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MONITORING OF AQUATIC IMPACTS ASSOCIATED WITH
CONSTRUCTION OF THE REDWOOD PARK BYPASS,
U.S. HIGHWAY 101

TEN-YEAR SUMMARY REPORT
1984 - 1994

by

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DECEMBER 1995

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EXECUTIVE SUMMARY

From 1984 to 1992, the physical habitat and biological resources were monitored on creeks within the Prairie Creek and Klamath River basins to evaluate the short-term impacts of construction of a U.S. Highway 101 bypass. We used cross-section and longitudinal stream channel surveys, photographs, benthic substrate/pool habitat mapping and freeze-core sampling of spawning gravels to estimate changes in aquatic habitat features over time. We periodically sampled juvenile salmonids and macroinvertebrates to evaluate changes in aquatic organisms over time.

Bypass construction from 1985 to 1992 did not substantially change stream morphology, pool volumes, or habitat structure in Prairie Creek reaches upstream of May Creek, in Prairie Creek tributaries, or in Klamath River tributaries. It did decrease pool volume and change channel structure immediately below May Creek because of channelization work. This impacted section was small relative to the rest of Prairie Creek. Aquatic macroinvertebrates did not appear to be adversely affected by the bypass.

The results suggested the bypass degraded gravel quality in the subsurface spawning gravels on Prairie Creek, particularly downstream of Boyes Creek. Subsurface fines increased on May Creek, also, but not the other Prairie Creek tributaries. Gravel quality degraded on the monitored Klamath River tributaries (McGarvey, North Fork Ah Pah, and Tarup Creeks), including the control site.

The bypass appeared to be responsible for a large portion of surface silt increases. Silt coverage more than doubled on lower Prairie Creek and its tributaries and tripled on McGarvey Creek and Ah Pah Creeks, ranging from 22% to 92% coverage of the original benthic surface area. The erosion control measures were not very effective for this fine material, especially in 1989 when erosion control structures were not in place on the project during an October storm.

Silt could not be measured effectively in the subsurface gravels using freeze-cores. Its effect on egg survival and juvenile salmonid production was studied in Prairie Creek from WY90 to WY94. The silt appeared to have an adverse effect on salmon egg survival in WY90, the first spawning year following the delivery of tons of sediment into the Prairie Creek watershed. This fine sediment also affected egg survival in later years when worms were abundant in the streambed. } ?

Some of the short-term impacts on Prairie Creek were mitigated in the late 1980's and early 1990's. The Klamath tributary impacts were mitigated during the early stages of the project. However, impacts may continue into the long-term until the fine sediment is removed from the affected streams. Periodic monitoring in the future would help ascertain when the sediment is removed and help determine future mitigation needs.

INTRODUCTION

To alleviate conflicts between visitor and commercial traffic on the portion of U.S. Highway 101 that travels through Redwood National and State Parks, Congress directed in Public Law 95-250 that a bypass to the highway be constructed east of Prairie Creek Redwoods State Park. The environmental impact statement (EIS)(USDOT et al. 1984) for the project predicted construction in the site's highly erodible terrain would deposit sediment into the project area streams, significantly reducing their aquatic productivity. Hence, extensive erosion control measures were designed into the construction phase of the project to reduce aquatic impacts. However, short-term losses of anadromous fishery resources over eight years of construction in the Prairie Creek watershed were still predicted to be high, estimated at 75-100% in May Creek, 25-45% in Boyes Creek, and 13.6% in the mainstem Prairie Creek. These losses were based on an estimate that spawning habitat would be degraded on the following: 2.2 miles of Prairie Creek up to Brown Creek, on the lower 0.8 miles of May Creek, and on the lower 1.4 miles of Boyes Creek. Although Brown Creek was expected to receive some sediment, the predicted amounts were so low that no fish losses were expected for this tributary. Estimates of fish losses in the Klamath River watershed were 60-90% in McGarvey Creek and 40-70% in Ah Pah Creek. These estimates were based on spawning habitat losses on 1.5 miles of the North Fork of Ah Pah Creek and 1 mile on McGarvey Creek.

To mitigate for the predicted fishery losses in the Prairie Creek watershed, a gated culvert was placed in a levee on the Redwood Creek estuary. It was designed to improve water quality and fish access to estuarine habitat in the south slough (USDI 1994). For losses predicted in the Klamath River drainage, funds were provided for fish replacement with hatchery stock and some instream restoration work on Ah Pah Creek.

A monitoring program was implemented to measure the relative success of the erosion control and mitigation efforts. Specifically, monitoring over the project period was needed to (1) determine the amount of sediment reaching the streams, and (2) assess the actual effects of the project on fish populations.

On November 26, 1984, Redwood National Park (RNP) and the California Department of Transportation (CalTrans) entered into an agreement to monitor biological conditions of streams affected by construction of the Redwood Park Bypass, U.S. Highway 101. The agreement stated that CalTrans would fund RNP for five years to conduct studies to evaluate the effectiveness of erosion control measures and determine impacts to anadromous fish habitat. The agreement was extended to June 1994 because the highway project was not completed until October 1992. During the summer from 1984-1985 to 1992, RNP monitored changes in stream channel morphology, gravel quality, benthic habitat features, pool volumes, juvenile salmonid fish, and aquatic macroinvertebrate abundance and diversity. This report presents and discusses those results in detail. Four progress reports were provided to CalTrans showing results for summer monitoring from 1984 to 1990 (RNP 1986, 1989, 1990, and Harrington 1987).

This report additionally discusses data from all monitoring efforts over the construction period including winter monitoring that the California Regional Water Quality Control Board (RWQCB) Cleanup and Abatement Orders No. 86-199 and 89-146 directed be undertaken in the Prairie Creek drainage. Order No. 86-199 was in response to 1986 inspections of the construction site that revealed a potential threat existed of large releases of fine sediment into North Fork Ah Pah and McGarvey Creeks, both tributaries to the Klamath River. The order required suspended sediment sampling, winter monitoring of gravel quality, stream surveys and photographs documenting sediment inputs. Results from this one year of winter monitoring in 1986-87 were presented in RNP (1987a).

On October 20, 1989, 3.73 inches of rainfall fell on the exposed embankment faces of the highway alignment without the proper drainage structures and other erosion control measures in place. The storm washed several hundred cubic yards of fine-grained surface sediment into the Prairie Creek stream system (RNP 1991). The initial monitoring program was designed to document only large cut or fill slope failures, which could send sediment of varying sizes into the stream system. Erosion of fine-grained surface sediment into the streams was not anticipated because straw and drainage structures were expected to be in place when storms arrived. For this reason, cleanup and abatement order No. 89-146 required additional winter monitoring, starting in fall 1989, specifically designed to determine impacts and persistence of the new fine sediment in the streams. Additional miles of stream were impacted that were not anticipated in the EIS: 2 more miles of Prairie Creek up to Ten Tapo Creek, 1 mile of Brown Creek, and 1 mile of Ten Tapo Creek were affected. To offset these new impacts, mitigation with a streamside hatchbox rearing program and an evaluation of its effectiveness was required. Results from those studies for 1989 to 1994 are presented in detail in RNP (1991), Meyer et al. (1994), and Meyer (1994). This report incorporates that information and all bypass monitoring data to finally conclude the short- and long-term effects of the highway bypass construction on aquatic resources.

PROJECT AREA DESCRIPTION

The highway crosses two watersheds: Prairie Creek and Klamath River watersheds. Prairie Creek flows through Redwood National Park and Prairie Creek Redwoods State Park (now called Redwood National and State Parks) near the town of Orick in northern California. Prairie Creek, tributary to the coastal stream Redwood Creek, is 14 miles (22 km) long and drains 14 square miles (35 ^{km}²). Much of the vegetation in the Prairie Creek watershed north of Boyes Creek watershed is old-growth redwood (*Sequoia sempervirens*) forest. Parts of the southern basin have been clear-cut or partially cut from the 1940's to 1970's. Agricultural lands dominate the floodplain of lower Prairie Creek. The geology of the project area is predominantly marine terrace deposits of sands and well rounded gravels (Strand 1963, Janda and Nolan 1975). The creeks support large runs of anadromous coho salmon (*Oncorhynchus kisutch*), steelhead trout (*O. mykiss*), and chinook salmon (*O. tshawytscha*). Cutthroat trout (*O. clarki*) are also common in Prairie Creek and its tributaries. Lamprey, sculpin, suckers, and stickleback are also present (Meyer 1994).

Two tributaries of the Klamath River watershed were affected by the bypass: North Fork Ah Pah Creek and McGarvey Creek. These drainages contain second-growth redwood and Douglas fir (*Pseudotsuga menziesii*) forests cut in the 1950's and early 1960's. The geology is predominantly Franciscan sand stone with some marine terrace deposits (Bailey and Irwin 1964). These tributaries provide spawning habitat for coho salmon and steelhead and cutthroat trout. The fishery and stream conditions in the project area are discussed in detail in the EIS (USDOT et al. 1984).

The Pacific Ocean strongly influences the project area. The area has a coastal mediterranean climate characterized by mild winters and warm, dry summers with frequent fog. The average annual rainfall is 70 inches (178 cm) at Elk Prairie in Prairie Creek Redwoods State Park and occurs mainly between October and June. The average temperature is nearly constant (low of 45 and high of 60 degrees Fahrenheit) throughout the year. Higher elevations east of RNP along the bypass alignment have slightly wider temperature variations and average 5-10 inches (13-25 cm) more precipitation annually.

HIGHWAY PROJECT DESCRIPTION AND LOCATION

The Redwood Park Bypass project is located in coastal northern California between Eureka and Crescent City. The bypass is a 4-lane paved highway that diverges five miles north of Orick and climbs northeast paralleling May Creek. As it approaches the ridge between Prairie Creek and the Klamath River, it veers northwesterly until it returns to the former U.S. Highway 101 route about 0.5 miles north of the Humboldt/Del Norte Country line (Figure 1). The alignment diverges south of May Creek, where a diamond interchange provides access to the southern entrance of Prairie Creek Redwoods State Park. The alignment is approximately 12 miles long, bypassing 9.8 miles of the former route. The initial 4.5 miles of road climb about 1,400 ft at a sustained grade of 5 to 7%. From its high point on the east side of the state park, the road descends at 4 to 6% for about 1.5 miles, follows a slight upgrade for about a mile, and drops about 6% on the final 4.6 miles.

Five streams are crossed by the alignment: McGarvey and Ah Pah Creeks, which are tributaries to the Klamath River; and May, Boyes, Brown and Ten Tapo Creeks, which are tributaries to Prairie Creek. Required earthwork for the project exceeded 10 million cubic yards. a 4-acre disposal site was filled in the headwaters of Ah Pah Creek, and mitigation for the riparian vegetation lost was undertaken (RNP 1993).

The southern interchange required channelization of 400 ft of Prairie Creek, which involved straightening and lining the banks with large boulders. The loss of 0.7 acre of wetlands and 13.6 acres of riparian habitat associated with the project was mitigated (RNP 1988).

Unstable soil conditions (poorly consolidated sands, gravels and clays over fractured shale bedrock) required stripping and placement of drainage blankets to intercept groundwater under all major fills, and it required benching of cut slopes drained by paved or gabion ditches and some horizontal drains to reduce the erosion of accumulated surface runoff. Some sediment retention

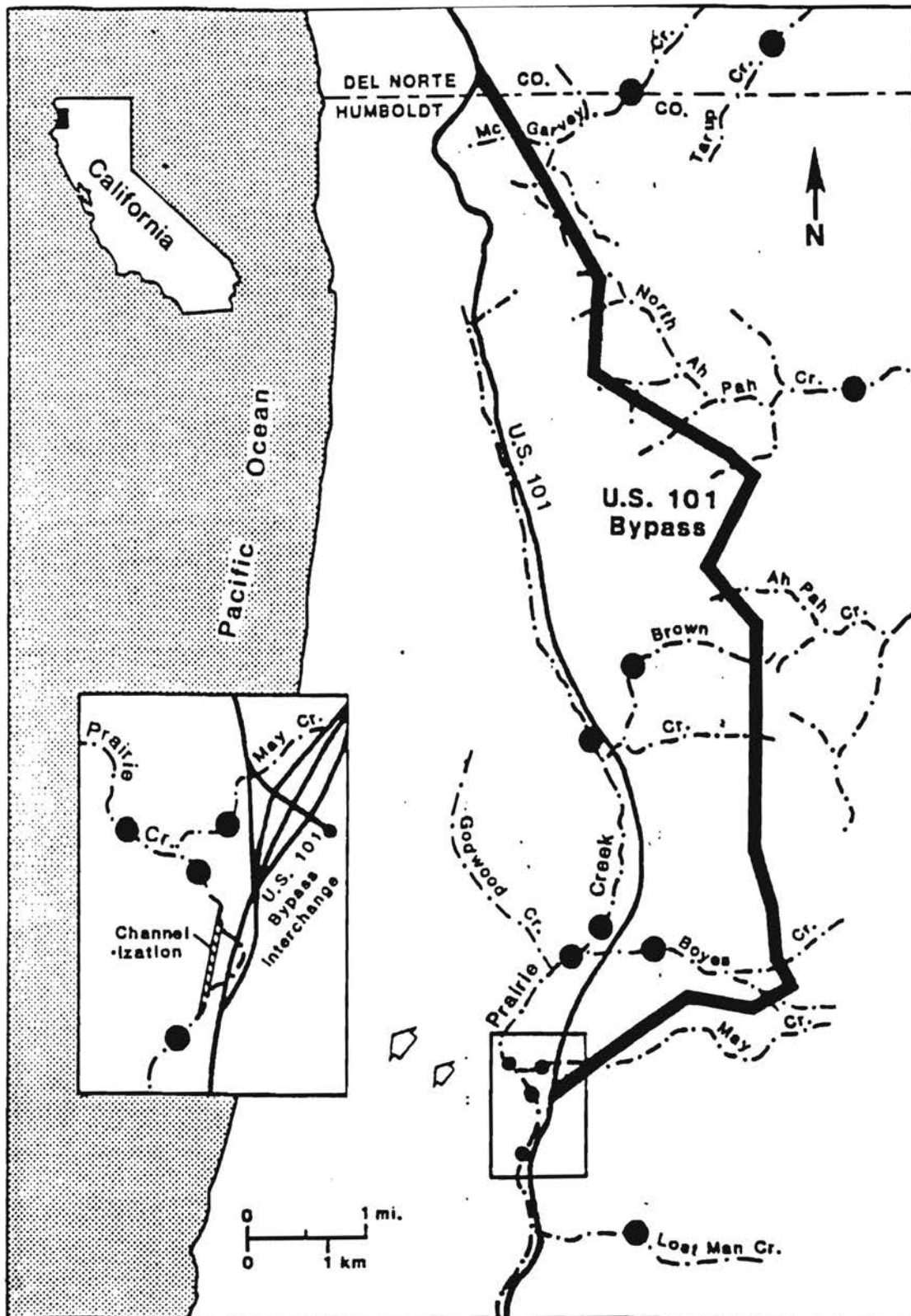


Figure 1. Location map of the Highway 101 bypass and monitoring sites.

ponds were constructed at the bottom of drains. a bridge was constructed across Boyes Creek to avoid unstable soil conditions. To strengthen stability of the slopes, embankments were hydroseeded with fertilizer to speed revegetation by alders.

Construction was discontinued during the winter months, and erosion control structures were placed on the alignment for protection from winter rains. These included straw on exposed slopes, filter fabric fences at the toes of slopes, and temporary drainage structures. In 1989, CalTrans requested extension of the October 15 deadline, the date set by the RWQCB for 100% completion of site winterization. The extension was not granted, but grading work continued without all erosion control structures in place, which led to subsequent stream damage and cleanup and abatement order No.89-146.

Construction was completed in 3 phases: (1) brushing and clearing, (2) grading, and (3) paving. Brushing began in the northern end of the project in 1984 and was completed in 1985. Grading was performed from 1986 to 1991, and paving was completed in 1991 and 1992.

METHODS

SITE SELECTION

We monitored six streams potentially affected by the project plus two unaffected control streams. The following criteria were used for site selection:

1. Downstream of highway construction;
2. Within the proximity of established CalTrans water quality monitoring sites;
3. Within a reach of stream accessible to anadromous fish;
4. Representative of general characteristics for anadromous stream reaches;
5. Relatively accessible.

Thirteen permanent monitoring sites were established to monitor changes in aquatic habitat features. These were divided into the following 3 watershed units, each with a control stream that was not anticipated to be affected by bypass construction:

Prairie Creek Unit

Prairie Creek above Brown Creek (control)(PABR)
Prairie Creek above Boyes Creek (PABY)
Prairie Creek below Boyes Creek (PBBY)
Prairie Creek above May Creek (PAMY)
Prairie Creek below May Creek (PBMY)
Prairie Creek below Channelization (PBCH)

Prairie Creek Tributary Unit

next page

Lost Man Creek (control)(LM)
May Creek (MY)
Boyes Creek (BY)
Brown Creek (BR)

Klamath River Tributary Unit

Tarup Creek (control)(TC)
North Fork Ah Pah Creek (AP)
McGarvey Creek (MG)

Although Brown Creek was not predicted to have fish losses, it was lumped with potentially affected sites in case sediment loads actually received were higher than predicted.

Watershed size, general logging history and general description of surface-rock types for Prairie Creek, May Creek, Boyes Creek, Brown Creek, Lost Man Creek (control stream), McGarvey Creek, North Fork Ah Pah Creek, and Tarup Creek (control stream) are given in Table 1. Figure 1 shows the 13 monitoring sites within the 3 watershed units.

Two monitoring sites were selected to survey juvenile fish. The May Creek monitoring site used for habitat monitoring was selected because the EIS estimated that the number of anadromous fish (coho salmon and steelhead trout) in the creek would be temporarily reduced by as much as 75-100%. The control site was placed on a western tributary to Prairie Creek called Godwood Creek. The site was close to the creek mouth. Godwood Creek has an uncut watershed similar in size to May Creek.

Directions for finding the monitoring sites are in Appendix ~~A~~ ^A.

AQUATIC HABITAT

To accurately estimate fish numbers each year in the project streams would be expensive. Many uncontrollable factors (e.g., sport and commercial fishing, ocean environmental conditions, hatchery management) influence fish numbers, making it difficult to attribute changes to highway construction impacts. Consequently, most effort was concentrated on monitoring the instream habitat (physical, biological, and chemical) which can directly affect fish numbers (Everest et al. 1983). Change in aquatic habitat features was documented by annually monitoring (1) longitudinal and cross sectional profiles, (2) quality and quantity of benthic substrate, woody cover and pools, (3) spawning gravel quality and relating it to salmonid survival, and (4) by photographing the 13 monitoring sites.

Scour and Fill of Streambed

Stream cross-sectional areas usually change and aggrade over a reach with increased sediment

Table 1. Watershed size in acres (hectares in parentheses), general logging history, and general type of surface rock for Prairie Creek, Brown Creek, Boyes Creek, May Creek, Lost Man Creek, McGarvey Creek, North Fork Ah Pah Creek, and Tarup Creek (USDOT et al. 1984, Iwatsubo et al. 1976).

Creek	Acres (hectares)	Logging History	Type of Surface Rock
Prairie	25,000 (10,125)	Old-growth and advanced second-growth redwood.	Marine terrace deposits of sands and well-rounded gravels.
Boyes	950 (385)	Predominantly old-growth redwood. Logging in headwaters, mid-1970's.	Predominantly marine terrace with some exposures of Franciscan sandstone.
May	1,200 (486)	Redwood. Extensively logged in 1940's and 1950's.	Predominantly marine terrace with some exposures of Franciscan sandstone.
Brown	1,200 (486)	Old-growth redwood. No logging.	Predominantly marine terrace with some exposures of Franciscan sandstone.
Lost Man	2,500 (1,013)	Old-growth and advanced second growth redwood.	Predominantly Franciscan sand-stone, some marine terrace deposits.
McGarvey	5,500 (2,228)	Predominantly clear-cut redwood and Douglas-fir.	Predominantly Franciscan sand-stone, some marine terrace deposits.
North Fork, Ah Pah	3,100 (1,256)	Predominantly clear-cut redwood and Douglas-fir.	Predominantly Franciscan sand-stone, some marine terrace deposits.
Tarup	4,400 (1,782)	Predominantly clear-cut redwood and Douglas-fir.	Predominantly Franciscan sand-stone, some marine terrace deposits.

load (Iwatsubo et al. 1976). The sediment fills in pools needed by rearing juvenile salmonids and holding spawners; it silts in gravel in spawning riffles, suffocating eggs or entrapping sac-fry; and it increases gravel mobility even during small winter storms, which can destroy redds (fish gravel nests) (California Department of Water Resources 1982).

Comparison of annual cross section surveys to document changes in streambed elevation required permanent monumented end points of known elevation for each survey. In 1984 and 1985, four to six permanent cross-sections were established at prominent habitat types (e.g., pools, riffles, and glides; see Appendix B) on each of the 13 monitoring sites. Monument pins, five feet (1.5 m) by 0.5 inch (1.3 cm) diameter steel bars, were driven 3.0 to 3.5 feet (0.9-1.1 m) into the top of the bank on each side of the stream. The monument pins were aligned with two reference pins and located by triangulation with a measuring tape, compass and level.

In 1989, the following monuments were re-established due to obliteration by construction activities associated with realignment of Prairie Creek: left monuments, cross-sections #1 and #2 on PBCH; left monuments, cross-sections #2 and #6 on PBMV. Construction work also obliterated cross section #7 on this reach; it was not re-established. The left monument of cross section #5 on PABR had to be re-established the same year after a tree fell on it.

Each year, cross sections were surveyed between two permanent end points of known elevation. When a monument was lost due to construction activities or trees falling, it was re-established using distance and bearing data from known reference points. Monument elevations were checked and corrected for any shifting before surveying.

Only 3 monitoring sites were surveyed in 1984: PAMY, PBMV, and PBCH. From 1985 to 1990, each of the permanent cross-sections on all 13 sites was surveyed except for cross section #2 on PBMV and cross sections #1 and #2 on PBCH in 1988. These cross sections were not surveyed in 1988 due to construction activities associated with the channelization of Prairie Creek, which occurred during the survey period. Surveying was discontinued after 1990 due to the small changes observed year to year. We used an auto level and fiberglass leveling rod for all surveys.

The distance and elevation data obtained during annual surveys were entered into a scour and fill software program which was developed at Redwood National Park. The program calculated the area of scour (degradation), fill (aggradation), and net change in area which occurred between two survey dates. The area of scour and fill was computed for the width of the active channel. The net change in cross-sectional area, mean change in streambed elevation and cumulative change in elevation starting in 1985 were computed for each year. Additionally, the distance and elevation data were plotted for each year to visually assess changes over time.

The net change in streambed cross-sectional area is the difference between fill and scour in the streambed. Mean change in streambed elevation is a normalized value used to compare the relative importance of changes across sections of different widths. This variable was derived by dividing the net change in streambed area by channel width.

The cumulative change in elevation for each water year was derived by adding the successive mean changes in streambed elevation. (a water year is defined as beginning in October and ending in September. For example, 1985 summer data were compared with 1986 summer data to produce the average change in elevation for water year 1986.) The cumulative changes in streambed elevation were graphed for each cross section using GRAPHER (1988), a computer graphics program produced by Golden Software, Inc. To evaluate the amount of change at a cross section, the absolute value of streambed area change was normalized. This value was derived by summing the absolute values of scour and fill at a cross section and dividing it by channel width.

Pool type was assigned to pools transected by cross sections. The pool type codes follow Bisson et al. (1981):

Pool Type #5	Backwater pools associated with boulders
Pool Type #7	Backwater pools associated with large organic debris
Pool Type #8	Trench pools associated with bedrock
Pool Type #10	Lateral scour pools associated with large debris
Pool Type #11	Lateral scour pools associated with rootwads
Pool Type #12	Lateral scour pools associated with bedrock
Pool Type #14	Glides

For the years 1985 to 1990, the middle channel and the left and right banks at each permanent cross section were annually photographed with a 35 mm camera equipped with a 28 mm lens to document visible habitat changes. The developed film produced either color slides or black and white prints. Photographs were compared over the years for each stream, and any noted changes were checked against any cross section profile changes found for that site.

Quality and Quantity of Benthic Substrate

Sedimentation can change the composition of benthic substrate in streams. Gravels can become silted in and finer substrates can become more predominant. Maps of the benthic substrate of the active channel (that portion of the streambed inundated annually with storm runoff) were produced annually in late summer or fall for each monitoring site at low flow conditions, except all sites were not completed for the years 1989 and 1990. Due to the October 1989 sedimentation event interrupting mapping activities, only BY, AP, MG, and TC were mapped in 1989. Only BY was adequately mapped in 1990. Also, the map for PBMV was incomplete in 1988 due to channelization activities in this vicinity.

Dominant surface substrate was visually estimated by trained observers and recorded as one of the following classes:

1. Silt - less than 0.005 in. (0.125 mm)
2. Sand - 0.005 in. (0.125 mm) to 0.08 in. (2 mm)

3. Gravel - 0.08 in. (2 mm) to 1.75 in. (44 mm)
4. Rubble - 1.75 in. (44 mm) to 5.0 in. (128 mm)
5. Cobble - 5.0 in. (128 mm) to 9.8 in. (250 mm)
6. Boulder - > 9.8 in. (250 mm)
7. Bedrock (including hard consolidated clay)
8. Organic (submerged leaf pack or algae)

When present, the second most dominant substrate was also recorded. Logs were mapped. They provide cover for fish and help maintain good habitat structure (e.g., scour pools, trap spawning gravels). Woody debris greater than 3 inches (76 mm) was mapped when it occurred on or over the active channel. Areas where vegetation mostly obscured the ground were classified as vegetation. If the substrate underneath the vegetation was visible and not a soil, its type was recorded also.

To map a site, steel bars were driven into the middle of the streambed at upper and lower ends and at significant bends in the stream reach. a measuring tape was stretched between the bars. a second measuring tape was placed at a 90 degree angle to the longitudinal tape to measure the distance to features including: the active channel bank, prominent morphological features, water lines, woody debris, and change of substrate demarcations. Measurements were made to the nearest 0.1 ft (3.0 cm) and plotted to scale on mylar plastic overlying 0.1 inch (3.0 mm) graph paper to produce the map. We recorded compass bearings of the longitudinal tape and cross sections to aid in relocating the longitudinal tape every year.

Finished maps were prepared by hand on mylar for the years 1985 to 1987. Maps from 1988 to 1992 were digitized into the Geographic Information System (GIS), pcArcInfo. a few maps, which showed little change, were not digitized. These included 1991 PABY, 1991 PABR, and 1991 May Creek. Changes in amounts of substrate types on the surface of the streambed were estimated for the digitized maps using the GIS. Changes were visually estimated for the hand drawn maps.

Pools and Stream Gradient

From 1985 to 1990, longitudinal profiles were surveyed along the thalweg (line connecting points of maximum water depth in a general downstream direction along the channel) of the monitoring site to detect any changes in stream reach gradient and determine residual pool depths. Residual pool depths are equivalent to the maximum depth of a full pool when the stream is not flowing (at 0 cfs).

Steel reinforcement bars were driven into the streambed at upper and lower ends of the monitoring reach. a measuring tape was attached to the bars and laid along the thalweg. An automatic level was set up over one monument. Using a survey rod, elevations were determined along the tape at breaks in slopes, particularly in pools, at edges of pools, and on riffle crests.

Survey heights were tied to the monuments to calculate elevation. Stream reach length and percent gradient were determined for each monitoring site in 1985.

Cross section and longitudinal profiles at permanent points can help detect gains and losses in pools; however we also documented pool volume changes over time for all pools in the reach that had the minimum depth needed to hold an adult fish. This provided more accurate information on the fate of this habitat type over time.

To detect any loss in pool volume in the monitoring sites, pool contours were mapped in one foot (30.5 cm) depth intervals every year from 1985 to 1992. Pool volumes were estimated using residual depths and residual pool contours, which are independent of water depth and are best for comparing pool volumes over time (Lisle 1986). Residual depth is defined as the vertical distance from the bottom of the pool up to the elevation in the water column that matches the ground elevation of the thalweg (lowest point) on the closest downstream riffle crest. The deepest point in the pool was measured, and the thalweg depth at the riffle crest was subtracted to obtain the residual maximum pool depth (H_r). The residual pool contour was obtained by adding the depth of the water at the thalweg of the downstream riffle crest to each integer foot interval on a survey rod to obtain the actual contour depth to be measured that day. The pool contours were mapped on the stream benthic habitat maps using the same method used to map benthic substrate. Residual pool surface area (A_r) was obtained by summing the area within the 1 foot (0.35 m) residual contour on the map using a planimeter or dot grid.

Unfortunately, from 1985 to 1989, the thalweg depth at the riffle crest was mistakenly not accounted for to obtain a residual pool contour. Fortunately, the thalweg depth at the riffle crest was reported and was used to calculate the residual depth. We calculated residual pool volumes for 1985 and 1987 in the following manner:

- (1) Pool surface area was obtained from the 1 foot pool contours on the stream maps. The radius of the pool surface area was estimated using the formula for a circle:

$$R = (a/\pi)^{1/2}$$

where: R = radius of pool
 a = pool surface area

- (2) The radius of the residual pool was determined by using the relationship between two right triangles with a common side:

$$R_r = R(H_r/H)$$

where: R = radius of pool, total depth
 R_r = radius of pool, residual depth
 H = total depth

H_r = residual depth

(3) Residual pool surface area was calculated using the circle formula,

$$A_r = \pi R_r^2$$

where: A_r = residual surface area
 R_r = radius of residual pool

We selected the years 1985, 1987, 1991 and 1992 to compare residual pool volumes. These were calculated using the formula for the volume of a cone,

$$V_r = 1/3 A_r H_r$$

where: V_r = residual pool volume
 A_r = residual surface area of pool
 H_r = residual depth of pool

Spawning Gravel Quality and Predicted Salmonid Egg Survival

Large sediment inputs into streams can decrease the availability of adequate well-oxygenated pore spaces within gravels needed to incubate salmonid eggs. To assess changes in spawning gravel quality resulting from bypass project construction, gravel composition of affected streams was determined annually. In a limited initial effort in 1984, three gravel samples each were taken from riffle crests at AP and MG during low-flow summer conditions. From 1985 to 1992, sampling was increased to six random gravel samples from riffle crests at each of the 13 monitoring sites during low-flow conditions.

a freeze-core bulk sampler, as described by Lotspeich and Reid (1980), was employed. This device froze a 16-inch (40.4 cm) by 5-inch (12.6 cm) diameter column of streambed gravel. a tripod and hoist were used to pull the frozen column from the stream.

The freeze-core sampler was constructed by CalTrans using designs from Everest et al. (1980). After extensive field use, the sampler was modified by replacing structurally weak aluminum elements on the tripod assembly with steel elements.

Each frozen core was placed horizontally on a device consisting of four, 4-inch (10.1 cm) wide subsample trays. The sampler probes were tapped with a hammer to dislodge the gravel into the subsample trays. The subsamples, representing each depth, were stored in porous bags and allowed to air dry for 4 to 5 months.

Subsamples were sieved for approximately 20 minutes using a Ro-tap sieving apparatus. The

following 5 sieve sizes, recommended for fisheries investigations (Platts et al. 1983) were used:

1. less than 0.005 in. (0.125 mm)
2. 0.005 in. (0.125 mm) to 0.04 in. (1.00 mm)
3. 0.04 in. (1.00 mm) to 0.16 in. (4.00 mm)
4. 0.16 in. (4.00 mm) to 1.25 in. (32.00 mm)
5. 1.25 in. (32.00 mm) to 5.00 in. (128.00 mm)

The gravel in each sieve was weighed and the grain-size composition of each subsample was computed.

In 1985, a sixth size fraction, greater than 5.00 inches (128.00 mm), was used. This fraction occurred rarely and produced high variance in those samples where it occurred. In subsequent years, gravel composition was adjusted by removing any gravel greater than 5.00 inches (128.00 mm).

We used three parameters to assess spawning gravel quality: percent fines, defined as particles less than 0.04 inch (1.00 mm) diameter; geometric mean; and the Fredle index. Percent fines and the Fredle index were computed for the total core sample by combining the 4 subsamples. The Fredle index (f), an index of substrate permeability and pore size, was calculated by the following method (Everest et al. 1982):

$$f = d_g / S_o$$

where: d_g = geometric mean = $(d_1^{w_1} \times d_2^{w_2} \times \dots \times d_n^{w_n})$

d_n = mid-point diameter of particles retained on the n th sieve

w_n = decimal fraction by weight of particles retained on the n th sieve

$S_o = (d_{75}/d_{25})^{1/4}$ = sorting coefficient

d_{75} and d_{25} = particle size diameters at which 75% and 25%, respectively, of the sample is finer on a weight basis.

The Fredle index for each sample was used to predict survival-to-emergence for coho salmon and steelhead trout using the relationship (Figure 2) developed by Phillips et al. (1975). The regression equation used was: $Y = 86.48737X + 4.36918$. Since survival rates based on the Fredle index were not available for chinook salmon, a relationship between the embryo survival index and survival-to-emergence for salmon and trout (Figure 3) developed by Shirazi and Seim (1981), was used. Their curve was derived by using the ratio of the geometric mean particle diameter (d_g) and the average egg diameter (d_e) of the species of interest (6.5 mm for chinook salmon). a BASIC language computer program developed for this study was used to generate gravel quality indices using these parameters.

In natural streams, fine sediment is often found in higher amounts deeper in the streambeds. If the bypass is having an effect, we would expect to see an increase in loads of fine sediment in the

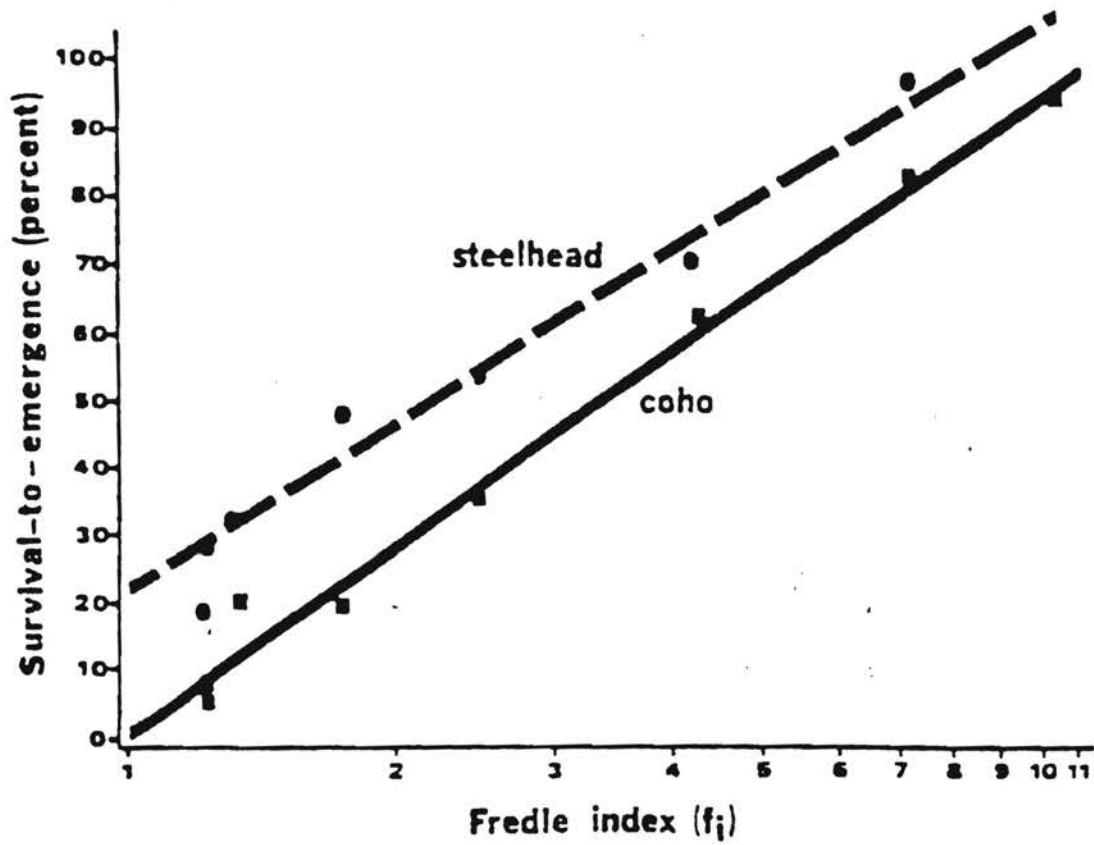


Figure 2. Relationship between Fredle index values and survival-to-emergence for Coho salmon and steelhead trout (Lotspeich and Everest, 1981).

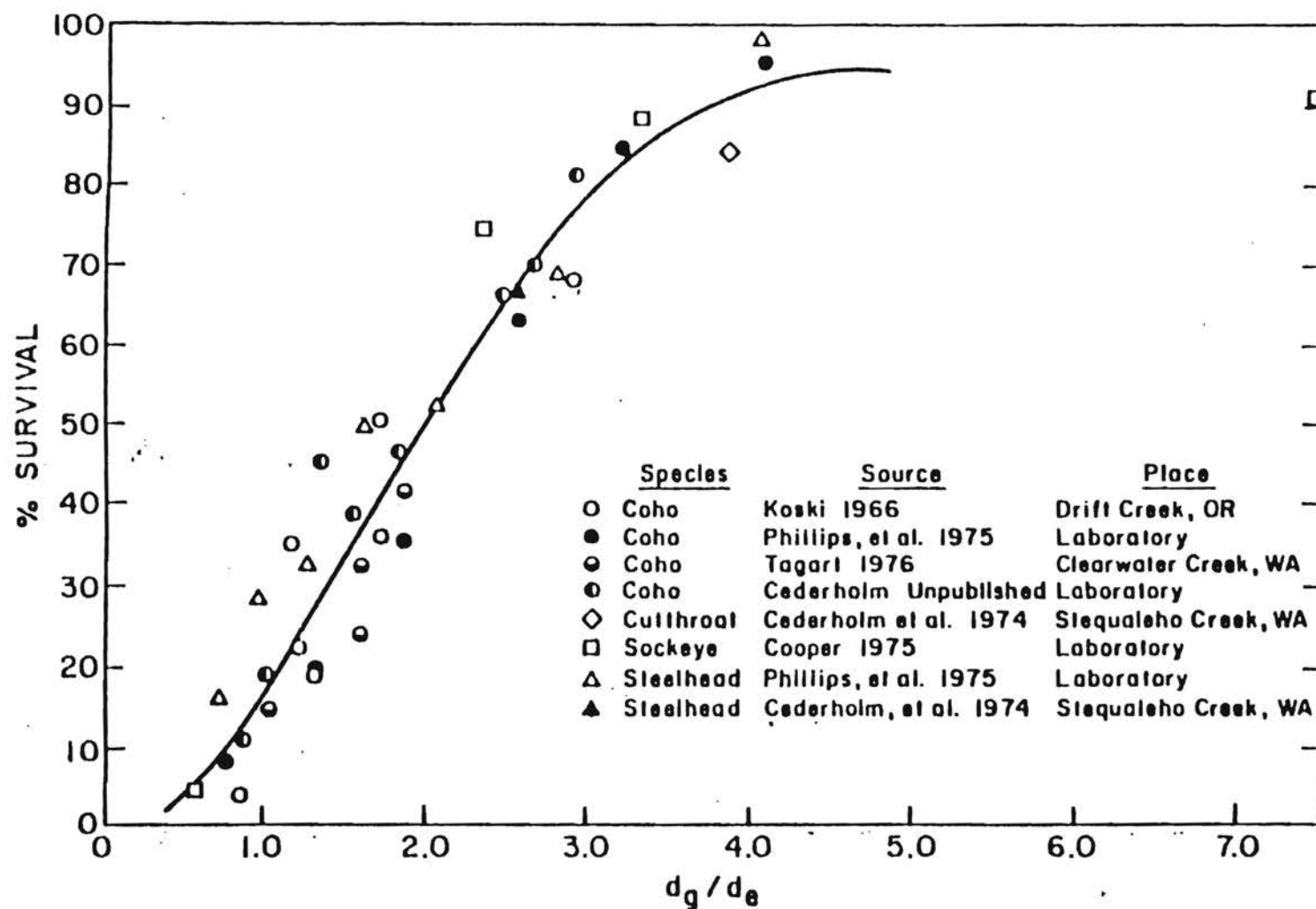


Figure 3. Relationship between the embryo survival index (d_g/d_e) and survival-to-emergence for salmon and trout, where d_g = geometric mean diameter of gravel sample and d_e = egg diameter of fish (Shirazi and Seim, 1981).

upper strata. Stratification of percent fines in the vertical gravel column was tested by conducting a one-way analysis of variance (ANOVA) procedure on the four depth subsamples.

Values from affected streams over the years during construction were visually compared with 1984 pre-construction data and statistically compared from 1985 to 1992. To test for a significant difference ($p < 0.05$) between gravel quality indexes from 1985 to other years and between the affected and control streams, a two-way ANOVA was used. Before using a statistical procedure, the data were tested for meeting the assumptions of ANOVA tests. When data severely violated the assumptions and log or arcsine square-root transformations did not correct the data, then the Kruskal-Wallis nonparametric procedure equivalent to ANOVA was used. Statistical analyses were run on the computer software program, Statistical Package for Social Sciences (SPSS 1988).

AQUATIC LIFE

Juvenile Salmonid Surveys

Juvenile salmonids in May Creek and Godwood Creek were sampled on September 10, 1985, August 22, 1986, September 3, 1987 and October 17, 1991. a 100-ft (30 m) section in May Creek and Godwood Creek was sampled using standard electrofishing techniques (Platts et al. 1983). Numbers of juvenile salmon and trout were estimated using the two-pass removal method (Seber and LeCren 1967). The following parameters were generated for both sites:

1. Total number by species of fish per 100 ft (30.5 m) of linear stream reach.
2. Mean and range of fork length for all species.

Aquatic Macroinvertebrates

Aquatic macroinvertebrates were sampled at the 13 monitoring sites in summer (May, June, or July) and fall (September or October) of 1985, 1987, and 1990. Sampling dates were about a month later in 1985 than in 1987, except for the autumn sampling at the Prairie and Klamath tributary sites, which had less than two weeks difference (Tables 2 and 3). In 1990, sampling dates were closer to 1985's dates in the summer and 1987's dates in the winter. a modified Surber sampler, called a portable macroinvertebrate box sampler (PIBS), with 0.0125 inch (0.32 mm) mesh net was used to sample riffle habitat (Strange 1989). Five samples were collected from riffles at random intervals along a transect laid out on the thalweg. Surface rocks in the PIBS were washed by hand to allow macroinvertebrates to wash into the net. Macroinvertebrates and debris were removed from the net and stored in jars containing 70% ethyl alcohol.

An Ekman dredge was used to sample pool habitat. When possible, three samples were collected at 1.0 ft (0.3 m) random intervals on a transect through the center of all pools. Dredge spoils were rinsed in a bucket with a 0.0125 inch (0.32 mm) mesh bottom, removed and stored in jars containing 70% ethyl alcohol. Pools at BR and TC could not be sampled in 1985 and 1987

Table 2. Sampling dates of benthic macroinvertebrates taken from POOLS found in Highway 101 bypass monitoring sites in the Prairie Creek watershed, Redwood National Park, California, 1985 and 1987.

Name of Creek	1985		1987		1990	
	Summer	Autumn	Summer	Autumn	Summer	Autumn
Ah Pah	7-11-85	10-12-85	5-28-87	10-18-87	7-18-90	09-25-90
McGarvey	7-11-85	10-11-85	5-27-87	10-17-87	-	09-27-90
Tarup	-	-	-	-	7-20-90	09-26-90
Boyes	7-09-85	10-16-85	6-05-87	10-07-87	7-11-90	10-02-90
Brown	-	-	-	-	-	09-28-90
Lost Man	7-08-85	10-16-85	6-05-87	10-05-87	7-17-90	10-09-90
May	7-08-85	10-18-85	6-05-87	10-04-87	-	10-10-90
Pr. Above Boyes	7-03-85	11-01-85	6-11-87	10-02-87	-	10-12-90
Pr. Below Boyes	7-03-85	11-01-85	6-11-87	10-02-87	7-23-90	10-15-90
Pr. Above Brown	7-03-85	11-02-85	6-09-87	10-03-87	-	10-11-90
Pr. Below Channelization	7-02-85	10-28-85	6-09-87	10-03-87	-	10-19-90
Pr. Above May	-	-	6-08-87	09-30-87	7-25-90	10-16-90
Pr. Below May	7-02-85	10-30-85	6-08-87	09-28-87	7-25-90	10-17-90

Table 3. Sampling dates of benthic macroinvertebrates taken from RIFFLES found in Highway 101 bypass monitoring sites in the Prairie Creek watershed, Redwood National Park, California, 1985 and 1987.

Name of Creek	1985		1987		1990	
	Summer	Autumn	Summer	Autumn	Summer	Autumn
Ah Pah	7-11-85	10-12-85	5-28-87	10-18-87	7-18-90	09-25-90
McGarvey	7-11-85	10-11-85	6-17-87	10-17-87	7-19-90	09-27-90
Tarup	-	10-09-85	5-27-87	10-18-87	7-20-90	09-26-90
Boyes	7-09-85	10-16-85	6-05-87	10-07-87	7-11-90	10-02-90
Brown	7-09-85	10-18-85	6-04-87	10-08-87	7-12-90	09-28-90
Lost Man	7-08-85	10-16-85	6-05-87	10-05-87	7-17-90	10-09-90
May	7-08-85	10-18-85	6-05-87	10-04-87	7-11-90	10-10-90
Pr. Above Boyes	7-03-85	11-01-85	6-11-87	10-02-87	7-24-90	10-12-90
Pr. Below Boyes	7-03-85	11-01-85	6-11-87	10-02-87	7-23-90	10-15-90
Pr. Above Brown	7-03-85	11-02-85	6-09-87	10-03-87	7-23-90	10-11-90
Pr. Below Channelization	7-02-85	10-28-85	6-09-87	10-03-87	7-26-90	10-19-90
Pr. Above May	7-02-85	10-30-85	6-08-87	09-30-87	7-25-90	10-16-90
Pr. Below May	7-02-85	10-30-85	6-08-87	09-28-87	7-25-90	10-17-90

because the bottom substrate was too coarse. Pools were sampled at the PAMY site only in 1987 and 1990.

To characterize microhabitat conditions and determine variables affecting the number of individuals and number of taxa found at each site, we estimated depth, velocity, temperature, substrate, microprofile, and canopy cover at each sample site along the riffles. In summer 1985, however, only depth and velocity were estimated. We used a meter stick to measure depth, pygmy meter for velocity, thermometer for temperature, and spherical densiometer, using the average of estimates facing the four cardinal directions, for canopy cover. Substrate was measured along a scale of coarseness as follows:

Dominant Substrate Type

- 1 = clay
- 2 = silt
- 3 = sand
- 4 = gravel
- 5 = rubble
- 6 = cobble
- 7 = boulder
- 8 = bedrock

Second Most Dominant Substrate Type

Of two most dominant substrates, the percent coverage of subdominant rock size if subdominant is smaller than the dominant type. If it is larger, the percent coverage of the dominant substrate was recorded. The percent was recorded as a decimal point added to the number for the dominant substrate type.

Example: 5.4 = rubble dominates (60%) with 40% gravel or smaller particles.
5.6 = 60% of the surface is rubble, and 40% is either cobble or larger particles.

Size classes were the same as reported previously under benthic substrate classifications. Clay particles were < 0.002 mm.

Microprofiles were sampled with a 20 x 20 inch square frame containing 100 sliding needles. The 100 point count frame was placed on the gravel, and the pins slid up or down depending on whether they landed in a crevice or on top of a rock. Height of each pin was measured from the horizontal board holding the needles in place to determine the microelevations for the square microprofile.

Except for microprofiles, the average microhabitat conditions were calculated for all Prairie Creek sites; other sites and all microprofile data have yet to be analyzed. Single and multiple regressions were run to determine which variables contributed most toward predicting number of macroinvertebrate individuals or taxa.

Macroinvertebrates from all samples were separated from organic debris in the laboratory under a dissecting microscope. Macroinvertebrates from some pool samples were separated from fine sediment using a concentrated sugar solution. All macroinvertebrates collected in 1985 and 1987

were identified to the lowest possible taxon using keys of Edmunds et al. (1976), Merritt and Cummins (1984), Pennak (1978), Usinger (1956), and Wiggins (1977). Body lengths (head to tip of abdomen) of macroinvertebrates greater than 0.04 inches (1.0 mm) were measured to the nearest 0.04 inch (1.0 mm) to estimate biomass using empirically derived length-mass relationships or published length-mass relationships (Smock 1980). Due to funding limitations, macroinvertebrates collected in 1990 were identified to order level only, and biomass was not estimated.

Macroinvertebrate taxa for samples taken in 1985 and 1987 were enumerated and classified according to functional groups described by Merritt and Cummins (1984):

1. Predators - carnivores that feed by engulfing whole or parts of living animal tissue.
2. Grazers - omnivores that feed by scraping periphyton, attached algae and associated material from mineral and organic surfaces.
3. Shredders - herbivores and detritivores that process coarse particulate organic matter (CPOM) as a food source.
4. Collectors - detritivores that feed by filtering suspended material or by gathering depositional material primarily consisting of decomposing fine particulate organic matter (FPOM).

a diversity index was calculated for each sample using the equation given by Wilhm and Dorris (1968):

$$\text{diversity index} = - \sum_{i=1}^S (n_i/n) \log_2 (n_i/n)$$

where: n = the total number of individuals of all taxa
 n_i = the number of individuals in the i^{th} taxon
 S = the total number of taxa in the community

Using a BASIC macroinvertebrate description program developed at Redwood National Park, the following parameters were generated for sample dates at the 13 monitoring sites:

1. Cumulative species list with mean number of individuals.
2. Mean number of taxa.
3. Mean number of individuals.
4. Mean biomass.
5. Percent functional group composition by individual.
6. Percent functional group composition by biomass.

In 1985, the chironomids were keyed only to the family taxon. Keying chironomids to the subfamily level is very time consuming, requiring mounting of heads on slides and examining them under a microscope. In 1987, a student keyed chironomids to subfamily, but in order to compare

data between years, they were lumped together as chironomids. Chironomids were classified as "collectors". Due to sorting errors in the laboratory, 1985 chironomid samples for LM and PBBY were lost, making data for these sites not comparable between 1985 and 1987. Unfortunately, LM was a control site, and hence could not be used to compare changes in 1985. PABR was substituted as the control site for the Prairie Creek Tributary Unit.

Using SPSS/PC+ V2.0 (1988) program, we performed one and two-way ANOVAs comparing the biomass, number of individuals, number of taxa, and diversity index parameters between 1985 and 1987 for each stream and between the affected and control streams. Diversity and number of taxa were calculated on the order level for 1990 data and for some Prairie, Brown, and Boyes Creek 1985 and 1987 data. This allowed us to compare changes at select sites from 1985 to 1990.

After the two-way ANOVA's were completed, a Scheffe's post-hoc comparison test was performed to test whether the change over time and between the affected and control site was significant. Sites where a variable significantly decreased ($P < 0.05$) in the affected site but did not similarly decrease in the control site were evaluated to determine if the decrease was from bypass activities. Such a non-parallel response between the affected and control site was considered significant when the interaction significance level was < 0.05 .

RESULTS AND DISCUSSION

Throughout this report, English and/or metric units are used, depending on instrumentation used to measure parameters. For ease of reading tables and results, results are not always presented in both units.

AQUATIC HABITAT

Scour and Fill in Streambed

Cross sections were surveyed only from 1985 to 1990. Amount of aggradation, degradation, net change in area and the average change in elevation are presented for all cross sections in Appendix B. Percentage of cross sections experiencing aggradation and degradation are presented in Table 4. Cumulative changes in streambed elevation and absolute change values for all cross sections surveyed are presented in Table 5.

Graphs of the stream cross section profiles surveyed in 1985 and 1990 are presented with graphs and tables of cumulative change in elevation for each of the five survey years in Appendix B. Of the 330 profiles developed over the 5 years, 13 profiles were unreliable due to monument loss or survey error and are not reported. Data and graphs for all 330 profiles are on diskettes filed in the Redwood National Park Arcata office.

PAMY, PBMV, and PBCH were surveyed in 1984, also. Changes at these sites from 1984 to

Table 4. Percentage of cross sections in study reaches which experienced aggradation (+) and degradation (-) during water years (WY) 1986 to 1990 and cumulatively for these years.

NAME OF UNIT	1985-1986		1986-1987		1987-1988		1988-1989		1989-1990		CUMULATIVE (1985-1990)	
Control Stream												
Affected streams in unit	+	-	+	-	+	-	+	-	+	-	+	-
	(n)	(n)	(n)	(n)	(n)	(n)	(n)	(n)	(n)	(n)	(n)	(n)
PRAIRIE CREEK UNIT												
Prairie Above Brown (control)	75 (3)	25 (1)	25 (1)	75 (3)	100 (5)	0 (0)	80 (4)	20 (1)	80 (4)	20 (1)	80 (4)	20 (1)
Affected streams in unit	54 (13)	46 (11)	46 (11)	54 (13)	52 (11)	48 (10)	48 (10)	52 (11)	58 (14)	42 (10)	46 (11)	54 (13)
PRAIRIE CREEK TRIBUTARIES UNIT												
Lost Man Creek (control)	100 (5)	0 (0)	80 (4)	20 (1)	20 (1)	80 (4)	80 (4)	20 (1)	60 (3)	40 (2)	100 (5)	0 (0)
Affected streams in unit	33 (5)	66 (10)	47 (7)	53 (8)	53 (8)	47 (7)	40 (6)	60 (9)	47 (7)	53 (8)	53 (8)	47 (7)
KLAMATH TRIBUTARIES UNIT												
Tarup Creek (control)	40 (2)	60 (3)	100 (5)	0 (0)	40 (2)	60 (3)	60 (3)	40 (2)	40 (2)	60 (3)	60 (3)	40 (2)
Affected streams in unit	60 (6)	40 (4)	90 (9)	10 (1)	60 (6)	40 (4)	40 (4)	60 (6)	40 (4)	60 (6)	60 (6)	40 (4)

Table 5. Summary of cumulative changes in elevation and absolute change in U.S. Highway 101 bypass study reaches, 1985 - 1990. Elevation changes reported by water year (WY) (October 1985 - September 1986 is Water Year 1986).

SUMMARY OF CUMULATIVE CHANGES IN ELEVATION 1985 - 1990							
STREAM	X-SEC #	WY 1986	WY 1987	WY 1988	WY 1989	WY 1990	ABSOLUTE CHANGE
PRAIRIE CREEK ABOVE BROWN CREEK	1	0.08	0.17	0.18	0.23	0.22	0.24
	2	0.25	0.06	0.08	0.12	0.14	0.52
	3	-	0.01	0.03	-0.06	-0.04	0.13
	4	-0.07	-0.2	-0.16	-0.08	0.03	0.43
	5	0.06	-0.01	0.13	0.35	0.4	0.54
PRAIRIE CREEK ABOVE BOYES CREEK	1	0.1	0.25	0.19	0.31	0.34	0.46
	2	0.07	0.06	0.16	0.24	0.26	0.28
	3	-0.09	-0.11	-0.12	-0.11	-0.11	0.13
	4	-0.16	-0.14	-0.16	-0.19	-0.17	0.25
	5	-0.32	-0.33	-0.11	-0.16	-0.35	0.79
PRAIRIE CREEK BELOW BOYES CREEK	1	-1.68	-1.84	-1.67	-1.27	-1.31	2.45
	2	0.16	0.33	0.23	0.72	0.73	0.93
	3	DATA UNRELIABLE					
	4	0.16	-0.03	0.06	0.04	0.03	0.47
	5	0.24	0.3	0.53	0.69	0.78	0.78

Table 5. Continued

SUMMARY OF CUMULATIVE CHANGES IN ELEVATION 1985 - 1990							
STREAM	X-SEC #	WY 1986	WY 1987	WY 1988	WY 1989	WY 1990	ABSOLUTE CHANGE
PRAIRIE CREEK ABOVE MAY CREEK	1	-0.05	-0.06	-0.05	0.04	-0.01	0.21
	2	-0.09	0.07	-0.04	-0.06	-0.21	0.53
	3	0.08	0.03	0.1	-0.02	-0.01	0.33
	4	0.06	-0.02	0.03	-0.13	-0.16	0.38
PRAIRIE CREEK BELOW MAY CREEK	1	0.06	0.02	-0.22	-0.18	-0.14	0.42
	2	0.13	-0.02		0.12	0.11	0.29
	3	-0.01	-0.01	-0.38	-0.51	-0.34	0.68
	4	-0.59	-0.62	-0.52	-0.97	-0.88	1.26
	5	0.08	0.09	0.02	-0.38	-0.34	0.6
	6	0.04	NO DATA 1987 - 1989				0.08
PRAIRIE CREEK BELOW CHANNELIZATION	1	-0.31	-0.32	-	1.38	1.31	0.39
	2	-0.05	0.11	-	0.52	0.47	0.26
	3	0.25	0.31	0.26	-0.47	-0.56	1.18
	4	0.44	0.37	0.19	0.18	0.29	0.81
	5	-0.01	0.1	0.03	0.04	0.27	0.43
	6	0.05	0.21	0.34	0.41	0.53	0.53

Table 5. Continued

SUMMARY OF CUMULATIVE CHANGES IN ELEVATION 1985 - 1990							
STREAM	X-SEC #	WY 1986	WY 1987	WY 1988	WY 1989	WY 1990	ABSOLUTE CHANGE
BOYES CREEK	1	0.01	0.01	0.02	0.01	0	0.04
	2	0.01	0.03	0	-0.05	-0.05	0.11
	3	0	-0.09	0.21	0.4	0.43	0.61
	4	-0.01	0.05	0.06	0.06	-0.12	0.26
BROWN CREEK	1	0.04	0.01	0.06	0.08	0.02	0.2
	2	-0.1	-0.24	-0.07	-0.09	-0.07	0.45
	3	0.05	-0.05	0.05	0	-0.11	0.41
	4	0.1	-0.04	-0.02	0.02	0.22	0.5
	5	0.02	-0.11	-0.08	-0.11	0.03	0.35
LOST MAN CREEK	1	0.04	0.16	0.01	0.07	0.13	0.43
	2	0.1	0.12	0.09	0.01	0.09	0.31
	3	0.42	0.63	0.36	0.55	0.72	1.26
	4	0	0.01	-0.01	0.11	0.03	0.23
	5	0.04	-0.08	0.08	0.09	0.04	0.38

Table 5. Continued

SUMMARY OF CUMULATIVE CHANGES IN ELEVATION 1985 - 1990							
STREAM	X-SEC #	WY 1986	WY 1987	WY 1988	WY 1989	WY 1990	ABSOLUTE CHANGE
MAY CREEK	1	0.08	0.18	0.08	-0.08	0.06	0.58
	2	0.2	0.18	-0.06	-0.01	0.07	0.59
	3	-0.28	-0.01	-0.1	-0.12	-0.04	0.74
	4	0.24	0.14	0.06	0.08	0.05	0.47
	5	-0.02	0.04	-0.12	-0.33	-0.35	0.47
	6	-0.27	-0.19	-0.41	-0.61	-0.63	0.79
AH PAH CREEK	1	-0.21	-0.21	-0.32	-0.37	-0.24	0.5
	2	0.12	0.13	0.18	0.16	0.11	0.25
	3	-0.07	0.07	0.2	0.01	-0.02	0.56
	4	0.14	0.15	0.47	0.05	0.01	0.93
	5	0.24	0.2	0.4	0.21	0.2	0.68
McGARVEY CREEK	1	0.13	0.27	0.34	0.51	0.51	0.51
	2	0.1	0.13	-0.76	-0.66	-0.69	1.15
	3	-0.18	-0.1	-0.13	-0.1	-0.09	0.33
	4	0.24	0.24	0.23	0.19	0.3	0.4
	5	-0.11	-0.06	-0.05	0.09	0.04	0.36

Table 5. Continued

SUMMARY OF CUMULATIVE CHANGES IN ELEVATION 1985 - 1990							
STREAM	X-SEC #	WY 1986	WY 1987	WY 1988	WY 1989	WY 1990	ABSOLUTE CHANGE
TARUP CREEK	1	-0.05	-0.05	-0.1	0.09	0.1	0.3
	2	-0.09	-0.09	-0.07	-0.05	-0.07	0.15
	3	0.09	0.14	0.2	0.19	0.11	0.29
	4	0.17	0.17	0.06	0.07	0	0.36
	5	-0.11	-0.09	-0.2	-0.28	-0.27	0.33

~~Table 5. Continued~~

1985 were minimal (RNP 1986). To standardize comparisons, changes from 1985 to 1990 are  only shown in this report.

Of 29 cross sections surveyed in the Prairie Creek Unit, 15 aggraded (9 pools, 6 riffles) and 14 degraded (11 pools, 2 riffles, 1 at a confluence) between 1985 and 1990 (Table 4). Eighty percent of the cross sections in PABR, control site for the Prairie Creek unit, aggraded compared to 46% in the bypass-affected cross sections in the unit. Cumulative and year to year mean streambed elevation changes were generally small. Only two cross sections, each crossing a pool, changed more than one cumulative foot (0.31 m) over the five water years surveyed: PBBY #1 (-1.31 ft), and PBCH #1 (+1.31 ft). Four cross sections, 1 riffle and 3 pools, increased over 0.5 ft (0.15 m); they were also in PBBY and PBCH, each downstream of a cross section that degraded over 0.5 ft (Table 5). Three cross sections demonstrated more than one foot of absolute change: PBBY #1 (2.45 ft), PBMV #5 (1.26 ft), and PBCH #3 (1.18 ft). The remaining cross sections exhibited only minor changes.

The largest changes in cumulative streambed elevation in the 20 cross sections of the Prairie Creek Tributary Unit were +0.72 ft at the control site, LM #3, and -0.63 ft at MY #6. The remaining changed less than 0.5 ft. LM #3 experienced 1.26 ft of absolute change; the rest in this unit experienced less than 0.80 ft absolute change. All of LM cross sections aggraded, whereas only 53% of the bypass-affected monitoring sites in this unit aggraded.

The fifteen cross sections located on the Klamath Tributary Unit experienced minor levels of change in cumulative streambed elevation and in absolute change. The greatest amount of streambed elevation change occurred at cross section #1 and #2 on MG; 0.51 ft in a pool and -0.69 feet on riffle habitat. This latter cross section also exhibited the greatest absolute change, 1.15 feet. Sixty percent of cross sections on TC, control for the Klamath Tributary Unit, aggraded; the same percentage aggraded on the bypass-affected monitoring sites in this unit.

The prominent habitat type (pool, riffle, confluence or glide) at each cross section did not change over the 5 survey years except at PBCH #1 and #2 which changed from pools to riffles following channelization work.

Photographs taken at permanently monumented stream cross sections during fall months of the years 1985 to 1990 were visually compared for each stream (photographs on file at Arcata RNP office). Except for the instances detailed below, photographs between years revealed no major physical changes other than slight ephemeral changes in water flow, vegetation, and organic debris at all sites.

PABR - The December 29, 1989, photograph of the right bank of cross section number five revealed that two large redwood trees had recently fallen over the stream. The stream channel did not appear to be affected, and the 1990 cross section profiles of the right bank of the channel showed no substantial change. On December 28, 1989, wind speeds of 35 mph

with gusts up to 45 mph were recorded in Eureka (National Weather Service Data, December, 1989). The trees were probably blown down during the high winds.

PBBY - The series of photographs and the cross section profile of cross section number one revealed that between 1985 and 1986 the left bank and channel eroded, forming a wider, deeper active channel. The left bank and channel lost between one and six feet in depth over a distance of approximately 30 feet. The central and right side portions of the stream channel experienced between one and three feet of aggradation over a width of approximately 15 feet between 1988 and 1989. The aggradation resulted in a movement of the active channel toward the left bank.

PBMY - a large deciduous tree, present in the 1985 photograph of cross section number three, disappeared in the 1986 photograph; the stream channel and banks did not seem to be affected. CalTrans placed large boulders and gabions on the left bank of the stream at cross section number two, six, and seven in 1988. Such construction activities destroyed the left bank monuments. Photo documentation was discontinued after 1988.

PBCH - The 1986 photographs of cross section number one show that a mass of alders fell from the right bank across the stream to the left bank. The right bank eroded approximately five feet in 1986, while the middle of the channel experienced up to three feet of aggradation. The photographs taken in 1988 of the left bank show newly placed boulders and a roadbed, work CalTrans accomplished during the preceding year. New cobbles and rubble were in the streambed. A pool had existed at cross section 2 from 1985 until 1988; the artificial aggradation created a new riffle, which is confirmed in the cross section profile. The degradation in cross section 3 between 1988 and 1989 was not noticeable in the photographs.

These results show that unnatural scour or filling of the streambed was minimal over the 5 to 6 years of surveying at most sites. The exception were the sites affected by the channelization activities on Prairie Creek below May Creek and just above PBCH. The channelization changed the habitat structure of Prairie Creek in this area. PBCH lost a pool and was the most degraded by this work.

Quality and Quantity of Benthic Substrate

Digitized stream benthic habitat maps from 1988 to 1992 are shown in Appendix C. Hand drawn maps from 1985 to 1987 were not digitized, and patterns were not standardized as they were for maps from 1988 to 1992. Maps for 1985 to 1987 are in RNP (1986, 1987, and 1989).

Percent of area dominated by surface sand, surface silt, surface sand and silt combined, and vegetation from 1988 to 1992 are presented in Appendix C. Percent of area having sand or silt as the second-most dominant substrate type are also reported. We found that between 1988 and 1992, mean coverage by surface silt (dominant or second-most dominant substrate

type) and silty soils supporting thick vegetation (vegetation replaced benthic habitat in our sites over time) increased from a mean of 23% to 37% on Prairie Creek, (2% increase on the control site), from 28% to 57% on Prairie Creek tributaries (from 3% to 22% on Lost Man Creek control site), and from 46% to 60% on affected Klamath tributaries (1% to 18% on Tarup Creek control site). When sand was included, however, percent surface fines and vegetation increased less on Prairie Creek because sand decreased on upper Prairie Creek (silt was deposited on sands, but sands were removed too). On all sites from just above May Creek downstream, surface fines increased. Surface fines (including sand and vegetation) increased or remained the same on the Prairie Creek tributaries, although sand still decreased over time. Surface fines on Tarup and Ah Pah creeks did not change much because sand decreased over time. Both sand and silt increased greatly on McGarvey Creek.

Percent of area covered by silt and vegetation (dominant or second-most dominant) was estimated visually from the hand-drawn field maps for 1985 to 1987 (on file in RNP Arcata office) to compare with the 1988 to 1992 data (Figures 4, 5 and 6). Boyes Creek and the average of sites on Prairie Creek below Boyes and May creeks showed a large increase in surface silt and vegetation in comparison to other upstream sites. The largest increases began in 1988. For years bracketing the 1989 storm, silt increased at all sites on Prairie Creek except below channelization (Figure 7). Silt on May and Brown creeks increased after the 1989 storm also. For the affected Klamath tributaries, increases were very large and most noticeable by 1987. McGarvey became worse every year until 1992. The control sites at Tarup and Lost Man Creek, on the other hand, did not increase substantially until 1992.

Surface silt subdominant with gravel or larger rocks increased on PBBY, PBMV, PBCH, Brown, Boyes, and May Creeks, but not on Lost Man Creek, the Klamath tributaries or on other sites on Prairie Creek mainstem between 1988 and 1992. Except Brown and McGarvey Creeks, sand as a subdominant decreased or remained the same. Sometimes the decrease in subdominant fines is due to the gravel becoming subdominant to the fines such as occurred on McGarvey Creek.

Boyes Creek may have gained silt in 1988 from bypass construction activities, but its basin has also been partially logged. The February 1986 storm increased the turbidity of Boyes Creek, but the large increase did not show up until a year later at the monitoring site and at sites on Prairie Creek below Boyes. There may have been a year's delay for the sediment to travel downstream and reach the downstream site. It is also possible sediment deposited from former logging days into Boyes Creek is being released following decay of woody barriers in the stream.

In 1988, a short stretch of Prairie Creek below May Creek was channelized, which explains the increased silt in these areas. The 1988 increases were more detrimental than the October 1989 storm. However, the 1989 storm appears to still have contributed silt to all bypass-affected sites, since the control sites did not show increases until 1992 (not including the control site, Prairie above Brown, which was affected by the October 1989 storm). The succession of drought years likely also increased silt, exacerbating the habitat degradation

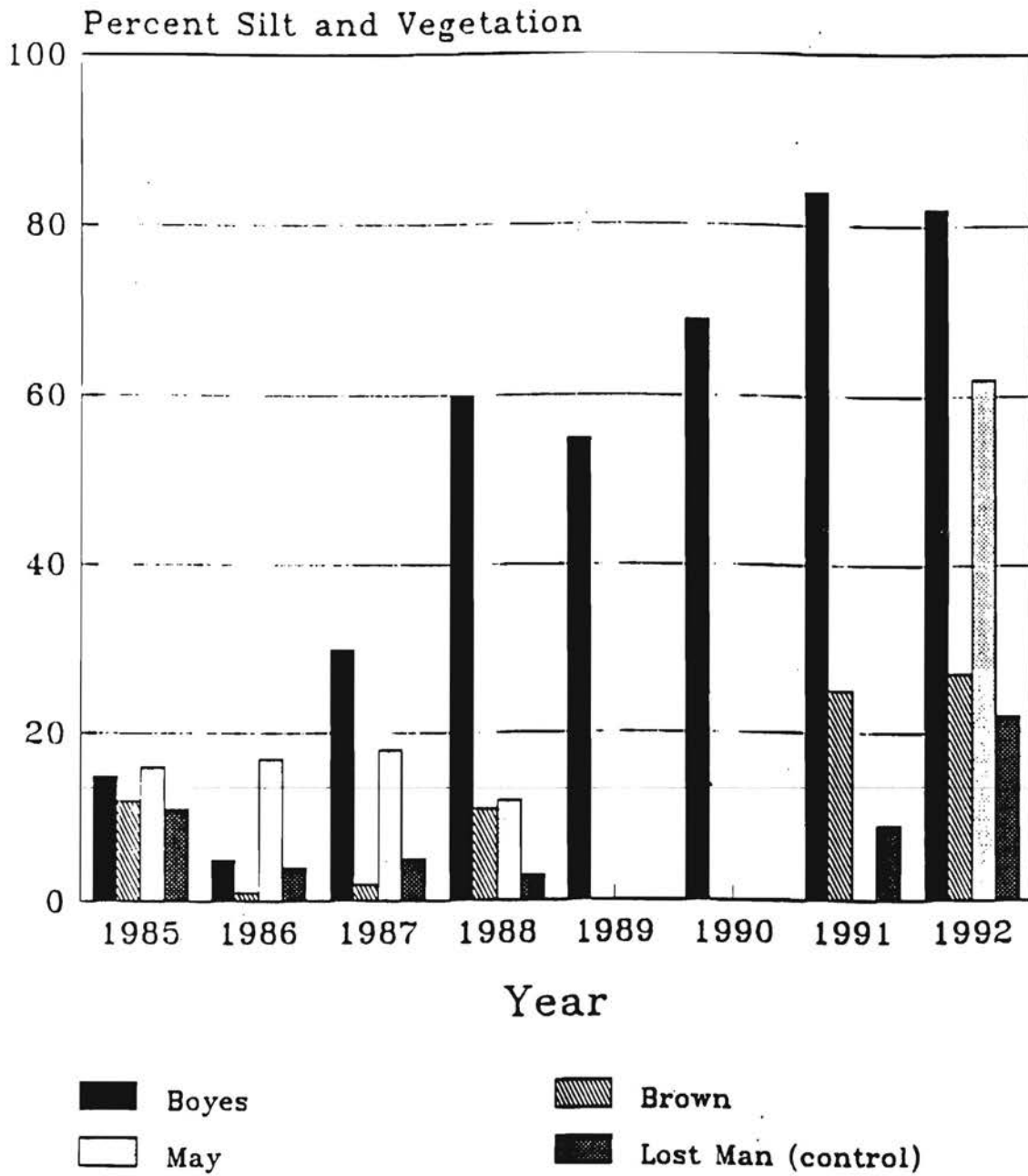


Figure 4.

Percent of substrate in which silt or vegetation growing on silt is the dominant or second most dominant substrate type on long term monitoring sites on Prairie Creek tributaries in summer or early fall. Data were not collected or analyzed for all sites from 1989 - 1991.

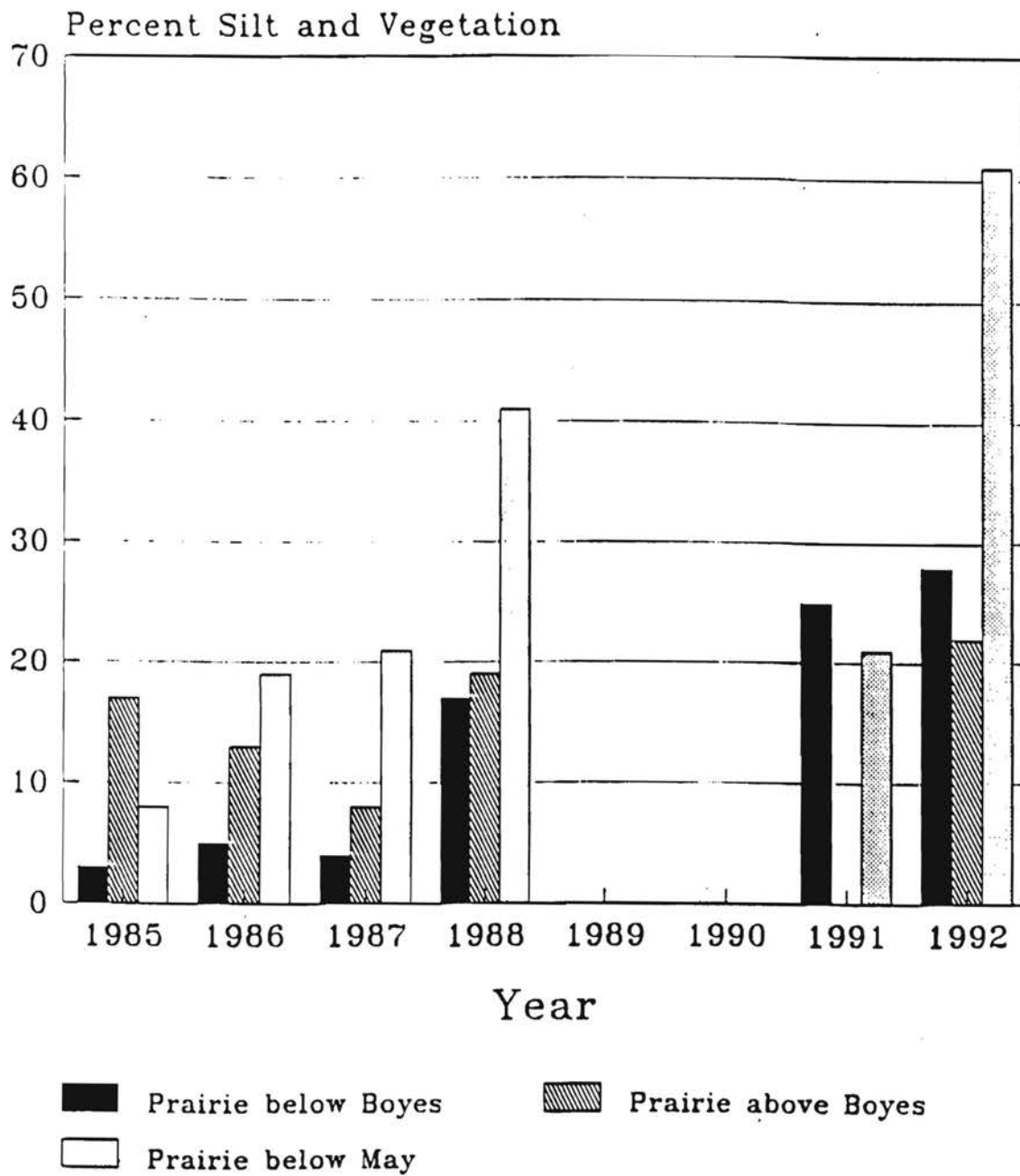


Figure 5. Percent of substrate in which silt or vegetation growing on silt is the dominant or second most dominant substrate type on long term monitoring sites averaged for each reach (two sites per reach) on Prairie Creek in summer or early fall. Data were not collected or analyzed for all sites from 1989 - 1991.

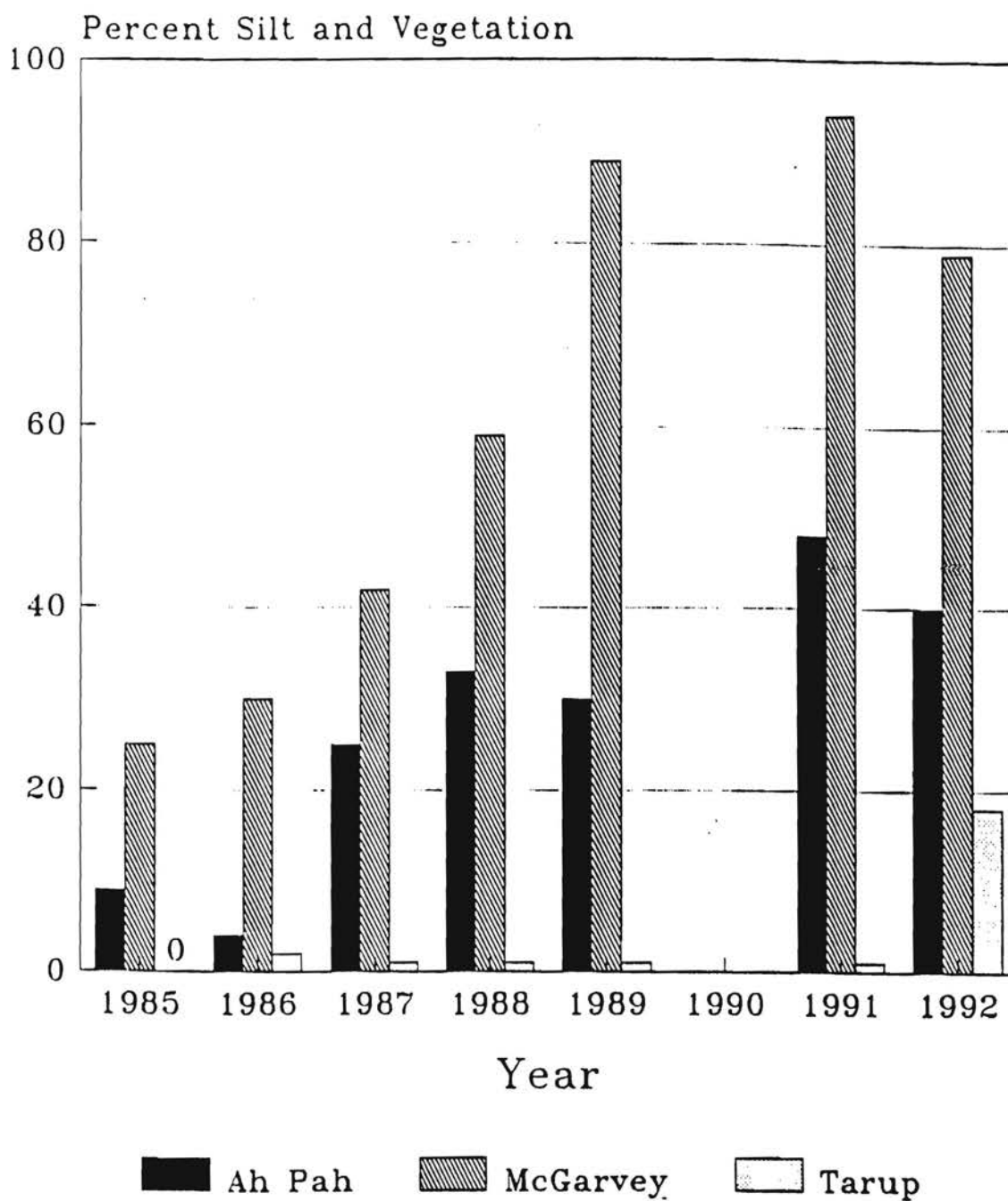


Figure 6. Percent of stream substrate in which silt or vegetation growing on silt is the dominant or second most dominant substrate type on long term monitoring sites on Klamath River tributaries in summer or early fall. Data were not collected or analyzed for all sites from 1989 - 1991.

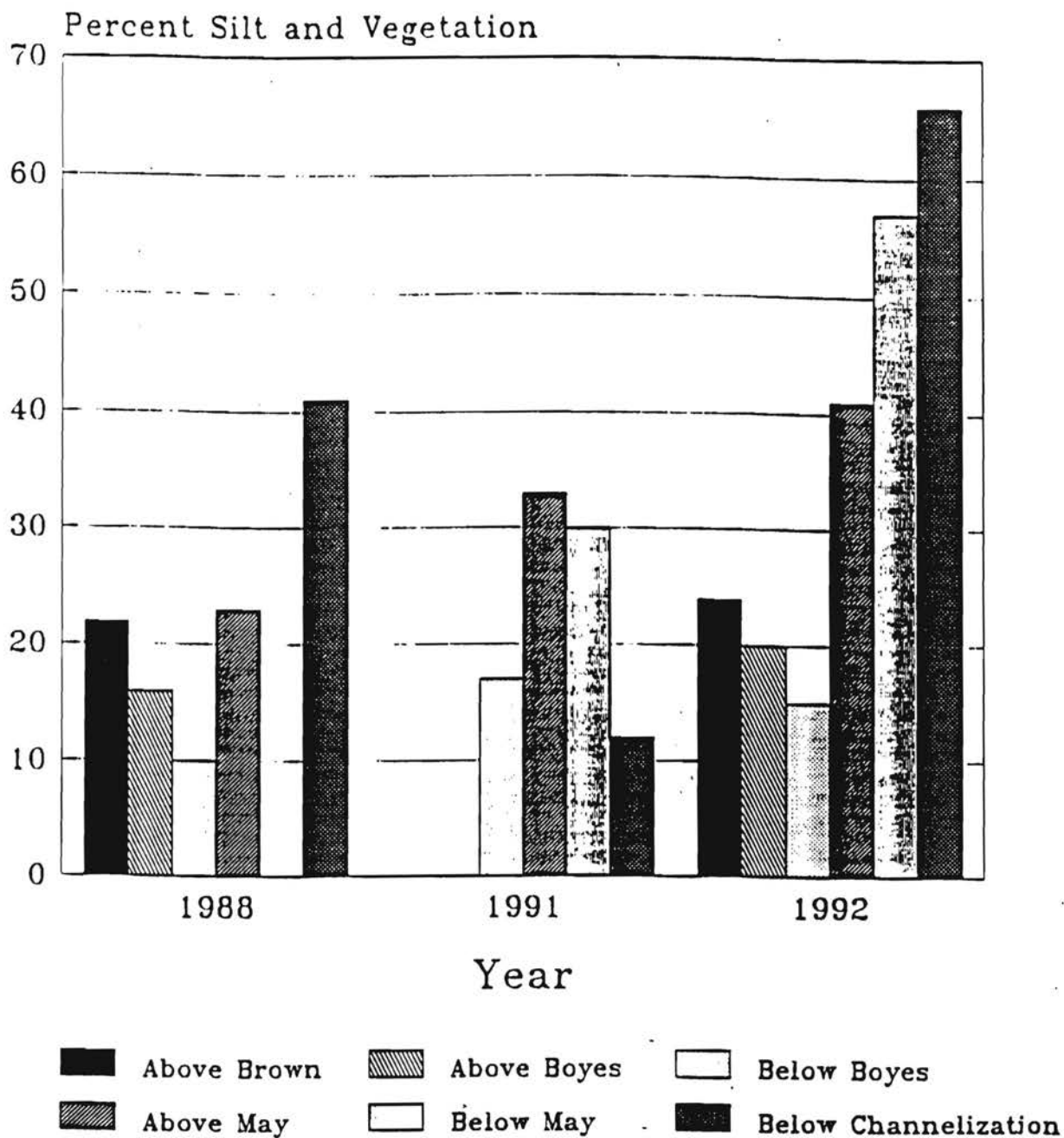


Figure 7. Percent of stream substrate in which silt or vegetation growing on silt is the dominant or second most dominant substrate type on individual long term monitoring sites on Prairie Creek in 1988, 1991 and 1992. Data are missing for some sites.

(1985 and 1987 to 1992 were below mean annual rainfall). Increases began in the early years in the Klamath tributaries. Former logging impacts may have been responsible for the largest increases or bypass construction activities affected these areas early on. Because of a potential threat of large releases of sediment into McGarvey and Ah Pah Creeks in 1987, winter monitoring at these sites was conducted in 1987. The results did not show gravel quality deteriorated over the winter (RNP 1987), but these surface silt results suggest that silt might have increased in the gravels, and the freeze-cores and pans were ineffective at sampling it.

Large woody debris within the stream channel shifted around over time; some were lost from the site, but other wood was recruited. Overall, change in woody debris, which acts as cover and provides habitat structure, was minimal (see Appendix C).

Pools and Stream Gradient

Longitudinal profiles of the monitoring sites from 1988 to 1990 are in Appendix D. Profiles for 1985 to 1987 are provided in RNP (1986, 1989) and Harrington (1987). Because the profile followed the stream thalweg, which varies year to year, the distances between pools and riffles along the profile are not comparable. Due to these thalweg length changes, reach lengths and percent gradients

also varied between years. Table 6 gives a relative comparison of the 13 monitoring sites using 1985 values (along with canopy cover measured that year). The profiles are useful for roughly interpreting locations of pools and riffles on the benthic habitat maps in Appendix C. Except for Lost Man Creek, the gradients of the control sites fell within the range of the bypass affected sites within the same unit.

In the Prairie Creek Unit, pools (defined as having a residual depth greater than 1 foot (0.3 m)) fluctuated in number, depth, and volume over the monitoring period (Table 7, Appendix E). The control site, PABR, maintained a similar average residual pool depth over the years; volume remained low, and surface area ranged from 17 to 45 m². Although individual pools grew or shrank, overall pool surface area and volume were similar between 1985 and 1992.

In contrast, PABY maintained similar number of pools and average depth, but lost about half the pool surface area and volume over time (all pools decreased in volume). On PBBY, one pool increased substantially in size between 1985 and 1987; half of its volume was lost again by 1992. Three new small pools were created in 1992; overall the pool volume almost doubled between 1985 and 1992.

On PAMY, one pool increased and another pool decreased in size, resulting in little change in overall pool surface area and volume over the monitoring period. On PBMV, at least three new pools were created in 1986 and lost again by 1991. Due to poor record-keeping, pool volume could not be adjusted for the riffle crest depth at this site for 1985, so 1986

Table 6. Stream reach length, percent gradient, and percent canopy cover for the 13 monitoring sites in 1985, U.S. Highway 101 Bypass Project.

Monitoring Site	Reach Length Feet (m)	Percent Gradient	Percent Canopy Cover
Prairie Creek Unit			
Prairie Creek above Brown (control)	320 (98)	0.52	90
Prairie Creek above Boyes	328 (100)	0.12	69
Prairie Creek below Boyes	270 (82)	0.18	79
Prairie Creek above May	298 (91)	0.24	68
Prairie Creek below May	397 (121)	0.50	72
Prairie Creek below Channelization	370 (113)	0.83	89
Prairie Creek Tributary Unit			
Lost Man Creek (control)	510 (156)	0.90	72
Brown Creek	151 (46)	1.64	96
Boyes Creek	207 (63)	1.38	96
May Creek	244	1.53	-
Klamath River Tributary Unit			
Tarup Creek (control)	212 (65)	1.30	98
North Fork Ah Pah Creek	285 (87)	1.30	94
McGarvey Creek	343 (105)	0.69	97

Table 7. Numbers of pools, total residual surface area, total residual water volume for all pools with residual depth of 30.5 cm or greater at the 13 monitoring sites, Redwood Park Bypass, U.S. Highway 101, for years 1985, 1987, 1991, and 1992.

PRAIRIE CREEK UNIT				
PRAIRIE ABOVE BROWN CREEK	1985	1987	1991	1992
Total Number of Pools	2	3	3	3
Average Residual Pool Depth (cm)	46	43	40	43
Total Residual Surface Area (m ²)	21	45	17	29
Total Residual Pool Volume (m ³)	3	6	2	4
PRAIRIE ABOVE BOYES CREEK	1985	1987	1991	1992
Total Number of Pools	3	3	4	3
Average Residual Pool Depth (cm)	94	70	88	88
Total Residual Surface Area (m ²)	198	163	134	92
Total Residual Pool Volume (m ³)	77	49	52	34
PRAIRIE BELOW BOYES CREEK	1985	1987	1991	1992
Total Number of Pools	3	3	4	6
Average Residual Pool Depth (cm)	55	79	67	55
Total Residual Surface Area (m ²)	45	127	77	86
Total Residual Pool Volume (m ³)	14	42	22	24
PRAIRIE BELOW CHANNELIZATION	1985	1987	1991	1992
Total Number of Pools	2	6	3	5
Average Residual Pool Depth (cm)	64	52	49	46
Total Residual Surface Area (m ²)	55	120	46	27
Total Residual Pool Volume (m ³)	14	26	8	4
PRAIRIE ABOVE MAY CREEK	1985	1987	1991	1992
Total Number of Pools	2	3	2	2
Average Residual Pool Depth (cm)	58	49	64	64
Total Residual Surface Area (m ²)	43	60	46	43
Total Residual Pool Volume (m ³)	8	13	10	11

Table 7. continued

PRAIRIE BELOW MAY CREEK	1986	1987	1991	1992
Total Number of Pools	5	7	3	3
Average Residual Pool Depth (cm)	55	49	61	73
Total Residual Surface Area (m ²)	320	294	123	126
Total Residual Pool Volume (m ³)	87	76	25	30

PRAIRIE CREEK TRIBUTARY UNIT

BROWN CREEK	1985	1987	1991	1992
Total Number of Pools	2	1	2	-
Average Residual Pool Depth (cm)	34	37	30	- Total
Residual Surface Area (m ²)	9	4	1	-
Total Residual Pool Volume (m ³)	1	.5	.01	-

BOYES CREEK	1985	1987	1991	1992
Total Number of Pools	2	2	2	2
Average Residual Pool Depth (cm)	58	37	49	52
Total Residual Surface Area (m ²)	7	6	4	5
Total Residual Pool Volume (m ³)	1	1	1	1

MAY CREEK	1985	1987	1991	1992
Total Number of Pools	2	3	1	3
Average Residual Pool Depth (cm)	43	52	61	49
Total Residual Surface Area (m ²)	6	28	19	21
Total Residual Pool Volume (m ³)	1	5	4	4

LOST MAN CREEK	1985	1987	1991	1992
Total Number of Pools	2	3	2	2
Average Residual Pool Depth (cm)	98	79	94	113
Total Residual Surface Area (m ²)	145	213	224	249
Total Residual Pool Volume (m ³)	56	72	77	97

Table 7. continued

KLAMATH RIVER TRIBUTARY UNIT

NORTH FORK AH PAH CREEK	1985	1987	1991	1992
Total Number of Pools	1	1	2	2
Average Residual Pool Depth (cm)	46	64	55	52
Total Residual Surface Area (m ²)	4	7	7	5
Total Residual Pool Volume (m ³)	.5	1	1	1
 MCGARVEY CREEK	 1985	 1987	 1991	 1992
Total Number of Pools	2	3	2	2
Average Residual Pool Depth (cm)	49	61	61	64
Total Residual Surface Area (m ²)	11	36	19	12
Total Residual Pool Volume (m ³)	2	8	4	3
 TARUP CREEK	 1985	 1987	 1991	 1992
Total Number of Pools	2	2	2	2
Average Residual Pool Depth (cm)	40	46	43	49
Total Residual Surface Area (m ²)	6	11	8	11
Total Residual Pool Volume (m ³)	1	2	1	2

volume data for PBMV were compared to later years. From 1986, pool volume decreased by almost 1/3 over the monitoring period. However, 1985 had 3 fewer pools than 1986, and the decrease was probably less than 1/3 between 1985 and 1992.

On PBCH, number of pools fluctuated. Overall, pool volume decreased by over one-third during the monitoring period, despite the large increase in one pool in 1987.

Substantial changes in pool volume between 1987 and 1991 (at sites not affected by the 1988 channelization), which can measure the effect of the October 1989 storm, only occurred at PBBY.

In the Prairie Creek Tributary Unit, the control site, LM, steadily gained in pool surface area and volume. In BR, pool volume dropped to 1/10 of 1985 levels. BY remained about the same, although one pool increased and the other decreased. MY pool volume, depth and surface area increased in 1987 and were maintained (Table 7).

Pool volume losses between years bracketing the October 1989 storm, 1987 and 1991, were minimal or none, except at BR. However, volume declines at this site began in 1987 before the October 1989 storm.

In the control site of the Klamath River Tributary Unit, TC, one pool slightly decreased and another increased, resulting in minimal net change in pool volume or surface area. MG gained a pool in 1987, and pool volume increased. However, pool volume returned to near the 1985 level by 1992. AP gained pool volume, depth, and area in 1987, but the difference between 1985 and 1992 was small (Table 6).

These data agree with cross-section and photography results that indicate pools were modified by the channelization activities in PBMV and PBCH. Despite the increase of surface silt, pool volume increased on Prairie Creek just below Boyes Creek, and it remained about the same on Boyes Creek. Pools naturally shift around and changes on Prairie Creek in the upper sites probably reflect this. Pool volume decreased on Brown Creek, but the volume was very low in the beginning.

Spawning Gravel Quality and Predicted Salmonid Egg Survival

Gravel Quality Indices. Percent fines < 1.0 mm, geometric mean, and fredle index were estimated for each monitoring site from summer 1985 to summer 1992 to determine gravel quality (Tables 8,9,10). Except where stated, interactions between sampling year and type of stream reach (control or bypass-affected) were not significant ($P > 0.05$). An insignificant interaction means any changes in the gravel quality indices over time in the bypass-affected sites probably had a parallel response in the control site.

In the Prairie Creek Unit, percent fine sediment < 1.0 mm by weight found in gravel within potential spawning riffle crests did not significantly change from 1985 to 1989 in the affected or control sites. Percent fines in PBBY combined with PABR in a 2-way ANOVA almost showed a significant change over time when 1990 data were added ($P = 0.052$); the change was significant when 1991 and 1992 were added ($P = 0.035$ and 0.025). The increase was less than 3%. Although the other sites did not significantly change over time; the mean at PAMY tended to increase in 1988; in PABY and PBMV it tended to increase in 1989. Percent fines in PBMV and PBCH averaged significantly higher fines than the control site, PABR, over the 8 years ($P < 0.01$). In contrast, PBBY averaged significantly lower fines than the control site ($P < 0.05$).

Geometric mean did not significantly change in any of the Prairie Creek sites from 1985 to 1989. In PBBY combined with PABR in a 2-way ANOVA, it significantly changed when 1990 ($P = 0.03$), 1991 ($P = 0.003$) and 1992 ($P = 0.005$) were added. PBMV and PBCH also showed a decrease in geometric mean, but not until 1991 data ($P = 0.002$ and < 0.001 , respectively) and 1992 data ($P = 0.003$ and $P = 0.034$) were added. Geometric mean showed a significant change among years in PAMY by 1992 ($P = 0.031$). PABY tended to show a decline in 1990; change among years at this site was not significant except when

years 1985 to 1991 were analyzed ($P = 0.03$). Changes became insignificant again when 1992 data were added. Averaged over the eight years, geometric mean was significantly higher than the control site in PABY and PBBY ($P < 0.01$). It was lower than the control site in PBMV and PBCH ($P < 0.001$). Gravels with lower geometric mean are usually considered poorer spawning sites.

Fredle index is usually positively correlated with egg survival. Similar to results for fines and the geometric mean, fredle index did not significantly change in any of the sites in the unit from 1985 to 1989. Like the geometric mean, fredle index in the PBBY and PABR combination in a 2-way ANOVA significantly decreased when 1990 ($P = 0.019$), 1991 ($P = 0.002$), and 1992 data ($P = 0.001$) were added. The fredle index decreased in PBMV when 1991 ($P = 0.004$) and 1992 ($P =$

Table 8. Percent fines (<1.000 mm) found in gravel samples on selected reaches of Prairie Creek tributaries for 1985 to 1992.

STREAM	1985	1986	1987	1988	1989	1990	1991	1992
Prairie Above Brown	8.06	7.37	7.77	8.89	7.22	12.54	8.74	9.43
Prairie Above Boyes	7.16	6.61	7.07	6.18	8.52	7.81	8.13	8.26
Prairie Below Boyes	6.25	5.32	5.64	7.85	7.07	9.00	8.52	8.54
Prairie Above May	7.44	7.51	7.51	9.92	13.85	9.74	9.78	9.38
Prairie Below May	9.57	9.59	12.04	7.80	15.44	11.65	13.04	13.69
Prairie Below Channelization	11.09	10.24	13.18	10.49	10.69	9.89	15.93	9.82
Lost Man	10.20	8.32	8.66	7.27	9.44	6.46	9.50	8.84
Brown	9.37	7.28	7.80	5.89	7.42	7.85	8.71	8.31
Boyes	8.79	10.22	11.20	9.95	8.63	11.86	8.87	9.24
May	16.73	12.94	11.86	12.75	12.66	14.78	20.49	23.07
Tarup	8.02	8.33	8.33	5.60	6.34	10.45	10.10	9.42
Ah Pah	9.80	12.16	11.75	9.85	7.96	12.12	10.21	10.18
McGarvey	16.08	13.94	13.24	15.78	21.10	23.23	18.81	18.31

Table 9. Geometric Means (in mm) of gravel found in gravel samples on selected reaches of Prairie Creek tributaries for 1985 to 1992.

STREAM	1985	1986	1987	1988	1989	1990	1991	1992
Prairie Above Brown	24.80	22.48	23.55	20.49	25.16	18.48	20.02	16.25
Prairie Above Boyes	29.79	27.19	32.62	28.17	27.12	24.12	26.18	24.44
Prairie Below Boyes	29.68	26.62	31.41	23.02	31.04	18.55	22.76	20.36
Prairie Above May	24.97	21.15	25.03	19.51	14.49	14.72	17.47	19.99
Prairie Below May	18.00	17.14	18.70	19.25	12.61	12.03	10.91	10.34
Prairie Below Channelization	18.08	14.62	14.57	14.94	15.71	13.93	10.19	13.29
Lost Man	23.99	20.93	21.74	26.52	25.06	26.50	19.94	21.36
Brown	19.38	21.73	25.96	28.67	24.59	24.03	23.54	22.35
Boyes	23.75	20.57	22.56	19.56	22.55	18.18	22.41	22.13
May	10.71	12.43	12.36	12.07	14.05	11.44	8.81	6.44
Tarup	26.50	19.28	23.28	29.42	24.28	20.63	15.55	17.03
Ah Pah	19.46	16.36	17.53	17.94	20.24	16.01	14.94	14.31
McGarvey	9.86	12.10	10.94	10.09	7.92	6.72	7.42	6.97

Table 10. Fredle Index values computed from gravel samples on selected reaches of Prairie Creek, Prairie Creek tributaries and Klamath River tributaries for 1985 to 1992.

STREAM	1985	1986	1987	1988	1989	1990	1991	1992
Prairie Above Brown	10.66	10.31	10.88	8.02	11.38	6.48	6.73	5.36
Prairie Above Boyes	16.31	13.61	19.20	14.50	13.41	10.27	12.03	11.11
Prairie Below Boyes	17.08	13.00	17.58	9.88	18.46	6.51	8.44	8.05
Prairie Above May	12.71	9.16	12.51	8.57	5.47	5.82	6.55	8.49
Prairie Below May	8.00	6.03	8.09	8.30	4.64	4.32	3.77	3.66
Prairie Below Channelization	7.88	5.85	5.49	6.37	6.88	6.04	3.53	5.39
Lost Man	12.34	8.28	8.53	12.66	12.47	11.79	5.54	8.39
Brown	7.33	9.70	12.00	14.63	11.07	9.14	8.64	8.21
Boyes	10.48	8.54	9.64	7.65	9.53	5.95	7.73	8.24
May	3.42	4.75	4.71	4.72	5.08	4.48	2.71	1.76
Tarup	14.10	8.18	10.20	16.53	10.89	7.83	5.47	6.07
Ah Pah	7.39	5.95	6.82	6.54	14.95	5.31	5.12	4.54
McGarvey	3.09	4.20	4.04	3.13	2.80	2.26	2.19	2.23

0.002) data were added. However, it appeared to first decrease in 1989 in PBMV. PAMY and PBCH showed a significant change when 1992 data were added ($P = 0.005$ and 0.01 , respectively). PAMY appeared to first decrease in 1988 or 1989, and PBCH appeared to first decrease in 1991. The interaction term was almost significant ($P = 0.055$); PAMY's Fredle index decreased sooner than PABR's. Although no change was significant for PABY, a decreasing trend was apparent, starting in 1990. Averaged over the eight years, fredle index differences between the control and affected sites were similar to geometric mean differences. The fredle index was significantly higher than the control site in PABY and PBBY ($P < 0.01$), and lower in PBMV and PBCH ($P < 0.001$).

In the Prairie Creek tributary unit, only May Creek showed a significant change in percent fines over time when 1992 data were added ($P = 0.003$). The interaction term was significant ($P = 0.037$); fines increased more in May Creek than the control site. The other sites showed no significant changes among years. Boyes and May Creek had significantly higher fines than the control site ($P < 0.01$ and < 0.001 , respectively).

None of the sites in the Prairie Creek tributary unit showed a significant change in geometric mean from 1985 to 1992. However, May Creek combined with the control site showed a change among years for 1985 to 1991 ($P = 0.018$), but no change when 1992 was added. May Creek values tended to decrease in 1991. May Creek also had significantly lower geometric mean values averaged over the 8 years than the control site ($P < 0.001$).

None of the sites in the Prairie Creek tributary unit showed a significant change in fredle index over time. May Creek had significantly lower fredle index values than the control site ($P < 0.001$).

None of the sites in the Klamath River tributary unit showed a significant change in percent fines over time, although McGarvey came close ($P = 0.059$). However fines were already high in this creek in 1984 ($> 20\%$; see RNP (1986)). Ah Pah and McGarvey Creek sites averaged higher fines than the control site, Tarup Creek ($P < 0.01$ and < 0.001).

Combined with the control site in a 2-way ANOVA, geometric mean significantly changed among years in Ah Pah Creek and McGarvey Creek when 1991 ($P < 0.001$, $P = 0.001$) and 1992 ($P = 0.001$) data were added. It appeared to first decrease in 1990 or 1991 in TC and AP, whereas the decrease first occurred in 1989 in MG. The interaction term was significant on McGarvey Creek ($P = 0.017$), because Tarup Creek's values decreased more than McGarvey. Average geometric mean values for the 8 years were lower in Ah Pah and McGarvey Creeks than the control site ($P < 0.001$).

Fredle index in Ah Pah and McGarvey Creeks significantly changed with the control site, Tarup, when 1992 data were added ($P < 0.001$ and $P = 0.003$, respectively). It appeared to first decrease in 1990 (or possibly 1989 for McGarvey). The interaction term ($p=?$) was significant on McGarvey and Ah Pah Creeks because Tarup's values decreased more. Fredle

index averaged lower values in Ah Pah ($P < 0.01$) and McGarvey ($P < 0.001$) Creeks than the control site.

For all sites, the average of coefficient of variation values (c.v.) from 1985 to 1990 was 32.3% for percent fines, 28.5% for geometric mean, and 42.5% for fredle index. Arcsin square-root transformed percent fines had 1/2 to 1/3 smaller c.v.'s. The Prairie Creek Tributary Unit had the least variability (c.v. = 26.6, 24.1, 40.3, respectively) followed by Prairie Creek Unit (c.v. = 34.9, 30.25, 40.2) and lastly the Klamath River Tributary Unit (c.v. = 35.4, 31.7, 47.0). 1985 values for Lost Man Creek were extremely variable and atypical of the c.v. found in this creek in the other years (Table 11). All F and P values from statistical analyses are on file in the Arcata RNP office.

Table 11. Coefficients of variation (%) for the gravel quality indexes, percent fines less than 1.00 mm (PF), geometric mean (GM) and Fredle index (FI) for gravel samples collected 1985 through 1990 at all 13 monitoring sites, Redwood Park Bypass, U.S. Highway 101.

Monitoring Sites	PF						GM						FI					
	85	86	87	88	89	90	85	86	87	88	89	90	85	86	87	88	89	90
Prairie Creek Unit																		
Pr Cr above Brown Cr	30	50	32	11	24	83	16	43	48	13	17	48	29	67	65	20	28	59
Pr Cr above Boyes Cr	32	17	27	29	18	25	23	17	11	24	18	29	40	30	24	42	32	38
Pr Cr below Boyes Cr	33	47	34	41	44	28	34	22	23	23	42	33	62	34	46	35	75	40
Pr Cr above May Cr	55	26	36	46	37	26	49	18	27	36	44	26	69	25	41	43	58	31
Pr Cr below May Cr	44	29	50	31	70	17	40	27	45	19	49	24	50	42	66	29	56	30
Pr Cr below Channel.	67	39	28	31	33	16	41	42	24	26	28	22	56	25	27	26	24	12
Prairie Creek Tributary Unit																		
Lost Man Creek	81	27	11	20	51	20	55	19	12	18	44	31	92	30	21	31	80	49
Brown Creek	20	27	15	20	21	30	17	28	10	20	22	26	29	38	20	32	36	41
Boyes Creek	21	23	18	22	22	31	20	32	18	29	20	28	34	58	34	51	31	42
May Creek	26	07	13	28	28	57	27	17	19	28	27	42	42	19	23	34	41	60
Klamath River Tributary Unit																		
Tarup Creek	37	20	46	16	14	61	37	26	21	28	17	44	73	34	32	49	29	62
North Fork Ah Pah Cr	36	21	65	29	23	65	39	26	38	20	29	50	48	38	53	30	43	65
McGarvey Creek	29	30	33	15	37	61	23	30	29	20	73	54	37	55	40	20	78	59

Stratification of Fines. In the Prairie Creek unit, fine sediment significantly changed with depth ($P < 0.05$) in at least one year for all sites except PBCH (Table 12). When there was a significant change, deeper strata had higher fines. The PABR control site did not show this stratification until 1988. PAMY, PBMV, and PBCH did not show any significant stratification most years.

In the Prairie Creek tributary unit, only in 1985 and 1991 did fines not significantly increase with depth in LM. Brown had results similar to the LM control site. However, Boyes Creek did not show this stratification most years.

In the Klamath River tributary unit, only in 1991 did fines not significantly increase with depth in the Tarup control site. AP showed significant stratification after 1988. In contrast, MG only sporadically showed significant stratification.

Table 12. Significance level of one-way ANOVA (or Kruskal-Wallis when required), which tested for differences between four gravel subsamples of consecutive 4-inch depths. For each subsample, $n = 6$. * = $P < 0.05$. - = $P \geq 0.05$.

Site	1985	1986	1987	1988	1989	1990	1991	1992
PABR	-	-	-	*	*	*	-	*
PABY	-	*	*	*	-	-	*	*
PBBY	*	*	*	-	*	*	*	-
PAMY	-	*	-	-	-	-	-	*
PBMY	-	-	-	-	*	*	-	-
PBCH	-	-	-	-	-	-	-	-
Lost Man	-	*	*	*	*	*	-	*
Brown	-	*	*	*	*	*	-	-
Boyes	-	-	*	-	-	-	-	*
May	-	*	-	-	*	*	-	*
Tarup	*	*	*	*	*	*	-	*
Ah Pah	-	-	-	*	*	*	*	*
McGarvey	-	*	-	*	-	-	*	-

These data show that fines increased, and geometric mean and fredle index correspondingly decreased over time at most Prairie Creek sites, including the control site. The control site was impacted by the bypass, also, however, during the October 1989 storm. For that reason, it was not a very effective control site after 1989 (Meyer 1994). In fact, decreases at that site began right after the 1989 storm. The Lost Man Creek control site was not affected by the bypass at any time, and it did not change over time, nor did Boyes or Brown Creeks. Thus, over 8 years, gravel quality tended to degrade a small amount in the Prairie Creek mainstem, but not in the tributaries, except May Creek. May Creek increased in fine sediment, whereas the control stream did not over the 8 years. This suggests the bypass was responsible for the degradation in May Creek.

The Klamath tributaries gained fine sediment, but, because Tarup Creek also gained sediment, and even degraded more than the affected tributaries, it is unlikely the bypass was responsible for the major part of the degradation. McGarvey Creek, in particular, already had such low gravel quality, its rate of degradation was much lower than the control stream. However, the bypass probably contributed additional surface sediment to the affected sites, as was discussed

earlier. It is unknown what activities were occurring on Tarup Creek over the monitoring period that might have contributed to its gravel quality degradation.

The degradation was close to being significantly different from the control site only on PAMY. This site degraded before the October 1989 storm, whereas the control site and other upstream sites degraded after the storm. This result supports that Boyes Creek was delivering sediment from the bypass to downstream sites around 1988, a conclusion drawn earlier in this report from evaluating changes in surface fines (although sediment sources other than the bypass are possible). Unfortunately, because the control site for the Prairie Creek unit was impacted by the bypass in 1989, it is difficult to establish that the bypass and not a regional effect such as drought, increased fines and degraded gravel quality after the October 1989 storm. However, the other control site in the Prairie Creek basin, Lost Man Creek did not change, which suggests the bypass may have been responsible. Means of fine sediment for pre- and post-storm data indicate that the storm tended to increase subsurface fine sediment in the Prairie Creek mainstem (Meyer 1994).

When freeze-core probes are pounded into the gravel, silt or clays may go in suspension and be lost from the sample. Also, most of these sized particles do not settle out in 45 minutes in the Imhoff cones. The long-term freeze-core data may underrepresent silt, the main size class observed during the October 1989 storm (RNP 1991). The freeze-core data may be documenting trends in sand more than silt. The finding that subsurface fines did not increase on Boyes or Brown Creeks using freeze-cores after the October storm may be more influenced by the declining sand trend discussed in the previous section rather than the increasing silt trend. Also, whereas the Prairie Creek mainstem had 6 monitoring sites, the tributaries only had 1 site. Changes throughout a tributary may have been missed if the site happened to not be representative of average stream conditions. This is particularly a problem in Lost Man Creek, which is the only control stream left to compare to Prairie Creek mainstem and tributary sites. Thus, conclusions that the bypass is responsible are tentative at best.

May Creek, PBMV, PBCH, AP, and MG already had higher levels of fine sediment than the control streams at the beginning of the bypass project, and these were the sites that had higher fines than the control sites over the monitoring period. They also had less stratification in fines than other sites. A natural stream usually has developed good stratification (PABR was an exception for some reason). Apparently, past logging activities had already affected these sites more than the past logging had affected Tarup and Lost Man Creek sites. (PABR has not been affected by logging, and its degradation is probably from the bypass and drought). Stream gradient and geology did not seem to make as large a difference. The Klamath tributaries declined in gravel quality, but, because Tarup Creek also declined, it is unlikely this was due to the bypass.

Predicted Salmonid Egg Survival. Due to the naturally high variation in the geometric mean and fredle index, confidence intervals for predicted egg survival were generally very wide. As a result, 95% confidence intervals for coho salmon egg survival in the first 3 years overlapped with the later years at all monitoring sites (Appendix F). Thus, significant changes were difficult to identify; however, increasing or decreasing trends in means (Tables 13, 14 and 15) over the 8 years are mentioned below.

Table 13. Predicted egg survival-to-emergence (%) for Coho salmon in Highway 101 bypass stream monitoring sites in the Prairie Creek and Klamath River watersheds, Redwood National Park, California.

STREAM	1985	1986	1987	1988	1989	1990	1991	1992
Prairie Above Brown	93.3	92.0	94.0	82.6	95.0	74.5	76.0	67.3
Prairie Above Boyes	95.0	95.0	95.0	95.0	95.0	91.9	95.0	94.8
Prairie Below Boyes	95.0	95.0	95.0	90.4	95.0	74.8	84.5	82.7
Prairie Above May	95.0	87.6	95.0	85.1	68.2	70.5	75.0	84.7
Prairie Below May	82.5	71.8	82.9	83.8	62.0	59.3	54.3	53.1
Prairie Below Channelization	81.9	70.7	68.4	73.9	76.8	71.9	51.8	67.7
Lost Man	95.0	83.8	84.9	95.0	95.0	95.0	74.8	84.3
Brown	79.2	89.7	95.0	95.0	94.7	87.5	85.4	83.5
Boyes	92.6	84.9	89.5	80.8	89.1	71.4	81.2	83.6
May	50.5	62.9	62.6	62.7	65.5	60.7	41.8	25.7
Ah Pah	79.5	71.4	76.5	74.9	95.0	67.1	65.7	61.2
Tarup	95.0	83.3	91.6	95.0	94.1	81.7	68.2	72.1
McGarvey	46.8	58.3	56.8	47.3	43.0	34.9	33.8	34.4

Table 14. Predicted egg survival-to-emergence (%) for Chinook salmon in Highway 101 bypass stream monitoring sites in the Prairie Creek and Klamath River watersheds, Redwood National Park, California.

STREAM	1985	1986	1987	1988	1989	1990	1991	1992
Prairie Above Brown	87.8	83.1	85.5	76.0	88.4	67.8	74.3	57.5
Prairie Above Boyes	95.0	91.8	95.0	93.4	91.7	86.5	90.3	87.1
Prairie Below Boyes	95.0	91.0	95.0	84.5	95.0	68.1	84.0	75.5
Prairie Above May	88.1	78.3	88.2	72.5	48.0	49.3	64.1	74.3
Prairie Below May	65.6	61.6	68.8	71.4	37.6	34.1	27.2	23.6
Prairie Below Channelization	66.0	48.7	48.4	50.4	54.6	45.0	22.7	41.6
Lost Man	86.3	77.6	80.4	90.8	88.3	90.8	74.1	79.1
Brown	71.9	80.4	89.9	94.1	87.4	86.4	85.5	82.6
Boyes	85.9	76.3	83.3	72.7	83.3	66.4	83.0	81.8
May	25.9	36.5	36.0	34.3	45.7	30.4	16.4	7.4
Ah Pah	72.3	58.0	63.4	65.3	75.1	56.2	50.4	47.1
Tarup	90.8	71.5	85.0	95.0	86.8	76.5	53.7	61.1
McGarvey	20.4	34.4	27.3	22.1	12.9	8.4	11.1	9.3

Table 15. Predicted egg survival-to-emergence (%) for Steelhead trout in Highway 101 bypass stream monitoring sites in the Prairie Creek and Klamath River watersheds, Redwood National Park, California.

STREAM	1985	1986	1987	1988	1989	1990	1991	1992
Prairie Above Brown	95.0	95.0	95.0	95.0	95.0	90.0	91.6	82.4
Prairie Above Boyes	95.0	95.0	95.0	95.0	95.0	95.0	95.0	95.0
Prairie Below Boyes	95.0	95.0	95.0	95.0	95.0	90.3	95.0	95.0
Prairie Above May	95.0	95.0	95.0	95.0	83.4	85.9	90.5	95.0
Prairie Below May	95.0	87.2	95.0	95.0	77.0	74.1	68.8	67.6
Prairie Below Channelization	95.0	86.1	83.6	89.4	92.4	45.0	66.3	82.9
Lost Man	95.0	95.0	95.0	95.0	95.0	95.0	90.3	95.0
Brown	94.9	95.0	95.0	95.0	95.0	95.0	95.0	95.0
Boyes	95.0	95.0	95.0	95.0	95.0	86.7	95.0	95.0
May	64.9	77.9	77.6	77.6	80.5	75.6	55.6	39.0
Ah Pah	95.0	86.7	92.1	90.5	95.0	82.2	80.8	76.1
Tarup	95.0	95.0	95.0	95.0	95.0	95.0	83.4	87.5
McGarvey	61.0	73.0	71.5	61.5	57.1	48.6	47.4	48.1

Based on geometric mean and egg diameter, predicted chinook salmon egg survival-to-emergence tended to decrease over time on all Prairie Creek Unit sites (including the control site), particularly after 1988 in PAMY and PBMV, and after 1989 in the rest of the sites. Based on the fredle index, predicted coho salmon egg survival-to-emergence also tended to decrease over time, except at PABV and PBCH. Based on the fredle index, steelhead trout egg survival tended to decrease only at PBMV (after 1988) and somewhat at PBCH (after 1989).

Predicted survival for all three species was highest in PABV and decreased from that point on downstream in Prairie Creek. PABR values fell between PBMV and PAMY.

Predicted coho salmon egg survival means dropped in PBMV by about 15%, 10% in PAMY, 45% in PBMV, and 15% in PBCH. They also dropped in PABR by about 30% and did not change much in PABV. Predicted chinook egg survival means dropped in PBMV about 20%, PAMY by about 20%, PBMV by about 65%, and PBCH by about 30%. They dropped about 35% in PABR and 10% in

PABY. Predicted steelhead egg survival stayed about the same in PABY, PBBY, and PAMY, but decreased 30% in PBMV and about 15% in PBCH. On average the change was more than the 14% predicted in the EIS for all three species. These predicted decreases were greater than Lost Man Creek's (see below), and could possibly be due to the bypass.

The only large change in the Prairie Creek tributary unit was that predicted chinook salmon, coho salmon, and steelhead trout egg survival tended to decrease in May Creek after 1990. Predicted survival values were similar between Lost Man and Brown Creeks. May Creek had the lowest values. Predicted egg survival dropped by over 50% for coho salmon, 75% for chinook salmon, and 40% for steelhead trout in May Creek over the 8-year period. It dropped by over 10% for coho salmon, 5% for chinook salmon, and stayed about the same for steelhead in Boyes Creek. In Brown Creek, it did not change much, as was predicted. In Lost Man Creek, it dropped about 10% for coho salmon, 10% for chinook salmon, and stayed about the same for steelhead trout. May Creek decreased a little less than predicted in the EIS for coho salmon and steelhead trout, and Boyes Creek decreased less than the 25% to 45% predicted in the EIS for the three species. Only May Creek spawning habitat decreased more than the control stream, so predicted decreases in Boyes Creek can not necessarily be attributed to the bypass.

In the Klamath Tributary Unit, egg survival-to-hatching values for all creeks in this unit tended to decrease in the last 3 monitored years (1990-1992) for all three species, except for coho salmon in Tarup Creek, which remained high until 1991. Tarup Creek had the highest predicted survival; McGarvey Creek had the lowest values. Predicted steelhead trout survival dropped by about 20% in AP, 30% in MG, and 10% in TC. Predicted chinook survival dropped about 30% in AP, 55% in MG, and 30% in TC. Predicted coho survival dropped about 20% in AP, 30% in MG, and 25% in TC. These were all substantially less than predicted losses in the EIS, which ranged from 60 to 90% for MG, and 40 to 70% for AP. Also, changes in the affected creeks were not significantly different than Tarup Creek, so the predicted decreases can not be solely attributed to the bypass.

Predicted coho salmon egg survival values were considerably higher than actual egg survival values measured in Prairie Creek from Water Year 1991 to Water Year 1993 (Meyer 1994). Actual Coho Salmon survival means in affected Prairie Creek reaches were 7% in WY91, 44% in WY92 and 41% in WY93. Actual eyed steelhead egg survival in Water Year 1990 for fertilized eggs was no more than 60%. Using the same predictive models for artificial redds post-incubation period (which always had higher fredle indices than summer riffle crests), egg survival would have been predicted to be 95% on Prairie Creek in Water Year 1992. The actual mean was well below the 95% confidence intervals. Unfortunately, actual egg survival data for Prairie Creek and Klamath River tributaries are lacking, except Lost Man Creek. Lost Man Creek egg survival values were between 20% and 30%, rather than the predicted 70% to 90% (and well outside predicted 95% confidence intervals). The predictive models should not be relied upon.

The predictive equations do not consider the interactions of worms, gravel framework, timing of storms, and other factors found to be important in determining egg survival (Meyer 1994). The analysis of egg survival and juvenile fish data in Meyer (1994) suggested the bypass, specifically

the October 1989 sedimentation event, was responsible for decreasing egg survival to very low levels in Prairie Creek mainstem in WY90 and WY91 (much lower than the above predicted values), but improved in WY92, when worms were scarce and stream flows were low. WY93 had higher flows; they mainly adversely affected a PBBY site that received high fines in its redd and had worms. Fish production approached pre-bypass levels by WY94, which was a low flow year. Thus, although egg survival was reduced, the extent of the degradation is variable year to year, depending on factors like worm abundance and size of flows. Studies and mitigation needs are recommended in Meyer (1994) to help offset losses and gage recovery of the Prairie Creek spawning gravels.

Fine sediment infiltration into redds from WY90 to WY92 was much higher in Brown Creek than Prairie Creek, suggesting egg survival was probably also reduced below the predicted values in affected Prairie Creek tributaries in the early 1990's. However, without actual egg survival data, we can not conclude that the bypass had an adverse effect on egg survival in Brown or Boyes Creek based on the gravel quality data. The increase in surface silt on Boyes, Brown, McGarvey, and Ah Pah Creeks may have been from the bypass since silt increased little on the unimpacted control streams from 1985 to 1991. As mentioned previously, silt is difficult to measure in the subsurface gravels; if it was present in substantial amounts, it may have decreased egg survival.

AQUATIC LIFE

Juvenile Salmonid Surveys. Abundance and composition of juvenile salmonid fish was estimated during the autumn in May and Godwood (control) monitoring sites (Table 16). In May Creek, numbers increased from 1985 to 1986 and then decreased in 1987 and again in 1991. In contrast, Godwood numbers remained the same from 1985 to 1987 and then dropped in 1991. Coho salmon dominated in May Creek some years and steelhead dominated or were about equal in other years. Coho salmon numbers in May Creek decreased over time, particularly following the October 1989 storm, but Godwood Creek salmon remained about the same. Steelhead trout, on the other hand, decreased in the control as well as the affected site after the 1989 storm. Steelhead dominated in Godwood Creek until 1991, when their numbers dropped off. Numbers actually dropped off before 1991 because steelhead trout were in low numbers in Godwood Creek in 1990 (Farro 1990). Although a population estimate was not conducted at the May Creek site in 1990, electrofishing in this section in May 1990 showed coho salmon young-of-the-year were scarce. Steelhead trout were fairly scarce, also, but these trout were scarce back in 1985 in this creek. Cutthroat trout were few in number, particularly in 1991 in both creeks. Older cutthroat trout (not young-of-the-year) were in fair numbers in lower May Creek during the electrofishing in May 1990. In general, average fork lengths were similar between the two sites.

These data and downstream migrant trapping and spawning data analyzed in Meyer (1994) suggested coho and chinook salmon production was adversely affected by the October 1989 storm in 1990 and 1991. The data do not support that steelhead trout were adversely affected.

Aquatic Macroinvertebrates

Table 16. Abundance and composition of juvenile fish estimated for 30 meter (100 ft) sections of May and Godwood Creeks, U.S. Highway 101 bypass, September 10, 1985, August 22, 1986, September 3, 1987, and October 17, 1991.

	<u>MAY CREEK</u>				<u>GODWOOD CREEK</u>			
	<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1991</u>	<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1991</u>
Total Estimate	51	69	28	7	40	44	46	14
95% C. I.	2	4	2	1	3	8	4	1
<u>Coho Salmon</u>								
Subtotal Estimate	44	10	13	4	3	8	4	9
Fork Length (cm)								
Average	5.8	6.5	5.3	7.6	5.5	6.4	6.1	7.1
Range	5.0-7.0	5.6-7.6	3.9-7.3	5.8-9.0	4.5-8.5	4.8-8.4	5.4-7.1	6.1-8.3
<u>Steelhead Trout</u>								
Subtotal Estimate	4	58	15	3	12	23	31	5
Fork Length (cm)								
Average	7.8	4.6	3.9	7.9	6.4	4.7	5.1	7.1
Range	7.0-8.5	3.2-6.4	3.0-6.0	5.2-10.8	5.5-9.0	3.5-5.6	3.5-8.7	6.1-9.0
<u>Cutthroat Trout</u>								
Subtotal Estimate	3	1	0	0	2	1	3	0
Fork Length (cm)								
Average	7.8	10.7	N/A	N/A	7.8	7.9	7.5	N/A
Range	6.0-9.5	10.7	N/A	N/A	5.5-10.0	7.9	5.4-11.0	N/A

Diversity, Richness, Biomass, and Abundance in 1985 and 1987. For all bypass-affected monitoring sites, average macroinvertebrate biomass, diversity index, number of individuals, and number of taxa (richness) were calculated for 1985 and 1987 and statistically compared using a two-way ANOVA to the control site, PABR (Appendix G). Significance levels reported for tests having significant interactions are from Scheffe's post-hoc comparison test. For sites lacking comparable samples between years or between the control and affected site (needed for a two-way ANOVA), one-way ANOVA's were performed on data that were comparable (Appendix G). Species lists and abundance for each site by season and habitat are on file in the RNP Arcata office.

In general, biomass, number of individuals and number of taxa significantly increased in autumn riffles between 1985 and 1987 in the Prairie Creek Unit. In the autumn, 1987 sampling was one month earlier than 1985 sampling in this unit, meaning more larval invertebrates may have hatched and left in 1985 than in 1987. In support of this, data collected in 1980 and 1981 (RNP 1986)

show number of individuals and taxa decreased from October to November in this unit. In combination with the control site in a 2-way ANOVA, PBCH increased in number of individuals and PBCH and PAMY increased in number of in summer riffles. In PBMV number of individuals in autumn pools increased, whereas number of individuals decreased in summer pools in PABY from 1985 to 1987.

The number of taxa in summer pools in PABY showed a significant decrease between 1985 and 1987, while PABR did not significantly change. However, the average of both years was greater in PABY than PABR.

For the combined years, the PABR control site, had similar or better diversity and similar or fewer individuals than the affected sites. Number of taxa was similar except PBCH, which had fewer taxa than PABR. Biomass was similar between control and affected sites.

Using 1987 results from one-way ANOVA only, PBBY had greater or the same biomass as the control site, and less or the same amount of diversity.

In the Prairie Creek Tributary Unit, the index variables generally did not significantly change from 1985 to 1987 in this unit. Only May Creek showed a potential adverse effect of the bypass from 1985 to 1987. Number of individuals in summer riffles on May Creek significantly declined from 1985 to 1987 while PABR did not significantly change. The only other significant changes were in the autumn at Brown and Boyes Creek. In combination with the PABR control site in a 2-way ANOVA, Brown Creek increased in number of taxa in autumn riffles, and Boyes Creek increased in biomass in autumn riffles and decreased in autumn pools.

For the combined two years, the PABR control site macroinvertebrates were more diverse (compared to some riffles on Boyes and May) or similar to affected sites; biomass and number of individuals and taxa were less or similar to Boyes Creek; number of taxa were less or similar to May Creek; biomass and number of individuals were similar to May Creek. On Brown Creek, summer riffles had fewer numbers of taxa and individuals than the control site, and biomass was similar.

Using one-way ANOVA results for 1987 data only, the LM control site for the tributaries was less diverse (compared to some summer sites on Brown and May) or similar to the 3 affected tributary sites. Biomass for LM was less or similar when compared to Boyes and May Creek, but biomass was greater than Brown Creek. More or similar numbers of individuals and taxa were found in Lost Man Creek than in the tributary sites.

In the Klamath River Tributary Unit, only autumn riffles had a complete data set for two-way ANOVAs. No significant changes were detected except that number of individuals declined from 1985 to 1987 at MG, but this also occurred at the control site. No adverse changes due to the bypass were found between 1985 and 1987; however, control data needed to determine effects were only available for autumn riffles.

Using one-way ANOVA results, diversity index of summer pools and number of individuals in autumn pools declined over time in AP. Number of taxa in autumn pools declined in McGarvey Creek.

Diversity index and number of taxa were higher on the control site, TC, than McGarvey at summer riffles (1987 only) and similar at autumn riffles (1985 and 1987 combined). Values at autumn riffles in AP were similar to TC, also.

For all units, only 2 of 108 macroinvertebrate variables tested using two-way ANOVA showed any change between 1985 and 1987 that could be connected to the bypass. Because the confidence level was set at 95%, 5 of 100 results accepted as significant may be in error, meaning the two significant results may likely be random error.

Diversity Index Comparison. In 1985 and 1987, all riffles except at PBMV, PBCH, and MG had diversity indices greater than 3.0 in all seasons and both years. a summer riffle on PBMV degraded from 3.0 in 1985 to 2.7 in 1987; its autumn riffles averaged 2.8 both years. PBCH was borderline, having a diversity index of 2.9 in both years at autumn riffles, but exceeded 3.0 at summer riffles. Between 1985 and 1987, McGarvey dropped from 3.8 to 2.6 on summer riffles and from 3.3 to 2.9 on autumn riffles.

Pools were less diverse than riffles. Values averaged over both years for pools were moderate for all sites except PBCH and AP. On PBCH, the mean for summer pools dropped from 2.2 in 1985 to 0.9 in 1987 and from 1.4 to 0.5 on AP. Thus, during the summer, pool habitat for these sites was likely poor for invertebrates.

In general, diversity indices, number of individuals, and number of taxa were lower in 1980 and 1981 samples than in 1985 and 1987 samples. This was likely due to use of artificial substrate samplers instead of PIBS. The former method requires time for bugs to colonize, the latter removes existing fauna from the substrate surface.

Functional Groups in 1985 and 1987. Percent composition of total number of individuals and biomass for each functional group were calculated for each sample and averaged for each site by season and habitat type (Appendix G). Standard errors were calculated for these data. Percentages in each functional group were also calculated when all the data for one site were combined. Although this latter method did not allow calculation of standard errors, it allowed the functional group percentages to total 100% as long as no species with "unknown" functional group designation was included.

Most changes in composition of functional groups by biomass or individuals were not large enough to be significant (and annual variation is usually high), so statistical tests were not run on these data. In general, in riffles from 1985 to 1987, grazers tended to increase and shredders and predators tended to decrease at lower sites in Prairie Creek and its tributaries (PAMY, PBMV, PBCH, MY), whereas the same or the opposite was true in the control site and upper affected Prairie Creek sites. Results for collectors varied. Between years, collectors tended to decrease in biomass in the summer in the lower sites, but number of individuals tended to increase in some of these sites. In pools, grazers tended to decrease and collectors tended to increase at most sites.

The proportion of grazers to collectors may decrease if algae becomes more abundant as a stream gains more fine sediment carrying nutrients into the stream. In general, the proportion did not decrease from 1985 to 1987 (Appendix G). The decrease in shredders occurred in control sites as well as affected sites, including Lost Man Creek from 1986 to 1987 (1986 data were from Strange (1989)) and on Prairie above Brown Creek from 1985 to 1987, so the change in shredders may not have been due to the bypass.

Macroinvertebrate abundance can vary according to substrate type, stream velocity, depth, temperature, and canopy cover. By removing the effect of these site to site differences, changes over time in macroinvertebrate communities can be more clearly detected. Thus, these variables were measured. Surprisingly, however, correlations between number of individuals and taxa and microhabitat variables using all 6 Prairie Creek sites for fall and summer 1985 and 1987 seasons were low. The strongest predictor of number of individuals was canopy cover in the fall season. The greater the canopy cover, the more macroinvertebrates were present. In autumn 1987, coarser substrates had more taxa, but this did not hold true in autumn 1985 (Table 17).

In a multiple regression, all 5 variables--depth, velocity, temperature, substrate, and canopy cover--accounted for 50%, 51%, and 57% ($= r^2$) of the variability in number of individuals in summer 1987, autumn 1985, and autumn 1987, respectively. These same variables accounted for 35%, 28%, and 86% of the variability in number of taxa in summer 1987, autumn 1985, and autumn 1987, respectively. In summer 1985, when only depth and velocity were sampled, these two variables accounted for 20% of the variability in number of individuals, but had no significant relationship to number of taxa.

Because correlations were not very strong in the mainstem sites, the data for the tributaries were not analyzed, and no adjustments were made to the invertebrate data. Average microhabitat characteristics at riffles at the time of sampling for invertebrates for all Prairie Creek Unit monitoring sites combined are reported in Table 18.

Table 17. Significant ($P < 0.05$) correlations between number of macroinvertebrate individuals or taxa and microhabitat variables sampled on Prairie Creek (data from PABR, PABY, PBBY, PAMY, PBMV, PBCH; $n=30$) in the summer and fall 1987. NS = no significant correlation.

Variable	Summer 1985	Summer 1987	Autumn 1985	Autumn 1987
Number of Individuals				
Velocity	-0.40*	NS	NS	0.45
Depth	NS	-0.39*	NS	NS
Substrate	NS	-0.56***	NS	0.44
Canopy Cover	NS	NS	0.69***	0.44
Number of Taxa				
Velocity	NS	-0.50**	-0.46*	NS
Temperature	NS	NS	NS	-0.45*
Substrate	NS	NS	NS	0.80***

* = $P < 0.05$

** = $P < 0.01$

*** = $P < 0.001$

Companions of 1990 Results to 1985 and 1987. Macroinvertebrate data collected in summer and fall 1990 were analyzed only to the order level. In RNP (1991), data were compared at the order level between summer and early fall results in 1985 and late fall and spring results in 1990. The seasons did not match because data had yet to be collected the following spring and summer in 1990. This report compares the 1990 summer and fall results that were later collected (Appendix G) to equivalent summer and fall results from 1985 and 1987. This order-level analysis gives further insight into the effect of the October 1989 storm on macroinvertebrates, but it is a poor substitute for analyzing and comparing data at the lowest taxonomic unit possible.

Table 18. Stream conditions under which invertebrates were sampled in randomly located riffles on six sites on Prairie Creek, five samples each, N = 30.

SEASON YEAR	MEAN SUBSTRATE CODE	S.D. ^a	MEAN CANOPY COVER (%)	S.D.	MEAN DEPTH (cm)	S.D.	MEAN VELOCITY (ft/sec)	S.D.	MEAN TEMPERATURE (°C)	S.D.	MEAN # TAXA	S.D.	MEAN # INDIVIDUALS	S.D.
SUMMER 1987	5.3 (4.6-5.8) ^b	0.4	21 (2-56)	15	12.7 (8-19)	3.3	1.8 (0-3.5)	0.9	13 (12-14)	0.8	31 (10-44)	7.2	533 (252-1161)	393.6
SUMMER 1985	-	-	-	-	18.1 (11-30)	5.3	1.2 (0.5-1.9)	0.4	-	-	24 (18-32)	3.9	493 (92-1229)	321.8
FALL 1987	5.2 (4.1-5.9)	0.6	32 (6-66)	17	10.3 (6-15)	2.7	1.4 (0.3-2.0)	0.6	14 (12-16)	1.2	37 (23-59)	8.6	1215 (241-2458)	551.4
FALL 1985	5.6 (4.8-6.4)	0.5	24 (2-90)	22	17.8 (10-28)	5.1	1.1 (0.3-2.0)	0.5	10 (9-12)	0.7	24 (15-34)	4.2	337 (99-735)	167.3

^a S.D. = Standard Deviation.

^b Range is in parentheses.

Mean number of individuals after the October 1989 storm on Prairie Creek in 1990 were within the range of means found in 1985 (Figure 8). The control site, PABR, was affected by the October storm and responded similar to the rest of the sites on Prairie Creek. Sharp decreases were not noticeable following the 1989 storm on the Prairie or Klamath tributaries, either, including Lost Man Creek and Tarup Creek (Figures 9 and 10). Variability in number of individuals is very high with coefficients of variation ranging from 0.45 to 0.74 on Prairie Creek, making it difficult to detect changes over time.

Mean diversity indices (based on taxonomic orders) increased over the years on Prairie Creek and Brown and Boyes Creek (Figures 11 and 12). Diversity indices by order were not recalculated for other sites. Mean number of macroinvertebrate orders on Prairie Creek and Brown and Boyes Creeks did not drop below 1985 levels after the October 1989 storm (Figures 13 and 14).

Comparison of Figures 8, 11, 13 and Appendix G to Figures 23 and 24 in RNP (1991) shows that number of individuals, orders, and diversity indices tended to be lower in autumn 1989 following the October sedimentation event than in autumn 1990. However, samples were collected a month later in 1989, and 1980 year round data on Prairie Creek (RNP 1986) showed that numbers tended to decrease over this fall time period. Also, the control reach above Ten Tapo Creek had values similar to downstream affected sites in 1989. Lost Man Creek had a larger, more diverse invertebrate community in its fall pools than the other Prairie Creek tributaries in 1990; otherwise, control sites were not that different from affected sites in 1990 (see Appendix G).

Comparison of composition of orders on Prairie Creek in Fall 1989 (Figure 29 in RNP 1991) to Fall 1990 in Appendix G shows composition in fall riffles did not change much over the year in the control site, but ephemeropterans were not as abundant in 1990 as in 1989 and dipterans were more abundant in 1990 than in 1989. In fact, the composition of orders in affected and control sites in fall 1990 was similar to spring 1990 and summer 1990. This suggests that the October 1989 storm temporarily increased ephemeropterans and decreased dipterans, but the balance switched back by spring of 1990. Usually ephemeropterans are decreased by sediment increases (Cline and Ward 1984).

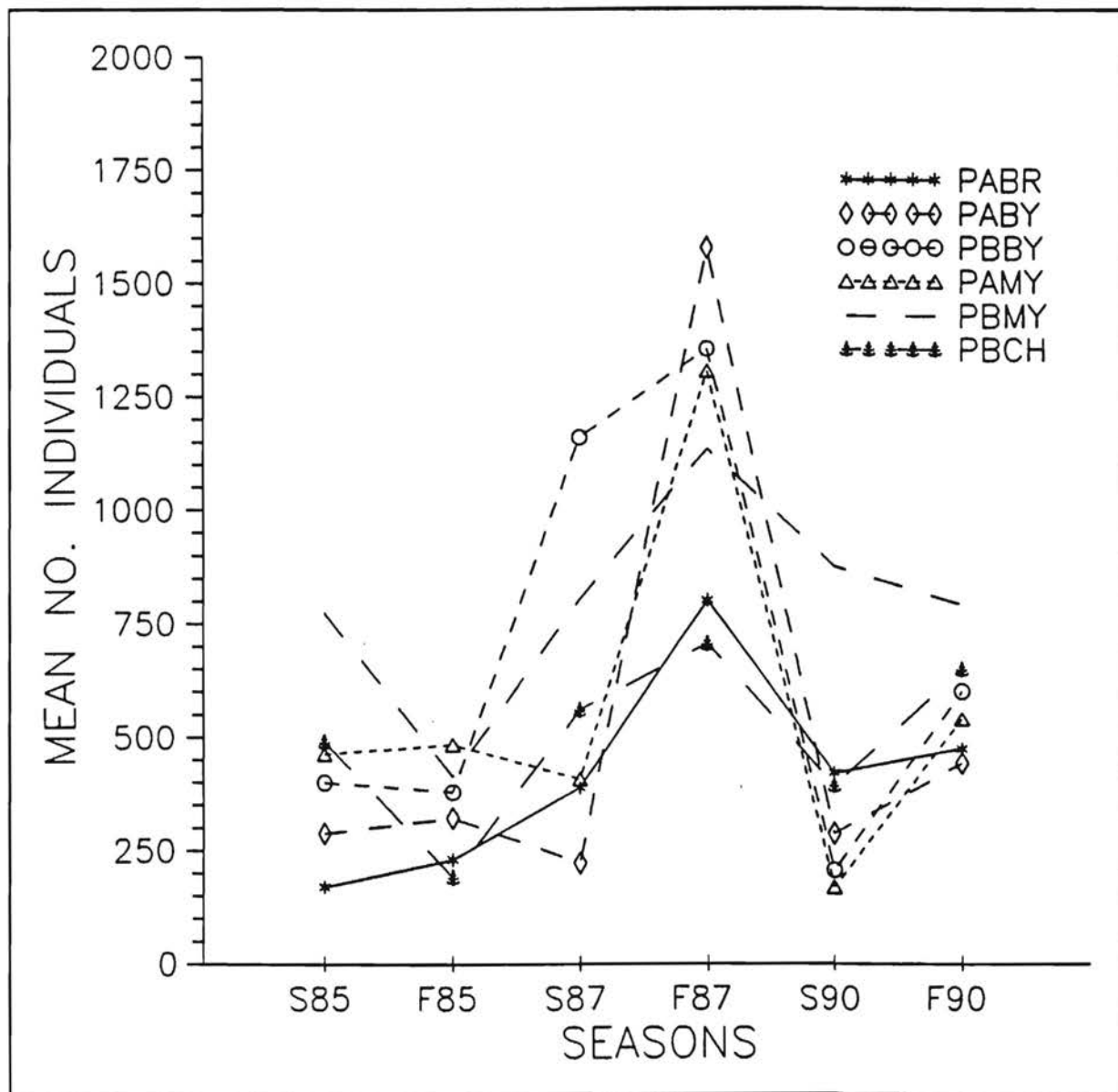


Figure 8. Mean number of macroinvertebrate individuals for summer and fall riffles on Prairie Creek, Northern California. S85 = Summer 1985, F85 = Fall 1985, etc.

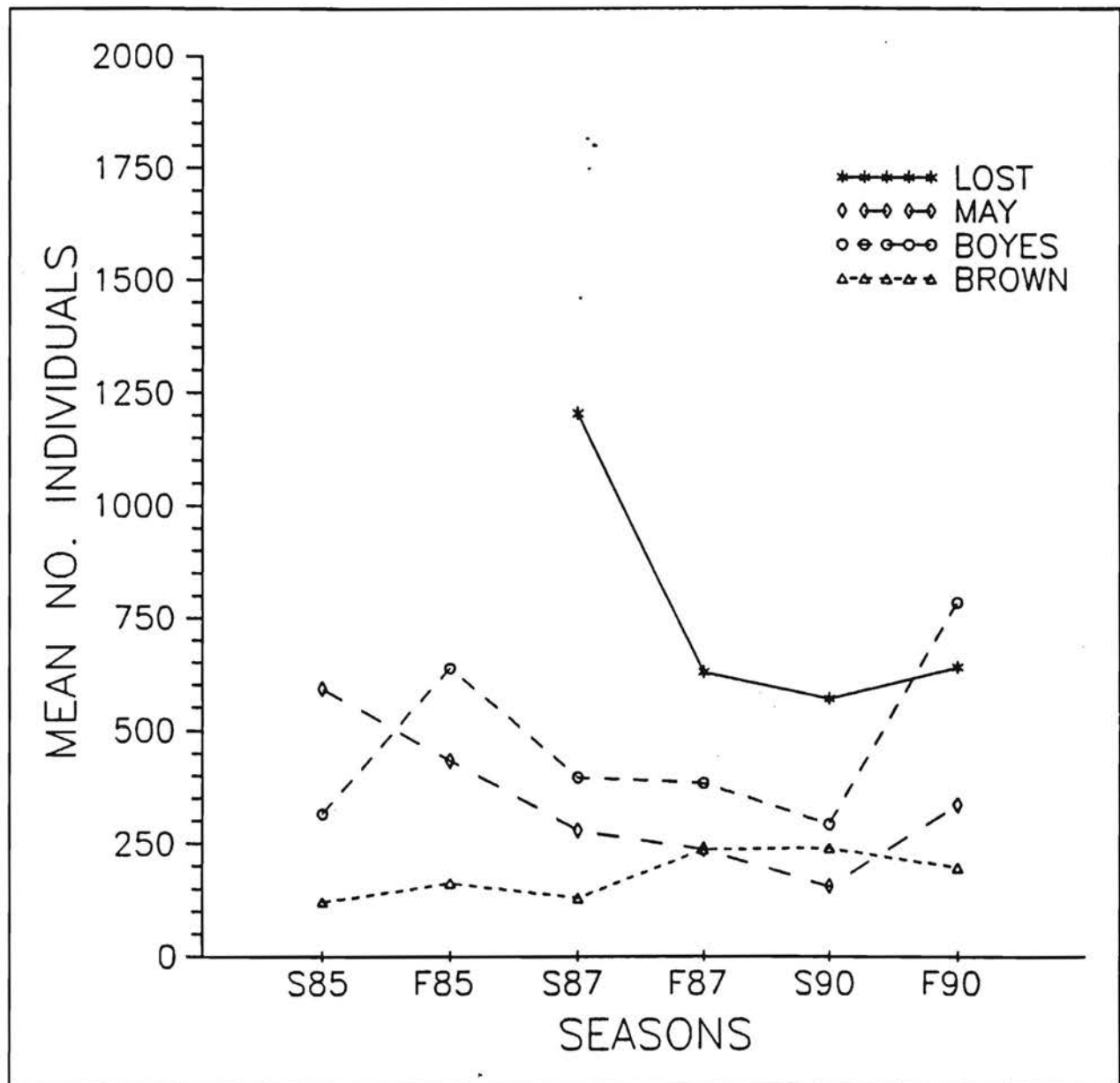


Figure 9. Mean number of macroinvertebrate individuals for summer and fall riffles on Prairie Creek tributaries, Northern California. S85 = Summer 1985, F85 = Fall 1985, etc.

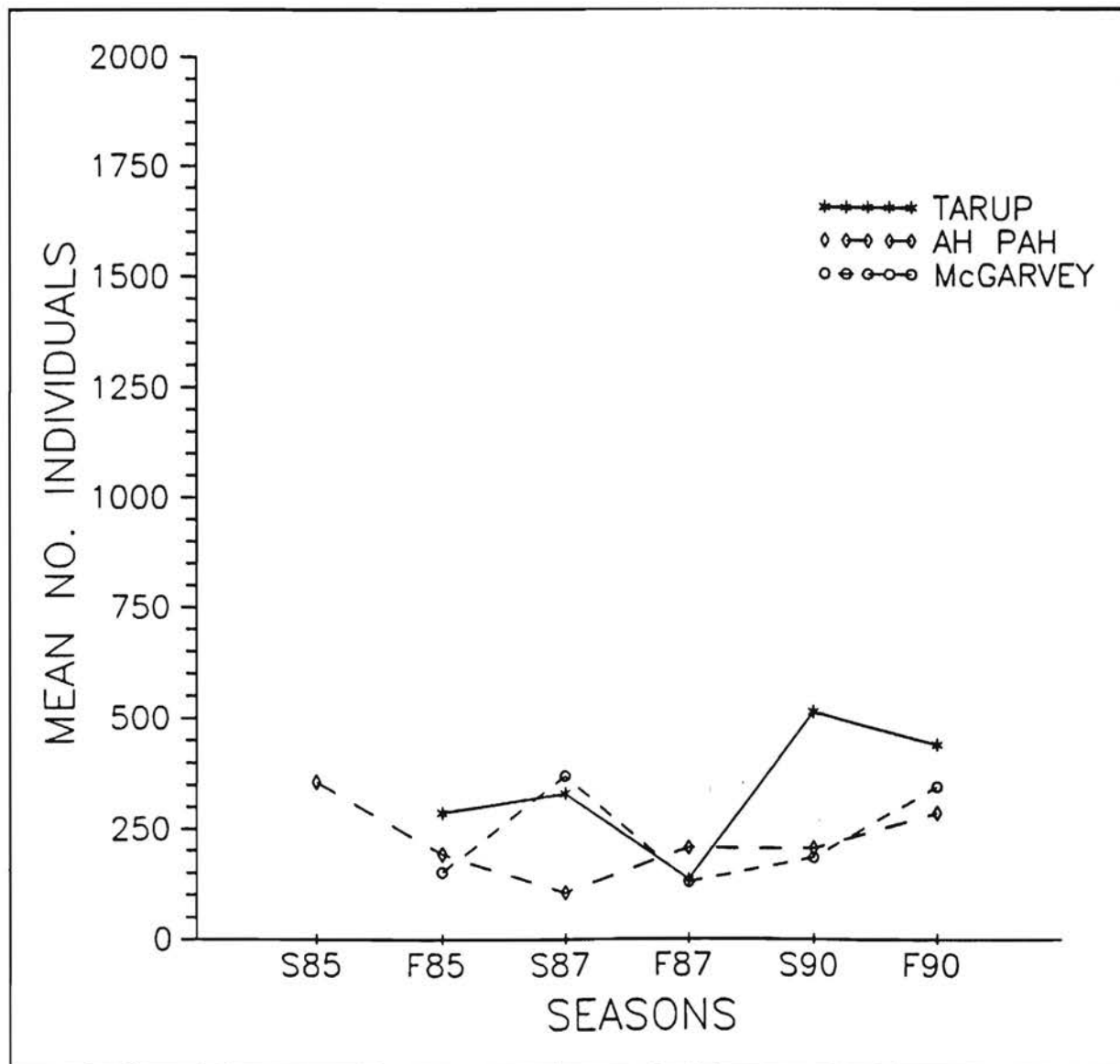


Figure 10. Mean number of macroinvertebrate individuals for summer and fall riffles in Klamath Basin tributaries, Northern California. S85 = Summer 1985, F85 = Fall 1985, etc.

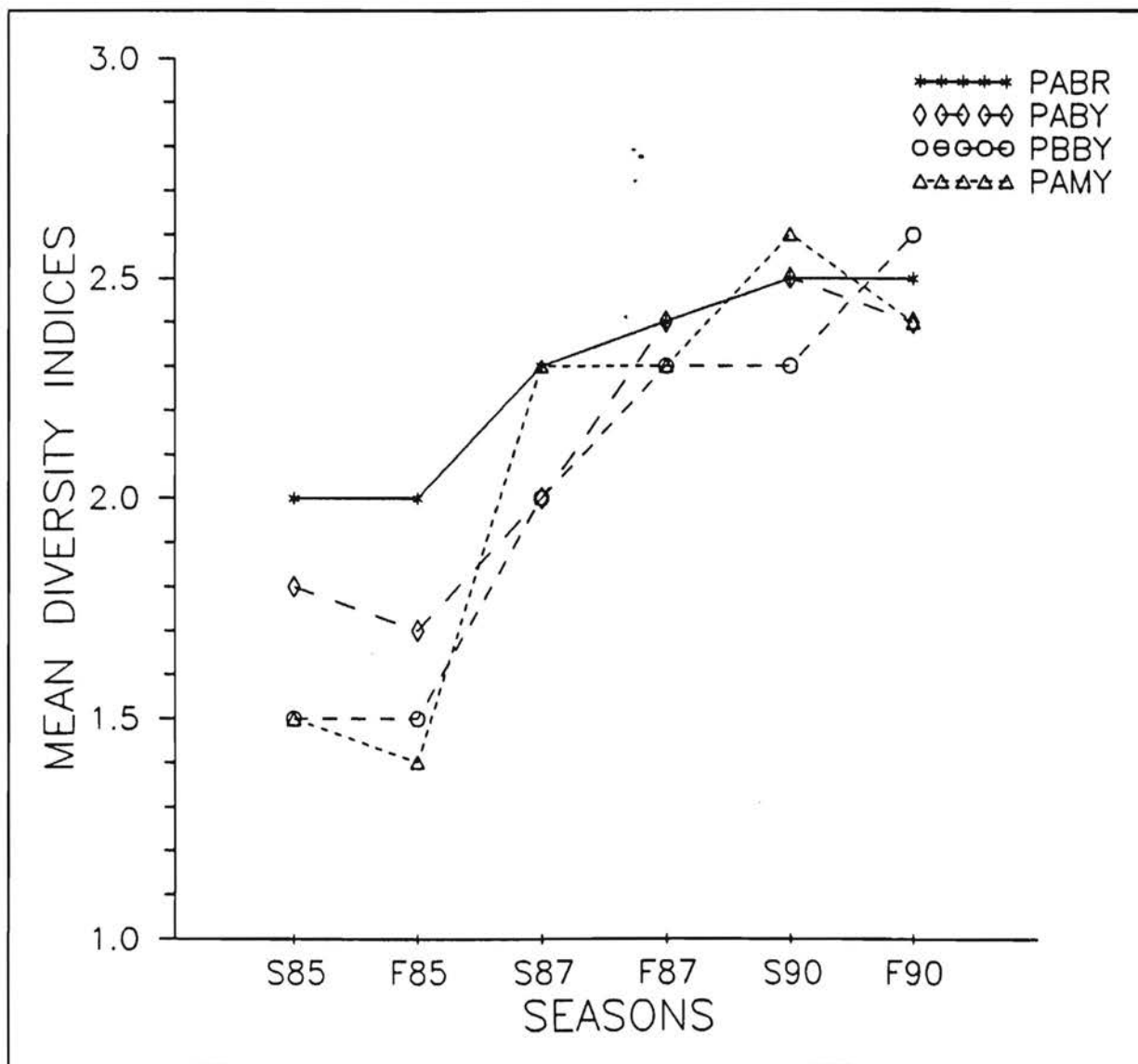


Figure 11. Mean order diversity indices of macroinvertebrates for Prairie Creek summer and fall riffles. S85 = Summer 1985, F85 = Fall 1985, etc.

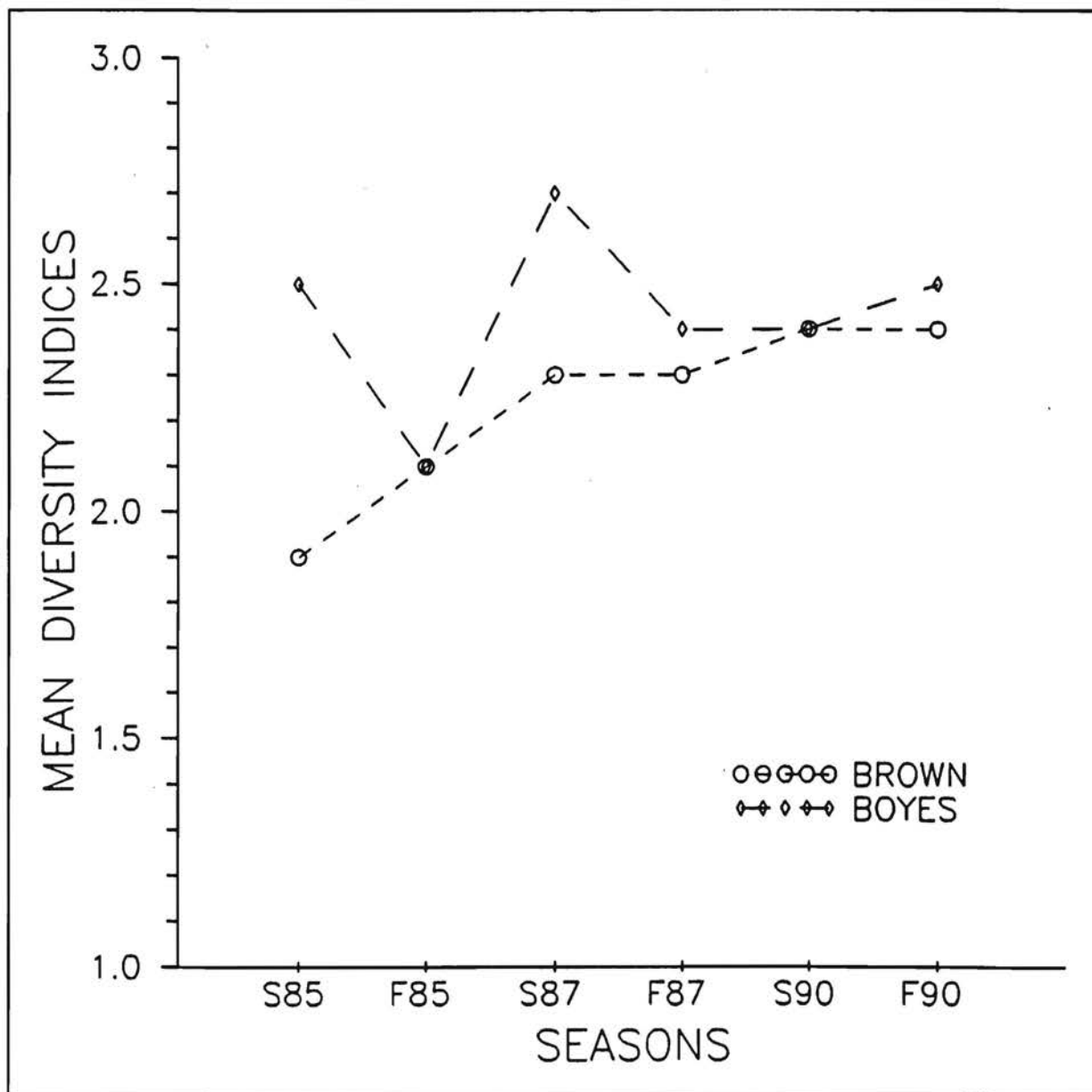


Figure 12. Mean order diversity indices for macroinvertebrates on Brown and Boyes Creek summer and fall riffles. S86 = Summer 1985, F85 = Fall 1985, etc.

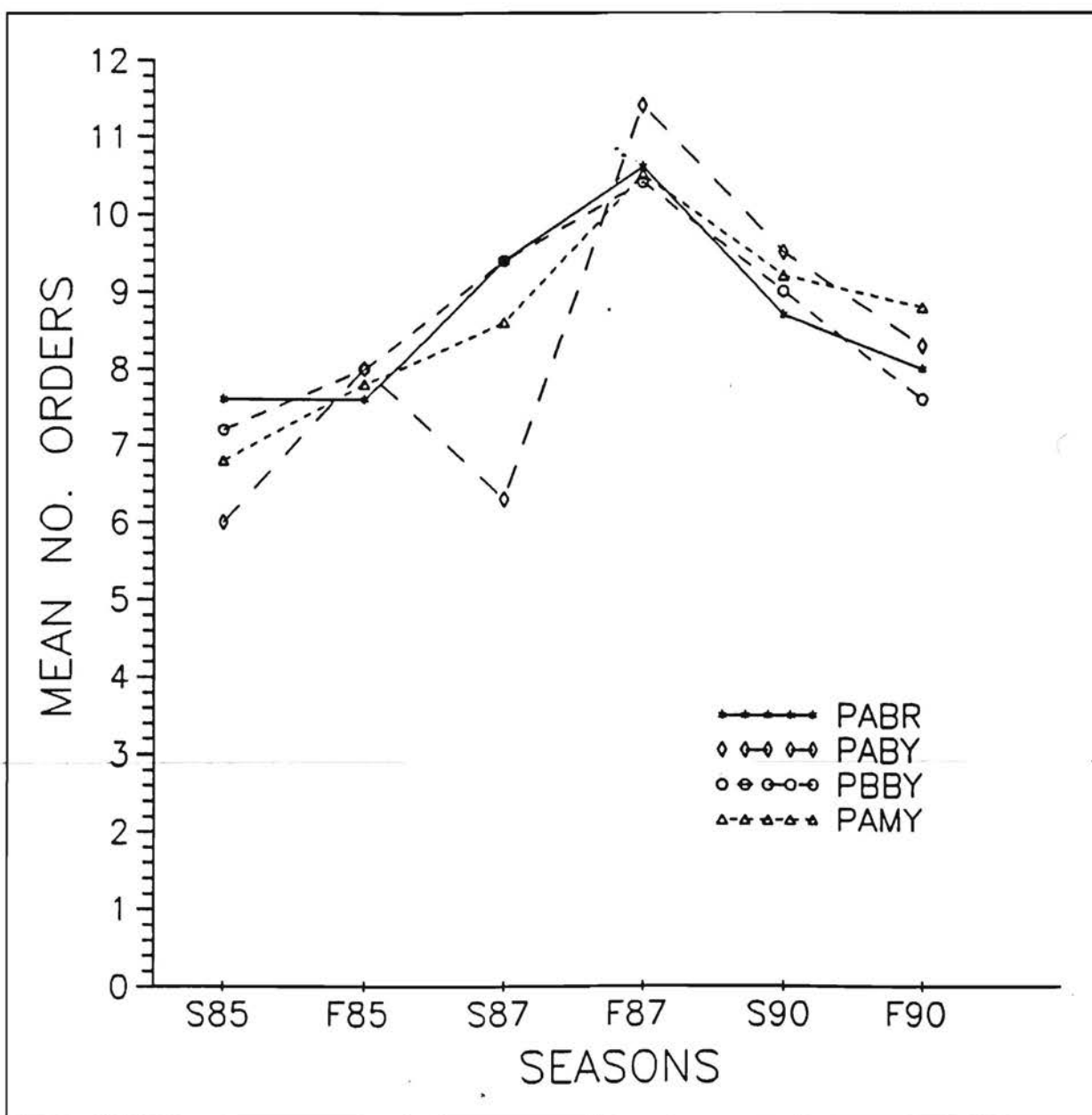


Figure 13. Mean number of macroinvertebrate orders for Prairie Creek summer and fall riffles. S85 = Summer 1985, F85 = Fall 1985, etc.

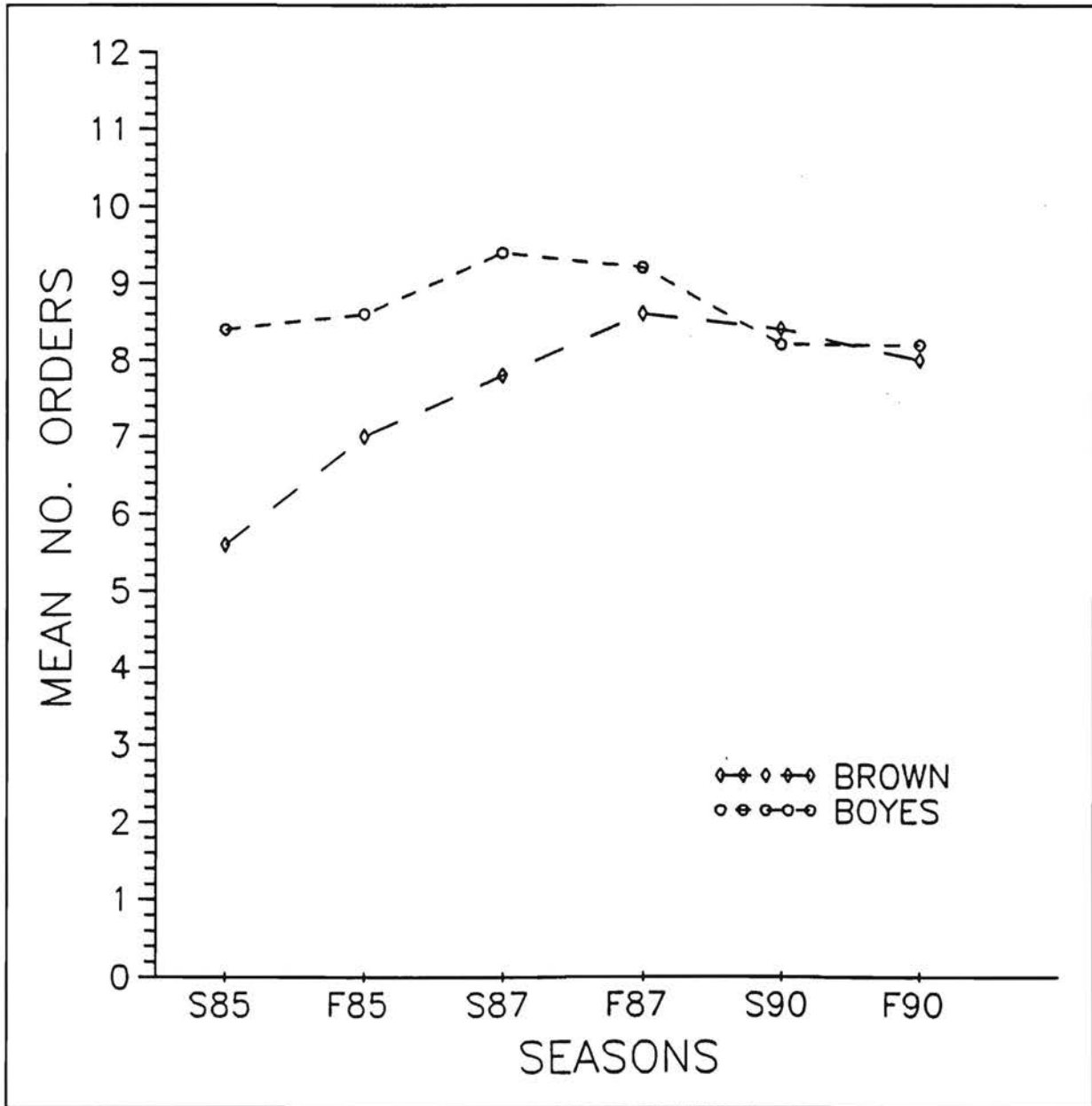


Figure 14. Mean number of macroinvertebrate orders on Brown and Boyes Creek summer and fall riffles. S85 = Summer 1985, F85 = Fall 1985, etc.

In summary, the evidence does not support that macroinvertebrate communities have been adversely affected since bypass construction. Further analysis of 1990 data for changes in genera and families would be required to substantiate this conclusion.

CONCLUSION

Bypass construction from 1985 to 1992 did not change stream morphology, pool volumes, or habitat structure in Prairie Creek reaches upstream of May Creek, in Prairie Creek tributaries, or in Klamath River tributaries. It did decrease pool volume and channel structure immediately below May Creek because of the channelization work. This impacted section was small, relative to the rest of Prairie Creek. Aquatic macroinvertebrates did not appear to be adversely affected by the bypass.

The bypass appeared to degrade gravel quality in the subsurface spawning gravels on Prairie Creek, particularly from below Boyes Creek to below May Creek. Subsurface fines increased on May Creek, also, but not the other Prairie Creek tributaries. Gravel quality degraded on all the Klamath River tributaries, including the control site.

Subsurface measurements did not effectively include sediment as fine as silt, which was difficult to measure. Surface silt was measured on benthic habitat maps, however. Percent of surface benthic substrate covered by silt increased on all sites, but largest increases were on Boyes Creek, on Prairie Creek below Boyes and May Creeks, and on McGarvey Creek. Vegetation encroachment was high on some sites, due to the succession of drought years, which increased conversion of coarser benthic substrates to fine sediment. The control reaches unaffected by the bypass did not substantially show the effect of this drought until 1992, while the affected reaches started showing changes in silt coverage in 1987 in the Klamath tributaries, in 1988 in Prairie Creek, and by 1991 in Brown and May Creeks. The bypass may have been responsible for these early increases. Surface silt more than doubled on lower Prairie Creek and its tributaries and tripled on McGarvey Creek and Ah Pah Creeks, ranging from 22% to 92% coverage of the original benthic surface area. Surface silt was lower on the unaffected control streams. The erosion control measures were not very effective for this fine material, especially in 1989 when they were not in place during the October storm. Noticeable flood events that carried large amounts of sediment down from the bypass were in February 1986 (largely affected Boyes, May, and lower Prairie Creeks) and October 1989 (largely affected Boyes, Brown, May, and Prairie Creeks), but the data show sediment increased during other times, also.

Models of subsurface fine sediment vs. survival predict that egg survival decreased over the eight years on Prairie Creek more than anticipated at the beginning of the project. Egg survival decreased less than anticipated on the Prairie Creek and Klamath tributaries, according to the models. However, actual egg survival from WY91 to WY93 on Prairie Creek and Lost Man Creek was much lower than the models predicted, particularly in WY91 on Prairie Creek, when egg survival was an order of magnitude lower. The predictive models are not useful because of the interaction of fine sediment with worms and the variability in annual peak stream discharge.

Egg survival was the lowest below Boyes Creek where surface silt and redd sedimentation were the highest. The increase in silt combined with worms may have been responsible for the

exceedingly low egg survival on Prairie Creek in WY91 and below Boyes Creek in WY93. Also, the fish that spawned in impacted reaches of the creek immediately following the October 1989 sedimentation event produced few juveniles, even though worms were not very abundant that year. Egg survival improved in WY94.

Infiltration of fines into redds on Brown Creek was twice as high as on Prairie Creek, suggesting egg survival was reduced more than predicted in the Prairie Creek tributaries, also. Juvenile coho salmon decreased over time in one reach in May Creek, but not in a control stream. Steelhead appeared to be less affected by the bypass. The large surface silt increases on the affected Klamath River tributary sites suggest that the bypass contributed to the deterioration of spawning habitat at Ah Pah and McGarvey Creeks, also.

The initial mitigation for bypass impacts was insufficient to offset actual impacts on Prairie Creek and its tributaries, so a hatchbox program was set up on Prairie Creek from WY90 to WY95 to supplement wild fish production. Its continuation is dependent on recovery of the stream conditions (see Meyer (1994) for recommendations). Because large decreases were predicted for the Klamath basin tributaries, the mitigation may have been adequate for short-term losses in that basin. However, long-term fishery losses on all the creeks continues to be an unknown quantity, and should be monitored periodically over time.

LITERATURE CITED

- Bailey, E.H., W.P. Irwin, and D.L. Jones, 1964. Franciscan and related rocks and their significance in the geology of western California. Calif. Div. of Mines and Geology Bull. 183:177 pp.
- Bisson, P.A., J.L. Nielsen, R.A. Palmason, and L.E. Grove, 1982 1981. A system of naming habitat types in small streams with examples of habitat utilization by salmonids during low streamflow. Pages 62-73 in N.B. Armantrout, editor. Proceedings of a symposium, acquisition and utilization of aquatic habitat inventory information. Western Division, American Fisheries Society. Portland, Or.
- Cline, L.D., and J.V. Ward, 1984. Biological and Physiochemical Changes Downstream from Construction of a Subalpine Reservoir, Colorado, USA. Regulated Rivers. pp. 223-243.
- Edmunds, G.F., S.L. Jensen, and L. Berner, 1976. The mayflies of North and Central America. University of Minnesota Press, Minneapolis, Mn. 330 pp.
- Everest, F.H., C.E. McLemore, and J.F. Ward, 1980. An improved tri-tube cryogenic gravel sampler. Res. Note PNW-350. U.S. Forest Service. USDA, Portland, Or. 8 pp.
- Everest, F.H., F.B. Lotspeich, and W.R. Meehan, 1982. New Perspectives on sampling, analysis and interpretation of spawning gravel quality. Pages 325-333 in N.B. Armantrout, editor. Proceedings of a symposium, acquisition and utilization of aquatic habitat inventory information. Western Division, American Fisheries Society. Portland, Or.
- Farro, M. 1990. Trinidad Fisherman's Salmon Enhancement, Prairie Creek Project 1989-1990, Final Report. Pacific Coast Federation of Fisherman's Associations Inc., Trinidad, Ca.
- Harrington, J.M., 1987. Monitoring of Aquatic Impacts Associated with Construction of Redwood Park Bypass, US Highway 101 Summary Report, Redwood National Park, Arcata, Ca. 75 pp.
- Iwatsubo, R.T., K.M. Nolan, D.R. Harden, and G.D. Glysson, 1976. Redwood Creek and Mill Creek drainage basins, Redwood National Park, Humboldt and Del Norte Counties, California. Open-File Report 76-678, US Geological survey, Menlo Park, Ca. 247 pp.
- Janda, R.J., K.M. Nolan, D.R. Harden, and S.M. Colman. 1975. Watershed conditions in the drainage basin of Redwood Creek,

- Bypass, Prairie Creek Redwoods State Park and Redwood National Park. 1990 Progress Report. USDOl, National Park Service, Arcata, Ca. 3 pp + app.
- Redwood National Park, 1991. Monitoring the Impacts and Persistence of Fines in the Prairie Creek Watershed. Progress Report prepared for the Calif. Dept. of Transportation. NPS, Arcata, Ca. 123 pp.
- Redwood National Park, 1993. Davison Riparian Mitigation Project. First Annual Report. National Park Service, Orick, Ca. 35 pp. + app.
- Pennak, R.W., 1978. Fresh-water invertebrates of the United States, 2nd ed. John Wiley and Sons, Inc. New York, NY. 803 pp.
- Shirazi, M.A., and W.K. Seim, 1979. A stream system evaluation - an emphasis on spawning habitat for salmonids. EPA-60013-79-109. U.S. Environ. Prot. Agency. Corvallis, Or. 37 pp.
- Seber, G.A., and E.D. LeCren, 1967. Estimating population parameters from catches large relative to the population. J. Anim. Ecol. 36:631-643.
- Smock, L.A., 1980. Relationships between body size and biomass of aquatic insects. Freshwater Biol. 10:375-383.
- Strand, R.G., 1963. Geologic map of California, Redding sheet, scale 1:250,000. Calif. Div. of Mines and Geol.
- Strange, T.L., 1989. Seasonal Analysis of species diversity and functional group organization of aquatic invertebrates in two coastal streams. Master's thesis. Humboldt State University, Arcata, Ca. 86 pp.
- U.S. Department of Transportation, U.S. Department of the Interior, and California Department of Transportation, 1984. Final Environmental Impact Statement, US 101 Bypass, Prairie Creek Redwoods State Park. 191 pp.
- Usinger, R.J., editor, 1956. Aquatic insects of California with keys to North American genera and California species. University of California. Berkeley, Ca. 508 pp.
- Wiggins, G.B., 1977. Larvae of North American caddisfly genera (Trichoptera). University of Toronto Press. Toronto, Ont. 401 pp.

- Humboldt County, California, as of 1973. U.S.G.S. Open File Report. 257 pp.
- Lotspeich, F.B., and B. Reid, 1980. A tri-tube freeze core procedure for sampling stream-gravel. Progr. Fish. Cult. 42:96-99.
- Merritt, R.W., and K.W. Cummins, ed. 1984. An introduction to the aquatic insects of North America, 2nd edition. Kendall/Hunt Publishing Co., Dubuque, Iowa. 722 pp.
- Meyer, C.B., R.M. Coey, R.D. Klein, M.A. Madej, D.W. Best, and V.L. Ozaki 1994. Monitoring the Impacts and Persistence of Fine Sediment in the Prairie Creek Watershed. Water Years 1991-1992. Redwood National Park, Orick, Ca. 144 pp.
- Meyer, C.B., 1994. Monitoring the Impacts and Persistence of Fine Sediment in the Prairie Creek Watershed: Results for Water Year 1993 and a summary of results for 1990-1993 with recommendations based on data from 1981-1994. Redwood National and State Parks, Orick, Ca. 78 pp.
- Meyer, C.B. 1994. Redwood Creek Basin Fisheries Summary 1980-1994. Redwood National Park, Orick, Ca. 90 pp + app.
- Platts, W.S., W.F. Megahan, and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. U.S. Forest Service, Forest and Range Experiment Station. General Technical Report INT-138. USDA, Ogden, Ut. 70 pp.
- Redwood National Park, 1986. Monitoring of Aquatic Impacts Associated with Construction of the U.S. 101 Bypass. USDO I, National Park Service, Arcata, Ca. 41 pp. + app.
- Redwood National Park, 1987. Monitoring of Aquatic Impacts Associated with Construction of the Redwood Park Bypass, US Highway 101 in Compliance with Cleanup and Abatement Order No. 86-199. USDO I, National Park Service, Arcata, Ca. 21 pp.
- Redwood National Park, 1988. Prairie Creek Wetland Riparian Rehabilitation. USDO I, National Park Service, Arcata, Ca. 3 pp.
- Redwood National Park, 1989. Monitoring of Aquatic Impacts Associated with Construction of Redwood Park Bypass, US Highway 101. 1987 Summary Report. USDO I, National Park Service, Arcata, Ca. 80 pp.
- Redwood National Park, 1990. Monitoring of Aquatic Impacts Associated with Construction of the Highway 101 Redwood Park

7/95

Draft #5

MONITORING OF AQUATIC IMPACTS ASSOCIATED WITH
CONSTRUCTION OF THE REDWOOD PARK BYPASS,
U.S. HIGHWAY 101

TEN-YEAR SUMMARY REPORT

1984 - 1994

by

Carolyn B. Meyer
Sandra Haux

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UNITED STATES DEPARTMENT OF INTERIOR

NATIONAL PARK SERVICE
REDWOOD NATIONAL PARK
ORICK, CA 95521

MARCH 1995

APPENDICES

APPENDIX A
BYPASS MONITORING SITE LOCATIONS

**U.S. 101 Bypass Monitoring
Site Locations**

Prepared by
Bruce Kvam (1988) and Chris Zimmerman (1990)

Klamath River Tributary Unit

On U. S. 101, 6.5 miles north of Prairie Creek Redwoods State Park Ranger Station to S line service road (mileage marker 133.54). Travel 2.5 miles to junction of S-line (road to B-line) and S-200 service line.

NORTH FORK AH PAH CREEK

At junction of S-line and S-200 go right on S-line. From fork, travel 1.6 miles on S service line to study reach (0.2 miles from gate). 5 X-sections.

MCGARVEY CREEK

At junction of S-line and S-10 take left. Travel 0.2 miles to junction of S-10 and S-200 (M-10) take left. Travel 2.3 miles to parking spot. Trail is on north side of road and goes down hill to middle of study section. 5 X-sections.

TARUP CREEK

At fork of S-10 and S-200 service lines, take left. At junction of S-10 and S-200 (M-10) take right. After 1.52 miles on the S-10, turn left to S-300 service line. 1.3 miles down line, S-320 line at left- stay right. Study reach .10 mile down S 300 from large redwood stump on left side of line. Site upstream of bridge crossing Tarup Creek. 5 X-sections. The right monument of cross section #2 also serves as the right monument of cross section #3.

Prairie Creek Unit

PRAIRIE CREEK ABOVE/BELOW BOYES CREEK

On U. S. 101, 5.5 miles north of Orick to Prairie Creek Redwoods State Park Ranger Station. Bridge that crosses Prairie Creek at Prairie Creek/Miners Ridge/James Irvine trailhead bisects Prairie Creek below Boyes Creek study reach. 5 X-sections. The right monument of cross section #2 also serves cross section #3. Above Boyes monitoring site upstream of Boyes Creek confluence. 5 X-sections. The left monument of cross section #2 also serves cross section #3.

PRAIRIE CREEK ABOVE BROWN CREEK

On U. S. 101, 1.85 miles north of Prairie Creek Ranger Station to Soroptimist Grove and Prairie Creek/Brown Creek trailhead (mileage marker 129.01). (Note: trail was removed during the winter of 1990). 512.5 feet down Prairie Creek trail, turn left at 'T' in trail. Path to creek at right 165 feet down Prairie Creek trail. Study site 100 feet down path. 5 X-sections.

PRAIRIE CREEK BELOW CHANNELIZATION

On U. S. 101 to Wolf Creek access road. After Wolf Creek Bridge, turn left and travel .29 miles to turnout at boulder pile. Trailhead by telephone pole. 6 X-sections.

PRAIRIE CREEK ABOVE/BELOW MAY CREEK

From Wolf Creek access road to Wolf Creek Bridge. Prairie Creek above May Creek monitoring reach upstream of bridge. 4 X-sections. Below May study site downstream of May Creek confluence. 7 X-sections. The right monument of cross section #1 also serves cross section #2.

Prairie Creek Tributary Unit

BOYES CREEK

North on U. S. 101, at Prairie Creek Ranger Station, turn right. Take first left after housing facility onto dirt road. 4 X-sections.

BROWN CREEK

North on U. S. 101, 1.85 miles from Prairie Creek Ranger Station to Soroptimist Grove (Prairie Creek above Brown Creek) turnout (mileage marker 129.01). Monitoring site 2,620 feet along Brown Creek trail. 5 X-sections. The left monument of cross section #3 also serves cross section #4.

LOST MAN CREEK

From U. S. 101, take Geneva Road (Lost Man Creek Picnic Area/mileage marker 124.30). Travel to RNP gate at picnic area. .10 mile behind gate, road at right to study reach. 5 X-sections. The left monument of cross section #2 also serves cross section #3.

MAY CREEK

From U. S. 101, take turnout at southern interchange of U. S. 101 Bypass (mileage marker 126.00). Trail to May Creek at mileage marker 126.06. 6 X-sections. The right monument of cross section #4 also serves cross sections #5 and 6.

APPENDIX B

CROSS SECTION NUMBERS AND HABITAT TYPE TRANSECTED AT MONITORING
SITES

SUMMARY OF CHANNEL CHANGES AT MONITORING SITES 1985 TO 1990

CROSS SECTION PROFILES 1985 AND 1990 AND CUMULATIVE ELEVATION
CHANGE 1985 TO 1990

Table B-1. Cross section number and habitat type transected at the 13 monitoring sites, U.S. 101 bypass monitoring project.

STREAM	X-SEC #	HABITAT TYPE
PRAIRIE CREEK UNIT		
PRAIRIE CREEK ABOVE BROWN CREEK (control for unit)	1	POOL (#10)
	2	RIFFLE
	3	POOL (#10/12)
	4	RIFFLE
	5	POOL (#7)
PRAIRIE CREEK ABOVE BOYES CREEK	1	RIFFLE
	2	RIFFLE
	3	POOL (#10)
	4	RIFFLE
	5	CONFLUENCE
PRAIRIE CREEK BELOW BOYES CREEK	1	POOL (#10)
	2	POOL (#12)
	3	POOL (#12)
	4	RIFFLE
	5	RIFFLE
PRAIRIE CREEK ABOVE MAY CREEK	1	POOL (#12)
	2	POOL (#10)
	3	POOL (#11)
	4	POOL (#10)
PRAIRIE CREEK BELOW MAY CREEK	1	POOL (#10)
	2	POOL (#10)
	3	POOL (#10)
	4	POOL (#10)
	5	POOL (#10)
	6	POOL (#10)

Table B-1. Continued

STREAM	X-SEC #	HABITAT TYPE
PRAIRIE CREEK UNIT (continued)		
PRAIRIE CREEK BELOW CHANNELIZATION	1	POOL (#10)
	2	POOL (#10)
	3	RIFFLE
	4	RIFFLE
	5	POOL (#10)
	6	POOL (#7)
PRAIRIE CREEK TRIBUTARY UNIT		
BOYES CREEK	1	RIFFLE
	2	RIFFLE
	3	POOL (#10)
	4	RIFFLE
BROWN CREEK	1	RIFFLE
	2	RIFFLE
	3	RIFFLE
	4	RIFFLE
	5	RIFFLE
LOST MAN CREEK (control for unit)	1	RIFFLE
	2	RIFFLE
	3	POOL (#12)
	4	RIFFLE
	5	RIFFLE
MAY CREEK	1	RIFFLE
	2	RIFFLE
	3	RIFFLE
	4	RIFFLE
	5	POOL (#10)
	6	POOL (#10)

Table B-1. Continued

STREAM	X-SEC #	HABITAT TYPE
KLAMATH TRIBUTARY UNIT		
AH PAH CREEK	1	RIFFLE
	2	RIFFLE
	3	POOL (#10)
	4	RIFFLE
	5	RIFFLE
McGARVEY CREEK	1	POOL (#10)
	2	RIFFLE
	3	RIFFLE
	4	POOL (#10)
	5	RIFFLE
TARUP CREEK (control for unit)	1	RIFFLE
	2	RIFFLE
	3	POOL (#10)
	4	RIFFLE
	5	RIFFLE

Table B-2. Summary of channel changes in U.S. Highway 101 bypass study reaches, 1985-1986, 1986-1987, 1987-1988, 1988-1989, 1989-1990.

SUMMARY OF CHANNEL CHANGES 1985 - 1986						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
PRAIRIE CREEK ABOVE BROWN CREEK	1	-1.11	3.26	2.15	26	0.08
	2	-2.61	12.17	9.56	38.6	0.25
	3	1986 DATA UNRELIABLE				
	4	-4.21	2.05	-2.16	32.6	-0.07
	5	-8.69	10.96	2.27	40.2	0.06
PRAIRIE CREEK ABOVE BOYES CREEK	1	-4.84	10.95	6.11	62	0.1
	2	-4.53	8.54	4.01	58.6	0.07
	3	-5.9	0.63	-5.27	55.6	-0.09
	4	-9.09	0.74	-8.35	52	-0.16
	5	-25.08	2.7	-22.38	69.3	-0.32
PRAIRIE CREEK BELOW BOYES CREEK	1	-86.39	1.26	-85.13	50.7	-1.68
	2	-15.31	23.43	8.12	52	0.16
	3	ALL DATA UNRELIABLE				
	4	-8.64	15.93	7.29	65.5	0.11
	5	-13.12	1.68	-11.44	48.6	-0.24

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1985 - 1986						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
PRAIRIE CREEK ABOVE MAY CREEK	1	-5.15	2.67	-2.48	48.1	-0.05
	2	-8.39	4.69	-3.7	42	-0.09
	3	-1.61	5.48	3.87	47.2	0.08
	4	-2.08	4.89	2.81	51	0.06
PRAIRIE CREEK BELOW MAY CREEK	1	-6.7	10.4	3.7	64.2	0.06
	2	-9.09	17.26	8.17	64.4	0.13
	3	-13.3	12.92	-0.38	68.4	-0.01
	4	-38.22	8.91	-29.31	50	-0.59
	5	-6.29	9.72	3.43	41.6	0.08
	6	-3.43	5.4	1.97	56	0.04
PRAIRIE CREEK BELOW CHANNELIZATION	1	-44.55	29.08	-15.47	50.4	-0.31
	2	-6.67	4.48	-2.19	44.6	-0.05
	3	-2.25	12.93	10.68	43.3	0.25
	4	-3.18	21.15	17.97	40.5	0.44
	5	-3.68	3.12	-0.56	40.5	-0.01
	6	-2.43	4.6	2.17	44	0.05

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1985 - 1986						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
BOYES CREEK	1	-3.51	3.74	0.23	39.1	0.01
	2	-2.06	2.32	0.26	48.2	0.01
	3	-4.04	4.01	-0.03	43.1	0
	4	-1.97	1.65	-0.32	45.2	-0.01
BROWN CREEK	1	-0.73	1.85	1.12	29	0.04
	2	-2.19	0.61	-1.58	16.4	-0.1
	3	-0.37	1.38	1.01	19.7	0.05
	4	-1.4	5	3.6	34.8	0.1
	5	-1.53	2.1	0.57	26	0.02
LOST MAN CREEK	1	-6.73	9.33	2.6	65.2	0.04
	2	-2.56	7.72	5.16	50	0.1
	3	-22.08	62.13	40.05	95.2	0.42
	4	-7.99	8.04	0.05	94.2	0
	5	-9.05	11.14	2.09	47	0.04

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1985 - 1986						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
MAY CREEK	1	-1.3	3.22	1.92	23	0.08
	2	-1.76	7.14	5.38	26.3	0.2
	3	-11.68	1.72	-9.96	36	-0.28
	4	-0.65	5.58	4.93	20.9	0.24
	5	-6.21	5.61	-0.6	34.7	-0.02
	6	-10.7	4.21	-6.49	23.9	-0.27
AH PAH CREEK	1	-10.61	4.38	-6.23	29.5	-0.21
	2	-2.3	9.92	7.62	62	0.12
	3	-8.26	5.25	-3.01	42.2	-0.07
	4	-0.73	4.89	4.16	28.7	0.14
	5	-0.91	11.81	10.9	46.1	0.24
McGARVEY CREEK	1	-1.13	6.5	5.37	41.5	0.13
	2	-0.8	4.04	3.24	34	0.1
	3	-7.71	0.39	-7.32	40.3	-0.18
	4	-1.36	11.01	9.65	40.1	0.24
	5	-6.22	1.4	-4.82	44.4	-0.11

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1985 - 1986						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
TARUP CREEK	1	-6.88	4.69	-2.19	46.9	-0.05
	2	-5.75	1.14	-4.61	51	-0.09
	3	-3.1	6.04	2.94	33.7	0.09
	4	-4.73	10.01	5.28	30.2	0.17
	5	-4.98	1.65	-3.33	31.5	-0.11

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1986 - 1987						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
PRAIRIE CREEK ABOVE BROWN CREEK	1	-1.06	3.48	2.42	26.00	0.09
	2	-10.19	2.70	-7.49	38.60	-0.19
	3	1986 DATA UNRELIABLE				
	4	-5.19	0.97	-4.22	32.60	-0.13
	5	-7.23	4.34	-2.89	40.20	-0.07
PRAIRIE CREEK ABOVE BOYES CREEK	1	-1.76	11.34	9.58	62.00	0.15
	2	-5.80	5.05	-0.75	58.60	-0.01
	3	-2.23	1.27	-0.96	55.60	-0.02
	4	-0.78	1.70	0.92	52.00	0.02
	5	-7.04	6.15	-0.89	69.30	-0.01
PRAIRIE CREEK BELOW BOYES CREEK	1	-10.72	2.83	-7.89	50.70	-0.16
	2	-7.25	15.96	8.71	52.00	0.17
	3	ALL DATA UNRELIABLE				
	4	-15.75	3.59	-12.16	65.50	-0.19
	5	-2.70	5.58	2.88	48.60	0.06

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1986 - 1987						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
PRAIRIE CREEK ABOVE MAY CREEK	1	-2.12	1.73	-0.39	48.10	-0.01
	2	-0.25	6.93	6.68	42.00	0.16
	3	-4.01	1.48	-2.53	47.20	-0.05
	4	-4.52	0.30	-4.22	51.00	-0.08
PRAIRIE CREEK BELOW MAY CREEK	1	-4.34	1.58	-2.76	64.20	-0.04
	2	-10.22	0.66	-9.56	64.40	-0.15
	3	-7.63	7.78	0.15	68.40	0.00
	4	-4.27	2.59	-1.68	50.00	-0.03
	5	-1.30	1.54	0.24	41.60	0.01
	6	-2.34	0.18	-2.16	56.00	-0.04
PRAIRIE CREEK BELOW CHANNELIZATION	1	-3.83	3.49	-0.34	50.40	-0.01
	2	-2.47	9.75	7.28	44.60	0.16
	3	-2.32	4.85	2.53	43.30	0.06
	4	-5.14	2.18	-2.96	40.50	-0.07
	5	-0.13	4.77	4.64	40.50	0.11
	6	-0.94	8.04	7.10	44.00	0.16

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1986 - 1987						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
BOYES CREEK	1	-3.89	3.70	-0.19	39.10	0.00
	2	-2.16	2.96	0.80	48.20	0.02
	3	-5.12	1.21	-3.91	43.10	-0.09
	4	-0.20	2.77	2.57	45.20	0.06
BROWN CREEK	1	-1.72	0.81	-0.91	29.00	-0.03
	2	-2.36	0.07	-2.29	16.40	-0.14
	3	-2.38	0.38	-2.00	19.70	-0.10
	4	-6.22	1.36	-4.86	34.80	-0.14
	5	-4.05	0.77	-3.28	26.00	-0.13
LOST MAN CREEK	1	-0.37	8.45	8.08	65.20	0.12
	2	-1.07	2.02	0.95	50.00	0.02
	3	-10.08	30.37	20.29	95.20	0.21
	4	-5.81	6.58	0.77	94.20	0.01
	5	-11.05	5.32	-5.73	47.00	-0.12

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1986 - 1987						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
MAY CREEK	1	-0.66	2.87	2.21	23.00	0.10
	2	-1.22	0.70	-0.52	26.30	-0.02
	3	-0.06	9.91	9.85	36.00	0.27
	4	-3.01	0.99	-2.02	20.90	-0.10
	5	-3.37	5.41	2.04	34.70	0.06
	6	-0.67	2.70	2.03	23.90	0.08
AH PAH CREEK	1	-2.44	2.34	-0.10	29.50	0.00
	2	-3.68	4.28	0.60	62.00	0.01
	3	-1.68	7.73	6.05	42.20	0.14
	4	-0.98	1.41	0.43	28.70	0.01
	5	-1.88	0.15	-1.73	46.10	-0.04
McGARVEY CREEK	1	-3.09	8.80	5.71	41.50	0.14
	2	-1.09	2.12	1.03	34.00	0.03
	3	-0.95	3.98	3.03	40.30	0.08
	4	-1.11	0.94	-0.17	40.10	0.00
	5	-2.23	4.46	2.23	44.40	0.05

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1986 - 1987						
STREAM	X-SEC #	SCOUR (FT ³)	FILL (FT ³)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
TARUP CREEK	1	-6.25	6.13	-0.12	46.90	0.00
	2	-1.31	1.14	-0.17	51.00	0.00
	3	-1.10	2.84	1.74	33.70	0.05
	4	-2.06	2.07	0.01	30.20	0.00
	5	-0.78	1.48	0.70	31.50	0.02

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1987 - 1988						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
PRAIRIE CREEK ABOVE BROWN CREEK	1	-4.80	5.15	0.35	26.00	0.01
	2	-2.57	3.22	0.65	38.60	0.02
	3	-2.31	2.74	0.43	22.90	0.02
	4	-2.61	3.82	1.21	32.60	0.04
	5	-1.68	7.37	5.69	40.20	0.14
PRAIRIE CREEK ABOVE BOYES CREEK	1	-5.53	1.72	-3.81	62.00	-0.06
	2	-4.31	10.18	5.87	58.60	0.10
	3	-2.72	2.23	-0.49	55.60	-0.01
	4	-1.94	0.67	-1.27	52.00	-0.02
	5	-5.89	21.04	15.15	69.30	0.22
PRAIRIE CREEK BELOW BOYES CREEK	1	-1.75	10.30	8.55	50.70	0.17
	2	-6.60	1.59	-5.01	52.00	-0.10
	3	ALL DATA UNRELIABLE				
	4	-5.33	11.52	6.19	65.50	0.09
	5	7.57	3.83	11.40	48.60	0.23

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1987 - 1988						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
PRAIRIE CREEK ABOVE MAY CREEK	1	-2.11	2.50	0.39	48.10	0.01
	2	-5.47	1.05	-4.42	42.00	-0.11
	3	-0.69	4.22	3.53	47.20	0.07
	4	-1.71	4.32	2.61	51.00	0.05
PRAIRIE CREEK BELOW MAY CREEK	1	-21.73	6.57	-15.16	64.20	-0.24
	2	NO DATA 1988				
	3	-31.72	6.39	-25.33	68.40	-0.37
	4	-7.26	12.35	5.09	50.00	0.10
	5	-3.97	0.90	-3.07	41.60	-0.07
	6	NO DATA 1987 - 90				

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1987 - 1988						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
PRAIRIE CREEK BELOW CHANNELIZATION	1	NO DATA 1988				
	2	NO DATA 1988				
	3	-5.55	3.21	-2.34	43.30	-0.05
	4	-9.67	2.19	-7.48	40.50	-0.18
	5	-4.79	2.09	-2.70	40.50	-0.07
	6	-1.58	7.25	5.67	44.00	0.13
BOYES CREEK	1	-3.50	4.03	0.53	39.10	0.01
	2	-3.32	2.06	-1.26	48.20	-0.03
	3	-5.15	6.37	1.22	43.10	0.03
	4	-0.89	1.53	0.64	45.20	0.01
BROWN CREEK	1	-0.90	2.49	1.59	29.00	0.05
	2	-0.04	2.77	2.73	16.40	0.17
	3	-0.59	2.59	2.00	19.70	0.10
	4	-2.16	2.79	0.63	34.80	0.02
	5	-0.99	1.77	0.78	26.00	0.03

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1987 - 1988						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
LOST MAN CREEK	1	-10.51	0.55	-9.96	65.20	-0.15
	2	-3.51	1.84	-1.67	50.00	-0.03
	3	-28.69	2.64	-26.05	95.20	-0.27
	4	-8.29	6.34	-1.95	94.20	-0.02
	5	-3.38	11.10	7.72	47.00	0.16
MAY CREEK	1	-3.55	1.28	-2.27	23.00	-0.10
	2	-6.25	0.02	-6.23	26.30	-0.24
	3	-4.41	1.31	-3.10	36.00	-0.09
	4	-2.53	0.79	-1.74	20.90	-0.08
	5	-6.60	1.15	-5.45	34.70	-0.16
	6	-6.62	1.37	-5.25	23.90	-0.22

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1987 - 1988						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
AH PAH CREEK	1	-6.33	3.10	-3.23	29.50	-0.11
	2	-3.56	6.40	2.84	62.00	0.05
	3	-1.86	7.15	5.29	42.20	0.13
	4	-0.56	9.66	9.10	28.70	0.32
	5	0.00	9.13	9.13	46.10	0.20
McGARVEY CREEK	1	-2.82	5.72	2.90	41.50	0.07
	2	-30.14	0.00	-30.14	34.00	-0.89
	3	-2.77	1.70	-1.07	40.30	-0.03
	4	-2.12	1.53	-0.59	40.10	-0.01
	5	-4.17	4.71	0.54	44.40	0.01
TARUP CREEK	1	-11.76	9.21	-2.55	46.90	-0.05
	2	-0.38	1.62	1.24	51.00	0.02
	3	-1.61	3.51	1.90	33.70	0.06
	4	-3.81	0.47	-3.34	30.20	-0.11
	5	-3.77	0.32	-3.45	31.50	-0.11

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1988 - 1989						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
PRAIRIE CREEK ABOVE BROWN CREEK	1	-0.42	1.69	1.27	26.00	0.05
	2	-2.79	4.25	1.46	38.60	0.04
	3	-3.32	1.27	-2.05	22.90	-0.09
	4	-0.81	3.34	2.53	32.60	0.08
	5	-4.51	13.31	8.80	40.20	0.22
PRAIRIE CREEK ABOVE BOYES CREEK	1	-1.09	8.54	7.45	62.00	0.12
	2	-2.22	6.82	4.60	58.60	0.08
	3	-2.35	2.95	0.60	55.60	0.01
	4	-2.63	1.27	-1.36	52.00	-0.03
	5	-9.59	6.05	-3.54	69.30	-0.05
PRAIRIE CREEK BELOW BOYES CREEK	1	-8.52	28.93	20.41	50.70	0.40
	2	-7.52	32.90	25.38	52.00	0.49
	3	ALL DATA UNRELIABLE				
	4	-6.72	5.13	-1.59	65.50	-0.02
	5	-1.27	8.86	7.59	48.60	0.16

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1988 - 1989						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
PRAIRIE CREEK ABOVE MAY CREEK	1	-0.71	5.07	4.36	48.10	0.09
	2	-5.00	4.31	-0.69	42.00	-0.02
	3	-8.62	2.81	-5.81	47.20	-0.12
	4	-11.60	3.26	-8.34	51.00	-0.16
PRAIRIE CREEK BELOW MAY CREEK	1	-2.99	5.27	2.28	64.20	0.04
	2	NO DATA 1988				
	3	-16.27	7.35	-8.92	68.40	-0.13
	4	-26.55	3.86	-22.69	50.00	-0.45
	5	-23.20	6.65	-16.55	41.60	-0.40
	6	NO DATA 1987 - 90				
PRAIRIE CREEK BELOW CHANNELIZATION	1	NO DATA 1988				
	2	NO DATA 1988				
	3	-34.52	2.72	-31.80	43.30	-0.73
	4	-6.93	6.52	-0.41	40.50	-0.01
	5	-1.61	1.86	0.25	40.50	0.01
	6	-1.03	3.98	2.95	44.00	0.07

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1988 - 1989						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
BOYES CREEK	1	-1.59	1.15	-0.44	39.10	-0.01
	2	-3.54	1.28	-2.26	48.20	-0.05
	3	-1.85	10.19	8.34	43.10	0.19
	4	-1.62	1.67	0.05	45.20	0.00
BROWN CREEK	1	-1.12	1.59	0.47	29.00	0.02
	2	-0.98	0.72	-0.26	16.40	-0.02
	3	-1.52	0.46	-1.06	19.70	-0.05
	4	-1.29	2.73	1.44	34.80	0.04
	5	-1.54	0.65	-0.89	26.00	-0.03
LOST MAN CREEK	1	-3.02	7.19	4.17	65.20	0.06
	2	-4.64	0.86	-3.78	50.00	-0.08
	3	-2.53	20.22	17.69	95.20	0.19
	4	-5.12	16.05	10.93	94.20	0.12
	5	-5.75	6.34	0.59	47.00	0.01

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1988 - 1989						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
MAY CREEK		-5.70	2.09	-3.61	23.00	-0.16
	1	-1.85	3.12	1.27	26.30	0.05
	2	-2.60	1.92	-0.68	36.00	-0.02
	3	-0.90	1.25	0.35	20.90	0.02
	4	-9.74	2.31	-7.43	34.70	-0.21
	5	-6.30	1.46	-4.84	23.90	-0.20
AH PAH CREEK	1	-4.36	2.76	-1.60	29.50	-0.05
	2	-5.01	3.82	-1.19	62.00	-0.02
	3	-8.66	0.82	-7.84	42.20	-0.19
	4	-12.14	0.13	-12.01	28.70	-0.42
	5	-9.83	1.15	-8.68	46.10	-0.19
McGARVEY CREEK	1	-4.01	11.27	7.26	41.50	0.17
	2	-0.15	3.61	3.46	34.00	0.10
	3	-1.21	2.37	1.16	40.30	0.03
	4	-4.13	2.49	-1.64	40.10	-0.04
	5	-0.10	6.46	6.36	44.40	0.14

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1988 - 1989						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
TARUP CREEK	1	-0.87	9.67	8.80	46.90	0.19
	2	-1.43	2.65	1.22	51.00	0.02
	3	-3.10	2.65	-0.45	33.70	-0.01
	4	-1.32	1.52	0.20	30.20	0.01
	5	-4.40	1.99	-2.41	31.50	-0.08

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1989 - 1990						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
PRAIRIE CREEK ABOVE BROWN CREEK	1	-1.62	1.24	-0.38	26.00	-0.01
	2	-0.72	1.68	0.96	38.60	0.02
	3	-1.91	2.45	0.54	22.90	0.02
	4	-0.82	4.29	3.47	32.60	0.11
	5	-4.54	6.67	2.13	40.20	0.05
PRAIRIE CREEK ABOVE BOYES CREEK	1	-4.44	6.14	1.70	62.00	0.03
	2	-2.88	4.08	1.20	58.60	0.02
	3	-1.79	1.56	-0.23	55.60	0.00
	4	-1.41	2.22	0.81	52.00	0.02
	5	-16.59	3.62	-12.97	69.30	-0.19
PRAIRIE CREEK BELOW BOYES CREEK	1	-8.35	6.47	-1.88	50.70	-0.04
	2	-5.60	6.04	0.44	52.00	0.01
	3	ALL DATA UNRELIABLE				
	4	-2.64	2.18	-0.46	65.50	-0.01
	5	-1.39	5.95	4.56	48.60	0.09

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1989 - 1990						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
PRAIRIE CREEK ABOVE MAY CREEK	1	-3.65	1.02	-2.63	48.10	-0.05
	2	-6.57	0.35	-6.22	42.00	-0.15
	3	-2.08	2.47	0.39	47.20	0.01
	4	-3.01	1.49	-1.52	51.00	-0.03
PRAIRIE CREEK BELOW MAY CREEK	1	-1.40	4.25	2.85	64.20	0.04
	2	-2.26	1.41	-0.85	64.40	-0.01
	3	-2.47	13.90	11.43	68.40	0.17
	4	-8.17	12.64	4.47	50.00	0.09
	5	-0.67	2.45	1.78	41.60	0.04
	6	NO DATA 1987 - 90				
PRAIRIE CREEK BELOW CHANNELIZATION	1	-7.06	3.34	-3.72	50.40	-0.07
	2	-5.78	3.52	-2.26	44.60	-0.05
	3	-7.63	3.52	-4.11	43.30	-0.09
	4	-1.87	6.22	4.35	40.50	0.11
	5	-0.12	9.56	9.44	40.50	0.23
	6	-0.74	5.96	5.22	44.00	0.12

Table B-2. Continued

SUMMARY OF CHANNEL CHANGES 1989 - 1990						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
BOYES CREEK	1	-2.57	2.35	-0.22	39.10	-0.01
	2	-1.86	2.08	0.22	48.20	0.00
	3	-2.68	3.96	1.28	43.10	0.03
	4	-8.52	0.56	-7.96	45.20	-0.18
BROWN CREEK	1	-2.72	1.00	-1.72	29.00	-0.06
	2	-0.77	1.17	0.40	16.40	0.02
	3	-3.24	1.11	-2.13	19.70	-0.11
	4	-0.83	7.81	6.98	34.80	0.20
	5	-0.25	3.94	3.69	26.00	0.14
LOST MAN CREEK	1	-0.43	4.42	3.99	65.20	0.06
	2	-0.77	4.77	4.00	50.00	0.08
	3	-9.17	25.00	15.83	95.20	0.17
	4	-11.85	3.99	-7.86	94.20	-0.08
	5	-7.00	4.61	-2.39	47.00	-0.05

Table B-2. Continued

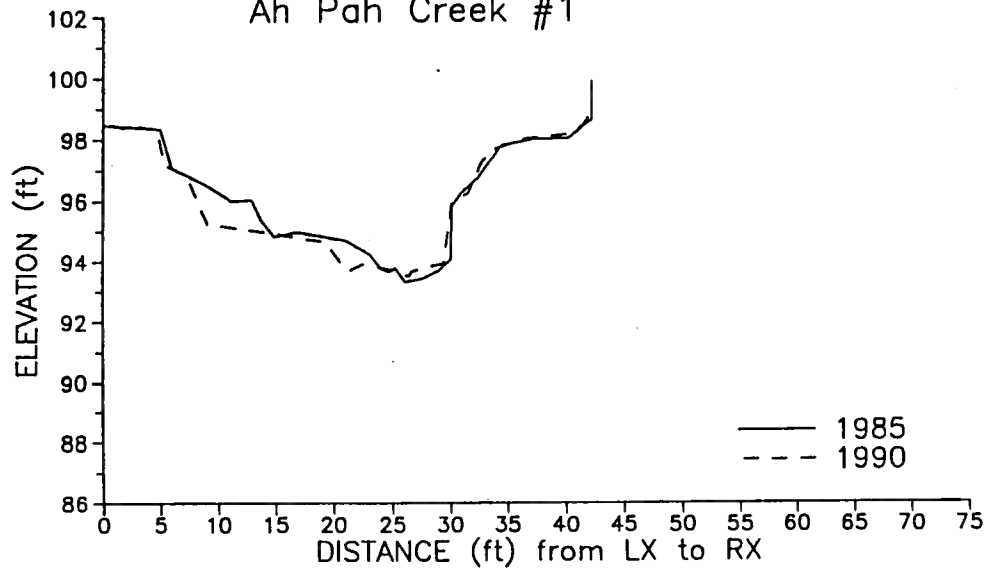
SUMMARY OF CHANNEL CHANGES 1989 - 1990						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
MAY CREEK	1	-2.84	6.10	3.26	23.00	0.14
	2	-0.70	2.71	2.01	26.30	0.08
	3	-1.07	4.02	2.95	36.00	0.08
	4	-1.61	0.92	-0.69	20.90	-0.03
	5	-3.60	3.07	-0.53	34.70	-0.02
	6	-3.66	3.18	-0.48	23.90	-0.02
AH PAH CREEK	1	-1.39	5.35	3.96	29.50	0.13
	2	-6.90	4.03	-2.87	62.00	-0.05
	3	-2.88	1.49	-1.39	42.20	-0.03
	4	-2.40	1.29	-1.11	28.70	-0.04
	5	-1.50	1.14	-0.36	46.10	-0.01
McGARVEY CREEK	1	-5.67	5.78	0.11	41.50	0.00
	2	-3.16	2.09	-1.07	34.00	-0.03
	3	-1.67	2.14	0.47	40.30	0.01
	4	-1.59	5.81	4.22	40.10	0.11
	5	-4.83	2.45	-2.38	44.40	-0.05

Table B-2. Continued

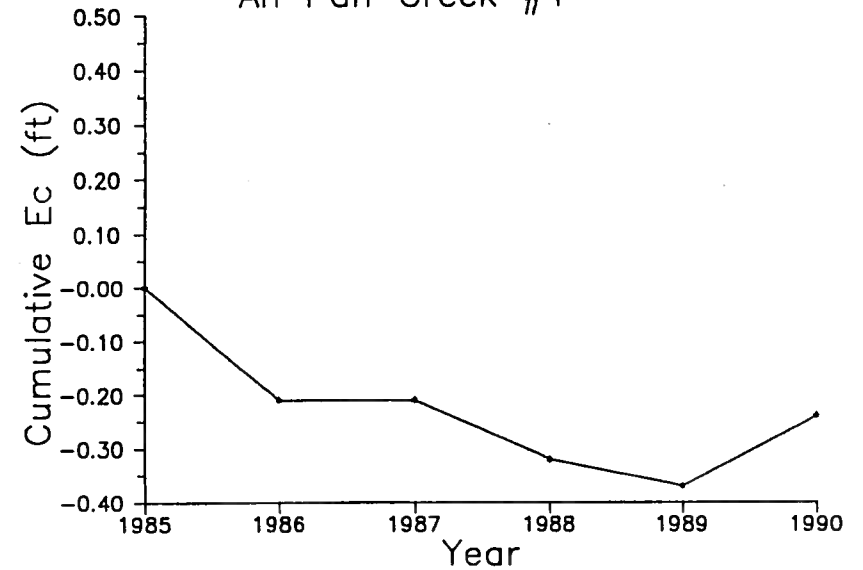
SUMMARY OF CHANNEL CHANGES 1989 - 1990						
STREAM	X-SEC #	SCOUR (FT ²)	FILL (FT ²)	NET CHANGE IN AREA (FT ²)	CHANNEL WIDTH (FT)	AVG. CHANGE IN ELEV. (FT)
TARUP CREEK	1	-1.80	2.23	0.43	46.90	0.01
	2	-1.85	0.67	-1.18	51.00	-0.02
	3	-4.17	1.61	-2.56	33.70	-0.08
	4	-2.68	0.52	-2.16	30.20	-0.07
	5	-1.10	1.29	0.19	31.50	0.01

Ah Pah Creek

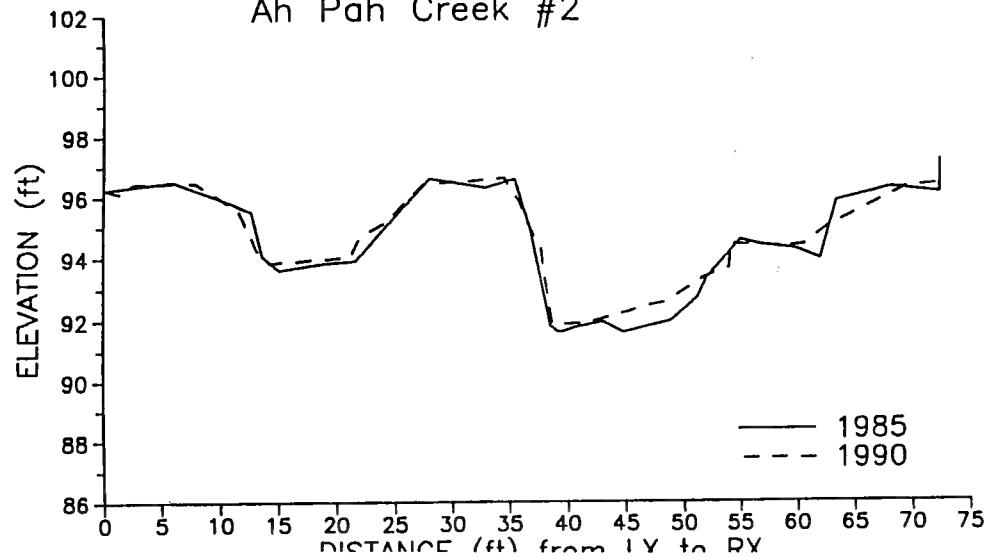
Ah Pah Creek #1



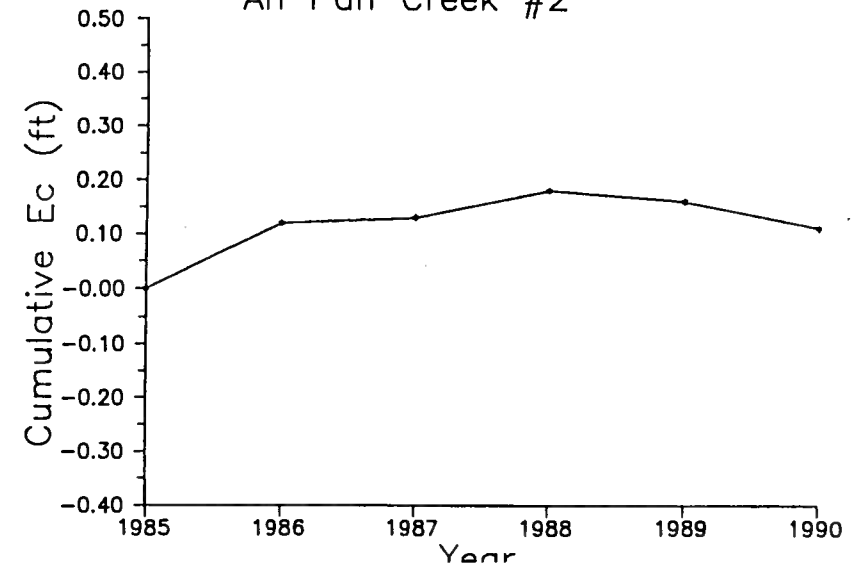
Ah Pah Creek #1



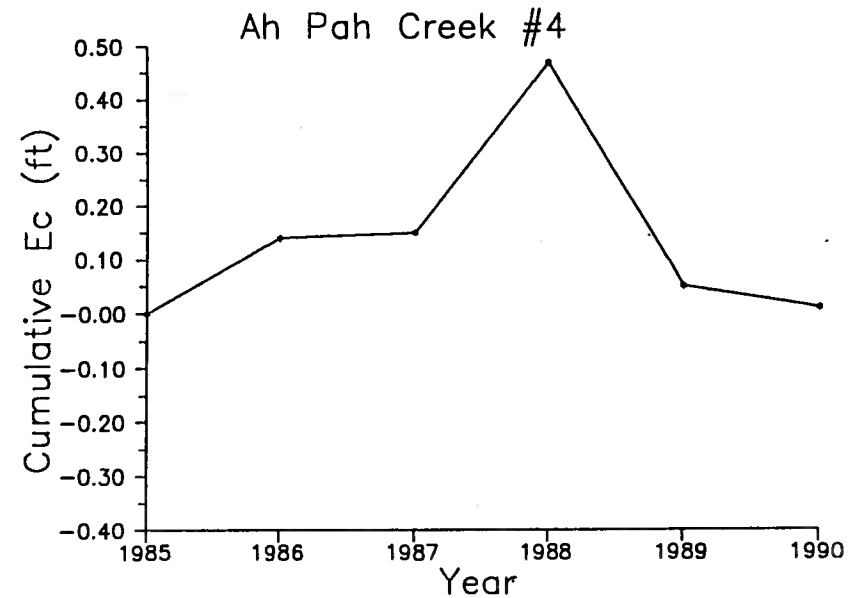
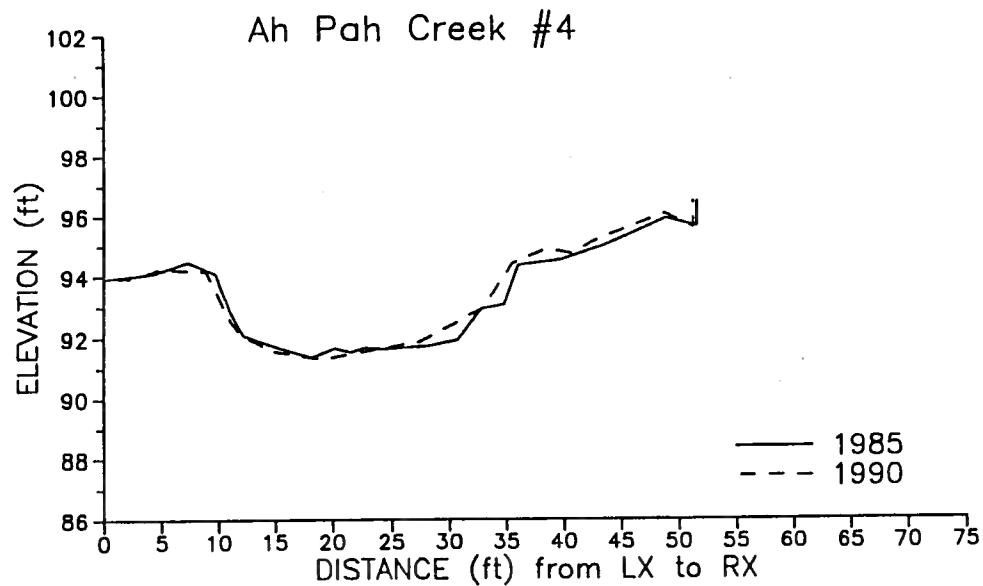
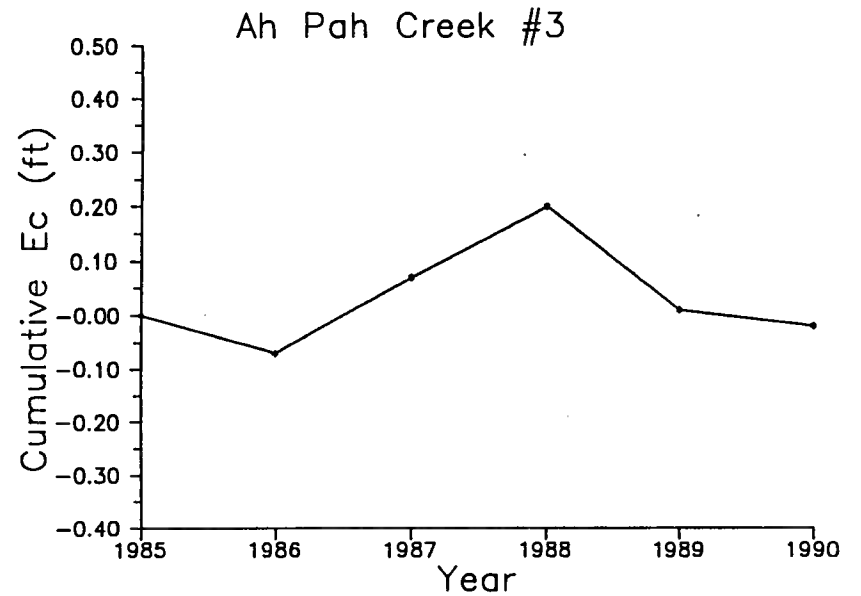
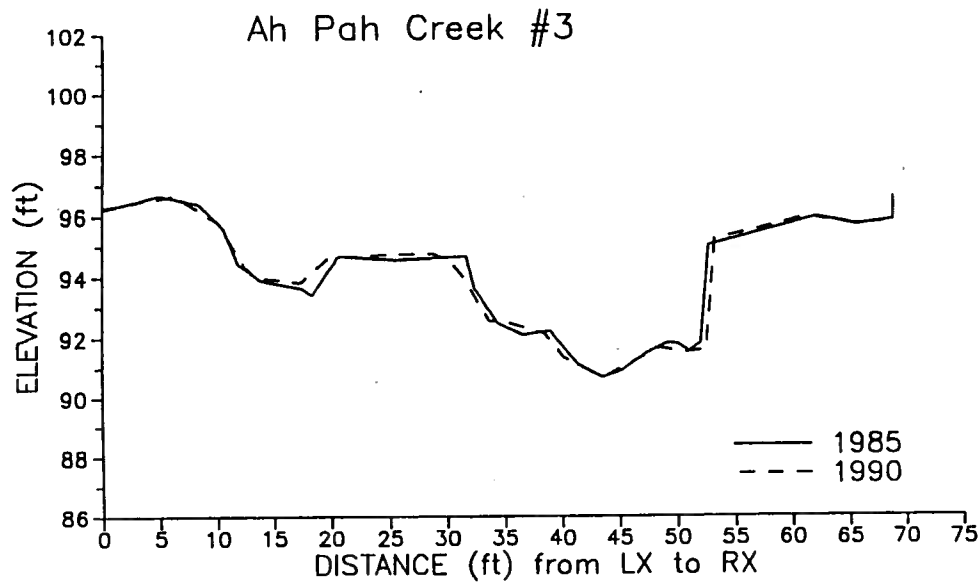
Ah Pah Creek #2



Ah Pah Creek #2

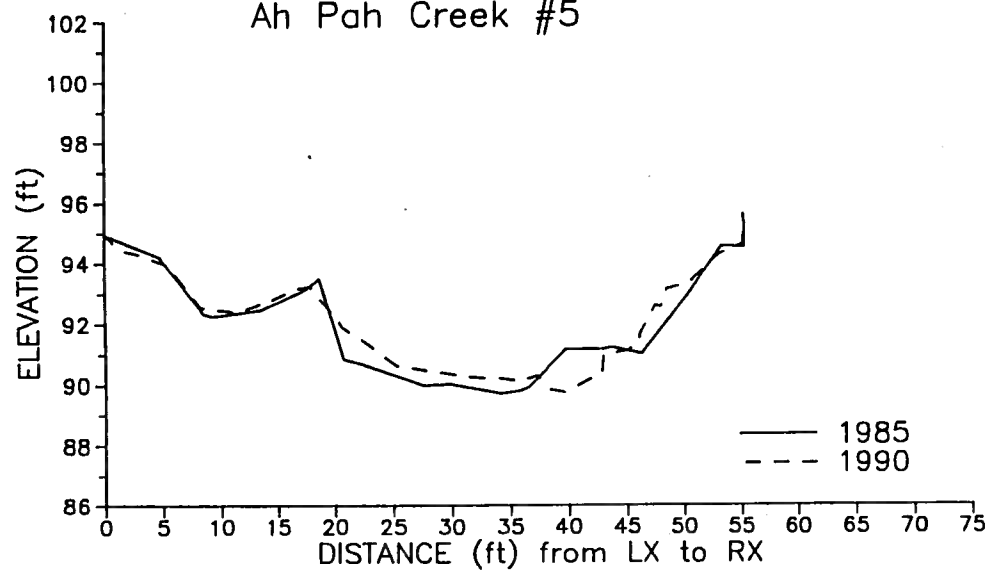


Ah Pah Creek

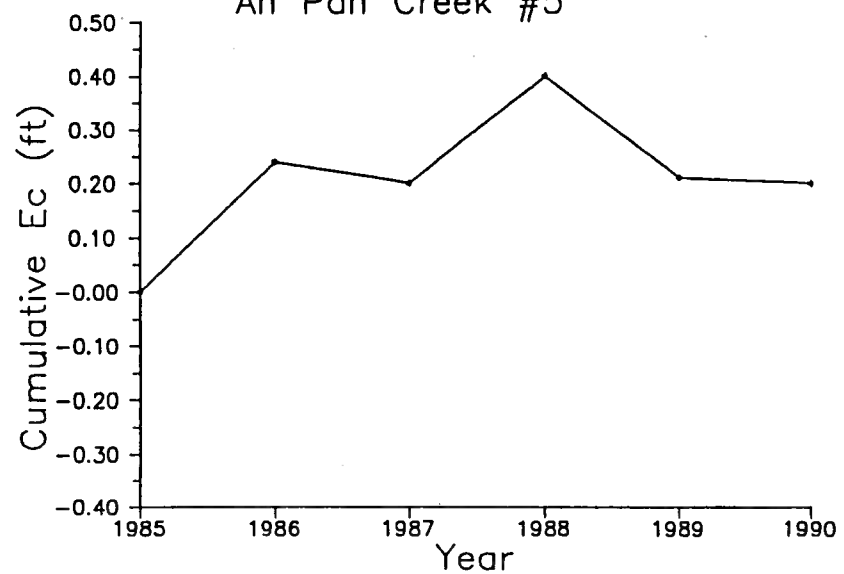


Ah Pah Creek

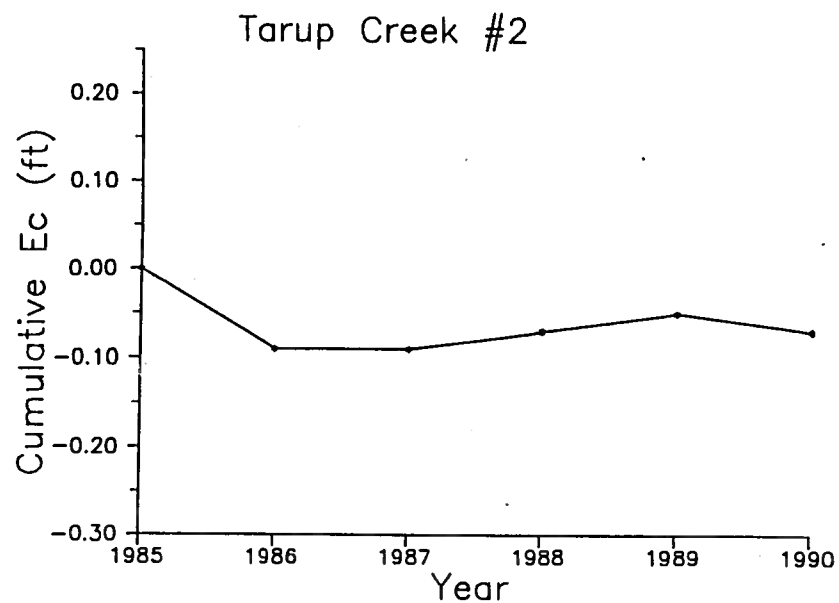
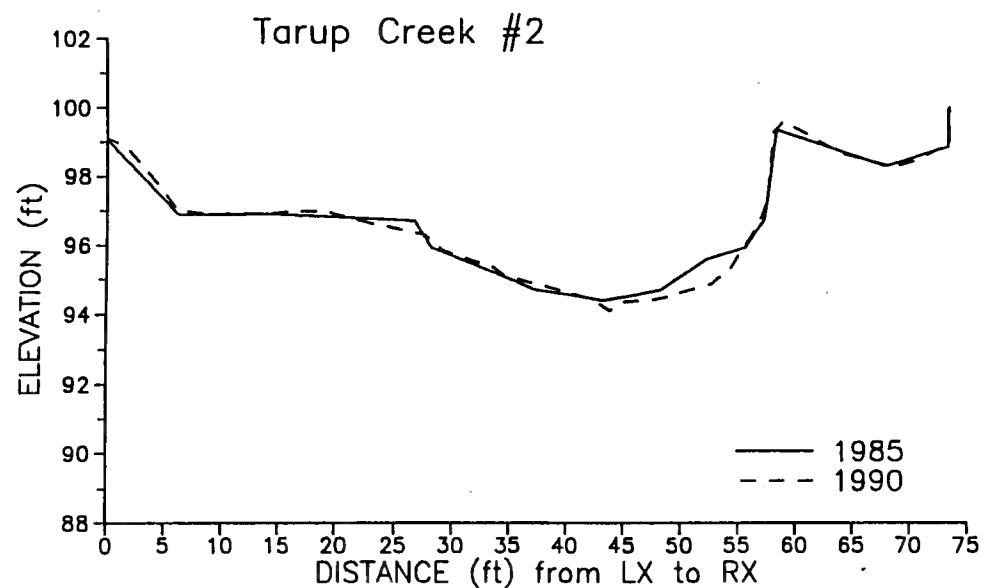
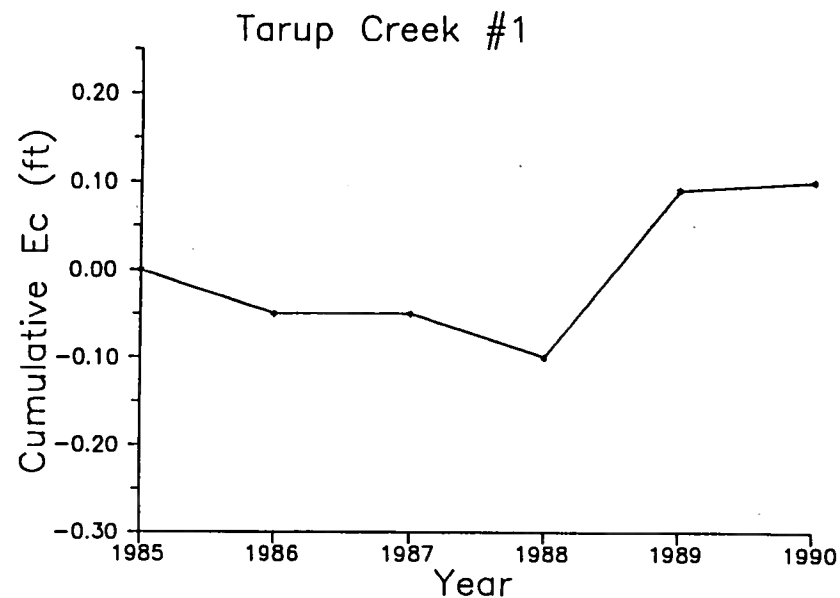
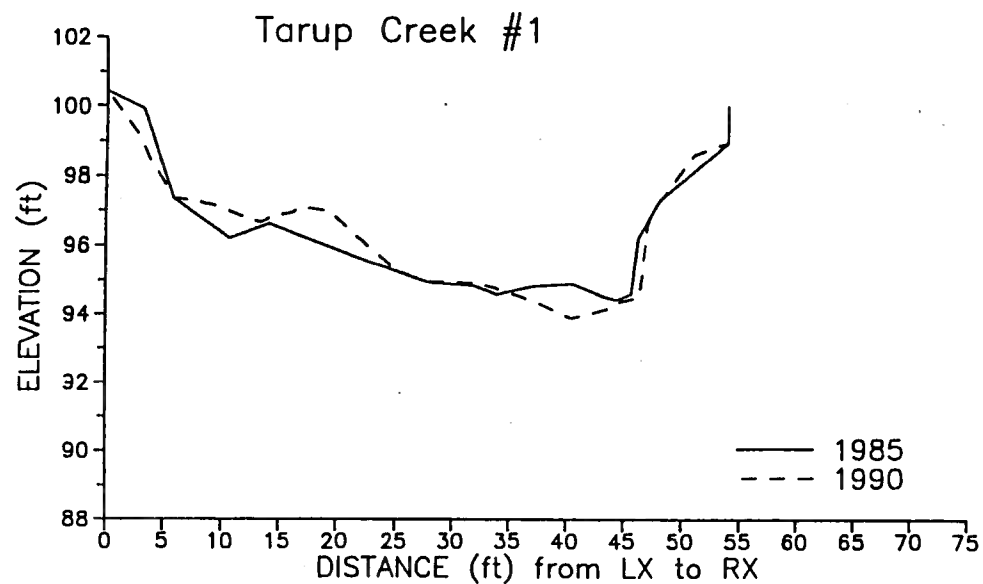
Ah Pah Creek #5



Ah Pah Creek #5

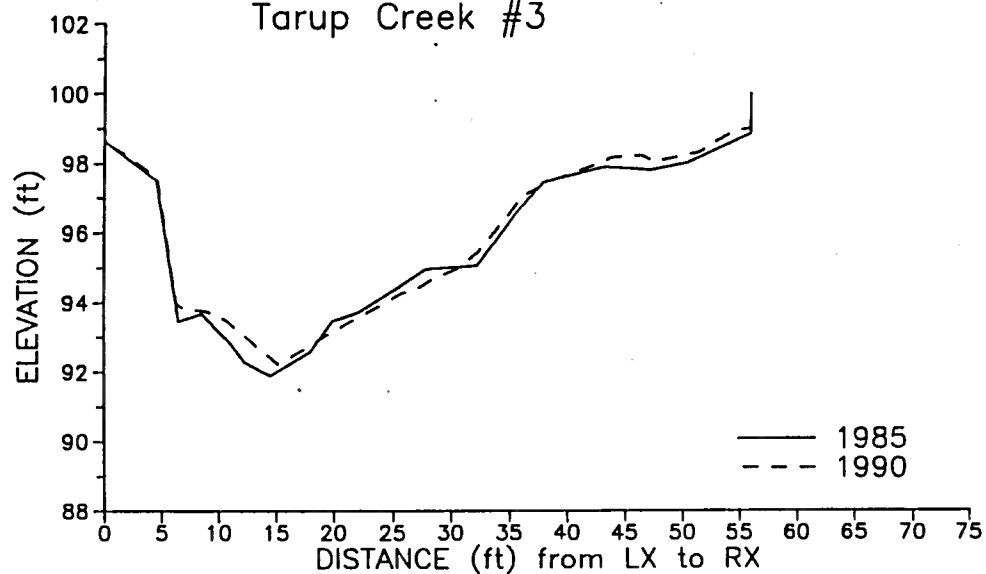


Tarup Creek

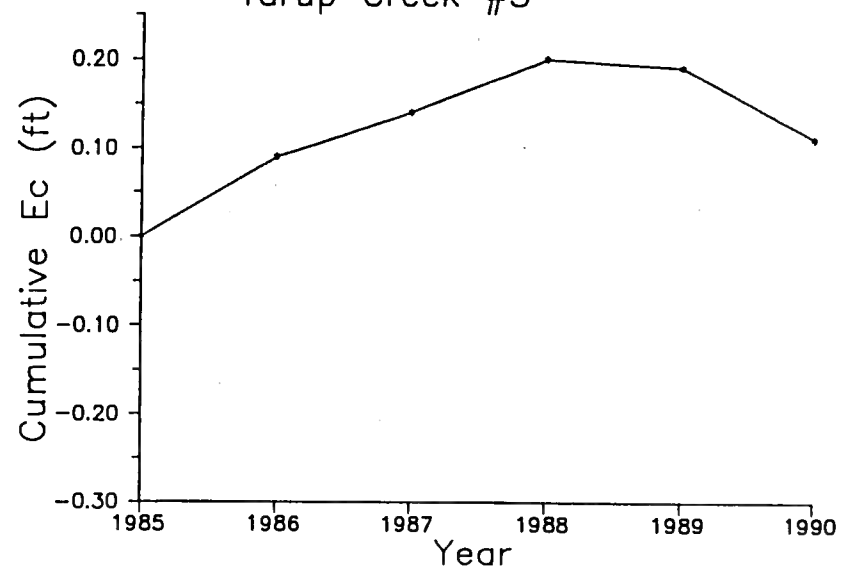


Tarup Creek

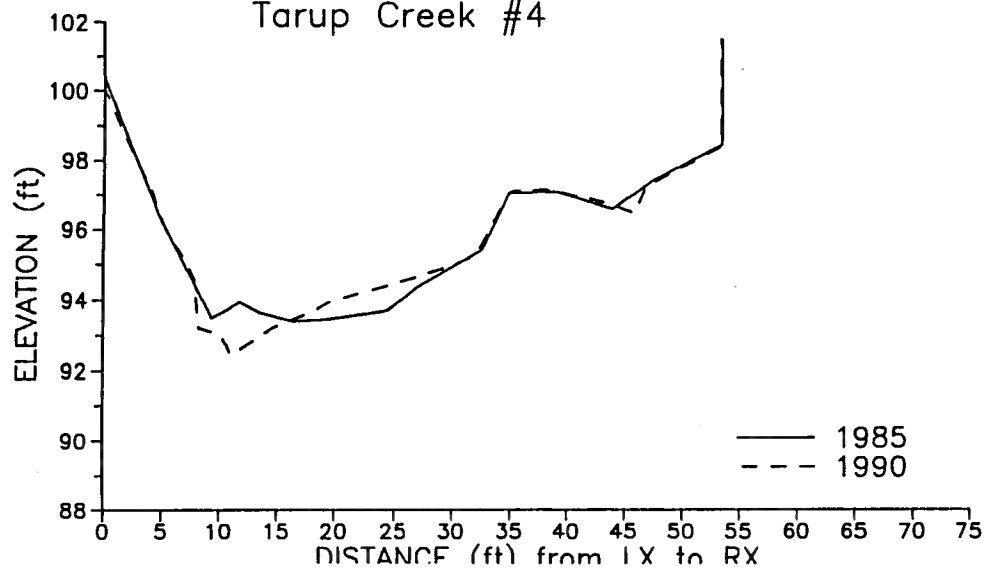
Tarup Creek #3



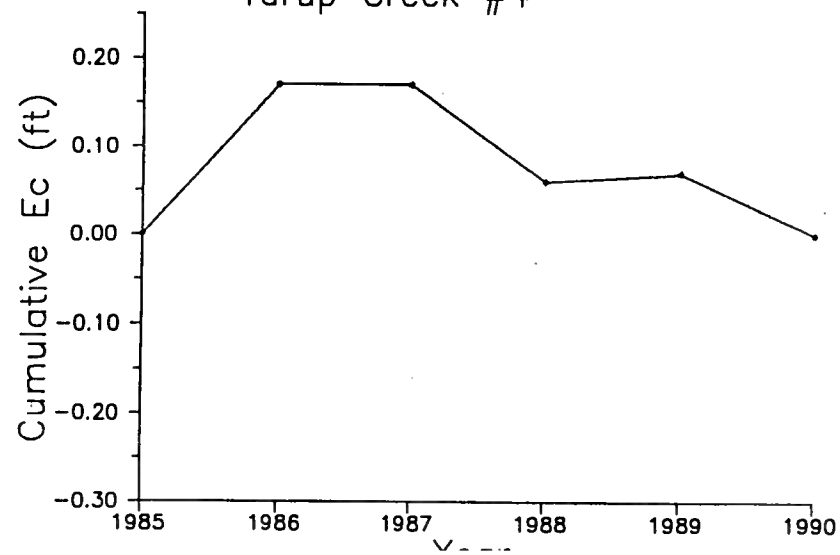
Tarup Creek #3



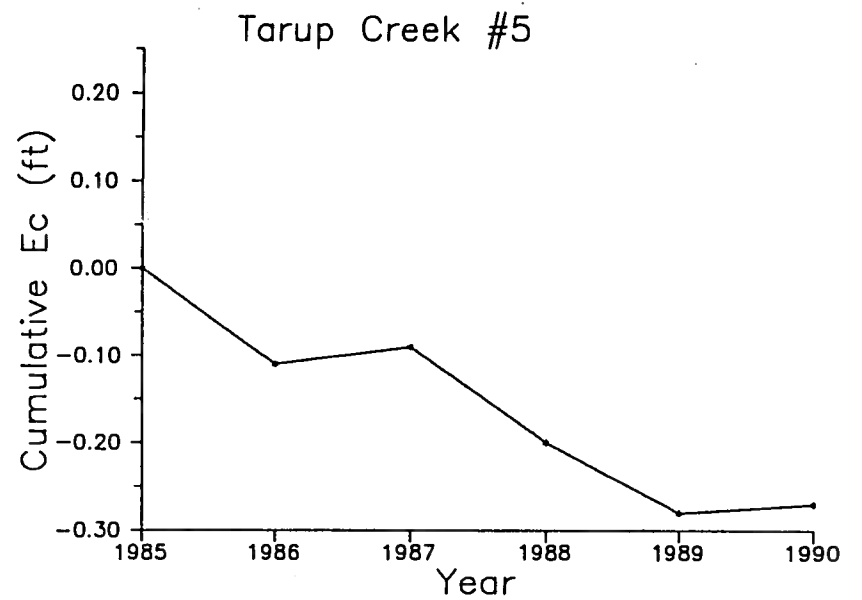
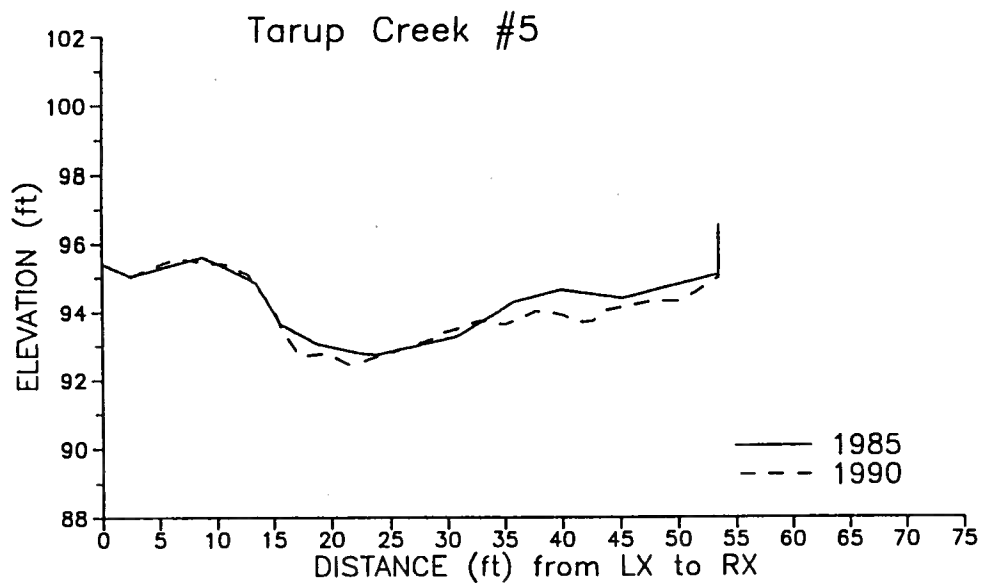
Tarup Creek #4



Tarup Creek #4

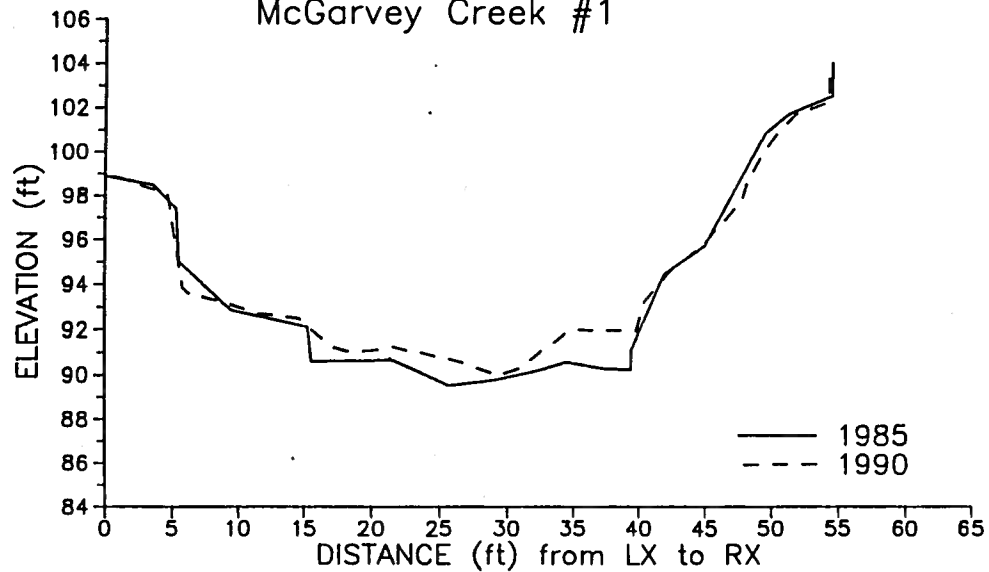


Tarup Creek

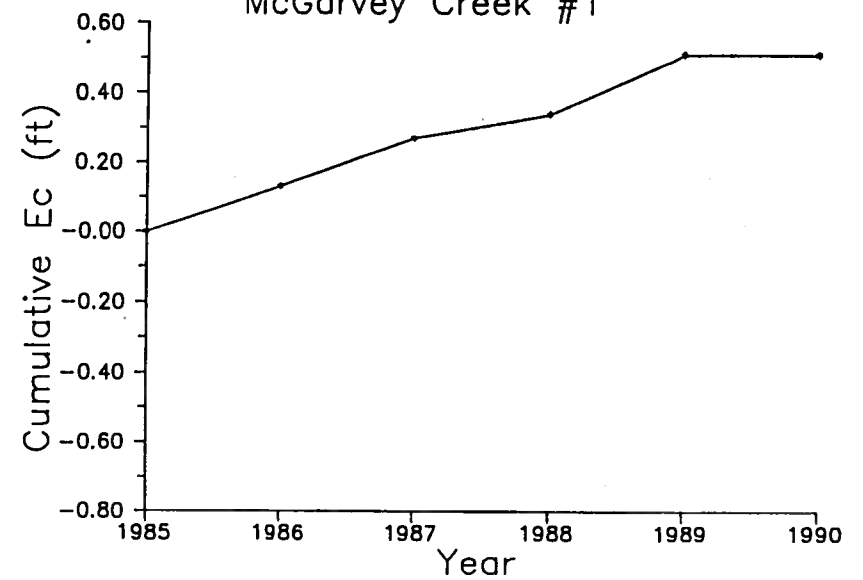


McGarvey Creek

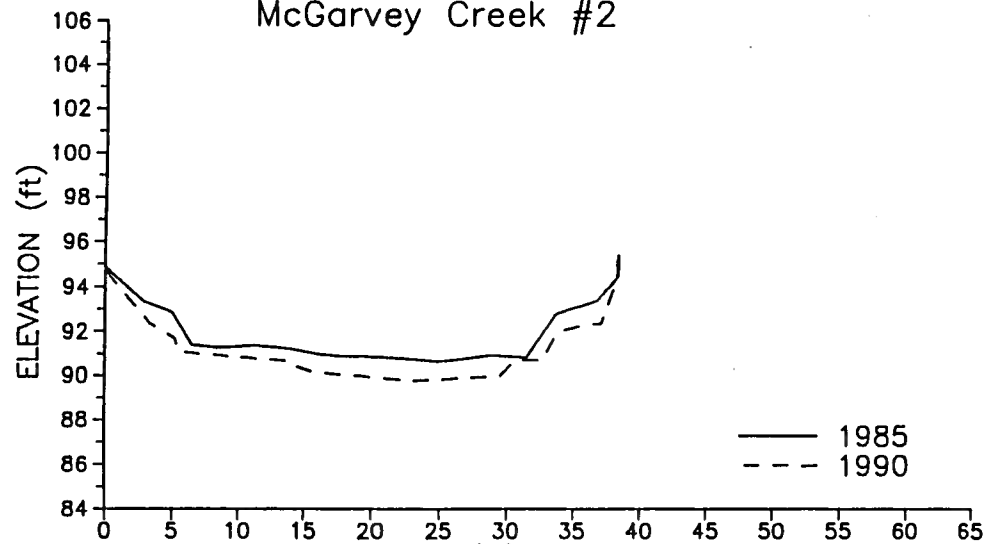
McGarvey Creek #1



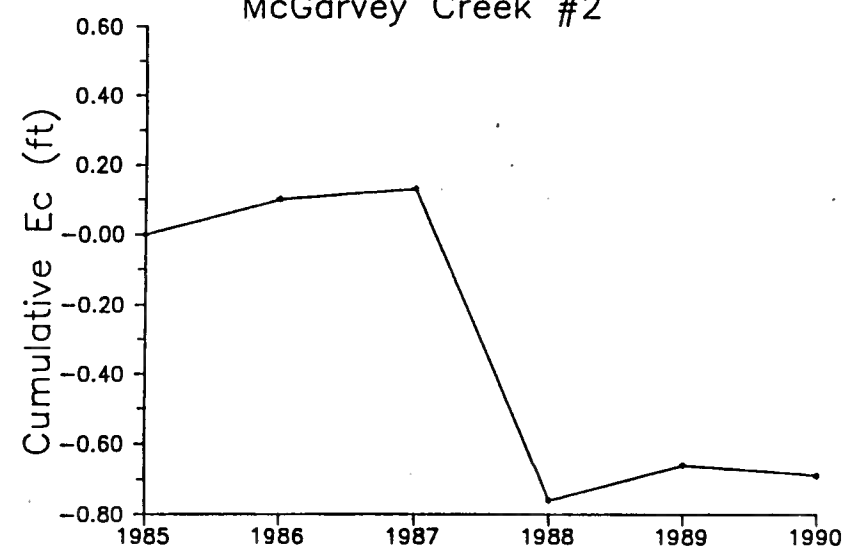
McGarvey Creek #1



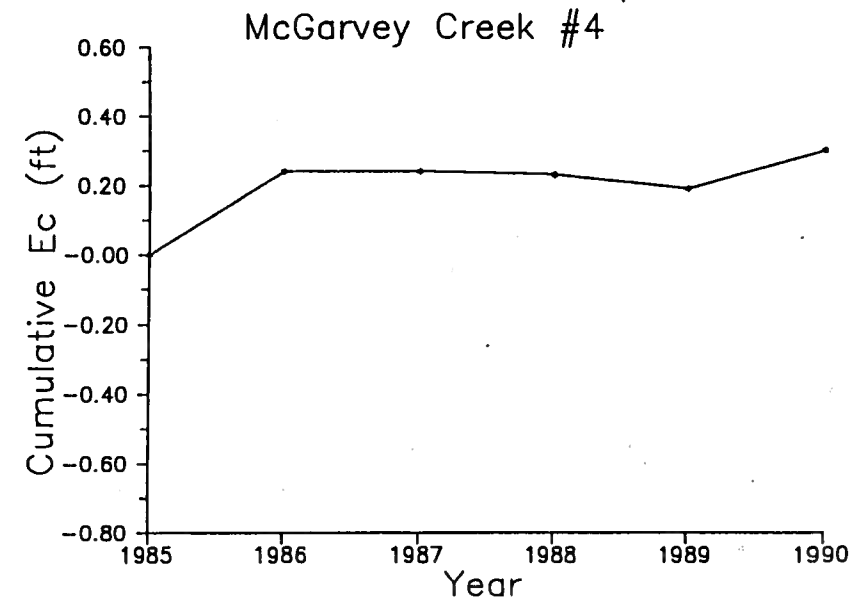
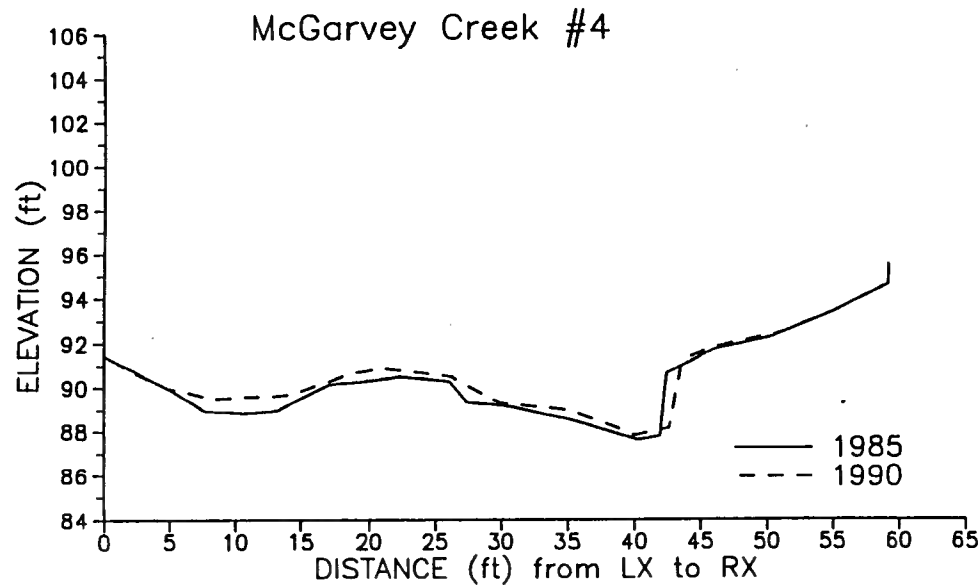
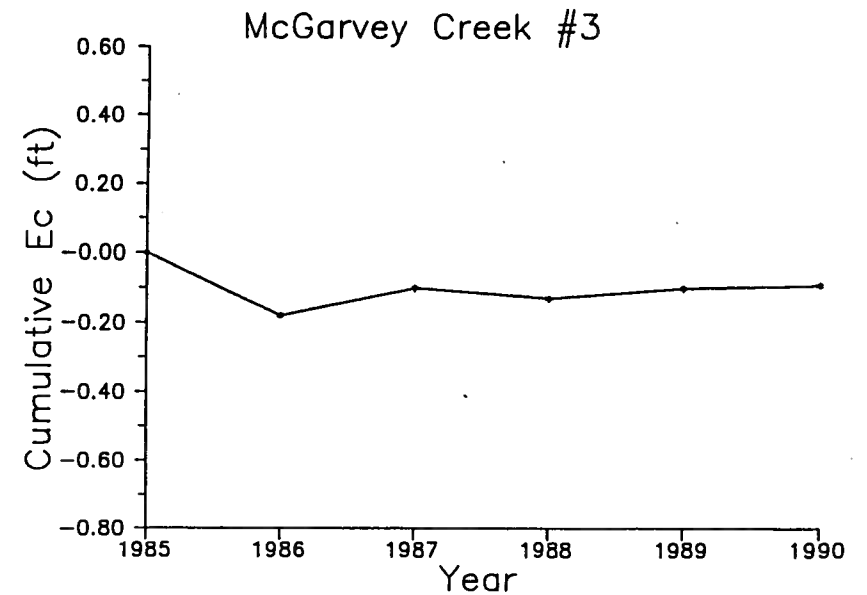
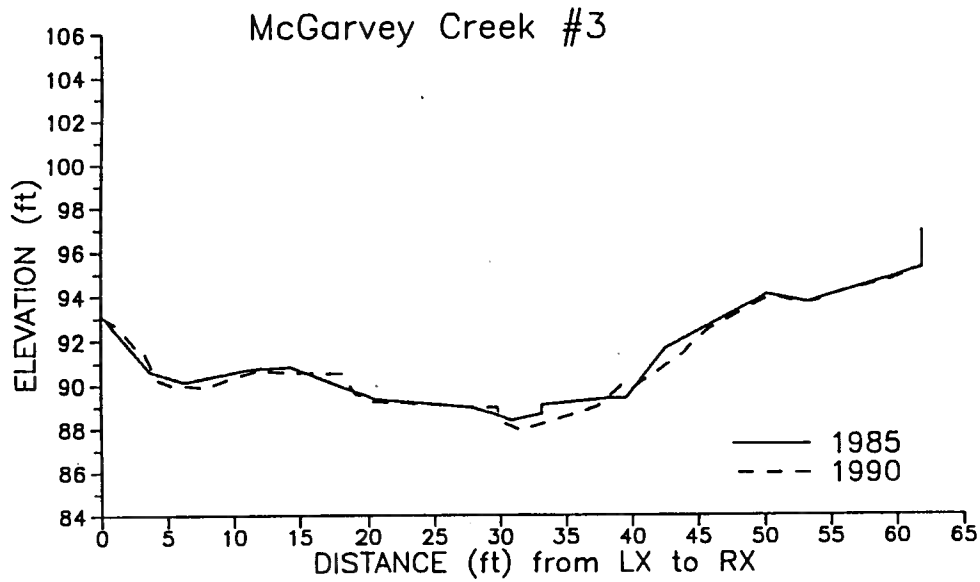
McGarvey Creek #2



McGarvey Creek #2

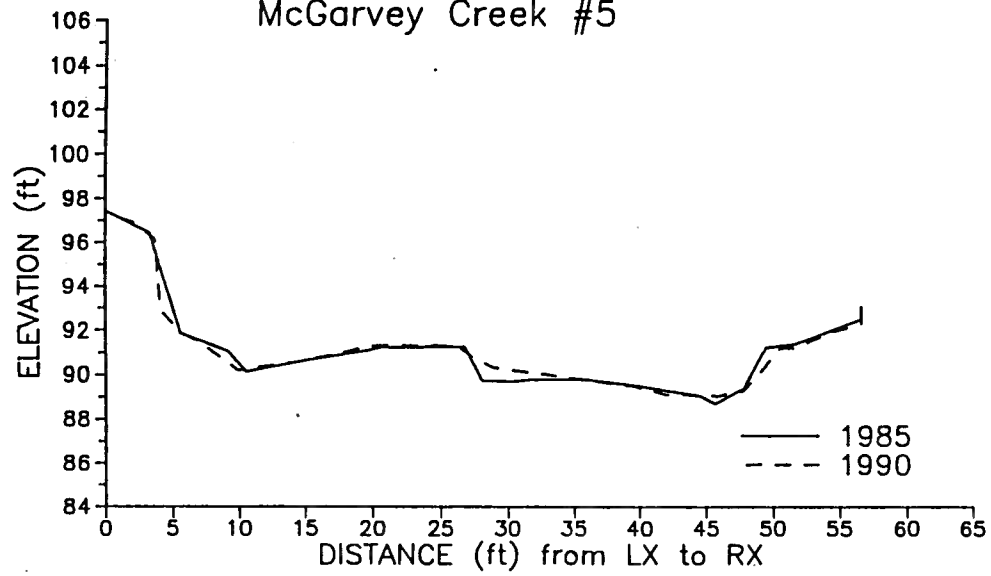


McGarvey Creek

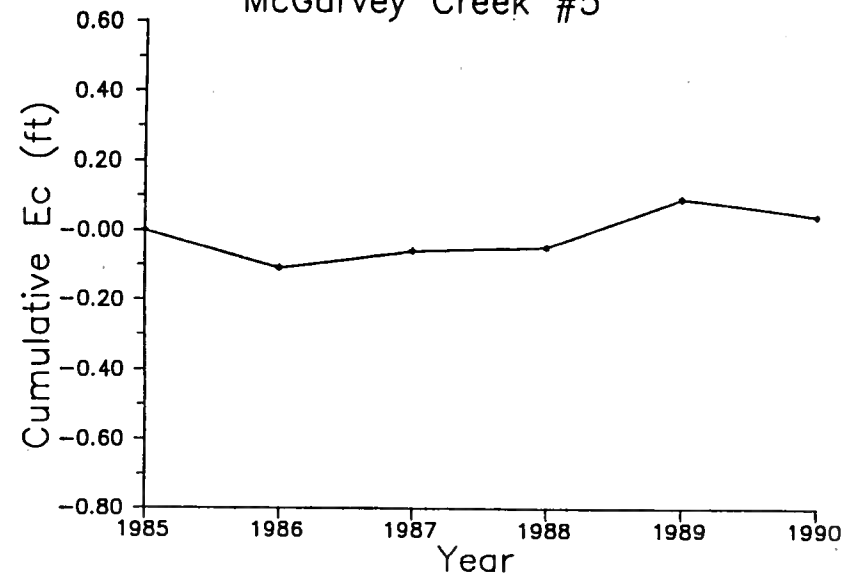


McGarvey Creek

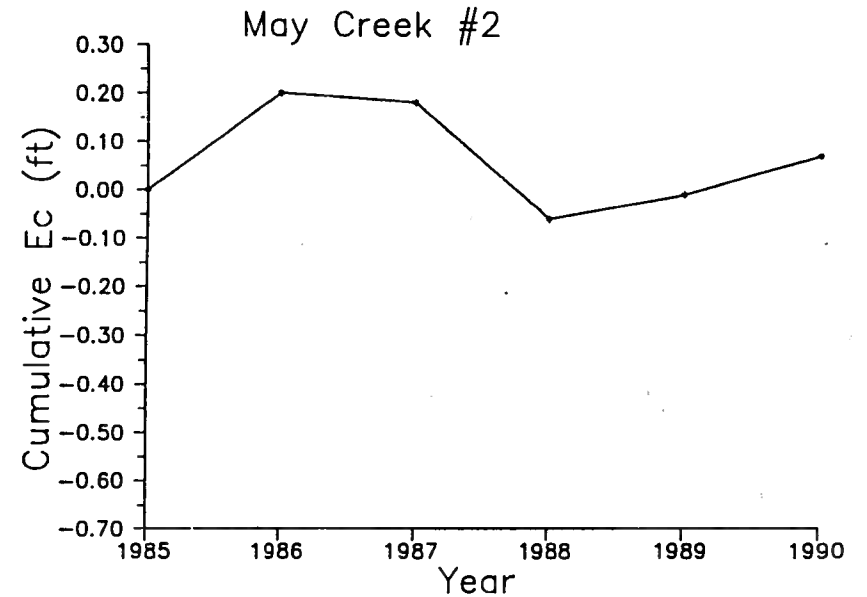
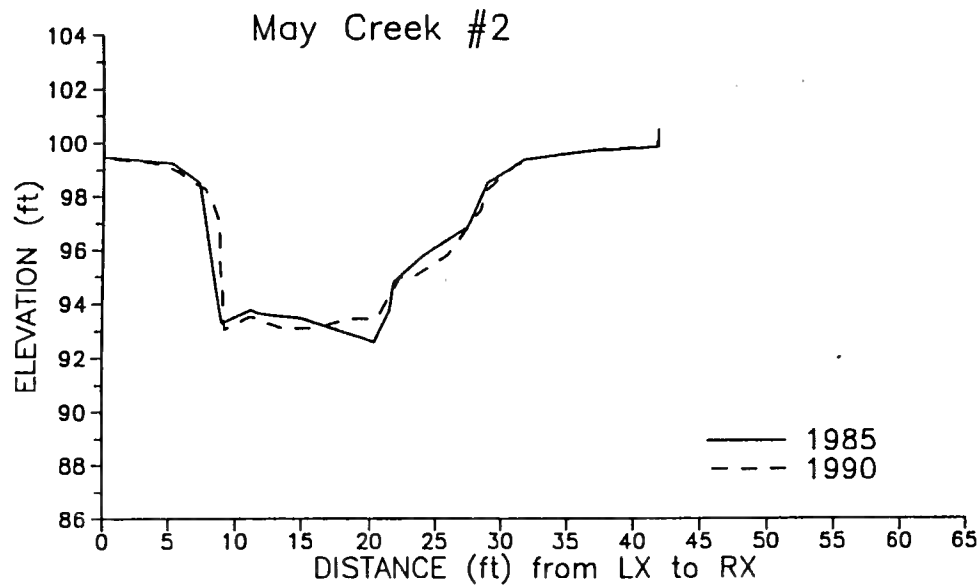
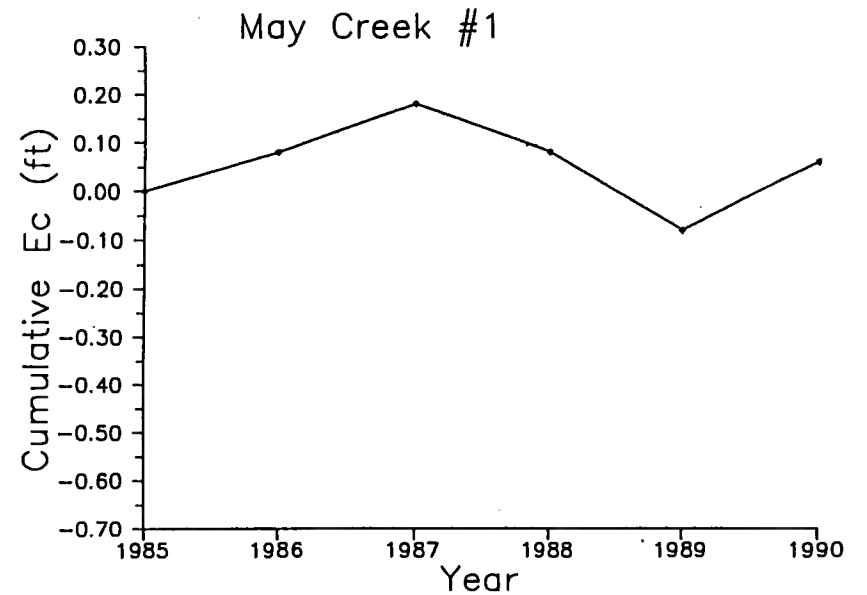
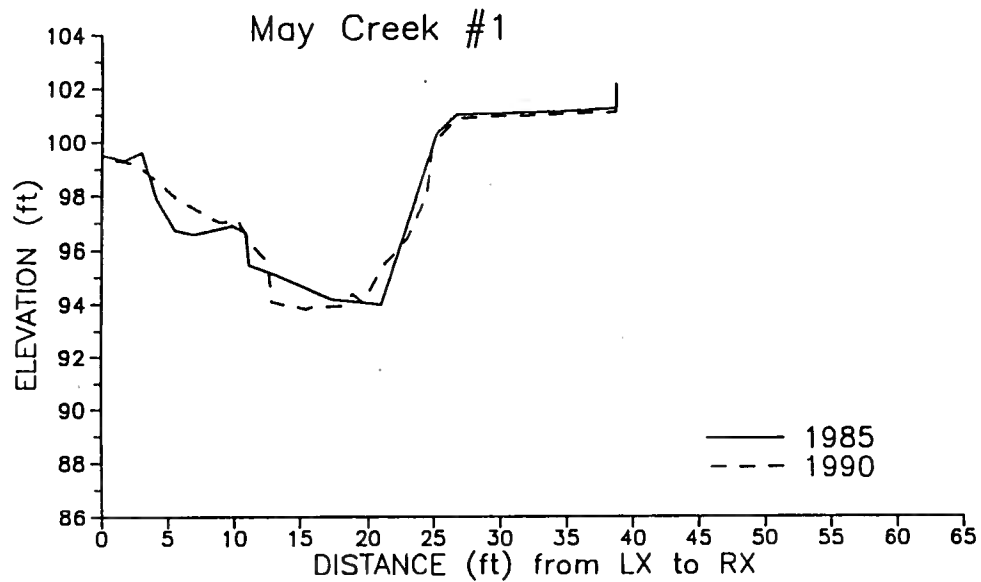
McGarvey Creek #5



McGarvey Creek #5

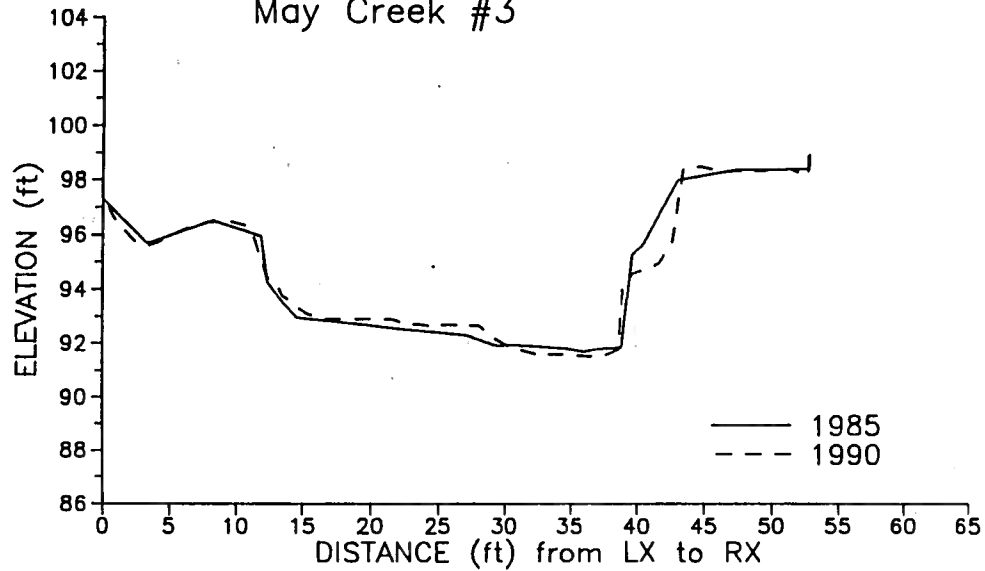


May Creek

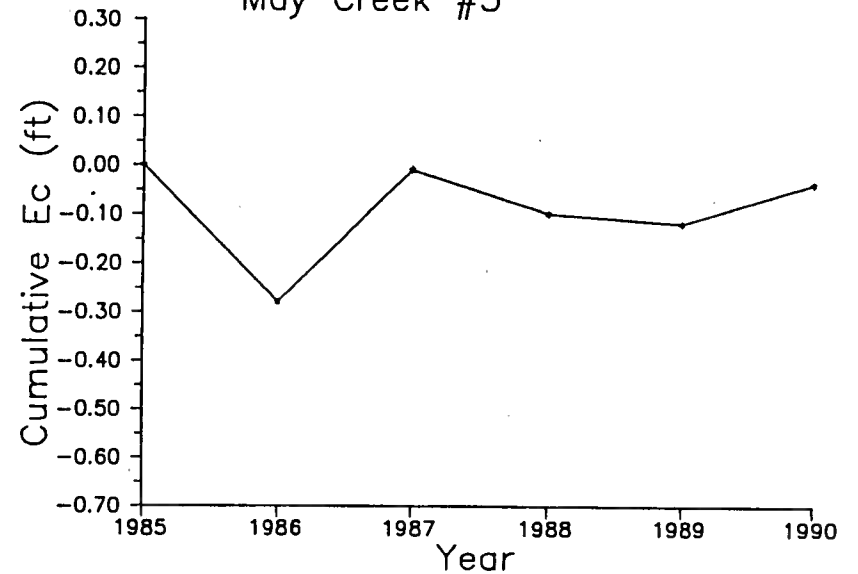


May Creek

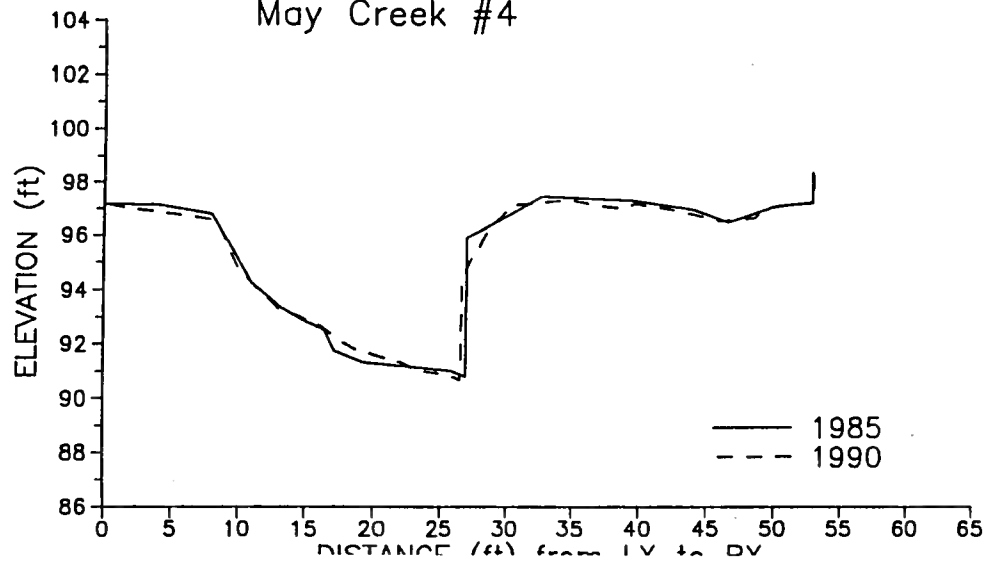
May Creek #3



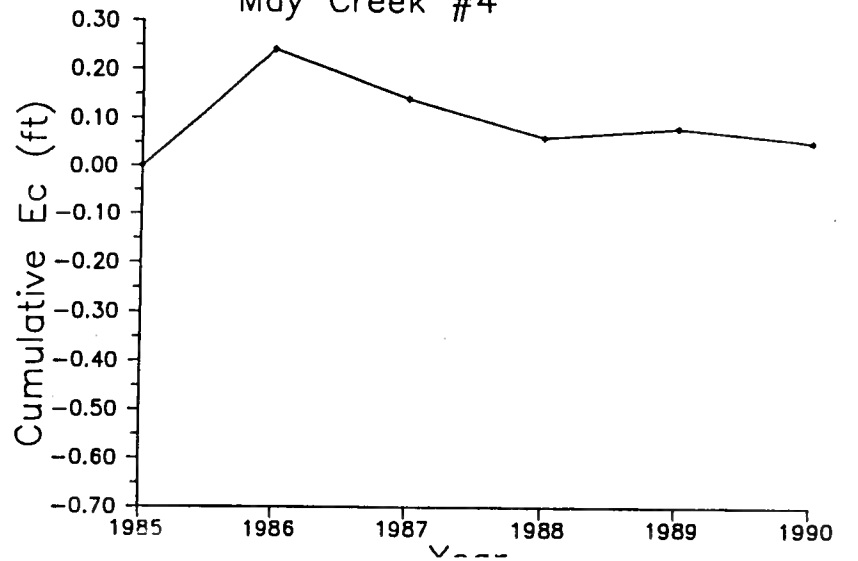
May Creek #3



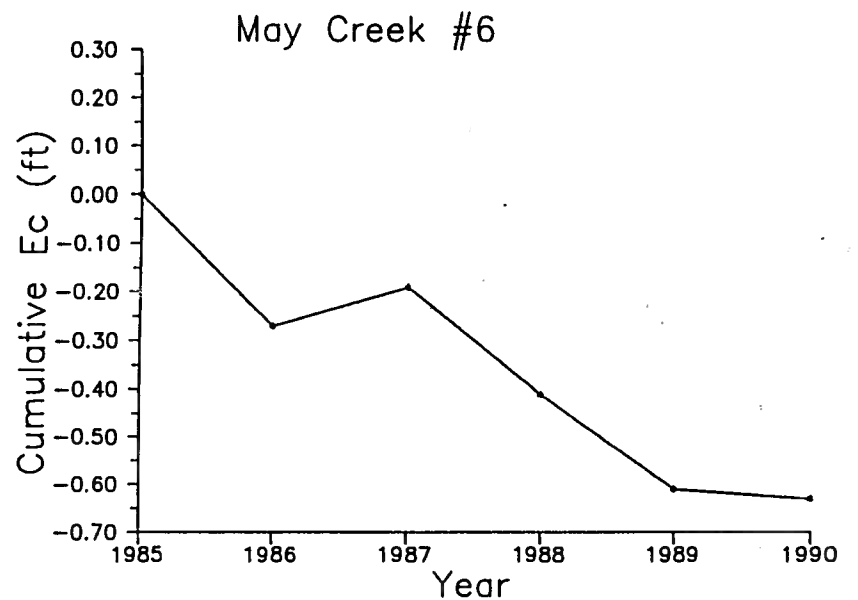
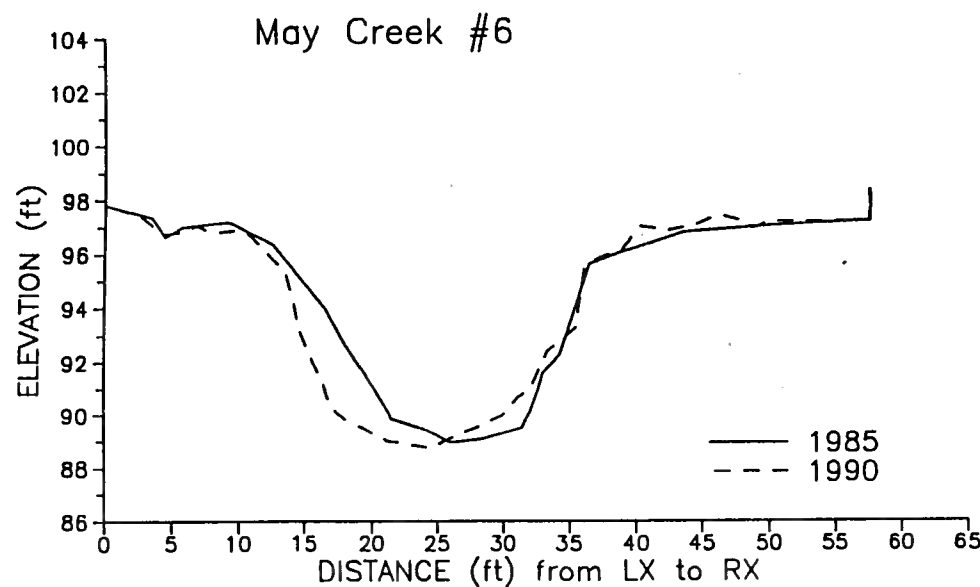
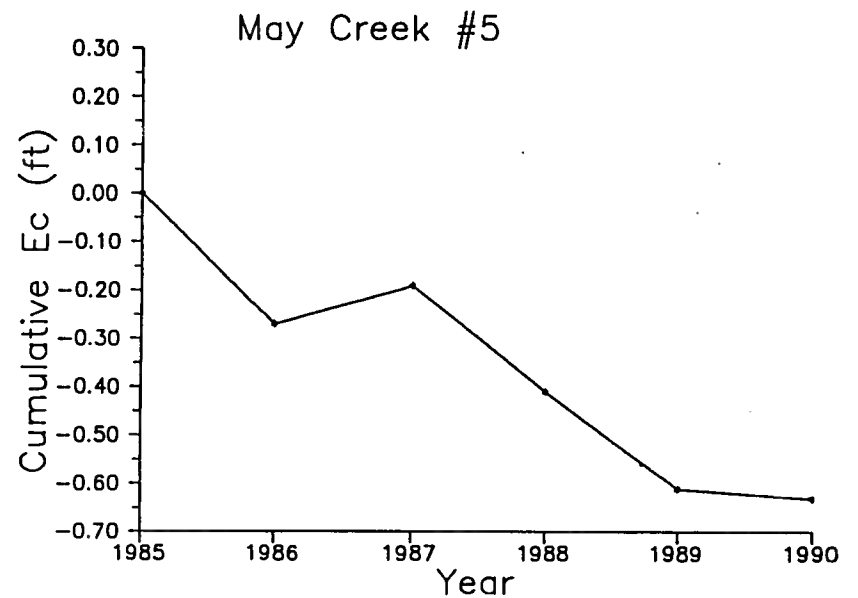
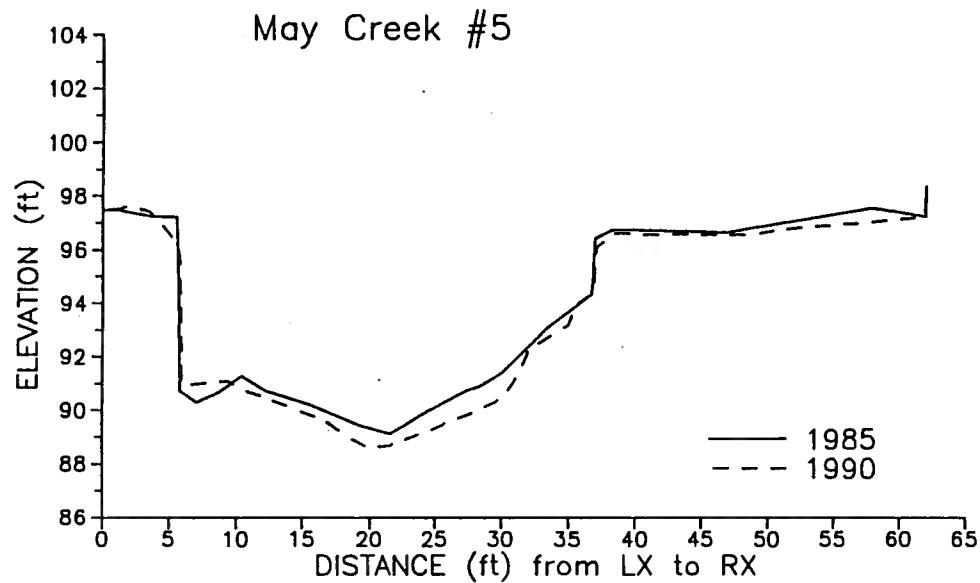
May Creek #4



May Creek #4

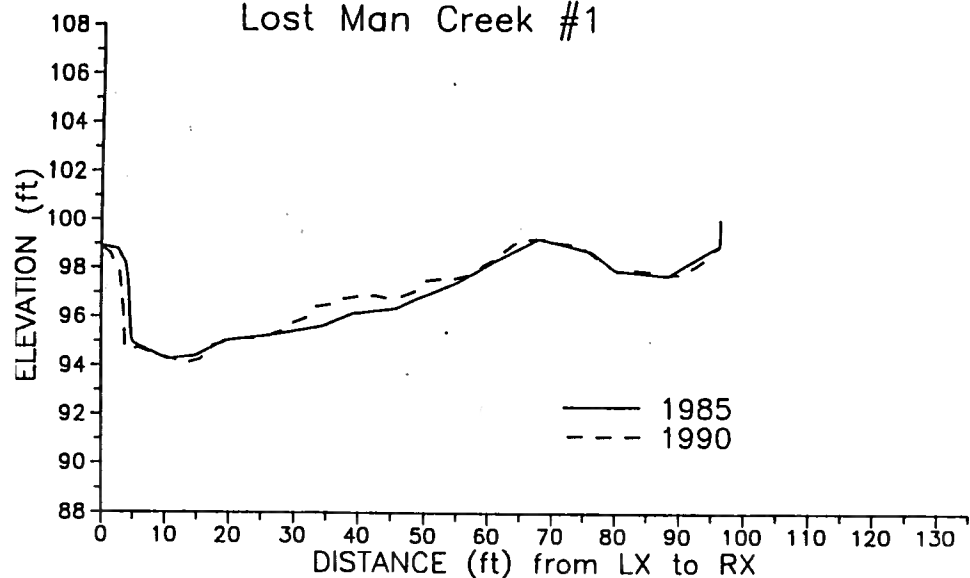


May Creek

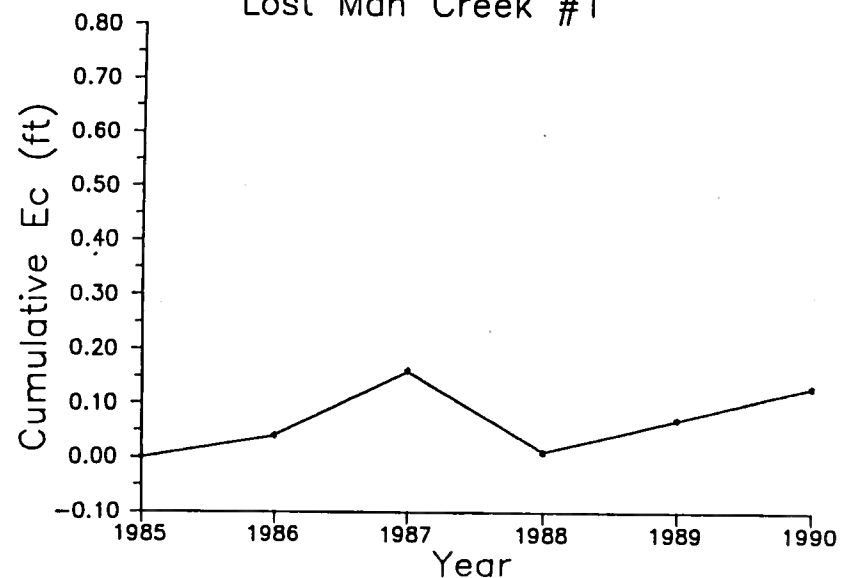


Lost Man Creek

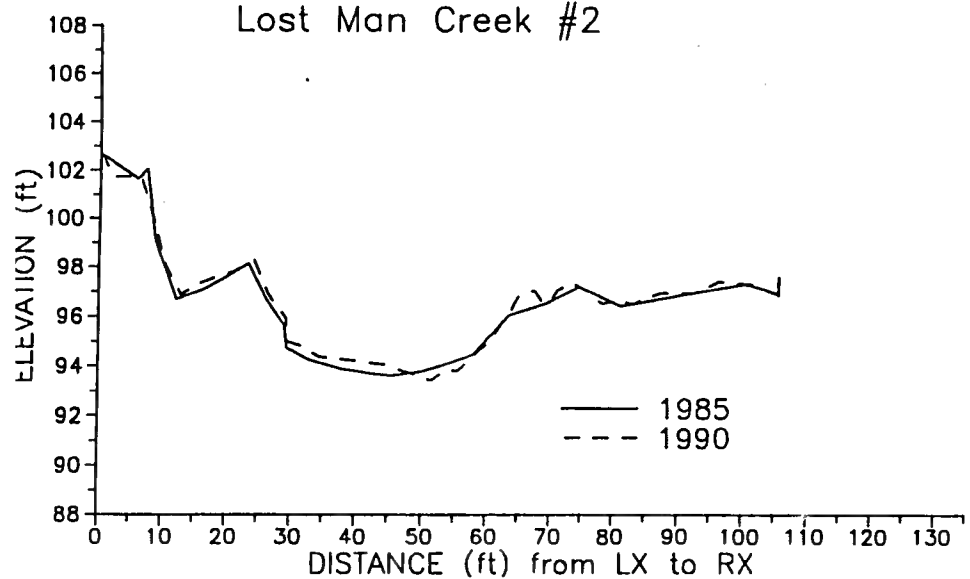
Lost Man Creek #1



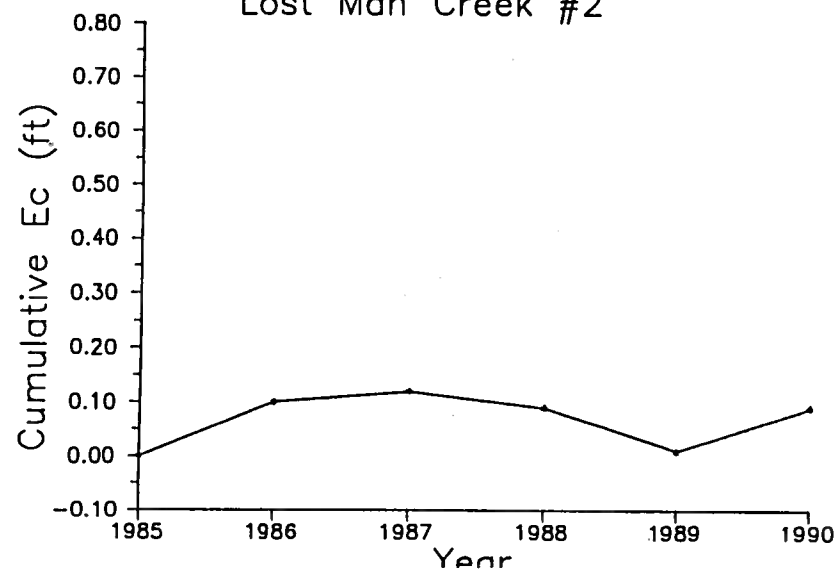
Lost Man Creek #1



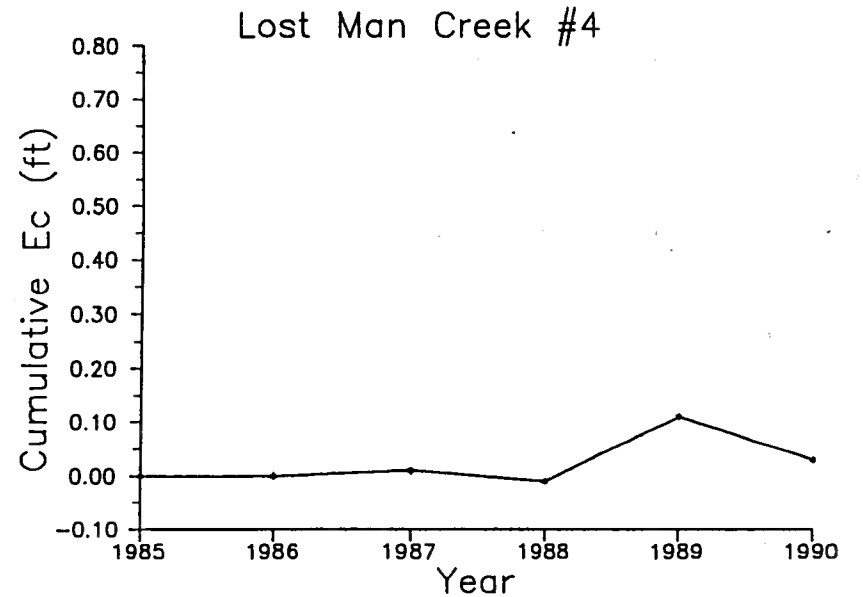
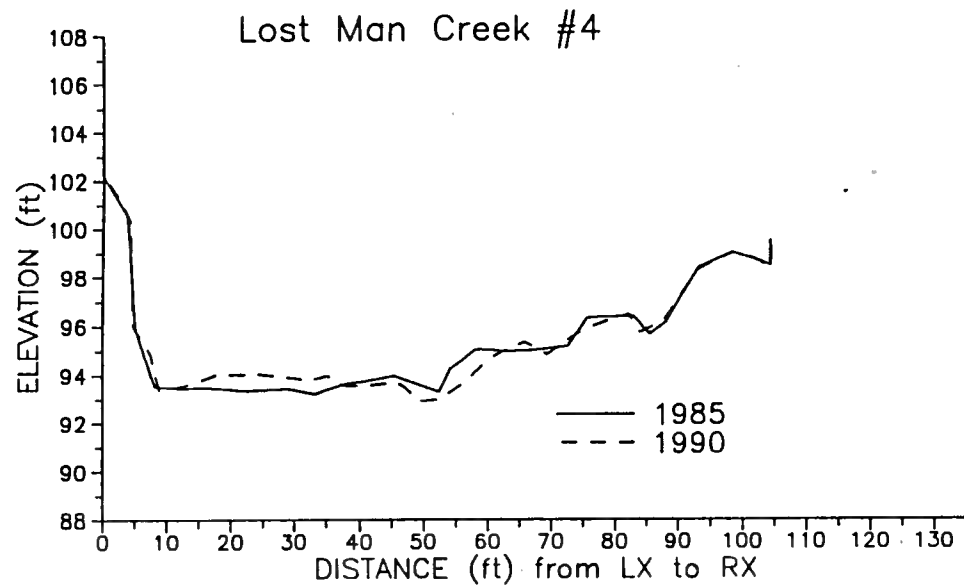
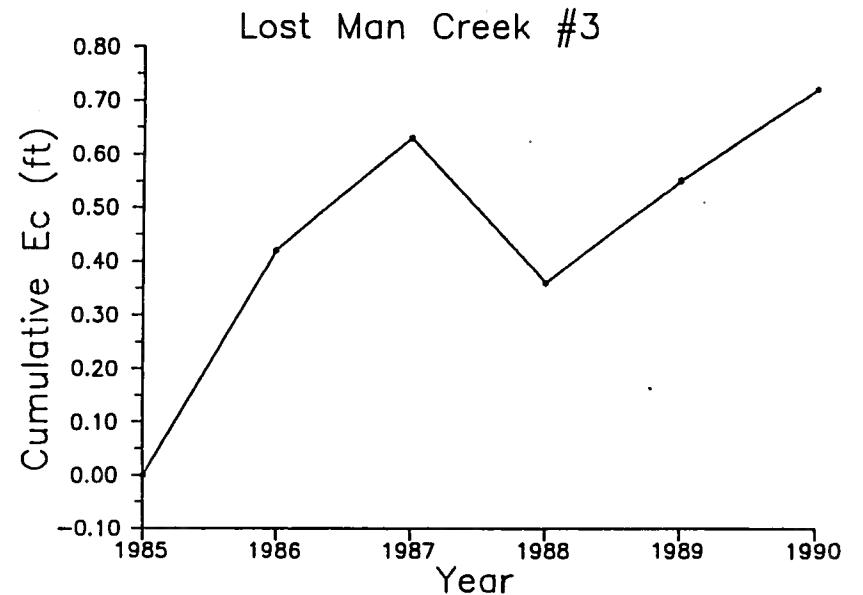
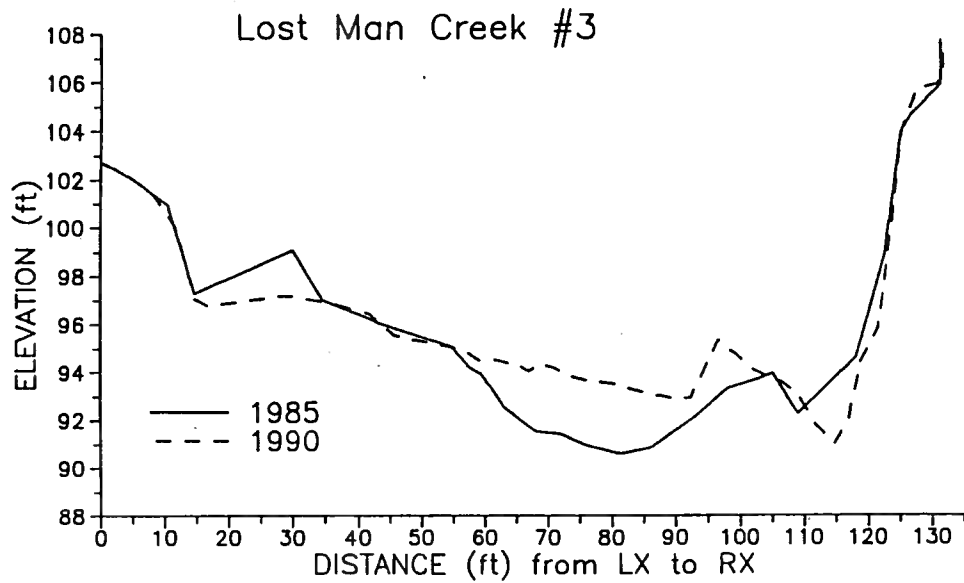
Lost Man Creek #2



Lost Man Creek #2

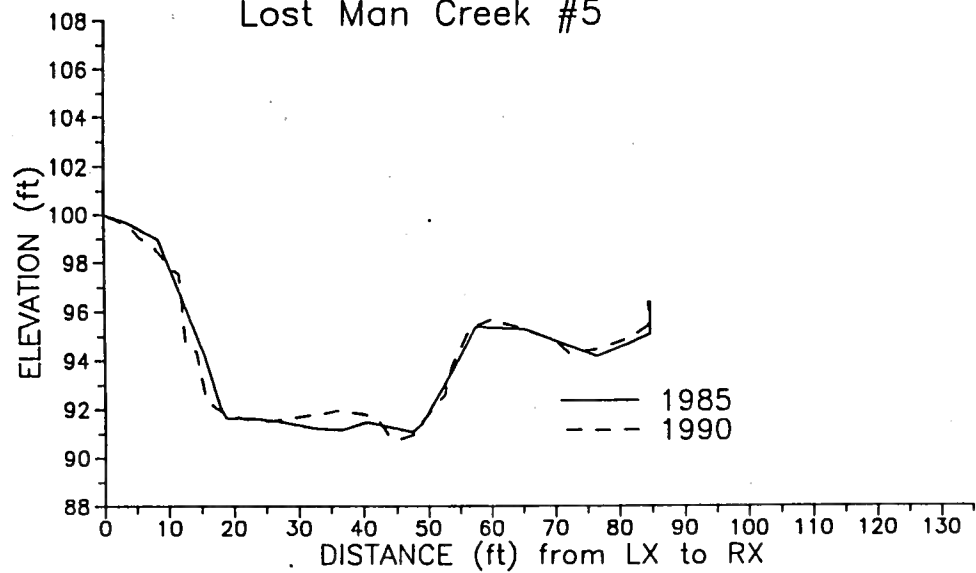


Lost Man Creek

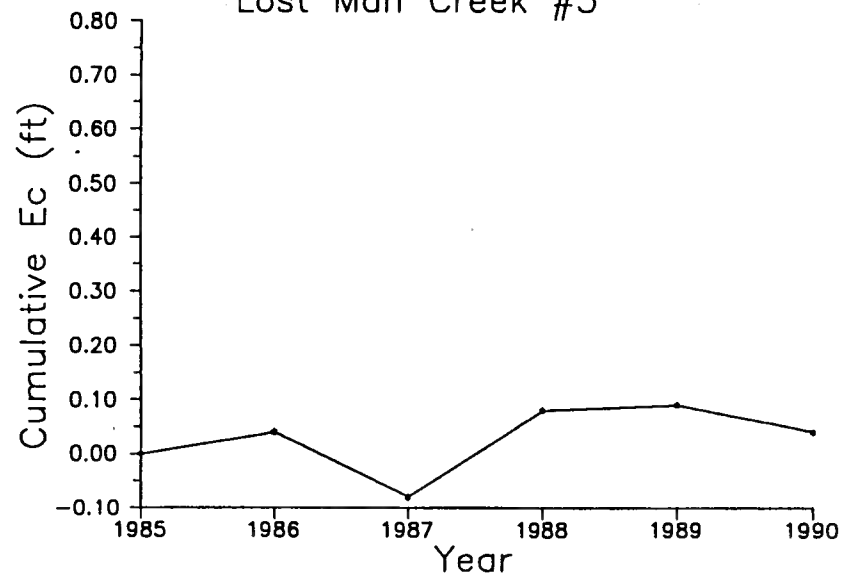


Lost Man Creek

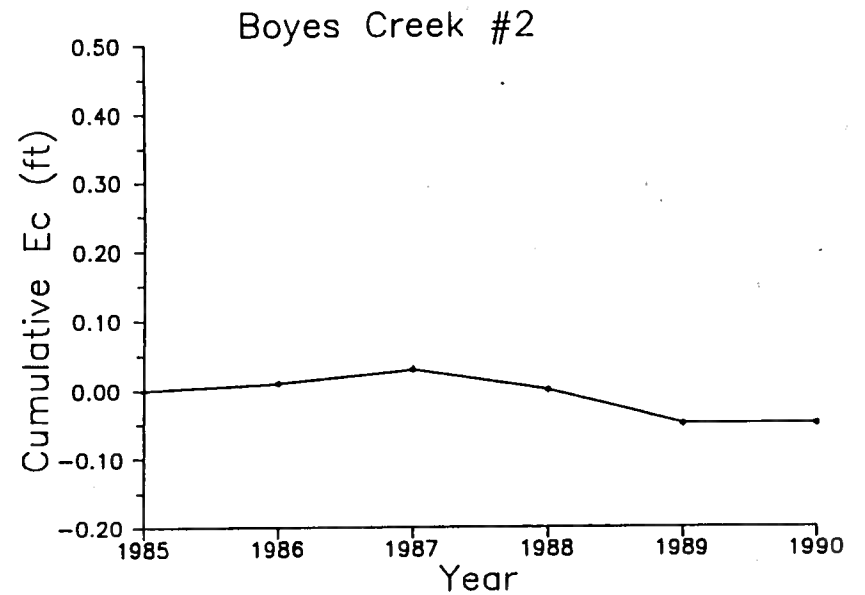
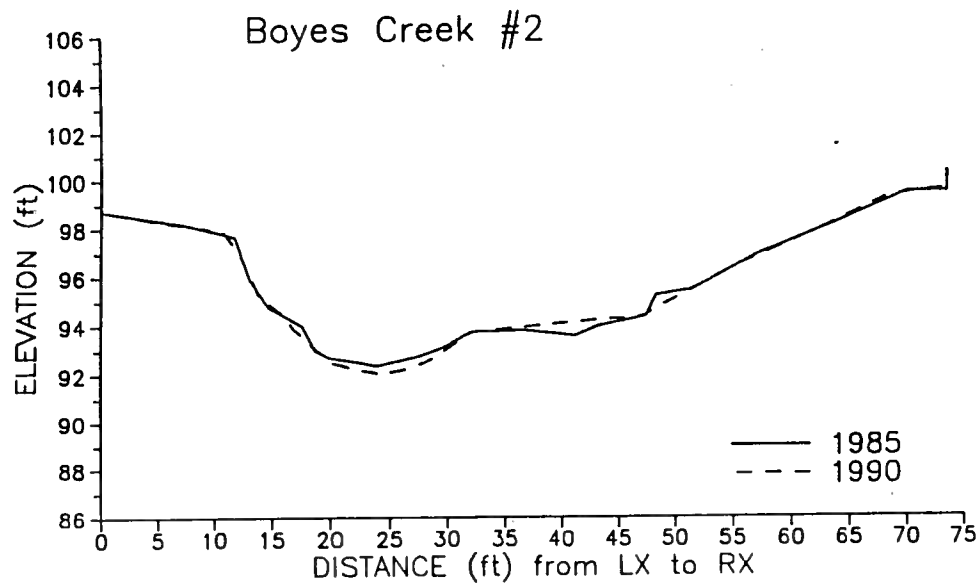
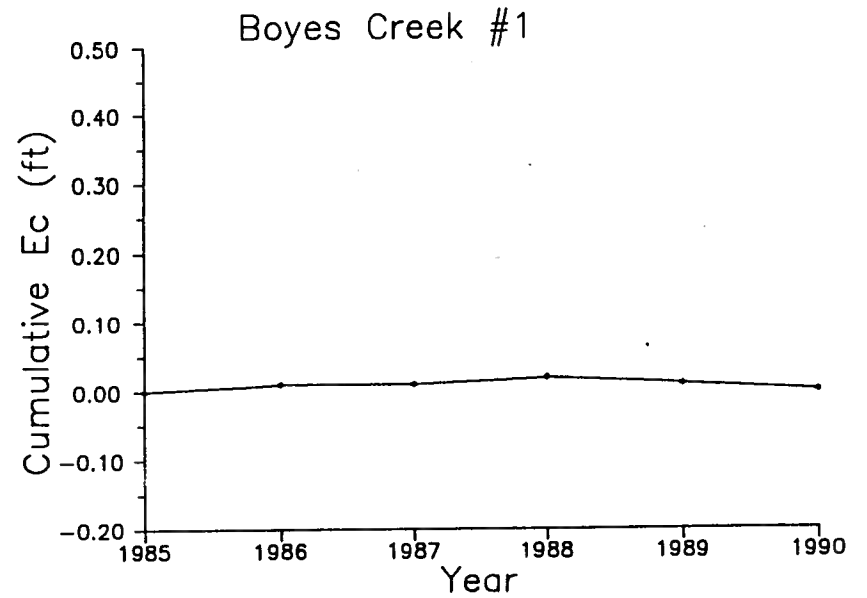
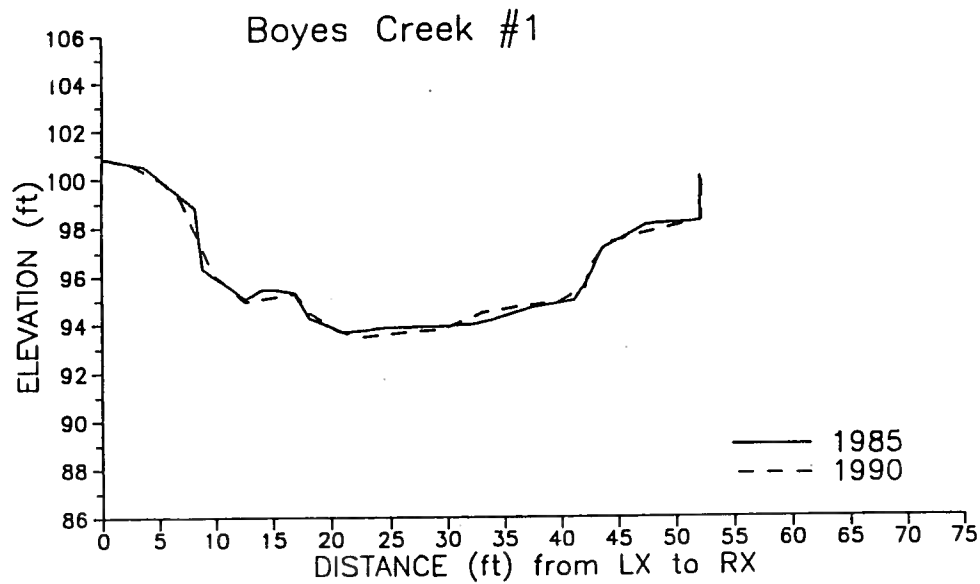
Lost Man Creek #5



Lost Man Creek #5

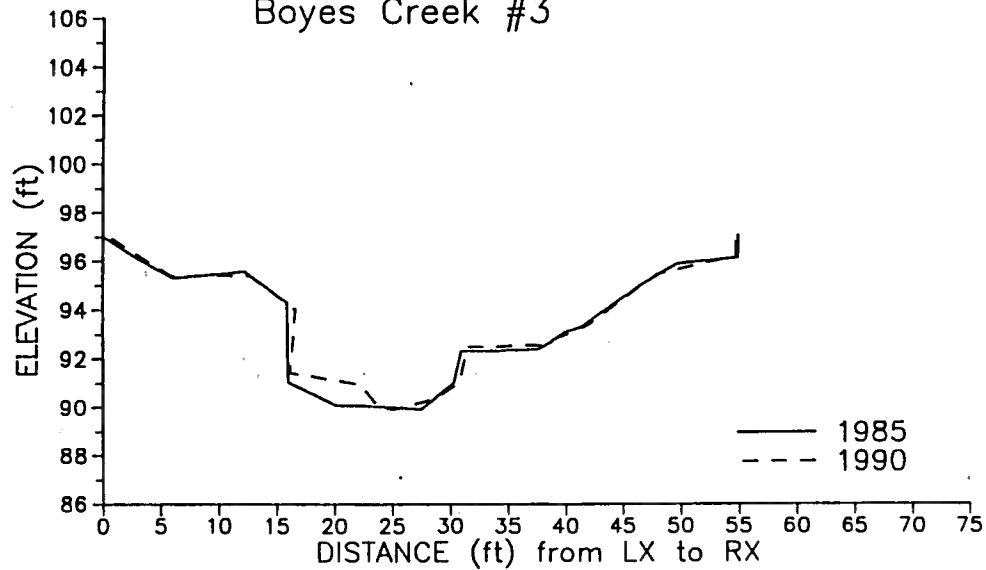


Boyes Creek

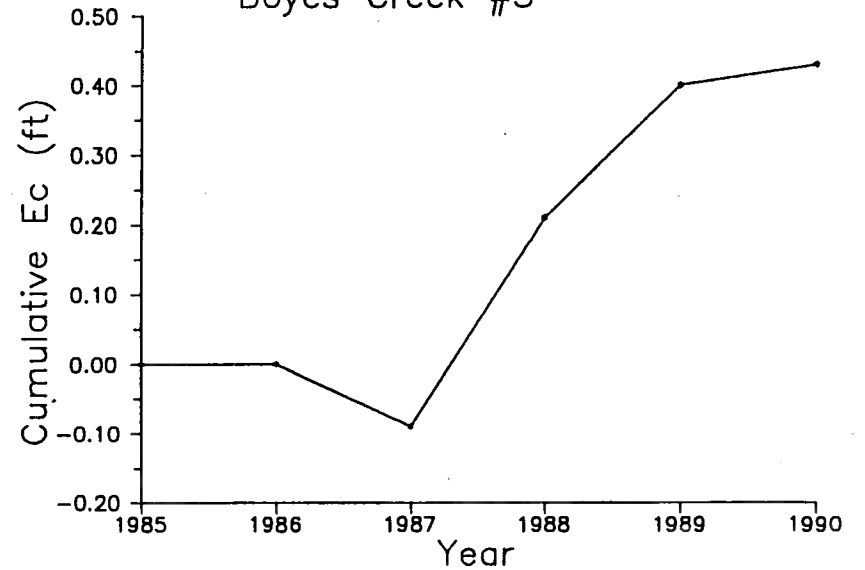


Boyes Creek

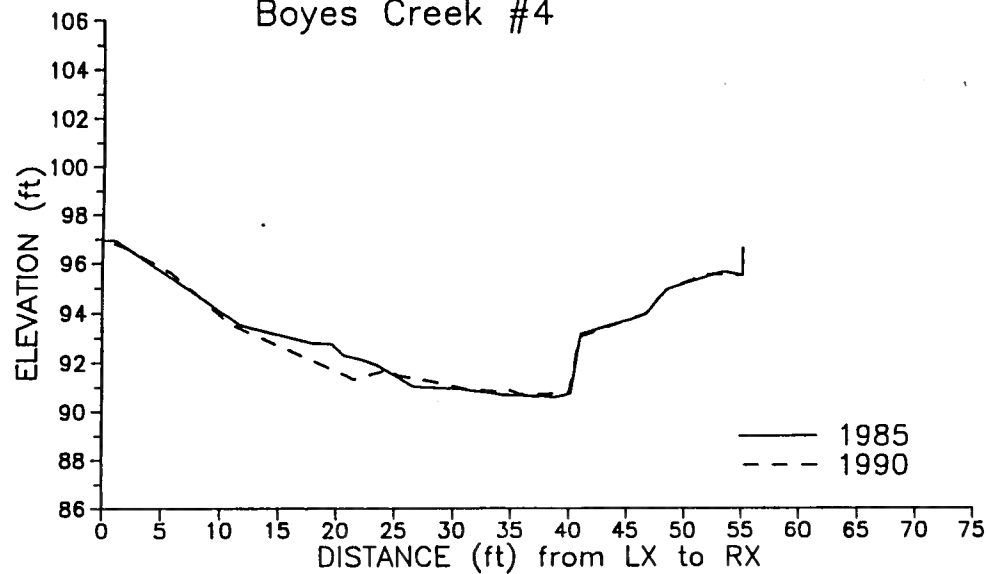
Boyes Creek #3



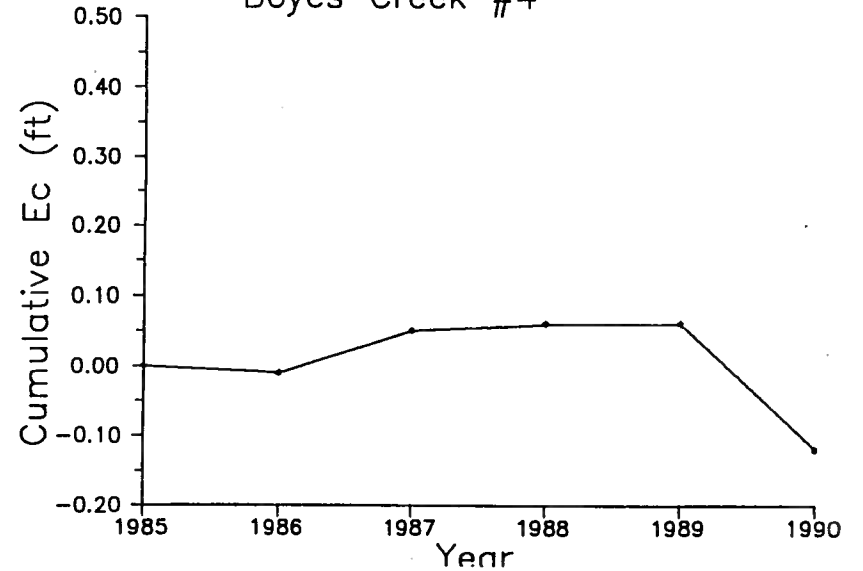
Boyes Creek #3



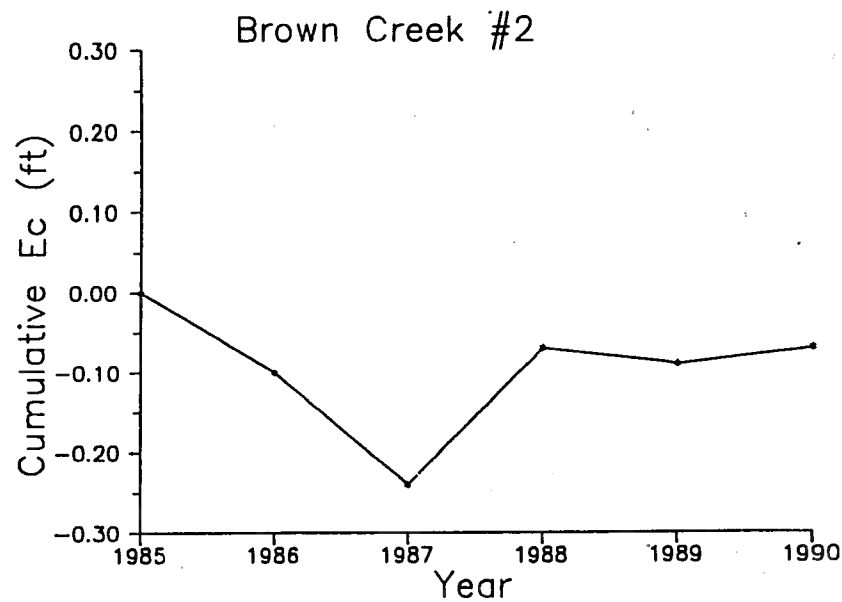
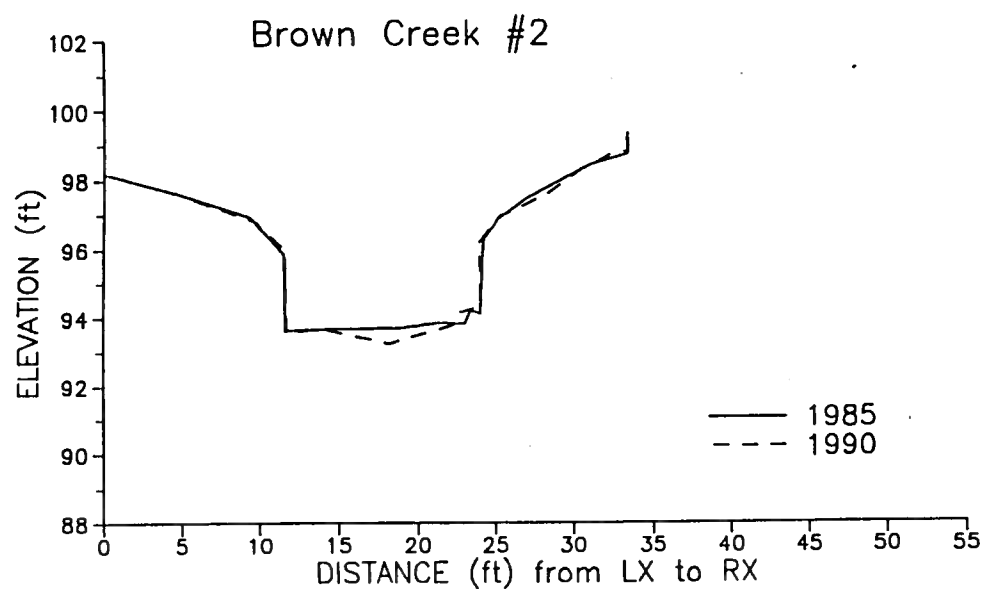
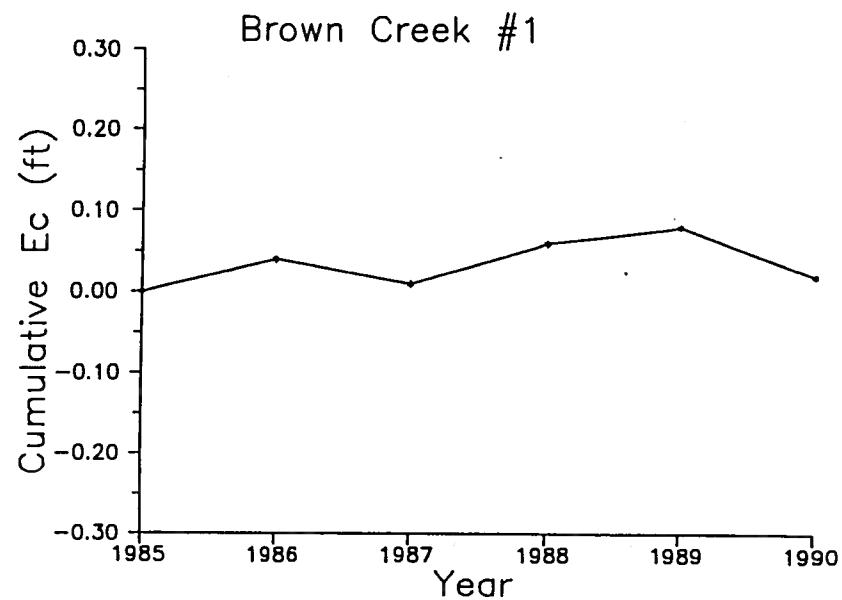
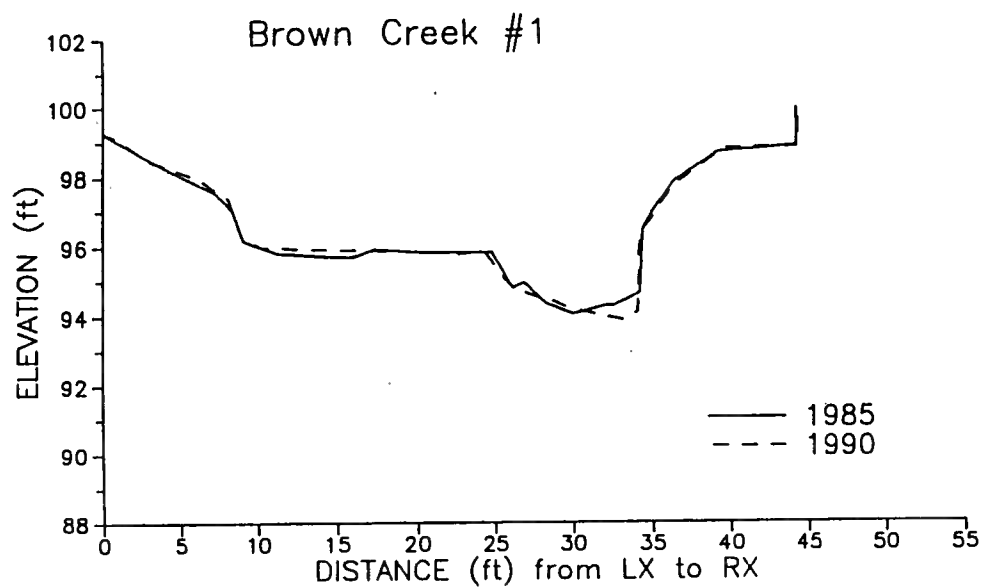
Boyes Creek #4



Boyes Creek #4

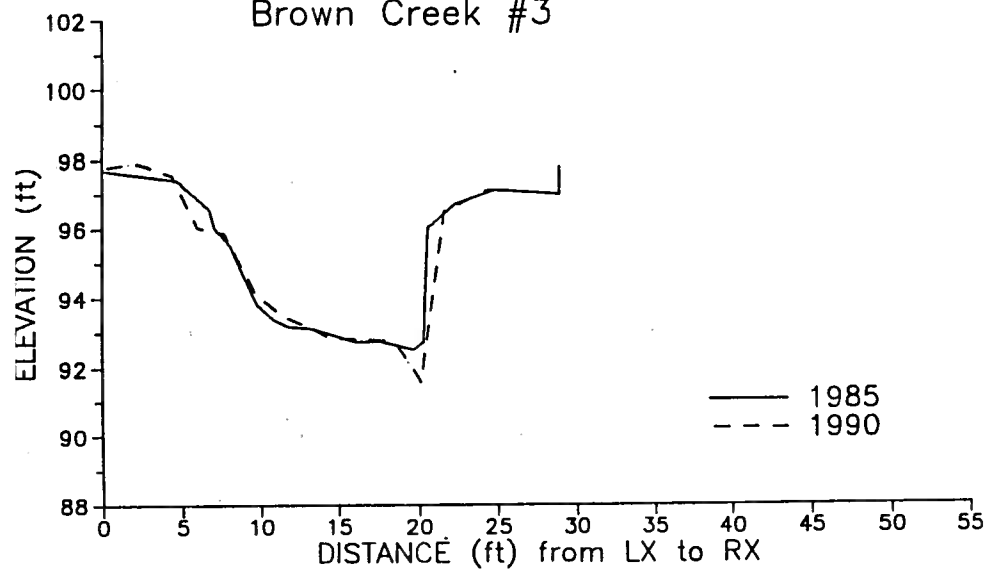


Brown Creek

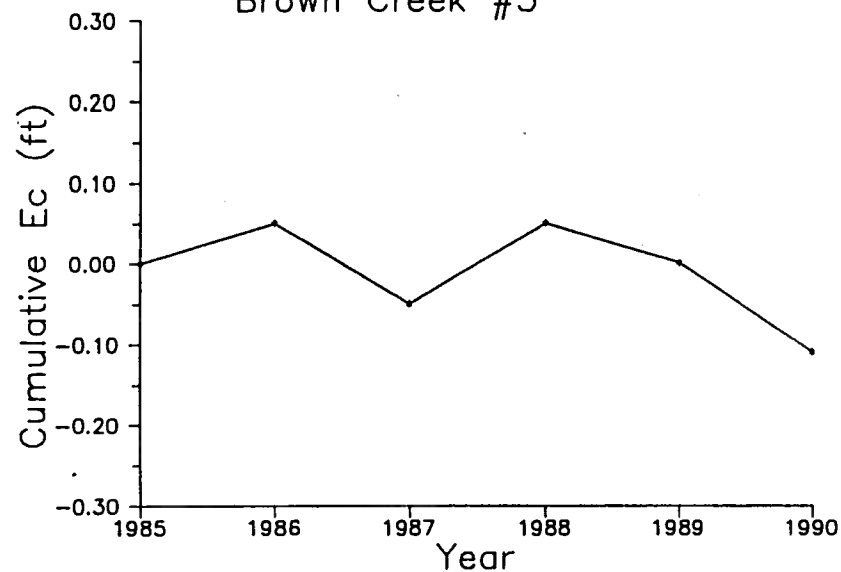


Brown Creek

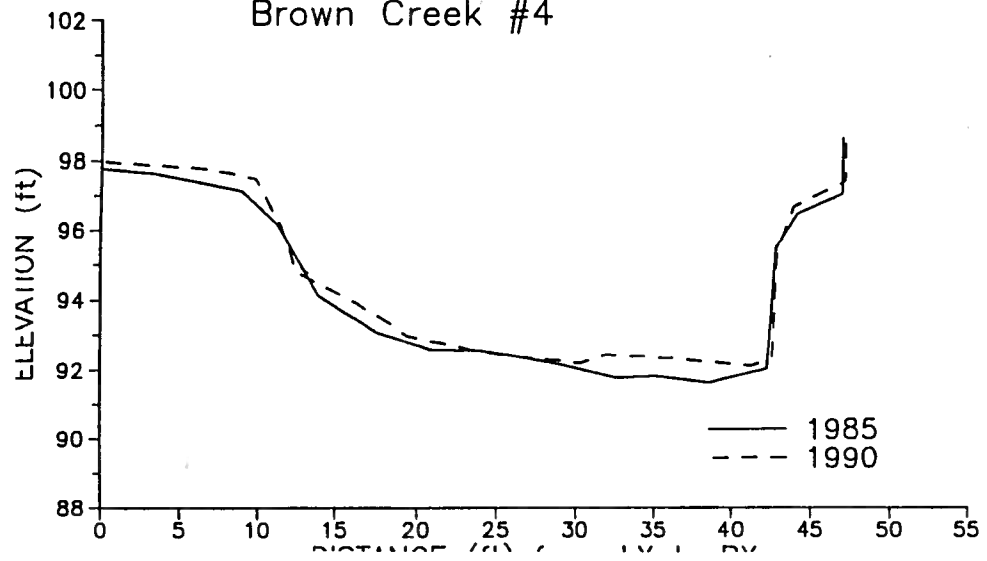
Brown Creek #3



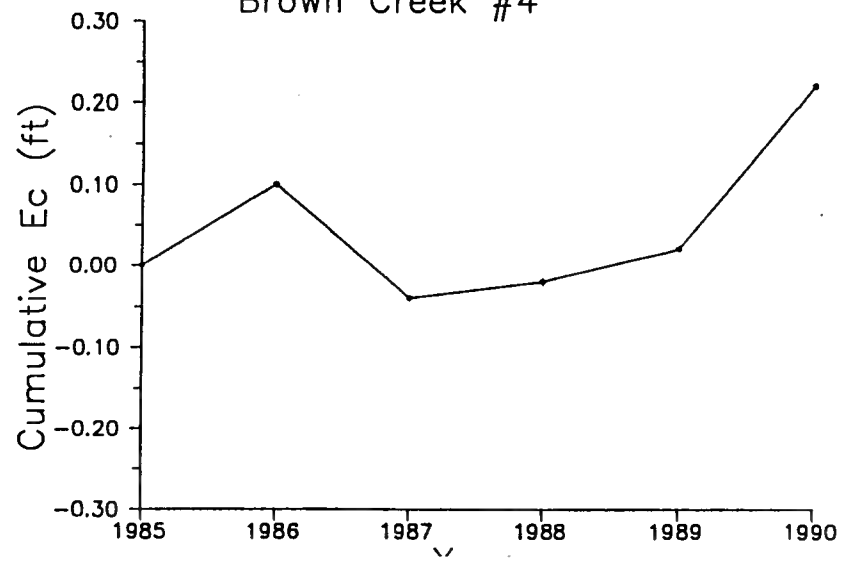
Brown Creek #3



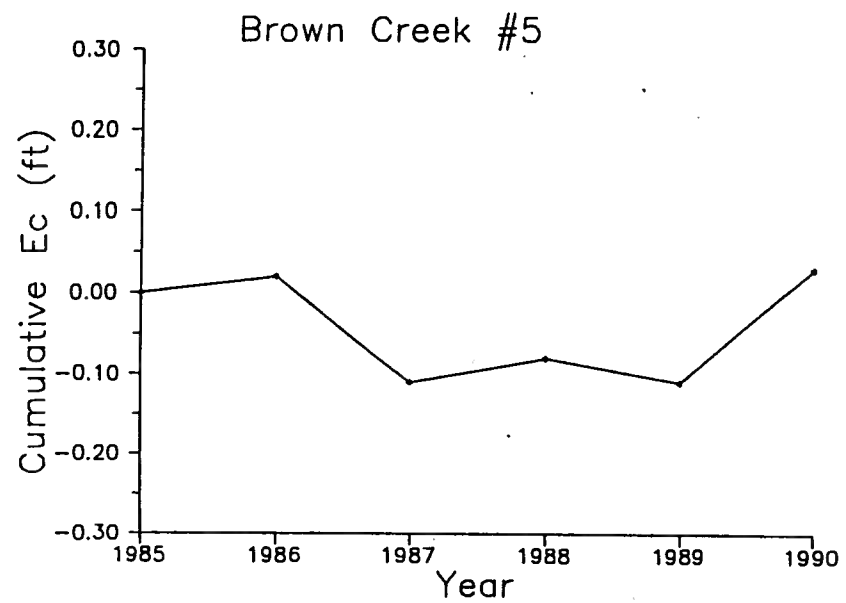
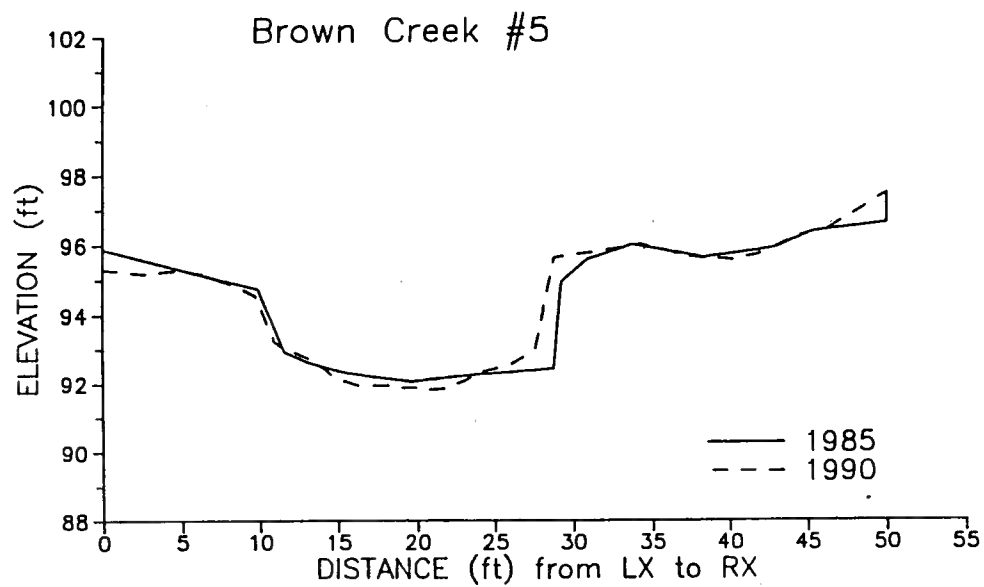
Brown Creek #4



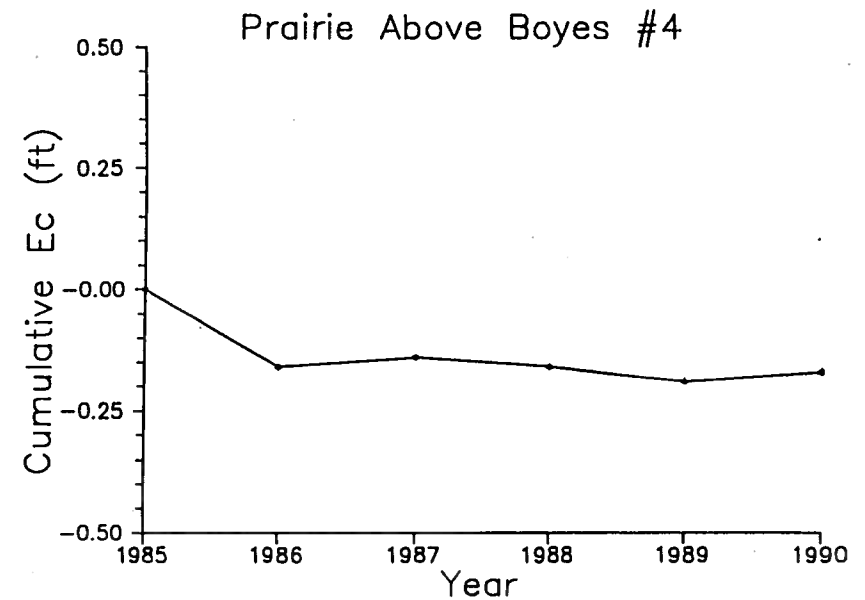
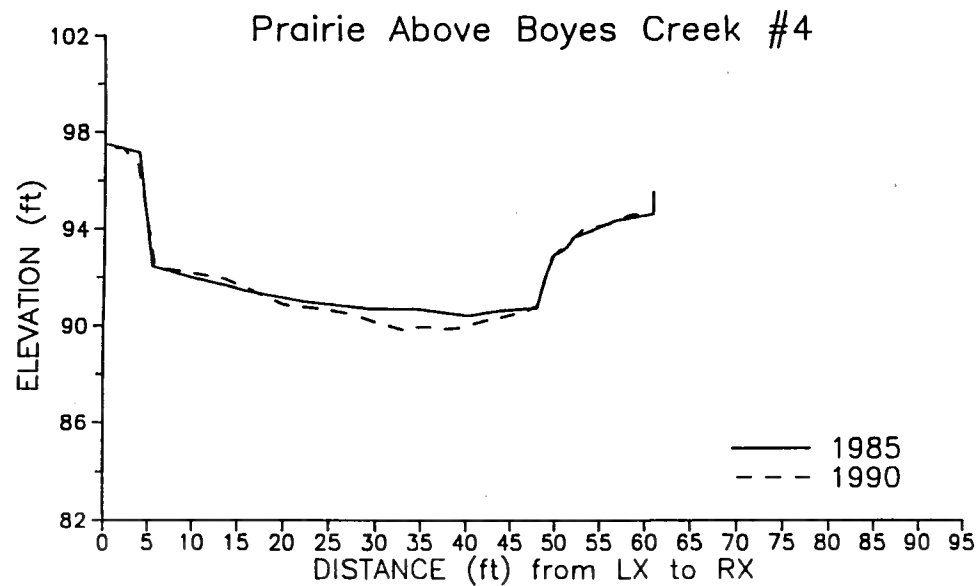
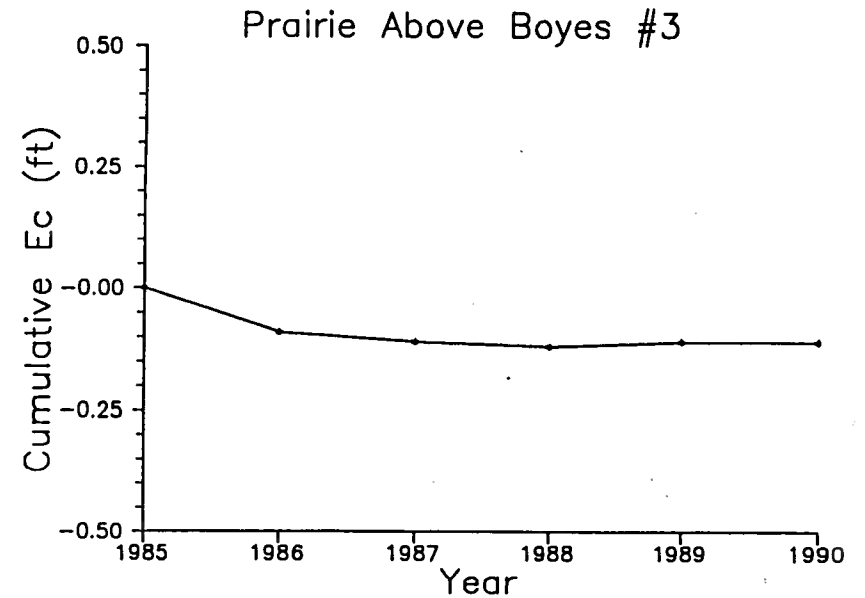
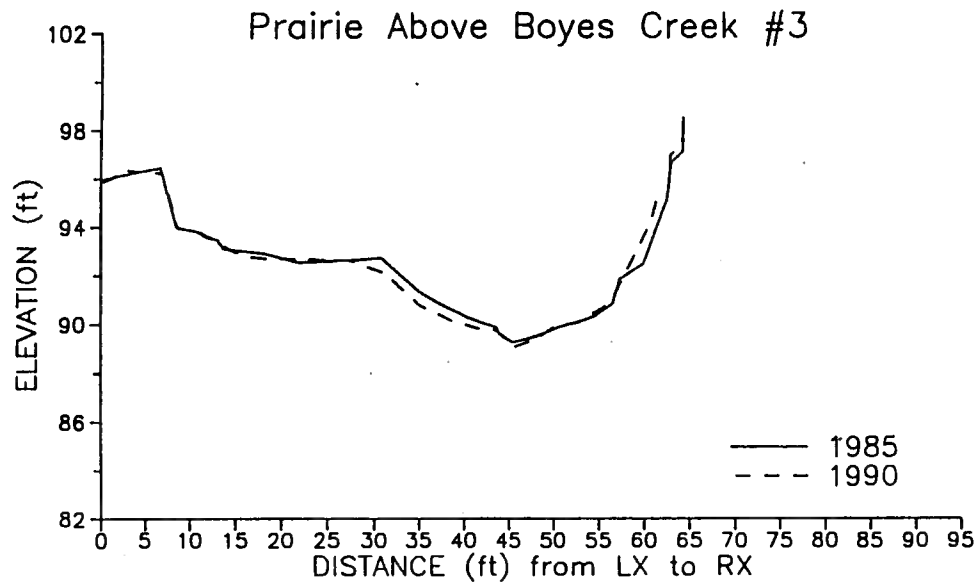
Brown Creek #4



Brown Creek

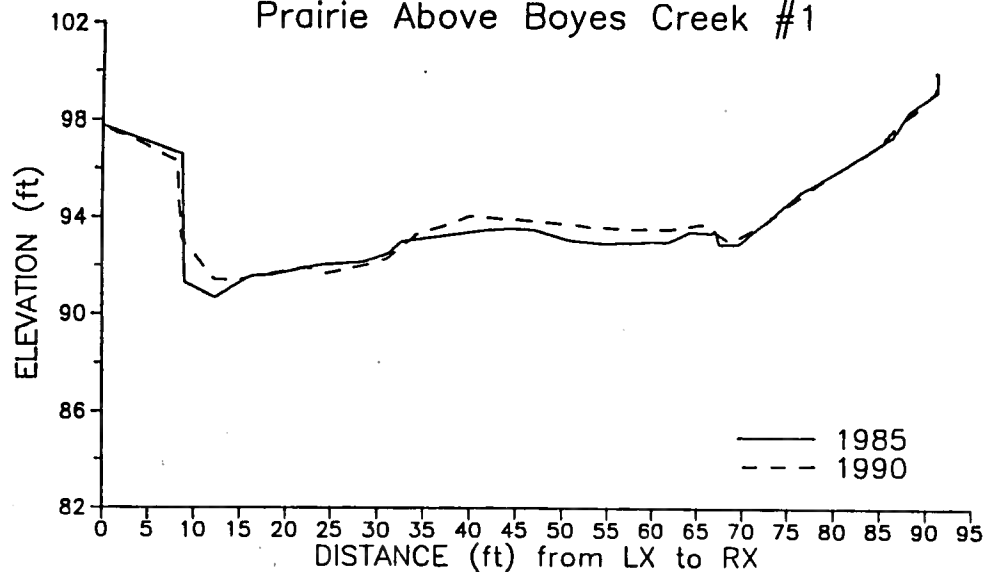


Prairie Creek Above Boyes Creek

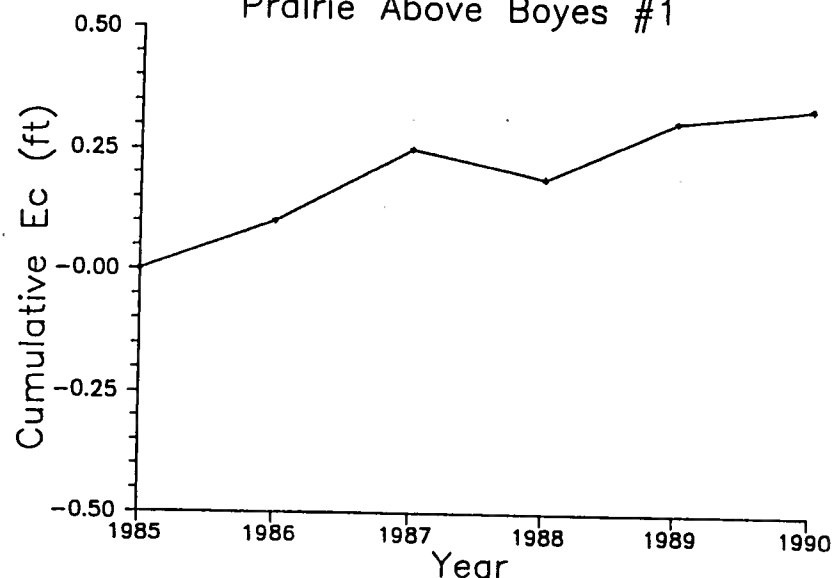


Prairie Creek Above Boyes Creek

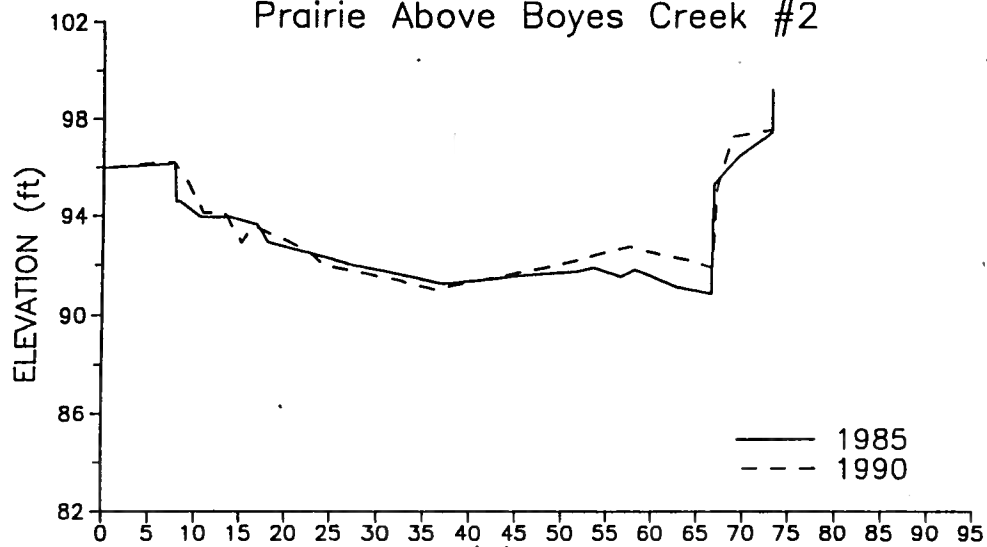
Prairie Above Boyes Creek #1



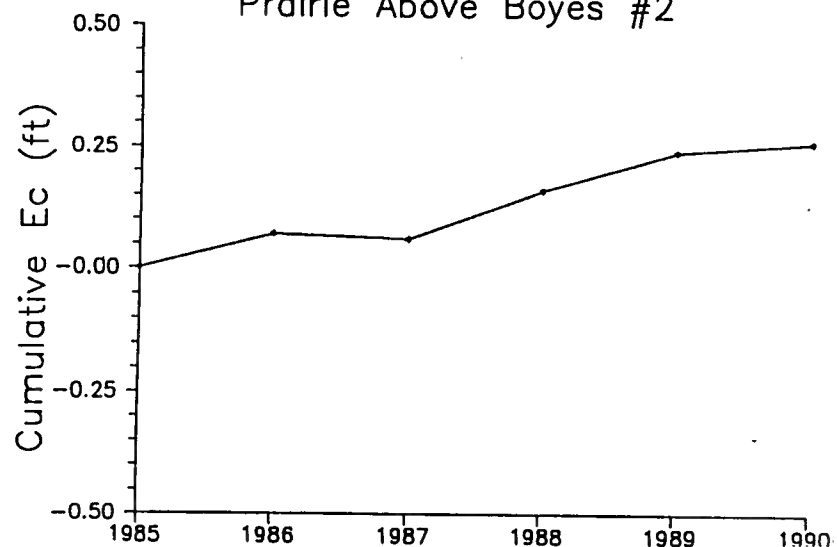
Prairie Above Boyes #1



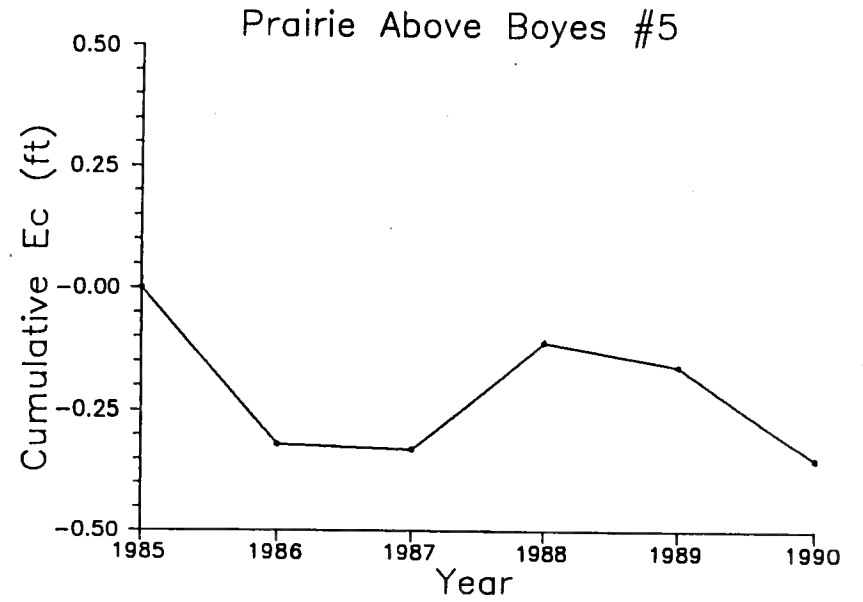
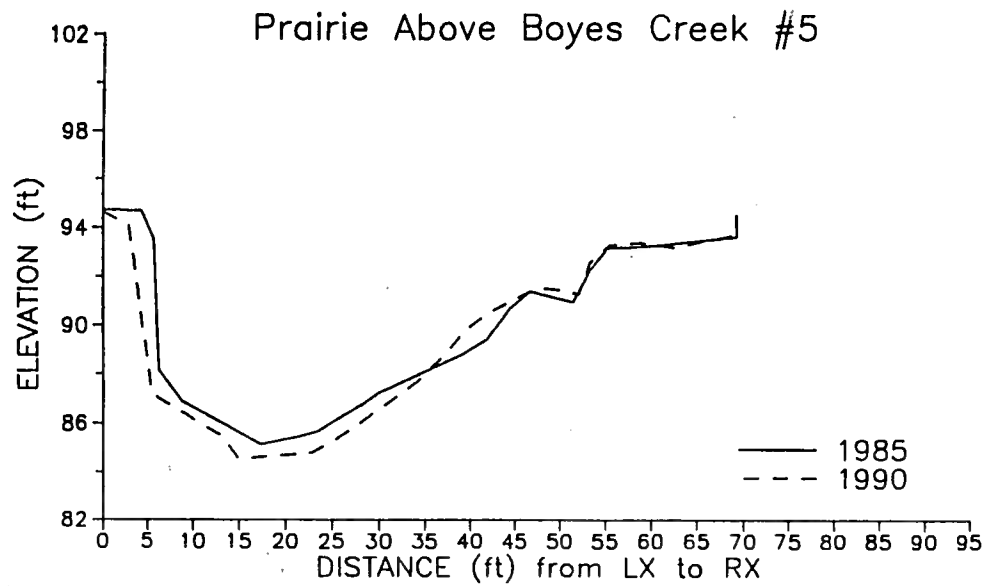
Prairie Above Boyes Creek #2



Prairie Above Boyes #2

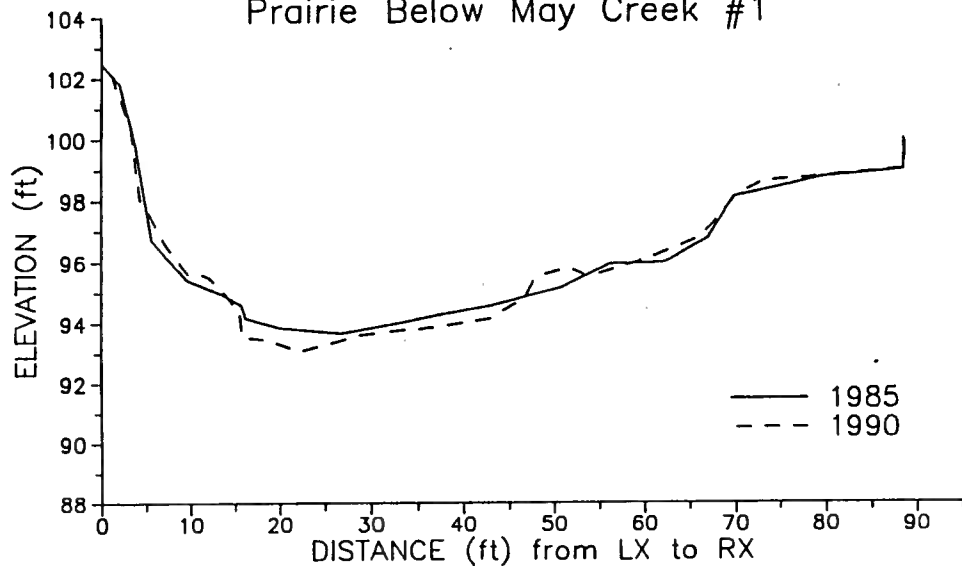


Prairie Creek Above Boyes Creek

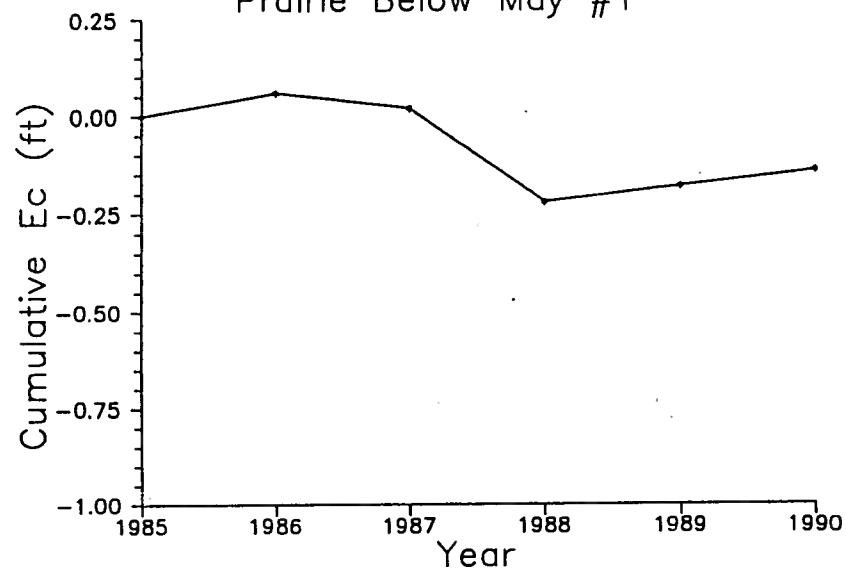


Prairie Creek Below May Creek

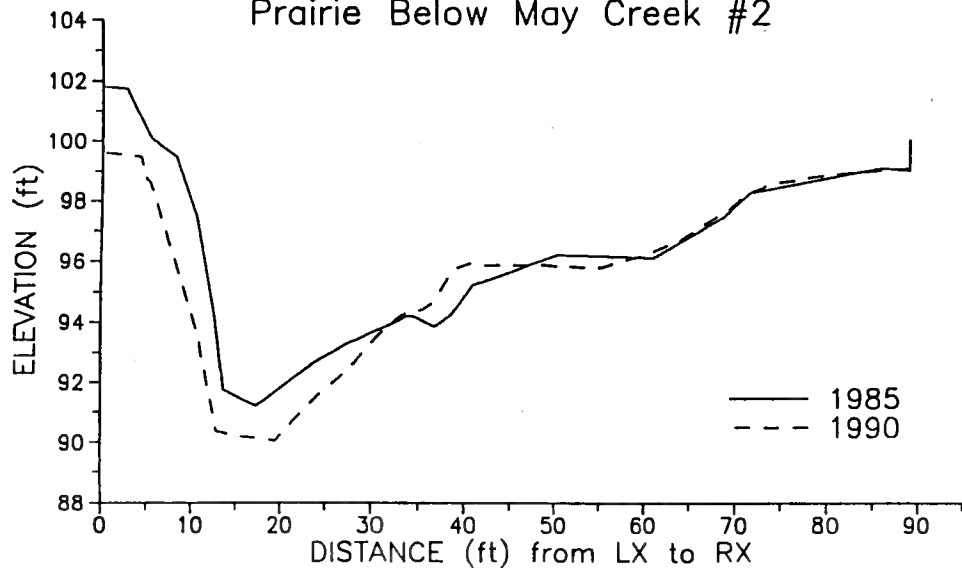
Prairie Below May Creek #1



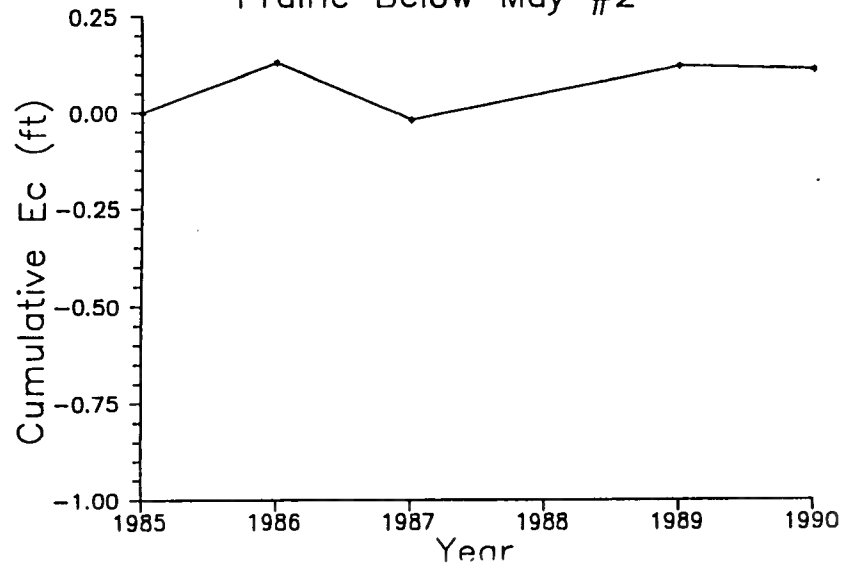
Prairie Below May #1



Prairie Below May Creek #2

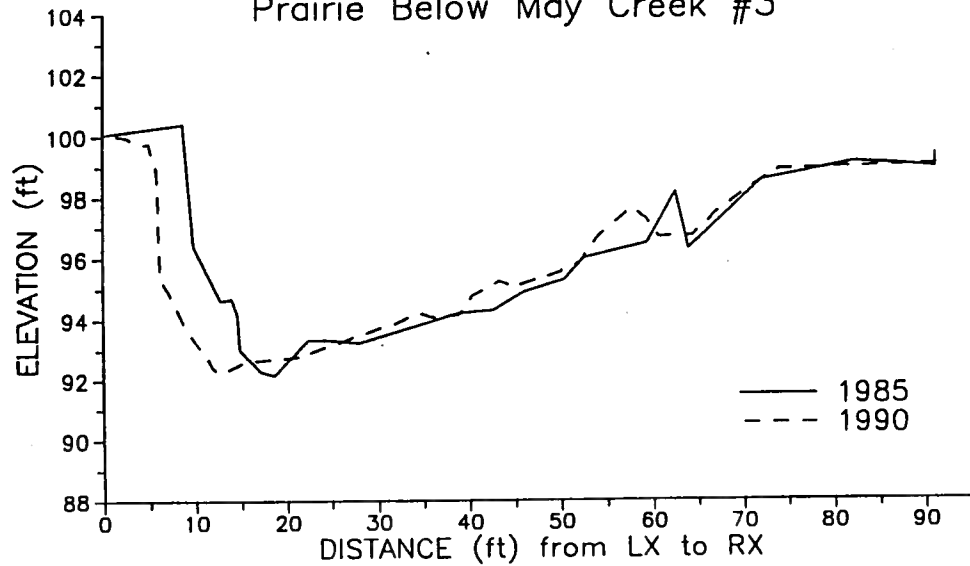


Prairie Below May #2

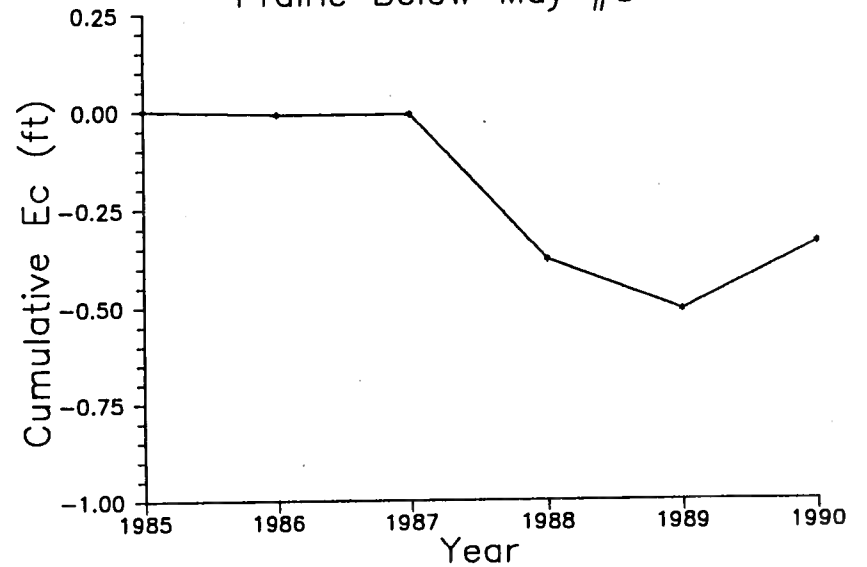


Prairie Creek Below May Creek

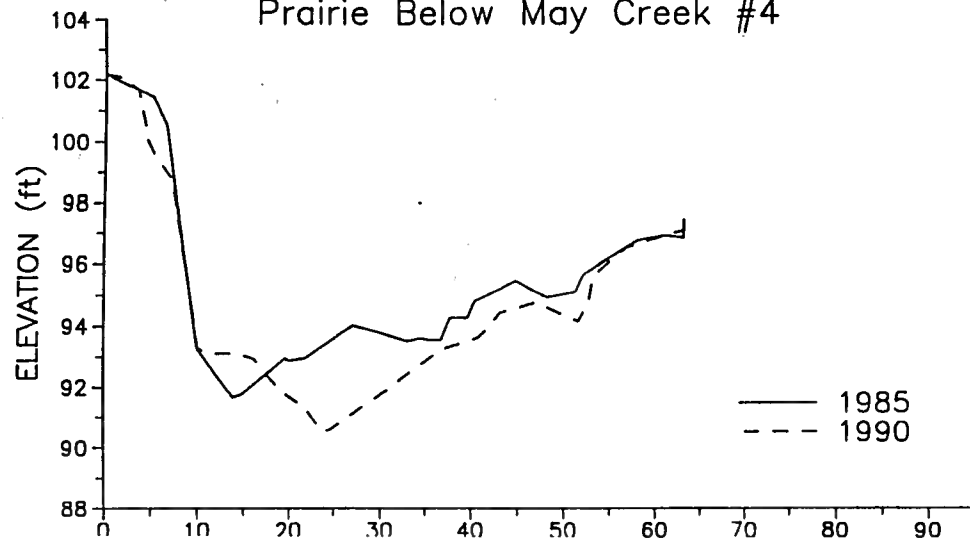
Prairie Below May Creek #3



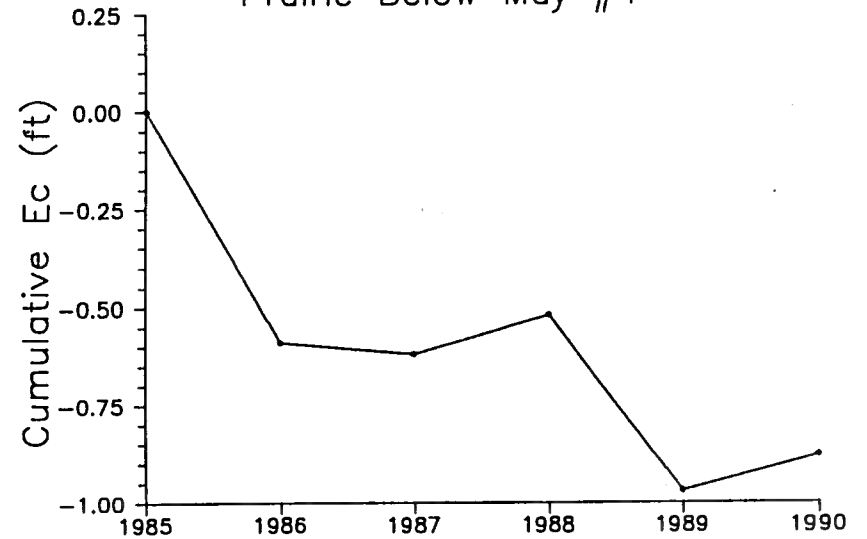
Prairie Below May #3



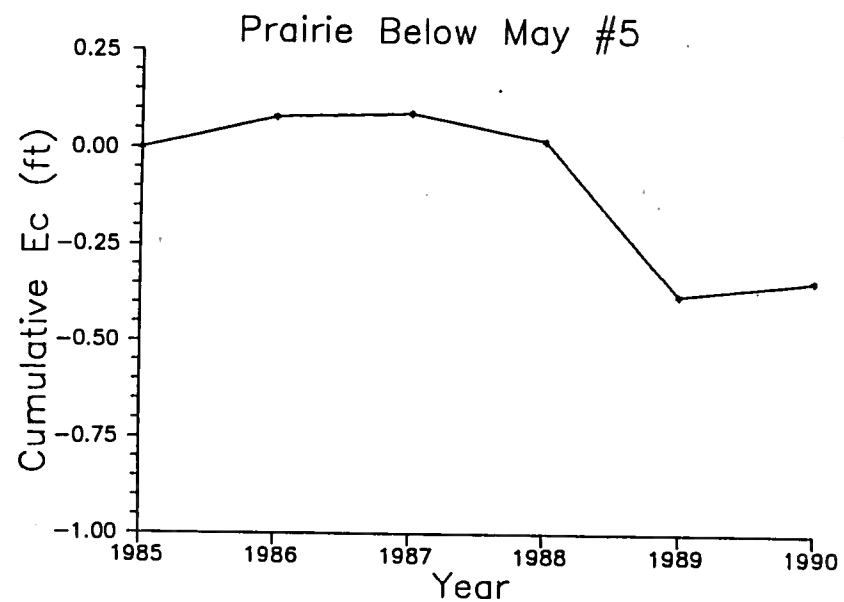
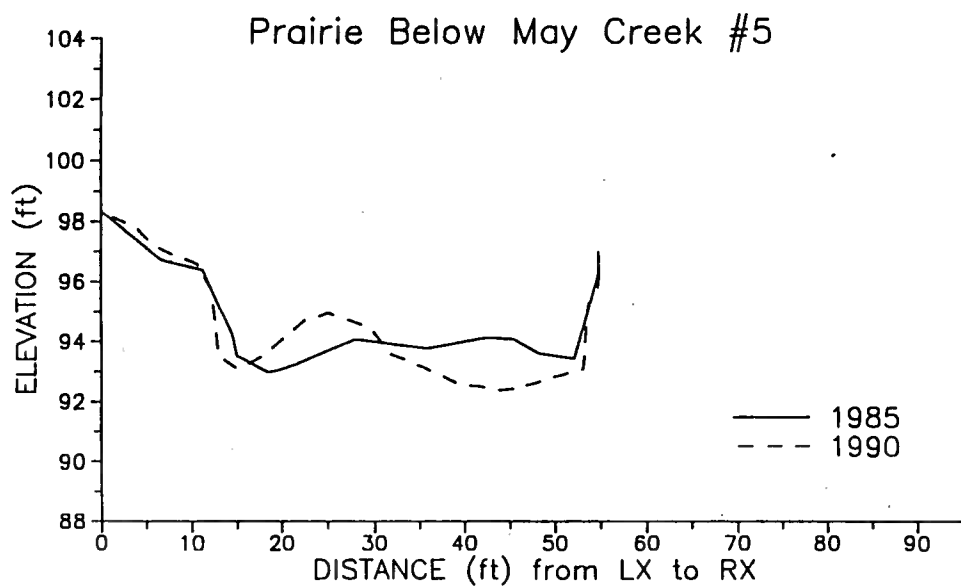
Prairie Below May Creek #4



Prairie Below May #4

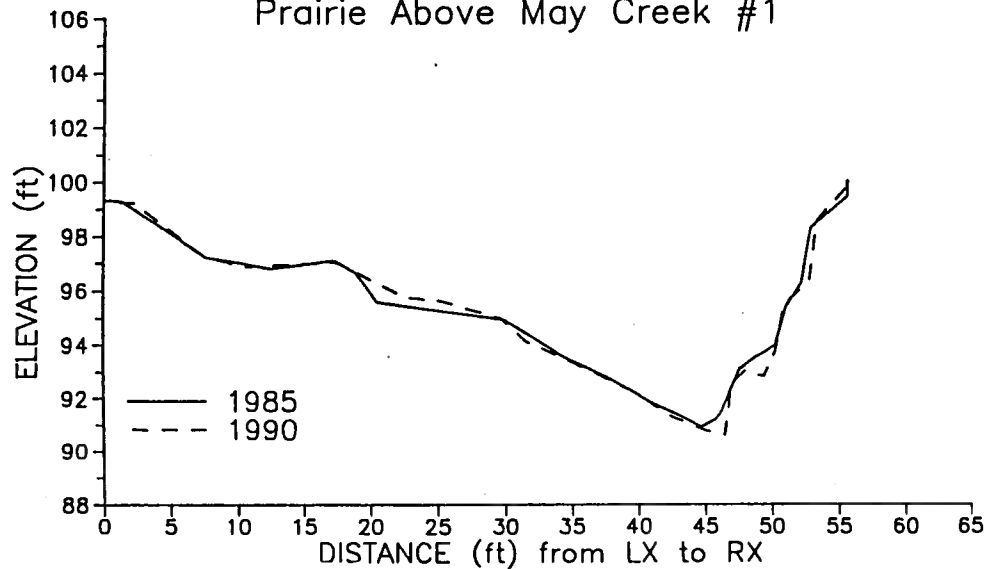


Prairie Creek Below May Creek

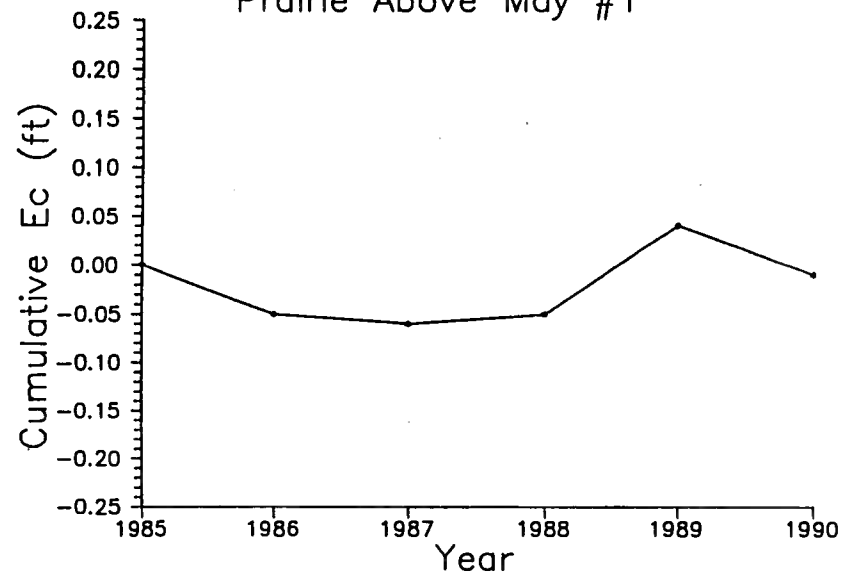


Prairie Creek Above May Creek

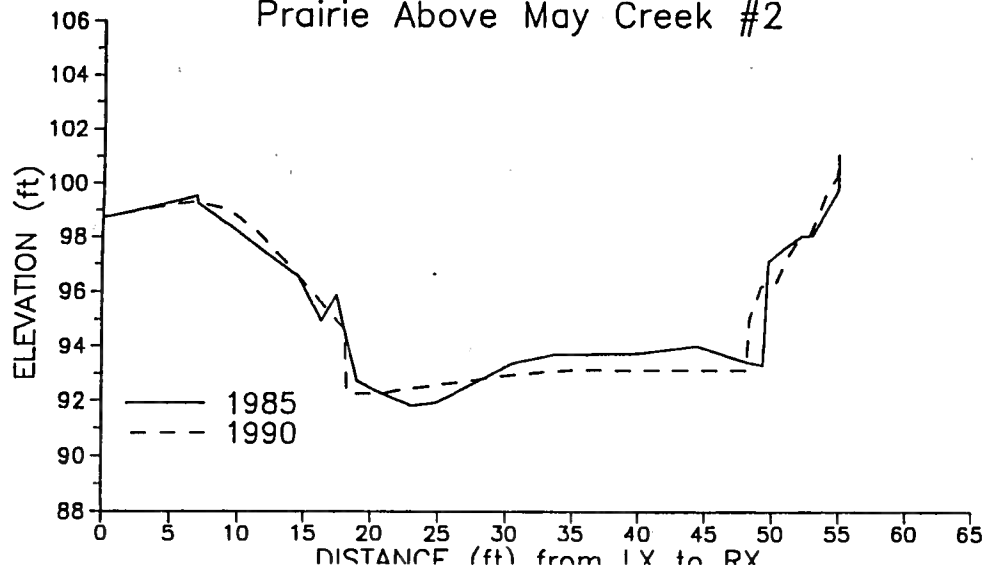
Prairie Above May Creek #1



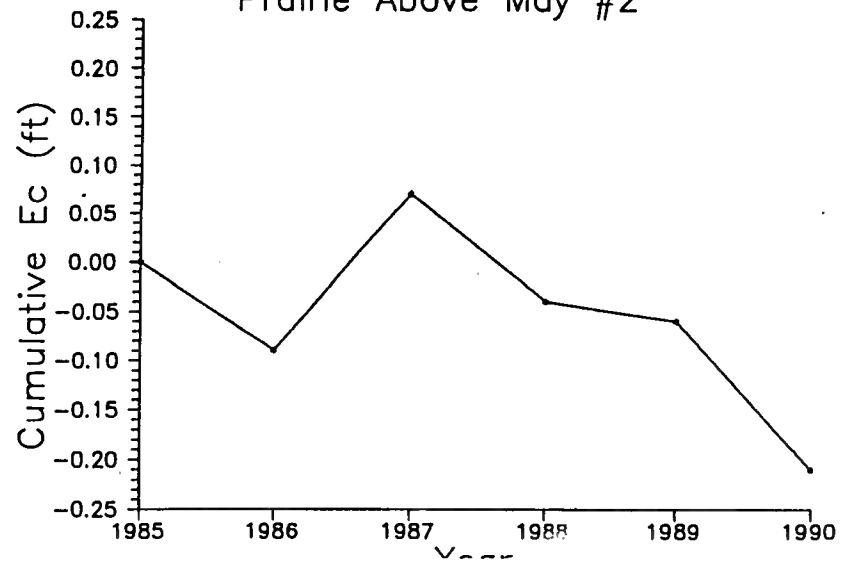
Prairie Above May #1



Prairie Above May Creek #2

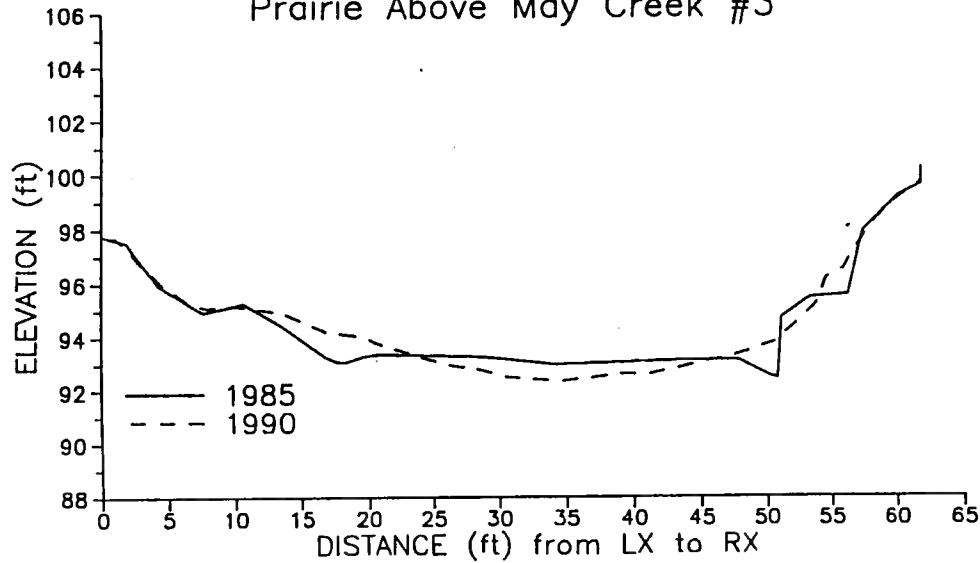


Prairie Above May #2

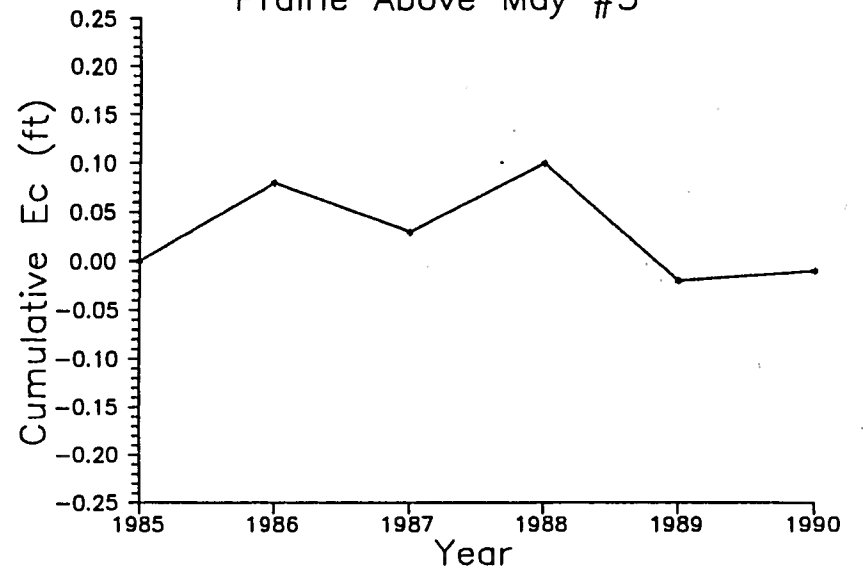


Prairie Creek Above May Creek

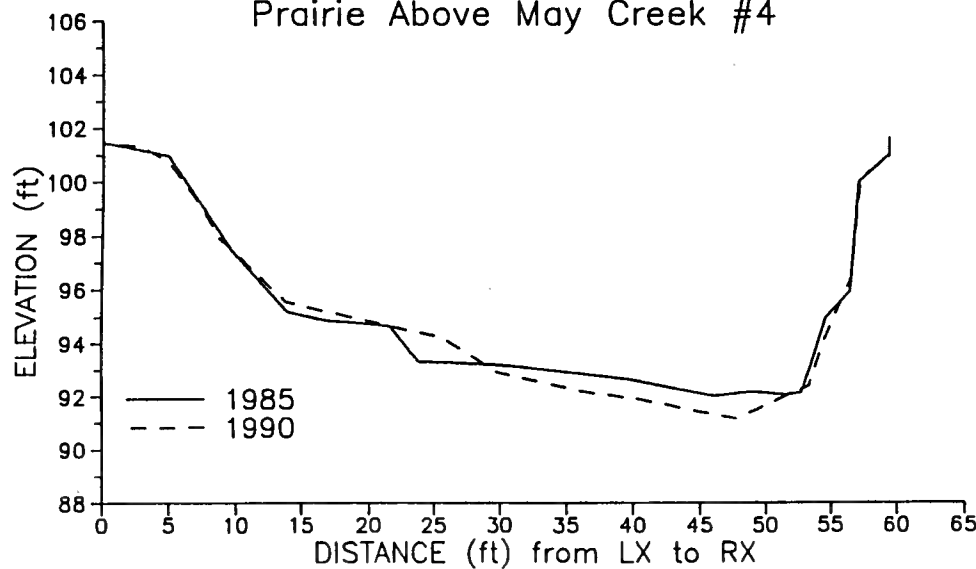
Prairie Above May Creek #3



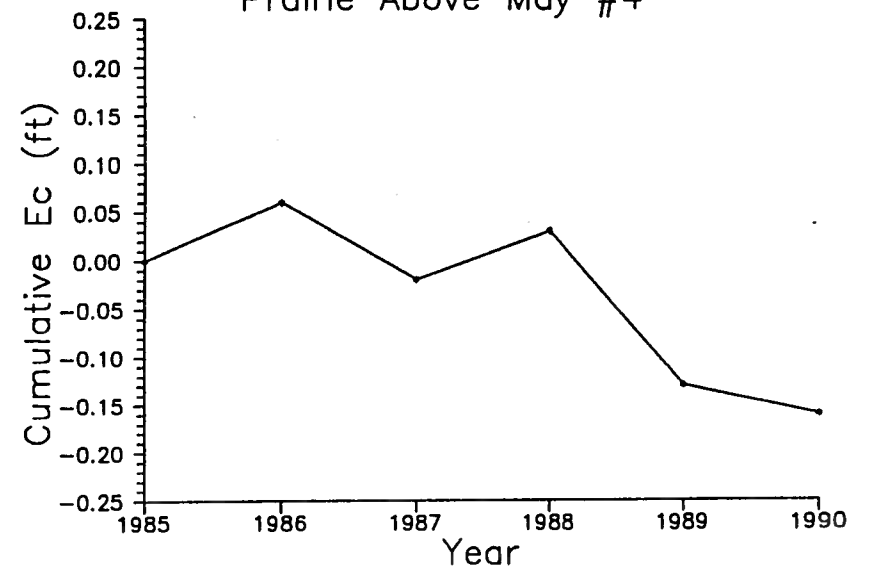
Prairie Above May #3



Prairie Above May Creek #4

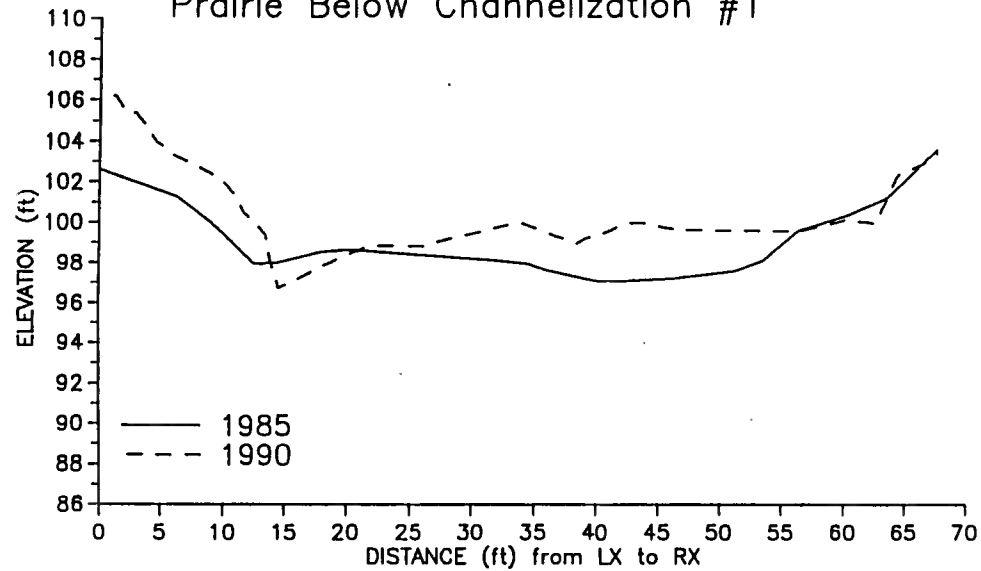


Prairie Above May #4

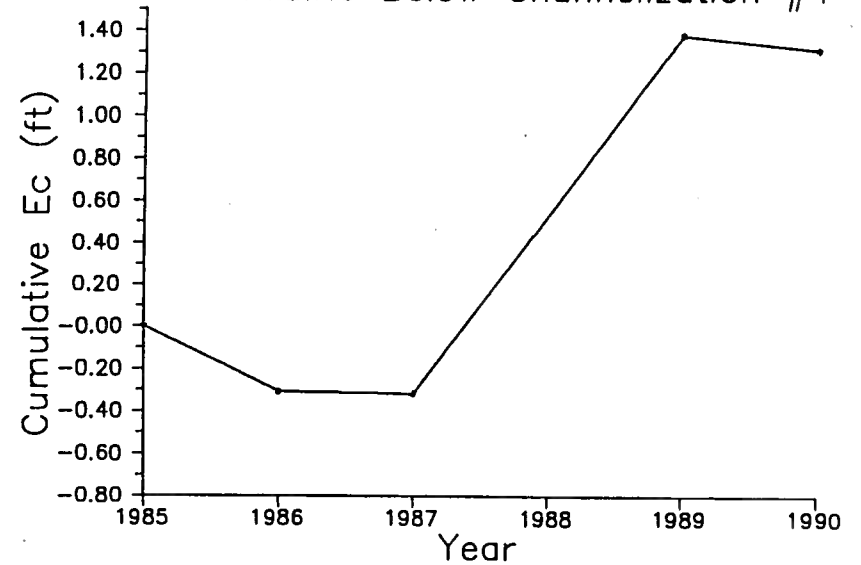


Prairie Creek Below Channelization

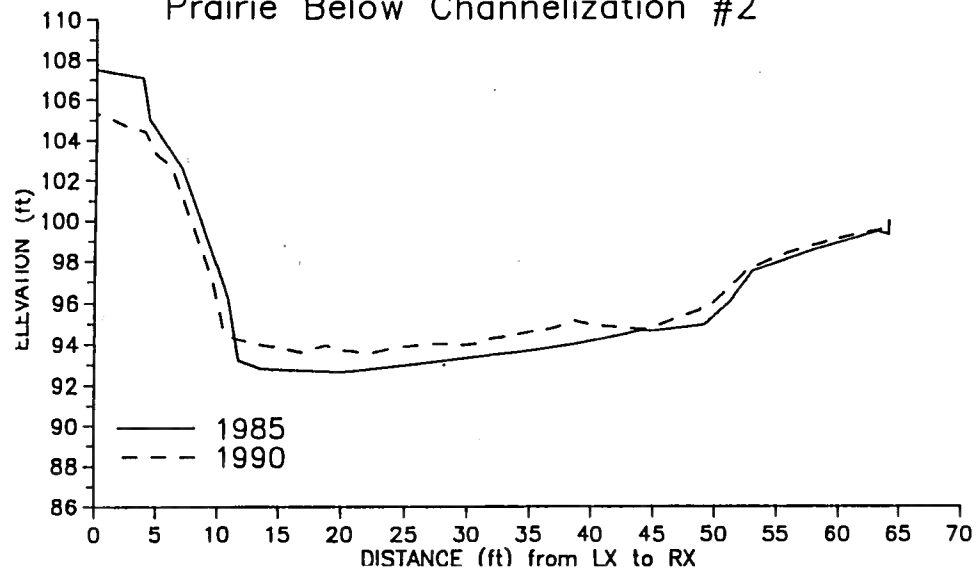
Prairie Below Channelization #1



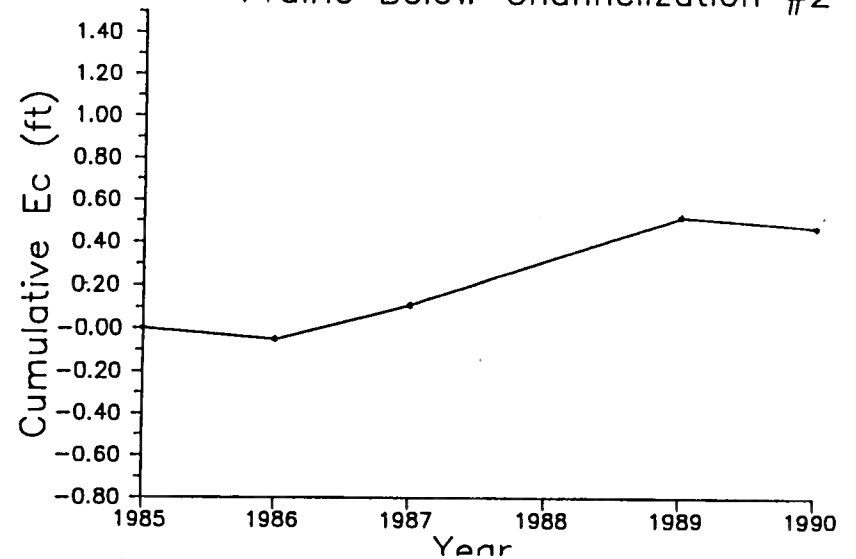
Prairie Below Channelization #1



Prairie Below Channelization #2

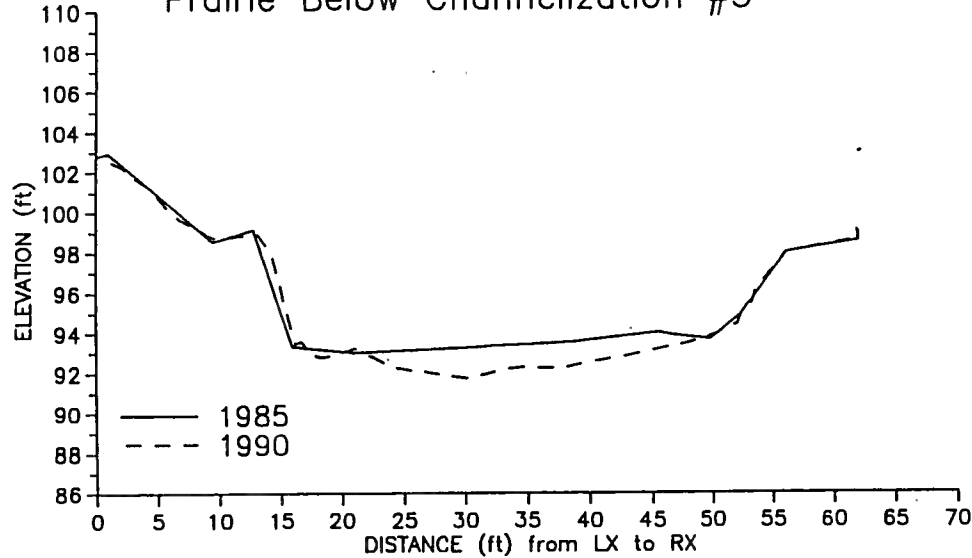


Prairie Below Channelization #2

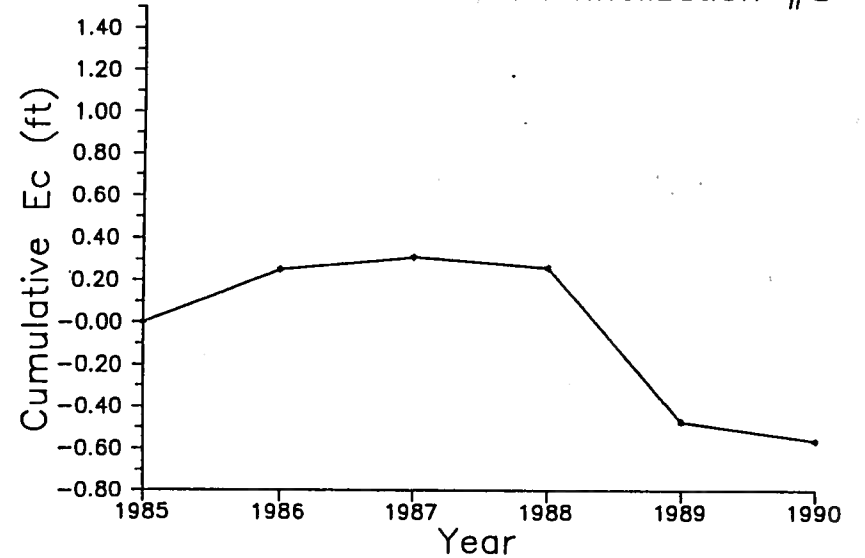


Prairie Creek Below Channelization

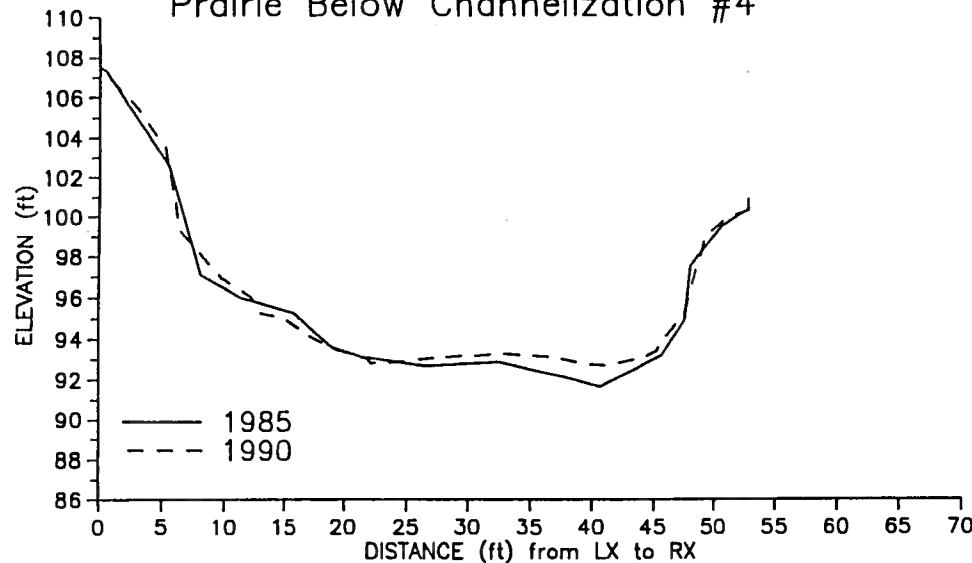
Prairie Below Channelization #3



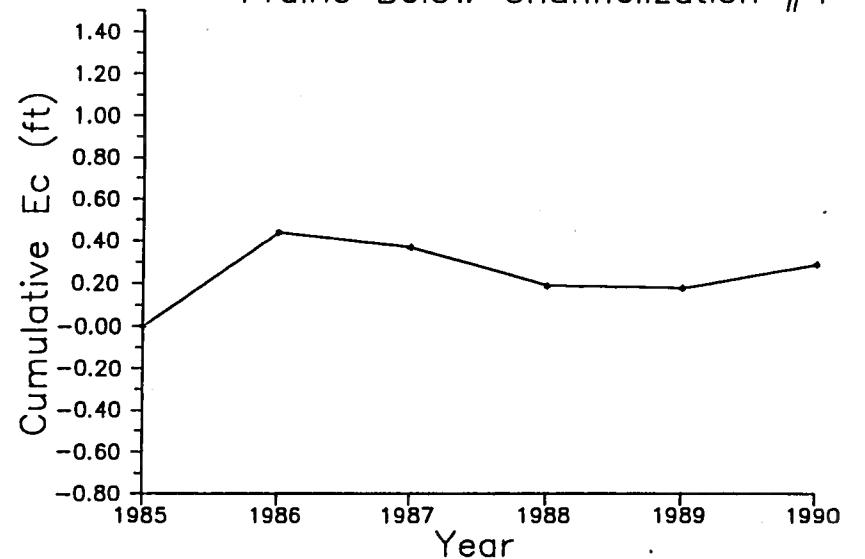
Prairie Below Channelization #3



Prairie Below Channelization #4

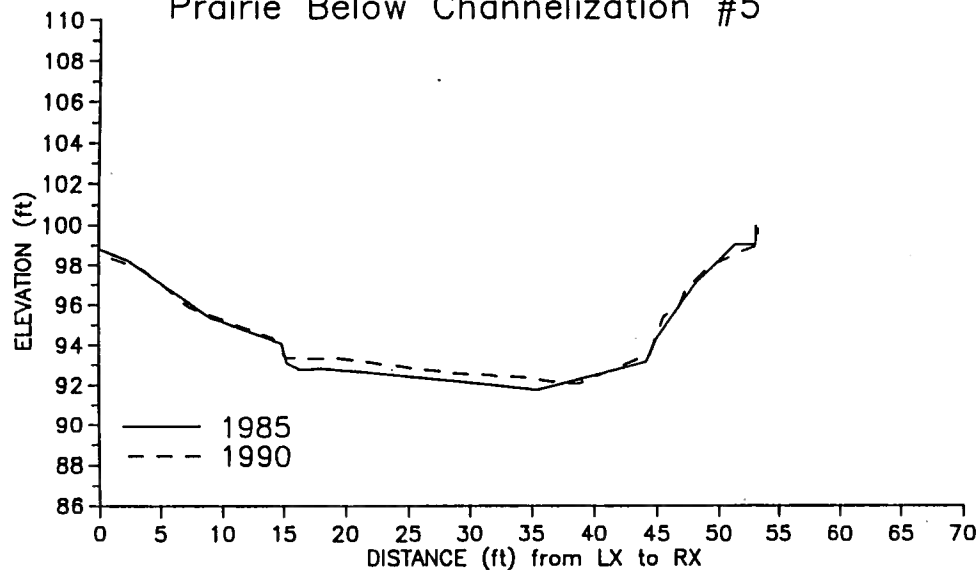


Prairie Below Channelization #4

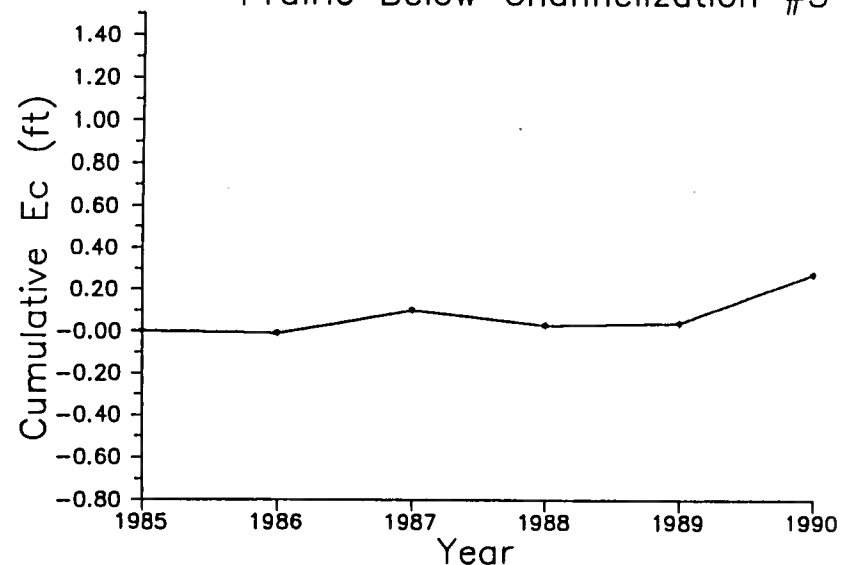


Prairie Creek Below Channelization

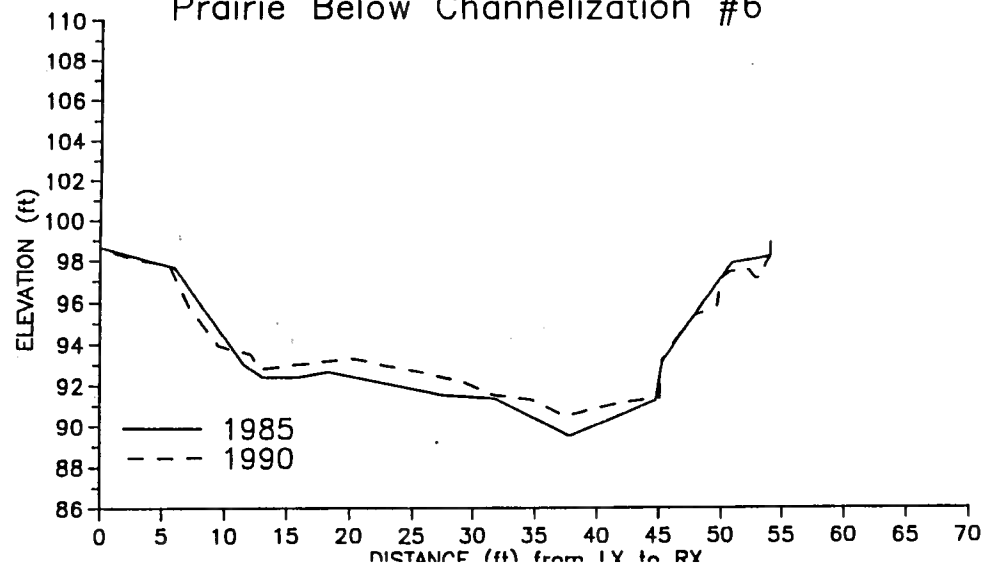
Prairie Below Channelization #5



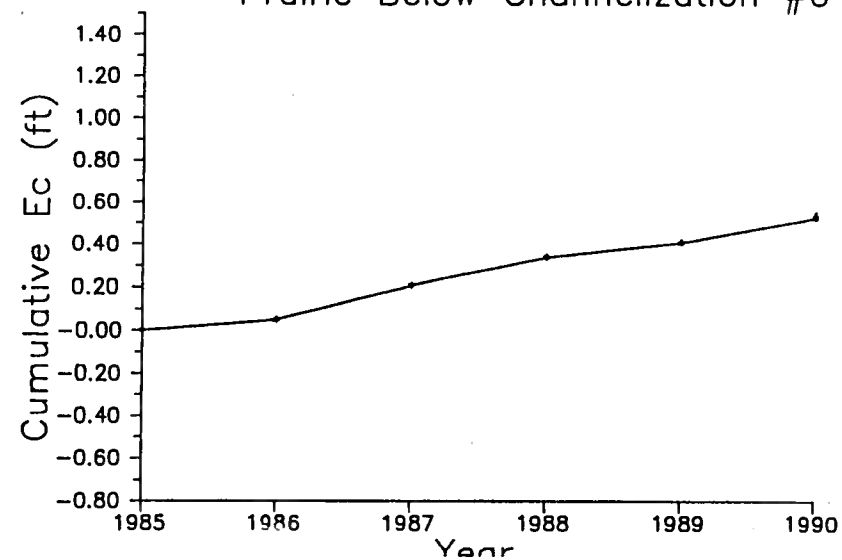
Prairie Below Channelization #5



Prairie Below Channelization #6

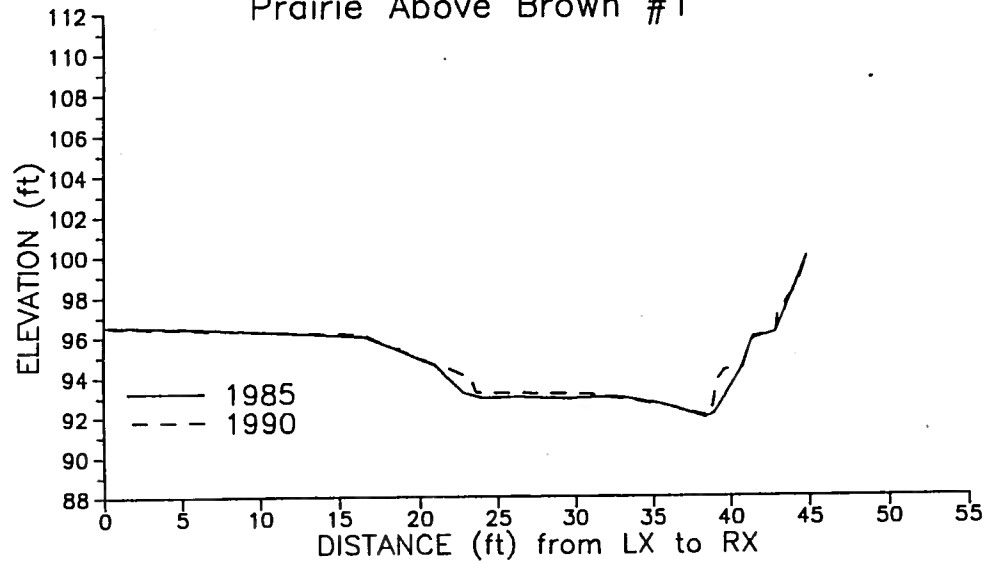


Prairie Below Channelization #6

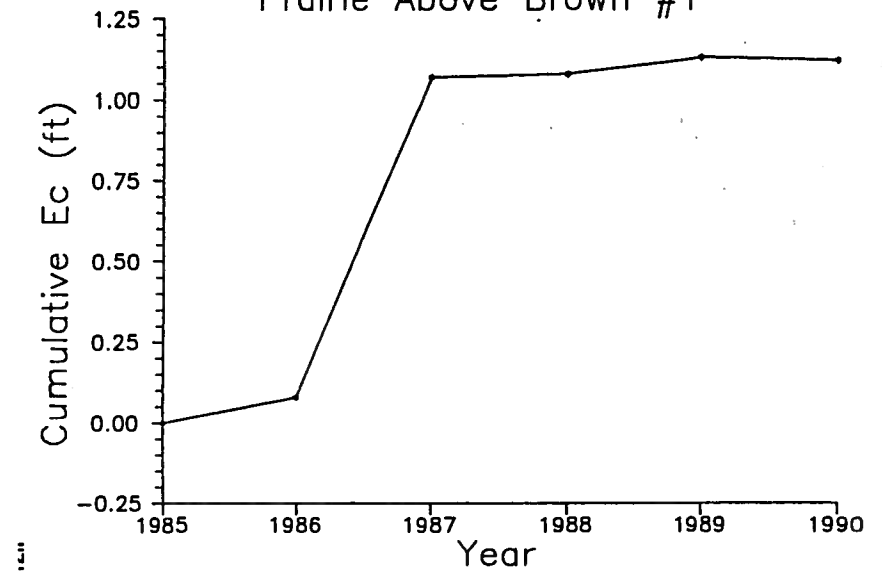


Prairie Creek Above Brown Creek

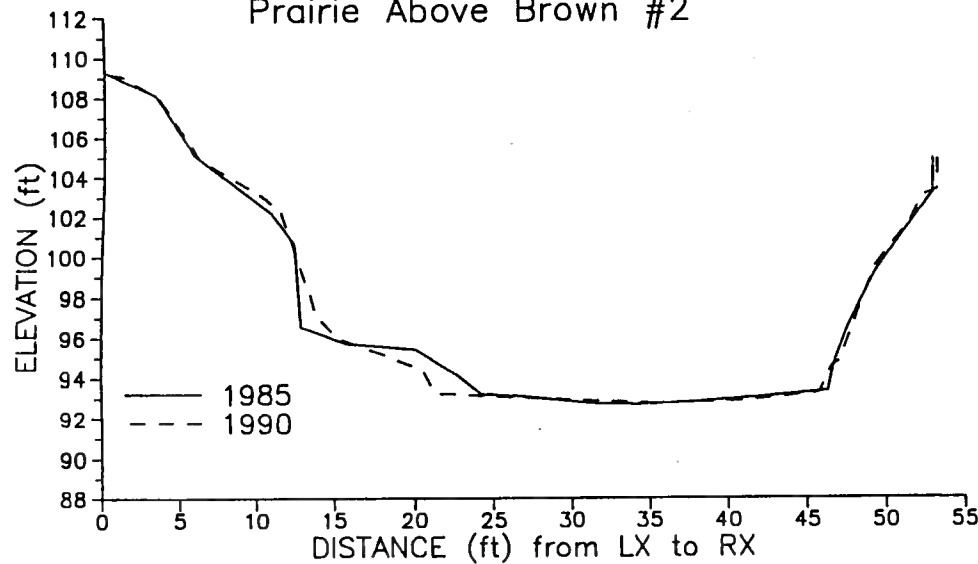
Prairie Above Brown #1



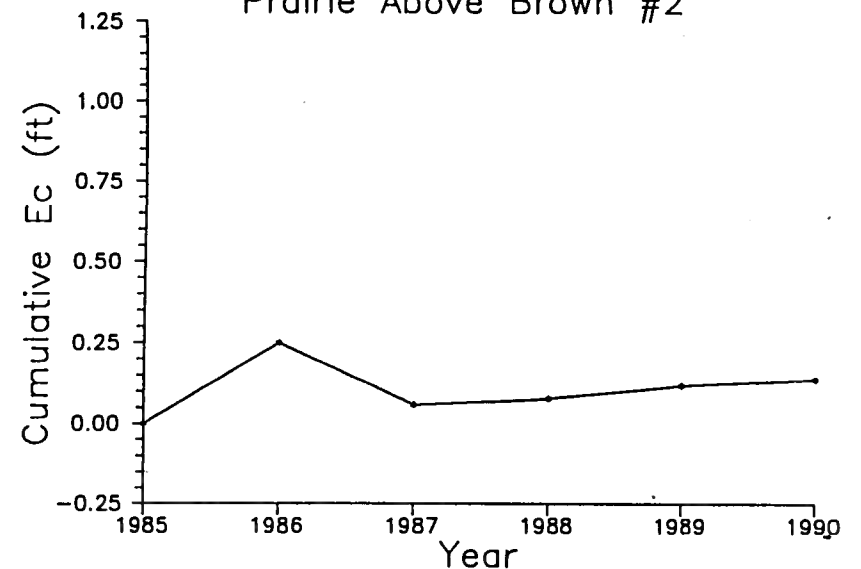
Prairie Above Brown #1



Prairie Above Brown #2

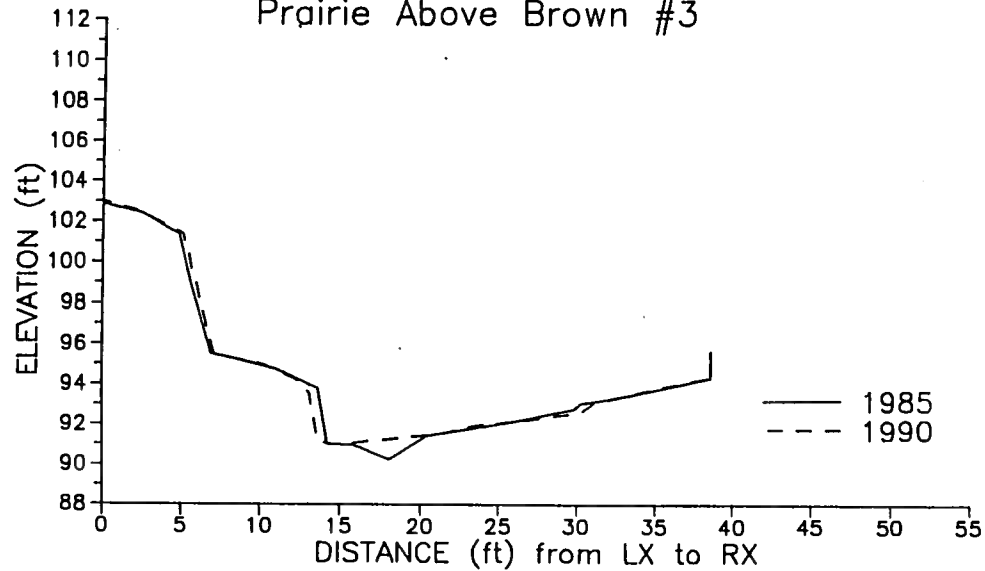


Prairie Above Brown #2

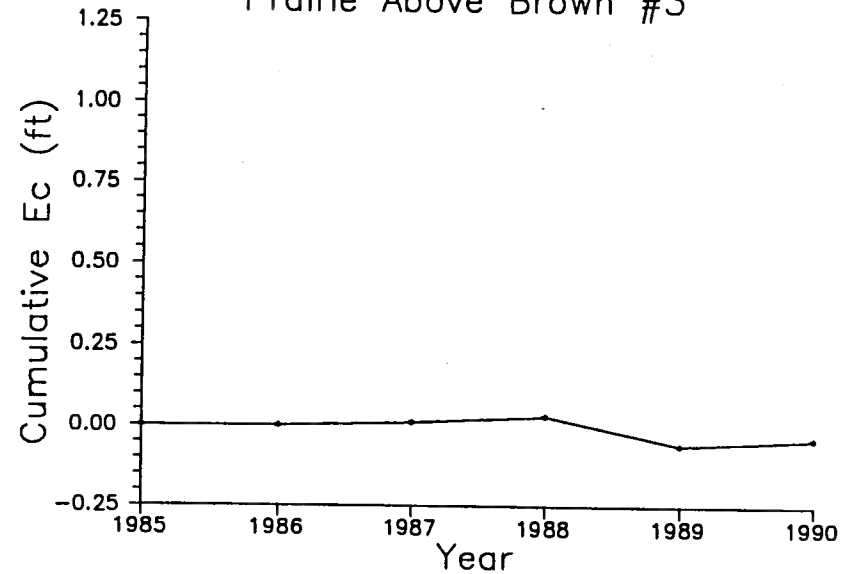


Prairie Creek Above Brown Creek

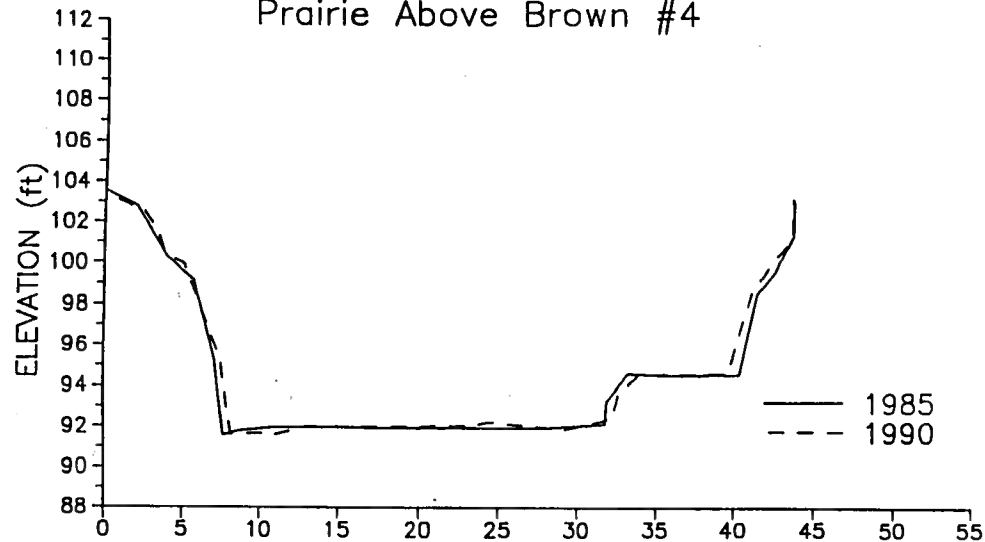
Prairie Above Brown #3



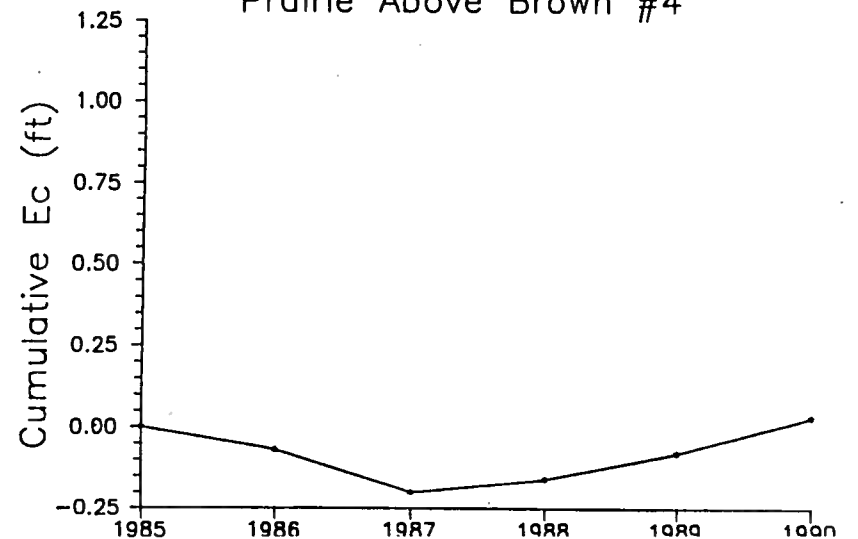
Prairie Above Brown #3



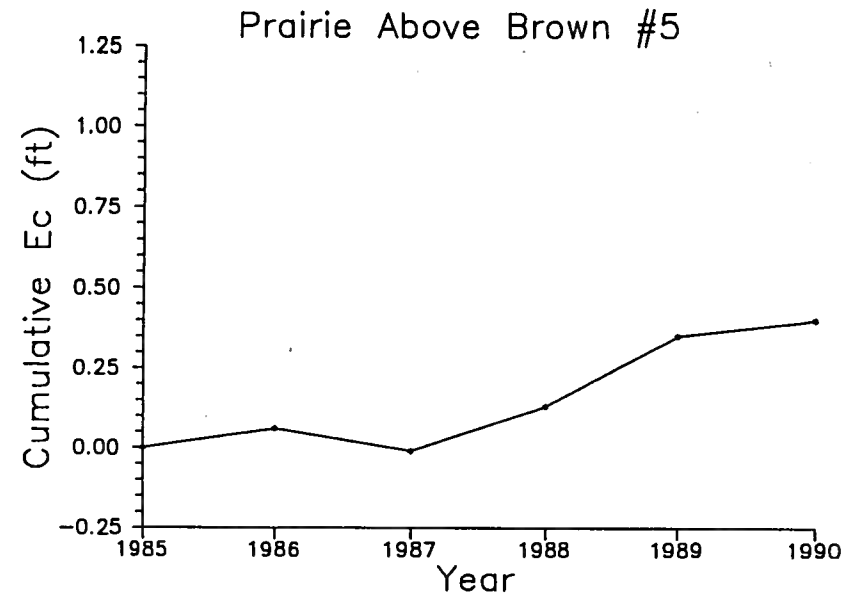
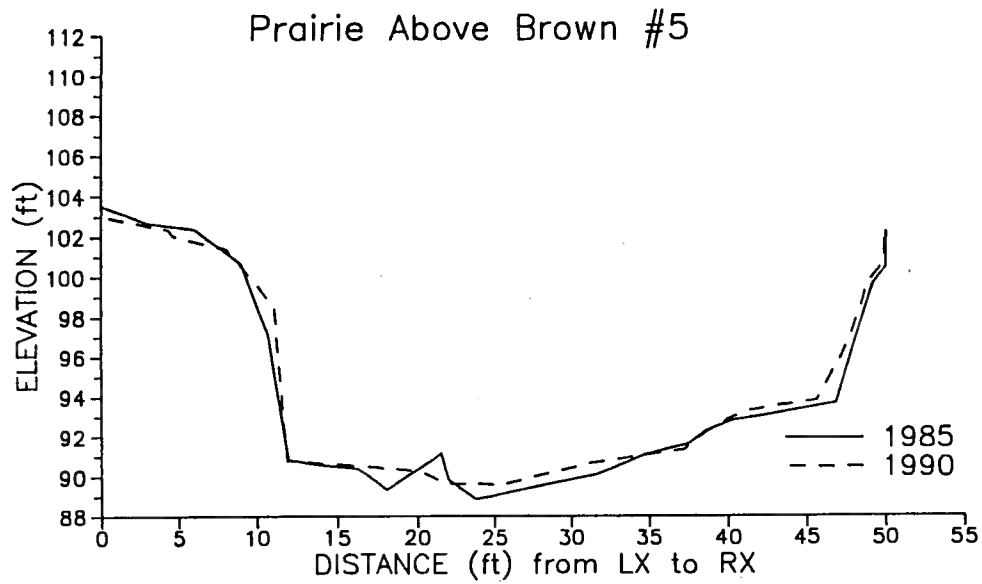
Prairie Above Brown #4



Prairie Above Brown #4



Prairie Creek Above Brown Creek



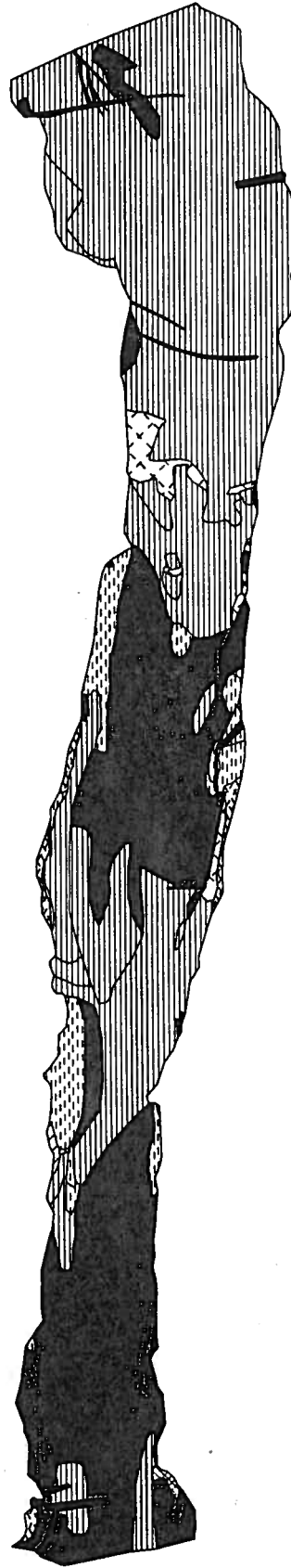
APPENDIX C

DIGITIZED STREAM BENTHIC HABITAT MAPS 1988 TO 1992

SUMMARY OF PERCENT AREA DOMINATED BY SURFACE SILT, SURFACE SAND,
SURFACE SILT AND SAND COMBINED AND WOODY DEBRIS

Prairie Creek Below Channelization, 1988

Scale 1:500

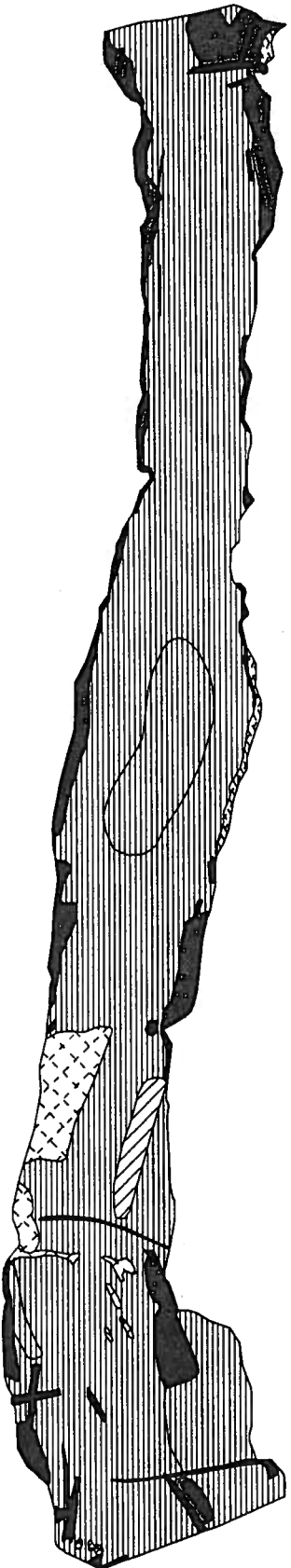


Legend:

Rubble	Silt	Sand	Gravel
Vegetation	Cobble	Boulders	Bedrock
Overhang	Leafpack	Woody Debris	

Prairie Creek Below Channelization, 1991

Scale 1:500

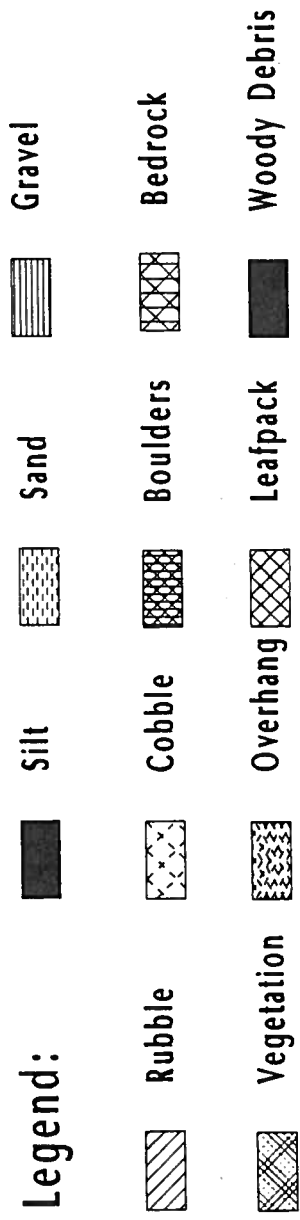
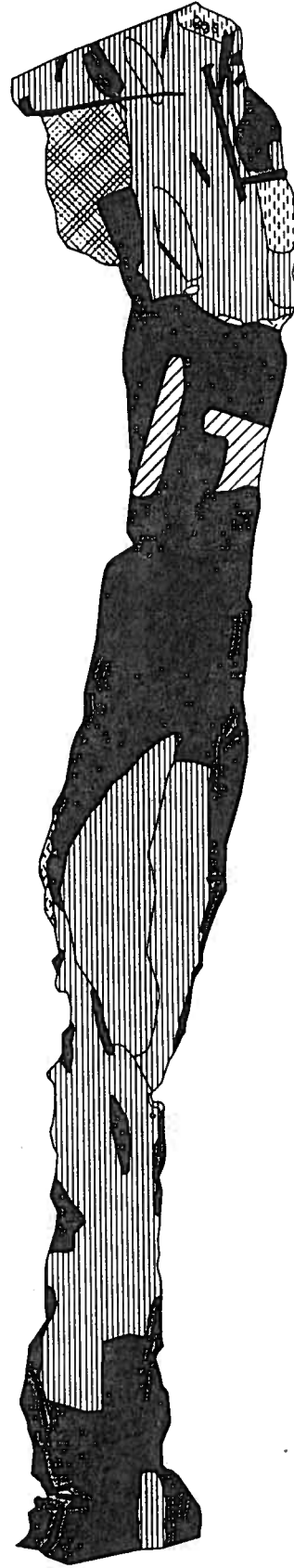


Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
			Woody Debris		

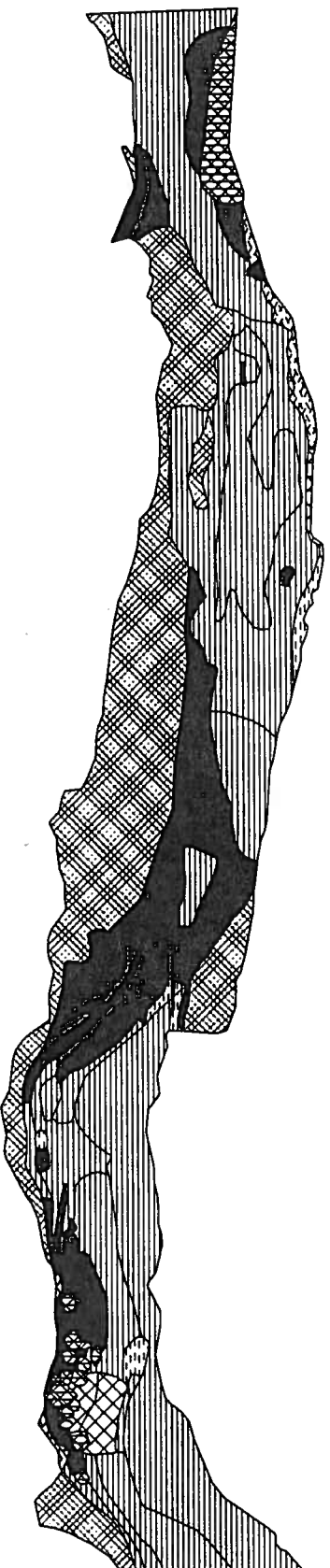
Prairie Creek Below Channelization, 1992

Scale 1:500



Prairie Creek Below May Creek, 1992

Scale 1:500

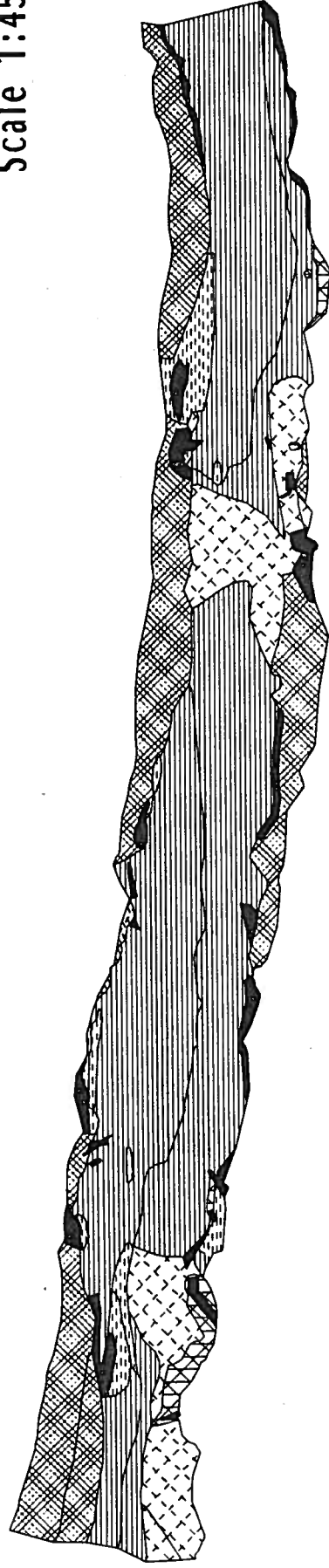


Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
					Woody Debris

Prairie Creek Above May Creek, 1988

Scale 1:450

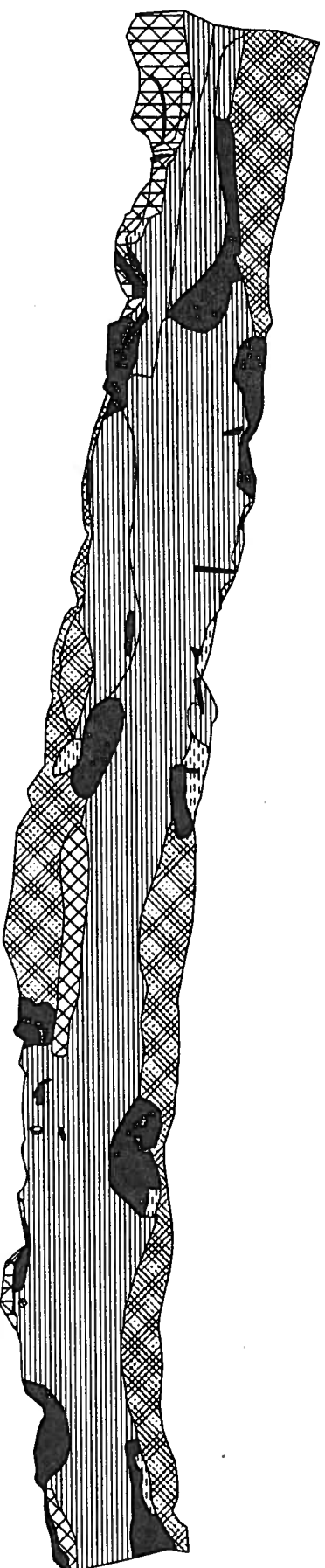


Legend:

	Rubble		Silt		Sand		Gravel
	Vegetation		Cobble		Boulders		Bedrock
			Overhang		Leafpack		Woody Debris

Prairie Creek Above May Creek, 1991

Scale 1:450

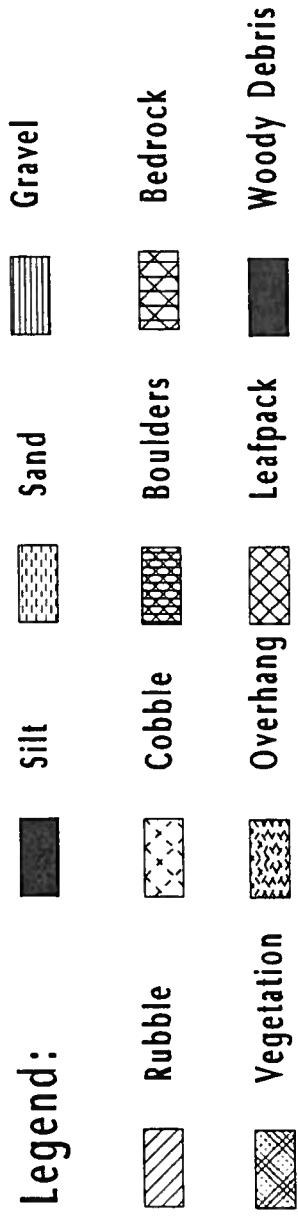
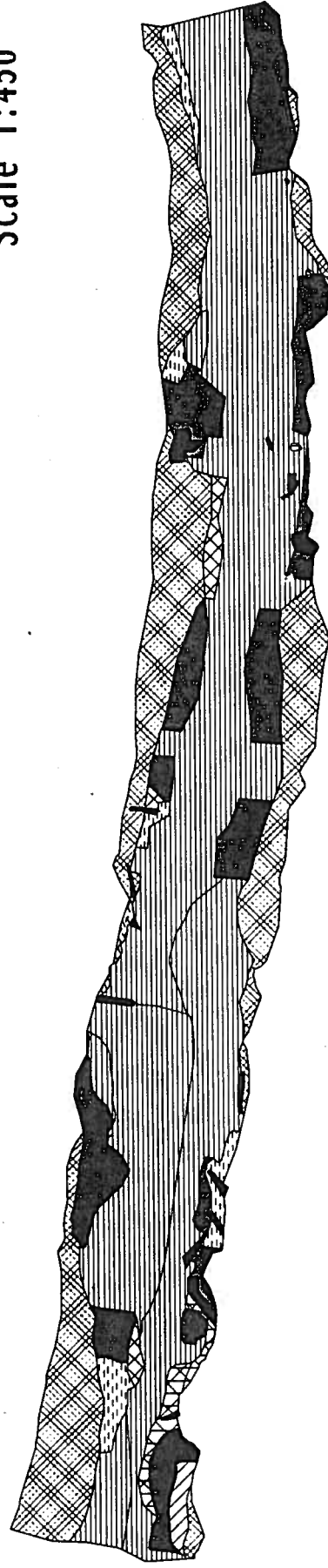


Legend:

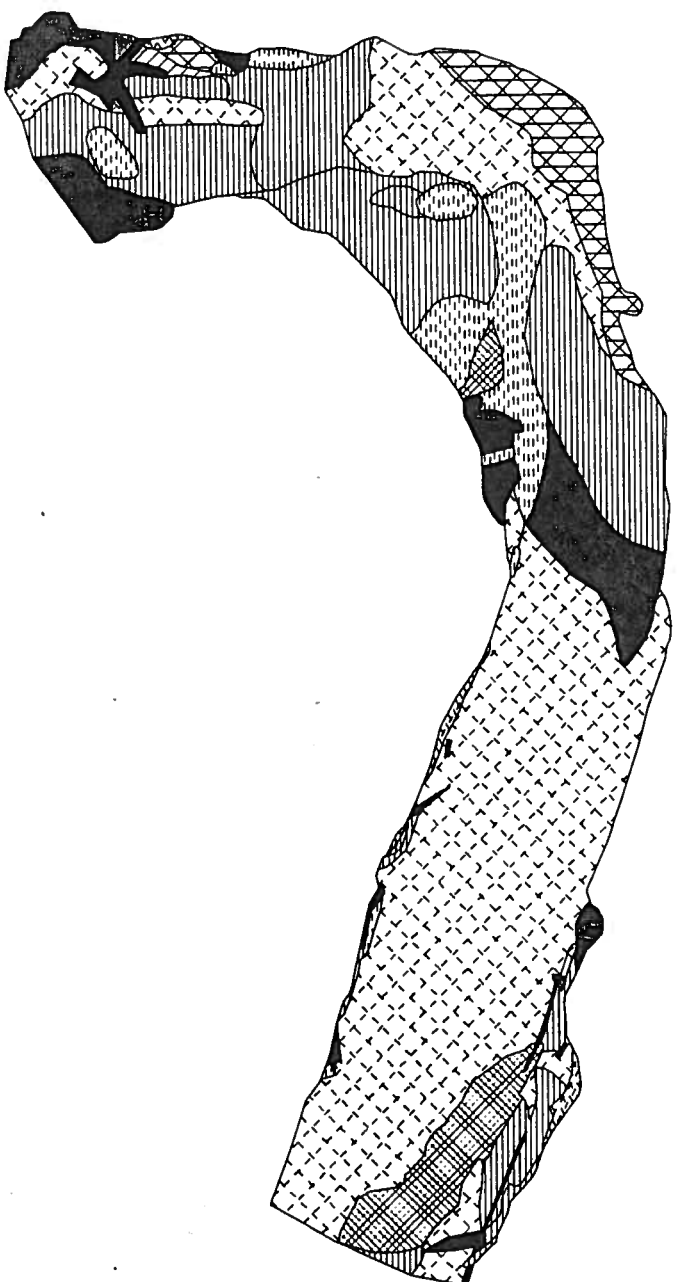
	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
			Woody Debris		

Prairie Creek Above May Creek, 1992

Scale 1:450



Prairie Creek Below Boyes Creek, 1988



Scale 1:400

Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
					Woody Debris

Prairie Creek Below Boyes Creek, 1991

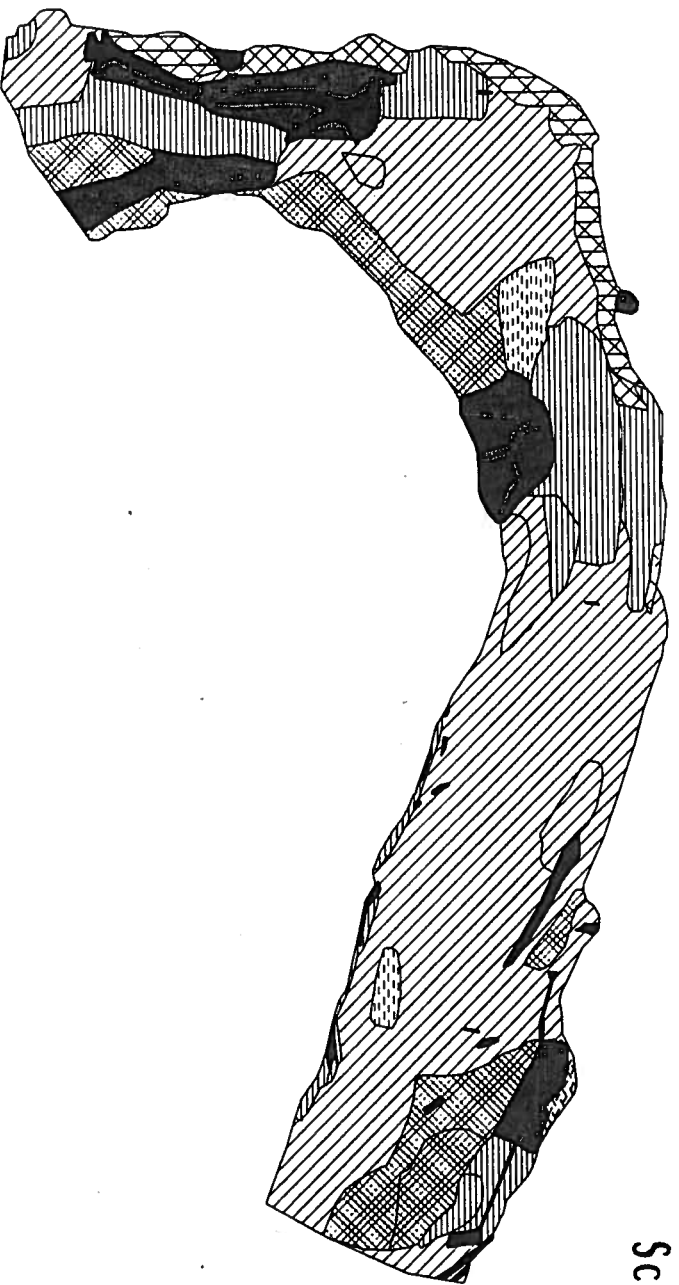
Scale 1:400



Legend:

	Rubble		Silt		Sand		Gravel
	Vegetation		Cobble		Boulders		Bedrock
			Overhang		Leafpack		Woody Debris

Prairie Creek Below Boyes Creek, 1992

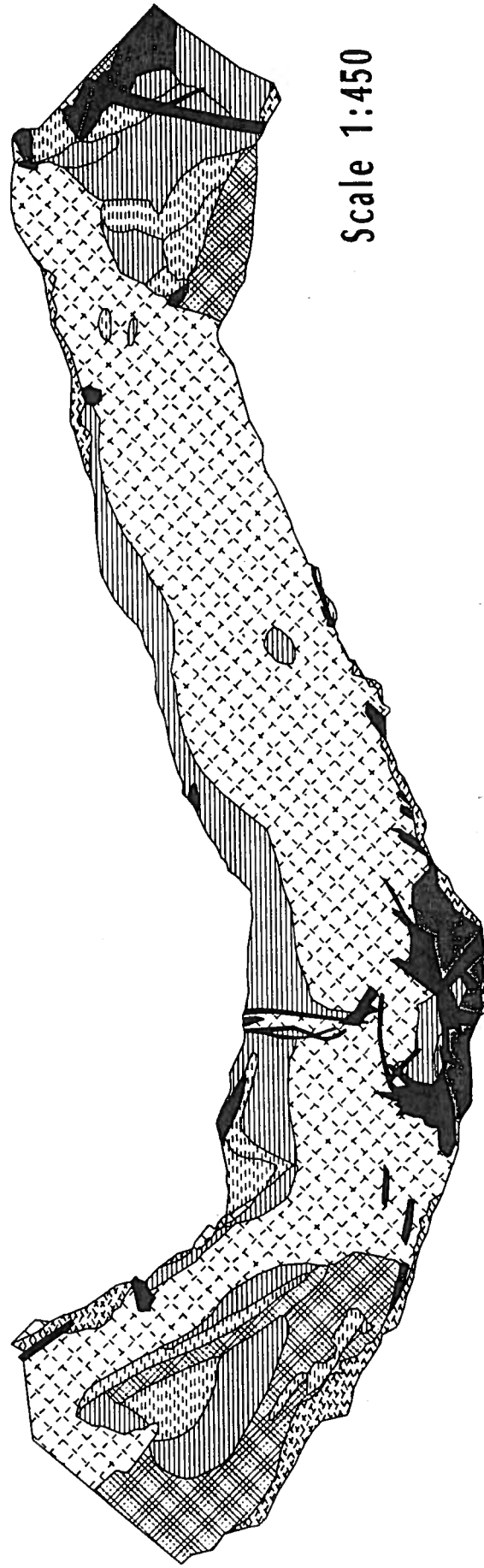


Scale 1:400

Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Bedrock		Vegetation		Overhang
	Leafpack		Woody Debris		

Prairie Creek Above Boyes Creek, 1988

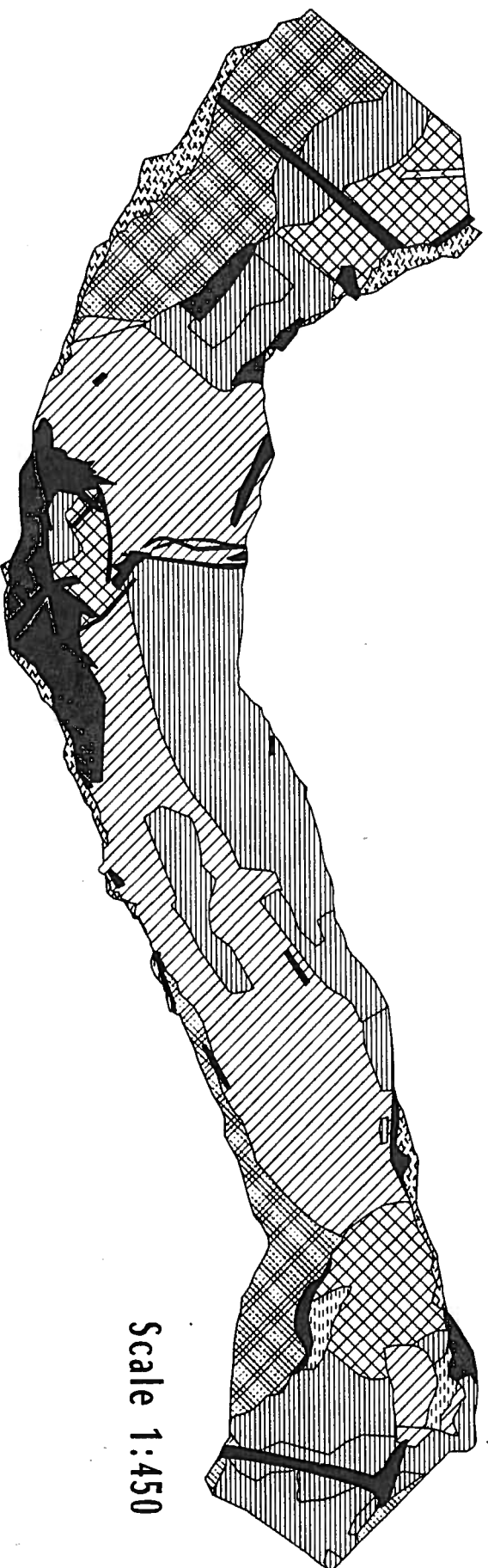


Scale 1:450

Legend:

	Rubble		Silt		Sand		Gravel
	Vegetation		Cobble		Boulders		Bedrock
			Overhang		Leafpack		Woody Debris

Prairie Creek Above Boyes Creek, 1992

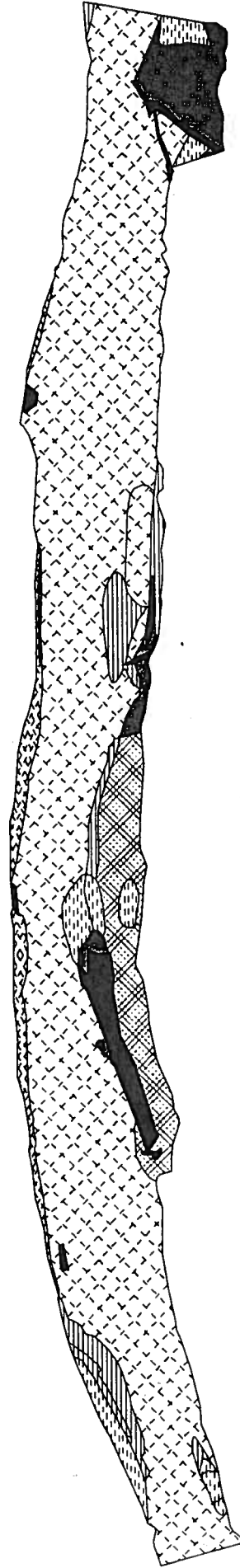


Scale 1:450

Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
	Woody Debris				

Scale 1:400

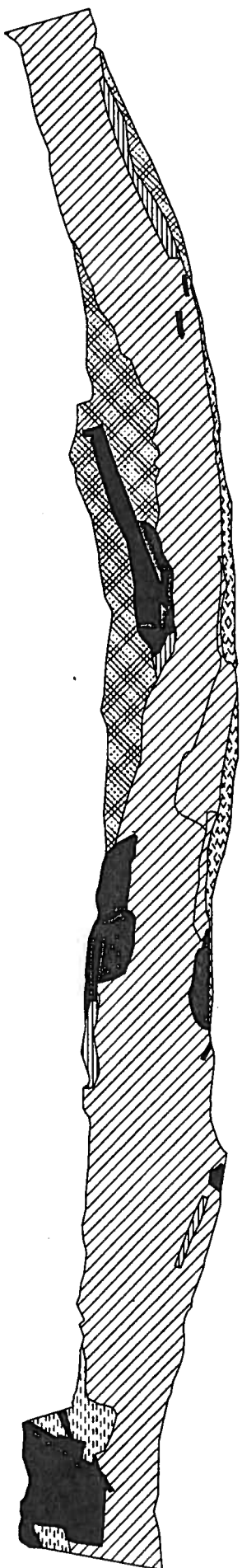


Legend:

	Rubble		Silt		Sand		Gravel
	Vegetation		Cobble		Boulders		Bedrock
			Overhang		Leafpack		Woody Debris

Prairie Creek Above Brown Creek, 1992

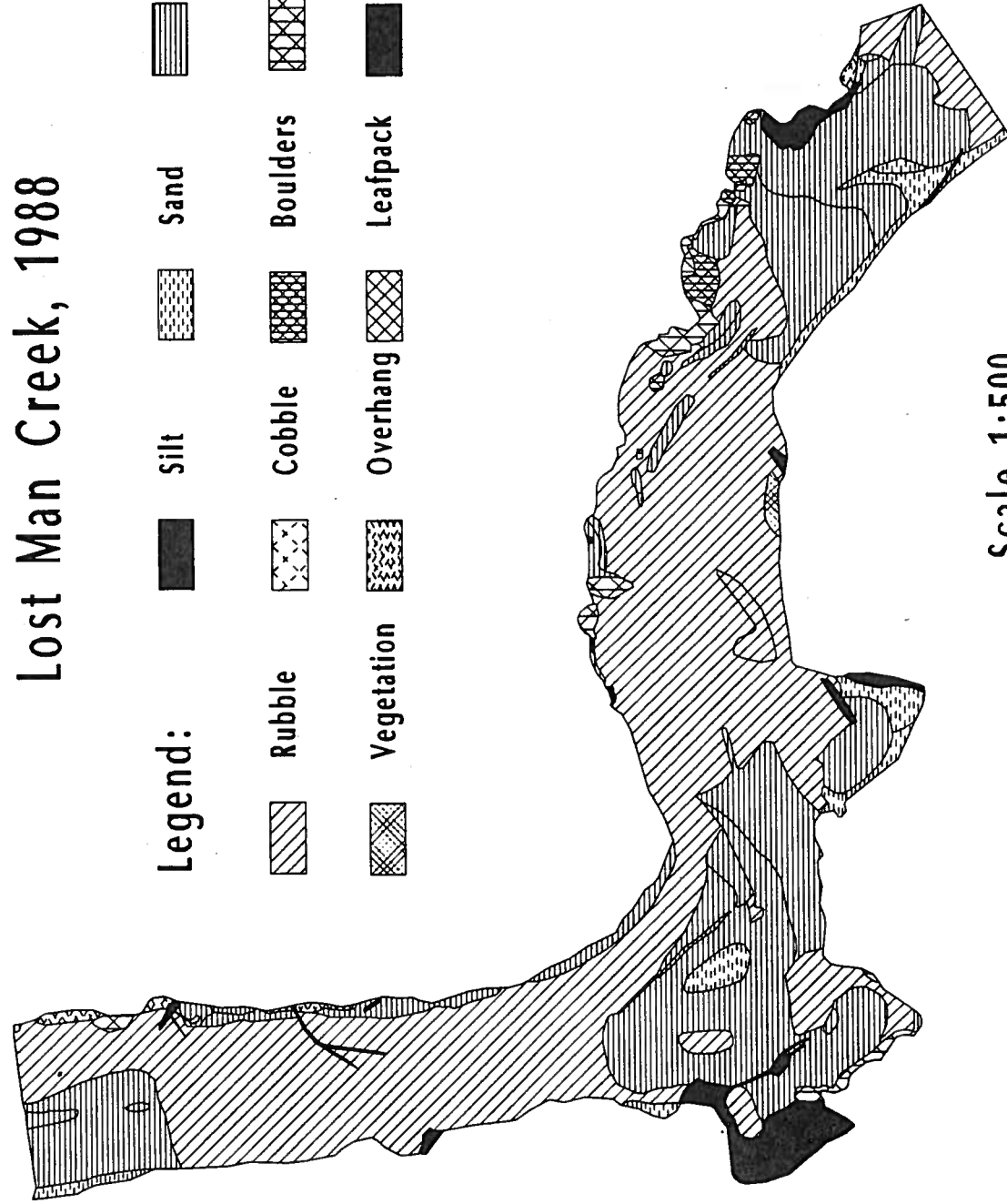
Scale 1:400



Legend:

- | | | | | | | |
|---|---|--------------|---|----------|---|----------|
|  |  | Silt |  | Sand |  | Gravel |
|  |  | Cobble |  | Boulders |  | Bedrock |
|  |  | Vegetation |  | Overhang |  | Leafpack |
| |  | Woody Debris | | | | |

Lost Man Creek, 1988



Legend:

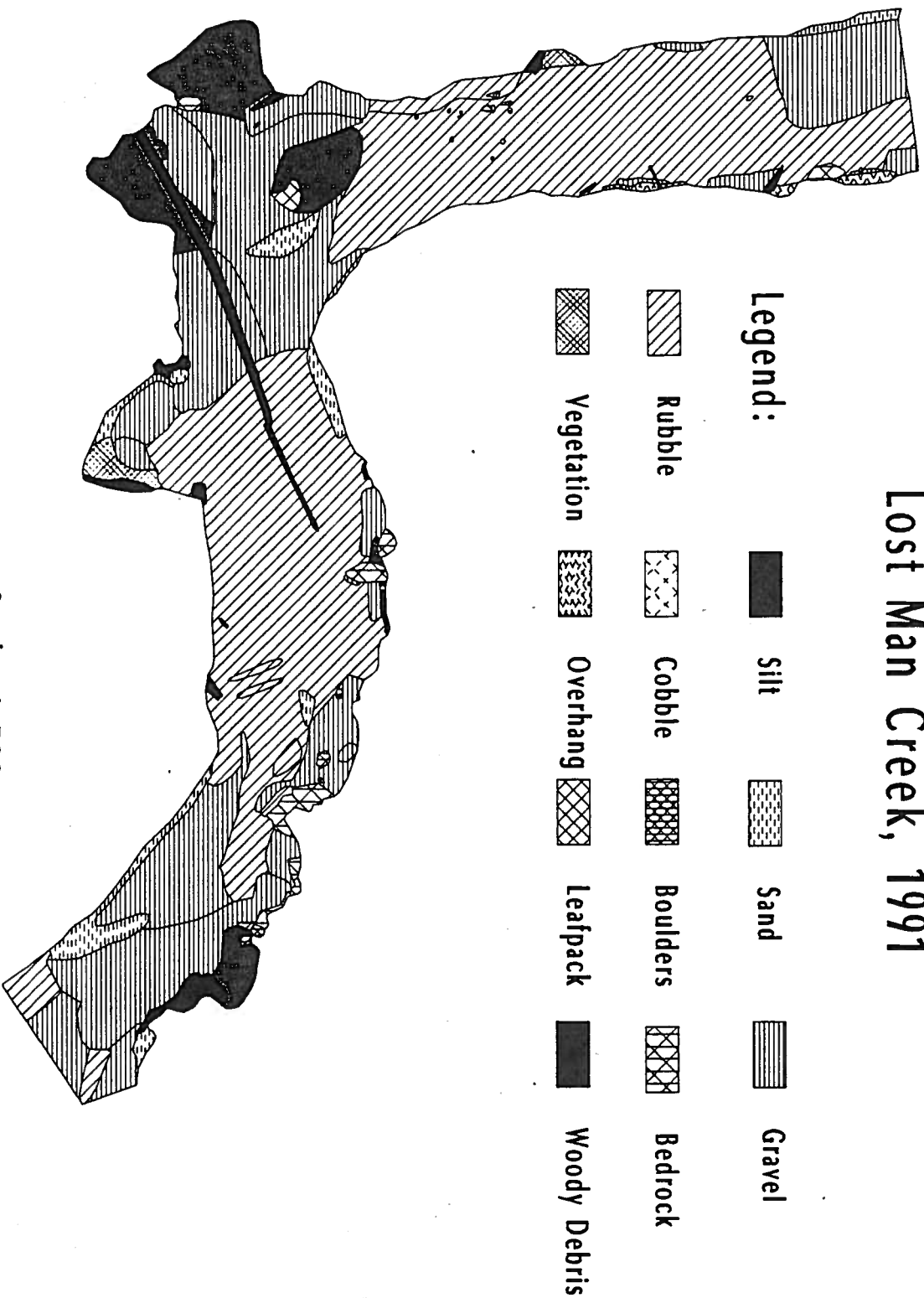
Silt Sand Gravel

Rubble Cobble Boulders Bedrock

Vegetation Overhang Leafpack Woody Debris

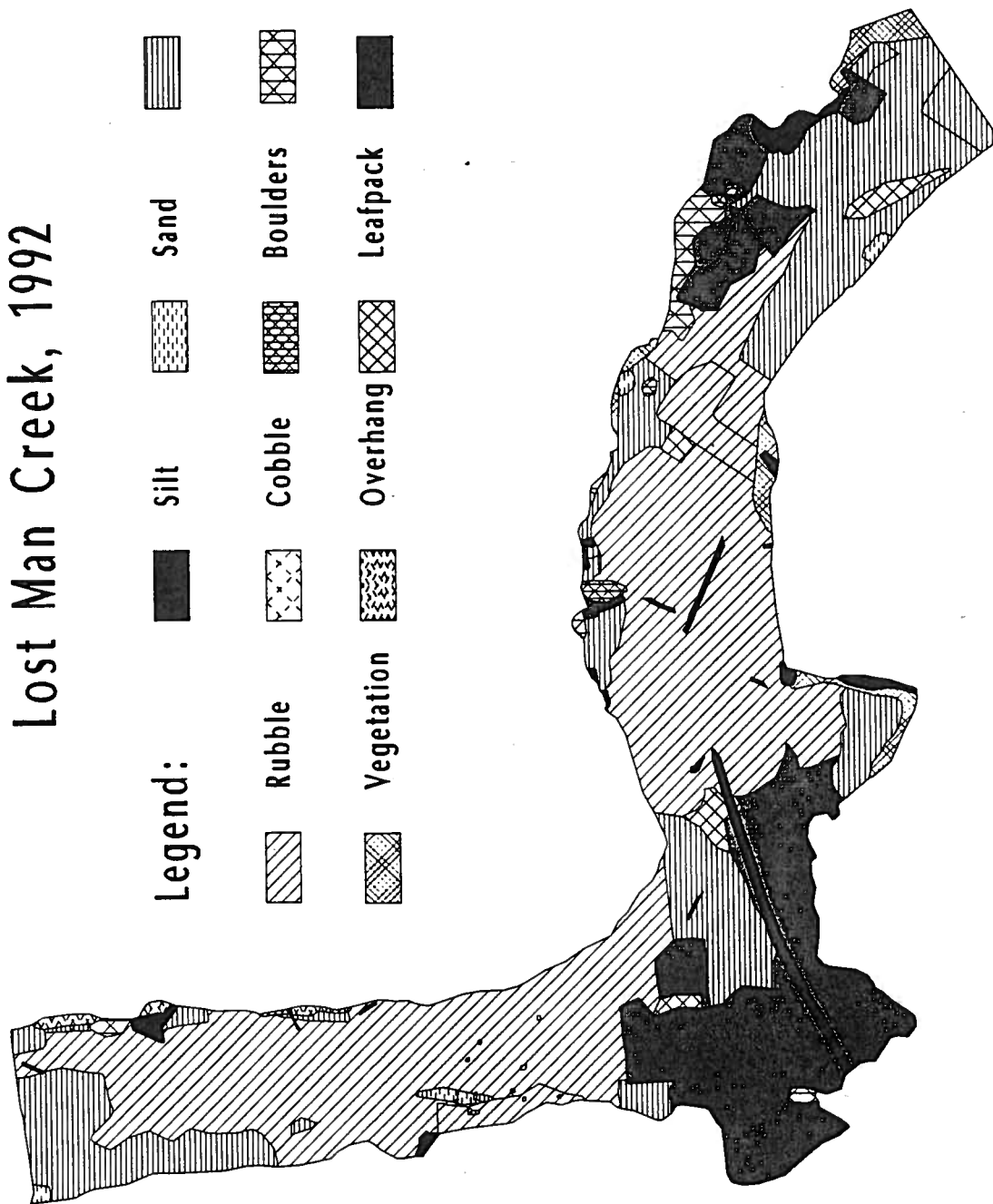
Scale 1:500

Lost Man Creek, 1991



Scale 1:500

Lost Man Creek, 1992



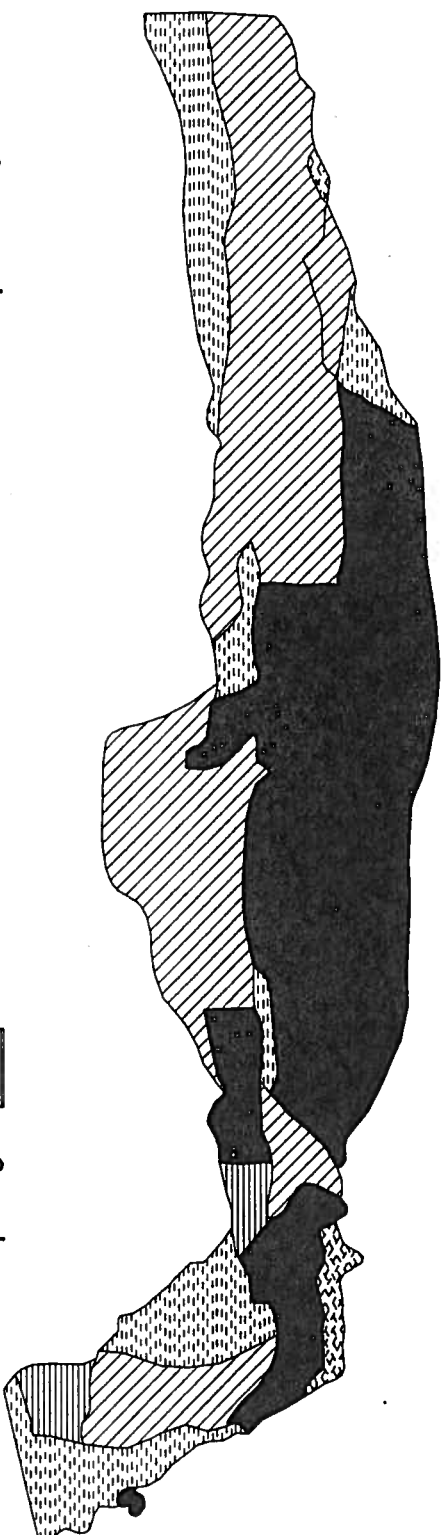
Legend:

	Rubble		Silt		Sand		Gravel
	Cobble		Overhang		Boulders		Bedrock
	Vegetation		Leafpack		Woody Debris		

Scale 1:500

Boyes Creek, 1989

Scale 1:300

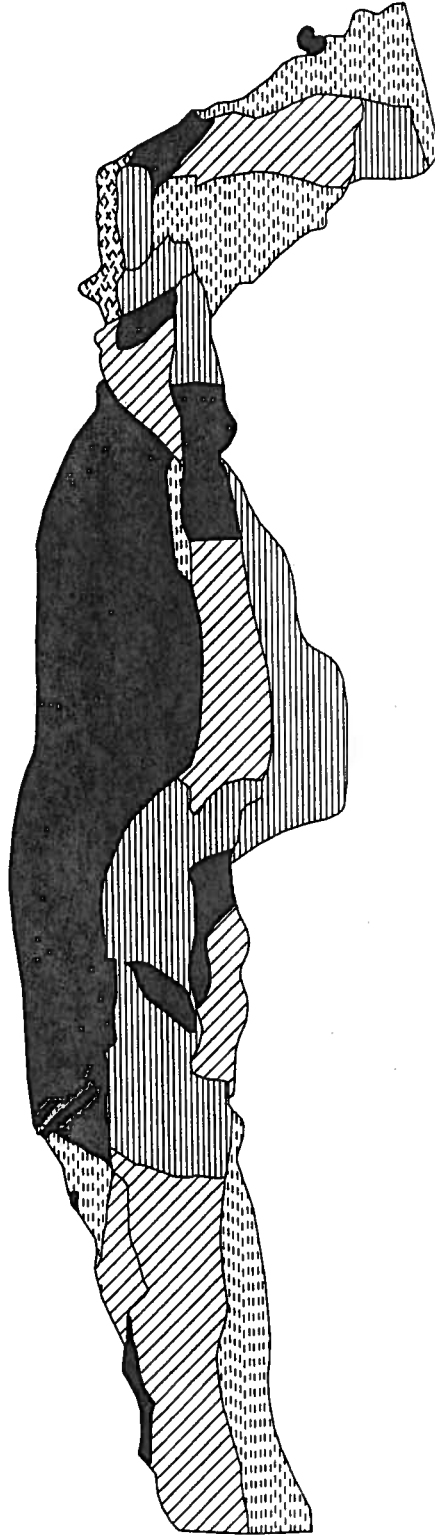


Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
			Woody Debris		
					Bedrock

Boyes Creek, 1990

Scale 1:300

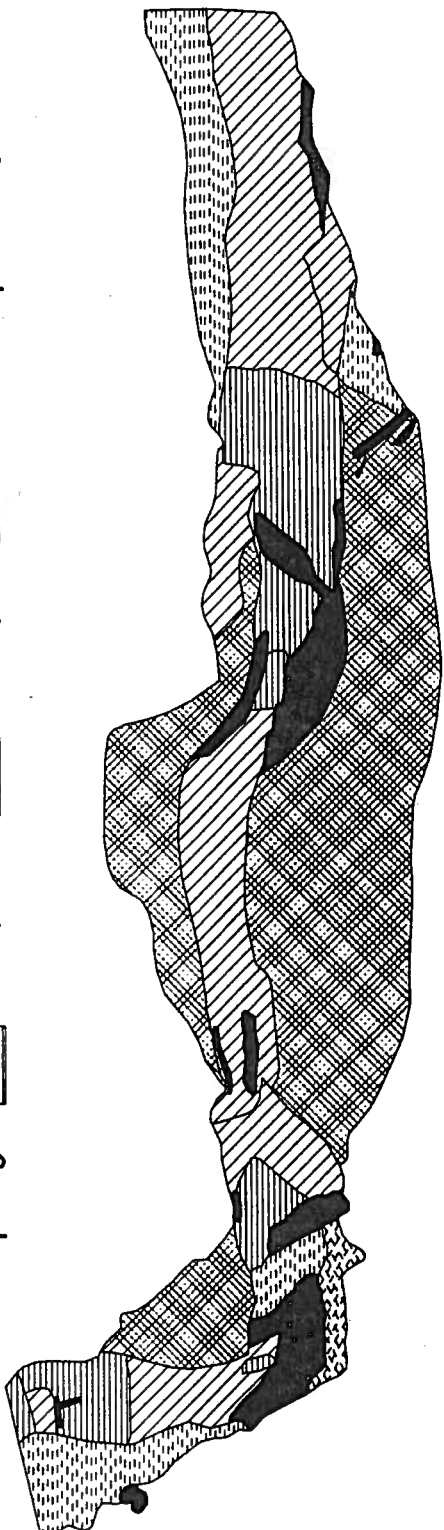


Legend:

	Rubble		Silt		Sand		Gravel
	Vegetation		Cobble		Boulders		Bedrock
	Overhang		Leafpack		Woody Debris		

Boyes Creek, 1991

Scale 1:300

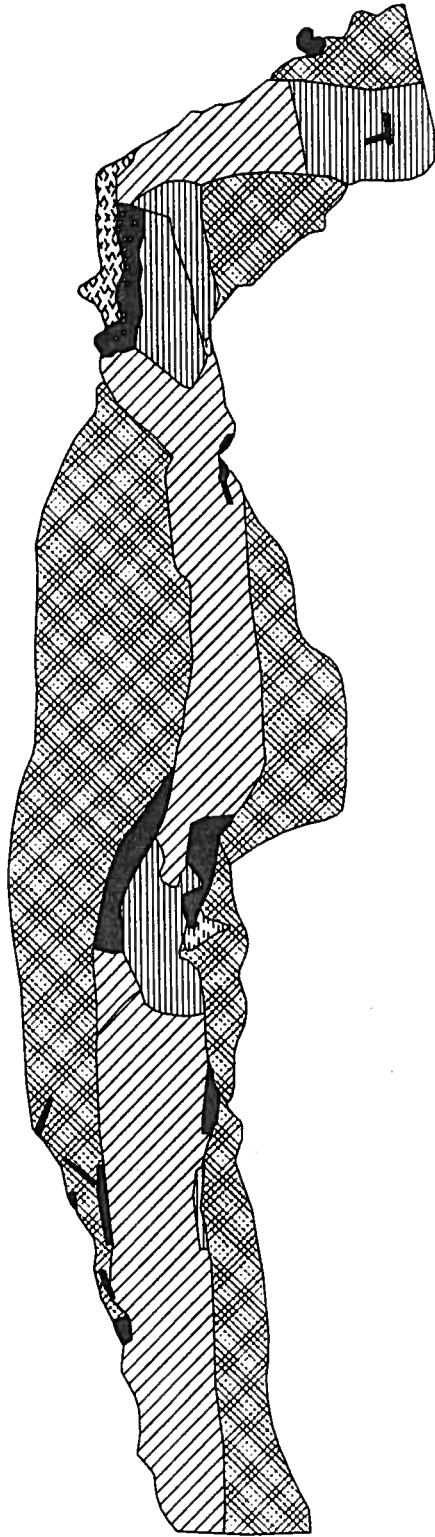


Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
			Woody Debris		

Boyes Creek, 1992

Scale 1:300

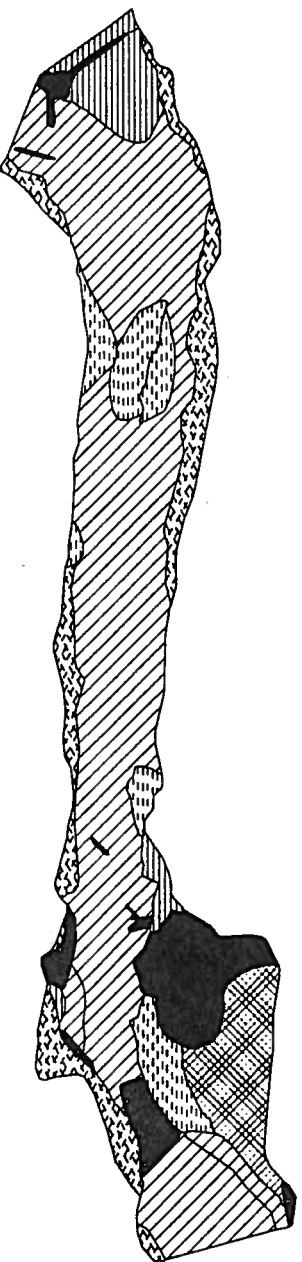


Legend:

	Rubble		Silt		Sand		Gravel
	Vegetation		Cobble		Boulders		Bedrock
	Overhang		Leafpack		Woody Debris		

Brown Creek, 1988

Scale 1:300

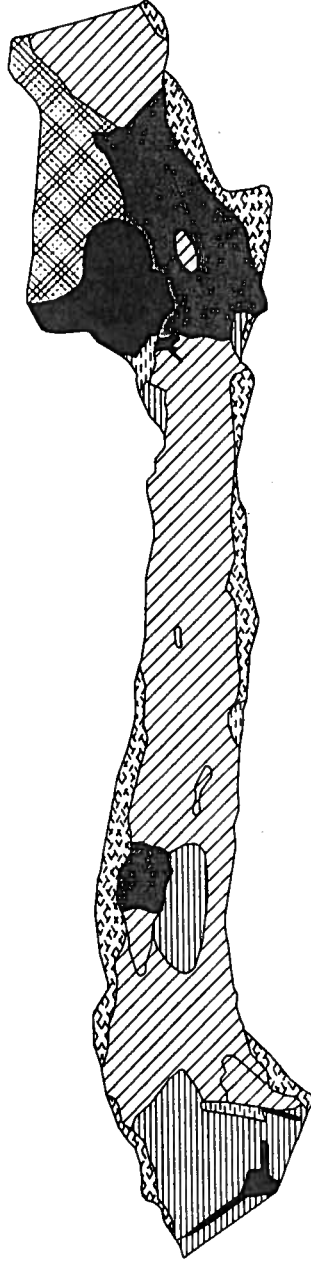


Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
			Woody Debris		
					Bedrock

Brown Creek, 1991

Scale 1:300

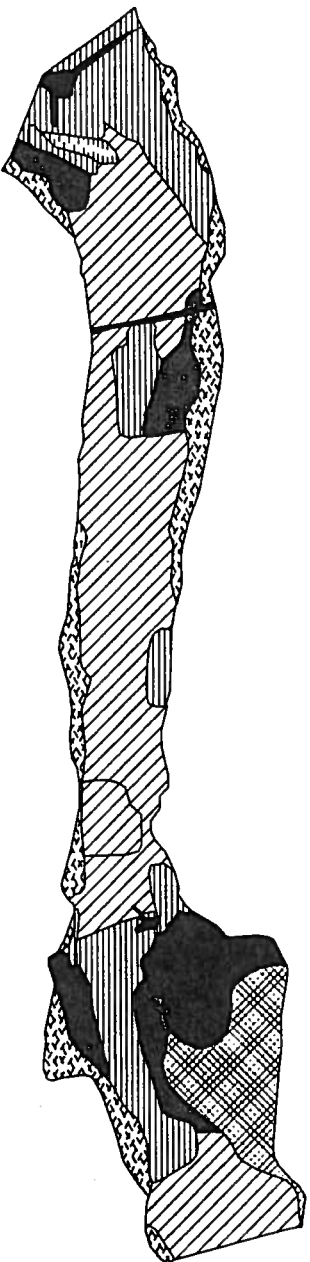


Legend:

	Rubble		Silt		Sand		Gravel
	Vegetation		Overhang		Leafpack		Woody Debris
			Cobble		Boulders		Bedrock

Brown Creek, 1992

Scale 1:300



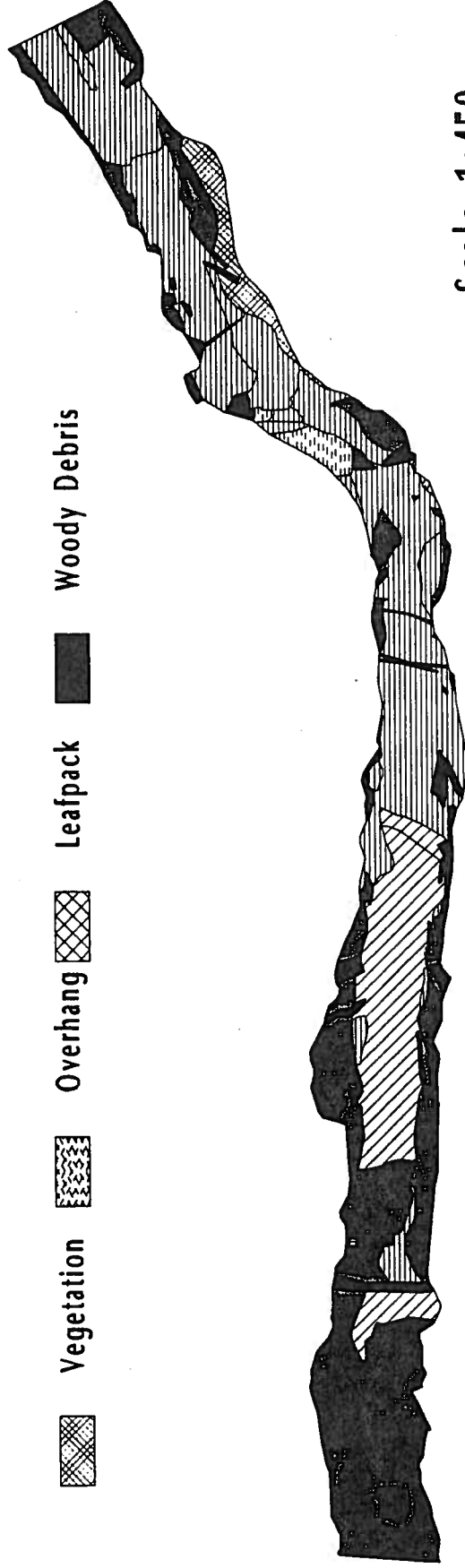
Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
			Woody Debris		

McGarvey Creek, 1988

Legend:

	Rubble		Silt		Sand		Gravel
	Vegetation		Cobble		Boulders		Bedrock
			Overhang		Leafpack		Woody Debris



Scale 1:450

McGarvey Creek, 1989

Legend:

Silt

Sand

Gravel

 Rubble

Cobble

Boulders

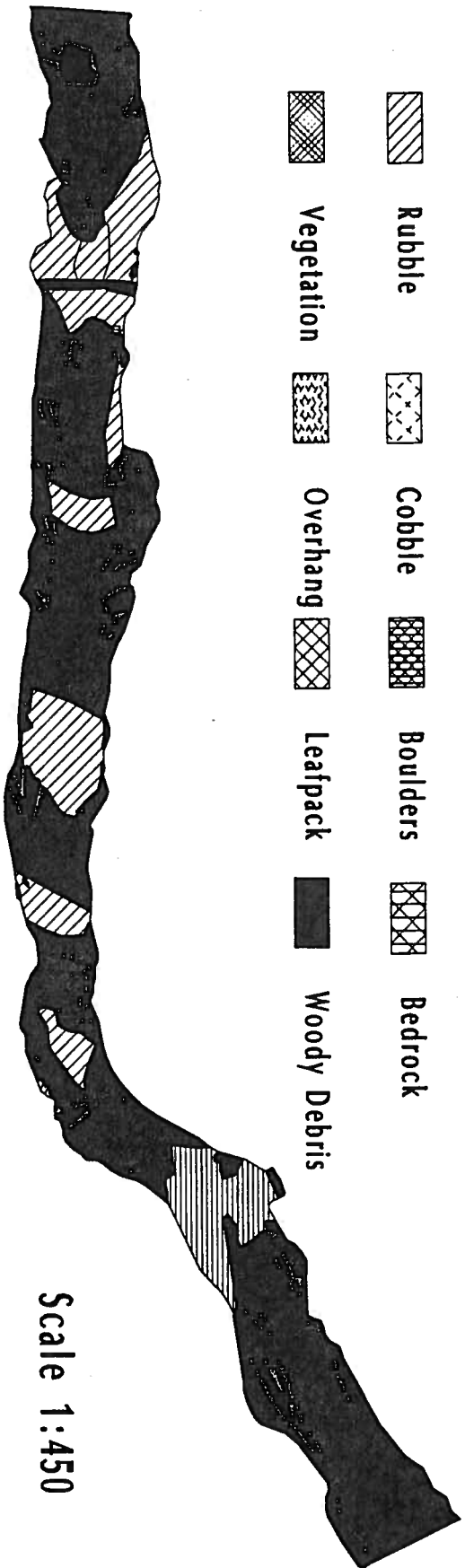
Bedrock

Vegetation

 Overhang

Leafpack

Woody Debris



Scale 1:450

McGarvey Creek, 1991

Legend:



Silt



Sand



Gravel



Rubble



Cobble



Boulders



Bedrock



Vegetation



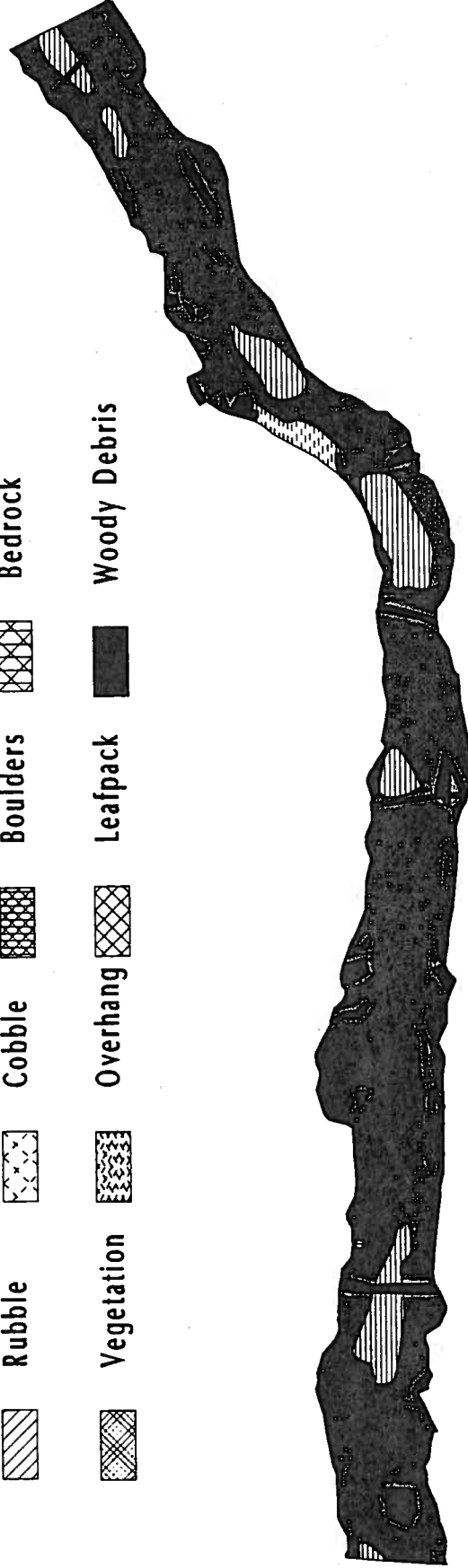
Overhang



Leafpack



Woody Debris

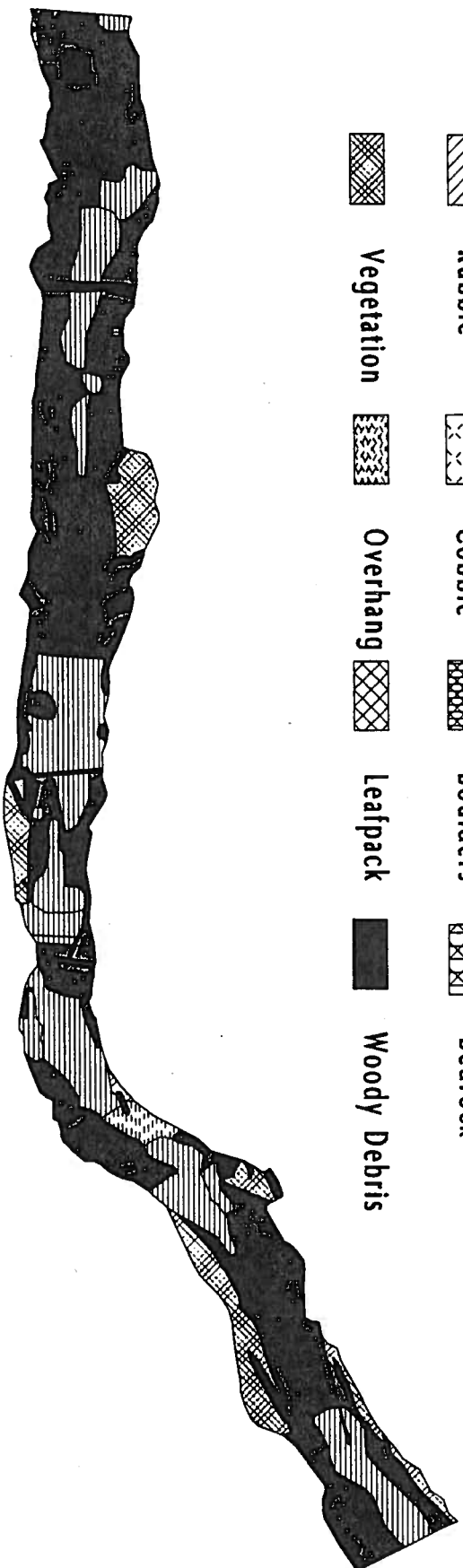


Scale 1:450

McGarvey Creek, 1992

Legend:

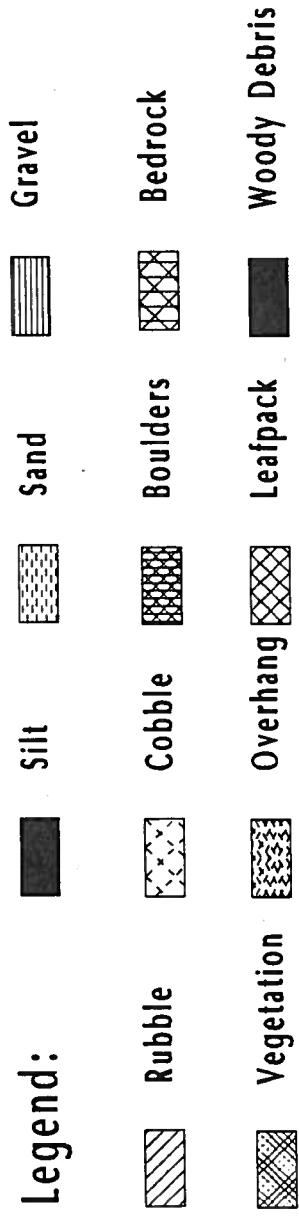
	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
					Woody Debris



Scale 1:450

Ah Pah Creek, 1988

Scale 1:400



Ah Pah Creek, 1989

Scale 1:400

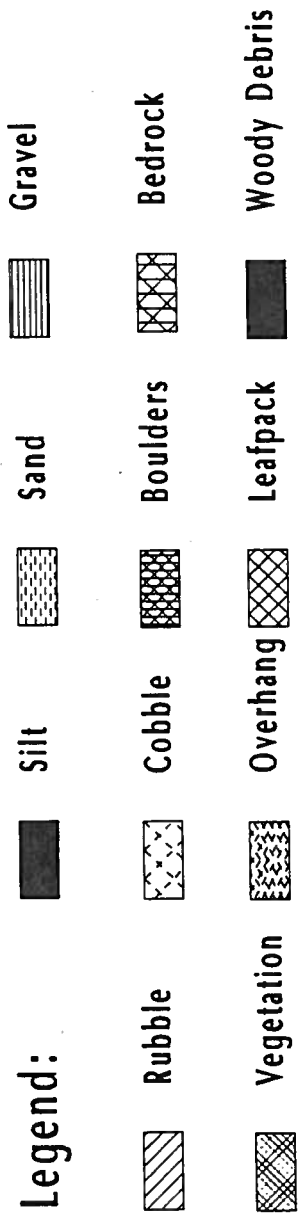
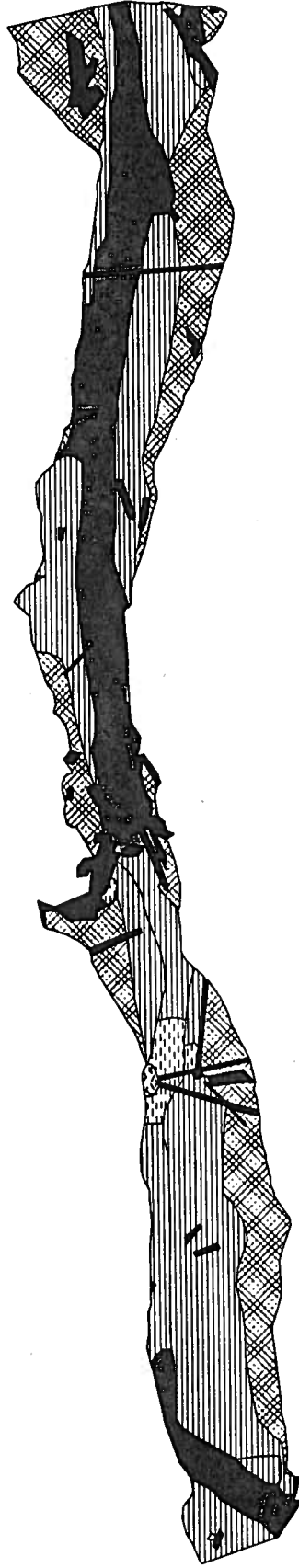


Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
			Woody Debris		

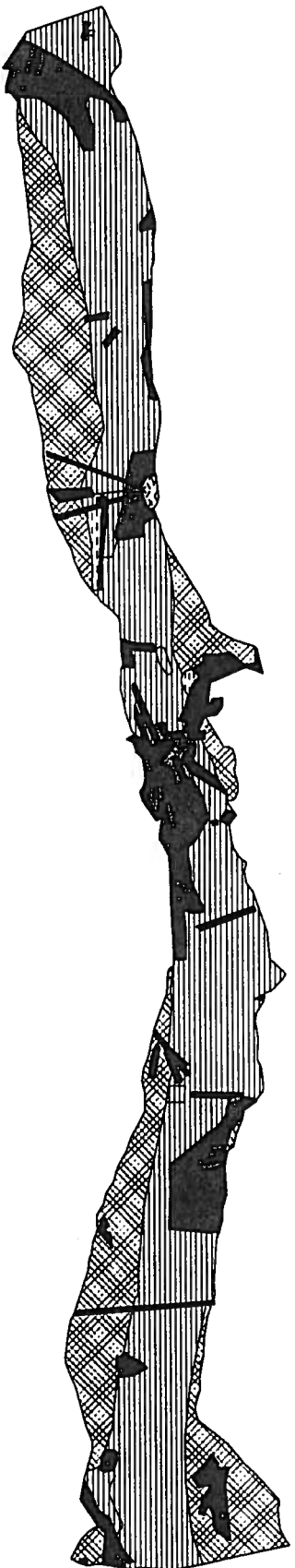
Ah Pah Creek, 1991

Scale 1:400



Ah Pah Creek, 1992

Scale 1:400

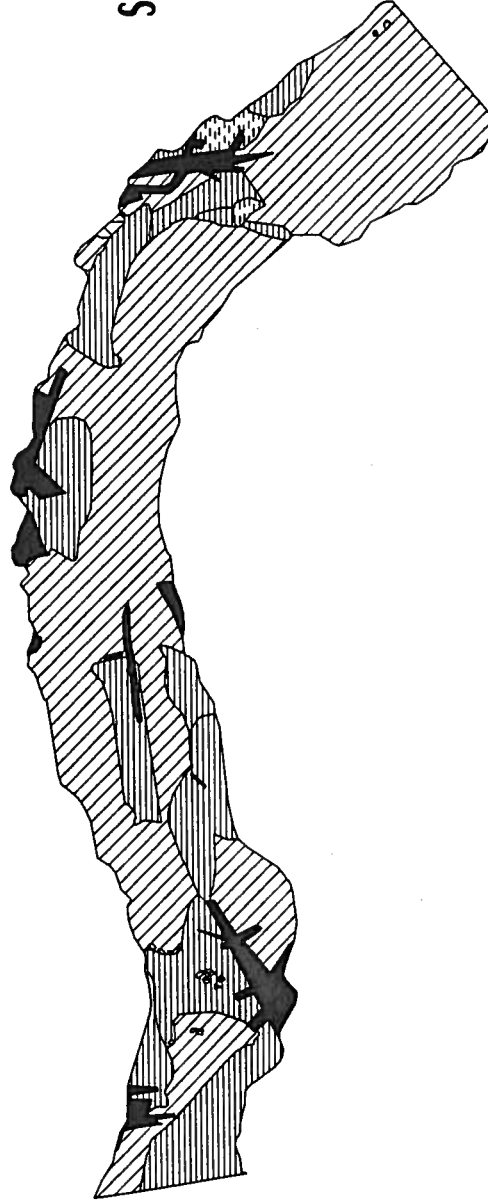


Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
			Woody Debris		

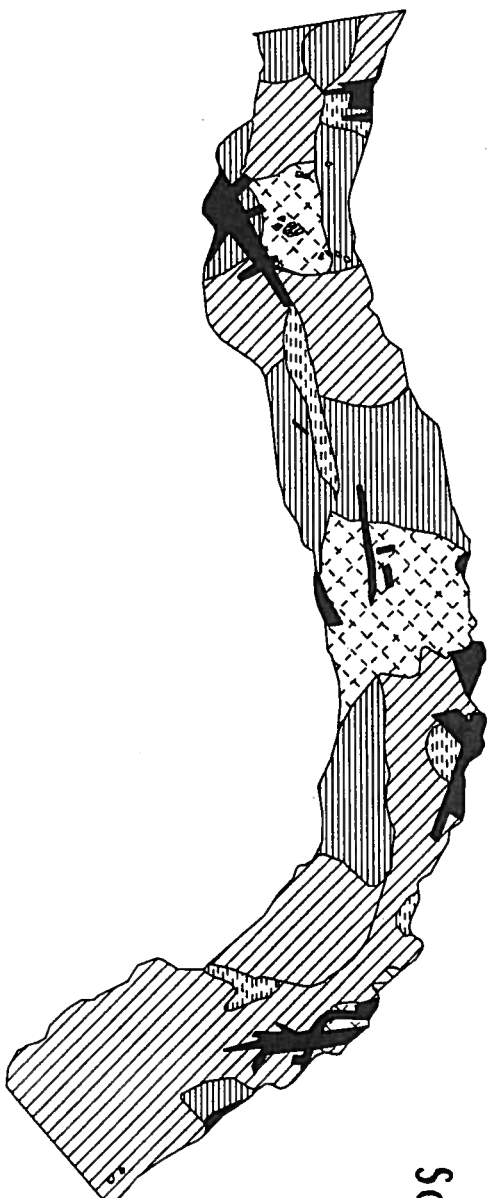
Tarup Creek, 1988

Scale 1:400



Legend:

Tarup Creek, 1989



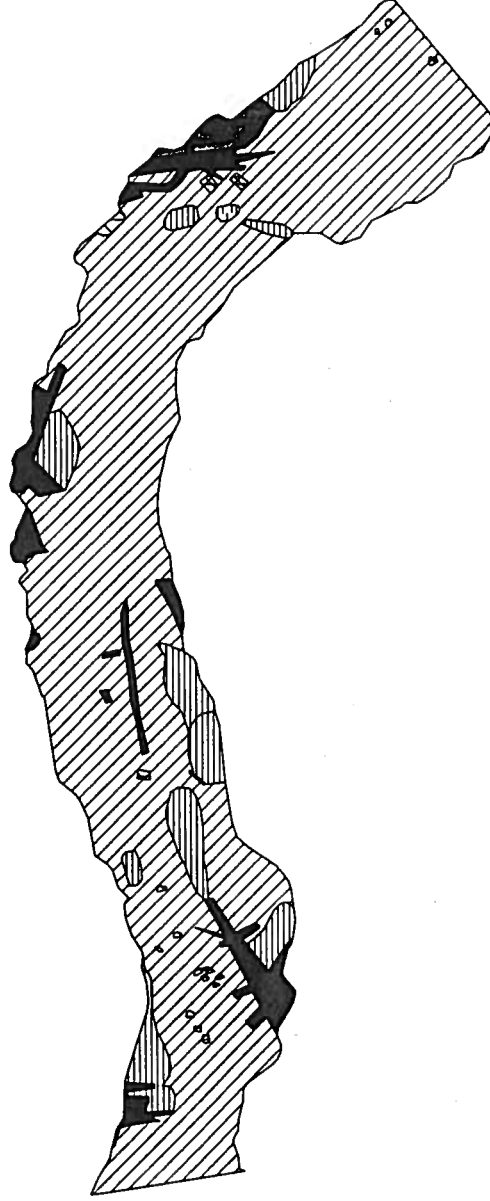
Scale 1:400

Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
			Bedrock		Woody Debris

Tarup Creek, 1991

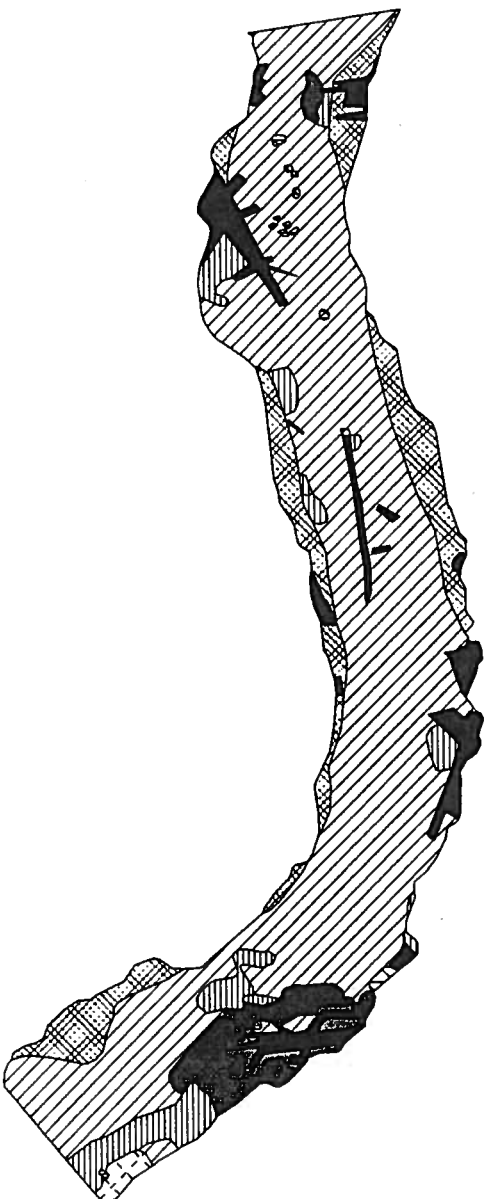
Scale 1:400



Legend:

	Rubble		Cobble		Boulders		Bedrock
	Vegetation		Overhang		Leafpack		Woody Debris

Tarup Creek, 1992



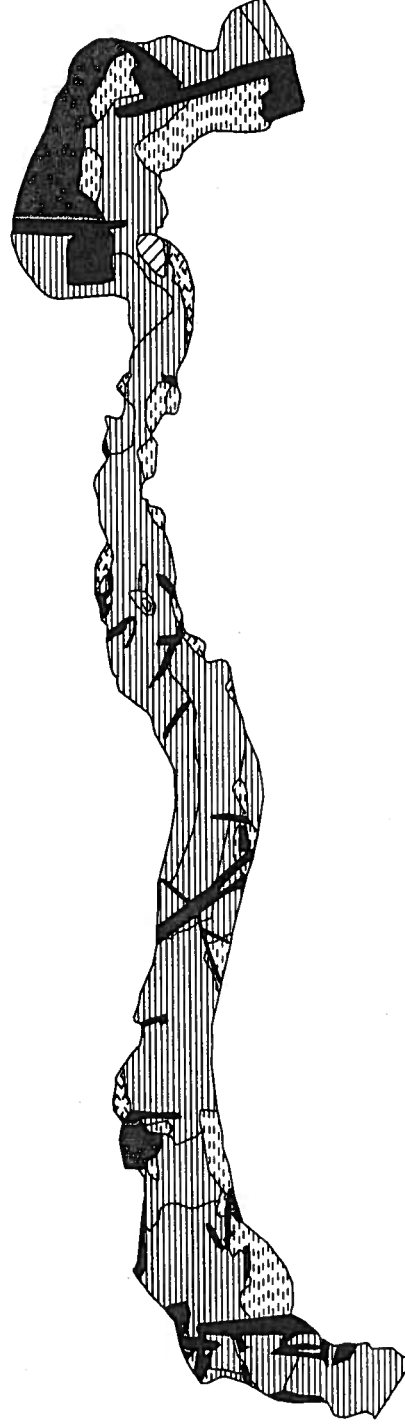
Scale 1:400

Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
			Woody Debris		

May Creek, 1988

Scale 1:400

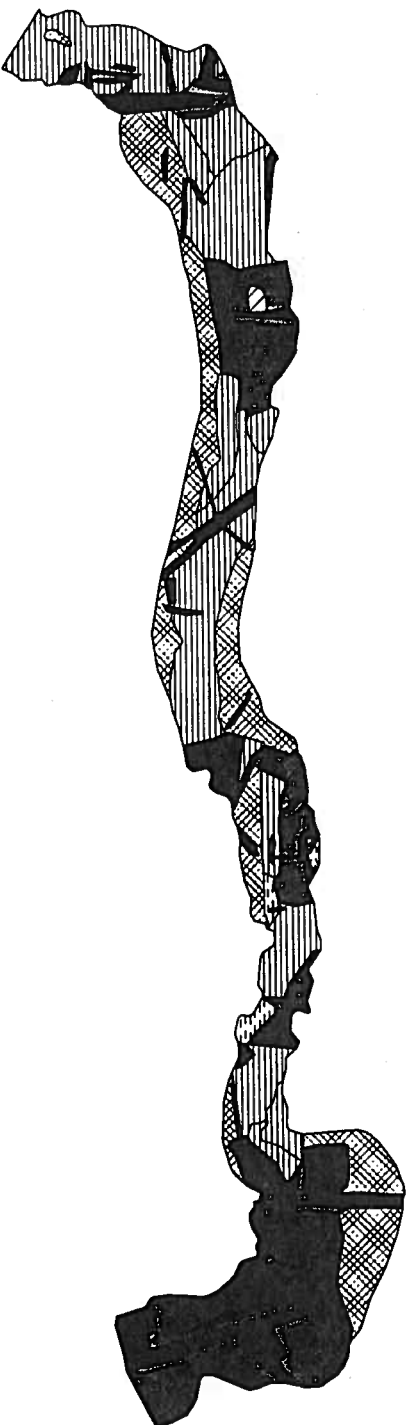


Legend:

	Rubble		Silt		Sand		Gravel
	Vegetation		Overhang		Boulders		Bedrock
					Leafpack		Woody Debris

May Creek, 1992

Scale 1:400



Legend:

	Silt		Sand		Gravel
	Rubble		Cobble		Boulders
	Vegetation		Overhang		Leafpack
			Woody Debris		

Table C-1. Percent silt identified as dominant or subdominant in bypass stream reaches.

Site						
Year	PABR	PABY	PBBY	PAMY	PBMY	PBCH
1988	14.81	7.44	9.80	7.67	*	41.14
1989	*	*	*	*	*	*
1990	*	*	*	*	*	*
1991	*	*	11.44	16.87	13.69	11.98
1992	11.27	4.88	15.31	16.86	31.68	61.68

Table C-2. Percent silt identified as dominant in bypass stream reaches.

Site						
Year	PABR	PABY	PBBY	PAMY	PBMY	PBCH
1988	4.88	3.42	7.33	3.48	*	34.34
1989	*	*	*	*	*	*
1990	*	*	*	*	*	*
1991	*	*	8.08	10.54	10.15	10.46
1992	7.96	4.40	10.86	15.14	17.11	42.55

Table C-3. Percent silt identified as subdominant in bypass stream reaches.

Site						
Year	PABR	PABY	PBBY	PAMY	PBMY	PBCH
1988	12.58	4.87	2.91	5.67	*	8.85
1989	*	*	*	*	*	*
1990	*	*	*	*	*	*
1991	*	*	5.97	7.31	5.52	2.03
1992	9.69	2.96	8.58	3.29	26.83	46.05

Table C-4. Percent sand identified as dominant or subdominant in bypass stream reaches.

Site						
Year	PABR	PABY	PBBY	PAMY	PBMY	PBCH
1988	8.53	17.03	28.35	39.74	*	21.50
1989	*	*	*	*	*	*
1990	*	*	*	*	*	*
1991	*	*	16.71	52.23	28.16	75.99
1992	2.77	8.06	8.40	35.71	13.17	18.72

Table C-5. Percent sand identified as dominant in bypass stream reaches.

Site						
Year	PABR	PABY	PBBY	PAMY	PBMY	PBCH
1988	4.14	7.06	7.26	4.05	*	5.10
1989	*	*	*	*	*	*
1990	*	*	*	*	*	*
1991	*	*	1.32	1.43	6.90	0.00
1992	1.98	0.92	7.80	2.50	1.26	1.47

Table C-6. Percent sand identified as subdominant in bypass stream reaches.

Site						
Year	PABR	PABY	PBBY	PAMY	PBMY	PBCH
1988	4.62	10.74	21.08	35.79	*	16.68
1989	*	*	*	*	*	*
1990	*	*	*	*	*	*
1991	*	*	15.49	52.73	23.35	75.99
1992	0.79	7.14	2.15	33.22	12.04	17.25

Table C-7. Percent fines, sand and/or silt, identified as dominant or subdominant in bypass stream reaches.

Site						
Year	PABR	PABY	PBBY	PAMY	PBMY	PBCH
1988	19.32	20.85	35.76	42.98	*	56.04
1989	*	*	*	*	*	*
1990	*	*	*	*	*	*
1991	*	*	28.04	67.53	41.40	81.07
1992	13.67	12.21	23.71	51.16	44.85	79.40

Table C-8. Percent fines, sand and/or silt, identified as dominant in bypass stream reaches.

Site						
year	PABR	PABY	PBBY	PAMY	PBMY	PBCH
1988	9.01	10.48	14.59	7.53	*	39.44
1989	*	*	*	*	*	*
1990	*	*	*	*	*	*
1991	*	*	9.40	11.97	17.05	10.46
1992	9.94	5.32	18.66	17.64	18.37	44.02

Table C-9. Percent fines, sand and/or silt, identified as subdominant in bypass stream reaches.

Site						
Year	PABR	PABY	PBBY	PAMY	PBMY	PBCH
1988	17.20	15.61	23.99	41.46	*	25.53
1989	*	*	*	*	*	*
1990	*	*	*	*	*	*
1991	*	*	21.46	60.04	28.87	78.02
1992	10.48	10.11	10.73	36.51	38.87	63.30

Table C-10. Percent silt identified as dominant or subdominant in bypass stream reaches.

Site				
Year	LOST MAN CK	BROWN CK	BOYES CK	MAY CK
1988	2.76	4.50	*	12.29
1989	*	*	55.48	*
1990	*	*	69.22	*
1991	8.62	16.30	52.47	*
1992	19.72	18.72	38.29	42.19

Table C-11. Percent silt identified as dominant in bypass stream reaches.

Site				
Year	LOST MAN CK	BROWN CK	BOYES CK	MAY CK
1988	1.91	2.94	*	7.48
1989	*	*	40.62	*
1990	*	*	34.53	*
1991	7.91	12.85	8.25	*
1992	19.62	7.99	3.90	31.09

Table C-12. Percent silt identified as subdominant in bypass stream reaches.

Site				
Year	LOST MAN CK	BROWN CK	BOYES CK	MAY CK
1988	2.76	2.61	*	9.09
1989	*	*	14.85	*
1990	*	*	34.69	*
1991	2.91	4.19	47.24	*
1992	2.80	12.67	37.88	18.01

Table C-13. Percent sand identified as dominant or subdominant in bypass stream reaches.

Site				
Year	LOST MAN CK	BROWN CK	BOYES CK	MAY CK
1988	23.78	14.61	*	57.24
1989	*	*	56.18	*
1990	*	*	48.96	*
1991	18.09	18.71	15.81	*
1992	14.32	15.72	9.13	6.38

Table C-14. Percent sand identified as dominant in bypass stream reaches.

Site				
Year	LOST MAN CK	BROWN CK	BOYES CK	MAY CK
1988	4.00	8.72	*	12.20
1989	*	*	16.64	*
1990	*	*	15.97	*
1991	3.59	1.18	11.45	*
1992	0.65	0.95	0.32	0.95

Table C-15. Percent sand identified as subdominant in bypass stream reaches.

Site				
Year	LOST MAN CK	BROWN CK	BOYES CK	MAY CK
1988	21.70	8.40	*	50.80
1989	*	*	39.54	*
1990	*	*	32.99	*
1991	16.46	17.52	4.36	*
1992	13.85	14.78	8.82	5.43

Table C-16. Percent fines, sand and/or silt, identified as dominant or subdominant in bypass stream reaches.

Site				
Year	LOST MAN CK	BROWN CK	BOYES CK	MAY CK
1988	25.68	17.77	*	62.97
1989	*	*	58.69	*
1990	*	*	72.22	*
1991	26.21	29.15	56.57	*
1992	34.04	31.40	47.10	48.22

Table C-17. Percent fines, sand and/or silt, identified as dominant in bypass stream reaches.

Site				
Year	LOST MAN CK	BROWN CK	BOYES CK	MAY CK
1988	5.91	11.66	*	19.68
1989	*	*	57.26	*
1990	*	*	50.50	*
1991	11.50	14.03	19.70	*
1992	20.27	8.94	4.22	32.04

Table C-18. Percent fines, sand and/or silt, identified as subdominant in bypass stream reaches.

Site				
Year	LOST MAN CK	BROWN CK	BOYES CK	MAY CK
1988	24.46	11.01	*	59.89
1989	*	*	54.39	*
1990	*	*	67.68	*
1991	19.37	21.71	51.60	*
1992	16.65	27.45	46.70	23.44

Table C-19. Percent silt identified as dominant or subdominant in bypass stream reaches.

Site			
Year	Tarup Ck	Ah Pah Ck	McGarvey Ck
1988	0.99	23.49	56.03
1989	0.15	20.64	88.97
1990	*	*	*
1991	1.24	23.08	91.20
1992	6.02	12.02	69.96

Table C-20. Percent silt identified as dominant in bypass stream reaches.

Site			
Year	Tarup Ck	Ah Pah Ck	McGarvey Ck
1988	0.00	21.70	33.77
1989	0.15	20.26	68.85
1990	*	*	*
1991	1.24	22.90	79.48
1992	6.02	11.52	54.81

Table C-21. Percent silt identified as subdominant in bypass stream reaches.

Site			
Year	Tarup Ck	Ah Pah Ck	McGarvey Ck
1988	0.99	5.15	36.32
1989	0.00	1.01	47.75
1990	*	*	*
1991	0.00	2.28	40.67
1992	0.00	1.19	35.59

Table C-22. Percent sand identified as dominant or subdominant in bypass stream reaches.

Site			
Year	Tarup Ck	Ah Pah Ck	McGarvey Ck
1988	17.62	12.04	9.94
1989	12.51	9.90	0.80
1990	*	*	*
1991	4.19	7.90	3.87
1992	2.14	2.85	10.78

Table C-23. Percent sand identified as dominant in bypass stream reaches.

Site			
Year	Tarup Ck	Ah Pah Ck	McGarvey Ck
1988	1.37	4.41	1.49
1989	4.24	5.45	0.00
1990	*	*	*
1991	0.16	1.72	1.29
1992	0.15	0.65	1.12

Table C-24. Percent sand identified as subdominant in bypass stream reaches.

Site			
Year	Tarup Ck	Ah Pah Ck	McGarvey Ck
1988	16.63	7.89	8.59
1989	10.99	6.97	0.80
1990	*	*	*
1991	4.19	6.30	2.58
1992	2.14	2.35	14.14

Table C-25. Percent fines, sand and/or silt, identified as dominant or subdominant in bypass stream reaches.

Site			
Year	TARUP CK	AH PAH CK	MCGARVEY CK
1988	17.62	32.38	65.48
1989	12.66	30.15	88.97
1990	*	*	*
1991	5.44	19.28	91.19
1992	8.16	13.35	84.09

Table C-26. Percent fines, sand and/or silt, identified as dominant in bypass stream reaches.

Site			
Year	TARUP CK	AH PAH CK	MCGARVEY CK
1988	17.62	13.04	44.91
1989	10.99	7.98	48.55
1990	*	*	*
1991	4.19	8.58	43.25
1992	2.14	3.54	49.73

Table C-27. Percent fines, sand and/or silt, identified as subdominant in bypass stream reaches.

Site			
Year	TARUP CK	AH PAH CK	MCGARVEY CK
1988	1.37	26.11	35.26
1989	4.39	25.71	68.85
1990	*	*	*
1991	1.40	24.62	80.77
1992	6.17	12.17	55.93

Table C-28. Percent vegetation identified as dominant or subdominant in bypass stream reaches.

Site						
Year	PABR	PABY	PBBY	PAMY	PBMY	PBCH
1988	7.35	10.08	4.85	21.51	*	0.15
1989	*	*	*	*	*	*
1990	*	*	*	*	*	*
1991	*	*	5.94	22.28	19.08	0.00
1992	13.15	15.20	12.91	23.71	25.26	4.24

Table C-29. Percent vegetation identified as dominant or subdominant in bypass stream reaches.

Site				
Year	LOST MAN CK	BROWN CK	BOYES CK	MAY CK
1988	0.26	7.11	*	0.00
1989	*	*	0.00	*
1990	*	*	0.00	*
1991	0.84	8.55	39.95	*
1992	1.98	8.30	50.49	20.46

Table C-30. Percent vegetation identified as dominant or subdominant in bypasss stream reaches.

Site			
Year	Tarup Ck	Ah Pah Ck	McGarvey Ck
1988	0.00	9.91	2.99
1989	0.00	9.51	0.00
1990	*	*	*
1991	0.00	24.95	2.74
1992	12.35	28.17	16.28

Table C-31. Total silt, dominant or subdominant, ft² (%) (vegetation not included)

	Prairie Ck.	Pr Ck. tribs	Klam. tribs	Total
1988	11337 (15.7)	3602 (12.0)	5498 (28.8)	20437 (16.9)
1992	17141 (23.7)	7855 (26.2)	6043 (31.7)	31039 (25.6)

Table C-32. Total silt, dominant or subdominant, ft² (%) (vegetation not included)

	1988	1992
Prairie Creek Reaches		
control (AB)	1218(14.8)	927(11.3)
AY,BB,AM,BM,BC	10119(15.8)	16215(25.3)
Prairie Creek Tributaries		
control (LM)	485(2.8)	3498(19.7)
BR,BY,MC	3117(25.1)	4357(35.1)
Klamath Tributaries		
control (TC)	57(1.0)	343(6.0)
AP,MG	5442(40.7)	5701(42.6)

Table C-33. Total fines, sand and/or silt, dominant or subdominant, ft² (%) (vegetation not included)

	1988	1992
Prairie Creek Reaches		
control (AB)	1589(19.3)	1124(13.7)
AY,BB,AM,BM,BC	24494(38.3)	26284(41.1)
Prairie Creek Tributaries		
control (LM)	4512(25.7)	6038(34.0)
BR,BY,MC	6290(50.7)	5439(43.9)
Klamath Tributaries		
control (TC)	1004(17.6)	465(8.2)
AP,MG	6671(49.9)	6782(50.7)

Table C-34. Total silt, dominant or subdominant, ft² (%) (includes vegetation)

	Prairie Ck.	Pr Ck. tribs	Klam. tribs	Total
1988	14198(19.7)	3605(12.0)	5499(28.8)	23302(19.2)
1992	17641(24.4)	8520(28.4)	6504(34.1)	32665(26.9)

Table C-35. Total silt, dominant or subdominant, ft² (%) (includes vegetation)

	1988	1992
Prairie Creek Reaches		
control (AB)	1218(14.8)	927(11.3)
AY,BB,AM,BM,BC	12980(20.3)	16714(26.1)
Prairie Creek Tributaries		
control (LM)	488(2.8)	3498(19.7)
BR,BY,MC	3117(25.1)	5022(40.5)
Klamath Tributaries		
control (TC)	57(1.0)	343(6.0)
AP,MG	5442(40.7)	6161(46.0)

Table C-36. Total fines, sand and/or silt, dominant or subdominant, ft² (%) (includes vegetation)

	1988	1992
Prairie Creek Reaches		
control (AB)	1589(19.3)	1124(13.7)
AY,BB,AM,BM,BC	27355(42.7)	26783(41.9)
Prairie Creek Tributaries		
control (LM)	4515(25.7)	6038(34.0)
BR,BY,MC	6290(50.7)	6104(49.2)
Klamath Tributaries		
control (TC)	1004(17.6)	465(8.2)
AP,MG	6671(49.9)	7242(54.1)

Table C-37. Total woody debris, ft² (%)

	Prairie Ck.	Pr. Ck. tribs	Klam. tribs	Total
1988	2162.4 (3.0)	1160.9 (3.9)	1457.9 (7.6)	4781.2 (3.9)
1992	2582.9 (3.6)	1386.5 (4.6)	1580.0 (8.3)	5549.5 (4.6)

Table C-38. Total area of bypass sites, ft²

	Prairie Ck		Prairie Ck Tribs		Klamath Tribs	
	AB	8224	LM	17569	TC	5695
	AY	17155	BR	2868	AP	6317
	BB	9465	BY	5134	MG	7063
	AM	11848	MY	4395		
	BM	12733				
	BC	12796				
Total	72221		29966		19075	