PHASE I
WATERSHED ASSESSMENT
FINAL REPORT

MOCCASIN CREEK,
BROWN COUNTY, SOUTH DAKOTA

South Dakota Watershed Protection Program
Division of Financial and Technical Assistance
South Dakota Department of Environment and Natural Resources
Steven M. Pirner, Secretary

October, 2003

SECTION 319 NONPOINT SOURCE POLLUTION CONTROL PROGRAM
ASSESSMENT/PLANNING PROJECT FINAL REPORT

MOCCASIN CREEK WATERSHED ASSESSMENT
FINAL REPORT

By

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Sponsor

South Brown Conservation District

9/1/03

This project was conducted in cooperation with the State of South Dakota and the United States Environmental Protection Agency, Region 8.

Grant # C6998131-02
Grant # C9998185-99

Acknowledgements

The cooperation of the following organizations and individuals is gratefully appreciated. The assessment of Moccasin Creek and its watershed could not have been completed without their assistance.

South Brown Conservation District

City of Aberdeen

Cory Medill, South Brown Conservation District

Tim Wilson, South Brown Conservation District

Robin Bobzien, City of Aberdeen

Stewart Nelson, City of Aberdeen

Brown County Natural Resource Conservation Service

SD DENR – Water Resource Assistance Program

SD Department of Game, Fish and Parks

SD Department of Health

SD Department of Transportation

Interfluve, Inc.

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Abbreviations

AFOs	Animal Feeding Operations
AGNPS	Agricultural Non-Point Source
AV Load	Average Load
BMPs	Best Management Practices
CPUE	Catch per Unit Effort
CV	Coefficient of Variance
DC	District Conservationist
DO	Dissolved Oxygen
NPS	Nonpoint Source
NRCS	Natural Resource Conservation Service
Q WTD C	Flow Weighted Concentration
SD DENR	South Dakota Department of Environment and Natural Resources
SD GF&P	South Dakota Department of Game, Fish & Parks
SU	Standard Units
TKN	Total Kjeldahl Nitrogen
μmhos/cm	micromhos/centimeter
USGS	United States Geologic Survey

Executive Summary

PROJECT TITLE: Moccasin Creek Project

PROJECT START DATE: January 22, 1999

PROJECT COMPLETION DATE: November 2001

FUNDING: TOTAL BUDGET: TBD

INITIAL 319 EPA GRANT:	$65,420.00	
INITIAL 104(b)(3) AND 604(b) GRANT	$12,320.50	
TOTAL EXPENDITURES OF 319 EPA FUNDS:	$65,420.00	
TOTAL EXPENDITURES OF 104(b)(3) AND 604(b) GRANT	$9,685.33	
TOTAL SECTION 319 MATCH ACCRUED:	$49,226.98	
BUDGET REVISIONS:	TBD	
TOTAL 604(b) EXPENDITURES	$8,000.00	March 2, 2001
TOTAL 604(b) EXPENDITURES	$6,450.00	June 14, 2001
TOTAL 604(b) EXPENDITURES	$15,000.00	September 20, 2001
TOTAL FEDERAL EXPENDITURES	$98,547.58	
TOTAL ALL EXPENDITURES:	$147,774.56	

NOTE:
Wylie Pond lies within the Moccasin Creek watershed. Moccasin Creek and Wylie Pond watershed assessments were two separate projects sponsored by South Brown Conservation District. Moccasin Creek was initially funded under EPA Clean Water Act Section 319. Sample collections specifically tied to Wylie Pond were funded under EPA Clean Water Act Section 604(b). Funding expenditures on the two projects were kept separate. To complete the Moccasin Creek assessment, additional funds were needed and were amended to the Wylie Pond 604(b) contract with the South Brown Conservation District. The Wylie Pond work plan under 604(b) was amended to show these changes. There were no 319 funds used to complete the Wylie Pond assessment. Because these water body assessments are written as two separate documents, the Wylie Pond document only shows expenditures for that project. The Moccasin Creek assessment document shows use of the funds remaining from the Wylie Pond 604(b) amendments.

SUMMARY OF ACCOMPLISHMENTS

The Moccasin Creek assessment project began in March 1999 and lasted through December 2002 when data analysis and compilation of a final report was completed. The assessment was conducted as a result of a formal request made to the state by the city of Aberdeen. The city of Aberdeen asked the South Brown Conservation District to sponsor the project. The Moccasin Creek watershed assessment met all of its milestones in a timely manner. Water quality monitoring and watershed modeling identified sources of impairment.

The primary goal for the project was to determine sources of impairment to Moccasin Creek and provide sufficient background data to drive an implementation project. Through identification of sources of impairment in the Moccasin Creek watershed, this goal was accomplished.

An EPA section 319 base grant along with additional 604 (b) and 104 (b)(3) funds were used for funding the Moccasin Creek project. The total amount of local match funds used was $49,226.98. The total federal dollars spent on the Moccasin Creek project calculates to $98,547.58.

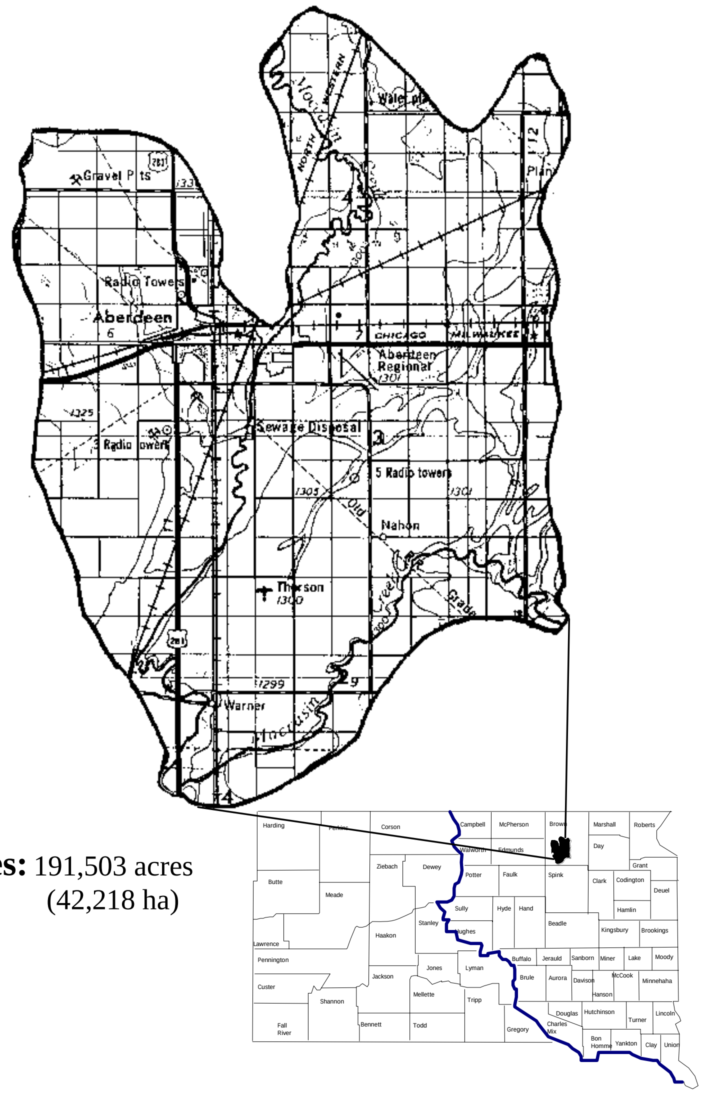
Introduction

Purpose

The purpose of this pre-implementation assessment is to determine the sources of impairment to Moccasin Creek in Brown County, South Dakota, and the tributaries in its watershed. The creeks and small tributaries are streams with loadings of sediment and nutrients related to snowmelt and spring rain events. The discharge from this watershed ultimately reaches the James River.

Foot Creek is the primary tributary to Moccasin Creek and drains a mix of grazing lands with some cropland acres. Winter feeding areas for livestock are present in the watershed. Moccasin Creek and Foot Creek carry sediment and nutrient loads that degrade water quality and cause increased sedimentation and eutrophication. The city of Aberdeen’s storm sewer system and wastewater treatment plant also add nutrient and sediment load to Moccasin Creek.

MOCCASIN CREEK WATERSHED
BROWN COUNTY



Total Acres: 191,503 acres
(42,218 ha)

Figure 1. Moccasin Creek Watershed, Brown County, South Dakota

Beneficial Uses

The State of South Dakota has assigned all of the water bodies that lie within its borders a set of beneficial uses. Along with these assigned uses are sets of standards for the chemical properties of streams. These standards must be maintained for the listed streams to fully support their assigned beneficial uses. All streams in the state receive the beneficial uses of (9) fish and wildlife propagation, recreation, and stock watering; and (10) irrigation. Part of Moccasin Creek is also listed on the list of beneficial uses as:

(6) Warmwater marginal fish life propagation waters
(8) Limited contact recreation-waters

Recreational Use

The headwaters of Moccasin Creek are located north of Aberdeen, SD, and flow to its confluence with the James River, east of Warner, SD. The creek is used for fishing and canoeing when flows permit. During the winter months the creek is used for snowmobiling and trail riding purposes.

Geology

The headwaters of Moccasin Creek and its tributary Foot Creek lie in the region known as the James Basin and the Lake Dakota Plain. The bed of ancient Lake Dakota is nearly flat with relief seldom exceeding ten feet except where stream valleys have been formed. Brown County is located between two coteaus. Directly west is the Coteau du Missouri and directly east is the Coteau des Prairies. Several streams flow down the slopes crossing the tilled highlands and the two coteaus to join the James River in the lower portion of the depression. Most of the county is dotted with numerous depressions in the glacial drift with a few large enough to hold significant amounts of water. Natural streams in the area include Mud Creek, Foot Creek, Elm Creek, Maple Creek, and Willow Creek. These creeks flow through Brown County and eventually discharge into the James River.

Brown County has a sub-humid continental climate with short, hot summers and long, cold winters. Below zero temperatures are very common in winter and temperatures of 100^{o} F are normally experienced on a monthly basis during the summer. The average annual precipitation is just over 19 inches per year (Spuhler, 1971).

Ground water in the area is obtained from confined bedrock deposits and also from glacial drift. Aquifers in the glacial drift zone contain about 3.6 million acre-feet of water storage and are recharged mainly by infiltration of precipitation. The bedrock aquifer contains approximately 61 million acre-feet of water storage and is recharged by subsurface inflow and from underlying bedrock aquifers (Schultz, 19994).

History

In the early 1900's, the city of Aberdeen began using the Moccasin Creek as a means to dispose of the cities wastewater. Due to the flat topography in the Aberdeen area, Moccasin Creek flowed very slowly southward to the James River. By 1909, odors from the stagnant Moccasin Creek were a big problem. City officials were called to inspect the situation due to unpleasant odors drifting over the city. At the time, newspaper reporters noted that it was very important to keep to the upwind side of the creek when approaching to avoid inhaling the stench of the sewage infested water. The city corrected the problem in 1912 when a treatment plant was installed. Additions and upgrades were made to the system in 1934 and 1950. Since that time, additional lift stations have been installed throughout the city to help overcome the flat topography and lack of natural flow. In addition, Moccasin Creek was straightened out and robbed of its natural meanders, which were needed to help move sediment and loadings through the system. It was noted the creek was also cleaned of obstructions at the same time to help speed up flow. In 1988, the Moccasin Creek

Restoration Committee was born. This group of individuals worked with problems such as public perception of the creek, lack of water flow, public access, etc. This group tried to improve the creek but with little success due to lack of local interest (Aberdeen American News, 1956).

In the early to mid 1980's, the city of Aberdeen dredged Moccasin Creek by means of a Mud Cat Dredge (owned by the city) and a backhoe. The city dredged the creek bed from 1st Avenue South to Melgaard Road. Dredging material from the project was used to fill a low area and to construct soccer fields along Moccasin Creek. The soccer fields are still being used by the city of Aberdeen.

Today, Moccasin Creek is still a slow-moving creek which is approximately 100 to 150 feet wide from left bank to right bank. The creek is full of silt (up to 5 feet deep in some areas) and contains a lot of garbage. When state employees surveyed cross sections of the creek channel in May 2002, it was noted that the mud was so deep it was nearly impossible to cross the creek while wearing chest waders. At the time of the survey, it was also noted that a lot of garbage (plastic, paper, tires, hypodermic needles, metal, etc.) still remains in Moccasin Creek.

Project Goals, Objectives, and Activities

Planned and Actual Milestones, Products, and Completion Dates

Objective 1. Monitoring Moccasin Creek/Tributaries

Sampling of Moccasin Creek began in March 1999 with six monitoring sites. Site MC-7 on Foot Creek was added the end of March 1999 (Figure 2). The flow equipment was used to help obtain a detailed summary of the daily discharges of nutrients and sediment from the watershed into Moccasin Creek. Samples from Foot Creek were easily gathered due to the continuous flow. The flow of Foot Creek is enhanced by the discharge of Richmond lake into Foot Creek. Site MC-2A was added in July 1999 to help monitor Aberdeen's storm sewer discharge. Sampling of nutrients, elutriate, solids parameters, and fecal coliform bacteria continued on Moccasin Creek through September 2001. In late January 2002, ice cover on Moccasin Creek was sufficiently thick to allow collection of a winter elutriate sample. The sample was analyzed for sediment particle size.

Moccasin Creek Sampling Sites

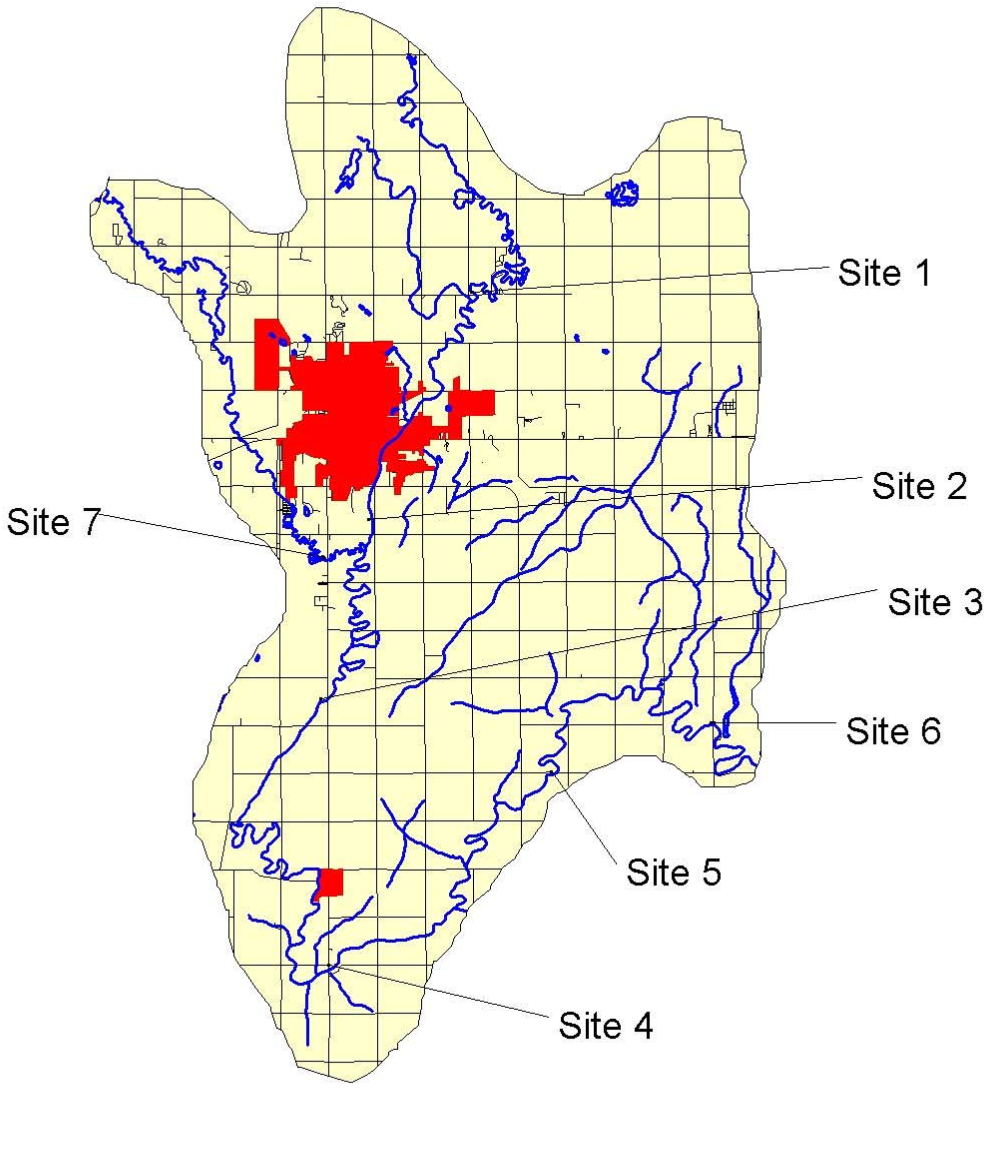


Figure 2. Moccasin Creek Sampling Sites

Objective 2. Quality assurance/quality control

Duplicate and blank samples were collected during the course of the project to provide defendable proof that sample data were collected in a scientific and reproducible manner. QA/QC data collection began, and was completed, on schedule with the proposed timeline. A total of 112 samples were taken in 1999 and 140 samples were collected in 2000. A total of 22 duplicates and 20 blanks were analyzed on 252 samples collected throughout the project. QA/QC data collection began in March of 1999 and was completed in November of 2000.

Objective 3. Evaluation of agricultural impacts via AGNPS

Collection of the data required for completion of the Agricultural Non-Point Source (AGNPS) model was finished on schedule during the project. The local coordinator utilized public records as well as personal contact with landowners and operators in the Moccasin Creek watershed to gather the required AGNPS data. AGNPS data indicated that the Moccasin Creek watershed had a low sediment deliverability rate at the outlet of Moccasin Creek. Data indicated that the Moccasin Creek watershed had a total nitrogen deliverability rate of 2.46 lbs./acre. The total phosphorus deliverability rate was considered to be lower than average at 0.58 lbs./acre. Analysis of the AGNPS data for each forty-acre cell in the watershed revealed that of 2,644 cells, there were 94 critical erosion cells, 37 critical nitrogen cells, and 48 critical phosphorus cells. The AGNPS report written for the Moccasin Creek project can be viewed in Appendix A.

Objective 4. Public participation and involvement

All of the landowners were contacted individually to assess the condition of animal feeding operations and land management practices located within the watershed. Responses to letters, phone calls, and personal contacts were excellent with most of the landowners cooperating to provide the needed information. Further information was provided to the community and stakeholders in the project at the South Brown Conservation District Board meetings and several meetings with city officials.

Objective 5. Stream channel analysis

Several cross sections of the Moccasin Creek channel were surveyed in July 1999 by DENR staff. In May and June of 2002, 32 additional cross sections were surveyed down from the northern edge of Aberdeen on Moccasin Creek downstream to the wastewater treatment plant south of Aberdeen. An initial feasibility study was conducted by Interfluve, Inc. of Bozeman, Montana as part of a contract agreement between South Brown Conservation District and Interfluve, Inc. The study was conducted to determine what methods, if any, could be used to help increase the flow and the appearance of Moccasin Creek. Results from that study can be found in Appendix B.

Objective 6. Storm sewer water quality monitoring

Seven of the larger storm sewers were sampled during 1999 and 2000 with storm-event-based sampling beginning in March 1999. Discharge measurements were taken at the same time. In October 2001, storm event samples collected from each of the seven storm sewers were forwarded immediately to PaleoScience, Miami, Florida, for *E. coli* testing. DNA fingerprinting methodology was used to determine the source of *E. coli*. The results of DNA fingerprinting from the seven storm sewers can be found in Appendix C.

Objective 7. Watershed restoration alternatives

Water quality sample field data and AGNPS data was collected and used to determine critical areas in the Moccasin Creek watershed.   Feasible management practices will be compiled into a list of alternatives for the development of an implementation project.

Objective 8. Produce and publish a final written report

The final report for the Moccasin Creek watershed assessment in Brown County was completed until December 2002. This delay was due to the necessity of completing the Wylie Pond TMDL that was funded through the same grant. Restoration and other BMPs for Moccasin Creek may be completed at a later time during project implementation.

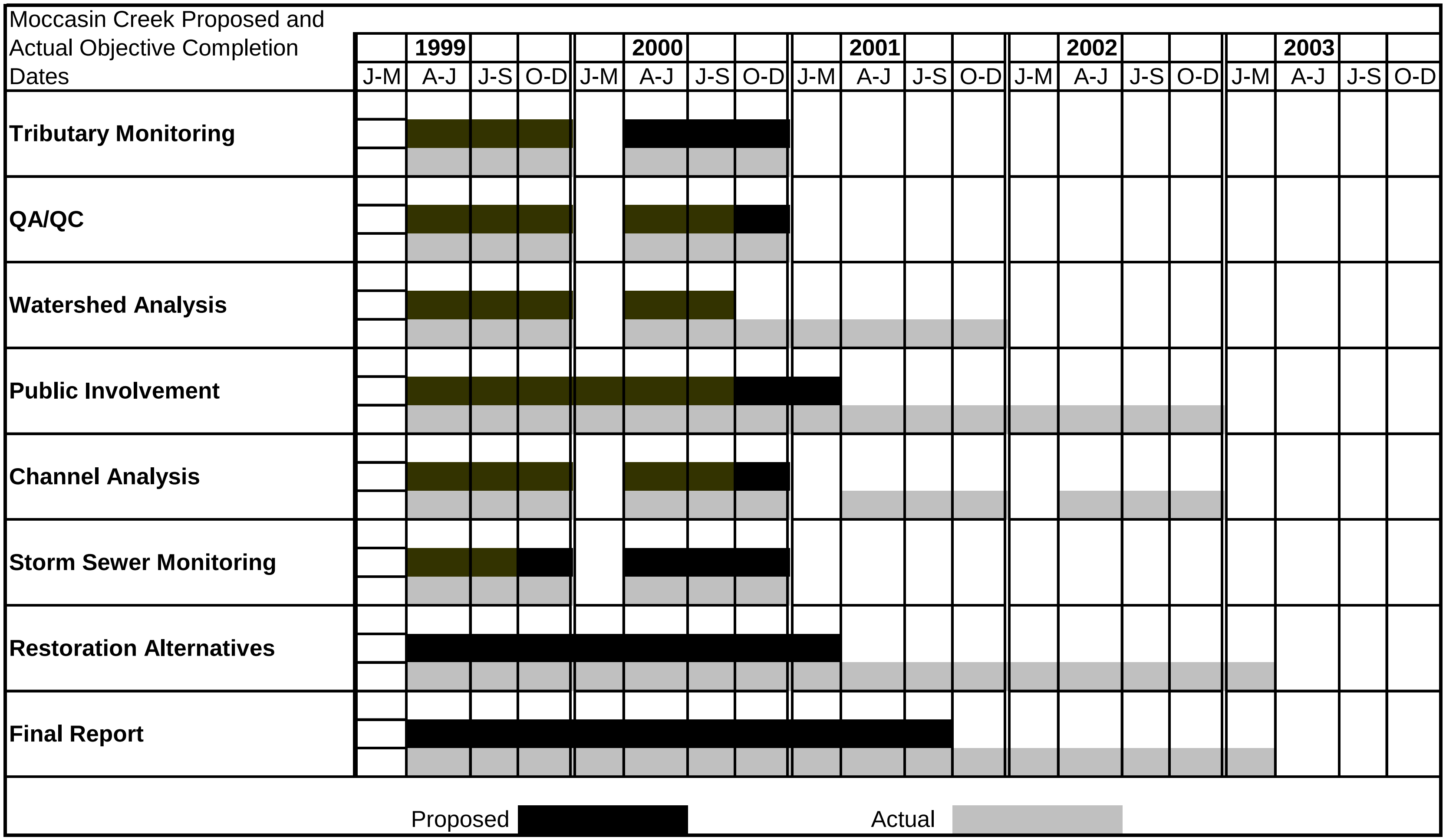
Evaluation of Goal Achievements

The goal of the watershed assessment completed for Moccasin Creek was to determine and document sources of impairment to the stream and to develop feasible alternatives for restoration. This was accomplished through the collection of tributary and in-stream data aided by the completion of the AGNPS watershed modeling tool and an engineering feasibility study conducted by Interfluve, Inc. of Bozeman, Montana. Through data analysis and modeling, identification of impairment sources was possible. The identification of these impairment sources will aid the state's non-point source (NPS) program by allowing strategic targeting of resources to portions of the watershed that will provide the greatest benefit per expenditure.

Table 1. Proposed and Actual Completion Dates

OBJECTIVE	PROPOSED COMPLETION DATE	ACTUAL COMPLETION DATE
1. Tributary Monitoring	October 2000	November 2000
2. QA/QC	October 2000	November 2000
3. AGNPS	December 2000	November 2001
4. Public Involvement	March 2001	December 2002
5. Channel Analysis	October 2000	June 2002
6. Storm Sewer Monitoring	October 2000	November 2000
7. Restoration Alternatives	March 2001	January 2003
8. Final Report	July 2001	January 2003

Table 2. Proposed and Actual Objective Completion Dates



Monitoring Results

Surface Water Chemistry

Flow Calculations

A total of 15 monitoring sites were selected along Moccasin Creek, which is a primary tributary of the James River. Of the 15 monitoring sites, eight sites were in-stream and seven were storm sewer discharge pipes from the city of Aberdeen's storm water system. The sites were selected to determine which portions of the watershed were contributing the greatest amount of nutrient and sediment load to the creek. The in-stream sites were equipped with Stevens Type F stage recorders. The remaining storm sewer sites were equipped with ISCO model 6700 flow meters which are capable of measuring depth and collecting samples. Water stages were monitored and recorded to the nearest $1/100^{th}$ of a foot for each of the eight in-stream sites. A Marsh-McBirney Model 210D flow meter and an AquaCalc 5000 open-channel flow computer were used to measure flows at various water levels in Moccasin Creek. The stages and flows were then used to create a stage/discharge table for each monitoring site. Stage-to-discharge tables may be viewed in Appendix D of this report.

Load Calculations

Total nutrient and sediment loads were calculated with the use of the U.S. Army Corps of Engineers eutrophication model known as FLUX. FLUX uses individual sample data in correlation with daily average discharges to develop six loading calculations for each given parameter. As recommended in the application sequence, a stratification scheme and method of calculation was determined using the total phosphorus load. This stratification scheme is then used for each of the additional parameters. The stratification scheme and calculation methods used for Moccasin Creek are listed in the following table. Sample data collected for Moccasin Creek may be found in Appendix E of this report.

Table 3. Flux Calculation Methods

SITE	STRATIFICATION SCHEME	CALCULATION METHOD
MC1	2 strata - Seasonal	Q WTD C
MC2	2 strata - Flow	AV Load
MC2A	3 strata - Flow	Q WTD C
MC3	2 strata - Flow	Q WTD C
MC4	2 strata - Flow	Q WTD C
MC5	2 strata - Flow	Q WTD C
MC6	3 strata - Flow	Q WTD C
MC7	3 strata - Flow	Q WTD C

Tributary Sampling Schedule

Water samples were collected at the eight in-stream monitoring sites on Moccasin Creek from the spring of 1999 through the fall of 2001. Most samples were collected using an integrated suspended sediment sampler. The sites that were equipped with GLS auto-sampling units sampled on their own and samples were usually collected within a few hours of the sample time. Water samples were then filtered, preserved, and packed in ice for shipping to the State Health Laboratory in Pierre, SD, for analysis. The laboratory assessed the following parameters:

Fecal Coliform Counts
Total Solids
Total Suspended Solids
Nitrate
Total Phosphorus
Total Dissolved Phosphorus
E. coli Bacteria Counts
Alkalinity
Total Dissolved Solids
Ammonia
Total Kjeldahl Nitrogen (TKN)
Volatile Total Suspended Solids
Un-ionized Ammonia

Personnel conducting the sampling at each of the sites recorded visual observations of weather and stream characteristics.

Precipitation
Odor
Film
Water Depth
Water Color
Wind
Presence of Fish
Turbidity
Ice Cover

Parameters measured in the field by sampling personnel were:

Water Temperature
Dissolved Oxygen
Air Temperature
Field pH

South Dakota Water Quality Standards

The State of South Dakota assigns two of the eleven beneficial uses to all streams and rivers (fish and wildlife propagation, recreation and stock watering (9) as well as irrigation (10)). All portions of Moccasin Creek located within the Moccasin Creek watershed must maintain the criteria that support these uses. In order for the creek to maintain these uses, there are seven standards that must be maintained. These standards, as well as the water quality values that must be met, are listed in Table 4 below.

Table 4. State Water Quality Standards

Site	Parameter	Criteria
All Sites	Nitrate	Average $\leq$50 mg/L for 3-samples in separate weeks within a 30-day period $\leq$88 mg/l (single sample)
All Sites	Alkalinity	Average $\leq$750 mg/L for 3-samples in separate weeks within a 30-day period $\leq$1,313 mg/L (single sample)

All Sites	Total Dissolved Solids	Average ≤2,500 mg/L for 3-samples in separate weeks within a 30-day period ≤ 4,375 mg/L daily maximum for a grab sample
All Sites	Conductivity	≤2,500µmhos (mean) <4,375µmhos (single sample)
All Sites	Total Petroleum Hydrocarbon Oil and Grease	≤10 mg/L ≤10 mg/L
All Sites	Sodium Adsorption Ratio	≤10
MC-1, MC-7	pH	≥ 6.0 and ≤9.5 su
*MC-2a, MC-2, MC-3, MC-4, MC-5, MC-6	pH	≥ 6.0 and ≤9.0 su
*MC-2a, MC-2, MC-3, MC-4, MC-5, MC-6	DO	≥ 4.0 mg/L
*MC-2a, MC-2, MC-3, MC-4, MC-5, MC-6	Fecal Coliform	geometric mean ≤1,000 colonies per 100 mg/ L for 5-samples in separate 24-hour periods for any 30-day period ≤2,000 mg/L daily maximum for a grab sample
*MC-2a, MC-2, MC-3, MC-4, MC-5, MC-6	Total Suspended Solids	Average ≤150 mg/L for 3-samples in separate weeks within a 30-day period ≤ 263 mg/L daily maximum for a grab sample
*MC-2a, MC-2, MC-3, MC-4, MC-5, MC-6	Temperature	≤90 degrees F
*MC-2a, MC-2, MC-3, MC-4, MC-5, MC-6	Un-ionized Ammonia	≤0.05 mg/L
*MC-2a, MC-2, MC-3, MC-4, MC-5, MC-6	Undisassociated Hydrogen Sulfide	≤0.002 mg/L (single grab)

Seasonal Loading

Seasonal loadings to Moccasin Creek were heavily influenced by summer runoff during the project period. Snowmelt and spring rainstorm events played a smaller role in loading. Table 5 depicts the percentage of discharge occurring in the watershed that entered the creek at different times of the sampling season. As shown in the chart below, in 1999 and 2000, over 45% of the seasonal loading came during the months of June, July, and August. Runoff events that occurred during the remainder of the year had a smaller impact on the water quality of Moccasin Creek. All BMPs implemented within the watershed should be designed with maximum protection to the creek provided during the summer months. However, spring and fall should also be taken into consideration due to the year-to-year variability in the pattern of rainfall and snowfall.

Table 5. Estimated seasonal Loading for Moccasin Creek to the James River

Date (1999 and 2000)	Days	Total Phosphorus Average Monthly Total Discharge (KG)	Seasonal Percent of Total Discharge
March	1	166	
April	30	3,649	27.7%
May	31	3,269	
June	30	3,130	
July	31	4,612	45.4%
August	31	3,849	
September	30	2,920	
October	31	3,602	26.9%
November	3	344	

Water Quality Analysis

The following sections will discuss the concentrations and loadings for each parameter sampled during the project. Parameter loads and their standard errors (CV) were calculated through the use of the FLUX model (U.S. Army Corps of Engineers loading model) for the eight in-stream monitoring stations on Moccasin Creek.

Water Budget

Flows at site MC-1 and MC-2A were minimal compared to the flows at the treatment plant (MC-2) and at Foot Creek (MC7). The combined flows at MC-2 and MC-7 made up over half of the total flow of Moccasin Creek. Due to the flat nature of the area (0.02% slope), backflows from constrictions downstream on Moccasin Creek and backflows from the James River greatly affected gaging at sites MC-4, MC-5, and MC-6. Water flowing downstream was either held up by the restrictions (cattle crossings or undersized culverts) or was distributed out over a flat topography that, in turn, gave an unreliable reading at the downstream sites (MC-4, MC-5, and MC-6). Data shows a loss of water at these locations compared to the amount of water that was gaged at the upstream sites.

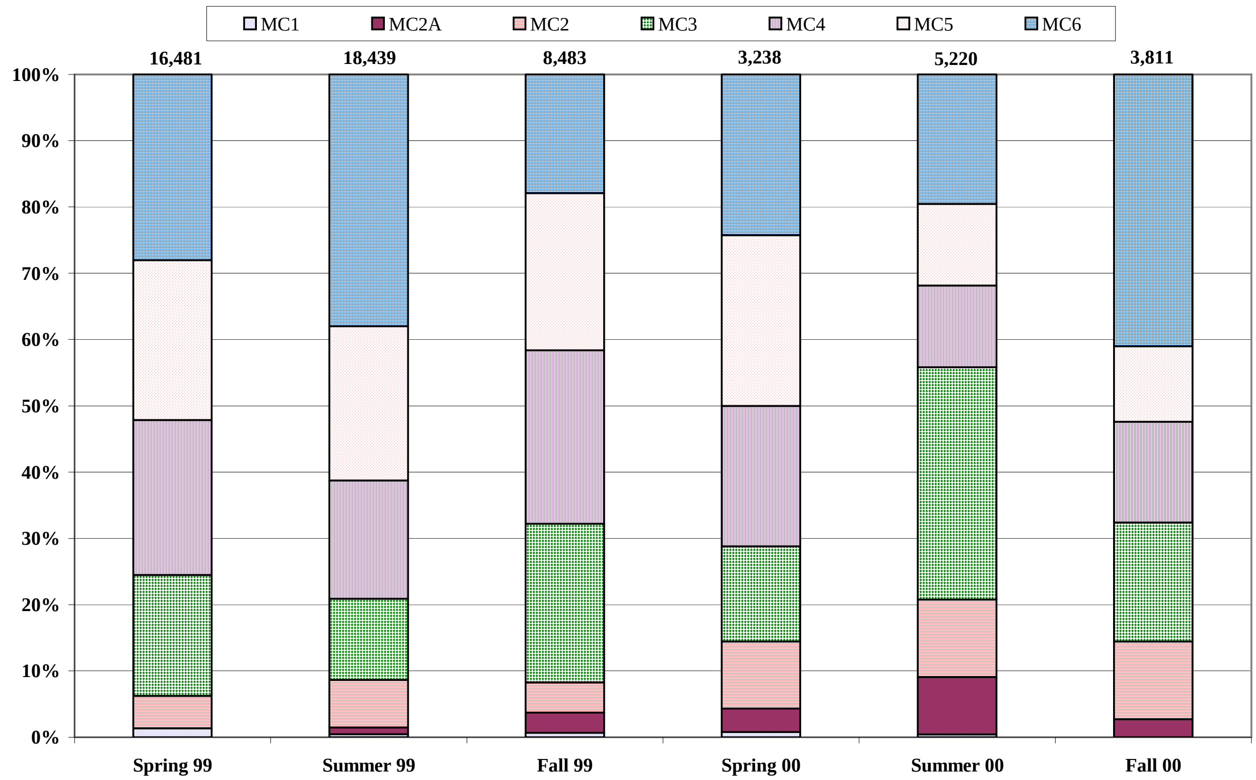


Figure 3. Hydrologic Loading in Acre-Feet By Season For Moccasin Creek, Brown County, South Dakota

Water Temperature

Water temperature is of great importance to any aquatic ecosystem. Many organisms and biological processes are temperature sensitive. Blue-green algae tend to dominate warmer waters while green algae tend to prefer cooler conditions. Water temperature also plays an important role in physical conditions. Oxygen dissolves in higher concentrations in cooler water as cooler water has the capacity to hold more dissolved oxygen than warm water. The toxicity of un-ionized ammonia is also directly related to warmer temperatures.

The water temperature in Moccasin Creek exhibited little variation from site to site. Temperatures showed seasonal variations that are consistent with its geographic location, steadily increasing in the spring and summer and consistently decreasing in the fall and winter. It can be reasonably expected that during most years the in-stream temperatures would be within a few degrees of the project data at their respective dates.

The lowest water temperatures were recorded in the spring and fall, as expected. Samples were not collected in the winter. The peak annual temperatures were reached during the summer months of July and August. One temperature reading exceeded the state standard of 32.2 degrees Celsius (90 degrees Fahrenheit) for Moccasin Creek in July, 2000. It is believed that hot temperatures during low flows warmed the stained, shallow water of Moccasin Creek to exceed this standard (Figure 4).

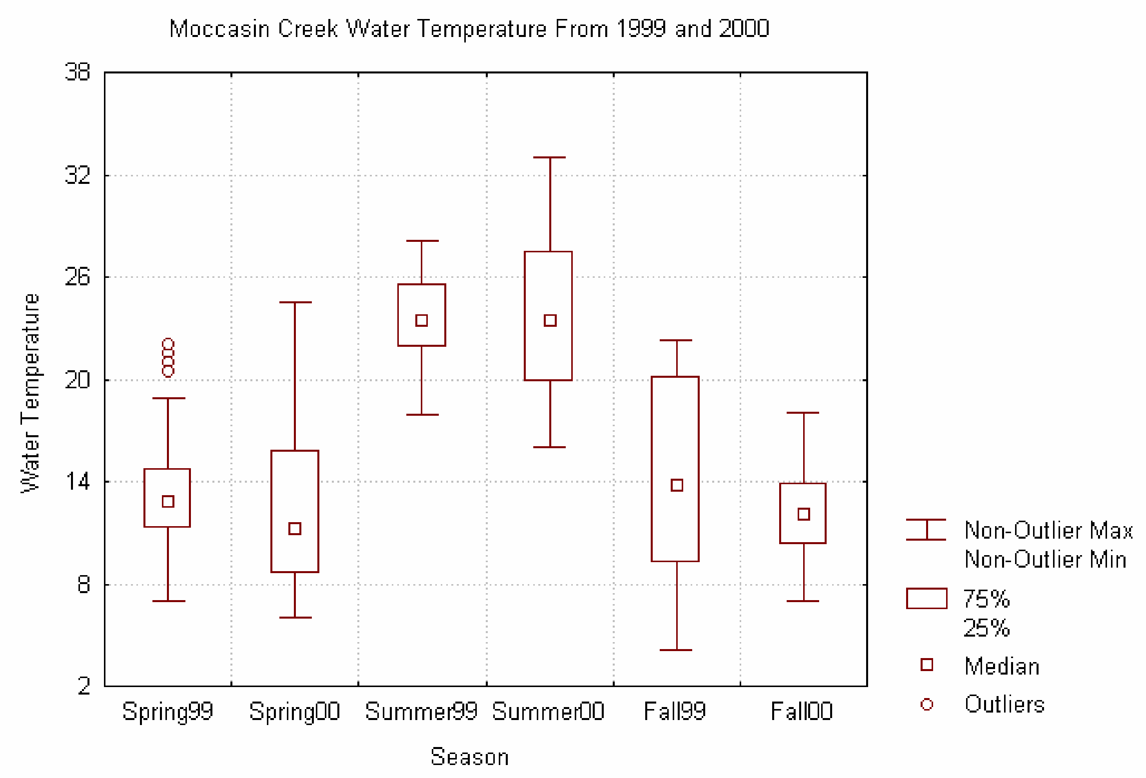


Figure 4. Water Temperature For Moccasin Creek, Brown County, South Dakota

Fecal Coliform Bacteria

Fecal coliform bacteria are found in the waste of warm-blooded animals. Some common types of bacteria are *E. coli*, S*almonella*, and *Streptococcus*, which are associated with livestock, wildlife, and human waste (Novotny, 1994). Fecal Coliform is used as an indicator to determine if pathogens may be present in a waterbody.

Portions of Moccasin Creek are listed for the beneficial uses of limited contact recreation and warmwater marginal fishlife propagation waters. Fecal coliform standards are assigned to the limited contact recreation beneficial use which begins at site MC-4 on Moccasin Creek. At the time the study took place, only sites MC-4, MC-5 and MC-6 had fecal coliform standards. The fecal coliform standard for a single grab sample is 2,000 colonies per 100 mL. A total of 201 fecal coliform samples were collected during the Moccasin Creek project.

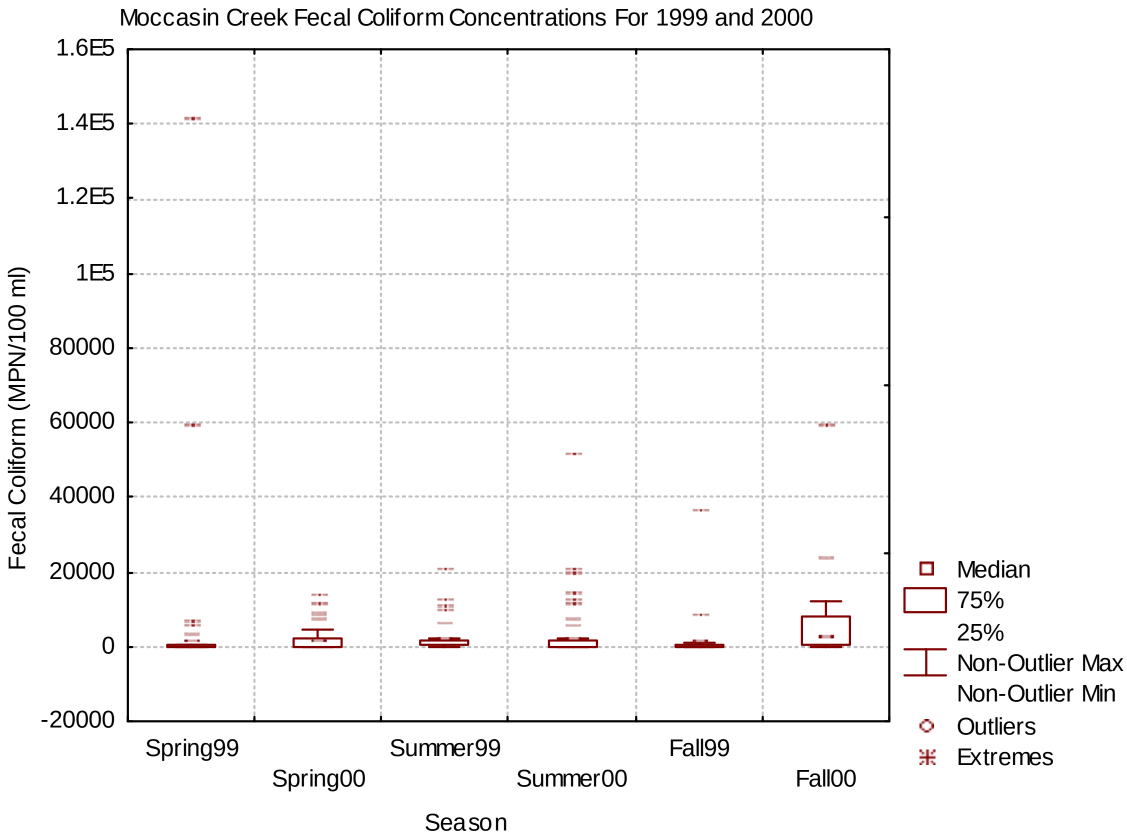


Figure 5. Fecal Coliform Bacteria Concentrations For Moccasin Creek, Brown County, South Dakota

Table 6 below shows the fecal coliform exceedences during the project period for single grab samples. The most likely source of these exceedences are probably from animal waste run-off, septic discharge, or bacteria existing in the sediment. Point sources do not appear to be the cause of the fecal coliform exceedences for the following reasons:

(1) during the time when standards were in affect, the city wastewater treatment facility was using chlorination to treat fecal coliform;

(2) the only other point source in the watershed is the city of Warner's municipal wastewater treatment ponds. The city of Warner's only recorded discharge occurred after sampling for the assessment was complete.

Table 6. Sites Exceeding Fecal Coliform Standards

Site	Date	Colonies/100mL
MC5	4/20/00	6,700
MC5	5/9/00	7,700
MC5	10/30/00	2,400

MC6	5/8/00	12,000
MC6	7/12/00	3,800

In November 2002, the Board of Water and Natural Resources reclassified Moccasin Creek to include the reach from Melgaard Road in Aberdeen to the James River. This would include all sites sampled during the project except sites MC-1 and MC-7. The city of Aberdeen has made plans to upgrade its wastewater treatment to meet this new classification.

Site MC-2A is located at Melgaard Road above the treatment plant. Fecal samples collected at this site would have been in violation of state standards had the standards been in affect at that time.

DNA ribotyping analysis was conducted on each of the seven storm sewer sites (Figure 6) on a storm event that occurred in November 2002. DNA ribotyping makes it possible to determine if a *E. coli* source is human or non-human. It was noted that *E. coli* from human sources were found in samples collected from storm sewer sites MCSS1, MCSS2, MCSS4, and MCSS6. The exact location of the contamination point within the city's storm sewers is unknown at this time. Other possible sources of *E. coli* found in the storm sewers included wildlife, bovine, and avian sources. Due to the natural variation in fecal coliform sampling and the fact that only one sample was collected during the project period, additional bacterial source sampling will be necessary before a fecal coliform TMDL can be written. Results of the DNA fingerprinting for *E. coli* can be found in Appendix C of this report.

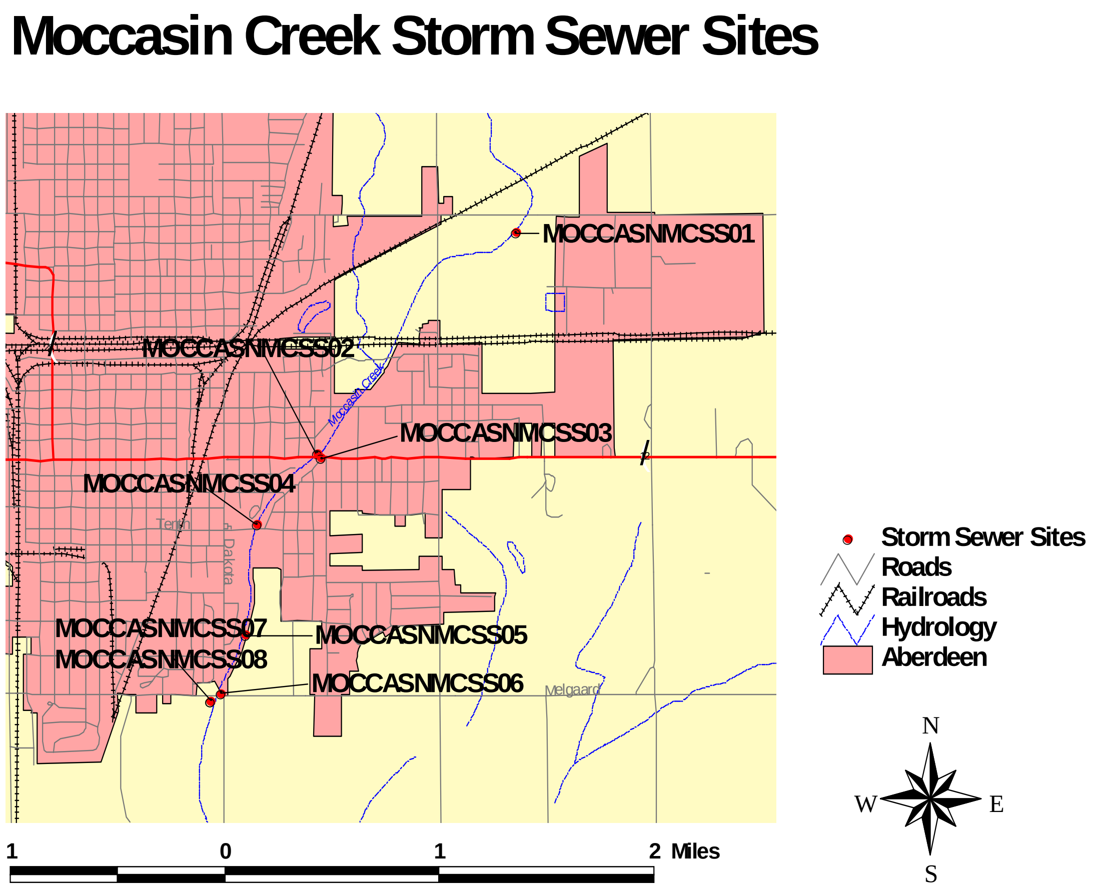


Figure 6. Moccasin Creek Storm Sewer Sites

Alkalinity

A lake's total alkalinity affects the ability of its water to buffer against changes in pH. Total alkalinity consists of all dissolved electrolytes (ions) with the ability to accept and neutralize protons (Wetzel, 2000). Historically, the term alkalinity referred to the buffering capacity of the carbonate system in water. Today, alkalinity is used interchangeably with acid neutralizing capacity (ANC), which refers to the capacity to neutralize strong acids such as HCL, H_2SO_4 and HNO_3. Alkalinity in water is due to any dissolved species (usually weak acid anions) with the ability to accept and neutralize protons (Wetzel, 2000). Due to the abundance of carbon dioxide (CO_2) and carbonates, most freshwater contains bicarbonates as its primary source of alkalinity. Alkalinity is commonly found in concentrations as high as 200 mg/L. Natural concentrations typically range from 20 mg/L to 200 mg/L (Lind, 1985).

The alkalinity in Moccasin Creek varied from a low of 57 mg/L in May of 2000 to a peak value of over 471 mg/L during November of 2000. During the spring and summer, photosynthesis carried on by algae and macrophytes utilizes a portion of the alkalinity. Ice cover and cold temperatures reduce this action during the fall and winter months allowing decomposition on the stream bottom to cause greater accumulation of carbon dioxide and bicarbonates in the water column.

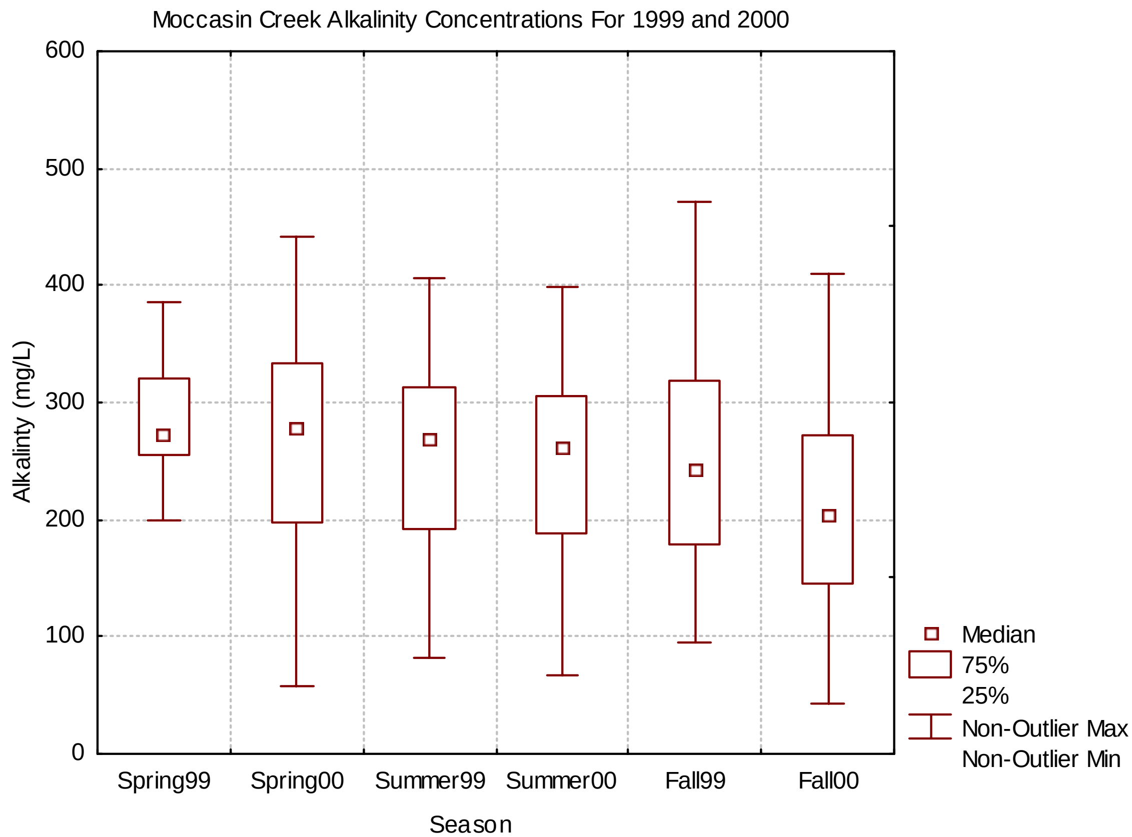


Figure 7. Alkalinity Concentrations For Moccasin Creek, Brown County, South Dakota

pH

pH is a measure of free hydrogen ions (H+) or potential hydrogen. More simply, it indicates the balance between acids and bases in water. It is measured on a logarithmic scale between 0 and 14 and is recorded as standard units (su). At neutrality (pH of 7) acid ions (H+) equal the base ions (OH-). Values less than 7 are considered acidic (more H+ ions) and greater than 7 are basic (more OH- ions). Algal and macrophyte photosynthesis act to increase a lake's pH. The decomposition of organic matter will reduce the pH. The extent to which this occurs is affected by the lake's ability to buffer against changes in pH. The presence of high alkalinity (>100-200 mg/L) represents considerable buffering capacity and will reduce the effects of both photosynthesis and decay in producing large fluctuations in pH.

pH concentrations exhibited only small differences between sites at Moccasin Creek. State standards require that the pH of Moccasin Creek be maintained between the values of 6.0 and 9.0. The single highest pH in Moccasin Creek of 9.69 was recorded at site MC-4 in March 2000 which exceeds state water quality standards. Site MC-4 had three additional readings over 9.00 in 2000. Site MC-5 had one exceedence in 1999 and seven in 2000. The lowest pH of 7.05 was taken in March, 1999. Values of pH over 9.00 are believed to have occurred due to a naturally high concentration of pH in the soil of the watershed or low stream flows and more evaporation probably due to algae growth.

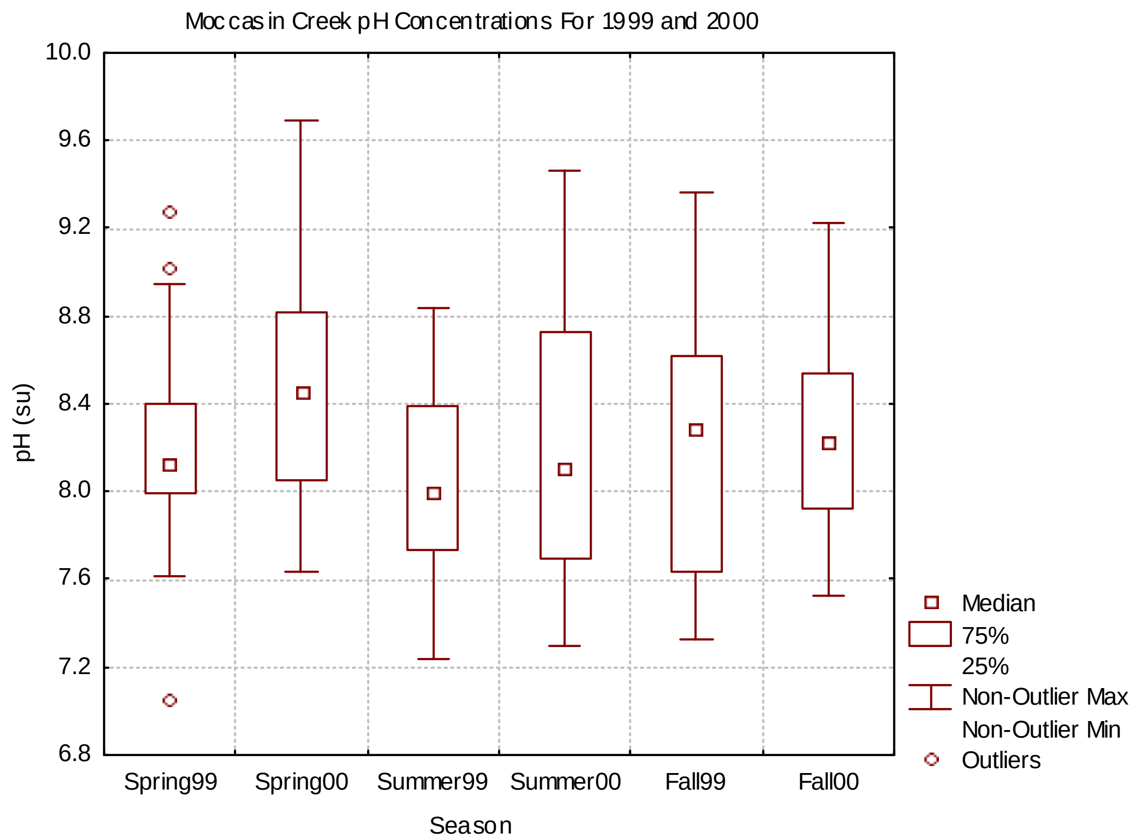


Figure 8. pH Concentrations For Moccasin Creek, Brown County, South Dakota

Dissolved Oxygen

There are many factors that influence the concentration of dissolved oxygen (DO) in a stream. Temperature is one of the most important of these factors. As the temperature of water increases, its ability to hold DO decreases. Daily and seasonal fluctuations in DO may occur in response to algal and bacterial action (Bowler, 1998). As algae photosynthesize during the day, they produce oxygen, which raises the DO concentration. As photosynthesis ceases at night, respiration utilizes available oxygen causing a decrease in concentration. During winters with heavy snow cover and times of heavy algal blooms, light penetration may be reduced to the point that the algae and aquatic macrophytes in the stream cannot produce enough oxygen to keep up with consumption (respiration) rates. This results in oxygen depletion and may ultimately lead to a fish kill.

Oxygen levels in Moccasin Creek increased downstream. Upstream samples from site MC-1 to MC-2 showed significantly less DO then those taken at downstream sites. There were eleven DO readings at site MC1 that were <5 mg/L, five at MC-2A, four at MC-2, and two at MC-3. These low levels were recorded during the summer months when water temperatures were at their highest. In October, water temperatures were cooling, the DO levels began to rise. Sites MC-4, MC-5, and MC-6 never had a DO reading below the state water quality standard (>5.0 mg/L) for Moccasin Creek. It is believed that low flows on the northern end of Moccasin Creek along with shallow water over organic rich sediment contributed to the low DO levels. It is also believed that higher levels of DO were present in lower Moccasin Creek due to deeper water, increased algal production, increased flows from Foot Creek, and the city of Aberdeen's wastewater treatment plant. DO levels at site MC-2A showed over 10% water quality exceedence according to fishery standards. The segment upstream of MC-2A will require a TMDL (Appendix F).

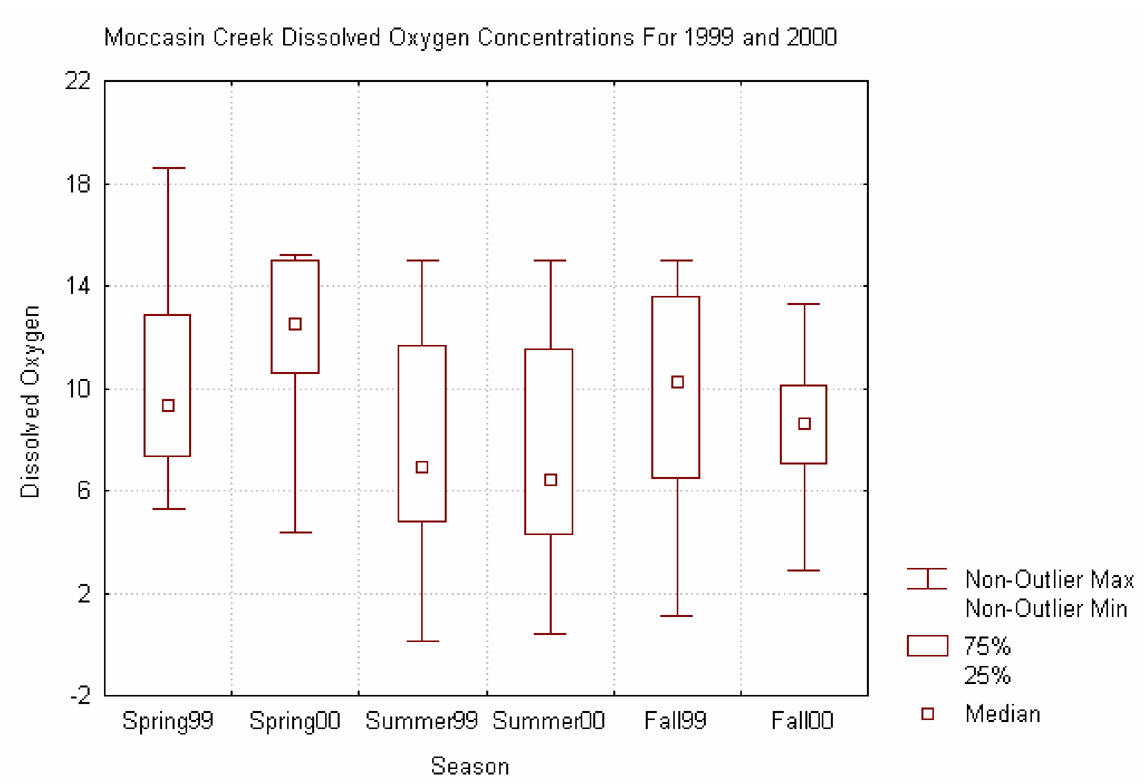


Figure 9. Dissolved Oxygen Concentrations For Moccasin Creek, Brown County, South Dakota

Solids

Total solids are the sum of all dissolved and suspended solids as well as all organic and inorganic materials that are found in a given volume of water. Dissolved solids are typically found at higher concentrations in ground water, and typically constitute the majority of the total solids concentration. Solids are addressed as four separate parts in the assessment; total solids, dissolved solids, suspended solids, and volatile suspended solids.

The state standard for dissolved solids is a mean of 2,500 mg/L or a single-sample maximum of 4,375 mg/L.

Moccasin Creek exhibited a large variation in total solids concentrations throughout the course of the sampling period. Peak values were observed in May 1999 at 2731 mg/L at site MC2. The lowest values were observed during the early summer samples collected in May 2000 at 183 mg/L at site MC6.

Total Suspended Solids

Suspended solids consist of particles of soil and organic matter that may be deposited in stream channels and lakes in the form of silt. Silt deposition into a stream bottom buries and destroys the complex bottom habitat. This habitat destruction reduces the diversity of aquatic insect, snail, and crustacean species. Shallow water increases and maintains higher temperatures.

Suspended solids concentrations in Moccasin Creek remained fairly low throughout the course of the year. The lowest concentrations were recorded at site MC-1 at 1 mg/L. It is believed the concentrations at MC1 are lower because the water sampled was base flow groundwater trickling into Moccasin Creek. During runoff events, the concentrations increase. There were seven samples collected throughout the course of the sampling period that exceeded the <150 mg/L state standard. The highest recorded suspended solids concentration was recorded in May 2000 at 224 mg/L (site MC-4). These higher concentrations of suspended solids were likely caused by algae blooms and/or light inorganic sediment or silt moving down the creek.

Volatile Suspended Solids

Volatile suspended solids followed the same trend as the total suspended solids with increased concentrations below Foot Creek and the city of Aberdeen's wastewater treatment plant. Lower concentrations were noted at sites MC-1 and MC-2 above Foot Creek and the treatment plant. Sites MC-4, MC-5, and MC-6 make up nearly 80% of the total volatile suspended solids loads. This is probably caused from algal blooms in that section of Moccasin Creek.

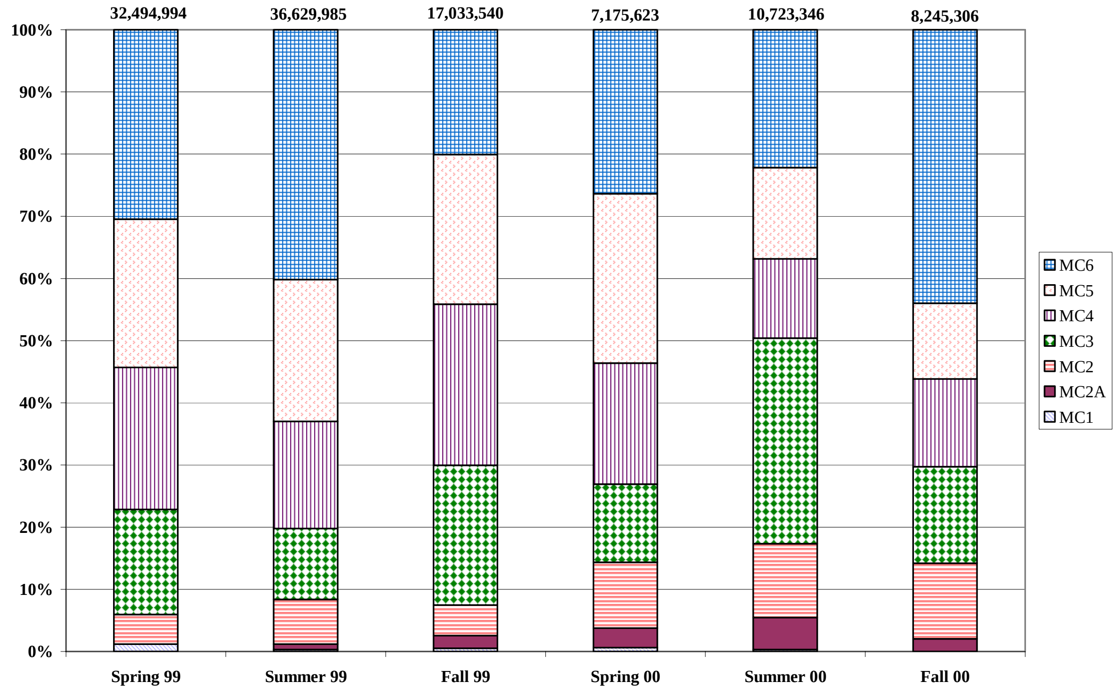


Figure 10. Total Suspended Solids Loadings By Season For Moccasin Creek, Brown County, South Dakota

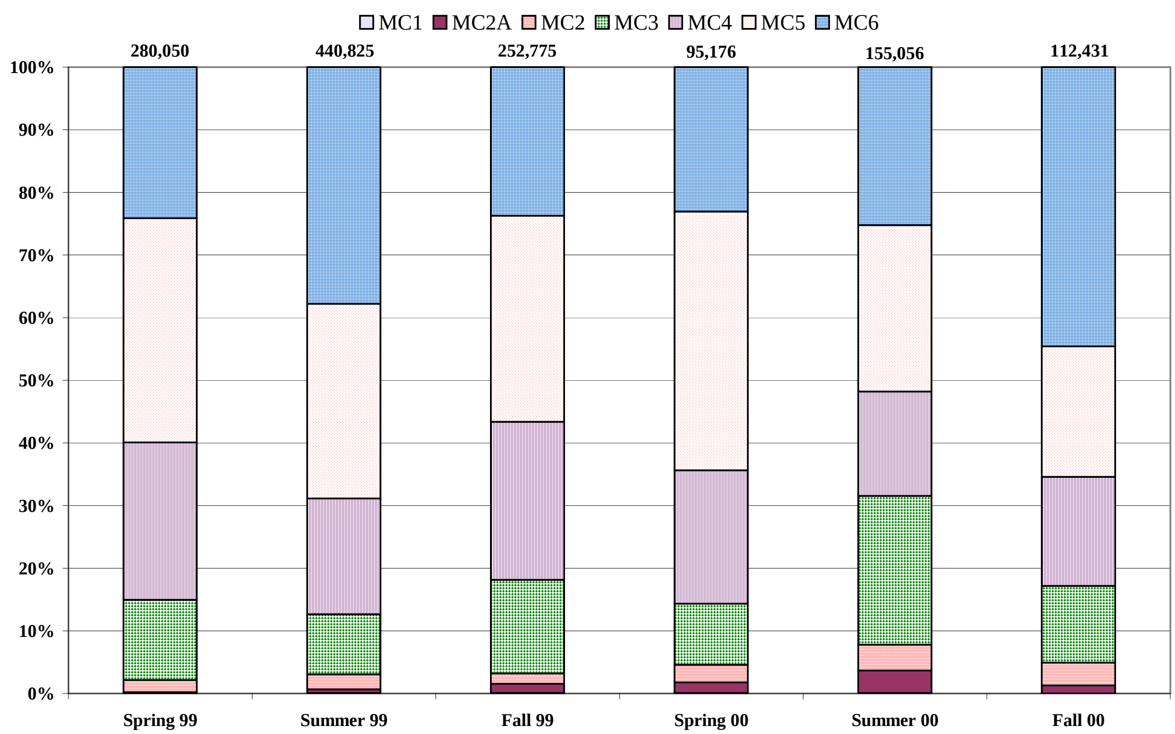


Figure 11. Total Volatile Suspended Solids Loading By Season For Moccasin Creek, Brown County, South Dakota

Nitrate/Nitrite

The water quality standards for wildlife propagation, recreation, and stock watering require that nitrate concentrations remain below 50 mg/L mean over any 30-day period of time and 88 mg/L for any single sample. The laboratory detection limit for nitrates is <0.1 mg/L. 67.5% of the nitrate samples collected from Moccasin Creek were at or below the detection level. There were no nitrate samples that exceeded state water quality standards. The single highest estimated nitrate sample on Moccasin Creek was collected in the spring of 1999 at MC4 at 1.3 mg/L which correlates with the single highest estimated seasonal loading of 4,201 kg at the same site.

As a standard testing procedure, nitrates and nitrites are measured and recorded together. This form of nitrogen is inorganic and readily available for plant use.

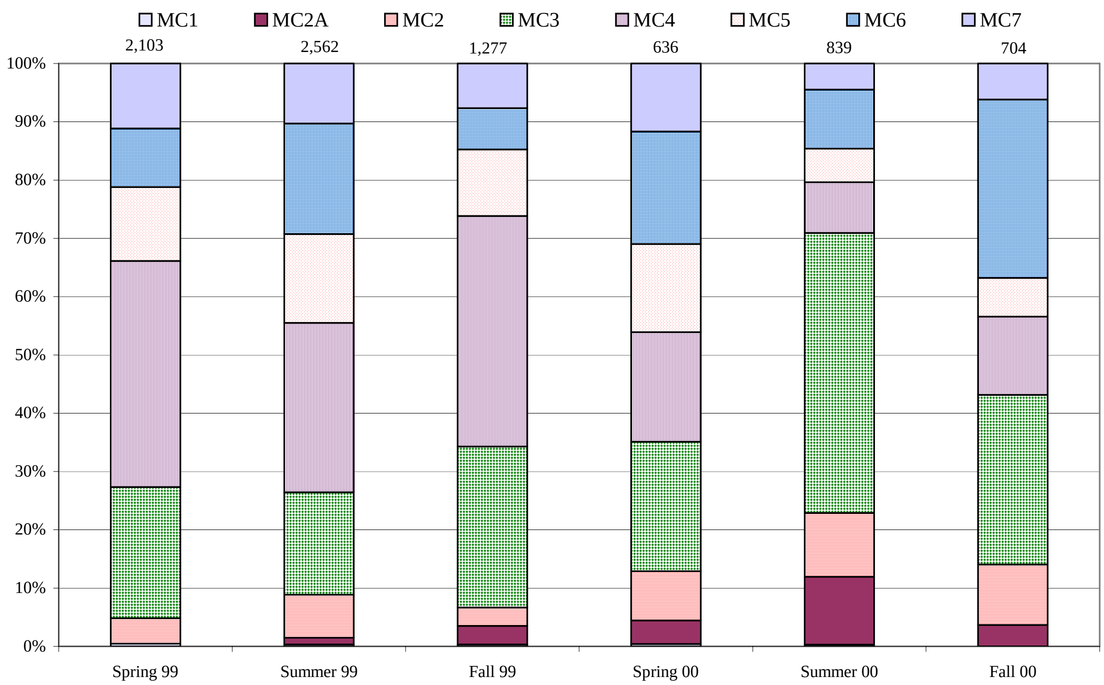


Figure 12. Nitrate Loading By Season For Moccasin Creek, Brown County, South Dakota

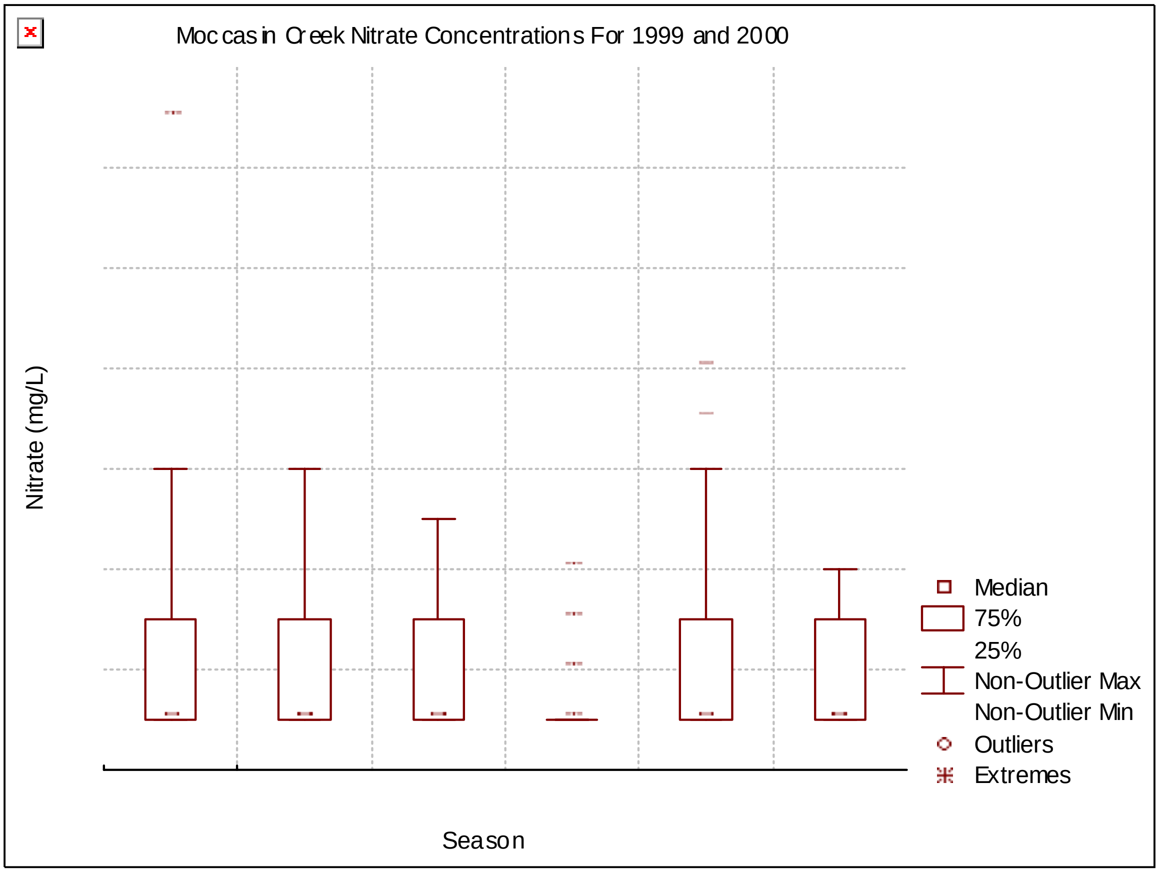


Figure 13. Nitrate Concentrations For Moccasin Creek, Brown County, South Dakota

Ammonia

Ammonia may be found in two forms, ionized and unionized. The unionized form can be extremely toxic to fish. The unionized fraction of ammonia is dependent on pH and temperature. As these two parameters increase, so does the unionized fraction of ammonia. Ammonia tends to remain in its ionic form (NH^{4+}) except under higher alkaline conditions (pH > 9.0) (Wetzel 2000). Unionized levels in excess of 5% are lethal to fish and other aquatic life.

On Moccasin Creek, state standards for ammonia begin to be applicable at site MC4 where the creek is considered a fishery and standards are in effect. Violations on March 29, 1999, March 22, 1999, March 23, 2000, April 20, 2000, June 5, 2000, and November 11, 2000 were most likely caused by discharge from the city of Aberdeen's wastewater treatment plant. Violations on September 7, 1999 and October 27, 2000 were most likely caused by run-off from animal feeding operations or break down of organic material in sediments of the creek. At site MC-2 and MC-3 (directly below Aberdeen's treatment plant) standards are not in affect because that portion of Moccasin Creek is not considered a fishery. Data shows there were 29 samples collected at MC-2 of which 16 samples would exceed state water quality standards if standards were in affect in this area. At site MC-3, 26 samples were collected and 12 samples would exceed standards. In the spring and fall of 2000, site MC-2 contributed up to 70% of the total inorganic nitrogen (ammonia plus nitrate) to Moccasin Creek.

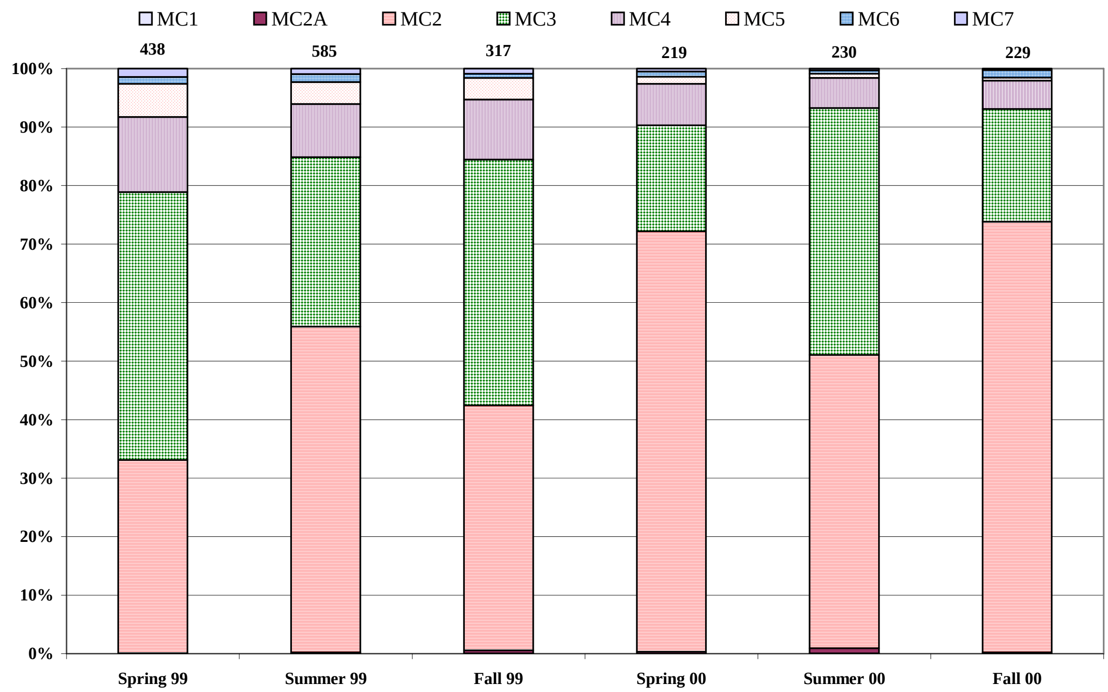


Figure 14. Ammonia Loadings By Season For Moccasin Creek, Brown County, South Dakota

TKN

TKN contains both ammonia and organic nitrogen. Typically organic nitrogen is the larger of the two components in TKN. However, because of the large ammonia discharges from the wastewater treatment plant, this is not always the case in Moccasin Creek. These individual components have already been discussed earlier in this report.

Inorganic Nitrogen

Inorganic nitrogen is the sum of the nitrate/nitrite and ammonia measurements and is a more plant-available form of nitrogen. The majority of the inorganic nitrogen was found at sites MC-2 and MC-3 located below the wastewater treatment plant. At this same location, the ammonia concentrations were also highest of all sites on Moccasin Creek. With increased concentrations of ammonia at site MC-2, one would expect to find higher amounts of total inorganic nitrogen at the site. In the spring and fall of 2000, site MC-2 contributed nearly 65% of the total inorganic nitrogen to Moccasin Creek. The single highest calculated inorganic nitrogen concentration on Moccasin Creek was collected at site MC-2 in the fall of 2000 at 19.40 mg/L.

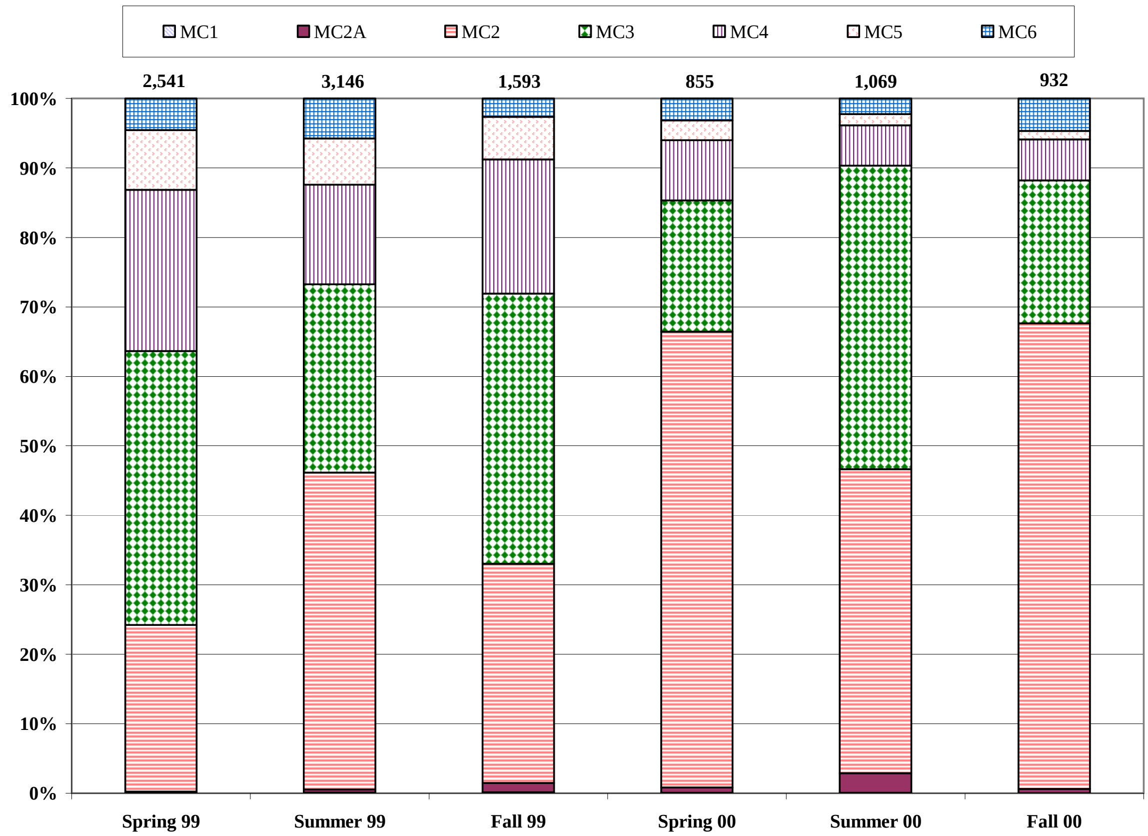


Figure 15. Inorganic Nitrogen Loading By Season For Moccasin Creek, Brown County, South Dakota

Organic Nitrogen

Organic nitrogen is calculated using TKN concentration minus the ammonia concentration. The majority of the organic nitrogen found in Moccasin Creek is found at sites MC-3, MC-4, MC-5, and MC-6. Site MC-2 loads the system with a lot of inorganic nitrogen and as the inorganic nitrogen moves downstream, plants such as algae, use and consume inorganic nitrogen for growth. Dead or decaying plants can be a source of organic nitrogen. This process best explains the reason why there is less organic nitrogen at site MC-2. Organic nitrogen increases as inorganic decreases when sampling downstream. The single highest calculated concentration of organic nitrogen was collected at site MC-3 on August 24, 2000 at 8.78 mg/L.

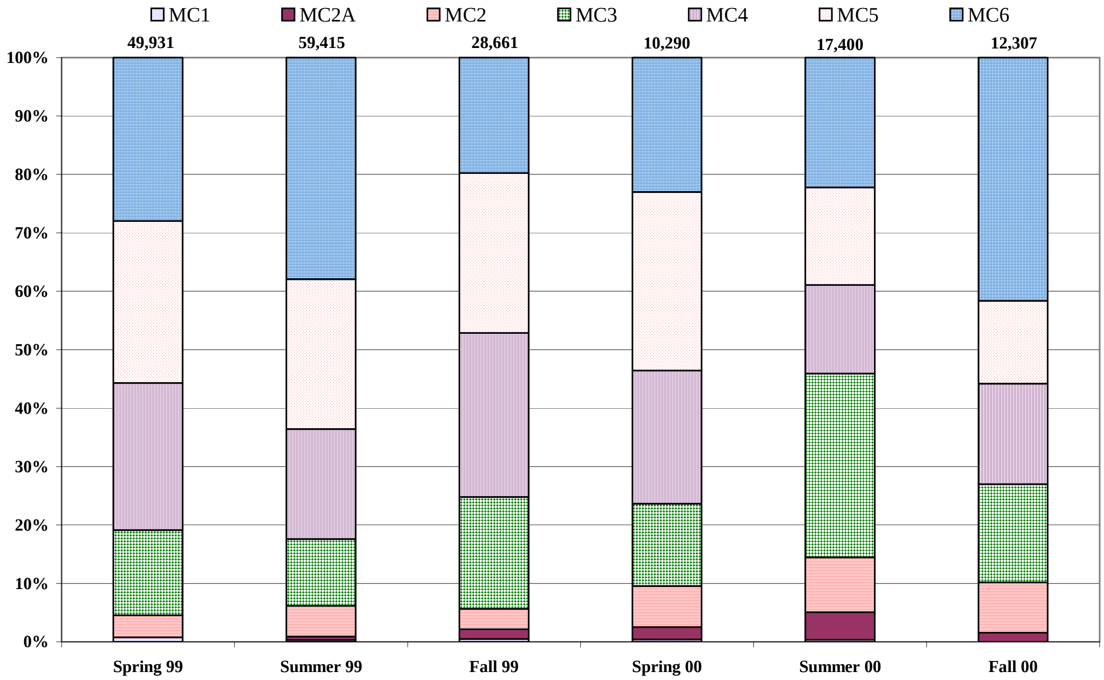


Figure 16. Organic Nitrogen Loading By Season For Moccasin Creek, Brown County, South Dakota

Total Nitrogen

Nitrogen is analyzed in three forms: nitrate/nitrite, ammonia, and Total Kjeldahl Nitrogen (TKN). From these four forms, total, organic, and inorganic nitrogen may be calculated. Nitrogen compounds are major cellular components of organisms. Because its availability may be less than the biological demand, environmental sources may limit productivity in freshwater ecosystems. Nitrogen is difficult to manage because it is highly soluble and very mobile in a given water body. In addition, there are bacterial species and species of blue-green algae capable of fixing atmospheric nitrogen for use by algae resulting in a virtually limitless supply of nitrogen for algae and plants.

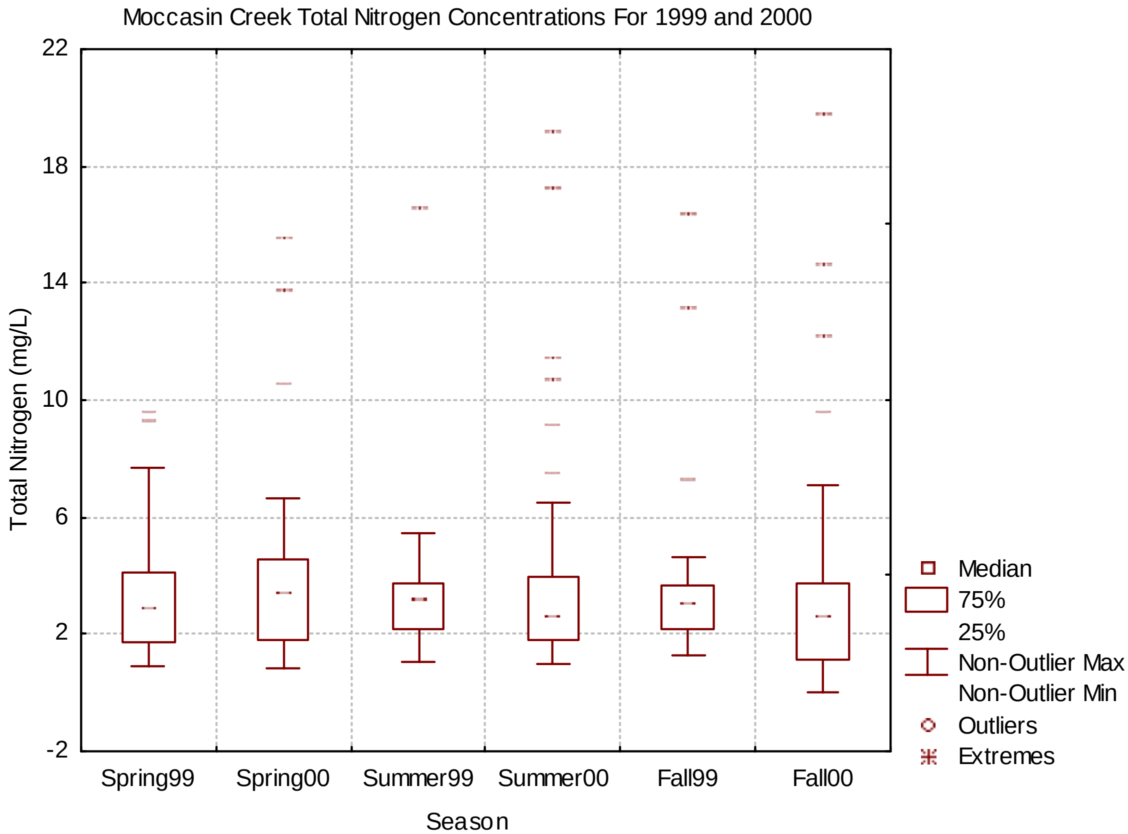


Figure 17. Total Nitrogen Concentrations For Moccasin Creek, Brown County, South Dakota

Data shows that the majority of total nitrogen loading to Moccasin Creek occurred at sites MC-2, MC-3, and MC-4. The high loadings are believed to be caused by the city of Aberdeen's wastewater treatment plant and runoff from animal feeding operations. Samples collected at downstream sites on the same days indicated that total nitrogen dropped off, suggesting that plants were consuming some of the nitrogen. Total nitrogen loadings at the two upstream sites MC-1 and MC-2A, remained relatively low at the same time.

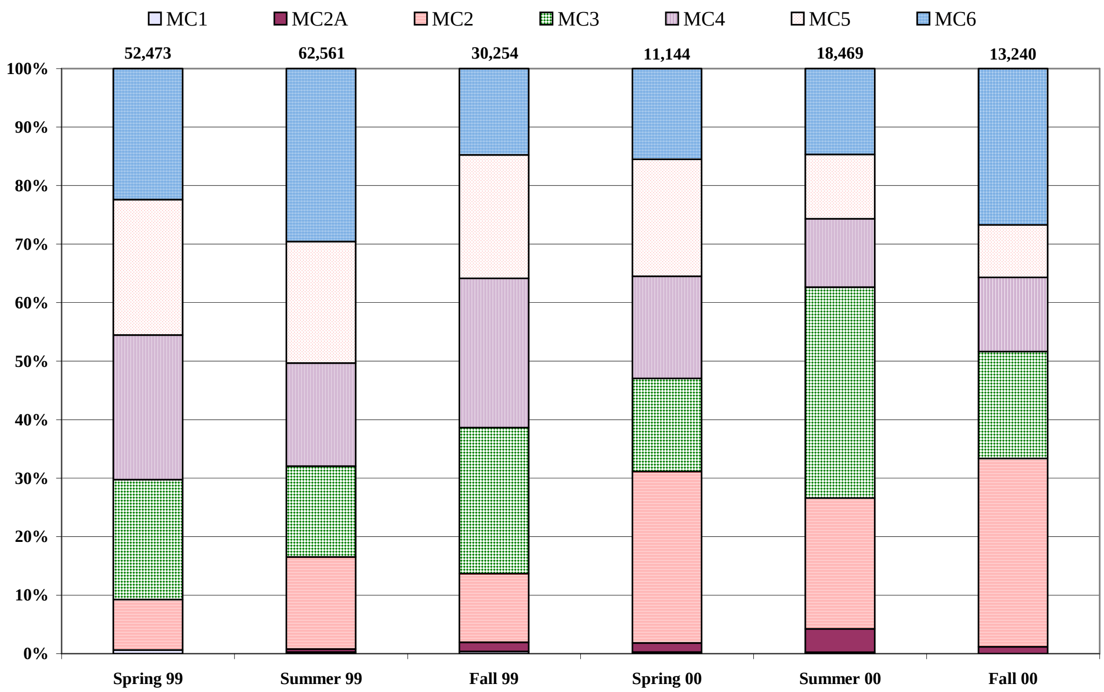


Figure 18. Total Nitrogen Loading By Season For Moccasin Creek, Brown County, South Dakota

Total Phosphorus

Phosphorus is one of the macronutrients required for primary production. When compared with carbon, nitrogen, and oxygen, it is typically the least abundant (Wetzel, 2000). Phosphorus loading to lakes can be of an internal or external nature. External loading refers to surface runoff over land, dust, and precipitation. Internal loading refers to the release of phosphorus from the bottom sediments to the water column of the stream. Total phosphorus is the sum of all attached and dissolved phosphorus in the lake.

Sites MC-1 and MC-2A contributed very little to the total phosphorus loading to Moccasin Creek. The remainder of the sites had large impacts on total phosphorus loading. The single highest phosphorus sample was taken from site MC-4 in the summer of 2000 at 3.22 mg/L. The lowest total phosphorus single sample was taken from site MC-7 in the spring of 2000 at 0.102 mg/L. When looking at seasonal loadings, the highest loading occurred in the summer of 1999 at 18,442 kg.

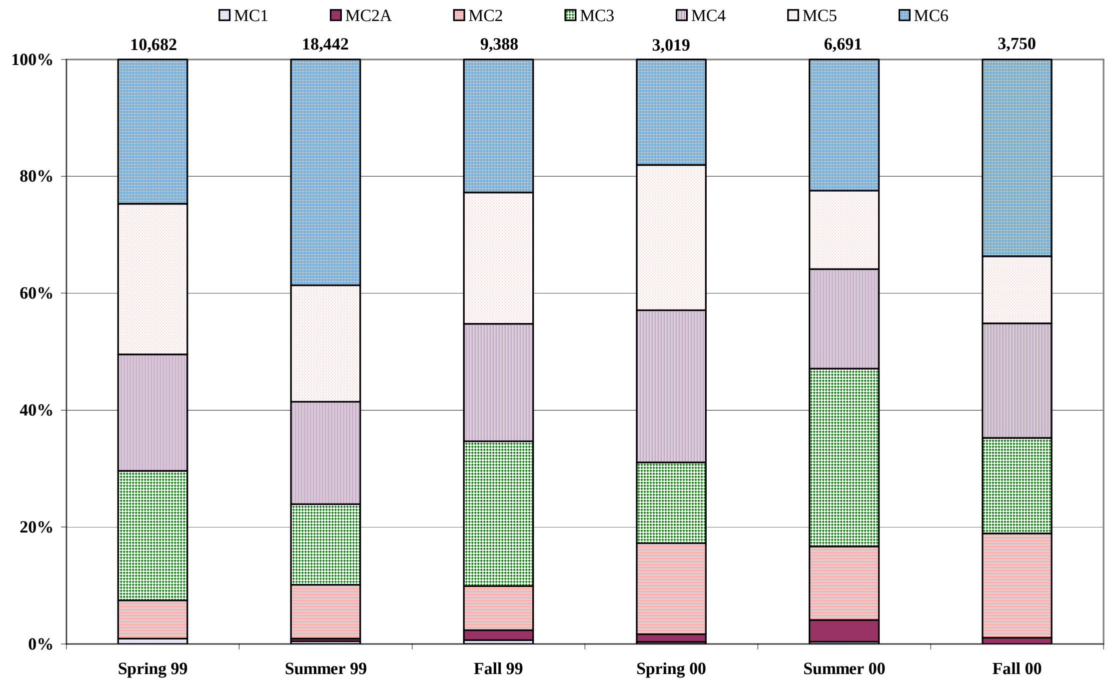


Figure 19. Total Phosphorus Loading By Season For Moccasin Creek, Brown County, South Dakota

Total Dissolved Phosphorus

Total dissolved phosphorus is the unattached portion of the total phosphorus load. It is found in solution, but readily binds to soil particles when they are present. Total dissolved phosphorus, including soluble reactive phosphorus, is more readily available to plant life than attached phosphorus. Typically, there is an indirect relationship between the percentage of dissolved phosphorus (39.57%) and the total suspended solids concentrations. This relationship does not appear to exist in Moccasin Creek. When looking at seasonal loadings, the highest loading occurred in the summer of 1999 at 10,501 kg.

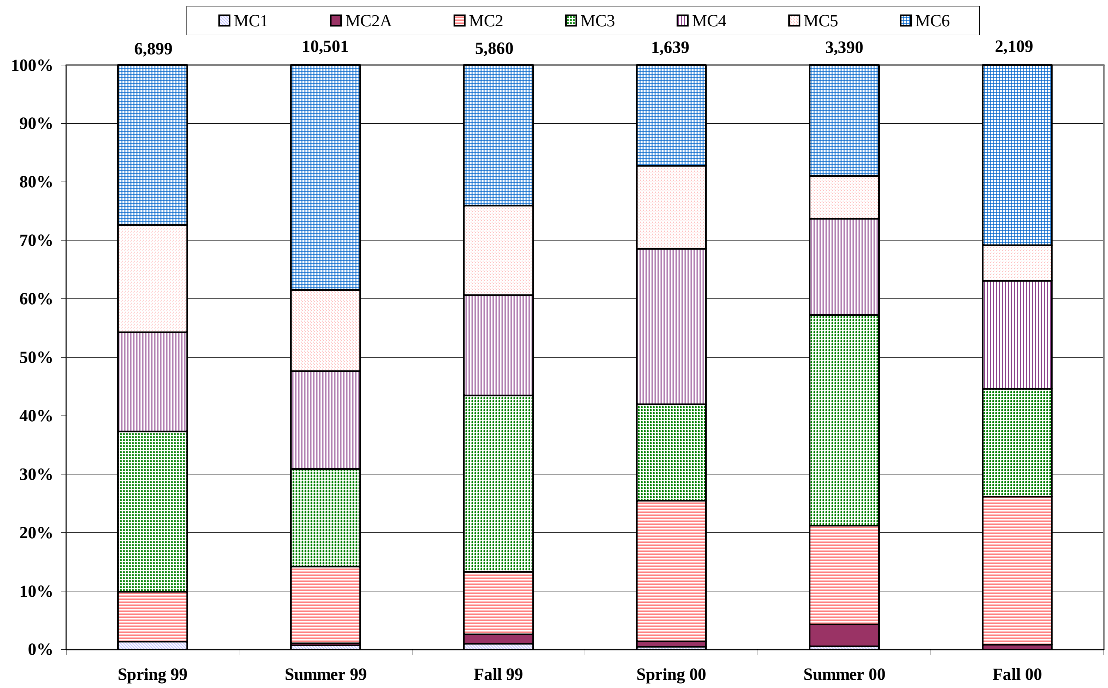


Figure 20. Total Dissolved Phosphorus Loadings By Season For Moccasin Creek, Brown County, South Dakota

Nitrogen

Nitrogen is assessed in four forms: nitrate/ nitrite, ammonia, and Total Kjeldahl Nitrogen (TKN). From these four forms, total, organic, and inorganic nitrogen may be calculated. Nitrogen compounds are major cellular components of organisms. Because its availability may be less than the biological demand, environmental sources may limit productivity in freshwater ecosystems. Nitrogen is difficult to manage because it is highly soluble and very mobile in water.

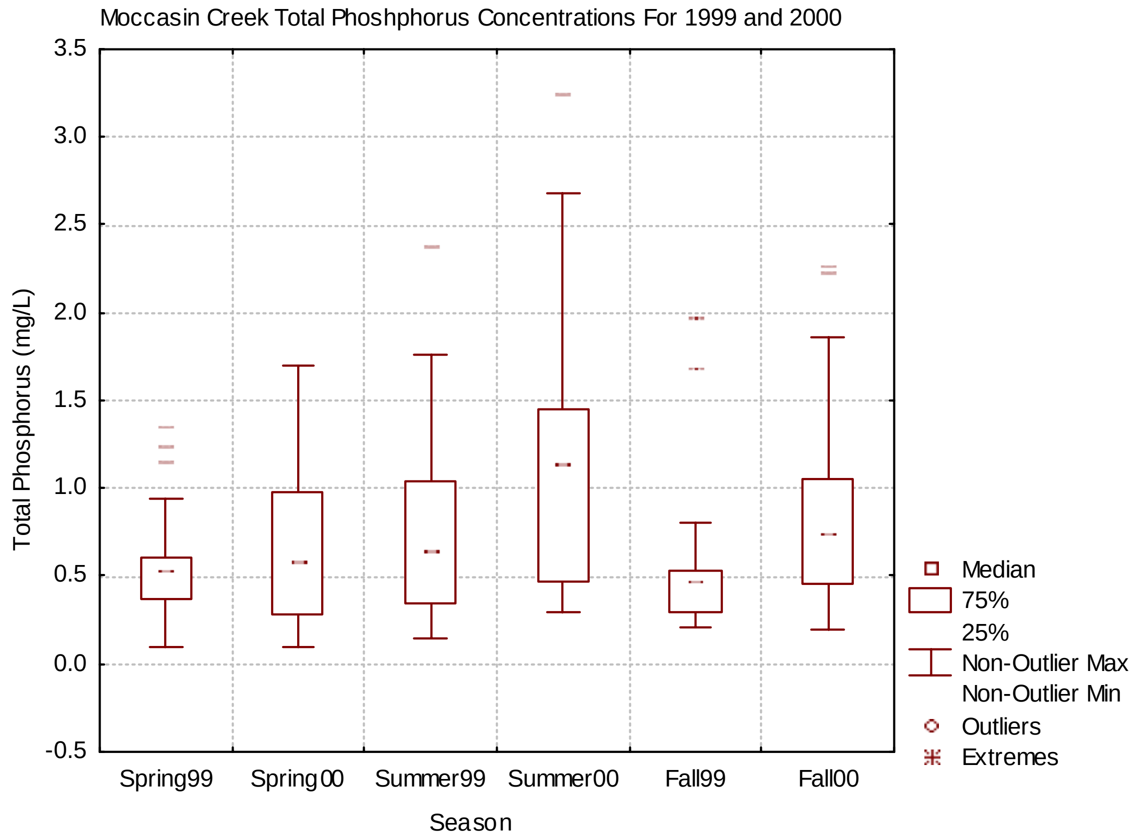


Figure 21. Total Phosphorus Concentrations For Moccasin Creek, Brown County, South Dakota

Tributary Site Summary

As discussed in the "watershed overview" section of the AGNPS report, the majority of the loadings to Moccasin Creek for nutrients and sediment comes from sites MC4, MC5, and MC6. Sub-watersheds MC4, MC5, and MC6 contribute 75% of the total sediment loading to the creek, hold all of the critical erosion cells in the Moccasin Creek watershed, and contain 61% of the total acreage of the entire watershed. Suspected sources of erosion are areas with a slope greater than 2.5% in combination with low grade soils and poor vegetative cover. Nutrient analysis produced similar results. The same sub-watersheds (MC4, MC5, and MC6) contributed 75% of the total nitrogen loading and most of the phosphorus loading.

Biological Monitoring

Fishery

The fish community in Moccasin Creek was sampled in 2002 using the electro-fishing method for gathering fish. A final report was published on the findings of the study conducted by the South Dakota Department of Environment and Natural Resources (SD DENR). Data sheets were completed by DENR staff showing fish species, length, date and time fish were caught. Moccasin Creek contains several different species of fish, but is not considered a major fishery in the area. Black bullhead populations dominate the Moccasin Creek fishery. Other fish found during the study include carp, fathead minnows, brook stickleback, and channel catfish. Most fish measured during the study were four to six inches in length. State fishing regulations apply to Moccasin Creek.

The South Dakota Game, Fish, and Parks (SDGF&P) department was contacted regarding the fish community on Moccasin Creek but fisheries information was not available.

Threatened and Endangered Species

There are no threatened or endangered species documented in the Moccasin Creek watershed according to Doug Backlund, SDGF&P. The US Fish and Wildlife Service lists the whooping crane and bald eagle as species that could potentially be found in the area. None of these species were encountered during this study; however, care should be taken when conducting mitigation projects in the Moccasin Creek watershed.

Bald eagles typically prefer large trees for perching and roosting. There is no confirmed documentation of bald eagles within the Moccasin Creek watershed, little impact to the species should occur. Any mitigation processes that take place should avoid the destruction of large trees that may be used as eagle perches.

Whooping cranes have never been documented in the Moccasin Creek watershed. Sightings in this area are likely only during fall and spring migration. When roosting, cranes prefer wide, shallow, open water areas such as flooded fields, marshes, artificial ponds, reservoirs, and rivers. Their preference for isolation and avoidance of areas that are surrounded by tall trees or other visual obstructions makes it unlikely that they will be present in the project area to be negatively impacted as a result of the implementation of BMPs. If whooping cranes are sighted during the implementation of mitigation practices, all disruptive activities should cease until the bird(s) leave the area.

Although there have never been any confirmed documentations of the western prairie fringed orchid in this watershed, habitat suitable for its survival does exist. Western prairie fringed orchid grows in tall grass prairies and meadows. Wetland draining and the conversion of rich soil prairies to agricultural cropland threaten the orchid's survival. Overgrazing, improper use of pesticides, and collecting also threaten its survival (Missouri, 2001). Proposed BMPs for the Moccasin Creek watershed should reduce the occurrence of overgrazing, ultimately enhancing the condition of local wetlands and increasing the survivability of this species, if it were ever to grow there.

Benthic Macroinvertebrates

The biological data was collected over a 45-day period during late summer and early fall of 2000. Rock baskets were the method of choice for collecting benthic macroinvertebrates during this designated index period. A description of the rock baskets and how they were deployed can be found in the standard protocols for the South Dakota Water Resources Assistance Program (SOP-SDWRAP). The macroinvertebrates were collected and shipped to a private consultant for identification and enumeration according to the SOP for SDWRAP. A standard count of 300 organisms was used in the calculation of 45 metrics (Table 7).

Testing of Candidate Metrics

The benthic macroinvertebrate community can be characterized through a wide variety of metrics. Each metric detects differences in the benthic community. The goal of calculating an adequate number of metrics and comparing them across varying site conditions and/or river basins is to be able to identify which metrics do a better job at discriminating between the site conditions.

A metric is a mathematical characterization of the aquatic macroinvertebrate community using the presence or absence of various genera/species of macroinvertebrates within a stream. Each group of insects (or lack thereof) can be used as indicators as to the health of the aquatic community and serve as long-term indicators of the water quality within the stream or lake.

The 45 metrics shown in Table 7 were calculated for each of the individual rock baskets (three baskets per site, (MCT-6 had one basket vandalized) for a total of 14 rock baskets). The three replicates (baskets at MCT-2, MCT-3, MCT-4 and MCT-7) determine which metrics had greater sensitivity for detecting differences between sampling sites. These 45 metrics were screened for their ability to detect changes between sampling sites (Table 7). All metrics fell into one of five general categories: taxonomic composition, taxonomic richness or abundance, feeding or trophic groups, life habit and degree of tolerance to stress in the environment.

Figure 22 illustrates how the statistical values are displayed for a box and whisker plot. This type of plot displays the minimum, maximum, and median values for a series of data points (metric values for the rock baskets). The outliers and extreme values are also calculated for the data set. The interquartile range or IQR in Figure 22 is that range of values between the 25^{th} and 75^{th} percentiles of the data points. The whiskers in the plot graphically refer to the minimum and maximum values that fall within the non-outlier range (Statsoft, 2000). After identifying which metrics exhibited the strongest differences between MCT-2, MCT-3, MCT-4 and MCT-7, box and whisker plots were used to display four of the five metrics.

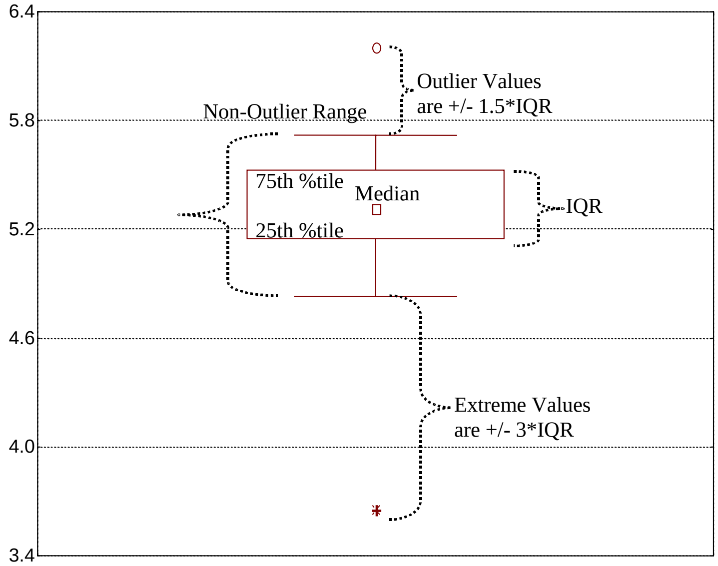


Figure 22. Example Of A Box And Whisker Plot

Table 7. Metrics Calculated for the Moccasin Creek Watershed Assessment

Category	#	Metric	Expected Response to Increasing Disturbance
Abundance Measures	1	Corrected abundance	Variable
	2	EPT abundance[1]	Decrease
	3	total taxa	Decrease
Dominance Measures	4	% 1 dominant taxon	Increase
	5	% 2 dominant taxa	Increase
	6	% 3 dominant taxa	Increase
Richness Measures	7	Species richness	Decrease
	8	EPT richness	Decrease
	9	Ephemeroptera richness	Decrease
	10	Trichoptera richness	Decrease
Community Composition	11	% Ephemeroptera	Decrease
	12	% Trichoptera	Decrease
	13	% EPT	Decrease
	14	% Coleoptera	Decrease
	15	% Diptera	Increase
	16	% Baetidae	Increase
	17	% Chironomidae	Increase
	18	% Oligochaeta	Increase
	19	% Ephemerellidae	Decrease
	20	% Hydropsychidae	Increase
	21	% Odonata	Increase
	22	% Simuliidae	Increase
Functional Group Composition	23	% filterers	Increase
	24	% gatherers	Decrease
	25	% predators	Decrease
	26	% scrapers	Decrease
	27	% shredders	Decrease
	28	filterer richness	Decrease
	29	gatherer richness	Decrease
	30	predator richness	Decrease
	31	scraper richness	Decrease
	32	shredder richness	Decrease
Diversity/Evenness Measures	33	Shannon-Weaver H' (log 10)	Decrease
	34	Shannon-Weaver H' (log 2)	Decrease
	35	Shannon-Weaver H' (log e)	Decrease
	36	Hilsenhoff Biotic Index (HBI)	Increase
	37	Margalef's Richness	Decrease
	38	Metals Tolerance Index	Increase
	39	Pielou's J'	Decrease
	40	Simpson's Heterogeneity	Decrease
	41	Jaccard Similarity Index	Decrease
	42	Percent Similarity	Decrease
Habit Metrics	43	Long-lived taxa richness	Decrease
	44	Clinger richness	Decrease
	45	% tolerant taxa	Increase

1=Ephemeroptera, Plecoptera, Trichoptera
Shaded metrics = Moccasin Creek core metrics.

Metrics were analyzed with a Kruskal-Wallis non-parametric test to determine if the metrics values differed between sites (df=3, n=14). Table 8 shows metrics that exhibited the strongest differences between all four sampling sites (core metrics). Core metrics chosen need to be selected from five main separate categories as well. In other words, there should not be five metrics chosen that fall within the taxonomic richness category. This is done to reduce the redundancy or the chance that two different metrics may be providing the same information.

Table 8. Kruskal-Wallis Analysis P-Values For Five-Core Metrics Chosen For Moccasin Creek

Metric	Differences between Sites((df=3, N=14) P values <0.05)
EPT Abundance	0.02
Percent Oligochaeta	0.02
Hilsenhoff Biotic Index	0.04
Species Richness	0.02
Percent Scrapers	0.03

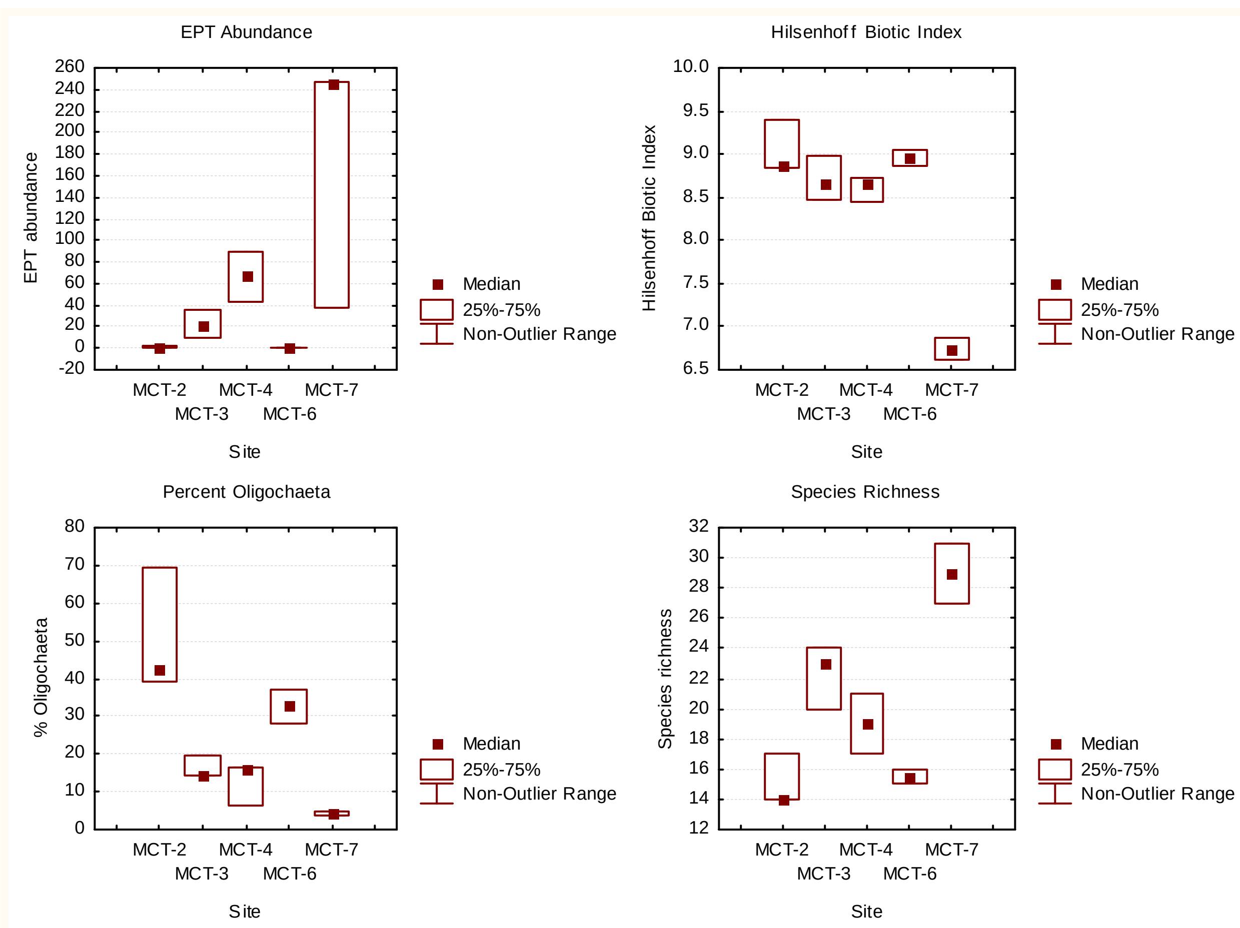


Figure 23. Core Metrics For Moccasin Creek

Metric Standardization

After the core metrics were determined from the Moccasin Creek rock basket data, all five metrics were incorporated into a multi-metric index. Each of the five metrics shown in Table 8 is a different measure of the benthic community. All five metrics were chosen because of their ability to show differences in conditions between sampling sites. The five individual metrics were averaged into a single multi-metric index. Each metric was scored on a standardized scale of 0 to 100. This gives equal weight to each metric, i.e. no metric is more important than any other (Tetra Tech, 2000). Those metrics which have increasing values due to decreasing perturbation are easily converted to a 100-point scale using the following process: of the five core metrics from Moccasin Creek, species richness, percent scraper, and EPT abundance are metrics that increase with decreasing perturbation. To convert these metrics to a standard 100-point scale (0=worst and 100=best) the following equation is used:

(Equation 1) $$score = \left(\frac{X}{X_{95} - X_{\min}} \right) \times 100$$

where, X = the metric value
X_{95} = the 95th percentile value
$X_{\min}$ = the minimum possible value, usually 0.

The 95th percentile (standard) value of the data distribution for each metric that increases with decreasing perturbation is used as the highest value possible. This is used as a quality control mechanism for reducing the influence that outlier and extreme values may have on the metric's data distribution (Tetra Tech, 2000).

Using this scoring method standardizes all the metrics to one scale giving each metric equal value. In some instances, using this equation may result in a value exceeding 100. When this happens, values greater than 100 should be scored no higher than 100. This is done to ensure equal weight for all metric values. No one metric can score higher than the maximum value of 100.

Reverse Metrics

Metrics which are expected to increase in value with increasing site perturbation (higher metric numbers represent worst sites) the 5th percentile value is used as the best score (100) when converting to a 100-point scale. Again, using the 5th percentile value instead of the minimum recorded value reduces the effect that outlier and extreme values may have on the data distribution. The minimum or 5th percentile (best) and maximum (worst) values for reverse metrics are converted to a 0 (worst) to 100 (best) point scales by using Equation 2.

(Equation 2) $$score = \left(\frac{X_{max} - X}{X_{max} - X_5} \right) \times 100$$

where, X = the metric value
X_5 = the 5th percentile value
X_{max} = the maximum possible value; 100% for percentage metrics such as % Oligochaeta and 10 for HBI (Tetra Tech, 2000).

The Hilsenhoff Biotic Index or HBI metric and the % Oligochaeta metric values were the remaining core metrics that have been termed reverse metrics, i.e. where the higher values indicate greater impairment (Table 7).

Index Development (IBI)

By converting all of the core metrics in Table 6 to a standard 100-point scale each metric contributes equally to the multi-metric index (0-100). A single multi-metric index was calculated by averaging the individual metric values for each site. Again, to ensure that each metric contributes equally to the final index, any individual metric scores exceeding the maximum 100 value were given a score of no more than 100.

Index Application (IBI)

There were no criteria or distinctions made between monitoring sites prior to index development due to the minimal number of monitoring sites. The final Index of Biotic Integrity (IBI) developed from this data is tentative and is based on reference site MCT-7 (Foot Creek). Both Moccasin Creek and Foot Creek originate in ecoregion level IV 46i Drift Plains and transition into the Glacial Lakes Basin ecoregion 46c. IBIs should only be used as a tool for ranking the monitoring sites within Moccasin Creek. As more data becomes available in these ecoregions (46 - Northern Glaciated Plains, 46c - Glacial Lakes Basin and 46i - Drift Plains) using similar collection methods, the IBI can be adjusted accordingly.

IBI values were ranked from lowest to highest for all five sites (Table 9). Based on this comparison, sites with lower IBI values were assumed to be more impaired than those with higher IBI values.

Table 9. Average metric values and Index of Biotic Integrity (IBI) scores by monitoring site for Moccasin Creek, Brown County, South Dakota.

Metric	MCT-2	Score	MCT-6	Score	MCT-3	Score	MCT-4	Score	MCT-7	Score
EPT Abundance	1.00	0.60	0.00	0.00	21.75	12.96	66.76	39.77	176.68	100.00
% Oligochaeta	50.27	49.74	32.73	67.28	16.03	83.99	12.83	87.19	4.12	95.90
% Scrapers	30.43	69.83	0.33	100.00	3.06	97.31	0.32	100.00	7.51	92.84
Species Richness	15.00	52.63	15.50	54.39	22.33	78.36	19.00	66.67	29.00	100.00
Hilsenhoff Biotic Index	9.04	9.97	8.96	10.81	8.69	13.52	8.61	14.42	6.74	33.70
IBI		**36.55**		**46.50**		**57.23**		**61.61**		**84.49**

To determine the cause for the changes in the IBI values at monitoring sites MCT-2, MCT-3, and MCT-4, seasonal loading of ammonia from the city of Aberdeen's wastewater treatment plant significantly impacted the macroinvertebrate community at site MCT-2, compared to the reference site (MCT-7) for species richness, EPT abundance, Percent Oligochaeta, and Hilsenhoff Biotic Index (HBI). EPT Abundance and HBI metrics are organic pollution sensitive metrics and would be affected by increased ammonia discharge from the wastewater treatment plant. This scenario was observed with increasing numbers of sensitive species and increased overall IBI values with increased distance downstream of the treatment plant (MCT-3 and MCT-4).

All Moccasin Creek monitoring sites with high HBI values and low species richness (diversity) are indicative of impacted urban streams. Overall, none of the Moccasin Creek sites compared to the reference site (MCT-7) with respect to the core metrics. Foot Creek metrics indicate it is a typical agricultural prairie stream with good diversity, moderate HBI values (agricultural impacts), lower numbers of oligochaets, and relatively good numbers of EPT taxa. This reach/section of Foot Creek should be protected, improved, or at least maintained in its present state with regards to agricultural impacts, habitat, and flow régime. Diversion of storm water runoff from half the city of Aberdeen to Foot Creek without retention structures may impact this community and over time reduce and then replace sensitive species with tolerant species, reduce diversity and increase HBI values which are more indicative of urban streams (Moccasin Creek).

Other Monitoring

Agricultural Non-Point Source Model (AGNPS)

Watershed Overview

Runoff, discharge from the city of Aberdeen's storm sewers and wastewater treatment plant, discharge from Foot Creek, and rainfall are the primary sources of water entering Moccasin Creek. The amount of ground water entering the Moccasin Creek is unknown at this time.

Subwatersheds

The Moccasin Creek drainage was divided into eight individual sub-watersheds; sub-watersheds MC-1, MC-2A, MC-2, MC-3, MC-4, MC-5, MC-6, and MC-7. Sub-watersheds MC-4, MC-5, and MC6 contribute 75% of the total sediment, hold all of the critical erosion cells, and comprise 61% of the total acreage of the total watershed. Suspected sources of erosion are areas with a slope greater than 2.5% in combination with low grade soils and poor vegetative cover. When a nutrient analysis was run with the AGNPS program on all eight sub-watersheds, the same three sub-watersheds (MC-4, MC-5, and MC-6) contributed 75% of the total nitrogen loading with 193,291 lbs and the most phosphorus loading.

The AGNPS model did not take into account loadings from the storm sewers or discharge from the treatment plant. The following is a discussion of the sources and loadings of each sub-watershed in the Moccasin Creek drainage from the AGNPS report:

MC-1

Sub-watershed MC-1 accounts for 4.16% of the Moccasin Creek watershed area with 108, 40-acre cells totaling 4,320 acres of drainage area. There were no critical cells for sediment loading. There were two critical cells for total nitrogen and two critical cells for total phosphorus in this area according to the AGNPS model. AGNPS estimated that subwatershed MC-1 contributed approximately 106 tons of sediment or .024477 ton/acre, 778 lbs. of phosphorus or 0.18 lb/acre, and 3,154 lbs. of nitrogen or 0.73 lb/acre on an annual basis to Moccasin Creek. Sub-watershed MC-1 contributes 2.14% of the total sediment load to Moccasin Creek, 2.23% of phosphorus, and 2.46% of the total nitrogen load.

MC-2A

Sub-watershed MC2A accounts for 13.14% of the Moccasin Creek watershed area with 346 cells totaling 13,840 acres of drainage area. There were no critical cells in this area for sediment loading. There were five critical cells for total nitrogen and five cells for total phosphorus according to the AGNPS model. Subwatershed MC-2A contributed approximately 466 tons of sediment or .033648 ton/acre, 2,491 lbs. of phosphorus or 0.180 lb/acre, and 10,518 lbs. of nitrogen or 0.76 lb/acre on an annual basis to Moccasin Creek. Sub-watershed MC-2A contributed 9.44% of the total sediment load to Moccasin Creek, 7.14% of phosphorus, and 8.08% of the total nitrogen load.

MC-2

Sub-watershed MC-2 accounts for 2.60% of the Moccasin Creek watershed area with 70 cells totaling 2,800 acres of drainage area. There were no critical cells for sediment, total nitrogen, or total phosphorus in this area according to the AGNPS model. Subwatershed MC-2 contributed approximately 128 tons of sediment or .045807 ton/acre, 308 lbs. of phosphorus or 0.110 lb/acre, and 1,092 lbs. of nitrogen or 0.39 lb/acre on an annual basis to Moccasin Creek. Sub-watershed MC-2 contributed 2.60% of the total sediment load to Moccasin Creek, 0.88% of phosphorus, and 0.82% of the total nitrogen load.

MC-3

Sub-watershed MC-3 accounts for 7.14% of the Moccasin Creek watershed area with 189 cells totaling 7,560 acres of drainage area. There were no critical cells in this area for sediment loading. There were two critical cells for total nitrogen and one cell for total phosphorus according to the AGNPS model. Subwatershed MC-3 contributed approximately 261 tons of sediment or .034525 ton/acre, 1,966 lbs. of phosphorus or 0.260 lb/acre, and 8,316 lbs. of nitrogen or 1.10 lb/acre on an annual basis to Moccasin Creek. Sub-watershed MC-3 contributed 5.29% of the total sediment load to Moccasin Creek, 5.63% of phosphorus, and 6.13% of the total nitrogen load.

MC-4

Sub-watershed MC-4 accounts for 11.90% of the Moccasin Creek watershed area with 315 cells totaling 12,600 acres of drainage area. There were three critical cells in this area for sediment loading, 21 for total nitrogen, and 17 for total phosphorus according to the AGNPS model. Subwatershed MC-4 contributed approximately 757 tons of sediment or .060056 ton/acre, 4,914 lbs. of phosphorus or 0.39 lb/acre, and 20,538 lbs. of nitrogen or 1.63 lb/acre on an annual basis to

Moccasin Creek. Sub-watershed MC4 contributed 15.34% of the total sediment load to Moccasin Creek, 14.08% of phosphorus, and 14.71% of the total nitrogen load.

MC-5

Sub-watershed MC-5 accounts for 16.40% of the Moccasin Creek watershed area with 433 cells totaling 17,320 acres of drainage area. There were 26 critical cells for erosion, three for total nitrogen, and seven for total phosphorus in this area according to the AGNPS model. Subwatershed MC-5 contributed approximately 986 tons of sediment or .056921 ton/acre, 5,889 lbs. of phosphorus or 0.340 lb/acre, and 23,902 lbs. of nitrogen or 1.38 lb/acre on an annual basis to Moccasin Creek. Sub-watershed MC-5 contributed 19.99% of the total sediment load to Moccasin Creek, 16.87% of phosphorus, and 17.36% of the total nitrogen load.

MC-6

Sub-watershed MC-6 accounts for 32.80% of the Moccasin Creek watershed area with 869 cells totaling 34,760 acres of drainage area. There were 65 critical cells for erosion, 18 for total nitrogen, and 15 for total phosphorus in this area according to the AGNPS model. Subwatershed MC-6 contributed approximately 1,639 tons of sediment or .04715 ton/acre, 10,776 lbs. of phosphorus or 0.31 lb/acre, and 43,102 lbs. of nitrogen or 1.24 lb/acre on an annual basis to Moccasin Creek. Sub-watershed MC-6 contributed 33.23% of the total sediment load to Moccasin Creek, 30.87% of phosphorus, and 32.07% of the total nitrogen load.

MC-7

Sub-watershed MC-7 accounts for 11.86% of the Moccasin Creek watershed area with 314 cells totaling 12,560 acres of drainage area. There were no critical cells for erosion, three for total nitrogen, and one for total phosphorus in this area according to the AGNPS model. Subwatershed MC-7 contributed approximately 590 tons of sediment or .046997 ton/acre, 7,787 lbs. of phosphorus or 0.62 lb/acre, and 36,926 lbs. of nitrogen or 2.94 lb/acre on an annual basis to Moccasin Creek. Sub-watershed MC-7 contributed 11.97% of the total sediment load to Moccasin Creek, 22.31% of phosphorus, and 18.37% of the total nitrogen load.

AGNPS is a data intensive watershed model that routes sediment and nutrients through a watershed by utilizing land uses and topography. The watershed is broken up into equally-sized portions, or cells of 40 acres. Each of these cells requires 26 parameters to be collected and entered into the program. Best Management Practices (BMPs) are then simulated by altering the land use in the individual cells.

The Moccasin Creek watershed was divided into 2,644 cells with a total of 105,760 acres. The watershed outlet drains into the James River approximately 13 miles southeast of Aberdeen. The dominant water flow within each 40-acre cell in the watershed was determined. Based upon the direction of water flow from each cell and natural drainage patterns within the watershed, eight sub-watersheds were delineated. Along with the direction of flow there were 26 watershed parameters collected and entered into the AGNPS model for each 40-acre cell. The AGNPS model then calculated the non-point source pollution loadings for each cell, sub-watershed and animal feeding area. The model also estimated hydrology run-off volume for each of the storm events modeled.

The model concluded that the implementation of the appropriate Best Management Practices be targeted to the critical cells and priority feeding areas. Animal feeding areas with an AGNPS rating of 50 or greater should be evaluated for potential operational or structural modifications in order to minimize future nutrient discharge. The model suggested that a reduction of 8% in phosphorus loadings and 6% in nitrogen loadings could be realized if the following feedlots were modified to include run-off containment systems and buffer zones: cell #13 and #20 at site MC-2A, cell # 4, #265, #311, #315A and #315B at site MC-4, cell #138, #244, #286A, #286B, #290 and #421 at site MC-5, cell #123, #179 at site MC-6, and cell #300 at MC-7.

The tillage practices on critical cells having high c-factors, poor grade soils and 3% slope or greater may also be modified to use conservation tillage practices. These practices might include strip cropping, limited-till and no-till. When the c-factors on 94 cells in the watershed were changed (representing no-till) the model showed a reduction potential of 7.5% for sediment loading.

The reduction in sediment and nutrients could be less or more depending on crop producer participation and modification costs. It is highly recommended that all critical cells and animal feeding areas be field verified in advance of implementing Best Management Practices.

Potential contributions of sediment from gullies, riparian areas, wind erosion and nutrients from septic systems within the Moccasin Creek watershed were not evaluated as part of the computer modeling assessment phase. The complete AGNPS analysis can be found in Appendix A of this report.

Quality Assurance Reporting (QA/QC)

Replicate and blank samples were collected during the course of the project to provide defendable proof that sample data were collected in a scientific and reproducible manner. QA/QC data collection began, and was completed, on schedule with the proposed timeline. A total of 112 samples were taken in 1999 and 140 samples were collected in 2000. A total of 22 duplicates and 20 blanks were analyzed on 229 samples collected throughout the project. QA/QC data collection began in March of 1999 and was completed in November of 2000.

Blank samples were very 'clean' with the exception of total solids concentrations. Six of the twenty blank samples collected had detectable concentrations of total solids, while the remaining samples had undetectable levels. It is unclear why these samples were contaminated, some possible causes could be improperly cleaned bottles, contamination in the field, or a contaminated distilled water supply. Approximately 30% of the total solids samples showed more than the 7 mg/l detection limit. Total solids ranged from 4 mg/l to 17 mg/l in all samples analyzed. Reasons for increased solids in the samples could have been from un-rinsed sample bottles or sample contamination. Regardless of the reason for the contamination, it is unlikely that contamination occurring at the concentrations detected in the blanks would greatly alter the results. The highest level measured in a blank was 17 mg/L collected on October 27, 2000.

Quality assurance and quality control samples were collected for 17.47% of the in-stream and tributary samples taken. A total of 229 tributary samples were collected along with seven sets of replicates and blanks.

Table 10. Moccasin Creek QA/QC Blank Samples

Moccasin Creek Blank Samples

DATE	ALK	TOTAL SOLIDS	SUSPENDED SOLIDS	AMMONIA	NITRATE	TKN	TOT PHOS	DIS PHOS	FECAL
Detection Limit	**7 or 6**	**7 or less**	**1**	**0.02**	**0.1**	**0.14 or 0.21**	**0.002**	**0.002**	**10 or 2**
3/29/1999	7	5	1	0.02	0.1	0.1	**0.007**	**0.007**	10
6/30/1999	7	**12**	1	0.02	0.1	0.14	0.002	0.002	10
7/20/1999	7	6	1	0.02	0.1	0.14	0.002	**0.003**	10
7/28/1999	7	5	1	0.02	0.1	0.14	**0.004**	**0.004**	10
8/5/1999	7	**8**	**2**	0.02	0.1	0.14	**0.004**	**0.005**	10
8/30/1999	7	4	**2**	0.02	0.1	0.14	0.002	0.002	10
11/3/1999	7	5	1	0.02	0.1	0.14	0.002	0.002	10
3/23/2000	6	**11**	1	0.02	0.1	0.21	0.002	0.002	10
5/9/2000	6	**9**	1	0.02	0.1	0.21	0.002	0.002	10
5/18/2000	6	7	1	0.02	0.1	0.21	0.002	0.002	10
6/5/2000	6	7	1	0.02	0.1	0.21	**0.004**	**0.005**	10
7/12/2000	6	**8**	1	0.02	0.1	0.21	0.002	0.002	10
8/2/2000	6	7	1	0.02	0.1	0.21	0.002	0.002	10
8/24/2000	6	7	**3**	0.02	0.1	0.21	0.002	**0.008**	10
8/31/2000	6	7	1	0.02	0.1	0.21	0.002	0.002	10
10/4/2000	6	7	1	0.02	0.1	0.21	0.002	0.002	2
10/26/2000	6	4	1	0.02	0.1	0.21	0.002	0.002	10
10/27/2000	6	**17**	1	0.02	0.1	0.21	0.002	0.002	
10/30/2000									10
11/2/2000	6	**11**	1	0.02	0.1	0.21	0.002	0.002	10

Table 11. Moccasin Creek Blank Samples Exceeding Detection Limits

Moccasin Creek Blanks Exceeding Standards

SITE	TIME	DATE	TSOL	Detection Limit
MC8	1630	6/30/1999	12	7 mg/l
MC8	1000	3/23/2000	11	7 mg/l
MC8	1530	5/9/2000	9	7 mg/l
MC8	1100	7/12/2000	8	7 mg/l
MC8	1430	10/27/2000	17	7 mg/l
MC8	1145	11/2/2000	11	7 mg/l

Replicate samples were collected to check sample techniques and variability within the parameters analyzed. The following table (Table 12) shows laboratory results of replicate samples (MC-9) taken from Moccasin Creek in 1999 and 2000. The chart illustrates a comparison of the duplicate (MC-9) sample with the site sample followed by the Industrial Average (IND) percent margin of error between the samples collected.

Table 12. Duplicate Sample and Replicate Sample Comparisons

Quality Assurance/Quality Control Samples Collected in Moccasin Creek Showing Industrial Statistic

SITE	DATE	pH	H20TMP	DO	ALK-M	TSOL	SSOL	AMMO	NITRATE	TKN	TOT(P)	DIS(P)	FEC	VTSS	TDS
MC9	4/14/1999	8.92	11.7	11.9	254	1640	44	0.02	0.1	2.17	0.274	0.114	10	22	1596
MC6	4/14/1999	8.95	12.1	12.1	262	1651	48	0.02	0.1	1.79	0.282	0.111	10	24	1603
IND		0.17%	1.68%	0.83%	1.55%	0.33%	4.35%	0.00%	0.00%	9.60%	1.44%	1.33%	0.00%	4.35%	0.22%
MC9	5/26/1999	8.07	20.5	7.1	262	1374	22	0.02	0.1	2.59	0.488	0.336	10	7	1352
MC6	5/26/1999	8.08	20.5	7.1	260	1380	22	0.02	0.1	2.46	0.482	0.352	20	7	1358
IND		0.06%	0.00%	0.00%	0.38%	0.22%	0.00%	0.00%	0.00%	2.57%	0.62%	2.33%	**33.33%**	0.00%	0.22%
MC9	6/7/1999	7.69	20.5	2	324	1578	1	0.02	0.1	1.86	0.343	0.331	280	1	1577
MC1	6/7/1999	7.67	20.5	1.8	326	1578	1	0.02	0.1	1.81	0.356	0.329	190	1	1577
IND		0.13%	0.00%	5.26%	0.31%	0.00%	0.00%	0.00%	0.00%	1.36%	1.86%	0.30%	**19.15%**	0.00%	0.00%
MC9	6/30/1999	7.54	19.2	4.8	151	1051	32	1.77	0.2	3.32	0.492	0.378	2400	16	1019
MC2	6/30/1999	7.59	19.1	4.7	154	1077	29	2.06	0.2	3.76	0.569	0.413	2000	6	1048
IND		0.33%	0.26%	1.05%	0.98%	1.22%	4.92%	7.57%	0.00%	6.21%	7.26%	4.42%	9.09%	**45.45%**	1.40%
MC9	7/8/1999	8.78	25.7	15	297	1897	108	0.02	0.1	3.09	1.09	0.435	700	48	1789
MC3	7/8/1999	8.71	25.5	15	290	1879	102	0.02	0.5	3.82	1.15	0.432	1800	44	1777
IND		0.40%	0.39%	0.00%	1.19%	0.48%	2.86%	0.00%	66.67%	10.56%	2.68%	0.35%	**44.00%**	4.35%	0.34%
MC9	7/28/1999	7.73	25.2	0.2	406	1536	2	0.02	0.1	2.5	0.912	0.885	710	2	1534
MC1	7/28/1999	7.73	25	0.1	406	1542	1	0.02	0.1	2.51	0.948	0.886	720	1	1541
IND		0.00%	0.40%	**33.33%**	0.00%	0.19%	**33.33%**	0.00%	0.00%	0.20%	1.94%	0.06%	0.70%	**33.33%**	0.23%
MC9	8/5/1999	8.2	26.5	7.7	174	1306	86	0.02	0.1	2.75	0.637	0.141	270	34	1220
MC4	8/5/1999	8.18	26.4	7.8	177	1318	90	0.02	0.1	3.1	0.648	0.144	220	36	1228
IND		0.12%	0.19%	0.65%	0.85%	0.46%	2.27%	0.00%	0.00%	5.98%	0.86%	1.05%	10.20%	2.86%	0.33%
MC9	10/12/1999	8.98	14	15	259	1322	72	0.02	0.1	3.11	0.307	0.368	50	22	1250
MC5	10/12/1999		14	15	262	1323	98	0.02	0.1	2.74	0.292	0.036	110	34	1225
IND		100.00%	0.00%	0.00%	0.58%	0.04%	**15.29%**	0.00%	0.00%	6.32%	2.50%	**82.18%**	**37.50%**	**21.43%**	1.01%
MC9	11/2/1999	7.94	11.8	9.1	333	2276	19	12.8	0.1	16.7	1.88	0.664	66000	10	2257
MC2	11/2/1999	7.95	11.9	9.2	323	2263	18	12.6	0.1	16.1	1.93	1.73	35000	10	2245
IND		0.06%	0.42%	0.55%	1.52%	0.29%	2.70%	0.79%	0.00%	1.83%	1.31%	**44.53%**	**30.69%**	0.00%	0.27%
MC9	11/3/1999	9.35	6	15	201	1385	92	0.02	0.1	4.27	0.469	0.031	10	38	1293
MC5	11/3/1999	9.36	6.1	15	212	1386	100	0.02	0.1	4.5	0.506	0.035	10	**42**	1286
IND		0.05%	0.83%	0.00%	2.66%	0.04%	4.17%	0.00%	0.00%	2.62%	3.79%	6.06%	0.00%	5.00%	0.27%

(cont.)

SITE	DATE	pH	H20TMP	DO	ALK-M	TSOL	SSOL	AMMO	NITRATE	TKN	TOT(P)	DIS(P)	FEC	VTSS	TDS
MC9	3/23/2000	9.29	9.8	15	177	1249	56	0.6	0.3	2.79	0.367	0.077	10	22	1193
MC5	3/23/2000	9.27	9.9	15	198	1242	62	0.58	0.3	3.31	0.384	0.062	10	22	1180
IND		0.11%	0.51%	0.00%	5.60%	0.28%	5.08%	1.69%	0.00%	8.52%	2.26%	10.79%	0.00%	0.00%	0.55%
MC9	5/23/2000	8.57	24.6	12.5	307	2244	176	0.02	0.1	2.06	0.885	0.12	300	40	2068
MC6	5/23/2000	8.55	24.5	12.4	309	2240	168	0.02	0.1	1.94	0.898	0.126	130	36	2072
IND		0.12%	0.20%	0.40%	0.32%	0.09%	2.33%	0.00%	0.00%	3.00%	0.73%	2.44%	**39.53%**	5.26%	0.10%
MC9	6/5/2000	8.85	21.3	15	260	2445	144	0.02	0.1	2.99	1.02	0.056	60	48	2301
MC5	6/5/2000	8.86	21.2	15	260	2452	172	0.02	0.1	2.5	0.98	0.071	140	60	2280
IND		0.06%	0.24%	0.00%	0.00%	0.14%	8.86%	0.00%	0.00%	8.93%	2.00%	11.81%	**40.00%**	11.11%	0.46%
MC9	7/12/2000	7.45	22.5	3.3	101	684	26	0.2	0.3	1.5	0.362	0.257	14000	6	658
MC2A	7/12/2000	7.45	22.5	3.2	92	643	25	0.02	0.3	1.28	0.346	0.274	13000	4	618
IND		0.00%	0.00%	1.54%	4.66%	3.09%	1.96%	**81.82%**	0.00%	7.91%	2.26%	3.20%	3.70%	**20.00%**	3.13%
MC9	8/2/2000	5.3	22.2	7.72	284	2302	21	10.4	0.1	11.6	1.56	1.34	120	8	2281
MC2	8/2/2000	7.71	22.1	5.4	285	2307	21	10.4	0.1	11.2	1.56	1.25	190	8	2286
IND		18.52%	0.23%	17.68%	0.18%	0.11%	0.00%	0.00%	0.00%	1.75%	0.00%	3.47%	**22.58%**	0.00%	0.11%
MC9	8/24/2000	8.69	23.1	7.4	308	1966	72	0.02	0.1	2.89	0.9	0.384	80	36	1894
MC5	8/24/2000	8.74	23.4	7.7	306	1980	84	0.02	0.1	3.45	0.968	0.407	110	38	1896
IND		0.29%	0.65%	1.99%	0.33%	0.35%	7.69%	0.00%	0.00%	8.83%	3.64%	2.91%	**15.79%**	2.70%	0.05%
MC9	8/31/2000	8.01	21.6	7.8	101	1033	68	2.54	0.1	5.9	0.886	0.479	17000	28	965
MC2	8/31/2000	7.84	20.9	7.9	127	1032	62	2.49	0.2	5.24	0.884	0.456	19000	14	970
IND		1.07%	1.65%	0.64%	11.40%	0.05%	4.62%	0.99%	**33.33%**	5.92%	0.11%	2.46%	5.56%	**33.33%**	0.26%
MC9	10/4/2000	8.93	10.6	8.6	259	2617	24	0.02	0.1	1.99	0.394	0.041	310	6	2593
MC5	10/4/2000	8.94	10.5	8.7	259	2624	30	0.02	0.1	2.14	0.458	0.144	240	16	2594
IND		0.06%	0.47%	0.58%	0.00%	0.13%	11.11%	0.00%	0.00%	3.63%	7.51%	**55.68%**	12.73%	**45.45%**	0.02%
MC9	10/26/2000	7.79		7.8	62	495	108	1.11	0.3	1.48	0.564	0.281	65000	14	387
MC2	10/26/2000	7.8	13.9	7.9	65	538	114	1.8	0.3	2.43	0.643	0.364	58000	6	424
IND		0.06%		0.64%	2.36%	4.16%	2.70%	**23.71%**	0.00%	**24.30%**	6.55%	12.87%	5.69%	**40.00%**	4.56%
MC9	10/27/2000	8.5	11	9	208	1922	50	0.02	0.1	2.39	0.488	0.118		18	1872
MC5	10/27/2000	8.52	11.1	9.3	207	1930	54	0.02	0.1	2.06	0.483	0.124		20	1876
IND		0.12%	0.45%	1.64%	0.24%	0.21%	3.85%	0.00%	0.00%	7.42%	0.51%	2.48%		5.26%	0.11%
MC9	10/30/2000	8.53	12.5	11.1									2500		
MC5	10/30/2000	8.54	12.6	11.2									2400		
IND		0.06%	0.40%	0.45%									2.04%		
MC9	11/2/2000	9.15	8	11.6	192	1954	184	0.02	0.1	3.06	0.91	0.104	1200	56	1770
MC5	11/2/2000	9.15	8	11.6	195	1961	172	0.02	0.1	2.87	0.872	0.104	800	44	1789
IND		0.00%	0.00%	0.00%	0.78%	0.18%	3.37%	0.00%	0.00%	3.20%	2.13%	0.00%	**20.00%**	12.00%	0.53%

Total Solids: Replicate samples taken for total solids do not indicate any significant problems when comparing numbers from the replicate sample and comparing them with the actual sample.

Total Suspended Solids: On July 28, 1999 there was a 33.33% margin of error between the replicate sample and the actual sample taken from site MC-1. On October 12, 1999 there was a 15.29% margin of error between the replicate sample and the actual sample taken from site MC-5. It is believed that natural variation was the cause for the differences in both of the samples.

Volatile Total Suspended Solids: There were six replicate samples of 21 total replicate samples that had a margin of error over 20%. These differences are probably due to natural variation.

Ammonia: There were some differences between replicate samples and the actual samples when looking at ammonia. On July 12, 2000, there was an 81% margin of error at site MC-2A and on October 26, 2000 there was a 23% margin of error between the sample and the replicate at site MC-2. These errors could have been derived from contaminated sample or natural variability. The remainder of the samples and replicates collected throughout the sampling period show a very minimal margin of error between the sample and the replicate (<1%).

Alkalinity: Replicate samples taken for alkalinity do not indicate any significant problems when comparing number from the replicate sample and comparing them with the actual samples. There is some variation, probably natural variation, in the samples taken on August 31, 2000 at site MC-2 but not enough difference to be concerned about.

Nitrates: Of all the nitrate samples taken throughout the sampling period for the Moccasin Creek project, only two replicates did not match the same numbers as the original sample. On July 8, 1999, there was a 66% margin of error between the original sample and the replicate sample taken at site MC-3. On August 31, 2000, there was a 33% margin of error between the original sample and the replicate sample taken at site MC-2. Because other samples taken the same day do not show variation between actual sample and replicate, it is believed the problem probably did not come from contaminated distilled water, but rather natural sample variation or a poorly rinsed sample bottle. All other samples collected throughout the year show no difference (0%) when comparing samples and replicates for nitrates.

TKN: There were no major differences between replicates and regular samples collected other than natural sample variability.

Total Phosphorus: All QA/QC samples collected for total phosphorus showed no difference between the actual sample taken and the replicate sample.

Total Dissolved Phosphorus: Of all the dissolved phosphorus samples taken throughout the sampling period for the Moccasin Creek project, there were two samples with differences between the original sample and the replicate sample. On November 2, 1999 there was a 44.53% margin of error and on October 4, 2000 at site MC-5 there was a 55.68% margin of error between the original sample and the replicate sample. These differences between the actual samples and the replicate samples could be due to a poorly rinsed sample bottle, poorly rinsed filter, or natural variability.

Cross Sectional Data

DENR staff surveyed cross sections on Moccasin Creek in May and June of 2002 to get a better understanding of the slope and drop of the creek channel. A total of 32 cross sections were taken along Moccasin Creek from the northern edge of the city of Aberdeen down to the city of Aberdeen's wastewater treatment plant. The data was collected and forwarded to Interfluve, Inc. to be used to complete the Moccasin Creek feasibility study. Figure 24 on the next page shows where each cross section was measured.

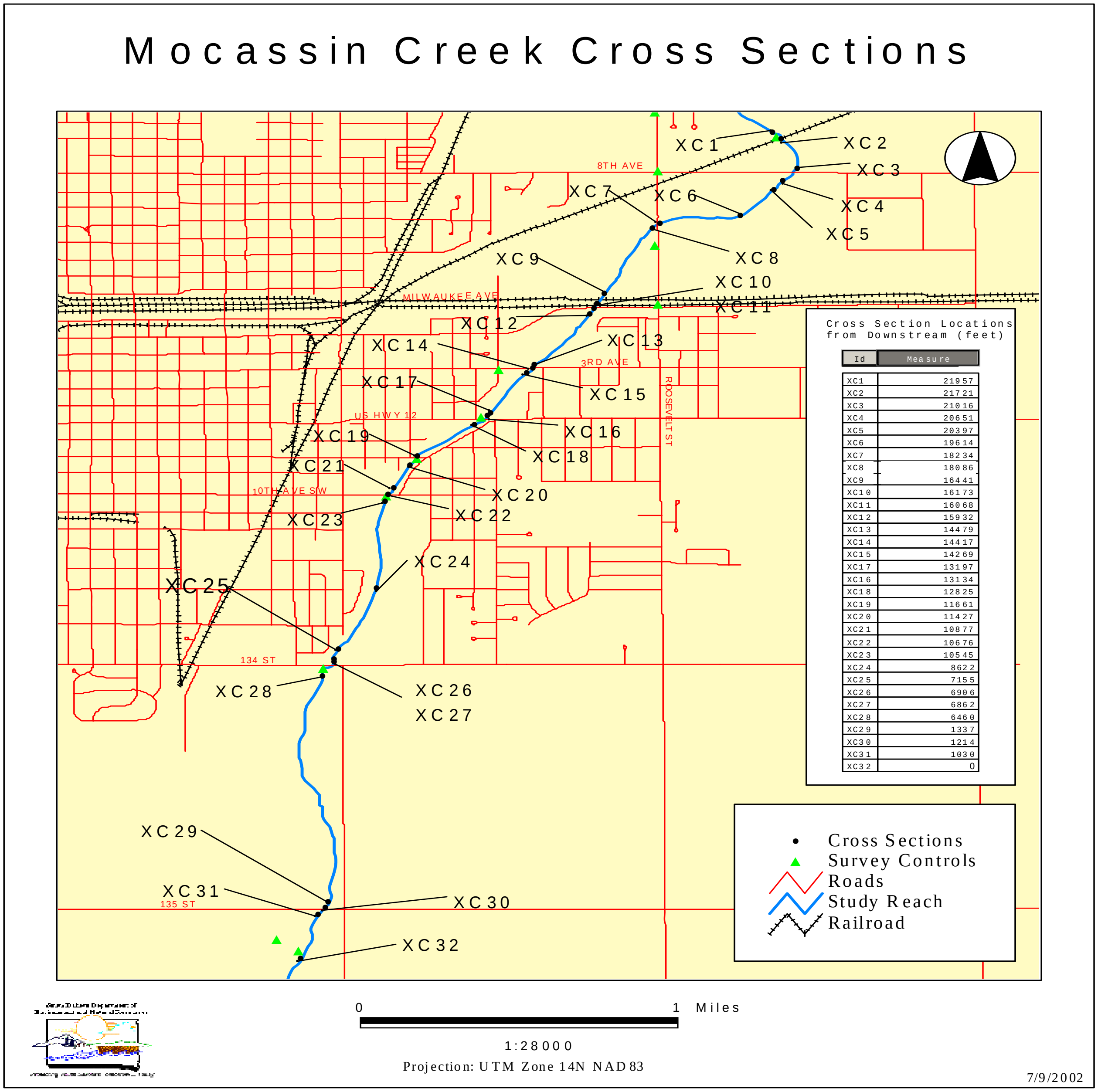


Figure 24. Moccasin Creek Cross Section Locations

Sediment Particulate Size Analysis

Sediment samples were collected in February 2002 by DENR staff to determine the particulate size of sediment residing in the Moccasin Creek channel.

Sample #1 was taken upstream of Roosevelt Avenue. At the time of sampling, it was noted that there was approximately four feet of sediment present in the stream channel.

Sample #2 was taken 100 yards downstream of Milwaukee Avenue. At the time of sampling, it was noted that there was approximately five feet or more of sediment present in the stream channel.

Sample #3 was taken between 6th Avenue and 8th Avenue, 100 feet upstream of Aldrich Street. At the time of sampling, it was noted that there was approximately five of sediment present in the stream channel.

Sample #4 was taken 75 feet upstream of the 10th Avenue car bridge. Sediment was collected from the gravel bar in front of a storm sewer outlet. Little to no sediment was located at the sampling location.

Sample #5 was taken between Melgaard Road and 10th Avenue just off from the soccer field by the bathroom. At the time of sampling, it was noted that there was approximately three feet of sediment present in the stream channel.

Sample #6 was taken south of the city of Warner, SD by site MC4. The sample was collected 40 yards upstream of the car bridge. At the time of sampling, it was noted that there was approximately five feet or more of sediment present in the stream channel.

Of all the samples analyzed, results showed that the majority of the material present in Moccasin Creek is fine silt. The sample collected at site 4 had the most sand of any sample collected. There was 9.3% coarse sand and 20.2% fine sand in that sample. Site 6 retained the most silt and clay with 48.1% silt and 46.8% clay.

Table 13 describes the material present at each site sampled and what percent of the material passed through different-sized screens.

Table 13. Sediment size for Moccasin Creek, Brown County, South Dakota

South Dakota Department of Transportation
Geotechnical -Soils Central Laboratory
700 E. Broadway Pierre S.Dak. 57501

Tests run according to SD101,SD102,SD207&SD103

Reported to **:** Barry McLaury
Reported By**:** Gary Olivier

PROJECT **:**

PCEMS**:**

Date**:** 2/15/2002
Updated 2/4/04

Submitted by **:** Sol Brich

COUNTY**:** Brown

Description**:**

LAB. SAMPLE #	1	2	3	4	5	6	
PIT #	0	0	0	0	0	0	
HOLE#	0	0	0	0	0	0	
FIELD SAMPLE #	1	0	0	0	0	0	
DEPTH	0	0	0	0	0	0	
wt. cu. ft.	0	0	0	0	0	0	
% passing 3/8	100.0	100.0	100.0	100.0	100.0	100.0	
% passing # 4	99.9	100.0	100.0	100.0	100.0	100.0	
% passing # 10	99.9	100.0	100.0	100.0	100.0	100.0	
% coarse sand	9.2	0.7	5.7	9.3	5.1	0.7	
% fine sand	7.9	4.4	3.0	20.2	4.4	4.4	
% silt	47.7	47.7	72.5	33.7	47.7	48.1	
% clay	35.2	47.2	18.8	36.8	42.8	46.8	
% passing # 40	90.7	99.3	94.3	90.7	94.9	99.3	
% passing # 200	82.9	94.9	91.3	70.5	90.5	94.9	
% coarse & fine sand	17.0	5.1	8.7	29.5	9.5	5.1	
liquid limit	0	0	0	0	0	0	
liquid plastic limit	0	0	0	0	0	24	
P. I.	0	0	0	0	0	0	
Tex. classification	SILT CLAY	SILT CLAY	SANDY SILT	SILT CLAY	SILT CLAY	SILT CLAY	
Texture #	2	2	7	2	2	2	
HRB	A-4	A-4	A-4	A-4	A-4	A-4	
GP Index	8	8	8	7	8	8	

Soil Legend

1 - clay silt	4-sand clay	7 - sand silt	10 - gravel	13 - gravel clay
2 - silty clay	5-clay sand	8 - sand	11 - gravel clay silt	14 - gravel sand c
3 - clay	6 - silt sand	9 - silt	12 - gravel silt clay	15 - gravel clay sa

Elutriate Sampling

As part of the Moccasin Creek stream channel analysis, elutriate samples were taken from several locations along Moccasin Creek. The samples were collected by DENR staff and forwarded to the South Dakota State Health Laboratory for analysis. It was noted by field staff that there was an oily substance that floated on the water surface when mud was extracted from the bottom at the 6th Avenue sampling location adjacent to the railroad bridge. The State Health Lab detected two compounds with the EPA E8270C testing method. They were 2-methylnapthalene and acenaphthene. Testing for creosol and BTEX was non-detect. Total purgeable hydrocarbon was 135 ug/L but they did not list specific compounds. Receiving water had no compound detected by EPA 8270C testing, TPH testing, BTEX testing or creosol testing.

It was never determined exactly what the oily substance was but it was noted that chemicals found in laboratory tests were the same chemical make-up of Creosote. This same oily substance was found along 3rd Avenue SE in 1980 when city workers were performing underground work. It was reported that the material looked and smelled like creosote. At that time, the city wastewater treatment plant was experiencing occasional slowdowns of its biological treatment systems. The city then installed three, 25 to 30-foot monitoring wells at the site. The creosote like material was encountered within 30 feet of the surface during drilling of one of the three wells. A black liquid was bailed from the well during evacuation procedures.

The source of the creosote type material is believed to have come from an abandoned creosote pit owned by the Chicago and Northwestern Railway (now Dakota, Minnesota, and Eastern Railway) back in the early 1900s. The pit was used to dip railroad ties to help protect the wood from the elements.

An ongoing investigation by the Environmental Protection Agency (EPA), Region VIII, is still in progress on Moccasin Creek to determine what the material is and where it is coming from. No remediation practices have been enacted to remove the creosote-type material.

Public involvement and coordination

State Agencies

The South Dakota Department of Environment and Natural Resources (SDDENR) was the primary state agency involved in the completion of this assessment. SDDENR provided equipment as well as technical assistance throughout the course of the Moccasin Creek project.

The South Dakota Department of Game, Fish and Parks also aided in the completion of the assessment by providing endangered species information in the Moccasin Creek area.

Federal Agencies

The Environmental Protection Agency (EPA) provided the primary source of funds for the completion of the watershed assessment on Moccasin Creek.

The Natural Resource Conservation Service (NRCS) provided technical assistance, particularly in the collection of soils data for the AGNPS portion of the report.

Local Governments; Industry, Environmental, and other Groups; and Public at Large

The South Brown Conservation District (SBCD) provided the local sponsorship that made this project possible. In addition to providing administrative sponsorship, SBCD also provided local matching funds, personnel, and work space to complete the Moccasin Creek assessment.

Public involvement consisted of individual meetings with landowners who provided a great deal of historic perspective on the watershed. Additionally, landowners were contacted through mailings to which most responded with information needed to complete the AGNPS model.

The city of Aberdeen provided financial aid, flow data from storm sewers, flow data from the wastewater treatment plant, and the history of Moccasin Creek.

Aspects of the Project That Did Not Work Well

Stevens-type stage recorders were left sitting dry at some sites when water levels were low. The stage recorders had to be moved and reinstalled in a deeper section of the creek several times in order to allow for continuous stage monitoring. Isco 6700 samplers often plugged up with fine sediment which did not allow samples to be taken automatically at given times.

Initial milestones were not met due to changes and additions to the work plan. Elutriate, *E. coli*, and fecal bacteria tracking were all added to the project work load. In addition, a consultant was hired on contract (Interfluve, Inc) to perform a feasibility study on Moccasin Creek. Detailed cross sections of the creek channel were needed to complete the feasibility study as well as sediment samples.

Low flows in Moccasin Creek caused sites to be moved which led to data that was hard to compare. Stage readings were not uniform due to the changes in elevation of the recorders each time they were moved. Stage data was then hard to work with when trying to determine the flows on Moccasin Creek.

The outlet of Moccasin Creek is located 13 miles southeast of Aberdeen. Sites MC-5 and MC-6 stage data were directly affected by backflows from the James River during high flow events. During backflow situations, stage data showed a high amount of water running down Moccasin Creek which was actually caused by a rise in elevation from backflow from the James River. Sites above MC-4 were not affected as the backflow from the James River never reached that far upstream.

Due to the extremely flat topography of the Moccasin Creek watershed, it was extremely difficult to determine the routing of water within each 40-acre cell in the watershed. Directional flow of water is needed to run the AGNPS watershed model.

Stages and velocities were measured in storm sewers. Unfortunately, not enough data was gathered to come up with a reasonable figure as to how much water was being discharged from the storm sewers into Moccasin Creek.

Future Activities Recommendations

There are a number of concerns that need to be addressed in the Moccasin Creek watershed. Mitigation processes in the watershed should take into consideration the following items:

Animal feeding operations appear to have a major impact on the nutrient load and fecal bacteria concentrations in Moccasin Creek. Containment of run-off from animal feeding operations will prove beneficial in reducing fecals and nutrients from entering Moccasin Creek. The most beneficial practices include run-off containment from feedlots and alternative water sources for livestock;

Areas in the watershed where slopes are greater than 2.5% in combination with low grade soils should be planted to grass or kept covered with crop residue;

Fencing along Moccasin Creek to keep livestock off the banks of the creek or proper grazing management would prove beneficial in reestablishing a healthy riparian area;

Future activities in the watershed should be directed towards the maintenance of the current conservation practices;

Nutrient reductions in the creek itself may offer accelerated improvements in water quality. This is most likely the quickest and most cost-effective means of dealing with algae blooms that occur in Moccasin Creek;

Narrowing up the channel and providing a meander in the existing channel may better help move sediment through the system;

Keeping the creek clean from garbage and debris would help keep base flows moving through the creek during low flows;

Removal or proper sizing of downstream creek crossings would help increase flow through the system and prevent water from ponding and becoming stagnant;

Installation of a bigger culvert(s) under the crossing at the wastewater treatment plant would also help increase flow and prevent ponding or backing up of water in Moccasin Creek;

Additional fecal coliform sampling will be required before a fecal coliform TMDL can be written, if needed;

Elutriate samples collected from Moccasin Creek near 6th Avenue detected a petroleum-based type material (creosote?) present in the sediment. EPA Region VII is currently investigating the source of the material and its location. The material, if possible, should be removed to avoid further contamination to Moccasin Creek; and

The city of Aberdeen plans to upgrade its wastewater treatment facility for treatment of ammonia in order to meet state standards for a marginal warm water fishery.

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Appendix A. AGNPS Data

REPORT ON THE
AGRICULTURAL NONPOINT SOURCE (AGNPS) ANALYSIS
OF THE MOCCASIN CREEK WATERSHED
BROWN COUNTY, SOUTH DAKOTA
SOUTH DAKOTA WATER RESOURCES ASSISTANCE PROGRAM

DIVISION OF FINANCIAL & TECHNICAL ASSISTANCE
SOUTH DAKOTA DEPARTMENT OF
ENVIRONMENT AND NATURAL RESOURCES

NOVEMBER 2001

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Executive Summary

The Moccasin Creek watershed is located in the southern half of Brown County. The size of the Moccasin Creek watershed area modeled is 191,503 acres. The watershed outlet drains into the James River approximately 13 miles southeast of Aberdeen.

In order to further evaluate the water quality status of the Moccasin Creek watershed, land use and geotechnical information was compiled. This information was then incorporated into a computer model. The primary objective of utilizing a computer model on Moccasin Creek watershed was to:

1) Evaluate and quantify Nonpoint Source (NPS) yields from each sub-watershed and determine the net loading to the James River.
2) Define critical NPS cells within each sub-watershed (elevated sediment, nitrogen and phosphorus).
3) Prioritize and rank each animal feeding area and quantify the nutrient loadings from each area.

Based on the results of the computer model, the following conclusions were formulated:

1. Watershed / Sub-watershed Analysis

Sediment

The AGNPS data indicated that the Moccasin Creek watershed had a low sediment deliverability rate at the outlet of Moccasin Creek. The computer model estimated the sediment deliverability rate to be .043 (tons/acre/year). At this rate Moccasin Creek delivers approximately 4,534 tons of sediment to the James River as a result of an average year of rainfall.

When a sediment analysis was performed on the sub-watersheds located with Moccasin Creek watershed, the model indicated that three of the eight delineated sub-watersheds appeared to have high sediment deliverability rates. The following table shows the values that apply:

Critical Sediment Sub-watersheds

Sub-Watershed	Outlet Cell #	Annual Sediment Yield (tons/acre)
MC4	280	0.06
MC5	53	0.06
MC6	869	0.05

These three sub-watersheds contribute 75% of the total sediment, hold all of the critical erosion cells, but contain only 61% of the total acreage of the watershed. The suspected sources of erosion are areas with slope greater than 2.5% in combination with low grade soils, and are currently in crop production or have poor vegetative cover.

Nutrients

The results from the AGNPS model revealed that Moccasin Creek watershed has a total nitrogen deliverability rate of 2.46 lb/acre. This number is considered to be average when compared to other watersheds in the area. The total phosphorus deliverability rate was considered to be lower than average, at 0.58 lbs/acre. When compared to other area watersheds, the nitrogen and phosphorus loading totals were calculated by combining the soluble and sediment bound loadings of each parameter. These estimated loadings are based on an average year of rainfall, as were the sediment numbers.

When a nutrient analysis was performed on the sub-watersheds located with Moccasin Creek watershed, the model indicated that three of the eight delineated sub-watersheds appeared to have comparably high nutrient deliverability rates. The following tables show the values that apply:

Critical Phosphorus Sub-watersheds | Critical Nitrogen Sub-watersheds

Sub-Watershed	Outlet Cell #	Annual Total Phosphorus (lbs/acre)	Sub-Watershed	Outlet Cell #	Annual Total Nitrogen (lbs/acre)
MC4	280	0.82	MC4	280	3.52
MC5	53	0.71	MC5	53	3.02
MC6	869	0.66	MC6	869	2.78

According to the model these three sub-watersheds listed above contribute 45,571 lbs. of phosphorus to the watershed each year. These sub-watersheds account for 75% of the total nitrogen loading, but retain only 61% of the total acreage of the entire watershed.

When the nitrogen analysis for each sub-watershed was done, it revealed that the same three sub-watersheds were responsible for elevated loadings of nitrogen. While only accounting for 61% of the total watershed, these three sub-watersheds contributed 74% of the total nitrogen loading with 193,291 lbs.

The AGNPS model indicated that a possible source of elevated nutrient loadings is due to the presence of animal feeding areas with an AGNPS feedlot rating of 50 or greater, which are located near water channels. Other possible sources are certain land use situations in combination with high fertilization levels.

2. <u>Critical NPS Cells</u>

Sediment

Analysis of the AGNPS data for each individual forty-acre cell in the Moccasin Creek watershed revealed that of 2,644 cells, 94 cells had erosion rates of greater than 2 tons/acre (25year event). These 94 cells represent only 4% of the entire Moccasin Creek watershed. The suspected sources of elevated erosion rates were land slopes greater than 2% in combination with poor grade soils and croplands accompanied by high c-factors. The high c-factors can be a product of limited or non-existent conservation tillage practices. The AGNPS model was run after changing all 94 cells to represent a no-till practice. These 94 cells amount to 3,760 acres of cropland. The model showed a potential for a 7.5% reduction in sediment delivered to the James River each year.

Nutrients

The analysis of the AGNPS critical cell data concerning nutrient yields (sediment bound + water-soluble) indicated that of the 2,644 cells located in the entire watershed, 37 had nitrogen yields greater than 8.3 lbs/acre and 48 had phosphorus yields greater than 2.3 lb/acre. This represents less than 2% of the total drainage area in the watershed. The suspected sources of elevated nutrient loads to the Moccasin Creek watershed were animal feeding areas located near water channels and the application of unincorporated fertilizers on croplands.

3. Feeding Area Evaluation

The analysis of the feeding areas within Moccasin Creek watershed revealed that of 76 feedlots, 8 had a rating between 50 and 60 and 8 more had a rating greater than 60. These ratings were determined by running the model with a 25-year storm event.

In order to evaluate the impact that these 16 feeding areas may have on the nutrient loading of the watershed, the model was run without these feeding areas present. The total phosphorus loading was reduced from 61,112 lbs/year to 56,326 lbs/year. This was an 8.00% reduction in total phosphorus. The nitrogen yield dropped from 259,681 lbs/year to 244,087 lbs/year, which was a 6.01% reduction. These 16 feeding areas should be evaluated for potential operational or structural modifications in order to minimize future nutrient discharge.

4. Conclusions

It is recommended that the implementation of the appropriate Best Management Practices be targeted to the critical cells and priority animal feeding areas. Animal feeding areas with an AGNPS rating of 50 or greater should be evaluated for potential operational or structural modifications in order minimize future nutrient discharge. The model suggested that a reduction of 8% in phosphorus loadings and 6% in nitrogen loadings could be realized if the following feedlots were modified to include runoff containment systems and buffer zones cell #’s: (13,20-MC-2a), (4,265,311,315a,315b- MC-4), (138,244,286a,286b,290,421- MC-5), (123,179-mc6), (300- MC-7).

The tillage practices on critical cells having high c-factors, poor grade soils and 3% slope or greater may also be modified to use conservation tillage practices. These practices might include strip cropping, limited-till and no-till. When the c-factors on 94 cells in the watershed were changed (representing no-till) the model showed a reduction potential of 7.5% for sediment.

The reduction in sediment and nutrients could be less or more depending on crop producer participation and modification costs. It is highly recommended that all critical cells and animal feeding areas be field verified in advance of implementing best management practices.

Potential contributions of sediment from gullies, riparian areas, wind erosion and nutrients from septic systems within the Moccasin Creek watershed were not evaluated as part of the computer modeling assessment phase.

MOCCASIN CREEK WATERSHED AGNPS ANALYSIS

In order to complement existing water quality data in the Moccasin Creek watershed, a computer model was selected in order to asses the Nonpoint source (NPS) loadings throughout the drainage. The model selected was the Agricultural Nonpoint Source Pollution Model (AGNPS) version 3.65. This model was developed by the USDA – Agricultural Research Service to analyze the water quality of runoff events in the watershed. The model predicts runoff volume and peak rate, eroded and delivered sediment, nitrogen, phosphorus, and chemical oxygen demand (COD) concentrations in the runoff and sediment. The model was designed to run utilizing a single storm event of equal magnitude for all acreage within the watershed. The model then analyzes the runoff data from the headwaters of the watershed to the outlet. The pollutants are routed in a step-wise fashion so the flow at any point may be examined. The AGNPS model was to be used to objectively compare different sub-watersheds and individual cells within a sub-watershed to other watersheds.

The Moccasin Creek watershed is located in the southern half of central Brown County. The size of the Moccasin Creek watershed that was modeled is 191,503 acres. The watershed outlet drains into the James River approximately 13 miles southeast of Aberdeen. The watershed was divided into cells, each of which had an area of 40 acres with the dimensions of 1,320 feet by 1,320 feet. The dominant fluid flow direction within each cell was then determined. Based on the fluid flow directions and drainage patterns, eight sub-watersheds were delineated. Along with the dominant fluid flow direction, 26 watershed parameters were collected and entered into the model for each cell. The model then calculated the nonpoint source pollution loadings for each cell, sub-watershed and animal feeding area and estimated hydrology runoff volume for each of the storm events modeled.

AGNPS GOALS

The primary objectives of running the AGNPS model on Moccasin Creek watershed was to:

Evaluate and quantify NPS loadings from each sub-watershed.
Define critical NPS cells within each sub-watershed (elevated sediment, nitrogen, phosphorus).
Priority ranking of each animal feeding area and quantify the nutrient loadings from each area.

The following is a brief overview of each objective:

OBJECTIVE 1 – EVALUATE AND QUANTIFY SUBWATERSHED LOADINGS

DELINEATION OF SUBWATERSHEDS
Based upon the fluid flow directions and drainage patterns, eight sub-watersheds were delineated:

SUBWATERSHED #	DRAINAGE AREA (acre)	OUTLET CELL #
1	4,320	98
2a	13,840	343
2	2,800	70
3	7,560	186
4	12,600	280
5	17,320	53
6	34,760	869
7	12,560	305

Moccasin Creek AGNPS model sub-watersheds and diagnostic feasibility water quality monitoring site sub-watershed nutrient sediment loadings:

SEDIMENT ANALYSIS

Sub-Watershed Outlet Cell # 1	Drainage Area (acres)	1 Month Event cell outlet (tons/acre)	6 Month Event cell outlet (tons/acre)	1 Year Event cell outlet (tons/acre)	Annual Total Sediment (tons/acre)	Annual Total Sed. (tons)	% of Total Sediment Yield	% of Water-shed area	25 Year Event Tot. Yield (tons/acre)	% of Total Sed. Yield
98	4320	51.64	38.55	15.55	0.024	106	2.14%	4.16%	5789.57	1.19%
343	13840	244.03	159.86	61.8	0.034	466	9.44%	13.14%	27013.16	5.55%
70	2800	70.72	39.85	17.69	0.046	128	2.60%	2.60%	5409.7	1.11%
186	7560	109.75	102.78	48.48	0.035	261	5.29%	7.14%	16379.02	3.36%
280	12600	300.01	310.73	145.96	0.060	757	15.34%	11.90%	54346.78	11.16%
53	17320	386.81	407.68	191.38	0.057	986	19.99%	16.40%	107160.4	22.00%
869	34760	656.71	664.69	317.53	0.047	1,639	33.23%	32.80%	251104.8	51.55%
305	12560	196.76	196.76	196.76	0.047	590	11.97%	11.86%	19938.27	4.09%
				TOTALS	**0.34958**	**4,932**	**100**	**100**	**487141.7**	**100**

*Each sub-watershed outlet contained a water-sampling site, which caused the data above to be the same as the data for each individual sampling site.

Diagnostic Feasibility Monitoring (site#) cell#	Drainage Area (acres)	1 Month Event cell outlet (tons/acre)	6 Month Event cell outlet (tons/acre)	1 Year Event cell outlet (tons/acre)	Annual Total Sediment (tons/acre)	Annual Total Sed. (tons)	% of Total Sediment Yield	% of Water-shed area	25 Year Event Tot. Yield (tons/acre)	% of Total Sediment Yield
(1) 98	4320	51.64	38.55	15.55	0.024477	106	2.14%	4.16%	5789.57	1.18%
(2a) 343	13840	244.03	159.86	61.8	0.033648	466	9.44%	13.1%	27013.16	5.86%
(2) 70	2800	70.72	39.85	17.69	0.045807	128	2.60%	2.60%	5409.7	1.04%
(3) 186	7560	109.75	102.78	48.48	0.034525	261	5.29%	7.14%	16379.02	3.51%
(4) 280	12600	300.01	310.73	145.96	0.060056	757	15.34%	11.9%	54346.78	10.38%
(5) 53	17320	386.81	407.68	191.38	0.056921	986	19.99%	16.4%	107160.4	20.63%
(6) 869	34760	656.71	664.69	317.53	0.04715	1,639	33.23%	32.8%	251104.8	53.08%
(7) 305	12560	196.76	196.76	196.76	0.046997	590	11.97%	11.9%	19938.27	4.33%
				TOTALS	**0.34958**	**4,932**	**100**	**100**	**487141.7**	**100**

Annual loadings were estimated by calculating the NPS loadings for an accumulation of rainfall events during an average year. This includes a 1 year 24 hour event of 1.95 inches (EI = 21.5), four semi-annual or 6 month rainfall events of 1.29 inches (EI = 35.2), and a series of seven smaller, 1-month rainfall events of .84 inches (EI = 22.4) for a total "R" factor of 80.
The 25 year event was modeled using a single rainfall event of 4.2 inches (EI = 109.5). Rainfall events of less than .84 inches were modeled and found to produce insignificant amounts of sediment and nutrient yields.

Moccasin Creek AGNPS model sub-watersheds and diagnostic feasibility water quality monitoring site sub-watershed nutrient sediment loadings (continued):

PHOSPHORUS ANALYSIS

Sub-Watershed Outlet Cell #	Drainage Area (acres)	1 Month Event cell outlet (lbs/acre)	6 Month Event cell outlet (lbs/acre)	1 Year Event cell outlet (lbs/acre)	Annual Total Phos. (lbs/acre)	Annual Total Phos. (lbs)	% of Total Phos. Yield	% of Water-shed area	25 Year Event Total Phos. (lbs/acre)	% of Total Phos. Yield
98	4320	0.05	0.13	0.23	0.180	778	2.23%	4.16%	77.66	2.73%
343	13840	0.05	0.13	0.23	0.180	2,491	7.14%	13.14%	241.4	8.49%
70	2800	0.04	0.07	0.13	0.110	308	0.88%	2.60%	51.14	1.80%
186	7560	0.08	0.18	0.29	0.260	1,966	5.63%	7.14%	184.51	6.49%
280	12600	0.12	0.27	0.43	0.390	4,914	14.08%	11.90%	460.47	16.19%

53	17320	0.1	0.24	0.37	0.340	5,889	16.87%	16.40%	605.31	21.28%
869	34760	0.09	0.22	0.35	0.310	10,776	30.87%	32.80%	1060.34	37.28%
305	12560	0.31	0.31	0.31	0.620	7,787	22.31%	11.86%	163.77	5.76%
				TOTALS	**2.39**	**34,908**	**100**	**100**	**2844.6**	**100**

*Each sub-watershed outlet contained a water-sampling site, which caused the data above to be the same as the data for each individual sampling site.

Diagnostic Feasibility Monitoring (site#) cell#	Drainage Area (acres)	1 Month Event cell outlet (lbs/acre)	6 Month Event cell outlet (lbs/acre)	1 Year Event cell outlet (lbs/acre)	Annual Total Phos. (lbs/acre)	Annual Total Phos. (lbs)	% of Total Phos. Yield	% of Water-shed area	25 Year Event Total Phos. (lbs/acre)	% of Total Phos. Yield
(1) 98	4320	0.05	0.13	0.23	0.180	778	2.23%	4.16%	77.66	2.73%
(2a) 343	13840	0.05	0.13	0.23	0.180	2,491	7.14%	13.14%	241.4	8.49%
(2) 70	2800	0.04	0.07	0.13	0.110	308	0.88%	2.60%	51.14	1.80%
(3) 186	7560	0.08	0.18	0.29	0.260	1,966	5.63%	7.14%	184.51	6.49%
(4) 280	12600	0.12	0.27	0.43	0.390	4,914	14.08%	11.90%	460.47	16.19%
(5) 53	17320	0.1	0.24	0.37	0.340	5,889	16.87%	16.40%	605.31	21.28%
(6) 869	34760	0.09	0.22	0.35	0.310	10,776	30.87%	32.80%	1060.34	37.28%
(7) 305	12560	0.31	0.31	0.31	0.620	7,787	22.31%	11.86%	163.77	5.76%
				TOTALS	**2.39**	**34,908**	**100**	**100**	**2844.6**	**100**

Annual loadings were estimated by calculating the NPS loadings for an accumulation of rainfall events during an average year. This includes a 1 year 24 hour event of 1.95 inches (EI = 21.5), four semi-annual or 6 month rainfall events of 1.29 inches (EI = 35.2), and a series of seven smaller, 1-month rainfall events of .84 inches (EI = 22.4) for a total "R" factor of 80.
The 25 year event was modeled using a single rainfall event of 4.2 inches (EI = 109.5). Rainfall events of less than .84 inches were modeled and found to produce insignificant amounts of sediment and nutrient yields.

Moccasin Creek AGNPS model sub-watersheds and diagnostic feasibility water quality monitoring site sub-watershed nutrient sediment loadings (continued):

NITROGEN ANALYSIS

Sub-Watershed Outlet Cell #	Drainage Area (acres)	1 Month Event cell outlet (lbs/acre)	6 Month Event cell outlet (lbs/acre)	1 Year Event cell outlet (lbs/acre)	Annual Total Nit. (lbs/acre)	Annual Total Nit. (lbs)	% of Total Nitrogen Yield	% of Water-shed area	25 Year Event Total Nit. (lbs/acre)	% of Total Nitrogen Yield
98	4320	0.19	0.54	0.99	0.73	3,154	2.46%	4.16%	281.11	2.89%

343	13840	0.2	0.56	1	0.76	10,518	8.08%	13.14%	864.89	8.90%
70	2800	0.12	0.27	0.49	0.39	1,092	0.82%	2.60%	147.7	1.52%
186	7560	0.32	0.78	1.34	1.1	8,316	6.13%	7.14%	653.49	6.72%
280	12600	0.49	1.14	1.89	1.63	20,538	14.71%	11.90%	1617.16	16.64%
53	17320	0.4	0.98	1.64	1.38	23,902	17.36%	16.40%	2027.47	20.85%
869	34760	0.34	0.9	1.54	1.24	43,102	32.07%	32.80%	3606.44	37.10%
305	12560	1.47	1.47	1.47	2.94	36,926	18.37%	11.86%	596.39	6.08%
				TOTALS	**10.17**	**147,548**	**100**	**100**	**9794.65**	**100**

*Each sub-watershed outlet contained a water-sampling site, which caused the data above to be the same as the data for each individual sampling site.

Diagnostic Feasibility Monitoring (site#) cell#	Drainage Area (acres)	1 Month Event cell outlet (lbs/acre)	6 Month Event cell outlet (lbs/acre)	1 Year Event cell outlet (lbs/acre)	Annual Total Nit. (lbs/acre)	Annual Total Nit. (lbs)	% of Total Nitrogen Yield	% of Water-shed area	25 Year Event Total Nit. (lbs/acre)	% of Total Nitrogen Yield
(1) 98	4320	0.19	0.54	0.99	0.73	3,154	2.46%	4.16%	281.11	2.89%
(2a) 343	13840	0.2	0.56	1	0.76	10,518	8.08%	13.14%	864.89	8.90%
(2) 70	2800	0.12	0.27	0.49	0.39	1,092	0.82%	2.60%	147.7	1.52%
(3) 186	7560	0.32	0.78	1.34	1.1	8,316	6.13%	7.14%	653.49	6.72%
(4) 280	12600	0.49	1.14	1.89	1.63	20,538	14.71%	11.90%	1617.16	16.64%
(5) 53	17320	0.4	0.98	1.64	1.38	23,902	17.36%	16.40%	2027.47	20.85%
(6) 869	34760	0.34	0.9	1.54	1.24	43,102	32.07%	32.80%	3606.44	37.10%
(7) 305	12560	1.47	1.47	1.47	2.94	36,926	18.37%	11.86%	596.39	6.08%
				TOTALS	**10.17**	**147,548**	**100**	**100**	**9794.65**	**100**

Annual loadings were estimated by calculating the NPS loadings for an accumulation of rainfall events during an average year. This includes a 1 year 24 hour event of 1.95 inches (EI = 21.5), four semi-annual or 6 month rainfall events of 1.29 inches (EI = 35.2), and a series of seven smaller, 1-month rainfall events of .84 inches (EI = 22.4) for a total "R" factor of 80.
The 25 year event was modeled using a single rainfall event of 4.2 inches (EI = 109.5). Rainfall events of less than .84 inches were modeled and found to produce insignificant amounts of sediment and nutrient yields.

SEDIMENT YIELD RESULTS

The AGNPS model calculated that the Moccasin Creek watershed had a moderate to low sediment deliverability rate. The estimated annual load delivered to the James River was 4,534 ton/year or .04lb/acre/year. A comparison of the sub-watershed totals for sediment yield to the aerial sizes is as follows:

SUBWATERSHED number (cell #)	% OF TOTAL SUBWATERSHED SEDIMENT LOAD	% OF WATERSHED AREA	# OF CRITICAL CELLS (cell erosion >2 tons/acre)

1 (98)	2.34%	4.16%	0
2a (343)	10.27%	13.14%	0
2 (70)	2.82%	2.60%	0
3 (186)	5.75%	7.14%	0
4 (280)	16.69%	11.90%	3
5 (53)	21.75%	16.40%	26
6 (869)	36.15%	32.80%	65
7 (305)	4.23%	11.86%	0
TOTAL	**100**	**100**	**94**

Sub-watersheds 4 (#280), 5(#53), and 6(#869) appeared to be delivering the largest amount of sediment to the watershed. The three sub-watersheds yield 74.59% of the sediment delivered by the entire watershed while occupying only 61.1% of the total watershed acreage. The three sub-watersheds contained 100% of the critical erosion cells. The high sediment yield can be attributed to land use and land slope. The source is primarily from agricultural land with slopes of 3% or above accompanied by a relatively high c-factor. The conversion of this acreage to high residue management system or rangeland should reduce the volume of sediment delivered to the James River.

NUTRIENT YIELD RESULTS

The AGNPS data indicates that the Moccasin Creek watershed has a total phosphorus (sediment bound + water-soluble) deliverability rate of .58 lb/acre/year (equivalent to 31 tons) and a total nitrogen (sediment bound + water-soluble) deliverability rate of 2.46 lb/acre/year (equivalent to 130 tons).

Sub-watersheds 4(#280), 5(#53) and 6(#869) appeared to be contributing higher levels of total phosphorus and nitrogen to the watershed. These three sub-watersheds contain 81% of the critical phosphorus cells and 78% of the critical nitrogen cells within the watershed. Collectively the critical sub-watersheds deliver 45,571 lbs. of phosphorus and 193,291 lbs. of nitrogen to the watershed in an average year. This calculates out to be 75% of the total phosphorus load and 74% of the total nitrogen load for the entire watershed.
The critical nitrogen sub-watersheds are as follows:

SUBWATERSHED number (cell #)	% OF TOTAL SUBWATERSHED NITROGEN LOAD	% OF WATERSHED AREA	# OF CRITICAL CELLS (total nitro. > 8 lbs/acre)
1 (98)	2.85%	4.16%	2
2a (343)	9.38%	13.14%	5
2 (70)	0.98%	2.60%	0
3 (186)	7.10%	7.14%	2
4 (280)	17.08%	11.90%	21
5 (53)	20.13%	16.40%	3
6 (869)	37.21%	32.80%	18
7 (305)	5.27%	11.86%	3
TOTAL	100	100	54

The critical phosphorus sub-watersheds are as follows:

SUBWATERSHED number (cell #)	% OF TOTAL SUBWATERSHED PHOSPHORUS LOAD	% OF WATERSHED AREA	# OF CRITICAL CELLS (total Phos.> 2.35 lbs/acre)
1 (98)	2.90%	4.16%	2
2a (343)	9.29%	13.14%	5
2 (70)	1.09%	2.60%	0
3 (186)	6.80%	7.14%	1
4 (280)	16.92%	11.90%	17
5 (53)	20.12%	16.40%	7
6 (869)	37.54%	32.80%	15
7 (305)	5.34%	11.86%	1
TOTAL	100	100	48

There are a total of 76 feedlots within Moccasin Creek watershed. Sixteen of these feedlots were given an AGNPS rating of 50 or greater. Thirteen of these sixteen feeding areas were located in sub-watersheds 4,5 and 6. This suggests that the high levels of phosphorus and nitrogen are a result of the feedlots that exist in these areas.

OBJECTIVE 2 – IDENTIFICATION OF CRITICAL NPS CELLS (ANNUALIZED)

Sub-Watershed	Critical Cell #	Cell Erosion (tons/acre)	Sub-Watershed	Critical Cell #	Total Phosphorus (lbs/acre)	Sub-Watershed	Critical Cell #	Total Nitrogen (lbs/acre)
MC6	691	6.23	MC5	286	12.66	MC5	286	63.05
MC6	723	5.37	MC4	315	6.4	MC4	315	22.74
MC6	596	5.01	MC2a	20	5.56	MC2a	20	21.62
MC6	783	4.88	MC2a	13	4.55	MC4	4	17.85
MC6	370	4.62	MC4	4	4.54	MC2a	13	15.22
MC4	280	4.59	MC4	311	3.98	MC4	311	14.16
MC6	741	4.44	MC6	783	3.9	MC4	314	13.54
MC6	624	4.35	MC4	314	3.86	MC4	30	13.46
MC6	771	4.29	MC4	30	3.76	MC1	60	12.79
MC6	628	4.28	MC1	60	3.29	MC1	80	12.41
MC5	273	4.25	MC6	337	3.26	MC5	290	11.43
MC6	720	4.15	MC6	629	3.22	MC7	198	11.41
MC6	659	3.96	MC6	681	3.18	MC2a	25	10.89

MC6	625	3.88	MC1	80	3.1	MC4	309	10.64
MC5	140	3.83	MC4	309	2.99	MC7	49	10.61
MC5	161	3.83	MC4	3	2.92	MC4	3	9.59
MC5	257	3.74	MC2a	25	2.78	MC4	134	9.23
MC6	681	3.74	MC4	134	2.74	MC2a	124	9.11
MC6	158	3.6	MC6	857	2.74	MC4	25	8.96
MC6	660	3.6	MC7	198	2.72	MC4	35	8.96
MC6	682	3.54	MC2a	124	2.68	MC4	77	8.96
MC6	629	3.48	MC6	790	2.67	MC4	213	8.96
MC6	569	3.37	MC6	653	2.61	MC6	783	8.91
MC6	402	3.28	MC4	25	2.6	MC4	76	8.84
MC6	337	3.27	MC4	35	2.6	MC4	214	8.84
MC5	272	3.25	MC4	77	2.6	MC6	411	8.75
MC6	847	3.25	MC4	213	2.6	MC6	592	8.68
MC6	683	3.24	MC4	76	2.54	MC2a	195	8.66
MC6	212	3.2	MC4	214	2.54	MC7	107	8.64
MC6	431	3.12	MC4	91	2.53	MC5	209	8.63
MC5	139	3.11	MC6	411	2.5	MC6	534	8.62
MC6	684	3.03	MC6	449	2.48	MC4	304	8.48
MC5	172	3	MC6	592	2.46	MC3	65	8.45
MC6	784	3	MC2a	195	2.45	MC6	358	8.42
MC6	846	3	MC5	152	2.43	MC6	525	8.34
MC6	654	2.94	MC5	209	2.43	MC6	591	8.32
MC6	688	2.94	MC6	534	2.43	MC6	653	8.32
MC6	197	2.9	MC5	290	2.41	MC6	496	8.28

Sub-Watershed	Critical Cell #	Cell Erosion (tons/acre)	Sub-Watershed	Critical Cell #	Total Phosphorus (lbs/acre)	Sub-Watershed	Critical Cell #	Total Nitrogen (lbs/acre)
MC6	140	2.85	MC6	369	2.39	MC3	157	8.23
MC6	795	2.85	MC6	448	2.39	MC6	648	8.2
MC6	373	2.81	MC4	71	2.36	MC4	144	8.17
MC5	68	2.8	MC5	18	2.36	MC4	145	8.17
MC5	269	2.8	MC6	234	2.36	MC4	147	8.17
MC5	287	2.8	MC6	567	2.36	MC4	160	8.17
MC5	334	2.72	MC3	65	2.35	MC4	174	8.17
MC6	742	2.71	MC4	304	2.35	MC4	176	8.17
MC6	366	2.65	MC5	306	2.35	MC6	609	8.16
MC6	433	2.59	MC7	49	2.35	MC6	493	8.14
MC6	686	2.59				MC6	619	8.09
MC6	816	2.59				MC6	649	8.09
MC6	718	2.55				MC6	860	8.06
MC5	289	2.52				MC6	238	8.04

MC6	189	2.52
MC6	790	2.51
MC6	570	2.49
MC5	49	2.47
MC6	85	2.46
MC5	237	2.45
MC5	292	2.4
MC5	180	2.39
MC6	593	2.38
MC6	719	2.38
MC5	81	2.28
MC5	98	2.28
MC5	141	2.28
MC5	256	2.28
MC5	260	2.28
MC5	261	2.28
MC5	262	2.28
MC5	297	2.28
MC6	95	2.28
MC6	97	2.28
MC6	211	2.28
MC6	268	2.28
MC6	194	2.27
MC6	404	2.24
MC6	196	2.23

Sub-Watershed	Critical Cell #	Cell Erosion (tons/acre)
MC6	566	2.23
MC6	568	2.23
MC6	303	2.21
MC6	430	2.2
MC4	179	2.15
MC5	274	2.12
MC6	270	2.1
MC6	338	2.1
MC6	505	2.1
MC6	867	2.1
MC5	291	2.09
MC6	277	2.09
MC6	495	2.09
MC6	29	2.05

MC6	561	8.04
MC6	564	8.04

MC6	139	2.05
MC4	91	2.04
MC6	754	2.03

An analysis of Moccasin Creek watershed indicated that there were approximately 94 cells having erosion rates greater than 2 tons/acre. This was only 3.6% of the total number of cells found in the Moccasin Creek watershed. The model indicated that the majority of these cells were located in areas that had a land slope of 2% or greater as well as the combination of a high c-factor and low surface condition constant.

The model showed 48 cells that would be considered critical phosphorus yield cells. These 48 cells account for less than 2% of the total watershed area. There were also 54 cells that were flagged as critical nitrogen yield cells. The nitrogen critical cells accounted for 2% of the total watershed area. The critical nutrient cells were found in areas where there were feedlots with large numbers of livestock located near the creek.

These designated critical cells should be considered for modification through the implementation of BMP's. They should be field verified for accuracy before any installation of BMP's.

OBJECTIVE 3 – PRIORITY RANKING OF ANIMAL FEEDING AREAS

MC1

Cell # 74

Nitrogen concentration (ppm)	38.149
Phosphorus concentration (ppm)	10.269
COD concentration (ppm)	525.982
Nitrogen mass (lbs)	103.967
Phosphorus mass (lbs)	27.987
COD mass (lbs)	1433.461
Animal feedlot rating number	**34**

Cell # 99

Nitrogen concentration (ppm)	42.261
Phosphorus concentration (ppm)	6.209
COD concentration (ppm)	328.696
Nitrogen mass (lbs)	36.868
Phosphorus mass (lbs)	5.416
COD mass (lbs)	286.747
Animal feedlot rating number	**13**

Cell # 94

Nitrogen concentration (ppm)	13.768
Phosphorus concentration (ppm)	9.735
COD concentration (ppm)	472.063
Nitrogen mass (lbs)	7.069
Phosphorus mass (lbs)	4.998
COD mass (lbs)	242.368
Animal feedlot rating number	**10**

Cell # 99

Nitrogen concentration (ppm)	54.000
Phosphorus concentration (ppm)	7.933
COD concentration (ppm)	420.000
Nitrogen mass (lbs)	15.016
Phosphorus mass (lbs)	2.206
COD mass (lbs)	116.794
Animal feedlot rating number	**1**

Cell # 94

Nitrogen concentration (ppm)	180.000
Phosphorus concentration (ppm)	51.000
COD concentration (ppm)	2700.000
Phosphorus mass (lbs)	36.173
Nitrogen mass (lbs)	127.670
COD mass (lbs)	1915.044
Animal feedlot rating number	**36**

MC2a

Cell # 13

Nitrogen concentration (ppm)	45.469
Phosphorus concentration (ppm)	17.820
COD concentration (ppm)	816.307
Nitrogen mass (lbs)	93.527
Phosphorus mass (lbs)	36.654
COD mass (lbs)	1679.085
Animal feedlot rating number	**36**

Cell # 13

Nitrogen concentration (ppm)	218.400
Phosphorus concentration (ppm)	61.880
COD concentration (ppm)	3276.000
Nitrogen mass (lbs)	505.647
Phosphorus mass (lbs)	143.267
COD mass (lbs)	7584.712
Animal feedlot rating number	**56**

Cell # 20

Nitrogen concentration (ppm)	56.584
Phosphorus concentration (ppm)	14.615
COD concentration (ppm)	747.022
Nitrogen mass (lbs)	642.104
Phosphorus mass (lbs)	165.843
COD mass (lbs)	8477.009
Animal feedlot rating number	**61**

Cell # 20

Nitrogen concentration (ppm)	26.029
Phosphorus concentration (ppm)	9.237
COD concentration (ppm)	408.260
Nitrogen mass (lbs)	97.944
Phosphorus mass (lbs)	34.757
COD mass (lbs)	1536.242
Animal feedlot rating number	**35**

Cell # 60

Nitrogen concentration (ppm)	42.900
Phosphorus concentration (ppm)	5.610
COD concentration (ppm)	891.000
Nitrogen mass (lbs)	26.932
Phosphorus mass (lbs)	3.522
COD mass (lbs)	559.367
Animal feedlot rating number	**21**

Cell # 76

Nitrogen concentration (ppm)	33.512
Phosphorus concentration (ppm)	8.220
COD concentration (ppm)	393.391
Nitrogen mass (lbs)	203.566
Phosphorus mass (lbs)	49.932
COD mass (lbs)	2389.597
Animal feedlot rating number	**41**

Cell # 173

Nitrogen concentration (ppm)	253.636
Phosphorus concentration (ppm)	69.082
COD concentration (ppm)	3640.909
Nitrogen mass (lbs)	218.256
Phosphorus mass (lbs)	59.446
COD mass (lbs)	3133.035
Animal feedlot rating number	**42**

Cell # 173

Nitrogen concentration (ppm)	34.020
Phosphorus concentration (ppm)	4.998
COD concentration (ppm)	264.600
Nitrogen mass (lbs)	28.303
Phosphorus mass (lbs)	4.158
COD mass (lbs)	220.134
Animal feedlot rating number	**9**

Cell # 176

Nitrogen concentration (ppm)	23.400
Phosphorus concentration (ppm)	3.060
COD concentration (ppm)	486.000
Nitrogen mass (lbs)	19.217
Phosphorus mass (lbs)	2.513
COD mass (lbs)	399.123
Animal feedlot rating number	**17**

Cell # 219

Nitrogen concentration (ppm)	26.250
Phosphorus concentration (ppm)	7.438
COD concentration (ppm)	393.750
Nitrogen mass (lbs)	64.885
Phosphorus mass (lbs)	18.384
COD mass (lbs)	973.282
Animal feedlot rating number	**29**

Cell # 219

Nitrogen concentration (ppm)	40.026
Phosphorus concentration (ppm)	8.825
COD concentration (ppm)	462.209
Nitrogen mass (lbs)	106.565
Phosphorus mass (lbs)	23.495
COD mass (lbs)	1230.572
Animal feedlot rating number	**32**

MC2

Cell # 54

Nitrogen concentration (ppm)	22.203
Phosphorus concentration (ppm)	3.047
COD concentration (ppm)	398.092
Nitrogen mass (lbs)	19.266
Phosphorus mass (lbs)	2.644
COD mass (lbs)	345.428
Animal feedlot rating number	**14**

Cell # 54

Nitrogen concentration (ppm)	51.955
Phosphorus concentration (ppm)	13.214
COD concentration (ppm)	699.545
Nitrogen mass (lbs)	114.208
Phosphorus mass (lbs)	29.047
COD mass (lbs)	1537.757
Animal feedlot rating number	**35**

MC3

Cell # 34

Nitrogen concentration (ppm)	20.212
Phosphorus concentration (ppm)	2.718
COD concentration (ppm)	386.941
Nitrogen mass (lbs)	35.973
Phosphorus mass (lbs)	4.837
COD mass (lbs)	688.657
Animal feedlot rating number	**24**

MC4

Cell # 4

Nitrogen concentration (ppm)	21.454
Phosphorus concentration (ppm)	3.372
COD concentration (ppm)	264.115
Nitrogen mass (lbs)	200.427
Phosphorus mass (lbs)	31.498
COD mass (lbs)	2467.442
Animal feedlot rating number	**41**

Cell # 30

Nitrogen concentration (ppm)	35.580
Phosphorus concentration (ppm)	9.205
COD concentration (ppm)	458.613
Nitrogen mass (lbs)	179.765
Phosphorus mass (lbs)	46.508
COD mass (lbs)	2317.112
Animal feedlot rating number	**41**

Cell # 4

Nitrogen concentration (ppm)	74.904
Phosphorus concentration (ppm)	20.510
COD concentration (ppm)	1062.478
Nitrogen mass (lbs)	883.175
Phosphorus mass (lbs)	241.830
COD mass (lbs)	12527.410
Animal feedlot rating number	**67**

Cell # 265

Nitrogen concentration (ppm)	157.146
Phosphorus concentration (ppm)	42.259
COD concentration (ppm)	2219.168
Nitrogen mass (lbs)	768.969
Phosphorus mass (lbs)	206.789
COD mass (lbs)	10859.150
Animal feedlot rating number	**63**

Cell # 265

Nitrogen concentration (ppm)	16.370
Phosphorus concentration (ppm)	4.391
COD concentration (ppm)	224.346
Nitrogen mass (lbs)	74.429
Phosphorus mass (lbs)	19.964
COD mass (lbs)	1020.032
Animal feedlot rating number	**30**

Cell # 277

Nitrogen concentration (ppm)	13.892
Phosphorus concentration (ppm)	6.970
COD concentration (ppm)	328.600
Nitrogen mass (lbs)	15.161
Phosphorus mass (lbs)	7.607
COD mass (lbs)	358.613
Animal feedlot rating number	**15**

Cell # 311

Nitrogen concentration (ppm)	164.711
Phosphorus concentration (ppm)	46.552
COD concentration (ppm)	2460.686
Nitrogen mass (lbs)	827.766
Phosphorus mass (lbs)	233.948
COD mass (lbs)	12366.300
Animal feedlot rating number	**65**

Cell # 315

Nitrogen concentration (ppm)	128.000
Phosphorus concentration (ppm)	34.227
COD concentration (ppm)	1800.000
Nitrogen mass (lbs)	454.776
Phosphorus mass (lbs)	121.605
COD mass (lbs)	6395.284
Animal feedlot rating number	**55**

Cell # 315

Nitrogen concentration (ppm)	154.155
Phosphorus concentration (ppm)	43.542
COD concentration (ppm)	2300.701
Nitrogen mass (lbs)	342.244
Phosphorus mass (lbs)	96.668
COD mass (lbs)	5107.844
Animal feedlot rating number	**51**

MC5

Cell # 138

Nitrogen concentration (ppm)	53.077
Phosphorus concentration (ppm)	14.854
COD concentration (ppm)	780.334
Nitrogen mass (lbs)	426.563
Phosphorus mass (lbs)	119.376
COD mass (lbs)	6271.250
Animal feedlot rating number	**57**

Cell # 244

Nitrogen concentration (ppm)	148.954
Phosphorus concentration (ppm)	41.863
COD concentration (ppm)	2205.108
Nitrogen mass (lbs)	412.873
Phosphorus mass (lbs)	116.036
COD mass (lbs)	6112.157
Animal feedlot rating number	**54**

Cell # 286

Nitrogen concentration (ppm)	234.124
Phosphorus concentration (ppm)	30.082
COD concentration (ppm)	1573.019
Nitrogen mass (lbs)	1294.345
Phosphorus mass (lbs)	166.306
COD mass (lbs)	8696.368

Animal feedlot rating number **60**

Cell # 286

Nitrogen concentration (ppm)	152.984
Phosphorus concentration (ppm)	42.766
COD concentration (ppm)	2245.069
Nitrogen mass (lbs)	306.578
Phosphorus mass (lbs)	85.702
COD mass (lbs)	4499.080

Animal feedlot rating number **49**

Cell # 286

Nitrogen concentration (ppm)	116.760
Phosphorus concentration (ppm)	32.969
COD concentration (ppm)	1741.682
Nitrogen mass (lbs)	296.712
Phosphorus mass (lbs)	83.780
COD mass (lbs)	4425.959

Animal feedlot rating number **49**

Cell # 286

Nitrogen concentration (ppm)	80.677
Phosphorus concentration (ppm)	21.941
COD concentration (ppm)	1131.538
Nitrogen mass (lbs)	593.612
Phosphorus mass (lbs)	161.442
COD mass (lbs)	8325.776

Animal feedlot rating number **60**

Cell # 290

Nitrogen concentration (ppm)	27.739
Phosphorus concentration (ppm)	4.390
COD concentration (ppm)	391.961
Nitrogen mass (lbs)	619.391
Phosphorus mass (lbs)	98.025
COD mass (lbs)	8752.271

Animal feedlot rating number **63**

Cell # 421

Nitrogen concentration (ppm)	84.767
Phosphorus concentration (ppm)	14.710
COD concentration (ppm)	1416.657
Nitrogen mass (lbs)	297.670
Phosphorus mass (lbs)	51.658
COD mass (lbs)	4974.751

Animal feedlot rating number **51**

MC6

Cell # 123

Nitrogen concentration (ppm)	151.887
Phosphorus concentration (ppm)	28.986
COD concentration (ppm)	2497.554
Nitrogen mass (lbs)	605.442
Phosphorus mass (lbs)	115.543
COD mass (lbs)	9955.577

Animal feedlot rating number **61**

Cell # 179

Nitrogen concentration (ppm)	93.457
Phosphorus concentration (ppm)	17.443
COD concentration (ppm)	1579.402
Nitrogen mass (lbs)	447.376
Phosphorus mass (lbs)	83.502
COD mass (lbs)	7560.602

Animal feedlot rating number **58**

Cell # 189

Nitrogen concentration (ppm)	25.090
Phosphorus concentration (ppm)	10.638
COD concentration (ppm)	492.016
Nitrogen mass (lbs)	52.667
Phosphorus mass (lbs)	22.331
COD mass (lbs)	1032.814
Animal feedlot rating number	**30**

Cell # 248

Nitrogen concentration (ppm)	52.898
Phosphorus concentration (ppm)	14.238
COD concentration (ppm)	729.243
Nitrogen mass (lbs)	47.616
Phosphorus mass (lbs)	12.817
COD mass (lbs)	656.420
Animal feedlot rating number	**22**

Cell # 259

Nitrogen concentration (ppm)	55.576
Phosphorus concentration (ppm)	15.146
COD concentration (ppm)	782.144
Nitrogen mass (lbs)	72.027
Phosphorus mass (lbs)	19.629
COD mass (lbs)	1013.662
Animal feedlot rating number	**28**

Cell # 330

Nitrogen concentration (ppm)	43.436
Phosphorus concentration (ppm)	10.744
COD concentration (ppm)	551.963
Nitrogen mass (lbs)	57.047
Phosphorus mass (lbs)	14.111
COD mass (lbs)	724.925
Animal feedlot rating number	**24**

Cell # 334

Nitrogen concentration (ppm)	56.552
Phosphorus concentration (ppm)	25.725
COD concentration (ppm)	1200.087
Nitrogen mass (lbs)	45.963
Phosphorus mass (lbs)	20.908
COD mass (lbs)	975.366
Animal feedlot rating number	**28**

Cell # 346

Nitrogen concentration (ppm)	55.376
Phosphorus concentration (ppm)	8.162
COD concentration (ppm)	427.026
Nitrogen mass (lbs)	41.698
Phosphorus mass (lbs)	6.146
COD mass (lbs)	321.549
Animal feedlot rating number	**14**

Cell # 653

Nitrogen concentration (ppm)	174.216
Phosphorus concentration (ppm)	49.191
COD concentration (ppm)	2598.649
Nitrogen mass (lbs)	181.565
Phosphorus mass (lbs)	51.266
COD mass (lbs)	2708.274
Animal feedlot rating number	**41**

Cell # 669

Nitrogen concentration (ppm)	99.000
Phosphorus concentration (ppm)	28.050
COD concentration (ppm)	1485.000
Nitrogen mass (lbs)	35.982
Phosphorus mass (lbs)	10.195
COD mass (lbs)	539.733
Animal feedlot rating number	**20**

Cell # 714 000

Nitrogen concentration (ppm)	28.738
Phosphorus concentration (ppm)	13.265
COD concentration (ppm)	617.477
Nitrogen mass (lbs)	63.777
Phosphorus mass (lbs)	29.438
COD mass (lbs)	1370.328
Animal feedlot rating number	**33**

Cell # 732

Nitrogen concentration (ppm)	72.627
Phosphorus concentration (ppm)	30.085
COD concentration (ppm)	1389.662
Nitrogen mass (lbs)	155.186
Phosphorus mass (lbs)	64.286
COD mass (lbs)	2969.387
Animal feedlot rating number	**44**

Cell # 774

Nitrogen concentration (ppm)	11.611
Phosphorus concentration (ppm)	3.735
COD concentration (ppm)	156.224
Nitrogen mass (lbs)	64.618
Phosphorus mass (lbs)	20.788
COD mass (lbs)	869.394

Animal feedlot rating number **25**

Cell # 848

Nitrogen concentration (ppm)	39.841
Phosphorus concentration (ppm)	11.139
COD concentration (ppm)	584.850
Nitrogen mass (lbs)	148.046
Phosphorus mass (lbs)	41.393
COD mass (lbs)	2173.261

Animal feedlot rating number **40**

Cell # 854

Nitrogen concentration (ppm)	46.357
Phosphorus concentration (ppm)	6.115
COD concentration (ppm)	939.462
Nitrogen mass (lbs)	90.586
Phosphorus mass (lbs)	11.950
COD mass (lbs)	1835.818

Animal feedlot rating number **37**

MC7

Cell # 49

Nitrogen concentration (ppm)	28.361
Phosphorus concentration (ppm)	6.889
COD concentration (ppm)	327.106
Nitrogen mass (lbs)	191.529
Phosphorus mass (lbs)	46.521
COD mass (lbs)	2209.049

Animal feedlot rating number **40**

Cell # 49

Nitrogen concentration (ppm)	17.787
Phosphorus concentration (ppm)	3.447
COD concentration (ppm)	137.757
Nitrogen mass (lbs)	127.669
Phosphorus mass (lbs)	24.744
COD mass (lbs)	988.793

Animal feedlot rating number **24**

Cell # 90

Nitrogen concentration (ppm)	41.713
Phosphorus concentration (ppm)	17.421
COD concentration (ppm)	802.892
Nitrogen mass (lbs)	83.965
Phosphorus mass (lbs)	35.067
COD mass (lbs)	1616.165

Animal feedlot rating number **35**

Cell # 93

Nitrogen concentration (ppm)	109.091
Phosphorus concentration (ppm)	30.909
COD concentration (ppm)	1636.364
Nitrogen mass (lbs)	107.986
Phosphorus mass (lbs)	30.596
COD mass (lbs)	1619.795

Animal feedlot rating number **34**

Cell # 107

Nitrogen concentration (ppm)	48.086
Phosphorus concentration (ppm)	12.230
COD concentration (ppm)	615.610
Nitrogen mass (lbs)	287.398
Phosphorus mass (lbs)	73.096
COD mass (lbs)	3679.344

Animal feedlot rating number **48**

Cell # 112

Nitrogen concentration (ppm)	138.772
Phosphorus concentration (ppm)	38.930
COD concentration (ppm)	2048.258
Nitrogen mass (lbs)	94.990
Phosphorus mass (lbs)	26.648
COD mass (lbs)	1402.043

Animal feedlot rating number **32**

Cell # 112

Nitrogen concentration (ppm)	89.797
Phosphorus concentration (ppm)	25.100
COD concentration (ppm)	1317.591
Nitrogen mass (lbs)	46.498
Phosphorus mass (lbs)	12.997
COD mass (lbs)	682.266
Animal feedlot rating number	**23**

Cell # 204

Nitrogen concentration (ppm)	13.225
Phosphorus concentration (ppm)	6.155
COD concentration (ppm)	286.537
Nitrogen mass (lbs)	24.241
Phosphorus mass (lbs)	11.281
COD mass (lbs)	525.213
Animal feedlot rating number	**21**

Cell # 236

Nitrogen concentration (ppm)	84.545
Phosphorus concentration (ppm)	23.955
COD concentration (ppm)	1268.182
Nitrogen mass (lbs)	129.456
Phosphorus mass (lbs)	36.679
COD mass (lbs)	1941.843
Animal feedlot rating number	**37**

Cell # 245

Nitrogen concentration (ppm)	39.943
Phosphorus concentration (ppm)	5.891
COD concentration (ppm)	307.498
Nitrogen mass (lbs)	101.996
Phosphorus mass (lbs)	15.042
COD mass (lbs)	785.203
Animal feedlot rating number	**26**

Cell # 259

Nitrogen concentration (ppm)	17.086
Phosphorus concentration (ppm)	2.723
COD concentration (ppm)	103.038
Nitrogen mass (lbs)	105.541
Phosphorus mass (lbs)	16.817
COD mass (lbs)	636.457
Animal feedlot rating number	**15**

Cell # 300

Nitrogen concentration (ppm)	61.068
Phosphorus concentration (ppm)	16.571
COD concentration (ppm)	869.377
Nitrogen mass (lbs)	347.171
Phosphorus mass (lbs)	94.207
COD mass (lbs)	4942.399
Animal feedlot rating number	**52**

Of the 76 feeding areas defined, 63 had an AGNPS rating greater than 1when modeled using a 25-year frequency storm event. Of these 63 feeding areas listed above, only 16 had an AGNPS rating of 50 or above. An analysis to evaluate the impacts of these feeding areas on Moccasin Creek watershed was performed by running the model with the feedlots ranked 50 or greater absent. The resulting data was then compared to the data output from the model run with the original data. Reductions in nutrients delivered to the watershed could then be calculated. The result of the calculations showed that there was potential for an 8% reduction in phosphorus and a 6% reduction in nitrogen. It is recommended that the 16 feedlots with an AGNPS rating of 50 or greater be evaluated for potential operational or structural modifications in order to minimize nutrient yields to the watershed.

The implementation of appropriate BMP's targeting these high nutrient yield feedlot areas, upon the completion of a field verification process, should produce the most cost effective treatment plan in reducing the nutrient yields.

In case of questions regarding this analysis, please contact the Department of Environment and Natural Resources at (605)773-4254.

Rainfall Specs For The Moccasin Creek Study

EVENT	RAINFALL	ENERGY INTENSITY
monthly	.84 inches	3.2
semi-annually	1.29 inches	8.8
1-year	1.95 inches	21.5
25-year	4.2 inches	109.5

NRCS R-factor for the Moccasin Creek watershed = 80

Annual Loadings Calculations

monthly events = 7 events X 3.2 = 22.4

semi-annual events = 4 events X 8.8 = 35.2

1-year event = 1 event X 21.5 = 21.5

Total = 80

OVERVIEW OF AGNPS DATA INPUTS

The Agricultural Nonpoint Source Pollution Model (AGNPS) is a computer simulation model developed to analyze the water quality of runoff from watersheds. The model predicts runoff volume and peak rate, eroded and delivered sediment, nitrogen, phosphorus, and chemical oxygen demand concentrations in the runoff and the sediment for a single storm event for all points in the watershed. Proceeding from the headwaters to the outlet, the pollutants are routed in a step-wise fashion so the flow at any point may be examined. AGNPS to be used to objectively evaluate the water quality of the runoff from agricultural watersheds and to present a means of objectively comparing different watersheds throughout the state. The model is intended for watersheds up to about 320,000 acres (8000 cells @ 40 acres/cell).

The model works on a cell basis. These cells are uniform square areas that divide the watershed (figure 1). This division makes it possible to analyze any area, down to 1.0 acres, in the watershed. The basic components of the model are hydrology, erosion, sediment transport, nitrogen (N), phosphorus (P), and chemical oxygen demand (COD) transport. In hydrology portion of the model, calculations were made for runoff volume and peak concentration flow. Total upland erosion, total channel erosion, and a breakdown of these two sources into five particle size classes (clay, silt, small aggregates, large aggregates, and sand) for each of the cells are calculated in the erosion portion. Sediment transport is also calculated for each of the cells in the five particle classes as well as the total. The pollutant transport portion is subdivided into one part handling soluble pollutants and another part handling sediment attached pollutants (figure 2).

PRELIMINARY EXAMINATION

A preliminary investigation of the watershed is necessary before the input file can be established. The steps to this preliminary examination are:

1) Detailed topographic map of the watershed (USGS map 1:24,000)
2) Establish the drainage boundaries
3) Divide watershed up into cells (40 acre, 1320 X 1320). Only those cells with greater than 50% of their area within the watershed boundary should be included.
4) Number the cells consecutively from one to the number of cells (begin at NW corner of watershed and proceed west to east then north to south.
5) Establish the watershed drainage pattern from the cells.

DATA FILE

Once the preliminary examination is completed, the input data file can be established. The data file is composed of the following 21 inputs per cell:

Data input for watershed

1) a) Area of each cell (acres)
   b) Total number of cells in watershed
   c) Precipitation for a 25 year, 24 hour rainfall
   d) Energy intensity value for storm event previously selected

Data input for each cell

1) Cell number
2) Receiving cell number
3) SCS number runoff curve number (use antecedent moisture condition II)
4) Land slope (topographic maps) average slope if irregular, water or marsh = 0
5) Slope shape factor water or marsh = 1 (uniform)
6) Field slope length water or marsh = 0, for S.D. assume slope length area 1
7) Channel slope (average), topo maps, if no definable channel, channel slope = ½ land slope, water or marsh = 0
8) Channel side slope, the average side slope (%), assume 10% if unknown, water or marsh = 0
9) Manning's roughness coefficient for the channel if no channel exists within the cell, select a roughness coefficient appropriate for the predominant surface condition within the cell
10) Soil erodibility factor water or marsh = 0
11) Cropping factor assume conditions at storm or worst case condition (fallow or seedbed periods), water or marsh = .00, urban or residential = .01
12) Practice factor worst case = 1.0, water or marsh = 0, urban or residential = 1.0
13) Surface condition constant a value based on land use at the time of the storm to make adjustments of the time it takes overland runoff to channelize.
14) Aspect a single digit indicating the principal direction of drainage from the cell (if no drainage = 0)
15) Soil texture, major soil texture and number to indicate each are:

Texture	Input Parameter
Water	0
Sand	1
Silt	2
Clay	3
Peat	4

16) Fertilization level, indication of the level of fertilization on the field.

Level	Assume Fertilization (lb./acre) N	P	Input
No Fertilization	0	0	0
Low Fertilization	50	20	1

Average Fertilization	100	40	2
High Fertilization	200	80	3

avg. manure-low fertilization
high manure-avg. fertilization
water or marsh = 0
urban or residential = 0 (for average practices)

17) Availability factor, the percent of fertilizer left in the top half inch of soil at the time of the storm. Worst case 100%, water or marsh = 0, urban or residential = 100%
18) Point source indicator: indicator of feedlot within the cell (0 = no feedlot, 1 = feedlot)

19) Gully source level: tons of gully erosion occurring in the cell or input from a sub-watershed
20) Chemical oxygen demand (COD), a value of COD for the land use in the cell.
21) Impoundment factor: number of impoundments in the cell (max. 13)
   a) Area of drainage into the impoundment
   b) Outlet pipe (inches)
22) Channel indicator: number which designates the type of channel found in the cell

DATA OUTPUT AT THE OUTLET OF EACH CELL

Hydrology
- Runoff volume
- Peak runoff rate
- Fraction of runoff generated within cell

Sediment Output
- Sediment yield
- Sediment concentration
- Sediment particle size distribution
- Upland erosion
- Amount of deposition
- Sediment generated within the cell
- Enrichment ratios by particle size
- Delivery ratios by particle size

Chemical Output
- Nitrogen
- Concentration of soluble material
- Mass of soluble material
- Phosphorus
- Sediment associated mass

Concentration of soluble material
Mass of soluble material
Chemical Oxygen Demand
Concentration
Mass

PARAMETER SENSITIVITY ANALYSIS

The most sensitive parameters affecting sediment and chemical yields are:
Land slope (LS)
Soil erodibility (K)
Cover-management factor (C)
Curve number (CN)
Practice factor (P)

Wylie Pond Watershed

The Wylie Pond watershed is located within Moccasin Creek subwatershed 2a in Brown County South Dakota. The size of the area modeled was 1,280 acres. The inlet of Wylie Pond is on the northeast corner of the pond, adjacent to highway 281. The pond does not have an outlet.

When the model was run with a 25-year rain event, none of the 32 cells within the watershed were considered to be critical areas. There were no existing feedlots within the 1,280-acre area. For an average year of rainfall the model showed a yield of 26.86 tons of sediment for the entire watershed. This yield averages out to be .02 ton per acre for the entire watershed. Phosphorus was estimated at .35 lb per acre and nitrogen at 1.13 lb per acre. When compared to the rest of Moccasin Creek watershed, these numbers were considered to be extremely low.

Physiography of Moccasin Creek Watershed

The physical geography of Brown County, South Dakota is part of the James River Lowland. The three major landforms are lake-plain, glacial uplands, and alluvial flood plains. The eastern two-thirds of the county is a nearly flat plain that is between 1,290 and 1,310 above sea level. The plain is the former bed of an extensive but shallow and short-lived glacial lake known as Lake Dakota. This lake was about 90 miles long and 27 miles wide. The lake plain does not have a well-developed natural drainage system.

The glacial uplands lie west of the lake plain and in the southeast corner of the county. They consist of deposits of glacial till that form smoothly rolling hills. The relief is dominantly undulating to hilly. The uplands are characterized by many potholes or closed basins and have a poorly defined drainage pattern.

Flood plains are along the major streams, including the Moccasin Creek. The James River and its tributaries form the natural drainage network of Brown County. The principal tributaries of the James River are Elm River and Moccasin Creek, both of which join the James from the West. The head of Moccasin Creek is near the Elm River. During periods of flooding, water from the Elm River flows into Moccasin Creek.

Reference:

Soil Survey of Brown County South Dakota

Appendix B. Sediment Transport Study

Table of Contents

Section 1 – Introduction

Inter-Fluve, Inc. is pleased to present a preliminary geomorphic and sediment transport assessment of existing conditions within Moccasin Creek. In addition, implementation measures that would be necessary to restore the channel to a form that will increase geomorphic and aesthetic function within the current urban environment are provided. Cities have begun to realize that urbanized streams, when viewed as an asset, can become the centerpiece of the communities through which they flow. Moccasin Creek currently traverses the city of Aberdeen, South Dakota from north to south through an overly wide, and frequently dredged, channel. Within this urban environment, stream discharges are strongly controlled by numerous bridges, culverts, the existing channel shape, storm drain inflows, and an extremely low gradient environment.

The geomorphic setting of a stream corridor is the result of the geologically controlled terrain through which it traverses. Moccasin Creek, Foot Creek, and the Elm River have been strongly influenced by Pleistocene age continental Illinoian and Wisconsin glacial landforms that shaped the area approximately 130,000 to 700,000 years ago. Historically, the creek appears to have been a highly sinuous, single thread channel that is controlled by an extremely low longitudinal gradient. Observation of aerial photographs and topographic mapping indicate that all streams in the area around the city of Aberdeen exhibit similar single thread, high sinuosity, low gradient tendencies when they have not been influenced by human activities. The region is topographically extremely flat and appears pockmarked with pothole ponds, infilled former pothole ponds, and meander cutoffs.

Within the urban environment, and at locations both upstream and downstream, the channel has been extensively straightened. Within the city of Aberdeen it has also been dredged to provide flood protection for the city. The combination of dredging, straightening, and alteration by bridges, culverts, and storm drain inflows has resulted in complete obliteration of the pre-existing channel. This has created a channel that 1) is overly wide, 2 is backwatered through most of the city, 3) is functionally deficient of natural attributes, 4) is continually trying to refill the dredged channel, and 5) is reportedly considered by the community to be less than aesthetically desirable.

This study was conducted as an initial assessment of conditions within the urbanized Moccasin Creek channel to determine measures that could be implemented to restore the channel to a form that would ultimately result in a valuable asset to the city.

The design of any stream corridor must consider the conceptual plan for the city, hydraulic and hydrologic influences, natural and man-made design controls, associated detrimental effects (effects on flooding or bridges) and detailed analytical evaluations to determine the expected longevity of the constructed feature. Proper natural channel design considers engineered stability in conjunction with geomorphic and biological function.

Section 2 – Scope of Work

2.1 Work Items

Inter-Fluve was contracted by the South Brown Conservation District to accomplish the following tasks to determine channelization and sediment transport opportunities in the urbanized reaches of Moccasin Creek. These tasks included:

- Determining the feasibility of confining base flows to a low-flow channel;
- Providing preliminary estimates of the size of any potential low-flow channel;
- Assessment of whether the channel velocities in the low-flow channel will maintain the channel under base-flow conditions;
- Assessment of the potential for sedimentation of the low-flow channel under high flow conditions;
- Assessment of upstream and downstream channel changes that would assist in sediment transport efforts through the reach;
- Initial assessment of potential regulatory hurdles that could impact project implementation;
- Determination of the best channel planform to accomplish project goals of increasing sediment conveyance and increasing channel aesthetics; and
- Determination of a conceptual channel hydrologic regime on which to base the design.

2.2 Data Collection

Inter-Fluve reviewed project data submitted by the City of Aberdeen, the South Brown Conservation District, the South Dakota Department of the Environment and Natural Resources (DENR), and the South Dakota Department of Transportation. In addition, Inter-Fluve investigated geologic reports, Moccasin Creek discharge data, conducted a brief site visit to view the stream first hand, and conducted feasibility level sediment transport analyses and channel sizing iterations to determine potential corridor configurations.

Data supplied to Inter-Fluve included:

- Aerial photos of the urbanized reach from 1958, 1975, 1979, 1994, and 1999. The most recent photograph series were also provided in digital format;
- Contour maps with one-foot contour intervals were supplied in electronic format (including those areas of the channel that are under water);
- HEC-2 hydraulic studies of Moccasin Creek that included Railroad Avenue bridge improvements and additions of the bike trail. These analyses were imported into

more recent HEC-RAS software and used as the basis for many of the hydraulic computations and cross-section data for the analyses;

- Storm sewer maps and water quality sampling results provided by the City of Aberdeen;
- 32 cross-sections provided by the South Dakota Department of Environment and Natural Resources; and
- Results of six channel bed material particle size distributions provided by the South Dakota Department of Transportaion. The location and depth of these samples was not provided.

Attempts to locate the Moccasin Creek Dredging Study were not successful and it is not known if it has been completed at this time. Inter-Fluve did not undertake any field data collection. All hydraulic computations were based on hydraulic information extracted from the HEC-2 data provided.

2.3 Site Review

Mr. Mike Rotar of Inter-Fluve spent one day in the field with Mr. Stu Nelson from the Aberdeen Public Works Department and met with Mr. Robin Bobzien from the Aberdeen Public Works Department to discuss the project. The site review provided an opportunity to view the project and assess site constraints and channel conditions that can only be performed by visual observation. Due to the short duration of the field visit actual measurements of natural and urbanized reaches of the stream were not conducted. However, the visit provided very valuable visual observations of existing site conditions and gave us the opportunity to better determine the feasibility level needs of the stakeholders.

2.4 Low-Flow Channel Assessment

Considerable effort was expended to estimate approximate channel dimensions for a low-flow channel to convey base flows through the project reach. Design of such a channel was not conducted under this limited scope of work but potential configurations were considered. It is quite probable that specific reaches within different segments of the project will require channel dimensions that vary along the longitudinal profile. Therefore gross assumptions of slope were used for the preliminary analyses.

The low flow channel assessment was laborious due to 1) the very low gradient of the stream, 2) the presence of a channel bed composed of silt and clay which lead to uncertainty in sediment transport analyses, 3) the existence of numerous bridges, culverts, and a very irregular longitudinal profile in the channel bed, 4) the very limited potential for increasing sinuosity within the existing narrow urban corridor, and 5) limited hydrologic data was available from USGS gage number 06471770 located at Aberdeen. This gage has a relatively limited record that dates back only to 1999. In light of this, we did not feel that it was appropriate to perform a regression analysis to predict long-term event recurrence intervals. Existing cross-sections obtained from natural channel reaches in the HEC-2 analyses were viewed to assist in determining potential bank-full channel dimensions.

Preliminary design of the low flow channel was conducted using data from the existing HEC-2 (imported into HEC-RAS) model, the USGS gage station, sediment data supplied by the DENR, and rudimentary sediment transport analyses utilizing incipient motion analyses.

Section 3 - Conceptual Design

Section 3.1 – Geomorphic Setting

Moccasin Creek, a tributary to the James River, flows southward through Brown County and the city of Aberdeen, South Dakota. The growth and urbanization of Aberdeen in the early 20th century lead to the channelization and widening of Moccasin Creek. The project reach for this report includes approximately four miles of channelized floodway, beginning at the railroad crossing north of 8th Avenue NE and extending downstream to Crystal Avenue which is located just north of the wastewater treatment plant and near the confluence with Foot Creek. Figures 1 and 2 present the project limits that were defined for this study. Similar observations to those described herein would likely also be appropriate for the dredged reach located downstream of Crystal Avenue if restoration of this area was desired.

A brief description of recent geologic history of the region is necessary to understand the present fluvial geomorphic characteristics of Moccasin Creek. During the mid- to late Pleistocene Epoch (0.7 to 0.13 m.y.), the Illinoian and Wisconsin ice sheets, respectively, moved southward across North America, and covered eastern South Dakota several times. As the glaciers advanced, they smoothed and scoured the terrain. As the ice melted and the glaciers retreated, they deposited sediments called glacial drift, composed of mostly fine silt and sands. The ice front stabilized temporarily to the south near Redfield, South Dakota, forming a natural ice dam. The glacial melt water formed a lake called Lake Dakota where glacial lake deposits of sands, silts, and clays accumulated. When the dam breached, catastrophic floodwaters eroded the James River valley. The present James River Valley is much wider and larger than one would expect given the small rivers and tributaries that exist today. Moccasin Creek possibly also exists within a slightly oversized valley as evidenced by what we have interpreted to be possible geomorphic bank full indicators on several of the HEC-2 channel cross-sections in the "undisturbed" reaches upstream and downstream of the city. These observations are based primarily on the HEC-2 cross-sections presented in Figures 1 and 2, and further detailed in Appendix A.

The nearly flat channel slope of Moccasin Creek may be attributed to the region's glacial history. Typical of a low gradient stream, non-channelized reaches of Moccasin Creek upstream and downstream of the project reach maintain a tortuous meander pattern, meaning the active channel forms very tight and intricate meander loops. Approximately one mile of non-channelized reach north of the project area has a sinuosity (channel length/valley length) of 2.4. The reach south of town, beginning at the confluence with Foot Creek, maintains a relatively natural meander planform with a sinuosity of 2.7. The meander belt width above and below the project reach ranges between 2,000 and 3,000 feet. The high sinuosity channel appears to be maintained by a relatively deep, but wide, channel configuration with relatively stable, vegetated, cohesive banks and floodplain surfaces. The active floodplain in the natural reaches appears quite wide. This floodplain would have included the area currently occupied by the city of Aberdeen prior to urbanization. When slope is extremely low, a relatively deep, narrow channel geometry (low width/depth ratio) is usually required to maintain sediment conveyance. If the cross-section data is correct, that does not appear to be the case for Moccasin Creek in the natural channel sections. They appear wide with relatively high width to depth ratios. The non-channelized segments of Moccasin Creek upstream of Aberdeen are about half the wetted channel width (60-80 feet) of the dredged project reach (approximately 150 feet wide).

3.2 Existing Project Reach Conditions

The 3.8-mile project reach is composed of channelized floodway that is crossed by 11 bridge structures. Average channel drop of 0.9 feet (computed from HEC-2 data between the inverts at the bridges at the project margins) over a corresponding channel length of 22,250 feet yields an average bed slope 0.000044, or 0.23 feet per mile of stream. When computed based on the topographic map, the slope of the project reach is approximately 0.000192, based on only 3 feet of vertical drop over a channel length of 15,600 feet (the length of channel between known 1- foot contour intervals). Approximately 2 feet of drop occurs at the railroad and Railroad Avenue. The majority of the project reach, from Railroad Avenue downstream to a point 3,000 feet below Melgaard Road has a computed bed slope of 0.00008. The floodway top width ranges between 80 and 180 feet with a sinuosity of less than 1.1. Bridge structures cause frequent local constriction and channel narrowing. The low slope values, coupled with restrictions and apparent grade controls at road crossings create hydraulic backwater and stagnant conditions at base flow. Immediately below the structures, the channel grade typically appears to increase slightly, allowing the channel to narrow temporarily with the increased flow velocities. There is no true low-flow channel in the flood channel unless the channel is not dredged. If left undredged, a low-flow channel tends to form through the vegetation as indicated by a distinct single-thread channel on the aerial photographs.

3.3 Historic Sedimentation Patterns and Maintenance

Historic aerial photographs of the project reach included coverage from 1958, 1975, 1979, 1994, and 1999. Analysis and interpretation of changes in channel width and extent of vegetation adjacent to the channel helped determine floodway segments that appear most prone to sedimentation, and historically, have required routine dredging or maintenance. It is important to recognize that this historic aerial photo analysis is limited to the quality and resolution of available photo coverage. Changes in channel dimensions, sediment yield, and distribution of vegetation could also be attributed to specific high-flow events or simply to the flow volume (stage/inundation) or time year that the photos were taken.

In 1958, Moccasin Creek appears completely channelized and clear of visible sediment or vegetation throughout the project reach, 8th NE Avenue to Crystal Road. It is also clear downstream to the confluence with Foot Creek. Historically, sedimentation has occurred immediately downstream of Melgaard Road for about 1,700 feet and upstream of the bridge for about 800 feet. By 1975, the sewage plant and pond facility had been increased in size and capacity. However, the wetted channel width in this segment was narrower in 1975 (30-40 feet) than indicated in the 1958 photo (50-80 feet). Vegetation was well established through this segment in both the 1975 and 1979 photos. Thus, the lower portion of the project reach downstream of Melgaard Road to Crystal Road was dredged at some time between 1979 and 1994.

In the mid-1970's, the city of Aberdeen purchased a dredge, with the intent to pump the sediment slurry to predetermined storage sites. The availability of water to pump the dredged slurry to the disposal sites properties was insufficient, and no further dredging with this equipment was attempted. In 1979, the City of Aberdeen initiated a Moccasin Creek Channel Dredging and Improvement Project, including disposal site construction. The city hired a private contractor to dredge portions of the floodway. A particularly cold winter allowed the contractor to access the floodway across the ice, break through the ice, and excavate portions of the channel. Sediment was then hauled to disposal cell sites immediately north of Crystal Road on the west side of the channel (personal communication, Stuart Nelson, Public Works, Office of City Engineers, Aberdeen SD.). As-built planform maps from the city engineer's office indicate an additional disposal site was located on the east side of the floodway immediately north of Melgaard Road. The 1979 As-Built Phase 1 plans show three project phase reaches: Phase 1- confluence of Foot Creek to Melgaard Road; Phase 2- Melgaard Road to 6th Avenue SE (Hwy 12); and Phase 3- 6th Avenue SE to the Railroad bridge.

Historically, channel narrowing caused by sedimentation and colonization of emergent plants is most prevalent downstream of Melgaard Road to Crystal Road and also downstream of Crystal Road. The 1979 photographs indicate that sedimentation and vegetation encroachment has also occurred downstream of the 10th Avenue bridge for about 800 feet to the footbridge, adjacent to the baseball fields. At present, a large bar deposit has formed along the right bank, upstream of 10th Avenue. The channel appears to have remained relatively stable farther upstream to 8th Avenue. Likewise, 1979 photos indicate vegetation encroachment was more sporadic, occurring in shorter segments (50-200 feet) immediately upstream of 8th Avenue, midway between 8th and 6th Avenue, and immediately upstream and downstream of 6th Avenue. The 1999 photos indicate that these areas have been dredged since 1979. The floodway segment between 3rd Avenue SE and the railroad bridge was also considerably narrowed by vegetation in 1979. Sometime between 1979 and 1994, Milwaukee Avenue was extended to the east, crossing Moccasin Creek immediately downstream of the railroad bridge. A wetland complex and tributary drainage on the right (west) floodway was subsequently converted to an oval pond. From the railroad crossing upstream to Roosevelt Bridge, the channel appears to have remained stable. Finally, historic channel narrowing and vegetation encroachment has occurred downstream of 8th Avenue NE. In 1958 and 1979, the channel is wide, but has narrowed to less than half its dredged width by 1994. The first 2,000 feet downstream of 8th Avenue NE appear to experience the greatest rate of sedimentation.

However, specific rates of sediment accumulation cannot be calculated unless specific post-dredging topography is available.

3.4 Hydrology and Hydraulics

The hydrologic record for Moccasin Creek is insufficient to perform a flood frequency analysis. USGS gaging station No. 06471770 in Aberdeen, SD offers two years (2000-2001) of stage height data, but no mean daily flow volumes or a rating curve to compare relative stage to discharge volumes. Instantaneous peak flows were reported as 60 cubic feet per second (cfs) and 100 cfs on July 7, 2000 and April 10, 2001, respectively. These are likely caused by thunderstorms in July and possibly snowmelt, rain-on-snow, or rainfall events in April. Specific meteorological data for the specific flooding time period would have to be obtained to discern the cause of the flooding.

Examination of the limited available flow data and recent storm hydrographs from stations in the project reach indicate that the hydrology of Moccasin Creek is flashy. Steep spikes in the hydrograph show the hydrology is likely driven by rainstorm and rain-on-snow events. Surface runoff from the surrounding watershed is delivered to the channel rapidly due to urban and agricultural development. Likewise, an increase in impervious surface areas and storm sewer drainage systems contribute high discharge, short duration flooding. At most times the base flow appears to be less than 1 cfs throughout the summer.

Large storm events that produce overland flow through the urban and agricultural land surface transport sediment to the channel. Low velocity backwater effects above bridges and in low gradient dredged reaches cause sediment to be deposited in the slack water. In addition, many of the dredged reaches between bridges have a channel bottom that is below the elevation of the channel at the bridge locations. This causes continual wide ponding, aquatic growth, and sediment deposition. Low base flows do not move the ponded water sufficiently to prevent excessive weed growth. The low velocities provided in the HEC-2 data suggest that deposition will occur at all but the highest discharges.

3.5 Sediment Transport

In an effort to better define site hydraulic conditions, the existing HEC-2 water surface profile analysis that was performed for the project reach previously by others, was used extensively. The existing HEC-2 model was imported into an early HEC-RAS model using the pre-existing input data. The HEC model was quite detailed due to the large number of road and railroad bridges that crossed the alignment. HEC-2 output specific to the project reach are contained in Appendix A. HEC-2 cross-section locations are also shown on Figures 4 through 8 along with project limits, bridge locations, road identifications, and the 1999 aerial photo base map.

Within the project reach, channel inverts for dredged cross-sections are presented in Appendix A in the section titled HEC-2 Data. It is very clear that inverts between bridges are typically at elevations lower than the channel inverts at the bridge crossings themselves. This condition will lead to ponding at low flow conditions and sediment deposition unless turbulence prevents deposition. Observation of the HEC-2 output indicates that channel shear stresses are rarely greater than 0.10 psf except within and directly above and below bridges or culverts. In these dredged areas, shear stress normally did not exceed 0.5 psf even in the most extreme events with discharges of 22,800 cfs and where water depths were as much as 25 feet above the channel invert at the Railroad Avenue/Railroad Bridge. It is instructive is that natural stream cross-sections upstream in the meandering sections (264848 and 262843) also have computed channel shear stresses that do not exceed 0.01. Since these cross-sections were not viewed directly, it is not possible to say whether they are geomorphically stable sections. However, air photos do not seem to indicate that they exhibit erosional or depositional features indicative of unstable reaches. Additionally, natural cross-sections 213750, 214980, and 221840 (immediately downstream of a dredged reach) indicate channel shear stress values (at all flows) less than 0.20 psf and in most cases, less than 0.10 psf. Again, these sections do not appear to be unstable. Channel velocities in sections 264848 and 262843 were computed to be 0.3 to 0.8 feet per second (fps) at all flows with energy grades that were typically in the range of 0.00001 or less. Channel velocities in sections 213750, 214980, and 221840 typically increased from approximately 1 fps at low flows to 3 fps at the highest flows and with energy grades of approximately 0.000200. Within the project reach, velocities varied considerably but were typically 1 to 2 fps between bridges and much higher in the immediate vicinity of bridges. Energy grades varied considerably.

Computation of the critical shear stresses and velocities necessary to initiate incipient motion for channel beds in silt and clay are difficult. Electro-chemical interactions in clays complicate shear stress determinations of incipient motion. Most hydraulic test data and field data have concentrated on sand and fine gravel sizes where uplift and drag forces on the coarser materials form the basis for theoretical and physical movement of particles. Therefore attempts at determining critical shear values to match expected values in the undisturbed sections were not fruitful. Sediment transport analyses most often utilize the Shields diagram to determine the point at which incipient particle motion will occur (Chow, 1988). However the diagram does not include data for fine-grained sediments that are found on this project site. Data forwarded to us suggest that the soils in the channel are silts and clays with a d_{50} of approximately 0.003 mm (or 3 micrometers) (see Appendix A, Particle Size Analyses). Mantz, 1977 extended the data for the Shields diagram to smaller particles (but none as fine as those present on this project) and determined that the critical shear stress for non-cohesive soils with median grain diameters of approximately 15 microns (0.015 mm) was approximately 0.4 to 0.6 psf. Mehta, 1989 presented data that suggest the shear stress necessary to overcome the particle settling velocity for silts and clays can vary considerably and is dependent on particle plasticity, turbulence, etc. as well as diameter. Breusers and Raudkivi, 1991 present similar observations and further suggest that the void ratio of the soil is very important. Chang, 1992 presents data generated by Fortier and Scobey that indicate maximum permissible channel shear stresses of 0.11 psf for silt loams and to 0.46 psf for very stiff clays. Values higher than these will lead to scour.

It is apparent that a quantitative evaluation of channel shear stress and velocity will not be sufficient to design a low flow channel. Numerous iterations were performed to determine if channel configurations could be developed that would provide sufficient shear to move the cohesive sediments through the system without deposition. Narrow channels with steep sides did not produce sufficient shear to exceed 0.4 to 0.6 psf and would thus potentially fill in over time. A channel with a 16 foot bottom width and 12:1 side slopes seemed to produce the highest shear stresses but required flows of 190 cfs to produce shear values of 0.014 psf. These are very nearly what was observed in the natural channel below the project when flows were similar.

3.6 Evaluation of Natural Cross-Sections

Clearly, sections of Moccasin Creek that have not been disturbed appear to be transporting sediment and do not seem to indicate signs of instability such as eroding banks, changing depositional bedforms, or changes in width of either the floodplain or channel. Therefore, five natural cross-sections were investigated to determine if there was a common form or shape that could be utilized to serve as a template through the project reach.

Bankfull indicators could not be observed due to the limited budget for this study. Therefore, the HEC-2 cross-sections were plotted and analyzed to determine if a common bank dimension, depth, or form was prevalent. Cross-sections 213750, 214980, and 221840 were located below the confluence with Foot Creek. They seemed to have a distinct slope break that potentially indicated a bankfull condition. This indicator was observed on all three sections. At this level, all indicated a discharge of approximately 190 cfs, a channel shear stress of 0.02 to 0.03 psf, a hydraulic radius of 2.0 to 2.5 feet, and a width to depth ratio of approximately 30. At the top of the upper bank a discharge of 930 cfs was calculated with a channel shear stress of 0.04 to 0.05 psf, a hydraulic radius of 3.2 to 3.4 feet (5.1 on 221840 but it spilled over the floodplain at this flow), and a width to depth ratio of 36 to 51. The trial design channel with the 16-foot bottom and 12:1 side slopes and a 4 foot depth at a flow of 190 cfs produced a channel shear stress of 0.014 psf, a hydraulic radius of 2.3, and a width to depth ratio of 28. The channel slope was assumed to be 0.0001.

Above the project, natural sections produced no clear delineation of the channel forming flow, but a bank-full flow was computed to be approximately 310 cfs. It is possible that a nested channel exists within this channel but the indicators were not picked up for the HEC-2 cross-sections. Further fieldwork would have to be conducted to determine if a lower frequency flow produces a channel forming flow at lesser discharge.

Preliminary analysis suggest that the potential for creating a channel that mimics the natural channel may be the best alternative for placing a low-flow channel within the existing flood channel. However, the lack of space to recreate meander patterns may require periodic maintenance in areas of high stress if erosion results. It is very clear that the existing channel would prefer to narrow, and that when it does, it tends to stay open. This has occurred even in the low gradient area below Melgaard Road. The tendency of the stream to create this channel over time suggests that opportunities exist for proper sizing of a self-maintaining channel through the urbanized area.

Section 4 - Conceptual Design Plan

4.1 Pilot Channel Geometry and Planform

Channel planform will be difficult to accurately judge analytically and indicators from natural sections will likely have to be employed to develop a low-flow channel. At this time, it appears that a distinct low-flow channel would not be appropriate. A channel with a slightly curved invert to channelize the low base flows of 1 cfs will be required to prevent stagnation. The channel would most likely be a broad channel with a width to depth ratio of approximately 30, a hydraulic radius at bankfull of 2 to 2.5, and side slopes of approximately 10 to 15:1. Exact duplication of the natural sections downstream of Foot Creek would probably not be appropriate since these sections take the combined flows of both Moccasin and Foot Creeks. Placement of fill on the existing channel side slopes will likely be required to produce a low-flow channel. A long-term, and less costly, approach would be to allow the channel to infill naturally and let a low-flow channel develop on its own. However, this may take considerable time and may not be in the best interest of the city if the present situation is a nuisance to the public or if it is desirable to expedite the project from an aesthetic standpoint.

Vegetation should be allowed to emerge to trap sediment and form a more functional natural channel. If flood elevations are a concern, the vegetation could be maintained to prevent the development of species or woody plants that would increase channel roughness to a point that it affected conveyance. Channel areas lower than the bridge channel bottoms will require channel fills. HEC-RAS analyses to verify that hydraulic conveyance is not affected will be required. It is our opinion that minor increases in channel bottom will likely not affect the larger flows but will likely affect the flows that are currently within the channel banks. The magnitude of this effect would depend on the depths of fill required. Above the existing banks, the overbank areas are exceedingly flat so 100-year flood levels would likely not be impacted much, if any. A Letter of Map Revision (LOMR) to the existing Flood Insurance Study (FIS) may be required to update flood insurance mapping.

Within the channel, native species appropriate for periodic inundation would provide the optimum reclamation. The city could consider wetland banking alternatives to sell created wetlands to SDDOT.

Excavation and/or placement of fill materials within the existing Moccasin Creek channel would fall under federal regulatory jurisdiction. The U.S. Army Corps of Engineers (Corps), pursuant to Section 404 of the Clean Water Act, regulates the discharge of dredge or fill material into waters of the U.S. Permits for regulated activities are issued under various forms of authorization. These include *individual* permits that are issued following a review of individual applications and *general* permits that authorize a category or categories of activities in specific geographical regions or nationwide. The term "general permit" refers to both those regional permits issued by district or division engineers on a regional basis and to nationwide permits which are issued by the Chief of Engineers through publication in the Federal Register, and are applicable throughout the nation. The nationwide permits are found in 33 CFR Part 330. If an activity is covered by a general permit, an application for a Corps permit does not have to be made. In such cases, a person must only comply with the conditions contained in the general permit to satisfy requirements of law for a Corps permit. In certain cases pre-notification may be required before initiating construction.

A cursory review of existing nationwide and regional Corps' permits indicates that construction of a low-flow pilot channel in Moccasin Creek would likely require an individual permit. Individual permit applications are subject to a public notice and comment period, which is typically 30 days. Final decisions on permit application are typically issued within 90 days of application submittal.

Inter-Fluve discussed other potential permitting requirements with South Dakota DENR and City of Aberdeen personnel. At this time, it appears that the Corps of Engineers 404 permit would be the primary permit required for this project. No other specific permits for work within the Moccasin Creek channel were identified.

Inflows from storm drains can be routed through constructed wetlands prior to entering the stream corridor. These can be constructed within the existing channel margins if necessary. These form an area for sediment deposition and can be maintained periodically to remove the sediment load once the channel has stabilized. Water Quality benefits may also occur as a result.

Dredging of the channel continues the cycle of deposition in the channel. This will be a continuing concern as long as runoff from urban and agricultural land continues to supply sediment. Overly wide constructed ponded areas, such as the dredged areas in Aberdeen, have been used upstream of pumping stations to reduce the sediment at pump intakes. Continual maintenance has been the result in these areas and is possibly an analog for Moccasin Creek through Aberdeen.

These analyses are preliminary in nature and should not be used as a basis for designing a template channel. Additional hydraulic work to incorporate aspects of storm drainage, specific discharge design, hydraulic action around bridges and culverts, and impacts to FEMA flood mapping will all be required. However, it appears that with thoughtful design, a channel can potentially be constructed through Aberdeen that would improve aesthetic attributes and perform hydraulically.

Section 5 – Bibliography

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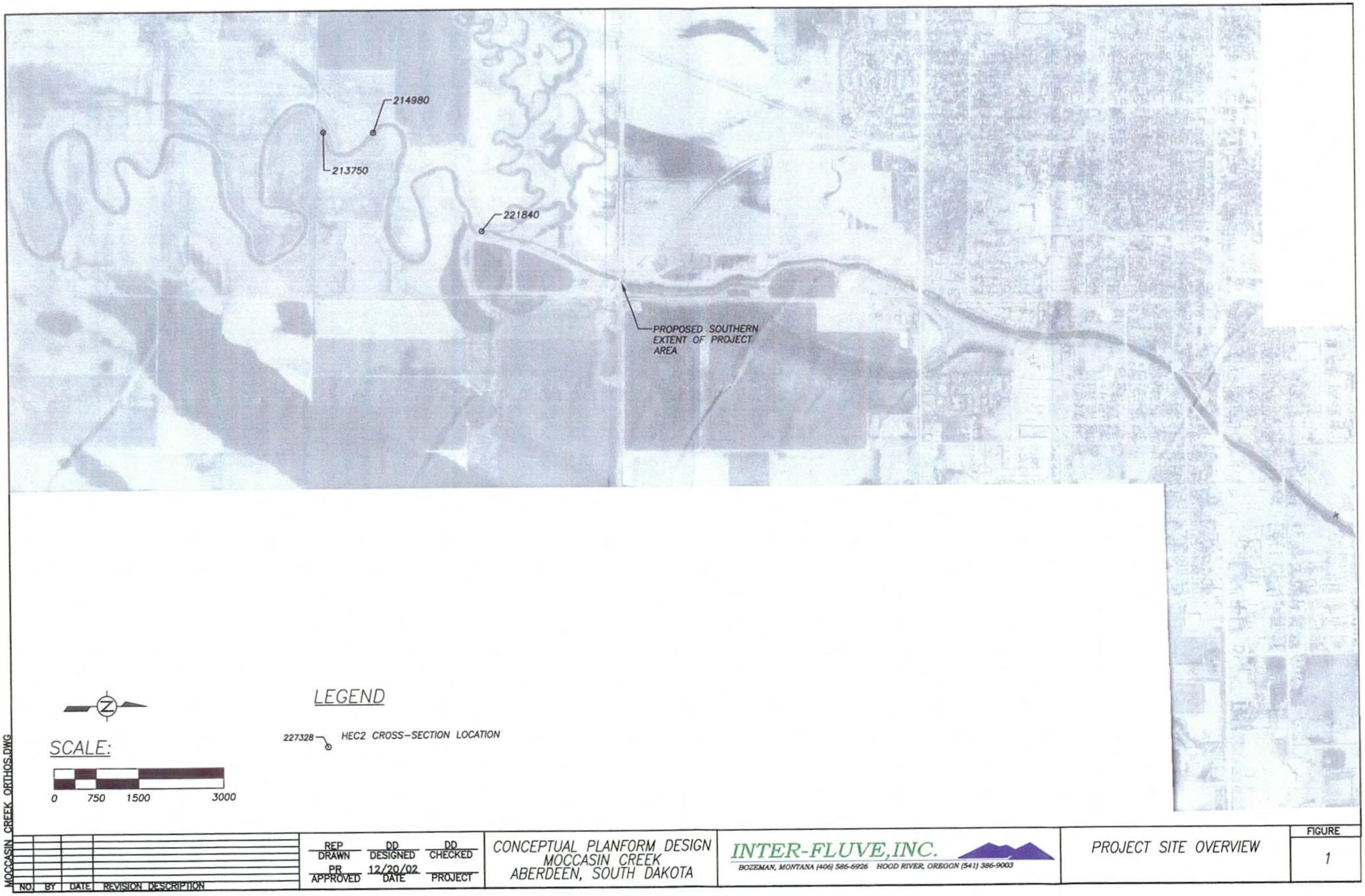
214980
213750
221840
PROPOSED SOUTHERN EXTENT OF PROJECT AREA
LEGEND
227328
HEC2 CROSS-SECTION LOCATION
SCALE:
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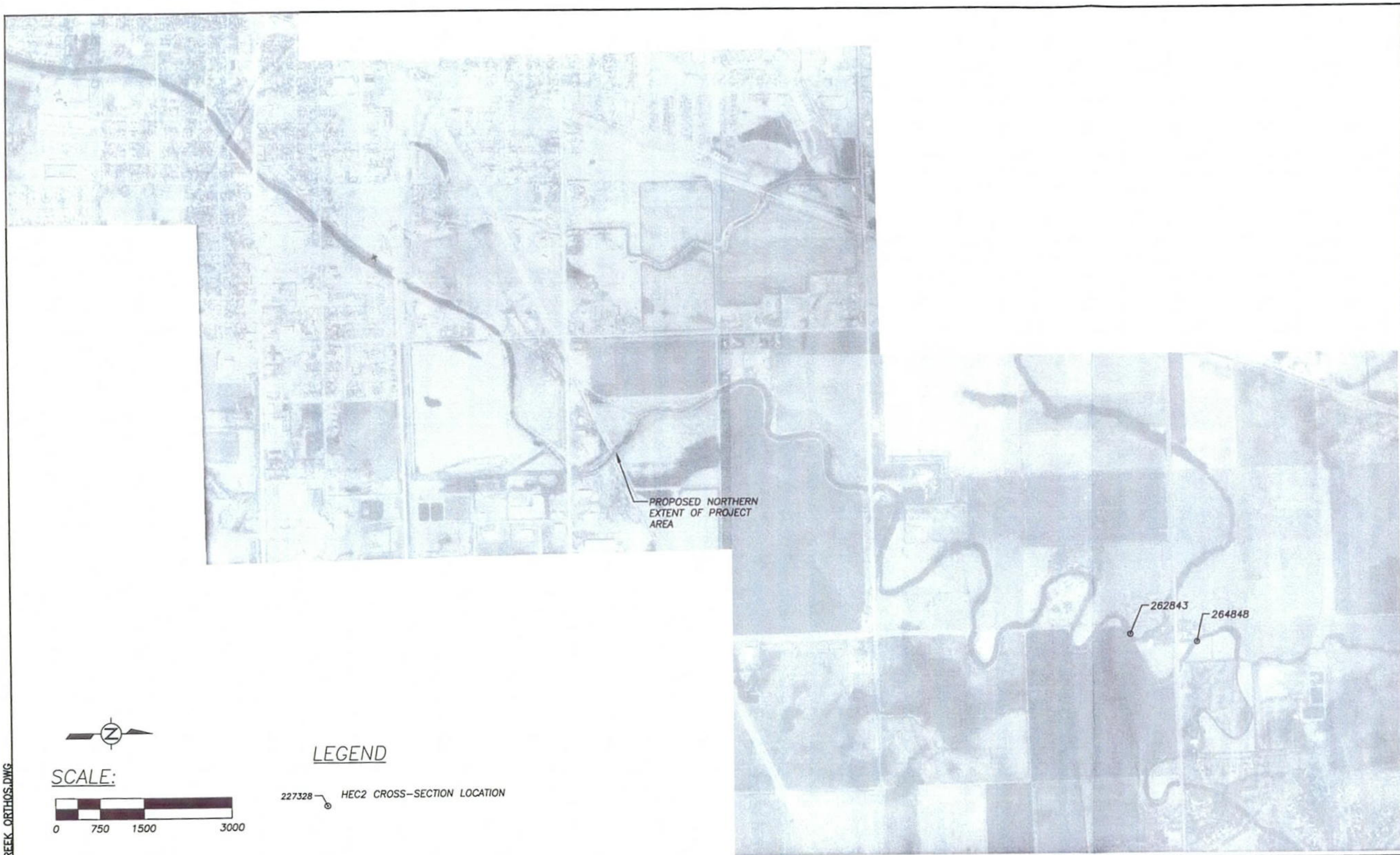
MOCCASIN CREEK ORTHOS.DWG
NO BY DATE REVISION DESCRIPTION
REP DRAWN
DD DESIGNED
DD CHECKED
PR APPROVED
12/20/02 DATE
PROJECT
CONCEPTUAL PLANFORM DESIGN
MOCCASIN CREEK
ABERDEEN, SOUTH DAKOTA
INTER-FLUVE, INC.
BOZEMAN, MONTANA (406) 586-6926 HOOD RIVER, OREGON (541) 386-9003
PROJECT SITE OVERVIEW
FIGURE
1



MOCCASIN CREEK ORTHOS.DWG

NO	BY	DATE	REVISION DESCRIPTION

REP DRAWN	DD DESIGNED	DD CHECKED
PR APPROVED	12/20/02 DATE	PROJECT

CONCEPTUAL PLANFORM DESIGN
MOCCASIN CREEK
ABERDEEN, SOUTH DAKOTA

INTER-FLUVE, INC.
BOZEMAN, MONTANA (406) 586-6926 HOOD RIVER, OREGON (541) 386-9003

PROJECT SITE OVERVIEW

FIGURE 2

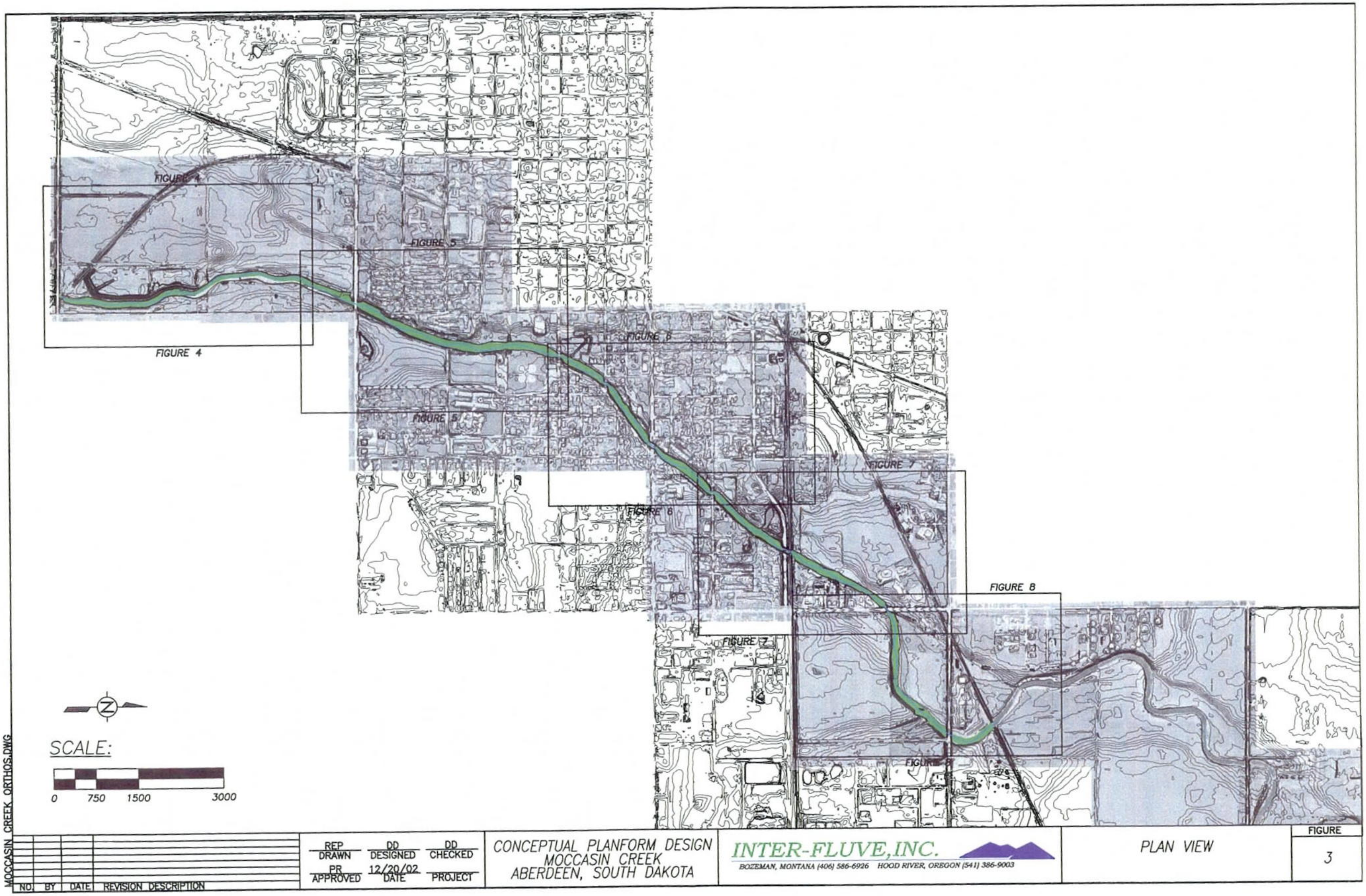
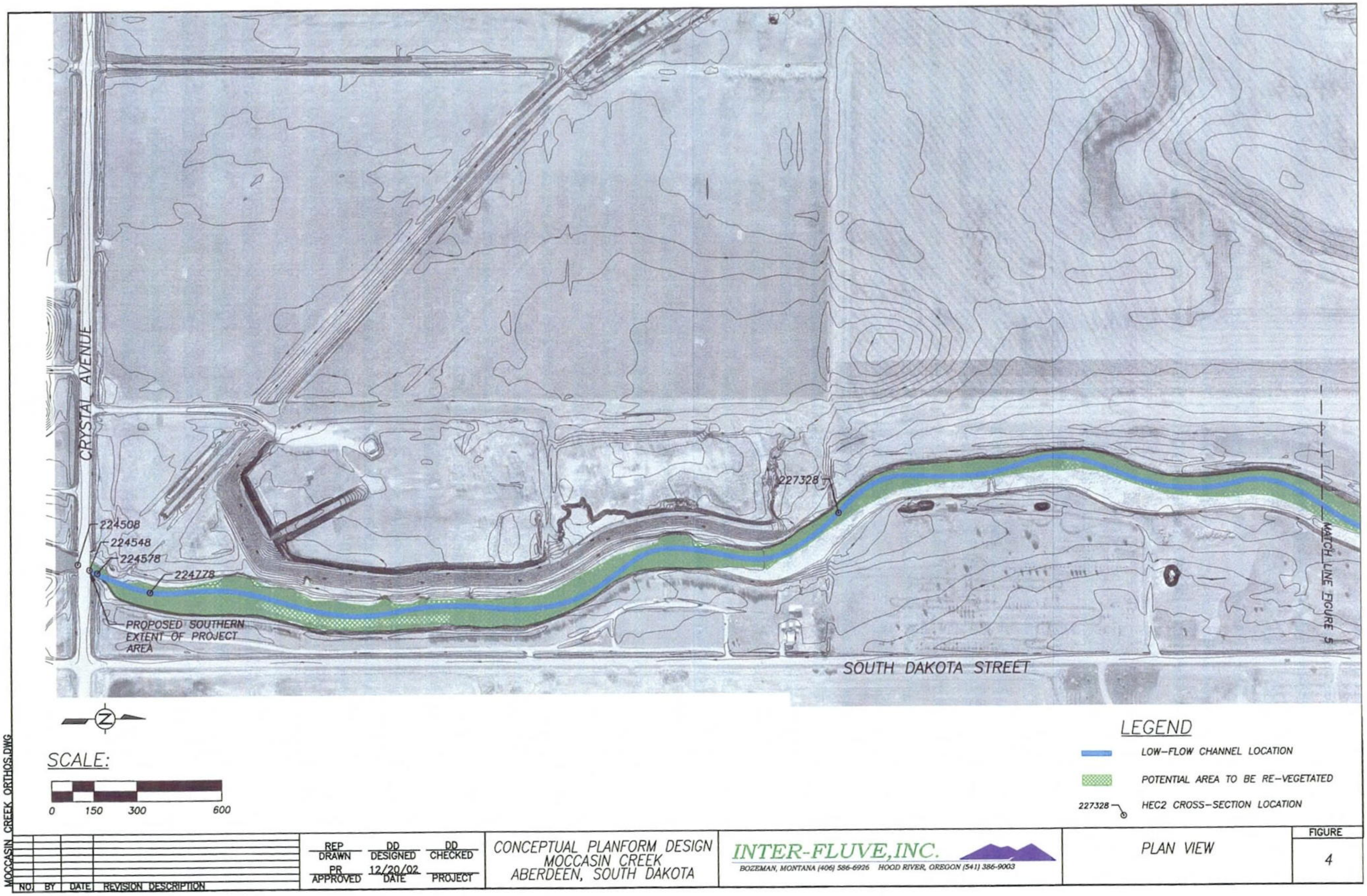
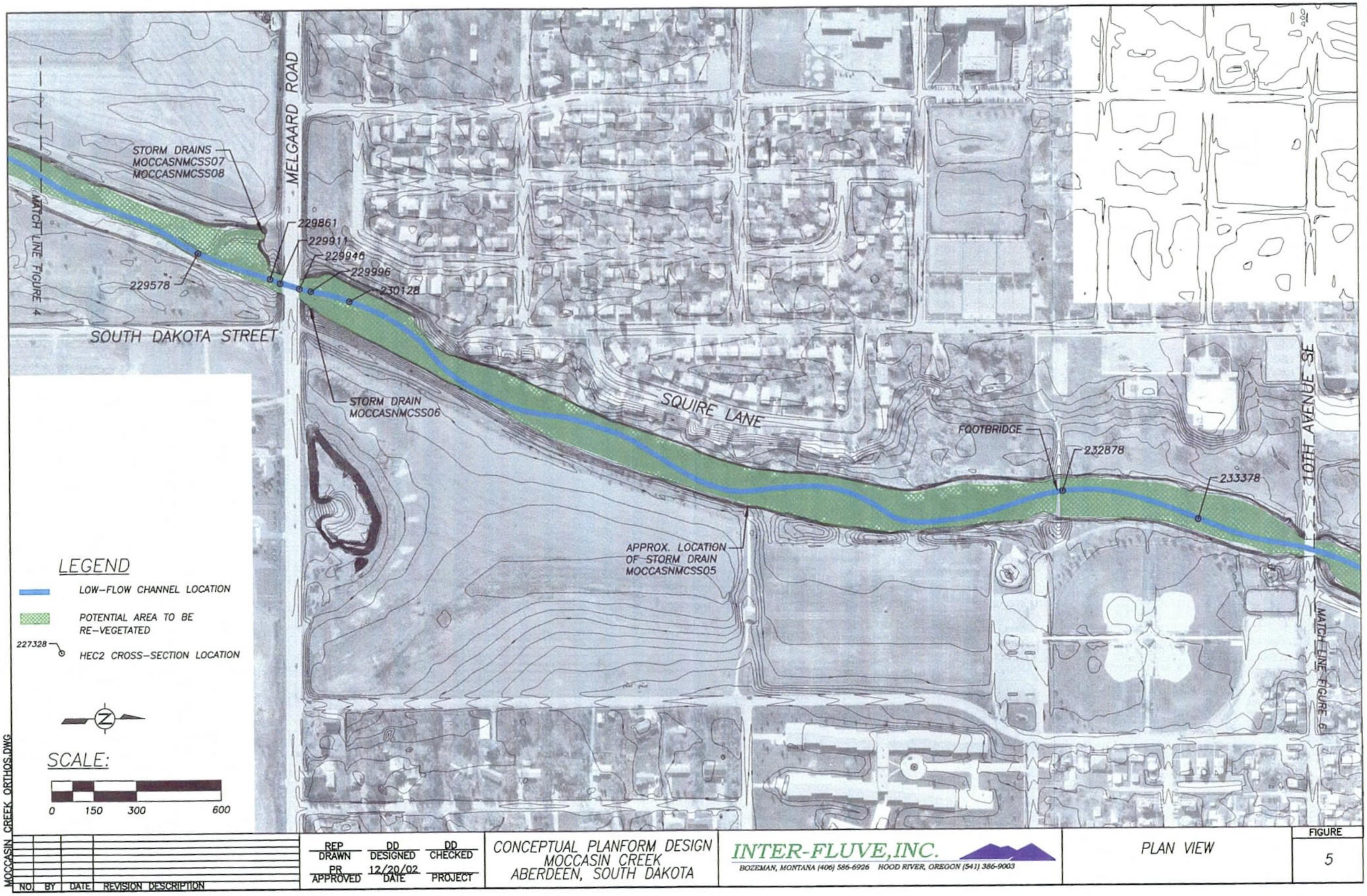
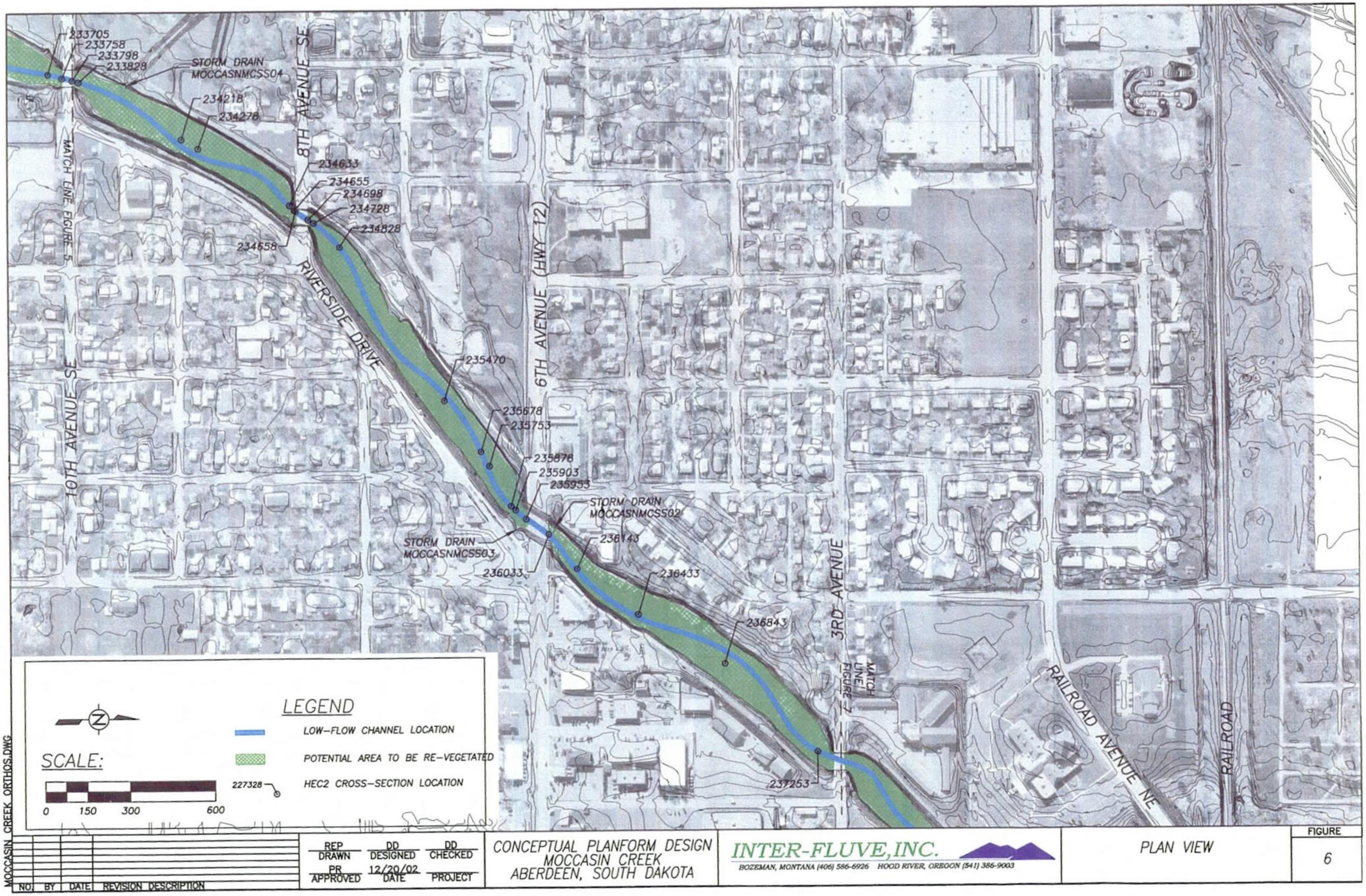
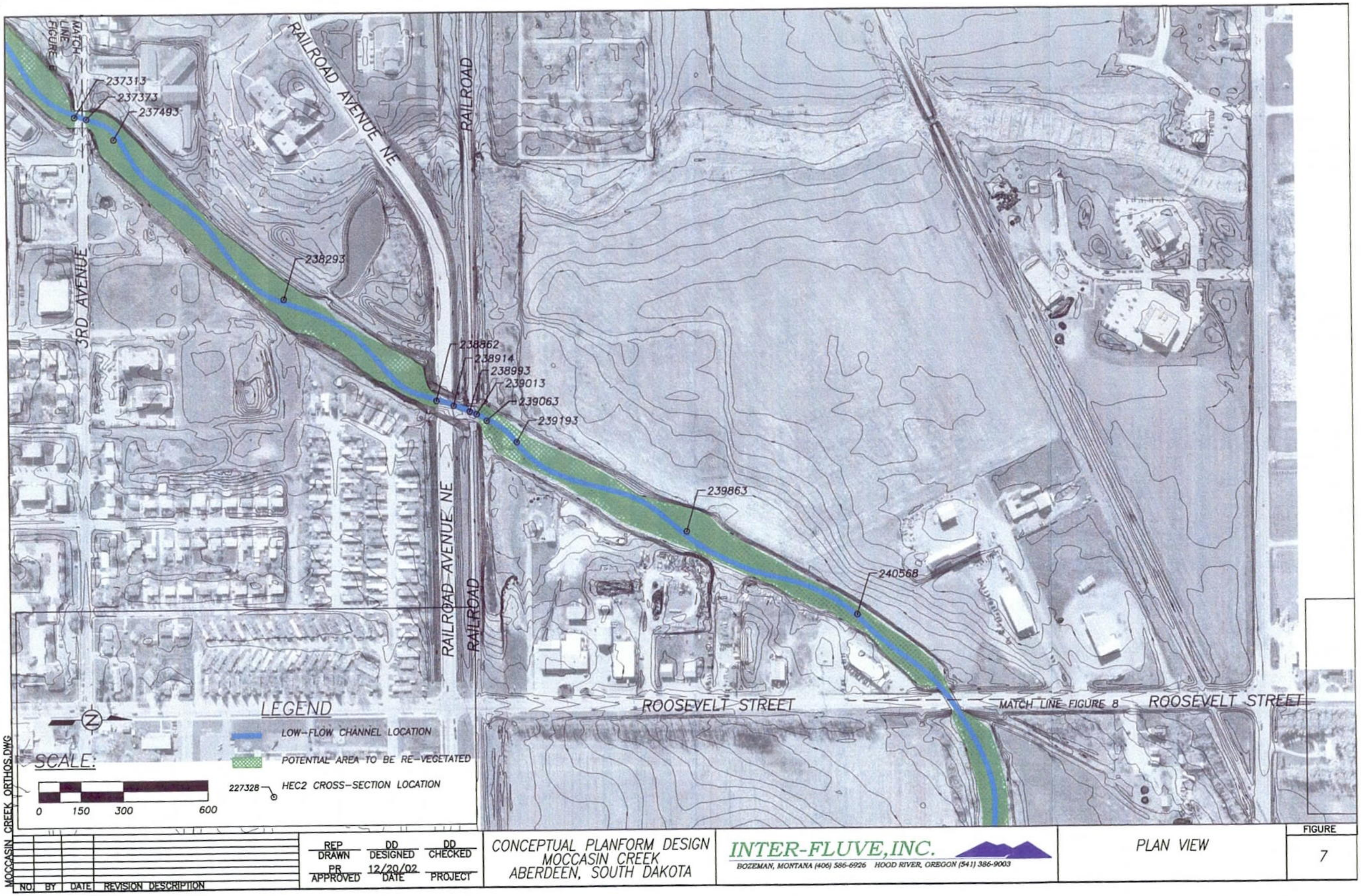


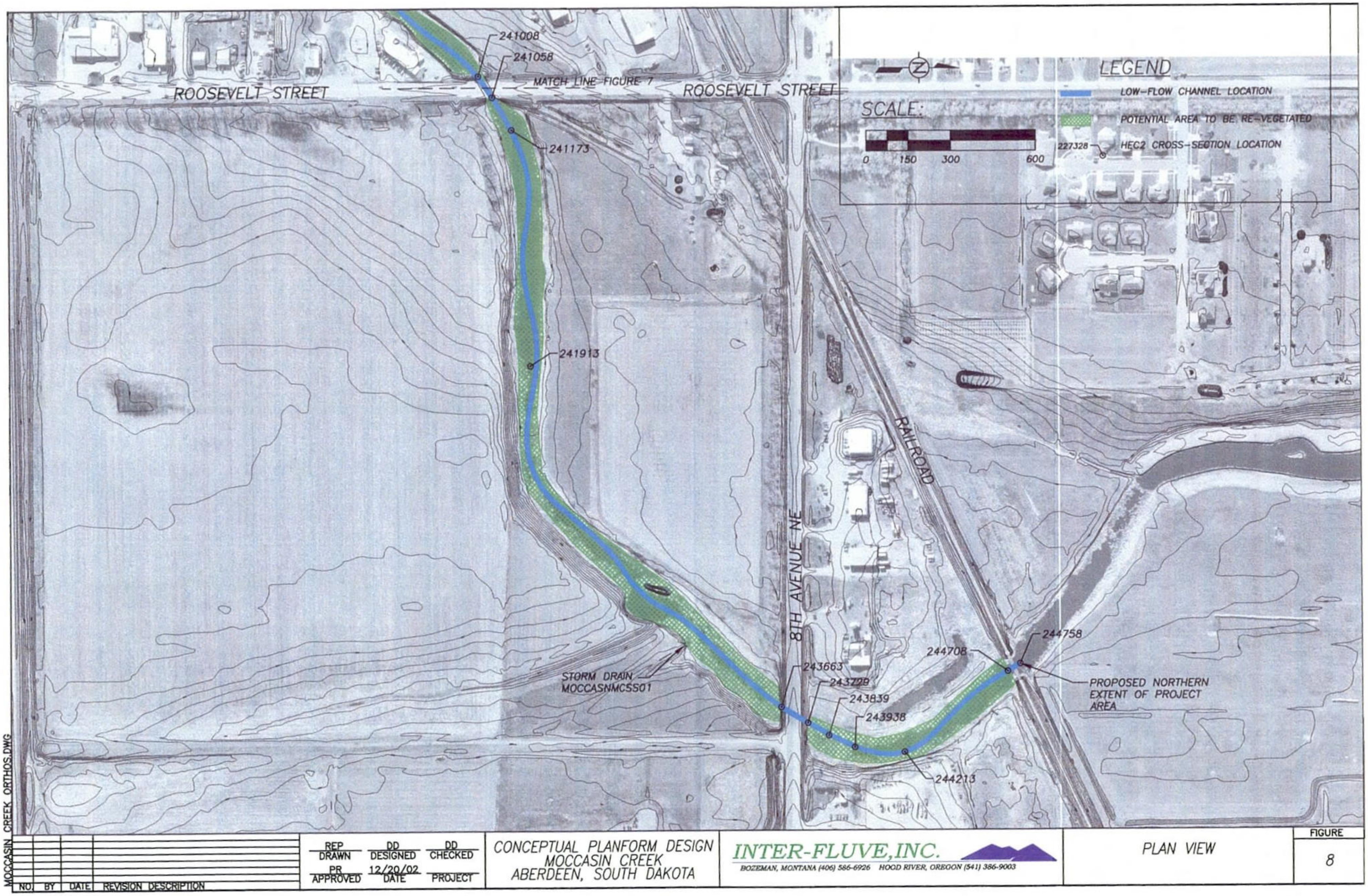
FIGURE 4
FIGURE 5
FIGURE 6
FIGURE 7
FIGURE 8
SCALE:
0 750 1500 3000
MOCCASIN CREEK ORTHOS.DWG
NO BY DATE REVISION DESCRIPTION
REP DRAWN
DD DESIGNED
DD CHECKED
PR APPROVED
12/20/02 DATE
PROJECT
CONCEPTUAL PLANFORM DESIGN
MOCCASIN CREEK
ABERDEEN, SOUTH DAKOTA
INTER-FLUVE, INC.
BOZEMAN, MONTANA (406) 586-6926 HOOD RIVER, OREGON (541) 386-9003
PLAN VIEW
FIGURE
3


CRYSTAL AVENUE
224508
224548
224578
224778
PROPOSED SOUTHERN EXTENT OF PROJECT AREA
227328
SOUTH DAKOTA STREET
MATCH LINE FIGURE 5
SCALE:
0 150 300 600
LEGEND
LOW-FLOW CHANNEL LOCATION
POTENTIAL AREA TO BE RE-VEGETATED
227328 HEC2 CROSS-SECTION LOCATION
MOCCASIN CREEK ORTHOS.DWG
NO BY DATE REVISION DESCRIPTION
REP DRAWN
DD DESIGNED
DD CHECKED
PR APPROVED
12/20/02 DATE
PROJECT
CONCEPTUAL PLANFORM DESIGN
MOCCASIN CREEK
ABERDEEN, SOUTH DAKOTA
INTER-FLUVE, INC.
BOZEMAN, MONTANA (406) 586-6926 HOOD RIVER, OREGON (541) 386-9003
PLAN VIEW
FIGURE
4

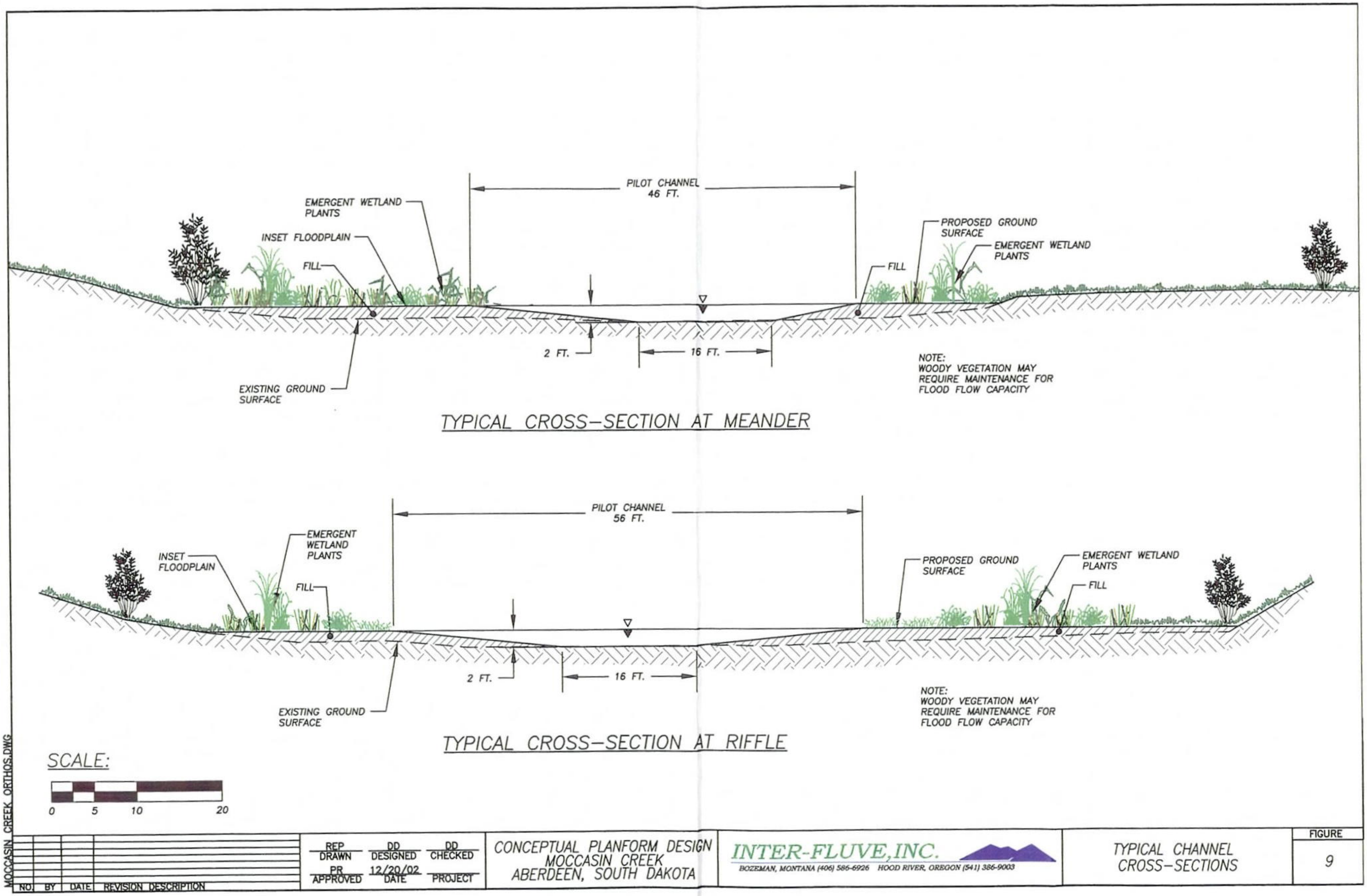

STORM DRAINS
MOCCASNMCSS07
MOCCASNMCSS08
MELGAARD ROAD
MATCH LINE FIGURE 4
229861
229911
229946
229996
230128
229578
SOUTH DAKOTA STREET
STORM DRAIN
MOCCASNMCSS06
SQUIRE LANE
FOOTBRIDGE
232878
233378
10TH AVENUE SE
APPROX. LOCATION
OF STORM DRAIN
MOCCASNMCSS05
MATCH LINE FIGURE 6
LEGEND
LOW-FLOW CHANNEL LOCATION
POTENTIAL AREA TO BE RE-VEGETATED
227328
HEC2 CROSS-SECTION LOCATION
N
SCALE:
0 150 300 600
MOCCASIN CREEK ORTHOS.DWG
NO BY DATE REVISION DESCRIPTION
REP DRAWN
DD DESIGNED
DD CHECKED
PR APPROVED
12/20/02 DATE
PROJECT
CONCEPTUAL PLANFORM DESIGN
MOCCASIN CREEK
ABERDEEN, SOUTH DAKOTA
INTER-FLUVE, INC.
BOZEMAN, MONTANA (406) 586-6926 HOOD RIVER, OREGON (541) 386-9003
PLAN VIEW
FIGURE
5

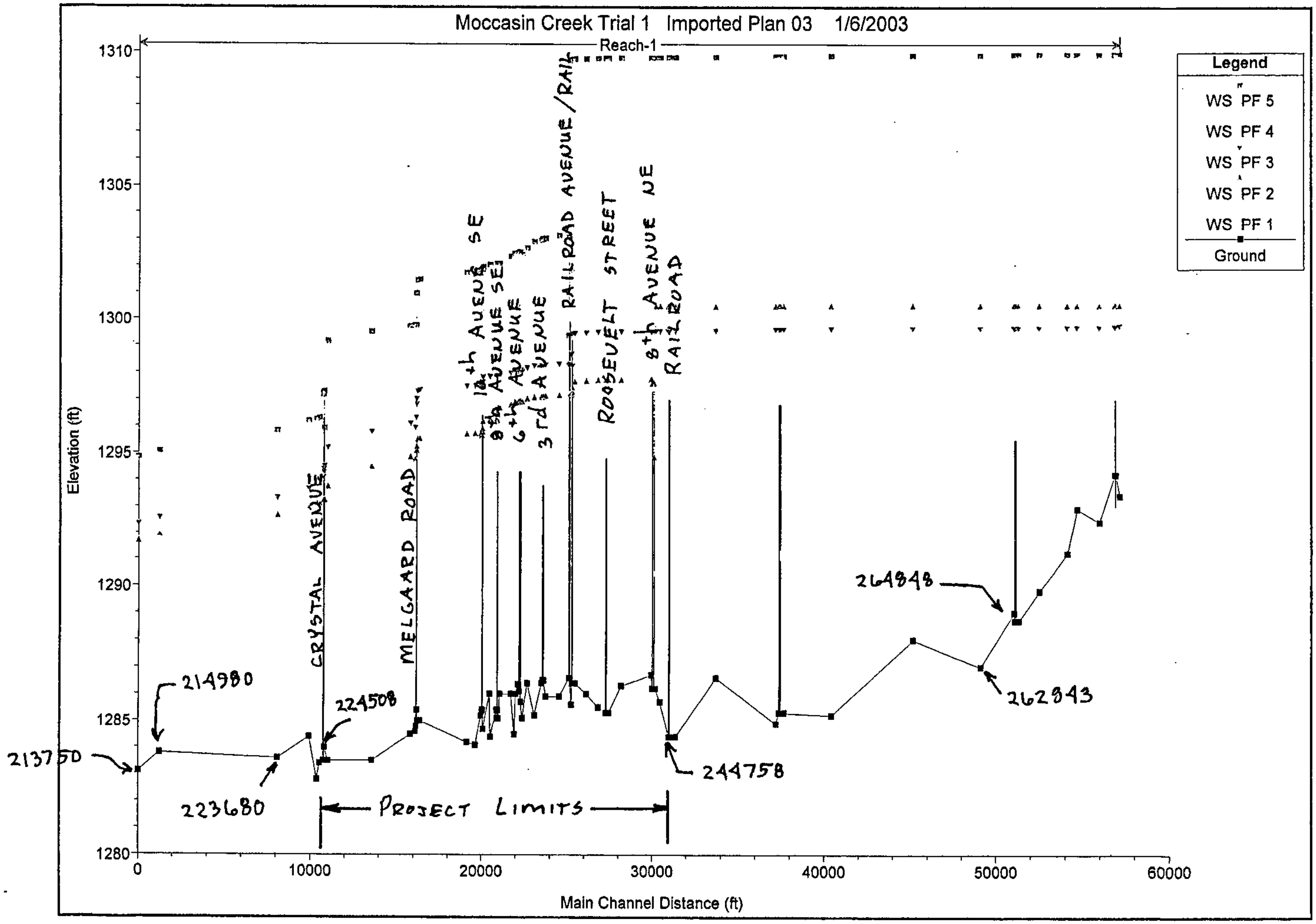

233705
233758
233798
233828
STORM DRAIN
MOCCASNMCSS04
234218
234278
8TH AVENUE SE
MATCH LINE FIGURE 5
234633
234655
234698
234728
234828
234658
RIVERSIDE DRIVE
6TH AVENUE (HWY 12)
10TH AVENUE SE
235470
235678
235753
235876
235903
235933
STORM DRAIN
MOCCASNMCSS02
STORM DRAIN
MOCCASNMCSS03
236033
236143
236433
236843
3RD AVENUE
MATCH LINE FIGURE 7
237253
RAILROAD AVENUE NE
RAILROAD
LEGEND
LOW-FLOW CHANNEL LOCATION
POTENTIAL AREA TO BE RE-VEGETATED
227328
HEC2 CROSS-SECTION LOCATION
SCALE:
0 150 300 600
MOCCASIN CREEK ORTHOS.DWG
NO BY DATE REVISION DESCRIPTION
REP DRAWN
DD DESIGNED
DD CHECKED
PR APPROVED
12/20/02 DATE
PROJECT
CONCEPTUAL PLANFORM DESIGN
MOCCASIN CREEK
ABERDEEN, SOUTH DAKOTA
INTER-FLUVE, INC.
BOZEMAN, MONTANA (406) 586-6926 HOOD RIVER, OREGON (541) 386-9003
PLAN VIEW
FIGURE
6


MATCH LINE FIGURE
237313
237373
237493
RAILROAD AVENUE NE
RAILROAD
3RD AVENUE
238293
238862
238914
238993
239013
239063
239193
239863
240568
RAILROAD AVENUE NE
RAILROAD
ROOSEVELT STREET
MATCH LINE FIGURE 8
ROOSEVELT STREET
LEGEND
LOW-FLOW CHANNEL LOCATION
POTENTIAL AREA TO BE RE-VEGETATED
227328
HEC2 CROSS-SECTION LOCATION
SCALE:
0 150 300 600
MOCCASIN CREEK ORTHOS.DWG
NO BY DATE REVISION DESCRIPTION
REP DRAWN
DD DESIGNED
DD CHECKED
PR APPROVED
12/20/02 DATE
PROJECT
CONCEPTUAL PLANFORM DESIGN
MOCCASIN CREEK
ABERDEEN, SOUTH DAKOTA
INTER-FLUVE, INC.
BOZEMAN, MONTANA (406) 586-6926 HOOD RIVER, OREGON (541) 386-9003
PLAN VIEW
FIGURE
7



ROOSEVELT STREET
MATCH LINE FIGURE 7
ROOSEVELT STREET
241008
241058
241173
241913
STORM DRAIN MOCCASNMCSS01
8TH AVENUE NE
RAILROAD
243663
243729
243839
243938
244213
244708
244758
PROPOSED NORTHERN EXTENT OF PROJECT AREA
LEGEND
LOW-FLOW CHANNEL LOCATION
POTENTIAL AREA TO BE RE-VEGETATED
227328
HEC2 CROSS-SECTION LOCATION
SCALE:
0 150 300 600
MOCCASIN CREEK ORTHOS.DWG
NO BY DATE REVISION DESCRIPTION
REP DRAWN
DD DESIGNED
DD CHECKED
PR APPROVED
12/20/02 DATE
PROJECT
CONCEPTUAL PLANFORM DESIGN
MOCCASIN CREEK
ABERDEEN, SOUTH DAKOTA
INTER-FLUVE, INC.
BOZEMAN, MONTANA (406) 586-6926 HOOD RIVER, OREGON (541) 386-9003
PLAN VIEW
FIGURE
8


PILOT CHANNEL
46 FT.
EMERGENT WETLAND PLANTS
INSET FLOODPLAIN
FILL
2 FT.
16 FT.
EXISTING GROUND SURFACE
PROPOSED GROUND SURFACE
EMERGENT WETLAND PLANTS
FILL
NOTE:
WOODY VEGETATION MAY REQUIRE MAINTENANCE FOR FLOOD FLOW CAPACITY
TYPICAL CROSS–SECTION AT MEANDER
PILOT CHANNEL
56 FT.
INSET FLOODPLAIN
EMERGENT WETLAND PLANTS
FILL
2 FT.
16 FT.
EXISTING GROUND SURFACE
PROPOSED GROUND SURFACE
EMERGENT WETLAND PLANTS
FILL
NOTE:
WOODY VEGETATION MAY REQUIRE MAINTENANCE FOR FLOOD FLOW CAPACITY
TYPICAL CROSS–SECTION AT RIFFLE
SCALE:
0 5 10 20
MOCCASIN CREEK ORTHOS.DWG
NO. BY DATE REVISION DESCRIPTION
REP DRAWN
DD DESIGNED
DD CHECKED
PR APPROVED
12/20/02 DATE
PROJECT
CONCEPTUAL PLANFORM DESIGN
MOCCASIN CREEK
ABERDEEN, SOUTH DAKOTA
INTER-FLUVE, INC.
BOZEMAN, MONTANA (406) 586-6926 HOOD RIVER, OREGON (541) 386-9003
TYPICAL CHANNEL CROSS–SECTIONS
FIGURE
9



Moccasin Creek Trial 1 Imported Plan 03 1/6/2003
Reach-1
Legend
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Elevation (ft)
Main Channel Distance (ft)
1310
1305
1300
1295
1290
1285
1280
0
10000
20000
30000
40000
50000
60000
CRYSTAL AVENUE
MELGAARD ROAD
14th AVENUE SE
8th AVENUE SE
6th AVENUE
3rd AVENUE
RAILROAD AVENUE/RAIL
ROOSEVELT STREET
8th AVENUE NE
RAILROAD
213750
214980
223680
224508
244758
262843
264848
PROJECT LIMITS

HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1

Reach	River Sta	Q Total	Min Ch El	Max Chl Dpth	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Hydr Radius C	Length Chnl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(ft)	(ft)
Reach-1	278063	66.00	1293.40	3.12	1296.52		1296.53	0.000158	0.71	101.76	87.24	0.10	0.02	1.55	224.00
Reach-1	278063	396.00	1293.40	7.12	1300.52		1300.52	0.000002	0.14	6848.46	5022.80	0.01	0.00	4.46	224.00
Reach-1	278063	1650.00	1293.40	6.40	1299.80		1299.81	0.000177	1.37	3256.07	4075.00	0.12	0.04	3.77	224.00
Reach-1	278063	4260.00	1293.40	8.71	1302.11		1302.11	0.000014	0.53	14939.30	5239.00	0.04	0.01	6.06	224.00
Reach-1	278063	13100.00	1293.40	16.57	1309.97		1309.97	0.000002	0.32	56090.26	5239.00	0.01	0.00	13.86	224.00
Reach-1	277839	66.00	1294.20	1.81	1296.01	1295.46	1296.33	0.005233	4.56	14.47	58.06	0.60	0.59	1.81	51.00
Reach-1	277839	396.00	1294.20	6.32	1300.52	1298.81	1300.52	0.000001	0.13	8613.82	5522.81	0.01	0.00	6.32	51.00
Reach-1	277839	1650.00	1294.20	5.58	1299.78	1298.81	1299.78	0.000076	1.16	4687.43	4958.09	0.09	0.03	5.58	51.00
Reach-1	277839	4260.00	1294.20	7.91	1302.11	1299.09	1302.11	0.000009	0.51	17456.18	5561.00	0.03	0.00	7.91	51.00
Reach-1	277839	13100.00	1294.20	15.77	1309.97	1299.59	1309.97	0.000001	0.31	61147.23	5561.00	0.01	0.00	15.77	51.00
Reach-1	277813.5	Culvert													
Reach-1	277788	66.00	1294.20	1.27	1295.47	1295.47	1296.13	0.016881	6.48	10.19	53.70	1.01	1.34	1.27	895.00
Reach-1	277788	396.00	1294.20	6.32	1300.52	1297.51	1300.52	0.000001	0.13	8609.10	5522.76	0.01	0.00	6.32	895.00
Reach-1	277788	1650.00	1294.20	5.58	1299.78	1298.59	1299.78	0.000076	1.16	4686.83	4957.95	0.09	0.03	5.58	895.00
Reach-1	277788	4260.00	1294.20	7.90	1302.10	1299.09	1302.10	0.000009	0.52	17380.83	5561.00	0.03	0.00	7.90	895.00
Reach-1	277788	13100.00	1294.20	15.76	1309.96	1299.60	1309.96	0.000001	0.31	61097.00	5561.00	0.01	0.00	15.76	895.00
Reach-1	276893	66.00	1292.40	1.96	1294.36		1294.37	0.000173	0.77	85.44	65.85	0.12	0.01	1.29	1270.00
Reach-1	276893	396.00	1292.40	8.12	1300.52		1300.52	0.000000	0.08	12017.49	5024.60	0.01	0.00	5.27	1270.00
Reach-1	276893	1650.00	1292.40	7.35	1299.75		1299.75	0.000013	0.52	8291.45	4681.62	0.04	0.00	4.83	1270.00
Reach-1	276893	4260.00	1292.40	9.69	1302.09		1302.09	0.000006	0.41	20145.69	5299.33	0.03	0.00	5.96	1270.00
Reach-1	276893	13100.00	1292.40	17.56	1309.96		1309.96	0.000002	0.35	61859.30	5302.00	0.02	0.00	13.72	1270.00
Reach-1	275623	66.00	1292.90	0.94	1293.84		1293.87	0.001743	1.48	57.13	99.90	0.33	0.07	0.60	560.00
Reach-1	275623	396.00	1292.90	7.62	1300.52		1300.52	0.000000	0.05	14763.74	4980.31	0.00	0.00	3.98	560.00
Reach-1	275623	1650.00	1292.90	6.84	1299.74		1299.74	0.000007	0.30	10921.51	4925.55	0.03	0.00	3.62	560.00
Reach-1	275623	4260.00	1292.90	9.18	1302.08		1302.08	0.000004	0.29	22669.14	5202.16	0.02	0.00	4.77	560.00
Reach-1	275623	13100.00	1292.90	17.05	1309.95		1309.96	0.000001	0.31	64017.97	5254.00	0.02	0.00	12.60	560.00
Reach-1	275063	66.00	1291.20	1.19	1292.39		1292.48	0.004423	2.43	27.18	42.89	0.54	0.17	0.63	1600.00
Reach-1	275063	396.00	1291.20	9.32	1300.52		1300.52	0.000000	0.04	19023.39	6052.58	0.00	0.00	5.65	1600.00
Reach-1	275063	1650.00	1291.20	8.54	1299.74		1299.74	0.000003	0.26	14442.18	5718.66	0.02	0.00	5.28	1600.00
Reach-1	275063	4260.00	1291.20	10.88	1302.08		1302.08	0.000003	0.28	28903.94	6534.95	0.02	0.00	6.77	1600.00
Reach-1	275063	13100.00	1291.20	18.75	1309.95		1309.95	0.000001	0.27	81032.57	6636.00	0.01	0.00	14.54	1600.00
Reach-1	273463	66.00	1289.80	2.32	1291.92		1291.93	0.000111	0.65	118.67	92.84	0.10	0.01	1.39	1220.00
Reach-1	273463	396.00	1289.80	10.92	1300.52		1300.52	0.000000	0.03	19806.28	4147.74	0.00	0.00	6.31	1220.00
Reach-1	273463	1650.00	1289.80	10.14	1299.74		1299.74	0.000001	0.19	16589.19	4099.60	0.01	0.00	5.93	1220.00
Reach-1	273463	4260.00	1289.80	12.48	1302.08		1302.08	0.000002	0.27	26379.15	4286.63	0.02	0.00	7.57	1220.00
Reach-1	273463	13100.00	1289.80	20.35	1309.95		1309.95	0.000001	0.34	61489.16	4500.00	0.02	0.00	15.34	1220.00
Reach-1	272243	66.00	1288.70	3.17	1291.87		1291.87	0.000027	0.32	257.10	208.68	0.05	0.00	1.36	154.00
Reach-1	272243	396.00	1288.70	11.82	1300.52		1300.52	0.000000	0.03	19883.35	4266.10	0.00	0.00	6.43	154.00
Reach-1	272243	1650.00	1288.70	11.04	1299.74		1299.74	0.000001	0.17	16559.83	4218.12	0.01	0.00	5.66	154.00
Reach-1	272243	4260.00	1288.70	13.38	1302.08		1302.08	0.000002	0.27	26659.98	4413.94	0.02	0.00	7.98	154.00
Reach-1	272243	13100.00	1288.70	21.25	1309.95		1309.95	0.000001	0.33	62653.03	4800.00	0.01	0.00	15.80	154.00
Reach-1	272089	66.00	1288.70	3.09	1291.79	1290.57	1291.84	0.000836	1.87	35.36	145.21	0.23	0.10	1.87	80.00
Reach-1	272089	396.00	1288.70	11.82	1300.52	1292.28	1300.52	0.000000	0.04	18984.12	4145.23	0.00	0.00	10.21	80.00
Reach-1	272089	1650.00	1288.70	11.04	1299.73	1296.19	1299.74	0.000002	0.23	15746.84	4084.58	0.01	0.00	9.46	80.00

HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 (Continued)

Reach	River Sta	Q Total	Min Ch El	Max Chl Dpth	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Hydr Radius C	Length Chnl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(ft)	(ft)
Reach-1	272089	4260.00	1288.70	13.38	1302.07	1298.41	1302.08	0.000002	0.33	25695.60	4413.92	0.02	0.00	11.70	80.00
Reach-1	272089	13100.00	1288.70	21.25	1309.95	1298.41	1309.95	0.000001	0.35	61669.14	4600.00	0.01	0.00	19.21	80.00
Reach-1	272049	Culvert													
Reach-1	272009	66.00	1288.70	3.04	1291.74	1290.57	1291.80	0.000901	1.91	34.57	143.18	0.24	0.10	1.83	20.00
Reach-1	272009	396.00	1288.70	11.82	1300.52	1292.28	1300.52	0.000000	0.05	17908.72	3841.88	0.00	0.00	10.21	20.00
Reach-1	272009	1650.00	1288.70	11.03	1299.73	1296.19	1299.73	0.000002	0.24	14909.21	3803.42	0.01	0.00	9.46	20.00
Reach-1	272009	4260.00	1288.70	13.37	1302.07	1297.81	1302.07	0.000003	0.35	24124.86	4066.01	0.02	0.00	11.69	20.00
Reach-1	272009	13100.00	1288.70	21.25	1309.95	1297.81	1309.95	0.000001	0.37	56387.10	4100.00	0.01	0.00	19.21	20.00
Reach-1	264848	150.00	1289.00	2.77	1291.77		1291.77	0.000104	0.61	252.31	176.19	0.08	0.01	1.65	1956.00
Reach-1	264848	2400.00	1289.00	11.52	1300.52		1300.52	0.000002	0.27	15253.22	2867.46	0.02	0.00	9.58	1956.00
Reach-1	264848	4160.00	1289.00	10.73	1299.73		1299.73	0.000010	0.57	13031.79	2810.00	0.03	0.01	8.79	1956.00
Reach-1	264848	8110.00	1289.00	13.07	1302.07		1302.07	0.000011	0.69	19746.82	2900.00	0.04	0.01	11.13	1956.00
Reach-1	264848	22800.00	1289.00	20.94	1309.94		1309.95	0.000007	0.79	42579.01	2900.00	0.03	0.01	18.99	1956.00
Reach-1	262843	150.00	1287.00	4.69	1291.69	1288.17	1291.69	0.000020	0.43	352.01	105.69	0.04	0.00	3.30	3930.00
Reach-1	262843	2400.00	1287.00	13.51	1300.51	1290.79	1300.51	0.000002	0.29	15962.88	2800.00	0.01	0.00	11.49	3930.00
Reach-1	262843	4160.00	1287.00	12.72	1299.72	1292.02	1299.72	0.000008	0.60	13747.58	2739.62	0.03	0.01	10.70	3930.00
Reach-1	262843	8110.00	1287.00	15.06	1302.06	1294.32	1302.06	0.000009	0.72	20282.16	2800.00	0.04	0.01	13.01	3930.00
Reach-1	262843	22800.00	1287.00	22.93	1309.93	1295.77	1309.94	0.000007	0.84	42339.00	2800.00	0.03	0.01	20.81	3930.00
Reach-1	258913	160.00	1288.00	3.56	1291.56		1291.56	0.000058	0.62	260.33	110.34	0.07	0.01	2.65	4740.00
Reach-1	258913	2300.00	1288.00	12.51	1300.51		1300.51	0.000001	0.22	19007.01	3000.00	0.01	0.00	11.39	4740.00
Reach-1	258913	4150.00	1288.00	11.70	1299.70		1299.70	0.000005	0.47	16583.79	3000.00	0.03	0.00	10.59	4740.00
Reach-1	258913	8050.00	1288.00	14.04	1302.04		1302.04	0.000006	0.59	23596.00	3000.00	0.03	0.01	12.91	4740.00
Reach-1	258913	22800.00	1288.00	21.92	1309.92		1309.93	0.000005	0.74	47241.14	3000.00	0.03	0.01	20.75	4740.00
Reach-1	254173	160.00	1285.20	6.28	1291.48	1286.61	1291.49	0.000007	0.31	511.37	169.43	0.03	0.00	4.47	2760.00
Reach-1	254173	2300.00	1285.20	15.31	1300.51	1289.31	1300.51	0.000002	0.32	14513.62	2400.00	0.02	0.00	13.47	2760.00
Reach-1	254173	4150.00	1285.20	14.49	1299.69	1290.43	1299.69	0.000008	0.65	12609.12	2235.63	0.03	0.01	12.65	2760.00
Reach-1	254173	8050.00	1285.20	16.82	1302.02	1292.34	1302.02	0.000011	0.84	18140.86	2400.00	0.04	0.01	14.98	2760.00
Reach-1	254173	22800.00	1285.20	24.70	1309.90	1295.83	1309.91	0.000009	1.00	37066.06	2400.00	0.04	0.01	22.84	2760.00
Reach-1	251413	160.00	1285.30	6.16	1291.46		1291.46	0.000013	0.38	428.56	119.93	0.03	0.00	4.04	194.00
Reach-1	251413	2300.00	1285.30	15.20	1300.50		1300.50	0.000003	0.43	11372.67	2411.88	0.02	0.00	13.05	194.00
Reach-1	251413	4150.00	1285.30	14.36	1299.66		1299.67	0.000018	0.96	9378.06	2348.11	0.05	0.01	12.21	194.00
Reach-1	251413	8050.00	1285.30	16.70	1302.00		1302.00	0.000019	1.10	15118.81	2600.00	0.05	0.02	14.54	194.00
Reach-1	251413	22800.00	1285.30	24.59	1309.89		1309.90	0.000011	1.10	35646.50	2600.00	0.04	0.01	22.40	194.00
Reach-1	251219	160.00	1285.30	6.03	1291.33	1287.47	1291.42	0.000336	2.47	64.78	118.58	0.18	0.12	5.66	85.00
Reach-1	251219	2300.00	1285.30	15.20	1300.50	1296.51	1300.50	0.000004	0.52	11374.29	2411.85	0.02	0.00	14.79	85.00
Reach-1	251219	4150.00	1285.30	14.36	1299.66	1296.51	1299.67	0.000023	1.19	9377.69	2348.03	0.06	0.02	13.95	85.00
Reach-1	251219	8050.00	1285.30	16.70	1302.00	1296.51	1302.00	0.000022	1.27	15069.34	2500.00	0.06	0.02	16.27	85.00
Reach-1	251219	22800.00	1285.30	24.59	1309.89	1296.51	1309.90	0.000012	1.21	34807.81	2500.00	0.04	0.02	24.13	85.00
Reach-1	251176.5	Culvert													
Reach-1	251134	160.00	1285.30	5.56	1290.86	1287.47	1290.98	0.000447	2.69	59.46	113.64	0.21	0.14	5.19	181.00
Reach-1	251134	2300.00	1285.30	15.20	1300.50	1294.61	1300.50	0.000004	0.52	11360.46	2411.35	0.02	0.00	14.78	181.00
Reach-1	251134	4150.00	1285.30	14.36	1299.66	1294.61	1299.67	0.000023	1.19	9374.54	2347.94	0.06	0.02	13.95	181.00
Reach-1	251134	8050.00	1285.30	16.69	1301.99	1294.61	1302.00	0.000022	1.27	15064.46	2500.00	0.06	0.02	16.27	181.00

HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 (Continued)

Reach	River Sta	Q Total	Min Ch El	Max Chl Dpth	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Hydr Radius C	Length Chnl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(ft)	(ft)
Reach-1	251134	22800.00	1285.30	24.59	1309.89	1295.99	1309.90	0.000012	1.21	34804.75	2500.00	0.04	0.02	24.13	181.00
Reach-1	250953	160.00	1284.90	6.01	1290.91	1286.66	1290.91	0.000023	0.51	330.36	101.80	0.05	0.01	3.98	3490.00
Reach-1	250953	2300.00	1284.90	15.60	1300.50	1289.99	1300.50	0.000005	0.53	9918.97	2231.71	0.03	0.00	13.52	3490.00
Reach-1	250953	4150.00	1284.90	14.75	1299.65	1291.53	1299.66	0.000021	1.05	8192.36	1674.69	0.05	0.02	12.68	3490.00
Reach-1	250953	8050.00	1284.90	17.08	1301.98	1294.28	1301.99	0.000026	1.32	13397.50	2398.69	0.06	0.02	15.00	3490.00
Reach-1	250953	22800.00	1284.90	24.99	1309.89	1296.12	1309.89	0.000013	1.22	33829.87	2600.00	0.04	0.02	22.86	3490.00
Reach-1	247463	160.00	1286.60	4.16	1290.76	1288.05	1290.77	0.000093	0.76	215.16	90.91	0.08	0.01	2.53	2350.00
Reach-1	247463	2300.00	1286.60	13.89	1300.49	1291.21	1300.49	0.000002	0.35	13450.23	2474.06	0.02	0.00	12.21	2350.00
Reach-1	247463	4150.00	1286.60	13.01	1299.61	1292.97	1299.61	0.000013	0.77	11299.30	2369.97	0.04	0.01	11.34	2350.00
Reach-1	247463	8050.00	1286.60	15.33	1301.93	1293.86	1301.93	0.000014	0.92	17126.11	2600.00	0.04	0.01	13.65	2350.00
Reach-1	247463	22800.00	1286.60	23.26	1309.86	1295.29	1309.86	0.000009	0.99	37732.50	2600.00	0.04	0.01	21.55	2350.00
Reach-1	245113	160.00	1284.40	6.30	1290.70		1290.70	0.000012	0.39	458.64	138.85	0.03	0.00	4.37	355.00
Reach-1	245113	2300.00	1284.40	16.08	1300.48		1300.48	0.000001	0.23	18283.14	2489.15	0.01	0.00	13.32	355.00
Reach-1	245113	4150.00	1284.40	15.20	1299.60		1299.60	0.000004	0.48	16093.23	2444.77	0.02	0.00	12.44	355.00
Reach-1	245113	8050.00	1284.40	17.51	1301.91		1301.91	0.000006	0.64	21855.58	2500.00	0.03	0.01	14.73	355.00
Reach-1	245113	22800.00	1284.40	25.44	1309.84		1309.85	0.000006	0.85	41677.35	2500.00	0.03	0.01	22.59	355.00
Reach-1	244758	160.00	1284.40	6.30	1290.70	1285.93	1290.70	0.000020	0.43	374.37	123.30	0.04	0.01	4.19	0.00
Reach-1	244758	2300.00	1284.40	16.08	1300.48	1288.97	1300.48	0.000001	0.19	17359.89	2389.14	0.01	0.00	12.02	0.00
Reach-1	244758	4150.00	1284.40	15.19	1299.59	1290.47	1299.60	0.000005	0.40	15256.47	2344.71	0.02	0.00	11.22	0.00
Reach-1	244758	8050.00	1284.40	17.51	1301.91	1292.98	1301.91	0.000008	0.52	20785.57	2400.00	0.02	0.01	13.30	0.00
Reach-1	244758	22800.00	1284.40	25.44	1309.84	1297.11	1309.84	0.000006	0.67	39813.89	2400.00	0.02	0.01	20.39	0.00
Reach-1	244733	Bridge													
Reach-1	244708	160.00	1284.40	6.29	1290.69	1285.93	1290.70	0.000020	0.43	374.35	123.30	0.04	0.01	4.19	495.00
Reach-1	244708	2300.00	1284.40	16.08	1300.48	1288.99	1300.48	0.000001	0.19	17359.60	2389.14	0.01	0.00	12.02	495.00
Reach-1	244708	4150.00	1284.40	15.19	1299.59	1290.48	1299.59	0.000005	0.40	15254.18	2344.66	0.02	0.00	11.22	495.00
Reach-1	244708	8050.00	1284.40	17.51	1301.91	1292.99	1301.91	0.000008	0.52	20781.47	2400.00	0.02	0.01	13.29	495.00
Reach-1	244708	22800.00	1284.40	25.44	1309.84	1296.41	1309.84	0.000006	0.67	39807.74	2400.00	0.02	0.01	20.39	495.00
Reach-1	244213	160.00	1285.70	4.99	1290.69		1290.69	0.000017	0.39	433.20	159.61	0.03	0.00	3.99	275.00
Reach-1	244213	2300.00	1285.70	14.78	1300.48		1300.48	0.000001	0.24	14763.90	2600.00	0.01	0.00	13.72	275.00
Reach-1	244213	4150.00	1285.70	13.89	1299.59		1299.59	0.000007	0.53	12443.85	2596.58	0.03	0.01	12.84	275.00
Reach-1	244213	8050.00	1285.70	16.20	1301.90		1301.91	0.000008	0.63	18463.00	2600.00	0.03	0.01	15.14	275.00
Reach-1	244213	22800.00	1285.70	24.13	1309.83		1309.84	0.000006	0.72	39077.97	2600.00	0.03	0.01	23.01	275.00
Reach-1	243938	160.00	1286.20	4.48	1290.68		1290.68	0.000020	0.32	497.83	183.68	0.03	0.00	2.71	99.00
Reach-1	243938	2300.00	1286.20	14.28	1300.48		1300.48	0.000001	0.20	15029.15	2525.08	0.01	0.00	12.01	99.00
Reach-1	243938	4150.00	1286.20	13.39	1299.59		1299.59	0.000005	0.43	12839.23	2297.89	0.02	0.00	11.12	99.00
Reach-1	243938	8050.00	1286.20	15.70	1301.90		1301.91	0.000007	0.56	18755.54	2650.00	0.03	0.01	13.43	99.00
Reach-1	243938	22800.00	1286.20	23.63	1309.83		1309.84	0.000005	0.67	39767.27	2650.00	0.03	0.01	21.34	99.00
Reach-1	243839	160.00	1286.20	4.37	1290.57	1287.70	1290.65	0.000551	2.31	69.16	179.39	0.20	0.15	4.32	110.00
Reach-1	243839	2300.00	1286.20	8.66	1294.86	1294.86	1299.19	0.011423	16.69	137.85	1644.26	1.00	6.14	8.62	110.00
Reach-1	243839	4150.00	1286.20	13.39	1299.59	1297.61	1299.59	0.000008	0.51	12685.13	2247.87	0.02	0.00	13.34	110.00
Reach-1	243839	8050.00	1286.20	15.70	1301.90	1297.61	1301.91	0.000008	0.64	18484.96	2600.00	0.03	0.01	15.66	110.00
Reach-1	243839	22800.00	1286.20	23.63	1309.83	1297.61	1309.84	0.000006	0.73	39099.93	2600.00	0.03	0.01	23.58	110.00
Reach-1	243784	Culvert													

PROJECT LIMIT

HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 (Continued)

Reach	River Sta	Q Total	Min Ch El	Max Chl Dpth	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Hydr Radius C	Length Chnl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(ft)	(ft)
Reach-1	243729	160.00	1286.20	4.11	1290.31	1287.70	1290.41	0.000676	2.46	65.04	169.49	0.22	0.17	4.07	66.00
Reach-1	243729	2300.00	1286.20	11.54	1297.74	1294.31	1297.74	0.000005	0.44	8748.76	1919.60	0.02	0.00	11.49	66.00
Reach-1	243729	4150.00	1286.20	13.39	1299.59	1294.31	1299.59	0.000006	0.51	12685.13	2247.87	0.02	0.00	13.34	66.00
Reach-1	243729	8050.00	1286.20	15.70	1301.90	1294.31	1301.90	0.000008	0.64	18476.40	2600.00	0.03	0.01	15.65	66.00
Reach-1	243729	22800.00	1286.20	23.63	1309.83	1294.73	1309.83	0.000006	0.73	39085.65	2600.00	0.03	0.01	23.58	66.00
Reach-1	243663	160.00	1286.70	3.65	1290.35		1290.36	0.000030	0.47	445.52	223.56	0.04	0.01	3.50	1750.00
Reach-1	243663	2300.00	1286.70	11.04	1297.74		1297.74	0.000004	0.39	8768.73	1717.92	0.02	0.00	10.88	1750.00
Reach-1	243663	4150.00	1286.70	12.89	1299.59		1299.59	0.000006	0.48	12321.07	2165.77	0.02	0.00	12.73	1750.00
Reach-1	243663	8050.00	1286.70	15.20	1301.90		1301.90	0.000007	0.62	17716.19	2400.00	0.03	0.01	15.04	1750.00
Reach-1	243663	22800.00	1286.70	23.13	1309.83		1309.83	0.000006	0.74	36740.66	2400.00	0.03	0.01	22.96	1750.00
Reach-1	241913	160.00	1286.30	4.01	1290.31		1290.31	0.000026	0.37	445.05	201.86	0.04	0.00	2.72	740.00
Reach-1	241913	2300.00	1286.30	11.43	1297.73		1297.73	0.000008	0.48	6480.14	1348.63	0.03	0.00	9.91	740.00
Reach-1	241913	4150.00	1286.30	13.28	1299.58		1299.58	0.000009	0.59	9107.79	1506.58	0.03	0.01	11.76	740.00
Reach-1	241913	8050.00	1286.30	15.59	1301.89		1301.89	0.000013	0.79	13706.89	2500.00	0.04	0.01	14.06	740.00
Reach-1	241913	22800.00	1286.30	23.51	1309.81		1309.82	0.000009	0.87	33528.06	2500.00	0.03	0.01	21.97	740.00
Reach-1	241173	160.00	1285.30	4.99	1290.29		1290.29	0.000016	0.37	523.33	162.07	0.03	0.00	4.72	115.00
Reach-1	241173	2300.00	1285.30	12.43	1297.73		1297.73	0.000007	0.47	8822.46	2010.40	0.02	0.01	12.14	115.00
Reach-1	241173	4150.00	1285.30	14.27	1299.57		1299.58	0.000008	0.54	12754.77	2231.65	0.03	0.01	13.99	115.00
Reach-1	241173	8050.00	1285.30	16.58	1301.88		1301.88	0.000010	0.67	18022.47	2300.00	0.03	0.01	16.29	115.00
Reach-1	241173	22800.00	1285.30	24.51	1309.81		1309.82	0.000008	0.78	36259.91	2300.00	0.03	0.01	24.21	115.00
Reach-1	241058	160.00	1285.30	4.96	1290.26	1286.52	1290.28	0.000212	1.14	140.63	123.70	0.09	0.05	3.64	0.00
Reach-1	241058	2300.00	1285.30	12.42	1297.72	1291.26	1297.73	0.000008	0.37	8461.52	1891.22	0.02	0.00	8.02	0.00
Reach-1	241058	4150.00	1285.30	14.27	1299.57	1294.00	1299.58	0.000008	0.42	11974.31	1900.00	0.02	0.00	9.24	0.00
Reach-1	241058	8050.00	1285.30	16.58	1301.88	1294.81	1301.88	0.000011	0.53	16352.98	1900.00	0.02	0.01	10.76	0.00
Reach-1	241058	22800.00	1285.30	24.51	1309.81	1294.89	1309.81	0.000010	0.66	31415.45	1900.00	0.02	0.01	16.00	0.00
Reach-1	241033	Bridge													
Reach-1	241008	160.00	1285.30	4.95	1290.25	1286.52	1290.27	0.000214	1.14	140.30	123.40	0.09	0.05	3.63	440.00
Reach-1	241008	2300.00	1285.30	12.42	1297.72	1291.24	1297.72	0.000008	0.37	8458.05	1891.13	0.02	0.00	8.01	440.00
Reach-1	241008	4150.00	1285.30	14.27	1299.57	1294.31	1299.57	0.000008	0.42	11970.83	1900.00	0.02	0.00	9.24	440.00
Reach-1	241008	8050.00	1285.30	16.58	1301.88	1294.31	1301.88	0.000011	0.53	16347.42	1900.00	0.02	0.01	10.76	440.00
Reach-1	241008	22800.00	1285.30	24.50	1309.80	1294.70	1309.81	0.000010	0.66	31408.02	1900.00	0.02	0.01	16.00	440.00
Reach-1	240568	160.00	1285.50	4.74	1290.24		1290.24	0.000020	0.40	483.60	157.90	0.03	0.01	4.47	705.00
Reach-1	240568	2300.00	1285.50	12.22	1297.72		1297.72	0.000008	0.50	8411.42	1988.03	0.03	0.01	11.93	705.00
Reach-1	240568	4150.00	1285.50	14.07	1299.57		1299.57	0.000008	0.55	12218.02	2100.00	0.03	0.01	13.78	705.00
Reach-1	240568	8050.00	1285.50	16.37	1301.87		1301.88	0.000011	0.69	17053.77	2100.00	0.03	0.01	16.08	705.00
Reach-1	240568	22800.00	1285.50	24.30	1309.80		1309.81	0.000009	0.82	33701.50	2100.00	0.03	0.01	24.00	705.00
Reach-1	239863	160.00	1286.00	4.22	1290.22		1290.23	0.000040	0.42	385.27	142.43	0.04	0.01	2.84	670.00
Reach-1	239863	2300.00	1286.00	11.69	1297.69		1297.71	0.000062	1.23	2609.39	735.70	0.07	0.04	10.29	670.00
Reach-1	239863	4150.00	1286.00	13.53	1299.53		1299.55	0.000072	1.48	4275.63	894.74	0.07	0.05	12.13	670.00
Reach-1	239863	8050.00	1286.00	15.83	1301.83		1301.86	0.000082	1.77	7780.38	1900.00	0.08	0.07	14.43	670.00
Reach-1	239863	22800.00	1286.00	23.78	1309.78		1309.80	0.000025	1.30	22886.45	1900.00	0.05	0.03	22.37	670.00
Reach-1	239193	160.00	1286.40	3.80	1290.20		1290.20	0.000030	0.41	416.61	160.58	0.04	0.01	3.43	130.00
Reach-1	239193	2300.00	1286.40	11.26	1297.66		1297.67	0.000041	1.04	2475.32	325.00	0.06	0.03	10.88	130.00

HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 (Continued)

Reach	River Sta	Q Total	Min Ch El	Max Chl Dpth	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Hydr Radius C	Length Chnl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(ft)	(ft)
Reach-1	239193	4150.00	1286.40	13.12	1299.52		1299.52	0.000027	0.93	7340.64	1575.25	0.05	0.02	12.74	130.00
Reach-1	239193	8050.00	1286.40	15.42	1301.82		1301.82	0.000029	1.09	11385.03	1800.00	0.05	0.03	15.03	130.00
Reach-1	239193	22800.00	1286.40	23.37	1309.77		1309.78	0.000016	1.08	25703.07	1800.00	0.04	0.02	22.99	130.00
Reach-1	239063	160.00	1286.40	3.79	1290.19	1287.31	1290.20	0.000096	0.73	218.37	160.41	0.07	0.02	3.41	0.00
Reach-1	239063	2300.00	1286.40	11.03	1297.43	1290.18	1297.61	0.000445	3.37	682.01	400.00	0.18	0.30	10.65	0.00
Reach-1	239063	4150.00	1286.40	13.11	1299.51	1291.83	1299.52	0.000034	1.04	6389.90	1340.00	0.05	0.03	12.73	0.00
Reach-1	239063	8050.00	1286.40	15.41	1301.81	1294.66	1301.82	0.000039	1.28	9786.68	1500.00	0.06	0.04	15.03	0.00
Reach-1	239063	22800.00	1286.40	23.36	1309.76	1299.21	1309.78	0.000023	1.28	21717.47	1500.00	0.05	0.03	22.98	0.00
Reach-1	239038	Bridge													
Reach-1	239013	160.00	1286.40	3.79	1290.19	1287.31	1290.19	0.000096	0.73	218.33	160.40	0.07	0.02	3.41	20.00
Reach-1	239013	2300.00	1286.40	10.80	1297.20	1290.18	1297.38	0.000479	3.45	667.06	400.00	0.19	0.31	10.42	20.00
Reach-1	239013	4150.00	1286.40	12.35	1298.75	1291.83	1298.76	0.000051	1.23	5412.10	1225.12	0.06	0.04	11.97	20.00
Reach-1	239013	8050.00	1286.40	15.40	1301.80	1294.66	1301.81	0.000039	1.26	9770.75	1500.00	0.06	0.04	15.02	20.00
Reach-1	239013	22800.00	1286.40	23.35	1309.75	1298.01	1309.77	0.000023	1.28	21701.72	1500.00	0.05	0.03	22.97	20.00
Reach-1	238993	210.00	1285.60	4.59	1290.19	1287.31	1290.19	0.000064	0.61	421.96	195.26	0.06	0.01	3.46	79.00
Reach-1	238993	2400.00	1285.60	11.64	1297.24	1289.97	1297.33	0.000272	2.61	996.74	100.00	0.14	0.18	10.49	79.00
Reach-1	238993	4290.00	1285.60	13.15	1298.75	1290.65	1298.76	0.000013	0.63	9427.15	1600.00	0.03	0.01	12.00	79.00
Reach-1	238993	8210.00	1285.60	16.20	1301.80	1292.36	1301.80	0.000013	0.71	14302.74	1600.00	0.03	0.01	15.04	79.00
Reach-1	238993	23200.00	1285.60	24.15	1309.75	1295.06	1309.76	0.000012	0.94	27028.71	1600.00	0.03	0.02	22.98	79.00
Reach-1	238914	210.00	1286.60	3.57	1290.17	1287.35	1290.18	0.000174	0.93	225.36	70.35	0.09	0.03	3.13	0.00
Reach-1	238914	2400.00	1286.60	10.57	1297.17	1290.27	1297.29	0.000521	2.81	852.68	116.00	0.18	0.23	7.22	0.00
Reach-1	238914	4290.00	1286.60	11.77	1298.37	1291.89	1298.67	0.001011	4.33	990.04	116.00	0.26	0.53	8.38	0.00
Reach-1	238914	8210.00	1286.60	14.82	1301.42	1294.47	1301.71	0.000855	4.87	2924.35	1786.39	0.25	0.60	11.32	0.00
Reach-1	238914	23200.00	1286.60	23.11	1309.71	1302.19	1309.75	0.000080	2.13	14174.61	1380.00	0.08	0.10	19.33	0.00
Reach-1	238888	Bridge													
Reach-1	238862	210.00	1286.60	3.57	1290.17	1287.35	1290.18	0.000174	0.93	225.23	70.35	0.09	0.03	3.13	569.00
Reach-1	238862	2400.00	1286.60	10.55	1297.15	1290.26	1297.28	0.000524	2.82	850.89	116.00	0.18	0.24	7.21	569.00
Reach-1	238862	4290.00	1286.60	11.73	1298.33	1291.89	1298.63	0.001028	4.36	985.07	116.00	0.26	0.54	8.34	569.00
Reach-1	238862	8210.00	1286.60	14.01	1300.61	1294.47	1301.20	0.001567	6.29	1676.69	1110.51	0.34	1.03	10.55	569.00
Reach-1	238862	23200.00	1286.60	16.52	1303.12	1302.23	1303.66	0.001759	7.64	5085.00	1380.00	0.37	1.42	12.97	569.00
Reach-1	238293	200.00	1285.90	4.22	1290.12		1290.13	0.000045	0.48	420.13	132.48	0.05	0.01	3.15	800.00
Reach-1	238293	2550.00	1285.90	11.25	1297.15		1297.17	0.000042	0.98	2825.01	450.00	0.05	0.03	9.84	800.00
Reach-1	238293	4000.00	1285.90	12.47	1298.37		1298.40	0.000061	1.28	3374.11	450.00	0.07	0.04	11.05	800.00
Reach-1	238293	7810.00	1285.90	14.83	1300.73		1300.78	0.000099	1.86	4435.00	450.00	0.09	0.08	13.39	800.00
Reach-1	238293	22600.00	1285.90	17.27	1303.17		1303.23	0.000133	2.40	12323.68	1500.00	0.11	0.13	15.81	800.00
Reach-1	237493	200.00	1285.90	4.19	1290.09		1290.09	0.000046	0.48	415.28	131.99	0.05	0.01	3.13	120.00
Reach-1	237493	2550.00	1285.90	11.22	1297.12		1297.13	0.000033	0.88	3852.94	1074.66	0.05	0.02	9.82	120.00
Reach-1	237493	4000.00	1285.90	12.44	1298.34		1298.35	0.000041	1.05	5269.18	1258.78	0.06	0.03	11.02	120.00
Reach-1	237493	7810.00	1285.90	14.80	1300.70		1300.71	0.000046	1.26	8610.66	1500.00	0.06	0.04	13.36	120.00
Reach-1	237493	22600.00	1285.90	17.16	1303.06		1303.12	0.000139	2.44	12156.68	1500.00	0.11	0.14	15.70	120.00
Reach-1	237373	200.00	1286.50	3.56	1290.06	1287.25	1290.08	0.000180	0.95	210.66	59.98	0.09	0.04	3.14	0.00
Reach-1	237373	2550.00	1286.50	10.61	1297.11	1290.37	1297.12	0.000131	1.53	3172.34	1300.00	0.08	0.07	8.11	0.00
Reach-1	237373	4000.00	1286.50	11.83	1298.33	1291.71	1298.34	0.000099	1.43	4760.85	1300.00	0.07	0.06	9.05	0.00

HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 (Continued)

Reach	River Sta	Q Total	Min Ch El	Max Chl Dpth	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Hydr Radius C	Length Chnl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(ft)	(ft)
Reach-1	237373	7810.00	1286.50	14.19	1300.69	1296.15	1300.70	0.000079	1.44	7828.35	1300.00	0.07	0.05	10.87	0.00
Reach-1	237373	22600.00	1286.50	16.53	1303.03	1297.41	1303.10	0.000227	2.71	10876.18	1300.00	0.12	0.18	12.67	0.00
Reach-1	237343	Bridge													
Reach-1	237313	200.00	1286.50	3.56	1290.06	1287.25	1290.08	0.000180	0.95	210.65	59.98	0.09	0.04	3.14	60.00
Reach-1	237313	2550.00	1286.50	10.59	1297.09	1290.37	1297.10	0.000134	1.54	3146.32	1300.00	0.08	0.07	8.10	60.00
Reach-1	237313	4000.00	1288.50	11.82	1298.32	1291.71	1298.33	0.000100	1.44	4745.61	1300.00	0.07	0.06	9.04	60.00
Reach-1	237313	7810.00	1288.50	14.18	1300.68	1296.14	1300.69	0.000080	1.44	7815.50	1300.00	0.07	0.05	10.86	60.00
Reach-1	237313	22600.00	1286.50	16.49	1302.99	1297.42	1303.06	0.000231	2.72	10824.44	1300.00	0.12	0.18	12.64	60.00
Reach-1	237253	200.00	1286.40	3.67	1290.07		1290.07	0.000013	0.27	753.30	227.85	0.03	0.00	3.52	410.00
Reach-1	237253	2550.00	1286.40	10.69	1297.09		1297.10	0.000029	0.85	4330.89	1084.34	0.05	0.02	10.54	410.00
Reach-1	237253	4000.00	1286.40	11.91	1298.31		1298.33	0.000038	1.05	5807.53	1323.43	0.05	0.03	11.77	410.00
Reach-1	237253	7810.00	1286.40	14.28	1300.68		1300.69	0.000043	1.27	9147.93	1430.00	0.06	0.04	14.13	410.00
Reach-1	237253	22600.00	1286.40	16.59	1302.99		1303.05	0.000137	2.50	13253.19	1652.00	0.11	0.14	16.44	410.00
Reach-1	236843	200.00	1285.20	4.86	1290.06		1290.06	0.000016	0.34	605.02	169.99	0.03	0.00	4.03	410.00
Reach-1	236843	2550.00	1285.20	11.87	1297.07		1297.08	0.000034	0.94	4462.50	1269.47	0.05	0.02	10.83	410.00
Reach-1	236843	4000.00	1285.20	13.10	1298.30		1298.31	0.000040	1.09	6149.97	1478.32	0.06	0.03	12.03	410.00
Reach-1	236843	7810.00	1285.20	15.46	1300.66		1300.67	0.000042	1.26	9922.16	1630.00	0.06	0.04	14.35	410.00
Reach-1	236843	22600.00	1285.20	17.74	1302.94		1302.99	0.000132	2.46	13634.83	1630.00	0.11	0.14	16.59	410.00
Reach-1	236433	200.00	1286.40	3.65	1290.05		1290.05	0.000046	0.47	421.92	135.71	0.05	0.01	3.08	290.00
Reach-1	236433	2550.00	1286.40	10.62	1297.02		1297.06	0.000109	1.56	2104.37	609.11	0.09	0.07	9.59	290.00
Reach-1	236433	4000.00	1286.40	11.83	1298.23		1298.28	0.000142	1.92	2959.44	806.41	0.10	0.10	10.77	290.00
Reach-1	236433	7810.00	1286.40	14.19	1300.59		1300.64	0.000155	2.28	5280.23	1095.00	0.11	0.13	13.08	290.00
Reach-1	236433	22600.00	1286.40	16.30	1302.70		1302.88	0.000468	4.37	7596.54	1095.00	0.20	0.44	15.15	290.00
Reach-1	236143	200.00	1285.10	4.92	1290.02		1290.03	0.000133	0.84	238.12	71.77	0.08	0.03	3.27	110.00
Reach-1	236143	2550.00	1285.10	11.82	1296.92		1297.00	0.000349	2.51	1364.48	531.60	0.15	0.18	8.20	110.00
Reach-1	236143	4000.00	1285.10	13.01	1298.11		1298.21	0.000381	2.87	2133.15	750.74	0.16	0.22	9.37	110.00
Reach-1	236143	7810.00	1285.10	15.40	1300.50		1300.58	0.000295	2.92	4420.04	1095.00	0.15	0.22	11.69	110.00
Reach-1	236143	22600.00	1285.10	17.37	1302.47		1302.70	0.000776	5.25	6578.23	1095.00	0.25	0.66	13.62	110.00
Reach-1	236033	200.00	1285.70	4.28	1289.98	1287.47	1290.00	0.000400	1.25	159.80	60.42	0.14	0.07	2.61	0.00
Reach-1	236033	2550.00	1285.70	11.25	1296.95	1291.25	1296.95	0.000038	0.74	5199.50	2137.75	0.05	0.02	6.93	0.00
Reach-1	236033	4000.00	1285.70	12.45	1298.15	1292.62	1298.16	0.000027	0.69	7902.45	2300.00	0.04	0.01	8.11	0.00
Reach-1	236033	7810.00	1285.70	14.83	1300.53	1295.41	1300.53	0.000019	0.69	13720.77	2500.00	0.04	0.01	10.45	0.00
Reach-1	236033	22600.00	1285.70	16.86	1302.56	1296.20	1302.58	0.000058	1.35	18797.06	2500.00	0.07	0.04	12.45	0.00
Reach-1	235993	Bridge													
Reach-1	235953	200.00	1286.10	3.88	1289.98	1287.34	1289.98	0.000107	0.63	319.30	125.94	0.07	0.02	2.49	50.00
Reach-1	235953	2550.00	1286.10	10.84	1296.94	1289.75	1296.94	0.000029	0.76	5508.68	2105.38	0.04	0.02	8.70	50.00
Reach-1	235953	4000.00	1286.10	12.05	1298.15	1290.59	1298.15	0.000024	0.74	8161.07	2300.00	0.04	0.01	9.81	50.00
Reach-1	235953	7810.00	1286.10	14.43	1300.53	1292.34	1300.53	0.000017	0.71	14417.86	2500.00	0.03	0.01	11.99	50.00
Reach-1	235953	22600.00	1286.10	16.45	1302.55	1296.20	1302.57	0.000053	1.38	19479.51	2500.00	0.06	0.05	13.85	50.00
Reach-1	235903	200.00	1286.35	3.63	1289.98		1289.98	0.000054	0.54	383.30	123.42	0.05	0.01	3.30	25.00
Reach-1	235903	2550.00	1286.35	10.54	1296.89		1296.93	0.000136	1.78	2241.22	1256.06	0.10	0.08	9.94	25.00
Reach-1	235903	4000.00	1286.35	11.76	1298.11		1298.14	0.000116	1.78	4452.61	2366.72	0.09	0.08	11.15	25.00
Reach-1	235903	7810.00	1286.35	14.17	1300.52		1300.53	0.000048	1.30	10414.06	2500.00	0.06	0.04	13.54	25.00

HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 (Continued)

Reach	River Sta	Q Total	Min Ch El	Max Chl Dpth	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Hydr Radius C	Length Chnl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(ft)	(ft)
Reach-1	235903	22600.00	1286.35	16.18	1302.53		1302.56	0.000116	2.22	15440.30	2500.00	0.10	0.11	15.54	25.00
Reach-1	235878	200.00	1286.35	3.62	1289.97	1286.96	1289.98	0.000054	0.54	383.14	123.41	0.05	0.01	3.30	125.00
Reach-1	235878	2550.00	1286.35	10.54	1296.89	1289.16	1296.93	0.000136	1.78	2236.93	1252.95	0.10	0.08	9.93	125.00
Reach-1	235878	4000.00	1286.35	11.76	1298.11	1290.08	1298.14	0.000117	1.78	4445.68	2364.06	0.09	0.08	11.15	125.00
Reach-1	235878	7810.00	1286.35	14.17	1300.52	1291.95	1300.53	0.000044	1.24	11243.62	2900.00	0.06	0.04	13.54	125.00
Reach-1	235878	22600.00	1286.35	16.18	1302.53	1298.16	1302.56	0.000099	2.04	17077.60	2900.00	0.09	0.10	15.54	125.00
Reach-1	235753	200.00	1286.00	3.97	1289.97	1286.70	1289.97	0.000032	0.44	459.00	131.30	0.04	0.01	3.62	75.00
Reach-1	235753	2550.00	1286.00	10.88	1296.88	1288.68	1296.91	0.000114	1.51	2317.23	1188.12	0.09	0.06	8.87	75.00
Reach-1	235753	4000.00	1286.00	12.10	1298.10	1289.52	1298.12	0.000106	1.59	4421.68	2265.34	0.09	0.07	10.08	75.00
Reach-1	235753	7810.00	1286.00	14.51	1300.51	1291.37	1300.52	0.000044	1.18	11181.62	2900.00	0.06	0.03	12.46	75.00
Reach-1	235753	22600.00	1286.00	16.51	1302.51	1297.89	1302.55	0.000100	1.96	16994.36	2900.00	0.09	0.09	14.45	75.00
Reach-1	235678	200.00	1284.50	5.47	1289.97	1285.34	1289.97	0.000016	0.37	545.78	121.39	0.03	0.00	4.70	208.00
Reach-1	235678	2550.00	1284.50	12.39	1296.89	1287.71	1296.90	0.000028	0.76	5307.93	1939.56	0.04	0.02	9.04	208.00
Reach-1	235678	4000.00	1284.50	13.61	1298.11	1288.62	1298.11	0.000027	0.80	7994.38	2479.15	0.04	0.02	10.24	208.00
Reach-1	235678	7810.00	1284.50	16.01	1300.51	1290.57	1300.52	0.000018	0.77	14774.42	2900.00	0.04	0.01	12.61	208.00
Reach-1	235678	22600.00	1284.50	18.02	1302.52	1294.37	1302.54	0.000053	1.44	20588.58	2900.00	0.07	0.05	14.59	208.00
Reach-1	235470	200.00	1286.00	3.96	1289.96	1286.73	1289.97	0.000051	0.55	373.91	112.38	0.05	0.01	3.53	642.00
Reach-1	235470	2550.00	1286.00	10.80	1296.80	1289.04	1296.88	0.000207	2.25	1188.46	121.00	0.12	0.13	10.31	642.00
Reach-1	235470	4000.00	1286.00	12.04	1298.04	1290.05	1298.10	0.000192	2.34	2757.42	952.34	0.12	0.14	11.53	642.00
Reach-1	235470	7810.00	1286.00	14.46	1300.46	1292.11	1300.51	0.000147	2.31	6001.42	1600.00	0.11	0.13	13.93	642.00
Reach-1	235470	22600.00	1286.00	16.38	1302.38	1298.39	1302.50	0.000364	3.97	9073.88	1600.00	0.18	0.36	15.83	642.00
Reach-1	234828	200.00	1286.00	3.93	1289.93	1286.73	1289.94	0.000037	0.46	443.63	134.86	0.04	0.01	3.49	100.00
Reach-1	234828	2550.00	1286.00	10.69	1296.69	1288.76	1296.75	0.000180	2.08	1239.56	121.00	0.11	0.11	10.19	100.00
Reach-1	234828	4000.00	1286.00	11.93	1297.93	1289.65	1297.98	0.000159	2.11	2854.00	917.18	0.11	0.11	11.42	100.00
Reach-1	234828	7810.00	1286.00	14.37	1300.37	1291.44	1300.41	0.000135	2.22	6052.69	1600.00	0.10	0.12	13.84	100.00
Reach-1	234828	22600.00	1286.00	16.13	1302.13	1297.00	1302.26	0.000380	4.02	8869.49	1600.00	0.18	0.37	15.59	100.00
Reach-1	234728	200.00	1285.10	4.83	1289.93		1289.94	0.000011	0.30	674.72	156.00	0.02	0.00	4.65	30.00
Reach-1	234728	2550.00	1285.10	11.59	1296.69		1296.73	0.000096	1.64	1572.73	138.00	0.09	0.07	11.41	30.00
Reach-1	234728	4000.00	1285.10	12.84	1297.94		1297.96	0.000071	1.51	4029.25	1092.75	0.07	0.06	12.65	30.00
Reach-1	234728	7810.00	1285.10	15.27	1300.37		1300.40	0.000071	1.70	7401.70	1600.00	0.08	0.07	15.09	30.00
Reach-1	234728	22600.00	1285.10	17.03	1302.13		1302.22	0.000236	3.33	10206.97	1600.00	0.14	0.25	16.84	30.00
Reach-1	234698	200.00	1285.40	4.52	1289.92	1286.15	1289.93	0.000083	0.75	268.14	59.98	0.06	0.02	3.90	0.00
Reach-1	234698	2550.00	1285.40	11.04	1296.44	1289.27	1296.67	0.000849	3.87	659.18	60.10	0.21	0.43	8.06	0.00
Reach-1	234698	4000.00	1285.40	12.53	1297.93	1290.61	1297.96	0.000170	1.88	3522.66	1243.15	0.09	0.10	9.15	0.00
Reach-1	234698	7810.00	1285.40	14.97	1300.37	1295.73	1300.40	0.000104	1.66	7076.06	1611.00	0.08	0.07	10.94	0.00
Reach-1	234698	22600.00	1285.40	16.72	1302.12	1297.70	1302.21	0.000297	3.02	9896.30	1611.00	0.13	0.23	12.22	0.00
Reach-1	234678	Bridge													
Reach-1	234658	200.00	1285.40	4.52	1289.92	1286.15	1289.93	0.000083	0.75	268.14	59.98	0.06	0.02	3.90	3.00
Reach-1	234658	2550.00	1285.40	10.84	1296.24	1289.27	1296.48	0.000896	3.94	647.32	60.10	0.21	0.45	7.95	3.00
Reach-1	234658	4000.00	1285.40	12.52	1297.92	1290.61	1297.94	0.000172	1.89	3502.81	1240.30	0.09	0.10	9.13	3.00
Reach-1	234658	7810.00	1285.40	14.97	1300.37	1295.73	1300.39	0.000104	1.66	7066.43	1611.00	0.08	0.07	10.93	3.00
Reach-1	234658	22600.00	1285.40	16.71	1302.11	1297.70	1302.20	0.000300	3.03	9869.75	1611.00	0.13	0.23	12.21	3.00
Reach-1	234655	200.00	1285.11	4.81	1289.92	1286.54	1289.93	0.000102	0.84	238.31	59.90	0.07	0.03	4.01	22.00

HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 (Continued)

Reach	River Sta	Q Total	Min Ch El	Max Chl Dpth	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Hydr Radius C	Length Chnl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(ft)	(ft)
Reach-1	234655	2550.00	1285.11	11.09	1296.20	1289.77	1296.47	0.000719	4.19	618.29	60.89	0.23	0.46	10.28	22.00
Reach-1	234655	4000.00	1285.11	12.81	1297.92	1291.14	1297.93	0.000047	1.18	5556.20	1428.14	0.06	0.03	12.00	22.00
Reach-1	234655	7810.00	1285.11	15.26	1300.37	1294.90	1300.38	0.000039	1.22	9265.17	1556.00	0.06	0.04	14.45	22.00
Reach-1	234655	22600.00	1285.11	17.01	1302.12	1296.30	1302.18	0.000141	2.51	11987.22	1556.00	0.11	0.14	16.20	22.00
Reach-1	234633	200.00	1285.40	4.52	1289.92		1289.93	0.000018	0.35	580.47	154.97	0.03	0.00	3.96	355.00
Reach-1	234633	2550.00	1285.40	10.90	1296.30		1296.35	0.000125	1.78	1467.22	142.00	0.10	0.08	10.34	355.00
Reach-1	234633	4000.00	1285.40	12.52	1297.92		1297.93	0.000030	0.95	6235.97	1428.14	0.05	0.02	11.96	355.00
Reach-1	234633	7810.00	1285.40	14.97	1300.37		1300.38	0.000030	1.08	9944.76	1556.00	0.05	0.03	14.41	355.00
Reach-1	234633	22600.00	1285.40	16.72	1302.12		1302.17	0.000118	2.30	12666.43	1556.00	0.10	0.12	16.16	355.00
Reach-1	234278	200.00	1284.40	5.52	1289.92	1285.18	1289.92	0.000015	0.34	583.77	128.55	0.03	0.00	4.48	60.00
Reach-1	234278	2550.00	1284.40	11.86	1296.26	1287.51	1296.30	0.000128	1.65	1604.09	241.47	0.09	0.07	9.29	60.00
Reach-1	234278	4000.00	1284.40	13.52	1297.92	1288.38	1297.92	0.000023	0.78	6610.62	1305.17	0.04	0.02	10.86	60.00
Reach-1	234278	7810.00	1284.40	15.96	1300.36	1290.23	1300.37	0.000029	0.99	10908.95	2397.00	0.05	0.02	13.24	60.00
Reach-1	234278	22600.00	1284.40	17.69	1302.09	1295.28	1302.13	0.000103	2.03	15041.96	2397.00	0.09	0.10	14.91	60.00
Reach-1	234218	200.00	1286.00	3.92	1289.92	1286.75	1289.92	0.000033	0.43	467.55	134.82	0.04	0.01	3.41	390.00
Reach-1	234218	2550.00	1286.00	10.25	1296.25	1288.64	1296.29	0.000150	1.73	1609.89	250.00	0.10	0.08	8.84	390.00
Reach-1	234218	4000.00	1286.00	11.91	1297.91	1289.44	1297.92	0.000025	0.79	6496.74	1304.94	0.04	0.02	10.43	390.00
Reach-1	234218	7810.00	1286.00	14.36	1300.36	1291.15	1300.37	0.000030	0.99	10792.13	2397.00	0.05	0.02	12.78	390.00
Reach-1	234218	22600.00	1286.00	16.08	1302.08	1294.71	1302.12	0.000108	2.03	14913.44	2397.00	0.09	0.10	14.42	390.00
Reach-1	233828	200.00	1284.70	5.21	1289.91	1285.68	1289.91	0.000024	0.39	518.68	144.63	0.04	0.01	3.71	30.00
Reach-1	233828	2550.00	1284.70	11.49	1296.19	1288.28	1296.24	0.000141	1.81	1429.36	145.00	0.10	0.09	9.98	30.00
Reach-1	233828	4000.00	1284.70	13.19	1297.89	1289.14	1297.91	0.000051	1.22	4807.02	1373.50	0.06	0.04	11.68	30.00
Reach-1	233828	7810.00	1284.70	15.63	1300.33	1290.80	1300.35	0.000052	1.39	9035.84	2000.00	0.07	0.05	14.12	30.00
Reach-1	233828	22600.00	1284.70	17.29	1301.99	1295.07	1302.07	0.000189	2.85	12346.63	2000.00	0.13	0.19	15.77	30.00
Reach-1	233798	200.00	1285.40	4.50	1289.90	1286.10	1289.90	0.000082	0.74	269.50	59.98	0.06	0.02	3.91	0.00
Reach-1	233798	2550.00	1285.40	10.51	1295.91	1289.22	1296.17	0.000970	4.04	630.77	60.09	0.22	0.47	7.79	0.00
Reach-1	233798	4000.00	1285.40	12.30	1297.70	1290.56	1297.86	0.000687	3.76	2049.03	1304.47	0.19	0.39	9.05	0.00
Reach-1	233798	7810.00	1285.40	14.91	1300.31	1293.45	1300.35	0.000204	2.33	6334.38	1800.00	0.11	0.14	10.97	0.00
Reach-1	233798	22600.00	1285.40	16.53	1301.93	1299.09	1302.05	0.000539	4.05	9257.84	1800.00	0.18	0.41	12.16	0.00
Reach-1	233778	Bridge													
Reach-1	233758	200.00	1285.40	4.50	1289.90	1286.10	1289.90	0.000082	0.74	269.49	59.98	0.06	0.02	3.91	53.00
Reach-1	233758	2550.00	1285.40	10.27	1295.67	1289.22	1295.94	0.001040	4.14	616.31	60.09	0.23	0.50	7.66	53.00
Reach-1	233758	4000.00	1285.40	12.09	1297.49	1290.55	1297.70	0.000866	4.17	1806.64	1383.30	0.21	0.48	8.89	53.00
Reach-1	233758	7810.00	1285.40	14.90	1300.30	1293.47	1300.32	0.000161	2.07	7490.78	2400.00	0.09	0.11	10.96	53.00
Reach-1	233758	22600.00	1285.40	16.50	1301.90	1299.01	1301.97	0.000378	3.39	11326.91	2400.00	0.15	0.29	12.14	53.00
Reach-1	233705	200.00	1285.20	4.70	1289.90		1289.90	0.000038	0.50	424.12	130.92	0.04	0.01	3.85	327.00
Reach-1	233705	2550.00	1285.20	10.53	1295.73		1295.83	0.000306	2.62	1006.26	105.00	0.15	0.18	9.67	327.00
Reach-1	233705	4000.00	1285.20	12.37	1297.57		1297.59	0.000078	1.48	4526.17	1330.12	0.08	0.06	11.52	327.00
Reach-1	233705	7810.00	1285.20	15.10	1300.30		1300.31	0.000055	1.44	9510.50	2000.00	0.07	0.05	14.24	327.00
Reach-1	233705	22600.00	1285.20	16.69	1301.89		1301.95	0.000198	2.93	12686.28	2000.00	0.13	0.20	15.83	327.00
Reach-1	233378	200.00	1284.10	5.79	1289.89		1289.89	0.000006	0.23	853.43	172.95	0.02	0.00	4.88	500.00
Reach-1	233378	2550.00	1284.10	11.63	1295.73		1295.75	0.000063	1.25	2158.31	250.00	0.07	0.04	10.37	500.00
Reach-1	233378	4000.00	1284.10	13.46	1297.56		1297.57	0.000036	1.05	6260.00	1657.90	0.05	0.03	12.18	500.00
Reach-1	233378	7810.00	1284.10	16.19	1300.29		1300.30	0.000033	1.15	11753.47	2322.09	0.05	0.03	14.86	500.00

HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 (Continued)

Reach	River Sta	Q Total	Min Ch El	Max Chl Dpth	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Hydr Radius C	Length Chnl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(ft)	(ft)
Reach-1	233378	22600.00	1284.10	17.74	1301.84		1301.89	0.000127	2.40	15373.51	2323.00	0.10	0.13	16.39	500.00
Reach-1	232878	200.00	1284.20	5.69	1289.89		1289.89	0.000009	0.29	710.29	157.94	0.02	0.00	4.85	2750.00
Reach-1	232878	2550.00	1284.20	11.51	1295.71		1295.72	0.000049	1.12	2873.99	500.00	0.06	0.03	10.67	2750.00
Reach-1	232878	4000.00	1284.20	13.35	1297.55		1297.55	0.000028	0.95	6711.00	1383.50	0.05	0.02	12.51	2750.00
Reach-1	232878	7810.00	1284.20	16.07	1300.27		1300.28	0.000030	1.12	10852.26	1652.00	0.05	0.03	15.23	2750.00
Reach-1	232878	22600.00	1284.20	17.57	1301.77		1301.83	0.000133	2.49	13333.69	1652.00	0.11	0.14	16.73	2750.00
Reach-1	230128	200.00	1285.00	4.85	1289.85		1289.86	0.000018	0.33	613.99	171.50	0.03	0.00	3.57	132.00
Reach-1	230128	2550.00	1285.00	10.54	1295.54		1295.56	0.000074	1.23	2550.48	500.00	0.07	0.04	9.02	132.00
Reach-1	230128	4000.00	1285.00	12.41	1297.41		1297.43	0.000075	1.40	3487.19	500.00	0.07	0.05	10.89	132.00
Reach-1	230128	7810.00	1285.00	15.21	1300.21		1300.22	0.000018	0.80	14862.54	2800.00	0.04	0.02	13.68	132.00
Reach-1	230128	22600.00	1285.00	16.52	1301.52		1301.55	0.000075	1.74	18535.15	2800.00	0.08	0.07	14.98	132.00
Reach-1	229996	200.00	1285.00	4.85	1289.85		1289.85	0.000011	0.33	613.67	171.48	0.03	0.00	3.57	50.00
Reach-1	229996	2550.00	1285.00	10.51	1295.51		1295.54	0.000073	1.57	1634.96	182.00	0.09	0.04	8.99	50.00
Reach-1	229996	4000.00	1285.00	12.35	1297.35		1297.42	0.000096	2.04	1971.28	182.00	0.11	0.07	10.83	50.00
Reach-1	229996	7810.00	1285.00	15.20	1300.20		1300.21	0.000026	1.23	15013.89	3080.00	0.06	0.02	13.67	50.00
Reach-1	229996	22600.00	1285.00	16.49	1301.49		1301.54	0.000110	2.70	18973.67	3080.00	0.12	0.10	14.95	50.00
Reach-1	229946	200.00	1285.40	4.44	1289.84	1286.05	1289.85	0.000040	0.67	297.48	66.98	0.06	0.01	3.93	35.00
Reach-1	229946	2550.00	1285.40	9.85	1295.25	1288.95	1295.48	0.000553	3.87	659.51	67.07	0.22	0.26	7.62	35.00
Reach-1	229946	4000.00	1285.40	11.48	1296.88	1290.19	1297.30	0.000857	5.20	769.21	573.10	0.27	0.46	8.56	35.00
Reach-1	229946	7810.00	1285.40	14.70	1300.10	1292.88	1300.19	0.000271	3.45	5691.63	2000.00	0.16	0.19	10.96	35.00
Reach-1	229946	22600.00	1285.40	15.60	1301.00	1299.69	1301.41	0.001281	7.80	7497.93	3242.00	0.35	0.93	11.63	35.00
Reach-1	229928.5	Culvert													
Reach-1	229911	200.00	1284.80	5.04	1289.84	1285.70	1289.85	0.000032	0.62	320.52	66.98	0.05	0.01	4.22	50.00
Reach-1	229911	2550.00	1284.80	10.28	1295.08	1288.60	1295.31	0.000519	3.79	671.96	67.07	0.21	0.25	7.77	50.00
Reach-1	229911	4000.00	1284.80	11.58	1296.38	1289.64	1296.82	0.000884	5.27	759.29	67.09	0.28	0.47	8.52	50.00
Reach-1	229911	7810.00	1284.80	15.26	1300.06	1292.56	1300.15	0.000271	3.49	5636.87	2000.00	0.16	0.19	11.16	50.00
Reach-1	229911	22600.00	1284.80	14.99	1299.79	1299.79	1300.81	0.002827	11.14	5101.96	2000.00	0.51	1.93	10.96	50.00
Reach-1	229861	200.00	1284.60	5.23	1289.83		1289.84	0.000301	0.81	247.98	214.17	0.13	0.02	1.15	283.00
Reach-1	229861	2550.00	1284.60	10.18	1294.78		1295.20	0.001570	5.49	526.63	100.00	0.37	0.58	5.89	283.00
Reach-1	229861	4000.00	1284.60	11.40	1296.00		1296.68	0.002095	7.01	648.41	100.00	0.44	0.90	6.85	283.00
Reach-1	229861	7810.00	1284.60	15.50	1300.10		1300.11	0.000015	0.83	19431.70	2600.00	0.04	0.01	11.19	283.00
Reach-1	229861	22600.00	1284.60	15.19	1299.79		1299.83	0.000146	2.52	18629.36	2600.00	0.13	0.10	10.88	283.00
Reach-1	229578	200.00	1284.50	5.25	1289.75		1289.76	0.000287	0.79	251.72	214.35	0.13	0.02	1.16	2250.00
Reach-1	229578	2550.00	1284.50	10.36	1294.86		1294.91	0.000161	1.60	1435.27	235.00	0.13	0.06	6.12	2250.00
Reach-1	229578	4000.00	1284.50	11.66	1296.16		1296.24	0.000211	2.34	1739.61	235.00	0.15	0.10	7.39	2250.00
Reach-1	229578	7810.00	1284.50	15.60	1300.10		1300.10	0.000013	0.77	21663.20	3000.00	0.04	0.01	11.29	2250.00
Reach-1	229578	22600.00	1284.50	15.26	1299.76		1299.79	0.000126	2.35	20644.77	3000.00	0.12	0.09	10.95	2250.00
Reach-1	227328	200.00	1283.50	5.73	1289.23	1286.21	1289.25	0.000177	1.33	252.00	117.40	0.12	0.04	3.63	2550.00
Reach-1	227328	2550.00	1283.50	11.00	1294.50	1290.41	1294.52	0.000181	2.26	3093.93	1188.08	0.14	0.09	7.90	2550.00
Reach-1	227328	4000.00	1283.50	12.33	1295.83	1291.60	1295.85	0.000132	2.13	4829.72	1320.00	0.12	0.08	9.15	2550.00
Reach-1	227328	7810.00	1283.50	16.54	1300.04	1293.08	1300.05	0.000045	1.58	10380.90	1320.00	0.07	0.04	13.11	2550.00
Reach-1	227328	22600.00	1283.50	16.05	1299.55	1294.10	1299.57	0.000077	2.02	30019.86	5359.23	0.10	0.06	12.65	2550.00
Reach-1	224778	200.00	1283.50	5.17	1288.67		1288.70	0.000270	1.48	255.76	153.70	0.14	0.05	3.10	200.00

HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 (Continued)

PROJECT LIMIT

Reach	River Sta	Q Total	Min Ch El	Max Chl Dpth	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Hydr Radius C	Length Chnl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(ft)	(ft)
Reach-1	224778	2550.00	1283.50	10.27	1293.77		1293.83	0.000440	3.29	1945.37	550.00	0.21	0.20	7.11	200.00
Reach-1	224778	4000.00	1283.50	11.75	1295.25		1295.32	0.000380	3.45	2761.31	550.00	0.20	0.20	8.50	200.00
Reach-1	224778	7810.00	1283.50	16.29	1299.79		1299.84	0.000185	3.15	5257.52	550.00	0.15	0.15	12.76	200.00
Reach-1	224778	22600.00	1283.50	15.70	1299.20		1299.24	0.000251	3.57	16563.93	3195.45	0.17	0.19	12.20	200.00
Reach-1	224578	200.00	1284.00	4.45	1288.45		1288.58	0.001634	2.84	70.49	31.88	0.34	0.22	2.13	30.00
Reach-1	224578	2550.00	1284.00	9.25	1293.25		1293.64	0.001833	5.33	561.62	139.00	0.41	0.57	5.02	30.00
Reach-1	224578	4000.00	1284.00	10.58	1294.58		1295.12	0.001905	6.34	746.65	139.00	0.44	0.75	6.32	30.00
Reach-1	224578	7810.00	1284.00	15.11	1299.11		1299.71	0.001082	6.80	1375.39	139.00	0.36	0.73	10.76	30.00
Reach-1	224578	22600.00	1284.00	11.96	1295.96	1295.68	1298.81	0.011655	17.82	2209.84	610.05	1.12	5.58	7.67	30.00
Reach-1	224548	200.00	1283.50	5.00	1288.50	1284.50	1288.52	0.000074	0.91	220.26	54.02	0.08	0.02	3.91	0.00
Reach-1	224548	2550.00	1283.50	9.74	1293.24	1288.52	1293.58	0.000932	4.64	549.98	2071.71	0.31	0.39	6.76	0.00
Reach-1	224548	4000.00	1283.50	10.96	1294.46	1290.06	1295.06	0.001350	6.20	644.85	3003.09	0.38	0.67	7.93	0.00
Reach-1	224548	7810.00	1283.50	15.91	1299.41	1292.96	1299.41	0.000009	0.67	26707.80	5139.01	0.03	0.01	12.68	0.00
Reach-1	224548	22600.00	1283.50	13.81	1297.31	1297.31	1297.39	0.000413	4.18	12463.47	2991.44	0.22	0.28	10.66	0.00
Reach-1	224528	Bridge													
Reach-1	224508	200.00	1283.50	5.00	1288.50	1284.50	1288.52	0.000074	0.91	220.24	54.02	0.08	0.02	3.91	220.00
Reach-1	224508	2550.00	1283.50	9.73	1293.23	1288.53	1293.57	0.000936	4.64	549.25	2064.60	0.31	0.39	6.76	220.00
Reach-1	224508	4000.00	1283.50	10.66	1294.16	1290.06	1294.81	0.001525	6.43	621.69	2775.76	0.40	0.73	7.65	220.00
Reach-1	224508	7810.00	1283.50	12.18	1295.68	1292.96	1297.41	0.003254	10.56	739.90	3629.95	0.60	1.85	9.10	220.00
Reach-1	224508	22600.00	1283.50	13.71	1297.21	1297.21	1297.30	0.000443	4.30	12164.98	2972.53	0.23	0.29	10.57	220.00
Reach-1	224288	200.00	1283.40	5.09	1288.49		1288.50	0.000070	0.89	224.09	54.07	0.08	0.02	3.97	158.00
Reach-1	224288	2550.00	1283.40	9.70	1293.10		1293.33	0.000743	4.11	801.98	190.00	0.27	0.31	6.68	158.00
Reach-1	224288	4000.00	1283.40	10.60	1294.00		1294.40	0.001109	5.44	973.08	190.00	0.34	0.52	7.54	158.00
Reach-1	224288	7810.00	1283.40	12.14	1295.54		1296.43	0.002061	8.35	1264.36	190.00	0.48	1.16	9.01	158.00
Reach-1	224288	22600.00	1283.40	12.95	1296.35		1296.44	0.000511	4.39	12301.41	3410.69	0.24	0.31	9.79	158.00
Reach-1	224130	200.00	1282.80	5.68	1288.48		1288.48	0.000122	0.70	287.58	167.05	0.09	0.01	1.84	450.00
Reach-1	224130	2550.00	1282.80	10.33	1293.13		1293.19	0.000219	2.17	1395.73	280.00	0.15	0.09	6.40	450.00
Reach-1	224130	4000.00	1282.80	11.26	1294.06		1294.17	0.000324	2.88	1656.05	280.00	0.19	0.15	7.31	450.00
Reach-1	224130	7810.00	1282.80	12.89	1295.69		1295.95	0.000585	4.42	2114.36	280.00	0.26	0.33	8.92	450.00
Reach-1	224130	22600.00	1282.80	13.52	1296.32		1296.36	0.000234	2.92	16948.65	4247.81	0.16	0.14	9.53	450.00
Reach-1	223680	200.00	1284.40	4.04	1288.44		1288.45	0.000057	0.63	317.84	114.84	0.07	0.01	2.74	1840.00
Reach-1	223680	2550.00	1284.40	8.53	1292.93		1293.06	0.000374	2.86	901.85	157.67	0.20	0.15	6.52	1840.00
Reach-1	223680	4000.00	1284.40	9.31	1293.71		1293.96	0.000631	4.01	1046.91	313.50	0.26	0.29	7.28	1840.00
Reach-1	223680	7810.00	1284.40	10.58	1294.98		1295.55	0.001246	6.26	1519.91	422.93	0.37	0.66	8.53	1840.00
Reach-1	223680	22600.00	1284.40	11.84	1296.24		1296.27	0.000170	2.53	16695.67	3847.20	0.14	0.10	9.76	1840.00
Reach-1	221840	200.00	1283.60	4.65	1288.25		1288.27	0.000195	1.11	193.78	141.50	0.12	0.03	2.56	6860.00
Reach-1	221840	2550.00	1283.60	9.06	1292.66		1292.68	0.000104	1.57	2915.17	973.31	0.10	0.04	6.91	6860.00
Reach-1	221840	4000.00	1283.60	9.78	1293.38		1293.41	0.000133	1.90	3614.19	978.43	0.12	0.06	7.61	6860.00
Reach-1	221840	7810.00	1283.60	10.88	1294.48		1294.53	0.000225	2.69	4691.39	986.26	0.16	0.12	8.70	6860.00
Reach-1	221840	22600.00	1283.60	12.25	1295.85		1295.89	0.000207	2.84	14983.65	3504.99	0.16	0.13	10.06	6860.00
Reach-1	214980	200.00	1283.80	3.05	1286.85		1286.87	0.000216	1.04	192.97	89.76	0.12	0.03	2.14	1230.00
Reach-1	214980	2550.00	1283.80	8.12	1291.92		1291.97	0.000248	2.01	2224.86	1803.69	0.15	0.08	5.21	1230.00
Reach-1	214980	4000.00	1283.80	8.82	1292.62		1292.68	0.000251	2.20	3506.60	1825.76	0.16	0.09	5.91	1230.00
Reach-1	214980	7810.00	1283.80	9.41	1293.21		1293.31	0.000506	3.32	4581.74	1844.07	0.23	0.21	6.49	1230.00

HEC-RAS Plan: Imported Pla River: RIVER-1 Reach: Reach-1 (Continued)

Reach	River Sta	Q Total	Min Ch El	Max Chl Dpth	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Hydr Radius C	Length Chnl
		(cfs)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(ft)	(ft)
Reach-1	214980	22600.00	1283.80	11.29	1295.09		1295.16	0.000371	3.37	14575.10	3903.13	0.20	0.19	8.37	1230.00
Reach-1	213750	200.00	1283.10	3.50	1286.60	1284.35	1286.61	0.000200	0.95	209.79	104.41	0.12	0.02	2.00	
Reach-1	213750	2550.00	1283.10	8.57	1291.67	1287.33	1291.71	0.000200	1.86	2515.85	2183.27	0.14	0.07	5.44	
Reach-1	213750	4000.00	1283.10	9.30	1292.40	1288.26	1292.44	0.000200	2.02	4525.67	3359.34	0.14	0.08	6.16	
Reach-1	213750	7810.00	1283.10	9.87	1292.97	1289.93	1293.00	0.000200	2.14	9870.35	5574.50	0.15	0.08	6.73	
Reach-1	213750	22600.00	1283.10	11.79	1294.89	1292.39	1294.92	0.000200	2.53	20641.50	5645.58	0.15	0.11	8.64	

South Dakota Department of Transportation
Geotechnical -Soils Central Laboratory
700 E. Broadway Pierre S.Dak. 57501

Tests run according to SD101,SD102,SD207&SD103

Reported to : Sol Brich
Reported By: Gary Olivier
Date: 2/15/2002

PROJECT :

PCEMS:

Submitted by : Sol Brich
Description:

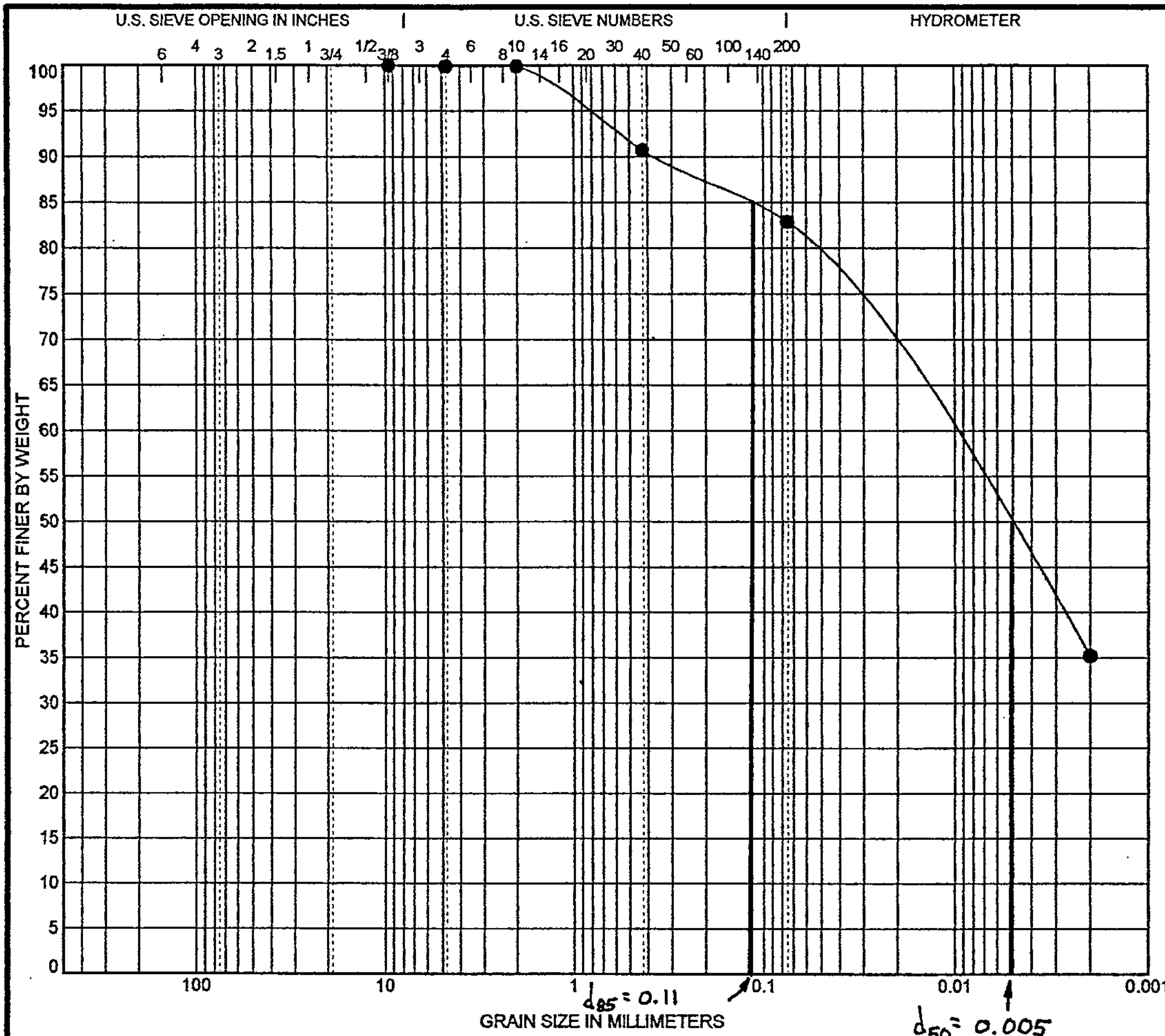
COUNTY: Brown

LAB. SAMPLE #	1	2	3	4	5	6				
PIT #	0	0	0	0	0	0				
HOLE#	0	0	0	0	0	0				
FIELD SAMPLE #	1	0	0	0	0	0				
DEPTH	0	0	0	0	0	0				
wt. cu. ft.	0	0	0	0	0	0				
% passing 3/8	100.0	100.0	100.0	100.0	100.0	100.0				
% passing # 4	99.9	100.0	100.0	100.0	100.0	100.0				
% passing # 10	99.9	100.0	100.0	100.0	100.0	100.0				
% coarse sand	9.2	0.7	5.7	9.3	5.1	0.7				
% fine sand	7.9	4.4	3.0	20.2	4.4	4.4				
% silt	47.7	47.7	72.5	33.7	47.7	48.1				
% clay	35.2	47.2	18.8	36.8	42.8	46.8				
% passing # 40	90.7	99.3	94.3	90.7	94.9	99.3				
% passing # 200	82.9	94.9	91.3	70.5	90.5	94.9				
% coarse & fine sand	17.0	48.4	8.7	29.5	9.5	5.1				
liquid limit	0	0	0	0	0	0				
liquid plastic limit	0	0	0	0	0	24				
P. I.	0	0	0	0	0	0				
Tex. classification	SILT CLAY	SILT CLAY	SANDY SILT	SILT CLAY	SILT CLAY	SILT CLAY				
Texture #	2	2	7	2	2	2				
HRB	A-4	A-4	A-4	A-4	A-4	A-4				
GP Index	8	8	8	7	8	8				

	11	12	13	14	15	16	17	18	19	20
LAB. SAMPLE #										
PIT #										
HOLE#										
FIELD SAMPLE #										
DEPTH										
wt. cu. ft.										
% passing 3/8										
% passing # 4										
% passing # 10										
% coarse sand										
% fine sand										
% silt										
% clay										
% passing # 40										
% passing # 200										
% coarse & fine sand										
liquid limit										
liquid plastic limit										
P. I.										
Tex. classification										
Texture #										
HRB										
GP Index										

Soil Legend

1 - clay silt	4-sand clay	7 - sand silt	10 - gravel	13 - gravel clay	16 - gravel silt sand
2 - silty clay	5-clay sand	8 - sand	11 - gravel clay silt	14 - gravel sand clay	17 - gravel sand silt
3 - clay	6 - silt sand	9 - silt	12 - gravel silt clay	15 - gravel clay sand	18 - gravel sand



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	1	1.0						

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	1	1.0	9.5	0.013			0.1	17.0	82.9	

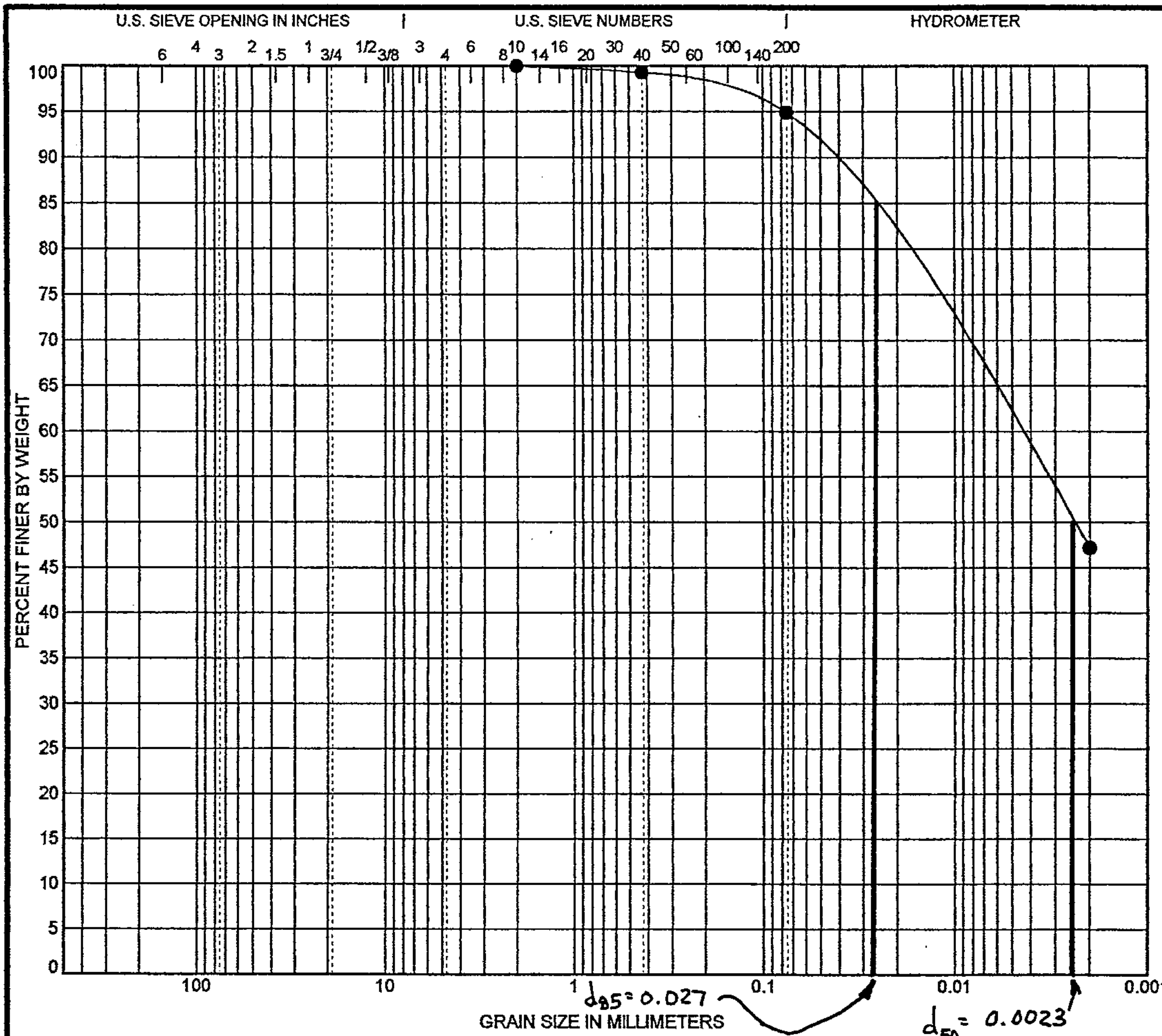
GRAIN SIZE DISTRIBUTION

Project: Moccasin Creek

Location:

Number:

PIEDMONT ENGINEERING, Inc.
1215 Apple's Way Belgrade, Montana 59714



Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● 2	1.0						

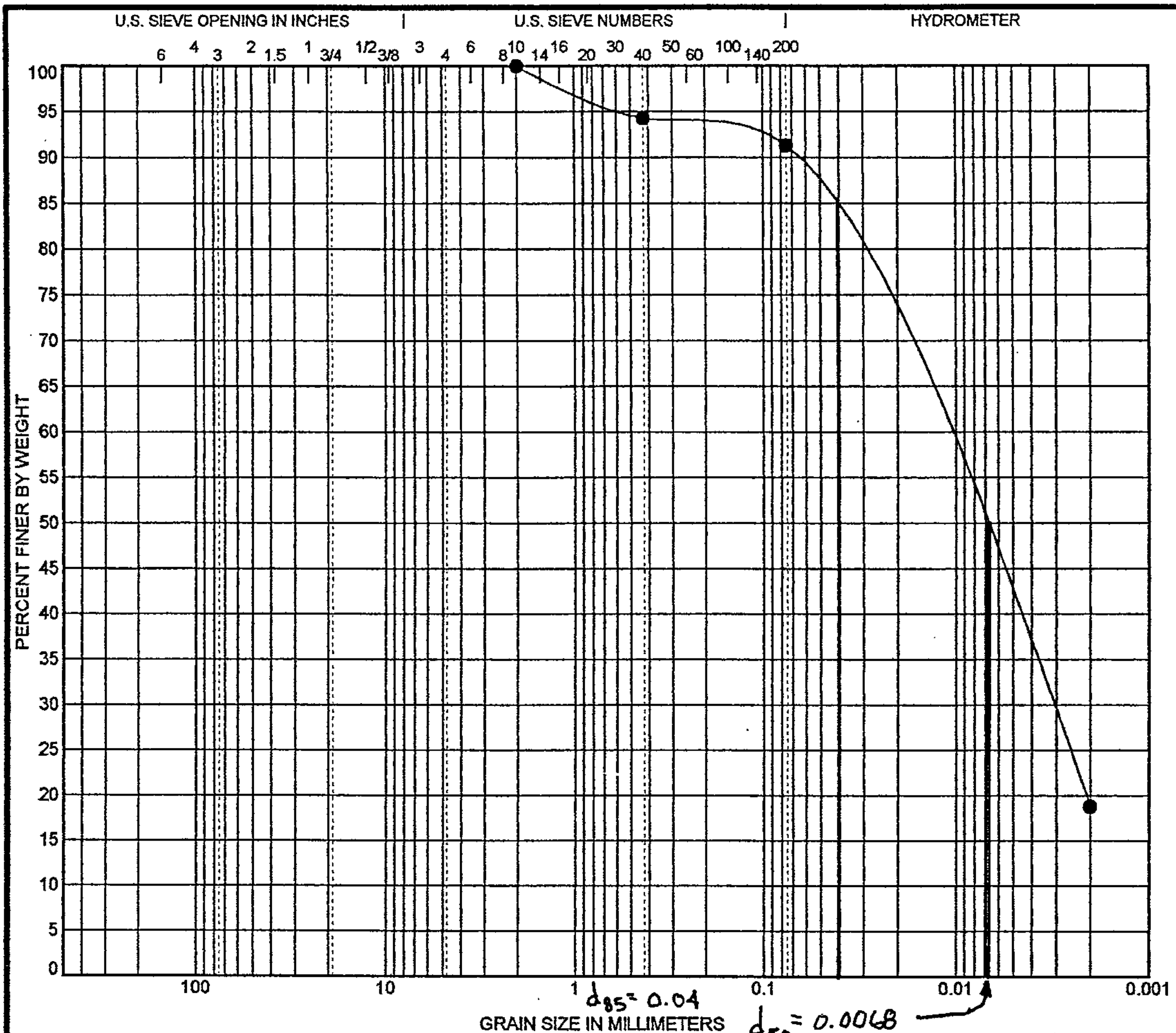
Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● 2	1.0	2	0.005			0.0	5.1	94.9	

US GRAIN SIZE MOCCREEK.GPJ PIEDMONT.GDT 1/7/03

PIEDMONT ENGINEERING, Inc.
1215 Apple's Way Belgrade, Montana 59714

GRAIN SIZE DISTRIBUTION

Project: Moccasin Creek
Location:
Number:



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● 3	1.0						

Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● 3	1.0	2	0.016	0.004		0.0	8.7	91.3	

US_GRAIN_SIZE MOCCREEK.GPJ PIEDMONT.GDT 1/7/03

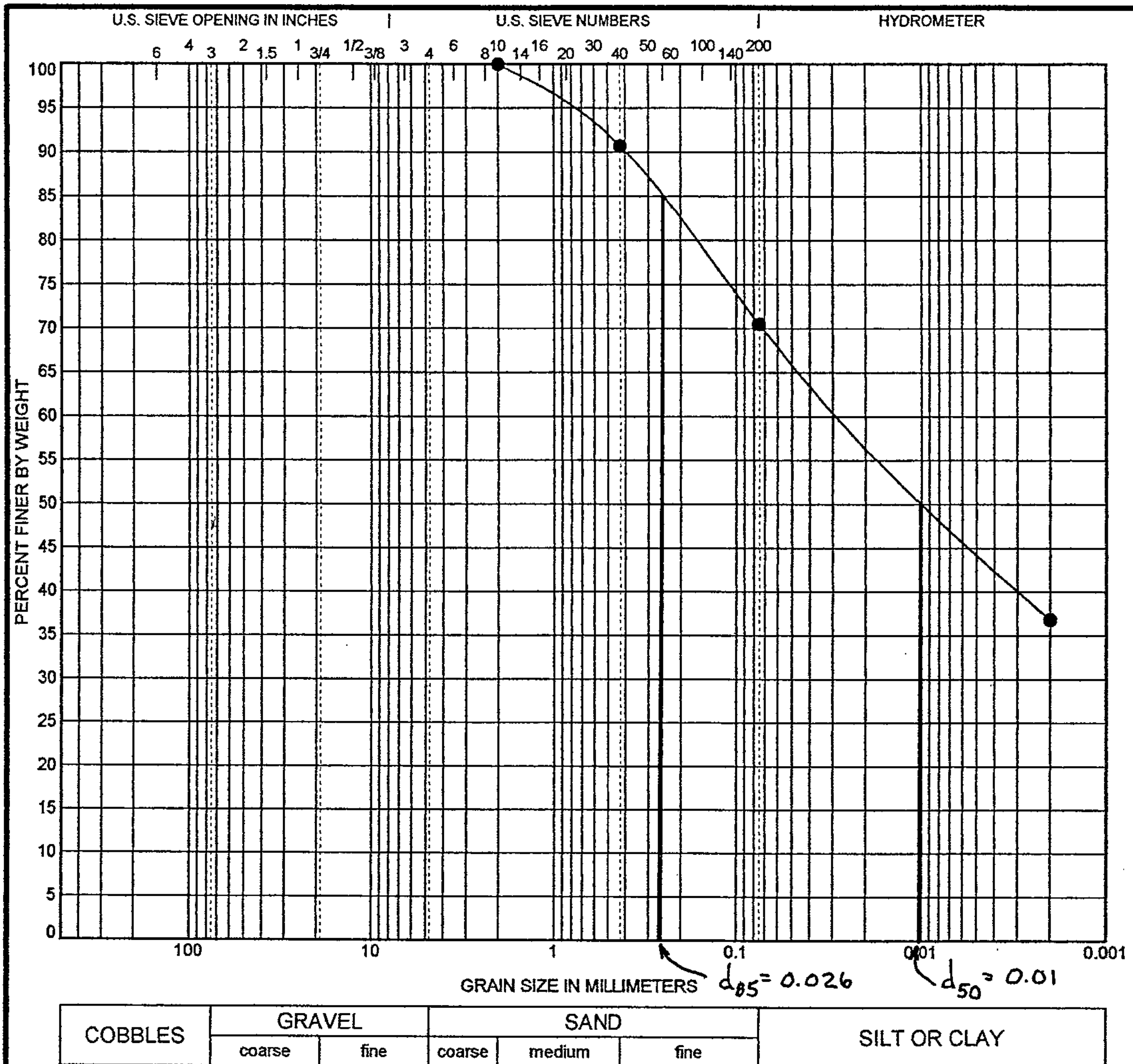
PIEDMONT ENGINEERING, Inc.
1215 Apple's Way Belgrade, Montana 59714

GRAIN SIZE DISTRIBUTION

Project: Moccasin Creek

Location:

Number:



Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● 4	1.0						

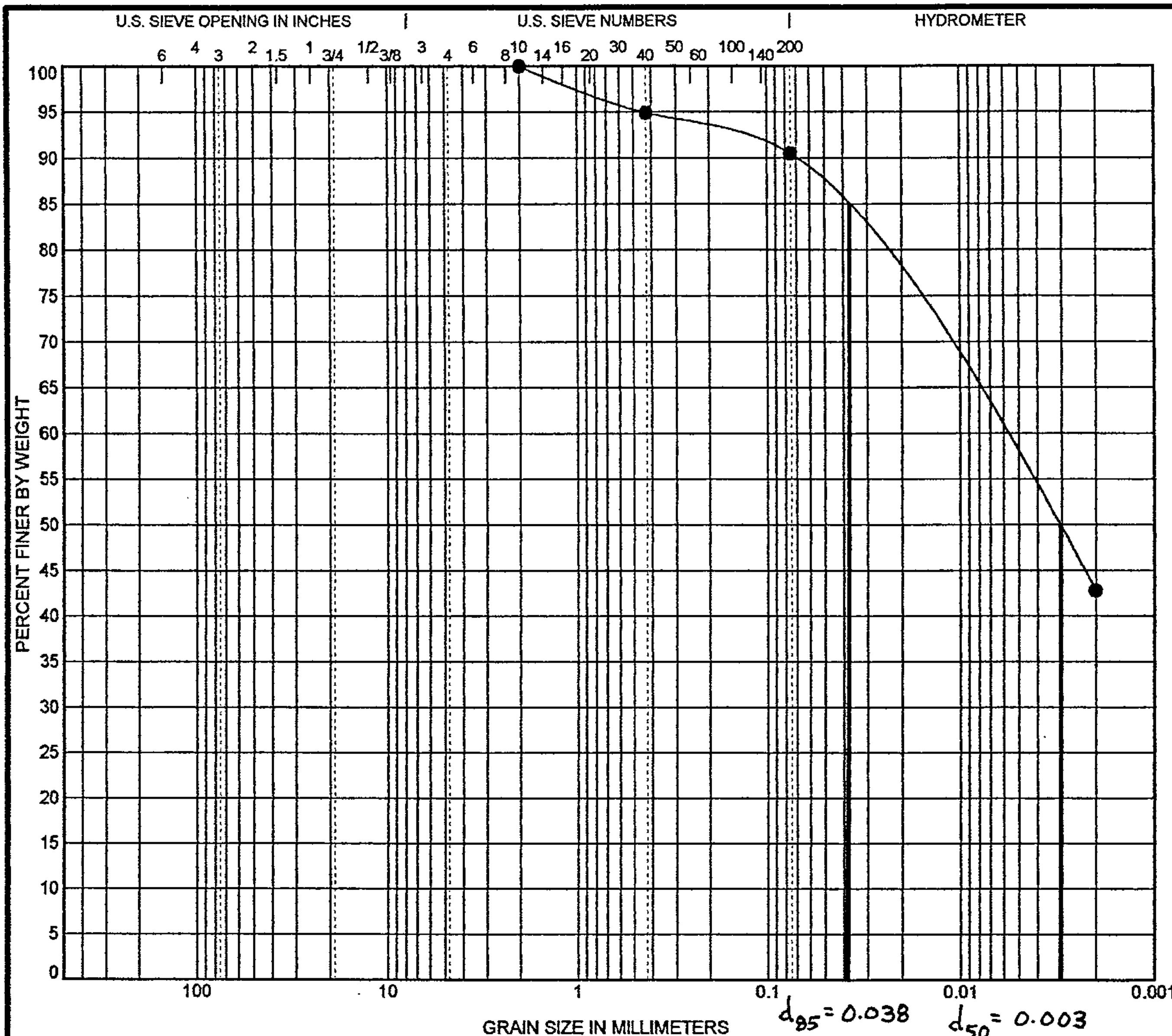
Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● 4	1.0	2	0.024			0.0	29.5	70.5	

PIEDMONT ENGINEERING, Inc.
1215 Apple's Way Belgrade, Montana 59714

GRAIN SIZE DISTRIBUTION

Project: Moccasin Creek
Location:
Number:

US GRAIN SIZE MOCCREEK.GPJ PIEDMONT.GDT 1/7/03



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	5	1.0						

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	5	1.0	2	0.007			0.0	9.5	90.5	

PIEDMONT ENGINEERING, Inc.
1215 Apple's Way Belgrade, Montana 59714

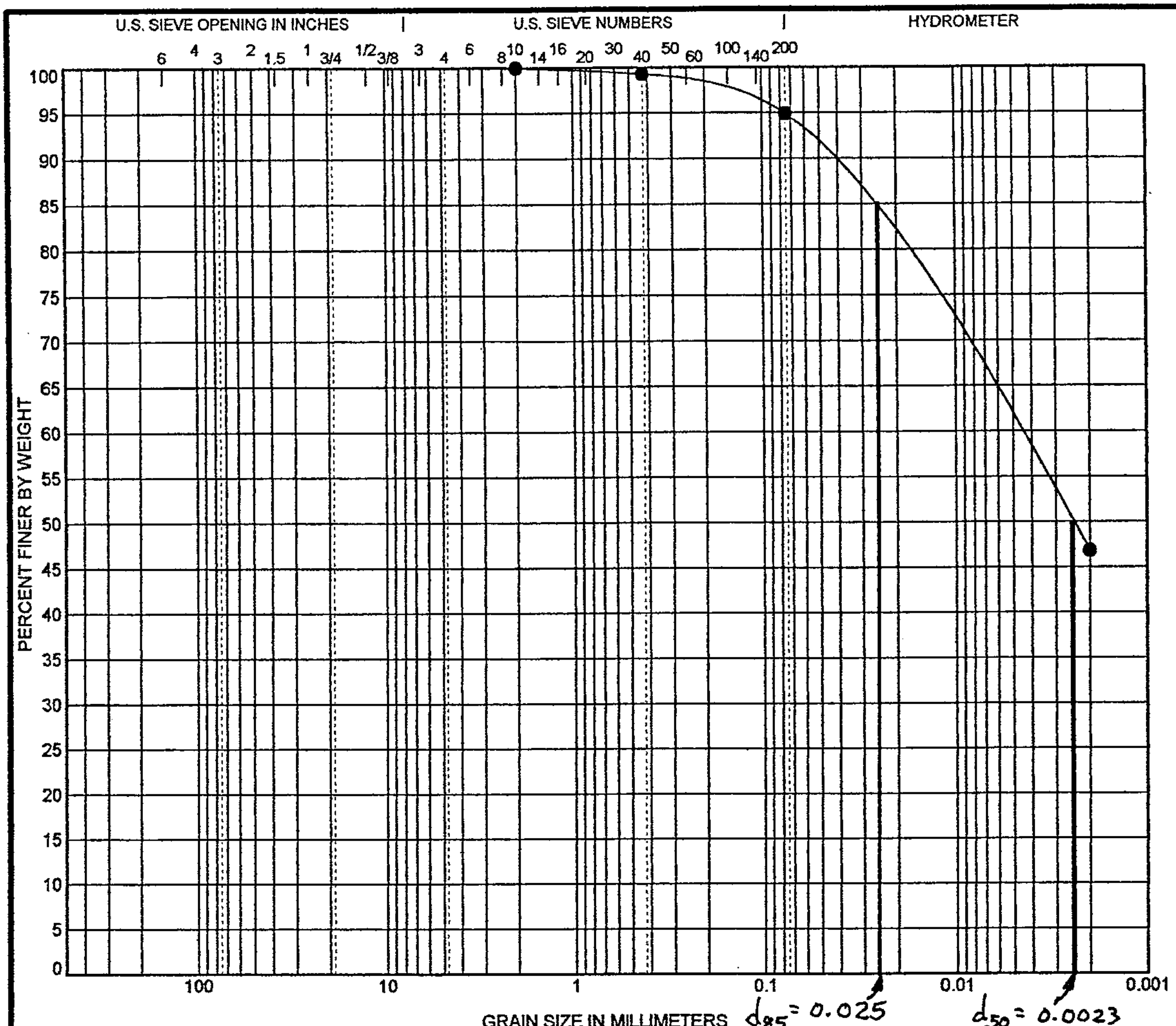
GRAIN SIZE DISTRIBUTION

Project: Moccasin Creek

Location:

Number:

US GRAIN SIZE MOCCREEK.GPJ PIEDMONT.GDT 1/7/03



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● 6	1.0						

Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● 6	1.0	2	0.005			0.0	5.1	94.9	

PIEDMONT ENGINEERING, Inc.
1216 Apple's Way Belgrade, Montana 59714

GRAIN SIZE DISTRIBUTION

Project: Moccasin Creek
Location:
Number:

US GRAIN SIZE MOCCREEK.GPJ PIEDMONT.GDT 1/7/03

X-SECTION DATA

213750

4500	1291.3
4600	1291.4
4700	1290.5
4800	1289.6
4814	1284.6
4825	1283.5
4833	1283.1
4852	1283.5
4876	1284.5
4891	1286.2
4900	1286.2
5000	1289.3
5100	1290.6
5200	1290.7
5300	1291.6
5400	1291.5

214980

4000	1291.2
4100	1290.9
4200	1291.1
4300	1290.9
4400	1291.5
4500	1291.8
4564	1290.5
4600	1289.6
4700	1289.7
4800	1286.8
4820	1284.9
4838	1284.0
4855	1283.9
4872	1283.8
4881	1284.9
4900	1290.2
5000	1291.1
5100	1291.4
5200	1291.6
5300	1291.8
5400	1295.0

221840

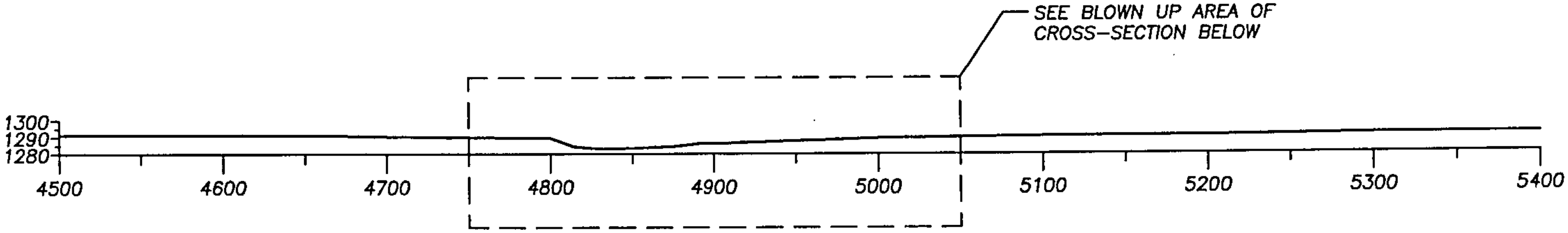
3600	1293.6
3687	1296.3
3700	1296.4
3730	1292.2
3780	1290.9
3800	1288.1
3811	1285.2
3818	1284.9
3826	1284.4
3837	12836
3845	1285.5
3869	1288.3
3900	1287.8
3988	1288.7
4000	1288.4
4127	1288.7
4180	1291.5
4300	1291.6
4400	1290.6
4500	1290.0

262843

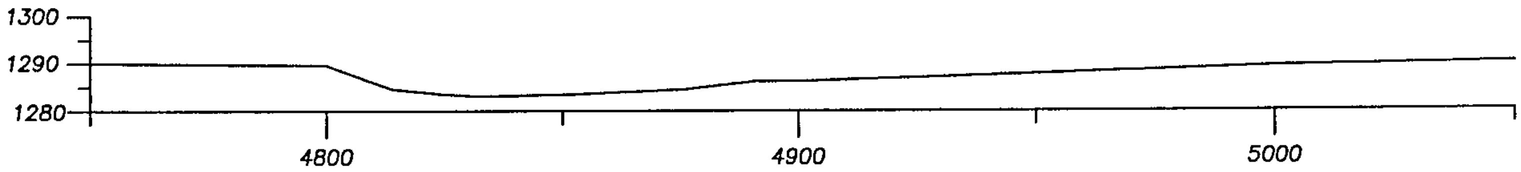
3800	1294.3
3900	1294.4
4000	1294.5
4100	1295.0
4140	1295.1
4200	1293.8
4223	1288.4
4256	1287.0
4304	1288.8
4321	1293.4
4400	1294.4
4500	1293.9
4600	1296.7
4700	1299.4
4800	1300.2
4900	1299.6
5000	1299.5

264848

3650	1295.4
3752	1295.2
3853	1294.1
3885	1294.0
3923	1294.0
3980	1293.6
4021	1291.3
4048	1290.4
4068	1289.3
4080	1289.1
4117	1289.0
4138	1290.8
4165	1291.9
4195	1294.0
4239	1294.5
4302	1294.8
4359	1295.6
4422	1296.9
4479	1297.6

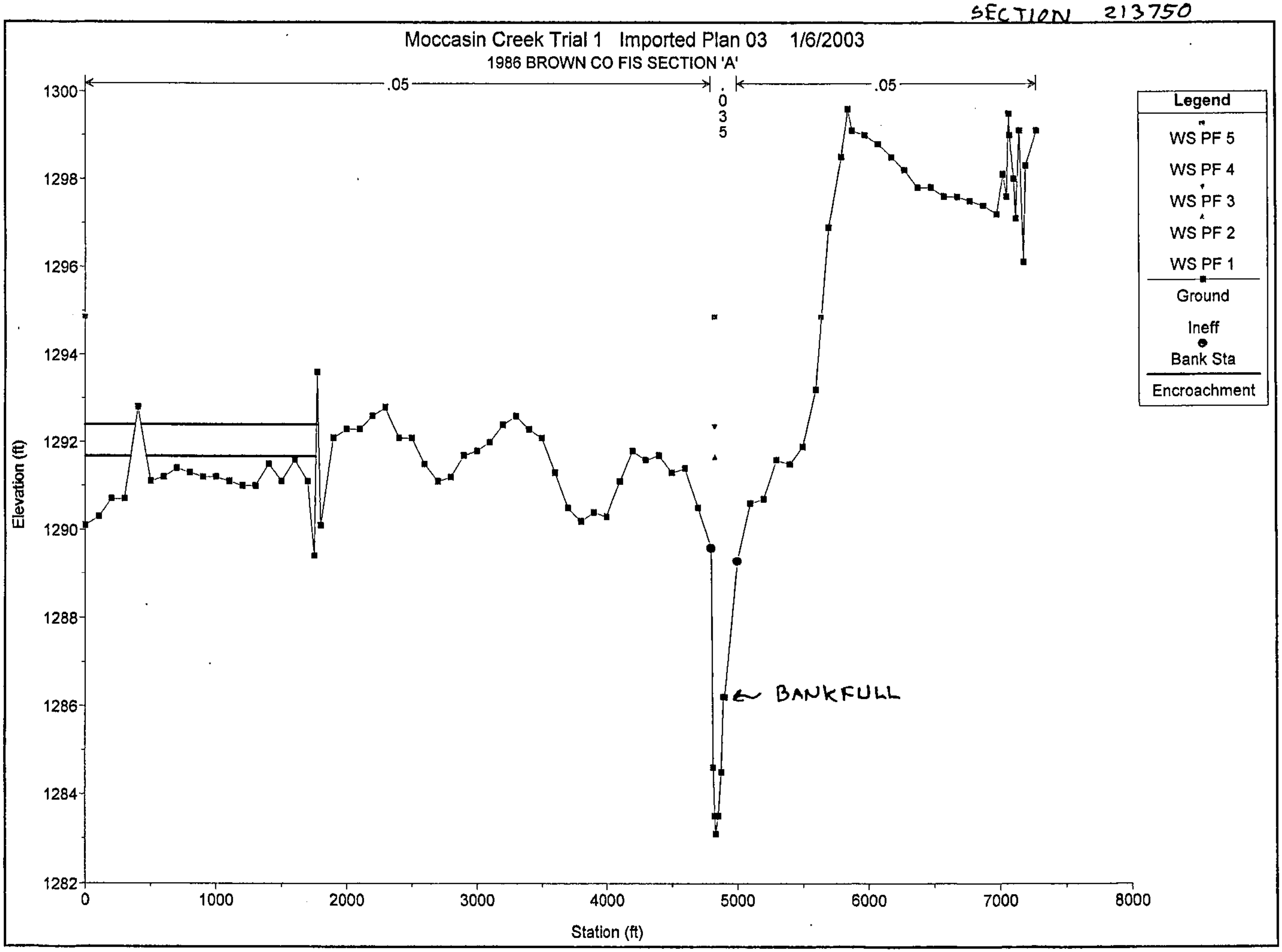


HEC2 CROSS-SECTION 213750

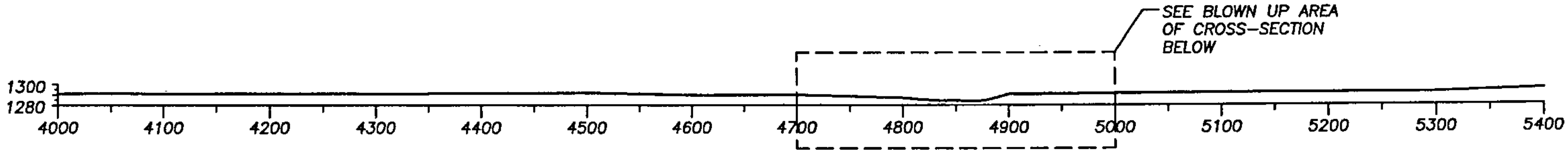


BLOWN UP AREA OF HEC2 CROSS-SECTION 213750

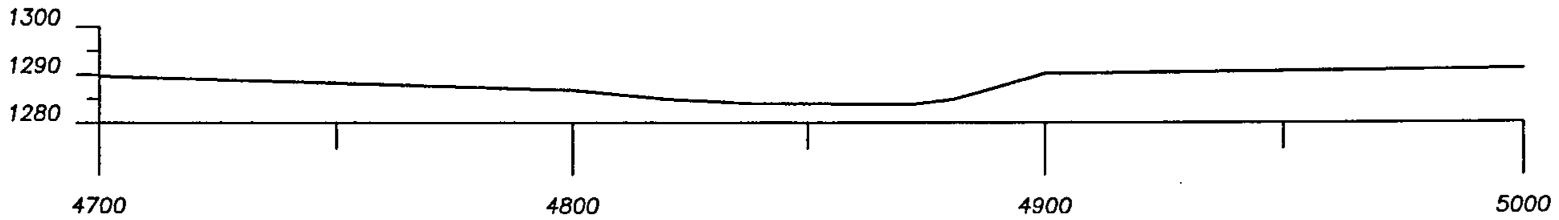
INTER-FLUVE, INC.
BOZEMAN, MONTANA (406) 586-6926 HOOD RIVER, OREGON (541) 386-9003



SECTION 213750
Moccasin Creek Trial 1 Imported Plan 03 1/6/2003
1986 BROWN CO FIS SECTION 'A'
.05
.035
.05
Legend
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Ineff
Bank Sta
Encroachment
Elevation (ft)
Station (ft)
1282
1284
1286
1288
1290
1292
1294
1296
1298
1300
0
1000
2000
3000
4000
5000
6000
7000
8000
BANKFULL

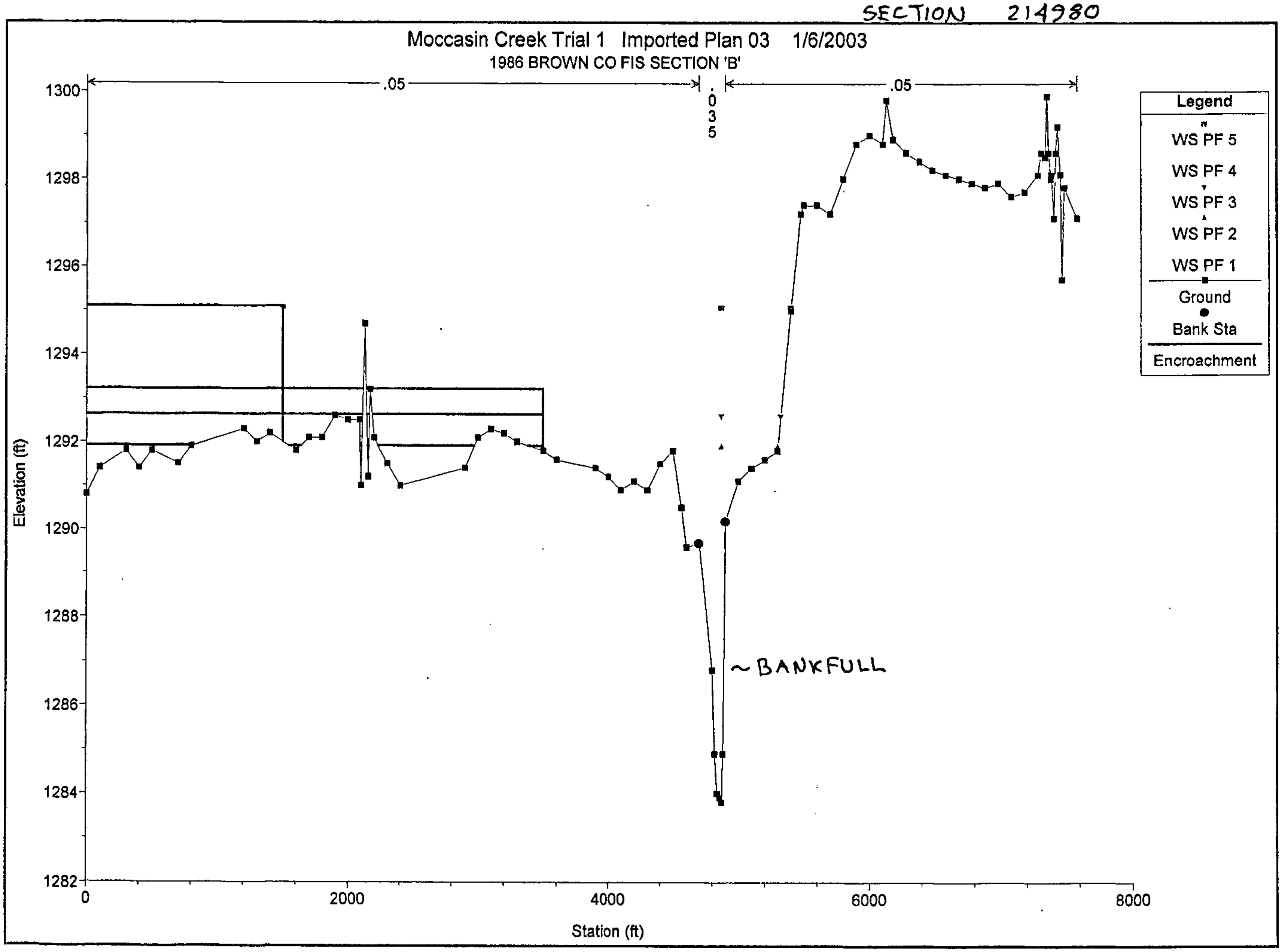


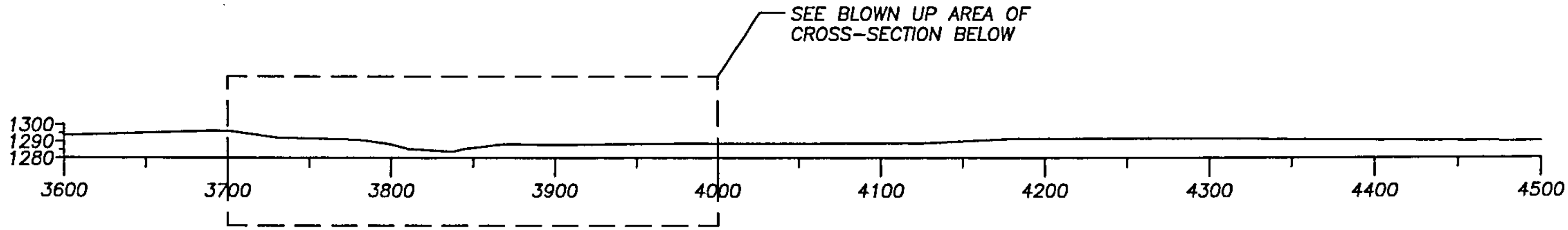
HEC2 CROSS-SECTION 214980



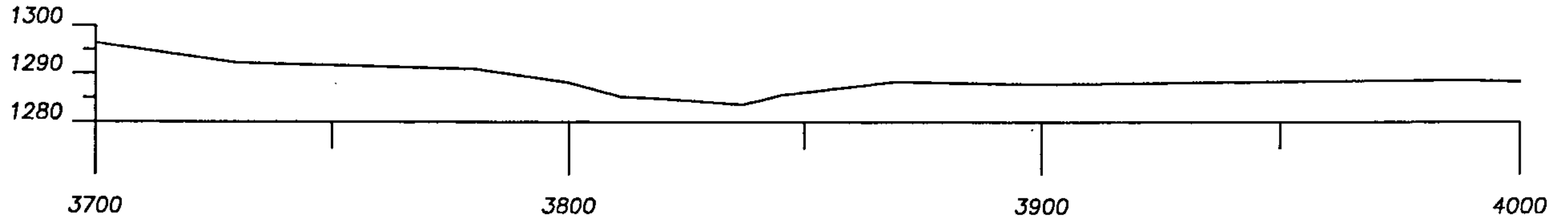
BLOWN UP AREA OF HEC2 CROSS-SECTION 214980

INTER-FLUVE, INC.
BOZEMAN, MONTANA (406) 586-6926 HOOD RIVER, OREGON (541) 386-9003


SECTION 214980
Moccasin Creek Trial 1 Imported Plan 03 1/6/2003
1986 BROWN CO FIS SECTION 'B'
.05
.035
.05
Legend
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Encroachment
~BANKFULL
Elevation (ft)
Station (ft)
1300
1298
1296
1294
1292
1290
1288
1286
1284
1282
0
2000
4000
6000
8000



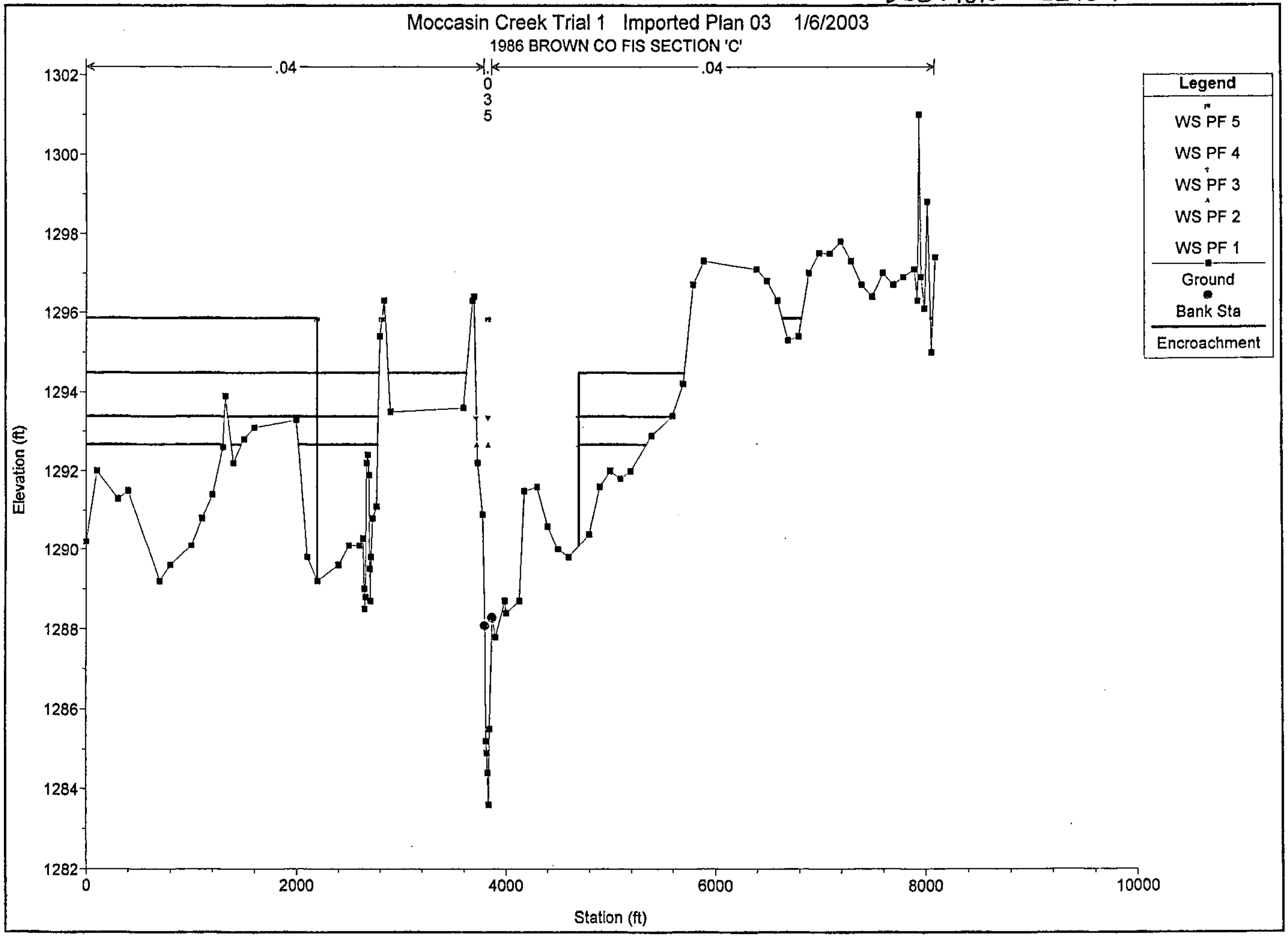
HEC2 CROSS-SECTION 221840

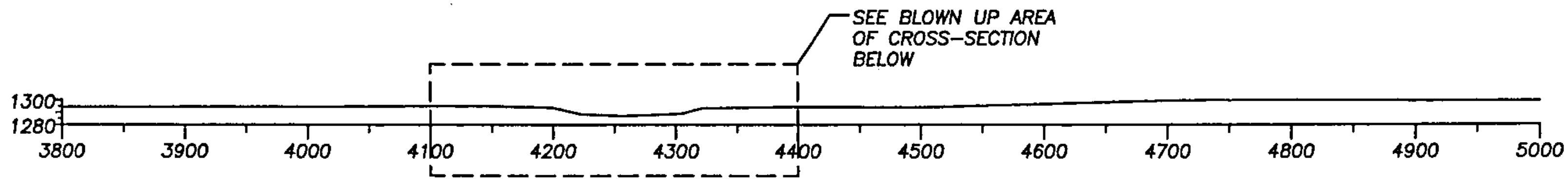


BLOWN UP AREA OF HEC2 CROSS-SECTION 221840

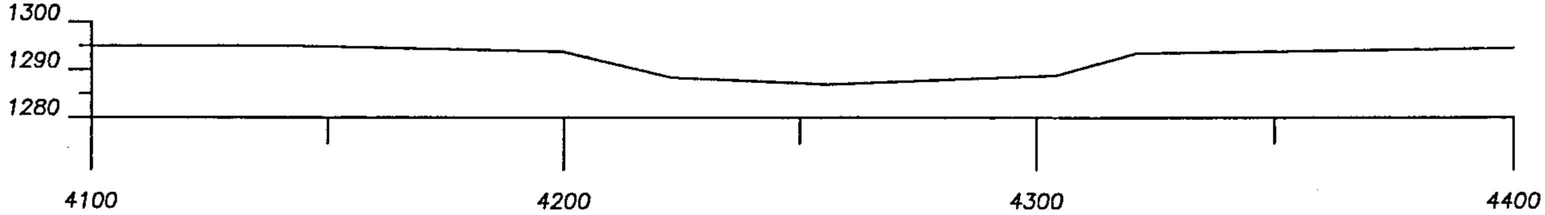
INTER-FLUVE,INC.
BOZEMAN, MONTANA (406) 586-6926 HOOD RIVER, OREGON (541) 386-9003

SECTION 221840





HEC2 CROSS-SECTION 262843



BLOWN UP AREA OF HEC2 CROSS-SECTION 262843

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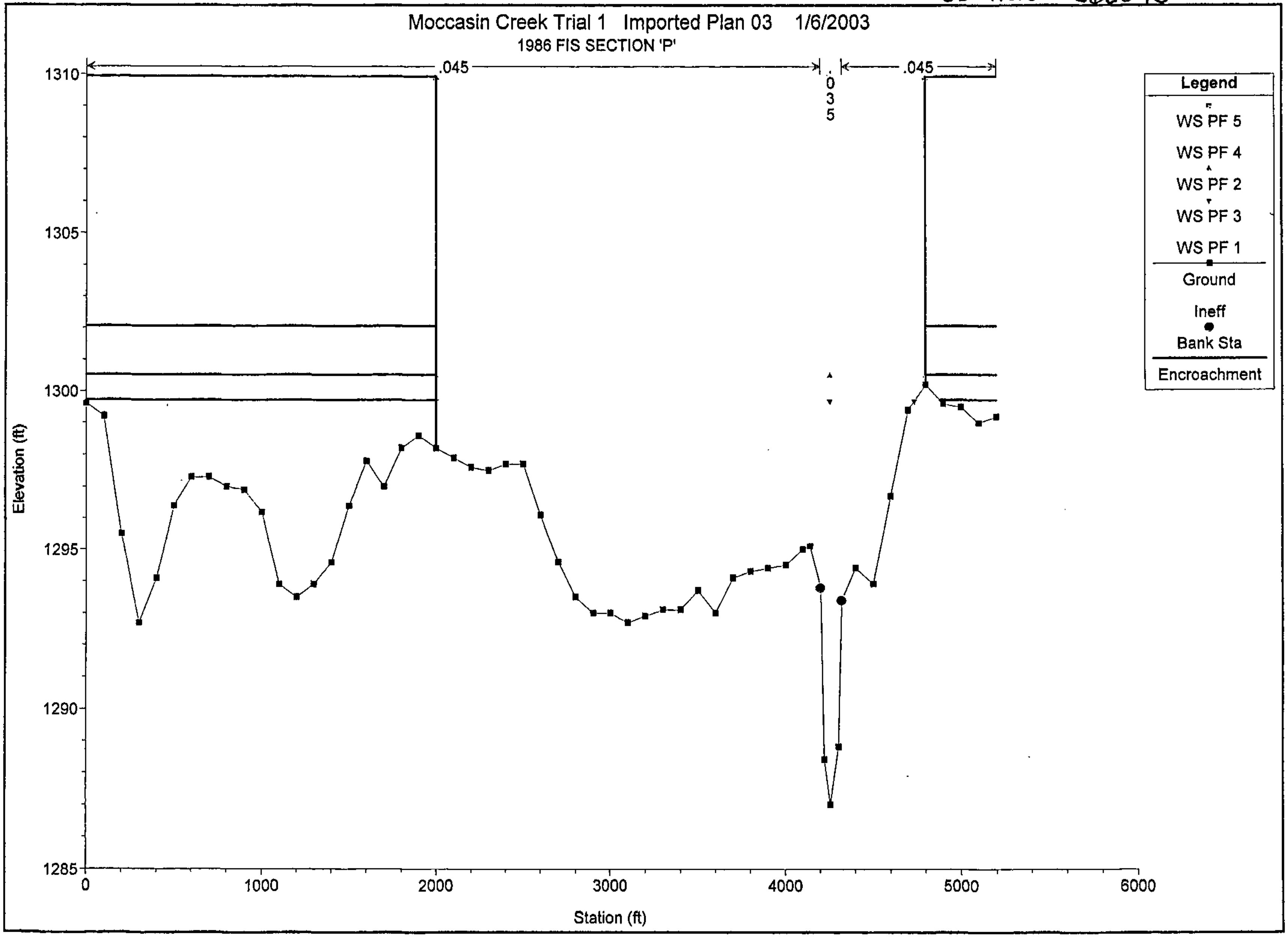
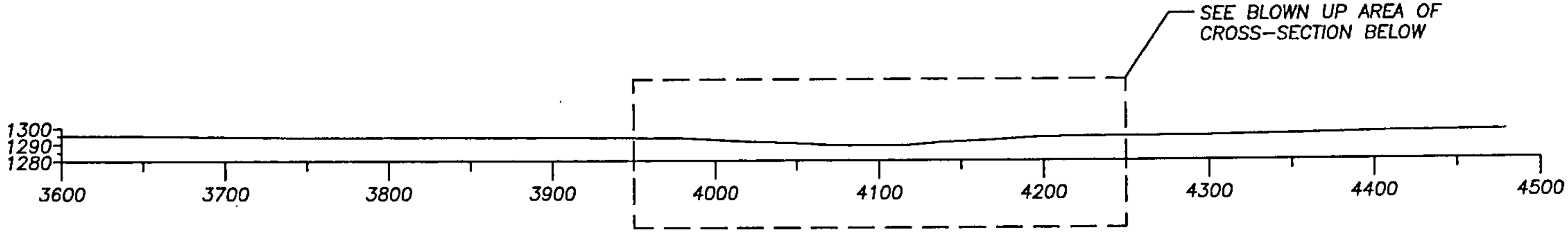
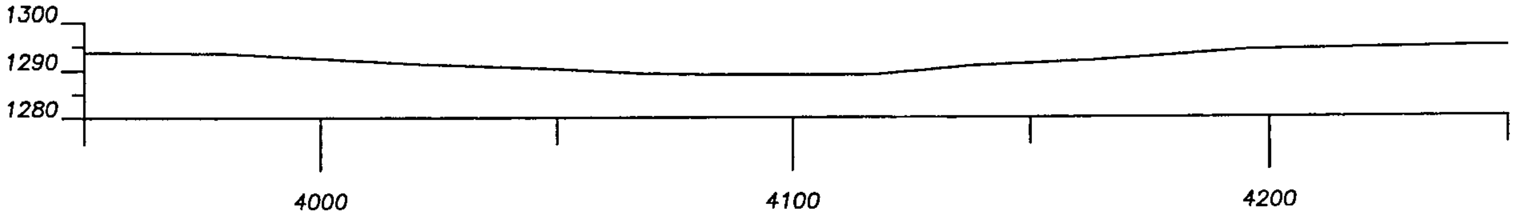
SECTION 262843





HEC2 CROSS-SECTION 264848



BLOWN UP AREA OF HEC2 CROSS-SECTION 264848

INTER-FLUVE, INC.
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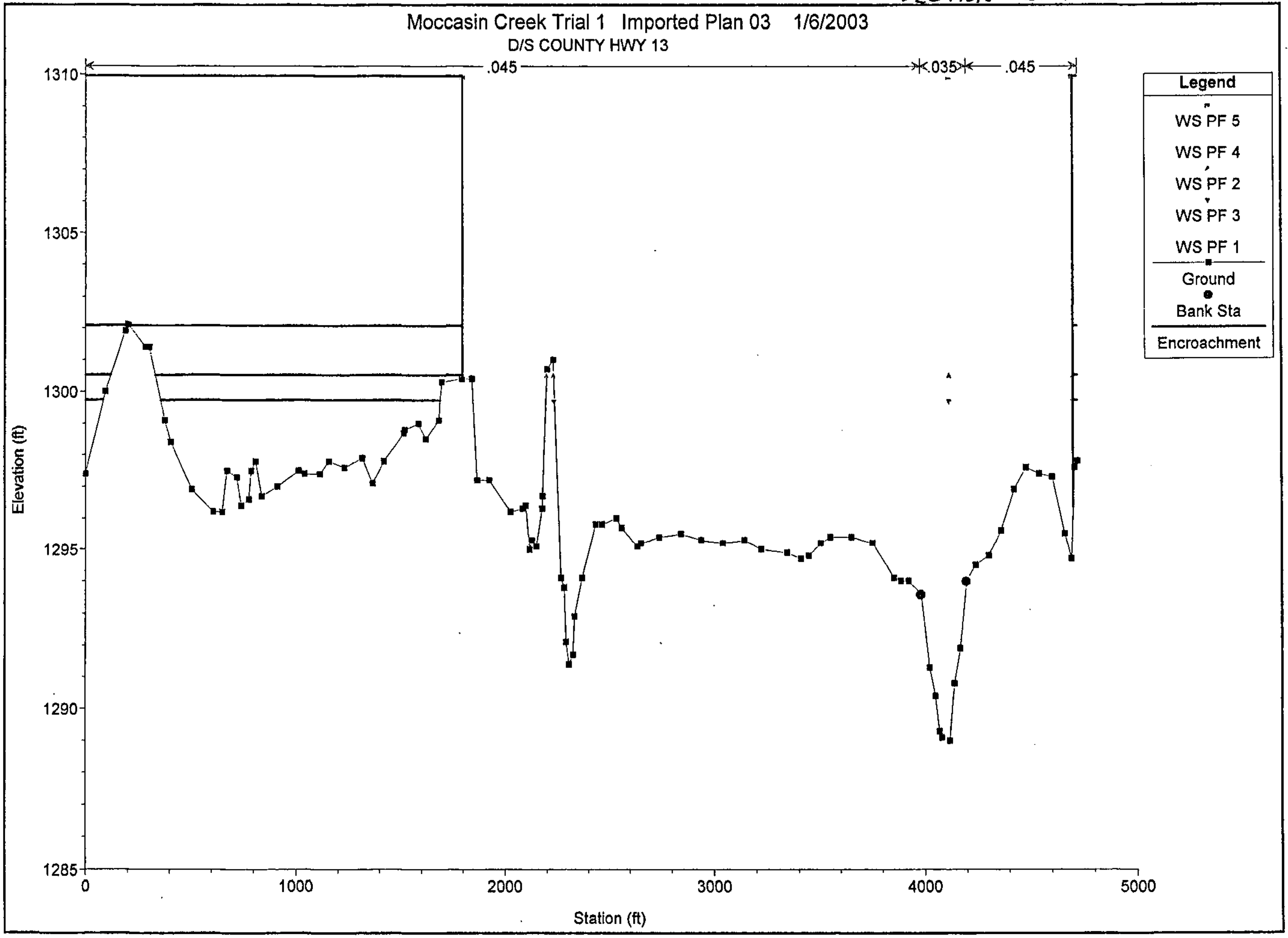
SECTION 264848



Moccasin CREEK F.S./C.D.
ABERDEEN, S.D.

Compute approximate bank-full in undisturbed sections upstream and downstream of dredged section

EXISTING HEC-2 flows from previous flood studies for Profile #1

Reach	Q
278063 - 264848	66
264848 - 258913	150
258913 - 238993	160
238993 - 238293	210
238293 - 213750	200

By Trial and Error
using Q = 100 for Sections 221840, 214980, 213750
all below bankfull

Q = 200
221840 is @ bankfull of low-flow channel
214980 is @ bankfull of low flow channel
213750 is ≈ 0.5 above bankfull of low flow channel @ bankfull @

Q = 190
221840 is slightly below low flow ←
214980 is slightly below but ≈ at bankfull ←
213750 is ≈ 0.4' high of bankfull

213750 is bankfull of low-flow @ ≈ 160 cfs ←

Main Channel Bankfull determinations

221840 is bankfull @

@ 1000 cfs
WS in 221840 is 0.25' low using adjacent channels
WS in 214980 is 0.35' high
WS in 213750 is 0.20 high

2/

@ 950 cfs WS is 0.05' high @ 213750
WS is 0.2' high @ 214980
WS is 0.35' low @ 221840 using adjacent channels

@ 930 cfs WS is ≈ at Bankfull @ 213750 ⇐
WS is ≈ 0.2' high @ 214980

Compute Bankfull @ Sections 262843, 264848

Set ineffective flow areas to prevent flow simulation in adjacent channels

Section	Ineffective flow areas set
262843	0–4200 & 4321 – 5200
264848	0–3980 & 4195 – 4720

@ 340 CFS WS ≈ 0.2' High @ 264848
WS ≈ 0.35' High @ 262843

@ 320 CFS WS within 0.02' @ 264848

@ 310 CFS WS with 0.05' @ 262843

using 310 CFS @ 264848
262843

~~@ 264848 max depth = 4.52~~

	264848	262843
Flow (cfs)	310	310
Max Chnl Depth (ft)	4.52	6.45
E.G. Slope	0.000045	0.000023
Vel. Chnl (ft/sec)	0.55	0.56
Flow Area (ft^2)	559.32	550.99
Top Width (ft)	274.13	961.18
Froude #	0.06	0.05
Shear Chan (psf)	0.01	0.01
Hyd. Radius (ft)	2.70	4.56
W/D	270	149

	213750	214980	221840
Flow (cfs)	190	190	190
Max. Chnl Depth (ft)	3.41	2.97	4.57
E.G. Slope	0.000200	0.000215	0.000196
Vel. Chnl (ft/sec)	0.94	1.02	1.09
Flow Area (ft²)	201.10	185.48	182.67
Top Width (ft)	101.45	87.34	126.97
Froude #	0.12	0.12	0.12
Shear Chnl (psf)	0.02	0.03	0.03
Hyd. Radius (ft)	1.97	2.11	2.50
W/D	30	30	28

	213750	214980	221840
Flow (cfs)	930	930	930
Max Chnl Depth (ft)	6.52	6.09	7.20
E.G. Slope	0.000200	0.000245	0.000113
Vel Chnl (ft/sec)	1.36	1.44	1.33
Flow Area (ft²)	688.78	666.30	1044.21
Top Width (ft)	~~0.13~~ 234.98	~~0.14~~ 310.45	~~0.10~~ 210.14
Froude #	0.13	0.14	0.10
Shear Chnl (psf)	0.04	0.05	0.04
Hyd. Radius (ft)	3.40	3.21	5.06
W/D	36	51	—

Calculate Average D_{50} for Sediment Samples

Sample #	d_{50} (mm)	d_{85} (mm)	d_{100} mm
1	0.005	0.11	9.5
2	0.0023	0.027	2
3	0.0068	0.04	2
4	0.01	0.026	2
5	0.003	0.038	2
6	0.0023	0.025	2
Σ	0.0294	0.2660	19.5
$\bar{x}$	0.005	0.04	3.25
mode	0.003	0.03	2

Compute Boundary Reynolds # (approx.)

$R^* = U^* d / \nu$ $\quad\quad \nu$ = kinematic viscosity

@ 10°C $\quad \nu = 1.306 \times 10^{6}\ m^2/sec$

Compute dimensionless parameter

$$\frac{d}{\nu}\left[0.1\left(\frac{\gamma_s}{\gamma}-1\right)g\,d\right]^{\frac{1}{2}}$$

$d = 0.003$ mm $= 0.000003$ m

$\gamma_s = 2.65$

$\gamma = 1$

$g = 9.81\ m/sec^2$

$$\frac{0.000003}{1.306\times10^{-6}}\left[0.1\left(\frac{2.65}{1}-1\right)\left(9.81\frac{m}{sec^2}\right)\left(0.000003\right)\right]^{\frac{1}{2}} = 0.0051$$

Upstream HEC terminus through project 244758

244758 - 262843 = 18,085' above

264848 - 244758 = 20,090 above

Downstream HEC terminus through project 224508

224508 - 213750 = 10,758 below

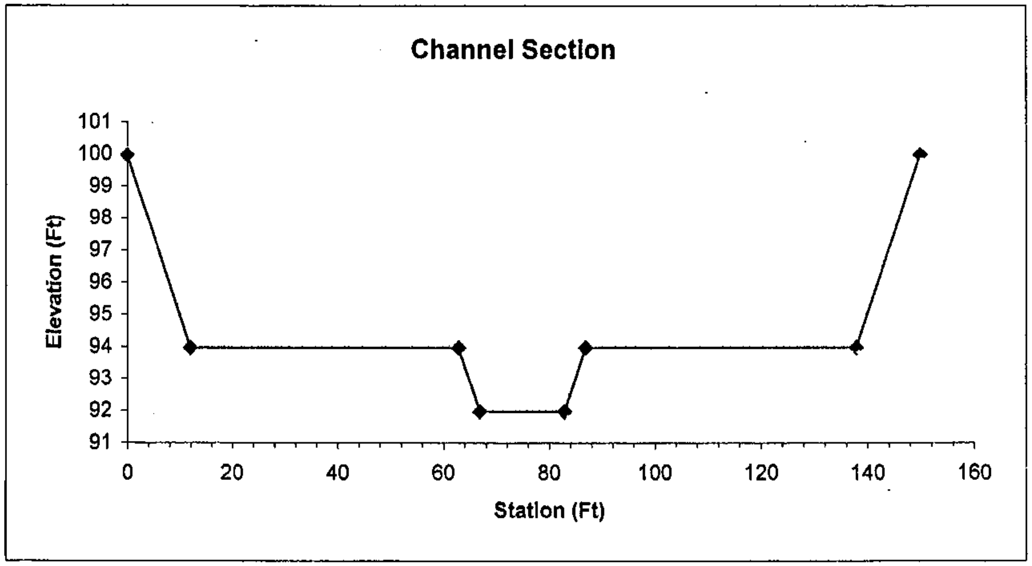
224508 - 214980 = 9528 below

224508 - 221840 = 2668 below

Project: Moccasin Creek
Approximate Average Flood Channel
Compound Channel Design
Shields Parameter 0.02

Floodplain elevation	100
Depth of high flow channel	6
Top width of high flow channel	150
side slope (H:1)	2
Depth of low flow channel	2
Bottom width of low flow channel	16
side slope (H:1)	2
Bottom width of high flow channel	126

X	Y
0	100
12	94
63	94
67	92
83	92
87	94
138	94
150	100



Moccasin Creek Channel Hydraulic Calculations

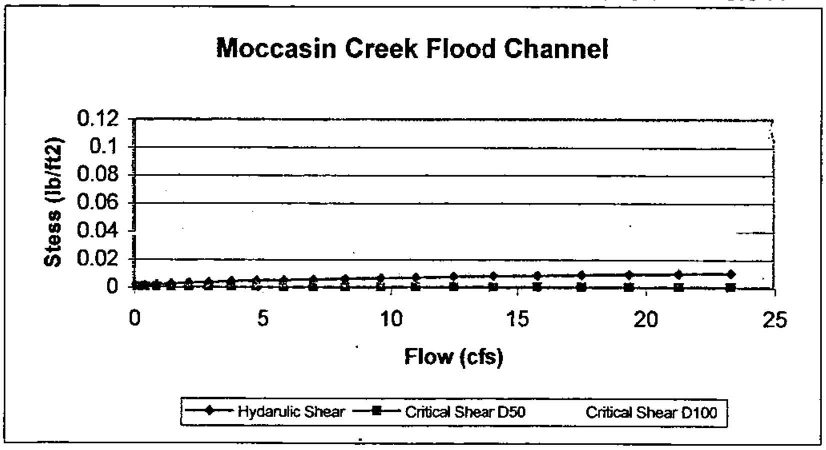
Approximate Average Flood Channel

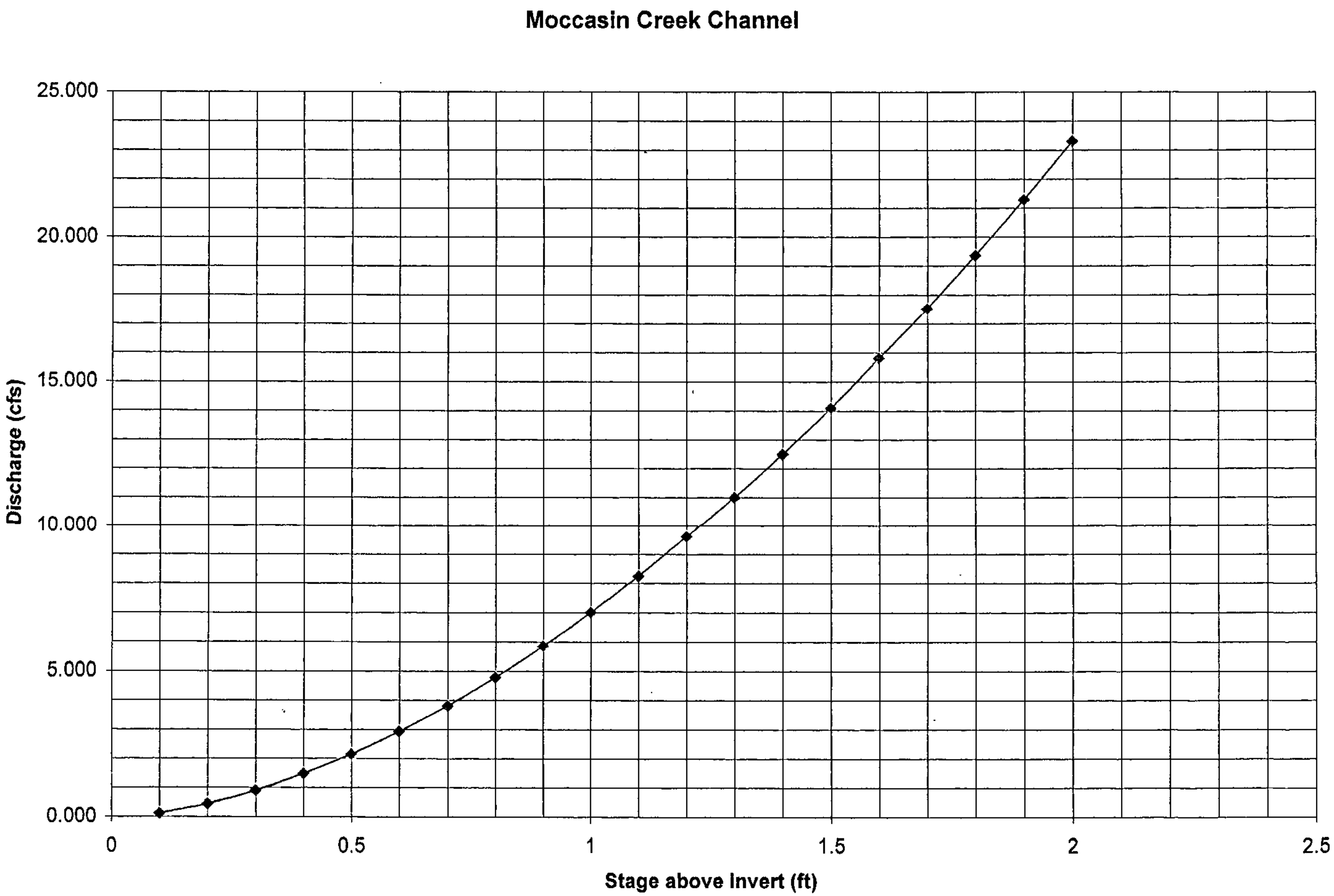
Bed Material	mm	ft		mm	ft
D_{50} =	0.003	0.000010	D_{100} =	2	0.00656

STAGE	AREA (ft^2)	Wetted Perim (ft)	R ft		SLOPE	n	VAVG (ft/s)	Q (cfs)	τ (lb/ft^2)	τ_{cD50} (lb/ft^2)	τ_{cD100} (lb/ft^2)
0.1	1.620	16.447	0.098	0.099	0.0001	0.035	0.091	0.147	0.0006	0.00002	0.041
0.2	3.280	16.894	0.194	0.195	0.0001	0.035	0.143	0.468	0.0012	0.00002	0.041
0.3	4.980	17.342	0.287	0.290	0.0001	0.035	0.185	0.923	0.0018	0.00002	0.041
0.4	6.720	17.789	0.378	0.382	0.0001	0.035	0.222	1.495	0.0024	0.00002	0.041
0.5	8.500	18.236	0.466		0.0001	0.035	0.256	2.175	0.0029	0.00002	0.041
0.6	10.320	18.683	0.552		0.0001	0.035	0.287	2.958	0.0034	0.00002	0.041
0.7	12.180	19.130	0.637		0.0001	0.035	0.315	3.837	0.0040	0.00002	0.041
0.8	14.080	19.578	0.719		0.0001	0.035	0.342	4.812	0.0045	0.00002	0.041
0.9	16.020	20.025	0.800		0.0001	0.035	0.367	5.877	0.0050	0.00002	0.041
1	18.000	20.472	0.879		0.0001	0.035	0.391	7.033	0.0055	0.00002	0.041
1.1	20.020	20.919	0.957		0.0001	0.035	0.413	8.277	0.0060	0.00002	0.041
1.2	22.080	21.367	1.033		0.0001	0.035	0.435	9.651	0.0064	0.00002	0.041
1.3	24.180	21.814	1.108		0.0001	0.035	0.456	11.025	0.0069	0.00002	0.041
1.4	26.320	22.261	1.182		0.0001	0.035	0.476	12.528	0.0074	0.00002	0.041
1.5	28.500	22.708	1.255		0.0001	0.035	0.495	14.117	0.0078	0.00002	0.041
1.6	30.720	23.155	1.327		0.0001	0.035	0.514	15.832	0.0083	0.00002	0.041
1.7	32.980	23.603	1.397		0.0001	0.035	0.532	17.548	0.0087	0.00002	0.041
1.8	35.280	24.050	1.467		0.0001	0.035	0.550	19.391	0.0092	0.00002	0.041
1.9	37.620	24.497	1.536		0.0001	0.035	0.567	21.318	0.0096	0.00002	0.041
2	40.000	24.944	1.604		0.0001	0.035	0.583	23.329	0.0100	0.00002	0.041

Moccasin Creek Channel Hydraulic Calculations
Approximate Average Flood Channel
Compound Channel Design

STAGE (Ft)	Q (cfs)	τ (lb/ft^2)	D_{50} (mm)	D_{100} (mm)	τ_{c50} (lb/ft^2)	τ_{c100} (lb/ft^2)
0.10	0.14709	0.000615	0.003	2.00	0.00002	0.041
0.20	0.468179	0.001211	0.003	2.00	0.00002	0.041
0.30	0.922799	0.001792	0.003	2.00	0.00002	0.041
0.40	1.494979	0.002357	0.003	2.00	0.00002	0.041
0.50	2.175349	0.002909	0.003	2.00	0.00002	0.041
0.60	2.957665	0.003447	0.003	2.00	0.00002	0.041
0.70	3.837481	0.003973	0.003	2.00	0.00002	0.041
0.80	4.81151	0.004488	0.003	2.00	0.00002	0.041
0.90	5.877264	0.004992	0.003	2.00	0.00002	0.041
1.00	7.032833	0.005486	0.003	2.00	0.00002	0.041
1.10	8.276745	0.005972	0.003	2.00	0.00002	0.041
1.20	9.651036	0.006448	0.003	2.00	0.00002	0.041
1.30	11.02533	0.006917	0.003	2.00	0.00002	0.041
1.40	12.52848	0.007378	0.003	2.00	0.00002	0.041
1.50	14.11685	0.007832	0.003	2.00	0.00002	0.041
1.60	15.83245	0.008279	0.003	2.00	0.00002	0.041
1.70	17.54806	0.008719	0.003	2.00	0.00002	0.041
1.80	19.39059	0.009154	0.003	2.00	0.00002	0.041
1.90	21.3177	0.009583	0.003	2.00	0.00002	0.041
2.00	23.32944	0.010006	0.003	2.00	0.00002	0.041

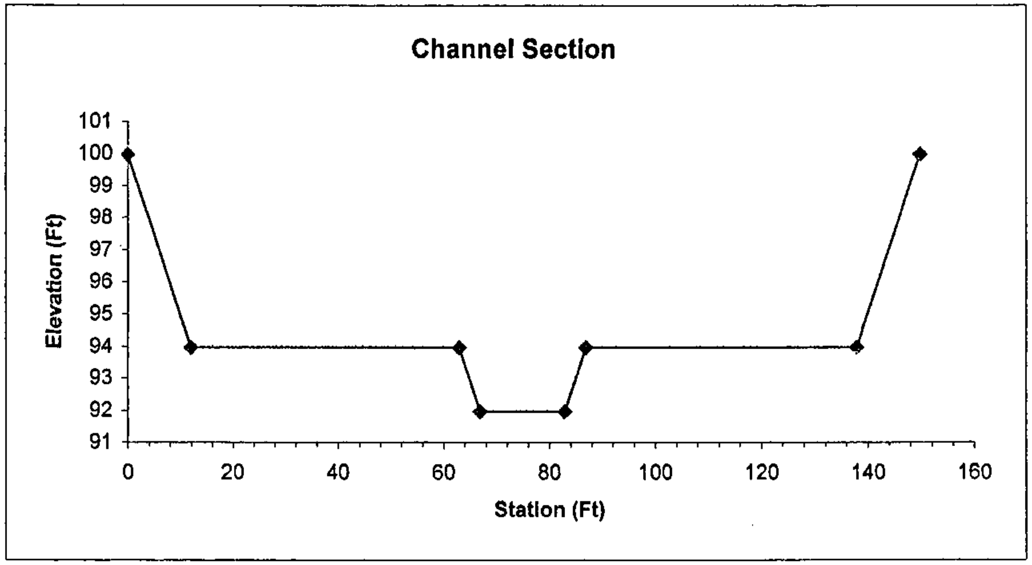



Moccasin Creek Channel
25.000
20.000
15.000
10.000
5.000
0.000
Discharge (cfs)
0
0.5
1
1.5
2
2.5
Stage above Invert (ft)

Project: Moccasin Creek
Approximate Average Flood Channel
Compound Channel Design
Shields Parameter 0.06

Floodplain elevation	100
Depth of high flow channel	6
Top width of high flow channel	150
side slope (H:1)	2
Depth of low flow channel	2
Bottom width of low flow channel	16
side slope (H:1)	2
Bottom width of high flow channel	126

X	Y
0	100
12	94
63	94
67	92
83	92
87	94
138	94
150	100



Moccasin Creek Channel Hydraulic Calculations

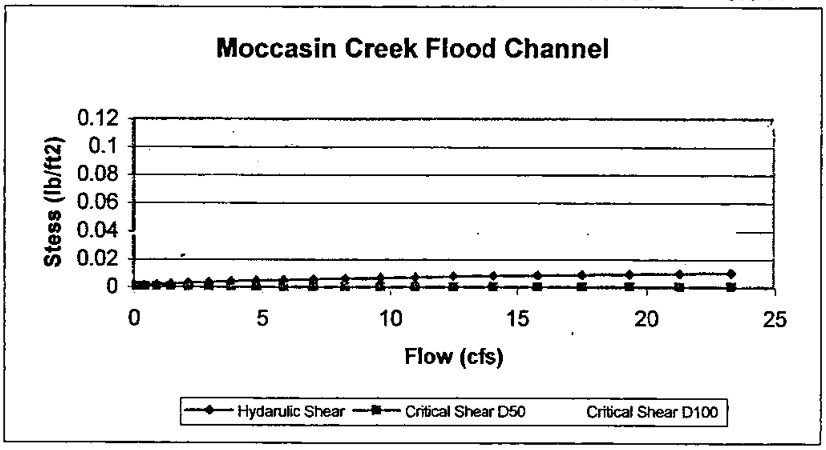
Approximate Average Flood Channel

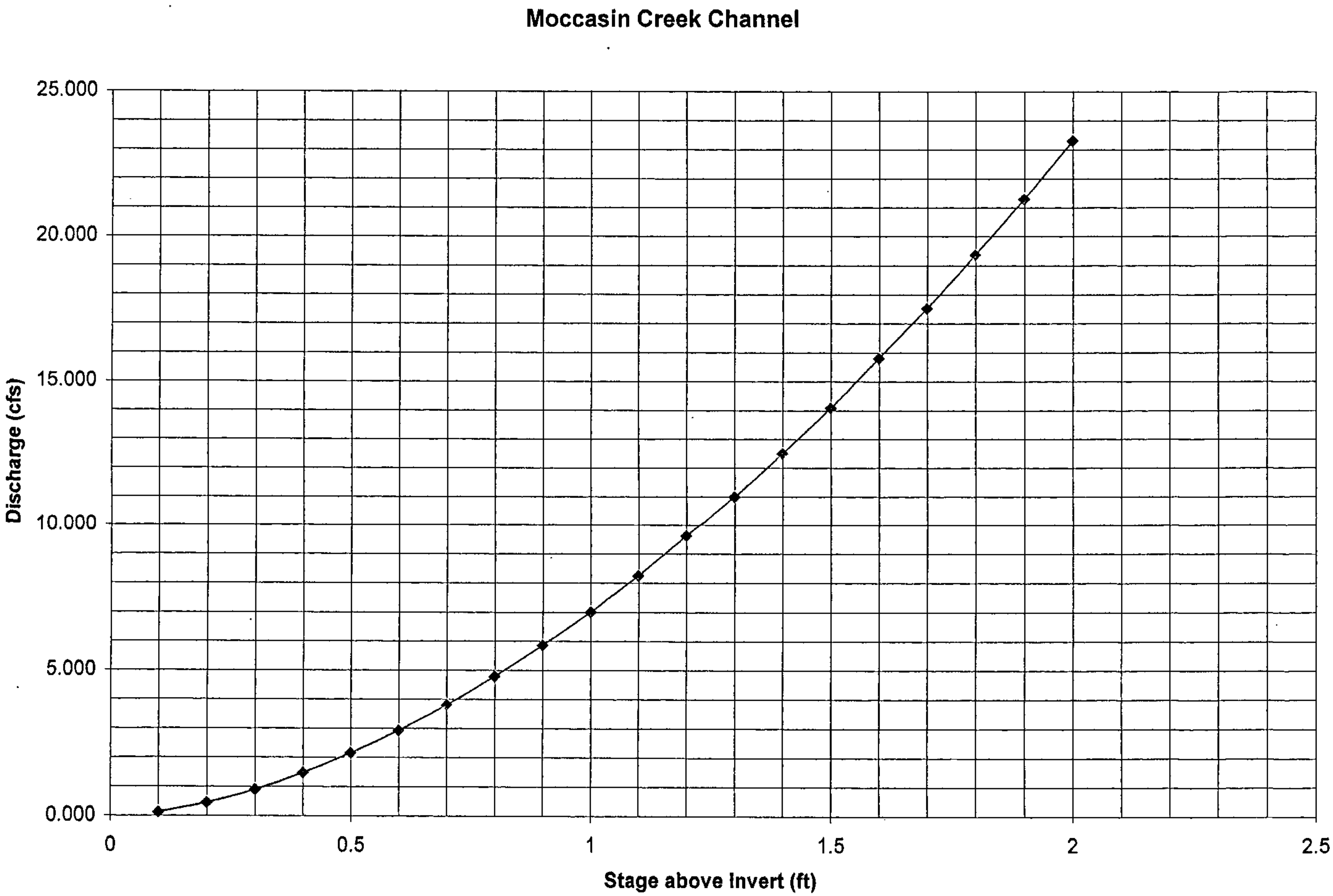
Bed Material	mm	ft		mm	ft
D_{50} =	0.003	0.000010	D_{100} =	2	0.00656

STAGE	AREA (ft^2)	Wetted Perim (ft)	R ft		SLOPE	n	VAVG (ft/s)	Q (cfs)	τ (lb/ft^2)	τ_{cD50} (lb/ft^2)	τ_{cD100} (lb/ft^2)
0.1	1.620	16.447	0.098	0.099	0.0001	0.035	0.091	0.147	0.00061	0.00006	0.041
0.2	3.280	16.894	0.194	0.195	0.0001	0.035	0.143	0.468	0.00121	0.00006	0.041
0.3	4.980	17.342	0.287	0.290	0.0001	0.035	0.185	0.923	0.00179	0.00006	0.041
0.4	6.720	17.789	0.378	0.382	0.0001	0.035	0.222	1.495	0.00236	0.00006	0.041
0.5	8.500	18.236	0.466		0.0001	0.035	0.256	2.175	0.00291	0.00006	0.041
0.6	10.320	18.683	0.552		0.0001	0.035	0.287	2.958	0.00345	0.00006	0.041
0.7	12.180	19.130	0.637		0.0001	0.035	0.315	3.837	0.00397	0.00006	0.041
0.8	14.080	19.578	0.719		0.0001	0.035	0.342	4.812	0.00449	0.00006	0.041
0.9	16.020	20.025	0.800		0.0001	0.035	0.367	5.877	0.00499	0.00006	0.041
1	18.000	20.472	0.879		0.0001	0.035	0.391	7.033	0.00549	0.00006	0.041
1.1	20.020	20.919	0.957		0.0001	0.035	0.413	8.277	0.00597	0.00006	0.041
1.2	22.080	21.367	1.033		0.0001	0.035	0.435	9.651	0.00645	0.00006	0.041
1.3	24.180	21.814	1.108		0.0001	0.035	0.456	11.025	0.00692	0.00006	0.041
1.4	26.320	22.261	1.182		0.0001	0.035	0.476	12.528	0.00738	0.00006	0.041
1.5	28.500	22.708	1.255		0.0001	0.035	0.495	14.117	0.00783	0.00006	0.041
1.6	30.720	23.155	1.327		0.0001	0.035	0.514	15.832	0.00828	0.00006	0.041
1.7	32.980	23.603	1.397		0.0001	0.035	0.532	17.548	0.00872	0.00006	0.041
1.8	35.280	24.050	1.467		0.0001	0.035	0.550	19.391	0.00915	0.00006	0.041
1.9	37.620	24.497	1.536		0.0001	0.035	0.567	21.318	0.00958	0.00006	0.041
2	40.000	24.944	1.604		0.0001	0.035	0.583	23.329	0.01001	0.00006	0.041

Moccasin Creek Channel Hydraulic Calculations
Approximate Average Flood Channel
Compound Channel Design

STAGE (Ft)	Q (cfs)	τ (lb/ft^2)	D_{50} (mm)	D_{100} (mm)	τ_{c50} (lb/ft^2)	τ_{c100} (lb/ft^2)
0.10	0.14709	0.000615	0.003	2.00	0.00006	0.041
0.20	0.468179	0.001211	0.003	2.00	0.00006	0.041
0.30	0.922799	0.001792	0.003	2.00	0.00006	0.041
0.40	1.494979	0.002357	0.003	2.00	0.00006	0.041
0.50	2.175349	0.002909	0.003	2.00	0.00006	0.041
0.60	2.957665	0.003447	0.003	2.00	0.00006	0.041
0.70	3.837481	0.003973	0.003	2.00	0.00006	0.041
0.80	4.81151	0.004488	0.003	2.00	0.00006	0.041
0.90	5.877264	0.004992	0.003	2.00	0.00006	0.041
1.00	7.032833	0.005486	0.003	2.00	0.00006	0.041
1.10	8.276745	0.005972	0.003	2.00	0.00006	0.041
1.20	9.651036	0.006448	0.003	2.00	0.00006	0.041
1.30	11.02533	0.006917	0.003	2.00	0.00006	0.041
1.40	12.52848	0.007378	0.003	2.00	0.00006	0.041
1.50	14.11685	0.007832	0.003	2.00	0.00006	0.041
1.60	15.83245	0.008279	0.003	2.00	0.00006	0.041
1.70	17.54806	0.008719	0.003	2.00	0.00006	0.041
1.80	19.39059	0.009154	0.003	2.00	0.00006	0.041
1.90	21.3177	0.009583	0.003	2.00	0.00006	0.041
2.00	23.32944	0.010006	0.003	2.00	0.00006	0.041





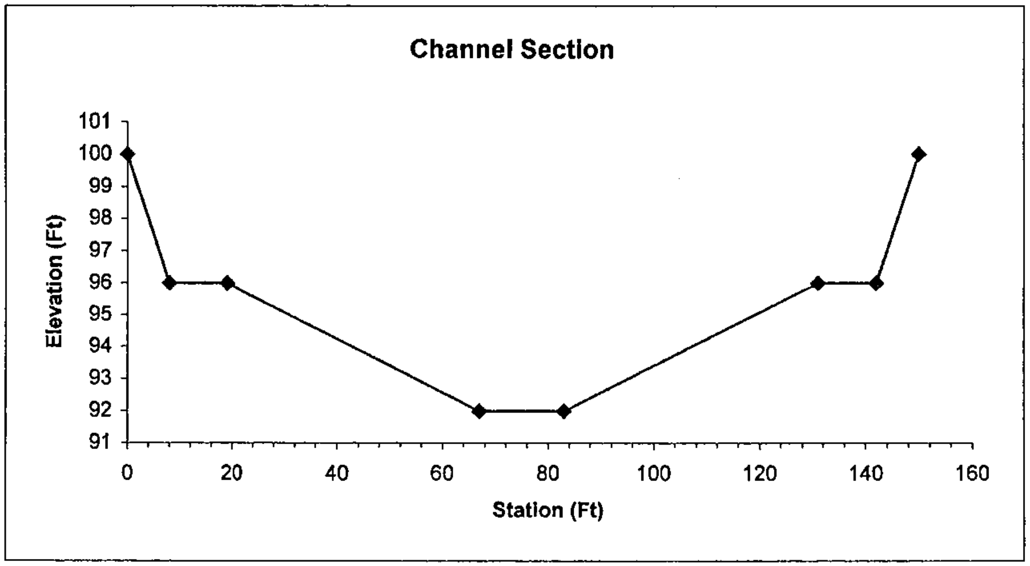
schydcalcsshields0-06.xls

1/9/2003

Project: Moccasin Creek
Approximate Average Flood Channel
Compound Channel Design
Shields Parameter 0.02

Floodplain elevation	100
Depth of high flow channel	4
Top width of high flow channel	150
side slope (H:1)	2
Depth of low flow channel	4
Bottom width of low flow channel	16
side slope (H:1)	12
Bottom width of high flow channel	38

X	Y
0	100
8	96
19	96
67	92
83	92
131	96
142	96
150	100



Moccasin Creek Channel Hydraulic Calculations

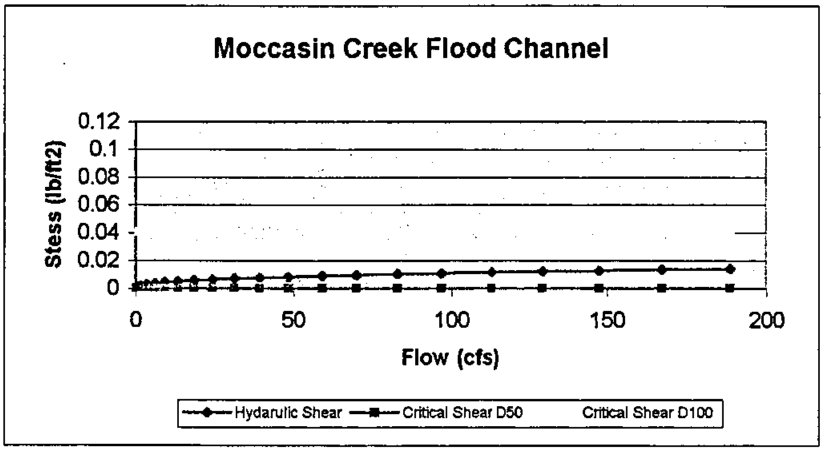
Approximate Average Flood Channel

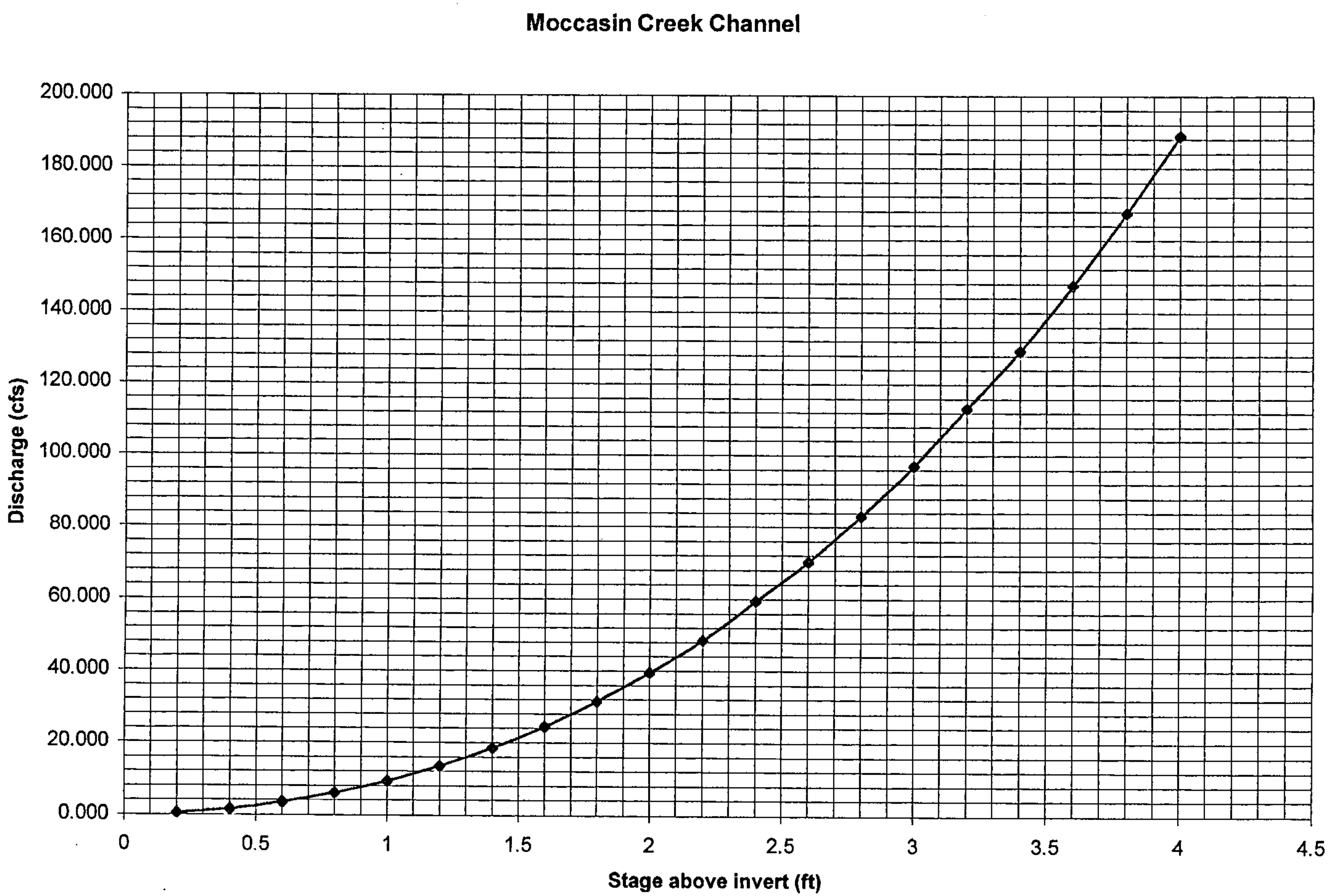
Bed Material	mm	ft		mm	ft
D_{50} =	0.003	0.000010	D_{100} =	2	0.00656

STAGE	AREA (ft^2)	Wetted Perim (ft)	R ft	SLOPE	n	VAVG (ft/s)	Q (cfs)	τ (lb/ft^2)	τ_{cD50} (lb/ft^2)	τ_{cD100} (lb/ft^2)
0.2	3.680	20.817	0.177	0.0001	0.035	0.134	0.493	0.0011	0.00002	0.041
0.4	8.320	25.633	0.325	0.0001	0.035	0.201	1.673	0.0020	0.00002	0.041
0.6	13.920	30.450	0.457	0.0001	0.035	0.253	3.517	0.0029	0.00002	0.041
0.8	20.480	35.267	0.581	0.0001	0.035	0.296	6.069	0.0036	0.00002	0.041
1	28.000	40.083	0.699	0.0001	0.035	0.335	9.384	0.0044	0.00002	0.041
1.2	36.480	44.900	0.812	0.0001	0.035	0.371	13.522	0.0051	0.00002	0.041
1.4	45.920	49.716	0.924	0.0001	0.035	0.404	18.540	0.0058	0.00002	0.041
1.6	56.320	54.533	1.033	0.0001	0.035	0.435	24.497	0.0064	0.00002	0.041
1.8	67.680	59.350	1.140	0.0001	0.035	0.465	31.449	0.0071	0.00002	0.041
2	80.000	64.166	1.247	0.0001	0.035	0.493	39.451	0.0078	0.00002	0.041
2.2	93.280	68.983	1.352	0.0001	0.035	0.521	48.559	0.0084	0.00002	0.041
2.4	107.520	73.800	1.457	0.0001	0.035	0.547	59.431	0.0091	0.00002	0.041
2.6	122.720	78.616	1.561	0.0001	0.035	0.573	70.302	0.0097	0.00002	0.041
2.8	138.880	83.433	1.665	0.0001	0.035	0.598	83.041	0.0104	0.00002	0.041
3	156.000	88.250	1.768	0.0001	0.035	0.622	97.092	0.0110	0.00002	0.041
3.2	174.080	93.066	1.870	0.0001	0.035	0.646	113.210	0.0117	0.00002	0.041
3.4	193.120	97.883	1.973	0.0001	0.035	0.670	129.328	0.0123	0.00002	0.041
3.6	213.120	102.699	2.075	0.0001	0.035	0.693	147.609	0.0129	0.00002	0.041
3.8	234.080	107.516	2.177	0.0001	0.035	0.715	167.395	0.0136	0.00002	0.041
4	256.000	112.333	2.279	0.0001	0.035	0.737	188.733	0.0142	0.00002	0.041

Moccasin Creek Channel Hydraulic Calculations
Approximate Average Flood Channel
Compound Channel Design

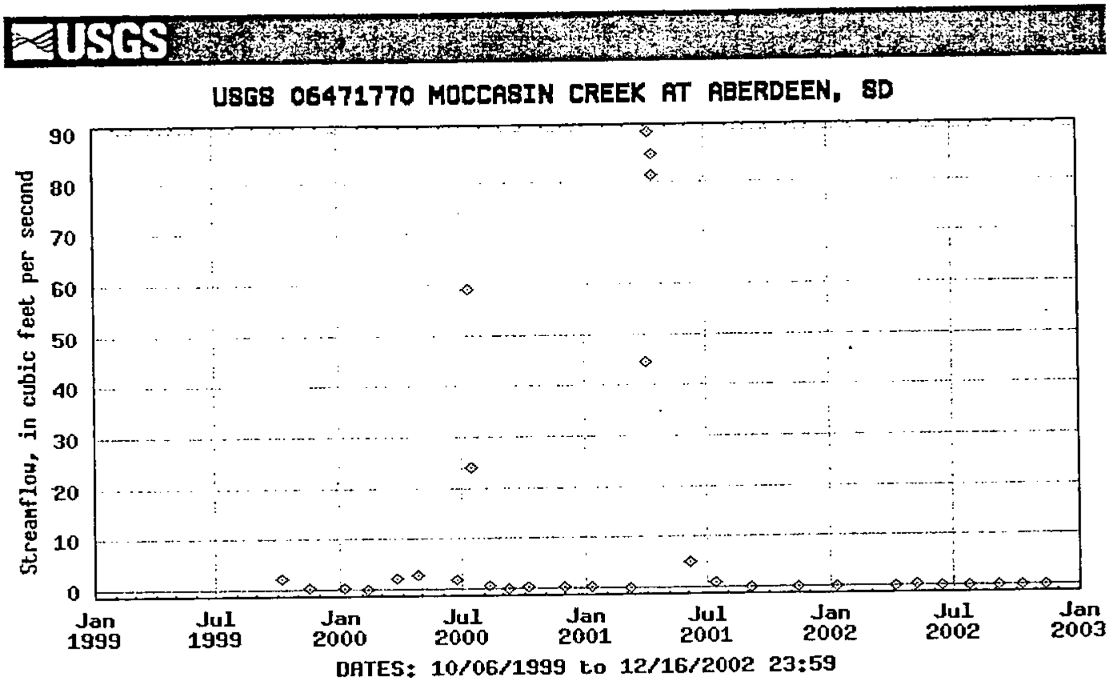
STAGE (Ft)	Q (cfs)	τ (lb/ft^2)	D_{50} (mm)	D_{100} (mm)	τ_{c50} (lb/ft^2)	τ_{c100} (lb/ft^2)
0.20	0.493466	0.001103	0.003	2.00	0.00002	0.041
0.40	1.67284	0.002025	0.003	2.00	0.00002	0.041
0.60	3.516626	0.002853	0.003	2.00	0.00002	0.041
0.80	6.06866	0.003624	0.003	2.00	0.00002	0.041
1.00	9.384405	0.004359	0.003	2.00	0.00002	0.041
1.20	13.52217	0.00507	0.003	2.00	0.00002	0.041
1.40	18.54049	0.005763	0.003	2.00	0.00002	0.041
1.60	24.49717	0.006444	0.003	2.00	0.00002	0.041
1.80	31.44896	0.007116	0.003	2.00	0.00002	0.041
2.00	39.45147	0.00778	0.003	2.00	0.00002	0.041
2.20	48.55914	0.008438	0.003	2.00	0.00002	0.041
2.40	59.43066	0.009091	0.003	2.00	0.00002	0.041
2.60	70.30218	0.009741	0.003	2.00	0.00002	0.041
2.80	83.04103	0.010387	0.003	2.00	0.00002	0.041
3.00	97.09216	0.011031	0.003	2.00	0.00002	0.041
3.20	113.2101	0.011672	0.003	2.00	0.00002	0.041
3.40	129.328	0.012311	0.003	2.00	0.00002	0.041
3.60	147.6091	0.012949	0.003	2.00	0.00002	0.041
3.80	167.3952	0.013585	0.003	2.00	0.00002	0.041
4.00	188.7327	0.014221	0.003	2.00	0.00002	0.041





schydcalcsshields12-04

1/10/2003



Provisional Data Subject to Revision

Peak Flows

	Q	G. Height
7/11/2000	60 (cfs)	4.58
4/10/2001	100	4.86

Gage datum 1290.00 ft' ASL

$DA = 57.6\ mi^2$

Appendix C. DNA Fingerprinting Results

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Tel: (1) 305-662-7760, Fax: (1) 305-468-6124, Email: info@paleoscience.com

E.col.I.D.™ – DNA Fingerprinting of *E.coli*

(Discriminant Analysis of Ribotype Profiles of *E. coli*)

Submitter: **Barry McLaury**
Submitter #: **#MC 551**
PaleoScience #: **PW 1153**
Date Reported: **November 1, 2001**

Fecal Coliform mpn*/100 ml	*E. coli* Isolate # (5 colonies of cultured *E.coli* were analyzed)	Probable Source
170	1	Human
	2	Human
	3	Human
	4	Human
	5	Human

* mpn = most probable number of fecal coliforms in 100mL of sample after 20 hrs of cultivation at 44.5°C.

Laboratory Comments

The DNA fingerprints of 5 colonies of E. coli cultured from the sample water statistically matched human sources recorded in a database of known source DNA fingerprints. The water was contaminated as demonstrated by both the MPN and DNA fingerprinting results. In this analysis, the chosen colonies of cultured E. coli all demonstrated human DNA fingerprints, suggesting human E. coli as a significant source of contamination. The results do not represent that human E. coli is the only E. coli in the system under investigation. Further analysis of multiple samples from multiple locations, in repetition would add further confidence. It is common to have multiple sources of E. coli in natural systems.

Method and theory explanation pages are included on a separate page in this report & on the website at www.paleoscience.com

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E.col.I.D.™ – DNA Fingerprinting of *E.coli*

(Discriminant Analysis of Ribotype Profiles of *E. coli*)

Submitter: Barry McLaury
Submitter #: #MC 552
PaleoScience #: PW 1154
Date Reported: November 1, 2001

Fecal Coliform mpn*/100 ml	*E. coli* Isolate # (5 colonies of cultured *E.coli* were analyzed)	Probable Source
> 2400	1	Human
	2	Human
	3	Human
	4	Animal (possibly Wildlife)
	5	Animal (possibly Wildlife)

* mpn = most probable number of fecal coliforms in 100mL of sample after 20 hrs of cultivation at 44.5°C.

Laboratory Comments

The E. coli isolates of 5 colonies cultured from the submitted water sample statistically matched both human and animal sources when compared to a database of known source DNA fingerprints. It is common to have E. coli from multiple sources in natural systems. In this analysis, the DNA fingerprints of the chosen colonies of cultured E. coli suggest this is the case. Defining a source for the E. coli is possible by collecting fecal matter from the predicted sources along with further contaminated water samples, and then looking for a direct DNA match. Further study using multiple samples from multiple locations would be needed to make a system wide prediction. This analysis represents a first approximation of the E. coli source based on a limited study with only a few fingerprints on a limited number of E.coli from one sample.

Method and theory explanation pages are included on a separate page in this report & on the website at www.paleoscience.com

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E.col.I.D.™ – DNA Fingerprinting of *E.coli*

(Discriminant Analysis of Ribotype Profiles of *E. coli*)

Submitter: Barry McLaury
Submitter #: #MC 553
PaleoScience #: PW 1155
Date Reported: November 1, 2001

Fecal Coliform mpn*/100 ml	*E. coli* Isolate # (5 colonies of cultured *E.coli* were analyzed)	Probable Source
240	1	Indeterminant
	2	Indeterminant
	3	Human
	4	Animal (possibly Wildlife)
	5	Animal (possibly Wildlife)

* mpn = most probable number of fecal coliforms in 100mL of sample after 20 hrs of cultivation at 44.5°C.

Laboratory Comments

The E. coli isolates of 3 colonies cultured from the submitted water sample statistically matched both human and animal sources when compared to a database of known source DNA fingerprints. An illustration of possible animal sources, based on a limited number of known fingerprints is also listed. Two of the colonies did not provide recognizable fingerprints. It is common to have E. coli from multiple sources within natural systems. In this analysis, the DNA fingerprints of the chosen colonies of cultured E. coli suggest this is the case. Defining a source for the E. coli may be possible by collecting fecal matter from the predicted sources along with further contaminated water samples, and then looking for a direct DNA match. Further study using multiple samples from multiple locations would be needed to make a system wide prediction. This experiment represents a first approximation of the E. coli source based on a limited study with only a few fingerprints on a limited number of E. coli from one sample.

Method and theory explanation pages are included on a separate page in this report & on the website at www.paleoscience.com

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E.col.I.D.™ – DNA Fingerprinting of *E.coli*

(Discriminant Analysis of Ribotype Profiles of *E. coli*)

Submitter: Barry McLaury
Submitter #: #MC 553 - duplicate
PaleoScience #: PW 1156
Date Reported: November 1, 2001

Fecal Coliform mpn*/100 ml	*E. coli* Isolate # (5 colonies of cultured *E.coli* were analyzed)	Probable Source
170	1	Animal (possibly Wildlife)
	2	Animal (possibly Wildlife)
	3	Animal (possibly Wildlife)
	4	Animal (possibly Avian)
	5	Animal (possibly Wildlife)

* mpn = most probable number of fecal coliforms in 100mL of sample after 20 hrs of cultivation at 44.5°C.

Laboratory Comments

The DNA fingerprints of 5 colonies of E. coli cultured from the water sample statistically matched animal sources recorded in a database of known DNA fingerprints. An illustration of possible animal sources, based on a limited number of known fingerprints is also listed. The results do not represent that animal E. coli is the only E. coli in the system under investigation. Further analysis of multiple samples from multiple locations, in repetition would yield further confidence. It is common to have multiple sources of E. coli in natural systems. In this analysis, the chosen colonies of cultured E.coli all suggested animal DNA fingerprints, suggesting animal E. coli as a significant source to the water.

Method and theory explanation pages are included on a separate page in this report & on the website at www.paleoscience.com

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E.col.I.D.™ – DNA Fingerprinting of *E.coli*

(Discriminant Analysis of Ribotype Profiles of *E. coli*)

Submitter:	**Barry McLaury**
Submitter #:	**#MC 554**
PaleoScience #:	**PW 1157**
Date Reported:	**November 1, 2001**

Fecal Coliform mpn*/100 ml	*E. coli* Isolate # (5 colonies of cultured *E.coli* were analyzed)	Probable Source
> 2400	1	Human
	2	Human
	3	Animal (possibly Wildlife)
	4	Animal (possibly Avian)
	5	Animal (possibly Avian)

* mpn = most probable number of fecal coliforms in 100mL of sample after 20 hrs of cultivation at 44.5°C.

Laboratory Comments

The E. coli isolates of 5 colonies cultured from the submitted water sample statistically matched both human and animal sources when compared to a database of known source DNA fingerprints. An illustration of possible animal sources, based on a limited number of known fingerprints is also listed. It is common to have E. coli from multiple sources within natural systems. In this analysis, the DNA fingerprints of the chosen colonies of cultured E. coli suggest this may be the case. Defining a source for the E. coli may be possible by collecting fecal matter from the predicted sources along with further contaminated water samples, and then looking for a direct DNA match. Further study using multiple samples from multiple locations would be needed to make a system wide prediction. This analysis represents a first approximation of the E. coli source based on a limited study with only a few fingerprints on a limited number of E. coli from one water sample.

Method and theory explanation pages are included on a separate page in this report & on the website at www.paleoscience.com

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E.col.I.D.™ – DNA Fingerprinting of *E.coli*

(Discriminant Analysis of Ribotype Profiles of *E. coli*)

Submitter: Barry McLaury
Submitter #: #MC 555
PaleoScience #: PW 1158
Date Reported: November 1, 2001

Fecal Coliform mpn*/100 ml	*E. coli* Isolate # (5 colonies of cultured *E.coli* were analyzed)	Probable Source
350	1	Animal (possibly Wildlife)
	2	Animal (possibly Wildlife)
	3	Animal (possibly Wildlife)
	4	Animal (possilby Bovine)
	5	Animal (possibly Wildlife)

* mpn = most probable number of fecal coliforms in 100mL of sample after 20 hrs of cultivation at 44.5°C.

Laboratory Comments

The DNA fingerprints of 5 colonies of E. coli cultured from the water sample statistically matched animal sources recorded in a database of known DNA fingerprints. An illustration of possible animal sources, based on a limited number of known fingerprints is also listed. The results do not represent that animal E. coli is the only E. coli source in the system under investigation. Further analysis of multiple samples from multiple locations, in repetition would yield further confidence. It is common to have multiple sources of E. coli in natural systems. Defining a source for the E.coli may be possible by collecting fecal matter from the predicted sources along with further contaminated water samples, and then looking for a direct DNA match. In this analysis, the chosen colonies of cultured E. coli all suggested animal DNA fingerprints, suggesting animal E. coli as a significant source to the water.

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E.col.I.D.™ – DNA Fingerprinting of *E.coli*

(Discriminant Analysis of Ribotype Profiles of *E. coli*)

Submitter: **Barry McLaury**
Submitter #: **#MC 556**
PaleoScience #: **PW 1159**
Date Reported: **November 1, 2001**

Fecal Coliform mpn*/100 ml	*E. coli* Isolate # (5 colonies of cultured *E.coli* were analyzed)	Probable Source
> 2400	1	Human
	2	Human
	3	Human
	4	Animal (possibly Wildlife)
	5	Animal (possibly Wildlife)

* mpn = most probable number of fecal coliforms in 100mL of sample after 20 hrs of cultivation at 44.5°C.

Laboratory Comments

The E. coli isolates of 5 colonies cultured from the submitted water sample statistically matched both human and animal sources when compared to a database of known source DNA fingerprints. An illustration of possible animal sources, based on a limited number of known fingerprints is also listed. It is common to have E. coli from multiple sources in natural systems. In this experiment, the DNA fingerprints of the chosen colonies of cultured E. coli suggest this may be the case. Defining a source for the E. coli may be possible by collecting fecal matter from the predicted sources along with further contaminated water samples, and then looking for a direct DNA match. Further study using multiple samples from multiple locations would be needed to make a system wide prediction. This analysis represents a first approximation of the E. coli source based on a limited study with only a few fingerprints on a limited number of E. coli from one water sample.

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E.col.I.D.™ – DNA Fingerprinting of *E.coli*

(Discriminant Analysis of Ribotype Profiles of *E. coli*)

Submitter: Barry McLaury
Submitter #: #MC 557
PaleoScience #: PW 1160
Date Reported: November 1, 2001

Fecal Coliform mpn*/100 ml	*E. coli* Isolate # (5 colonies of cultured *E.coli* were analyzed)	Probable Source
> 2400	1	Animal (possibly Wildlife)
	2	Animal (possibly Wildlife)
	3	Animal (possibly Bovine)
	4	Animal (possibly Wildlife)
	5	Animal (possibly Avian)

* mpn = most probable number of fecal coliforms in 100mL of sample after 20 hrs of cultivation at 44.5°C.

Laboratory Comments

The DNA fingerprints of 5 colonies of E. coli cultured from the water sample statistically matched animal sources recorded in a database of known DNA fingerprints. An illustration of possible animal sources, based on a limited number of known fingerprints is also listed. The results do not represent that animal E. coli is the only E. coli in the system under investigation. Further analysis of multiple samples from multiple locations, in repetition would yield further confidence. It is common to have multiple sources of E. coli in natural systems. Defining a source for the E. coli may be possible by collecting fecal matter from the predicted sources along with further contaminated water samples, and then looking for a direct DNA match. In this experiment, the chosen colonies of cultured E. coli all suggested animal DNA fingerprints, suggesting animal E. coli as a significant source to the water.

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E.col.I.D.™ – DNA Fingerprinting of *E.coli*

(Discriminant Analysis of Ribotype Profiles of *E. coli*)

Submitter: Barry McLaury
Submitter #: #MC 558
PaleoScience #: PW 1161
Date Reported: November 1, 2001

Fecal Coliform mpn*/100 ml	*E. coli* Isolate # (5 colonies of cultured *E.coli* were analyzed)	Probable Source
49	1	Animal (possibly Avian)
	2	Animal (possibly Avian)
	3	Animal (possibly Avian)
	4	Animal (possibly Wildlife)
	5	Animal (possibly Wildlife)

* mpn = most probable number of fecal coliforms in 100mL of sample after 20 hrs of cultivation at 44.5°C.

Laboratory Comments

The DNA fingerprints of 5 colonies of E. coli cultured from the water sample statistically matched animal sources recorded in a database of known DNA fingerprints. An illustration of possible animal sources, based on a limited number of known fingerprints is also listed. The results do not represent that animal E. coli is the only E. coli in the system under investigation. Further analysis of multiple samples from multiple locations, in repetition would yield further confidence. It is common to have multiple sources of E. coli in natural systems. Defining a source for the E. coli may be possible by collecting fecal matter from the predicted sources along with further contaminated water samples, and then looking for a direct DNA match. In this analysis, the chosen colonies of cultured E. coli all suggested animal DNA fingerprints, suggesting animal E. coli as a significant source to the water.

Method and theory explanation pages are included on a separate page in this report & on the website at www.paleoscience.com

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DNA Fingerprinting Method Explanation

E. coli were enumerated by taking plates that are positive for fecal coliforms, transferring the membrane filter to EC with MUG media (Difco), and incubating for an additional 24 hours at 37°C. Colonies that fluoresced under UV light were counted as *E. coli*. and isolated for ribotyping.

Ribotyping of *E.coli* isolates was accomplished by the method of Parveen *et al* (1999)[1]. Chromosomal DNA was extracted from *E.coli* isolates and digested with *Hind*/III. Fragments were separated by agarose electrophoresis. The cDNA from the *E.coli* 16S rDNA was labeled with digoxigenin-dUTP and used as probes. *E.coli* ribotype profiles were then compared to our source library by discriminant analysis. The statistical analysis and comparison performed is similar to the method elaborated in Carson *et al* (2001)[2].

DNA Fingerprinting Theory Explanation

After cultivating *E. coli* from the submitted sample, one or more *E. coli* isolates are selected. Isolates are clusters of *E.coli* colonies on an agar plate. A DNA fingerprinting analysis called ribotyping is performed on each *E. coli* isolate selected. This genetic fingerprint comes from genes that code for ribosomal ribonucleic acids (rRNA) of *E. coli*. Ribosomal RNA together with various proteins make up the cell structure called a ribosome.

The ribosome is the cell structure where proteins are manufactured. In order to produce proteins, the messenger RNA and the amino acids are transferred to the ribosome. As the ribosome moves down the messenger RNA it places the correct amino acid in the growing protein. It has been shown that looking at small differences in the DNA that codes for these 16S and 23S rRNA's help identify different strains of *E. coli*.

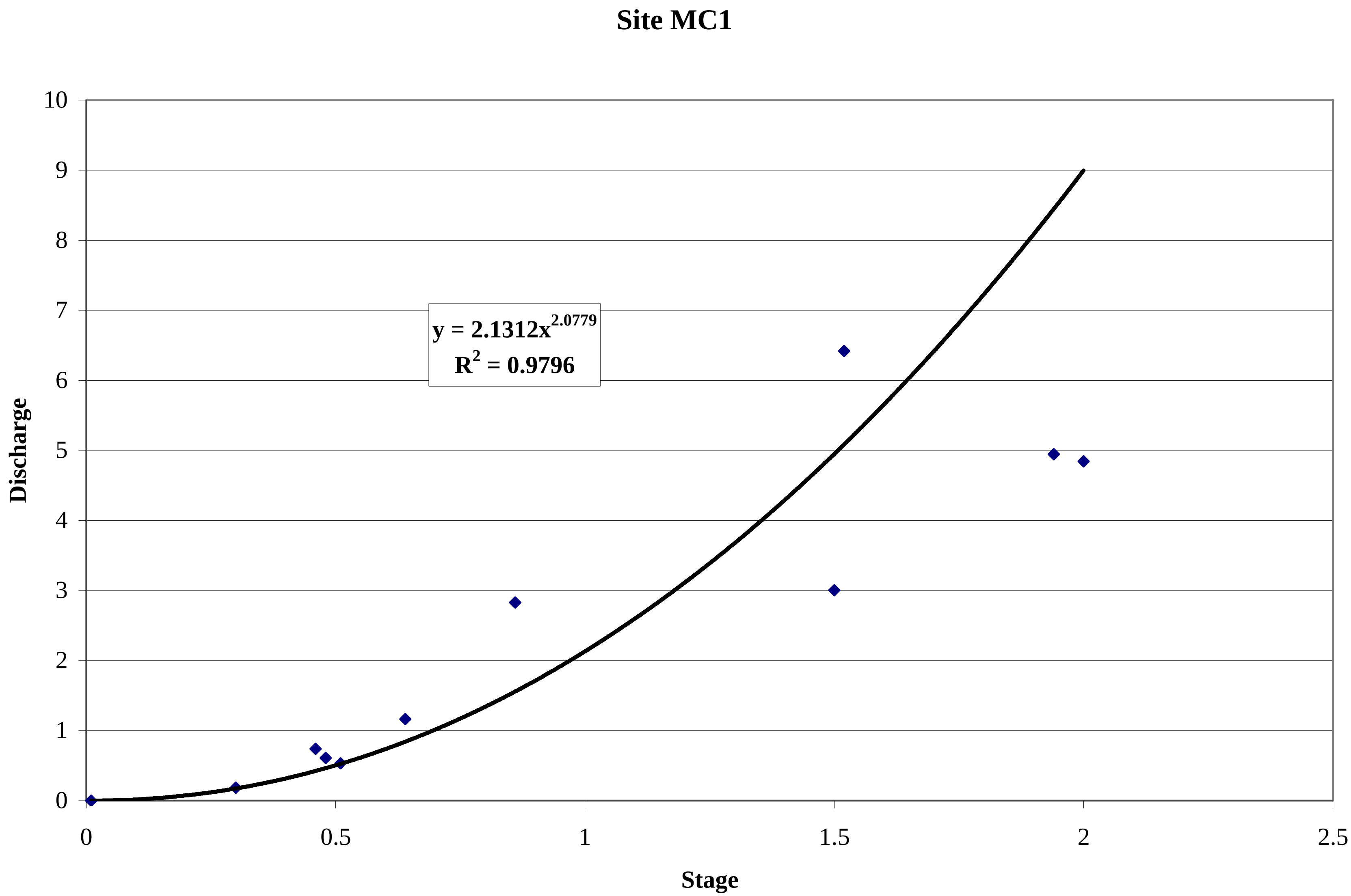
Ribosomal genes are also known to be highly conserved in microbes, meaning that the genetic information coding for rRNA will vary much less within bacteria of the same strain than it will between bacterial strains. This characteristic allows for a greater ability to distinguish between different bacterial strains.

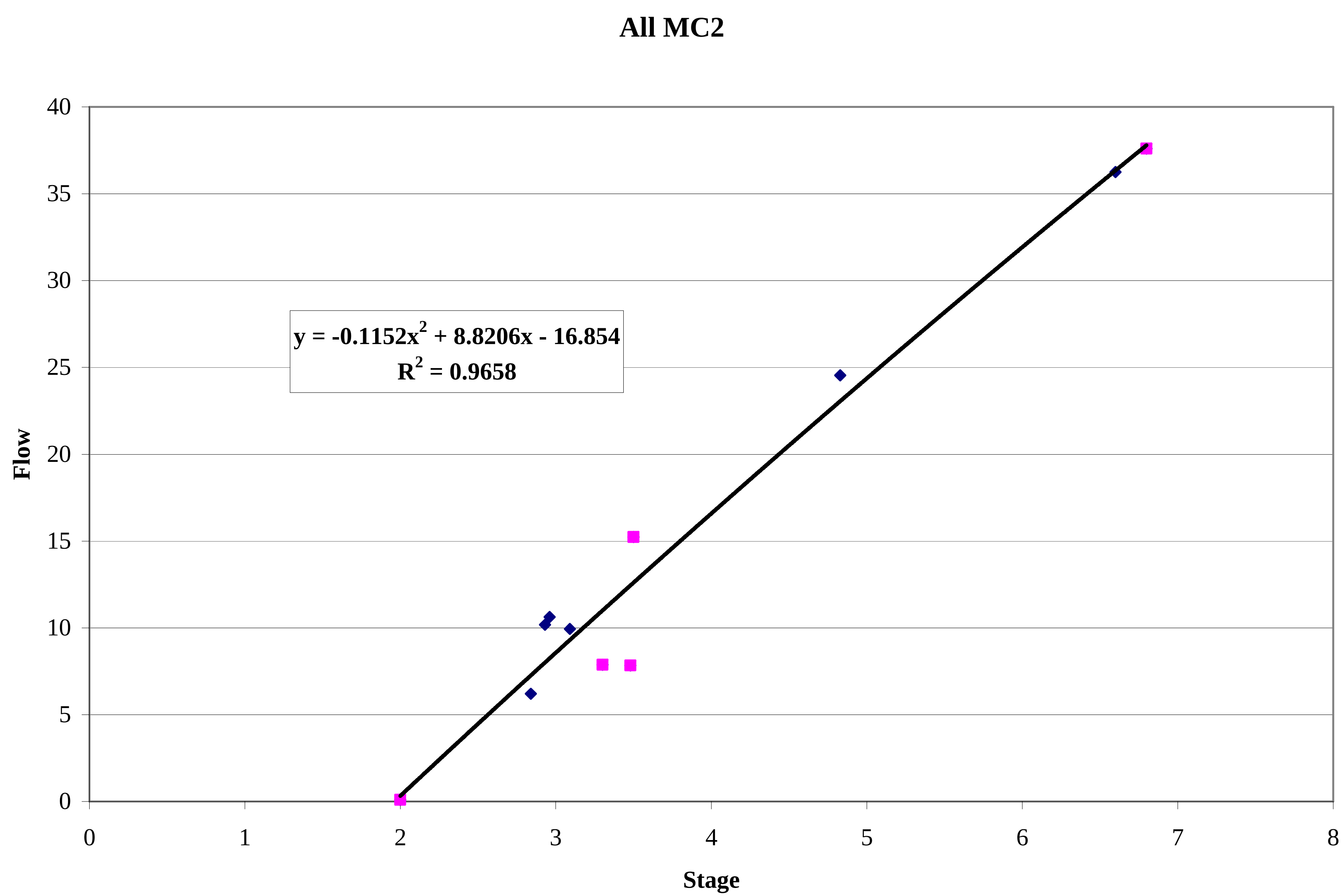
In ribotyping, restriction enzymes are used to cut the genes coding for rRNA into pieces, and electrophoresis separates the pieces by size through a gel. Genetic probes then visualize locations of different-size fragments of DNA in the gel, which appear as bands. The banding pattern of DNA fragments corresponding to the relevant rRNA is known as the ribotype. The banding patterns are compared to a database of other *E. coli* strains and matched for each determined species.

[1] Parveen, Salina, Portier, Kenneth M., Robinson, Kevin, Edmiston, Lee, Tamplin, Mark L.
Discriminant Analysis of Ribotype Profiles of Escherichia coli for Differentiating Human and Nonhuman Sources of Fecal Pollution
Appl. Environ. Microbiol. (1999) 65: 3142-3147

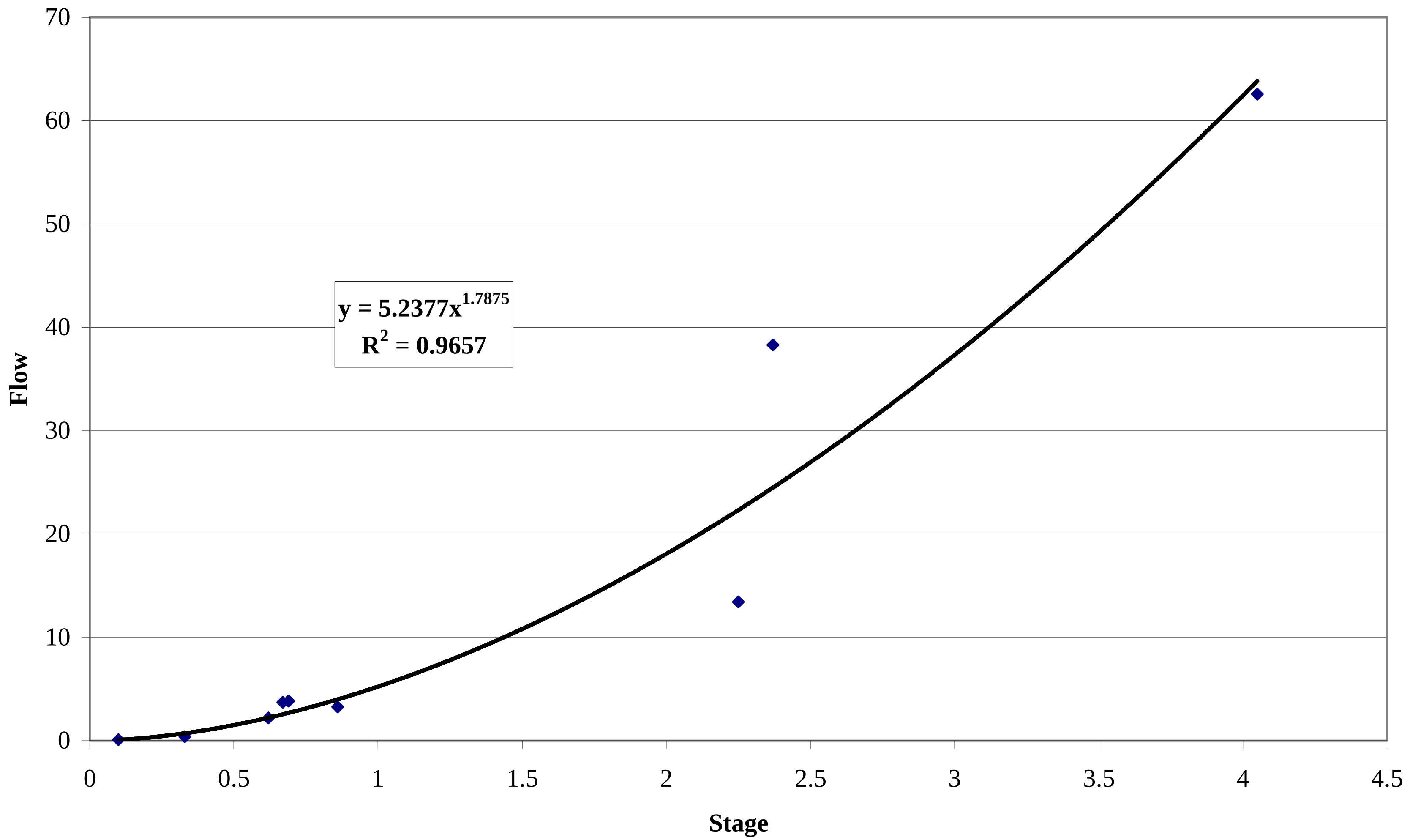
[2] Carson, C. Andrew, Shear, Brian L., Ellersieck, Mark R., Asfaw, Amha
Identification of Fecal Escherichia coli from Humans and Animals by Ribotyping
Appl. Environ. Microbiol. (2001) 67: 1503-1507

Appendix D. Stage To Discharge Tables

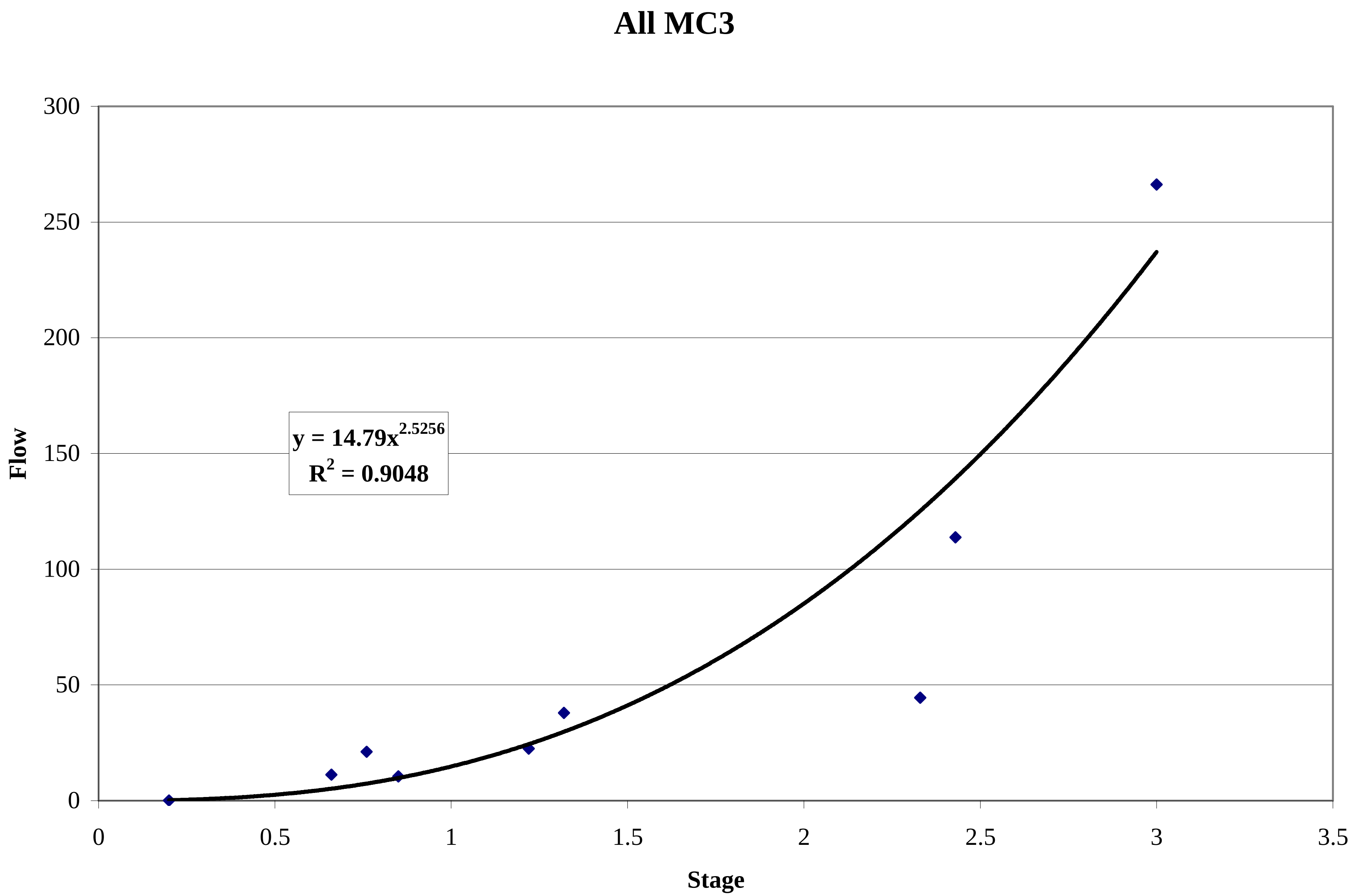

Site MC1
y = 2.1312x^2.0779
R^2 = 0.9796
Discharge
Stage
0
1
2
3
4
5
6
7
8
9
10
0
0.5
1
1.5
2
2.5

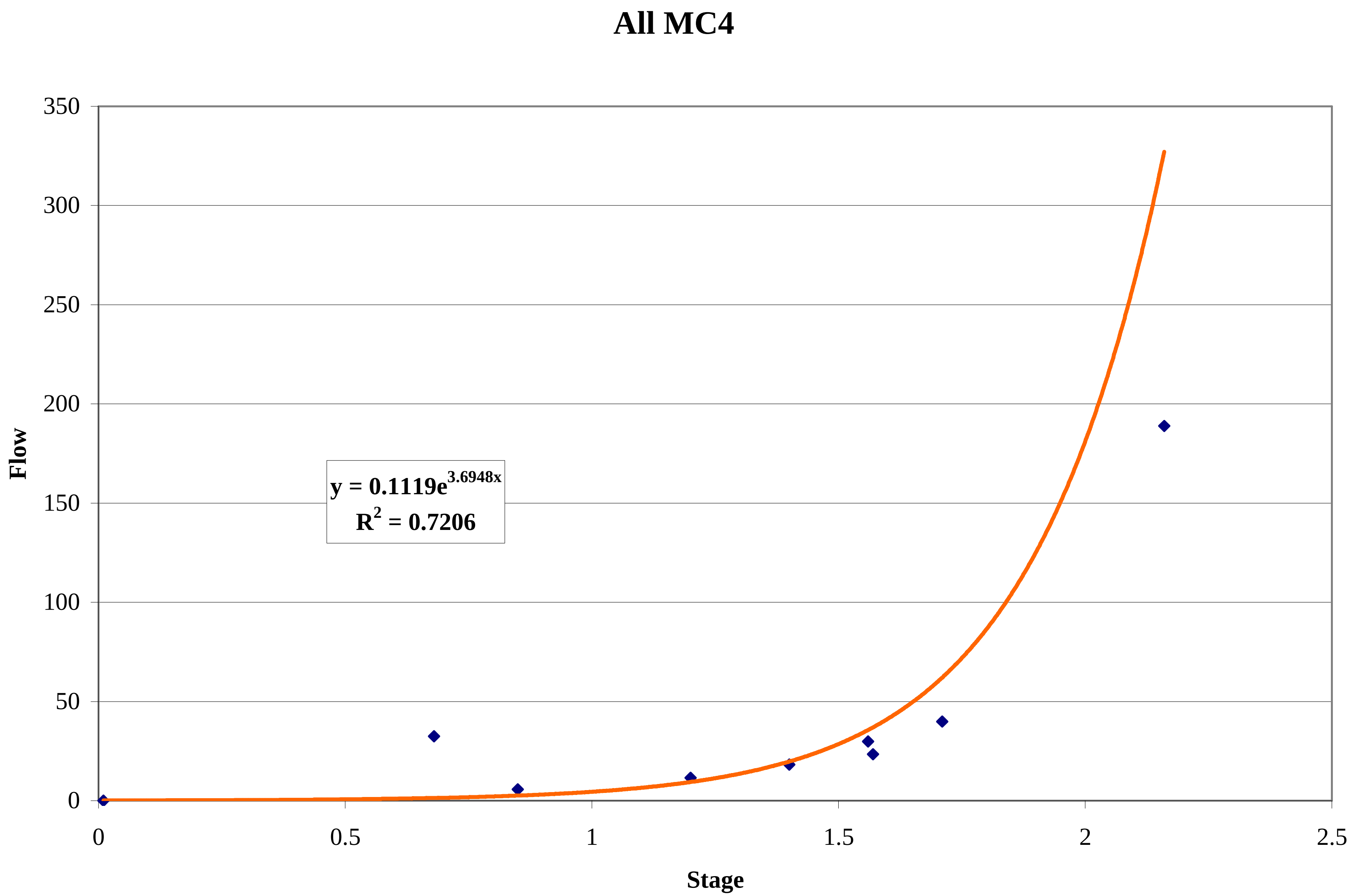

All MC2
y = -0.1152x2 + 8.8206x - 16.854
R2 = 0.9658
Flow
Stage
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8

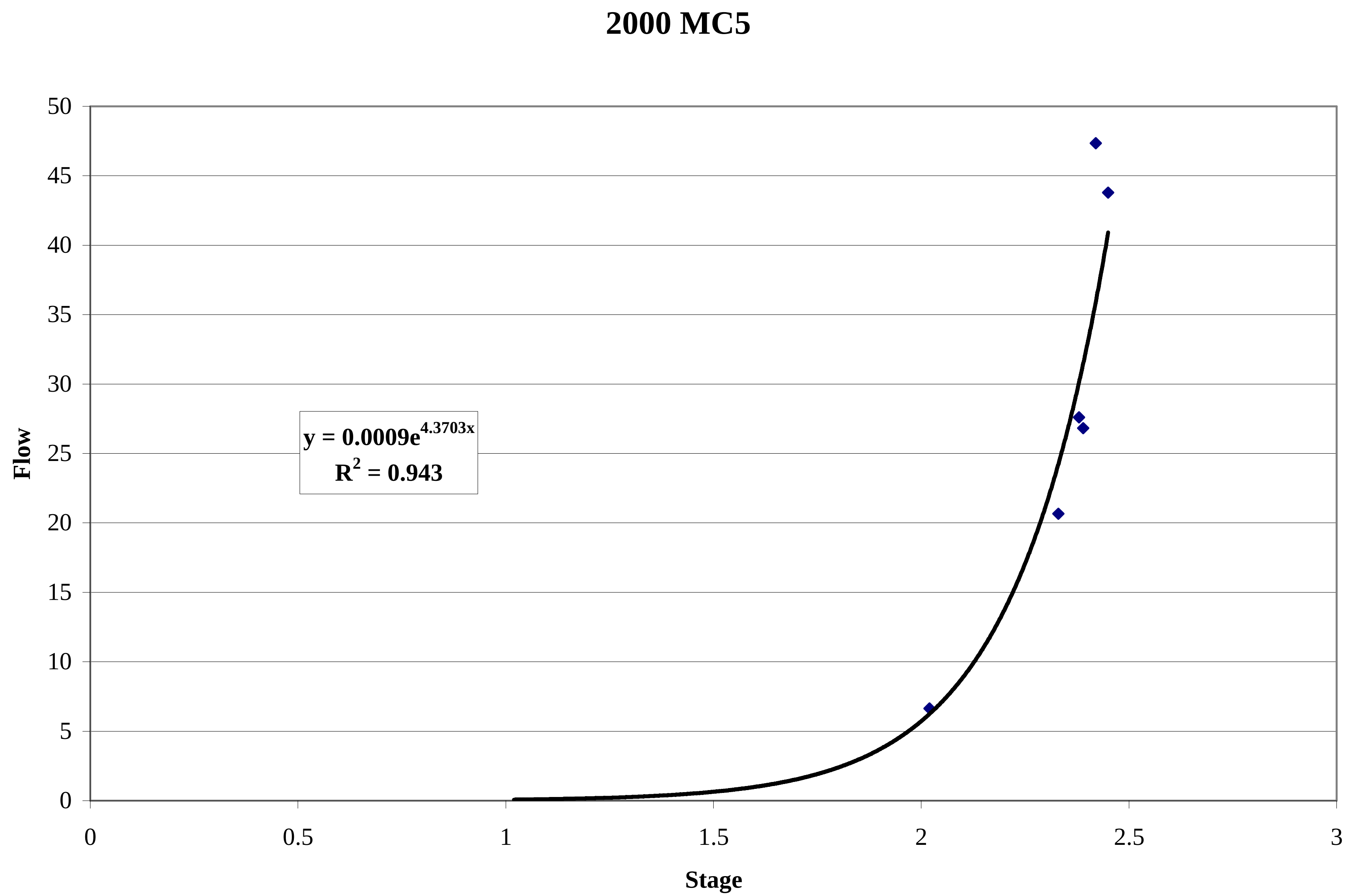
All MC2a

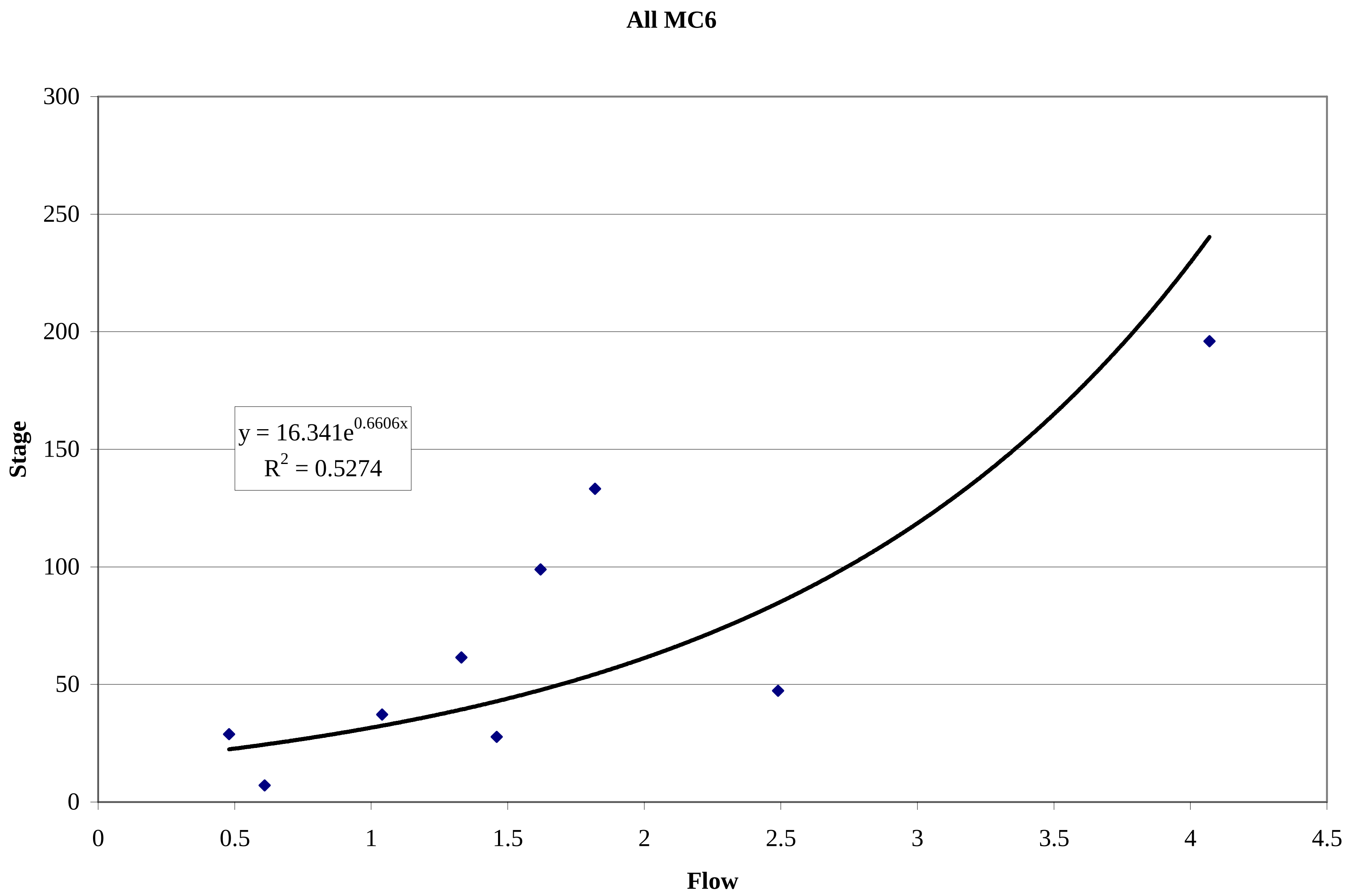


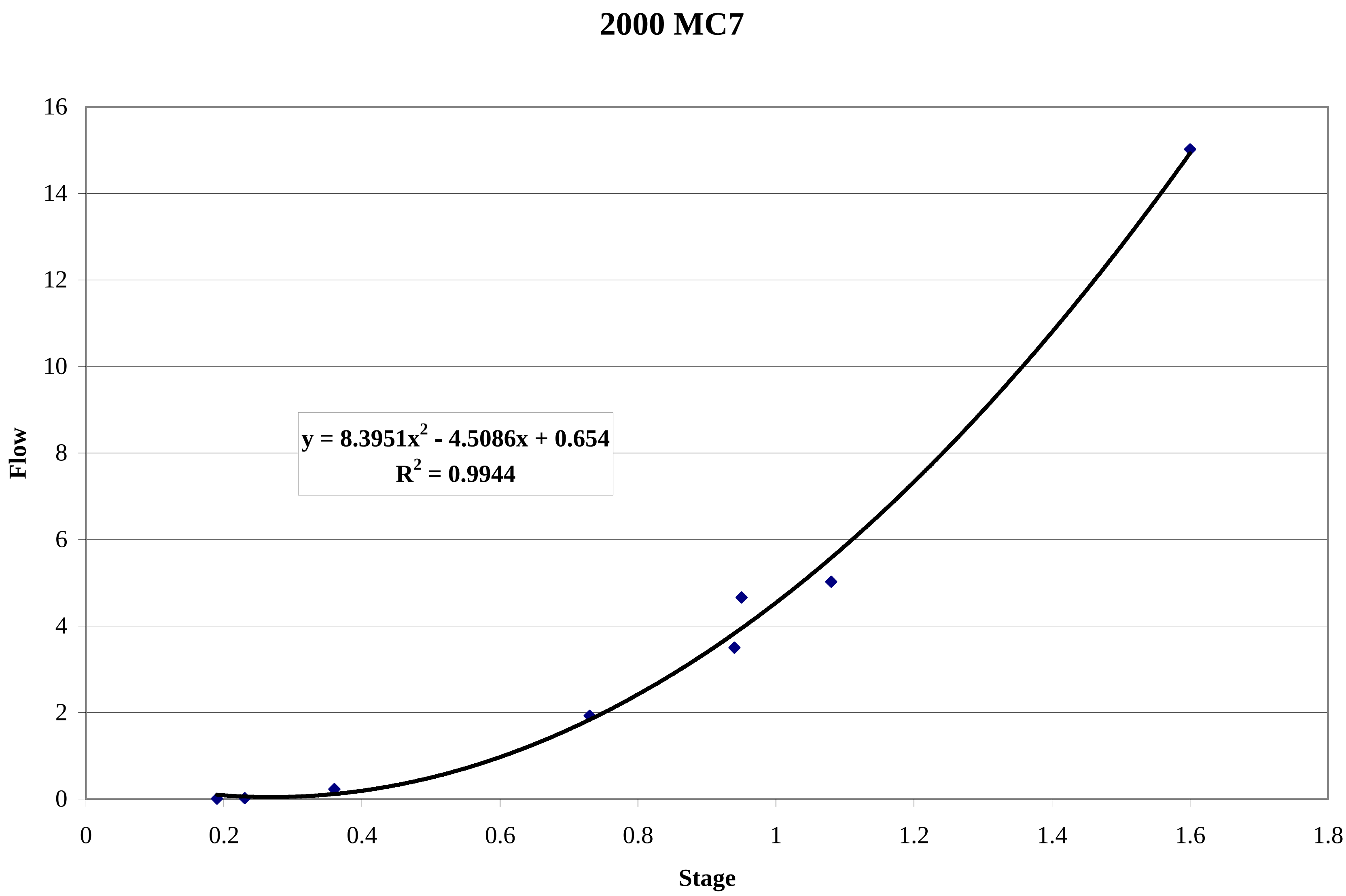
y = 5.2377x^1.7875
R^2 = 0.9657
Flow
Stage
70
60
50
40
30
20
10
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5


All MC3
y = 14.79x^2.5256
R^2 = 0.9048
Flow
Stage
300
250
200
150
100
50
0
0
0.5
1
1.5
2
2.5
3
3.5


All MC4
350
300
250
200
150
100
50
0
Flow
y = 0.1119e^3.6948x
R^2 = 0.7206
0
0.5
1
1.5
2
2.5
Stage


2000 MC5
Flow
Stage
y = 0.0009e^4.3703x
R^2 = 0.943
50
45
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3


All MC6
300
250
200
150
100
50
0
Stage
y = 16.341e^0.6606x
R2 = 0.5274
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Flow


2000 MC7
16
14
12
10
8
6
4
2
0
Flow
y = 8.3951x2 - 4.5086x + 0.654
R2 = 0.9944
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Stage

Appendix E. Stream Sample Data

SITE	DATE	pH	H2O TEMP (C)	DO	ALK-M	ALK-P	SOLIDS, TOT	SOLIDS, SUSP	AMMONIA	NITRATE	TKN	PHOS, TOTAL	PHOS, DISS	FECAL	VTSS
MC1	3/29/1999	8.24	7	11.7	323	0	912	3	0.02	0.1	1.02	0.258	0.201	10	3
MC1	4/14/1999	8.05	12.7	7.3	355	0	1143	5	0.02	0.1	1.12	0.217	0.196	90	5
MC1	5/6/1999	7.99	14.3	5.3	385	0	1356	4	0.02	0.1	1.2	0.522	0.457	140	1
MC1	5/11/1999	8.04	12.1	6.1	378	0	1235	2	0.02	0.1	1.59	0.43	0.404	350	1
MC1	5/26/1999	8.01	18.9	9.2	374	0	1663	1	0.02	0.1	1.42	0.471	0.442	360	1
MC1	6/7/1999	7.67	20.5	1.8	326	0	1578	1	0.02	0.1	1.81	0.356	0.329	190	1
MC1	6/30/1999	7.87	17.9	0.7	355	0	1616	1	0.02	0.1	1.94	0.618	0.61	1500	1
MC1	7/8/1999	7.65	23.1	0.2	332	0	1436	3	0.02	0.1	2.1	0.766	0.693	9000	1
MC1	7/28/1999	7.73	25	0.1	406	0	1542	1	0.02	0.1	2.51	0.948	0.886	720	1
MC1	8/5/1999	7.61	21.9	0.4	382	0	1554	5	0.05	0.1	2.21	0.751	0.691	370	1
MC1	9/7/1999	7.33	19.1	1.1	211	0	803	24	0.13	0.3	1.88	0.722	0.573	200	6
MC1	10/12/1999	7.68	10.9	2.6	419	0	1448	7	0.07	0.1	1.61	0.547	0.523	190	2
MC1	11/2/1999	8.28	4.7	9.5	471	0	1507	4	0.02	0.1	1.74	0.477	0.401	20	1
MC1	3/21/2000	7.85	7.1	13.7	334	0	1103	5	0.02	0.1	1.62	0.378	0.273	10	2
MC1	4/18/2000	8.32	11.5	11.8	442	0	1562	9	0.05	0.1	2	0.428	0.324	10	1
MC1	4/20/2000	8.22	6	10	398	0	1453	8	0.14	0.1	1.72	0.423	0.328	170	3
MC1	5/9/2000	8.1	16.1	5.1	406	0	1456	5	0.02	0.1	2.22	1.1	0.377	170	3
MC1	6/5/2000	8.58	16.2	6.4	349	21	1465	6	0.02	0.1	1.96	0.76	0.715	140	1
MC1	7/6/2000	8.04	25.1	2.2	278	0	893	7	0.02	0.1	1.17	0.989	0.966	230	3
MC1	7/12/2000	7.71	22.2	0.4	309	0	1014	9	0.02	0.1	2.37	1.28	1.14	50000	2
MC1	7/19/2000	7.67	17.9	2.3	327	0	1025	4	0.02	0.1	1.52	1.2	1.14	210	1
MC1	8/2/2000	8.04	22	2.3	340	0	1244	7	0.03	0.1	1.77	1.33	1.19	1500	6
MC1	11/1/2000														
MC1	11/2/2000	8.16	7.5	9.7	398	0	1456	15	0.02	0.1	2.2	1.05	0.828	140	8
MC2	3/29/1999	7.05	8.5	12.3	230	0	1594	14	6.98	0.2	9.17	1.12	0.996	1E+05	9
MC2	4/14/1999	7.89	12.1	8.8	324	0	2427	11	4.07	0.1	7.58	0.945	0.711	58000	9
MC2	5/6/1999	7.62	14	5.3	207	0	1431	30	2.53	0.3	3.75	0.609	0.446	4100	7
MC2	5/11/1999	7.77	12.1	6.2	248	0	1743	25	2.17	0.4	4.69	0.546	0.372	1600	5
MC2	5/26/1999	7.68	17.4	7.3	365	0	2731	18	4.82	0.1	9.02	1.31	1.07	60	7
MC2	6/7/1999	7.63	21.5	5.4	184	0	1255	14	1.63	0.2	3.51	0.283	0.211	430	6
MC2	6/30/1999	7.59	19.1	4.7	154	0	1077	29	2.06	0.2	3.76	0.569	0.413	2000	6
MC2	7/8/1999	7.76	23.9	3.9	143	0	1089	26	0.99	0.5	2.8	0.382	0.216	19000	6
MC2	8/5/1999	7.44	21.1	6.2	275	0	1985	14	14.6	0.1	16.3	2.34	2.19	230	5
MC2	8/30/1999	7.34	20.3	3.8	115	0	708	30	3.38	0.3	5.15	0.699	0.53	4300	7
MC2	9/7/1999	7.35	20.2	4.7	175	0	1153	22	1.22	0.7	3.24	0.608	0.518	480	7
MC2	10/12/1999	7.8	15.8	7.6	328	0	2212	20	11.1	0.1	12.9	1.65	1.61	6800	7
MC2	11/2/1999	7.95	11.9	9.2	323	0	2263	18	12.6	0.1	16.1	1.93	1.73	35000	10
MC2	3/21/2000	7.83	10.2	10.5	276	0	2063	11	12.5	0.1	15.3	1.66	1.45	5600	2
MC2	4/18/2000	8.05	12.6	11.3	285	0	2230	12	11.4	0.1	13.5	1.59	1.39	4600	5
MC2	4/20/2000	7.72	8.3	10.4	106	0	757	58	4.3	0.5	5.38	0.732	0.519	10000	8
MC2	5/9/2000	7.63	15.8	4.9	212	0	1672	18	7.99	0.1	10.3	0.981	0.819	2000	7
MC2	6/5/2000	7.6	16	6.4	258	0	2205	13	14.4	0.1	17	1.97	1.78	160	4

SITE	DATE	pH	H2O TEMP (C)	DO	ALK-M	ALK-P	SOLIDS, TOT	SOLIDS, SUSP	AMMONIA	NITRATE	TKN	PHOS, TOTAL	PHOS, DISS	FECAL	VTSS
MC2	7/6/2000	7.51		5.3	233	0	1940	15	8.06	0.1	10.4	1.45	1.17	380	8
MC2	7/12/2000	7.3	23.5	2.8	68	0	431	26	0.69	0.3	1.53	0.348	0.242	10000	6
MC2	7/19/2000	7.62	18.5	3.3	226	0	1493	15	4.53	0.1	5.61	1.02	0.973	1700	2
MC2	8/2/2000	7.71	22.1	5.4	285	0	2307	21	10.4	0.1	11.2	1.56	1.25	190	8
MC2	8/24/2000	7.55	22.9	7	267	0	2010	8	16.3	0.1	18.9	2.41	2.23	110	4
MC2	8/31/2000	7.84	20.9	7.9	127	0	1032	62	2.49	0.2	5.24	0.884	0.456	19000	14
MC2	9/22/2000	8.16	13.9	9.9	196	0	1740	44	10.36	0.2	11.8	1.86	1.33		12
MC2	9/25/2000	7.54	17.1	6										22000	
MC2	10/4/2000	7.85	16.2	6.9	262	0	1747	9	19.3	0.1	19.5	2.23	2.18	8100	7
MC2	10/5/2000	7.93	12.9	8.1	197	0	1416	22	9.23	0.1	9.32	1.4	1.18	11000	8
MC2	10/26/2000	7.8	13.9	7.9	65	0	538	114	1.8	0.3	2.43	0.643	0.364	58000	6
MC2	11/1/2000														
MC2	11/1/2000	7.62	14.9	5.6	113	0	807	78	3.15	0.3	4.44	0.762	0.445	12000	1
MC2	11/1/2000														
MC2	11/1/2000														
MC2A	7/23/1999	7.55	24.6	2.8	94	0	659	43	0.03	0.4	1.23	0.351	0.153		13
MC2A	8/5/1999	7.98	25.6	5.1	218	0	1605	106	0.02	0.1	1.51	0.601	0.108	1200	16
MC2A	8/30/1999	7.24	20	2.7	82	0	544	21	0.36	0.4	1.46	0.338	0.234	11000	4
MC2A	9/7/1999	7.39	20.1	3.9	141	0	878	17	0.19	0.8	1.72	0.457	0.423	480	4
MC2A	10/12/1999	8.28	12.2	9.1	353	0	2162	58	0.02	0.1	2.12	0.304	0.089	50	16
MC2A	11/2/1999	8.62	7.5	13.4	350	8	2538	40	0.02	0.4	2.43	0.366	0.038	10	20
MC2A	3/21/2000	8.59	8.3	15.2	292	8	2563	26	0.02	0.1	1.7	0.238	0.114	10	6
MC2A	4/18/2000	8.49	11.9	14.6	313	14	2261	54	0.02	0.1	1.84	0.244	0.072	10	8
MC2A	4/20/2000	8.02	7.4	11.8	75	0	496	68	0.57	0.5	1.6	0.281	0.13	500	8
MC2A	5/9/2000	7.85	18.2	4.4	198	0	1424	70	0.14	0.2	1.8	0.431	0.176	3800	14
MC2A	7/6/2000	7.74	27.4	4.8	158	0	1314	41	0.05	0.1	1.36	0.401	0.198	2100	10
MC2A	7/12/2000	7.45	22.5	3.2	92	0	643	25	0.02	0.3	1.28	0.346	0.274	13000	4
MC2A	7/19/2000	7.41	18	3	128	0	700	23	0.15	0.2	1.16	0.44	0.34	11000	4
MC2A	8/2/2000	8.07	26.2	5.2	297	0	2028	72	0.02	0.1	1.8	0.443	0.162	30	14
MC2A	8/24/2000	8.54	27.5	12.3	211	10	1774	78	0.02	0.1	2.17	0.455	0.103	710	28
MC2A	8/31/2000	8.08	21.8	8.2	85	0	694	72	0.06	0.4	1.85	0.355	0.116	18000	12
MC2A	9/22/2000	8.22	11.3	7.7	204	0	1909	208	0.03	0.1	1.78	0.548	0.058		20
MC2A	9/25/2000	8.08	12.5	10.2										840	
MC2A	10/5/2000	8.31	10.4	7.9	135	0	1081	46	0.29	0.3	1.78	0.394	0.067	7800	16
MC2A	10/26/2000	7.85	13.5	8.6	43	0	397	124	0.2	0.3	1.05	0.442	0.18	12000	12
MC2A	11/1/2000	7.71	13.8	7.1	62	0	423	66	0.43	0.4	1.26	0.327	0.124	11000	2
MC3	3/29/1999	8.41	11.3	18.6	199	1	1101	41	1.93	0.4	3.96	0.585	0.391	580	12
MC3	4/14/1999	8.04	10.5	8.9	255	0	1402	82	0.8	0.2	2.8	0.512	0.351	5100	24
MC3	5/6/1999	7.87	13.9	6.9	277	0	1681	43	1.82	0.4	4.72	0.687	0.467	520	6
MC3	5/11/1999	7.93	12.8	6.8	265	0	1597	25	1.01	0.6	3.37	0.482	0.355	210	3

SITE	DATE	pH	H2O TEMP (C)	DO	ALK-M	ALK-P	SOLIDS, TOT	SOLIDS, SUSP	AMMONIA	NITRATE	TKN	PHOS, TOTAL	PHOS, DISS	FECAL	VTSS
MC3	5/26/1999	7.98	21	8.4	261	0	1447	20	0.2	0.4	2.2	0.421	0.319	50	3
MC3	6/7/1999	8.08	24	11.9	269	0	1783	21	0.04	0.5	2.55	0.386	0.324	190	6
MC3	6/30/1999	8.46	22.2	15	304	17	2024	40	0.58	0.4	3.87	1.1	0.802	110	18
MC3	7/8/1999	8.71	25.5	15	290	15	1879	102	0.02	0.5	3.82	1.15	0.432	1800	44
MC3	8/5/1999	8.39	25.8	15	243	4	1404	104	0.28	0.3	2.76	0.603	0.112	170	36
MC3	8/30/1999	7.91	23	6.4	126	0	864	96	2.86	0.3	5.15	0.77	0.362	7800	20
MC3	9/7/1999	7.62	21.2	5.1	207	0	1122	76	0.76	0.4	2.5	0.382	0.172	280	20
MC3	10/12/1999	8.39	12.5	10.8	274	1	1289	40	1.46	0.3	3.52	0.488	0.34	740	8
MC3	11/3/1999	8.51	4.1	14	315	0	1596	42	3.68	0.3	6.8	0.805	0.592	450	14
MC3	3/22/2000	8.82	8.5	15	307	20	1823	12	4.2	0.1	6.57	0.993	0.777	10	1
MC3	4/20/2000	8.55	11.2	14.3	159	0	1023	28	2.15	0.6	3.72	0.55	0.388	800	9
MC3	5/9/2000	8.4	19	14.1	166	0	1051	24	1.56	0.3	3.65	0.89	0.661	1700	13
MC3	6/5/2000	8.08	19	6.3	220	0	1526	26	5.67	0.1	7.25	1.16	0.95	310	10
MC3	7/6/2000	7.55	28	3.6	186	0	1229	56	0.57	0.2	2.21	1.1	0.845	640	12
MC3	7/12/2000	7.57	26.5	4.8	189	0	1453	30	2.45	0.4	4.46	0.951	0.764	1700	8
MC3	7/19/2000	7.54	19.2	4.1	251	0	1465	59	0.98	0.2	1.95	1.1	0.868	410	9
MC3	8/2/2000	8.41	26.4	10.8	266	5	1980	25	0.02	0.1	2.28	1.18	1.01	260	9
MC3	8/24/2000	8.26	25.2	12.2	273	0	2036	74	0.11	0.1	8.89	2.16	1.58	220	30
MC3	9/1/2000	7.62	17.4	2.9	145	0	1202	34	3.86	0.3	6.77	1.34	0.908		12
MC3	10/4/2000	8.39	10.1	11.3	260	0	1833	64	13.9	0.3	14.2	2.2	2.03	170	12
MC3	10/27/2000	7.53	11	4.3	67	0	451	38	2.28	0.3	3.34	0.791	0.563		2
MC3	10/30/2000	7.71	12.9	5.7										770	
MC3	11/2/2000	8.04	7	10.4	136	0	905	25	3.65	0.4	4.63	0.727	0.554	480	5
MC4	3/29/1999	8.86	11	15	262	19	1392	18	0.62	0.5	2.91	0.586	0.351	10	13
MC4	4/14/1999	8.47	11.2	12.1	278	10	1508	22	0.02	0.3	2.7	0.496	0.279	10	18
MC4	5/6/1999	8.4	14	12.2	315	0	1816	62	0.12	0.4	3.94	0.815	0.393	260	18
MC4	5/11/1999	8.39	13.2	7.1	248	0	1473	51	0.68	1.3	2.84	0.694	0.499	500	9
MC4	5/26/1999	8.33	21.5	13.3	264	0	1554	29	0.02	0.1	2.81	0.436	0.265	10	9
MC4	6/7/1999	8.75	24.9	15	290	19	1781	52	0.02	0.1	3.56	0.337	0.161	260	24
MC4	6/30/1999	8.61	23.5	11.7	260	20	1857	102	0.02	0.1	3.38	0.902	0.263	310	36
MC4	7/8/1999	8.28	26.5	7.3	258	0	1427	60	0.02	0.1	2.88	1.46	1.19	210	21
MC4	8/5/1999	8.18	26.4	7.8	177	0	1318	90	0.02	0.1	3.1	0.648	0.144	220	36
MC4	8/30/1999	8.49	23.2	13.6	151	0	1546	56	0.02	0.1	5.07	0.591	0.18	210	30
MC4	9/7/1999	7.59	21.5	6	159	0	823	46	0.88	0.3	2.42	0.225	0.058	220	13
MC4	10/12/1999	8.95	13.9	15	254	25	1322	50	0.02	0.6	2.86	0.337	0.131	70	20
MC4	11/3/1999	9.06	5.2	15	282	26	1361	32	0.14	1	2.67	0.414	0.165	10	18
MC4	3/22/2000	9.69	10.8	15	224	49	1738	27	1.89	0.4	4.9	1.09	0.427	10	16
MC4	4/20/2000	9.01	11.8	15	274	11	1986	29	1.11	0.6	3.97	0.704	0.445	10	7
MC4	5/9/2000	9.16	21.9	15	297	12	1896	224	0.02	0.1	3.22	1.13	0.208	160	52
MC4	6/5/2000	8.81	20.2	15	361	29	2473	106	1.64	0.1	6.4	3.22	1.56	180	66
MC4	7/6/2000	9.09	29.8	13.4	209	43	1364	162	0.02	0.1	4.62	1.75	0.55	280	66
MC4	7/12/2000	8.91	31.2	15	182	5	1210	78	0.1	0.2	3.65	2.68	1.56	490	28

SITE	DATE	pH	H2O TEMP (C)	DO	ALK-M	ALK-P	SOLIDS, TOT	SOLIDS, SUSP	AMMONIA	NITRATE	TKN	PHOS, TOTAL	PHOS, DISS	FECAL	VTSS
MC4	7/19/2000	7.59	19.8	4.2	176	0	902	30	0.65	0.1	1.64	1.48	1.26	290	7
MC4	8/2/2000	8.84	28.8	13.3	263	23	1516	58	0.02	0.1	2.43	0.904	0.573	90	26
MC4	8/24/2000	8.37	24.9	8.4	280	4	1895	58	0.02	0.1	2.65	1.06	0.649	1600	24
MC4	9/1/2000	8.48	17.1	5	272	0	2164	56	0.02	0.1	2.43	0.558	0.195		16
MC4	10/4/2000	8.85	10	7.9	200	0	2163	76	0.02	0.1	3.34	1.06	0.488	130	34
MC4	10/27/2000	8.72	11	9.4	182	0	1832	58	0.63	0.1	3.67	0.776	0.348		24
MC4	10/30/2000	8.07	12.4	7.3										170	
MC4	11/2/2000	8.35	7	11	129	0	743	88	2.79	0.2	3.64	1.08	0.743	100	14
MC5	3/29/1999	9.02	9.4	15	264	38	1294	23	0.02	0.1	2.14	0.371	0.187	10	15
MC5	3/29/1999	9.28	10	15	262	39	1433	36	0.02	0.1	2.15	0.518	0.263	10	16
MC5	4/14/1999	8.84	11.2	14.2	277	15	1599	36	0.02	0.1	2.51	0.43	0.207	10	18
MC5	5/6/1999	8.32	14.7	8.9	295	0	1679	88	0.02	0.1	2.86	1.2	0.636	50	26
MC5	5/11/1999	8.39	14.3	14.1	337	5	1938	88	0.02	0.1	4.03	0.917	0.35		30
MC5	5/26/1999	8.68	22.1	15	273	18	1578	80	0.02	0.1	2.63	0.519	0.079	20	26
MC5	6/7/1999	8.84	25.8	13.4	250	15	1485	96	0.1	0.5	3.32	0.326	0.097	850	26
MC5	6/30/1999	8.58	23.5	9.8	288	22	1677	84	0.02	0.1	3.57	0.96	0.411	150	16
MC5	7/8/1999	8.57	26.3	8.4	323	0	1996	98	0.02	0.1	3.24	1.4	0.736	240	34
MC5	8/5/1999	8.29	28.1	9.9	213	0	1279	70	0.02	0.1	2.87	1.04	0.587	220	24
MC5	8/30/1999	8.61	22.2	12.1	192	10	1538	64	0.02	0.1	2.7	0.414	0.057	120	24
MC5	9/7/1999	8.54	22.2	11.9	95	8	509	42	0.86	0.3	2.67	0.236	0.049	780	16
MC5	10/12/1999		14	15	262	28	1323	98	0.02	0.1	2.74	0.292	0.036	110	34
MC5	11/3/1999	9.36	6.1	15	212	23	1386	100	0.02	0.1	4.5	0.506	0.035	10	42
MC5	3/23/2000	9.27	9.9	15	198	29	1242	62	0.58	0.3	3.31	0.384	0.062	10	22
MC5	4/20/2000	8.91	11	15	198	0	2000	90	0.02	0.1	4.18	0.761	0.064	6700	34
MC5	5/9/2000	9.32	22.7	15	277	54	1960	152	0.02	0.1	5.45	1.7	0.625	7700	104
MC5	6/5/2000	8.86	21.2	15	260	5	2452	172	0.02	0.1	2.5	0.98	0.071	140	60
MC5	7/6/2000	8.91	30.3	9	180	22	2206	90	0.02	0.1	3.91	1.66	0.91	70	52
MC5	7/12/2000	9.46	32.6	15	175	24	1117	70	0.02	0.1	3.8	1.46	0.558	1100	30
MC5	7/19/2000	8.86	19.7	12.5	226	18	1494	72	0.02	0.1	2.16	1.2	0.68	90	32
MC5	8/2/2000	9.07	29.1	15	268	45	1554	132	0.06	0.1	2.8	1.61	0.489	40	60
MC5	8/24/2000	8.74	23.4	7.7	306	27	1980	84	0.02	0.1	3.45	0.968	0.407	110	38
MC5	9/1/2000	8.58	17.5	4.5	321	0	2303	88	0.02	0.1	3.21	0.706	0.158		22
MC5	10/4/2000	8.94	10.5	8.7	259	13	2624	30	0.02	0.1	2.14	0.458	0.144	240	16
MC5	10/27/2000	8.52	11.1	9.3	207	0	1930	54	0.02	0.1	2.06	0.483	0.124		20
MC5	10/30/2000	8.54	12.6	11.2										2400	
MC5	11/2/2000	9.15	8	11.6	195	27	1961	172	0.02	0.1	2.87	0.872	0.104	800	44
MC6	4/14/1999	8.95	12.1	12.1	262	1	1651	48	0.02	0.1	1.79	0.111	0.282	10	24
MC6	5/6/1999	8.14	15.5	7.6	280	0	1670	31	0.02	0.1	1.85	0.421	0.242	40	8
MC6	5/11/1999	8.34	14.3	9.9	321	0	1771	41	0.02	0.1	3.02	0.593	0.3	10	20

SITE	DATE	pH	H2O TEMP (C)	DO	ALK-M	ALK-P	SOLIDS, TOT	SOLIDS, SUSP	AMMONIA	NITRATE	TKN	PHOS, TOTAL	PHOS, DISS	FECAL	VTSS
MC6	5/26/1999	8.08	20.5	7.1	260	0	1380	22	0.02	0.1	2.46	0.482	0.352	20	7
MC6	6/7/1999	8.32	25.6	10.2	300	4	1628	27	0.02	0.1	2.33	0.378	0.267	20	13
MC6	6/30/1999	8.3	23	6.9	313	7	1592	30	0.02	0.1	2.83	1.36	0.991	100	20
MC6	7/8/1999	8.22	26.3	6.1	302	0	1838	31	0.02	0.1	2.92	1.3	0.959	10	18
MC6	8/5/1999	8.14	26.3	6.9	296	0	1637	20	0.02	0.1	2.4	1.76	1.1	10	13
MC6	8/30/1999	8.26	23.2	12.1	238	0	1464	32	0.02	0.1	3.65	1.06	0.701	80	28
MC6	9/7/1999	8.9	22.3	13.6	155	26	1281	50	0.02	0.1	2.73	0.49	0.181	100	36
MC6	10/12/1999		13.6	13.5	235	23	1291	70	0.02	0.1	3.19	0.414	0.034	20	30
MC6	11/3/1999	8.74	6.2	12.4	183	6	1405	50	0.02	0.1	2.76	0.378	0.075	10	20
MC6	3/23/2000	8.8	8.6	14.4	263	0	1759	80	0.64	0.2	3.31	0.516	0.09	10	24
MC6	4/20/2000	9.01	14.5	15	230	0	2062	84	0.02	0.1	3.14	0.709	0.155	10	32
MC6	5/8/2000	7.89	12.1	8.2	57	0	183	13	0.13	0.5	1.05	0.219		12000	4
MC6	5/23/2000	8.55	24.5	12.4	309	0	2240	168	0.02	0.1	1.94	0.898	0.126	130	36
MC6	6/5/2000	8.72	26.1	1.5	281	4	2261	160	0.02	0.1	2.17	0.929	0.128	120	48
MC6	7/6/2000	8.79	33	13.9	257	20	2338	144	0.02	0.1	3.68	1.31	0.623	200	56
MC6	7/12/2000	8.6	29.4	12.9	149	0	1325	60	0.02	0.4	2.75	1.3	0.831	3800	14
MC6	7/19/2000	8.21	19.9	6.4	231	0	1313	46	0.15	0.1	2.76	1.41	1.17	140	12
MC6	8/2/2000	8.33	28.9	8.3	285	0	1457	42	0.06	0.1	2.27	1.86	1.46	10	16
MC6	8/24/2000	8.76	22.8	4.2	305	19	1718	96	0.02	0.1	3.27	1.11	0.425	30	42
MC6	9/1/2000	8.68	17.5	4.3	301	4	2068	70	0.02	0.1	2.93	0.809	0.319		24
MC6	10/4/2000	9.23	12	9.7	212	18	2849	36	0.02	0.1	2.94	0.488	0.266	60	14
MC6	10/27/2000	8.55	11.3	11.3	192	0	2613	90	0.02	0.1	3.67	0.957	0.202		40
MC6	10/30/2000	8.51	13	9.5										400	
MC6	11/2/2000	8.48	8	10	227	0	2176	70	0.02	0.1	2.68	0.464	0.07	340	22
MC6		8.9	22.3	13.6	155	26	1281	50	0.02	0.1	2.73	0.49	0.181	100	36
MC7	3/29/1999	8.24	11	12.9	249	1	849	5	0.02	0.1	0.8	0.092	0.079	30	3
MC7	4/14/1999	8.12	10.5	9.6	226	0	844	9	0.02	0.1	0.98	0.2	0.164	10	9
MC7	5/6/1999	8.08	14.5	8.4	301	0	1085	22	0.02	0.1	1.6	0.106	0.201	500	5
MC7	5/11/1999	8.08	12.2	9.7	311	0	1173	8	0.02	0.1	1.31	0.259	0.18	180	2
MC7	5/26/1999	8.06	20.5	9.3	228	0	934	30	0.02	0.1	1.72	0.175	0.114	160	4
MC7	6/7/1999	7.91	23	7.2	258	0	1021	39	0.05	0.1	2.11	0.144	0.086	270	6
MC7	6/30/1999	7.85	21.2	6.6	313	0	1153	44	0.02	0.1	2.16	0.284	0.203	2000	8
MC7	7/8/1999	7.85	25.4	7	305	0	1147	39	0.02	0.1	1.19	0.326	0.209	2400	7
MC7	7/20/1999	7.99	26.9	4.8	343	0	1320	144	0.02	0.1	0.99	0.34	0.161	1400	22
MC7	8/5/1999	7.76	24.9	5.5	261	0	993	58	0.24	0.1	1.43	0.286	0.188	1100	10
MC7	8/30/1999	7.83	20.9	6.3	318	0	1129	41	0.02	0.1	1.37	0.267	0.19	730	8
MC7	9/7/1999	7.63	20	6.8	215	0	884	65	0.02	0.2	1.39	0.274	0.062	400	10
MC7	10/12/1999	8.23	12.3	9.7	249	0	956	16	0.02	0.1	1.18	0.231	0.178	260	4
MC7	11/3/1999	8.39	4.1	12.1	287	0	1022	20	0.02	0.1	1.2	0.204	0.14	40	4
MC7	3/21/2000	8.31	7.3	12.4	341	0	1211	9	0.02	0.1	0.73	0.102	0.064	10	2
MC7	4/18/2000	8.52	11.2	12.2	384	9	1452	14	0.02	0.1	0.92	0.163	0.112	10	2
MC7	4/20/2000	8.45	8.6	12.5	361	0	1425	13	0.02	0.2	1.06	0.201	0.15	10	3

SITE	DATE	pH	H2O TEMP (C)	DO	ALK-M	ALK-P	SOLIDS, TOT	SOLIDS, SUSP	AMMONIA	NITRATE	TKN	PHOS, TOTAL	PHOS, DISS	FECAL	VTSS
MC7	5/9/2000	8.32	18.5	8.2	394	0	1582	52	0.02	0.1	1.17	0.258	0.155	250	10
MC7	6/5/2000	8.23	18.6	7.6	398	0	1737	98	0.02	0.1	1.22	0.312	0.159	490	14
MC7	7/6/2000	8.02	27.5	4.3	394	0	1581	90	0.02	0.1	1.4	0.448	0.305	1000	20
MC7	7/12/2000	7.99	26.8	4.4	339	0	1419	66	0.02	0.1	1.35	0.459	0.312	700	4
MC7	7/19/2000	8.12	18.9	6.2	315	0	1207	32	0.04	0.1	0.97	0.36	0.332	1300	6
MC7	8/2/2000	7.98	26	4.3	338	0	1422	152	0.04	0.1	0.88	0.486	0.247	5500	18
MC7	8/24/2000	8.16	26	8.2	345	0	1417	33	0.02	0.1	0.96	0.296	0.234	1600	8
MC7	9/1/2000	8.09	18	5.4	331	0	1408	43	0.02	0.1	1.07	0.294	0.15		3
MC7	10/4/2000	7.91	9	13.3	410	0	1375	23	0.23	0.1	0.86	0.36	0.131	1900	2
MC7	10/27/2000	8.21	10.7	8.6	316	0	1521	31	0.02	0.1	1.38	0.216	0.105		7
MC7	10/30/2000	8.23	12.2	9.3										790	
MC7	11/2/2000	8.53	8	11	376	0	1561	26	0.02	0.1	0.92	0.199	0.122	1100	6
MC8	3/29/1999	7.2	18	15	7	0	5	1	0.02	0.1	0.1	0.007	0.007	10	1
MC8	6/30/1999	8.27	23.2	7.4	7	0	12	1	0.02	0.1	0.14	0.002	0.002	10	1
MC8	7/20/1999	7.65	27.1	5.1	7	0	6	1	0.02	0.1	0.14	0.002	0.003	10	1
MC8	7/28/1999	7.73	25.8	0.2	7	0	5	1	0.02	0.1	0.14	0.004	0.004	10	1
MC8	8/5/1999	7.8	22	4.2	7	0	8	2	0.02	0.1	0.14	0.004	0.005	10	1
MC8	8/30/1999	7.2	20.1	3	7	0	4	2	0.02	0.1	0.14	0.002	0.002	10	2
MC8	11/3/1999	7.85	4.2	12.2	7	0	5	1	0.02	0.1	0.14	0.002	0.002	10	1
MC8	3/23/2000	7.5	8.8	12.4	6	0	11	1	0.02	0.1	0.21	0.002	0.002	10	1
MC8	5/9/2000	7.42	23	9.1	6	0	9	1	0.02	0.1	0.21	0.002	0.002	10	1
MC8	5/18/2000	7.6	16.2	8.1	6	0	7	1	0.02	0.1	0.21	0.002	0.002	10	1
MC8	6/5/2000	7.65	16	6.2	6	0	7	1	0.02	0.1	0.21	0.004	0.005	10	1
MC8	7/12/2000	7.5	22.5	3.3	6	0	8	1	0.02	0.1	0.21	0.002	0.002	10	1
MC8	8/2/2000	7.63	23.7	2.9	6	0	7	1	0.02	0.1	0.21	0.002	0.002	10	1
MC8	8/24/2000	8.8	23	7.2	6	0	7	3	0.02	0.1	0.21	0.002	0.008	10	2
MC8	8/31/2000	7.77	21.6	7.7	6	0	7	1	0.02	0.1	0.21	0.002	0.002	10	1
MC8	10/4/2000	7.65	11	8.2	6	0	7	1	0.02	0.1	0.21	0.002	0.002	2	1
MC8	10/26/2000	7.7	13.8	8	6	0	4	1	0.02	0.1	0.21	0.002	0.002	10	1
MC8	10/27/2000	7.42	11.4	6	6	0	17	1	0.02	0.1	0.21	0.002	0.002		1
MC8	10/30/2000	8	13.1	8										10	
MC8	11/2/2000	7.07	8	4	6	0	11	1	0.02	0.1	0.21	0.002	0.002	10	1
MC9	4/14/1999	8.92	11.7	11.9	254	4	1640	44	0.02	0.1	2.17	0.274	0.114	10	22
MC9	5/26/1999	8.07	20.5	7.1	262	0	1374	22	0.02	0.1	2.59	0.488	0.336	10	7
MC9	6/7/1999	7.69	20.5	2	324	0	1578	1	0.02	0.1	1.86	0.343	0.331	280	1
MC9	6/30/1999	7.54	19.2	4.8	151	0	1051	32	1.77	0.2	3.32	0.492	0.378	2400	16
MC9	7/8/1999	8.78	25.7	15	297	15	1897	108	0.02	0.1	3.09	1.09	0.435	700	48
MC9	7/28/1999	7.73	25.2	0.2	406	0	1536	2	0.02	0.1	2.5	0.912	0.885	710	2
MC9	8/5/1999	8.2	26.5	7.7	174	0	1306	86	0.02	0.1	2.75	0.637	0.141	270	34
MC9	10/12/1999	8.98	14	15	259	25	1322	72	0.02	0.1	3.11	0.307	0.368	50	22

SITE	DATE	pH	H2O TEMP (C)	DO	ALK-M	ALK-P	SOLIDS, TOT	SOLIDS, SUSP	AMMONIA	NITRATE	TKN	PHOS, TOTAL	PHOS, DISS	FECAL	VTSS
MC9	11/2/1999	7.94	11.8	9.1	333	0	2276	19	12.8	0.1	16.7	1.88	0.664	66000	10
MC9	11/3/1999	9.35	6	15	201	22	1385	92	0.02	0.1	4.27	0.469	0.031	10	38
MC9	3/23/2000	9.29	9.8	15	177	0	1249	56	0.6	0.3	2.79	0.367	0.077	10	22
MC9	5/23/2000	8.57	24.6	12.5	307	0	2244	176	0.02	0.1	2.06	0.885	0.12	300	40
MC9	6/5/2000	8.85	21.3	15	260	6	2445	144	0.02	0.1	2.99	1.02	0.056	60	48
MC9	7/12/2000	7.45	22.5	3.3	101	0	684	26	0.2	0.3	1.5	0.362	0.257	14000	6
MC9	8/2/2000	5.3	22.2	7.72	284	0	2302	21	10.4	0.1	11.6	1.56	1.34	120	8
MC9	8/24/2000	8.69	23.1	7.4	308	28	1966	72	0.02	0.1	2.89	0.9	0.384	80	36
MC9	8/31/2000	8.01	21.6	7.8	101	0	1033	68	2.54	0.1	5.9	0.886	0.479	17000	28
MC9	10/4/2000	8.93	10.6	8.6	259	15	2617	24	0.02	0.1	1.99	0.394	0.041	310	6
MC9	10/26/2000	7.79		7.8	62	0	495	108	1.11	0.3	1.48	0.564	0.281	65000	14
MC9	10/27/2000	8.5	11	9	208	0	1922	50	0.02	0.1	2.39	0.488	0.118		18
MC9	10/30/2000	8.53	12.5	11.1										2500	
MC9	11/2/2000	9.15	8	11.6	192	0	1954	184	0.02	0.1	3.06	0.91	0.104	1200	56