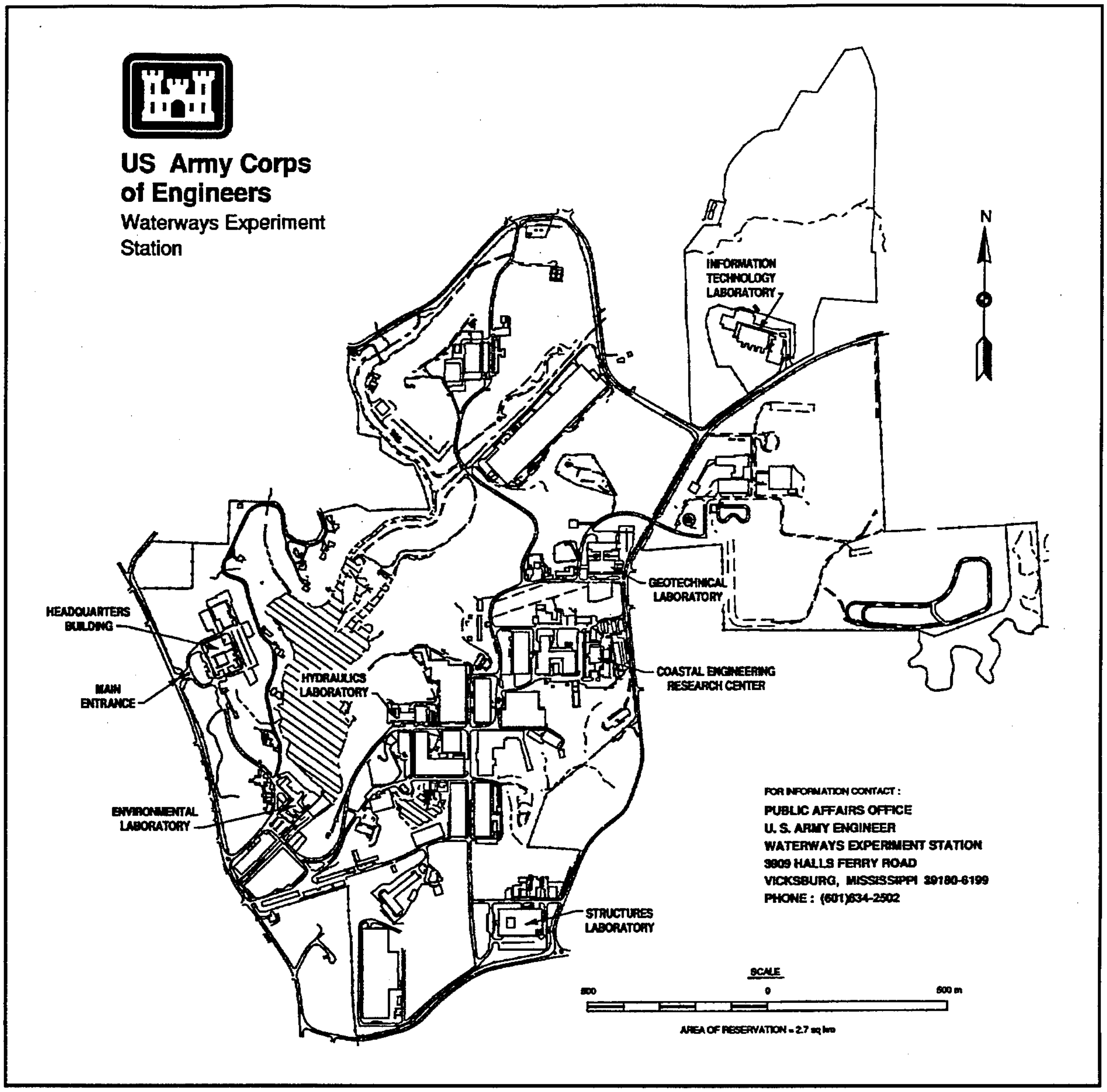

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Environmental Impact Research Program

US Army Corps of Engineers
Waterways Experiment Station

Assessing Benefits of Channel Modification for Aquatic Habitat in Tailwaters and Local Flood Control Channels

Low-Flow Habitat Rehabilitation-Evaluation, RCHARC Methodology, Rapid Creek, South Dakota (TR EL-96-8)

ISSUE: Aquatic habitat quality is dependent on water quality, bed slope, water temperature, dissolved oxygen, substrate, vegetation, and hydraulic parameters in the stream. The Riverine Community Habitat Assessment and Restoration Concept (RCHARC) is a methodology developed by the USAE Waterways Experiment Station, Environmental Laboratory, to compare hydraulic parameters (depth and velocity) between natural, degraded, and restored channel reaches. The methodology is generally applied to alternate reaches in the same stream; therefore, the habitat quality variables must also be closely matched. RCHARC assumes that if the diversity of hydraulic and habitat quality parameters for a "comparison standard" reach can be replicated in the stream restoration reach, then the aquatic habitat quality can be enhanced. The RCHARC Methodology has been successfully applied to large, warm-water rivers (Nestler, Schneider, and Latka 1993).

RESEARCH OBJECTIVE: The objective of this study was to Beta test the RCHARC methodology for its applicability to northern, cold-water flood control channels.

SUMMARY: The field site selected for testing the RCHARC methodology was Rapid Creek, located in and adjacent to Rapid City, SD. Natural (comparison standard) and the restored reaches were identified for comparison. Field crews were dispatched in June and October 1993 to collect field data during high- and low-flow conditions, respectively. Data collected included cross-sectional profiles, discharge, depth and velocity pairs, dissolved oxygen, water temperature, thalweg and water surface elevation profiles, suspended and bed-load samples, armor layer and substrate samples, and photographic documentation. A HEC-2 simulation was conducted to evaluate the flood control capacity of each reach. Output from HEC-2 served as input to the RCHARC model. The RCHARC model was run comparing the cumulative frequency distribution of hydraulic depth and velocity pairs for the natural (standard) and restored reaches. The RCHARC output was plotted in the three dimensions of velocity versus depth versus frequency of occurrence. The bivariate plots of the comparison reaches were qualitatively evaluated at similar discharges, and common characteristics were found in the depth-velocity comparison. The RCHARC methodology was determined to be a reasonable approach to habitat rehabilitation that may be used in conjunction with a traditional flood channel design and evaluation. A procedure is proposed for conducting a comprehensive flood control/aquatic habitat quality analysis. Recommendations for enhancing the RCHARC methodology are presented.

AVAILABILITY: The report is available on Interlibrary Loan Service from the U.S. Army Engineer Waterways Experiment Station (WES) Library, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199; telephone (601) 634-2355.

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About the Authors: The report was written by M. R. Peters, S. R. Abt, and C. C. Watson, Colorado State University, and J. C. Fischenich, USAE Waterways Experiment Station, Vicksburg, Mississippi. Point of Contact at WES is K. S. Long, telephone (601) 634-3521

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Preface

This report was prepared by the Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES), and Colorado State University (CSU) as part of the Environmental Impact Research Program (EIRP). The research reported herein is part of a work unit entitled "Assessing Benefits of Channel Modification for Aquatic Habitat in Tailwaters and Local Flood Control Channels," Work Unit 32698. Drs. M. R. Peters, S. R. Abt, and C. C. Watson, Hydraulics Program, CSU, and Mr. J. C. Fischenich, EL, WES, designed the research plan, oversaw data collection, and prepared this report. Funding was provided by Appropriation No. 96X3122, Construction General. The EIRP is sponsored by Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to WES under the purview of EL. The technical monitors were Dr. John Bushman, Mr. David P. Buelow, and Mr. Dave Mathis, HQUSACE; Dr. Roger T. Saucier, EL, WES, was Program Manager unitl December 1994. Dr. Russell F. Theriot currently serves as Program Manager, EIRP.

The study was performed under the direct supervision of Dr. Norman R. Francingues, Chief, Environmental Engineering Division; and Dr. John Keeley, Director, EL. Dr. John Nestler, Water Quality and Contaminant Modeling Branch, Ecosystems and Processes Division (WQMCB, EPED), EL, was the Principal Investigator of the project. Ms. D. H. Tillman and Ms. L. T. Schneider, WQMCB, EPED, EL, provided in-house technical review.

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Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4046.873	square meters
cubic feet	0.02831685	cubic meters
feet	0.3048	meters
inches	25.4	millimeters
miles (U.S. statue)	1.609347	kilometers
pounds (force) per square foot	47.88026	pascals
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square meters

1 Introduction

Background

In June 1972, heavy runoff resulting from a 100-year precipitation event centered on the lower portion of the Rapid Creek Drainage Basin caused massive flooding. In Rapid City, SD, 230 lives were lost, and over $100,000,000 in property damage was caused. To prevent similar disasters in the future, flood control modifications to Rapid Creek were performed by the U.S. Army Engineer District, Omaha. A 3,000-ft reach of Rapid Creek was enlarged from an approximately 40-ft-wide channel to a 95-ft-plus-wide channel (Glover and Ford 1990). The change in channel morphology proved to be extremely detrimental to the trout population and other aquatic habitat in the area. The Rapid City experience indicates that the U.S. Army Corps of Engineers (USACE) is capable of providing flood capacity where warranted. The Corps' role has been broadened to incorporate the concepts of aquatic habitat enhancement, aesthetics, and recreation into the stream restoration process.

Traditionally, the process of channelizing waterways for development and flood control has been conducted without regard to the many natural resources and fragile habitat components within riparian areas. Protection of life and property has always been paramount to the hydraulic engineering community and its attempt to control rivers and streams. Wide, straightened floodways cleared of vegetation are often constructed because they efficiently convey the high-flood flows. In this time of heightened environmental awareness, engineering has become increasingly important to channel modifications with greater regard to the natural resources that may be affected. Low-flow channels with meanders, pools and riffles, overhanging vegetation and ledges, boulders, snags, and other habitat features are being integrated into existing floodways and proposed flood control projects. Such features have been incorporated into rehabilitation/restoration projects on the Blue River, Breckenridge, CO; the South Platte River, Denver, CO; Wildcat and San Pablo Creeks, Richmond, CA; and Rapid Creek, Rapid City, SD. The design of the habitat-enhancing structures implemented in these and many other cases has been accomplished by experienced engineers and wildlife biologists using available guidelines, elements from successful projects, and computer modeling techniques.

The increasing need to consider habitat impacts associated with channelization projects requires the development of a comprehensive methodology or procedure. Popular modeling tools utilized by hydraulic engineers such as HEC-1 and HEC-2 do not have provisions for the evaluation of habitat differences between natural and proposed channel modifications. Fluvial analyses utilizing these programs must currently be augmented with a separate habitat study. The Riverine Community Habitat Assessment and Restoration Concept (RCHARC) program offers hydraulic engineers an opportunity to add an environmental/habitat dimension to studies of proposed development, restoration, and flood control projects.

The RCHARC model, developed by Nestler, Schneider, and Latka (1993), can be used to compare bivariate depth-velocity frequency distributions of channel reaches to determine the difference in habitat quality. The most common use of this methodology would be to compare the habitat value of a proposed or restored reach with a target (comparison standard) reach or with that of the preproject reach. Existing methods of habitat evaluation include the U.S. Department of the Interior Fish and Wildlife Service's Physical Habitat Simulation System (PHABSIM), field studies, and design guidelines established by wildlife biologists and hydraulic engineers. In the case of the Rapid Creek study, RCHARC was selected to evaluate habitat differences between natural and restored reaches of Rapid Creek, Rapid City, SD.

Field data collection was conducted on Rapid Creek to measure the velocity, depth, and channel geometry at 12 cross sections in a 3,300-ft reach of the restored channel and 12 cross sections in a 3,700-ft reach of the natural (standard) channel upstream of the restored reach. Data were collected when the flow was out of the low-flow channel (high-flow condition) and when the flow was contained within the low-flow channel (low-flow condition). The data obtained from Rapid Creek were processed using the RCHARC procedure. One-dimensional (1-D) modeling using HEC-2 was performed to augment the field data by simulating discharges or flows other than those observed in the field. The HEC-2 runs were designed to simulate flow at three stages: 150 percent higher than the observed high-flow condition, 50 percent lower than the observed low-flow condition, and an intermediate-flow condition (the average of the observed high- and low-flow conditions). An RCHARC analysis was performed at the three simulated flow stages, and the output was analyzed with the RCHARC output from the field-observed flows. The natural and restored channel reaches were compared with respect to the quality of their habitat. The RCHARC habitat evaluation technique was compared with other methods including HEC-1, HEC-2, PHABSIM, project design guidelines, and field habitat assessment procedures. The operational procedure of RCHARC is documented, and its effectiveness is evaluated.

Objectives

The goal of this study was to apply and evaluate the RCHARC methodology. Specific project objectives included:

a. Collecting hydraulic data during two field visits (high- and low-stage conditions) to Rapid Creek.

b. Conducting an RCHARC analysis using the field data to evaluate the similarity of habitat between the restored and natural reaches.

c. Assembling and performing an HEC-2 analysis to simulate three additional discharges through the natural and restored reaches (1.5 × field-measured high flow, 0.5 × field-measured low flow, and intermediate or average of field-measured high and low flows).

d. Conducting an RCHARC analysis of the simulated conditions.

e. Documenting, in a step-wise manner, the RCHARC methodology.

f. Evaluating the results from the RCHARC study and comparing RCHARC with HEC-2.

g. Recommending guidelines for the design and assessment of restored channels to meet both flood control and habitat rehabilitation objectives.

2 Review of Literature

Introduction

Existing methods of habitat evaluation used in the design of hydraulic structures were examined and assessed. Four major components of a stream system determine the productivity of the fishery or value of aquatic habitat: flow regime, physical habitat structure (channel form, substrate, vegetation), water quality, and watershed energy inputs (including sediment, nutrients, and organic mater) (Milhous, Updike, and Schneider 1989). HEC-1, HEC-2, PHABSIM, RCHARC, project guidelines, and field habitat assessment procedures were reviewed focusing on these four stream system components.

Computer models are commonly used in conducting hydraulic engineering studies. The Hydrologic Engineering Center's HEC-1 and HEC-2 models may be used to propose and evaluate hydraulic design alternatives. PHABSIM, developed by the Fish and Wildlife Service, is a computer model capable of hydraulic simulation and habitat quantification in terms of Weighted Usable Area (WUA). The RCHARC program was developed to compare hydraulic parameters indicative of habitat quality between similar stream reaches or project alternatives. Guidelines resulting from field observations and successful rehabilitation projects can be used in the design of habitat-sensitive channel modifications. Field observations may be used to rate the quality of habitat at a specific location and to determine what modifications should be considered. Each of these procedures will be presented and briefly discussed.

However, prior to the discussion of the specific hydraulic modeling and habitat assessment procedures, a brief review and historic perspective of applicable instream features and their effects on fishery productivity is warranted. In addition, several case studies will be presented.

Fishery Productivity in Modification and Natural Channels

A review of selected literature suggested that differences in the results of case studies can be attributed to variables such as poor design and planning, differences in species, temporal scale following modification, and incomplete restoration. For example, construction of fish lunkers in an unstable channel of high-sediment supply could result in lunker structures inundated with sediment. The following literature review is divided into three segments: a historic perspective, factors affecting success of channel modification, and case studies.

Historic perspective

The history of instream features for channel modification probably dates to the first settlements of floodplains. Historic accounts document the use of channel modification by Native Americans, restricting the stream to create pools and to form appropriate location for traps into which the fish would be directed. Southeastern Native Americans built V-shaped weirs of rocks, pointing downstream. The crest of the weir was shaped to force the flow to the center of the V to conical fish traps that were placed downstream. Thus, the current would force fish into the trap and the force of the current would deter fish from swimming out of the trap. Some remains of these fish traps can be found in southeastern rivers today (Hudson 1980).

Schiechtl (1980) documented that as early as 1880, Demontzey wrote about a form of a live crib wall that was used as a low dam or barrage. Hunter (1991) has provided a history of stream restoration for fisheries enhancement in the United States that is summarized in the following paragraphs.

In this century, the first commitment to trout habitat restoration emerged in early 1934 by the U.S. Bureau of Sport Fisheries (USBF). The USBF moved to enhance many national forest streams using the labor available during the economic depression of the period. For example, between 1933 and 1935, a total of 31,084 stream structures were constructed on 406 mountain streams. However, monitoring of the constructed features was limited, and the effectiveness of the enhancements has not been evaluated. The U.S. Department Agriculture (USDA) Forest Service (1952) published the second edition of Fish Stream Improvement Handbook, which reflected the experience of the 1930's. Ray J. White and O.M. Brynildson (1967) published Guidelines for Management of Trout Stream Habitat in Wisconsin. This handbook placed added emphasis on the use of vegetation prior to the use of structural elements and emphasized the need for preproject planning. Habitat restoration has, since then, been championed by private conservation and environmental groups (Hunter 1991).

Unfortunately, the historic accounts of fishery habitat restoration suggest that the engineering profession has been largely excluded in the design and construction of habitat enhancement features. The mainstream engineering profession remains as the predominant group who will design, construct, and maintain infrastructure on the nation's waterways, including navigation, flood control, and transportation routes. Engineering design professionals must be involved in habitat enhancement design if improved habitat is to be considered as an overall design goal in major projects and not only as a mitigation afterthought.

Factors affecting success of channel modification

Brookes (1990) reported the criteria that determine success based on the experiences of 15 restoration projects in Denmark and Britain. A thorough feasibility and planning study must precede a successful restoration project. The type of restoration work included in a project is constrained by a number of factors, including the physical environment and the project objectives. The detailed design needs to be tailored to the individual river reaches under consideration. Project planning should consider the timing and supervision of construction and make recommendations on the nature of maintenance. A management plan is desirable, and postproject appraisal is essential to evaluate the long-term hydraulic and environmental performances. These criteria were applied to two projects carried out recently: River Lambourn in Berkshire, England, and the Elbaek in central Jutland, Denmark. Both projects appear to have been successful because the stream power is in the middle range of values, neither too high to cause significant erosion, nor too low to be inundated with sediment. A maximum of 25 trout per 100 sq m was recorded on the River Elbaek at locations at which few trout had been previously observed. Existing methods of assessing the feasibility of restoration projects are crude but provide some guidance in avoiding severe problems. Most of the available techniques are not applicable to high-energy river channels.

Swales (1989) reported on numerous studies conducted over the past 20 years that have documented marked reductions in the abundance and diversity of fish populations as a direct result of the loss and degradation of instream habitat due to river regulation. Stream habitat improvement methodology is reviewed; the main techniques available are described; and the actual and potential uses of improvement methodology in mitigating the adverse effects of river regulation fisheries are described. Effects of channelization include decreased habitat diversity, loss of cover, removal of the pool-riffle pattern, loss of aquatic vegetation, and alterations in discharge and water quality. Impoundments create a barrier to fish movement, and downstream discharges change flow regimes and water quality. The basic concept behind mitigation using instream habitat improvement devices is that the natural adjustment process can be considerably accelerated by artificially manipulating stream characteristics to improve habitat conditions for fish and other biological communities. River fisheries can be improved by addressing five basic components of fish habitat: (1) adequate value and depth of water for each life stage; (2) adequate water quality; (3) appropriate discharge amount and pattern; (4) cover for shade, concealment, and orientation; and (5) adequate food to maintain metabolic processes, growth, and reproduction. Various mitigation techniques are employed depending on whether the habitat loss is due to channelization or impoundment. Three major categories of improvement structures are: structures that impound to modify stream flow, structures that provide cover, and structures or treatments that modify the channel substrate. For the instream habitat improvement methodology to be acceptable to river engineers, the techniques employed should aim to improve conditions for fish and other aquatic communities without severely compromising the engineering objectives of the river regulation scheme. Compensating for the effects of improvement structures that are counter to those of the river regulation scheme can be accomplished by including these features at the design stage as an integral part of the river regulation scheme.

Frissell and Nawa (1992) observed that in recent years an increasing share of fishery management resources has been committed to alteration of fish habitat with artificial stream structures. Rates and causes of damage or failure were evaluated for 161 fish habitat structures in 15 streams in southwest Oregon and southwest Washington, following a flood of a magnitude that recurs every 2 to 10 years. The incidence of functional impairment and outright failure varied widely among streams. The median failure rate was 18.5 percent, and the median damage rate, combining structures that were impairment plus those that failed, was 60 percent. Frissell and Nawa reported that modes of failure were diverse and bore no simple relationship to structure design. Damage was frequent in low-gradient stream segments and widespread in streams with signs of recent watershed disturbance, high-sediment loads, and unstable channels. Comparison of estimated 5- to 10-year damage rates from 46 projects throughout western Oregon and southwest Washington showed high but variable rates (median, 14-percent range, 0 to 100 percent) in regions where peak discharge at 10-year recurrence intervals has exceeded 1.0 cu m/second/sq km. Results suggest that commonly prescribed structural modifications often are inappropriate and counterproductive in streams with high or elevated sediment loads, high-peak flows, or highly erodible bank materials. Restoration of fourth-order and larger alluvial valley streams, which have the greatest potential for fish production in the Pacific Northwest, will require reestablishment of the watershed and riparian processes. Improvement in fishery productivity requires that the stream modification be designed for the environment in which it is constructed. These data indicate that poor engineering design practices and a lack of the overall consideration for physical processes were common in fish habitat structures.

Detenbeck et al. (1992) reported on the recovery rates of aquatic communities from natural and anthropogenic disturbances. To evaluate the relative effect of site-specific factors, disturbance characteristics, and community structure on the recovery of temperate-stream fish communities, the case histories of 49 sites and recorded data on 411 recovery end points were studied. Most data were derived from studies of low-gradient third-order and fourth-order temperate streams located in forested or agricultural watersheds. Species composition and richness and total density all recovered within 1 year for over 70 percent of systems studied. Lotic fish communities were not resilient in the absence of mitigation efforts and, in these cases, recovery was limited by habitat quality. Following pulse disturbances, site-specific factors, and disturbance-specific factors all affected rates of recovery. Centrarchids and minnows were most resilient to disturbance, whereas salmonid populations were least resilient of all families considered. Rock substrate, nest-spawning species required significantly longer time periods to either recolonize or reestablish predisturbance population densities than did species within other reproductive guilds. Recovery was enhanced by the presence of refugia but was delayed by barriers to migration, especially when source populations for recolonization were relatively distant. Median population recovery times for systems in which disturbance occurred during or immediately prior to spawning were significantly less than median recovery times for systems in which disturbances occurred immediately after spawning. Assessment of fish productivity following channel modifications must consider these factors.

Comparison of the effects on fishery productivity caused by channel modification, even by the effects of similar constructed elements of habitat enhancement, are therefore, not particularly valid without comparison of the aquatic species, and physical condition of the stream such as sediment supply, sediment type, recent flood sequences, adjacent land use, and others. Frissell and Nawa (1992) provided an example of apparently poor engineering design. Therefore, design standards must be comparable for meaningful comparison of fish productivity between projects. Jensen and Platts (1990) provided the proper elements of a restoration plan as shown in Figure 1. Comparison of the effectiveness of beneficial channel modification or restoration is likely to be incomplete unless projects adhere to similar standards in planning and design.

Case studies

Toth (1993) reported that the channelization of the Kissimmee River in central Florida destroyed or degraded most of the fish and wildlife habitat once provided by the river and adjacent floodplain wetlands. Between 1984 and 1989 a demonstration project was conducted to evaluate the feasibility of restoring the biological resources. Reintroduction of flow through former river channels improved river channel habitat diversity and led to favorable responses by fish and invertebrate communities. However, results indicated that more complete restoration of biological attributes requires reestablishment of historic inflow characteristics. Flood control regulation of headwater lakes has changed river discharge regimes to be pulse-like and include extended low- or no-flow periods. High- and low-flow periods may be out of phase compared with typical seasonal patterns that occurred before channelization. Present flow characteristics preclude effective river restoration by contributing to chronic low dissolved oxygen regimes and repetitive fish kills that directly impact fish reproduction and limit floodplain inundation. Simulation modeling was used to develop a modified headwater lakes regulation schedule, which reestablishes season flow pattern, smooths discharge peaks, and maintains base flows for a greater portion of the year. Implementation of the new discharge regime, combined with extensive canal backfilling, will lead to discharge and stage characteristics that meet established criteria for achieving ecosystem restoration goals. Therefore, partial restoration efforts may not fully succeed. Planning for channel restoration must be made in a comprehensive fashion. Lack of favorable response to an increment of the plan may only be evidence that the complete plan implementation is necessary.

Burgess (1985) tested the value of habitat improvement as a means of increasing trout biomass. A section of an unnamed, spring-fed mountain stream that divided to form two parallel sections of approximately 100 m in length was

PRELIMINARY PLANNING
SCOPE
OBJECTIVES
APPROACH

BASELINE INVENTORY

1. Topographic and Hydrologic Surveys
2. Soil Survey
3. Plant Survey
4. Fish and Wildlife Surveys
5. Baseline Report

INPUT TO
FINAL
PROJECT PLAN

PROJECT DESIGN

1. Topographic and Hydrologic
2. Soil Design
3. Restoration Design
4. Habitat Features
5. Maintenance

GENERAL
PROJECT
SCHEDULES

CONSTRUCTION
Execution of
Project Plans
and Schedules

INSPECTION
Quality Control
Compliance and
Corrections

MONITORING
Evaluate the project goals and objectives:
a) Select parameters for study
b) Define frequency and duration

Figure 1. Elements of a restoration plan

selected for study. One section was selected for habitat improvement, while the other was left unmanaged and served as a control. To ensure control of discharge through the two sections, flow control structures were constructed at the head of each. As a result, flows through the two sections could be equalized, or flow through one section could be cut off completely to allow the collection of fish and crayfish from the drained section. Habitat improvement in the study area involved the construction of small rock dams and deflectors. Before habitat improvement, less than 10 percent of the stream channel consisted of pools. Afterward, the riffle: pool ratio in the improved section was approximately 1:1. In-stream cover in the form of logs and rafts of alders lashed together was introduced into the improved section, usually in pools and near areas of high food availability. This study demonstrated that in addition to increasing trout biomass, stream habitat improvement also affected populations of nontarget organisms. Crayfish populations increased substantially in the improved section, which likely resulted in the increased use of that area by mink and raccoons. In this case, no significant loss of trout biomass occurred as a result of increased use of the area by mammalian predators. In areas where no alternate prey species are available, some trout might be lost as a result of predation. It is unlikely, however, that predation by mink would negate the value of habitat improvement as a management tool. The management techniques employed in this study had several advantages. The structures were simple to build using readily available materials. Labor requirements were low, and all work was accomplished using hand tools.

Maughan, Nelson, and Ney (1978) evaluated the effects of stream rehabilitation devices on four southeastern Virginia trout streams. The study measured various physical parameters and fish and benthic macroinvertebrate populations in both improved and reference sections of the streams. Specifically, the streams were investigated to determine the effectiveness of stream improvement structures in providing increased habitat for trout and nongame species and the possible influences of the devices on aquatic invertebrates. The structures examined included log dams, gabion deflectors, and random boulder emplacements. In some cases, large pools were impounded above the dams. Noticeable pool formation occurred below all dams. Runs and pools were associated with 11 of 18 gabions. The use of boulders to increase cover met with variable success. Total fish biomass, and invertebrate numbers generally did not differ significantly between improved and reference sections. Maughan, Nelson, and Ney concluded that the utility of various stream improvement devices is dependent on proper placement and on a correct assessment of the various limiting factors. Since each stream has a unique combination of biological, physical, and chemical parameters, stream improvement should include proper selection, design, and installation of stream improvement structures.

Glover and Ford (1990) reported on the conversion of channelized streams to productive trout fishery streams. Rapid Creek and Spearfish Creek in the Black Hills of South Dakota were channelized, resulting in the loss of 56 km of stream and a general decline in brown trout (Salmo trutta) populations. Structures used to convert 16.7 km of the channelized Rapid Creek into productive fishery at a cost of $526,000 were: 200 wing deflectors; 8 bank covers; 1,087 m of riprap;

480 boulder groups; and 17,660 metric tons of rock. Structures used in Spearfish Creek on 6 km of stream cost $187,000 and included: 65 wing deflectors; 1 bank cover; 804 m of riprap; 185 bolder clusters, 6 rock ledge pools; and 5,340 metric tons of rock. The wild brown trout population in three areas on Rapid Creek increased by: 90 percent at Sioux Park, 400 percent at Baken Park, and 200 percent at Black Hills park from 1978 to 1988. Brown trout populations have increased up to 200 percent in Spearfish Creek from 1985 to 1990. These stream improvement projects have benefited the wild brown trout population and have effectively turned 22.7 km of channelized stream into aesthetically pleasing and productive areas.

Shields, Cooper, and Knight (1993) reported concerned efforts to reestablish warm-water fisheries following destruction of habitat from channel incision. On the basis of literature review and a pilot study, revegetation of about 1 km of Hotopha Creek, Mississippi, was modified. Approximately 2,550 native willow cuttings, 1.5 m long, were planted along the base of the incised flow channel. A ridge of stone was placed on the water side of the plantings, and 17 rock spurs were constructed by extending existing spur dikes from the opposite bank. Woody cover along the treated bank increased from 38 percent to 66 percent of the bank line after one growing season. Survival of individual plants was reduced from an estimated 60 percent to an observed 34 percent by competition from the exotic kudzu vine. Mean depth and mean scour hole depth, corrected for stage variation, increased 44 percent and 82 percent, respectively. Mean scour hole width increased 130 percent. The mean length of fish and the number of fish species approximately doubled, while the total weight of fish captured by a unit of sampling effort increased by an order of magnitude.

The literature demonstrates that success or failure can occur from well-intended channel modification. Poor planning, improper design of constructed elements, lack of data to establish performance, and lack of a common baseline from which projects can be compared make definitive measures of success in fishery improvement difficult. A thorough literature of the subject should be developed with the intent of establishing a comparative database.

HEC-1

HEC-1 (Hydrologic Engineering Center 1985) is a computer model used to simulate surface runoff. Drainage basins are divided into subbasins that may represent channels, reservoirs, or surface entities. A set of parameters specifies the characteristics of the subbasin components, and mathematical relations are used to describe the interaction of physical processes of the various components. The modeling process results in the computation of streamflow hydrographs at desired locations of the river basin. HEC-1 does not have provisions for directly evaluating habitat or channel hydraulics, but hydrologic output from this model can ultimately be incorporated into a study of hydraulic and habitat response.

Input parameters to the HEC-1 flood hydrograph package include: a precipitation hyetograph; watershed, drainage basin, or subbasin physical characteristics; interception and infiltration relations; identification of preferred overland and channel flow routing techniques; resistance to flow relations; and the preferred reservoir storage and/or routing techniques. The simulation output presents a summary of the input values and operating options, a runoff hydrograph(s), and any coefficients derived from the compilation.

The computer generated hydrographs are useful and, in some cases, required for many facets of channel design and restoration. For example, information obtained from the HEC-1 study may be used to estimate flow rates for the sizing of channels and the evaluation of channel stability. The same hydrograph information is useful in habitat evaluation. An understanding of high- and low-flow runoff quantities is necessary for the successful design of a flood control channel or channel restoration features. Channel restoration features are designed with several discharges in mind: low- and normal-flow levels for habitat considerations, and high levels for stability and hydraulic impacts.

Other methods for obtaining discharge values include direct measurement, research of historic gage station records, and reservoir release schedules. Field surveys of velocity and depth within a channel at high- and low-flow stages can be used to directly calculate high- and low-flow runoff values. Research of gage station records (if available) will yield instantaneous flow values, which can be analyzed for high- and low-flow trends.

HEC-2

HEC-2 is a computer model capable of calculating water surface elevation profiles for steady, gradually varied flow in streams and channels (Hydrologic Engineering Center 1990). Hydrologic information and existing (from a field survey or topographic map) or proposed (from proposed design) channel geometry, channel profile data, and cross-sectional roughness values are entered into the HEC-2. The standard step backwater method, which incorporates Manning's equation to solve the 1-D energy equation with energy loss due to friction, is used by HEC-2 to compute a water surface elevation at a each cross section for specified flow and channel roughness values. HEC-2 assumes steady, gradually varied, 1-D flow conditions that seldom exist in actual projects. HEC-2 provides a reasonable approximation of water surface elevation and average channel velocity.

Profile computations begin with a cross section with known or assumed starting conditions. Input parameters include identification of the flow direction and regime, cross-sectional geometry, initial water surface elevation, discharge, channel and overbank roughness, and reach lengths. Also, the user may stipulate numerous flow options (i.e., culverts, bridge decks, etc.), bridge losses, and optional friction losses in the flow routing process. Program outputs include a summary of the input value, the water surface elevation and average velocity at each cross section, cross-sectional plot, and a profile of the water surface and thalweg elevations.

The ability of HEC-2 to generate water surface elevations and average channel velocities under various flow conditions is valuable in habitat evaluation. Direct measurement of multiple water surfaces by field surveys can be more costly and time consuming than modeling water surfaces with HEC-2. Velocity-depth data collected in the field can be augmented by velocity-depth pairs generated using HEC-2 reducing costly field data collections.

Alternative methods to HEC-2 for determining flow and water surface relations include field water surface and velocity-depth survey, and water stage data from staff gages or automated water surface recording equipment. Established stage discharge relations can be referenced to obtain discharge for the measured water surface elevations. Additional field work and installation of staff gages/automated instrumentation is costly and time intensive. HEC-2 cannot directly evaluate habitat, but can be valuable as a hydraulic modeling tool in habitat evaluation studies.

PHABSIM

PHABSIM (Physical Habitat Simulation, developed by Milhous, Updike, and Schneider 1989) is a composite of two groups of computer programs, one for hydraulic simulation and the other for habitat simulations. PHABSIM is capable of generating water surface elevation profiles, velocity-depth distributions for these profiles, and ultimately WUA of habitat for a channel under specific flow conditions. The PHABSIM system has three basic steps: (1) simulate water surface elevations; (2) simulate flow velocities; and (3) simulate physical habitat (Milhous, Updike, and Schneider 1989). Figure 2 (adapted from Milhous, Updike, and Schneider 1989) presents the major components and linkages for PHABSIM.

The basic data required for initiating the PHABSIM methodology are hydrologic and hydraulic parameters. Hydrologic and hydraulic data are processed into water surface elevations by use of the Corps' HEC-2 or PHABSIM's hydraulic simulation models: STGQS4 (stage versus discharge relations), MANSQ (Manning's equation), or WSP (standard step backwater method). PHABSIM's IFG4 is used to calculate velocity and depth pairs at each cross section. Indexes of habitat quality for a given parameter, species, and lifestage known as suitability curves are referenced and coefficients calculated to assess the habitat value of each cross section. The channel index of each subsection of each cross section is determined with consideration of substrate and other habitat variables (i.e., average depth, percent cover, percent pools, average flow velocity, and pH).

The stream components contributing to the habitat suitability index for brook trout (Raleigh 1982) are presented in Figure 3. Variables that affect all life stages of the brook trout (adult, juvenile, fry, embryo, and other stages) are summarized as variables V_1 - V_{17}. The values for each of these 17 variables are obtained from suitability curves similar to those displayed in Figure 4 (Raleigh 1982). Habitat coefficients for each life stage are calculated using the V_i

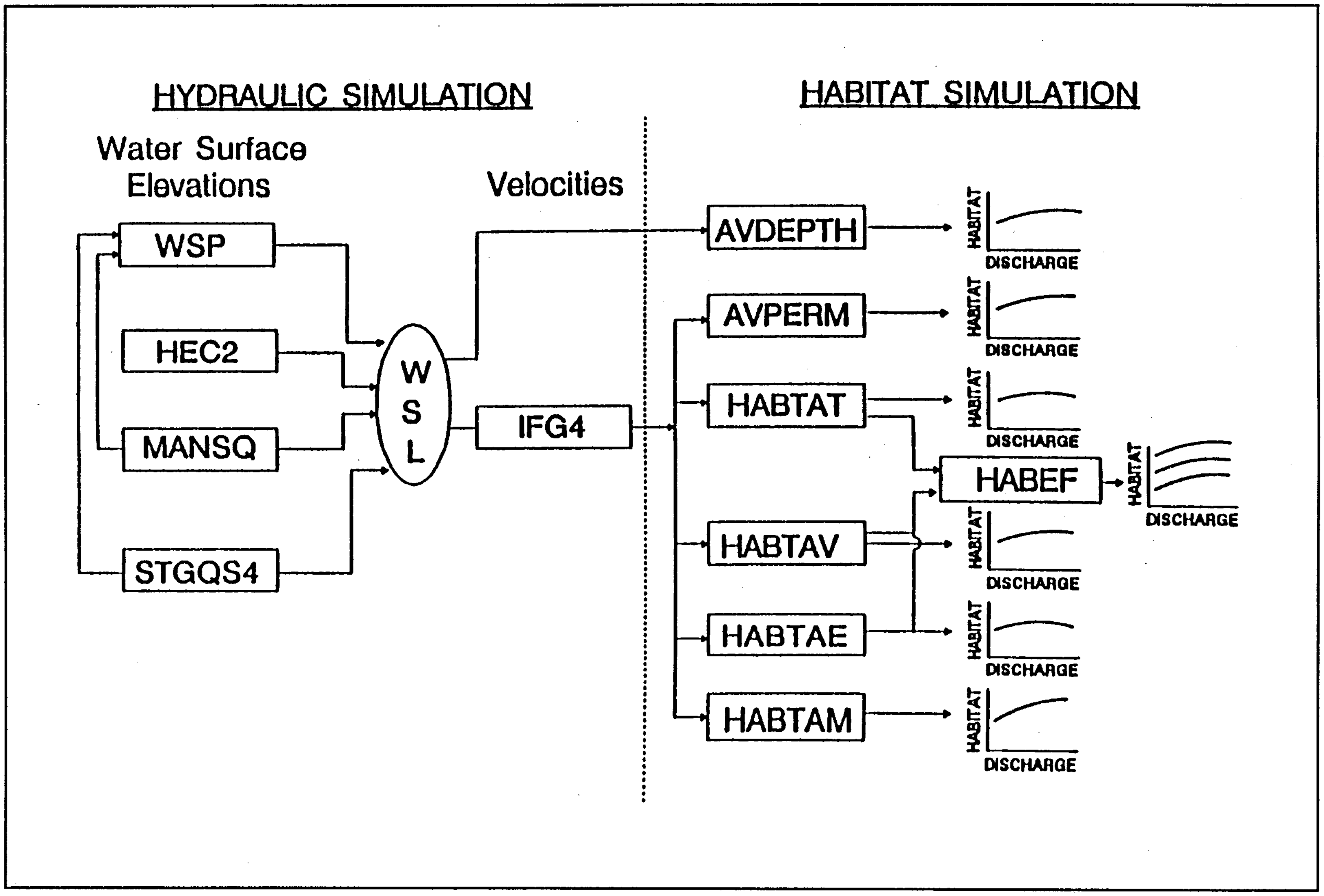


Figure 2. Major linkages for Version II of the Physical Habitat Stimulation System

variables and the relations presented in Figure 5 (Raleigh 1982). For example, the adult coefficient C_A is calculated using the first equation in Figure 5, where V_4, V_6, V_{10}, and V_{15} are known. A Habitat Suitability Index (HSI) is then calculated (see Equal Component Value Method on the last page of Figure 5). HSI may be used as a channel index *ci* in PHABSIM, and may be visualized as in Equation 1:

$$HSI = \frac{MODEL\ OUTPUT\ OF\ POUNDS\ FISH\ PER\ ACRE}{REGIONAL\ OPTIMUM\ POUNDS\ FISH\ PER\ ACRE} \tag{1}$$

The maximum value of HSI is one. The closer the value is to one, the better the brook trout habitat. The *ci* must be calculated at each velocity-depth point across

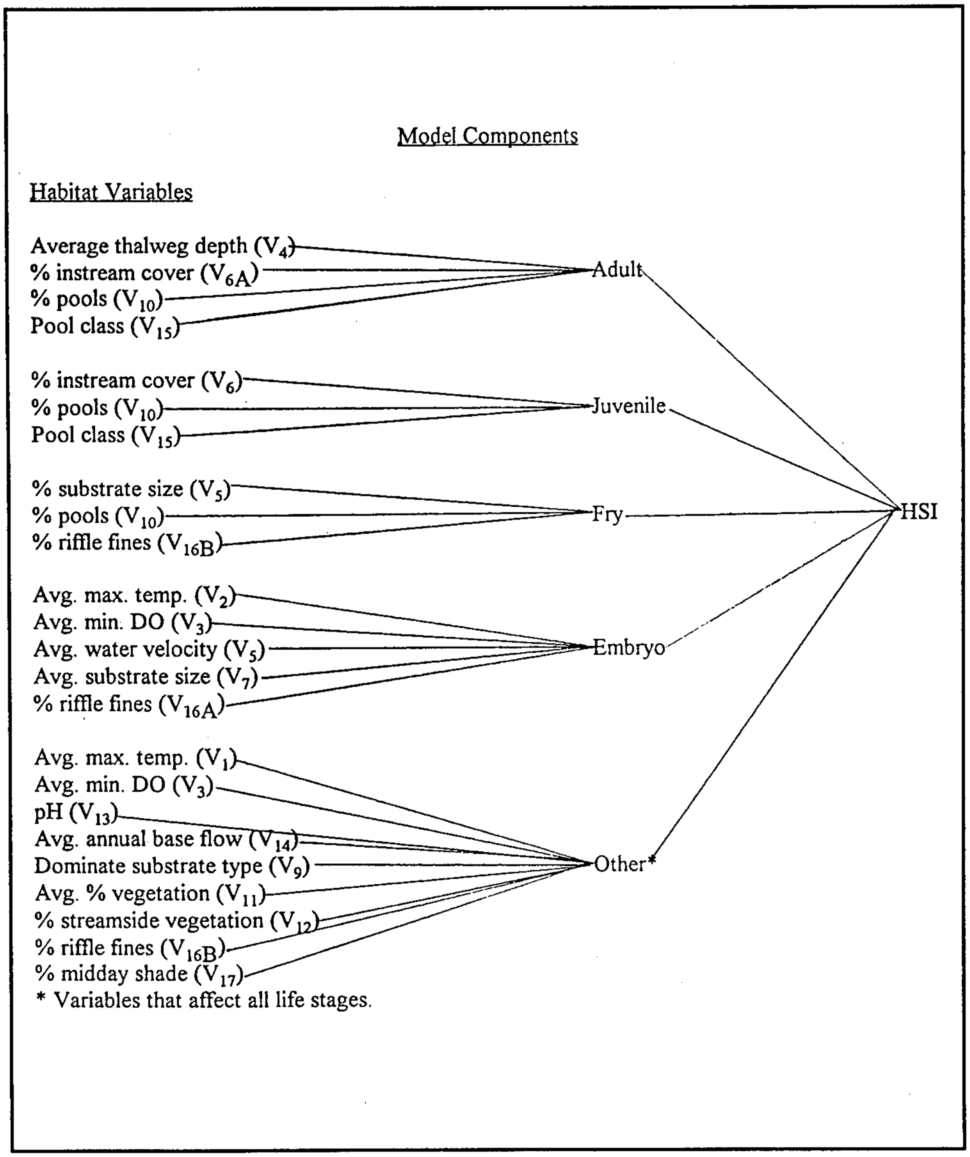


Figure 3. Relations among model variables, components, and HSI

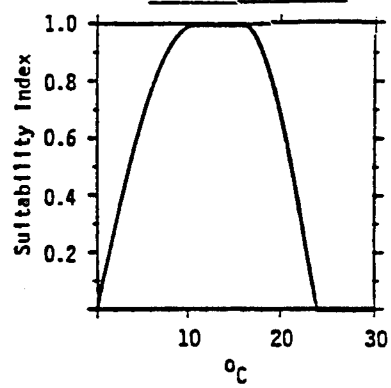
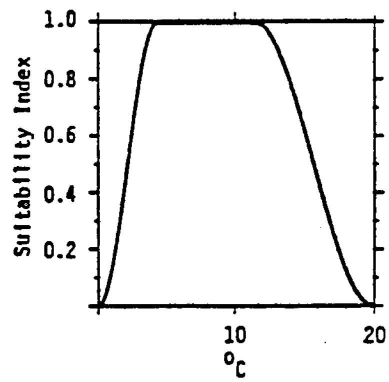
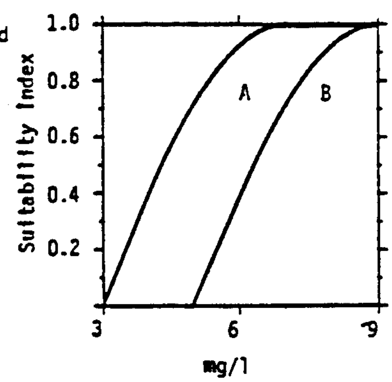
Habitat	Variable		Suitability graph
R,L	V_1	Average maximum water temperature (°C) during the warmest period of the year (adult, juvenile, and fry). For lacustrine habitats, use temperature strata nearest optimum in dissolved oxygen zones of > 3 mg/l.	
R	V_2	Average maximum water temperature (°C) during embryo development.	
R,L	V_3	Average minimum dissolved oxygen (mg/l) during the late growing season low water period and during embryo development (adult, juvenile, fry, and embryo). For lacustrine habitats, use the dissolved oxygen readings in temperature zones nearest to optimum where dissolved oxygen is > 3 mg/l.	

Figure 4. Suitability curve A = ≤ 15˚ C B + > 15˚ C examples (V_1, V_2, V_3)

Riverine Model

This model uses a life stage approach with five components: adult, juvenile, fry, embryo, and other.

Adult (C_A). C_A variables: V_4, V_6, V_{10}, and V_{15}

$$\textit{Case 1: Where } V_6 \textit{ is } > (V_{10} \times V_{15})^{1/2};$$

$$C_A = \left[V_4 \times V_6 \,(V_{10} \times V_{15})^{1/2}\right]^{1/3}$$

$$\textit{Case 2: Where } V_6 \textit{ is } \leq (V_{10} \times V_{15})^{1/2};$$

$$C_A = \left[V_4 \,(V_{10} \times V_{15})^{1/2}\right]^{1/2}$$

If V_4 or $(V_{10} \times V_{15})^{1/2}$ is ≤ 0.4 in either equation, then C_A = the lowest score.

Juvenile (C_J). C_J variables: V_6, V_{10}, and V_{15}

$$C_J = \frac{V_6 + V_{10} + V_{15}}{3}$$

Or, if any variable is ≤ 0.4, C_J = the lowest variable score.

Fry (C_F). C_F variables: V_8, V_{10}, and V_{16}

$$C_F = [V_{10} \,(V_8 \times V_{16})^{1/2}\,]^{1/2}$$

Or, if V_{10} or $(V_s \times V_{16})^{1/2}$ is ≤ 0.4, C_F = the lowest factor score.

Figure 5. Habitat coefficient derivations (C_A, C_J, C_F) (Sheet 1 of 3)

Embryo (C_E). C_E variables: V_2, V_3, V_5, V_7, and V_{16}

Steps:

a. A potential spawning site is a ≥ 0.5 m^2 area of gravel, 0.3 to 8.0 cm in size, covered by flowing water ≥ 15 cm deep. At each spawning site sampled, record:

(1) Average water velocity over the site

(2) Average size of all gravel between 0.3 and 8.0 cm

(3) Percent fines < 0.3 cm in the gravel

(4) Total area in m^2 of each site

b. Derive a spawning site suitability index (V_S) for each site by combining V_5, V_7, and V_{16} values following:

$$V_S = (V_5 \times V_7 \times V_{16})^{1/3}$$

c. Derive a weighted average $(\bar{V}_S)$ for all sites included in the sample. Select the best V_S scores until all sites are included, or until brook trout habitat has been included, whichever comes first.

$$\bar{V} = \frac{\sum_{i=1}^{n} A_i \; V_{si}}{total\ habitat\ area} \ / \ 0.05 \ (output\ cannot > 1.0)$$

where A_i = the area of each spawning site in m^2 ($\sum A_i$ cannot exceed 5% of the total brook trout habitat)

V_{si} = the individual SI scores from the best spawning areas until all spawning sites have been included or until SI's from an area equal to 5% of the total brook trout habitat being evaluated has been included, whichever occurs first

d. Derive C_E

$$C_E = the\ lowest\ score\ of\ V_2, V_3,\ or\ \bar{V}_S$$

Figure 5. (Sheet 2 of 3)

Other (C_O). C_O variables: V_1, V_3, V_9, V_{11}, V_{12}, V_{13}, V_{14}, V_{16}, and V_{17}

$$C_O = \left[\frac{(V_9 \times V_{16})^{1/2} + V_{11}}{2} \times (V_1 \times V_3 \times V_{12} \times V_{13} \times V_{14} \times V_{17})^{1/N} \right]^{1/2}$$

where N = the number of variables within the parentheses. Note that variables V_{11}, V_{12}, and V_{17} are optional, and therefore, can be omitted.

HSI determination. HSI scores can be derived for a single life stage, a combination of two or more life stages, or all life stages combined. In all cases, except for the embryo component (C_E), an HSI is obtained by combining one or more life stage component scores with the other component (C_O) score.

Equal Component Value Method. The equal component value method assumes that each component exerts equal influence in determining the HSI. This method should be used to determine the HSI unless information exists that individual components should be weighted differently. Components: C_A, C_J, C_F, C_E, and C_O.

$$HSI = (C_A \times C_J \times C_F \times C_E \times C_O)^{1/N}$$

Or, if any component is ≤ 0.4, the HSI = the lowest component value; if C_A is < the equation value, the HSI = C_A.

where N = the number of components in the equation.

Solve the equation for the number of components included in the evaluation. There will be a minimum of two, one, or more life stage components and the component (C_O), unless only the embryo life stage (C_E) is being evaluated, in which case the HSI = C_E).

Figure 5. (Sheet 3 of 3)

each cross section for use in the determination of cell (three-dimensional (3-D) velocity-depth area between adjacent cross sections) habitat values.

The cell's habitat value is derived in terms of WUA by applying the Milhous, Updike, and Schneider (1989) relation:

$$WUA(Q) = \sum_{i=1}^{n} f\,[v(i) \times d(i) \times ci(i)] \tag{2}$$

From Equation 2, WUA at a specified flow is calculated as the sum of all incremental cell (i) WUA's throughout the reach. Cell WUA is a function of *v* (velocity), *d* (depth), and *ci* (channel index). The total area of the channel is the sum of all incremental channel widths multiplied by the distance between these widths. The WUA closest to the total area of the channel indicates the best habitat alternative. WUA can be calculated at numerous flows for comparison of habitat at different stages.

PHABSIM is useful for evaluating water management policy effects on a stream's habitat modifications. Discharge from a reservoir, for example, can have a positive or negative impact on the downstream habitat. A PHABSIM analysis may be used to determine the optimum release schedules and discharges. A limitation of PHABSIM is that channel index is complex and difficult to determine as evidenced by the brook trout example. Application of PHABSIM becomes complex when a multitude of fish species are considered at different life stages–each fish and life stage may require different velocities, depths, substrate, habitat features, and ultimately different channel indices.

Utilization of PHABSIM can become an extremely complex process when performing a habitat assessment. Since a suitability curve exists for each life stage of each species within a habitat, it becomes cumbersome to optimize the multitude of suitability curves that affect the local ecosystem. In many cases, the detailed components of the numerous suitability curves are not emphasized or lost in the analysis. However, the flow depth-velocity diversity appears to significantly impact the general habitat quality independent of the number of suitability curves included in the assessment.

RCHARC

The RCHARC concept relates the effects of flow alterations on aquatic biota (Nestler, Schneider, and Latka 1993). The system combines the conceptual elements of the Index of Biotic Integrity (IBI) (Karr et al., 1986) and the PHABSIM system. RCHARC requires use of the river system as a "comparison standard" for the analysis against which the various project alternatives can be evaluated. The comparison standard river system (CSRS) is considered to represent the ideal habitat conditions, both in terms of channel configuration and seasonally varying flow characteristics, for the aquatic community in the project river system. The CSRS can be selected based on professional consensus, physical similarity to the project system, or similarity of the aquatic community in the standard system to what is desired in the project system.

RCHARC does not directly assess impacts on species using life stage-specific suitability curves. This is considered implicit in the methodology (Nestler, Schneider, and Latka 1993). For a given flow, there is a distribution of depth and velocity associated with that flow. These distributions represent the habitat template upon which the community is structured. Changes in the frequency distribution of depth and velocity will result in associated changes in the fish community. Depiction of a stream reach in terms of frequency distributions of depth and velocity is likely to capture the stream heterogeneity having value to aquatic biota both at the population and community levels. The holistic perspective of the RCHARC provides a better framework to evaluate the system differences between the CSRS and the project stream(s) by better describing the fluvial geomorphic factors that affect habitat (Hill, Platts, and Beschta 1991).

Rather than unweave or bisect the complex tapestry of habitat requirement for each species within an ecosystem, RCHARC simply compares the underlying patterns of depths and velocities in two or more comparative systems and uses the results as the basis of the community-level impact analysis. The degree of impact is roughly approximated by the degree to which the physical habitat changes between the target and the standard systems. The analysis focuses on a comparison of bivariate velocity-depth pairs and their frequency of occurrence in the target and standard systems. RCHARC provides a comprehensive and simplified analysis compared to the numerous suitability curves and channel indices of the PHABSIM model.

Design Guidelines and Field Observations

Channel features, such as meanders, boulders, pool riffle sequences, sills, dikes, deflectors, and bank cover, are often incorporated into the channel(s) to improve habitat. Unfortunately, little guidance exists for the design of these features or the evaluation of their habitat benefits. The assessment and design of channel modifications for habitat purposes may be improved by use of field observations or established guidelines derived from biologist input, engineering judgement, and the success of past projects. One means of accomplishing this is by estimating a "comparison reach" as a template upon which to base the design for the project reach. This approach assumes that the reaches are similar and that the "comparison reach" has suitable habitat. Stream classification methodologies can be useful in establishing similarity. Following the establishment of stream reach similarity, it is important to identify stream features that provide attractive habitat in the comparison reach. Habitat features can be segmented and scored for comparison of natural and modified/restored reaches.

A classification system can be used to affirm that two different streams or stream reaches are similar enough to compare habitat. Table 1 (based on Rosgen 1993) presents the Rosgen classification system that is based on channel

Table 1
Summary of Delineative Criteria for Broad-Level Classification (Based on Rosgen 1993)

Stream Type	General Description	Entrench-ment Ratio	W/D Ratio	Sinu-osity	Slope	Landforms/Soils/Features
As +	Very steep, deeply entrenched, debris transport streams	<1.4	<12	1.0 to 1.1	>0.10	Very high relief. Erosional, bedrock, or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with/deep scour pools;waterfalls
A	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.	<1.4	<12	1.0 to 1.2	0.04 to 0.10	High relief. Eronsional of depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step-pool bed morphology.
B	Moderately entrenched, moderate gradient, riffle dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4 to 2.2	>12	<1.2	<0.2 to 0.039	Moderate relief, colluvial deposition and/or residual soils. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate w/occasional pools.
C	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well-defined floodplains.	>2.2	>12	<1.4	<0.02	Broad valleys w/terraces. In association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channel. Riffle-pool bed morphology.
D	Braided channel with longitudinal and traverse bars. Very wide channel with eroding banks.	n/a	>40	n/a	<0.04	Broad valleys with aluvial and colluvial fans. Glacial debris and depositional features. Active lateral adjustment, w/abundance of sediment supply.
DA	Anastomosing (multiple channels) narrow and deep with expansive well-vegetated floodplain and associated wetlands. Very gentle relief with highly variable sinuosities, stable streambanks.	>4.0	<40	variable	<0.005	Broad, low-gradient valleys with fine alluvium and/or lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition w/well-vegetated bars that are laterally stable with broad wetland floodplains.
E	Low gradient, meandering riffle/pool stream with low width/depth ratio and little deposition. Very efficient and stable. High meander width ratio.	>2.2	<12	>1.5	<0.02	Broad valley/meadows. Alluvial materials with floodplain. Highly sinuous with stable, well-vegetated banks. Riffle-pool morphology with very low width/depth ratio.
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio	<1.4	12	>1.4	<0.02	Entrenched in highly weathered material. Gentle gradients, with a high W/D ratio. Meandering laterally unstable with high bank-erosion rates. Riffle-pool morphology.
G	Entrenched "gully" step/pool and low width/depth ratio on moderate gradients.	<1.4	<12	>1.2	0.02 to 0.039	Gully, step-pool morphology w/moderate slopes and low W/I ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials, i.e., fans or deltas. Unstable, with grade control problems and high bank erosion.

morphology. The Rosgen system classifies a stream by its entrenchment ratio (width of flood prone area over channel bankfull surface width), width-depth ratio (width over depth), sinuosity (ratio of stream length to valley length), slope, and a description of the landform, soils, and geologic features. Rosgen developed this classification system to assess streams for restoration. Many other classification systems exist. Systems such as those developed by Brice (1984), Leopold and Wolman (1957), and Schumm (1977) classify streams by slope, discharge, channel pattern, and sediment transport parameters.

After channel classification has been performed to verify the similarity of channel reaches, habitat can be assessed and comparisons made. Table 2,

Table 2
Habitat Assessment Field Data Sheet Riffle/Run Prevalence (after Barbour and Stribling 1991)

Habitat Parameter	Category: Optimal	Suboptimal	Marginal	Poor
1. Bottom substrate/ instream cover (a)	Greater than 50% mix of rubble, gravel, submerged logs, undercut banks, or other stable habitat. 16-20	30-50% mix of rubble, gravel, or other stable habitat. Adequate habitat. 11-15	10-30% mix of rubble, gravel, or other stable habitat. Habitat availability less than desirable. 6-10	Less than 10% rubble, gravel, or other stable habitat. Lack of habitat is obvious 0-5
2. Embeddednes s (b)	Gravel, cobble, and boulder particles are between 0-25% surrounded by fine sediment. 16-20	Gravel, cobble, and boulder particles are between 25-50% surrounded by fine sediment. 11-15	Gravel, cobble, and boulder particles are between 50-75% surrounded by fine sediment. 6-10	Gravel, cobble, and boulder particles are over 75% surrounded by fine sediment. 0-5
3. ≤ 015 cms (5cfs) - Flow at rep. low	Cold >0.05 cms(2cfs) Warm >0.15 cms (5cfs) 16-20	0.03-0.05 cms (1-2 cfs) 0.050.15 cms (2-5 cfs) 11-15	0.01-0.03 cms (.5-1 cfs) .03-0.05 cms (1-cfs) 6-10	<0.01 cms (0.5 cfs) <0.03 cms (1 cfs) 0.5
OR >0.15 cms (5cfs)- velocity/depth	Slow (<0.3 m/s), deep (>0.5 m): slow, shallow (<0.5 m): fast (>0.3 m/s), deep; fast, shallow habitats all present. 16-20	Only three of the four habitat categories present (missing riffles or runs receive lower score than missing pools. 11-15	Only two of the four habitat categories present (missing riffles or runs receive lower score). 6-10	dominated by one velocity-depth category (usually pools). 0-5

(Sheet 1 of 3)

Table 2 (Continued)				
	Category			
Habitat Parameter	Optimal	Suboptimal	Marginal	Poor
4. Canopy cover (shading) (c) (d) (g)	A mixture of conditions where some areas of water surface fully exposed to sunlight, and other receiving various degrees of filtering light. 16-20	Covered by sparse canopy; entire water surface receiving filtered light. 11-15	Completely covered by dense canopy; water surface completely shaded OR nearly full sunlight reaching water surface. Shading limited to <3 hours per day. 6-10	Lack of canopy, full sunlight reaching water surface. 0-5
5. Channel alteration (a)	Little or no enlargement of islands or point bars, and/or no channelization. 12-15	Some new increase in bar formation, mostly from coarse gravel; and/or some channelization present 8-11	Moderate deposition of new gravel, coarse sand on old and new bars: and/or embankments on both banks. 4-7	Heavy deposits of the material, increased bar development and/or extensive channel-ization. 0-3
6. Bottom scouring and deposition (a)	Less than 5% of the bottom affected by scouring and/or deposition. 12-15	5-30% affected. Scour at constrictions and where graces steepen. Some deposition in pools. 8-11	30-50% affected. Deposits and/or scour at obstructions, constructions, and bends. Filling of pools prevalent. 4-7	More than 50% of the bottom changing frequently. Pools were absent due to deposition. Only rocks in riffle expected. 0-3
7. Pool/riffle, run/bend ratio (a) (distance between riffles divided by stream.	Ratio: 5-7. Variety of habitat. Repeat pattern of sequence relatively frequent. 12-15	7-15. Infrequent repeat pattern. Variety of macron habitat less than optimal. 8-11	15-25. Occasional riffle or bend. Bottom contours provide some habitat. 4-7	>25., Essentially a straight stream. Generally all flat or shallow riffle habitat. 0-3
8. Lower bank channel capacity (b)	Overbank (lower) flows rare. Lower bank W/D ratio <7. (Channel width divided by depth or height of lower bank.) 12-15	Overbank (lower) flows occasional. W/D ratio 8-15. 3-11	Overbank (lower) flows common. W/D ratio 15-25. 4-7	Peak flows not contained or contoured through channelization W/D ratio >25. 0-3
				(Sheet 2 of 3)

Table 2 (Concluded)

Habitat Parameter	Category			
	Optimal	Suboptimal	Marginal	Poor
9: Upper bank stability (a)	Upper bank stable. No evidence of erosion or bank failure. Side slopes generally < 30°. Little potential for future problems 9-10	Moderately stable. Infrequent, small areas of erosion mostly healed over. Side slopes up to 40° on one bank. Slight potential in extreme floods. 6-8	Moderately unstable. Moderate frequency and size of erosional areas. Side slopes up to 60° on some banks. High erosion potential during extreme high flow. 3-5	Unstable. Many eroded areas. "Raw" areas frequent along straight sections and bends. Side slopes >60° common. 0-2
10. Bank vegetative protection (d)	Over 90% of the streambank surfaces covered by vegetation. 9-10	70-89% of the streambank surfaces covered by vegetation. 6-8	50-79% of the streambank surfaces covered by vegetation. 3-5	Less than 50% of the streambank surfaces covered by vegetation. 0-2
OR Grazing or other disruptive pressure (b)	Vegetative disruption minimal or not evident. Almost all potential plant biomass at present stage of development remains. 9-10	Disruption evident but not affecting community vigor. Vegetative use is moderate, and at least one-half of the potential plant biomass remains. 6-8	Disruption obvious: some patches of bare soil or closely cropped vegetation present. Less than one-half of the potential plant biomass remains. 3-5	Disruption of streambank vegetation is very high. Vegetation has been removed to 2 in. or less in average stubble height. 0-2
11. Streambank cover (b)	Dominant vegetation is shrub. 9-10	Dominant vegetation is of tree form. 6-8	Dominant vegetation is grass or forbes. 3-5	Over 50% of the streambank has no vegetation and dominant material is soil, rock, bridge materials, culverts, or mine tailings. 0-2
12. Ripianan vegetative zone width (east buffered side) (e) (f) (g)	>18 m 9-10	Between 12 and 18 m 6-8	Between 6 and 12 m 3-5	<6 m 0-2
Column Totals				

(Sheet 3 of 3)

Habitat Assessment Field Data Sheet (after Barbour and Stribling 1991) categorizes habitat features and provides an opportunity to score comparison reaches with regard to habitat quality. Barbour and Stribling's (1991) habitat assessment is based on substrate, embeddedness, flow rate, cover, channel alteration, scour/deposition, pool-riffle sequences, low-flow channel capacity, upper bank stability, bank vegetation, and riparian vegetation zone. Quantitative and qualitative field observations may be made, and each parameter is scored (depending on category) from optimal to poor. High scores indicate superior habitat.

Parameters that score poorly in the habitat assessment may be improved by designing habitat modification features into the restored channel. A summary of common design parameters and their recommended guidelines is presented in Table 3 (Abt, Peters, and Watson 1993). These guidelines can be used for preliminary design of a series of channel modifications. Habitat may be reassessed and more features added until scores for the restored reach approach the desired scores of the comparison reach. The proposed habitat features may affect channel hydraulics, and the HEC-2 model should be assembled to assess any hydraulic changes. The impact of these structures on velocity-depth trends can be evaluated by RCHARC incorporating the HEC-2 output for simulated water surface information.

Habitat assessment can be accomplished by field evaluation of specific parameters, including channel morphology, hydraulics, and attractive environmental features. The reviewed field assessment methods establish comparison reach similarity, rank habitat categorically with respect to numerous habitat features, and propose channel modifications to enhance habitat quality. Field habitat assessment and design guidelines are useful for a qualitative and quantitative comparison of project (restored) and standard reaches, and may aid in the design of habitat features. Existing field habitat assessment procedures and design guidelines cannot quantitatively assess the hydraulic impact of a set of proposed modifications.

Table 3
Low-Flow Channel Criteria for Enhancing Aquatic Habitat (Adapted from Abt, Peters, and Watson 1993)

Design Parameter	Recommended Criteria
Low-Flow Design Flow	1- to 2-year recurrence
Minimum Flow Depth	0.3 m
Bend Radius	Three times channel width for small streams
Meander	1.1 < sinuosity < 1.5, or match adjacent reaches
Randomly Placed Rocks	Not effective in fine-grained streams, place where velocity > 1 m/s, 1-rock per 28 sq m of channel, 0.6 m minimum diameter, no greater than 0.2 channel width
Pools	Pool-to-pool interval of five to seven widths, place in bends, pools no longer than three channel widths, no shorter than one channel width, place on alternating sides
Riffles	Place in straight reaches, riffle length: 1/2 to 2/3 pool length, riffle width 10 percent to 15 percent wider than pool, alternate pools and riffles
Deflector Wing	Place on maximum 3-percent channel slope, five to seven channel widths apart, anchor more than 1.2 m into bank, height: 0.15 to 0.30 m above low-flow water surface, install on alternate banks, extend into low-flow channel 0.25 to 0.33 channel width, bank protection may be needed on opposite bank
Sill	Height of one-third design discharge flow depth, keyed into bed minimum of twice height, bank protection needed one to three channel widths downstream.
Dike	Length less than 15 percent to 25 percent channel width, space of three to six times dike length, orient 90 to 150 deg, height: 0.15 to 0.3 m above low-flow water surface.
Bank Cover	Cover placed at low-flow water surface, place on outer bank, depth greater than 1 m
Microorganisms	Recommended velocities of 0.3 to 0.8 mps
Food Production	Recommended velocities of 0.5 to 1.1 mps

3 Approach to Research

Introduction

A study was conducted to evaluate the RCHARC methodology. Two river reaches, natural (standard) and restored, are required to effectively apply RCHARC. The selected comparison reaches were located on Rapid Creek in or adjacent to Rapid City, SD. The natural (standard) reach was immediately upstream of Rapid City, adjacent to the State of South Dakota fish hatchery. An area map is presented in Figure 6. The restored (comparison) reach was located in downtown Rapid City.

The RCHARC model requires velocity and depth values for multiple cross sections within the two comparison reaches. Field surveys were performed at each reach for two flow conditions. HEC-2 analyses were performed to provide velocity and depth values for three additional discharges. Both observed and simulated velocity-depth pairs were processed by RCHARC, and the output from the five RCHARC runs was analyzed to evaluate the performance of the model on the Rapid Creek study. Figure 7 presents a flow chart of the data acquisition/processing procedure used for the RCHARC study.

Procedure

Field data acquisition

Two sets of data were collected on Rapid Creek, at high-flow and at low-flow conditions. The high-flow survey was performed in June 1993 (average discharge in the natural (standard) reach was 7.08 m^3/s, in the restored reach average discharge was 8.21 m^3/s). In October 1993, the low-flow survey was conducted, and the average discharge in the natural reach was 0.57 m^3/s. In the restored reach, average discharge was 1.42 m^3/s.

On the first survey, 12 cross sections were staked for each reach (standard and restored). The cross sections were spaced two to three stream widths apart, and cross-sectional locations were chosen to best represent channel variability. All 24 cross sections (natural and restored) were photographed and described in a log. These sections were surveyed to record channel geometries, water surface elevations, and relative locations within the reach. Velocity and depth

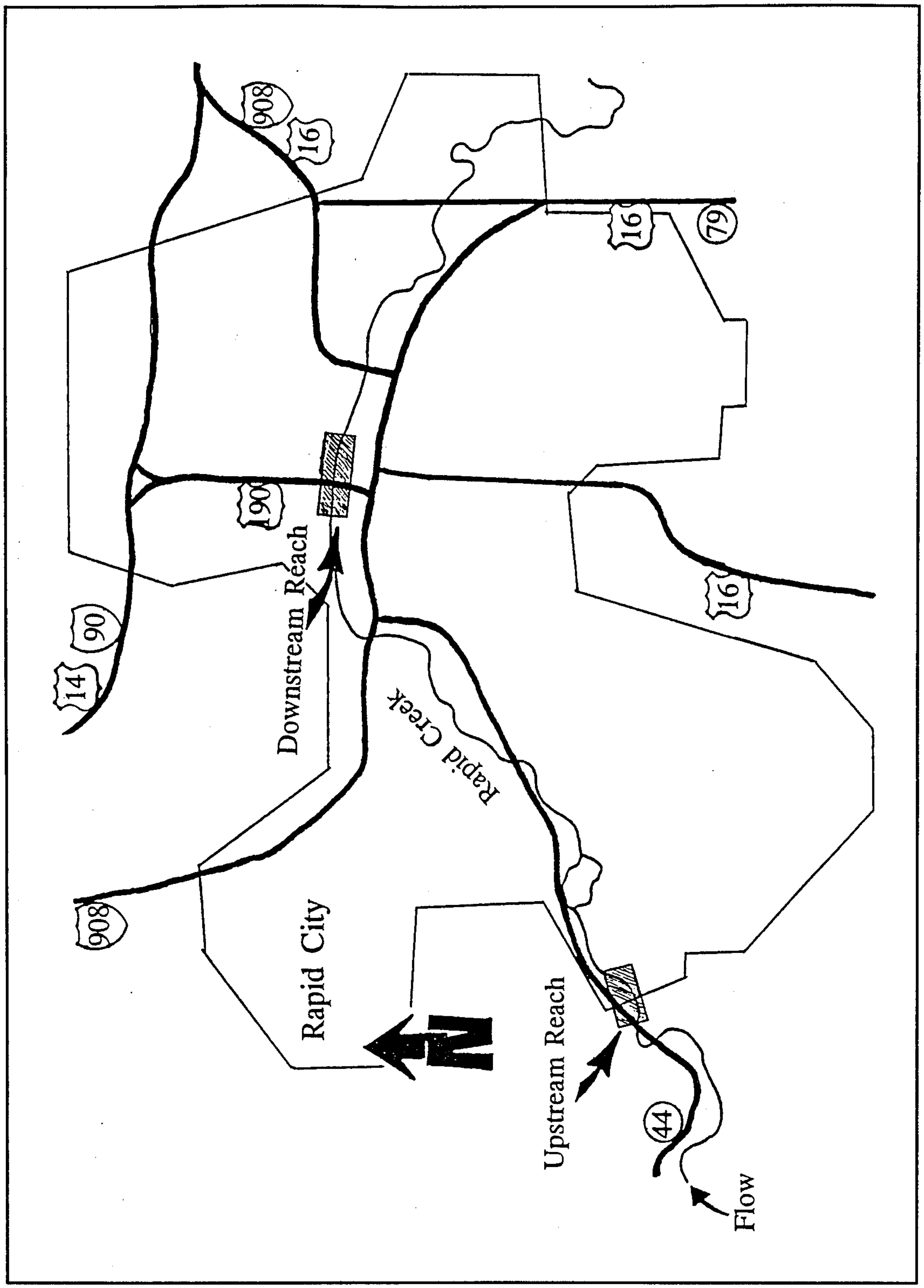


Figure 6. Rapid Creek Reach location map

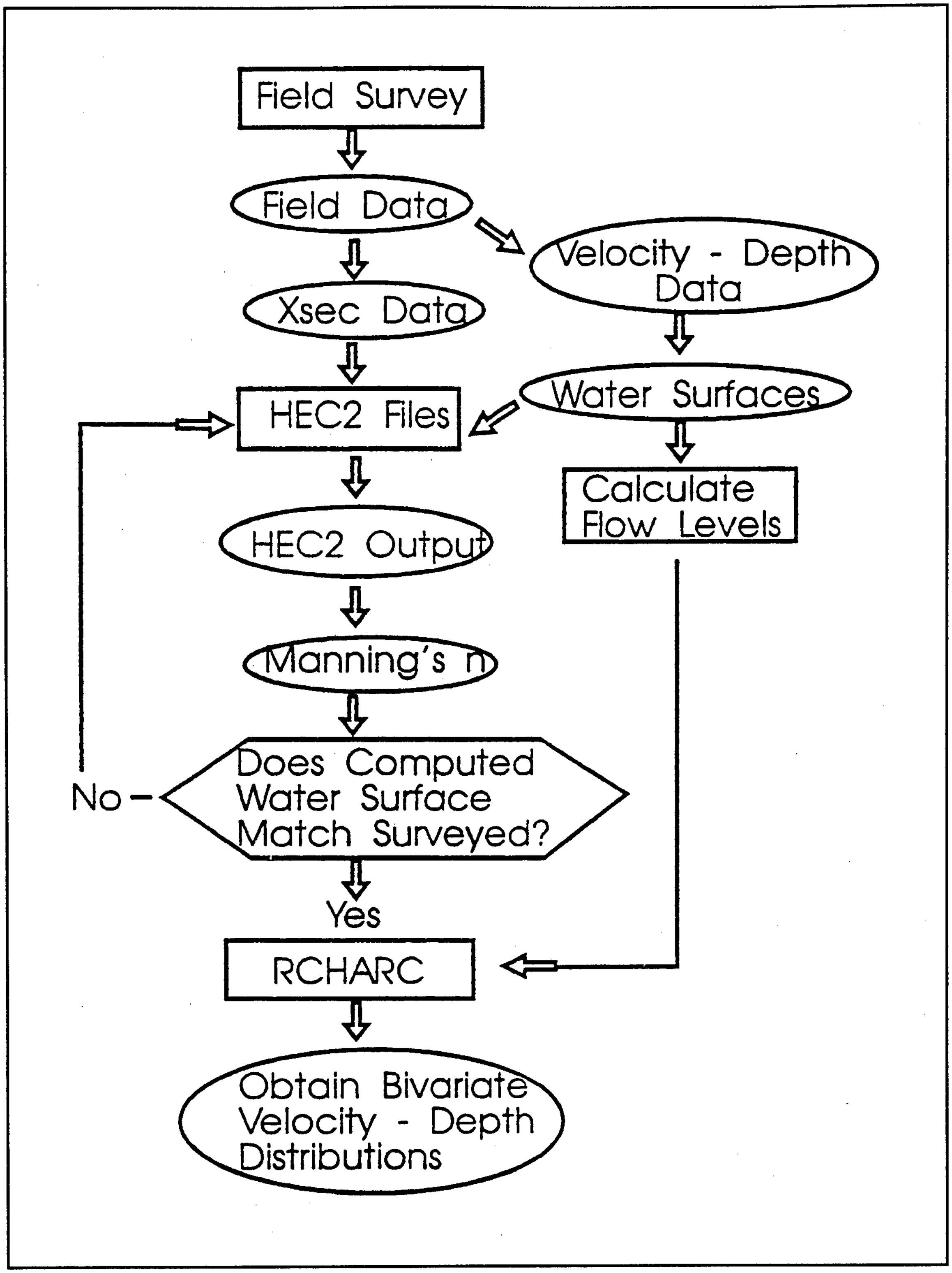


Figure 7. Approach to RCHARC analysis

measurements were obtained at approximately 20 subsections of each cross section, following guidelines set forth by the Water Measurement Manual (U.S. Department of the Interior, Bureau of Reclamation 1984). Typical field notes for the cross-sectional surveys and velocity-depth measurements are presented in Appendix A. Survey data including survey point number, horizontal and vertical angle, and upper, middle, and lower stadia readings were recorded in the survey field notes. Station, depth, velocity, and percent depth were recorded in the velocity-depth field notes. A typical layout for the velocity-depth measurements of a generic cross section is illustrated in Figure 8. It should be noted that two velocity measurements (taken at 20 percent and 80 percent from the water surface) were recorded if the depth was greater than 1 ft. If the depth was less than 1 ft, one velocity measurement was obtained at 60-percent depth. Temperature and dissolved oxygen levels were measured five times at one section of each reach. Suspended and bedload sediment samples were acquired at representative cross sections of the standard and restored reaches. A U.S. DH-48 depth-integrating suspended sediment sampler, as described in Sediment Engineering (ASCE 1977), was utilized for the collection of suspended sediment data. For bed-load sampling, a Helley-Smith type bed-load sampler was used. The mobility and low cost of this type of sampler (Julien 1993) made it convenient for the Rapid Creek field work. A Milhous sampler was employed in the gathering of armor layer and substrate samples (Hogan 1993).

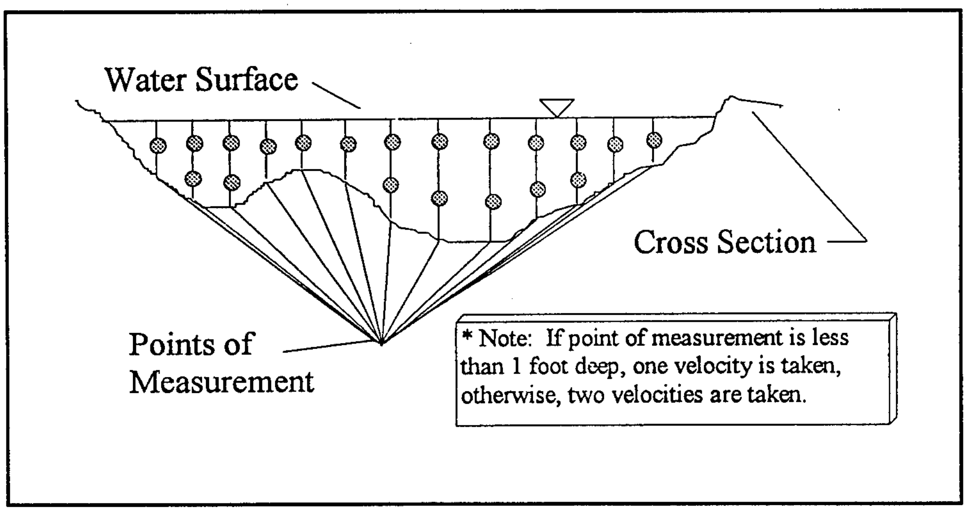


Figure 8. Lateral distribution of velocity-depth measurements

The second survey, at low flow, recorded velocity and depth measurements at the same sections as the first survey. Water surface elevations and the channel thalweg were surveyed to verify section locations and determine the low-flow water surface elevation. All cross sections (standard and restored) were documented with photographs, a written log, and videotape. Temperature and dissolved oxygen were measured at each cross section. Suspended and bed-load sediment samples were obtained at the same sections as in the first survey. The channel substrate and armor layer were sampled at one cross section of the standard and restored reaches.

Data reduction

The field data required for processing were reviewed and reduced before input into the RCHARC model. The horizontal and vertical survey of the cross-sectional geometry was entered into a spreadsheet, and the appropriate procedures for relating horizontal and vertical angles and stadia readings were applied to the raw data to generate X-Y-Z coordinates. Velocity and depth data were also entered into a spreadsheet for entry into RCHARC input files. The spreadsheet computed the water surface elevations and discharge at each cross section.

Two HEC-2 decks (one for the standard reach and one for the restored reach) were created to model hydraulics through the surveyed cross sections for the field measured discharge or flow conditions. These hydraulic models represented the observed channel geometry and calculated discharge values for each of the 24 surveyed cross sections. HEC-2 geometry points (GR cards) were derived from the survey data. Discharge (input on QT cards) for each cross section was calculated using the spreadsheets. The relation $Q = VA$ was used to calculate flow (discharge) values. (Discharge equals velocity times cross-sectional area). Velocity and depth were measured at approximately 20 subsections for each cross section (Figure 8). Velocity (average velocity if two values were measured) multiplied by the incremental width and depth of each subsection resulted in the cell discharge for that subsection. The sum of the incremental discharges for a cross section determined cross-sectional discharge.

Manning's n values for left overbank, right overbank, and channel per cross section were estimated and input into the HEC-2 decks. HEC-2, using the stream geometry, cross-sectional discharge, and Manning's n values calculated water surface elevation at each section. An example of the HEC-2 deck (the deck used to model the restored channel) is illustrated in Appendix B. Since the water surface was surveyed, the measured water surface elevations could be compared to those calculated by HEC-2. The Manning's n values were then adjusted to calibrate the HEC-2 models to field observations. The two original decks (for restored and standard reaches) were calibrated and used to model channel hydraulics under the three additional simulated flows.

Flow simulation

A set of three simulated discharges was modeled to broaden the database for entry into RCHARC. The first simulated discharge, referred to as lowest simulated flow, was defined as half the observed low flow. The second modeled flow, referenced as the intermediate simulated flow, was defined as the average of the high and low observed flows. The third modeled flow, highest simulated flow, was 1.5 times the observed high flow. HEC-2 runs were performed to determine water surface elevations at each cross section for the three simulated discharge conditions. The HEC-2 water surfaces for the simulated flows were input into IFG4, a subprogram of PHABSIM, to simulate lateral flow-velocity distributions for each cross section. Figure 8 illustrates a field measured lateral flow-velocity distribution.

Output evaluation

Once the field data had been obtained and reduced, RCHARC was used to gain insight into the comparative habitat values of the standard and restored reaches. The velocity-depth pairs measured in the field were directly entered into RCHARC. RCHARC sorts velocity-depth pairs by grouping them into predefined intervals. For the purpose of this study, the depths were segmented into tenths of a meter, and the velocities were segmented into tenths of a meter per second. All flow depths between 0 and 0.1 m were grouped together, and their corresponding flow velocities were ranked. Frequencies of occurrence for each velocity-depth pair were calculated in the RCHARC program. Three-dimensional (3-D) plots of the bivariate (two variables) depth and velocity distributions were generated to compare and assess habitat quality.

The IFG4 (from PHABSIM) program was used to compute velocity-depth pairs for both the standard and restored reaches. The velocity-depth pairs were processed through RCHARC in the same manner as the field observed flows. Bivariate depth and velocity frequency distributions were plotted for the simulated flows. A more detailed account of the RCHARC process is presented in Chapter 4.

Output from the RCHARC model was evaluated based on similarity of velocity-depth frequency distributions between the standard and restored reaches for a specified flow condition. The model was evaluated for five flow conditions: high and low observed flows, highest, intermediate, and lowest simulated flows. Chapter 5 chronicles the results of the RCHARC analysis. The applicability and usability of the RCHARC model is discussed in Chapter 6.

4 RCHARC Model Operation

Introduction

The RCHARC model provides a linkage between field observations, survey results, and an understanding of habitat diversity. Input of observed or computed hydraulic parameters is grouped and ranked by RCHARC for comparison of channel reaches. Assuming that habitat similarity is related to hydraulic similarity, hydraulic diversity may be compared and habitat quality correlations drawn.

The required RCHARC input includes depth and velocity relations, discharge, and water surface elevation. Velocity-depth pairs measured throughout both comparison reaches (standard and restored) were processed through IFG4 to develop stage-discharge relations. The three simulated discharges (lower than, intermediate, and higher than the observed flows) were then processed by IFG4 to generate simulated velocity-depth pairs. The velocity-depth data (observed and generated) were input into RCHARC. RCHARC sorted and regrouped the velocity-depth pairs by discharge, depth, and velocity. The frequency of occurrence for each velocity-depth grouping was computed by RCHARC. Bivariate (depth and velocity) output was plotted (in three dimensions) against its frequency of occurrence to visualize similarities and differences in channel hydraulics. Since habitat qualities such as discharge, slope, substrate, topwidth, etc. (Chapter 2) were similar, RCHARC was considered applicable. The velocity-depth distributions were used to compare hydraulic diversity between the two reaches, and habitat similarity was evaluated. Figure 9 depicts a flow chart of the RCHARC data processing sequence.

Procedure

Foundation

The data required to apply RCHARC were collected from field surveys of Rapid Creek, as indicated in Chapter 3. Flow depth and velocity, cross-sectional geometry, water-surface elevation, and channel-thalweg information were collected in addition to the water temperature, dissolved oxygen, suspended and bedload sediment, channel substrate and armor layer samples. Written and photographic logs were compiled, and a videotape of the stream was made for analysis and reference. The field data were entered into spreadsheets to determine cross-sectional geometry, water surface elevations, and channel profile. Velocity-depth pairs were also entered into spreadsheets for the calculation of discharge at each cross section of the natural and restored reaches.

Cross-sectional water surface elevations, necessary for input into RCHARC, could be calculated once HEC-2 decks were created. Observed hydraulic parameters including cross-sectional geometry, slope, discharge, and water surface elevations were modeled as indicated in Chapter 3.

IFG4

The IFG4 program accepts input, including two calibration sets of depth and velocity pairs, cross-sectional geometry, and channel slope, and generates a lateral flow-velocity distribution for a specified discharge as indicated in Chapter 3. An IFG4 input file, DS1A (restored Section 1, lowest simulated flow) is presented in Appendix C. The calibration sets of depth and velocity pairs are those observed at high and low discharge.

To model the cross-sectional lateral flow-velocity distribution, IFG4 segments the cross section into cells and calculates the depth and velocity at each cell. IFG4 considers a cell (i) as the area between bisectors of adjacent channel geometry points (i -1, and i + 1) and the water surface (Figure 10). Roughness is calculated for all cells across the cross section, so that for a given discharge, water surface elevation and velocity-depth pairs may be computed. Output from the IFG4 run of file DS1A is illustrated in Appendix D. The IFG4 output presents tables of both calibration velocity-depth sets, corrections, and depth-velocity pairs for the specified discharge. IFG4 output of cell velocity and depth, when compiled for all the cells of each cross section of a particular channel reach, serves as the input for RCHARC.

RCHARC

Depth and velocity pairs are sorted by RCHARC for the purpose of hydraulic and habitat comparison. RCHARC input consists of velocity-depth pairs (observed or generated by IFG4). The format for an RCHARC input file (DSA.OUT) is presented in Appendix E. The first card (line) of an RCHARC input file is signaled by an *A* in the first field (column). The columns of the *A* card represent river mile, discharge (cfs), and water surface elevation (ft), respectively. One *A* card is necessary for each cross section at each desired flow condition. A series of *B* cards, which follow the *A* card, encode cross-sectional geometry, depth (ft), and velocity (ft/s) from left to right. Another *A* card follows the first set of *B* cards, specifying another discharge for the first cross section. *B* cards specify velocity-depth relations for the discharge specified in their individual *A* cards. The sequence of *A* and *B* cards is repeated until all

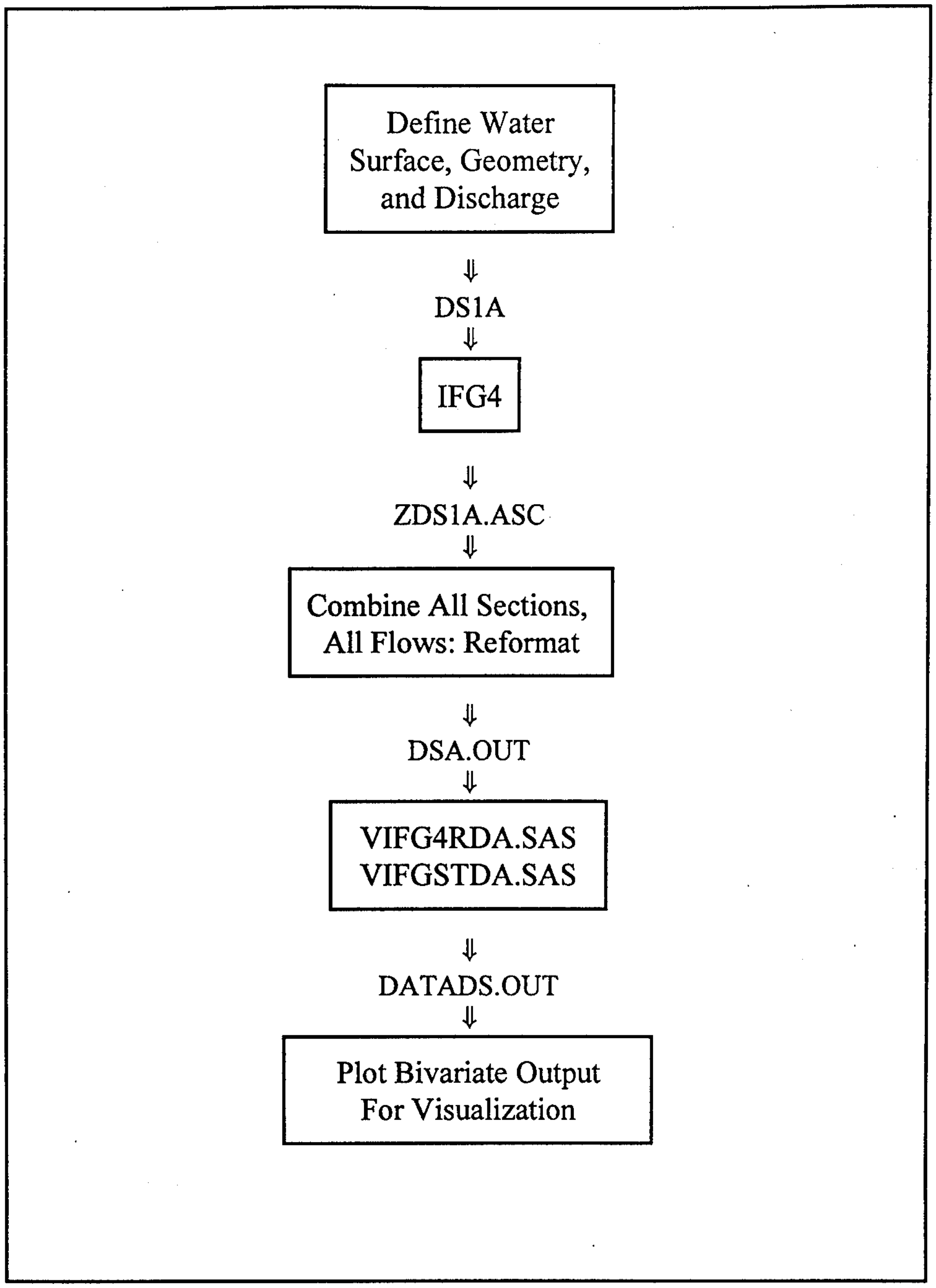


Figure 9. RCHARC input/output

discharges for the first cross section are entered, then a new *A* card is created for the next cross section. Field observations of velocity and depth, or velocity-depth pairs generated by IFG4, are arranged into the prescribed format, and RCHARC is run for the standard and restored reaches.

RCHARC consists of two primary programs: VIFG4RDA.SAS and VIFGSTDA.SAS. The input files, *.OUT, (of the format illustrated by DSA.OUT) are processed by the two main RCHARC programs. There are four

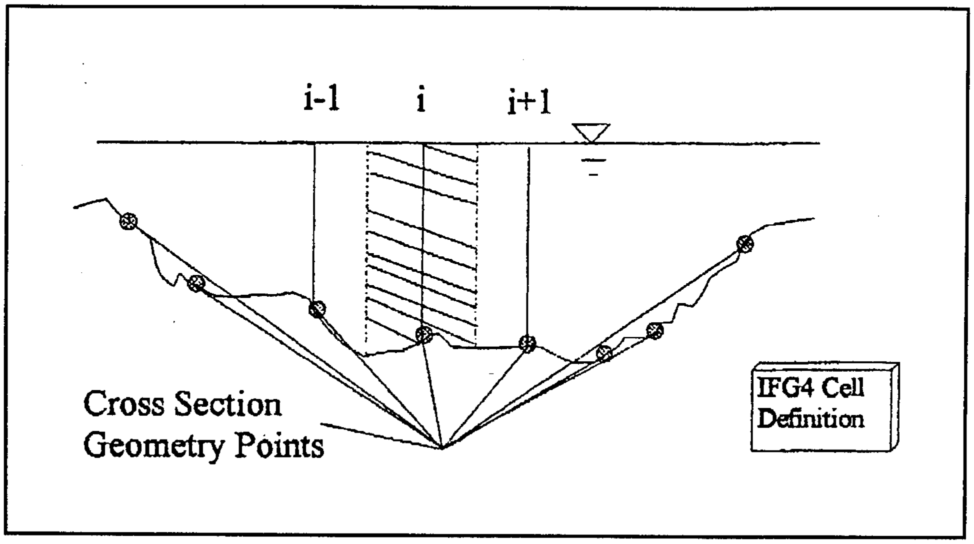


Figure 10. IFG4 cell definition

*.OUT files, DSA.OUT, DS.OUT, USA.OUT, US.OUT, that represent the restored and standard reaches under simulated and observed flows. SAS, a statistical programming language, must be invoked to run the *.SAS RCHARC programs. The SAS programs convert velocity from English to S.I. units. The velocity-depth pairs are then arranged into groups from 0 to 0.1 m, 0.1 to 0.2 m, 0.2 to 0.3 m, etc. for depth, and 0 to 0.1 m/s, 0.1 to 0.2 m/s, 0.2 to 0.3 m/s, etc. for velocity. The velocity-depth pairs that fall into each group, 0.1 m by 0.1 m/s, are counted and weighted by the volume of their individual cells. The cell, in this case, is the same as an IFG4 cell, except it has a dimension upstream and downstream of the cross section.

Output from the RCHARC SAS programs is presented in Appendix F (DATADSA.OUT). The DATADSA.OUT output file represents the three simulated flows for the restored reach. Three other *.OUT files, DATADS.OUT, DATAUS.OUT, DATAUSA.OUT, represent the observed flows for the restored reach and the observed and simulated flows for the natural reach. The *.OUT files tabulate depth-velocity group, number of depth-velocity occurrences within that group, and percent of total occurrence for each group per discharge.

Visualization

The RCHARC output is graphed to evaluate hydraulic diversity. A 3-D view of velocity versus depth plotted against percent occurrence of each velocity-depth pair is presented in Figure 11. The bivariate graphic is useful in understanding and comparing velocity-depth distributions. RCHARC methodology assumes that diverse distributions of velocity-depth pairs lead to diverse habitat. Conclusions of habitat similarity may be made by comparing plots of velocity and depth distributions between comparison reaches, or different discharges.

Similarity of the bivariate surface or frequency of given velocity-depth pairs indicates similar hydraulic conditions between comparison reaches.

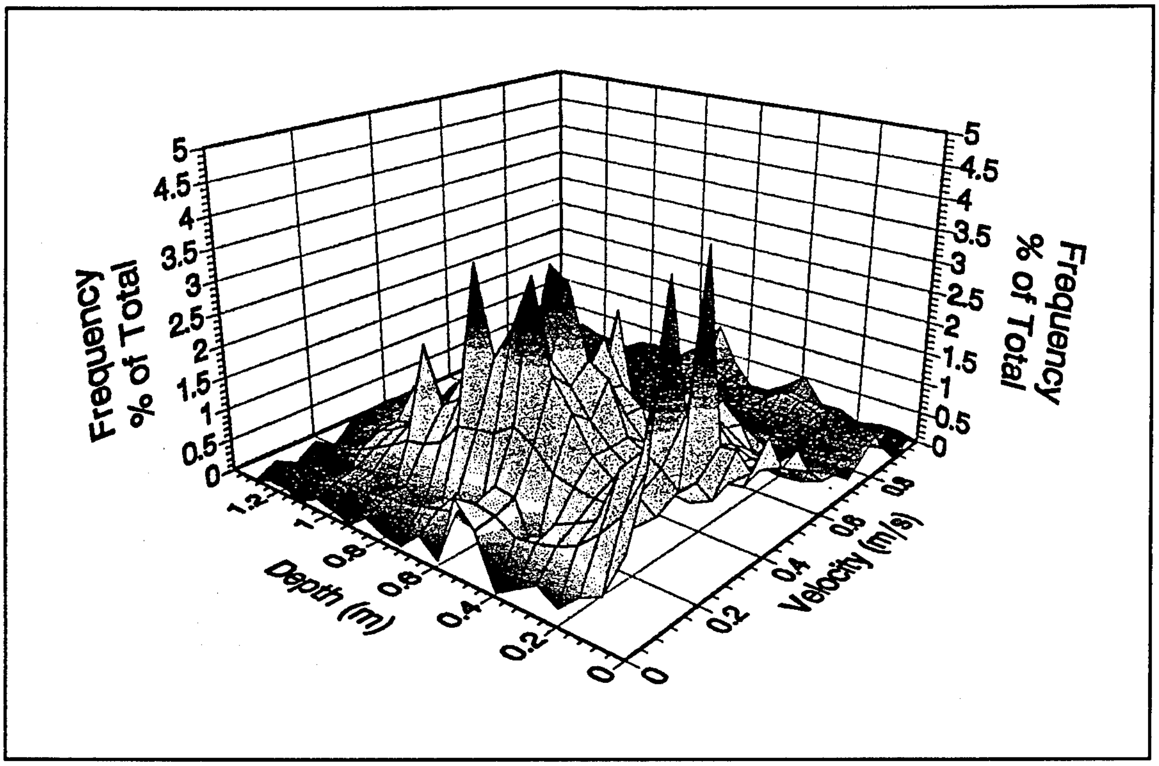


Figure 11. Sample bivariate depth velocity versus frequency

5 Results of RCHARC Analysis

Overview

Field data collected on Rapid Creek yielded information to qualitatively and quantitatively analyze the standard and restored stream reaches. The field data, including channel geometry, thalweg profiles, water surface elevations, and velocity-depth pairs were surveyed. Temperature and dissolved oxygen levels were measured, and suspended and bedload sediment samples were collected. The channel bed was characterized by armor layer and substrate samples taken from representative cross sections.

HEC-2 and RCHARC input files were created from the reduced field data and hydraulic and habitat evaluations were performed. The output from these models was then analyzed, and conclusions were drawn regarding the standard and restored reaches of Rapid Creek.

Data Comparison

Field data

The Rapid Creek field data were collected in the 12 cross sections for both the standard and restored reaches shown in Figures 12 and 13, respectively. Figures 14 and 15 show typical cross sections from the standard and restored reaches, respectively. Longitudinal thalweg profiles for both reaches are presented in Figures 16 and 17. The velocity-depth measurements for the cross sections (at high and low flows) are presented in Appendix A.

Water surface elevations were surveyed at each cross section for high- and low-flow conditions. The relative water surface elevations measured at high and low flows are presented in Table 4. The channel discharge at each cross section was calculated from the velocity-depth measurements and is presented in Table 5. Simulated discharge values, high, intermediate, and low, are also presented in Table 5.

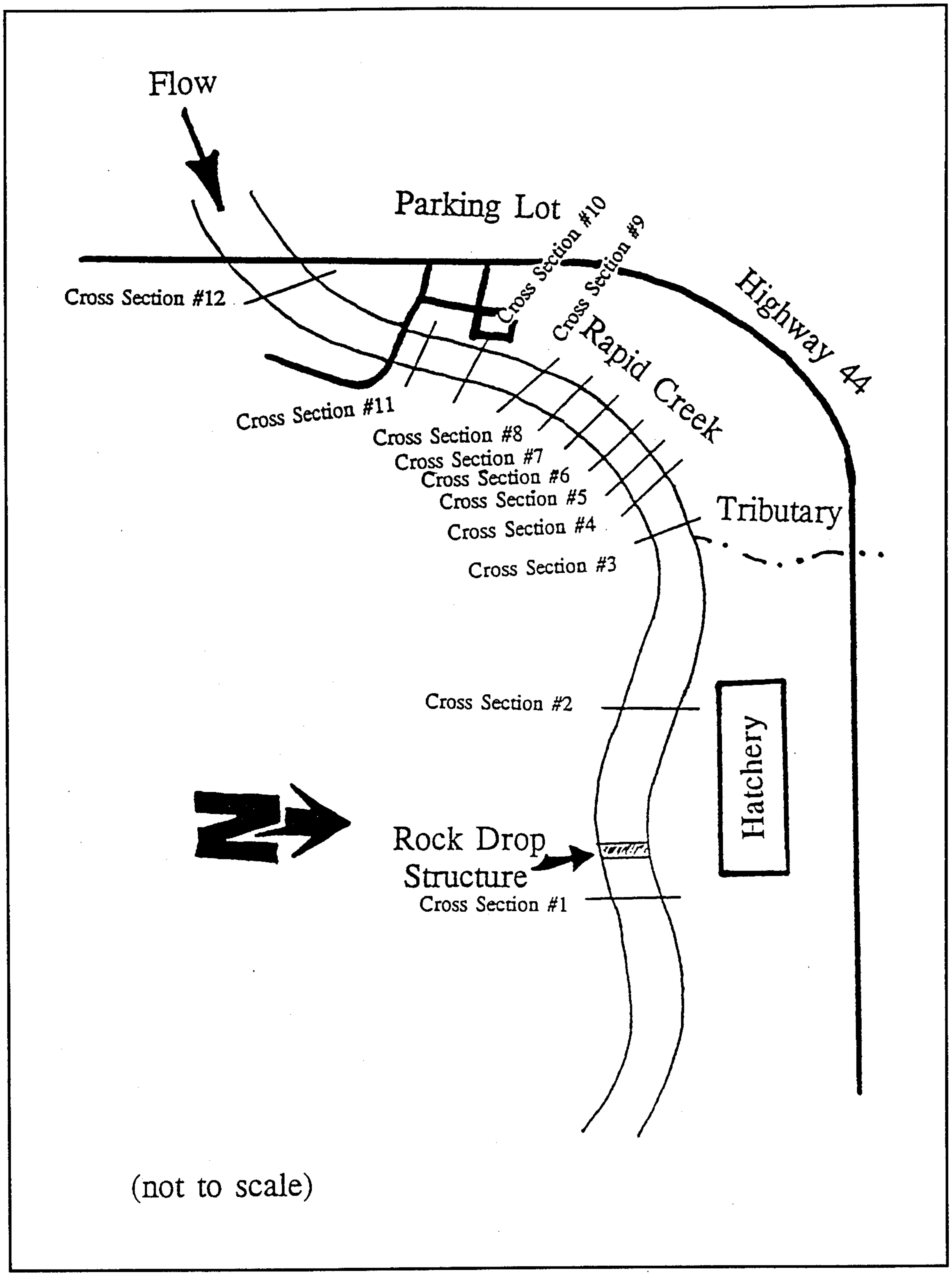


Figure 12. Natural reach cross sections map

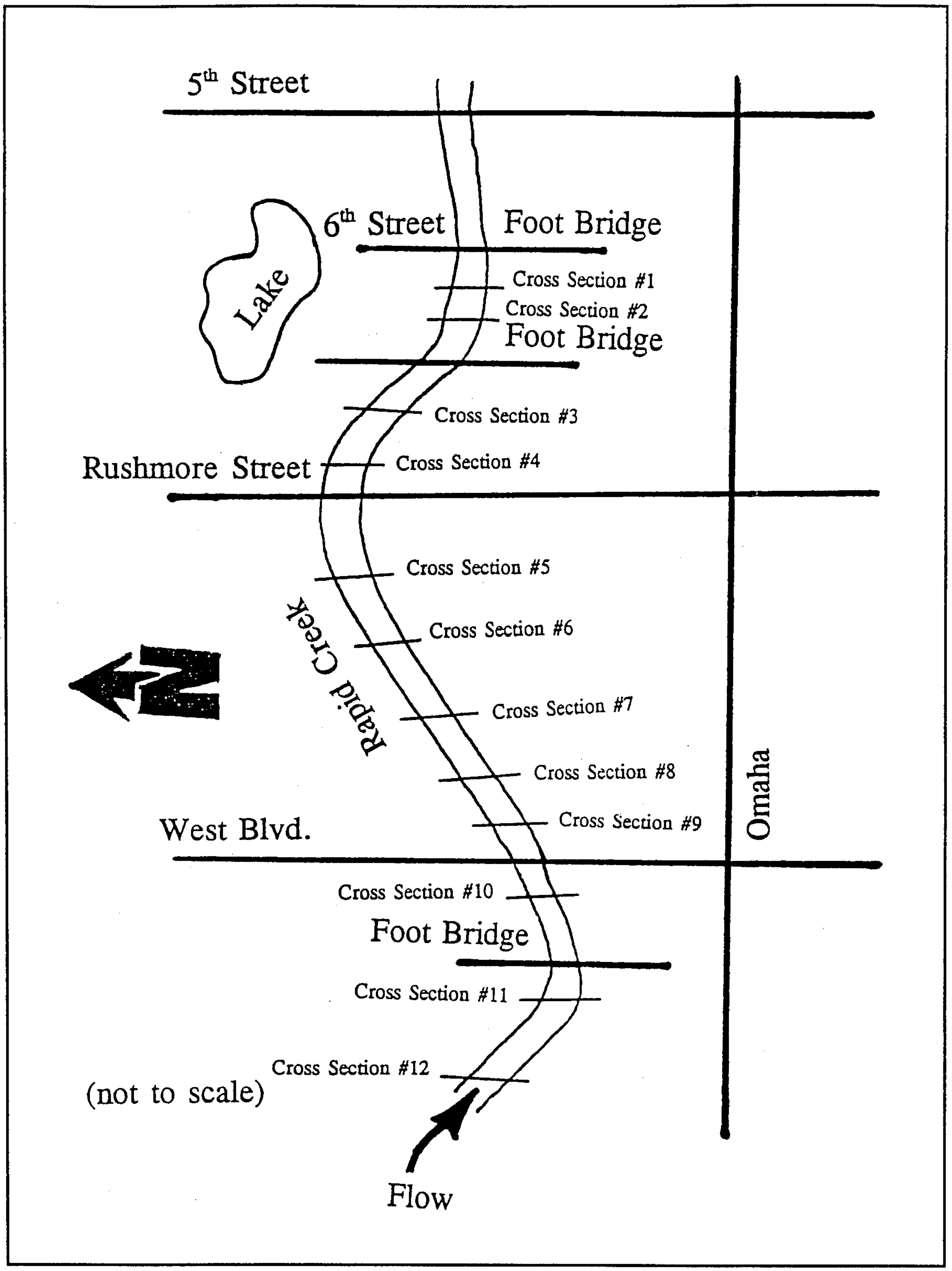


Figure 13. Restored reach cross sections map

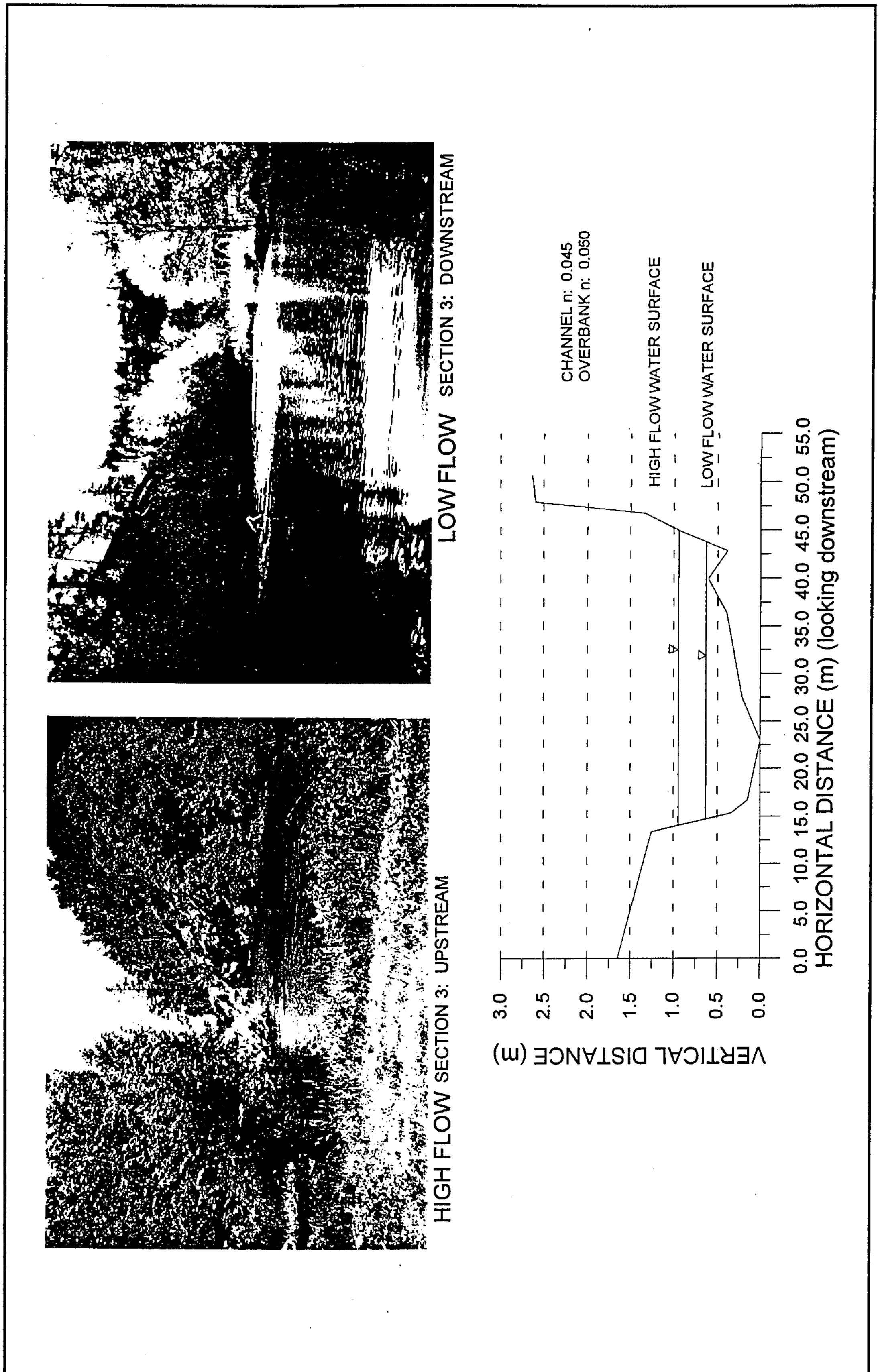


Figure 14. Natural cross section 3

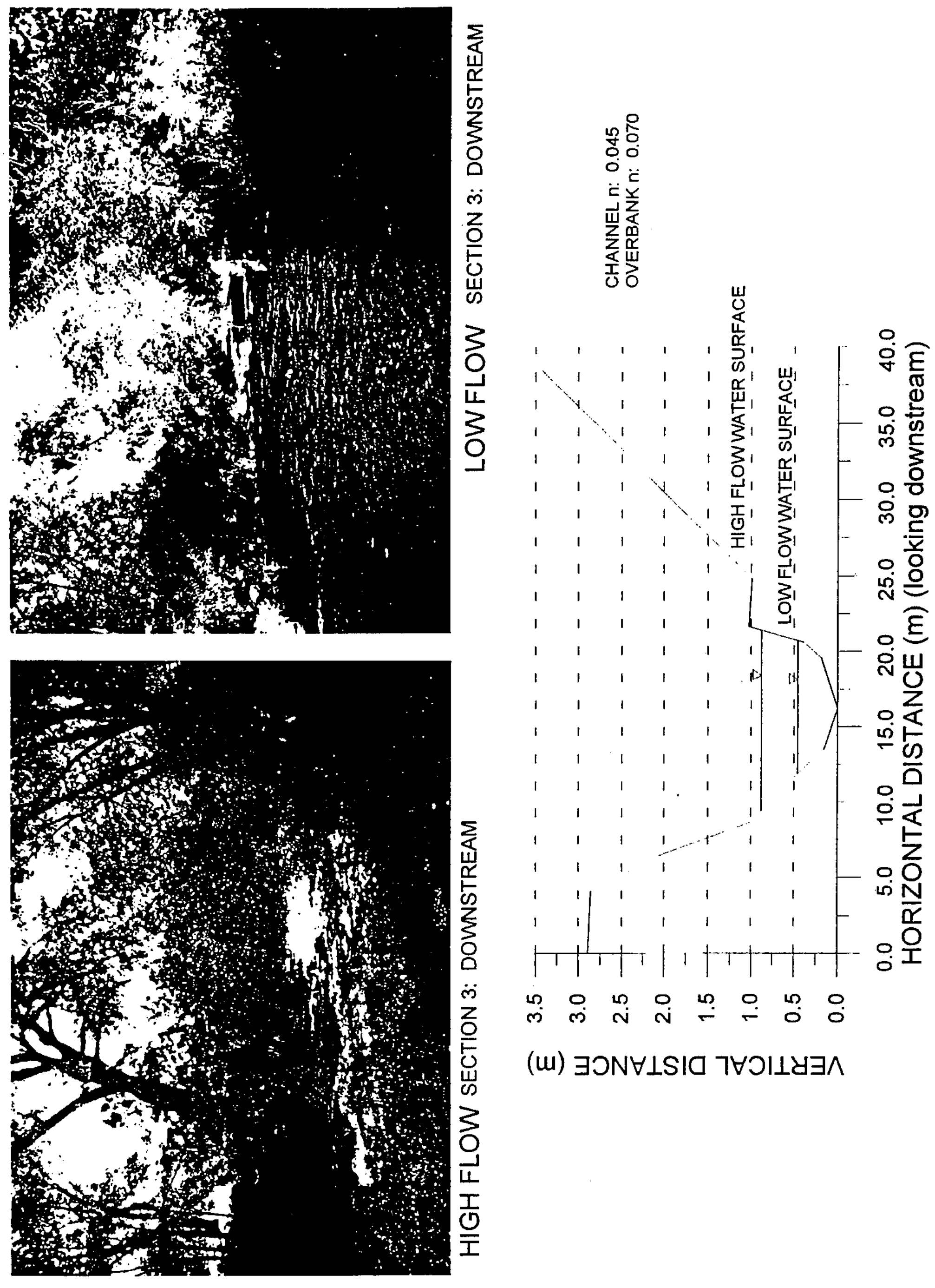


Figure 15. Restored cross section 3

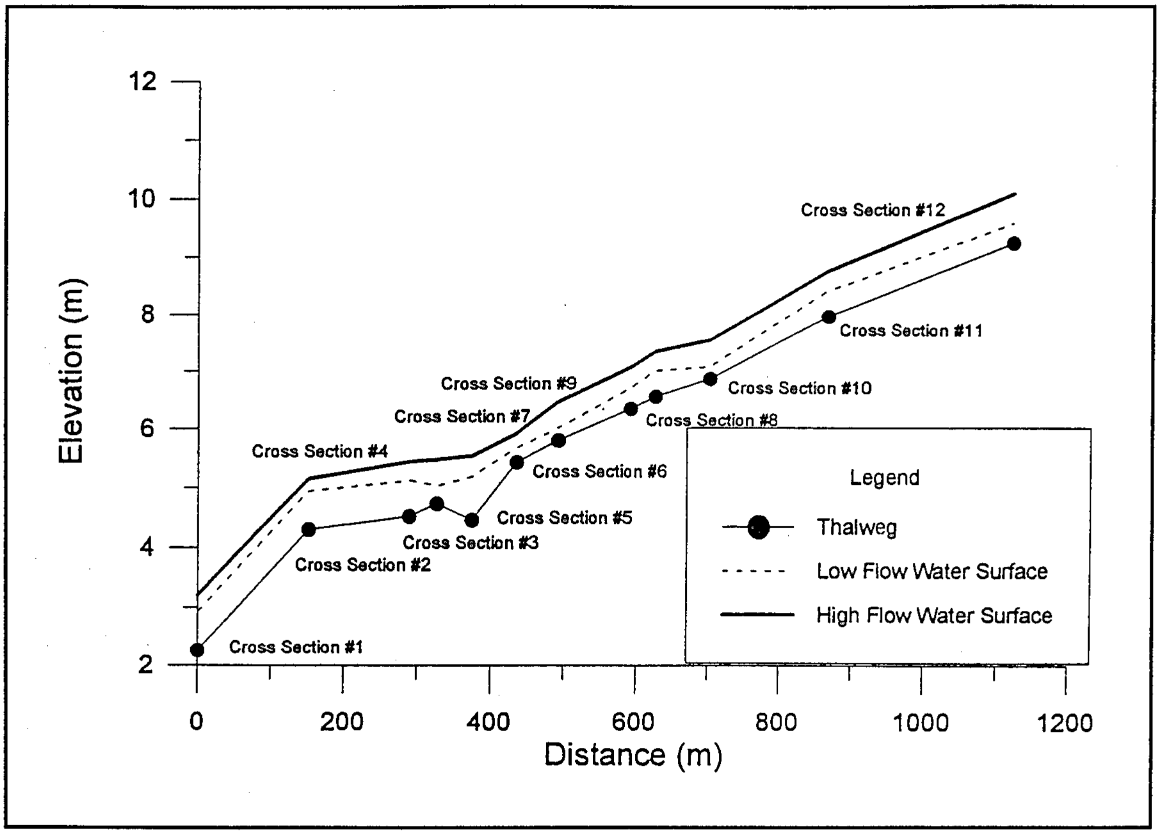


Figure 16. Natural reach longitudinal profile

Water temperature and dissolved oxygen measurements were obtained at both reaches. During high-flow conditions, the dissolved oxygen levels in the restored reach ranged from 9.7 to 11.0 mg/l, and water temperatures ranged from 11 to 17 °C. The standard reach had slightly higher dissolved oxygen levels of 11.2 to 12.0 mg/l and a constant temperature of about 10 °C. At low flow, the restored reach dissolved oxygen levels ranged from 8.3 to 16.1 mg/l with a water temperature of about 16 °C. The standard reach had 3.5 to 7.5 mg/l dissolved oxygen levels with water temperatures of about 13 °C.

Bedload and suspended sediment samples were obtained for both the standard and restored reaches of Rapid Creek. Appendix G presents the sediment gradation curves for the bedload sediment at high- and low-flow conditions. Sediment transport capacity was calculated for suspended and bedload sediment at high and low flows and is summarized in Table 6.

Armor layer and substrate samples were obtained to characterize the channel beds of the standard (natural) and restored reaches. Substrate gradation curves for the standard (natural) and restored reaches are depicted in Appendix H. Appendix H also presents the standard reach and restored reach armor layer gradation curves.

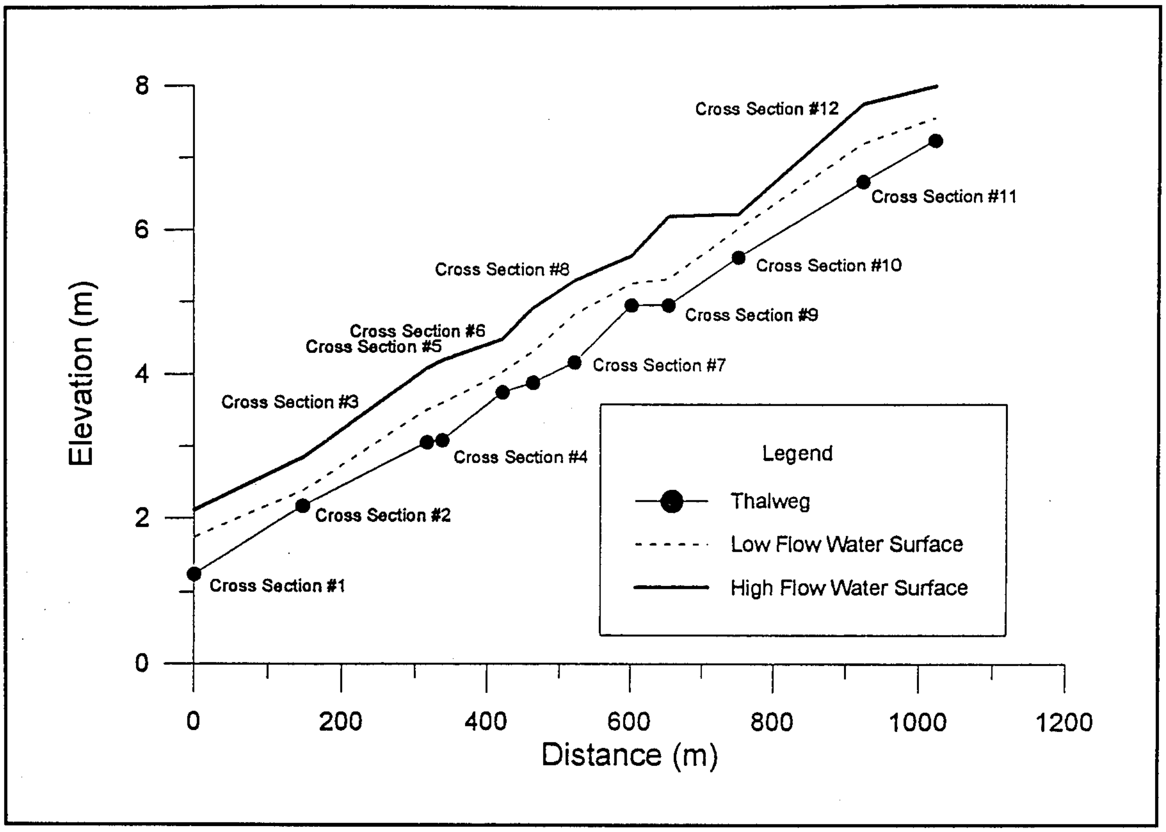


Figure 17. Restored reach longitudinal profile

Standard and restored reach field data comparison

Physical aspects of the channel reaches were quantified from the field data collected. Standard and restored reaches both possessed bend and straight sections. The standard cross sections tend to be slightly wider (average observed topwidth was 4.57 m wider at low flow and 2.56 m wider at high flow) than the restored sections.

Bed slopes were derived from the thalweg profiles presented in Figures 16 and 17. The standard reach has a bed slope of 0.0062, and the restored reach has a bed slope of 0.0058. Since the difference in slope between the standard and restored reaches is only 0.0004, the reach slopes were considered similar.

Velocity-depth data for the representative cross sections are recorded in Appendix A. The standard reach tends to exhibit lower velocity values than the restored reach. The average velocity in the restored reach was 0.64 m/sec under observed low-flow condition. The standard reach average velocity was 0.30 m/sec for the observed low-flow condition. Under the observed high-flow condition, the restored reach had an average velocity of 1.16 m/sec, while the standard reach had an average velocity of 0.94 m/sec.

Table 4
Recorded Water Surface Elevations

Section	Water Surface Elevation	
	High Flow, m	Low Flow, m
Restored Reach		
1	2.23	1.74
2	2.83	2.38
3	4.08	3.51
4	4.08	3.60
5	4.45	4.02
6	4.75	4.30
7	5.27	4.82
8	5.61	5.24
9	6.16	5.30
10	6.37	6.00
11	7.89	7.19
12	7.89	7.53
Standard Reach		
Section	High Flow, m	Low Flow, m
1	3.35	2.93
2	5.12	4.94
3	5.43	5.12
4	5.39	5.03
5	5.58	5.18
6	5.91	5.67
7	6.40	6.00
8	7.07	6.71
9	7.32	6.98
10	7.56	7.07
11	9.02	8.41
12	10.03	9.57

Table 5
Measured and Simulated Flow Values

Restored Reach					
	Measured Flows, m^3/s		Simulated Flows, m^3/s		
Section	High	Low	High	Intermed.	Low
1	7.99	1.52	11.98	4.75	0.76
2	10.20	1.48	15.29	5.84	0.74
3	8.08	1.53	12.12	4.81	0.77
4	7.57	1.28	11.35	4.42	0.64
5	8.26	1.42	12.39	4.84	0.71
6	8.87	1.34	13.31	5.10	0.67
7	7.79	1.29	11.69	4.54	0.64
8	8.10	1.29	12.15	4.69	0.64
9	7.17	1.25	10.75	4.21	0.63
10	7.97	1.32	11.95	4.64	0.66
11	8.81	1.31	13.22	5.06	0.65
12	8.03	1.49	12.05	4.76	0.75
Standard Reach					
	Measured Flows, m^3/s		Simulated Flows, m^3/s		
Section	High	Low	High	Intermed.	Low
1	1.49	0.88	6.48	2.60	0.44
2	2.82	0.58	4.23	1.70	0.29
3	6.88	0.57	10.32	3.73	0.29
4	7.24	0.51	10.86	3.88	0.26
5	7.14	0.45	10.71	3.79	0.23
6	8.02	0.57	12.03	4.30	0.28
7	7.73	0.52	11.60	4.13	0.26
8	7.47	0.58	11.20	4.03	0.29
9	7.18	0.47	10.76	3.82	0.24
10	8.39	0.37	12.59	4.38	0.19
11	11.18	0.54	16.76	5.86	0.27
12	8.09	0.50	12.13	4.29	0.25

Table 6
Calculated Suspended Sediment Transport

Sample Number	Sediment Concentration by Volume, mg/l	Sediment Transport
High Flow, Restored Reach[1]		
1	25.75	17956.11
2	19.36	13503.94
3	15.04	10484.68
4	20.52	14309.8
5	17.77	12392.71
6	18.54	12929.6
7	17.85	12449.68
High Flow, Natural Reach[2]		
1	20.81	15070.4
2	12.55	9091.941
3	23.29	16868.18
4	20	14485.34
5	18.49	13391.41
6	25.26	18297.3
7	33.78	24468.49
Low Flow, Restored Reach[3]		
1 D/S	9.59	1266.993
2 D/S	10.77	1422.456
3 D/S	21.27	2809.78
4 D/S	12.38	1635.397
5 D/S	11.43	1510.111
6 D/S	11.48	1517.458
7 D/S	46.24	6109.549

[1] kg/day based on 8.07 m^3/s.
[2] kg/day based on 8.38 m^3/s.
[3] kg/day based on 1.53 m^3/s.

(Continued)

Table 6 (Concluded)			
Low Flow, Natural Reach[4]			
Sample Number	Sediment Concentration by Volume, mg/l	Sediment Transport	
1 U/S	92.03	2927.384	
2 U/S	5.41	1721.1409	
3 U/S	14.88	473.2229	
4 U/S	7.27	231.188	
5 U/S	5.57	177.1126	
6 U/S	22.26	708.0689	
7 U/S	11.93	379.6153	
Bedload Sediment Transport			
	Sample Size, g	Time, min	Sediment Transport, kg/day
Restored Reach High Flow	173.5	20	12.492
	4.137	20	0.297864
Restored Reach Low Flow	0.265	20	0.01908
	2.339	20	0.168408
Natural Reach High Flow	0.779	20	0.056088
	1.652	20	0.046944
Natural Reach Low Flow	2.07	20	0.14904
	0.372	20	0.026784

[4] kg/day based on 0.37 m^3/s.

Water surface elevations were surveyed for each cross section under high- and low-flow conditions. The recorded water surface elevations for the standard and restored reaches surveyed are summarized in Table 4. Arbitrary elevation datums were assigned to both reaches, and the water surface elevations were linked to the topography. Depths were considered similar for both reaches (average depth was 0.39 m for both reaches at observed low flow; 0.88 m for the restored reach and 0.85 m for the standard reach at observed high flow). At the observed low flow, measured depths ranged from 0.21 m to 0.52 m for the restored reach and 0.15 m to 0.67 m for the standard reach. At the high observed flow, measured depths ranged from 0.73 m to 1.10 m for the restored reach and 0.49 m to 1.10 m for the standard reach.

The calculated high- and low-flow discharges and the simulated discharges for each cross section are presented in Table 5. Discharge values were generally higher in the restored reach (average discharge for the restored reach was

0.85 m^3/s higher at low observed flow and 1.05 m^3/s higher at high observed flow). The higher discharge at the restored reach is attributed to the additional drainage that contributes to Rapid Creek over the 8.05 km between the reaches.

The dissolved oxygen levels were 9.7 to 11.0 mg/l (10.0 mg/l average) in the restored reach and 11.2 to 12.0 mg/l (11.7 mg/l average) in the standard reach during the high-flow condition. The 1.7-mg/l average difference in dissolved oxygen is not considered significant when DO levels exceed 7.5 mg/l. The average water temperatures were 14.3 °C in the restored reach and 9.6 °C in the standard reach during high-flow conditions.

The restored reach had 8.4 to 16.1 mg/l (12.6 mg/l average) of dissolved oxygen, while the standard reach had 3.5 to 7.5 mg/l (5.0 mg/l average) dissolved oxygen under low observed discharge. The average water temperatures were 16.2 °C in the restored reach and 13.5 °C in the standard reach. Dissolved oxygen levels and temperatures were considered similar between reaches at high flow. However, at low flow, the natural reach had a lower dissolved oxygen content, probably caused by the wider channel, lower average velocity, and fewer riffles to aerate the stream.

Bedload samples were collected in each reach. During the high-flow condition, the median grain size D_{50} was approximately 0.3 to 0.4 mm in both reaches. At low flow, the average D_{50} for the standard reach was 1.25 mm and the restored reach D_{50} was 2.6 mm. The larger bedload material observed at low flow may be attributed to an upstream disturbance. This disturbance loosened the bed, initiated its transport, and resulted in sampling error. The bedload samples were relatively small (0.3 to 4.1 grams collected over 20 minutes). The small bedload sample size indicates that little sediment transport was caused by bedload motion. Appendix G presents the bedload sample gradation curves. At the observed high-flow condition, the restored reach has a suspended sediment transport capacity of 10,000 to 18,000 kg/day, while the standard reach has a suspended sediment transport capacity of 9,000 to 24,000 kg/day. At the observed low-flow condition, the restored reach has a higher suspended sediment transport capacity of 1,000 to 6,000 kg/day versus the 200 to 3,000 kg/day for the standard reach. The calculated sediment transport capacities for each reach (based on suspended and bed load samples) are summarized in Table 6.

The armor layer and substrate were sampled in both standard and restored reaches. Armor layer and substrate sample gradation curves are presented in Appendix H. The armor layer D_{50} was 70 mm in the standard reach and 54 mm in the restored reach. Substrate D_{50} for the standard and restored reaches were 20 mm and 43 mm, respectively.

HEC-2 Results

HEC-2 decks were prepared to simulate the hydraulic responses of the standard and restored reaches based upon the input geometry, slope, discharge, and water surface elevation values. The HEC-2 models were calibrated at observed discharge levels to verify the channel roughness expressed as Manning's n.

The calibrated HEC-2 decks were run five times for each reach. The five runs consisted of high- and low-observed flow conditions and simulated discharges that were lower than the low observed flow, between the high- and low-observed flows, and higher than the observed high flow. The HEC-2 results for the five discharge conditions are presented in Appendix I. Information presented in the tables of Appendix I includes the cross section number SECNO, the horizontal distance to the next downstream cross section in feet XLCH, the minimum elevation or channel thalweg in feet ELMIN, the discharge in cubic feet per second Q, the channel water surface elevation in feet CWSEL, the average flow depth in feet DEPTH, the channel velocity in feet per second VCH, the channel cross-sectional area in square feet AREA, and the channel topwidth in feet TOPWID for each flow condition.

Table 7 presents the average discharge, depth, velocity, and topwidth values for the standard and restored reaches for the five simulated flow conditions. The average discharge in the restored reach is 0.40 m^3/s to 1.53 m^3/s higher than the standard reach in all simulations. However, the average depth is similar for both reaches ($\pm$ 0.06 m) at each simulated discharge. The restored reach has a higher average velocity than does the standard reach (0.21 to 0.34 m/sec) for all discharges. The channel topwidth in the standard reach is higher (1.22 to 4.57 m) than the restored reach. The standard reach is generally wider, slower, and lower in discharge than the restored reach.

RCHARC Results

RCHARC provided a habitat comparison between the standard and restored reaches of Rapid Creek. The RCHARC methodology is based on the assumption that, given similarity of habitat parameters (i.e., bed slope, water temperature, dissolved oxygen, cover, etc.), habitat comparisons may be made through the examination of the bivariate depth-velocity distributions. Channel reaches with similar bivariate distributions (frequency of given velocity-depth pairs) possess similar hydraulic characteristics. If the reaches exhibit comparable bed slopes, water temperatures, dissolved oxygen levels, stream cover, etc., a comparison of hydraulic parameters will yield an indication of overall habitat similarity. The observed field data were processed through the RCHARC model, then the simulated flow output from HEC-2 was processed.

Table 7 Average Hydraulic Parameters					
HEC-2 Simulation	Reach	Q, m^3/s	Depth, m	Vel, m/s	T.W., m
Low Observed Flow	Restored	1.39	0.40	0.64	8.84
	Natural	0.54	0.40	0.30	13.41
High Observed Flow	Restored	8.24	0.88	1.16	17.68
	Natural	7.19	0.85	0.94	20.12
Lowest Simulated Flow	Restored	0.68	0.27	0.55	7.92
	Natural	0.28	0.34	0.27	12.19
Intermediate Simulated Flow	Restored	4.81	0.70	0.94	12.80
	Natural	3.88	0.70	0.73	16.76
Highest Simulated Flow	Restored	12.35	1.04	1.31	20.42
	Natural	10.82	1.00	1.07	21.64

The RCHARC output of the observed flows, restored reach run is presented in Appendix F. The output from the restored reach RCHARC simulation does not easily lend itself to comparative analysis. In the interest of reducing output and facilitating analysis, the RCHARC results were plotted in three dimensions (depth, velocity, and frequency of occurrence) as presented in Figures 18 through 27. Each figure presents the 3-D bivariate plot of velocity depth versus frequency of occurrence in either the standard or restored reach for one of the five flow conditions. The bivariate distributions at specific discharge levels may be qualitatively evaluated and habitat similarities compared. The frequency of occurrence of depth-velocity pairs was classified as low, intermediate, and high where: low = 0 to 1 percent, intermediate = 1 to 2 percent, and high = >2 percent.

A qualitative comparison of the bivariate distributions at each discharge was performed. The observed standard reach, low-flow condition bivariate distribution is presented in Figure 18. A comparison made with the bivariate distribution for the restored reach low-flow condition (Figure 19) reveals that the standard reach has less diversity of depth and velocity than does the restored reach. The standard reach has a higher concentration of low velocity, greater depth values, while the restored reach has more intermediate depth, intermediate velocity pairs. A comparison of the standard and restored reach bivariate plots at high observed flow conditions (Figures 20, and 21, respectively), indicates that both reaches possess similar velocity-depth distributions. Both reaches have a high concentration of low-depth, low-velocity pairs representing overbank flow. Low concentrations of intermediate depths, and low-to-intermediate velocity pairs occur in the standard reach. Intermediate to deep depths and intermediate velocity pairs are observed in the restored reach. The majority of the velocity-depth pairs is distributed in an even manner over the remaining surface.

Bivariate plots of the lowest simulated flow condition, Figures 22 (standard) and 23 (restored), reveal a more diverse velocity-depth distribution in the restored reach. Both reaches have a high occurrence of low-velocity values at all depths.

A comparison of bivariate plots at the intermediate simulated flow indicates that both reaches have a spike at low depth, low velocity. The standard reach (Figure 24) has a concentration of medium depth, low-to-intermediate velocity values. The restored reach (Figure 25) has a small spike at medium velocity, medium depth values. Both reaches exhibit similar distributions.

Bivariate plots for the highest simulated flow condition, Figures 26 (standard) and 27 (restored), show a concentration of low depth, low velocity values for both reaches. Again, the standard reach appears to have a concentration of intermediate depth, low-to-medium velocity values. The standard reach is more diverse than the restored reach at this flow condition.

The bivariate plots for the restored and standard reaches are similar at the flow values presented. At the lowest simulated flow, the restored reach has a more diverse distribution of velocity-depth values while the standard reach has concentrated low-velocity values at all depths. The observed low-flow condition exhibited the same trend: slightly more diverse distribution for the restored reach but a concentration of low velocity, low depth values in both reaches. The intermediate simulated flow again shows the low velocity, low depth trend in both reaches. The standard reach indicates a more diverse velocity-depth distribution at the intermediate simulated discharge than the restored reach. At the high observed flow condition, similar results were observed: the concentration of low velocity, low depth values observed in both reaches were considered diverse. Both reaches have a concentration of low depth, low velocity values at the high simulated flow, but the standard reach appears to be more diverse. Since RCHARC cannot quantitatively correlate hydraulic parameters, a qualitative comparison of the bivariate plots is the only means of comparing habitat quality.

The results of the bivariate velocity-depth analysis between the standard and restored reaches of Rapid Creek indicate similar hydraulic conditions. At lower flow conditions, the restored reach is more hydraulically diverse than the standard reach. From the intermediate simulated to observed high discharges, the standard and restored reaches have similar characteristics. A comparison of the highest simulated flow condition indicates that more diverse hydraulic conditions exist in the standard reach than in the restored channel. The more diverse velocity-depth distribution in the standard reach at high-flow conditions reflects the topographic variation in the extreme overbanks. The extreme overbanks in the restored reach are comparatively more homogeneous. The restored reach exhibited similar or greater hydraulic diversity than the standard reach except at the highest simulated flow. Since both reaches exhibit similar slope, water temperature, dissolved oxygen, vegetation, etc., the habitat quality of the restored reach is considered comparable to the standard reach.

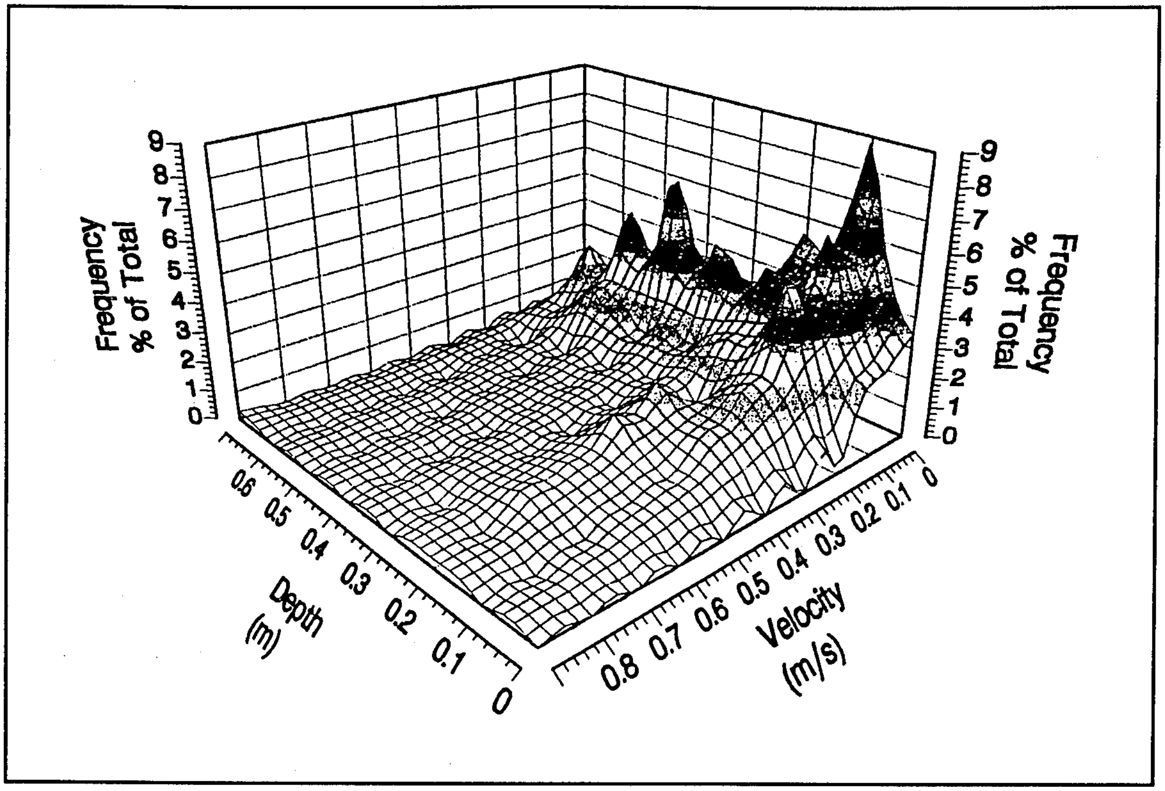


Figure 18. Velocity-depth bivariate distribution; Rapid Creek standard reach, low-flow condition

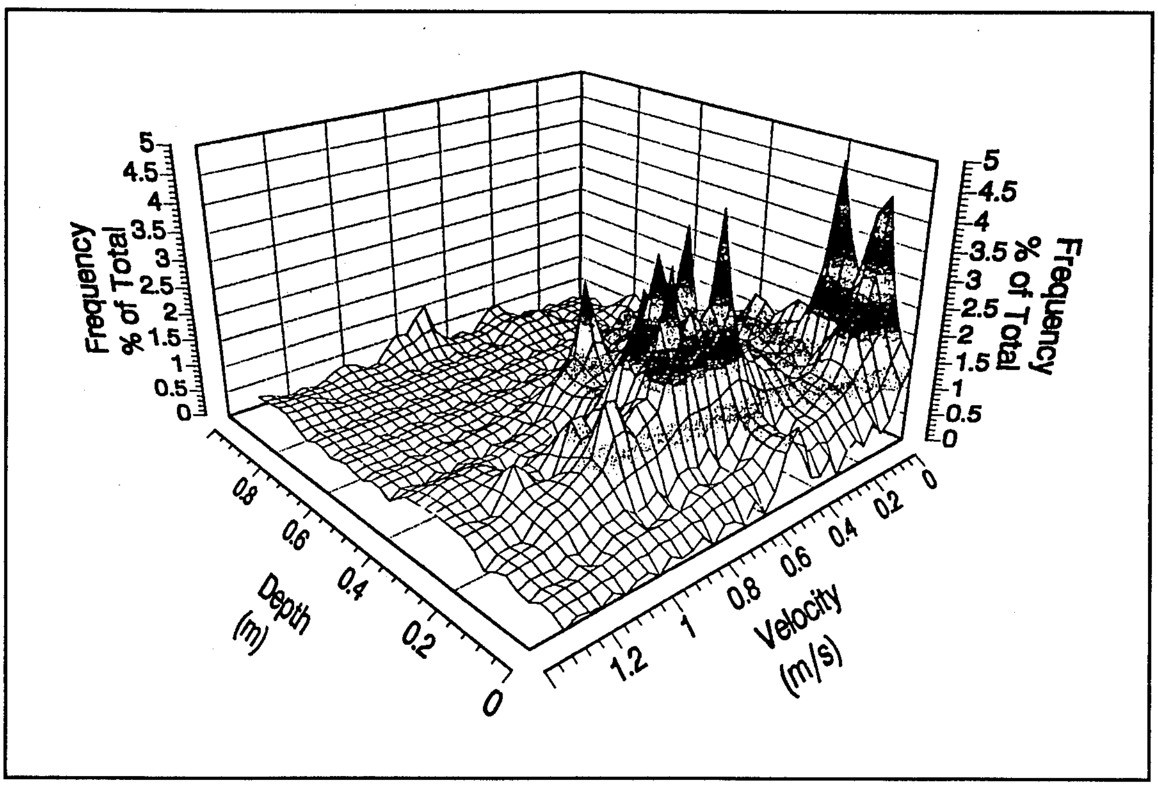


Figure 19. Velocity-depth bivariate distribution; Rapid Creek restored reach, low-flow condition

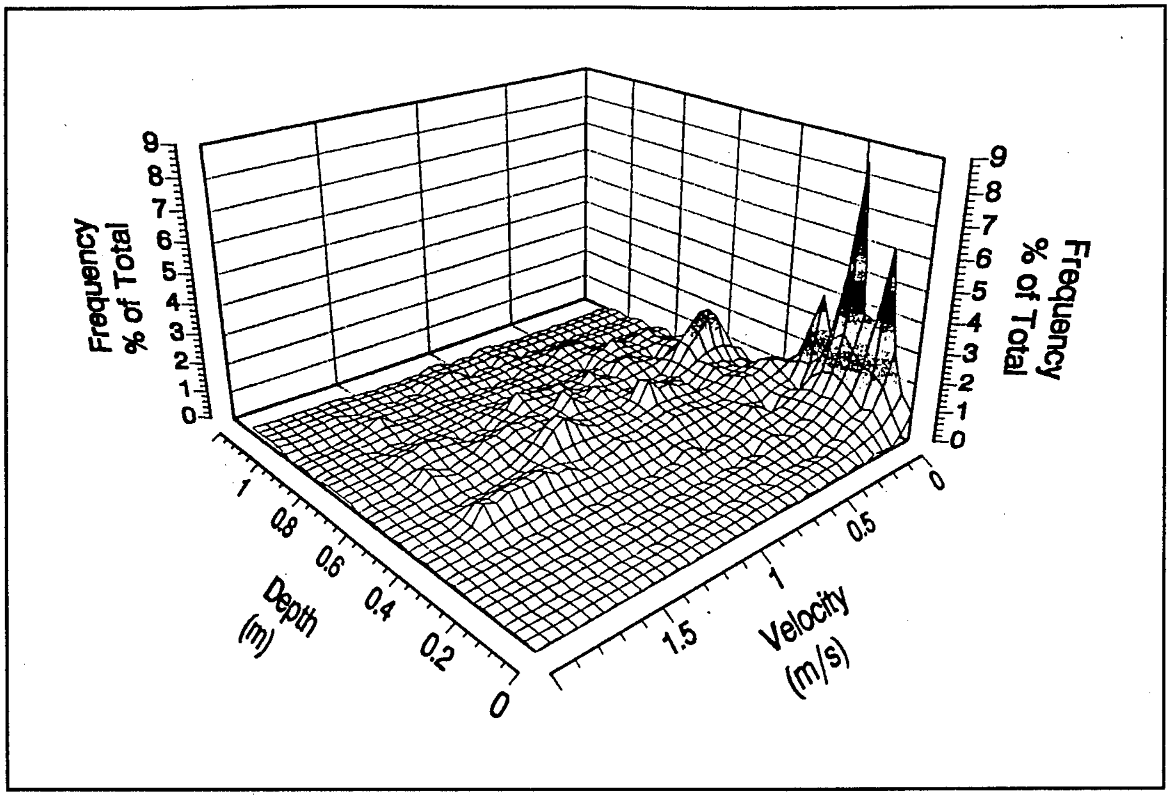


Figure 20. Velocity-depth bivariate distribution; Rapid Creek standard reach, high-flow condition

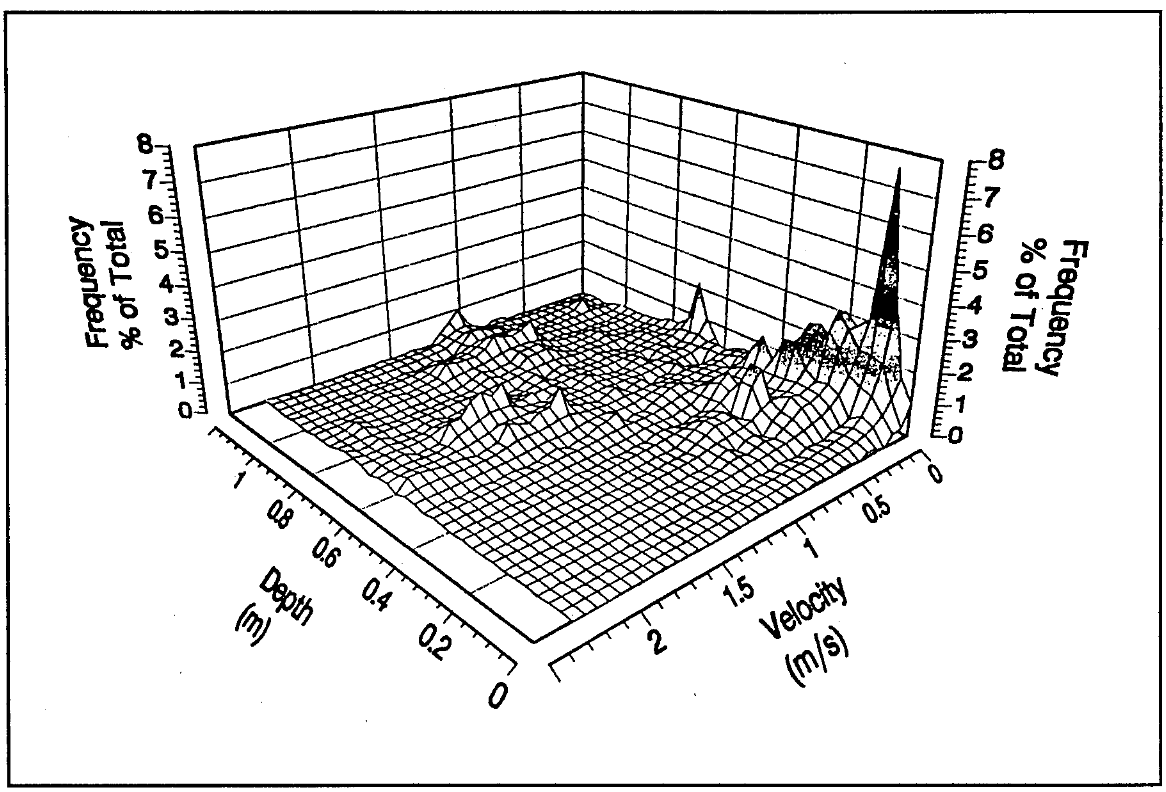


Figure 21. Velocity-depth bivariate distribution; Rapid Creek restored reach, high-flow condition

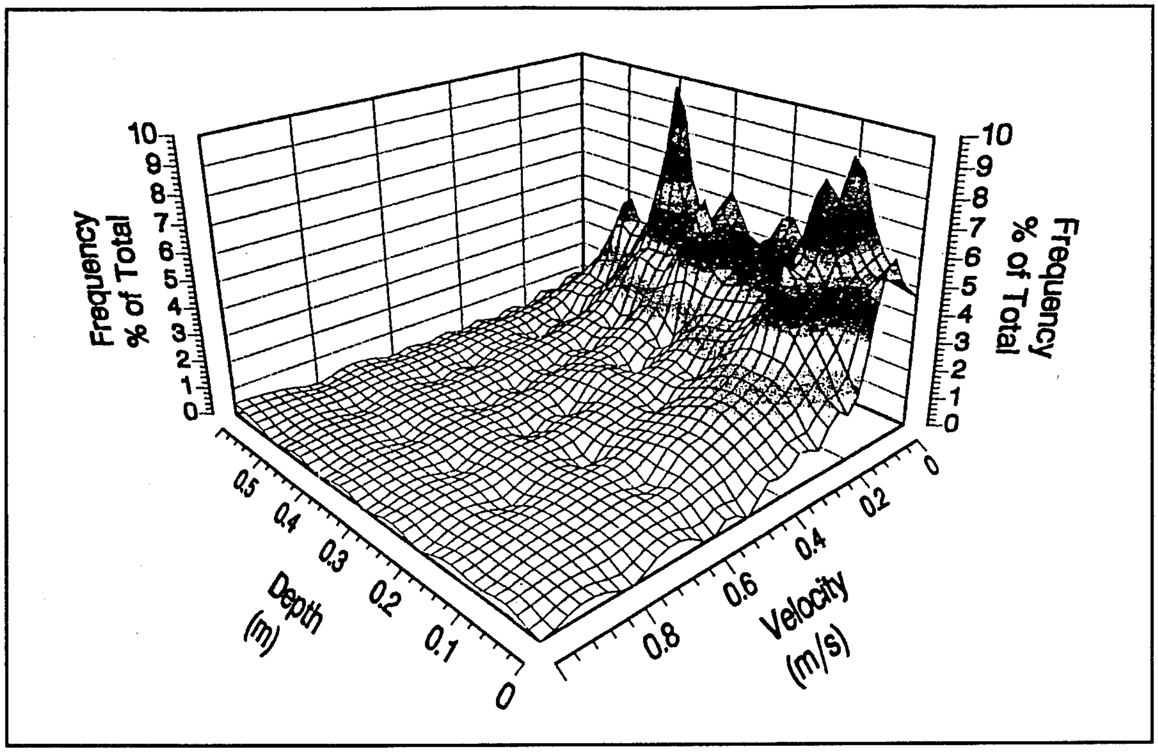


Figure 22. Velocity-depth bivariate distribution; Rapid Creek standard reach, lowest simulated flow

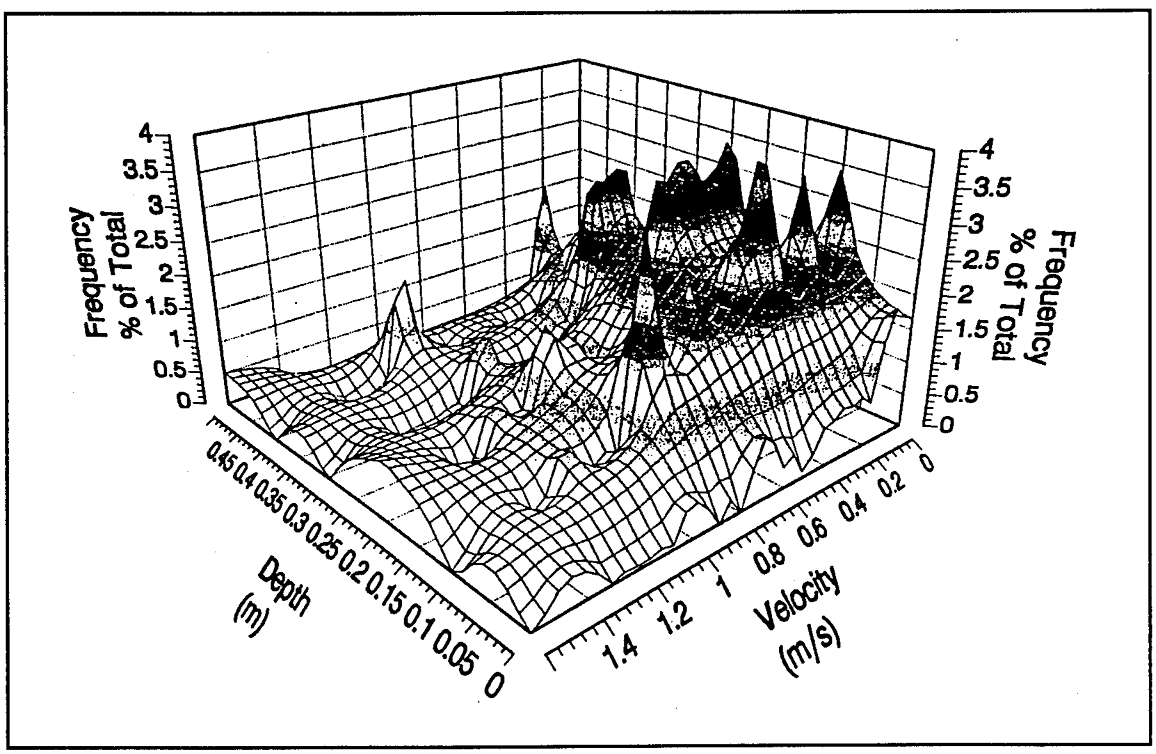


Figure 23. Velocity-depth bivariate distribution; Rapid Creek restored reach, lowest simulated flow

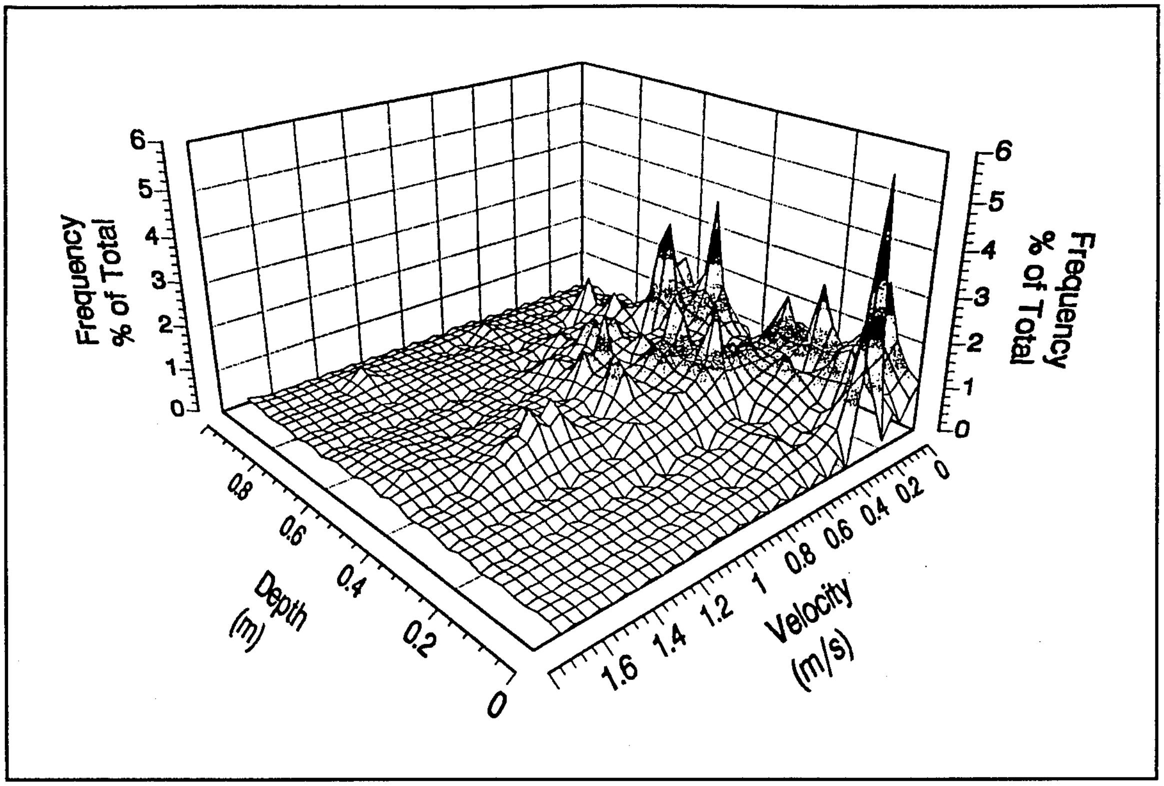


Figure 24. Velocity-depth bivariatedistribution; Rapid Creek standard reach, intermediate simulated flow

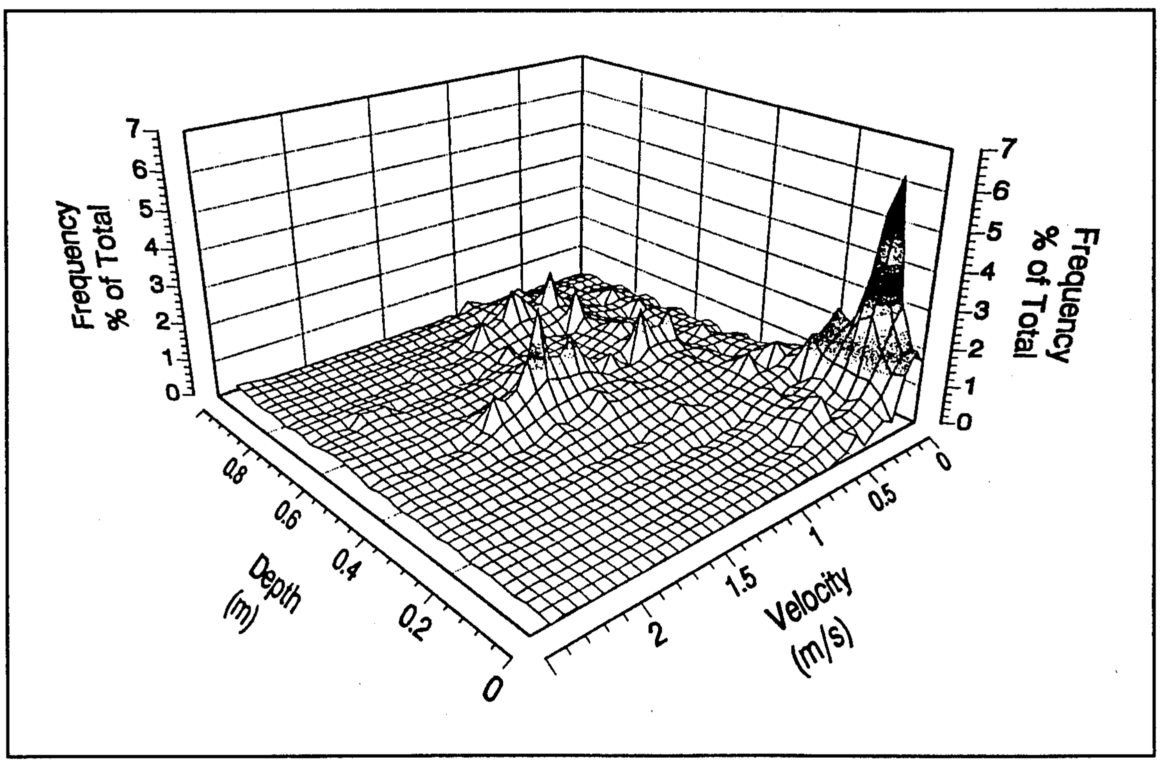


Figure 25. Velocity-depth bivariate distribution; Rapid Creek restored reach, intermediate simulated flow

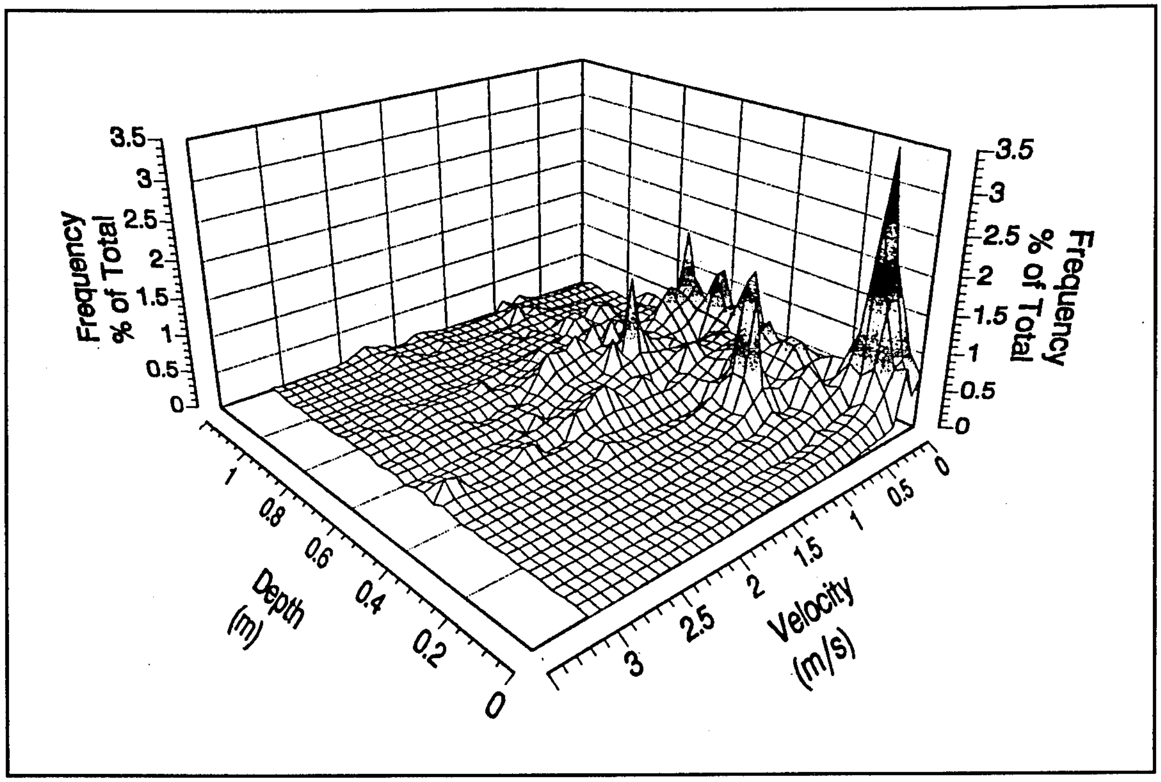


Figure 26. Velocity-depth bivariate distribution; Rapid Creek standard reach, highest simulated flow

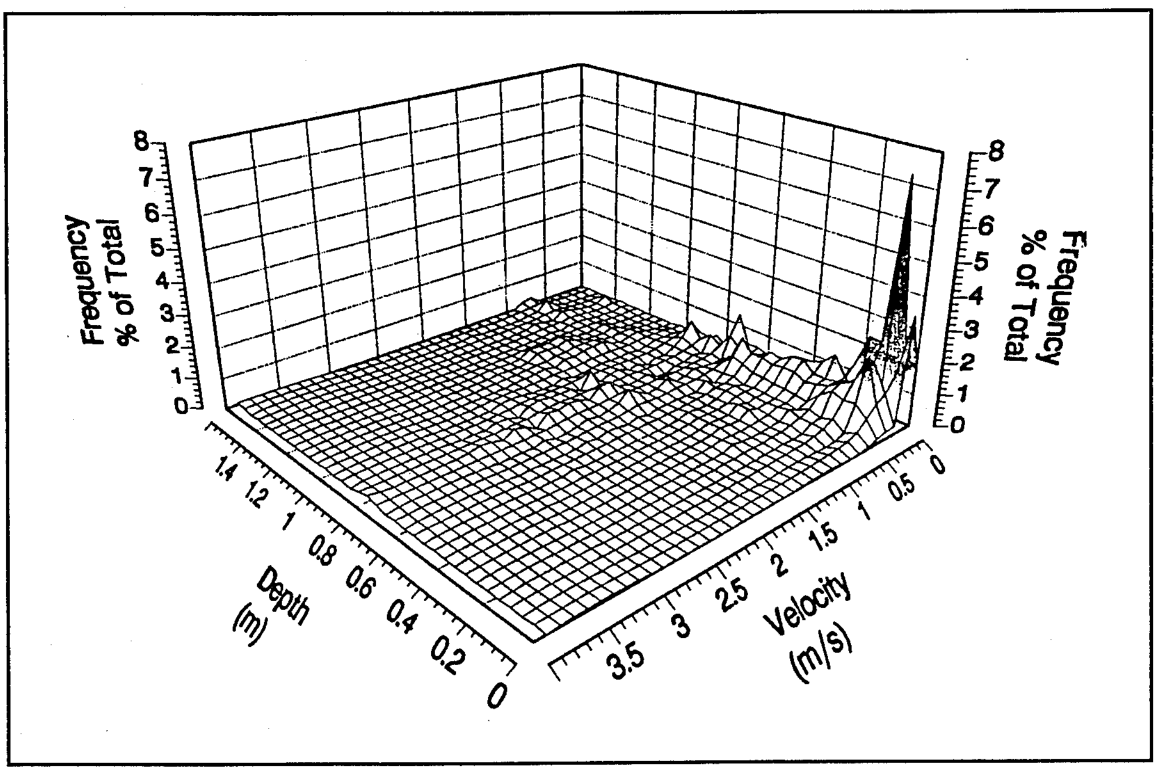


Figure 27. Velocity-depth bivariate distribution; Rapid Creek restored reach, highest simulated flow

Hydraulic and Habitat Design HEC-2 / RCHARC Comparison

HEC-2 approach

HEC-2 is traditionally used in the design of flood control features. Physical descriptions of the proposed channel (i.e., 3-D channel geometry, roughness coefficients, and the design discharge) are entered into the HEC-2 deck. HEC-2 computes water surface elevations, average velocity, average depth, topwidth, and other hydraulic parameters.

The HEC-2 deck can be used to simulate a specific section of a channel for any desired discharge condition. Once the channel geometry has been obtained (surveyed, or scaled from a topographic map) and entered into the HEC-2 format, hydraulic response of the channel (water surface elevation, flow velocity and depth, etc.) may be predicted. Engineers simulate existing channels and channel modifications with HEC-2 to evaluate flood conveyance.

HEC-2 is a valuable tool in hydraulic design. The results from HEC-2 studies and analysis may be used by designers as a guide in the improvement of hydraulic facilities. A major shortcoming of HEC-2, however, is its inability to directly assess habitat quality.

RCHARC / HEC-2 approach

RCHARC, in addition to HEC-2, may be used to provide an assessment of habitat impact resulting from specific channel alterations. Field observations and/or HEC-2 output serve as input parameters for RCHARC. Analysis of RCHARC bivariate output indicates hydraulic and habitat similarity between comparison reaches.

With the addition of a habitat evaluation program, such as RCHARC, typical hydraulic design projects can account for and assess habitat components. Flood control designs may be augmented with habitat enhancing structures such as meanders, boulders, pool riffle sequences, sills, dikes, deflectors, and bank cover. The hydraulic impact of specific habitat enhancement features may be simulated by incorporating them into the channel geometry of an existing HEC-2 deck. Low-flow channels built into a flood control channel may often include habitat enhancements without significantly affecting the high-flow conveyance of the main channel.

In the case of the Rapid Creek study, RCHARC results indicated that the restored reach exhibited similar hydraulic responses to that of the standard reach. Habitat variables such as dissolved oxygen, water temperature, and overhanging vegetation were similar between the comparison reaches. Since the RCHARC results and other habitat variables were similar for standard and restored reaches, it was concluded that the standard and restored reaches have similar habitat quality.

6 Summary, Conclusions, and Recommendations

Summary

An evaluation of the RCHARC model developed by the USACE was performed using field data collected on Rapid Creek. The field data were used as input for assessing the RCHARC model and to ascertain the hydraulic characteristics of the channel. A comparison of the RCHARC and HEC-2 methods is presented.

Hydraulic (HEC-2) Approach Conclusions

The traditional approach to channel design involves the study and modeling of hydraulic parameters in a proposed or existing channel. HEC-2 is a computer model for calculating water surface elevation, average flow velocity, flow depth and topwidth for a specific discharge. A knowledge of channel geometry and stream flow hydrology is necessary to execute the HEC-2 study. The HEC-2 analysis can be used to predict channel hydraulic response to various discharges. Flood control or structural habitat enhancement features may be modeled by HEC-2 to assess its hydraulic performance. Proposed modifications that may cause adverse hydraulic characteristics may be replaced or refined until the desired balance of flood control and habitat is achieved. The advantages and disadvantages of using the HEC-2 simulation approach for channel design are summarized.

Advantages

a. Advantages of conducting the HEC-2 hydraulic study on a channel are:

(1) HEC-2 is a traditional, accepted means of evaluating the flow capacity of a channel. Hydraulic analyses conducted with HEC-2 are commonly understood by engineers in the private, corporate, and Government sectors.

(2) HEC-2 is a relatively simple method for evaluating channel hydraulics. An experienced HEC-2 user can conduct an analysis in a timely, cost-effective manner. An array of existing field conditions may be evaluated with a minimum number of modifications to the program. The modular nature of HEC-2 decreases the need for extensive field work.

(3) HEC-2 can be useful for many types of riparian studies. Hydraulic information derived from HEC-2 simulations may be broadly used in urban growth studies, sediment analysis, and/or habitat analysis.

Disadvantages

b. The disadvantages of using HEC-2 are:

(1) HEC-2 is often viewed by hydraulic engineers as the only component of a stream study. The consideration of ecological habitat and other riparian elements is necessary for a complete assessment and understanding of the potential impacts resulting from channel modification.

(2) HEC-2 is unable to evaluate velocity and depth pairs laterally across a single cross section. Output from the HEC-2 simulation is in terms of average depth and velocity for an entire cross section.

(3) The HEC-2 simulation package is not easily understood by the nonengineering community.

(4) HEC-2 was not designed for, nor is commonly applied to, habitat assessment.

(5) HEC-2 analysis is not sensitive to slight changes in geometric diversity.

(6) The results of the HEC-2 flood control analysis can lead to a short-term solution. If increased runoff due to future development, erosion/sedimentation problems, and habitat impact considerations of modification are not considered, additional studies may eventually be required.

Habitat (RCHARC) Approach

The RCHARC model provides a means to compare the habitat quality potential of a proposed or rehabilitated channel reach with a reference ("standard comparison") channel reach exhibiting adequate habitat diversity. The inclusion of an RCHARC analysis to a traditional hydraulic design allows for a more comprehensive assessment of proposed channel modifications. The RCHARC approach to channel assessment incorporates the hydraulic information derived from the field into a formal habitat comparison. RCHARC sorts velocity and depth by their paired occurrence, and the bivariate distributions are compared for standard degraded, proposed, or restored reaches. If similarity is determined between the comparison reaches hydraulic parameters, habitat quality should be similar.

Advantages

a. The advantages of conducting an RCHARC analysis are:

(1) Because HEC-2 is used to determine the average channel hydraulic conditions for input into RCHARC, all the advantages of HEC-2 can be realized with an RCHARC analysis.

(2) RCHARC output may be used to compare hydraulic (velocity and depth) conditions and habitat similarity between proposed channel reaches.

(3) Similar hydraulic parameters at specified discharges indicate similar habitat and should also lead to similar sediment transport capacities.

(4) When depth and velocity frequency distributions are dissimilar between comparison reach conditions, habitat enhancement features, including dikes, boulders, pools, riffles, drops, etc., may be considered. Alternative designs may be introduced and assessed using RCHARC. The alternative designs may be analyzed and refined until RCHARC assessment indicates desirable habitat.

(5) The combined RCHARC/HEC-2 channel assessment procedure requires a team approach to evaluating the comparison reaches. Biologists, landscape architects, engineers, and geomorphologists may be needed to fully assess aesthetics, habitat, classify stream characteristics, and design flood control structures.

Disadvantages

b. The disadvantages of an RCHARC study are:

(1) Compared to the HEC-2 study, an RCHARC analysis is slightly more complex. Water surface elevation and cross-sectional geometry from HEC-2 must be reformatted and processed for input into RCHARC.

(2) The RCHARC procedure provides a quantitative means of evaluating comparison reaches. However, a procedure for performing a quantitative analysis has not yet been fully developed.

RCHARC Model Evaluation Summary

The RCHARC model provides output that allows the user to assess habitat quality (depth and velocity) between comparison or paired channel reaches. The premise is that the bivariate flow depth and velocity frequency distribution may be compared between two or more reaches; the more similar the bivariate frequency distributions, the more similar the habitat. A comparison of depth and velocity frequency distributions between two channel reaches with similar channel slope, water temperature, dissolved oxygen content, and vegetation, indicates the similarity of habitat quality between the reaches.

The RCHARC methodology requires the acquisition of field data, performance of an HEC-2 analysis, and execution of the IFG4 program (from PHABSIM), and execution of the RCHARC model. The RCHARC output is a distribution of the frequency of depth and velocity pairs. The bivariate frequency distribution of these depth and velocity pairs may be plotted using 3-D graphing software. The bivariate plots for the evaluation reaches are qualitatively compared at specific discharge levels.

RCHARC is applicable to all types of streams since it quantifies similarity of hydraulic parameters between reaches of the same stream. If the natural reach is considered to have good habitat (evidenced by fish counts or other biologic or qualitative manner) and the comparison reach has similar depth-velocity diversity, then the comparison reach is considered to have similar habitat quality. A comparable quality of habitat is expected.

The Rapid Creek RCHARC model results confirm field observations. The bivariate plots indicate that for each flow level studied, the standard and restored reaches have similar velocity-depth distributions. In addition, the standard and restored reaches have similar slope, water temperature, dissolved oxygen levels, and vegetation. Therefore, the RCHARC analysis indicates that the predicted habitat quality of the restored reach should be similar to that of the standard reach. During the course of the field surveys, similar quantities and sizes of fish were observed in the restored and standard reaches. Both the standard and restored reaches of Rapid Creek are considered gold metal level I fisheries by the South Dakota Department of Game Fish and Parks. Level I indicates at least 370 fish (200 mm or longer) per surface hectare.

Recommended guidelines for design and assessment studies

Historically, channel modification has focused on flood conveyance. However, channel modifications now are designed with aesthetic, habitat, flood control, and recreational considerations. Habitat considerations must be addressed in channel design. Modified channels must not only be capable of safely conveying flood flows but also provide habitat quality that is similar to natural conditions. Therefore, the proposed channel evaluation procedure presented in Figure 28 is recommended for a comprehensive assessment of channel design and/or modifications.

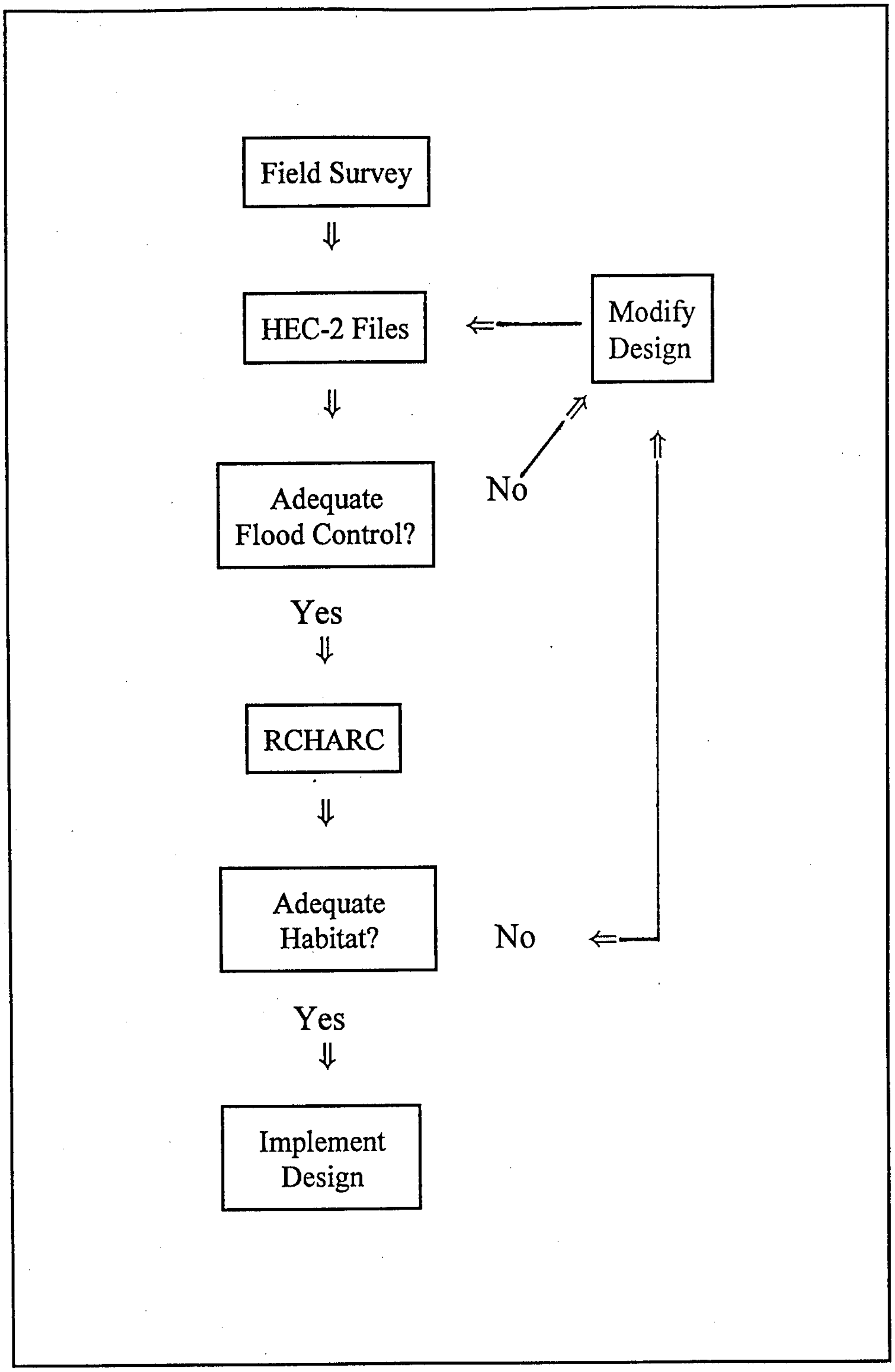


Figure 28. RCHARC / HEC-2 design flow chart

The proposed channel assessment procedure as indicated in Figure 28 is as follows:

Step 1: Collect pertinent field data. Field work should include topographic, water surface elevations, velocity and depth measurements, bed material and sediment sampling, water temperature and dissolved oxygen measurements, and observations of channel vegetation (Chapter 3).

Step 2: Create HEC-2 files. The field data must be reduced and input into HEC-2 decks. Channel geometry, water surface, roughness, discharge, and profile are needed for HEC-2.

Step 3: Assess flood control. Does the HEC-2 output indicate that the proposed design meet flood protection requirements? If flood control requirements are met, continue to Step 4. If flood control requirements are not met, adjustments must be made to the proposed design to comply, return to Step 2.

Step 4: RCHARC. Habitat is assessed using RCHARC to determine similarity of the velocity-depth distribution between the proposed design reach and a control reach.

Step 5: Assess Habitat. Does the RCHARC output reveal similar velocity-depth distributions between design and standard reaches? If the designed habitat is similar to the standard reach, continue to Step 6. If not, adjust design, and return to Step 2.

Step 6: Implement Design. If flood control and habitat analyses yield positive results, the design is completed and construction initiated.

Recommendations for RCHARC improvement

Although RCHARC is a relatively simple, sensible, and credible way to assess habitat between comparison channel reaches, several recommended enhancements are that:

a. In addition to the 10 cross sections per reach suggested by RCHARC, cross sections should be surveyed at noticeable grade changes (i.e., drop structures, riffles, etc.). More cross sections will improve the HEC-2 analyses and add to the database of velocity-depth pairs.

b. At least some of the velocity-depth points across each cross section should be included in the cross-sectional survey. Water surface elevation can be calculated from these points in addition to the bank stations.

c. The same instrumentation be used throughout the data acquisition process. This will eliminate any discrepancies resulting from inconsistently calibrated equipment.

d. A more comprehensive sampling of substrate and armor layer be conducted and included in the RCHARC methodology.

e. Careful attention is paid to the determination of Manning's n. IFG4 can be utilized to generate Manning's n values for each cell of the cross sections studied.

f. A spreadsheet approach be developed to implement RCHARC. The SAS programs that comprise the RCHARC computer model aspect of RCHARC require much output\input data restructuring. A spreadsheet would be more user friendly and efficient.

g. A quantitative element be added to the RCHARC analysis. The bivariate plots used in the Rapid Creek analysis were effective as visualization tools; however, a quantitative comparison of the reaches would be an improvement. Quantitative results would be useful in evaluating habitat design alternatives.

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Appendix A
Sample Velocity - Depth Data

Velocity & Depth

Discharge – 20.3 c.f.s.

Section #	Natural 3

Subsection #	STA (from LFT)	Depth (Ft)	Velocity (fps)	at Depth (Fraction)	Discharge (cfs)
1	0	0	0	0.8	0.0
				0.8	
				0.2	
2	7	1.4	0	0.8	0.0
				0.8	
				0.2	
3	12	1.7		0.8	1.7
			0.1	0.8	
			0.3	0.2	
4	17	2		0.6	2.0
			0.1	0.8	
			0.3	0.2	
6	22	1.9		0.6	2.4
			0.1	0.8	
			0.4	0.2	
8	27	1.9		0.6	1.2
			0.05	0.8	
			0.2	0.2	
7	32	1.8		0.6	2.3
			0.2	0.8	
			0.3	0.2	
8	37	1.3		0.8	1.3
			0.1	0.8	
			0.3	0.2	
9	42	1.2		0.6	0.8
			0	0.8	
			0.2	0.2	
10	47	1	0.1	0.6	0.5
				0.8	
				0.2	
11	52	0.9	0.1	0.6	0.5
				0.8	
				0.2	
12	57	0.5	0.1	0.6	0.3
				0.8	
				0.2	
13	62	0.6	0.1	0.8	0.3
				0.9	
				0.2	
14	67	0.9	0.2	0.8	0.9
				0.8	
				0.2	
15	72	0.7	0.2	0.6	0.7
				0.8	
				0.2	
16	77	0.3	0	0.6	0.0
				0.8	
				0.2	
17	79	0	0	0.8	0.0
				0.8	
				0.2	
18	88.5	0	0	0.8	0.0
				0.8	
				0.2	
19	90	0.4	0.9	0.8	0.6
				0.8	
				0.2	
20	92	0.8	1.4	0.6	1.7
				0.8	
				0.2	
21	94	0.7	1.9	0.6	2.7
				0.8	
				0.2	
22	96	0.4	0.5	0.6	0.4
				0.8	
				0.2	
23	98	0.5	0.4	0.6	0.5
				0.8	
				0.2	
24	100.5	0	0	0.8	0.0
				0.8	
				0.2	
25				0.6	
				0.8	
				0.2	

Velocity & Depth

Section #	Natural 3

Discharge = 242.9 c.f.s.

Subsection #	STA (from LFT)	Depth (Ft)	Velocity (fps)	at Depth (Fraction)	Discharge (cfs)
1	0	0	0	0.6	0.0
				0.8	
				0.2	
2	6	2.5		0.6	1.4
			0.1	0.8	
			0.1	0.2	
3	11	2.8		0.6	1.4
			0.1	0.8	
			0.1	0.2	
4	16	3		0.6	22.5
			1	0.8	
			2	0.2	
5	21	2.7		0.6	18.2
			0.8	0.8	
			1.8	0.2	
6	26	3		0.6	28.3
			1.1	0.8	
			2.4	0.2	
7	31	2.7		0.6	27.0
			1.5	0.8	
			2.5	0.2	
8	36	2.6		0.6	20.2
			1.1	0.8	
			2	0.2	
9	41	2.2		0.6	14.3
			1.2	0.8	
			1.4	0.2	
10	46	2.2		0.6	17.6
			1.3	0.8	
			1.8	0.2	
11	51	2.2		0.6	15.0
			0.8	0.8	
			1.3	0.2	
12	59	2.1		0.6	3.9
			0	0.8	
			0.5	0.2	
13	66	2		0.6	4.2
			0.5	0.8	
			0.2	0.2	
14	71	1.7		0.6	11.9
			1.1	0.8	
			1.7	0.2	
15	76	1.4		0.6	12.6
			1.3	0.8	
			2.3	0.2	
16	82	0.8	0	0.6	0.0
				0.8	
				0.2	
17	86	1.5		0.6	19.0
			1.3	0.8	
			3.3	0.2	
18	93	1.6		0.6	16.3
			2.3	0.8	
			2.8	0.2	
19	96	1.6		0.6	11.2
			1.5	0.8	
			2	0.2	
20	101	0	0	0.6	0.0
				0.8	
				0.2	
21				0.6	
				0.8	
				0.2	
22				0.6	
				0.8	
				0.2	
23				0.6	
				0.8	
				0.2	
24				0.6	
				0.8	
				0.2	
25				0.6	
				0.8	
				0.2	

Velocity & Depth

Section #	Restored 3

Discharge= 54.2 c.f.s.

Subsection #	STA (from LFT)	Depth (Ft)	Velocity (fps)	at Depth (Fraction)	Discharge (cfs)
1	0	0	0	0.6	0.0
				0.8	
				0.2	
2	3.5	1	0	0.6	0.0
				0.8	
				0.2	
3	4	1	0.9	0.6	0.7
				0.8	
				0.2	
4	5	1.1		0.6	1.2
			0.9	0.8	
			1.2	0.2	
5	6	1.2		0.6	1.3
			0.9	0.8	
			1.2	0.2	
6	7	1.3		0.6	1.6
			1.1	0.8	
			1.4	0.2	
7	8	1.3		0.6	1.7
			0.9	0.8	
			1.7	0.2	
8	9	1.4		0.6	2.2
			1	0.8	
			2.1	0.2	
9	10	1.2		0.6	1.9
			0.7	0.8	
			2.5	0.2	
10	11	1.6		0.6	4.3
			2	0.8	
			3.4	0.2	
11	12	1.5		0.6	3.2
			1.3	0.8	
			3	0.2	
12	13	1.4		0.6	3.7
			2	0.8	
			3.3	0.2	
13	14	1.6		0.6	4.5
			2.3	0.8	
			3.3	0.2	
14	15	1.6		0.6	3.8
			2.6	0.8	
			2.1	0.2	
15	16	1.6		0.6	4.2
			2.2	0.8	
			3	0.2	
16	17	1	4.1	0.6	6.2
				0.8	
				0.2	
17	19	0.8	4.2	0.6	5.0
				0.8	
				0.2	
18	20	0.9	3.6	0.6	3.2
				0.8	
				0.2	
19	21	0.9	3.2	0.6	2.9
				0.8	
				0.2	
20	22	1	1	0.6	2.8
				0.8	
				0.2	
21	26.5	0	0	0.6	0.0
				0.8	
				0.2	
22				0.6	
				0.8	
				0.2	
23				0.6	
				0.8	
				0.2	
24				0.6	
				0.8	
				0.2	
25				0.6	
				0.8	
				0.2	

Velocity & Depth

Section #	Restored 3

Discharge- 285.4 c.f.s.

Subsection #	STA (from LFT)	Depth (Ft)	Velocity (fps)	at Depth (Fraction)	Discharge (cfs)
1	0	0	0	0.6	0.0
				0.8	
				0.2	
2	5	0.9	0.3	0.6	1.1
				0.8	
				0.2	
3	8	1	0	0.6	0.0
				0.8	
				0.2	
4	10	1.5	0.2	0.6	0.6
				0.8	
				0.2	
5	12	1.9	0.7	0.6	2.0
				0.8	
				0.2	
6	13	2.1		0.6	3.6
			0.2	0.8	
			2.1	0.2	
7	15	2.6		0.6	13.3
			2.1	0.8	
			3	0.2	
8	17	2.9		0.6	18.6
			3.1	0.8	
			3.3	0.2	
9	19	2.9		0.6	18.9
			3.3	0.8	
			3.2	0.2	
10	21	3.2		0.6	20.8
			2.1	0.8	
			4.4	0.2	
11	23	3.1		0.6	22.6
			3.1	0.8	
			4.2	0.2	
12	25	3.1		0.6	28.5
			4.2	0.8	
			5	0.2	
13	27	3		0.6	26.7
			3.9	0.8	
			5	0.2	
14	29	3		0.6	24.3
			3	0.8	
			5.1	0.2	

Subsection #	STA (from LFT)	Depth (Ft)	Velocity (fps)	at Depth (Fraction)	Discharge (cfs)
15	31	3		0.6	25.8
			3.5	0.8	
			5.1	0.2	
16	33	2.8		0.6	24.6
			3.9	0.8	
			4.9	0.2	
17	35	2.8		0.6	23.0
			3.7	0.8	
			4.5	0.2	
18	37	2.6		0.6	16.6
			2.5	0.8	
			3.9	0.2	
19	39	2.1		0.6	9.9
			2.2	0.8	
			2.5	0.2	
20	41	2		0.6	4.6
			0.3	0.8	
			2	0.2	
21	43	0	0	0.6	0.0
				0.8	
				0.2	
22				0.6	
				0.8	
				0.2	
23				0.6	
				0.8	
				0.2	
24				0.6	
				0.8	
				0.2	
25				0.6	
				0.8	
				0.2	

Appendix B
HEC-2 Deck - Restored Reach

```
T1    Rapid Creek Downstream
T2    Surveyed June 1993
T3    Low Flow Habitat Evaluation (LOW AND HIGH FLOWS)
J1    0    3    0    0    0    0    0    0    5.8    0
J2    0    0
NC 0.035  0.035  0.038   0.1   0.3
QT    2   282   53.5
X1    1    14  95.27 122.22    0    0    0
GR 13.02     0   9.97   54.2   7.17  79.23   6.25  93.10   5.80  95.27
GR  4.67 100.67   4.10 107.32   5.73 119.91   4.18 121.40   5.80 122.22
GR  6.05 122.35   6.93 123.60   6.95 141.79   8.91 155.90
NC 0.035  0.035  0.038
QT    2   360   52.2
X1    2    13  49.46  81.78 470.80 479.10 480.70
GR 14.06     0   9.83  34.86   9.93  45.83   9.20  46.57   7.90  49.46
GR  7.66  49.99   7.11  55.19   7.22  71.07   7.07  80.26   7.90  81.78
GR  8.80  83.43   9.32  85.59  10.59 111.00
NC 0.035  0.035  0.045
QT    2  285.4   54.2
X1    3    14  41.15  67.71 559.20 556.30 555.00
GR 19.51     0  19.40  13.52  16.84  21.04  13.31  28.44  11.81  37.40
GR 11.30  41.15  10.54  44.24  10.01  53.18  10.63  64.19  11.27  67.66
GR 11.30  67.71  13.38  71.11  13.28  81.48  21.22 126.36
NC 0.035  0.035  0.105
QT    2  267.2   45.2
X1    4    16  76.65 111.40  68.20  71.80  69.50
GR 20.41     0  20.44  25.96  18.60  44.00  18.16  56.02  17.99  61.06
GR 16.07  65.32  13.57  69.37  12.52  74.55  11.80  76.65  11.05  78.84
GR 10.13  85.06  10.14  94.23  10.97 103.13  11.72 111.10  11.80 111.40
GR 13.40 117.50
NC 0.035  0.035  0.040
QT    2  291.7   50.0
X1    5    18  52.29  87.86 280.90 270.50 277.40
GR 18.53     0  18.24  18.56  17.07  28.29  18.29  34.13  16.06  47.09
GR 13.10  52.29  12.62  53.13  12.80  53.14  12.34  55.34  12.27  63.65
GR 12.47  76.18  12.26  81.71  12.46  86.54  13.10  87.86  14.10  89.91
GR 14.67  91.35  14.57  92.96  17.69 116.86
NC 0.035  0.035  0.070
QT    2  313.3   47.2
X1    6    17  25.80  75.31 141.30 140.70 138.20
GR 19.62     0  20.80  16.95  16.89  22.98  15.60  24.00  14.20  25.80
GR 13.62  26.54  14.17  28.73  14.92  36.56  14.83  44.68  15.30  54.40
GR 14.03  59.18  13.41  61.19  12.68  69.46  13.13  73.11  14.20  75.31
GR 15.43  77.84  15.60  79.00
NC 0.035  0.035  0.075
```

```
QT    2  275.1    45.4
X1    7     15  10.96  45.45 178.20 186.20 187.20
GR 19.37      0  17.35   6.44  16.40   9.58  15.40  10.96  15.01  11.51
GR 14.42  12.60  13.71  19.46  13.65  25.46  14.56  26.36  13.91  30.43
GR 14.00  36.43  15.00  44.34  15.40  45.45  16.74  49.16  17.33  54.45
NC 0.035  0.035  0.055
QT    2  285.9    45.4
X1    8     14  48.65  77.49 272.30 257.40 264.70
GR 22.49      0  22.25  21.02  20.34  35.97  18.50  42.93  17.42  46.95
GR 17.00  48.65  16.66  50.02  16.40  55.08  16.16  61.20  16.65  72.10
GR 16.83  77.12  17.00  77.49  18.16  80.02  18.40  84.70
NC 0.035  0.035  0.055
QT    2  253.1    44.3
X1    9     17  81.37 102.23 165.90 169.70 167.80
GR 24.84      0  23.94  29.98  21.67  44.42  20.28  59.40  19.32  65.90
GR 19.09  78.91  17.70  81.37  17.34  82.01  16.47  89.10  16.17  92.14
GR 16.97 101.08  17.70 102.23  19.41 104.92  19.10 119.94  18.58 135.00
GR 18.63 140.02  20.25 156.00
NC 0.035  0.035  0.100
QT    2  281.3    46.5
X1   10     20  40.00  69.34 317.50 328.50 322.60
GR 24.37      0  23.21  23.12  22.26  31.56  21.04  37.07  19.57  40.29
GR 19.40  41.35  18.46  47.21  18.60  59.73  19.05  67.70  19.40  69.34
GR 19.89  71.63  20.29  80.61  20.92  96.08  20.85 103.13  21.07 107.11
GR 21.18 109.10  20.84 113.17  20.47 117.28  20.36 118.86  23.92 138.98
NC 0.035  0.035  0.020
QT    2  311.1    46.1
X1   11     16  49.91  77.17 578.20 554.90 564.00
GR 28.44      0  28.15  19.98  27.80  28.62  25.68  36.18  24.10  39.76
GR 23.48  46.01  23.05  49.91  22.35  56.25  21.86  64.37  22.65  76.45
GR 23.05  77.17  25.24  81.14  24.66 123.32  24.74 140.72  25.34 153.73
GR 25.90 162.30
NC 0.035  0.035  0.035
QT    2  283.6    52.7
X1   12     12  51.53  80.86 312.30 318.80 320.90
GR 30.92      0  30.86  22.78  28.35  40.87  26.14  44.93  24.70  51.53
GR 24.14  54.10  23.73  60.79  24.32  79.08  24.70  80.86  24.74  81.05
GR 25.23  97.77  26.15 104.04
EJ


ER
```

Appendix C
IFG4 Input File DS1A

```
RAPID CREEK DOWNSTREAM REACH DATA SET AUG 1993 MRP
IFG4 DATA SET
IOC     1110100000001000001000
QARD  26.8
XSEC  1.0      0.0 .90     4.1    0.0020
      1.0  0.0 13.0 54.2 10.0 78.4  7.3 84.4  6.8 86.4  6.7 88.4  6.6
      1.0 90.4  6.4 92.4  6.3 94.4  6.0 95.8  5.7 96.4  5.6 96.8  5.5
      1.0 98.4  5.1 98.8  5.1 99.8  4.8100.4  4.7100.8  4.6101.8  4.6
      1.0102.4  4.5102.8  4.5103.8  4.4104.4  4.3104.8  4.3106.4  4.2
      1.0106.8  4.1107.8  4.1108.4  4.1108.8  4.1110.4  4.1110.8  4.1
      1.0112.4  4.1112.8  4.1114.8  4.2115.9  4.2116.8  4.2117.8  4.2
      1.0118.8  4.2118.9  4.2120.8  5.1121.4  5.7122.2  6.0123.4  6.8
      1.0124.4  6.9141.8  7.0155.9  8.9
NS    1.0     1.00     1.00     1.00     1.00     1.00     1.00
NS    1.0     1.00     1.00     1.00     1.00     1.00     1.00
NS    1.0     1.00     1.00     1.00     1.00     1.00     1.00
NS    1.0     1.00     1.00     1.00     1.00     1.00     1.00
NS    1.0     1.00     1.00     1.00     1.00     1.00     1.00
NS    1.0     1.00     1.00     1.00     1.00     1.00     1.00
NS    1.0     1.00     1.00     1.00     1.00     1.00     1.00
NS    1.0     1.00     1.00     1.00
CAL1  1.0.    7.30 282.0
VEL1  1.0          0.00 0.31 0.53 0.25 0.54 0.66 0.94 0.41 0.16 0.23
VEL1  1.0 0.50 0.78 1.46 1.88 2.06 2.51 2.78 2.85 3.04 3.15 3.27 3.75
VEL1  1.0 4.08 4.92 5.42 5.57 6.17 5.78 4.24 4.31 4.64 4.83 4.52 4.16
VEL1  1.0 3.82 3.78 3.23 3.06 2.82 2.52 0.00
CAL2  1.0     5.70 53.5
VEL2  1.0                                   0.00 0.06 0.10
VEL2  1.0 0.66 0.80 1.00 1.06 1.10 1.30 1.30 1.30 1.30 1.45 1.55 1.67
VEL2  1.0 1.70 1.75 0.70 0.00 0.00 0.00 2.52 3.15 1.35 1.76 2.10 2.45
VEL2  1.0 2.65 2.68 3.25 0.00
ENDJ
```

Appendix D
IFG4 Output ZDS1A.ASC

"Program: IFG4   Version 2.5"
"Last Modification Date: 92/02/26"

"PROGRAM - IFG4 RUN DATE 94/02/15. TIME 12.42.36."
"   RAPID CREEK DOWNSTREAM REACH DATA SET AUG 1993 MRP   "
"   IFG4 DATA SET   "

"DISCHARGE CALCULATIONS FOR CROSS SECTION   1.00 SET 1"

"VERTICAL" "LEFT AREA" "RIGHT AREA" "CELL AREA" "CELL DISCHARGE"

"VERTICAL"	"LEFT AREA"	"RIGHT AREA"	"CELL AREA"	"CELL DISCHARGE"
4	1.50	1.10	1.30	0.40
5	1.10	1.30	1.20	0.64
6	1.30	1.60	1.45	0.36
7	1.60	1.90	1.75	0.95
8	1.90	2.30	2.10	1.39
9	2.30	2.03	2.17	2.04
10	2.03	0.99	1.51	0.62
11	.099	0.70	0.85	0.14
12	0.70	3.20	1.95	0.45
13	3.20	0.88	2.04	1.02
14	0.88	2.35	1.62	1.26
15	2.35	1.53	1.94	2.83
16	1.53	1.06	1.30	2.43
17	1.06	2.70	1.88	3.87
18	2.70	1.65	2.17	5.46
19	1.65	1.12	1.39	3.85
20	1.12	2.85	1.99	5.66
21	2.85	1.77	2.31	7.02
22	1.77	1.20	1.49	4.68
23	1.20	4.88	3.04	9.94
24	4.88	1.26	3.07	11.51
25	1.26	3.20	2.23	9.10
26	3.20	1.92	2.56	12.60
27	1.92	1.28	1.60	8.67
28	1.28	5.12	3.20	17.82
29	5.12	1.28	3.20	19.74
30	1.25	5.12	3.20	18.50
31	5.12	1.28	3.20	13.57
32	1.28	6.30	3.79	16.33
33	6.30	3.41	4.85	22.53
34	3.41	2.79	3.10	14.97
35	2.79	3.10	2.95	13.31
36	3.10	3.10	3.10	12.90
37	3.10	0.31	1.70	6.51
38	0.31	5.04	2.67	10.10
39	5.04	1.14	3.09	9.97
40	1.14	1.16	1.15	3.52
41	1.16	1.08	1.12	3.16
42	1.08	0.45	0.77	1.93
43	0.45	6.09	3.27	0.00
44	6.09	0.33	3.21	0.00
45	0.33	0.00	0.17	0.00
"TOTAL"	" "	" "	92.62	281.74

"DISCHARGE CALCULATIONS FOR CROSS SECTION 1.00 SET 2"

"VERTICAL"	"LEFT AREA"	"RIGHT AREA"	"CELL AREA"	"CELL DISCHARGE"
11	0.03	0.06	0.05	0.00
12	0.06	0.64	0.35	0.03
13	0.64	0.24	0.44	0.27
14	0.24	0.75	0.50	0.40
15	0.75	0.57	0.66	0.66
16	0.57	0.42	0.50	0.52
17	0.42	1.10	0.76	0.84
18	1.10	0.69	0.89	1.16
19	0.69	0.48	0.58	0.76
20	0.48	1.25	0.57	1.12
21	1.25	0.81	1.03	1.34
22	0.81	0.56	0.68	0.99
23	0.56	2.32	1.44	2.23
24	2.32	0.62	1.47	2.45
25	0.62	1.60	1.11	1.89
26	1.60	0.96	1.28	2.24
27	0.96	0.64	0.80	0.56
28	0.64	2.56	1.60	0.00
29	2.56	0.64	1.60	0.00
30	0.64	2.56	1.60	0.00
31	2.56	0.64	1.60	4.03
32	0.64	3.10	1.87	5.89
33	3.10	1.65	2.37	3.21
34	1.65	1.35	1.50	2.64
35	1.35	1.50	1.43	2.99
36	1.50	1.50	1.50	3.68
37	1.50	0.15	0.82	2.19
38	0.15	2.00	1.07	2.87
39	2.00	0.18	1.09	3.53
40	0.18	0.00	0.09	0.00
"TOTAL"	" "	" "	31.55	48.53

"ANALYSIS FOR CROSS SECTION 1.00"

"CALIBRATION OF STAGE - DISCHARGE RELATIONSHIP FOR GIVEN DISCHARGES"

"DISCHARGE"	"STAGE"	PLOTTING STAGE"
282.000	7.300	3.200
53.500	5.700	1.600

"STAGE OF ZERO FLOW IS 4.10"

"STAGE - DISCHARGE RELATIONSHIP"

"CALIBRATION DETAILS FOR CROSS SECTION 1.00"

"VERTICAL"	"X"	"Y"	"CHANNEL INDEX"	"MANNINGS N"	"N OBS"	"CORR COEF"	"1-VEL"	"2-VEL"
1	0.0	13.0	1.0	0.000	0	0.00	0.00	0.00
2	54.2	10.1	1.0	0.000	0	0.00	0.00	0.00
3	78.4	7.3	1.0	0.000	0	0.00	0.00	0.00
4	84.4	6.8	1.0	0.135	1	0.00	0.31	0.00
5	86.4	6.7	1.0	0.089	1	0.00	0.53	0.00
6	88.4	6.6	1.0	0.210	1	0.00	0.25	0.00
7	90.4	6.4	1.0	0.115	1	0.00	0.54	0.00
8	92.4	6.3	1.0	0.101	1	0.00	0.66	0.00
9	94.4	6.0	1.0	0.085	1	0.00	0.94	0.00
10	95.8	5.7	1.0	0.223	1	0.00	0.41	0.00
11	96.4	5.6	1.0	0.239	2	1.00	0.16	0.06
12	96.8	5.5	1.0	0.228	2	1.00	0.23	0.10
13	98.4	5.1	1.0	0.072	2	1.00	0.50	0.66
14	98.8	5.1	1.0	0.059	2	1.00	0.78	0.80
15	99.8	4.8	1.0	0.062	2	1.00	1.46	1.00
16	100.4	4.7	1.0	0.063	2	1.00	1.88	1.06
17	100.8	4.6	1.0	0.065	2	1.00	2.06	1.10
18	101.8	4.6	1.0	0.055	2	1.00	2.51	1.30
19	102.4	4.5	1.0	0.058	2	1.00	2.78	1.30
20	102.8	4.5	1.0	0.058	2	1.00	2.85	1.30
21	103.8	4.4	1.0	0.061	2	1.00	3.04	1.30
22	104.4	4.3	1.0	0.058	2	1.00	3.15	1.45
23	104.8	4.3	1.0	0.054	2	1.00	3.27	1.55
24	106.4	4.2	1.0	0.052	2	1.00	3.75	1.67
25	106.8	4.1	1.0	0.054	2	1.00	4.08	1.70
26	107.8	4.1	1.0	0.052	2	1.00	4.92	1.75
27	108.4	4.1	1.0	0.130	2	0.00	5.42	0.70
28	108.8	4.1	1.0	0.026	1	0.00	5.57	0.00
29	110.4	4.1	1.0	0.024	1	0.00	6.17	0.00
30	110.8	4.1	1.0	0.025	1	1.00	5.78	0.00
31	112.4	4.1	1.0	0.036	2	1.00	4.24	2.52
32	112.8	4.1	1.0	0.029	2	1.00	4.31	3.15
33	114.8	4.2	1.0	0.065	2	1.00	4.64	1.35
34	115.9	4.2	1.0	0.050	2	1.00	4.83	1.76
35	116.8	4.2	1.0	0.042	2	1.00	4.52	2.10
36	117.8	4.2	1.0	0.036	2	1.00	4.16	2.45
37	118.8	4.2	1.0	0.033	2	1.00	3.82	2.65
38	118.9	4.2	1.0	0.033	2	1.00	3.78	2.68
39	120.8	5.1	1.0	0.015	2	1.00	3.23	3.25
40	121.4	5.7	1.0	0.030	1	0.00	3.06	0.00
41	122.2	6.0	1.0	0.028	1	0.00	2.82	0.00
42	123.4	6.8	1.0	0.017	1	0.00	2.52	0.00
43	124.4	6.9	1.0	0.000	0	0.00	0.00	0.00
44	141.8	7.0	1.0	0.000	0	0.00	0.00	0.00
45	155.9	8.9	1.0	0.000	0	0.00	0.00	0.00

"CALCULATED DISCHARGE	"WSEL"	"GIVEN DISCHARGE"	"LEFT EDGE"	"RIGHT EDGE"
281.74	7.30	282.00	78.40	144.03
48.53	5.70	53.50	95.80	121.40

"CALIBRATION DETAILS FOR CROSS SECTION 1.00"

"SIMULATED Q"	"WSEL"	"LEFT EDGE"	"RIGHT EDGE"
26.8	5.3	97.6	121.0

`VERTICAL"	"X"	"N"	"DEPTH"	"AREA"	"VELOCITY
12	96.8	" "	0.10	0.1	0.00
13	98.4	"0.072"	0.20	0.1	0.54
14	98.8	"0.059"	0.35	0.3	0.58
15	99.8	"0.062"	0.55	0.3	0.62
16	100.4	"0.063"	0.65	0.3	0.60
17	100.8	"0.065"	0.70	0.7	0.61
18	101.8	"0.055"	0.75	0.4	0.71
19	102.4	"0.058"	0.80	0.3	0.68
20	102.8	"0.058"	0.85	0.8	0.68
21	103.8	"0.061"	0.95	0.6	0.66
22	104.4	"0.058"	1.00	0.4	0.76
23	104.8	"0.054"	1.05	1.7	0.82
24	106.4	"0.052"	1.15	0.5	0.86
25	106.7	"0.054"	1.20	1.2	0.85
26	107.8	"0.052"	1.20	0.7	0.82
27	108.4	"0.130"	1.20	0.5	0.22
28	108.8	"0.026"	1.20	1.9	2.08
29	110.4	"0.024"	1.20	0.5	2.31
30	110.8	"0.025"	1.20	1.9	2.16
31	112.4	"0.036"	1.20	0.5	1.47
32	112.8	"0.029"	1.15	2.3	2.00
33	114.8	"0.065"	1.10	1.2	0.58
34	115.9	"0.050"	1.10	1.0	0.84
35	116.8	"0.042"	1.10	1.1	1.10
36	117.8	"0.036"	1.10	1.1	1.42
37	118.8	"0.033"	1.10	0.1	1.64
38	118.9	"0.033"	0.65	1.2	1.68
39	120.8	"0.015"	0.10	0.0	2.35
40	121.4	" "	0.00	0.0	0.00

"SUMMARY OF CALIBRATION FLOWS (CFS)"

"CROSS SECTION "	1	2
1.00	282.00	53.50

"MEAN"	"STD DEV"	"COEF OF VARIATION"
282.00	0.00	0.00
53.50	0.00	0.00

Appendix E
RCHARC Input File DSA.OUT

A	0.00	25.00	5.30		
B	54.20	0.00	0.00	0.00	9.00
B	78.40	54.20	0.00	0.00	9.00
B	84.40	78.40	0.00	0.00	9.00
B	86.40	84.40	0.00	0.00	9.00
B	88.40	86.40	0.00	0.00	9.00
B	90.40	88.40	0.00	0.00	9.00
B	92.40	90.40	0.00	0.00	9.00
B	94.40	92.40	0.00	0.00	9.00
B	95.80	94.40	0.00	0.00	9.00
B	96.40	95.80	0.00	0.00	9.00
B	96.80	96.40	0.10	0.00	9.00
B	98.40	96.80	0.20	0.54	9.00
B	98.80	98.40	0.35	0.58	9.00
B	99.80	98.80	0.55	0.62	9.00
B	100.40	99.80	0.65	0.60	9.00
B	100.80	100.40	0.70	0.61	9.00
B	101.80	100.80	0.75	0.71	9.00
B	102.40	101.80	0.80	0.68	9.00
B	102.80	102.40	0.85	0.68	9.00
B	103.80	102.80	0.95	0.66	9.00
B	104.40	103.80	1.00	0.76	9.00
B	104.80	104.40	1.05	0.82	9.00
B	106.40	104.80	1.15	0.86	9.00
B	106.80	106.40	1.20	0.85	9.00
B	107.80	106.80	1.20	0.82	9.00
B	108.40	107.80	1.20	0.22	9.00
B	108.80	108.40	1.20	2.08	9.00
B	110.40	108.80	1.20	2.31	9.00
B	110.80	110.40	1.20	2.16	9.00
B	112.40	110.80	1.20	1.47	9.00
B	112.80	112.40	1.15	2.00	9.00
B	114.80	112.80	1.10	0.58	9.00
B	115.90	114.80	1.10	0.84	9.00
B	116.80	115.90	1.10	1.10	9.00
B	117.80	116.80	1.10	1.42	9.00
B	118.80	117.80	1.10	1.64	9.00
B	118.90	118.80	0.65	1.68	9.00
B	120.80	118.90	0.10	2.35	9.00
B	121.40	120.80	0.00	0.00	9.00
B	122.20	121.40	0.00	0.00	9.00
B	123.40	122.20	0.00	0.00	9.00
B	124.40	123.40	0.00	0.00	9.00
B	141.80	124.40	0.00	0.00	9.00
B	155.90	141.80	0.00	0.00	9.00
A	0.00	175.00	6.70		
B	54.20	0.00	0.00	0.00	9.00
B	78.40	54.20	0.00	0.00	9.00
B	84.40	78.40	0.00	0.00	9.00
B	86.40	84.40	0.04	0.00	9.00
B	88.40	86.40	0.18	0.05	9.00
B	90.40	88.40	0.33	0.23	9.00
B	92.40	90.40	0.53	0.33	9.00
B	94.40	92.40	0.83	0.58	9.00
B	95.80	94.40	1.03	0.28	9.00
B	96.40	95.80	1.13	0.11	9.00
B	96.80	96.40	1.38	0.17	9.00
B	98.40	96.80	1.58	0.52	9.00
B	98.80	98.40	1.73	0.75	9.00
B	99.80	98.80	1.93	1.24	9.00
B	100.40	99.80	2.03	1.50	9.00
B	100.80	100.40	2.08	1.62	9.00
B	101.80	100.80	2.13	1.95	9.00
B	102.40	101.80	2.18	2.10	9.00
B	102.80	102.40	2.23	2.13	9.00
B	103.80	102.80	2.33	2.23	9.00
B	104.40	103.80	2.38	2.36	9.00
B	104.80	104.40	2.43	2.48	9.00
B	106.40	104.80	2.53	2.79	9.00
B	106.80	106.40	2.58	2.97	9.00
B	107.80	106.80	2.58	3.41	9.00
B	108.40	107.80	2.58	2.74	9.00
B	108.80	108.40	2.58	4.61	9.00
B	110.40	108.80	2.58	5.10	9.00
B	110.80	110.40	2.58	4.78	9.00
B	112.40	110.80	2.58	3.45	9.00
B	112.80	112.40	2.53	3.74	9.00
B	114.80	112.80	2.48	3.02	9.00
B	115.90	114.80	2.48	3.37	9.00
B	116.80	115.90	2.48	3.40	9.00
B	117.80	116.80	2.48	3.37	9.00
B	118.80	117.80	2.48	3.26	9.00
B	118.90	118.80	2.03	3.25	9.00
B	120.80	118.90	1.28	3.09	9.00
B	121.40	120.80	0.83	2.10	9.00
B	122.20	121.40	0.34	1.74	9.00
B	123.40	122.20	0.00	0.00	9.00
B	124.40	123.40	0.00	0.00	9.00
B	141.80	124.40	0.00	0.00	9.00
B	155.90	141.80	0.00	0.00	9.00
A	0.00	450.00	7.90		
B	54.20	0.00	0.29	0.00	9.00
B	78.40	54.20	0.84	0.34	9.00
B	84.40	78.40	1.14	0.51	9.00
B	86.40	84.40	1.24	0.81	9.00
B	88.40	86.40	1.39	0.37	9.00
B	90.40	88.40	1.54	0.74	9.00
B	92.40	90.40	1.74	0.87	9.00
B	94.40	92.40	2.04	1.17	9.00
B	95.80	94.40	2.24	0.49	9.00
B	96.40	95.80	2.34	0.20	9.00
B	96.80	96.40	2.59	0.27	9.00
B	98.40	96.80	2.79	0.45	9.00
B	98.80	98.40	2.94	0.75	9.00
B	99.80	98.80	3.14	1.56	9.00
B	100.40	99.80	3.24	2.10	9.00
B	100.80	100.40	3.29	2.33	9.00
B	101.80	100.80	3.34	2.86	9.00
B	102.40	101.80	3.39	3.25	9.00
B	102.80	102.40	3.44	3.35	9.00
B	103.80	102.80	3.54	3.63	9.00
B	104.40	103.80	3.59	3.70	9.00
B	104.80	104.40	3.64	3.81	9.00
B	106.40	104.80	3.74	4.44	9.00
B	106.80	106.40	3.79	4.91	9.00
B	107.80	106.80	3.79	6.15	9.00
B	108.40	107.80	3.79	8.68	9.00
B	108.80	108.40	3.79	6.06	9.00
B	110.40	108.80	3.79	6.71	9.00
B	110.80	110.40	3.79	6.29	9.00
B	112.40	110.80	3.79	4.68	9.00
B	112.80	112.40	3.74	4.52	9.00
B	114.80	112.80	3.69	6.09	9.00
B	115.90	114.80	3.69	6.00	9.00
B	116.80	115.90	3.69	5.30	9.00
B	117.80	116.80	3.69	4.60	9.00
B	118.80	117.80	3.69	4.06	9.00
B	118.90	118.80	3.24	3.99	9.00
B	120.80	118.90	2.49	3.13	9.00
B	121.40	120.80	2.04	3.67	9.00
B	122.20	121.40	1.49	3.52	9.00
B	123.40	122.20	1.04	4.13	9.00

B	124.40	123.40	0.94	1.21	9.00
B	141.80	124.40	0.44	1.13	9.00
B	155.90	141.80	0.00	0.00	9.00
A	0.09	25.00	7.60		
B	34.90	0.00	0.00	0.00	9.00
B	44.60	34.90	0.00	0.00	9.00
B	45.60	44.60	0.00	0.00	9.00
B	47.60	45.60	0.00	0.00	9.00
B	49.60	47.60	0.00	0.00	9.00
B	49.70	49.60	0.03	0.00	9.00
B	51.60	49.70	0.11	0.39	9.00
B	52.70	51.60	0.21	0.94	9.00
B	53.60	52.70	0.31	1.52	9.00
B	53.90	53.60	0.41	1.90	9.00
B	55.20	53.90	0.46	1.40	9.00
B	55.60	55.20	0.46	2.00	9.00
B	55.90	55.60	0.46	2.50	9.00
B	56.90	55.90	0.46	2.95	9.00
B	57.60	56.90	0.46	2.70	9.00
B	58.40	57.60	0.46	2.46	9.00
B	59.60	58.40	0.46	3.38	9.00
B	59.90	59.60	0.41	3.56	9.00
B	60.90	59.90	0.36	1.06	9.00
B	61.60	60.90	0.36	2.82	9.00
B	61.90	61.60	0.36	3.65	9.00
B	63.60	61.90	0.36	2.15	9.00
B	63.90	63.60	0.36	1.95	9.00
B	65.60	63.90	0.36	1.44	9.00
B	65.90	65.60	0.36	1.36	9.00
B	67.60	65.90	0.36	1.18	9.00
B	67.90	67.60	0.36	1.15	9.00
B	69.60	67.90	0.36	1.69	9.00
B	69.90	69.60	0.36	1.82	9.00
B	71.90	69.90	0.36	4.05	9.00
B	72.60	71.90	0.36	4.25	9.00
B	73.90	72.60	0.41	3.81	9.00
B	75.60	73.90	0.46	2.91	9.00
B	75.90	75.60	0.46	2.78	9.00
B	77.60	75.90	0.46	2.21	9.00
B	77.90	77.60	0.46	2.12	9.00
B	79.60	77.90	0.46	1.34	9.00
B	79.90	79.60	0.23	1.22	9.00
B	81.40	79.90	0.00	0.00	9.00
B	81.60	81.40	0.00	0.00	9.00
B	87.60	81.60	0.00	0.00	9.00
B	110.00	87.60	0.00	0.00	9.00
A	0.09	175.00	8.70		
B	34.90	0.00	0.00	0.00	9.00
B	44.60	34.90	0.00	0.00	9.00
B	45.60	44.60	0.00	0.00	9.00
B	47.60	45.60	0.44	0.00	9.00
B	49.60	47.60	0.88	1.61	9.00
B	49.70	49.60	1.03	1.64	9.00
B	51.60	49.70	1.23	2.24	9.00
B	52.70	51.60	1.33	3.09	9.00
B	53.60	52.70	1.43	3.81	9.00
B	53.90	53.60	1.53	4.02	9.00
B	55.20	53.90	1.58	4.20	9.00
B	55.60	55.20	1.58	4.70	9.00
B	55.90	55.60	1.58	4.90	9.00
B	56.90	55.90	1.58	4.97	9.00
B	57.60	56.90	1.58	4.80	9.00
B	58.40	57.60	1.58	4.50	9.00
B	59.60	58.40	1.58	4.49	9.00
B	59.90	59.60	1.53	4.62	9.00
B	60.90	59.90	1.48	3.80	9.00
B	61.60	60.90	1.48	4.87	9.00

B	61.90	61.60	1.48	5.31	9.00
B	63.60	61.90	1.48	5.57	9.00
B	63.90	63.60	1.48	5.48	9.00
B	65.60	63.90	1.48	5.30	9.00
B	65.90	65.60	1.48	5.22	9.00
B	67.60	65.90	1.48	4.99	9.00
B	67.90	67.60	1.48	4.98	9.00
B	69.60	67.90	1.48	5.55	9.00
B	69.90	69.60	1.48	5.47	9.00
B	71.90	69.90	1.48	5.60	9.00
B	72.60	71.90	1.48	4.61	9.00
B	73.90	72.60	1.53	4.67	9.00
B	75.60	73.90	1.58	4.59	9.00
B	75.90	75.60	1.58	4.48	9.00
B	77.60	75.90	1.58	3.91	9.00
B	77.90	77.60	1.58	3.76	9.00
B	79.60	77.90	1.58	2.83	9.00
B	79.90	79.60	1.28	2.60	9.00
B	81.40	79.90	0.93	1.41	9.00
B	81.60	81.40	0.44	1.24	9.00
B	87.60	81.60	0.00	0.00	9.00
B	110.00	87.60	0.00	0.00	9.00
A	0.09	450.00	9.90		
B	34.90	0.00	0.05	0.41	9.00
B	44.60	34.90	0.00	0.00	9.00
B	45.60	44.60	0.60	0.00	9.00
B	47.60	45.60	1.65	2.19	9.00
B	49.60	47.60	2.10	2.54	9.00
B	49.70	49.60	2.25	2.58	9.00
B	51.60	49.70	2.45	3.17	9.00
B	52.70	51.60	2.55	4.25	9.00
B	53.60	52.70	2.65	5.11	9.00
B	53.90	53.60	2.75	5.28	9.00
B	55.20	53.90	2.80	6.76	9.00
B	55.60	55.20	2.80	6.74	9.00
B	55.90	55.60	2.80	6.44	9.00
B	56.90	55.90	2.80	6.10	9.00
B	57.60	56.90	2.80	6.04	9.00
B	58.40	57.60	2.80	5.75	9.00
B	59.60	58.40	2.80	4.93	9.00
B	59.90	59.60	2.75	5.02	9.00
B	60.90	59.90	2.70	6.62	9.00
B	61.60	60.90	2.70	6.04	9.00
B	61.90	61.60	2.70	6.08	9.00
B	63.60	61.90	2.70	8.34	9.00
B	63.90	63.60	2.70	8.53	9.00
B	65.60	63.90	2.70	9.35	9.00
B	65.90	65.60	2.70	9.40	9.00
B	67.60	65.90	2.70	9.39	9.00
B	67.90	67.60	2.70	9.49	9.00
B	69.60	67.90	2.70	9.29	9.00
B	69.90	69.60	2.70	8.78	9.00
B	71.90	69.90	2.70	6.27	9.00
B	72.60	71.90	2.70	4.61	9.00
B	73.90	72.60	2.75	4.93	9.00
B	75.60	73.90	2.80	5.46	9.00
B	75.90	75.60	2.80	5.38	9.00
B	77.60	75.90	2.80	4.91	9.00
B	77.90	77.60	2.80	4.73	9.00
B	79.60	77.90	2.80	3.85	9.00
B	79.90	79.60	2.50	3.56	9.00
B	81.40	79.90	2.15	2.13	9.00
B	81.60	81.40	1.30	1.95	9.00
B	87.60	81.60	0.25	0.74	9.00
B	110.00	87.60	0.00	0.00	9.00
A	0.20	25.00	11.10		
B	13.50	0.00	0.00	0.00	9.00

B	21.00	13.50	0.00	0.00	9.00
B	28.20	21.00	0.00	0.00	9.00
B	33.20	28.20	0.00	0.00	9.00
B	36.20	33.20	0.00	0.00	9.00
B	38.20	36.20	0.00	0.00	9.00
B	40.20	38.20	0.00	0.00	9.00
B	41.20	40.20	0.18	0.00	9.00
B	43.20	41.20	0.42	0.60	9.00
B	43.70	43.20	0.52	0.74	9.00
B	44.20	43.70	0.57	0.50	9.00
B	45.20	44.20	0.62	0.60	9.00
B	46.20	45.20	0.67	0.59	9.00
B	47.20	46.20	0.72	0.76	9.00
B	48.20	47.20	0.82	0.80	9.00
B	49.20	48.20	0.87	0.63	9.00
B	50.20	49.20	0.92	1.05	9.00
B	51.20	50.20	0.97	2.15	9.00
B	52.20	51.20	1.02	1.48	9.00
B	53.20	52.20	1.02	1.90	9.00
B	54.20	53.20	0.97	2.07	9.00
B	55.20	54.20	0.92	1.63	9.00
B	56.20	55.20	0.87	1.56	9.00
B	57.20	56.20	0.82	3.72	9.00
B	58.20	57.20	0.77	3.85	9.00
B	59.20	58.20	0.72	3.47	9.00
B	60.20	59.20	0.62	3.04	9.00
B	61.20	60.20	0.57	2.53	9.00
B	62.20	61.20	0.52	0.49	9.00
B	63.20	62.20	0.37	0.35	9.00
B	65.20	63.20	0.13	0.12	9.00
B	66.70	65.20	0.00	0.00	9.00
B	67.20	66.70	0.00	0.00	9.00
B	69.20	67.20	0.00	0.00	9.00
B	71.20	69.20	0.00	0.00	9.00
B	81.50	71.20	0.00	0.00	9.00
B	126.40	81.50	0.00	0.00	9.00
A	0.20	175.00	12.60		
B	13.50	0.00	0.00	0.00	9.00
B	21.00	13.50	0.00	0.00	9.00
B	28.20	21.00	0.07	0.00	9.00
B	33.20	28.20	0.38	0.08	9.00
B	36.20	33.20	0.78	0.10	9.00
B	38.20	36.20	1.13	0.13	9.00
B	40.20	38.20	1.43	0.51	9.00
B	41.20	40.20	1.73	0.87	9.00
B	43.20	41.20	1.98	2.02	9.00
B	43.70	43.20	2.08	2.16	9.00
B	44.20	43.70	2.13	1.99	9.00
B	45.20	44.20	2.18	2.23	9.00
B	46.20	45.20	2.23	2.24	9.00
B	47.20	46.20	2.28	2.38	9.00
B	48.20	47.20	2.38	2.41	9.00
B	49.20	48.20	2.43	2.29	9.00
B	50.20	49.20	2.48	2.68	9.00
B	51.20	50.20	2.53	3.29	9.00
B	52.20	51.20	2.58	3.33	9.00
B	53.20	52.20	2.58	3.83	9.00
B	54.20	53.20	2.53	3.85	9.00
B	55.20	54.20	2.48	3.61	9.00
B	56.20	55.20	2.43	3.45	9.00
B	57.20	56.20	2.38	4.02	9.00
B	58.20	57.20	2.33	4.05	9.00
B	59.20	58.20	2.28	3.96	9.00
B	60.20	59.20	2.18	3.97	9.00
B	61.20	60.20	2.13	3.94	9.00
B	62.20	61.20	2.08	2.67	9.00
B	63.20	62.20	1.93	2.41	9.00

B	65.20	63.20	1.68	1.56	9.00
B	66.70	65.20	1.48	1.93	9.00
B	67.20	66.70	0.93	1.74	9.00
B	69.20	67.20	0.22	0.57	9.00
B	71.20	69.20	0.00	0.00	9.00
B	81.50	71.20	0.00	0.00	9.00
B	126.40	81.50	0.00	0.00	9.00
A	0.20	450.00	14.20		
B	13.50	0.00	0.00	0.00	9.00
B	21.00	13.50	0.38	0.00	9.00
B	28.20	21.00	1.20	0.25	9.00
B	33.20	28.20	1.90	0.42	9.00
B	36.20	33.20	2.30	0.22	9.00
B	38.20	36.20	2.65	0.24	9.00
B	40.20	38.20	2.95	0.79	9.00
B	41.20	40.20	3.25	1.28	9.00
B	43.20	41.20	3.50	2.78	9.00
B	43.70	43.20	3.60	2.94	9.00
B	44.20	43.70	3.65	3.55	9.00
B	45.20	44.20	3.70	3.88	9.00
B	46.20	45.20	3.75	3.91	9.00
B	47.20	46.20	3.80	3.79	9.00
B	48.20	47.20	3.90	3.76	9.00
B	49.20	48.20	3.95	3.91	9.00
B	50.20	49.20	4.00	3.85	9.00
B	51.20	50.20	4.05	3.63	9.00
B	52.20	51.20	4.10	4.48	9.00
B	53.20	52.20	4.10	4.86	9.00
B	54.20	53.20	4.05	4.70	9.00
B	55.20	54.20	4.00	4.81	9.00
B	56.20	55.20	3.95	4.59	9.00
B	57.20	56.20	3.90	3.73	9.00
B	58.20	57.20	3.85	3.71	9.00
B	59.20	58.20	3.80	3.78	9.00
B	60.20	59.20	3.70	4.06	9.00
B	61.20	60.20	3.65	4.40	9.00
B	62.20	61.20	3.60	5.59	9.00
B	63.20	62.20	3.45	5.68	9.00
B	65.20	63.20	3.20	5.15	9.00
B	66.70	65.20	3.00	2.86	9.00
B	67.20	66.70	2.45	2.65	9.00
B	69.20	67.20	1.35	1.47	9.00
B	71.20	69.20	0.80	0.78	9.00
B	81.50	71.20	0.43	1.25	9.00
B	126.40	81.50	0.00	0.00	9.00
A	0.21	25.00	11.40		
B	26.00	0.00	0.00	0.00	9.00
B	44.00	26.00	0.00	0.00	9.00
B	56.00	44.00	0.00	0.00	9.00
B	61.00	56.00	0.00	0.00	9.00
B	65.30	61.00	0.00	0.00	9.00
B	69.40	65.30	0.00	0.00	9.00
B	70.50	69.40	0.00	0.00	9.00
B	73.50	70.50	0.00	0.00	9.00
B	76.60	73.50	0.00	0.00	9.00
B	77.50	76.60	0.21	0.00	9.00
B	79.50	77.50	0.61	0.19	9.00
B	81.50	79.50	0.86	0.72	9.00
B	82.60	81.50	0.96	1.29	9.00
B	83.10	82.60	1.01	1.93	9.00
B	83.50	83.10	1.11	2.29	9.00
B	84.60	82.50	1.26	2.68	9.00
B	85.50	84.60	1.31	3.11	9.00
B	86.10	85.50	1.31	3.36	9.00
B	87.50	86.10	1.31	3.56	9.00
B	89.10	87.50	1.31	3.74	9.00
B	89.50	89.10	1.31	3.79	9.00

B	90.60	89.50	1.31	3.73	9.00
B	91.50	90.60	1.31	3.60	9.00
B	92.10	91.50	1.31	3.53	9.00
B	93.50	92.10	1.26	3.45	9.00
B	95.10	93.50	1.21	3.40	9.00
B	95.50	95.10	1.11	3.40	9.00
B	97.50	95.50	0.96	3.32	9.00
B	98.10	97.50	0.86	3.19	9.00
B	99.50	98.10	0.71	2.99	9.00
B	101.10	99.50	0.61	2.95	9.00
B	101.50	101.10	0.56	3.08	9.00
B	102.60	101.50	0.46	3.09	9.00
B	103.50	102.60	0.36	3.06	9.00
B	104.10	103.50	0.26	2.99	9.00
B	105.50	104.10	0.11	0.99	9.00
B	107.50	105.50	0.01	1.22	9.00
B	109.50	107.50	0.00	0.00	9.00
B	111.60	109.50	0.00	0.00	9.00
B	113.50	111.60	0.00	0.00	9.00
B	115.50	113.50	0.00	0.00	9.00
B	117.50	115.50	0.00	0.00	9.00
B	118.00	117.50	0.00	0.00	9.00
B	121.50	118.00	0.00	0.00	9.00
A	0.21	175.00	12.80		
B	26.00	0.00	0.00	0.00	9.00
B	44.00	26.00	0.00	0.00	9.00
B	56.00	44.00	0.00	0.00	9.00
B	61.00	56.00	0.00	0.00	9.00
B	65.30	61.00	0.00	0.00	9.00
B	69.40	65.30	0.00	0.00	9.00
B	70.50	69.40	0.05	0.00	9.00
B	73.50	70.50	0.55	0.07	9.00
B	76.60	73.50	1.15	0.35	9.00
B	77.50	76.60	1.55	0.41	9.00
B	79.50	77.50	2.00	0.51	9.00
B	81.50	79.50	2.25	0.75	9.00
B	82.60	81.50	2.35	1.53	9.00
B	83.10	82.60	2.40	1.33	9.00
B	83.50	83.10	2.50	1.72	9.00
B	84.60	82.50	2.65	2.42	9.00
B	85.50	84.60	2.70	2.83	9.00
B	86.10	85.50	2.70	3.01	9.00
B	87.50	86.10	2.70	3.38	9.00
B	89.10	87.50	2.70	2.93	9.00
B	89.50	89.10	2.70	2.89	9.00
B	90.60	89.50	2.70	2.67	9.00
B	91.50	90.60	2.70	2.70	9.00
B	92.10	91.50	2.70	2.72	9.00
B	93.50	92.10	2.65	2.36	9.00
B	95.10	93.50	2.60	2.14	9.00
B	95.50	95.10	2.50	2.16	9.00
B	97.50	95.50	2.35	2.16	9.00
B	98.10	97.50	2.25	2.36	9.00
B	99.50	98.10	2.10	2.30	9.00
B	101.10	99.50	2.00	2.41	9.00
B	101.50	101.10	1.95	2.46	9.00
B	102.60	101.50	1.85	2.51	9.00
B	103.50	102.60	1.75	2.46	9.00
B	104.10	103.50	1.65	2.37	9.00
B	105.50	104.10	1.50	2.21	9.00
B	107.50	105.50	1.30	1.89	9.00
B	109.50	107.50	1.10	0.55	9.00
B	111.60	109.50	0.70	0.41	9.00
B	113.50	111.60	0.20	0.17	9.00
B	115.50	113.50	0.00	0.00	9.00
B	117.50	115.50	0.00	0.00	9.00
B	118.00	117.50	0.00	0.00	9.00
B	121.50	118.00	0.00	0.00	9.00
A	0.21	450.00	13.90		
B	26.00	0.00	0.00	0.00	9.00
B	44.00	26.00	0.00	0.00	9.00
B	56.00	44.00	0.00	0.00	9.00
B	61.00	56.00	0.00	0.00	9.00
B	65.30	61.00	0.17	0.00	9.00
B	69.40	65.30	0.49	0.68	9.00
B	70.50	69.40	0.94	0.26	9.00
B	73.50	70.50	1.69	0.40	9.00
B	76.60	73.50	2.29	0.58	9.00
B	77.50	76.60	2.69	0.63	9.00
B	79.50	77.50	3.14	0.72	9.00
B	81.50	79.50	3.39	1.00	9.00
B	82.60	81.50	3.49	2.03	9.00
B	83.10	82.60	3.54	3.26	9.00
B	83.50	83.10	3.64	3.44	9.00
B	84.60	82.50	3.79	3.61	9.00
B	85.50	84.60	3.84	3.98	9.00
B	86.10	85.50	3.84	4.04	9.00
B	87.50	86.10	3.84	4.25	9.00
B	89.10	87.50	3.84	4.91	9.00
B	89.50	89.10	3.84	5.01	9.00
B	90.60	89.50	3.84	4.98	9.00
B	91.50	90.60	3.84	4.69	9.00
B	92.10	91.50	3.84	4.54	9.00
B	93.50	92.10	3.79	4.81	9.00
B	95.10	93.50	3.74	5.18	9.00
B	95.50	95.10	3.64	5.15	9.00
B	97.50	95.50	3.49	4.74	9.00
B	98.10	97.50	3.39	4.15	9.00
B	99.50	98.10	3.24	3.59	9.00
B	101.10	99.50	3.14	3.91	9.00
B	101.50	101.10	3.09	3.96	9.00
B	102.60	101.50	2.99	3.84	9.00
B	103.50	102.60	2.89	3.84	9.00
B	104.10	103.50	2.79	3.68	9.00
B	105.50	104.10	2.64	3.26	9.00
B	107.50	105.50	2.44	2.34	9.00
B	109.50	107.50	2.24	1.15	9.00
B	111.60	109.50	1.84	0.69	9.00
B	113.50	111.60	1.29	0.42	9.00
B	115.50	113.50	0.79	1.44	9.00
B	117.50	115.50	0.49	0.93	9.00
B	118.00	117.50	0.22	0.81	9.00
B	121.50	118.00	0.00	0.00	9.00
A	0.26	25.00	12.90		
B	18.60	0.00	0.00	0.00	9.00
B	28.30	18.60	0.00	0.00	9.00
B	34.10	28.30	0.00	0.00	9.00
B	47.10	34.10	0.00	0.00	9.00
B	51.30	47.10	0.00	0.00	9.00
B	52.30	51.30	0.06	0.00	9.00
B	53.30	52.30	0.17	0.34	9.00
B	53.80	53.30	0.42	1.60	9.00
B	55.30	53.80	0.62	1.78	9.00
B	56.80	55.30	0.62	0.75	9.00
B	57.30	56.80	0.62	1.02	9.00
B	58.30	57.30	0.62	1.53	9.00
B	59.30	58.30	0.62	2.08	9.00
B	59.80	59.30	0.62	2.38	9.00
B	61.30	59.80	0.62	1.93	9.00
B	62.80	61.30	0.62	1.52	9.00
B	63.30	62.80	0.62	1.36	9.00
B	64.30	63.30	0.62	1.09	9.00
B	65.30	64.30	0.62	1.11	9.00
B	65.80	65.30	0.62	1.11	9.00

B	67.30	65.80	0.62	0.87	9.00
B	68.80	67.30	0.57	1.06	9.00
B	69.30	68.80	0.52	1.04	9.00
B	70.30	69.30	0.52	1.00	9.00
B	71.30	70.30	0.52	1.28	9.00
B	71.80	71.30	0.52	1.38	9.00
B	73.30	71.80	0.52	1.31	9.00
B	74.80	73.30	0.52	0.74	9.00
B	75.30	74.80	0.47	1.07	9.00
B	76.30	75.30	0.47	1.75	9.00
B	77.30	76.30	0.52	1.53	9.00
B	77.80	77.30	0.52	1.44	9.00
B	79.30	77.80	0.57	2.06	9.00
B	80.80	79.30	0.62	1.96	9.00
B	81.30	80.80	0.62	1.75	9.00
B	82.30	81.30	0.62	1.35	9.00
B	83.30	82.30	0.62	0.32	9.00
B	83.80	83.30	0.57	1.07	9.00
B	85.30	83.80	0.32	0.69	9.00
B	87.30	85.30	0.06	0.11	9.00
B	89.30	87.30	0.00	0.00	9.00
B	91.30	89.30	0.00	0.00	9.00
B	93.00	91.30	0.00	0.00	9.00
B	116.80	93.00	0.00	0.00	9.00
A	0.26	175.00	14.00		
B	18.60	0.00	0.00	0.00	9.00
B	28.30	18.60	0.00	0.00	9.00
B	34.10	28.30	0.00	0.00	9.00
B	47.10	34.10	0.17	0.00	9.00
B	51.30	47.10	0.63	1.67	9.00
B	52.30	51.30	1.08	3.34	9.00
B	53.30	52.30	1.28	1.75	9.00
B	53.80	53.30	1.53	0.24	9.00
B	55.30	53.80	1.73	0.76	9.00
B	56.80	55.30	1.73	0.92	9.00
B	57.30	56.80	1.73	1.08	9.00
B	58.30	57.30	1.73	1.49	9.00
B	59.30	58.30	1.73	1.91	9.00
B	59.80	59.30	1.73	2.09	9.00
B	61.30	59.80	1.73	2.34	9.00
B	62.80	61.30	1.73	2.89	9.00
B	63.30	62.80	1.73	3.03	9.00
B	64.30	63.30	1.73	3.23	9.00
B	65.30	64.30	1.73	3.57	9.00
B	65.80	65.30	1.73	3.75	9.00
B	67.30	65.80	1.73	4.05	9.00
B	68.80	67.30	1.68	4.05	9.00
B	69.30	68.80	1.63	3.97	9.00
B	70.30	69.30	1.63	3.76	9.00
B	71.30	70.30	1.63	3.78	9.00
B	71.80	71.30	1.63	3.99	9.00
B	73.30	71.80	1.63	4.36	9.00
B	74.80	73.30	1.63	3.59	9.00
B	75.30	74.80	1.58	3.78	9.00
B	76.30	75.30	1.58	4.33	9.00
B	77.30	76.30	1.63	4.32	9.00
B	77.80	77.30	1.63	4.23	9.00
B	79.30	77.80	1.68	4.50	9.00
B	80.80	79.30	1.73	3.96	9.00
B	81.30	80.80	1.73	3.70	9.00
B	82.30	81.30	1.73	3.08	9.00
B	83.30	82.30	1.73	1.93	9.00
B	83.80	83.30	1.68	2.34	9.00
B	85.30	83.80	1.43	1.62	9.00
B	87.30	85.30	0.73	0.58	9.00
B	89.30	87.30	0.12	0.76	9.00
B	91.30	89.30	0.00	0.00	9.00

B	93.00	91.30	0.00	0.00	9.00
B	116.80	93.00	0.00	0.00	9.00
A	0.26	450.00	15.20		
B	18.60	0.00	0.00	0.00	9.00
B	28.30	18.60	0.00	0.00	9.00
B	34.10	28.30	0.00	0.00	9.00
B	47.10	34.10	0.73	0.00	9.00
B	51.30	47.10	1.75	4.24	9.00
B	52.30	51.30	2.20	5.34	9.00
B	53.30	52.30	2.40	2.54	9.00
B	53.80	53.30	2.65	0.09	9.00
B	55.30	53.80	2.85	0.45	9.00
B	56.80	55.30	2.85	0.91	9.00
B	57.30	56.80	2.85	1.00	9.00
B	58.30	57.30	2.85	1.33	9.00
B	59.30	58.30	2.85	1.65	9.00
B	59.80	59.30	2.85	1.77	9.00
B	61.30	59.80	2.85	2.31	9.00
B	62.80	61.30	2.85	3.56	9.00
B	63.30	62.80	2.85	4.03	9.00
B	64.30	63.30	2.85	4.94	9.00
B	65.30	64.30	2.85	5.69	9.00
B	65.80	65.30	2.85	6.12	9.00
B	67.30	65.80	2.85	7.72	9.00
B	68.80	67.30	2.80	7.01	9.00
B	69.30	68.80	2.75	6.88	9.00
B	70.30	69.30	2.75	6.46	9.00
B	71.30	70.30	2.75	5.77	9.00
B	71.80	71.30	2.75	6.03	9.00
B	73.30	71.80	2.75	7.07	9.00
B	74.80	73.30	2.75	6.96	9.00
B	75.30	74.80	2.70	6.32	9.00
B	76.30	75.30	2.70	6.08	9.00
B	77.30	76.30	2.75	6.46	9.00
B	77.80	77.30	2.75	6.47	9.00
B	79.30	77.80	2.80	5.94	9.00
B	80.80	79.30	2.85	5.03	9.00
B	81.30	80.80	2.85	4.80	9.00
B	82.30	81.30	2.85	4.14	9.00
B	83.30	82.30	2.85	4.20	9.00
B	83.80	83.30	2.80	3.07	9.00
B	85.30	83.80	2.55	2.17	9.00
B	87.30	85.30	1.85	0.84	9.00
B	89.30	87.30	0.90	2.20	9.00
B	91.30	89.30	0.50	1.06	9.00
B	93.00	91.30	0.28	1.21	9.00
B	116.80	93.00	0.00	0.00	9.00
A	0.29	25.00	13.80		
B	16.90	0.00	0.00	0.00	9.00
B	23.00	16.90	0.00	0.00	9.00
B	24.00	23.00	0.00	0.00	9.00
B	25.00	24.00	0.04	0.00	9.00
B	27.00	25.00	0.04	0.33	9.00
B	29.00	27.00	0.00	0.00	9.00
B	31.00	29.00	0.00	0.00	9.00
B	33.00	31.00	0.00	0.00	9.00
B	35.00	33.00	0.00	0.00	9.00
B	39.00	35.00	0.00	0.00	9.00
B	44.00	39.00	0.00	0.00	9.00
B	46.00	44.00	0.00	0.40	9.00
B	52.00	46.00	0.00	1.40	9.00
B	57.00	52.00	0.00	1.50	9.00
B	58.80	57.00	0.00	2.12	9.00
B	59.00	58.80	0.14	0.00	9.00
B	61.00	59.00	0.32	0.01	9.00
B	61.80	61.00	0.42	0.02	9.00
B	62.80	61.80	0.52	0.23	9.00

B	63.00	62.80	0.57	0.40	9.00
B	63.80	63.00	0.62	1.28	9.00
B	64.80	63.80	0.72	2.68	9.00
B	65.80	64.80	0.82	1.72	9.00
B	66.80	65.80	0.92	2.24	9.00
B	67.80	66.80	1.02	3.26	9.00
B	68.80	67.80	1.07	2.58	9.00
B	69.80	68.80	1.07	2.94	9.00
B	70.00	69.80	1.02	3.01	9.00
B	70.80	70.00	0.87	3.19	9.00
B	72.00	70.80	0.77	3.18	9.00
B	73.30	72.00	0.67	3.32	9.00
B	74.00	73.30	0.37	2.77	9.00
B	74.60	74.00	0.09	3.40	9.00
B	75.00	74.60	0.00	0.06	9.00
B	78.00	75.00	0.00	0.00	9.00
B	79.00	78.00	0.00	0.00	9.00
B	86.00	79.00	0.00	0.00	9.00
A	0.29	175.00	15.00		
B	16.90	0.00	0.00	0.00	9.00
B	23.00	16.90	0.00	0.00	9.00
B	24.00	23.00	0.12	0.00	9.00
B	25.00	24.00	0.79	0.32	9.00
B	27.00	25.00	1.09	2.94	9.00
B	29.00	27.00	0.74	0.84	9.00
B	31.00	29.00	0.54	0.39	9.00
B	33.00	31.00	0.34	0.89	9.00
B	35.00	33.00	0.19	0.16	9.00
B	39.00	35.00	0.19	0.33	9.00
B	44.00	39.00	0.19	0.47	9.00
B	46.00	44.00	0.07	0.33	9.00
B	52.00	46.00	0.22	0.00	9.00
B	57.00	52.00	0.69	0.68	9.00
B	58.80	57.00	0.94	2.81	9.00
B	59.00	58.80	1.24	0.63	9.00
B	61.00	59.00	1.59	2.23	9.00
B	61.80	61.00	1.69	2.44	9.00
B	62.80	61.80	1.79	4.04	9.00
B	63.00	62.80	1.84	4.53	9.00
B	63.80	63.00	1.89	5.79	9.00
B	64.80	63.80	1.99	6.78	9.00
B	65.80	64.80	2.09	6.16	9.00
B	66.80	65.80	2.19	6.51	9.00
B	67.80	66.80	2.29	7.05	9.00
B	68.80	67.80	2.34	6.71	9.00
B	69.80	68.80	2.34	6.89	9.00
B	70.00	69.80	2.14	6.92	9.00
B	70.80	70.00	2.04	7.34	9.00
B	72.00	70.80	1.94	7.82	9.00
B	73.30	72.00	1.64	4.93	9.00
B	74.00	73.30	1.34	3.48	9.00
B	74.60	74.00	1.14	3.19	9.00
B	75.00	74.60	0.52	1.99	9.00
B	78.00	75.00	0.00	0.00	9.00
B	79.00	78.00	0.00	0.00	9.00
B	86.00	79.00	0.00	0.00	9.00
A	0.29	450.00	16.10		
B	16.90	0.00	0.00	0.00	9.00
B	23.00	16.90	0.24	0.00	9.00
B	24.00	23.00	0.89	0.38	9.00
B	25.00	24.00	1.84	0.73	9.00
B	27.00	25.00	2.14	3.26	9.00
B	29.00	27.00	1.79	1.09	9.00
B	31.00	29.00	1.59	0.56	9.00
B	33.00	31.00	1.39	1.51	9.00
B	35.00	33.00	1.24	0.37	9.00
B	39.00	35.00	1.24	1.01	9.00

B	44.00	39.00	1.24	1.07	9.00
B	46.00	44.00	1.04	1.01	9.00
B	52.00	46.00	1.19	3.04	9.00
B	57.00	52.00	1.74	1.16	9.00
B	58.80	57.00	1.99	3.49	9.00
B	59.00	58.80	2.29	8.14	9.00
B	61.00	59.00	2.64	8.35	9.00
B	61.80	61.00	2.74	8.71	9.00
B	62.80	61.80	2.84	9.20	9.00
B	63.00	62.80	2.89	9.66	9.00
B	63.80	63.00	2.94	8.04	9.00
B	64.80	63.80	3.04	7.16	9.00
B	65.80	64.80	3.14	7.67	9.00
B	66.80	65.80	3.24	7.34	9.00
B	67.80	66.80	3.34	6.91	9.00
B	68.80	67.80	3.39	7.17	9.00
B	69.80	68.80	3.39	7.01	9.00
B	70.00	69.80	3.34	6.99	9.00
B	70.80	70.00	3.19	7.41	9.00
B	72.00	70.80	3.09	8.15	9.00
B	73.30	72.00	2.99	7.19	9.00
B	74.00	73.30	2.69	4.41	9.00
B	74.60	74.00	2.39	2.39	9.00
B	75.00	74.60	2.19	2.05	9.00
B	78.00	75.00	1.34	2.39	9.00
B	79.00	78.00	0.54	1.75	9.00
B	86.00	79.00	0.24	1.16	9.00
A	0.32	25.00	15.40		
B	6.40	0.00	0.00	0.00	9.00
B	7.10	6.40	0.00	0.00	9.00
B	10.10	7.10	0.05	0.00	9.00
B	11.10	10.10	0.40	0.11	9.00
B	12.00	11.10	0.85	0.37	9.00
B	13.10	12.00	1.05	0.02	9.00
B	14.00	13.10	1.15	0.03	9.00
B	15.10	14.00	1.25	0.10	9.00
B	16.00	15.10	1.35	0.16	9.00
B	17.10	16.00	1.45	0.22	9.00
B	17.50	17.10	1.60	0.24	9.00
B	19.10	17.50	1.70	0.58	9.00
B	20.50	19.10	1.70	0.59	9.00
B	21.10	20.50	1.70	0.61	9.00
B	22.00	21.10	1.70	0.64	9.00
B	23.10	22.00	1.70	0.67	9.00
B	23.50	23.10	1.75	0.69	9.00
B	25.10	23.50	1.40	0.51	9.00
B	27.10	25.10	1.10	0.47	9.00
B	28.50	27.10	1.25	0.53	9.00
B	29.10	28.50	1.35	0.54	9.00
B	30.00	29.10	1.45	0.54	9.00
B	31.10	30.00	1.50	0.76	9.00
B	31.50	31.10	1.45	0.83	9.00
B	33.10	31.50	1.40	0.88	9.00
B	34.50	33.10	1.40	1.05	9.00
B	35.10	34.50	1.40	0.96	9.00
B	36.00	35.10	1.35	0.81	9.00
B	37.10	36.00	1.30	0.76	9.00
B	37.50	37.10	1.20	0.76	9.00
B	39.10	37.50	1.00	0.44	9.00
B	40.50	39.10	0.85	0.07	9.00
B	41.10	40.50	0.75	0.04	9.00
B	42.00	41.10	0.65	0.20	9.00
B	43.10	42.00	0.45	0.11	9.00
B	45.10	43.10	0.25	0.73	9.00
B	46.00	45.10	0.10	0.55	9.00
B	54.10	46.00	0.00	0.00	9.00
B	56.80	54.10	0.00	0.00	9.00

A	0.32	175.00	16.80		
B	6.40	0.00	0.00	0.00	9.00
B	7.10	6.40	0.38	0.00	9.00
B	10.10	7.10	1.12	1.24	9.00
B	11.10	10.10	1.77	0.68	9.00
B	12.00	11.10	2.22	0.76	9.00
B	13.10	12.00	2.42	0.41	9.00
B	14.00	13.10	2.52	0.71	9.00
B	15.10	14.00	2.62	1.24	9.00
B	16.00	15.10	2.72	1.47	9.00
B	17.10	16.00	2.82	1.70	9.00
B	17.50	17.10	2.97	1.77	9.00
B	19.10	17.50	3.07	2.26	9.00
B	20.50	19.10	3.07	2.18	9.00
B	21.10	20.50	3.07	2.15	9.00
B	22.00	21.10	3.07	2.18	9.00
B	23.10	22.00	3.07	2.23	9.00
B	23.50	23.10	3.12	2.16	9.00
B	25.10	23.50	2.77	1.72	9.00
B	27.10	25.10	2.47	1.99	9.00
B	28.50	27.10	2.62	1.92	9.00
B	29.10	28.50	2.72	1.88	9.00
B	30.00	29.10	2.82	1.84	9.00
B	31.10	30.00	2.87	1.91	9.00
B	31.50	31.10	2.82	2.01	9.00
B	33.10	31.50	2.77	2.27	9.00
B	34.50	33.10	2.77	2.25	9.00
B	35.10	34.50	2.77	2.16	9.00
B	36.00	35.10	2.72	2.07	9.00
B	37.10	36.00	2.67	2.14	9.00
B	37.50	37.10	2.57	2.06	9.00
B	39.10	37.50	2.37	1.54	9.00
B	40.50	39.10	2.22	0.60	9.00
B	41.10	40.50	2.12	0.35	9.00
B	42.00	41.10	2.02	0.41	9.00
B	43.10	42.00	1.82	0.25	9.00
B	45.10	43.10	1.62	2.09	9.00
B	46.00	45.10	0.78	2.00	9.00
B	54.10	46.00	0.00	0.00	9.00
B	56.80	54.10	0.00	0.00	9.00
A	0.32	450.00	17.80		
B	6.40	0.00	0.56	1.09	9.00
B	7.10	6.40	1.21	1.39	9.00
B	10.10	7.10	2.11	2.68	9.00
B	11.10	10.10	2.76	0.89	9.00
B	12.00	11.10	3.21	0.91	9.00
B	13.10	12.00	3.41	1.61	9.00
B	14.00	13.10	3.51	2.86	9.00
B	15.10	14.00	3.61	3.95	9.00
B	16.00	15.10	3.71	4.03	9.00
B	17.10	16.00	3.81	4.24	9.00
B	17.50	17.10	3.96	4.27	9.00
B	19.10	17.50	4.06	4.04	9.00
B	20.50	19.10	4.06	3.76	9.00
B	21.10	20.50	4.06	3.66	9.00
B	22.00	21.10	4.06	3.66	9.00
B	23.10	22.00	4.06	3.68	9.00
B	23.50	23.10	4.11	3.45	9.00
B	25.10	23.50	3.76	2.87	9.00
B	27.10	25.10	3.46	3.67	9.00
B	28.50	27.10	3.61	3.31	9.00
B	29.10	28.50	3.71	3.18	9.00
B	30.00	29.10	3.81	3.05	9.00
B	31.10	30.00	3.86	2.75	9.00
B	31.50	31.10	3.81	2.84	9.00
B	33.10	31.50	3.76	3.32	9.00
B	34.50	33.10	3.76	3.00	9.00
B	35.10	34.50	3.76	2.96	9.00
B	36.00	35.10	3.71	3.00	9.00
B	37.10	36.00	3.66	3.27	9.00
B	37.50	37.10	3.56	3.09	9.00
B	39.10	37.50	3.36	2.59	9.00
B	40.50	39.10	3.21	1.60	9.00
B	41.10	40.50	3.11	0.92	9.00
B	42.00	41.10	3.01	0.50	9.00
B	43.10	42.00	2.81	0.31	9.00
B	45.10	43.10	2.61	3.54	9.00
B	46.00	45.10	1.51	3.45	9.00
B	54.10	46.00	0.23	1.09	9.00
B	56.80	54.10	0.00	0.00	9.00
A	0.37	25.00	16.90		
B	21.00	0.00	0.00	0.00	9.00
B	36.00	21.00	0.00	0.00	9.00
B	42.90	36.00	0.00	0.00	9.00
B	43.70	42.90	0.00	0.00	9.00
B	46.70	43.70	0.00	0.00	9.00
B	48.00	46.70	0.02	0.00	9.00
B	49.00	48.00	0.14	1.06	9.00
B	49.70	49.00	0.29	1.52	9.00
B	50.50	49.70	0.34	2.00	9.00
B	51.70	50.50	0.34	2.47	9.00
B	52.00	51.70	0.39	2.57	9.00
B	53.70	52.00	0.49	2.21	9.00
B	55.10	53.70	0.54	2.23	9.00
B	55.70	55.10	0.59	1.96	9.00
B	56.50	55.70	0.64	1.69	9.00
B	57.70	56.50	0.64	2.43	9.00
B	58.00	57.70	0.69	2.59	9.00
B	59.70	58.00	0.74	1.41	9.00
B	61.20	59.70	0.74	1.67	9.00
B	61.70	61.20	0.69	1.25	9.00
B	63.50	61.70	0.64	0.07	9.00
B	63.70	63.50	0.64	0.46	9.00
B	64.00	63.70	0.59	1.31	9.00
B	65.50	64.00	0.54	1.60	9.00
B	65.70	65.50	0.54	1.77	9.00
B	67.00	65.70	0.54	3.06	9.00
B	67.70	67.00	0.49	3.01	9.00
B	68.50	67.70	0.44	2.86	9.00
B	69.70	68.50	0.39	1.20	9.00
B	70.00	69.70	0.34	0.88	9.00
B	71.70	70.00	0.19	0.79	9.00
B	73.00	71.70	0.14	2.31	9.00
B	73.70	73.00	0.24	2.26	9.00
B	74.50	73.70	0.19	2.09	9.00
B	75.70	74.50	0.14	0.65	9.00
B	76.00	75.70	0.07	0.38	9.00
B	77.50	76.00	0.00	0.00	9.00
B	77.70	77.50	0.00	0.00	9.00
B	79.70	77.70	0.00	0.00	9.00
B	84.70	79.70	0.00	0.00	9.00
B	96.00	84.70	0.00	0.00	9.00
A	0.37	175.00	17.90		
B	21.00	0.00	0.00	0.00	9.00
B	36.00	21.00	0.00	0.00	9.00
B	42.90	36.00	0.00	0.00	9.00
B	43.70	42.90	0.22	0.00	9.00
B	46.70	43.70	0.59	0.28	9.00
B	48.00	46.70	0.89	0.81	9.00
B	49.00	48.00	1.14	1.47	9.00
B	49.70	49.00	1.29	1.85	9.00
B	50.50	49.70	1.34	2.43	9.00
B	51.70	50.50	1.34	3.22	9.00
B	52.00	51.70	1.39	3.47	9.00

B	53.70	52.00	1.49	4.58	9.00
B	55.10	53.70	1.54	4.80	9.00
B	55.70	55.10	1.59	4.77	9.00
B	56.50	55.70	1.64	4.49	9.00
B	57.70	56.50	1.64	4.63	9.00
B	58.00	57.70	1.69	4.79	9.00
B	59.70	58.00	1.74	4.66	9.00
B	61.20	59.70	1.74	4.57	9.00
B	61.70	61.20	1.69	4.21	9.00
B	63.50	61.70	1.64	2.43	9.00
B	63.70	63.50	1.64	3.69	9.00
B	64.00	63.70	1.59	4.54	9.00
B	65.50	64.00	1.54	4.32	9.00
B	65.70	65.50	1.54	4.36	9.00
B	67.00	65.70	1.54	4.75	9.00
B	67.70	67.00	1.49	4.66	9.00
B	68.50	67.70	1.44	4.87	9.00
B	69.70	68.50	1.39	4.35	9.00
B	70.00	69.70	1.34	3.97	9.00
B	71.70	70.00	1.19	3.32	9.00
B	73.00	71.70	1.14	3.74	9.00
B	73.70	73.00	1.24	3.47	9.00
B	74.50	73.70	1.19	3.46	9.00
B	75.70	74.50	1.14	2.74	9.00
B	76.00	75.70	1.04	2.31	9.00
B	77.50	76.00	0.89	1.88	9.00
B	77.70	77.50	0.42	1.70	9.00
B	79.70	77.70	0.00	0.00	9.00
B	84.70	79.70	0.00	0.00	9.00
B	96.00	84.70	0.00	0.00	9.00
A	0.37	450.00	18.80		
B	21.00	0.00	0.00	0.00	9.00
B	36.00	21.00	0.16	0.00	9.00
B	42.90	36.00	0.47	0.78	9.00
B	43.70	42.90	0.97	1.20	9.00
B	46.70	43.70	1.47	0.55	9.00
B	48.00	46.70	1.77	1.27	9.00
B	49.00	48.00	2.02	1.66	9.00
B	49.70	49.00	2.17	1.97	9.00
B	50.50	49.70	2.22	2.57	9.00
B	51.70	50.50	2.22	3.53	9.00
B	52.00	51.70	2.27	3.88	9.00
B	53.70	52.00	2.37	6.26	9.00
B	55.10	53.70	2.42	6.71	9.00
B	55.70	55.10	2.47	7.05	9.00
B	56.50	55.70	2.52	6.92	9.00
B	57.70	56.50	2.52	6.10	9.00
B	58.00	57.70	2.57	6.22	9.00
B	59.70	58.00	2.62	7.99	9.00
B	61.20	59.70	2.62	7.14	9.00
B	61.70	61.20	2.57	7.25	9.00
B	63.50	61.70	2.52	12.94	9.00
B	63.70	63.50	2.52	9.66	9.00
B	64.00	63.70	2.47	7.96	9.00
B	65.50	64.00	2.42	6.72	9.00
B	65.70	65.50	2.42	6.49	9.00
B	67.00	65.70	2.42	5.67	9.00
B	67.70	67.00	2.37	5.55	9.00
B	68.50	67.70	2.32	6.06	9.00
B	69.70	68.50	2.27	7.79	9.00
B	70.00	69.70	2.22	7.90	9.00
B	71.70	70.00	2.07	6.36	9.00
B	73.00	71.70	2.02	4.55	9.00
B	73.70	73.00	2.12	4.12	9.00
B	74.50	73.70	2.07	4.26	9.00
B	75.70	74.50	2.02	5.29	9.00
B	76.00	75.70	1.92	5.31	9.00
B	77.50	76.00	1.77	2.74	9.00
B	77.70	77.50	1.27	2.57	9.00
B	79.70	77.70	0.62	1.46	9.00
B	84.70	79.70	0.21	0.93	9.00
B	96.00	84.70	0.00	0.00	9.00
A	0.40	25.00	16.90		
B	30.00	0.00	0.00	0.00	9.00
B	44.40	30.00	0.00	0.00	9.00
B	59.10	44.40	0.00	0.00	9.00
B	62.10	59.10	0.00	0.00	9.00
B	65.10	62.10	0.00	0.00	9.00
B	70.10	65.10	0.00	0.00	9.00
B	74.10	70.10	0.00	0.00	9.00
B	78.10	74.10	0.00	0.00	9.00
B	80.10	78.10	0.00	0.00	9.00
B	82.00	80.10	0.00	0.00	9.00
B	84.00	82.00	0.00	0.00	9.00
B	85.10	84.00	0.07	0.00	9.00
B	86.00	85.10	0.19	1.45	9.00
B	87.00	86.00	0.29	1.79	9.00
B	88.00	87.00	0.39	1.36	9.00
B	89.10	88.00	0.49	2.95	9.00
B	90.10	89.10	0.59	4.03	9.00
B	91.00	90.10	0.69	5.24	9.00
B	92.10	91.00	0.74	5.30	9.00
B	93.00	92.10	0.69	5.10	9.00
B	94.00	93.00	0.59	2.45	9.00
B	95.10	94.00	0.49	2.89	9.00
B	96.00	95.10	0.39	3.65	9.00
B	97.00	96.00	0.29	2.98	9.00
B	98.00	97.00	0.19	2.70	9.00
B	99.00	98.00	0.09	2.12	9.00
B	100.10	99.00	0.02	3.15	9.00
B	101.10	100.10	0.00	0.00	9.00
B	102.10	101.10	0.00	0.00	9.00
B	106.10	102.10	0.00	0.00	9.00
B	116.40	106.10	0.00	0.00	9.00
B	122.10	116.40	0.00	0.00	9.00
B	132.10	122.10	0.00	0.00	9.00
B	136.10	132.10	0.00	0.00	9.00
B	140.10	136.10	0.00	0.00	9.00
B	144.10	140.10	0.00	0.00	9.00
B	156.30	144.10	0.00	0.00	9.00
A	0.40	175.00	19.00		
B	30.00	0.00	0.00	0.00	9.00
B	44.40	30.00	0.00	0.00	9.00
B	59.10	44.40	0.00	0.00	9.00
B	62.10	59.10	0.00	0.00	9.00
B	65.10	62.10	0.00	0.00	9.00
B	70.10	65.10	0.00	0.00	9.00
B	74.10	70.10	0.00	0.00	9.00
B	78.10	74.10	0.29	0.00	9.00
B	80.10	78.10	1.12	0.55	9.00
B	82.00	80.10	1.77	1.82	9.00
B	84.00	82.00	1.92	1.97	9.00
B	85.10	84.00	2.07	2.69	9.00
B	86.00	85.10	2.22	3.06	9.00
B	87.00	86.00	2.32	3.22	9.00
B	88.00	87.00	2.42	4.28	9.00
B	89.10	88.00	2.52	3.59	9.00
B	90.10	89.10	2.62	3.85	9.00
B	91.00	90.10	2.72	4.01	9.00
B	92.10	91.00	2.77	3.93	9.00
B	93.00	92.10	2.72	3.83	9.00
B	94.00	93.00	2.62	3.19	9.00
B	95.10	94.00	2.52	3.23	9.00
B	96.00	95.10	2.42	3.30	9.00

B	97.00	96.00	2.32	3.06	9.00
B	98.00	97.00	2.22	2.90	9.00
B	99.00	98.00	2.12	2.66	9.00
B	100.10	99.00	2.02	2.79	9.00
B	101.10	100.10	1.67	1.93	9.00
B	102.10	101.10	0.69	0.62	9.00
B	106.10	102.10	0.00	0.00	9.00
B	116.40	106.10	0.00	0.00	9.00
B	122.10	116.40	0.14	0.00	9.00
B	132.10	122.10	0.32	0.30	9.00
B	136.10	132.10	0.37	0.45	9.00
B	140.10	136.10	0.19	0.76	9.00
B	144.10	140.10	0.00	0.00	9.00
B	156.30	144.10	0.00	0.00	9.00
A	0.40	450.00	21.50		
B	30.00	0.00	0.00	0.00	9.00
B	44.40	30.00	0.60	0.00	9.00
B	59.10	44.40	1.39	0.80	9.00
B	62.10	59.10	1.84	0.98	9.00
B	65.10	62.10	2.19	0.50	9.00
B	70.10	65.10	2.29	0.63	9.00
B	74.10	70.10	2.34	0.69	9.00
B	78.10	74.10	2.74	0.79	9.00
B	80.10	78.10	3.64	0.94	9.00
B	82.00	80.10	4.29	1.85	9.00
B	84.00	82.00	4.44	3.24	9.00
B	85.10	84.00	4.59	3.30	9.00
B	86.00	85.10	4.74	3.01	9.00
B	87.00	86.00	4.84	2.94	9.00
B	88.00	87.00	4.94	5.14	9.00
B	89.10	88.00	5.04	2.70	9.00
B	90.10	89.10	5.14	2.57	9.00
B	91.00	90.10	5.24	2.40	9.00
B	92.10	91.00	5.29	2.32	9.00
B	93.00	92.10	5.24	2.27	9.00
B	94.00	93.00	5.14	2.48	9.00
B	95.10	94.00	5.04	2.33	9.00
B	96.00	95.10	4.94	2.15	9.00
B	97.00	96.00	4.84	2.12	9.00
B	98.00	97.00	4.74	2.05	9.00
B	99.00	98.00	4.64	2.03	9.00
B	100.10	99.00	4.54	1.79	9.00
B	101.10	100.10	4.19	1.15	9.00
B	102.10	101.10	2.99	0.69	9.00
B	106.10	102.10	2.19	0.45	9.00
B	116.40	106.10	2.39	0.48	9.00
B	122.10	116.40	2.64	0.54	9.00
B	132.10	122.10	2.84	0.80	9.00
B	136.10	132.10	2.89	0.98	9.00
B	140.10	136.10	2.69	1.66	9.00
B	144.10	140.10	1.89	0.43	9.00
B	156.30	144.10	1.29	0.85	9.00
A	0.47	25.00	19.40		
B	23.10	0.00	0.00	0.00	9.00
B	31.60	23.10	0.00	0.00	9.00
B	37.10	31.60	0.00	0.00	9.00
B	40.10	37.10	0.00	0.00	9.00
B	41.10	40.10	0.11	0.40	9.00
B	42.60	41.10	0.26	0.68	9.00
B	43.10	42.60	0.36	0.64	9.00
B	44.10	43.10	0.51	0.62	9.00
B	45.10	44.10	0.66	0.82	9.00
B	45.60	45.10	0.86	0.93	9.00
B	47.20	45.60	0.96	1.18	9.00
B	48.60	47.20	0.91	0.91	9.00
B	49.10	48.60	0.91	0.94	9.00
B	50.10	49.10	0.91	1.08	9.00
B	51.10	50.10	0.91	1.36	9.00
B	51.60	51.10	0.91	1.51	9.00
B	53.10	51.60	0.91	1.48	9.00
B	54.60	53.10	0.86	1.62	9.00
B	55.10	54.60	0.81	1.61	9.00
B	56.10	55.10	0.81	1.55	9.00
B	57.10	56.10	0.81	1.24	9.00
B	57.60	57.10	0.81	1.13	9.00
B	59.10	57.60	0.81	1.40	9.00
B	60.60	59.10	0.76	1.30	9.00
B	61.10	60.60	0.71	1.39	9.00
B	62.10	61.10	0.66	1.59	9.00
B	63.10	62.10	0.61	1.24	9.00
B	63.60	63.10	0.56	1.10	9.00
B	65.10	63.60	0.46	1.48	9.00
B	66.60	65.10	0.41	1.19	9.00
B	67.10	66.60	0.36	0.81	9.00
B	68.10	67.10	0.16	0.16	9.00
B	69.10	68.10	0.00	0.12	9.00
B	70.50	69.10	0.00	0.00	9.00
B	71.10	70.50	0.00	0.00	9.00
B	75.10	71.10	0.00	0.00	9.00
B	83.10	75.10	0.00	0.00	9.00
B	93.10	83.10	0.00	0.00	9.00
B	95.10	93.10	0.00	0.00	9.00
B	113.20	95.10	0.00	0.00	9.00
B	115.10	113.20	0.00	0.00	9.00
B	121.10	115.10	0.00	0.00	9.00
B	139.00	121.10	0.00	0.00	9.00
A	0.47	175.00	20.50		
B	23.10	0.00	0.00	0.00	9.00
B	31.60	23.10	0.00	0.00	9.00
B	37.10	31.60	0.43	0.00	9.00
B	40.10	37.10	0.95	0.22	9.00
B	41.10	40.10	1.15	1.03	9.00
B	42.60	41.10	1.30	2.14	9.00
B	43.10	42.60	1.40	2.40	9.00
B	44.10	43.10	1.55	2.52	9.00
B	45.10	44.10	1.70	2.81	9.00
B	45.60	45.10	1.90	2.92	9.00
B	47.20	45.60	2.00	3.18	9.00
B	48.60	47.20	1.95	3.65	9.00
B	49.10	48.60	1.95	3.90	9.00
B	50.10	49.10	1.95	3.99	9.00
B	51.10	50.10	1.95	4.17	9.00
B	51.60	51.10	1.95	4.26	9.00
B	53.10	51.60	1.95	4.19	9.00
B	54.60	53.10	1.90	4.23	9.00
B	55.10	54.60	1.85	4.21	9.00
B	56.10	55.10	1.85	4.32	9.00
B	57.10	56.10	1.85	4.25	9.00
B	57.60	57.10	1.85	3.98	9.00
B	59.10	57.60	1.85	3.60	9.00
B	60.60	59.10	1.80	3.58	9.00
B	61.10	60.60	1.75	3.65	9.00
B	62.10	61.10	1.70	3.66	9.00
B	63.10	62.10	1.65	3.36	9.00
B	63.60	63.10	1.60	3.04	9.00
B	65.10	63.60	1.50	2.43	9.00
B	66.60	65.10	1.45	1.86	9.00
B	67.10	66.60	1.40	1.56	9.00
B	68.10	67.10	1.20	0.75	9.00
B	69.10	68.10	0.95	0.33	9.00
B	70.50	69.10	0.75	0.30	9.00
B	71.10	70.50	0.55	0.27	9.00
B	75.10	71.10	0.25	1.50	9.00
B	83.10	75.10	0.03	0.36	9.00

B	93.10	83.10	0.00	0.00	9.00
B	95.10	93.10	0.00	0.00	9.00
B	113.20	95.10	0.00	0.00	9.00
B	115.10	113.20	0.04	0.00	9.00
B	121.10	115.10	0.00	0.00	9.00
B	139.00	121.10	0.00	0.00	9.00
A	0.47	450.00	21.30		
B	23.10	0.00	0.00	0.00	9.00
B	31.60	23.10	0.15	0.00	9.00
B	37.10	31.60	1.00	0.84	9.00
B	40.10	37.10	1.80	0.32	9.00
B	41.10	40.10	2.00	1.53	9.00
B	42.60	41.10	2.15	3.47	9.00
B	43.10	42.60	2.25	4.26	9.00
B	44.10	43.10	2.40	4.62	9.00
B	45.10	44.10	2.55	4.75	9.00
B	45.60	45.10	2.75	4.74	9.00
B	47.20	45.60	2.85	4.80	9.00
B	48.60	47.20	2.80	6.66	9.00
B	49.10	48.60	2.80	7.23	9.00
B	50.10	49.10	2.80	7.01	9.00
B	51.10	50.10	2.80	6.68	9.00
B	51.60	51.10	2.80	6.54	9.00
B	53.10	51.60	2.80	6.46	9.00
B	54.60	53.10	2.75	6.27	9.00
B	55.10	54.60	2.70	6.25	9.00
B	56.10	55.10	2.70	6.61	9.00
B	57.10	56.10	2.70	7.18	9.00
B	57.60	57.10	2.70	6.83	9.00
B	59.10	57.60	2.70	5.30	9.00
B	60.60	59.10	2.65	5.45	9.00
B	61.10	60.60	2.60	5.43	9.00
B	62.10	61.10	2.55	5.10	9.00
B	63.10	62.10	2.50	5.08	9.00
B	63.60	63.10	2.45	4.63	9.00
B	65.10	63.60	2.35	2.89	9.00
B	66.60	65.10	2.30	2.16	9.00
B	67.10	66.60	2.25	2.01	9.00
B	68.10	67.10	2.05	1.48	9.00
B	69.10	68.10	1.80	0.50	9.00
B	70.50	69.10	1.60	0.45	9.00
B	71.10	70.50	1.40	0.44	9.00
B	75.10	71.10	1.10	2.24	9.00
B	83.10	75.10	0.70	1.75	9.00
B	93.10	83.10	0.45	1.18	9.00
B	95.10	93.10	0.45	1.02	9.00
B	113.20	95.10	0.55	1.18	9.00
B	115.10	113.20	0.55	1.33	9.00
B	121.10	115.10	0.25	1.18	9.00
B	139.00	121.10	0.00	0.00	9.00
A	0.57	25.00	23.10		
B	20.00	0.00	0.00	0.00	9.00
B	28.60	20.00	0.00	0.00	9.00
B	35.30	28.60	0.00	0.00	9.00
B	40.30	35.30	0.00	0.00	9.00
B	46.30	40.30	0.04	0.00	9.00
B	50.30	46.30	0.18	0.14	9.00
B	52.30	50.30	0.38	0.31	9.00
B	54.30	52.30	0.63	0.07	9.00
B	57.30	54.30	0.83	1.27	9.00
B	58.30	57.30	0.88	1.75	9.00
B	59.30	58.30	0.93	1.80	9.00
B	60.30	59.30	1.03	1.66	9.00
B	61.30	60.30	1.08	1.70	9.00
B	62.30	61.30	1.13	1.49	9.00
B	63.30	62.30	1.23	1.37	9.00
B	64.40	63.30	1.23	1.44	9.00

B	65.30	64.40	1.13	1.32	9.00
B	66.30	65.30	1.08	1.45	9.00
B	67.30	66.30	1.03	1.34	9.00
B	68.30	67.30	0.93	1.18	9.00
B	69.30	68.30	0.88	1.09	9.00
B	70.30	69.30	0.83	1.18	9.00
B	71.30	70.30	0.73	1.00	9.00
B	72.30	71.30	0.68	0.41	9.00
B	73.30	72.30	0.63	0.08	9.00
B	74.30	73.30	0.53	0.25	9.00
B	75.30	74.30	0.48	0.57	9.00
B	76.40	75.30	0.24	0.06	9.00
B	77.30	76.40	0.00	0.00	9.00
B	80.30	77.30	0.00	0.00	9.00
B	83.30	80.30	0.00	0.00	9.00
B	86.30	83.30	0.00	0.00	9.00
B	94.30	86.30	0.00	0.00	9.00
B	110.30	94.30	0.00	0.00	9.00
B	120.30	110.30	0.00	0.00	9.00
B	134.30	120.30	0.00	0.00	9.00
B	144.30	134.30	0.00	0.00	9.00
B	152.30	144.30	0.00	0.00	9.00
B	162.30	152.30	0.00	0.00	9.00
A	0.57	175.00	25.05		
B	20.00	0.00	0.00	0.00	9.00
B	28.60	20.00	0.00	0.00	9.00
B	35.30	28.60	0.50	0.00	9.00
B	40.30	35.30	1.30	1.15	9.00
B	46.30	40.30	1.80	1.57	9.00
B	50.30	46.30	2.10	1.82	9.00
B	52.30	50.30	2.30	1.94	9.00
B	54.30	52.30	2.55	0.22	9.00
B	57.30	54.30	2.75	0.80	9.00
B	58.30	57.30	2.80	1.00	9.00
B	59.30	58.30	2.85	1.13	9.00
B	60.30	59.30	2.95	1.85	9.00
B	61.30	60.30	3.00	2.52	9.00
B	62.30	61.30	3.05	3.05	9.00
B	63.30	62.30	3.15	2.89	9.00
B	64.40	63.30	3.15	2.80	9.00
B	65.30	64.40	3.05	2.65	9.00
B	66.30	65.30	3.00	2.78	9.00
B	67.30	66.30	2.95	2.79	9.00
B	68.30	67.30	2.85	2.78	9.00
B	69.30	68.30	2.80	2.75	9.00
B	70.30	69.30	2.75	2.80	9.00
B	71.30	70.30	2.65	2.71	9.00
B	72.30	71.30	2.60	2.19	9.00
B	73.30	72.30	2.55	1.53	9.00
B	74.30	73.30	2.45	1.89	9.00
B	75.30	74.30	2.40	2.20	9.00
B	76.40	75.30	2.15	1.35	9.00
B	77.30	76.40	1.05	2.25	9.00
B	80.30	77.30	0.10	0.93	9.00
B	83.30	80.30	0.00	0.00	9.00
B	86.30	83.30	0.00	0.00	9.00
B	94.30	86.30	0.00	0.00	9.00
B	110.30	94.30	0.00	0.00	9.00
B	120.30	110.30	0.00	0.00	9.00
B	134.30	120.30	0.00	0.00	9.00
B	144.30	134.30	0.00	0.00	9.00
B	152.30	144.30	0.00	0.00	9.00
B	162.30	152.30	0.00	0.00	9.00
A	0.57	450.00	26.70		
B	20.00	0.00	0.00	0.00	9.00
B	28.60	20.00	0.41	0.00	9.00
B	35.30	28.60	1.76	0.66	9.00

B	40.30	35.30	3.01	1.47	9.00
B	46.30	40.30	3.51	1.68	9.00
B	50.30	46.30	3.81	1.81	9.00
B	52.30	50.30	4.01	1.88	9.00
B	54.30	52.30	4.26	0.19	9.00
B	57.30	54.30	4.46	0.36	9.00
B	58.30	57.30	4.51	0.43	9.00
B	59.30	58.30	4.56	0.51	9.00
B	60.30	59.30	4.66	1.09	9.00
B	61.30	60.30	4.71	1.69	9.00
B	62.30	61.30	4.76	2.39	9.00
B	63.30	62.30	4.86	2.29	9.00
B	64.40	63.30	4.86	2.14	9.00
B	65.30	64.40	4.76	2.06	9.00
B	66.30	65.30	4.71	2.10	9.00
B	67.30	66.30	4.66	2.20	9.00
B	68.30	67.30	4.56	2.32	9.00
B	69.30	68.30	4.51	2.37	9.00
B	70.30	69.30	4.46	2.34	9.00
B	71.30	70.30	4.36	2.42	9.00
B	72.30	71.30	4.31	2.69	9.00
B	73.30	72.30	4.26	3.33	9.00
B	74.30	73.30	4.16	2.71	9.00
B	75.30	74.30	4.11	2.32	9.00
B	76.40	75.30	3.86	3.14	9.00
B	77.30	76.40	2.76	2.04	9.00
B	80.30	77.30	1.71	2.49	9.00
B	83.30	80.30	1.51	2.16	9.00
B	86.30	83.30	1.56	0.58	9.00
B	94.30	86.30	1.76	1.46	9.00
B	110.30	94.30	1.96	1.24	9.00
B	120.30	110.30	2.01	1.38	9.00
B	134.30	120.30	1.91	1.05	9.00
B	144.30	134.30	1.61	1.12	9.00
B	152.30	144.30	1.11	0.95	9.00
B	162.30	152.30	0.81	0.66	9.00
A	0.63	25.00	24.40		
B	22.80	0.00	0.00	0.00	9.00
B	40.90	22.80	0.00	0.00	9.00
B	44.90	40.90	0.00	0.00	9.00
B	46.00	44.90	0.00	0.00	9.00
B	49.00	46.00	0.00	0.00	9.00
B	52.00	49.00	0.16	0.00	9.00
B	54.10	52.00	0.37	1.23	9.00
B	55.50	54.10	0.42	1.57	9.00
B	56.00	55.50	0.42	1.68	9.00
B	57.00	56.00	0.47	1.92	9.00
B	58.00	57.00	0.52	1.93	9.00
B	58.50	58.00	0.57	1.97	9.00
B	60.00	58.50	0.67	0.84	9.00
B	61.00	60.00	0.67	2.39	9.00
B	61.50	61.00	0.62	3.28	9.00
B	63.00	61.50	0.62	3.41	9.00
B	64.00	63.00	0.62	3.41	9.00
B	64.50	64.00	0.57	3.44	9.00
B	66.00	64.50	0.52	4.03	9.00
B	67.00	66.00	0.52	3.40	9.00
B	67.50	67.00	0.47	3.10	9.00
B	69.00	67.50	0.42	3.11	9.00
B	70.00	69.00	0.42	2.35	9.00
B	70.50	70.00	0.37	2.01	9.00
B	72.00	70.50	0.32	2.06	9.00
B	73.00	72.00	0.32	1.77	9.00
B	73.50	73.00	0.27	1.73	9.00
B	75.00	73.50	0.22	2.20	9.00
B	76.00	75.00	0.22	1.32	9.00
B	76.50	76.00	0.17	1.26	9.00
B	78.00	76.50	0.07	0.23	9.00
B	79.30	78.00	0.01	0.07	9.00
B	81.00	79.30	0.00	0.00	9.00
B	82.00	81.00	0.00	0.00	9.00
B	84.00	82.00	0.00	0.00	9.00
B	87.00	84.00	0.00	0.00	9.00
B	90.00	87.00	0.00	0.00	9.00
B	93.00	90.00	0.00	0.00	9.00
B	96.00	93.00	0.00	0.00	9.00
B	99.00	96.00	0.00	0.00	9.00
B	102.00	99.00	0.00	0.00	9.00
B	104.00	102.00	0.00	0.00	9.00
B	109.00	104.00	0.00	0.00	9.00
A	0.63	175.00	25.40		
B	22.80	0.00	0.00	0.00	9.00
B	40.90	22.80	0.00	0.00	9.00
B	44.90	40.90	0.00	0.00	9.00
B	46.00	44.90	0.11	0.00	9.00
B	49.00	46.00	0.52	0.66	9.00
B	52.00	49.00	1.07	1.25	9.00
B	54.10	52.00	1.37	2.76	9.00
B	55.50	54.10	1.42	3.44	9.00
B	56.00	55.50	1.42	3.68	9.00
B	57.00	56.00	1.47	4.09	9.00
B	58.00	57.00	1.52	4.39	9.00
B	58.50	58.00	1.57	4.38	9.00
B	60.00	58.50	1.67	3.53	9.00
B	61.00	60.00	1.67	4.36	9.00
B	61.50	61.00	1.62	4.74	9.00
B	63.00	61.50	1.62	4.98	9.00
B	64.00	63.00	1.62	5.11	9.00
B	64.50	64.00	1.57	5.10	9.00
B	66.00	64.50	1.52	5.19	9.00
B	67.00	66.00	1.52	4.93	9.00
B	67.50	67.00	1.47	4.82	9.00
B	69.00	67.50	1.42	4.78	9.00
B	70.00	69.00	1.42	4.47	9.00
B	70.50	70.00	1.37	4.25	9.00
B	72.00	70.50	1.32	4.07	9.00
B	73.00	72.00	1.32	3.81	9.00
B	73.50	73.00	1.27	3.34	9.00
B	75.00	73.50	1.22	1.95	9.00
B	76.00	75.00	1.22	3.82	9.00
B	76.50	76.00	1.17	3.71	9.00
B	78.00	76.50	1.07	2.38	9.00
B	79.30	78.00	0.87	1.71	9.00
B	81.00	79.30	0.67	1.16	9.00
B	82.00	81.00	0.62	2.35	9.00
B	84.00	82.00	0.57	1.90	9.00
B	87.00	84.00	0.47	1.61	9.00
B	90.00	87.00	0.37	2.04	9.00
B	93.00	90.00	0.27	1.97	9.00
B	96.00	93.00	0.12	1.68	9.00
B	99.00	96.00	0.01	0.23	9.00
B	102.00	99.00	0.00	0.00	9.00
B	104.00	102.00	0.00	0.00	9.00
B	109.00	104.00	0.00	0.00	9.00
A	0.63	450.00	26.40		
B	22.80	0.00	0.00	0.00	9.00
B	40.90	22.80	0.13	0.00	9.00
B	44.90	40.90	0.36	0.52	9.00
B	46.00	44.90	0.81	0.76	9.00
B	49.00	46.00	1.46	1.42	9.00
B	52.00	49.00	2.01	1.82	9.00
B	54.10	52.00	2.31	3.37	9.00
B	55.50	54.10	2.36	4.16	9.00
B	56.00	55.50	2.36	4.46	9.00

B	57.00	56.00	2.41	4.87	9.00
B	58.00	57.00	2.46	5.41	9.00
B	58.50	58.00	2.51	5.32	9.00
B	60.00	58.50	2.61	5.90	9.00
B	61.00	60.00	2.61	4.80	9.00
B	61.50	61.00	2.56	4.66	9.00
B	63.00	61.50	2.56	4.91	9.00
B	64.00	63.00	2.56	5.11	9.00
B	64.50	64.00	2.51	5.06	9.00
B	66.00	64.50	2.46	4.80	9.00
B	67.00	66.00	2.46	4.85	9.00
B	67.50	67.00	2.41	4.90	9.00
B	69.00	67.50	2.36	4.83	9.00
B	70.00	69.00	2.36	5.02	9.00
B	70.50	70.00	2.31	5.05	9.00
B	72.00	70.50	2.26	4.68	9.00
B	73.00	72.00	2.26	4.55	9.00
B	73.50	73.00	2.21	3.78	9.00
B	75.00	73.50	2.16	1.50	9.00
B	76.00	75.00	2.16	5.32	9.00
B	76.50	76.00	2.11	5.19	9.00
B	78.00	76.50	2.01	6.24	9.00
B	79.30	78.00	1.81	7.18	9.00
B	81.00	79.30	1.61	8.19	9.00
B	82.00	81.00	1.56	3.80	9.00
B	84.00	82.00	1.51	3.08	9.00
B	87.00	84.00	1.41	2.80	9.00
B	90.00	87.00	1.31	3.91	9.00
B	93.00	90.00	1.21	4.31	9.00
B	96.00	93.00	1.06	4.46	9.00
B	99.00	96.00	0.56	2.46	9.00
B	102.00	99.00	0.16	0.38	9.00
B	104.00	102.00	0.08	0.38	9.00
B	109.00	104.00	0.00	0.00	9.00

Appendix F
RCHARC Output File
DATADSA.OUT

The SAS System

Observation	Discharge	Depth	Velocity	Count	Percent
1	30	0	0	23.4	6.78064
2	30	0	0.1	6.7	1.94147
3	30	0	0.2	2.1	0.60852
4	30	0	0.3	2.4	0.69545
5	30	0	0.4	2	0.57954
6	30	0	0.5	0	0
7	30	0	0.6	1	0.28977
8	30	0	0.7	3.2	0.92727
9	30	0	0.8	0	0
10	30	0	0.9	0	0
11	30	0	1	1.7	0.49261
12	30	0	1.1	0	0
13	30	0	1.2	0	0
14	30	0	1.3	0	0
15	30	0	1.6	0	0
16	30	0.1	0	11.9	3.44828
17	30	0.1	0.1	4	1.15908
18	30	0.1	0.2	12.7	3.68009
19	30	0.1	0.3	2.9	0.84034
20	30	0.1	0.4	15.5	4.49145
21	30	0.1	0.5	10.7	3.10055
22	30	0.1	0.6	6.2	1.79658
23	30	0.1	0.7	9.1	2.63692
24	30	0.1	0.8	4.5	1.30397
25	30	0.1	0.9	12.7	3.68009
26	30	0.1	1	1.2	0.34773
27	30	0.1	1.1	1.5	0.43466
28	30	0.1	1.2	3.3	0.95624
29	30	0.1	1.3	0.7	0.20284
30	30	0.1	1.6	0	0
31	30	0.2	0	5.4	1.56476
32	30	0.2	0.1	8.3	2.4051
33	30	0.2	0.2	13.6	3.94089
34	30	0.2	0.3	11.5	3.33237
35	30	0.2	0.4	13.8	3.99884
36	30	0.2	0.5	13.1	3.796
37	30	0.2	0.6	7.6	2.20226
38	30	0.2	0.7	5.1	1.47783
39	30	0.2	0.8	2.3	0.66647
40	30	0.2	0.9	5.7	1.6517
41	30	0.2	1	7	2.0284
42	30	0.2	1.1	2	0.57954
43	30	0.2	1.2	3.5	1.0142
44	30	0.2	1.3	0	0
45	30	0.2	1.6	2.9	0.84034
46	30	0.3	0	2.5	0.72443
47	30	0.3	0.1	4.5	1.30397
48	30	0.3	0.2	7.4	2.14431
49	30	0.3	0.3	7.4	2.14431
50	30	0.3	0.4	12.6	3.65112
51	30	0.3	0.5	12.5	3.62214

Observation	Discharge	Depth	Velocity	Count	Percent
52	30	0.3	0.6	2.5	0.72443
53	30	0.3	0.7	2.4	0.69545
54	30	0.3	0.8	1	0.28977
55	30	0.3	0.9	1.2	0.34773
56	30	0.3	1	4.8	1.3909
57	30	0.3	1.1	0	0
58	30	0.3	1.2	0	0
59	30	0.3	1.3	0	0
60	30	0.3	1.6	0	0
61	30	0.4	0	2.9	0.84034
62	30	0.4	0.1	1.7	0.49261
63	30	0.4	0.2	7.9	2.28919
64	30	0.4	0.3	6	1.73863
65	30	0.4	0.4	3.7	1.07215
66	30	0.4	0.5	0	0
67	30	0.4	0.6	0.8	0.23182
68	30	0.4	0.7	2	0.57954
69	30	0.4	0.8	2.1	0.60852
70	30	0.4	0.9	0.9	0.26079
71	30	0.4	1	2.2	0.6375
72	30	0.4	1.1	7	2.0284
73	30	0.4	1.2	0.4	0.11591
74	30	0.4	1.3	0	0
75	30	0.4	1.6	0	0
76	30	0.5	0	0	0
77	30	0.5	0.1	0.4	0.11591
78	30	0.5	0.2	7.1	2.05737
79	30	0.5	0.3	0	0
80	30	0.5	0.4	0	0
81	30	0.5	0.5	0	0
82	30	0.5	0.6	0	0
83	30	0.5	0.7	0	0
84	30	0.5	0.8	0	0
85	30	0.5	0.9	0	0
86	30	0.5	1	0	0
87	30	0.5	1.1	0	0
88	30	0.5	1.2	0	0
89	30	0.5	1.3	0	0
90	30	0.5	1.6	0	0
91	180	0	0	20	3.57398
92	180	0	0.1	13	2.32309
93	180	0	0.2	2	0.3574
94	180	0	0.3	3	0.5361
95	180	0	0.4	0	0
96	180	0	0.5	3	0.5361
97	180	0	0.6	0	0
98	180	0	0.7	0	0
99	180	0	0.8	0	0
100	180	0	0.9	0	0
101	180	0	1	0	0
102	180	0	1.1	0	0
103	180	0	1.2	0	0
104	180	0	1.3	0	0
105	180	0	1.4	0	0

Observation	Discharge	Depth	Velocity	Count	Percent
106	180	0	1.5	0	0
107	180	0	1.6	0	0
108	180	0	1.7	0	0
109	180	0	1.8	0	0
110	180	0	1.9	0	0
111	180	0	2	0	0
112	180	0	2.1	0	0
113	180	0	2.2	0	0
114	180	0	2.4	0	0
115	180	0.1	0	41	7.32666
116	180	0.1	0.1	26.9	4.80701
117	180	0.1	0.2	6	1.07219
118	180	0.1	0.3	2	0.3574
119	180	0.1	0.4	0.2	0.03574
120	180	0.1	0.5	8	1.42959
121	180	0.1	0.6	6	1.07219
122	180	0.1	0.7	0	0
123	180	0.1	0.8	0	0
124	180	0.1	0.9	0	0
125	180	0.1	1	0	0
126	180	0.1	1.1	0	0
127	180	0.1	1.2	0	0
128	180	0.1	1.3	0	0
129	180	0.1	1.4	0	0
130	180	0.1	1.5	0	0
131	180	0.1	1.6	0	0
132	180	0.1	1.7	0	0
133	180	0.1	1.8	0	0
134	180	0.1	1.9	0	0
135	180	0.1	2	0	0
136	180	0.1	2.1	0	0
137	180	0.1	2.2	0	0
138	180	0.1	2.4	0	0
139	180	0.2	0	12.7	2.26948
140	180	0.2	0.1	12.1	2.16226
141	180	0.2	0.2	11	1.96569
142	180	0.2	0.3	2	0.3574
143	180	0.2	0.4	1.7	0.30379
144	180	0.2	0.5	4.2	0.75054
145	180	0.2	0.6	3.3	0.58971
146	180	0.2	0.7	1	0.1787
147	180	0.2	0.8	0	0
148	180	0.2	0.9	0	0
149	180	0.2	1	0	0
150	180	0.2	1.1	0	0
151	180	0.2	1.2	0	0
152	180	0.2	1.3	0	0
153	180	0.2	1.4	0	0
154	180	0.2	1.5	0	0
155	180	0.2	1.6	0	0
156	180	0.2	1.7	0	0
157	180	0.2	1.8	0	0
158	180	0.2	1.9	0	0
159	180	0.2	2	0	0

Observation	Discharge	Depth	Velocity	Count	Percent
160	180	0.2	2.1	0	0
161	180	0.2	2.2	0	0
162	180	0.2	2.4	0	0
163	180	0.3	0	2.6	0.46462
164	180	0.3	0.1	5.4	0.96497
165	180	0.3	0.2	7.3	1.3045
166	180	0.3	0.3	0	0
167	180	0.3	0.4	8.5	1.51894
168	180	0.3	0.5	3.9	0.69693
169	180	0.3	0.6	2.1	0.37527
170	180	0.3	0.7	2.7	0.48249
171	180	0.3	0.8	1.2	0.21444
172	180	0.3	0.9	3.8	0.67906
173	180	0.3	1	1.6	0.28592
174	180	0.3	1.1	1.3	0.23231
175	180	0.3	1.2	0	0
176	180	0.3	1.3	0	0
177	180	0.3	1.4	0	0
178	180	0.3	1.5	0	0
179	180	0.3	1.6	0	0
180	180	0.3	1.7	0	0
181	180	0.3	1.8	0	0
182	180	0.3	1.9	0	0
183	180	0.3	2	0	0
184	180	0.3	2.1	0	0
185	180	0.3	2.2	0	0
186	180	0.3	2.4	0	0
187	180	0.4	0	0	0
188	180	0.4	0.1	3.5	0.62545
189	180	0.4	0.2	3.2	0.57184
190	180	0.4	0.3	1	0.1787
191	180	0.4	0.4	5	0.8935
192	180	0.4	0.5	3	0.5361
193	180	0.4	0.6	5.7	1.01858
194	180	0.4	0.7	4.7	0.83989
195	180	0.4	0.8	2.4	0.42888
196	180	0.4	0.9	3	0.5361
197	180	0.4	1	4.8	0.85776
198	180	0.4	1.1	3.5	0.62545
199	180	0.4	1.2	5.7	1.01858
200	180	0.4	1.3	1.7	0.30379
201	180	0.4	1.4	1	0.1787
202	180	0.4	1.5	2.8	0.50036
203	180	0.4	1.6	0	0
204	180	0.4	1.7	0	0
205	180	0.4	1.8	0	0
206	180	0.4	1.9	0	0
207	180	0.4	2	0	0
208	180	0.4	2.1	0	0
209	180	0.4	2.2	0	0
210	180	0.4	2.4	0	0
211	180	0.5	0	0	0
212	180	0.5	0.1	1.4	0.25018
213	180	0.5	0.2	4.5	0.80415

Observation	Discharge	Depth	Velocity	Count	Percent
214	180	0.5	0.3	3	0.5361
215	180	0.5	0.4	0	0
216	180	0.5	0.5	9	1.60829
217	180	0.5	0.6	8.9	1.59042
218	180	0.5	0.7	11	1.96569
219	180	0.5	0.8	1	0.1787
220	180	0.5	0.9	6.2	1.10793
221	180	0.5	1	2	0.3574
222	180	0.5	1.1	9.5	1.69764
223	180	0.5	1.2	11	1.96569
224	180	0.5	1.3	10	1.78699
225	180	0.5	1.4	17.9	3.19871
226	180	0.5	1.5	10.8	1.92995
227	180	0.5	1.6	5.3	0.94711
228	180	0.5	1.7	6	1.07219
229	180	0.5	1.8	0	0
230	180	0.5	1.9	0	0
231	180	0.5	2	0	0
232	180	0.5	2.1	0	0
233	180	0.5	2.2	0	0
234	180	0.5	2.4	0	0
235	180	0.6	0	0	0
236	180	0.6	0.1	2.6	0.46462
237	180	0.6	0.2	2	0.3574
238	180	0.6	0.3	0	0
239	180	0.6	0.4	1	0.1787
240	180	0.6	0.5	1	0.1787
241	180	0.6	0.6	9.5	1.69764
242	180	0.6	0.7	4.9	0.87563
243	180	0.6	0.8	4.2	0.75054
244	180	0.6	0.9	1.6	0.28592
245	180	0.6	1	1.7	0.30379
246	180	0.6	1.1	2.9	0.51823
247	180	0.6	1.2	3	0.5361
248	180	0.6	1.3	7	1.25089
249	180	0.6	1.4	0.2	0.03574
250	180	0.6	1.5	0	0
251	180	0.6	1.6	0	0
252	180	0.6	1.7	0	0
253	180	0.6	1.8	0.8	0.14296
254	180	0.6	1.9	1	0.1787
255	180	0.6	2	0	0
256	180	0.6	2.1	1	0.1787
257	180	0.6	2.2	0.8	0.14296
258	180	0.6	2.4	1.2	0.21444
259	180	0.7	0	0	0
260	180	0.7	0.1	1.1	0.19657
261	180	0.7	0.2	4.3	0.76841
262	180	0.7	0.3	0	0
263	180	0.7	0.4	1.6	0.28592
264	180	0.7	0.5	2.7	0.48249
265	180	0.7	0.6	4	0.7148
266	180	0.7	0.7	10.2	1.82273

Observation	Discharge	Depth	Velocity	Count	Percent
267	180	0.7	0.8	0.4	0.07148
268	180	0.7	0.9	2.9	0.51823
269	180	0.7	1	1.9	0.33953
270	180	0.7	1.1	1	0.1787
271	180	0.7	1.2	4	0.7148
272	180	0.7	1.3	1	0.1787
273	180	0.7	1.4	0	0
274	180	0.7	1.5	0	0
275	180	0.7	1.6	0	0
276	180	0.7	1.7	0	0
277	180	0.7	1.8	0	0
278	180	0.7	1.9	0	0
279	180	0.7	2	2	0.3574
280	180	0.7	2.1	2.2	0.39314
281	180	0.7	2.2	0	0
282	180	0.7	2.4	0	0
283	180	0.8	0	0	0
284	180	0.8	0.1	2	0.3574
285	180	0.8	0.2	3.9	0.69693
286	180	0.8	0.3	0	0
287	180	0.8	0.4	2	0.3574
288	180	0.8	0.5	3	0.5361
289	180	0.8	0.6	5.3	0.94711
290	180	0.8	0.7	11.2	2.00143
291	180	0.8	0.8	5.2	0.92924
292	180	0.8	0.9	8.5	1.51894
293	180	0.8	1	10.5	1.87634
294	180	0.8	1.1	4.1	0.73267
295	180	0.8	1.2	5.9	1.05432
296	180	0.8	1.3	0	0
297	180	0.8	1.4	0.4	0.07148
298	180	0.8	1.5	0.4	0.07148
299	180	0.8	1.6	1.6	0.28592
300	180	0.8	1.7	0	0
301	180	0.8	1.8	0	0
302	180	0.8	1.9	0	0
303	180	0.8	2	0	0
304	180	0.8	2.1	0	0
305	180	0.8	2.2	0	0
306	180	0.8	2.4	0	0
307	180	0.9	0	0	0
308	180	0.9	0.1	0	0
309	180	0.9	0.2	0	0
310	180	0.9	0.3	2	0.3574
311	180	0.9	0.4	0	0
312	180	0.9	0.5	1.5	0.26805
313	180	0.9	0.6	3.4	0.60758
314	180	0.9	0.7	5.6	1.00071
315	180	0.9	0.8	4.9	0.87563
316	180	0.9	0.9	2	0.3574
317	180	0.9	1	0	0
318	180	0.9	1.1	0	0
319	180	0.9	1.2	0	0
320	180	0.9	1.3	0	0
321	180	0.9	1.4	0	0

Observation	Discharge	Depth	Velocity	Count	Percent
322	180	0.9	1.5	0	0
323	180	0.9	1.6	0	0
324	180	0.9	1.7	0	0
325	180	0.9	1.8	0	0
326	180	0.9	1.9	0	0
327	180	0.9	2	0	0
328	180	0.9	2.1	0	0
329	180	0.9	2.2	0	0
330	180	0.9	2.4	0	0
331	180	1	0	0	0
332	180	1	0.1	0	0
333	180	1	0.2	0	0
334	180	1	0.3	0	0
335	180	1	0.4	0	0
336	180	1	0.5	0	0
337	180	1	0.6	0	0
338	180	1	0.7	0.4	0.07148
339	180	1	0.8	0	0
340	180	1	0.9	2.1	0.37527
341	180	1	1	0	0
342	180	1	1.1	0	0
343	180	1	1.2	0	0
344	180	1	1.3	0	0
345	180	1	1.4	0	0
346	180	1	1.5	0	0
347	180	1	1.6	0	0
348	180	1	1.7	0	0
349	180	1	1.8	0	0
350	180	1	1.9	0	0
351	180	1	2	0	0
352	180	1	2.1	0	0
353	180	1	2.2	0	0
354	180	1	2.4	0	0
355	450	0	0	41.6	4.00269
356	450	0	0.1	39.9	3.83912
357	450	0	0.2	0	0
358	450	0	0.3	0	0
359	450	0	0.4	0	0
360	450	0	0.5	0	0
361	450	0	0.6	0	0
362	450	0	0.7	0	0
363	450	0	0.8	0	0
364	450	0	0.9	0	0
365	450	0	1	0	0
366	450	0	1.1	0	0
367	450	0	1.2	0	0
368	450	0	1.3	0	0
369	450	0	1.4	0	0
370	450	0	1.5	0	0
371	450	0	1.6	0	0
372	450	0	1.7	0	0
373	450	0	1.8	0	0
374	450	0	1.9	0	0
375	450	0	2	0	0

Observation	Discharge	Depth	Velocity	Count	Percent
376	450	0	2.1	0	0
377	450	0	2.2	0	0
378	450	0	2.3	0	0
379	450	0	2.4	0	0
380	450	0	2.5	0	0
381	450	0	2.6	0	0
382	450	0	2.7	0	0
383	450	0	2.8	0	0
384	450	0	2.9	0	0
385	450	0	3.9	0	0
386	450	0.1	0	80.7	7.76484
387	450	0.1	0.1	0	0
388	450	0.1	0.2	21.5	2.0687
389	450	0.1	0.3	34.5	3.31954
390	450	0.1	0.4	35	3.36765
391	450	0.1	0.5	0	0
392	450	0.1	0.6	0	0
393	450	0.1	0.7	0	0
394	450	0.1	0.8	0	0
395	450	0.1	0.9	0	0
396	450	0.1	1	0	0
397	450	0.1	1.1	0	0
398	450	0.1	1.2	0	0
399	450	0.1	1.3	0	0
400	450	0.1	1.4	0	0
401	450	0.1	1.5	0	0
402	450	0.1	1.6	0	0
403	450	0.1	1.7	0	0
404	450	0.1	1.8	0	0
405	450	0.1	1.9	0	0
406	450	0.1	2	0	0
407	450	0.1	2.1	0	0
408	450	0.1	2.2	0	0
409	450	0.1	2.3	0	0
410	450	0.1	2.4	0	0
411	450	0.1	2.5	0	0
412	450	0.1	2.6	0	0
413	450	0.1	2.7	0	0
414	450	0.1	2.8	0	0
415	450	0.1	2.9	0	0
416	450	0.1	3.9	0	0
417	450	0.2	0	28.4	2.73261
418	450	0.2	0.1	0	0
419	450	0.2	0.2	13.1	1.26046
420	450	0.2	0.3	8.4	0.80824
421	450	0.2	0.4	24	2.30925
422	450	0.2	0.5	9	0.86597
423	450	0.2	0.6	0	0
424	450	0.2	0.7	3	0.28866
425	450	0.2	0.8	0	0
426	450	0.2	0.9	0	0
427	450	0.2	1	0	0
428	450	0.2	1.1	0	0
429	450	0.2	1.2	0	0

Observation	Discharge	Depth	Velocity	Count	Percent
430	450	0.2	1.3	0	0
431	450	0.2	1.4	0	0
432	450	0.2	1.5	0	0
433	450	0.2	1.6	0	0
434	450	0.2	1.7	0	0
435	450	0.2	1.8	0	0
436	450	0.2	1.9	0	0
437	450	0.2	2	0	0
438	450	0.2	2.1	0	0
439	450	0.2	2.2	0	0
440	450	0.2	2.3	0	0
441	450	0.2	2.4	0	0
442	450	0.2	2.5	0	0
443	450	0.2	2.6	0	0
444	450	0.2	2.7	0	0
445	450	0.2	2.8	0	0
446	450	0.2	2.9	0	0
447	450	0.2	3.9	0	0
448	450	0.3	0	0	0
449	450	0.3	0.1	26.3	2.53055
450	450	0.3	0.2	6	0.57731
451	450	0.3	0.3	15.5	1.49139
452	450	0.3	0.4	1.8	0.17319
453	450	0.3	0.5	0	0
454	450	0.3	0.6	0	0
455	450	0.3	0.7	6	0.57731
456	450	0.3	0.8	0	0
457	450	0.3	0.9	0	0
458	450	0.3	1	0	0
459	450	0.3	1.1	0	0
460	450	0.3	1.2	0	0
461	450	0.3	1.3	1.2	0.11546
462	450	0.3	1.4	3	0.28866
463	450	0.3	1.5	0	0
464	450	0.3	1.6	0	0
465	450	0.3	1.7	0	0
466	450	0.3	1.8	0	0
467	450	0.3	1.9	0	0
468	450	0.3	2	0	0
469	450	0.3	2.1	0	0
470	450	0.3	2.2	0	0
471	450	0.3	2.3	0	0
472	450	0.3	2.4	0	0
473	450	0.3	2.5	0	0
474	450	0.3	2.6	0	0
475	450	0.3	2.7	0	0
476	450	0.3	2.8	0	0
477	450	0.3	2.9	0	0
478	450	0.3	3.9	0	0
479	450	0.4	0	0	0
480	450	0.4	0.1	13.7	1.31819
481	450	0.4	0.2	19.7	1.89551
482	450	0.4	0.3	21.2	2.03983
483	450	0.4	0.4	5.7	0.54845

Observation	Discharge	Depth	Velocity	Count	Percent
484	450	0.4	0.5	2	0.19244
485	450	0.4	0.6	0.2	0.01924
486	450	0.4	0.7	3	0.28866
487	450	0.4	0.8	0.2	0.01924
488	450	0.4	0.9	9	0.86597
489	450	0.4	1	0	0
490	450	0.4	1.1	0	0
491	450	0.4	1.2	3	0.28866
492	450	0.4	1.3	3	0.28866
493	450	0.4	1.4	0	0
494	450	0.4	1.5	0	0
495	450	0.4	1.6	0	0
496	450	0.4	1.7	0	0
497	450	0.4	1.8	0	0
498	450	0.4	1.9	0	0
499	450	0.4	2	0	0
500	450	0.4	2.1	0	0
501	450	0.4	2.2	0	0
502	450	0.4	2.3	0	0
503	450	0.4	2.4	0	0
504	450	0.4	2.5	0	0
505	450	0.4	2.6	0	0
506	450	0.4	2.7	0	0
507	450	0.4	2.8	0	0
508	450	0.4	2.9	0	0
509	450	0.4	3.9	0	0
510	450	0.5	0	0	0
511	450	0.5	0.1	7.4	0.71202
512	450	0.5	0.2	14.7	1.41441
513	450	0.5	0.3	14	1.34706
514	450	0.5	0.4	14.3	1.37593
515	450	0.5	0.5	0	0
516	450	0.5	0.6	0	0
517	450	0.5	0.7	5	0.48109
518	450	0.5	0.8	4.5	0.43298
519	450	0.5	0.9	2	0.19244
520	450	0.5	1	0	0
521	450	0.5	1.1	1.7	0.16357
522	450	0.5	1.2	1	0.09622
523	450	0.5	1.3	4.2	0.40412
524	450	0.5	1.4	0	0
525	450	0.5	1.5	0	0
526	450	0.5	1.6	0	0
527	450	0.5	1.7	0	0
528	450	0.5	1.8	0	0
529	450	0.5	1.9	0	0
530	450	0.5	2	0	0
531	450	0.5	2.1	0	0
532	450	0.5	2.2	0	0
533	450	0.5	2.3	0	0
534	450	0.5	2.4	0	0
535	450	0.5	2.5	1.7	0.16357
536	450	0.5	2.6	0	0
537	450	0.5	2.7	0	0

Observation	Discharge	Depth	Velocity	Count	Percent
538	450	0.5	2.8	0	0
539	450	0.5	2.9	0	0
540	450	0.5	3.9	0	0
541	450	0.6	0	0	0
542	450	0.6	0.1	9	0.86597
543	450	0.6	0.2	3.1	0.29828
544	450	0.6	0.3	19	1.82815
545	450	0.6	0.4	28	2.69412
546	450	0.6	0.5	3	0.28866
547	450	0.6	0.6	3	0.28866
548	450	0.6	0.7	0	0
549	450	0.6	0.8	5	0.48109
550	450	0.6	0.9	0	0
551	450	0.6	1	0	0
552	450	0.6	1.1	2.4	0.23092
553	450	0.6	1.2	0	0
554	450	0.6	1.3	1.5	0.14433
555	450	0.6	1.4	1.3	0.12508
556	450	0.6	1.5	0	0
557	450	0.6	1.6	2	0.19244
558	450	0.6	1.7	0	0
559	450	0.6	1.8	0	0
560	450	0.6	1.9	3.2	0.3079
561	450	0.6	2	0	0
562	450	0.6	2.1	0	0
563	450	0.6	2.2	1.3	0.12508
564	450	0.6	2.3	0	0
565	450	0.6	2.4	0	0
566	450	0.6	2.5	0	0
567	450	0.6	2.6	0	0
568	450	0.6	2.7	0	0
569	450	0.6	2.8	0	0
570	450	0.6	2.9	0	0
571	450	0.6	3.9	0	0
572	450	0.7	0	0	0
573	450	0.7	0.1	19.3	1.85702
574	450	0.7	0.2	15.1	1.4529
575	450	0.7	0.3	0	0
576	450	0.7	0.4	2	0.19244
577	450	0.7	0.5	1.5	0.14433
578	450	0.7	0.6	3.1	0.29828
579	450	0.7	0.7	4.1	0.3945
580	450	0.7	0.8	2.4	0.23092
581	450	0.7	0.9	1.5	0.14433
582	450	0.7	1	6	0.57731
583	450	0.7	1.1	2.7	0.25979
584	450	0.7	1.2	0.8	0.07697
585	450	0.7	1.3	1.9	0.18282
586	450	0.7	1.4	4.5	0.43298
587	450	0.7	1.5	7	0.67353
588	450	0.7	1.6	3	0.28866
589	450	0.7	1.7	2	0.19244
590	450	0.7	1.8	0.8	0.07697
591	450	0.7	1.9	1.7	0.16357

Observation	Discharge	Depth	Velocity	Count	Percent
592	450	0.7	2	3.1	0.29828
593	450	0.7	2.1	0	0
594	450	0.7	2.2	0	0
595	450	0.7	2.3	0	0
596	450	0.7	2.4	1.5	0.14433
597	450	0.7	2.5	0.2	0.01924
598	450	0.7	2.6	0	0
599	450	0.7	2.7	0	0
600	450	0.7	2.8	0	0
601	450	0.7	2.9	0	0
602	450	0.7	3.9	0	0
603	450	0.8	0	0.5	0.04811
604	450	0.8	0.1	2.4	0.23092
605	450	0.8	0.2	10.6	1.01992
606	450	0.8	0.3	1	0.09622
607	450	0.8	0.4	0	0
608	450	0.8	0.5	4	0.38487
609	450	0.8	0.6	0.9	0.0866
610	450	0.8	0.7	1.5	0.14433
611	450	0.8	0.8	0	0
612	450	0.8	0.9	0	0
613	450	0.8	1	3.3	0.31752
614	450	0.8	1.1	2.3	0.2213
615	450	0.8	1.2	0	0
616	450	0.8	1.3	1.8	0.17319
617	450	0.8	1.4	2.7	0.25979
618	450	0.8	1.5	5.6	0.53882
619	450	0.8	1.6	5.2	0.50034
620	450	0.8	1.7	2	0.19244
621	450	0.8	1.8	3.7	0.35601
622	450	0.8	1.9	7.3	0.7024
623	450	0.8	2	4.5	0.43298
624	450	0.8	2.1	3.9	0.37525
625	450	0.8	2.2	4.5	0.43298
626	450	0.8	2.3	0	0
627	450	0.8	2.4	2	0.19244
628	450	0.8	2.5	3.7	0.35601
629	450	0.8	2.6	0.3	0.02887
630	450	0.8	2.7	1.1	0.10584
631	450	0.8	2.8	3.4	0.32714
632	450	0.8	2.9	2.5	0.24055
633	450	0.8	3.9	1.8	0.17319
634	450	0.9	0	0	0
635	450	0.9	0.1	4.2	0.40412
636	450	0.9	0.2	14.3	1.37593
637	450	0.9	0.3	6.6	0.63504
638	450	0.9	0.4	6	0.57731
639	450	0.9	0.5	1.5	0.14433
640	450	0.9	0.6	0	0
641	450	0.9	0.7	1.5	0.14433
642	450	0.9	0.8	0	0
643	450	0.9	0.9	2	0.19244
644	450	0.9	1	0	0
645	450	0.9	1.1	2.1	0.20206

Observation	Discharge	Depth	Velocity	Count	Percent
646	450	0.9	1.2	4.6	0.44261
647	450	0.9	1.3	2	0.19244
648	450	0.9	1.4	0.3	0.02887
649	450	0.9	1.5	7.5	0.72164
650	450	0.9	1.6	0.3	0.02887
651	450	0.9	1.7	2.7	0.25979
652	450	0.9	1.8	3	0.28866
653	450	0.9	1.9	1.5	0.14433
654	450	0.9	2	4.7	0.45223
655	450	0.9	2.1	4.2	0.40412
656	450	0.9	2.2	2.8	0.26941
657	450	0.9	2.3	0	0
658	450	0.9	2.4	1.5	0.14433
659	450	0.9	2.5	2	0.19244
660	450	0.9	2.6	0	0
661	450	0.9	2.7	0	0
662	450	0.9	2.8	1	0.09622
663	450	0.9	2.9	0.2	0.01924
664	450	0.9	3.9	0	0
665	450	1	0	0	0
666	450	1	0.1	0	0
667	450	1	0.2	2	0.19244
668	450	1	0.3	2.9	0.27903
669	450	1	0.4	1	0.09622
670	450	1	0.5	3.5	0.33677
671	450	1	0.6	0.6	0.05773
672	450	1	0.7	0.4	0.03849
673	450	1	0.8	1.6	0.15395
674	450	1	0.9	1	0.09622
675	450	1	1	1	0.09622
676	450	1	1.1	1.4	0.13471
677	450	1	1.2	1.7	0.16357
678	450	1	1.3	0.6	0.05773
679	450	1	1.4	0	0
680	450	1	1.5	0	0
681	450	1	1.6	2	0.19244
682	450	1	1.7	0	0
683	450	1	1.8	0	0
684	450	1	1.9	0	0
685	450	1	2	0	0
686	450	1	2.1	2.2	0.21168
687	450	1	2.2	2	0.19244
688	450	1	2.3	1.8	0.17319
689	450	1	2.4	0	0
690	450	1	2.5	0	0
691	450	1	2.6	0	0
692	450	1	2.7	0	0
693	450	1	2.8	0	0
694	450	1	2.9	0	0
695	450	1	3.9	0	0
696	450	1.1	0	0	0
697	450	1.1	0.1	0	0
698	450	1.1	0.2	0	0
699	450	1.1	0.3	2	0.19244

Observation	Discharge	Depth	Velocity	Count	Percent
700	450	1.1	0.4	0	0
701	450	1.1	0.5	6	0.57731
702	450	1.1	0.6	1.1	0.10584
703	450	1.1	0.7	0	0
704	450	1.1	0.8	2	0.19244
705	450	1.1	0.9	6.3	0.60618
706	450	1.1	1	5.6	0.53882
707	450	1.1	1.1	4.1	0.3945
708	450	1.1	1.2	6.4	0.6158
709	450	1.1	1.3	1	0.09622
710	450	1.1	1.4	5	0.48109
711	450	1.1	1.5	0	0
712	450	1.1	1.6	2.9	0.27903
713	450	1.1	1.7	2	0.19244
714	450	1.1	1.8	1.1	0.10584
715	450	1.1	1.9	2	0.19244
716	450	1.1	2	0	0
717	450	1.1	2.1	0	0
718	450	1.1	2.2	0	0
719	450	1.1	2.3	0	0
720	450	1.1	2.4	0	0
721	450	1.1	2.5	0	0
722	450	1.1	2.6	0	0
723	450	1.1	2.7	0	0
724	450	1.1	2.8	0	0
725	450	1.1	2.9	0	0
726	450	1.1	3.9	0	0
727	450	1.2	0	0	0
728	450	1.2	0.1	0	0
729	450	1.2	0.2	0	0
730	450	1.2	0.3	0	0
731	450	1.2	0.4	0	0
732	450	1.2	0.5	0	0
733	450	1.2	0.6	6	0.57731
734	450	1.2	0.7	0	0
735	450	1.2	0.8	1.1	0.10584
736	450	1.2	0.9	1.3	0.12508
737	450	1.2	1	1.1	0.10584
738	450	1.2	1.1	10.1	0.97181
739	450	1.2	1.2	7.1	0.68315
740	450	1.2	1.3	2.9	0.27903
741	450	1.2	1.4	6.1	0.58693
742	450	1.2	1.5	6.9	0.66391
743	450	1.2	1.6	0	0
744	450	1.2	1.7	0	0
745	450	1.2	1.8	0.4	0.03849
746	450	1.2	1.9	1.4	0.13471
747	450	1.2	2	1.6	0.15395
748	450	1.2	2.1	0	0
749	450	1.2	2.2	0	0
750	450	1.2	2.3	0	0
751	450	1.2	2.4	0	0
752	450	1.2	2.5	0	0
753	450	1.2	2.6	0.6	0.05773

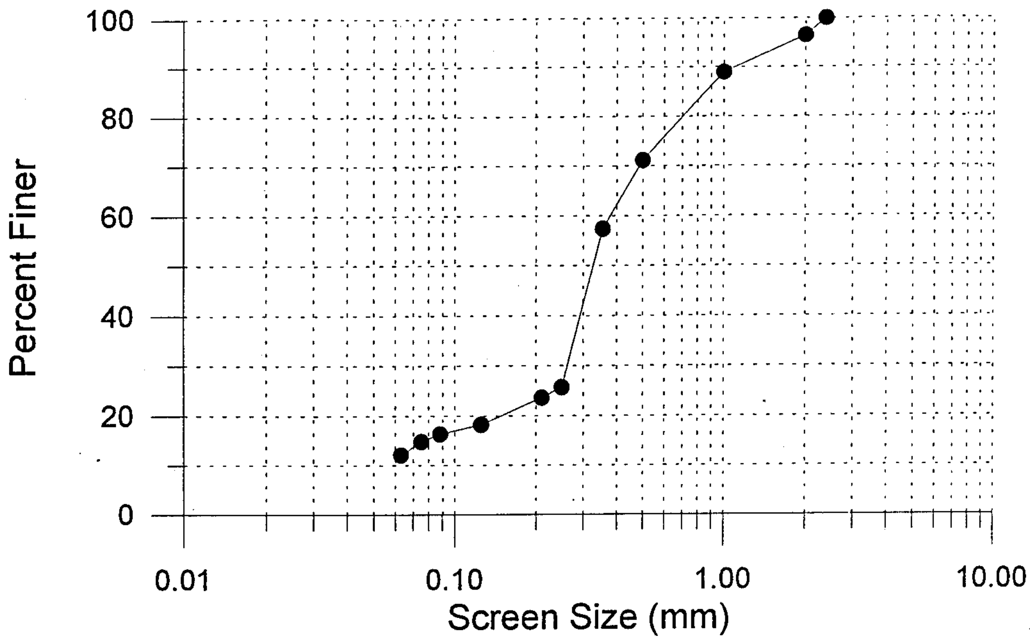
Observation	Discharge	Depth	Velocity	Count	Percent
754	450	1.2	2.7	0	0
755	450	1.2	2.8	0	0
756	450	1.2	2.9	0	0
757	450	1.2	3.9	0	0
758	450	1.3	0	0	0
759	450	1.3	0.1	2	0.19244
760	450	1.3	0.2	0	0
761	450	1.3	0.3	0	0
762	450	1.3	0.4	1	0.09622
763	450	1.3	0.5	0	0
764	450	1.3	0.6	1.9	0.18282
765	450	1.3	0.7	2	0.19244
766	450	1.3	0.8	2	0.19244
767	450	1.3	0.9	0	0
768	450	1.3	1	1	0.09622
769	450	1.3	1.1	0.4	0.03849
770	450	1.3	1.2	0	0
771	450	1.3	1.3	0	0
772	450	1.3	1.4	0	0
773	450	1.3	1.5	0	0
774	450	1.3	1.6	0	0
775	450	1.3	1.7	0	0
776	450	1.3	1.8	0	0
777	450	1.3	1.9	0	0
778	450	1.3	2	0	0
779	450	1.3	2.1	0	0
780	450	1.3	2.2	0	0
781	450	1.3	2.3	0	0
782	450	1.3	2.4	0	0
783	450	1.3	2.5	0	0
784	450	1.3	2.6	0	0
785	450	1.3	2.7	0	0
786	450	1.3	2.8	0	0
787	450	1.3	2.9	0	0
788	450	1.3	3.9	0	0
789	450	1.4	0	0	0
790	450	1.4	0.1	4	0.38487
791	450	1.4	0.2	1	0.09622
792	450	1.4	0.3	1	0.09622
793	450	1.4	0.4	0	0
794	450	1.4	0.5	2.1	0.20206
795	450	1.4	0.6	3	0.28866
796	450	1.4	0.7	4	0.38487
797	450	1.4	0.8	0	0
798	450	1.4	0.9	0.9	0.0866
799	450	1.4	1	3.1	0.29828
800	450	1.4	1.1	0	0
801	450	1.4	1.2	0	0
802	450	1.4	1.3	0	0
803	450	1.4	1.4	0	0
804	450	1.4	1.5	0	0
805	450	1.4	1.6	0	0
806	450	1.4	1.7	0	0
807	450	1.4	1.8	0	0

Observation	Discharge	Depth	Velocity	Count	Percent
808	450	1.4	1.9	0	0
809	450	1.4	2	0	0
810	450	1.4	2.1	0	0
811	450	1.4	2.2	0	0
812	450	1.4	2.3	0	0
813	450	1.4	2.4	0	0
814	450	1.4	2.5	0	0
815	450	1.4	2.6	0	0
816	450	1.4	2.7	0	0
817	450	1.4	2.8	0	0
818	450	1.4	2.9	0	0
819	450	1.4	3.9	0	0
820	450	1.5	0	0	0
821	450	1.5	0.1	0	0
822	450	1.5	0.2	0	0
823	450	1.5	0.3	0	0
824	450	1.5	0.4	0	0
825	450	1.5	0.5	0	0
826	450	1.5	0.6	1.9	0.18282
827	450	1.5	0.7	5.1	0.49071
828	450	1.5	0.8	1.1	0.10584
829	450	1.5	0.9	1	0.09622
830	450	1.5	1	0	0
831	450	1.5	1.1	0	0
832	450	1.5	1.2	0	0
833	450	1.5	1.3	0	0
834	450	1.5	1.4	0	0
835	450	1.5	1.5	0	0
836	450	1.5	1.6	1	0.09622
837	450	1.5	1.7	0	0
838	450	1.5	1.8	0	0
839	450	1.5	1.9	0	0
840	450	1.5	2	0	0
841	450	1.5	2.1	0	0
842	450	1.5	2.2	0	0
843	450	1.5	2.3	0	0
844	450	1.5	2.4	0	0
845	450	1.5	2.5	0	0
846	450	1.5	2.6	0	0
847	450	1.5	2.7	0	0
848	450	1.5	2.8	0	0
849	450	1.5	2.9	0	0
850	450	1.5	3.9	0	0
851	450	1.6	0	0	0
852	450	1.6	0.1	0	0
853	450	1.6	0.2	0	0
854	450	1.6	0.3	0	0
855	450	1.6	0.4	0	0
856	450	1.6	0.5	0	0
857	450	1.6	0.6	0	0
858	450	1.6	0.7	2.9	0.27903
859	450	1.6	0.8	2	0.19244
860	450	1.6	0.9	0	0
861	450	1.6	1	0	0

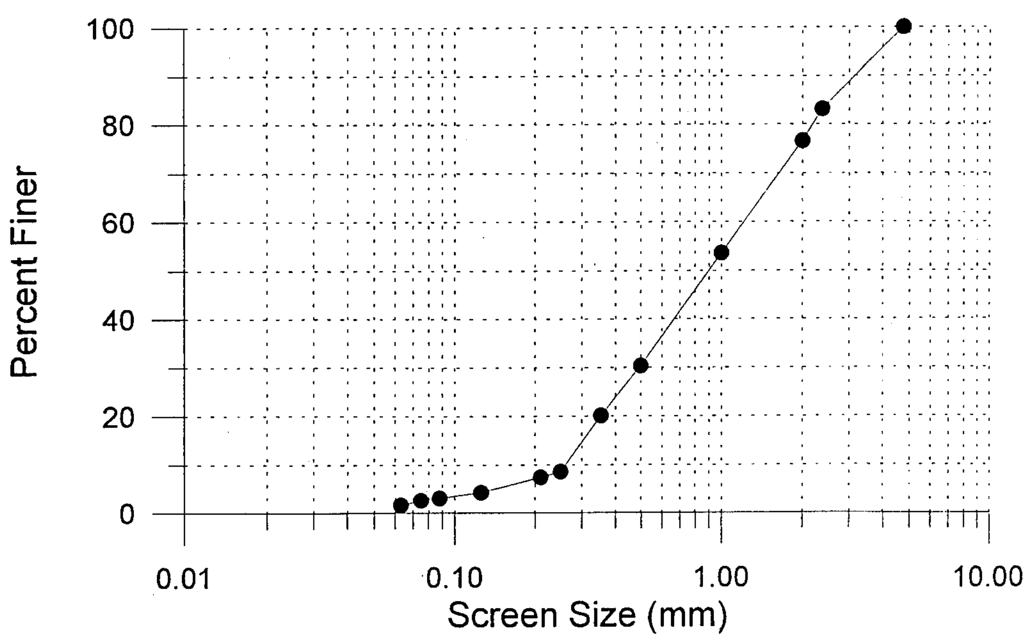
Observation	Discharge	Depth	Velocity	Count	Percent
862	450	1.6	1.1	0	0
863	450	1.6	1.2	0	0
864	450	1.6	1.3	0	0
865	450	1.6	1.4	0	0
866	450	1.6	1.5	0	0
867	450	1.6	1.6	0	0
868	450	1.6	1.7	0	0
869	450	1.6	1.8	0	0
870	450	1.6	1.9	0	0
871	450	1.6	2	0	0
872	450	1.6	2.1	0	0
873	450	1.6	2.2	0	0
874	450	1.6	2.3	0	0
875	450	1.6	2.4	0	0
876	450	1.6	2.5	0	0
877	450	1.6	2.6	0	0
878	450	1.6	2.7	0	0
879	450	1.6	2.8	0	0
880	450	1.6	2.9	0	0
881	450	1.6	3.9	0	0

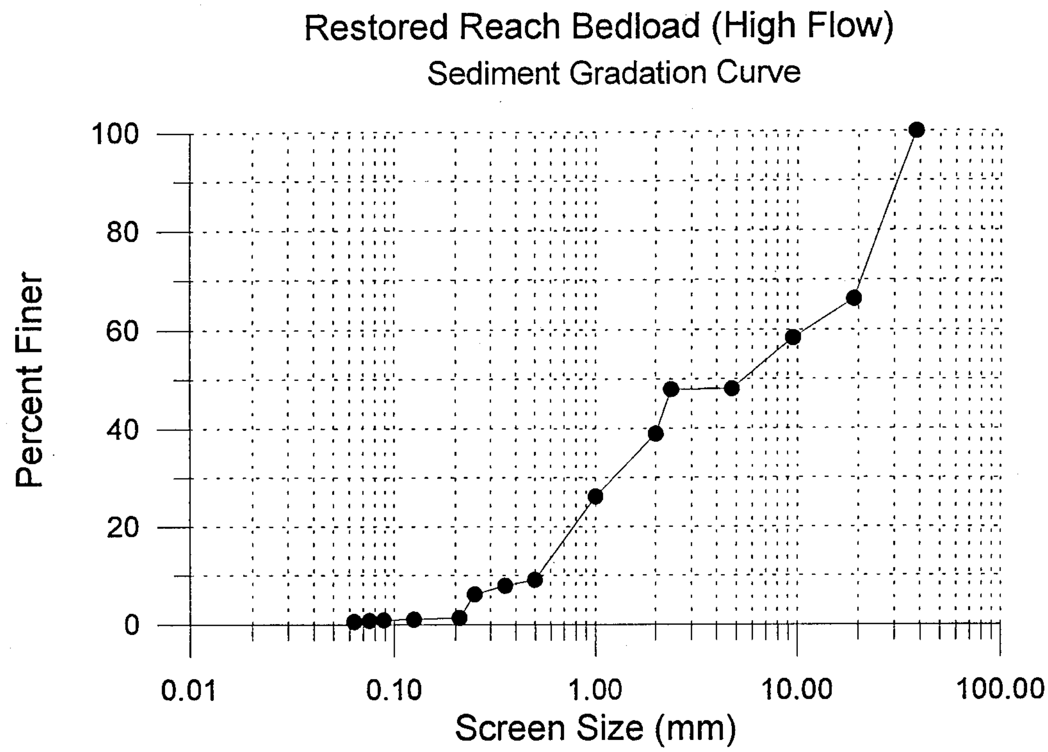
Appendix G
Bedload Gradation Curves

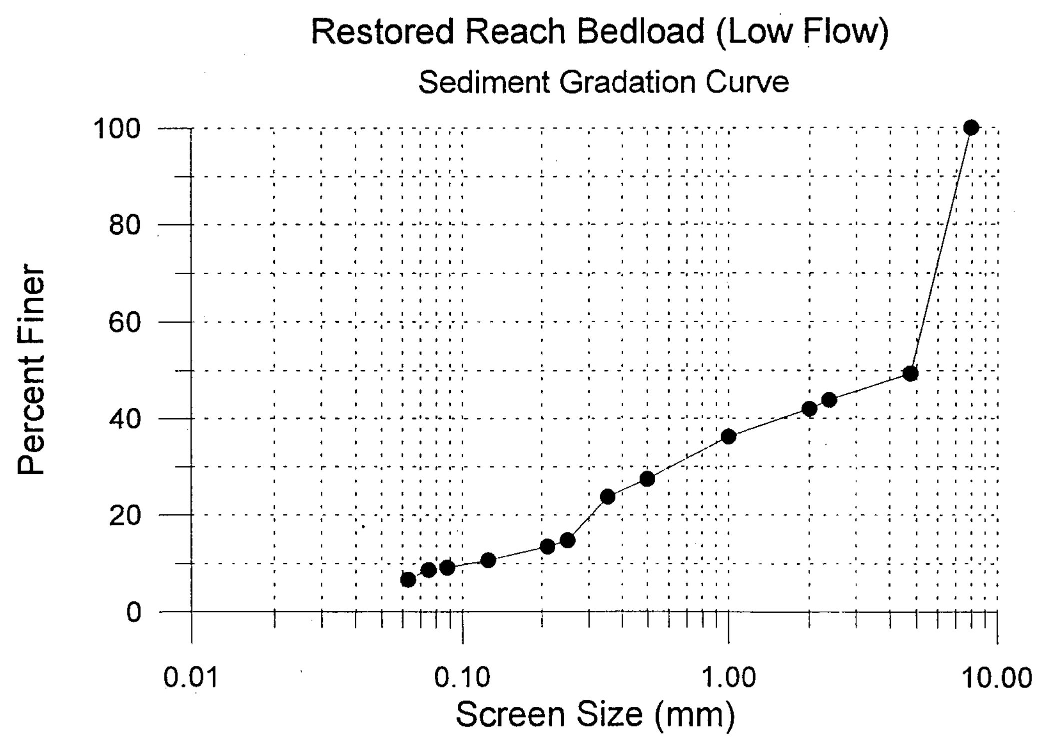
Natural Reach Bedload (High Flow)
Sediment Gradation Curve



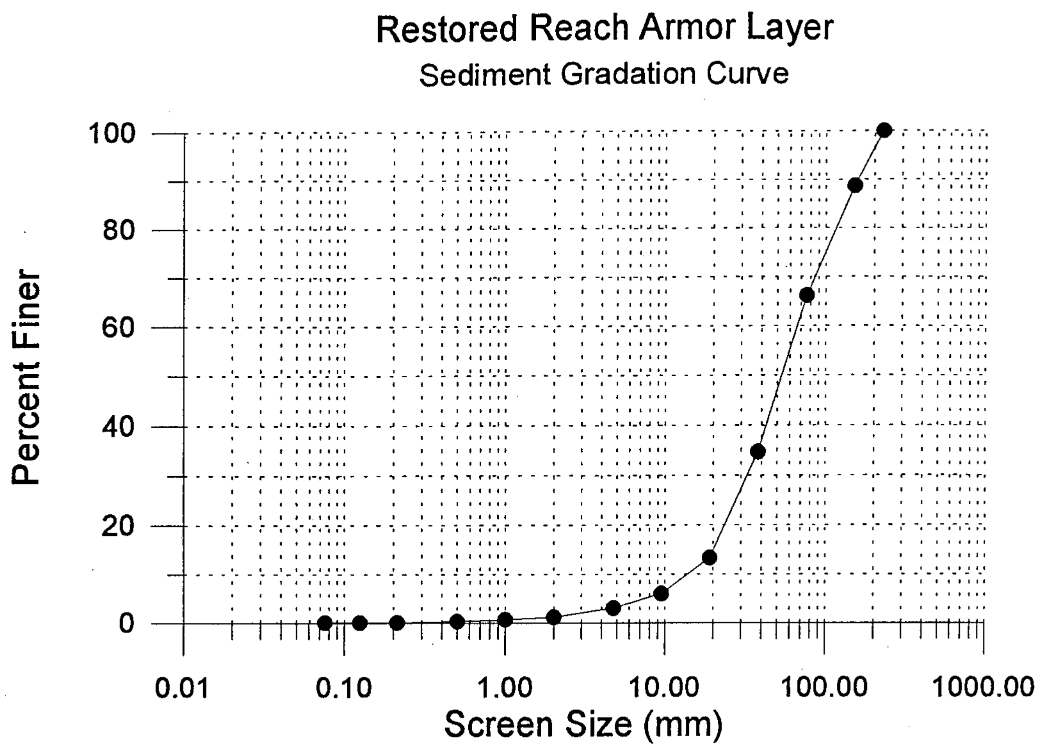
Natural Reach Bedload (Low Flow)
Sediment Gradation Curve

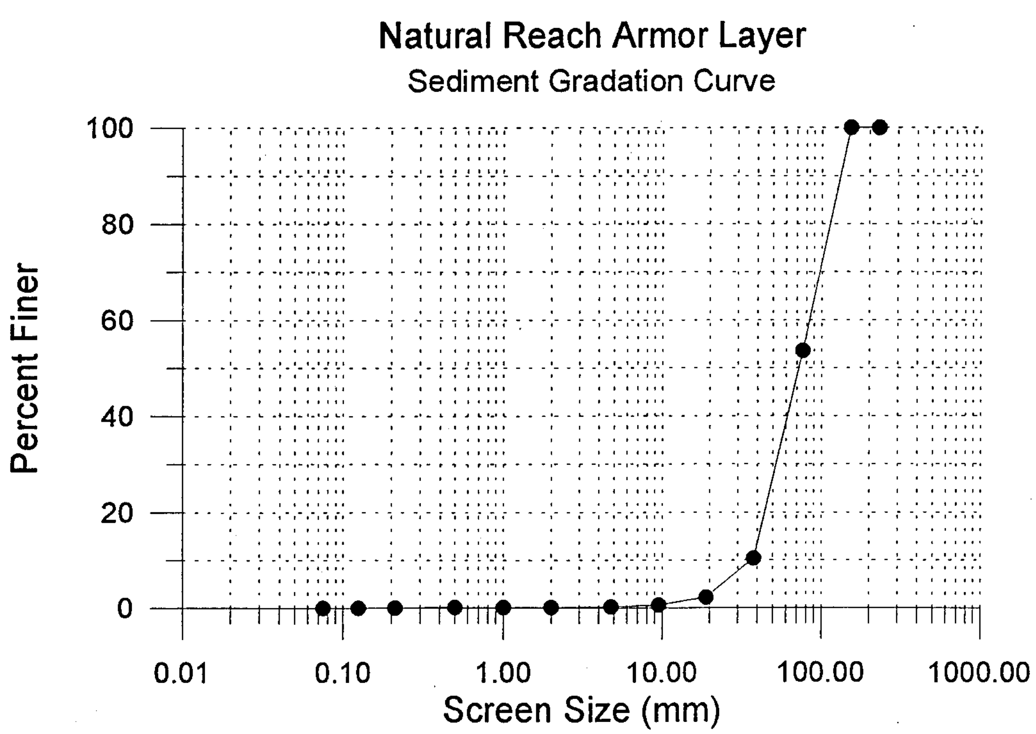


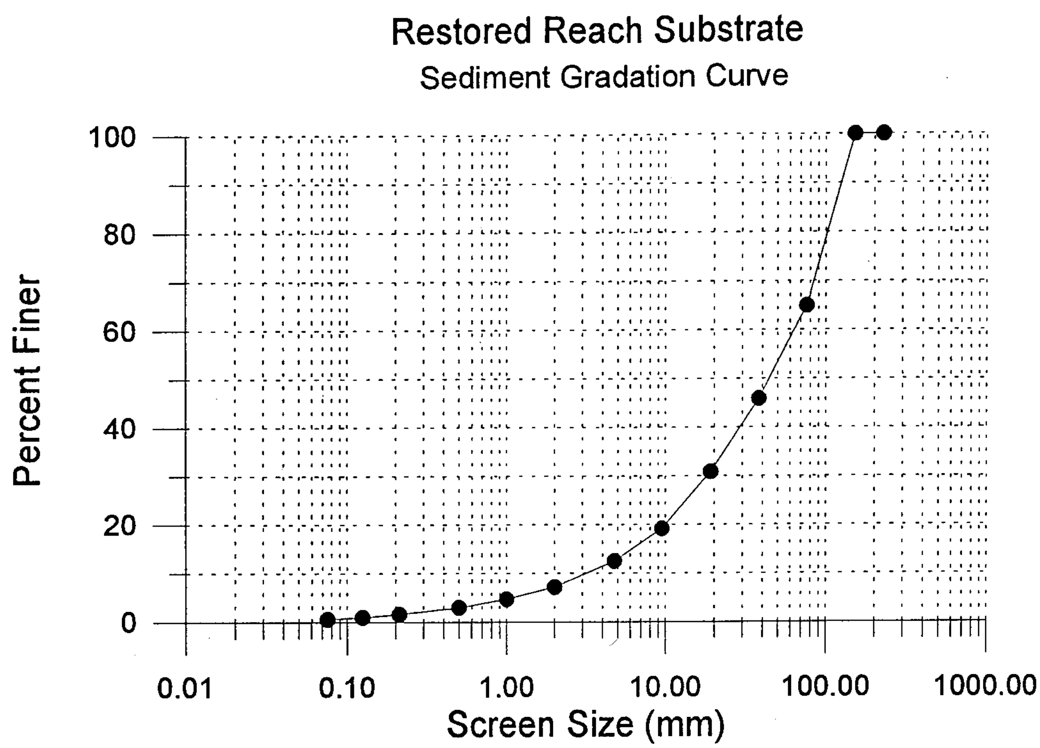

Restored Reach Bedload (High Flow)
Sediment Gradation Curve
Percent Finer
100
80
60
40
20
0
0.01
0.10
1.00
10.00
100.00
Screen Size (mm)

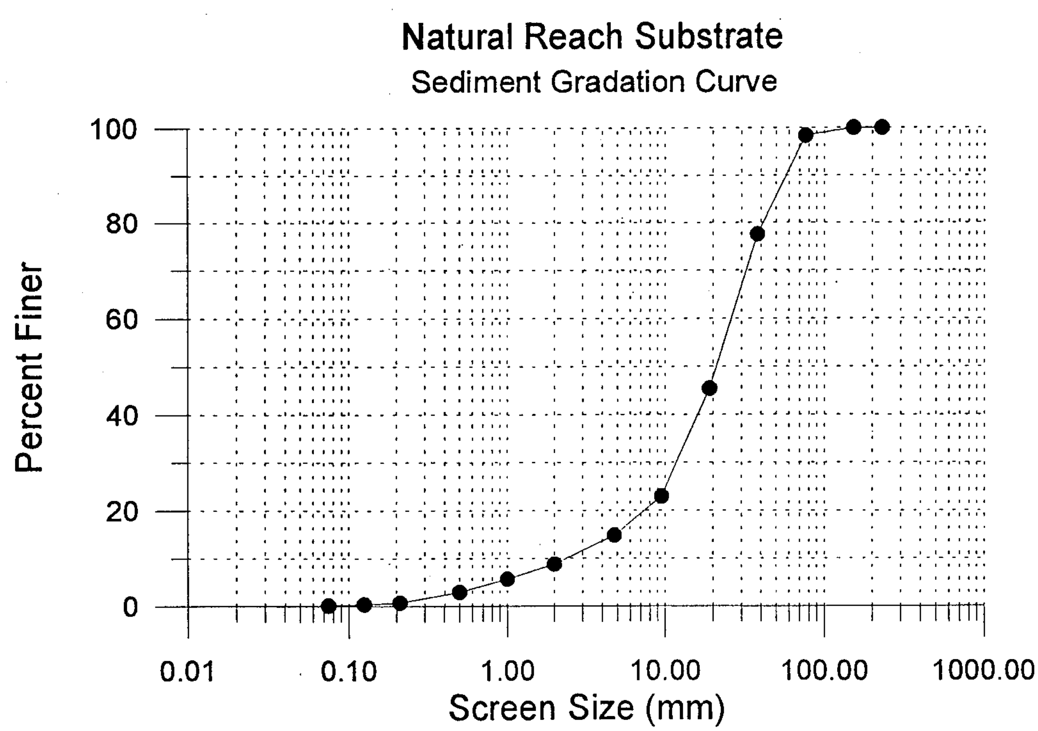

Restored Reach Bedload (Low Flow)
Sediment Gradation Curve
Percent Finer
100
80
60
40
20
0
0.01
0.10
1.00
10.00
Screen Size (mm)

Appendix H
Armor Layer & Substrate Gradation Curves


Restored Reach Armor Layer
Sediment Gradation Curve
Percent Finer
100
80
60
40
20
0
0.01
0.10
1.00
10.00
100.00
1000.00
Screen Size (mm)


Natural Reach Armor Layer
Sediment Gradation Curve
Percent Finer
100
80
60
40
20
0
0.01
0.10
1.00
10.00
100.00
1000.00
Screen Size (mm)


Restored Reach Substrate
Sediment Gradation Curve
Percent Finer
100
80
60
40
20
0
0.01
0.10
1.00
10.00
100.00
1000.00
Screen Size (mm)


Natural Reach Substrate
Sediment Gradation Curve
Percent Finer
100
80
60
40
20
0
0.01
0.10
1.00
10.00
100.00
1000.00
Screen Size (mm)

Appendix I
HEC-2 Output Summaries

RESTORED REACH LOW OBSERVED FLOW

SECNO	XLCH	ELMIN	Q	CWSEL	DEPTH	VCH	AREA	TOPWID
1	0	4.1	53.5	5.8	1.7	1.61	33.29	25.17
2	480.7	7.07	52.2	7.75	0.68	3.01	17.36	34.84
3	555	10.01	54.2	11.52	1.51	1.88	28.9	29.1
4	69.5	10.13	45.2	11.75	1.62	1.23	36.61	34.42
5	277.4	12.26	50	13.05	0.79	2.14	23.31	35.37
6	138.2	12.68	47.2	14.17	1.49	2.81	16.78	19.49
7	187.2	13.65	45.4	15.3	1.65	1.17	38.93	34.09
8	264.7	16.16	45.4	17.05	0.89	2.78	16.32	29.16
9	167.8	16.17	44.3	17.72	1.55	2.12	20.88	20.92
10	322.6	18.46	46.5	19.45	0.99	2.36	19.84	28.5
11	564	21.86	46.1	23.54	1.68	1.34	34.5	32.73
12	320.9	23.73	52.7	24.72	0.99	2.75	19.15	29.53

NATURAL REACH LOW OBSERVED FLOW

SECNO	XLCH	ELMIN	Q	CWSEL	DEPTH	VCH	AREA	TOPWID
1	0	7.36	31.1	9.6	2.24	1.09	28.47	31.79
2	247.3	14.06	20.6	16.17	2.11	0.2	102.62	73.55
3	223.9	14.82	20.3	16.81	1.99	0.2	104.71	94.94
4	121.8	15.54	18.1	16.82	1.28	0.4	45.39	62.53
5	155.4	14.65	15.9	16.86	2.21	0.57	27.85	30.07
6	100.8	17.82	20.1	18.4	0.58	1.15	17.48	53.71
7	185.6	19.04	18.3	19.63	0.59	2.12	8.64	33.67
8	329.5	20.76	20.6	21.93	1.17	0.96	21.55	44.83
9	55.5	21.54	16.7	22.91	1.37	0.37	44.59	44.36
10	250.1	22.51	13.1	23	0.49	1.76	7.43	27.04
11	543.5	26.08	18.9	27.02	0.94	1.63	11.6	19.4
12	834.5	30.34	17.5	31.29	0.95	1.94	9.01	18.1

RESTORED REACH HIGH OBSERVED FLOW

SECNO	XLCH	ELMIN	Q	CWSEL	DEPTH	VCH	AREA	TOPWID
1	0	4.1	282	7.3	3.2	3.66	92.7	66.24
2	480.7	7.07	360	9.49	2.42	4.55	81.63	42.67
3	555	10.01	285.4	12.83	2.82	4.15	73.4	38.9
4	69.5	10.13	267.2	13.29	3.16	2.87	98.14	46.32
5	277.4	12.26	291.7	14.66	2.4	3.53	85.39	43.86
6	138.2	12.68	313.3	15.59	2.91	4.56	70.81	54.95
7	187.2	13.65	275.1	17.2	3.55	2.52	112.26	46.33
8	264.7	16.16	285.9	18.52	2.36	4.68	66.68	41.85
9	167.8	16.17	253.1	19.14	2.97	4.85	62.11	54.5
10	322.6	18.46	281.3	21.26	2.8	2.81	111.48	87.9
11	564	21.86	311.1	25.17	3.31	3.24	118.73	107.7
12	320.9	23.73	283.6	26.18	2.45	3.96	90.32	59.18

NATURAL REACH HIGH OBSERVED FLOW

SECNO	XLCH	ELMIN	Q	CWSEL	DEPTH	VCH	AREA	TOPWID
1	0	7.36	152.5	11	3.64	2	82.8	64.43
2	247.3	14.06	99.6	17.47	3.41	0.5	203.51	80.32
3	223.9	14.82	242.9	17.68	2.86	1.33	189.93	100.05
4	121.8	15.54	255.6	17.79	2.25	2.15	122.17	85.99
5	155.4	14.65	252.1	18.19	3.54	3.28	83.64	51.02
6	100.8	17.82	283.3	19.96	2.14	2.68	111.8	73.38
7	185.6	19.04	273.1	20.67	1.63	5.17	63.42	97.04
8	329.5	20.76	263.7	23.46	2.7	2.62	107.41	66.17
9	55.5	21.54	253.4	24.44	2.9	2.1	121.93	58.01
10	250.1	22.51	296.3	25.09	2.58	3.98	86.9	48.93
11	543.5	26.08	394.6	29.02	2.94	6.62	63.97	32.7
12	834.5	30.34	285.5	33.82	3.48	4.24	78.76	32.58

RESTORED REACH LOWEST SIMULATED FLOW

SECNO	XLCH	ELMIN	Q	CWSEL	DEPTH	VCH	AREA	TOPWID
1	0	4.1	26.8	5.22	1.12	1.35	19.9	21.86
2	480.7	7.07	26.1	7.52	0.45	2.61	9.99	29.74
3	555	10.01	27.1	11.16	1.15	1.43	19	26.18
4	69.5	10.13	22.6	11.35	1.22	0.95	23.81	29.19
5	277.4	12.26	25	12.73	0.47	2.04	12.24	33.81
6	138.2	12.68	23.6	13.87	1.19	2.05	11.53	16.32
7	187.2	13.65	22.7	14.83	1.18	0.97	23.39	31.16
8	264.7	16.16	22.7	16.85	0.69	2.16	10.5	27.89
9	167.8	16.17	22.2	17.4	1.23	1.53	14.49	19.88
10	322.6	18.46	23.2	19.01	0.55	2.84	8.18	22.94
11	564	21.86	23	23.17	1.31	1	22.99	28.57
12	320.9	23.73	26.4	24.42	0.69	2.48	10.65	26.72

NATURAL REACH LOWEST SIMULATED FLOW

SECNO	XLCH	ELMIN	Q	CWSEL	DEPTH	VCH	AREA	TOPWID
1	0	7.36	15.6	9.11	1.75	0.94	16.54	18.89
2	247.3	14.06	10.3	15.8	1.74	0.14	76.08	71.21
3	223.9	14.82	10.2	16.69	1.87	0.11	93.93	91
4	121.8	15.54	9.05	16.7	1.16	0.24	38.1	59.04
5	155.4	14.65	8	16.71	2.06	0.34	23.51	27.25
6	100.8	17.82	10	18.27	0.45	1	10.04	47.81
7	185.6	19.04	9.15	19.55	0.51	1.41	6.48	28.57
8	329.5	20.76	10.3	21.74	0.98	0.79	12.98	41.84
9	55.5	21.54	8.35	22.67	1.13	0.24	34.31	42.69
10	250.1	22.51	6.55	22.82	0.31	2.26	2.9	18.65
11	543.5	26.08	9.45	26.84	0.76	1.17	8.1	17.29
12	834.5	30.34	8.75	31.01	0.67	1.87	4.67	13.63

RESTORED REACH INTERMEDIATE SIMULATED FLOW

SECNO	XLCH	ELMIN	Q	CWSEL	DEPTH	VCH	AREA	TOPWID
1	0	4.1	167.8	6.96	2.86	2.59	70.95	59.36
2	480.7	7.07	206.1	8.73	1.66	3.97	52.59	36.71
3	555	10.01	169.8	12.3	2.29	3.25	54.03	34.91
4	69.5	10.13	156.2	12.67	2.54	2.25	71.08	40.89
5	277.4	12.26	170.8	14	1.74	2.95	59.03	39.02
6	138.2	12.68	180.2	15.1	2.42	4.06	45.25	47.84
7	187.2	13.65	160.2	16.61	2.96	1.87	87.27	39.95
8	264.7	16.16	165.6	17.89	1.73	4.02	42.93	34.23
9	167.8	16.17	148.7	18.57	2.4	3.83	39.7	23.74
10	322.6	18.46	163.9	20.61	2.15	2.76	63.02	54.63
11	564	21.86	178.6	24.59	2.73	2.52	74.43	41.33
12	320.9	23.73	168.2	25.6	1.87	3.48	57.46	52.84

NATURAL REACH INTERMEDIATE SIMULATED FLOW

SECNO	XLCH	ELMIN	Q	CWSEL	DEPTH	VCH	AREA	TOPWID
1	0	7.36	91.8	10.54	3.18	1.54	61.52	38.14
2	247.3	14.06	60.1	16.99	2.93	0.37	165.33	78.38
3	223.9	14.82	131.6	17.22	2.4	0.94	144.29	97.34
4	121.8	15.54	136.8	17.3	1.76	1.73	80.47	83.03
5	155.4	14.65	134	17.69	3.04	2.37	59.62	45.7
6	100.8	17.82	151.7	19.37	1.55	2.14	72.45	60.24
7	185.6	19.04	145.7	20.18	1.14	4.91	31	44.84
8	329.5	20.76	142.2	22.98	2.22	1.96	76.25	60.57
9	55.5	21.54	135	23.9	2.36	1.46	92.23	51.32
10	250.1	22.51	154.7	24.42	1.91	3.13	54.63	44.59
11	543.5	26.08	206.8	28.3	2.22	5.09	41.89	28.26
12	834.5	30.34	151.5	32.92	2.58	3.41	50	30.27

RESTORED REACH HIGHEST SIMULATED FLOW

SECNO	XLCH	ELMIN	Q	CWSEL	DEPTH	VCH	AREA	TOPWID
1	0	4.1	423	7.97	3.87	3.99	140.39	76.99
2	480.7	7.07	540	10.01	2.94	5.42	108.88	66.25
3	555	10.01	428.1	13.46	3.45	4.77	100.48	54.32
4	69.5	10.13	400.8	13.95	3.82	3.32	129.98	48.75
5	277.4	12.26	437.6	15.28	3.02	4.07	114.44	49.9
6	138.2	12.68	470	16.08	3.4	5	97.57	55.38
7	187.2	13.65	412.6	17.69	4.04	3.15	135.8	49.09
8	264.7	16.16	428.8	19.09	2.93	5.33	91.01	43.99
9	167.8	16.17	379.6	19.69	3.52	5.47	105.32	87.08
10	322.6	18.46	422	21.75	3.29	2.97	155.38	92.84
11	564	21.86	466.6	25.63	3.77	3.71	172.84	121.93
12	320.9	23.73	425.4	26.66	2.93	4.62	119.06	60.07

NATURAL REACH HIGHEST SIMULATED FLOW

SECNO	XLCH	ELMIN	Q	CWSEL	DEPTH	VCH	AREA	TOPWID
1	0	7.36	228.8	11.65	4.29	2.13	131.56	86.35
2	247.3	14.06	149.4	17.92	3.86	0.64	240.43	82.16
3	223.9	14.82	364.4	18.13	3.31	1.62	234.79	101.43
4	121.8	15.54	383.4	18.23	2.69	2.47	160.67	86.9
5	155.4	14.65	378.2	18.61	3.96	3.95	106.24	55.39
6	100.8	17.82	425	20.44	2.62	3.11	150.29	83.19
7	185.6	19.04	409.6	21	1.96	5.36	96.08	100.3
8	329.5	20.76	395.6	23.83	3.07	3.21	132.65	69.07
9	55.5	21.54	380.1	24.89	3.35	2.62	149.15	63.71
10	250.1	22.51	444.4	25.63	3.12	4.65	113.47	49.67
11	543.5	26.08	591.9	29.6	3.52	7.78	83.95	36.12
12	834.5	30.34	428.2	34.59	4.25	4.91	104.36	34.06

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13. ABSTRACT *(Maximum 200 words)*

Aquatic habitat quality is dependent on water quality, bed slope, water temperature, dissolved oxygen, substrate, vegetation, and hydraulic parameters in the stream system. The Riverine Community Habitat Assessment and Restoration Concept (RCHARC) is a methodology developed by the U.S. Army Engineer Waterways Experiment Station, Environmental Laboratory, to compare hydraulic parameters (depth and velocity) between natural, degraded, and restored channel reaches. The methodology is generally applied to alternate reaches in the same stream; therefore, the habitat quality variables must also be closely matched. RCHARC assumes that if the diversity of hydraulic and habitat quality parameters for a "comparison standard" reach can be replicated in the stream restoration reach, then the aquatic habitat quality can be enhanced. The RCHARC Methodology has been successfully applied to large, warm-water rivers. The objective of this study was to Beta test the RCHARC methodology for its applicability to cold-water flood control channels. The results of the Beta test and analysis conducted at Rapid Creek, South Dakota, are reported herein.

(Continued)

14. SUBJECT TERMS

Aquatic habitat	Erosion	Habitat diversity
Biotechnical	Fish	Species diversity
Channel stability	Flood control	Streams
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13. ABSTRACT (Concluded).

The field site selected for testing the RCHARC methodology was Rapid Creek, located in and adjacent to Rapid City, SD. Natural (comparison standard) and restored reaches were identified for comparison. Field crews were dispatched in June and October 1993 to collect field data during high- and low-flow conditions, respectively. Data collected included cross-sectional profiles, discharge, depth and velocity pairs, dissolved oxygen, water temperature, thalweg and water surface elevation profiles, suspended and bed-load samples, armor layer and substrate samples, and photographic documentation.

The data were compiled, placed into a comprehensive database, and analyzed. A HEC-2 simulation was conducted to evaluate the flood control capacity of each reach. Output from HEC-2 served as input to the RCHARC model. The RCHARC model was run comparing the cumulative frequency distribution of hydraulic depth and velocity pairs for the natural (standard) and restored reaches. The RCHARC output was plotted in the three dimensions of velocity versus depth versus frequency of occurrence. The bivariate plots of the comparison reaches were qualitatively evaluated for similarity at similar discharges. The reaches displayed close similarities in the depth-velocity comparison.

The RCHARC methodology was determined to be a reasonable approach to habitat rehabilitation that may be used in conjunction to a traditional flood channel design and evaluation. A procedure is proposed for conducting a comprehensive flood control/aquatic habitat quality analysis. Recommendations for enhancing the RCHARC methodology are presented.