Boulder Creek Fish Survey

Application of Rabid Bioassessment Protocol V-Fish

and

The Index of Biotic Integrity at Boulder Creek

Before and After Implementation Of

Best Management Practices

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ABSTRACT

The City of Boulder is conducting a comprehensive pollution control project designed to improve water quality within the Boulder Creek basin. The water quality management plan for the basin includes point source and nonpoint source pollution controls as neither control type alone can result in a stream that consistently meets state water quality standards.

Environmental investigations by the City of Boulder demonstrated that nonpoint source pollution contributed to periodic exceedances of water quality standards. It was recognized that nonpoint source pollution problems were correctable and could be controlled by using a variety of state approved improvements termed Best Management Practices (BMPs).

A severely disturbed section of Boulder Creek, the Phase I Demonstration Reach, was chosen for BMP treatments designed to reduce nonpoint source pollution and restore aquatic ecosystem function. The reach is characterized by channelization, poor aquatic habitat, streambank erosion, high water temperature, and an overgrazed riparian zone.

A fish survey was conducted before and after implementation of BMPs. Fish were sampled and evaluated following U.S. Environmental Protection Agency recommended Rapid Bio-Assessment Protocol V-Fish (RBP-V) and the Index of Biotic Integrity (IBI). The IBI is an objective, reproducible stream assessment approach which measures the "health" of a water resource using attributes of the fish population found living there (Karr, 1981). The IBI and RBP-V allow quantitative comparison of stream "health" before and after Best Management Practice treatment.

Pre-and-post-treatment fish sampling results indicated that Boulder Creek ecosystem health is poor at the Demonstration Reach. Thirteen total fish species were collected. Few adult fish were collected and many fish were diseased. Dominant species were the sand shiner Notropis stramineus, Iowa darter Etheostoma exile, and white sucker Catostomus commersoni. Post-treatment sampling was conducted two months after treatment, before the aquatic ecosystem had fully responded to BMP improvements. Poor habitat quality is the primary reason for the poor condition of the Demonstration Reach fish population.

The 1989-1990 fish biodiversity was compared to results from a 1903 fish survey conducted at approximately the same location. Fish biodiversity has been reduced, number of introduced species has increased, and 60 percent of the 22 historical species have been extirpated.

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INTRODUCTION

The City of Boulder is attempting to control nonpoint source (NPS) pollution within the Boulder Creek basin extending from the Indian Peaks Wilderness headwaters to the confluence with St. Vrain Creek. Boulder Creek Phase I Demonstration Reach, located east of the City of Boulder, was selected for state approved improvements termed Best Management Practices (BMPs) designed to control NPS pollution, enhance fish habitat, and improve water quality.

Investigations by the City of Boulder between 1985 and 1988 demonstrated that NPS pollution contributed to periodic and/or episodic exceedances of water quality standards. The control of point source pollution alone has not enabled Boulder Creek to consistently meet water quality standards.

NPS pollution effecting the Boulder Creek basin includes sediment, fertilizer, pesticides, ammonia, fecal coliform, and storm sewer inputs (City of Boulder, 1990). Causes of NPS pollution include channelization, overland flow, overgrazing, streambank erosion, irrigation return flows, development, and road sanding (City of Boulder, 1990).

The Phase I Demonstration Reach was selected for BMP implementation due to its severely disturbed condition. Pre-treatment demonstration reach habitat was characterized by streambank erosion, lack of instream cover, lack of pool habitat, warmwater, and an overgrazed riparian zone consisting mainly of grasses and cottonwood trees.

Channelization, which creates a straight channel for a meandering stream, has shortened historical reach length, increased flow velocity, accelerated erosion, and degraded fish habitat.

Specific BMPs have been selected to provide cost-effective water quality improvement, and attain the state designated Class I Warmwater Aquatic Life use classification as defined in the Colorado Water Quality Act. BMPs applied at the demonstration reach during winter 1989-1990 included revegetation, fencing, wetland creation, terracing, bank stabilization, aeration, and flow concentration (Appendix 1).

The fish population at Boulder Creek Phase I Demonstration Reach was surveyed pre-and-post-treatment to assess aquatic ecosystem health and provide baseline data for City of Boulder nonpoint source (NPS) pollution control project Phase I. Rapid Bioassesment Protocol V-Fish (RBP-V) and the Index of Biotic Integrity (IBI) were applied to provide a reproducible assessment of Boulder Creek condition and health.

The IBI is an objective fish community assessment approach which measures quality of a water resource using attributes of the fish population found living there. Biotic integrity is possessed by ecosystems in which composition, structure, and function have not been adversely impaired by human activities (Karr, 1981).

The IBI is based on twelve criteria termed metrics which incorporate historical records and the knowledge of professional ichthyologists (Table 1). Metrics evaluate the ecological characteristics of a sampled fish population in terms of species richness and composition, fish abundance and condition, and trophic class.

Fish sampling data were used to rate each metric 5 (best), 3, or 1 in comparison to values expected for an undisturbed fish community in a stream of similar size in the same region. Metric ratings were summed to produce an IBI score. The IBI score is a measure of biotic integrity and an indicator of stream health.

The 1989-1990 fish biodiversity was compared with results from a historic 1904 study of Boulder Creek fishes (Juday, 1904). A 1984 fish survey documents species found above and below the 75th Street Wastewater Treatment Plant (WWTP) (Windell, 1984).

Objectives of this study were to apply the IBI before and after BMP implementation (pre-and-post-treatment), compare and contrast present fish population with the historical record, and provide baseline data for future analysis of project efficacy.

LOCATION

The study was located east of the City of Boulder on lower Boulder Creek (Figures 1, 2). The upper boundary was located at 95th street, 3.5 miles downstream of the WWTP, the study area extended 1.5 miles eastward across Boulder Valley Farm to 107th Street (Figure 3). This section of Boulder Creek is a fifth order plains stream.

METHODS

Experimental design for fish monitoring involved pre-and-post-treatment sampling utilizing RBP-V, (Plafkin, 1989) which is based on the IBI (Karr, 1981) (Figures 4, 5). Fish were sampled during fall 1989 and spring 1990 at three 100 meter stations selected to contain pools, riffles, and glides (Figure 6).

Sampling was conducted using a bT-2 backpack generator and a low conductivity electrofishing unit with a variable voltage pulsator set at 150 watts. A five member crew used nets to capture stunned fish, which were identified, measured, weighed, examined for fin rot or disease, and released.

IBI Application

An IBI score was calculated for each station. Metric criteria used to calculate the IBI score were adapted to a fifth order stream in the South Platte River Basin (Table 1), (Fausch, 1987). Ecological characteristics are required of each species to rate metrics (Table 2).

Metrics were rated and summed to produce an IBI score for each station. IBI score may range from 12 to 60 and provides a measure of ecosystem health in terms of six classes: excellent (57-60), good (48-52), fair (39-44), poor (28-35), very poor (12-23), and no fish. A difference of four or more points is considered significant (Karr, 1985).

RESULTS

Thirteen species of fish were identified during pre-and-post-treatment sampling, 8 native to Colorado and 5 introduced. Dominant species were the sand shiner Notropis Stramineus and the Iowa darter Etheostoma exile. Commonly collected fish were the white sucker Catostomus commersoni, creek chub Semotilus atromaculatus, longnose sucker Catostomus catostomus, fathead minnow Pimephalus promelas, longnose dace Rhynichthys cataractae, and largemouth bass Micropterus salmoides. Pre-project sampling netted 13 species and 249 fish, 8 species and 142 fish were collected post-project. (Table 3, Figure 7).

Iowa darters were found in moving water with rubble substrate. Sand shiners were found isolated in large schools near instream debris. The other remaining species were captured in pools, near instream debris, and under cut banks. The stream channel was filled with lush aquatic vegetation pre-treatment, but lacked vegetation post-treatment.

IBI Scores

Aquatic ecosystem health rated poor at each of the three sample stations. Pre-treatment scores were 38, 29, and 32 for the upper, middle, and lower stations, respectively. Post-treatment scores were 30, 34, and 34 (Figure 8).

Percent Diseased Fish

Post-treatment percent diseased fish increased at all stations and total number of diseased fish increased 10 percent (Figure 9). Fish were considered diseased if there was fin rot, fungus, or other evidence of disease. Data showed that post-treatment percent diseased fish decreased in a downstream direction.

Percent Tolerant Species

Tolerant species are adaptable to degradation of water quality, spawning habitat, cover habitat, and food resources due to erosion, siltation, pollution, and channelization (Fausch, 1987). Percentage of total fish collected which are classified tolerant to habitat degradation and pollution was 53 percent pre-treatment and 68 percent post-treatment (Table 4) (Fausch, 1987). Tolerant fish were the sand shiner, fathead minnow, river carp, and white sucker. The Iowa darter was classified intolerant, and the remaining species are of intermediate tolerance.

Fish Size

Few adult fish were collected and most fish were young of the year less than 7 centimeters long. Number of fish greater than 20 cm (8 inches) was 9 pre-treatment and 1 post-treatment (Figure 10). Fish biomass was one kilogram per 100 meters of stream in the fall and one-half kilogram per 100 meters in spring (Figure 11).

DISCUSSION

Low biotic integrity, low biomass, and small fish size indicate Boulder Creek Demonstration Reach ecosystem health is poor and has been severely impacted by human disturbances. Pre-and-post-treatment IBI scores do not significantly differ, a significant difference being four or more points. Collections were made in different seasons, but fall and spring IBI scores are generally similar (Fausch, 1989).

Comparison of pre-and-post-treatment data showed a post-treatment decline in both number of species and number of individuals. Number of fish and number of species may have decreased due to a Great Blue Heron rookery located near the middle station which was empty in fall but home to over 100 nesting pairs of birds in spring. Great Blue Herons are a local fish predator and may have consumed fish from Boulder Creek prior to spring sampling. Instream construction activities required for BMP application may have also adversely affected fish population.

Percent diseased fish may have increased post-treatment because low winter stream flow which consists of over 50 percent WWTP effluent.

Boulder Creek has a high proportion of tolerant fishes which thrive despite poor water and habitat quality. NPS pollution and channelization have reduced the number and size of less adaptable species.

The primary reasons for low biotic integrity are fish habitat degradation caused by channelization, removal of instream woody debris, destruction of riparian vegetation, NPS pollution, and poor water quality.

Channelization results in increased rates of erosion and deposition as the stream attempts to reach a state of equilibrium. Accelerated streambank erosion increases the sediment load and pools become filled with sediment. Habitat alterations such as channelization are the most important factors limiting biotic integrity, while wastewater treatment plant effluents and water quality appear less important (Fausch, 1989).

No significant changes in biotic integrity have occurred immediately post-treatment. Pre-and-post-treatment results serve as an evaluation of the Boulder Creek fish population in 1989-1990 and may be used as baseline data in the evaluation of NPS pollution control project Phase I.

Time is required for the effects of BMP improvements to be realized. Fencing has been installed and recently planted riparian zone vegetation requires time to grow. As time progresses, the quality and health of the Demonstration Reach fish population should improve, IBI scores should increase, and the state aquatic life use classification should be attained.

Historical Comparison

The 1989-1990 fish biodiversity was compared to results from a 1903 survey of Boulder Creek fishes from approximately the same location (Juday, 1904). Of the 21 native species collected in 1903, 60 percent have been extirpated (Table 5). Trout species have disappeared from eastern Boulder Creek. The Iowa darter and plains topminnow, collected in 1989-1990, are uncommon in Colorado (Propst, 1986). Number of introduced species has increased 500 percent, and dominant species have changed from the lake chub Couesius plumbeus and longnose sucker to the sand shiner and Iowa darter.

Phase II Pre-project Data

Pre-project fishery data for City of Boulder NPS pollution control project Phase II, located upstream of Phase I, is contained in appendix 2.

ACKNOWLEDGEMENTS

I would like to thank the people who have assisted with this project. Electrofishing volunteers were Ines Conrad, Jim Emmett, John Grove, Garth Harwood, David Mckee, Mike Rotar, Petra Schultz, and Mike Tomky. John Woodling assisted in fish identification and electrofishing, and Greg Griffin in photography and electrofishing. John Windell was my falculty sponser and helped with every stage of this project. This study was supported by an Undergraduate Research Opportunity Program Grant.

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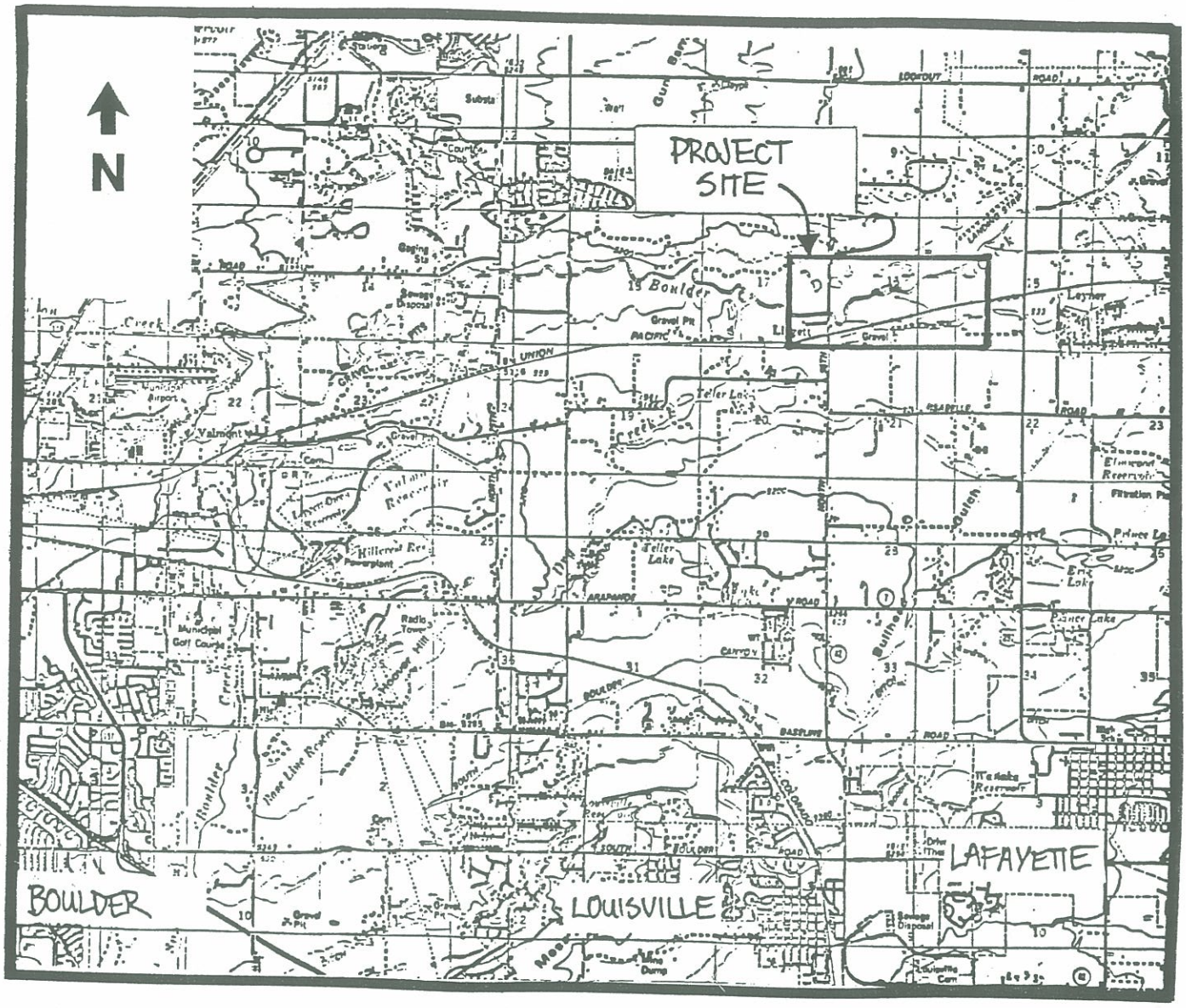


Figure 1. Location of Demonstration Reach on lower Boulder Creek.

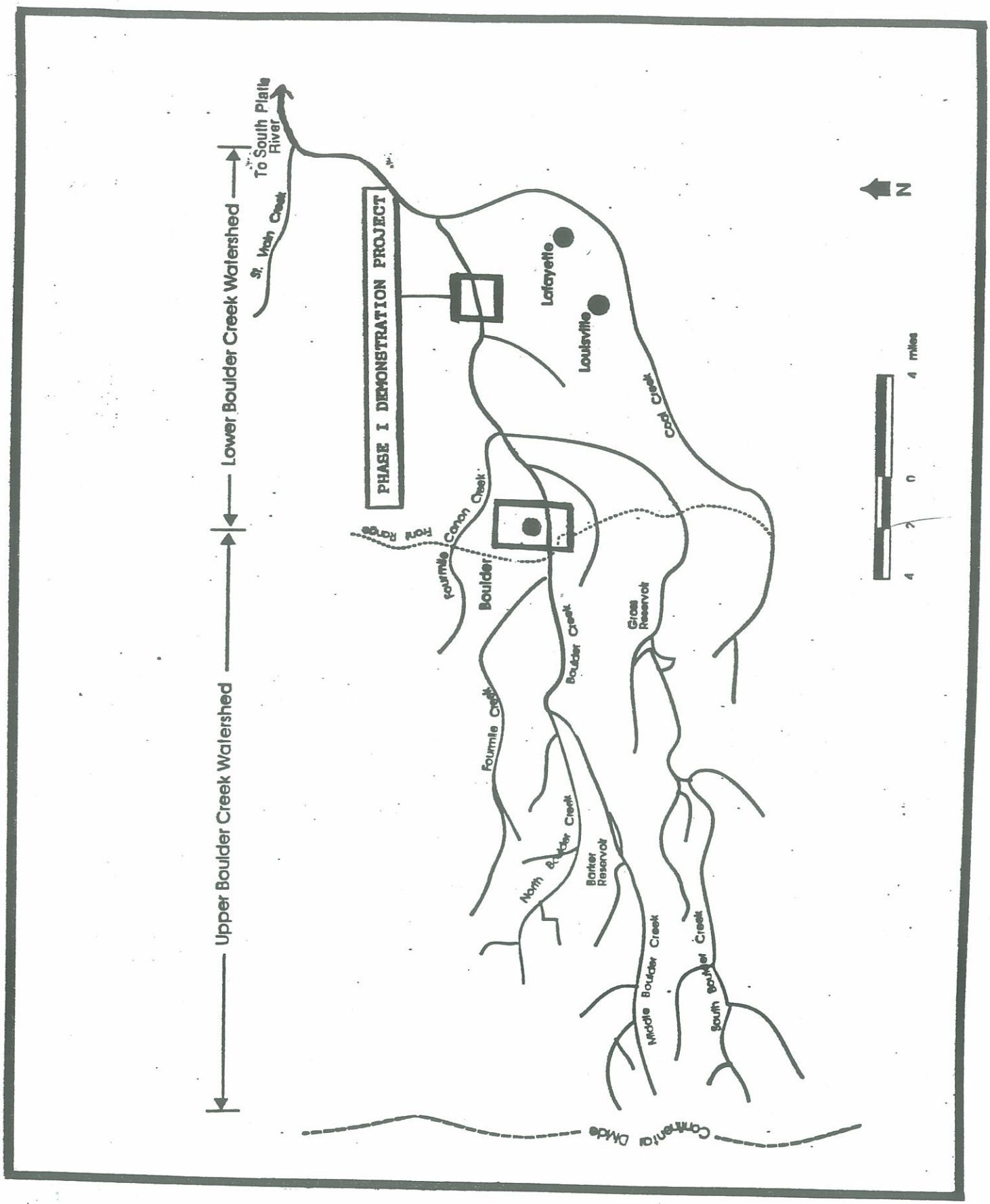


Figure 2. Location of Demonstration Reach within Boulder Creek watershed.

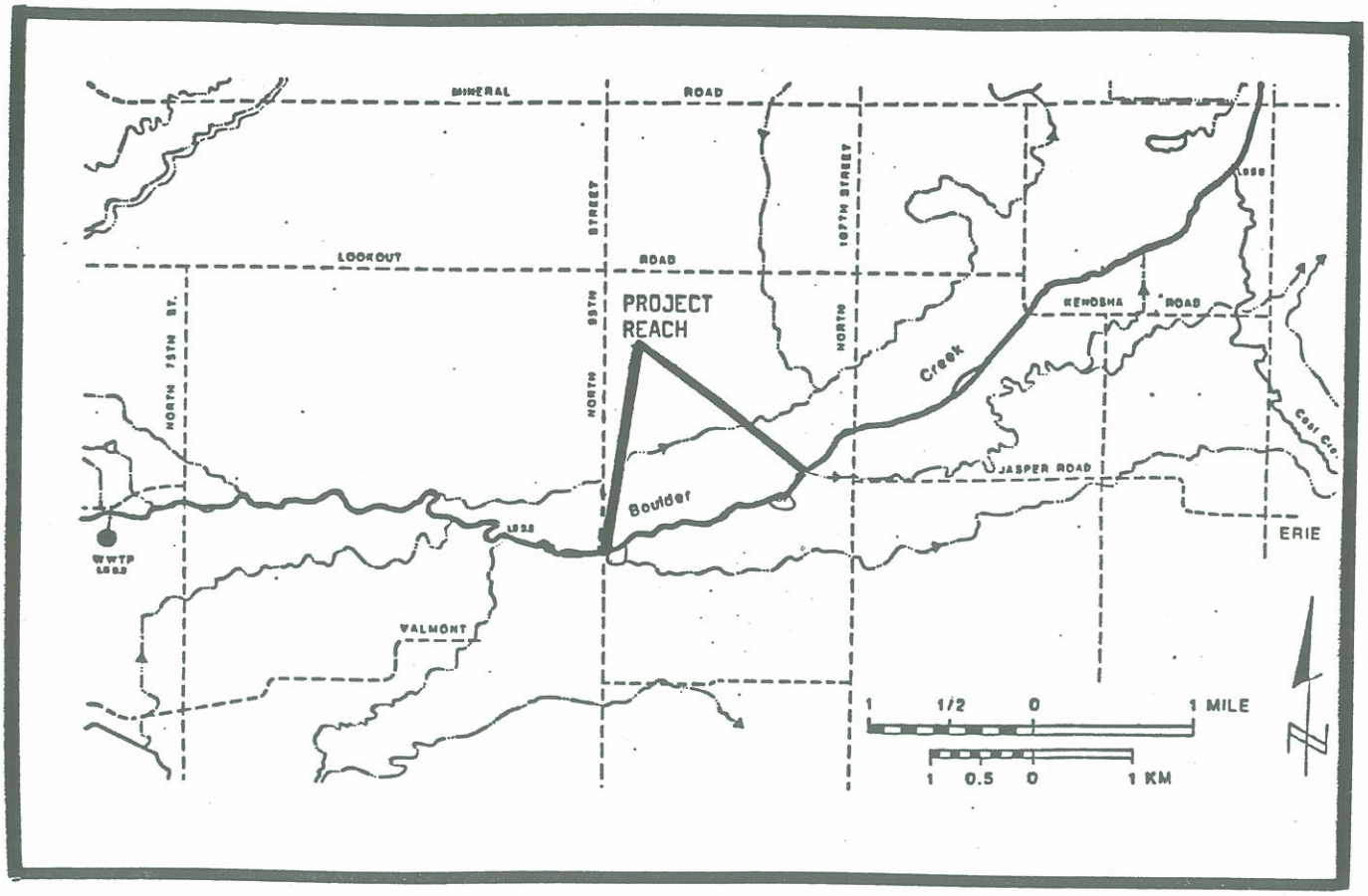


Figure 3. Location of Demonstration Reach on Boulder Valley Farm Property.

METHODS

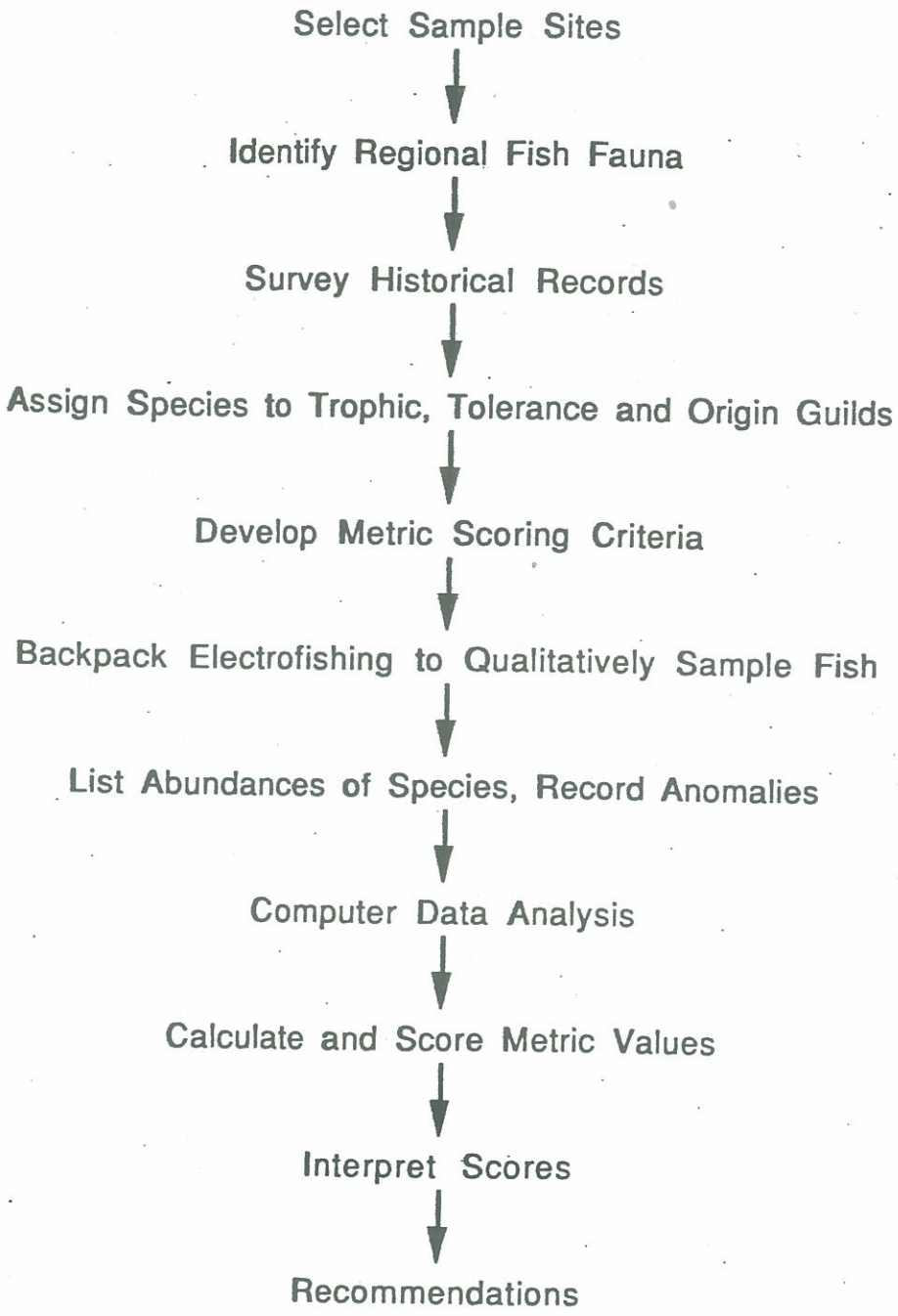


Figure 4. Flow chart of Rapid Bioassessment Protocol V - Fish (Plafkin, 1989)

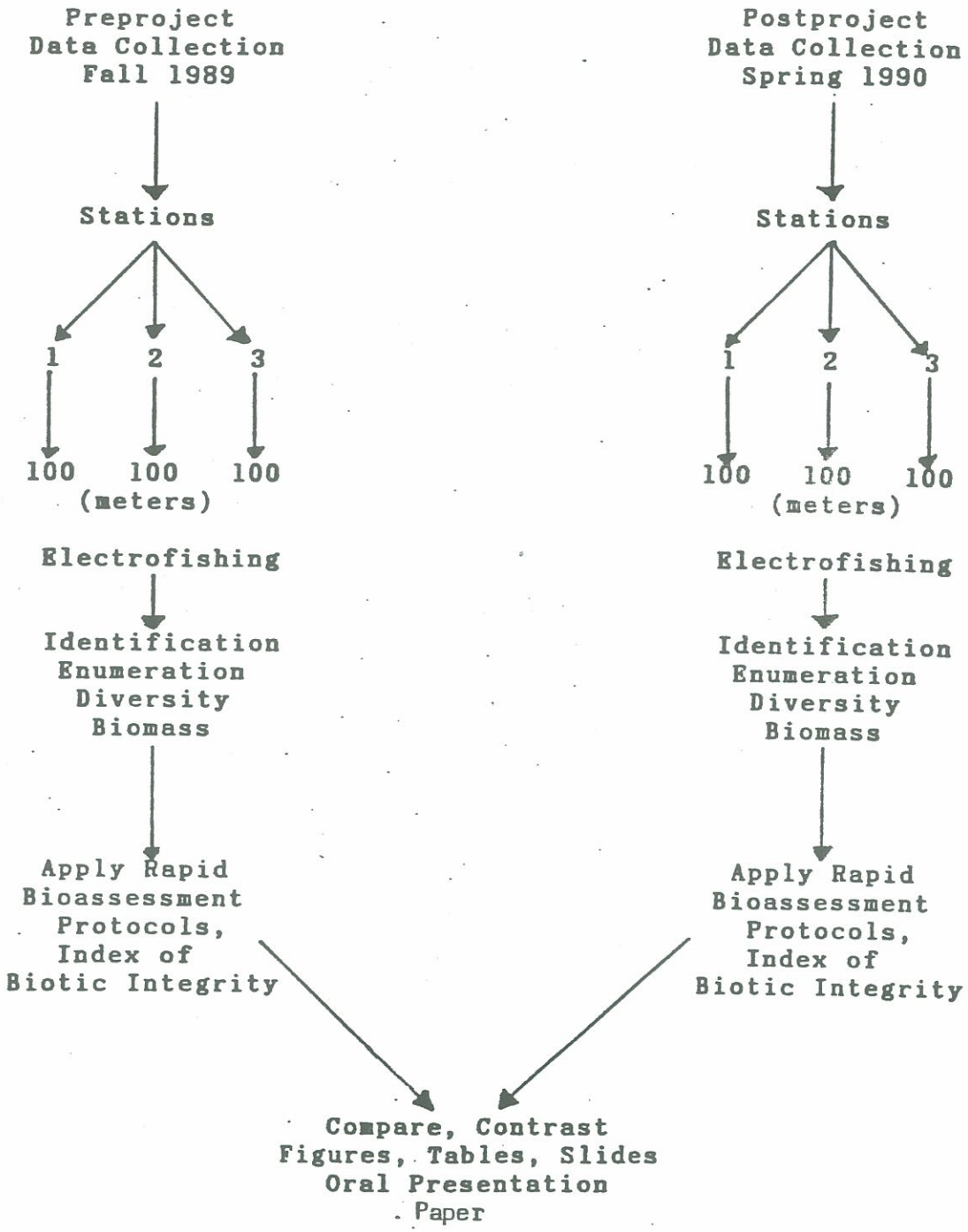


Figure 5. Experimental design for fish fauna study.

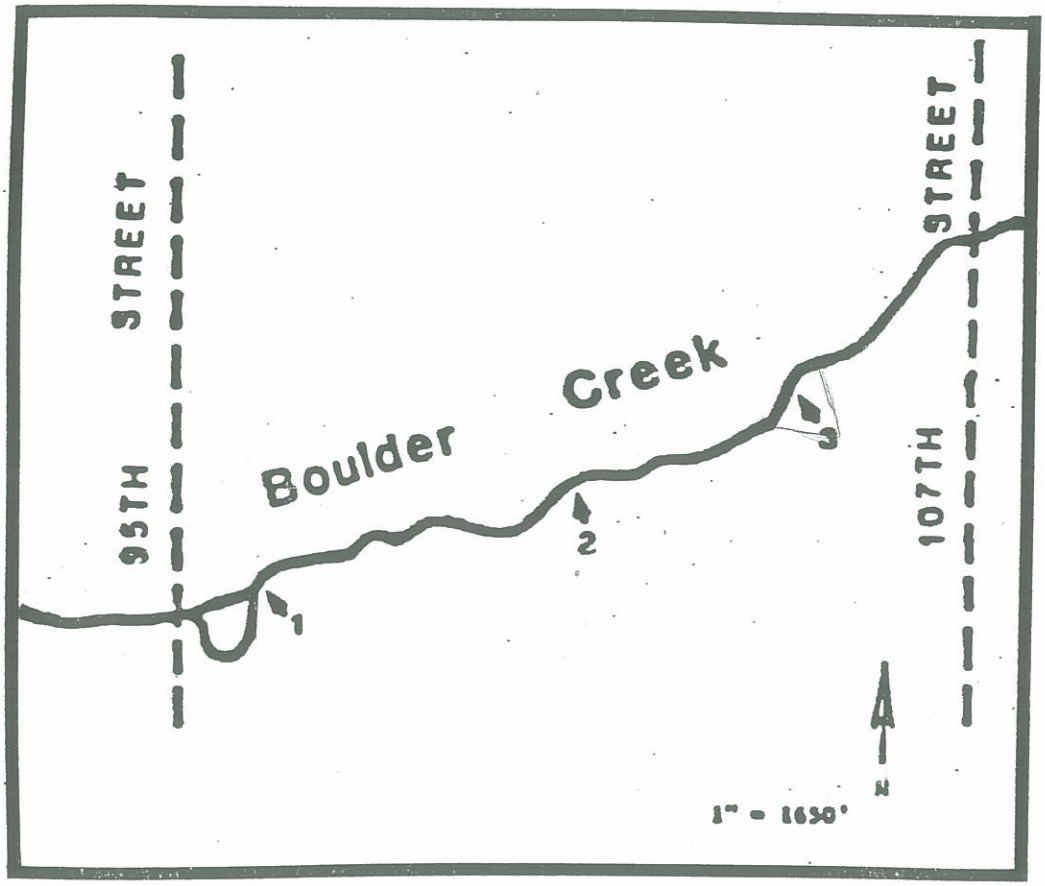
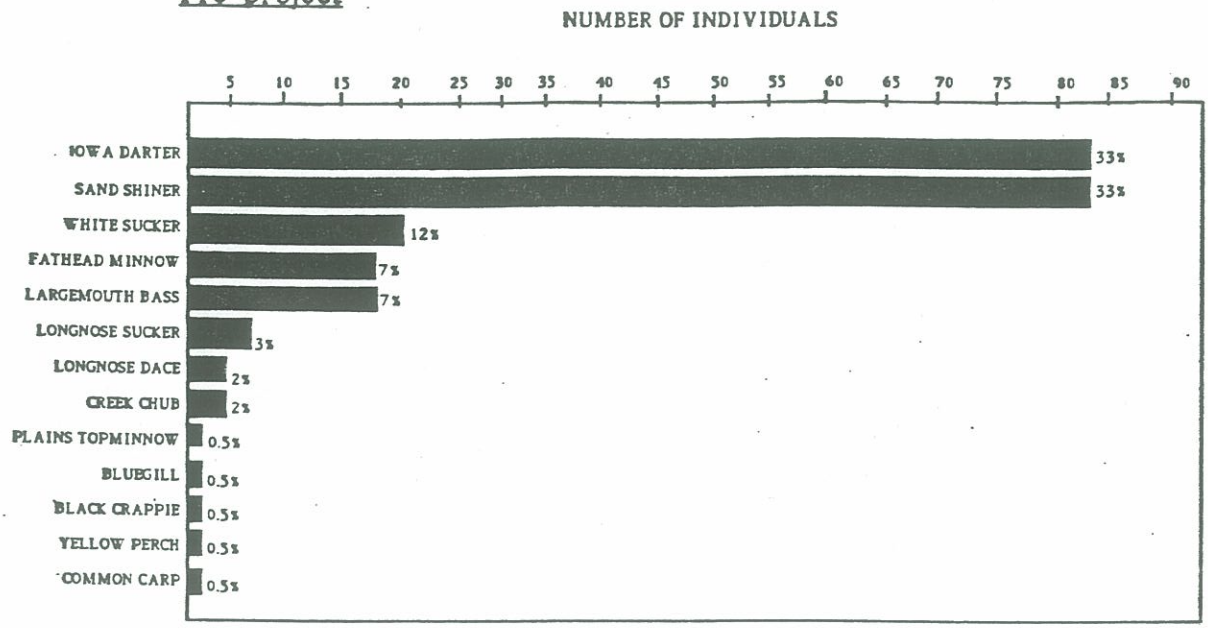


Figure 6. Locations of sample stations.



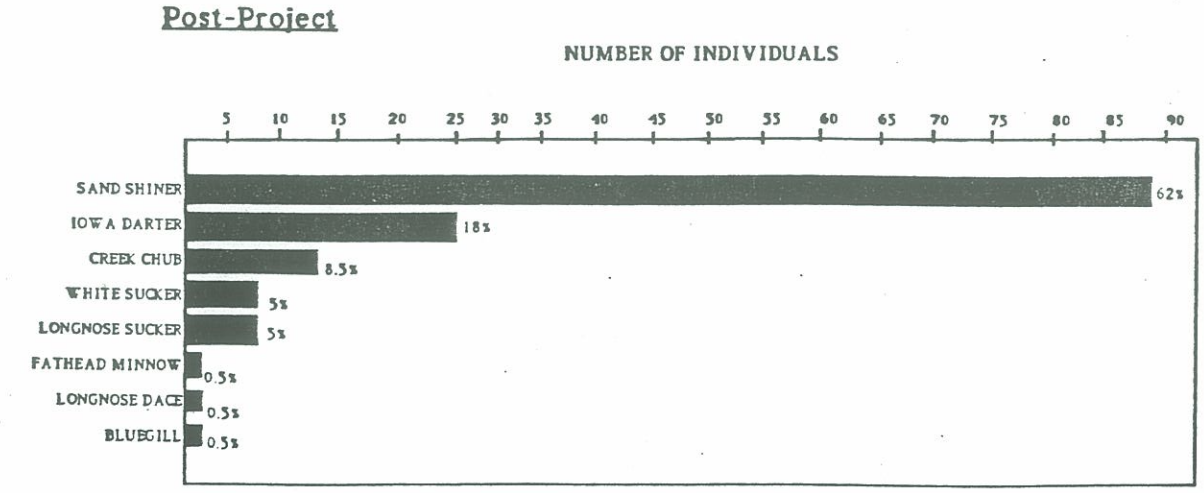


Figure 7. Number of fish collected at three 100m sample stations.

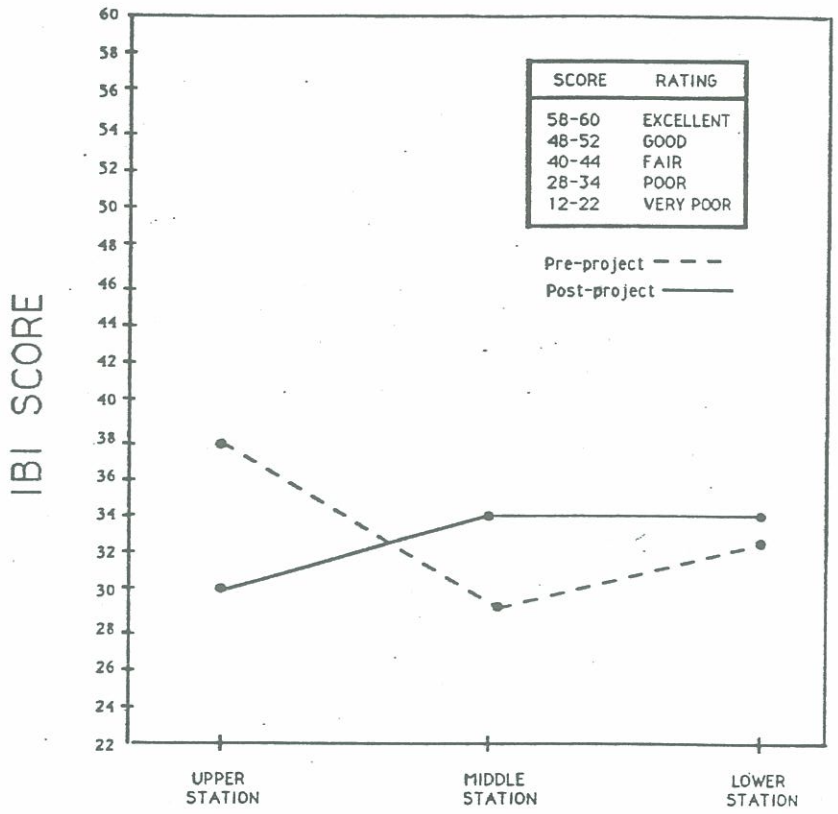


Figure 8. Pre-and-post-project IBI scores.

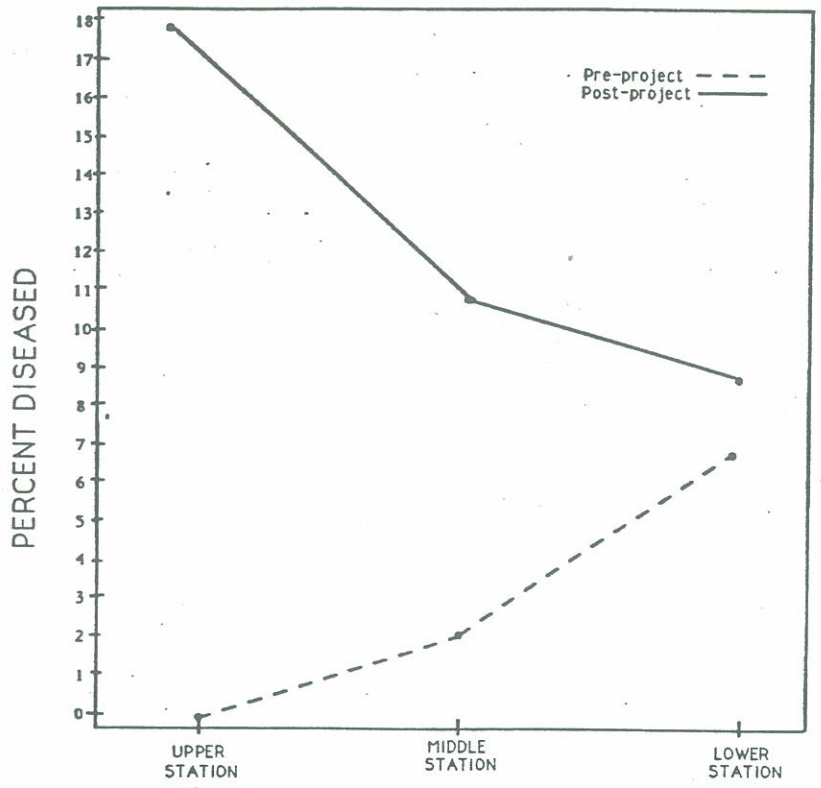
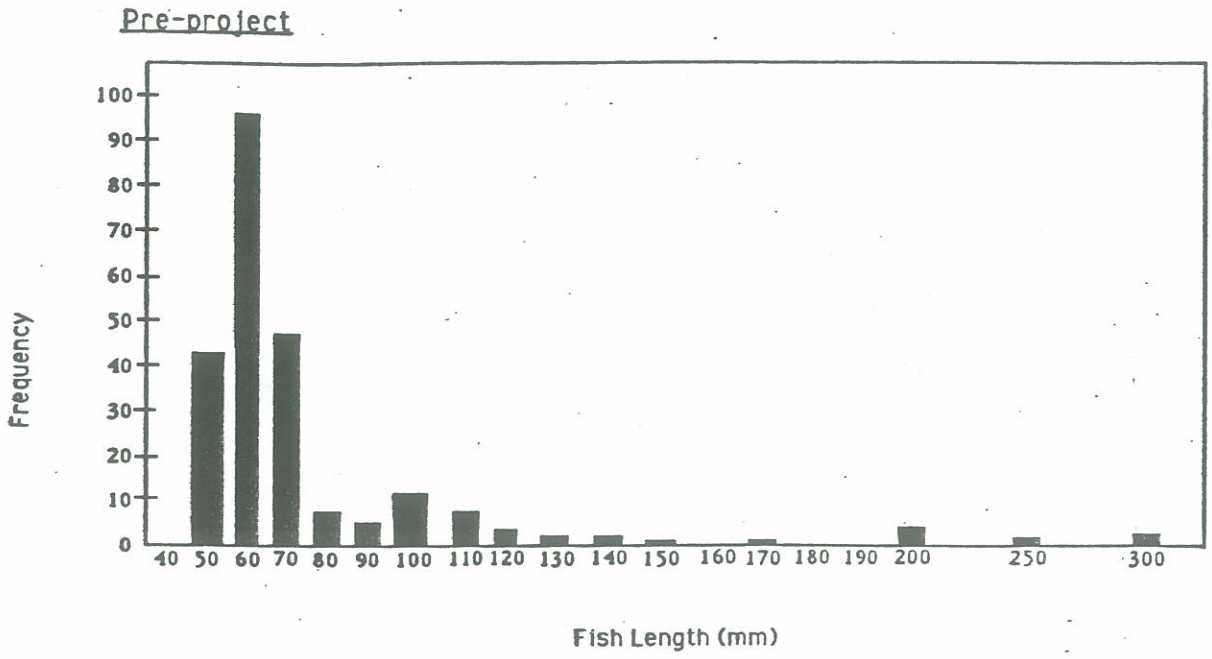


Figure 9. Percent diseased fish.



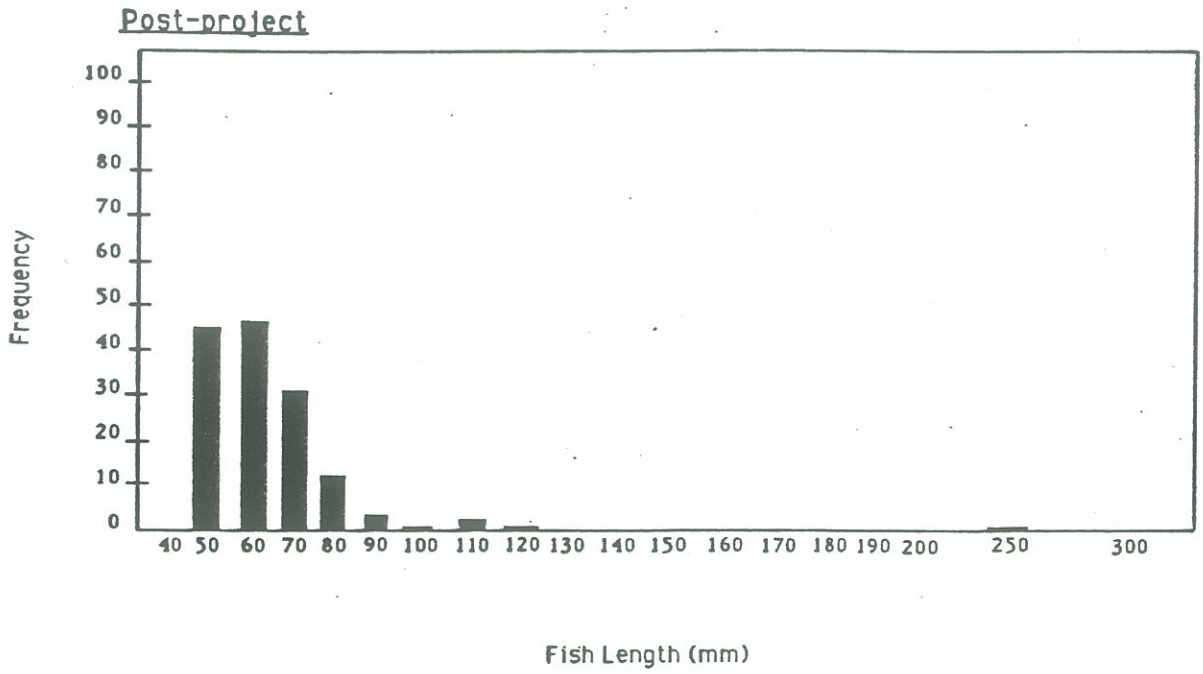


Figure 10. Fish length and frequency distribution.

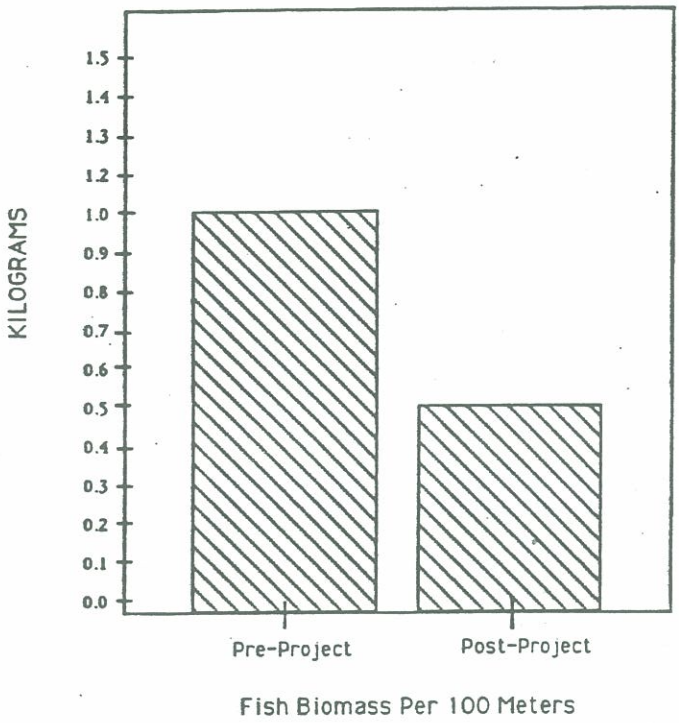


Figure 11. Pre-and-post-project fish biomass.

Table 1.

Metrics[1] used in assessment of fish communities of Boulder Creek Demonstration Reach, Phase I.

METRIC	SCORING 5	3	1
1. Total number of fish species	>6	4 - 6	<4
2. Number and identity of Darter species	>1	1	0
3. Number and identity of Sunfish species[2]	>1	1	0
4. Number and identity of Sucker species	>1	1	0
5. Number and identity of Minnow species	>4	3 - 4	<3
6. Number and identity of intolerant species	>1	1	0
7. Proportion of individuals as White Suckers	10%	10-25%	>25%
8. Proportion of individuals as omnivores	< 20%	20-45%	>45%
9. Proportion of individuals as specialized invertebrate feeders	>45%	20-45%	<20%
10. Number of individuals in sample	> 500	150-500	< 150
11. Proportion of individuals introduced species	< 2%	2-10%	>10%
12. Proportion of individuals with anomalies, fin rot, or disease	< 2%	2-5 %	>5%

[1]As adapted by Fausch (1987) for a fifth order stream in the South Platte River Basin.

[2]Excluding largemouth bass.

Table 2. Ecological characteristics of fish species used to rate metrics.

FAMILY	SPECIES	DESCRIPTIONS
Cyprinidae (minnow)	Notropis stramineus	N,O,T
	Pimephalus promelas	N,O,T
	Rhynichthys cataractae	N,Iv
	Semotilus atromaculatus	N,O
	Cyprinus carpio	I,O,T
Centrarchidae (sunfish)	Micropterus salmoides	I,Iv
	Lepomis machrochirus	I
	Pomoxis nigromaculatus	I,Iv
Catostomidae (sucker)	Catostomus commersoni	N,O,T
	Catostomus catostomus	N,O
Percidae	Etheostoma exile	N,Iv,Int
	Perca flavescens	I
Cyprinidontidae	Fundulus sciadicus	N,Iv

N = Native
I = Introduced
Iv = Specialized invertebrate feeder
O = Omnivore
T = Tolerant
Int = Intolerant

Table 3. Fish species collected during pre-and-post-project sampling.

Family	Common Name	Species	Number of Individuals	Percent Total
PRE-PROJECT: 13 SPECIES				
Cyprinidae	Sand Shiner	Notropis stramineus	83	33.0
	Fathead Minnow	Pimephalus promelas	17	7.0
	Creek Chub	Semotilus atromaculatus	4	2.0
	Longnose Dace	Rhynichthys cataractae	4	2.0
	Common Carp[1]	Cyprinus carpio	1	0.5
Percidae	Iowa Darter	Etheostoma exile	83	33.0
	Yellow Perch[1]	Perca flavescens	1	0.5
Catostomidae	White Sucker	Catostomus commersoni	30	12.0
	Longnose Sucker	Catostomus catostomus	6	3.0
Centrarchidae	Largemouth Bass[1]	Micropterus salmoides	17	7.0
	Black Crappie[1]	Pomoxis nigromaculatus	1	0.5
	Bluegill[1]	Lepomis macrochirus	1	0.5
Cyprinodontidae	Plains Topminnow	Fundulus sciadicus	1	0.5
			249 total	
POST-PROJECT: 8 SPECIES				
Cyprinidae	Sand Shiner	Notropis stramineus	88	62.0
	Creek Chub	Semotilus atromaculatus	12	8.5
	Fathead Minnow	Pimephalus promelas	1	0.5
	Longnose Dace	Rhynichthys cataractae	1	0.5
Percidae	Iowa Darter	Etheostoma exile	25	18.0
Catostomidae	White Sucker	Catostomus commersoni	7	5.0
	Longnose Sucker	Catostomus catostomus	7	5.0
Centrarchidae	Bluegill[1]	Lepomis macrochirus	1	0.5
			142 total	

[1]Introduced Species

Table 4. Proportion of fish collected tolerant to habitat degradation and pollution. (Three 100m sample stations)

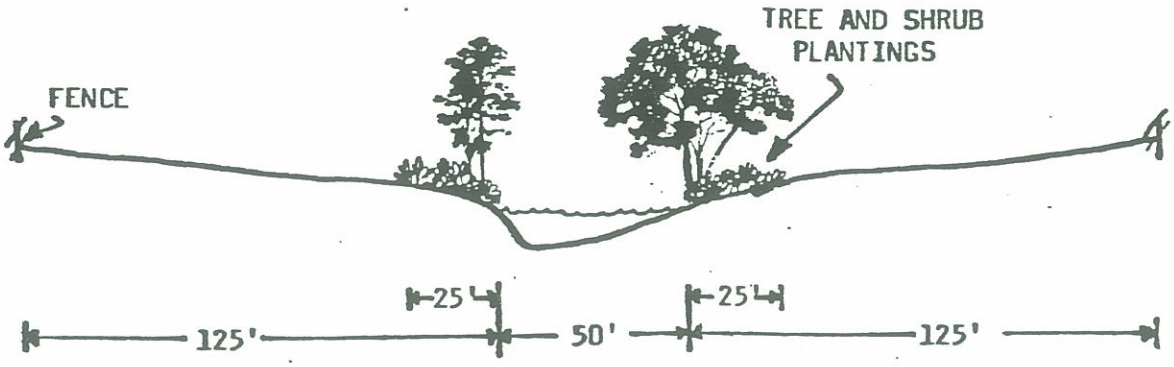
Pollution Tolerance	Number of Species Collected	Number of Individuals Collected	Percent of Individuals Collected
PRE-PROJECT			
Tolerant	4	131	53
Intolerant	1	83	33
Intermediate Tolerance	8	35	14
POST-PROJECT			
Tolerant	3	96	68
Intolerant	1	25	18
Intermediate Tolerance	4	21	14

Table 5. Historic Boulder Creek fish survey results based on collections made during September and October 1903, five miles east of the City of Boulder. 1989-1990 fish survey results are included.

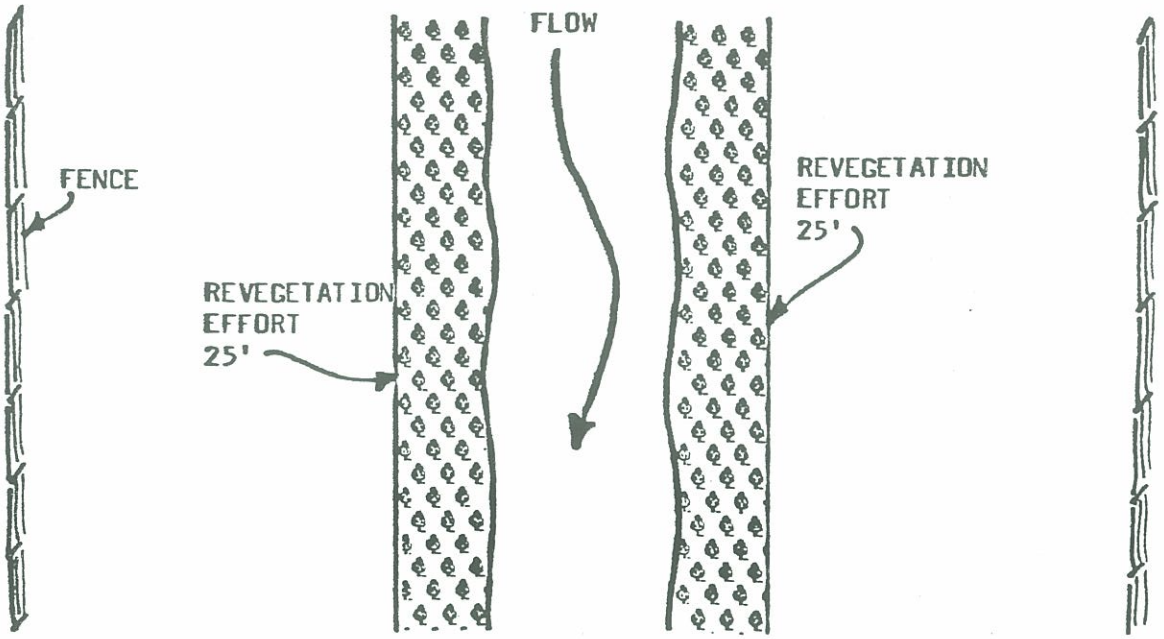
Family	Common Name	Species	Found 1989-1990
Cyprinidae	Fathead Minnow	Pimephalus promelas	Yes
	Creek Chub	Semotilus atromaculatus	Yes
	Longnose Dace	Rhynichthys cataractae	Yes
	Sand Shiner	Notropis stramineus	Yes
	Common Shiner	Notropis cornutus	
	Blacknose Shiner	Notropis heterolepis	
	Bigmouth Shiner	Notropis dorsalis	
	Brassy Minnow	Hybognathus hankisoni	
	Suckermouth Minnow	Phenacobius mirabilis	
	N. Redbelly Dace	Phoxinus eos	
	Hornyhead Chub	Nocomis biguttatus	
	Lake Chub	Couesius plumbeus	
	Stoneroller	Campostoma anomalum	
Percidae	Iowa Darter	Etheostoma exile	Yes
	Johnny Darter	Etheostoma nigrum	
Catostomidae	White Sucker	Catostomus commersoni	Yes
	Longnose Sucker	Catostomus catostomus	Yes
	River Carpsucker	Carpiodes carpio	
Cyprinodontidae	Plains Topminnow	Fundulus sciadicus	Yes
	Plains Killifish	Fundulus zebrinus	
Salmonidae	Greenback Cutthroat	Salmo clarki stomias	
	Brook Trout	Salvelinus fontinalis	

Juday 1905
Cockerell 1908
Ellis 1914

TYPICAL CROSS SECTION

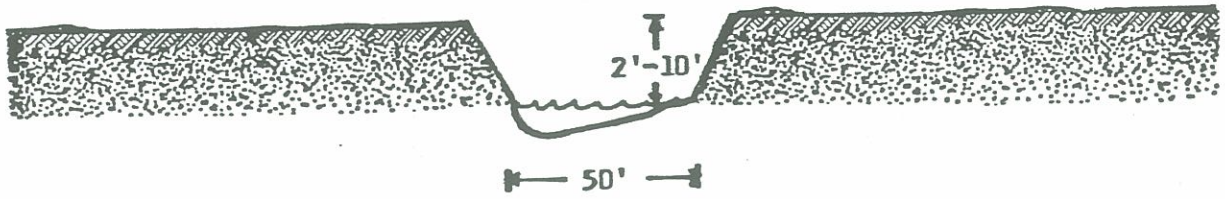


PLAN VIEW

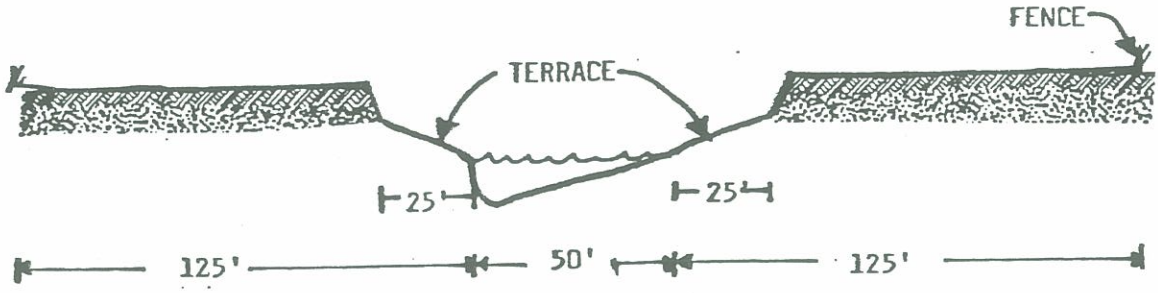


Riparian corridor revegetation, illustrating a 25 foot wide planting zone.

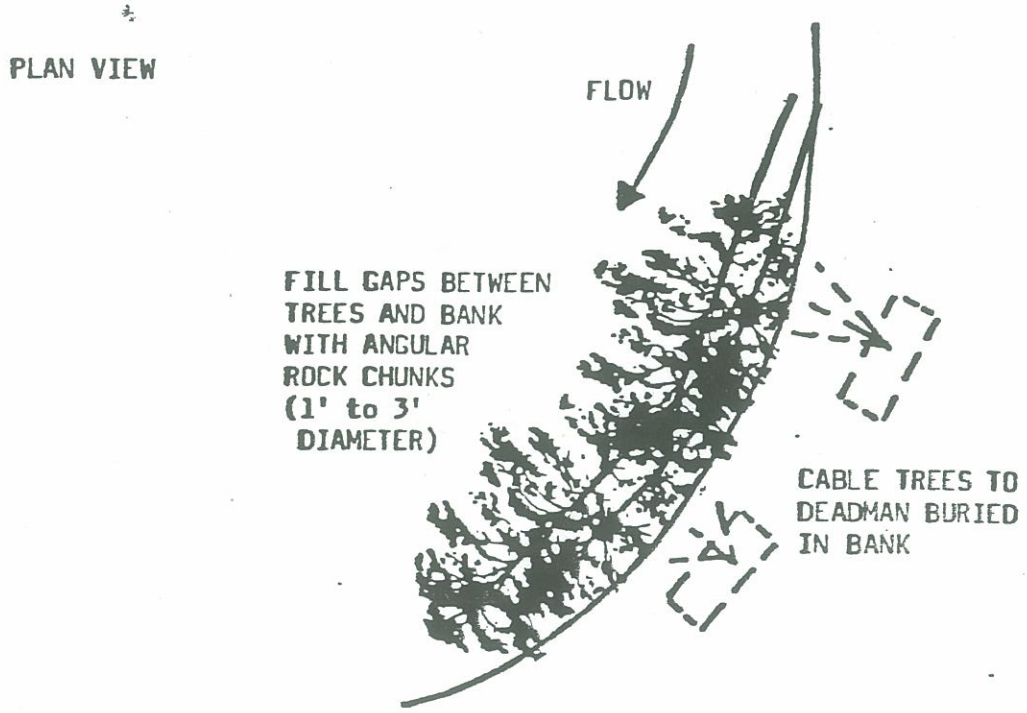
TYPICAL CROSS SECTION
EXISTING CONDITIONS

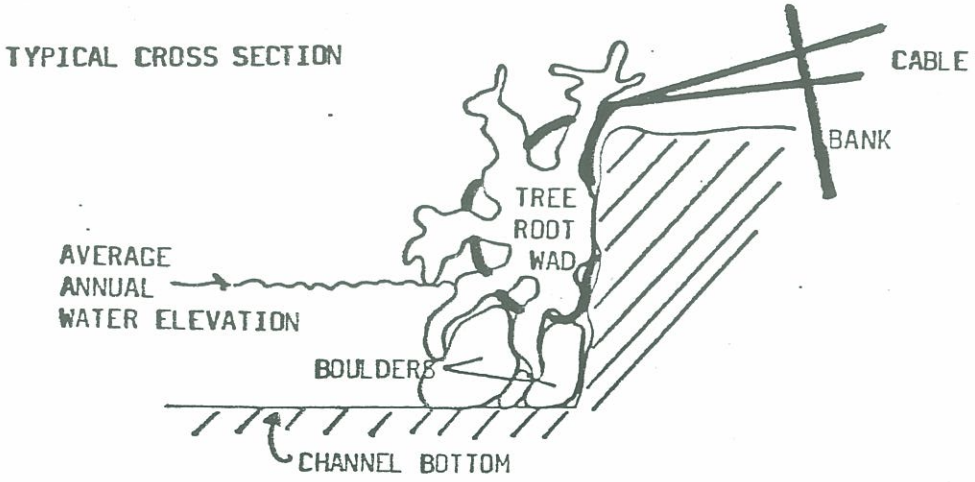


TYPICAL CROSS SECTION
PROPOSED CONDITIONS

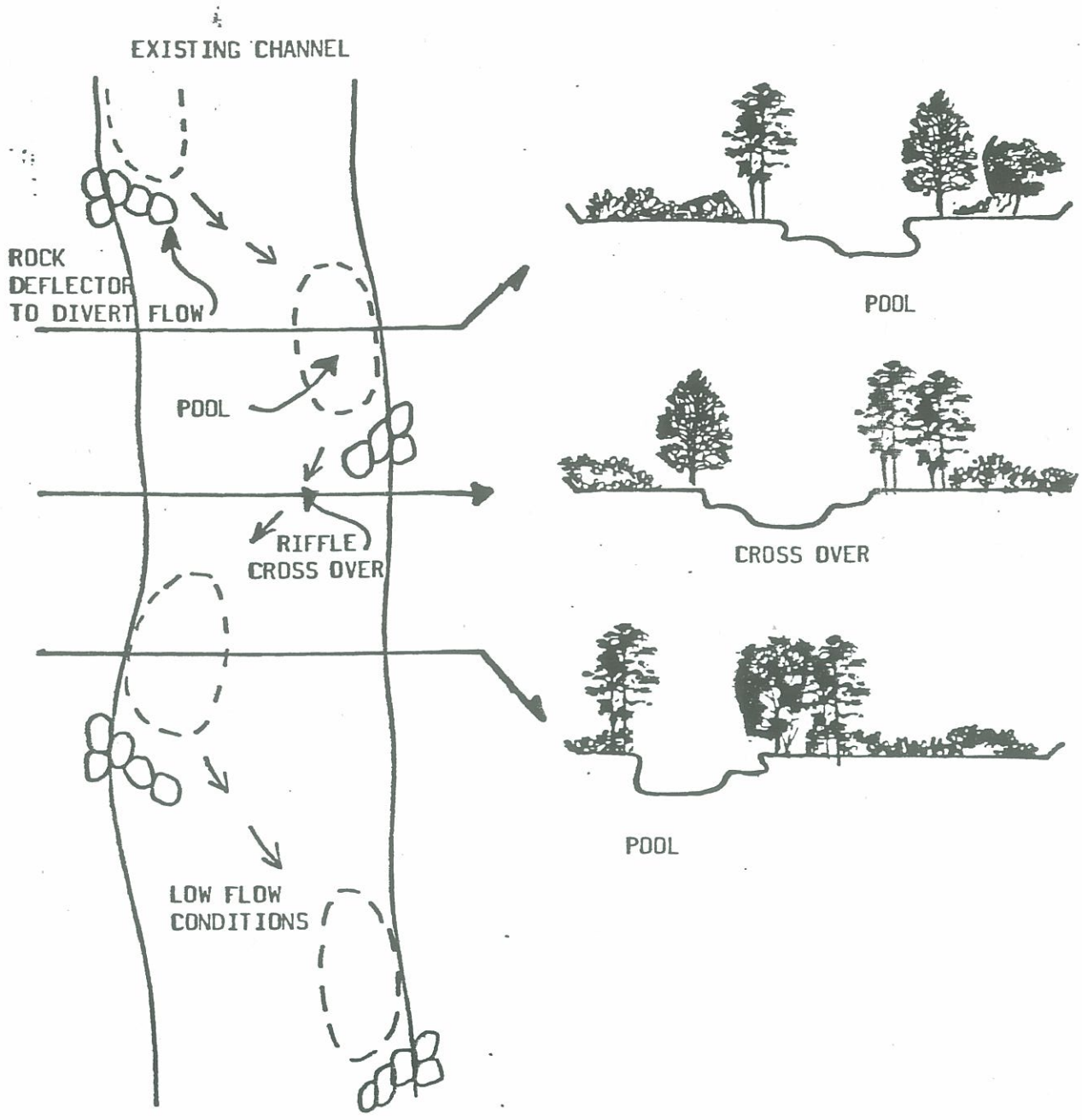


Typical cross sections for streambank terracing (not to scale).



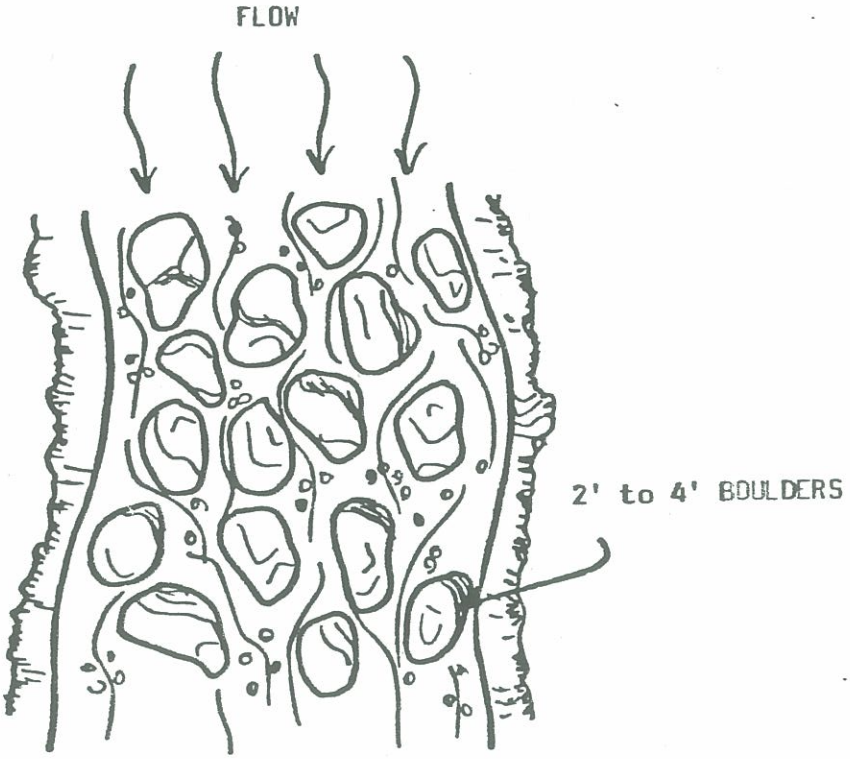


Tree revetment for repair of eroding banks.

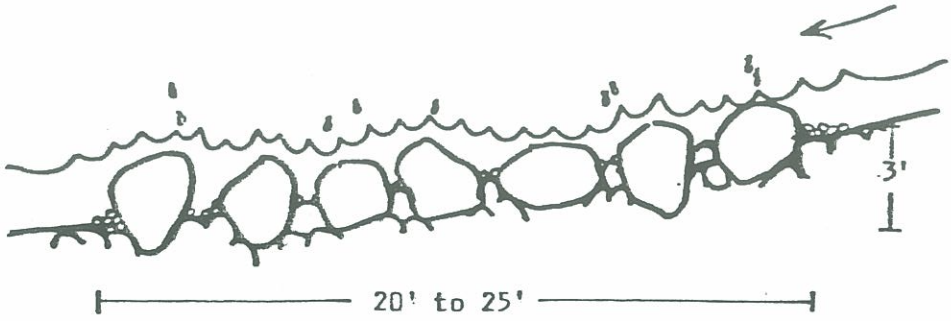


Restoration of a low flow (thalweg) channel to concentrate flows. Rock deflector structures are used to direct flow.

PLAN VIEW



CROSS SECTION VIEW



Typical plan and cross sectional views of reaeration structure (not to scale).

APPENDIX 2

BOULDER CREEK - PHASE II PRE-PROJECT DATA
SPRING, 1990

Upper Station (WQ4)

Common Name	Number of Individuals	Number Diseased
Longnose Sucker	5	3
White Sucker	1	1
Creek Chub	1	1
Bluegill	1	-
	8 total	

IBI Score = 20 (Very Poor)
Diseased = 63 %
Biomass = 0.1 kg per 100 m

Middle Station (WQ5)

Common Name	Number of Individuals	Number Diseased
Creek Chub	16	2
Longnose Sucker	12	5
Sand Shiner	2	-
	30 total	

IBI Score = 22 (Very Poor)
Diseased = 23 %
Biomass = 0.2 kg per 100 m

Lower Station (WQ6)

Common Name	Number of Individuals	Number Diseased
White Sucker	72	15
Longnose Sucker	22	14
Creek Chub	11	3
Longnose Dace	6	1
Bluegill	1	-
Sand Shiner	1	-
	113 total	

IBI Score = 26 (Poor/Very Poor)
Diseased = 29 %
Biomass = 4.o kg per 100 m

Lower station habitat quality was excellent, the best found in either Phase I or II.

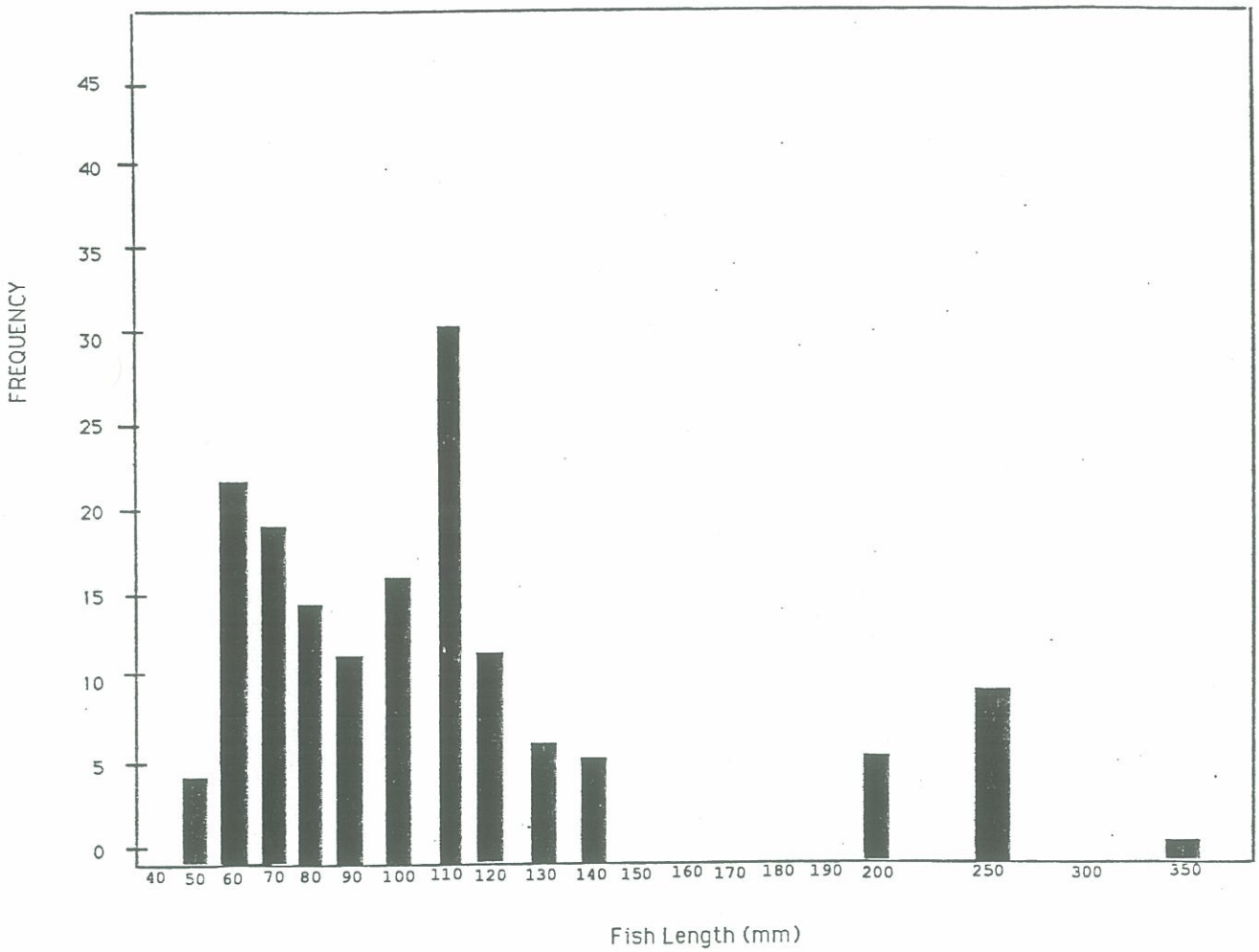
APPENDIX 2

Fish species collected at Phase II in Spring 1990. (Three 100m sample stations)

Family	Common Name	Species	Number of Individuals	Percent of Total %
Cyprinidae	Sand Shiner	Notropis stramineus	3	2.0
	Creek Chub	Semotilus atromaculatus	28	19.0
	Longnose Dace	Rhynichthys cataractae	6	4.0
Catostomidae	White Sucker	Catostomus commersoni	73	48.0
	Longnose Sucker	Catostomus catostomus	39	26.0
Centrarchidae	Bluegill	Lepomis macrochirus	2	1.0
			151 Total	

APPENDIX 2

FISH LENGTH AND FREQUENCY DISTRIBUTION



PHASE II - PRE-PROJECT. SPRING 1990