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Value of Instream Habitat Structures to Smallmouth Bass


Before


After

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Value of Instream Habitat Structures to Smallmouth Bass

SCFW F-87-R

April 1, 1988, to June 30, 1991

By

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Executive Summary

During this three-year sport fish restoration project, the Illinois Department of Conservation and the Illinois State Water Survey installed and evaluated two habitat enhancement techniques in Franklin Creek State Park. A modified Wisconsin "lunker" technique of bank cover enhancement was installed in 1989. The construction site had complete vegetative cover by June 1990, when a large flood completely inundated the valley to a depth of 9 feet. No damage occurred to the lunker installation.

The effectiveness of the lunkers to enhance smallmouth bass (SMB) populations was evaluated against preconstruction fishery data of the site in 1989 and from postconstruction data with a similar control site 1000 feet downstream. Both population density and biomass of SMB increased significantly when compared to the downstream control.

The second habitat enhancement technique, also installed in 1989, was tree revetment, a low-cost installation in which trees are cabled to an eroding bank. Vegetative cover and bank soils were eroded by the June 1990 flood. Thus additional trees had to be cabled to the site during 1990. The site has not become completely revegetated even after additional plantings of willows during 1990.

The response of SMB populations to tree revetment habitat was also compared to 1989 preconstruction data and an upstream control. SMB population density and biomass increased significantly but not as dramatically as in the lunker application.

Habitat evaluations by the Illinois Environmental Protection Agency found a general stability of habitat quality in the habitat enhancement sites while the control sites had decreased habitat quality. The greatest habitat changes were increases in water depth, undercut bank, rocky substrate, and brush debris at the habitat enhancement sites. Stream geometry and streambed slope remained stable at the habitat enhancement sites. Water quality was similar during all three years of the study.

Introduction

In the agricultural Midwest, stream fisheries have long suffered from habitat degradation due to inappropriate stream and land management practices (Karr et al., 1985; Trautman, 1981). Channelization, riparian clearing, and disruption of the normal hydrograph have acted in concert to degrade the environment of both sport and nongame fishes (Smith, 1971; Roseboom and Russell, 1985). The single most pervasive impact, sedimentation, exacts a heavy toll on those species requiring coarse substrate (i.e., gravel, cobble, and/or boulders) to carry out their life functions (Judy et al.; 1984, Paragamiah, 1991).

The smallmouth bass (SMB), *Micropterus dolomieu*, is a popular sport fish that has been so affected. Many authors (Paragamian, 1981; Rankin, 1986; McClendon and Rabeni, 1987; Lyons, 1991) have correlated SMB populations with habitat variables including substrate type and, to a lesser extent, instream cover. Among these authors, there is general consensus that physical habitat often limits the distribution (i.e., presence/absence) and abundance of SMB populations in warm-water streams.

Habitat limitations are particularly evident in Illinois, where over 30 percent of the state's stream miles have been channelized (Conlin, 1976), and statewide sediment loss rates are among the greatest in the upper Midwest (Crews, 1983; Anonymous, 1982). In an effort to restore SMB fisheries and stream fish communities in general, the Illinois Department of Conservation (IDOC) is exploring ways to enhance the physical stream environment through habitat improvement methods. In doing so, IDOC fisheries staff have drawn heavily on the experiences of stream habitat managers throughout the Midwest. Since habitat restoration is relatively new to warm-water streams (Lyons and Courtney, 1990; Fajen, 1981), the considerable body of habitat work reported from cold-water (i.e., trout) streams is particularly valuable.

In an exhaustive review of 45 trout habitat improvement projects conducted in Wisconsin, Hunt (1988) reported "success" (i.e., at least 25 percent increase) in approximately 60 percent of all trout population parameters measured before and after habitat enhancement. Hunt cited sizable gains in abundance, biomass, and angler harvest of brook trout *(Salvelinus fontinalis)* following intensive installation of bank covers and current deflectors on Lawrence Creek (1971, 1976). In another long-term study, Glover and Ford (1990) reported dramatic increases (90 to 400 percent) in brown trout *(Salmo trutta)* populations concurrent with a decline in suckers (*Catostomus* sp.) after similar measures were employed on channelized sections of Rapid Creek in South Dakota. In both of these studies, the authors credited the addition of overhead cover, along with the deepening and narrowing of pools, as major benefits accruing to trout habitat.

Coarse substrate occurs in stream segments where water currents scour (erode) the streambed and bank. In Illinois streams, the increased runoff rates from agricultural land conversion and stream channelization have increased channel scour in the alluvial valleys of the Illinois prairie so that rocky cobble is often found at massive bank erosion sites. However, the increased sedimentation rates from the additional channel erosion bury downstream habitat. Such massive bank erosion is characteristic of channelized streams in alluvial valleys where geomorphic thresholds have been exceeded by stream and watershed modifications (Harvey and Watson, 1986).

Bank erosion and meander migration in floodplain streams result from convergent and divergent flows during high flow events (Keller, 1976). Pools are formed by current scour at the apex of a stream meander during high flows. Riffles are formed by divergence of streamflows, which slows current and drops the heavier streambed materials - usually where the stream channel thalweg moves to the opposite bank of a meandering stream (Beschta and Platts, 1986).

Therefore, the slow deep pools and more rapidly moving riffles at normal streamflow are the relic forms of the high flow currents during flood events. In fact, the flow conditions at normal or low streamflows are exactly the opposite of high flow scour and deposition areas in a meandering stream (Keller, 1976). The formation of pools during high flow events is enhanced when the bank above the pool is steeper than the opposite bank.

Obviously, not all measures used in enhancing trout streams are directly applicable to warm-water systems. Differences in stream geomorphology and species habitat requisites make universal use of any single technique questionable. Lyons and Courtney (1990) reported mixed results in their review of 22 warm-water habitat projects in which flood and ice damage, sedimentation of structures, and improper design or location were often cited as reasons for failure. Because of the volatile hydrologic environment present in many midwestern watersheds (particularly those with heavily farmed alluvial valleys), careful attention should be given to selection and design of habitat structures.

Toward this end, IDOC decided to investigate instream habitat structures that could fulfill several important prerequisites. First, the structures should enhance habitat requirements of SMB: deeply scoured pools with coarse substrate and cover from current and predators (Coble, 1975; Probst et al., 1984; Edwards et al., 1982). Second, they should be documented to withstand extreme discharges (i.e., flooding) with minimal required maintenance. Lastly, since bank erosion can contribute over half of the sediment input into Illinois streams (Roseboom and White, 1990), the structures should also provide long-term streambank stabilization.

With Federal Aid to Fish Restoration funds, IDOC contracted with the Illinois State Water Survey (SWS) to test two such methods on a state-owned stretch of Franklin Creek in northern Illinois. One technique, the "lunker" structure, is a modular bank cover with successful application in the extremely flashy streams of southwestern Wisconsin's coulee region (Ventrano, 1988). Another method, tree revetment, has protected streambanks and added instream cover on similarly unstable streams in the Missouri Ozarks (Gough, 1990).

Watershed and Stream Characteristics

The Franklin Creek watershed includes 18,300 acres with over 70 percent of the watershed in rowcrops on the flat upland prairie. The rowcrop areas are generally confined to the four sub-watersheds that join together within three miles of the study reach. One sub-watershed also contains the small town of Franklin Grove and its sewage treatment plant. With the exception of rural homes, the remainder of the watershed is woodland and pastures on the steeper lands along the stream valley bluffs. The topography drops from 836 feet msl to 680 feet msl at the study reach. Many springs and a densely wooded riparian zone enhance stream quality in the lower three-mile segment.

Franklin Creek is a third order stream over nine miles long. The lower mile of stream contains the four sampling stations (figure 1). The upstream control site and tree revetment site are located 3000 feet upstream of the lunker and downstream control sites (figure 2). The upstream control is wide rocky "run" habitat featuring submerged roots and treetops. The tree revetment site was a single meander bend with eroding banks and little instream cover. The lunker site was a shallow run along an eroding meander where instream cover was limited to submerged vegetation. The downstream control site was an eroding stream meander with a deep pool and fallen trees. Both habitat enhancement sites are 1000 feet from their respective control sites.

Both the control sites and habitat enhancement sites have similar physical channel characteristics. Streambed slopes vary from 0.001-0.003 while width/depth ratios are 8-10. Maximum water depths range from 1.5 to 2.5 feet during normal streamflow.

Streambanks at the sites are 8 feet to 10 feet high. With the exception of tree-covered rock banks along the upstream control, the original streambanks were vertical walls barren of riparian vegetation. At the top of bank, tree root systems extend only 4 feet into soil so that the lowest bank soils are not protected from scour.

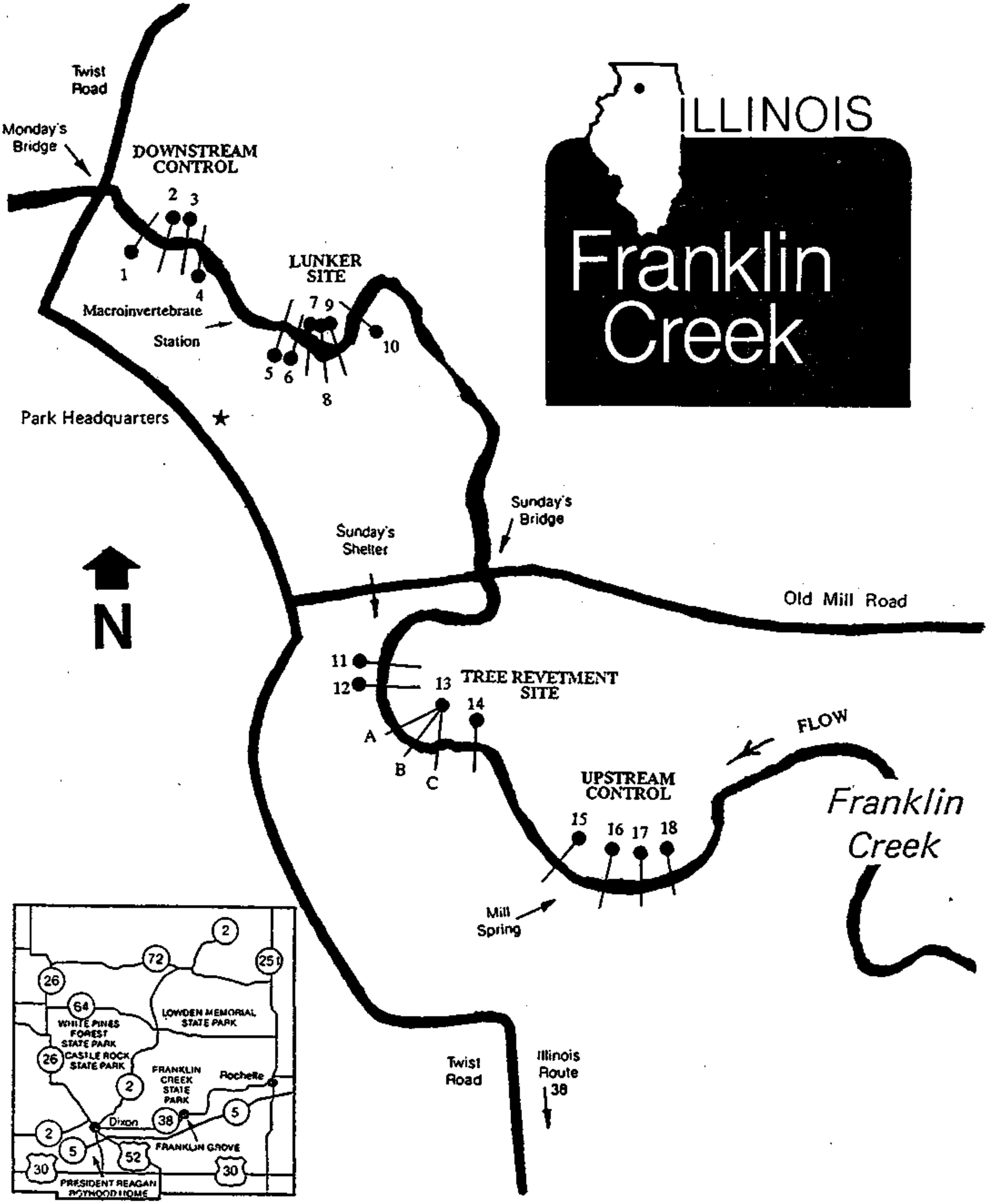
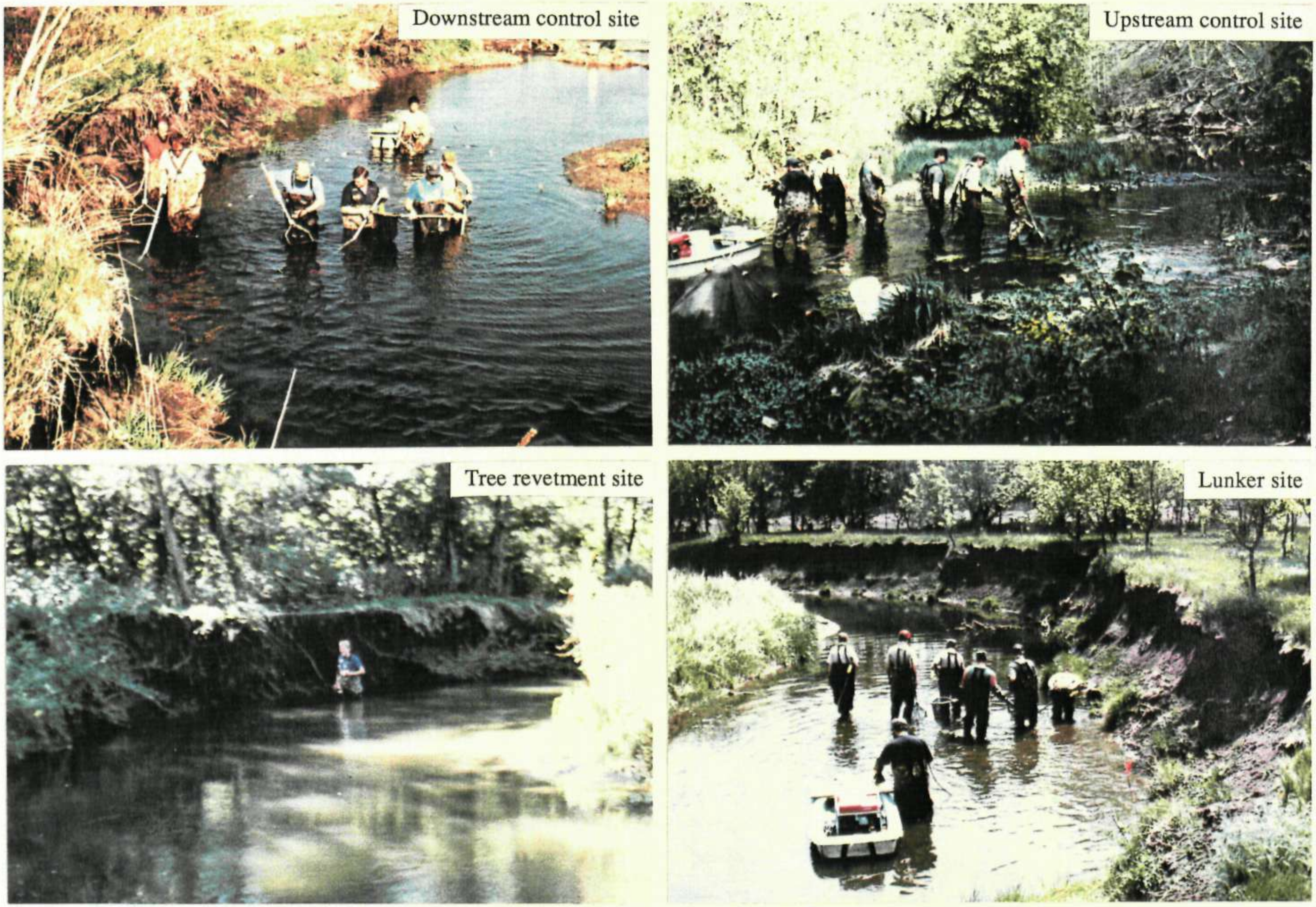


Figure 1. Franklin Creek study area (IDOC, n.d.)


Downstream control site

Upstream control site

Tree revetment site

Lunker site

Figure 2. Monitoring sites on Franklin Creek

Habitat Enhancement Techniques

Lunker Habitat

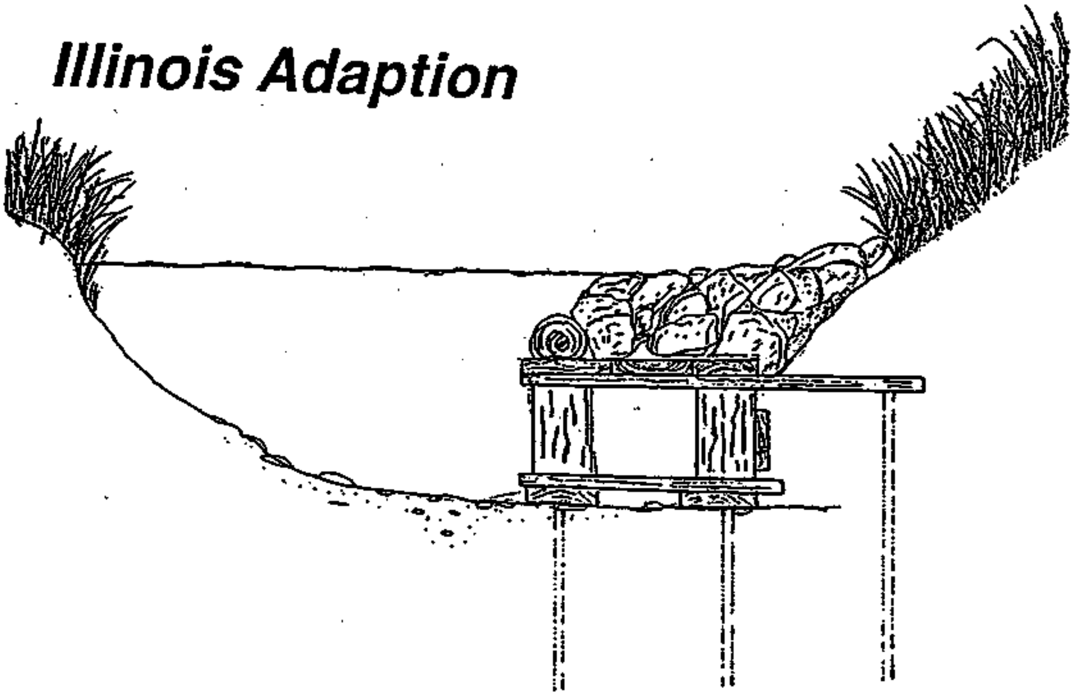
The Wisconsin "lunker" technique requires placements of large wooden platforms in the stream along the base of the eroding bank (figure 3). The wooden structures are held in place with rebar and riprap. A rock wall is constructed over the stream edge of the lunkers. The streambank is then graded over the lunkers at a 1:5 or 1:10 slope and seeded (Ventrano, 1986).

For this project, lunkers were constructed as in the Wisconsin design except a blocking log of hedge was bolted to each lunker in place of the constructed rock wall. This technique adaption also reduced construction time and expense. Since the stream channels were very unstable, the lunkers were not placed as far into the stream channel is as usual in Wisconsin. This reduced the probability of streambed downcutting during major floods.

Lunkers were placed along the vertical eroding banks (figure 4), which were 10 to 15 feet high. Rebar was driven into the streambed and riprap was placed between the bank and the lunker. The hedge blocking log reduced movement of rock off the lunker during flood events. Lunkers were positioned so that the riprap above them was below the water's surface during normal streamflow. Bank soils were not graded over the riprap. The adaption increased the amount of coarse substrate available, especially for underyearling SMB. The cervices in the riprap and wooden lunkers provided fish shelter while the adjacent willows and grasses increased insect populations. This approach of increasing habitat diversity (physical heterogeneity) is similar to the approach recommended by Rabeni (1990).

The streambank was then graded to a 1:1 slope. Bank soils were shallowly spread over land adjacent to the bank and reseeded with grasses. With a steep bank slope, floods will scour the pool at the base of the bank. This scour will maintain pool depth and reduce sediment deposition on coarse substrate and within the lunkers (Keller, 1976) as in a natural meander. This habitat enhancement follows the stream geometry indicated by the stream erosional pattern.

To reduce bank erosion rates to more natural rates in this reach of increased scour, willow posts were placed into holes 6 feet deep along the entire length of sloped bank. The holes were



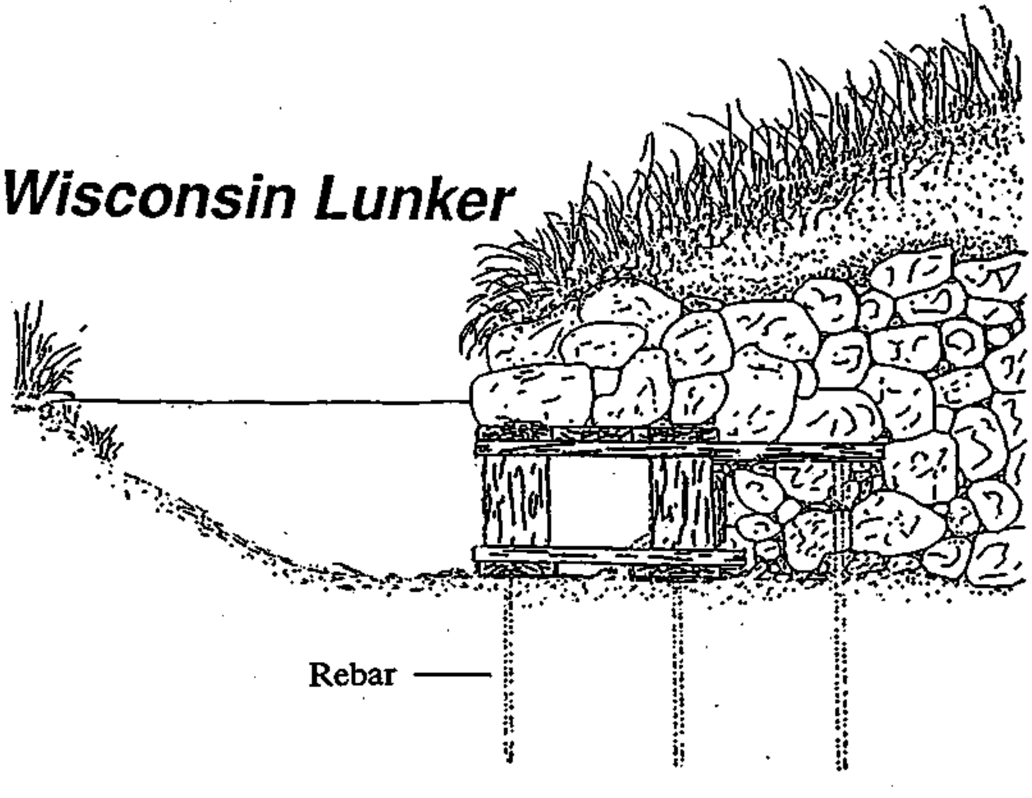


Figure 3. Wisconsin and Illinois lunker designs

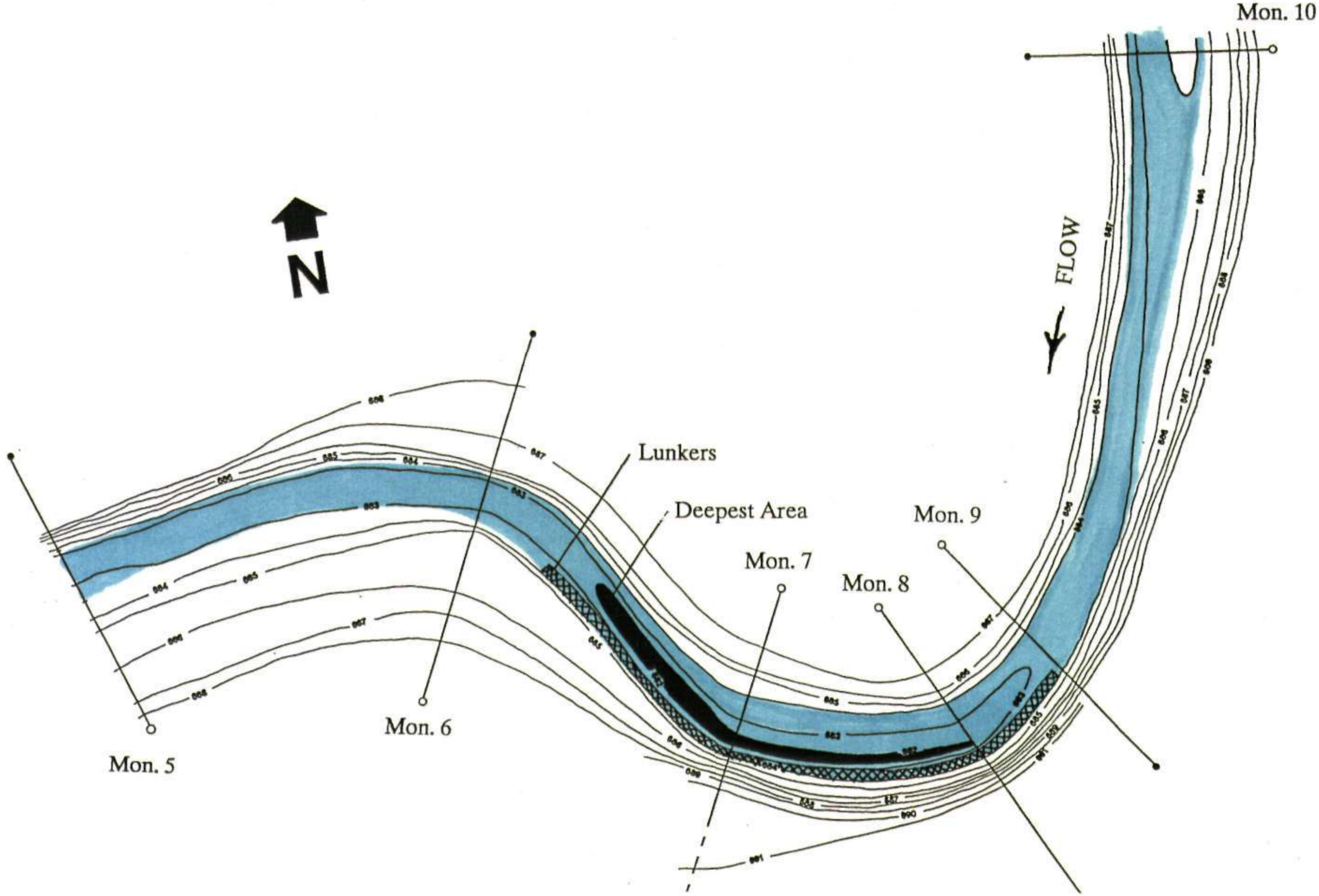


Figure 4. Topographic plan view of lunker site

driven into the sloped bank with a 6 foot steel ram and excavator. The bank was immediately seeded with annual rye and timothy. On the trial Court Geek site, prairie grasses and flowers were later seeded. By the second summer, herbaceous vegetation had become dominant except along the water's edge. The succession to prairie grasses was hastened by the grazing of cattle on willows along the upper bank. The project plan had called for the manual removal of willow posts once the grasses were established.

In Wisconsin, the lunker technique is not usually applied to the highly unstable stream channels (highly degraded), which can be common in portions of Illinois. With the success of willow post bank stabilization already demonstrated along Court Creek (Roseboom and White, 1990), the project adapted this low-cost vegetative approach to reduce riprap and earth-shaping expenditures on major bank erosion sites. The Illinois adaption introduced willow posts as immediate bank protection until cool-season or prairie grasses became established. In this adaption, the willows serve as a "band-aid" on the raw soil until herbaceous vegetation is deeply rooted.

At Franklin Creek State Park, the bank erosion site endangered the show corral and judging stand. Therefore willow posts and cool-season grasses were established along the stream side. While the grasses were becoming established, the willow posts were sprayed with an animal deterrent (Ropel) to minimize post losses to a large beaver population. Once the grasses were established, however, use of the animal deterrent was discontinued. Then when beavers chewed off willow posts, their well established root masses allowed regrowth from the stump and held soils in place along the water's edge (figure 5).

The major costs of construction and installation (table 1) were labor, riprap, and equipment, 37,16, and 17 percent, respectively. Costs can be reduced further with volunteer labor for lunker construction. Because installation of lunkers requires close coordination between equipment operators and labor personnel, volunteers should have construction experience. Involvement of environmentally active organizations could reduce the cost of prairie planting by half.

Tree Revetment Habitat

Tree revetments have been used for bank protection in the United States since the 1930s (Lester, 1946). In the 1980s, George Palmiter started a resurgence in the use of hedge tree revetments for stream stabilization in Ohio (Willeke and Baldrin, 1982; 1984). Palmiter's adaptions to major bank erosion sites in western Illinois were less successful. Tree revetments were held by fenceposts and heavy gage wire. At severe erosion sites, the hedge revetments washed out during major floods. Large earth anchors (Laconia) were then used to hold the hedge tree revetments at major erosion sites. While the hedge trees with earth anchors were not removed by floods, high-velocity currents scoured the loess soil from the banks before vegetation became established (Roseboom and White, 1990).

As applied in Missouri streams, tree revetments are a line of overlapping trees, usually hedge or cedar, along the base of an eroding streambank (figure 6). They reduce scour along bank soils but promote it further out in the stream channel. The mid-channel scour forms a deeper pool (Gough, 1990) and usually exposes rocky substrate below depositional sands and silts.

At Franklin Creek, tree revetments were made from osage orange trees cut from an adjacent pasture. The trees were trucked near the bank erosion site in a wooded section of the park and carried to the site. Park regulations prevented the use of heavy equipment in this portion of the park so all stabilization efforts were manual.

Starting at the downstream end of the erosion site, Laconia earth anchors were hand driven into the bank so that the tree's butt end faced upstream into the bank. The next tree was positioned so that its upper one third overlapped the butt of the tree previously anchored. The upper end of the next tree was also cabled to the Laconia anchor.

When all hedge revetments were in place, 18-inch willow cuttings were planted throughout the entire bank. During the second year, small willows with root balls were augured into the bank portions without vegetation.

With the exception of Laconia earth anchors, the cost of material was merely the cost of labor to cut and transport the hedge trees and willow cuttings from local sites. Four men worked for four days to cut, transport, and install the 40 hedge trees (see table 2).

June flood, 1990

Beavers cut willow posts, but regrowth is rapid

Fall fish survey, 1991

IDOC fish survey checks cobble on top of lunkers

Figure 5. Lunker site after construction

Hedge tree held by Laconia earth anchor

June flood, 1990

Canoeists during high flows

Spring fish survey, 1991

Figure 6. Tree revetment site during and after construction, and floods

Table 1. Project Costs for Lunker Installation on Franklin Creek (per 8 foot module)

Lunker construction	
Lumber (oak planks)	$ 48
Reinforcing rod	$ 14
Labor @ $10/hr	$ 35
Lunker installation	
Equipment (riprap)	$ 17
Labor @ $10/hr	$ 40
Bank preparation	
Equipment (grading)	$ 7
Equipment (willow posts)*	$ 11
Riprap @ $10/ton**	$ 32
TOTAL	
Per 8 ft lunker	$204
(For typical 300 ft site)	$7350

Notes:
* Willow post holes @ $2.40/6 ft hole (3 rows of posts on 6 ft spacing)
** Riprap delivered to site

Table 2. Project Costs of Tree Revetment Installation on Franklin Creek

Labor (4 people @ $8/hr)	
A. Tree cutting and transport (84 hrs)	$672
B. Revetment installation (116 hrs)	$928
C. Willow cuttings (64 hrs)	$512
Labor sub-total (264 hrs)	$2112
Supplies	
Laconia earth anchors (30 @ $9.33 ea)	$280
Contractual	
Backhoe rental (8 hrs @ $25/hr)	$200
TOTAL (160 ft of revetment @$16.20/ft)	$2592

Habitat Evaluations

Stream Transect Evaluations

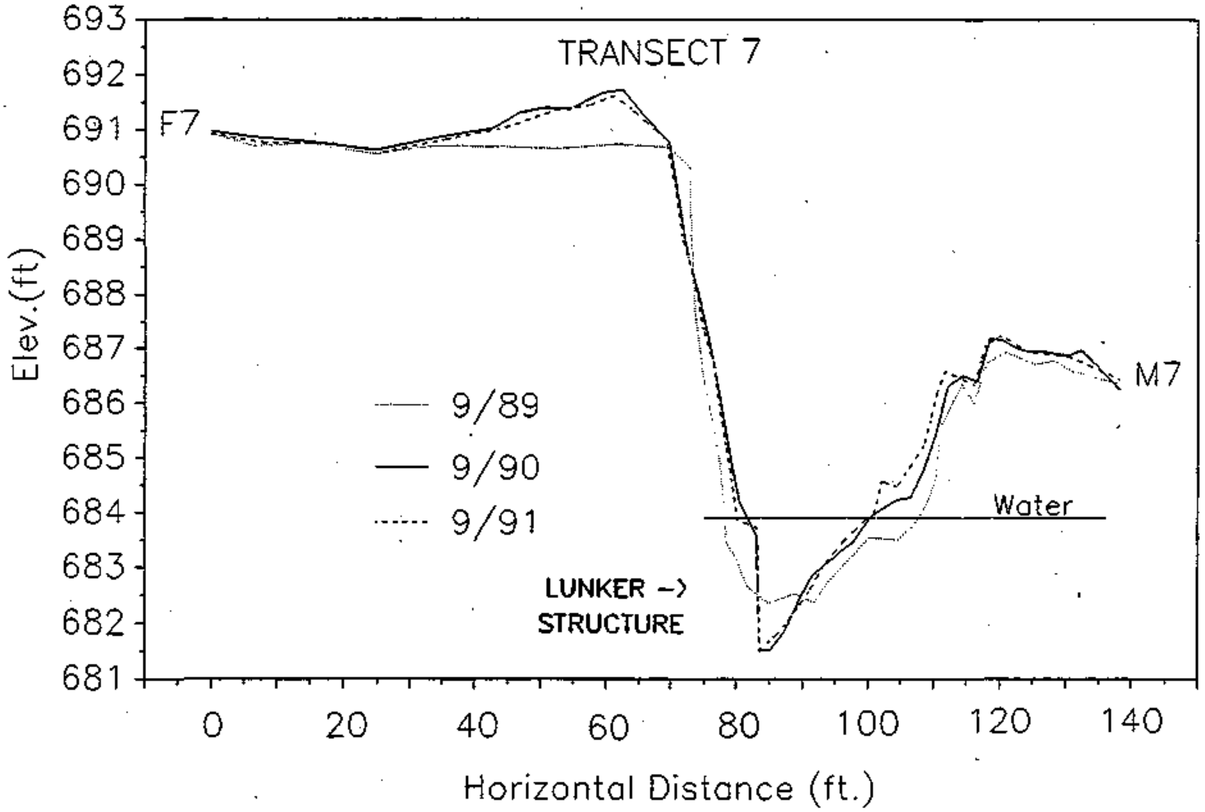
Lunker Transects

Stream transects of the lunker site remained constant after installation. Scour of the stream current kept sediment from filling in the lunkers. Pool depth remained at the same depth as when the lunkers were installed. Stream transects (figure 7) reveal some downcutting (channel scour) in the streambed near the lunkers. Scour kept riprap and stream cobble from being covered with sand or silt.

Geomorphic principles require monitoring of the habitat installation to insure that stream channel instability did not result from the lunker installation and vegetative bank stabilization. Transects 9 and 10 across the upstream riffles showed no evidence of streambed downcutting above the lunker site (figure 8). The riffles are the grade controls on the streambed and channel instability would cause erosion of the riffle bed.

Vegetative stabilization was placed on the steeply sloped (1:1) bank, and no sign of bank erosion has been detected. This observation is similar to studies after five years of monitoring on other willow post bank stabilization sites (Roseboom and White, 1990). Both grasses and beaver-browsed willow appeared in healthy stands in 1991 (figure 8).

The most obvious habitat alteration was the 240 linear feet (480 square feet) of shallow rocky cobble above the wooden lunkers. Under this layer of rock cobble, the lunkers formed a wooden overhang with shade and lessened currents for the same distance. Scour from the major flood in June 1990 removed silt and sand from the stream channel adjacent to the lunkers. Large riprap (15-18 inch diameter) in the scour channel added even more coarse structure to the exposed stream cobble. Additional riprap was added upstream and downstream of the lunker chain to anchor the submerged structures. The additional rock created more habitat for both small and large fishes in the riffle areas.



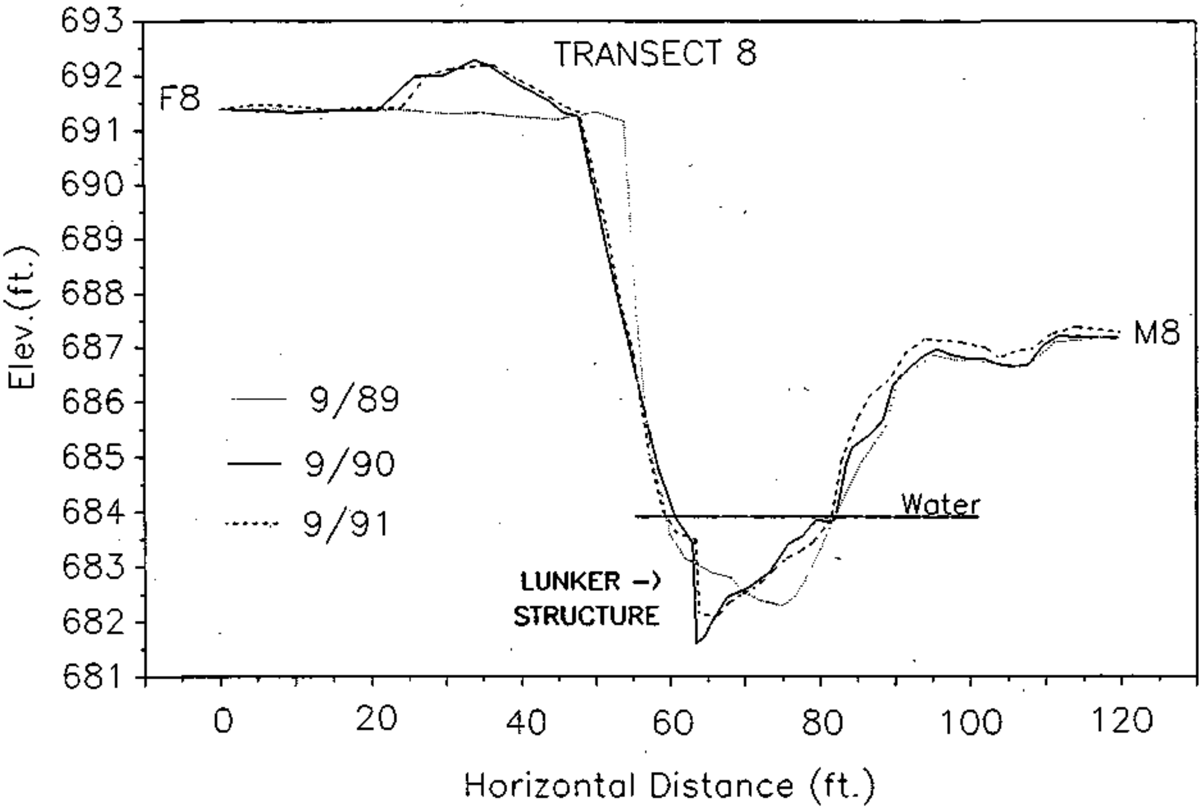


Figure 7. Stream channel configuration at lunker transects

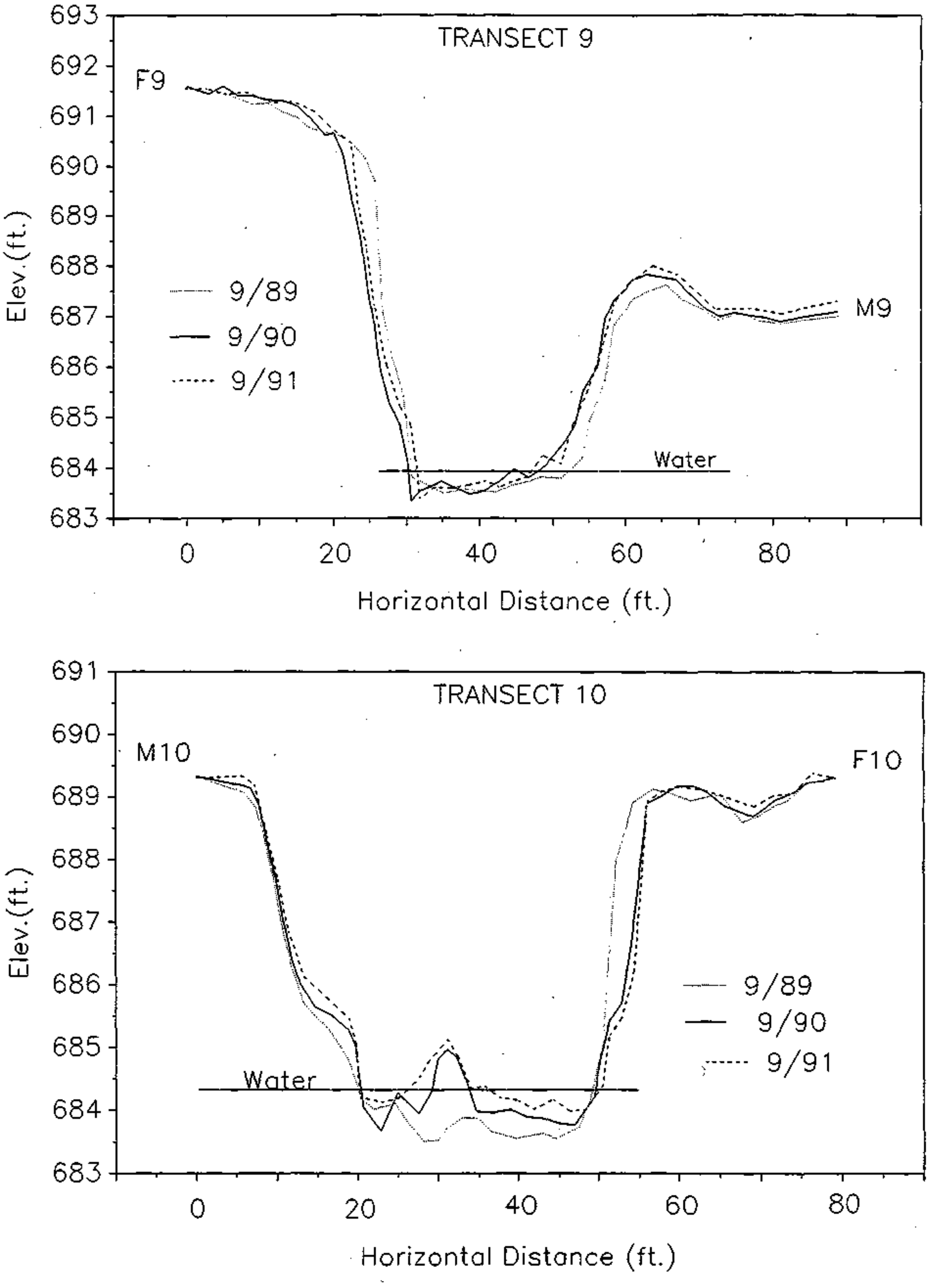


Figure 8. Stream channel configuration upstream of lunker site

As shown in transects 7 and 8, the pool adjacent to the lunkers became deeper and more narrow as the sand deposited on the point bar on the inside of the meander. Almost all scour occurred during the 1990 June flood when the stream rose 8 feet and deposited sand on the point bar.

During the drought of 1991, low streamflows deposited some sediment within the lunkers. However, streams are dynamic so that occasional high floods will scour out the gradual sedimentation occurring in the pool during low flow periods. Riffle areas upstream (transects 9 and 10) and downstream (transects 5 and 6, see figure 9) show no evidence of increased scour as a result of channel instability from the introduction of the lunkers to the meander.

Tree Revetment Transects

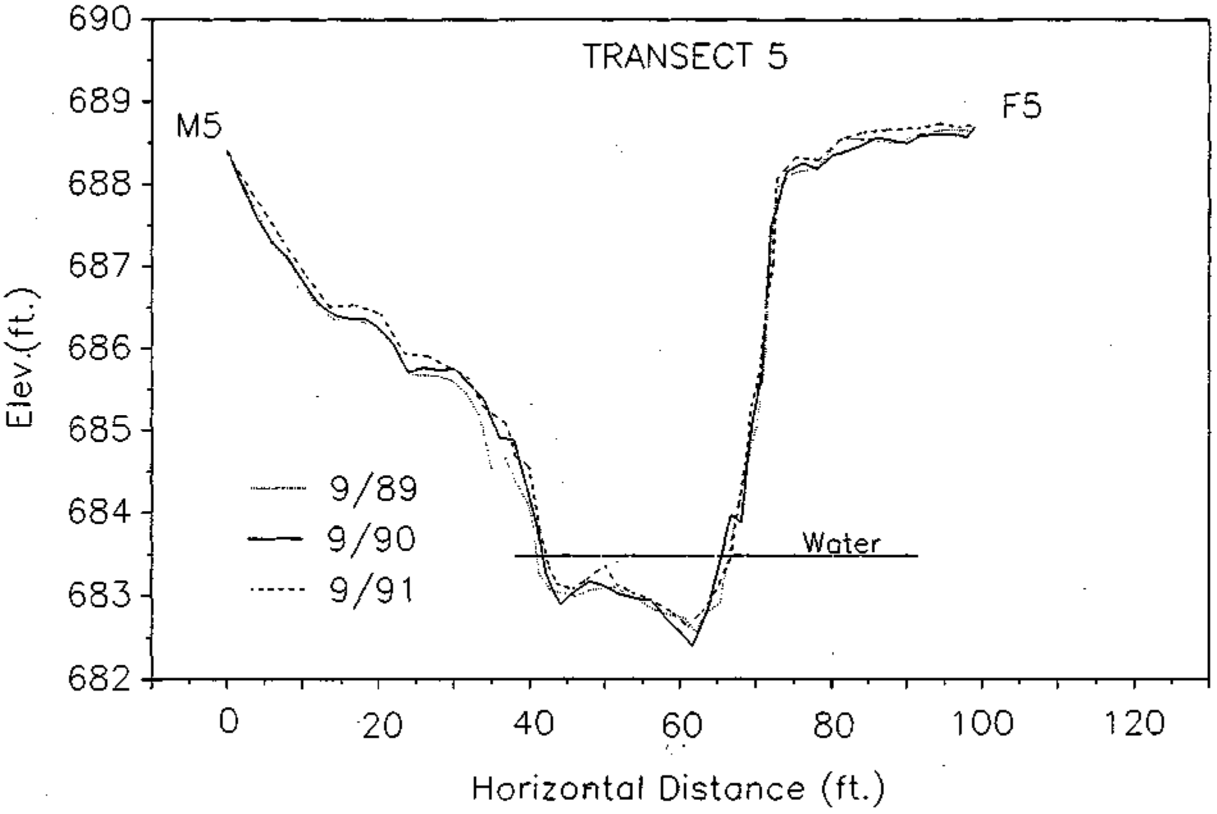
Sedimentation and natural revegetation have proceeded rapidly within the hedge trees along the upper half of the revetment site. However, scour eroded soil behind the hedge trees below the apex of the meander during June 1990. Even small willow cuttings were eroded out, with the loss of 2 feet of bank soil on transect 13B (figure 10).

Hedge trees were added to the lower end of revetment site one year after installation. These hedge trees were placed in the scour hole behind the original revetments.

Illinois EPA Habitat Evaluation

Instream substrate types and channel morphology were quantitatively collected at each reach sampled for fish using a method modified by the Illinois Environmental Protection Agency (IEPA) from Gorman and Karr (1978).

Each of the four study areas (lunker site, tree revetment site, and upstream and downstream controls) were divided into ten segments of equal length resulting in 11 transects per area. Intervals between transects were determined by the total length of the respective control or habitat improvement site which ranged from 215 to 585 feet. Transect length and upstream and downstream limits of each site were permanently established and remained fixed for the duration of the study. Measurements for depth, velocity, and substrate type were recorded at



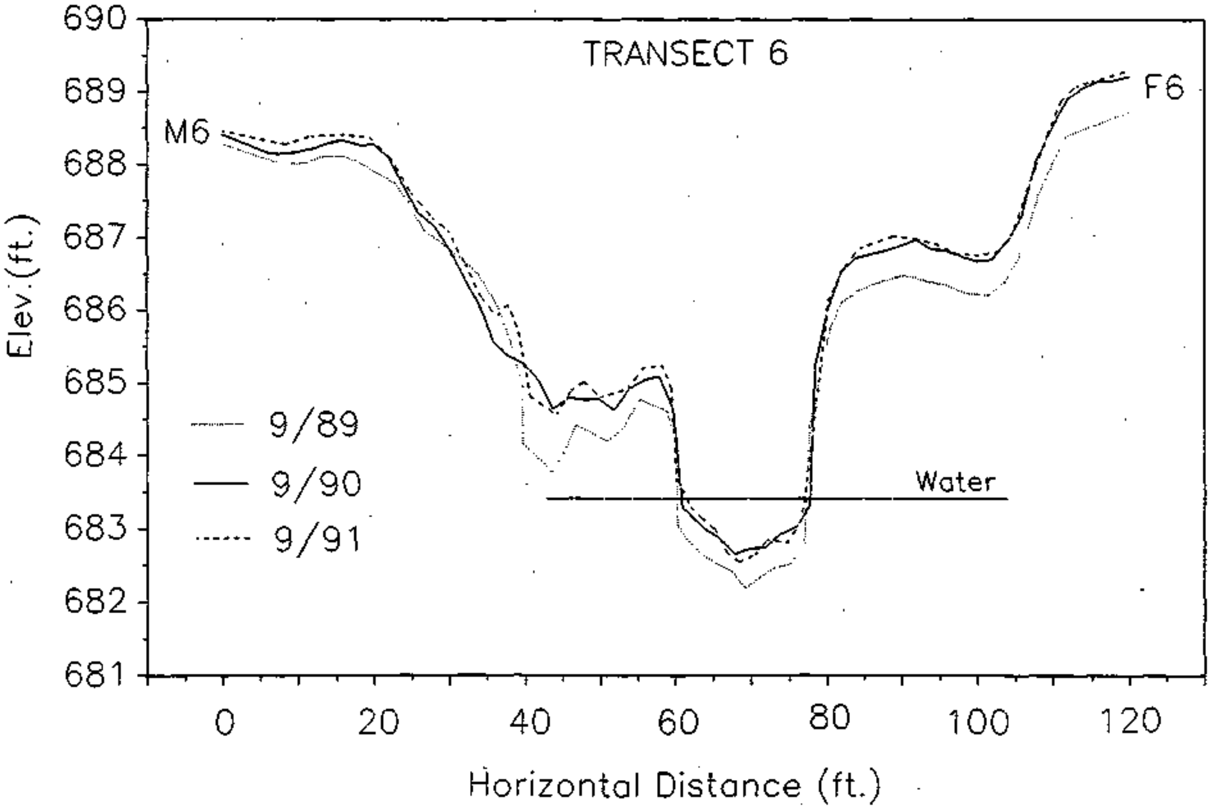


Figure 9. Stream channel configuration downstream of lunker site

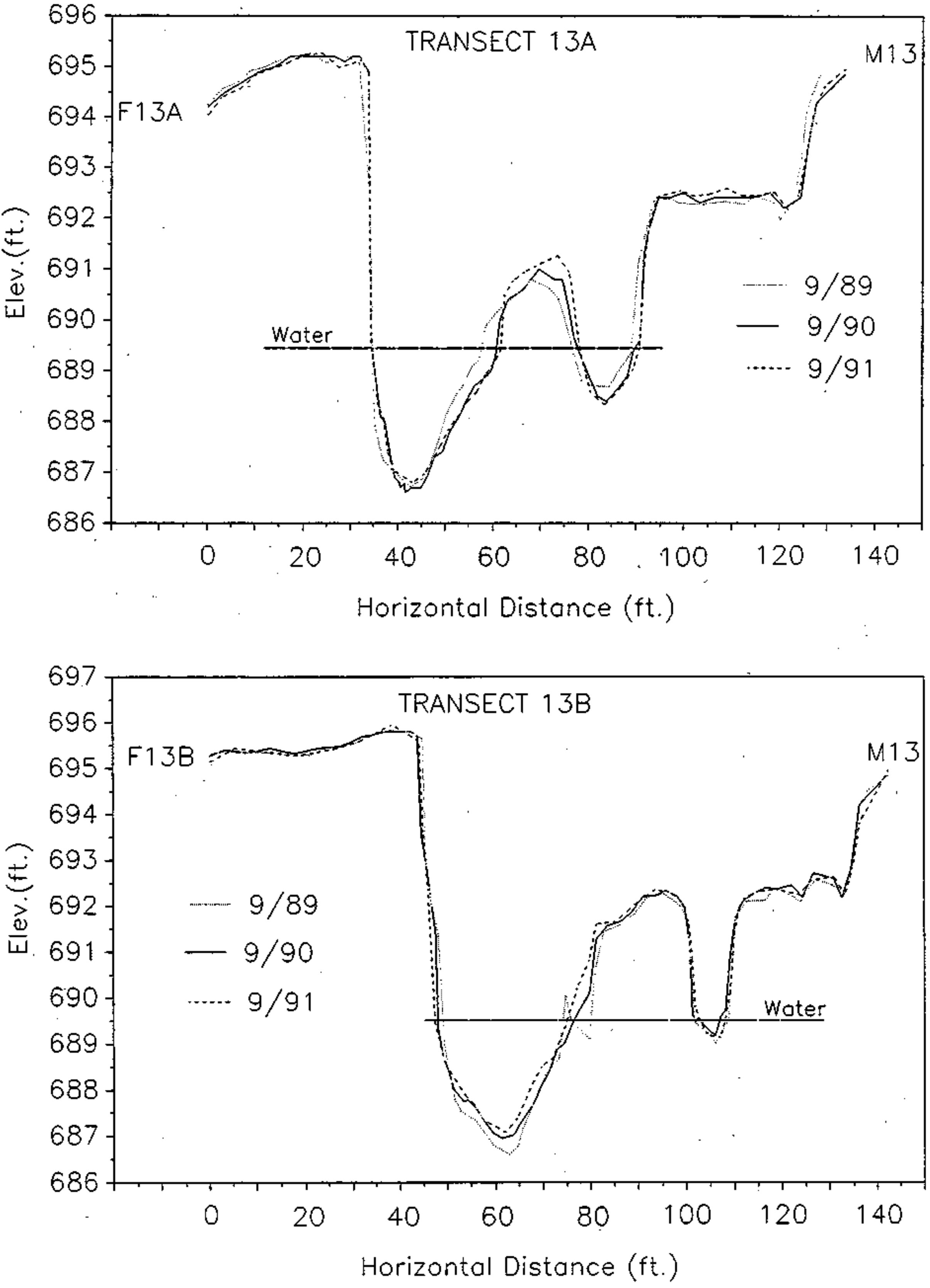


Figure 10. Channel geometry at tree revetment site

evenly spaced sample points on each established transect (EPA, 1987). Habitat variables were recorded at two-foot intervals at each of the 11 established transects. Ten substrate types and eight instream cover types (table 3) were used to categorize the dominant substrate and cover at each point on each transect.

Velocity was measured at each two-foot transect interval with a standard pygmy flow meter and a top setting wading rod. The top setting wading rod allows the meter to be suspended at 0.6 fraction of the total water depth, which represents the average velocity of me water column.

The percent of stream surface area comprised of pool, riffle, and run in each study area was estimated. Percent of instream cover and stream shade were also estimated.

The Index of Biotic Integrity (IBI) assesses the health of a fish community using 12 fish community metrics (Karr et al., 1986). IEPA subjected 15 stream habitat metrics, Water Quality Index (WQI), and discharge data to multiple regression analysis against the I.BI and derived a biotic potential equation (PIBI) to predict the IBI based on habitat variables. The PIBI calculation is based on four habitat variables accounting for the greatest variance against the IBI. PIBI values can range from about 27 to 53 but routinely fall between 35 and 50 for typical third- to sixth-order Illinois streams (Hite and Bertrand, 1989).

The PIBI can be used to indicate change at an established station when the station is routinely sampled over a period of time and at similar flow conditions. However, due to the lack of sensitivity of the PIBI calculation, the resultant values should be viewed as relative rather than absolute. PIBI values at all four stations were generally stable throughout the three-year study period.

The upstream control was assigned the highest PIBI values (43 to 44) for all sites during all three years of the study. Results from the upstream control indicated consistently lower percentages of silt/mud-sized particles (5.7, 3.7, and 4.7 percent), compared to the percentages of silt/mud at the other stations (ranging from 9.6 to 28.3 percent, mean 19.7 percent). Also the upstream control had substantially more cobble and boulders as streambed substrate (35 to 46 percent) than the other three stations (1 to 18 percent) for the entire study period (table 3).

Table 3. Franklin Creek Instream Habitat Characteristics, 1989-1991

	Upstream control			Tree revetment			Lunker			Downstream control		
	1989	1990	1991	1989	1990	1991	1989	1990	1991	1989	1990	1991
Mean width (ft)	31	36	35	29	31	30	24	25	24	23	23	24
Mean depth (ft)	0.6	0.7	0.5	0.9	1.2	1.0	0.6	0.8	0.6	1.2	0.9	0.7
Mean velocity (ft/sec)	0.28	0.19	0.18	0.18	0.14	0.12	0.39	0.32	0.36	0.13	0.30	0.25
Pool(%)	12.5	17.8	15.5	17.3	27.5	65.3	11.0	13.8	14.9	68.0	14.8	26.9
Riffle *(%)*	10.9	15.0	24.5	0.0	2.1	1.1	4.3	19.7	5.9	1.0	0.8	1.5
Run(%)	76.6	67.2	60.0	82.7	70.4	33.6	83.9	66.5	79.2	31.0	84.4	71.6
Shade (%)	63.2	71.0	50.6	47.6	54.0	18.8	8.1	7.1	16.7	6.9	7.2	16.4
Substrate												
Silt/mud (%)	5.7	3.7	4.7	28.3	25.6	16.2	17.3	13.3	25.9	15.6	9.6	25.6
Sand(%)	4.7	2.7	12.1	24.2	20.6	26.0	12.3	34.4	17.0	32.5	41.7	16.6
Fine gravel (%)	1.9	8.0	4.2	8.1	11.3	24.0	12.3	7.0	17.0	18.1	15.6	24.8
Medium gravel (%)	15.1	20.9	16.2	11.1	18.8	13.0	16.1	14.1	19.3	23.4	17.4	22.3
Coarse gravel (%)	26.4	29.4	23.0	25.3	18.1	13.7	23.5	19.5	13.3	9.1	14.8	9.9
Small cobble (%)	19.8	22.5	26.7	2.0	4.4	5.8	14.8	8.6	5.2	1.3	0.9	0.0
Large cobble *(%)*	23.6	5.9	11.5	1.0	1.2	1.3	3.7	2.3	1.5	0.0	0.0	0.8
Boulder (%)	2.8	6.9	1.6	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0
Bedrock (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Claypan(%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.0
Instream cover												
Boulder (%)	4.4	1.6	9.2	0.0	0.2	0.1	0.3	2.3	0.5	0.0	0.0	0.1
Undercut bank (%)	0.2	0.3	1.2	0.9	0.1	2.0	0.7	4.2	3.6	0.2	0.6	1.1
Rock ledge (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Submerged tree roots (%)	0.0	0.3	0.4	0.0	0.0	0.2	0.4	0.1	0.0	0.1	0.1	0.1
Brush-debris jam (%)	2.6	1.0	0.4	1.2	4.1	2.2	0.6	0.1	0.0	4.2	1.6	0.4
Logs(%)	1.5	3.2	1.1	2.1	4.6	1.4	0.2	2.5	1.4	0.3	0.2	0.2
Aquatic vegetation (%)	1.5	0.0	8.7	3.8	0.3	4.7	5.5	0.0	6.9	2.4	0.4	0.5
Submerged terrestrial veg. *(%)*	0.	0.60	0.0	0.4	5.8	2.2	2.7	5.0	1.4	6.4	1.6	2.1
Other - overhanging veg. (%)	0.0	0.0	0.0	0.8	0.0	0.0	1.8	0.0	0.0	5.4	0.0	0.0
Total instream cover (%)	10.2	7.0	21.0	9.2	15.1	12.8	12.2	14.2	13.8	19.0	4.5	4.5
PIBI	42.8	43.7	43.4	37.5	40.9	43.5	40.6	41.2	39.7	43.1	40.9	40.2
Total reach surface area (Avg. W * Avg. L)	8166	9787	9628	10244	10336	9928	13012	14683	14713	4884	4999	5171
Total wetted usable area (Avg. W * Avg. L * Avg. D)	4900	6851	4814	9220	12403	9928	7807	11746	8828	5861	4499	3620

PIBI values at the downstream control site showed a slight downward trend (43, 41, and 40) over the study period. Percentages of combined gravel and cobble substrates showed relative stability during the study period, ranging from 51.9, 48.7, and 57.8 percent, respectively. However, one significant change noted in substrate composition was the fluctuation of silt/mud from 15.6, 9.6, and 25.6 percent for each year of the study. This may have been a manifestation of the low water conditions of 1991 and subsequent lack of "flushing flows" that normally move fine particles downstream.

Instream cover at the downstream control site decreased considerably after the first year of the study. A loss of brush-debris jams, submerged vegetation, and overhanging terrestrial vegetation accounted for the change. Instream cover types and percentages remained relatively constant for the final two years of the study.

At the tree revetment site, percentage of substrate reported as gravel and cobble increased each year of the study from 47.5 to 53.8 to 57.8 percent, respectively. This increase in coarse substrate and converse decrease in silt/mud and sand-particle-sized substrate may be due to the stabilization of the bank and resultant decrease of sediment input from bank slumping. The tree revetment site essentially changed from a run (83 percent of area) to a pool (65 percent of area) after installation of the trees. The brush-debris component of instream cover showed the greatest increase because of the introduction of the revetment bundles. This trend is emphasized if only the stream length bordering the added tree revetments is considered (table 4). The percentage of pool increases from 74 percent and the percent of brush-debris ranges from 5 to 10 percent of the area. The PIBI increased from 40 to 43 over the three-year study.

The lunker site had no clear trends as PIBI values varied slightly between 40 and 42 during the study period. Percent of substrate reported as silt/mud and sand increased considerably after the first year from 29.6 to 44.7 and 42.9 percent for the final two years. Percent of instream cover reported as boulders increased after the first year. This increase is evident in the modified stream section where percent instream cover recorded as boulder ranged from 0.1 to 4.6 to 1.2, percent, respectively. Most noticeably, instream cover as undercut bank

Table 4. Franklin Creek Instream Habitat Characteristics, 1989-1991, for Modified Sections within Each Study Reach

	Lunker			Tree Revetment		
	1989	1990	1991	1989	1990	1991
Mean width (ft)	20	22	22	29	32	28
Mean depth (ft)	0.55	0.77	0.60	0.89	1.15	1.05
Mean velocity (ft/sec)	0.42	0.34	0.29	0.17	0.13	0.10
Pool(%)	8.8	15.8	10.0	15.7	39.4	74.4
Riffle (%)	4.0	12.7	11.0	0.0	0.0	2.8
Run(%)	95.2	71.5	79.0	84.3	60.6	22.8
Shade (%)	3.5	4.0	11.0	53.0	68.4	24.8
Substrate						
Silt/mud (%)	12.5	6.1	20.8	30.6	22.0	25.0
Sand(%)	12.5	51.1	13.2	22.2	22.0	26.9
Fine gravel (%)	15.6	6.1	26.4	11.1	8.5	25.0
Medium gravel (%)	21.9	8.2	15.1	22.2	22.0	5.8
Coarse gravel *(%)*	12.5	26.5	13.2	13.9	18.7	11.6
Small cobble (%)	18.8	2.0	9.4	0.0	3.4	3.8
Large cobble (%)	6.2	0.0	0.0	0.0	3.4	3.8
Boulder (%)	0.0	0.0	1.9	0.0	0.0	0.0
Bedrock (%)	0.0	0.0	0.0	0.0	0.0	0.0
Claypan(%)	0.0	0.0	0.0	0.0	0.0	0.0
Instream cover						
Boulder (%)	0.1	4.6	1.2	0.0	0.2	0.2
Undercut bank (%)	0.1	9.5	7.1	0.4	0.0	2.4
Rock ledge (%)	0.0	0.0	0.0	0.0	0.0	0.0
Submerged tree roots (%)	0.9	0.0	0.0	0.0	0.0	0.0
Brush-debris jam (%)	0.6	0.0	0.0	1.7	9.7	5.1
Logs(%)	0.4	5.0	2.7	1.9	5.5	1.5
Aquatic vegetation *(%)*	4.3	0.0	1.6	8.5	0.0	8.3
Submerged terrestrial veg.(%)	2.3	5.3	1.4	0.8	5.4	0.8
Other - overhanging veg. (%)	1.0	0.0	0.0	0.0	0.0	0.0
Total instream cover (%)	9.9	24.5	14.0	13.3	20.8	18.3
PIBI	41	42	40	40	42	43
Total reach surface area (Avg. W * Avg. L)	5591	6406	6465	4241	4403	3927
Total wetted usable area (Avg. W * Avg. L * Avg. D)	3075	4933	3879	3774	5063	4123

increased from 0.1 percent to 9.5 and 7.1 percent of the modified section in the last two years (table 4).

Buildup of lunkers' sandy point bar following the June 1990 discharge complicated our analysis of substrate trends within this station. The proportion of coarse material (gravel, cobble, and boulder) actually declined from 75 to 42.8 percent between 1989 and 1990 (table 4). Examination of individual transect data, however, reveals continued scour of LN's thalweg after improvement. Starting from the lunkers' outer edge and progressing streamward, one 4-8-foot wide zone of channelbed was maintained in gravel and cobble along most of the lunkers during 1990-1991. Pool depths generally ranged from 1.5 to 2.5 feet in this area.

Meanwhile, current velocities usually ranged from 0.1 to 0.7 feet per second (ft/sec) along the face of the lunkers. While 0.7 ft/sec is slightly above the velocity range preferred by adult SMB (Edwards et al., 1982; Rankin, 1986), current velocities were likely slower within the lunker structures themselves. In fact, a 1990 reading taken within the actual lunker "crawl space" measured only 0.15 ft/sec compared to 0.32 ft/sec at the structure's outer face. If this velocity pattern held true for lunkers as a whole, these structures provided the combination of slow to moderate flow, coarse substrate, and instream cover, which has been well documented for SMB (Coble, 1975; Lyons, 1991; Probst, et al., 1984).

The loss of aquatic vegetation was noted at all sites when a large flood scoured the pools during June 1990. Aquatic vegetation returned to all sites except the downstream control by the following year.

Water Quality Evaluation

Macroinvertebrates were used in this study to monitor the general water quality conditions during the fish sampling segment of the year. Aquatic macroinvertebrates, animals within the aquatic system visible to the naked eye, are capable of being retained by a U.S. standard no. 30 mesh sieve (Weber, 1973). These common, easily collected organisms have limited mobility and are present throughout the growing season. An abundant, diverse community of macroinvertebrates is important for a reliable food source for fish. Macroinvertebrates are sensitive to changes in the aquatic environment.

The relative sensitivity of macroinvertebrate taxa to water quality, forms the basis of the IEPA's Macroinvertebrate Biotic Index (MBI). Each taxon (usually genus) is assigned a tolerance value of 0 to 11, with 11 being the most tolerant. In this study, the Chironomidae were not keyed out to genus, and were assigned a value of 6 (the mean value of Chironomidae genera). The MBI is calculated by multiplying the tolerance value of each taxon by its abundance and dividing the sum of these by the total abundance. It represents the mean tolerance value of the individuals in the sample.

The macroinvertebrate sampling station was established just below the lunker enhancement site but above the lower control station (figure 1). It consisted of a metal sign post from which an artificial substrate could be suspended at mid-water depth. The artificial substrates were modified Hester-Dendy multiple plates described by Fullner (1971), and consist of 14 hardboard plates with variable spacing. The sampler has a known surface area (0.16 square meters or m^2), thus allowing for quantitative sampling. Approximately every six weeks, substrates were recovered and placed in ziplock bags. The refrigerated bags were returned to the lab and frozen until they were picked, counted, and identified.

The results of the individual samples are found in table 5. Sixteen taxa were recovered during the three-year study. The communities colonizing the artificial substrates were dominated by Chironomidae (midge fly larvae), which accounted for 70 percent of the total population. The mayfly nymph Stenonema and the sow bug Asellus, comprised 10 and 11 percent of the population, respectively. On a per-sample basis, the taxa ranged from 4 to 11, and the population

Table 5. Macroinvertebrates Collected at Franklin Creek on Modified Hester Dendy Samplers (individuals/m^2)

Organism	IEPA tolerance value	Sample collection dates 6/1/89	7/26/89	9/11/89	10/30/89	7/10/90	8/17/90	10/19/90	6/10/91	7/10/91	8/1/91	9/17/91
Centroptilum	2	6		6								
Gammarus	3				25						6	6
Leptocella	3						44					
Calopteryx	4						6	6				
Stenonema	4	6	113	56	6	69	269	44	119	69	81	138
Ceratopogonidae	5		6							6		
Dubiraphia	5		50	6			19	13		6	13	6
Hyalella	5		6					13				
Hydropsyche	5			6	6	19	6	38	6			
Asellus	6	56	100	125	13	213	200	56	238	13	6	6
Caenis	6	6	13	6	6		6	19	6		13	6
Chironomidae	6	450	1,019	319	675		263	956	50	1,425	519	919
Ischium	6		31	13	13			6			50	25
Stenelmis	7		6	6	13	6	50	6	38	6	6	19
Physa	9		13							19	25	31
Chironomus	11							19		38		
Total number of individuals		524	1,357	543	757	307	863	1,176	457	1,582	719	1,156
Total number of taxa		5	10	9	8	4	9	11	6	8	9	9
IEPA MBI		5.9	5.8	5.7	5.9	5.5	5.2	5.9	5.5	6.1	5.8	5.8

ranged from 307 to 1,582 individuals/m^2 . There was relatively little variation in the MBI between samples, which ranged from 5.2 to 6.1. The earliest samples each year were generally lower in abundance and diversity. This spring low probably results from some macroinvertebrates still at the egg stage in late spring.

The sample means for each year of the study are shown in table 6. Although there are variations in the macroinvertebrate community, due to seasonal and other factors, the annual means are remarkably similar. The data for the year before construction (1989) are similar to the two years following construction (1990 and 1991). Therefore, the water quality, as measured by the macroinvertebrate community, is similar.

Table 6. Macroinvertebrate Annual Sample Means for Franklin Creek

	1989	1990	1991
Total number of individuals	795	782	979
Total number of taxa	8	8	8
IEPA MBI	5.8	5.5	5.8

Fishery Response to Habitat Enhancement

Methodology

To assess the response of Franklin Creek's fish community (particularly SMB) habitat improvement efforts, seasonal fish surveys were conducted on each treatment and control station. Sampling employed a towable "stream shocker" featuring three anode probes powered by a 2100W generator operating at 150 volts DC and from 4 to 10 amps. Prior to shocking runs, each station's upper and lower limits were blocked, usually at riffles, with a 1/4 inch mesh seine. Electrofishing commenced at the lower block net and progressed upstream through the station. All stunned smallmouth bass and channel catfish (Ictalurus punctatus) were dipnetted and held in an aerated washtub for later processing.

After the last run, each yearling and older SMB was weighed, measured, and marked with a fin clip unique to its station; SMB over 10 inches (254 millimeters or mm) in length were also marked with a numbered floy tag. Young-of-year (YOY) smallmouth were measured without weighing or marking, and channel catfish (CCF) were weighed and measured only. Within each seasonal sampling period (spring, summer, and fall), two such surveys were conducted one week apart to obtain mark-recapture estimates. During summer sampling, we employed a fourth sampling run (the first week) wherein fish of all species were collected, weighed, and measured.

Data analysis involved the calculation of a modified Peterson mark-recapture estimate (Bailey, 1951; 1952) as well as two "maximum likelihood" depletion estimates (Carle and Strub, 1978) for yearling and older SMB from each station per season. YOY bass, due to their relatively low vulnerability to capture, were excluded from these estimates. Rather, YOY numbers were simply summed over the three sampling runs and expressed as catch per unit effort (i.e., number/acre). For yearling and older SMB, body weights were incorporated in order to derive biomass estimates. All SMB data were extrapolated to a "number per acre" (i.e., density) or "pounds per acre" (biomass) standard to account for differences in wetted area among the four stations.

Statistical testing was predicated on the null hypothesis that SMB density and biomass were unaffected by our habitat improvement efforts. To test this, we used ANOVA (Statgraphics, 1986) with "Year", i.e., preimprovement (1989) vs. postimprovement (1990-1991) and "Season" as the main effects. Rather than using actual density (or biomass) estimates as the dependent variable, however, we employed the difference between treatment and control stations in order to minimize serial autocorrelation (Lyons, 1990). Since field data were not normally distributed, we performed a natural log transformation, $X = In (X + 1)$, prior to the application of any parametric statistics (Zar, 1984).

We conducted a total of 18 electrofishing surveys (each consisting of at least three runs) at each of the four stations from 1989 to 1991. While we attempted to derive mark-recapture estimates for yearling and older SMB, low numbers of recaptures made these estimates generally unreliable (table 7). Since it was impractical to leave our stations blocked during the one-week interval between sampling trips, fish movement into and out of sampling stations was likely, thus violating a basic assumption of mark-recapture surveys (Seber, 1973).

Conversely, our depletion sampling yielded relatively narrow confidence intervals (table 7), with most stations nearing "depletion" (0 to 2 individuals caught) by the third electrofishing run. Exclusion of YOY bass from depletion estimates helped to minimize the size bias often associated with such sampling (Gatz and Loar, 1988). YOY catches were reported separately as raw "catch per acre" rather than population estimates.

Population estimates were widely variable throughout the course of the study (table 7). The mean density of yearling and older SMB was 49.5 fish/acre (n=72, SD=40.9), with most estimates falling between 25 and 75 fish/acre. Meanwhile, SMB biomass (i.e. standing crop) averaged 12.5 lbs/acre (n=72, SD 12.3). These figures are comparable to those for other Midwest streams.

Funk (1975) reported a mean standing crop of 7.7 lb/acre SMB in Courtois Creek, MO. Larimore (1961) estimated density and standing crop of 17.2 SMB and 0.24 lb/acre, respectively, from electrofishing samples on Jordan Creek, IL. Paragamian (1981) reported much higher standing crops (up to 160 lb/acre of SMB age 2 and older) on the Maquoketa River, IA, but this

Table 7. Population Estimates (N) of Yearling and Older Smallmouth Bass Collected from Franklin Creek, 1989 to 1991. Each "Season" includes one mark-recapture estimate (Peterson index) and two (date specific) depletion estimates (maximum weighted likelihood). 95% confidence intervals (CI) follow all estimates. NE = no estimate. Numbers in parentheses refer to mark or recap without SMB.

	Downstream control		Lunkers		Tree revetments		Upstream control	
Date	N	(95% CI)	N	(95% CI)	N	(95% CI)	N	(95% CI)
Spring	8	± 9.6	15.8	± 10.3	20	± 16.4	62	± 45.4
5/16/89	2	(2-6.0)	7	(7-7.7)	6	(6-7.3)	11	(10-16.5)
5/23/89	3	(3)	8	(8-9.0)	9	(9-10.0)	38	(30-55.1)
Summer	8	± 6.4	22	± 18.4	10	± 8.8	57	± 32.2
7/11/89	4	(4)	6	(6-7.3)	4	(4-6.9)	26	(26-27.9)
7/18/89	3	(3-4.4)	10	(10-10.5)	3	(3)	7	(7-9.7)
Fall	24	± 22.2	20	± 19.6	32.1	± 16.3	34	± 17.8
9/12/89	8	(8-8.6)	10	(10-10.2)	15	(15-15.9)	20	(17-29.4)
9/19/89	5	(5-6.5)	1	(1)	14	(14-14.3)	14	(11-26.0)
Spring	49	± 62.9	48	± 63.7	12	± 11.8	136	± 182.9
4/25/90	7	(7-7.6)	4	(4)	3	(3-5.5)	8	(8-10.7)
5/1/90	6	(6-7.3)	11	(11-11.4)	7	(7-8.7)	16	(16-16.5)
Summer	20	± 16.0	13.3	± 4.1	12	± 11.8	36	± 4.3
7/9/90	11	(10-15.8)	10	(10-10.8)	6	(6-7.9)	20	(20-21.7)
7/17/90	3	(3)	11	(11-12.1)	1	(1-5.0)	8	(8-8.2)
Fall	NE		28.8	± 14.1		NE	6.7	± 4.1
10/2/90	1	(1)	18	(18-18.3)	4	(4-5.1)	4	(4-5.1)
10/9/90	0		7	(7-7.2)	0		4	(4-5.1)
Spring	NE		35	± 43.4	NE		10.7	± 8.3
4/23/91	0		8	(7-14.8)	0		4	(4-8.0)
4/30/91	2	(2)	4	(4)	5	(5-5.9)	7	(7-9.3)
Summer	16	± 19.2	10.1	± 2.2	39	± 51.9	10	± 9.8
7/9/91	4	(4-4.4)	9	(9)	3	(3)	5	(5-6.2)
7/17/91	3	(3-3.5)	8	(8-8.2)	12	(12-12.4)	1	(1-2.4)
Fall	NE		16.5	± 7.1	NE		NE	
9/24/91	0		11	(11-12.5)	3	(3)	2	(2)
10/1/91	0		8	(8-8.2)	0		0	

is a much larger system (1724 sq. mi. drainage). While Forbes (1989) reported similar data from the Galena River in southwest Wisconsin, her estimates for a small tributary, Pat's Creek, are in line with those on Franklin Creek (density from 21.9 to 151.0 SMB/acre, standing crop from 10.9 to 28.2 lb/acre).

One should exercise caution in comparing data across studies, however. Our Franklin Creek fish stations were all under 300 ft long and were concentrated primarily in potential adult SMB habitat, i.e., pools and runs. The aforementioned studies involved sampling of much larger stretches, e.g., over six miles in the Missouri study, wherein a greater component of less favorable habitat (i.e., shallow runs, riffles) was likely surveyed. Therefore, our estimates for Franklin Creek could be somewhat inflated relative to those of other midwestem researchers.

Lunker Response

Evaluation of our habitat improvement efforts showed a positive, yet delayed, response of SMB to lunkers (figure 11). Mean annual density of yearling and older SMB increased by 27 percent in the lunker station (LN) during the first-year postimprovement (1990), including a doubling of the fall estimate (figure 11). Meanwhile, density in the downstream control (DC) rose by only 9.4 percent between years. By the second year postimprovement (1991), mean LN density had leveled off to the preimprovement figure (54 SMB/acre) concurrent with a sharp decline in DC (SMB density about one-third of that in 1989). While these data may imply that, by 1991, the lunkers were "drawing" SMB from the nearby control station, returns of tagged and fin-clipped fish do not support this.

A two-way ANOVA tested "between station" (DC vs. LN) differences in SMB density against two main effects, year and season. To evaluate habitat improvement, the two "years" were 1989 (preimprovement) and a combined 1990-1991 (postimprovement). SMB density differences (LN minus DC) were significantly greater ($p<0.05$) in 1990-1991 than in 1989. We also found significant interaction between the two main effects. According to Zar (1984), the interaction between factors means that the effect of one factor (i.e., "year" or habitat improvement) is somewhat dependent on the presence of the other factor (i.e., season). In our

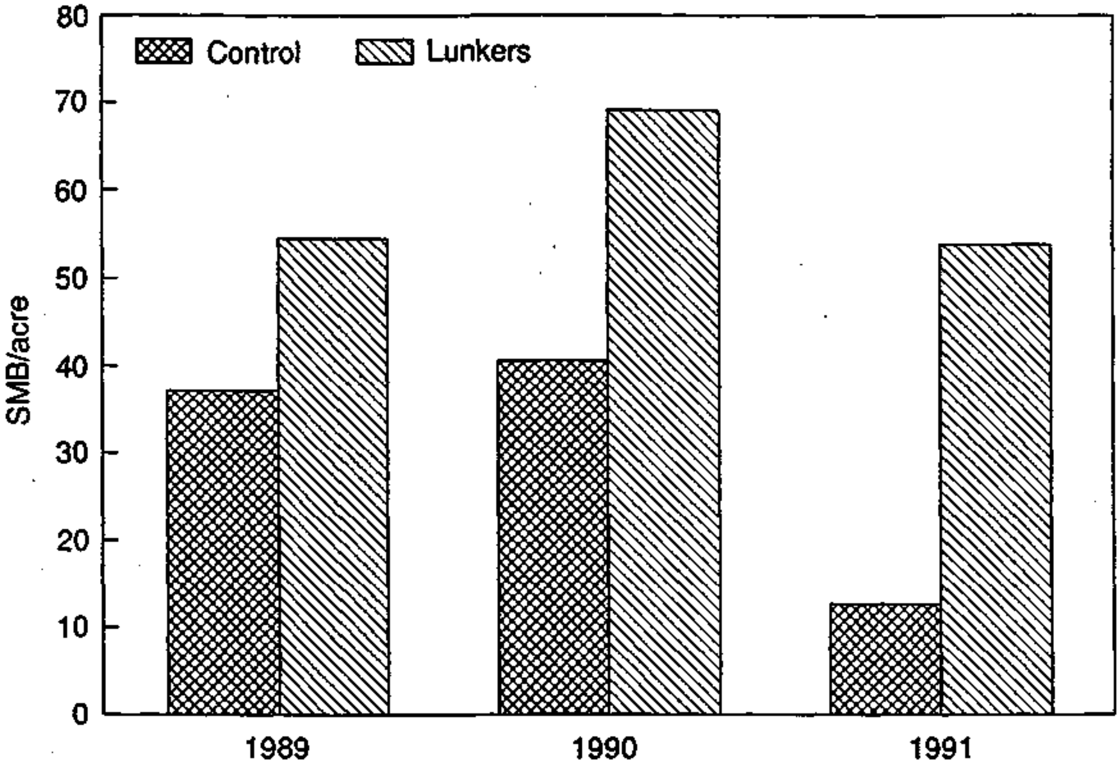


Figure 11. Annual mean density (number/acre) of smallmouth bass collected from downstream control and lunker stations on Franklin Creek, 1989 to 1991

case, it appears that the lunkers had their greatest influence on SMB populations during the fall (figure 12).

SMB biomass (lb/acre) showed a similar trend throughout the study (figure 13). This was statistically obscured, however, by a huge discrepancy between stations in spring 1989 (figure 14). Due to equipment delays, we commenced sampling in mid-May (compared to late April 1990 and 1991). Several large spawning SMB were collected from LN, resulting in 22.3 lb/acre here compared to 0.5 lb/acre in DC. So, while summer and fall data show a substantial positive impact of the lunkers on SMB biomass (LN's estimate more than doubled between preimprovement and postimprovement while DCs remained constant), inclusion of spring data rendered the ANOVA comparison of standing stock differences nonsignificant. "Year" x season interaction was still significant, however.

Young-of-year SMB showed the most dramatic response to habitat improvement (figure 15). Catch per unit effort for YOY bass was essentially equal (~ 60 YOY/acre) between DC and LN in 1989. After installation of lunkers, this parameter doubled (1990) and tripled (1991) its "preimprovement" level in LN while falling off slightly both years in DC. One way ANOVA showed a significant increase in YOY "differences" (LN minus DC) over this period. The riprap piled loosely atop lunkers and inundated with a few inches of water harbored the great bulk of young SMB (along with YOY rock bass and green sunfish) in LN. Presumably, this zone provided a refuge from predators and a ready food supply of benthic invertebrates. Use of rocky stream margins by young SMB is well documented (Livingstone and Rabeni, 1991; Paragamian, 1973) in other studies.

While YOY abundance in LN implied use of lunkers by spawning bass, we were unable to substantiate this on Franklin Creek. Postimprovement fish sampling did not coincide with the SMB spawning period (May and June in northern Illinois), and observations would have been impractical given the structure's overhead design. Hoff (1991) studied SMB use of a similar structure, the half-log, in Wisconsin lakes. He observed male SMB tending nests directly underneath structures and reported significant gains in both nest density (number/km) and reproduction (YOY/km) in treatment lakes following half-log installation. In Tennessee streams,

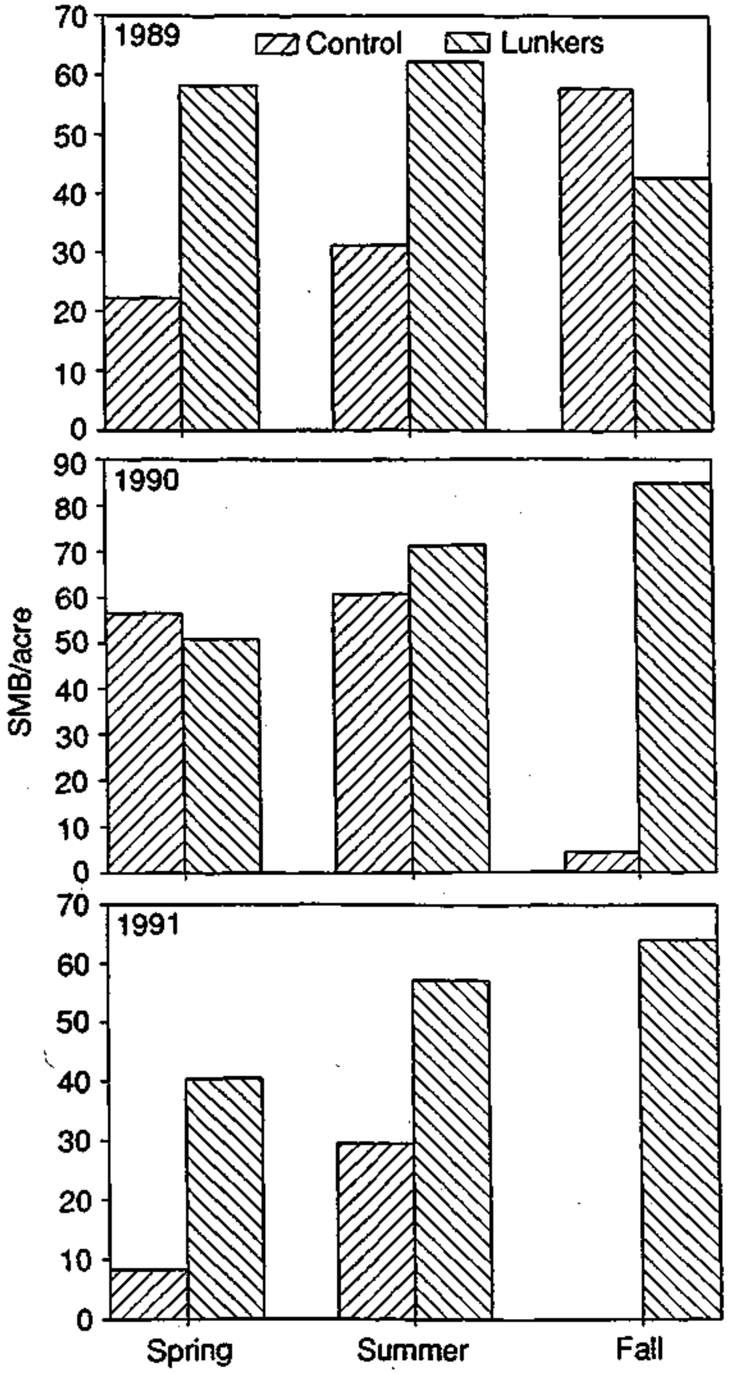


Figure 12. Seasonal mean density (number/acre) of smallmouth bass collected from downstream control and lunker stations on Franklin Creek, 1989 to 1991

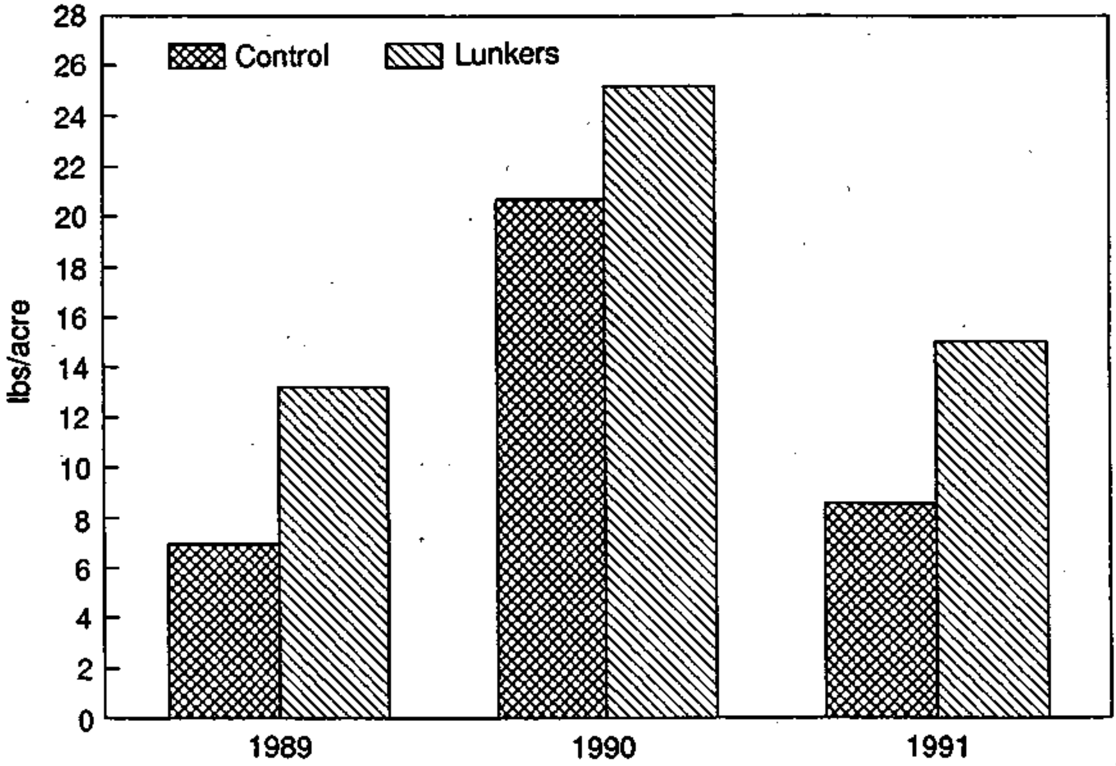


Figure 13. Annual mean biomass (pounds/acre) of smallmouth bass collected from downstream control and lunker stations on Franklin Creek, 1989 to 1991

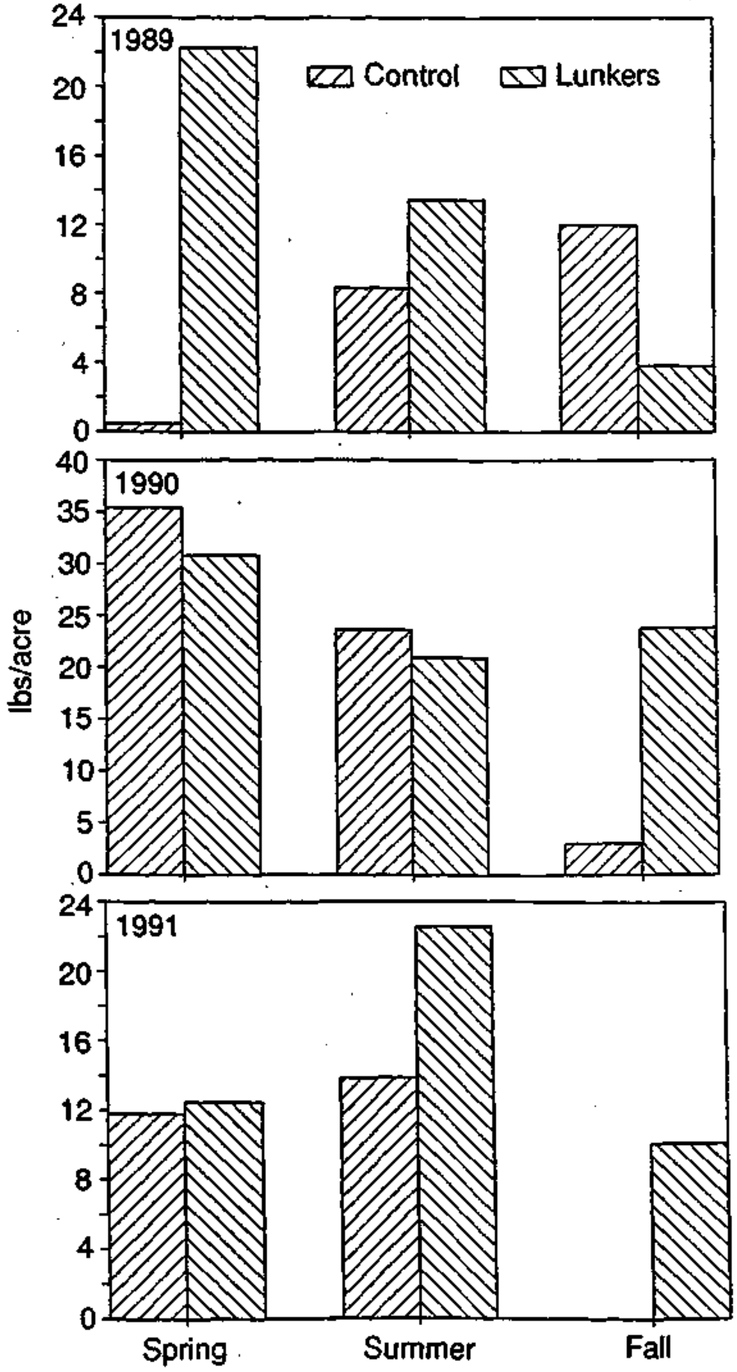


Figure 14. Seasonal mean biomass (pounds/acre) of smallmouth bass collected from downstream control and lunker stations on Franklin Creek, 1989 to 1991

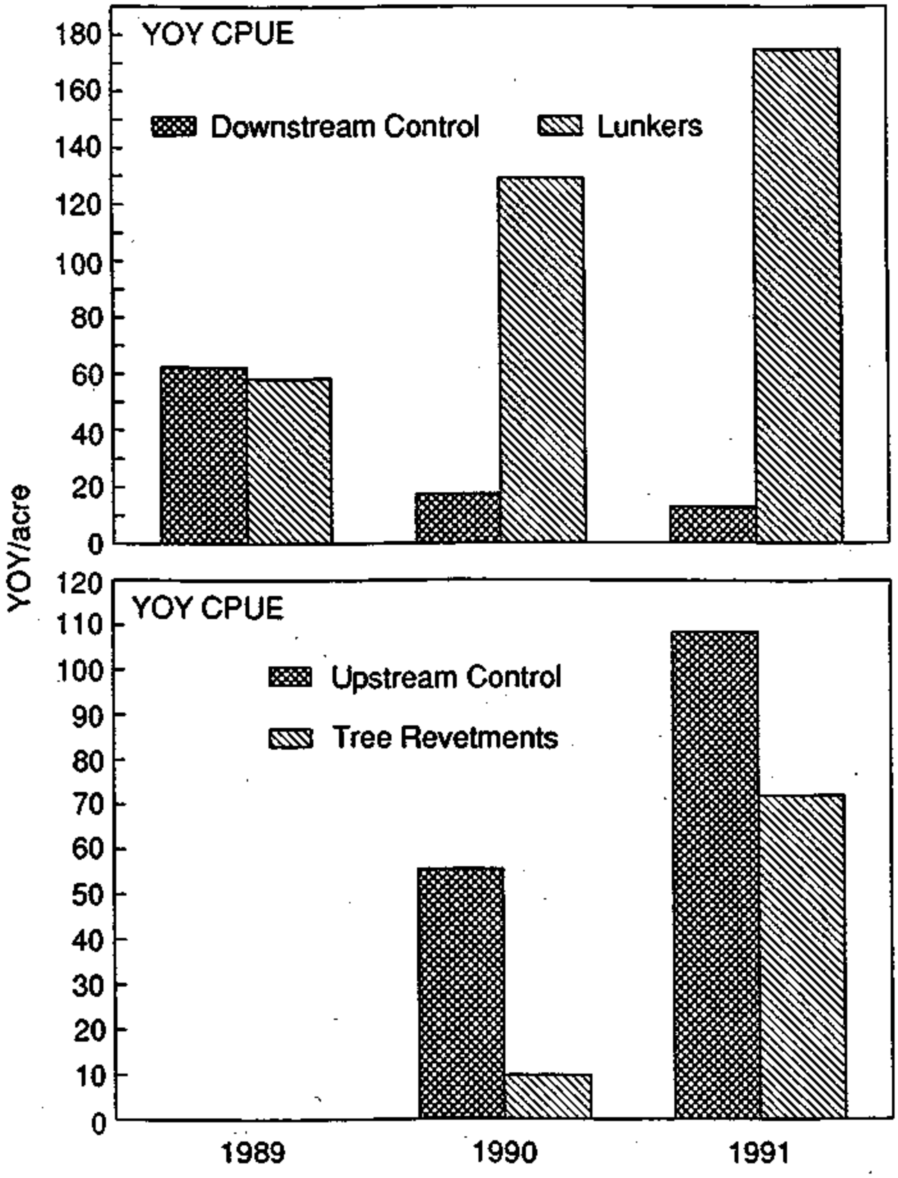


Figure 15. Catch per unit effort (number/acre) of young-of-year smallmouth bass collected during fall sampling on Franklin Creek, 1989 to 1991

61 percent of SMB nests observed over a two-year period were associated with overhead cover (Reynolds and O'Bara, 1991).

One unexpected finding was the apparent use of lunkers for spawning by channel catfish (CCF). Although our original intent was to routinely collect this species during our SMB depletion runs, only 14 of our 72 samples yielded any CCF at all. Of these 14 collections, ten were during summer and nearly 80 percent of individual CCF were taken during the first (i.e., "marking") sample. So, we present CCF data only from the first sampling venture during each of the three summers (figure 16).

Prior to July 1990, no single survey had yielded more than a single CCF. Summer 1990 found them at each of our stations with LN supporting the largest contingent. Here, several large breeding males were captured (five over one pound), resulting in a CCF standing crop (73.8 lb/acre) nearly double any such estimate for SMB over the course of our study. By 1991, this figure had fallen off (to 39.6 lbs/acre) but not nearly as much as in DC. Evidence of spawning was circumstantial (i.e., coloration of males) as no CCF were "flowing" with milt or eggs. However, water temperatures had yet to reach optimal CCF spawning range (Becker, 1983) in both years. Lunkers may emulate the undercut bank habitat often sought by spawning CCF (Pflieger, 1975; Scott and Crossman, 1973).

Effects of lunkers on nongame fish species are difficult to discern from a limited data set (table 8). While LN showed increasing numbers and biomass of catostomids over the three-year period (particularly white suckers), station DC paralleled this trend. One interesting finding was a steady drop in the proportion of cyprinids in LN over the course of the study, which may have been partly due to increasing predation as SMB standing crop rose concurrently. Sunfish composition showed a slight shift from rock bass to green sunfish in LN, although both species were found usually as fingerlings here.

Tree Revetment Response

Apparently, SMB showed as delayed a response to tree revetments as they did to lunkers. Both upstream stations (TR = tree revetment, UC = upstream control) showed a decline in SMB

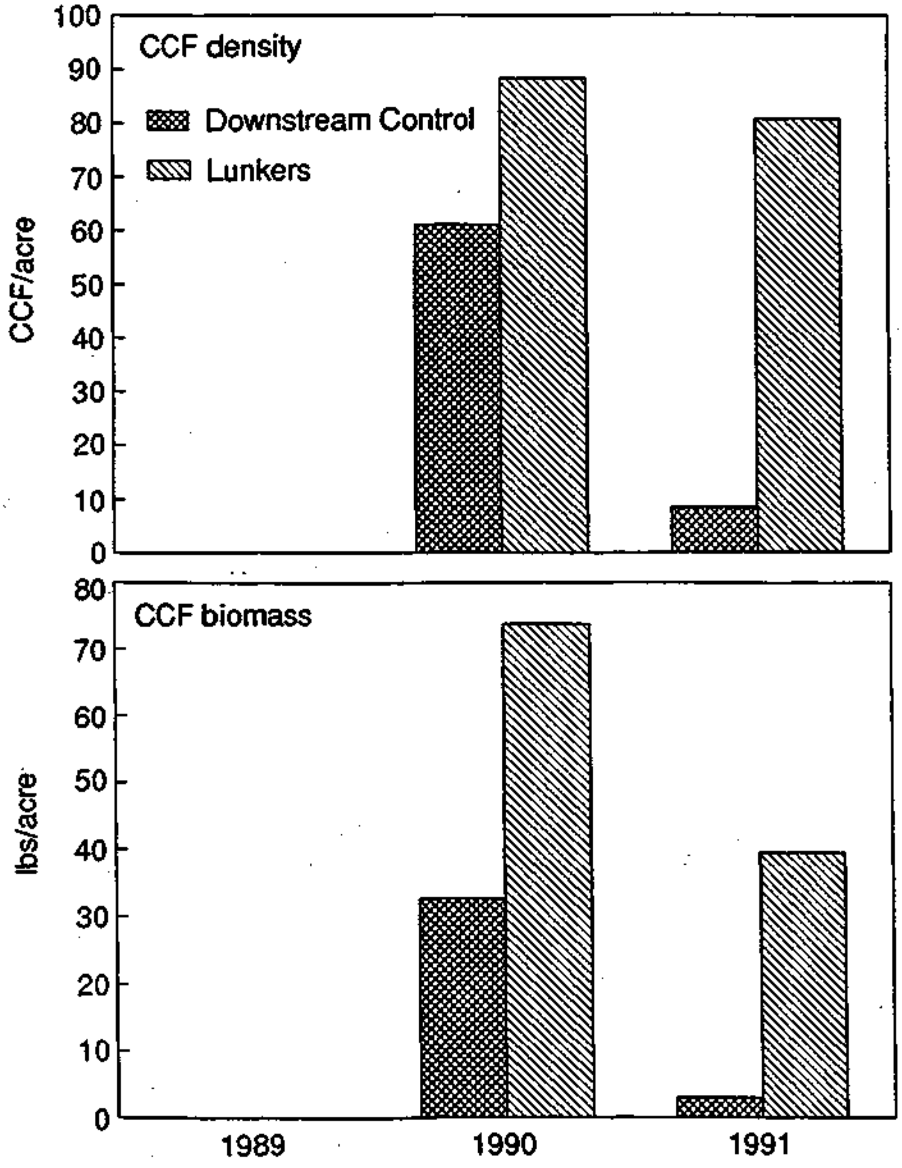


Figure 16. Summer density (number/acre) and biomass (pounds/acre) of channel catfish (CCF) collected from downstream control and lunker stations on Franklin Creek, 1989 to 1991

Table 8. Numbers of Fish (Excluding SMB and CCF) Collected from Downstream Stations during Summer Sampling on Franklin Creek, 1989-1991

	Control			Lunkers		
	1989	1990	1991	1989	1990	1991
Central mudminnow	2	0	0	0	0	0
Common carp	0	2	0	0	1	0
Creek chub	11	4	1	4	3	0
Hornyhead chub	43	2	18	27	19	10
Common shiner	26	7	12	42	21	1
Bigmouth shiner	103	0	0	1	1	0
Rosyface shiner	10	0	2	2	3	0
Sand shiner	13	1	0	0	4	0
Ozark minnow	0	0	0	1	5	0
Bluntnose minnow	44	9	6	22	26	0
Fathead minnow	0	0	0	0	1	0
Common stoneroller	53	6	3	30	32	4
Quillback	0	2	0	0	1	0
Golden redhorse	0	0	0	0	1	1
Shorthead redhorse	0	2	2	0	11	4
Northern hogsucker	3	2	0	1	0	2
White sucker	2	13	15	15	25	25
Stonecat	0	0	0	1	0	0
Brook stickleback	0	0	0	1	0	0
Green sunfish	0	0	3	0	2	9
Rockbass	5	6	4	8	2	3
Fantail darter	2	0	0	7	0	1
Johnny darter	13	1	0	3	7	1
Total individuals	330	57	66	165	165	61
Total species	15	13	11	15	19	12

density the first year postimprovement (figure 17). By 1991, however, UC had continued this trend while TR rebounded slightly. Density data are somewhat misleading here as UC usually harbored a large component of yearling and older SMB. For example, 1989's sampling yielded an estimate of 103 SMB/acre here, but the standing crop was less than 8 lb/acre. Of all four stations, UC had the largest component of shallow, rocky habitat favored by "yearling" bass (table 5).

Examination of upstream SMB biomass trends (figure 18) still shows a "first-year" decline in TR but a much healthier return (relative to density) in the second year post-treatment. By 1991, TR's mean SMB biomass was over four-fold that of UC, compared to a two-fold difference in 1989. Unlike that of the downstream stations, this trend was interrupted by a year of adjustment (1990) in which the control slightly surpassed the treatment station both in mean SMB density and biomass (figures 17 and 18). Therefore, ANOVA comparing SMB "differences" (TR minus UC) across years (1989 vs. 1990-91) and seasons proved nonsignificant ($p>0.05$), as did "Year" x "Season" interaction, for both SMB density and biomass.

SMB did not show a strong seasonal response to tree revetments as observed in lunkers (figures 19 and 20). In each of the three study years, the standing crop of TR exceeded that of UC in spring and fall. Summer sampling showed the reverse pattern (figure 20), however, until 1991 when TR had become superior across all seasons. Again, great numbers of yearling SMB in the control station somewhat clouded seasonal trends in density. By 1991, however, SMB/acre in TR surpassed that of UC in all three seasons (figure 19).

The time lag shown by SMB in responding to habitat improvement (both upstream and downstream) is not surprising, as fish populations often take several years to reach equilibrium with new or altered habitat. In fact, Hunt (1976) did not observe a peak response by brook trout on Lawrence Creek, WI, until five to six years after habitat improvement and thus recommends a waiting period of three to four years between habitat work and postimprovement fish surveys.

Similarly, Lyons (1990) suggests a post-evaluation of twice the generation time of the target species (at least six years) in order to track successive year classes. In this context, the

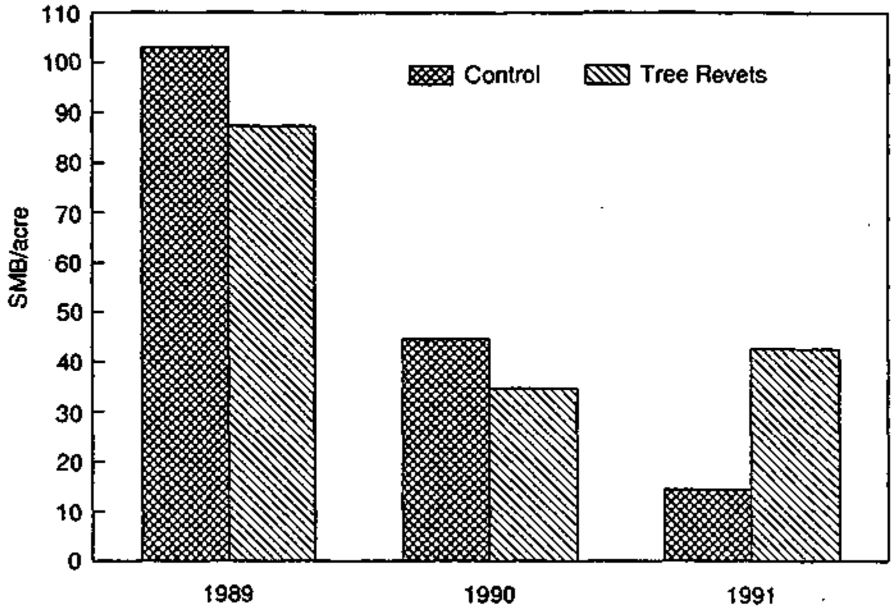


Figure 17. Annual mean density (number/acre) of smallmouth bass collected from upstream control and tree revetment stations on Franklin Creek, 1989 to 1991

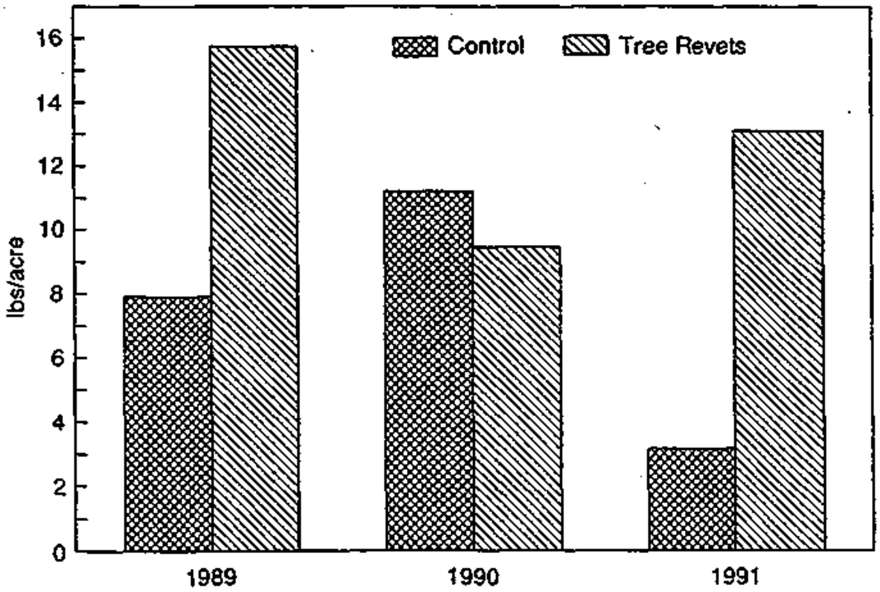


Figure 18. Annual mean biomass (pounds/acre) of smallmouth bass collected from upstream control and tree revetment stations on Franklin Creek, 1989 to 1991

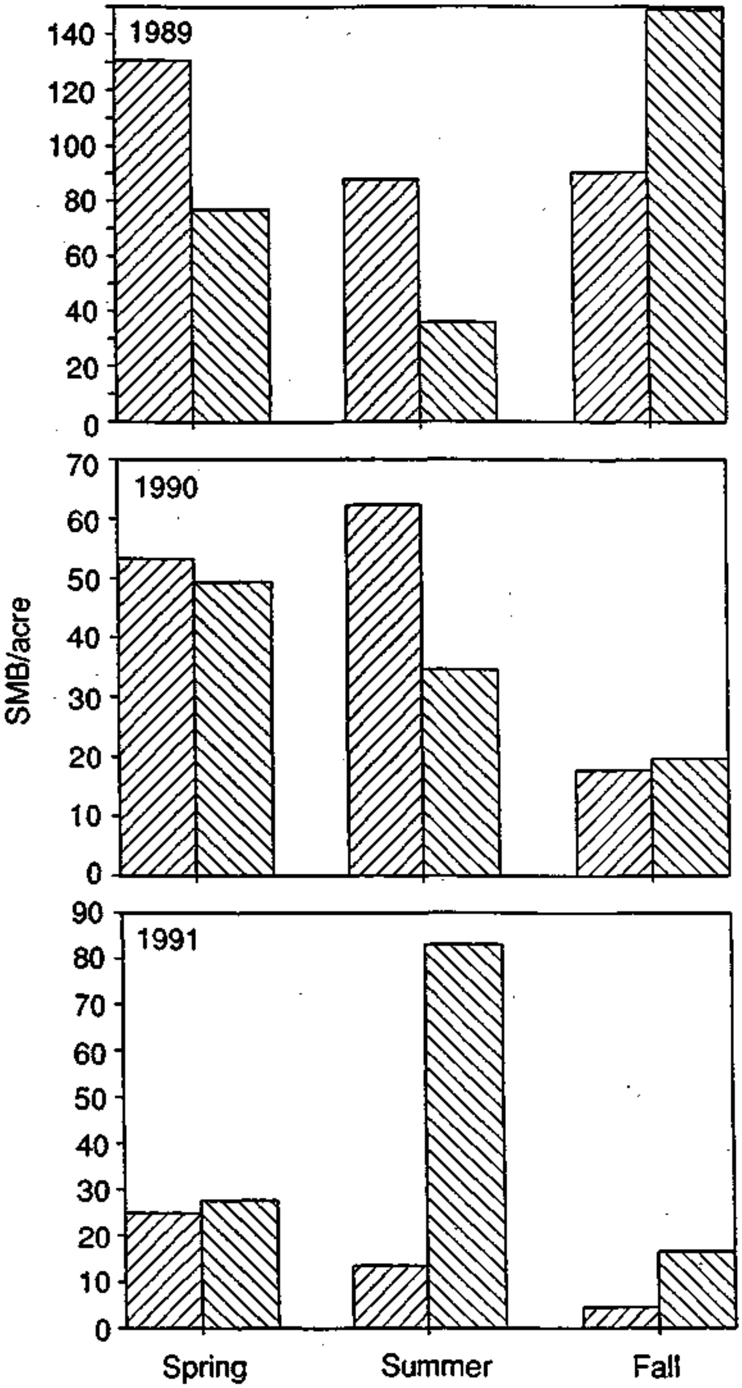


Figure 19. Seasonal mean density (number/acre) of smallmouth bass collected from upstream control and tree revetment stations on Franklin Creek, 1989 to 1991

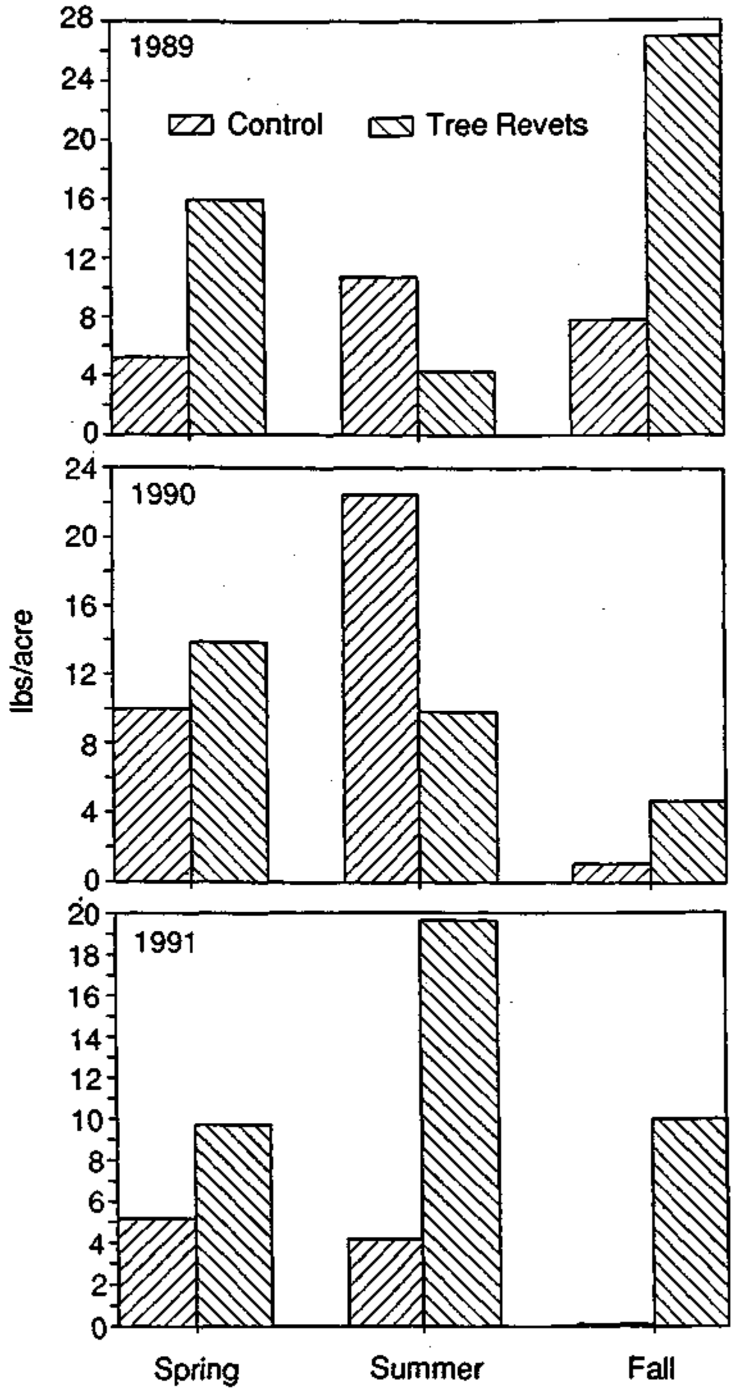


Figure 20. Seasonal mean biomass (pounds/acre) of smallmouth bass collected from upstream control and tree revetment stations on Franklin Creek, 1989 to 1991

two-year response by Franklin Creek's SMB to both lunkers and tree revetments is most encouraging.

Fall YOY data from the two upper stations (figure 15) do not indicate substantial use of tree revetments as spawning or nursery habitat. While catch-per-acre of YOY SMB increased in TR following improvement, this trend was paralleled by a much higher density in the nearby control (UC), where rocky shallows and vegetation afforded ideal nursery environs. Collections of small fishes was relatively difficult in the dense, brushy tree revetments, however, so TR's YOY density was probably underestimated relative to that of the other stations. Nonetheless, a one-way ANOVA of YOY/acre "differences" (TR minus UC) found no significant effect of habitat improvement.

Whereas CCF showed a more immediate response to lunkers (figure 15) than did SMB, their reaction to tree revetments was delayed. We collected no CCF from either upstream station in summer 1989, and only three (one from TR, two from UC) a year later. Our July 1991 "marking" sample on TR yielded seven CCF between 0.5 and 1.0 lbs (77.6 CCF/acre, 24.7 lbs/acre). No CCF were taken here in spring or fall 1991, suggesting use of tree revetments by spawning catfish only.

Impacts of tree revetments on nongame fishes (table 9) appear more favorable than that of lunkers. A general increase in abundance and species richness of TR was evident between 1989 and 1991 (1990 data are incomplete due to inadvertent loss of a preserved fish sample). As in LN, white suckers became more abundant following habitat improvement here. Hunt (1988) reported a doubling of white sucker density following application of several habitat enhancement techniques on Foulds Creek, WI, but biomass (lb/mile) had actually declined. On Franklin Creek, total weight of catostomids in our TR sample more than doubled from 1989 to 1991. Green sunfish showed a dramatic increase over this period as well. This well-documented habitat "generalist" (Smith, 1979; Pflieger, 1975) appeared to benefit both from the introduction of rock in LN and brush in TR.

Table 9. Numbers of Fish (Excluding SMB and CCF) Collected from Upstream Stations during Summer Sampling on Franklin Creek, 1989-1991

	Control			Tree revetments		
	1989	1990	1991	1989	1990	1991
Central mudminnow	0	0	0	0	0	1
Common carp	0	0	0	3	3	1
Creek chub	19	8	9	8	0	2
Hornyhead chub	33	38	21	2	6	5
Suckermouth minnow	0	1	0	0	0	0
Common shiner	14	18	3	1	0	23
Rosyface shiner	0	4	2	0	0	2
So redbelly dace	0	0	1	0	0	0
Ozark minnow	1	3	0	0	0	3
Bluntnose minnow	18	10	10	8	3	32
Common stoneroller	112	35	19	1	0	1
River carpsucker	0	0	0	0	0	1
Golden redhorse	0	0	0	0	0	1
Shorthead redhorse	0	0	0	0	0	2
Northern hogsucker	1	0	0	0	0	0
White sucker	15	6	1	13	10	22
Yellow bullhead	0	0	0	1	0	0
Stonecat	5	0	2	0	0	0
Largemouth bass	0	1	0	0	0	0
Green sunfish	2	3	10	1	2	19
Rock bass	2	5	10	2	2	1
Fantail darter	17	11	11	5	0	3
Johnny darter	4	2	0	4	0	2
Total individuals	243	145	99	- 49	26*	121
Total species	13	14	12	12	6*	17

* 1990 data are incomplete due to inadvertent loss of a preserved fish sample.

Movement between Stations

A common criticism of stream habitat improvement structures is that they function simply as fish attractors, drawing sport fish from unimproved stream sections and making them more vulnerable to angler harvest (to the long-term detriment of the target population). Thus, a secondary objective of our fish surveys was to ascertain, through marking of fish, the extent and direction of SMB movements prior to and following our habitat improvement efforts. Week-to-week variations in population estimates (i.e., between "marking" and "recapture" samples, table 7) indicated bass were moving in and out of sampling stations over the course of the study.

Returns of tagged and fin-clipped fish, however, show an extremely low degree of "station to station" SMB movement over the three-year period. Since we used fin clips unique to each station (DC = left pectoral, LN = left pelvic, etc.), original capture site was evident either through fresh marks or regenerated fin rays. Of a total of 111 fin-clipped SMB recaptured over the course of the study, only five (4.5 percent) were collected from a station other than that of their original capture. In only two instances were the improved sections shown to have drawn fish from elsewhere. An individual fin-clipped in DC was captured in LN during 1990, and a fish marked in UC was collected in TR in 1991. Conversely, two SMB previously clipped in LN were taken in DC (1990).

Since floy tagging was limited to larger fish (>10 inches), number of tag returns was much lower than that of fin clips. Nonetheless, 17 tagged fish were recaptured, 12 of which (70.5 percent) were collected from their original tagging site. Of the five tagged fish that had relocated, four appeared in DC (two moved from LN, one from TR, and one from UC). The higher rate of inter-station movement among floy-tagged individuals is consistent with Beam (1990), who reported larger home ranges for older SMB in Huron River, MI. Presumably, this was a result of increased foraging demands by larger fish. In our study, one 12 inch SMB had been originally fin-clipped (date unknown), in DC, captured and tagged fall 1989 in UC, and recaptured back in DC in spring 1990.

Such wandering was an exception on Franklin Creek, however. For the most part, SMB recaptures corroborated this species' long-documented affinity to a "home pool" (Larimore, 1952; Funk 1955). This was most evident in the lunker site during summer sampling. In July 1990, 8 out of 11 SMB marked the first week were recaptured a week later, and in July 1991 the return rate was 7 out of 11. After installation of the lunkers, a 10 inch tagged fish was collected from LN on four consecutive samples (both summer and fall 1991 excursions), and a 12 inch specimen was collected here three different times between summer 1990 and spring 1991. SMB failed to show this degree of fidelity to any other station over the course of the study.

Conclusions and Recommendations

As instream habitat structures, both lunkers and tree revetments protected the stream channel stability, increased desired habitat characteristics in the treated sites, and increased smallmouth bass and channel catfish populations. As based upon a very limited number of sites and a short monitoring period, the lunker technique appears to be more successful at preserving channel stability, increasing the most important habitat factors (rocky cobble and undercut streambank), and increasing the numbers of smallmouth bass for only a small increase in expenditure.

Recommendations would include the installation and monitoring of Junkers over a substantial stream length, for example, the one mile segment of Franklin Creek upstream and downstream of the present lunker installation. This would allow a continuation of the long-term monitoring required for essential decisions on habitat management.

Tree revetment techniques should be altered by substituting cedar trees for hedge trees because of the cedar's greater limb density and durability. Revegetation techniques of bank soils behind cedar revetment should further test planting of small willows with intact root systems. If smaller test sites prove successful with these tree revetment modifications, then a larger stream segment should also be treated with cedar tree revetments.

Finally, the lunker technique should be tested on small rivers such as the Mackinaw, where landowners routinely attempt stream channelization in vain attempts to reduce bank erosion. The lunker bank stabilization technique should increase the gamefish populations as well as protect floodplain fields.

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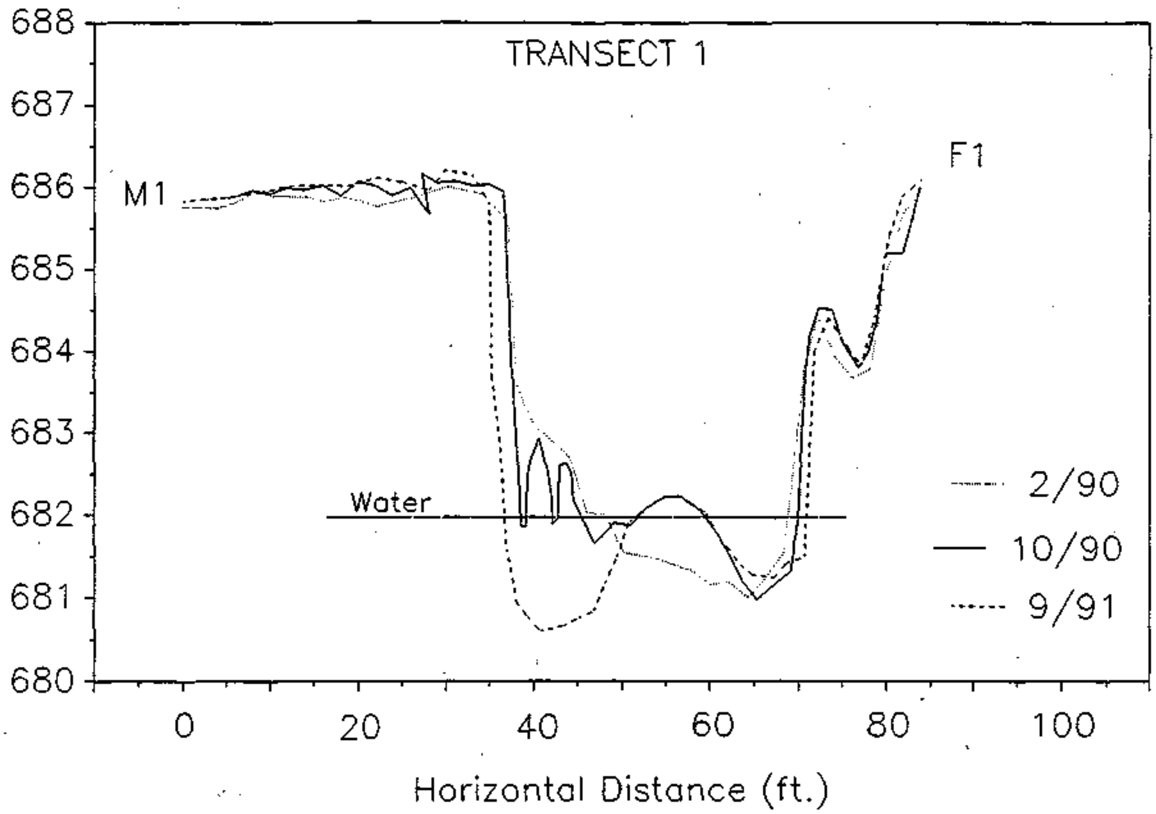
Appendix A.   Franklin Creek Surveyed Transects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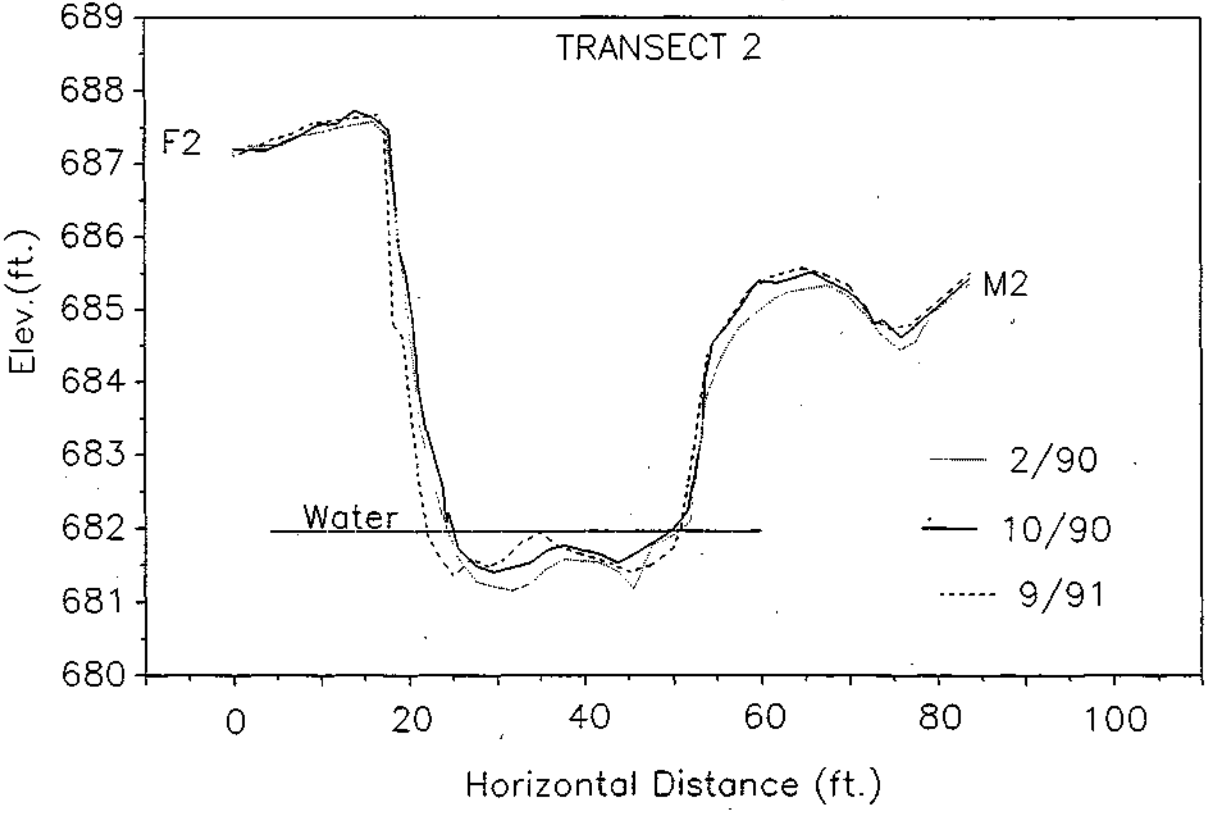
688
687
686
685
684
683
682
681
680
M1
F1
Water
2/90
10/90
9/91
0
20
40
60
80
100
Horizontal Distance (ft.)


TRANSECT 2
689
688
687
686
685
684
683
682
681
680
Elev.(ft.)
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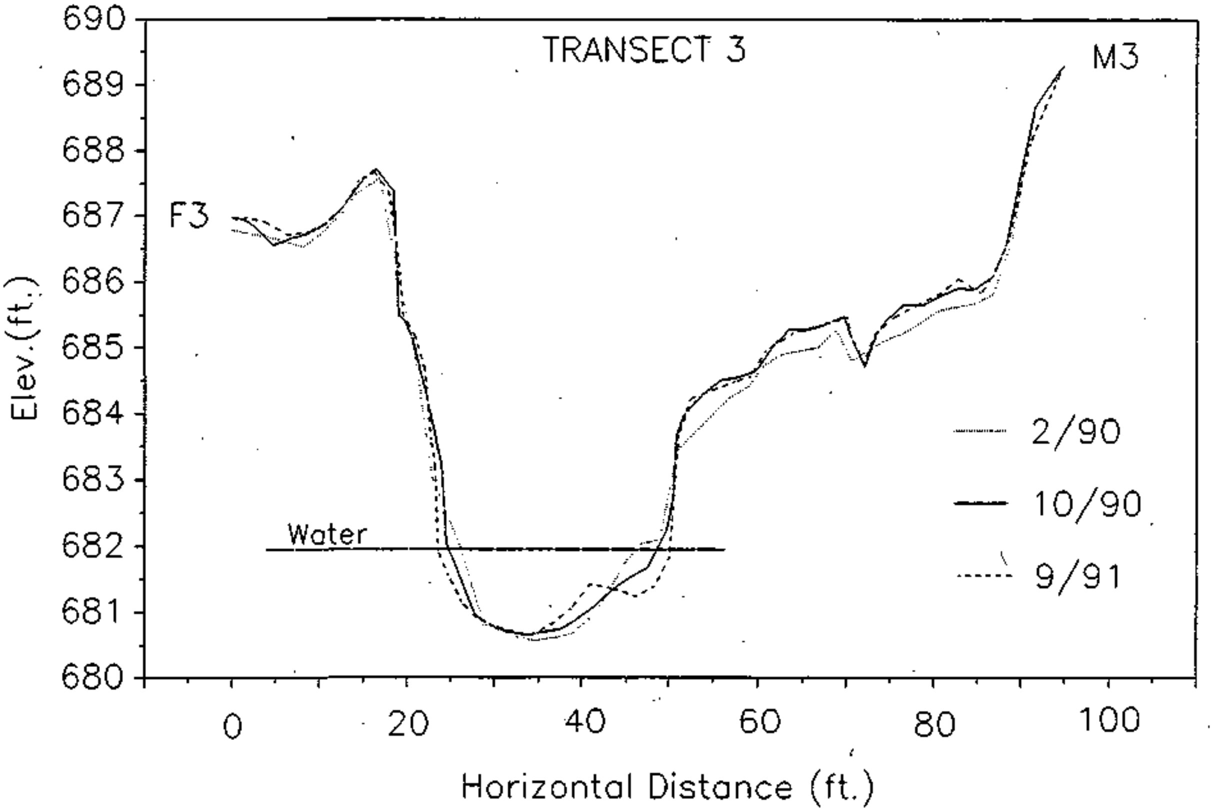
M2
Water
2/90
10/90
9/91
0
20
40
60
80
100
Horizontal Distance (ft.)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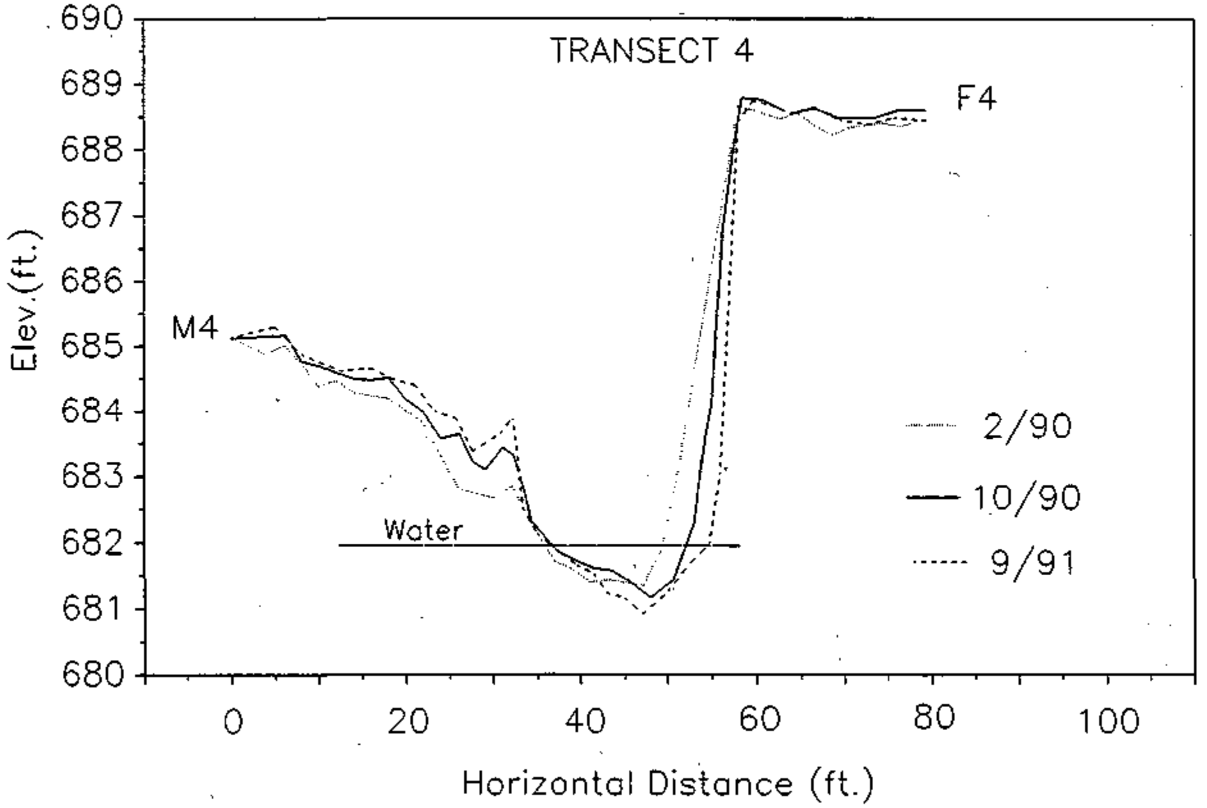
690
689
688
687
686
685
684
683
682
681
680
0
20
40
60
80
100
Horizontal Distance (ft.)
Water
2/90
10/90
9/91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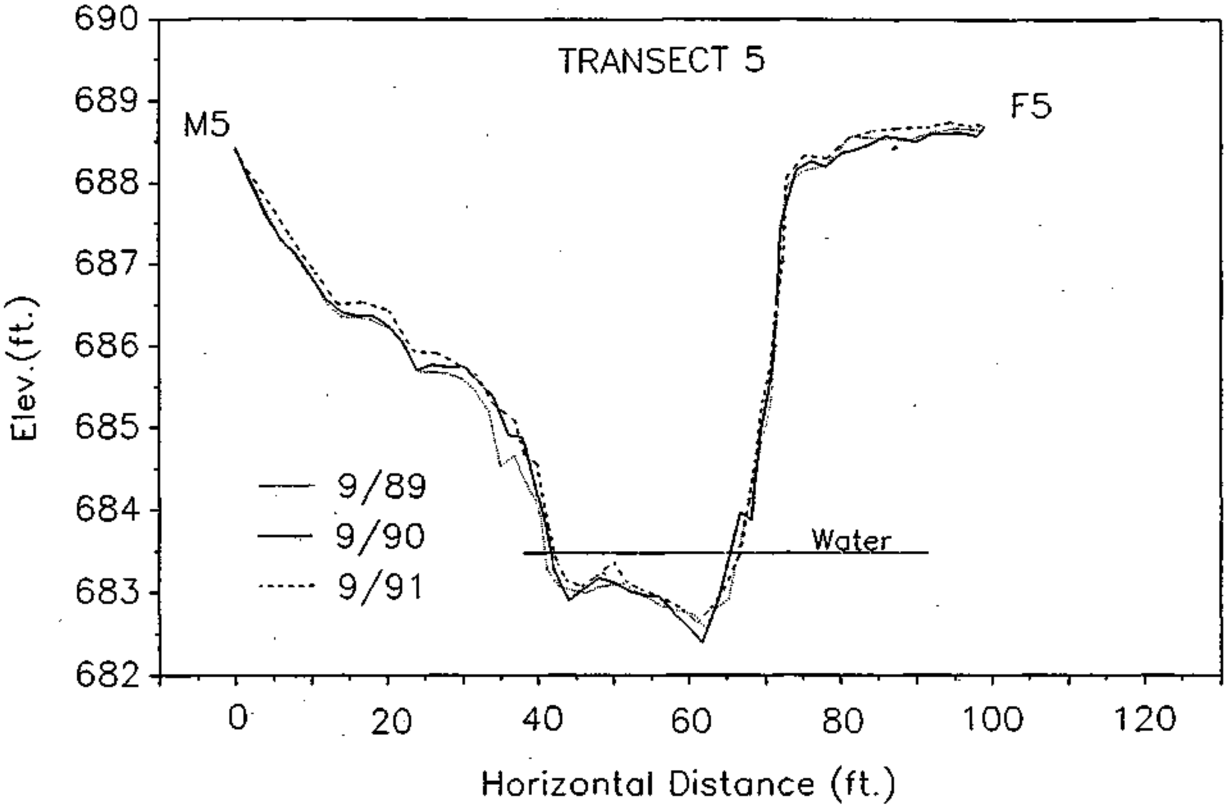
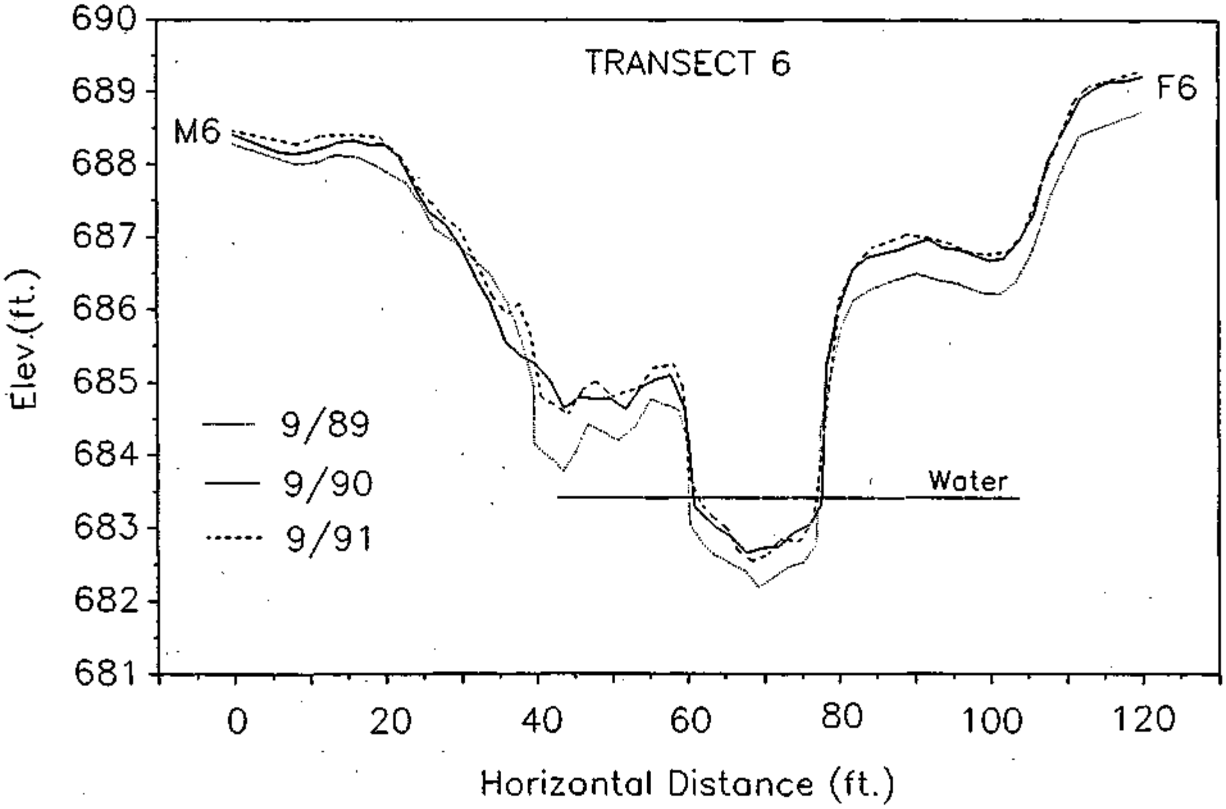
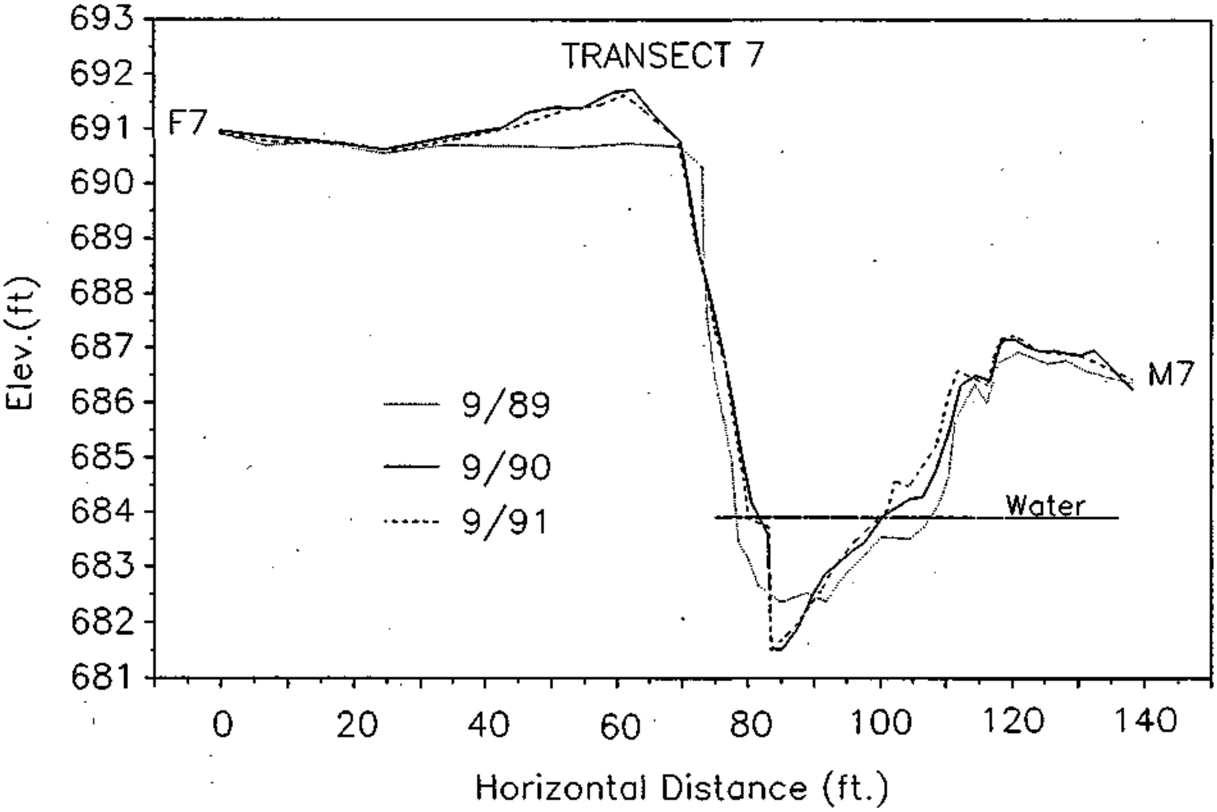
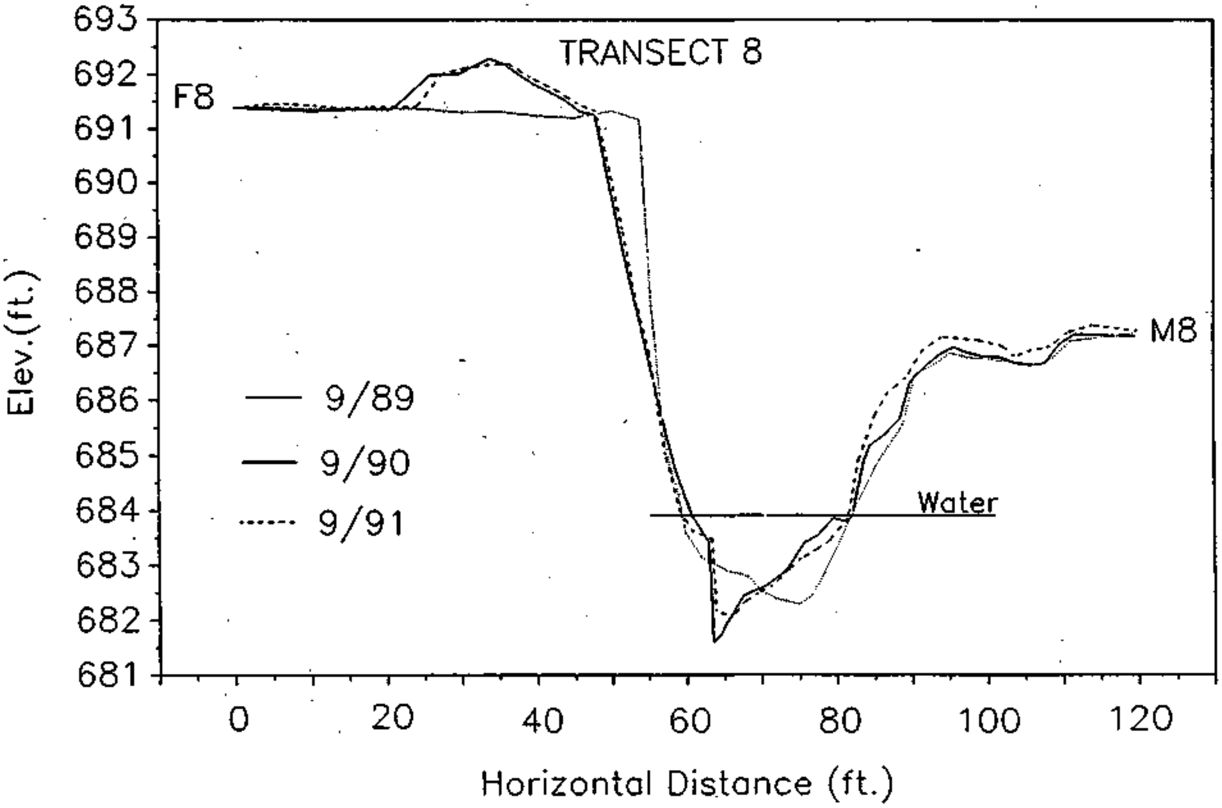
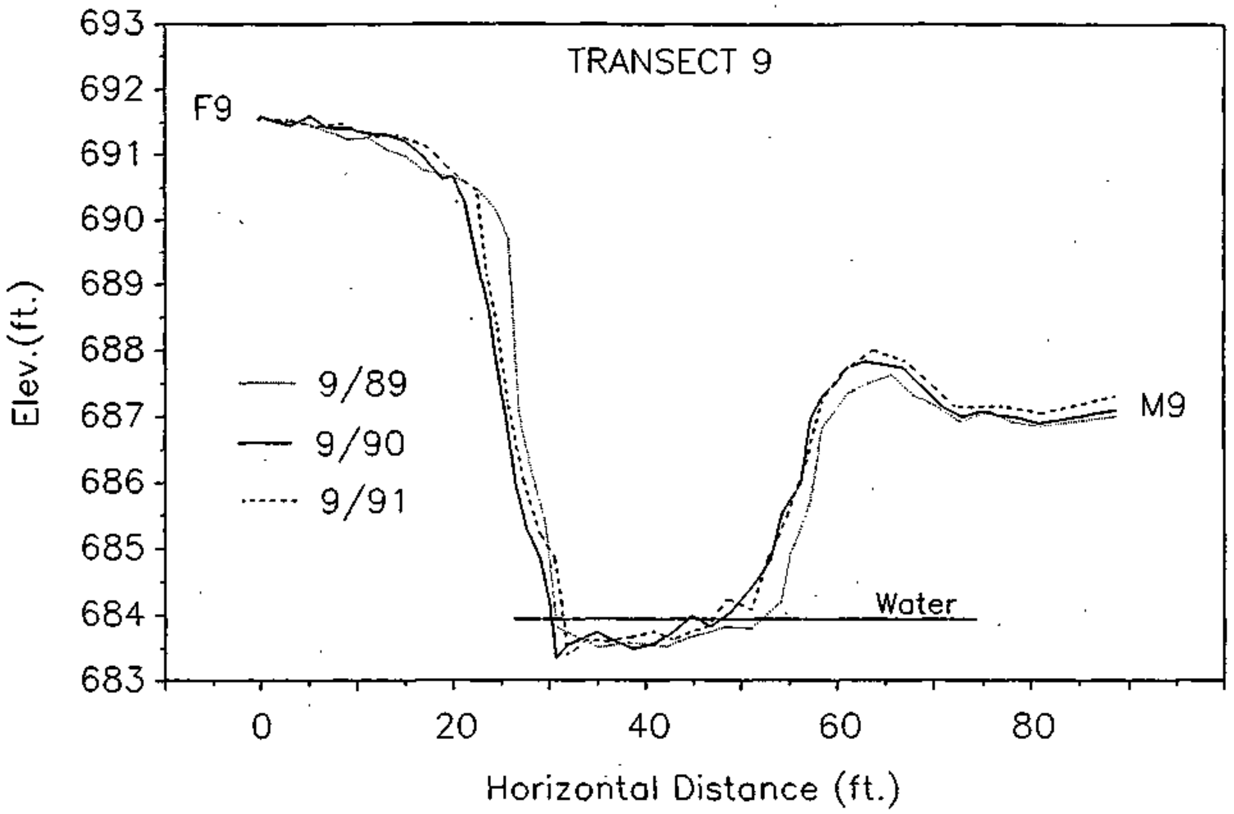
688
687
686
685
684
683
682
681
680
0
20
40
60
80
100
Horizontal Distance (ft.)
Water
2/90
10/90
9/91

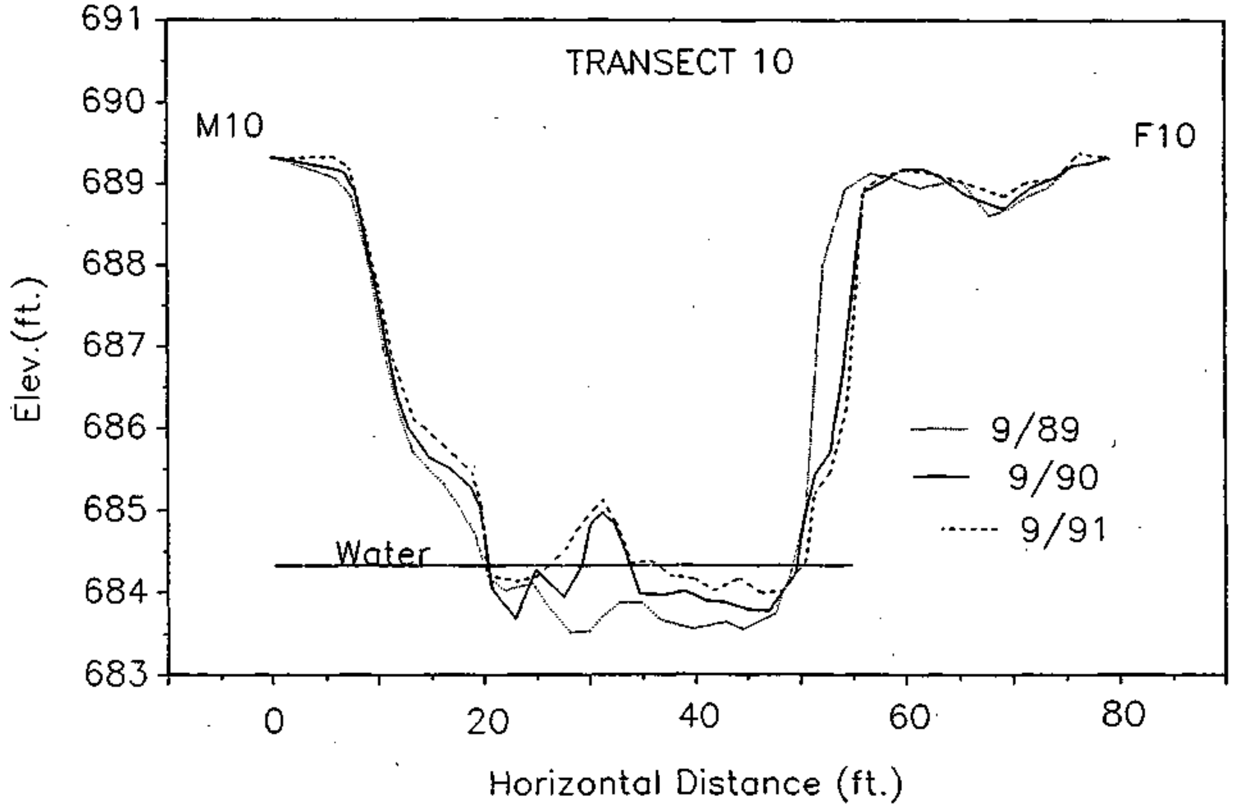

TRANSECT 5
M5
F5
Elev.(ft.)
690
689
688
687
686
685
684
683
682
0
20
40
60
80
100
120
Horizontal Distance (ft.)
9/89
9/90
9/91
Water

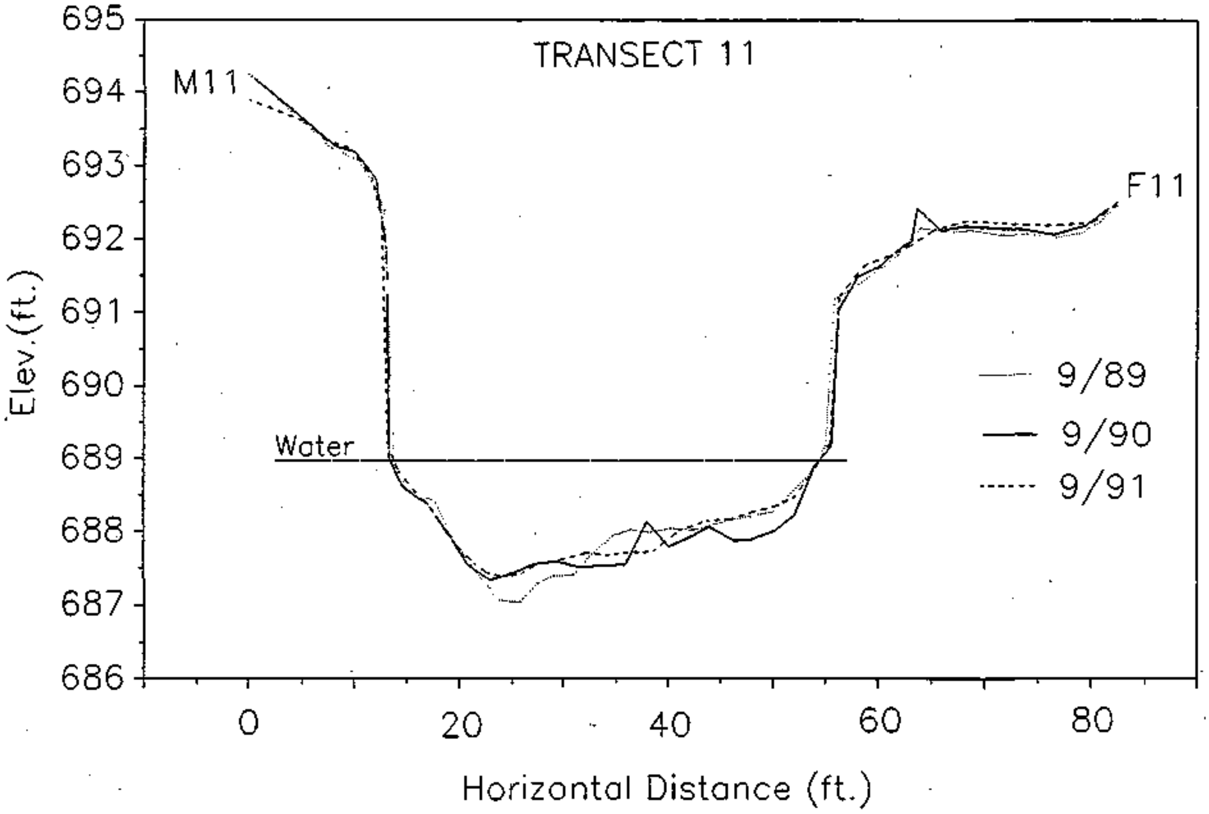

TRANSECT 6
M6
F6
Elev.(ft.)
690
689
688
687
686
685
684
683
682
681
0
20
40
60
80
100
120
Horizontal Distance (ft.)
9/89
9/90
9/91
Water

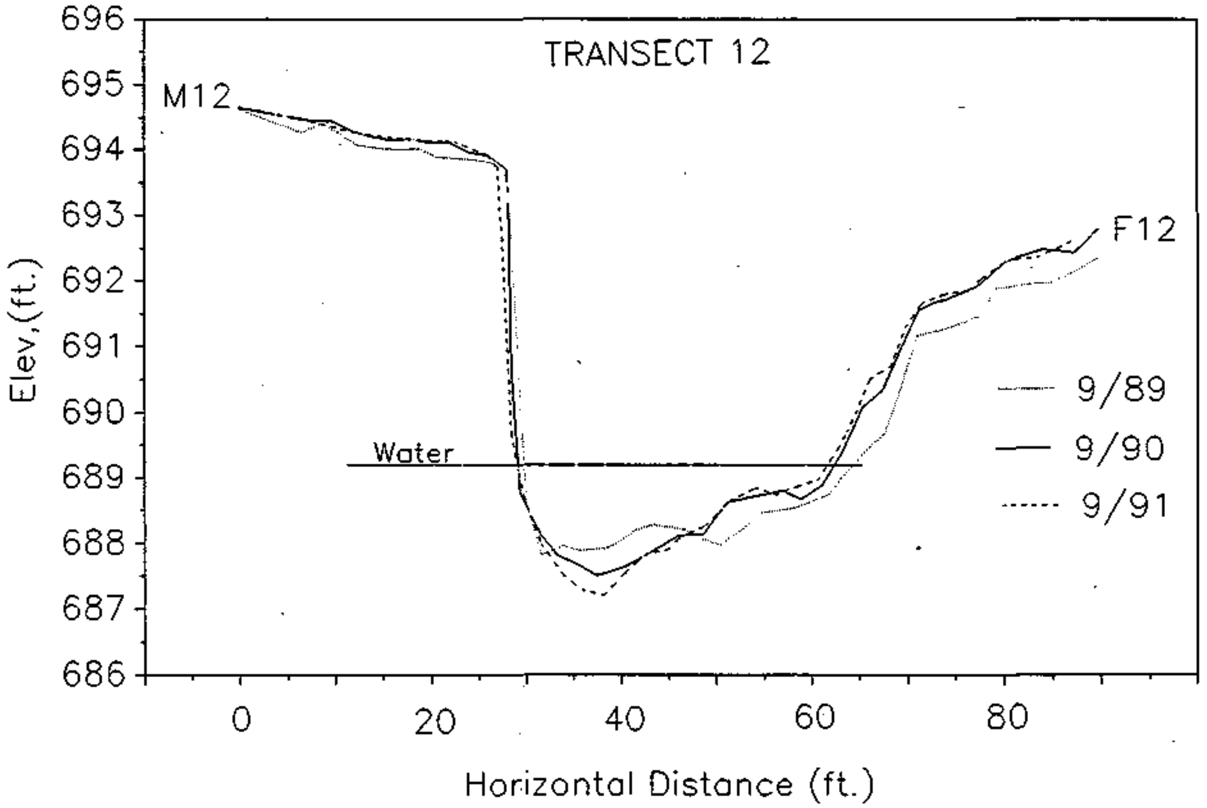

TRANSECT 7
F7
M7
Water
9/89
9/90
9/91
Elev.(ft)
693
692
691
690
689
688
687
686
685
684
683
682
681
0
20
40
60
80
100
120
140
Horizontal Distance (ft.)

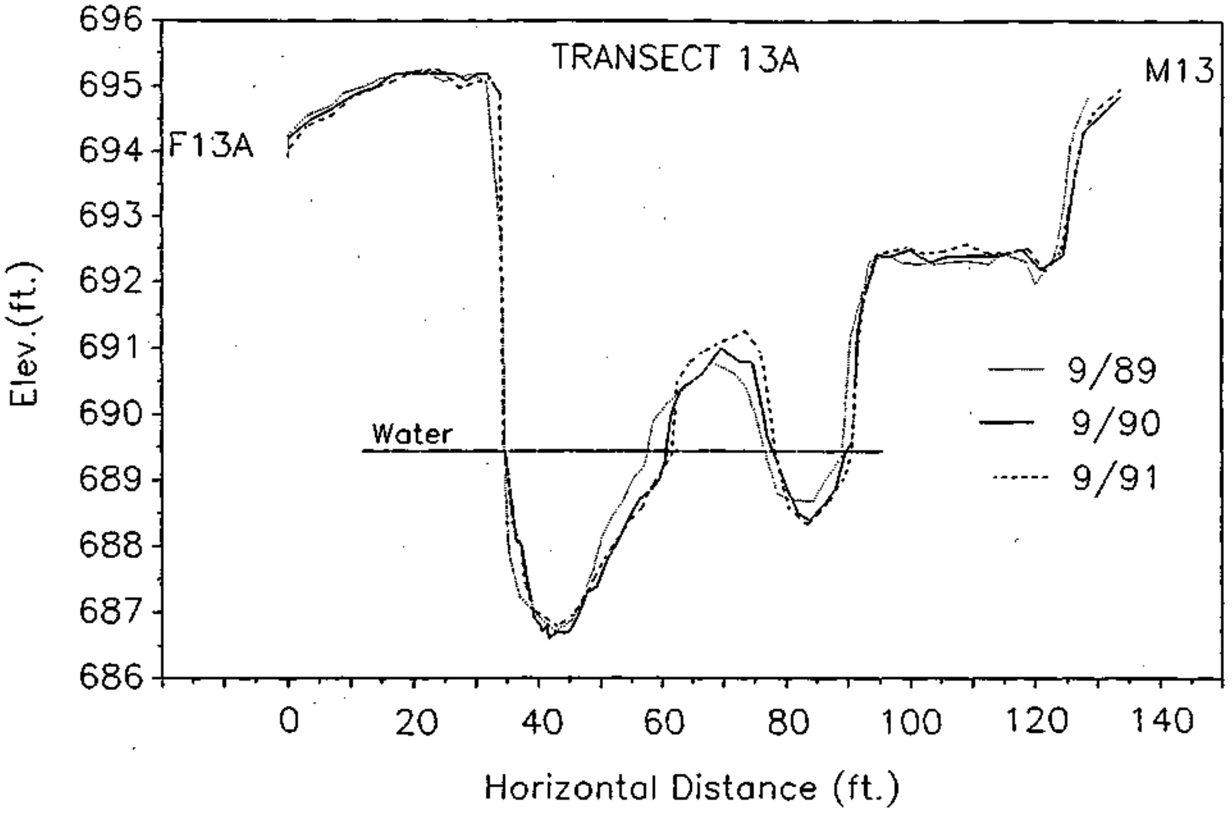

TRANSECT 8
F8
M8
Water
9/89
9/90
9/91
Elev.(ft.)
693
692
691
690
689
688
687
686
685
684
683
682
681
0
20
40
60
80
100
120
Horizontal Distance (ft.)

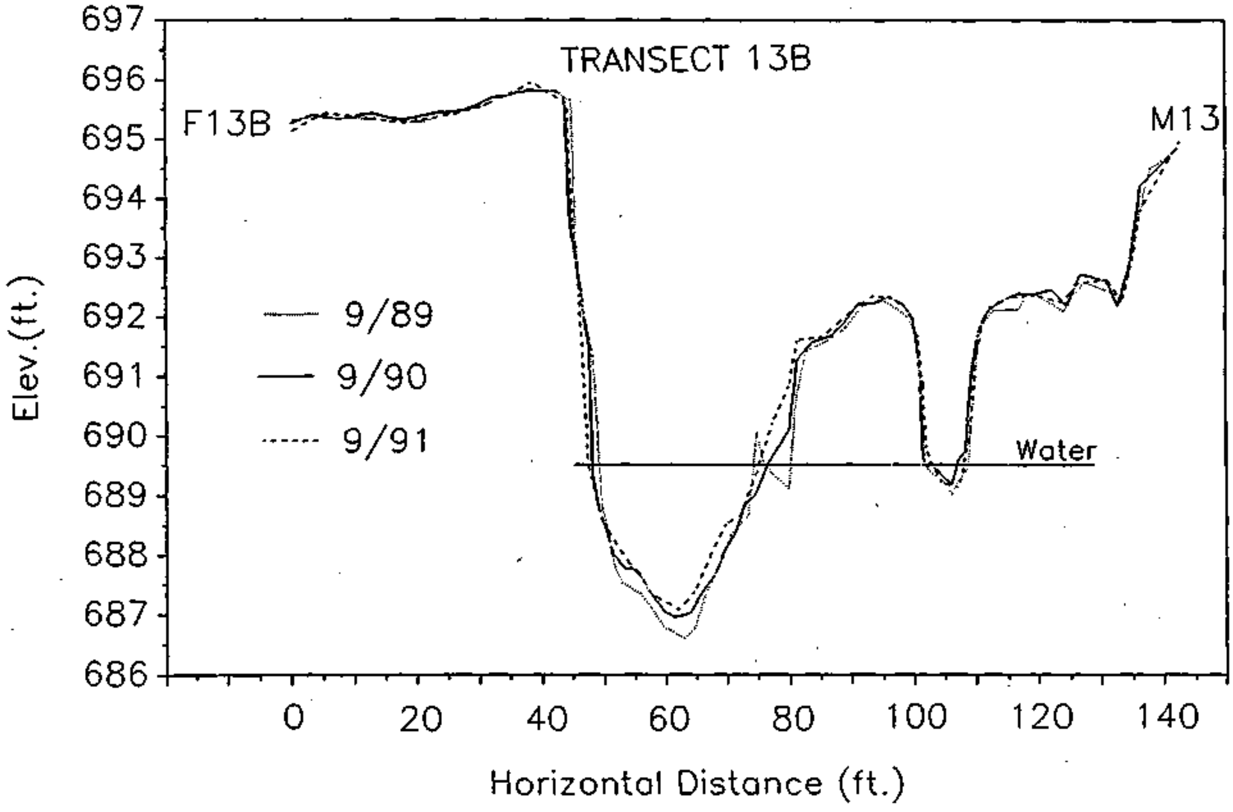

TRANSECT 9
F9
M9
9/89
9/90
9/91
Water
Elev.(ft.)
693
692
691
690
689
688
687
686
685
684
683
0
20
40
60
80
Horizontal Distance (ft.)

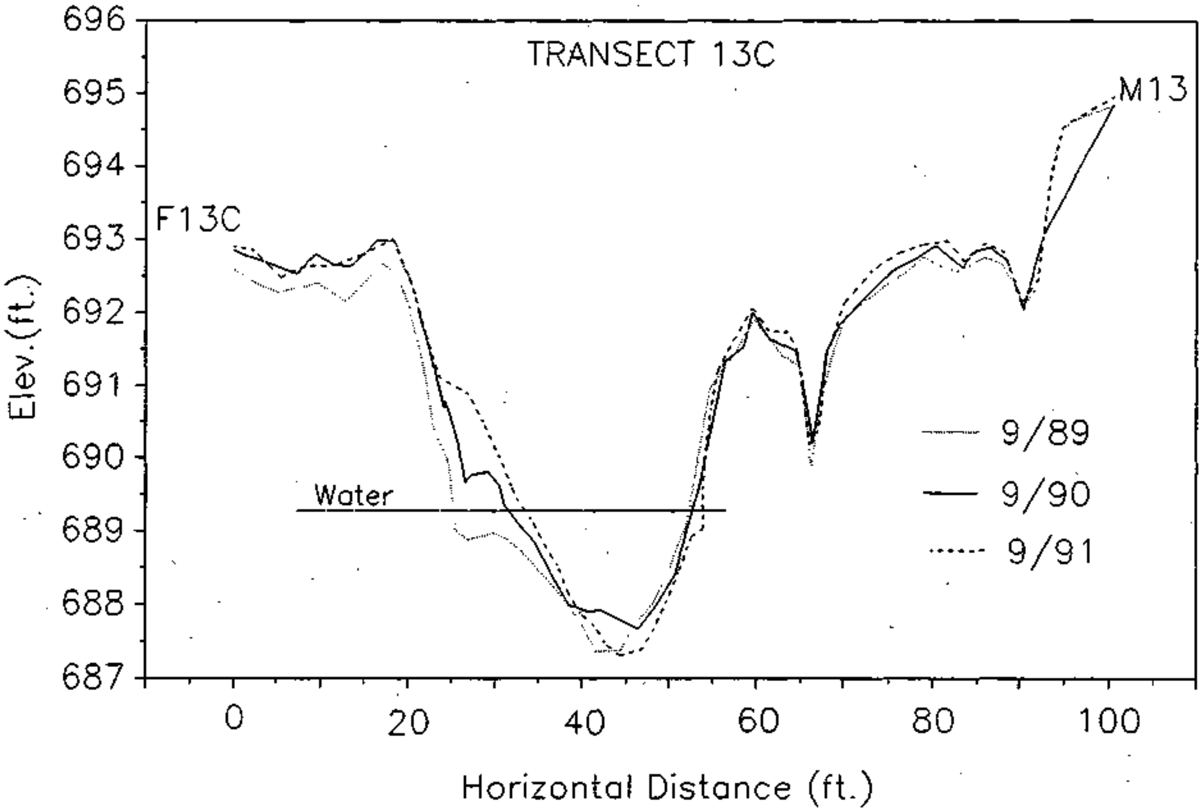

TRANSECT 10
M10
F10
9/89
9/90
9/91
Water
Elev.(ft.)
691
690
689
688
687
686
685
684
683
0
20
40
60
80
Horizontal Distance (ft.)

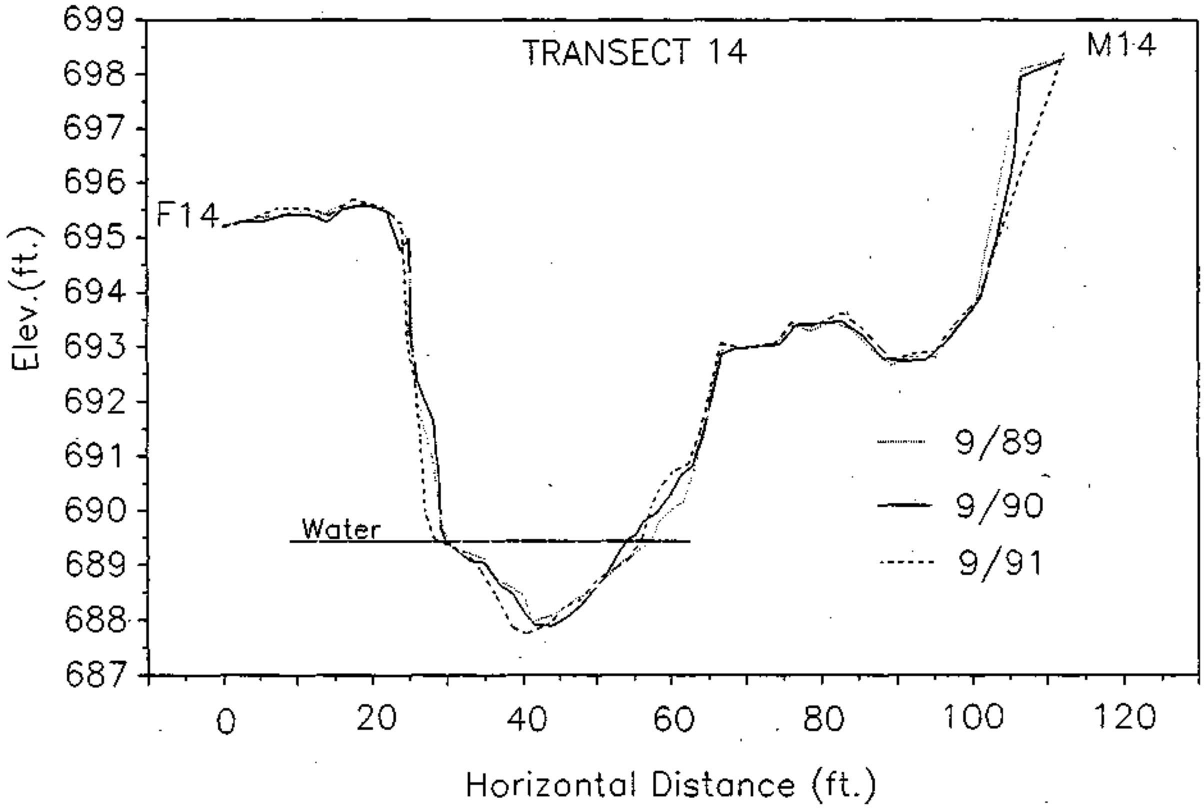

TRANSECT 11
M11
F11
Water
9/89
9/90
9/91
Elev. (ft.)
695
694
693
692
691
690
689
688
687
686
0
20
40
60
80
Horizontal Distance (ft.)

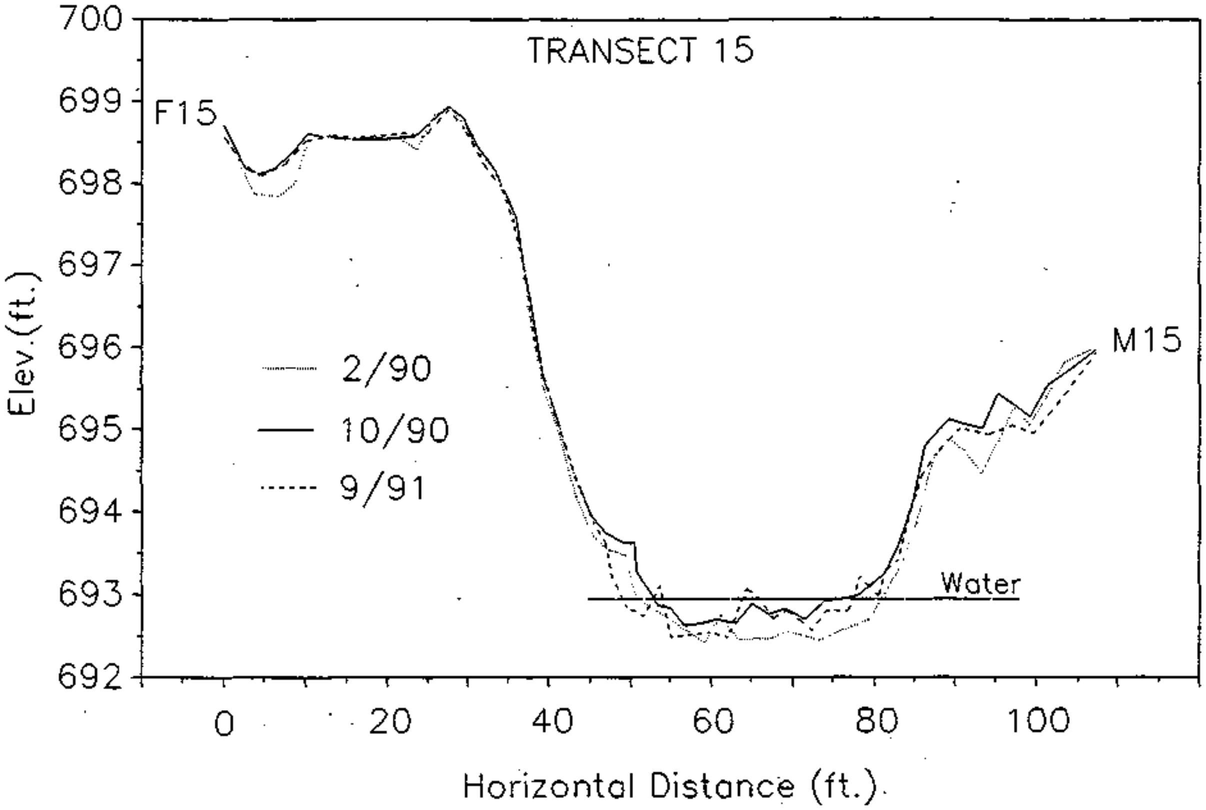

TRANSECT 12
M12
F12
Water
9/89
9/90
9/91
Elev. (ft.)
696
695
694
693
692
691
690
689
688
687
686
0
20
40
60
80
Horizontal Distance (ft.)

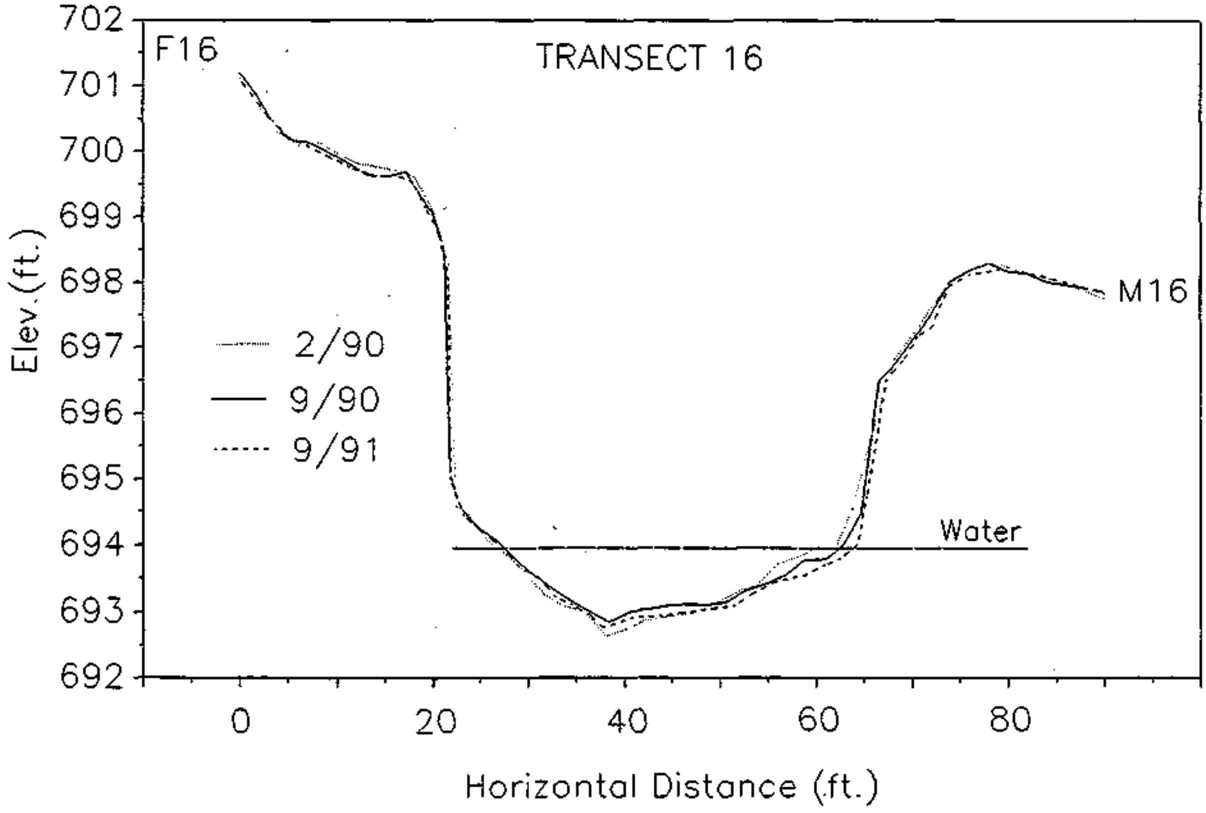

TRANSECT 13A
F13A
M13
Water
9/89
9/90
9/91
Elev.(ft.)
696
695
694
693
692
691
690
689
688
687
686
0
20
40
60
80
100
120
140
Horizontal Distance (ft.)

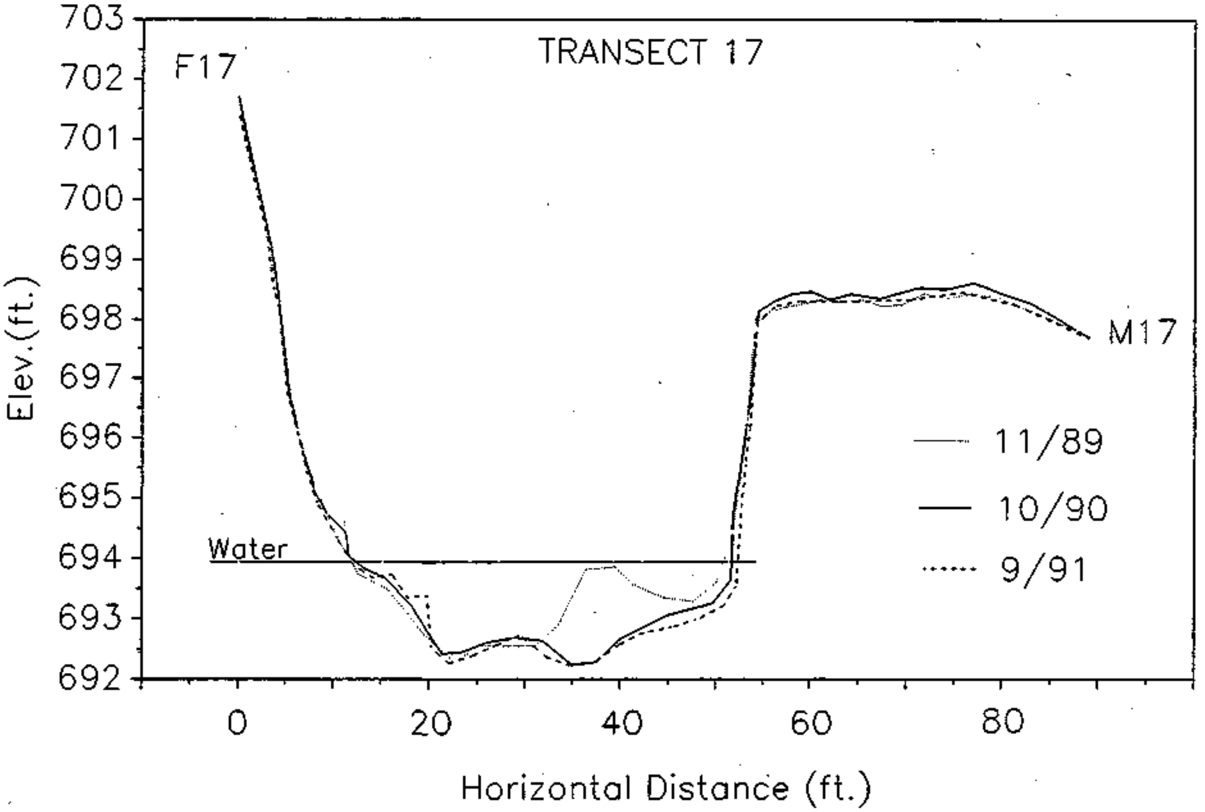

TRANSECT 13B
F13B
M13
Water
9/89
9/90
9/91
Elev.(ft.)
697
696
695
694
693
692
691
690
689
688
687
686
0
20
40
60
80
100
120
140
Horizontal Distance (ft.)

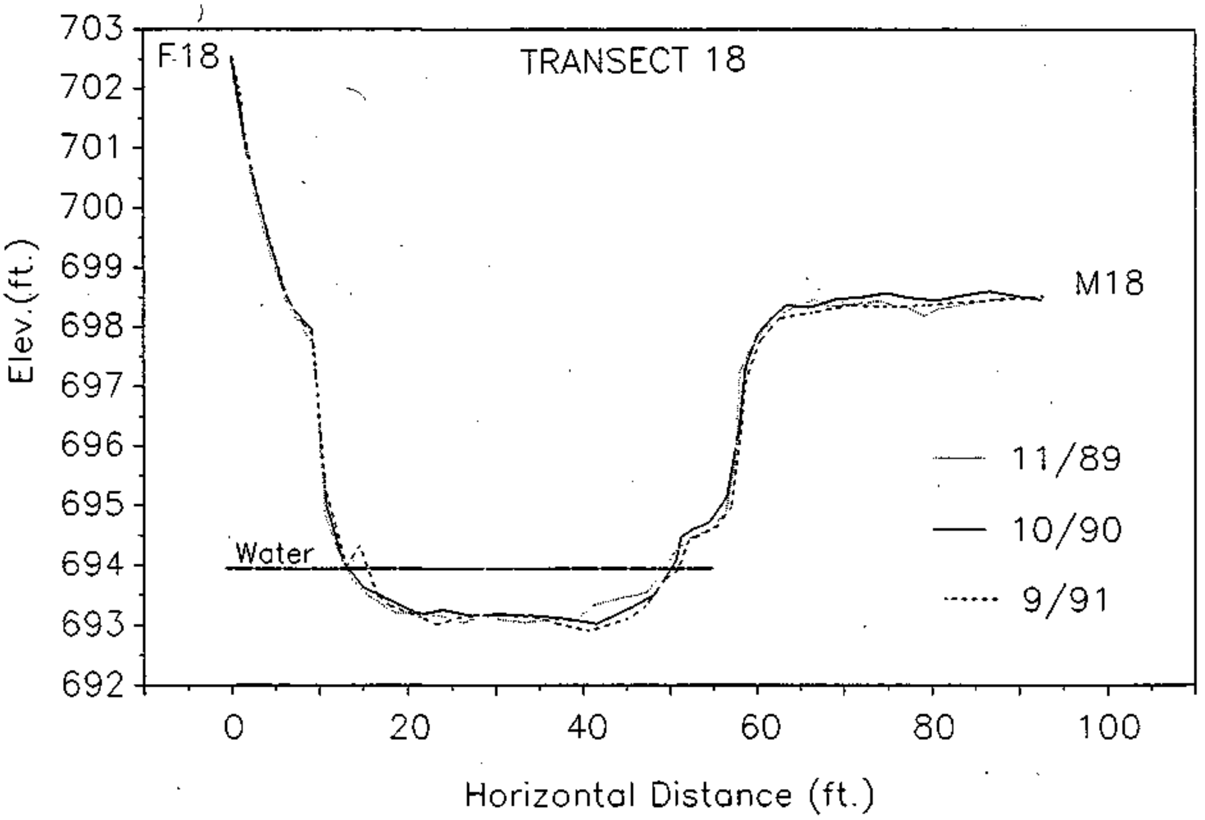

TRANSECT 13C
Elev. (ft.)
696
695
694
693
692
691
690
689
688
687
Horizontal Distance (ft.)
0
20
40
60
80
100
F13C
M13
Water
9/89
9/90
9/91


TRANSECT 14
Elev. (ft.)
699
698
697
696
695
694
693
692
691
690
689
688
687
Horizontal Distance (ft.)
0
20
40
60
80
100
120
F14
M14
Water
9/89
9/90
9/91


TRANSECT 15
F15
M15
2/90
10/90
9/91
Water
Elev.(ft.)
700
699
698
697
696
695
694
693
692
0
20
40
60
80
100
Horizontal Distance (ft.)


TRANSECT 16
F16
M16
2/90
9/90
9/91
Water
Elev.(ft.)
702
701
700
699
698
697
696
695
694
693
692
0
20
40
60
80
Horizontal Distance (ft.)


TRANSECT 17
F17
M17
Water
Elev.(ft.)
703
702
701
700
699
698
697
696
695
694
693
692
0
20
40
60
80
Horizontal Distance (ft.)
11/89
10/90
9/91


TRANSECT 18
F18
M18
Water
Elev.(ft.)
703
702
701
700
699
698
697
696
695
694
693
692
0
20
40
60
80
100
Horizontal Distance (ft.)
11/89
10/90
9/91