Fishery Interim Summary Report Series No. 08-02

South Bog Stream Brook Trout Habitat Restoration

By Forrest R. Bonney

Caring for Maine's Outdoor Future

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SOUTH BOG STREAM BROOK TROUT HABITAT RESTORATION INTERIM SUMMARY REPORT NO. 3 (2003-2007)

SUMMARY

South Bog Stream, a tributary to Rangeley Lake in Western Maine, provides habitat for wild brook trout (*Salvelinus fontinalis*) and, to a lesser extent, landlocked salmon (*Salmo salar*). The lower portion of the stream historically served as spawning and nursery habitat for Rangeley Lake's salmonid population.

A survey of South Bog Stream conducted in 2001 indicated a lack of deep pools, which provide critical adult brook trout habitat. Consequently, a program was undertaken in 2004 to restore pools to that portion of the stream proximate to South Shore Drive with the goal of increasing the contribution of stream-reared brook trout to the lake. Three stream restoration projects were implemented from 2004-2007 along a 1,900 foot-long reach two miles upstream of Rangeley Lake. The study reach is monitored annually to determine the efficacy of the projects in providing improved brook trout habitat as well as to determine whether restoration efforts, including reconstructed pools, retain their form and function in the face of high flows. This report explains the parameters chosen to evaluate the project and summarizes the results of the first four years of measurements. It will be necessary to collect several years' more data to know whether these projects are successful biologically and are resilient to stream flows.

KEY WORDS: AGE & GROWTH, HABITAT EVALUATION, STREAM, HABITAT IMPROVEMENT, POPULATION ESTIMATE, WATER QUALITY

INTRODUCTION

Brook trout provide the primary sport fishery in South Bog Stream, a tributary to Rangeley Lake in Franklin County (Figures 1 & 2). Although the stream has suitable water quality for trout (Table 1), there has been a decline in both the quality of the habitat and the fishery in recent decades. In response, a physical and biological survey of South Bog Stream was conducted by Regional staff and volunteers during the summer of 2001. This survey was conducted to quantify brook trout habitat and to document habitat degradation. The survey demonstrated the need to restore reaches of the stream to improve brook trout habitat. A restoration program was initiated in 2004 and is described herein.

A description of the drainage, histories of land use, fisheries management, and stream surveys, as well as information on geomorphic assessments and water classification, were presented in Interim Summary Reports 1 and 2.

HABITAT RESTORATION

Three sections of South Bog Stream proximate to South Shore Drive were chosen for restoration work that was completed from 2004 to 2007:

- **Upper Section**: Stream restoration work designed by Parish Geomorphic was completed from August 16-18, 2005 by M&H Logging of Rangeley. This phase of work extended from the South Shore Road Bridge to 258 feet upstream and consisted of reshaping the channel and gravel bar to adjust the width-to-depth ratio and slope to facilitate water and sediment transport through the reach. The slope was established by a series of keystone structures which, through scour, create a series of pool. Also, the aggraded bar was lowered to facilitate high flow events through the bridge, and root wads were added to protect the outside bank from erosion. This work was funded by the Maine Department of Transportation as mitigation for wetland impacts associated with the rebuilding of U.S. Route 4 in Phillips and Madrid. Results are reported in separate annual reports as an MDOT monitoring requirement.

- **Middle Section**: This reach extended downstream from the South Shore Drive bridge. Work was completed August 21-25, 2006, by M&H Logging of Rangeley under the direction of Field Geology Services. This, the third and final restored section, extended approximately 600 feet. This work was funded by the FERC Upper and Middle Settlement Restoration Fund and consisted of the following work:
  - Construction of three rock weirs. These are large, V-shaped structures that extend upstream from each bank, thus concentrating the flow by directing it toward the stream center, and accelerating it to scour a large pool below the structure to enhance adult brook trout habitat. The weirs were constructed of rocks up to 5 feet in length to resist movement during high flows.
  - Placement of 15 large logs to narrow over-widened stream reaches at the upstream and downstream sections of the middle project area. All logs were cabled to boulders so that they will remain in place during high flows. Their function is to trap silt and sediment along the steams' perimeter, thereby narrowing the channel and concentrating the flow.

- **Lower Section**: This section began 1,524 feet downstream of South Shore Drive bridge and extended 158 feet. On August 23 and 24, 2004, M & H Logging, Rangeley, installed five paired log deflectors in this reach. Parish Geomorphic designed the structures and oversaw installation. This work was funded by grants from the Trout and Salmon Foundation, the Rangeley Region Guides' and Sportsmen's Association, and Trout Unlimited. The log deflectors are constructed of cedar logs and are 'V' shaped with the point directed into the flow. They were placed approximately across from each other with the intent of narrowing the stream, concentrating the flow, and scouring pools. Pools were created downstream of the log deflectors by removing bottom materials with an excavator and using the spoil to fill behind the log deflectors. Annual monitoring revealed that the pools created coincident with the log deflectors were slowly filling in, indicating that the constricted flow was not effective in maintaining depth by scour. As a result, three rock weirs (described above) designed by Field Geology Services were constructed August 20-24, 2007, at the site of the lowermost deflectors and immediately downstream to reestablish effective pools.

PROJECT MONITORING

The Fisheries Division of the Maine Department of Inland Fisheries and Wildlife is responsible for developing and implementing project monitoring. Several methodologies are being used to evaluate the performance of the restoration projects, including measurements of both physical and biological parameters. The methodologies that prove effective will be retained and possibly applied to other projects statewide.

Quantifiable performance evaluation of a variety of treatment techniques with limited resources has proved to be challenging. Annual measurements of cross sectional transects are effective in monitoring pool depths of the log deflectors and rock weirs, as well as overall stream response as measured at control sites. The evaluation of the keystone riffle/pool sequence requires very detailed measurements because pools are small and numerous. The measurement of the thalweg and other indicators at 5-foot increments, initiated in 2007, has proven to be the most effective measurement method to date. The performance of logs with attached rootwads in trapping sediment is perhaps best monitored by annual photo documentation.

Geomorphic assessment

Geomorphic assessment consisted of both longitudinal (along the channel) and cross-sectional stream measurements for the length of the study area, a total of 1,730 feet (Figure 3; Tables 2, 3, 4, 7, 8, 9; Appendices A and B). These measurements monitor both lateral and elevational changes in the stream channel and are repeated annually to determine changes in the slope, width, and depth of the stream. In addition to 14 cross sectional transects located at the restoration sites, seven additional transects are measured upstream, between, and downstream of the restoration sites as controls. Pebble counts are made annually at all transect sites to monitor changes in substrate size over time (Tables 5 and 6). Transects were established at the Upper and Middle restoration sites two years prior to the construction phase; no measurements were taken at the Lower restoration site or at some of the weir sites prior to construction. Photographs were taken at the transects looking both upstream and downstream; separate photographs were taken of the structures (Appendices C and D).

Fish species complex and abundance

Four reaches (totaling 623 linear feet) have been electrofished to date (Table 10). In addition to brook trout, four other fish species have been sampled (Table 11). Brook trout have accounted for 56% of the number of fish sampled. As additional data are gathered, we will evaluate the numbers of fish caught in each treatment area for changes in species abundance and in brook trout age composition.

Macroinvertebrate assessment

Aquatic insects were sampled approximately 100 feet upstream of the South Shore Drive bridge in the summers of 2003, 2004, and 2006 (Table 12). Samples were collected at five locations per event with a 500-micron mesh kick net. The dominance of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddis flies) is indicative of good water quality. Plecoptera in particular require cold water. We anticipate that changes in aquatic insect diversity will correlate to changes in water velocity and/or substrate size.

RESULTS AND DISCUSSION

Monitoring is ongoing and only preliminary results have been determined to date. The upper (keystone) treatment has retained its formation after two years in place and has proved resistant to high flows and effective in concentrating low flows, providing an active flood plain, maintaining a favorable width-to-depth ratio, and providing shallow pools for brook trout. A layer of topsoil applied to the newly-constructed floodplain eroded substantially during storm events that occurred within weeks of placement (first photo, Appendix D). Although the loss of this soil unfortunately added sediment to the stream, the structural integrity of the keystone treatment was not compromised.

The four rock weirs immediately downstream of the bridge have been effective in maintaining pools of several feet in depth and have retained their form after one year in place. The associated root wads are effective in encouraging pool scour and provide excellent cover for brook trout. The logs positioned at the first meander bend downstream of the bridge have been effective in trapping sediment. The logs on the overwidened reach located 850 downstream of the bridge have not, to date, been effective in trapping sediment but remain anchored in place.

The log deflectors constructed 1,650 feet downstream of the bridge have trapped sediment along the stream edges and have maintained pools to an extent, but annual monitoring revealed that the pools were slowly filling in. As a result, two rock weirs were constructed among the log deflectors and an additional one was constructed immediately downstream in 2007 to add additional pools to the reach. Cross sectional transects were constructed to monitor these structures.

RECOMMENDATIONS

Overall, a variety of treatments along an 1,800-foot-long reach of South Bog Stream have maintained their form after at least one year in place, but further evaluation is required to determine their efficacy in improving brook trout habitat. To that end, we recommend the following sampling regime:

- Continue annual longitudinal and cross-sectional sampling as outlined above, including annual photo-documentation at each transect and each structure. An annual photographic record of those structures that are difficult to physically measure (e.g., the amount of silt trapped by logs) may be the most efficient method of monitoring changes over time.
- Refine electrofishing results by quantifying the number of fish associated with each structure, rather than by reach only.
- Present results of measurements in an annual report; evaluate significant changes in habitat and fish populations in a final report.

ACKNOWLEDGMENTS

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- FishAmerica Foundation
- Rangeley Region Guides and Sportsman's Association
- Trout and Salmon Foundation
- Trout Unlimited
- U. S. Fish and Wildlife Service
- Upper/Middle Dams Relicensing Settlement Committee

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Figure 1. South Bog Stream drainage.

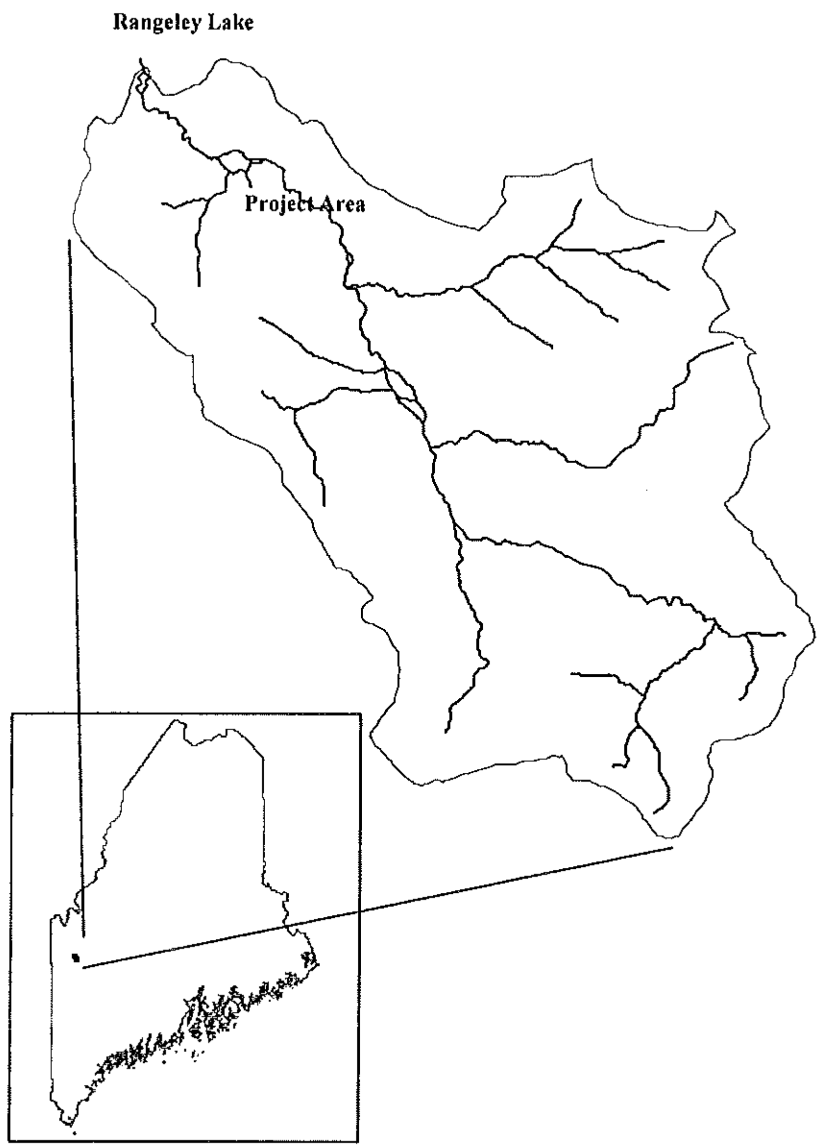


Figure 2. Location of stream restoration project.

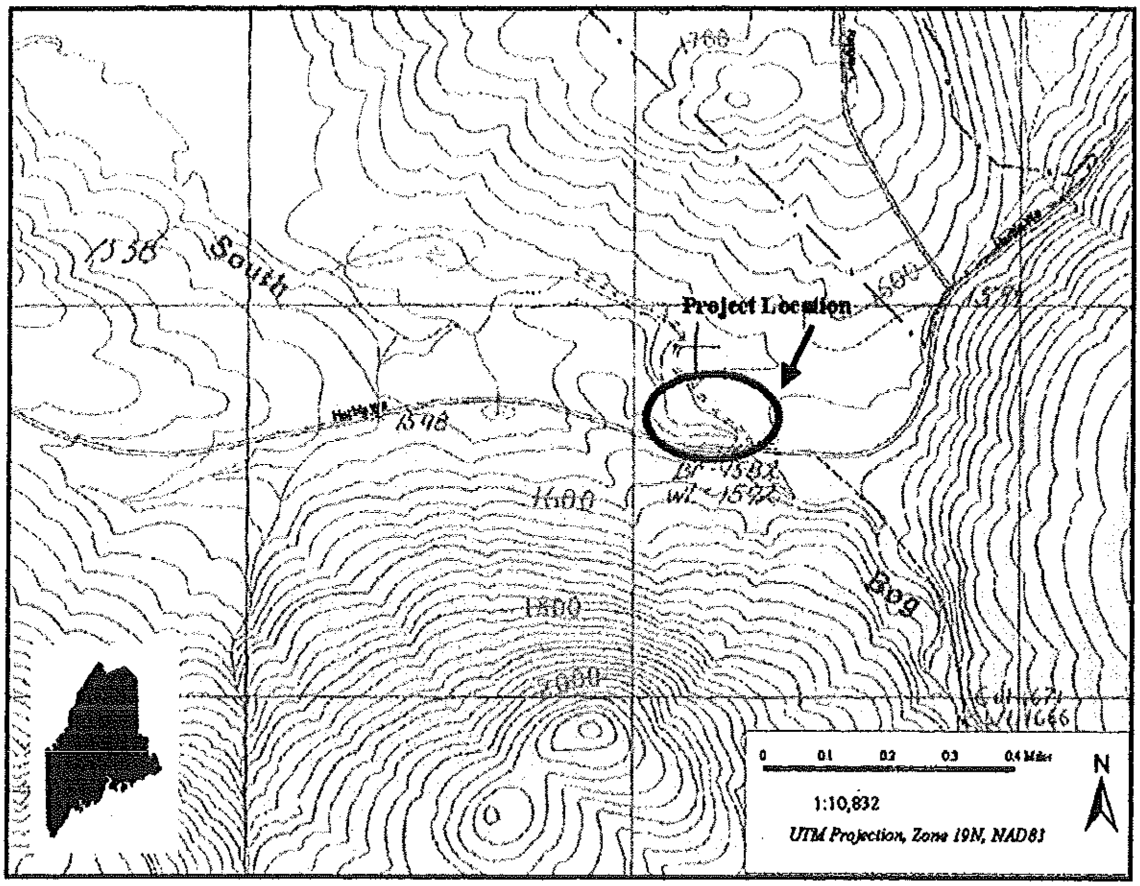


Table 1. Instantaneous water quality conducted 750 feet downstream of the South Shore Drive bridge.

Date	Transect	Temperature (°F)	Oxygen(mg/L)	pH	Alkalinity[1]	Conductivity[2]
8/9/2005	7	68	8.6	6.6	5	27
8/18/2006	7	57	10.5	6.2	4	24
7/16/2007	7	61	7.2	6.5	8	18

[1] A measure of the capacity of the substances dissolved in the water to neutralize acid.
[2] A measure of water's ability to conduct electrical current.

Figure 3. Location of transects (T). Numbers indicate distance in feet from uppermost transect. "W" indicates location of rock Weir; "D" indicates log Deflectors, and "L" indicates Logs with root wads.

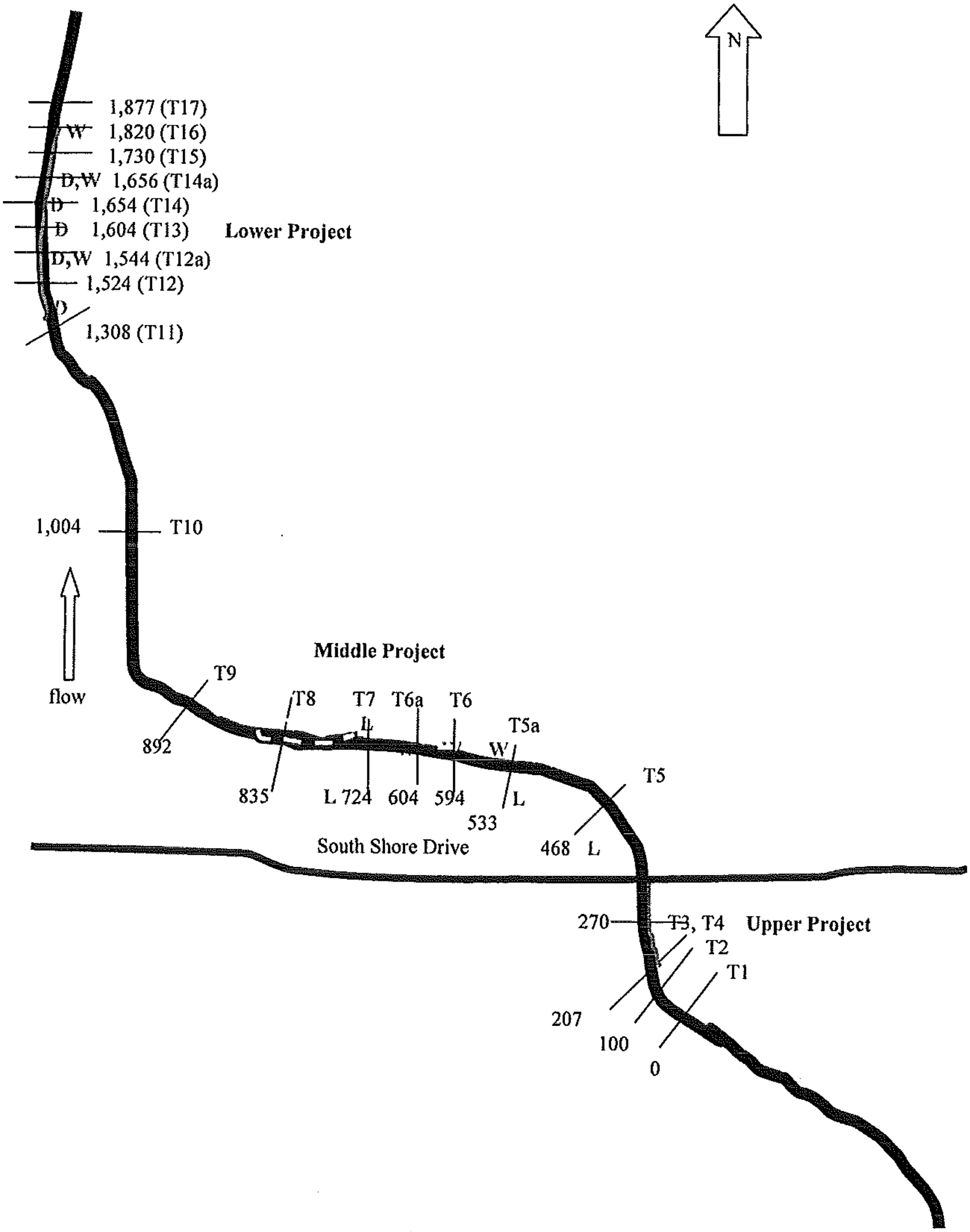


Table 2. Transect summary beginning 358 ft. upstream of South Shore Drive bridge. All measurements in feet.

				GPS coordinates, left pin		
Transect	Station[3]	Left pin Elev.	Flow type	North	West	Comments
1	0	103.04	Riffle	19T 0365399	4974763	Control
2	100	99.65	Riffle			
3	207	99.05	Riffle			**Begin keystone riffle/pool**
4	270	102.18	Riffle	19T 0365316	4974827	
	358		Riffle			Bridge; **end riffle/pool**
	392		Riffle			Lower end bridge
5	468	95.18	Riffle	19T 0365285	4974888	Begin middle project
5a	533		Pool			Mid pool, **Weir 1**
6	594	91.93	Riffle	19T 0365266	4974890	Mid pool, **Weir 2**
6a	703		Pool			Mid pool, **Weir 3**
7	724	91.05	Riffle	19T 0365204	4974894	
8	835	88.45	Riffle	19T 0365178	4974906	Split channel
9	892	87.91	Run	19T 0365156	4974907	Split channel
10	1,004	86.04	Riffle	19T 0365148	4974910	End middle project
	1,125					Begin mass wasting
	1,205					End mass wasting
11	1,308	82.58	Pool	19T 0365132	4975044	
	1,518		Riffle			**Log deflectors**
12	1,524	80.68	Riffle	19T 0365840	4975044	
12a	1,540		Pool			**Weir 1**
	1,544		Riffle/head of pool			**Log deflectors**
	1,593		Head of pool			**Log deflectors**
13	1,604	80.95	Pool	19T 0365067	4975064	
	1,627		Foot of pool			
	1,646		Head of pool			**Log deflectors**
14	1,654	80.28	Head of pool	19T 0365047	4975082	
14a	1,656		Pool			**Weir 2**
	1,676		Pool			**Log deflectors**
15	1,730	78.90	Run	19T 0365088	4975099	
16	1,820		Pool			**Weir 3**
17	1,877		Riffle			Control

[3] Distance in feet from uppermost transect.

Table 3. Longitudinal profile, beginning 358 feet upstream of South Shore Drive bridge. All measurements in feet.

Year	Station	Left top of bank	Water surface	Thalweg	Bankfull elevation	Physical feature
2003	100		96.83	95.51	98.65	Riffle
	175		95.70	94.21	96.64	End riffle; begin pool
	207		95.53	94.22	96.74	Top riffle
	350		92.37	89.97		End riffle; begin pool
	358					Upper end of bridge
	392					Lower end of bridge
	450		92.40	90.48	93.92	Top riffle
	763		85.95	84.28	87.27	End riffle; begin pool
	819		85.90	84.8	86.62	Top riffle
	870		84.17	82.77	85.63	End riffle; begin pool
	920		84.10	82.98	85.28	Top riffle
	982		82.42	81.37	83.14	End riffle; begin pool
	1,004		82.36	81.38	83.72	
2005	0	103.23	99.16	98.33	99.53	Riffle
	50	101.5	97.3	96.34	98.75	Riffle
	100	99.6	96.46	95.31	97.74	Run
	150		95.75	94.58	96.75	
	200		95.35	93.47	96.76	Pool
	250	98.65	94.79	93.87	97.27	
	300	96.1	93.66	92.75	95.64	Riffle
	350		92.05	90.73		Run
	358					Upper end of bridge
	392					Lower end of bridge
	400		91.86	90.51		
	450	94.44	91.74	90.79		Riffle
2006	100	96.70	95.00	98.69		Riffle
	150	96.15	94.21	97.86		Riffle
	170	95.26	94.71	96.91		Head of pool; **begin project**
	200	95.21	92.91	97.01		Riffle
	216	95.16	93.71	97.06		Foot of pool
	250	94.16	93.01	96.31		Riffle
	257	93.75	92.79	96.21		Riffle; Transect 3
	300	93.46	91.70	92.65		Riffle
	314	93.20	92.37	92.37		Riffle; Transect 4
	350	92.40	91.50	93.91		Riffle
	375	91.96	91.11	93.66		Riffle; upper end of bridge; **end project.**

Table 3 (con't). Longitudinal profile, beginning 358 feet upstream of South Shore Drive bridge. All measurements in feet.

Year	Station	Bankfull elevation	Water surface	Thalweg	Physical feature
2007	100	98.92	96.86	95.32	Riffle
	105	98.95	96.7	95.2	Pool
	110	99.04	96.62	94.96	Pool
	115	98.9	96.4	95.2	Pool
	120	98.75	96.24	95.4	Pool
	125	98.4	96.1	95.2	Riffle
	130	98.24	95.98	94.98	Riffle
	135	98	95.9	94.75	Riffle
	140	97.86	95.86	94.68	Pool
	145	97.4	95.85	94.3	Pool
	150	97	95.83	94.9	Pool
	155	96.95	95.8	94.7	Riffle
	160	96.92	95.76	94.52	Riffle
	165	96.8	95.65	94.54	Riffle
	170	96.76	95.58	94.56	Riffle; begin keystone project
	175	96.72	95.4	94.76	Riffle
	180	96.68	95.32	94.02	Constructed pool
	185	96.54	95.32	93.96	Constructed pool
	190	96.62	95.34	93.06	Constructed pool
	195	96.63	95.32	93.15	Constructed pool
	200	96.64	95.3	93.28	Constructed pool
	205	96.98	95.32	93.66	Pool
	210	96.94	95.34	93.62	Pool
	215	96.94	95.26	94.44	Pool
	220	96.78	95.28	94.42	Riffle
	225	96.88	95.2	93.52	Riffle
	230	96.62	94.94	94.19	Pool
	235	96.5	94.64	93.8	Pool
	240	96.46	94.32	93.08	Pool
	245	96.56	94.32	92.74	Riffle
	250	96.24	94.24	93.18	Pool
	255	96.28	94.22	92.86	Pool; Transect 3
	260	96.3	94.04	92.9	Pool
	265	96.26	94.06	92.98	Riffle
	270	96.18	93.9	92.66	Riffle
	275	96.24	93.82	92.58	Riffle
	280	96.3	93.82	92.66	Pool
	285	96.12	93.8	92.66	Pool
	290	96.36	93.74	92.74	Pool
	295	96.04	93.72	92.78	Pool
	300	95.96	93.62	92.22	Pool
	305	95.84	93.4	92.18	Riffle
	310	95.74	93.34	92.42	Pool
	315	95.48	93.26	92.23	Pool; Transect 4
	320	95.6	93.02	92.12	Pool
	325	95.28	92.9	91.96	Riffle
	330	95.48	92.88	91.62	Riffle

Table 3 (con't). Longitudinal profile, beginning 358 feet upstream of South Shore Drive bridge. All measurements in feet.

Year	Station	Bankfull elevation	Water surface	Thalweg	Physical feature
2007	335	95.36	92.78	91.78	Riffle
(con't)	340	95.34	92.58	91.78	Riffle
	345	95.02	92.58	91.4	Riffle
	350	94.72	92.5	91.24	**Constructed pool**
	355	94.72	92.4	91.4	**Constructed pool**
	360	94.38	92.26	91.72	**Constructed pool**
	365	94.52	92.22	91.44	Riffle; upper end of bridge; **end project.**

Table 4. Cross sectional transect summary by transect and year. Post-treatment data bolded.

Transect	Station	Flow type	Year	Treatment phase	Bankfull width (ft.)	Mean depth (ft.)	Xc area (ft^2)	Width/ depth ratio	Treatment section
1	0	Riffle	2005	Control	42	4.34	182	9.7	Upper
			2006	Control	42	4.46	187	9.4	Upper
			2007	Control	42	4.39	184	9.6	Upper
2	100	Riffle	2004	Control	37	3.33	123	11.1	Upper
			2005	Control	37	3.31	122	11.2	Upper
			2006	Control	37	4.65	119	11.5	Upper
			2007	Control	37	3.15	117	11.7	Upper
3	207	Riffle	2004	Pre	73	2.16	158	33.8	Upper
			2005	Pre	73	2.17	158	33.6	Upper
			2005	**Post**	**17**	**3.67**	**62**	**4.6**	Upper
			2006	**Post**	**26**	**3.44**	**89**	**7.6**	Upper
			2007	**Post**	**29**	**3.27**	**95**	**8.9**	Upper
4	270	Riffle	2005	Pre	115	2.57	296	44.7	Upper
			2005	**Post**	**107**	**3.03**	**324**	**4.6**	Upper
			2006	**Post**	**36**	**4.64**	**167**	**7.8**	Upper
			2007	**Post**	**36**	**3.96**	**143**	**7.0**	Upper
5	468	Riffle	2004	Control	33	3.90	129	8.5	Middle
			2005	Control	33	3.97	131	8.3	Middle
			2006	Control	33	4.07	134	8.1	Middle
			2007	Control	33	3.79	125	8.7	Middle
5a	533	Weir 1	**2006**	**Post**	**19**	**3.44**	**65**	**5.5**	Middle
			2007	**Post**	**19**	**4.08**	**7.7**	**4.7**	Middle
6	594	Riffle	2004	Pre	35	3.73	131	9.4	Middle
			2005	Pre	35	3.69	129	9.5	Middle
			2006	Pre	35	3.41	119	10.3	Middle
		Weir 2	**2006**	**Post**	**36**	**3.32**	**120**	**10.8**	Middle
			2007	**Post**	**36**	**3.48**	**125**	**10.3**	Middle
6a	703	Weir 3	**2006**	**Post**	**24**	**2.78**	**67**	**8.6**	Middle
			2007	**Post**	**24**	**3.35**	**80**	**7.2**	Middle
7	724	Riffle	2004	Control	62	4.65	288	13.3	Middle
			2005	Control	62	4.64	288	13.4	Middle
			2006	Control	62	4.85	301	12.8	Middle
			2007	Control	62	4.75	295	13.1	Middle
8	835	Riffle	2004	Control	88	3.23	284	27.2	Middle
			2005	Control	88	3.21	282	27.4	Middle
			2006	Control	88	3.38	297	26.0	Middle
			2007	Control	88	3.34	294	26.3	Middle

Table 4. Cross sectional transect summary by transect and year (con't).

Transect	Station	Flow type	Year	Treatment phase	Bankfull width (ft.)	Mean depth (ft.)	Xc area (ft²)	Width/ depth ratio	Treatment section
9	892	Run	2004	Control	69	3.81	263	18.1	Middle
			2005	Control	69	3.79	262	18.2	Middle
			2006	Control	.	.	.	.	Middle
			2007	Control	69	4.08	282	16.9	Middle
10	1,004	Riffle	2004	Control	25	4.05	101	6.2	Middle
			2005	Control	25	3.97	99	6.3	Middle
			2006	Control	25	3.95	99	6.3	Middle
			2007	Control	25	3.94	99	6.3	Middle
11	1,308	Pool	2004	Control	41	4.11	169	10.0	Middle
			2005	Control	41	4.09	168	10.0	Middle
			2006	Control	41	4.1	168	10.0	Middle
			2007	Control	41	4.07	167	10.1	Middle
12	1,524	Head of pool	**2004**	**Post**	**47**	**2.36**	**111**	**19.9**	Lower
			2005	**Post**	**47**	**2.88**	**135**	**16.3**	Lower
			2006	**Post**	**47**	**2.79**	**131**	**17.2**	Lower
			2007	**Post**	**47**	**2.96**	**139**	**15.8**	Lower
12a	1,544	Pool	**2007**	**Post**	**30**	**4.52**	**137**	**6.6**	Lower
13	1,604	Pool	**2004**	**Post**	**28**	**4.91**	**137**	**5.7**	Lower
			2005	**Post**	**28**	**4.95**	**139**	**5.7**	Lower
			2006	**Post**	**29**	**4.90**	**142**	**5.9**	Lower
			2007	**Post**	**29**	**5.01**	**145**	**5.8**	Lower
14	1,654	Head of pool	**2004**	**Post**	**35**	**4.88**	**171**	**7.2**	Lower
			2005	**Post**	**35**	**4.24**	**148**	**8.3**	Lower
			2006	**Post**	**35**	**4.06**	**142**	**8.6**	Lower
			2007	**Post**	**35**	**4.63**	**162**	**7.6**	Lower
14a	1,656	Pool	**2007**	**Post**	**29**	**2.35**	**68**	**12.3**	Lower
15	1,730	Riffle	2004	Control	38	3.80	144	10.0	Lower
			2005	Control	38	3.90	148	9.7	Lower
			2006	Control	38	3.85	146	9.9	Lower
			2007	Control	38	3.85	146	9.9	Lower
16	1,820	Pool	**2007**	**Post**	**26**	**3.64**	**95**	**7.1**	Lower
17	1,877	Riffle	2007	Control	45	3.21	144	14.0	Lower

Table 5. Pebble count summary by transect and year. Samples from treatment transects are bolded.

Transect	Station	Flow type	Year	Diameter (mm) percentiles[4]				
				D16	D35	D50	D84	D95
1	0	Riffle	2005	18	50	85	250	500
			2006	15	40	65	160	300
			2007	27	85	130	290	475
2	100	Riffle	2005	30	70	95	250	400
			2006	10	65	90	230	350
			2007	28	80	130	300	450
3	207	Riffle	2005	15	32	50	160	260
			2006	**38**	**65**	**80**	**180**	**260**
			2007	**14**	**75**	**150**	**250**	**350**
4	270	Riffle	2005	20	55	80	190	375
			2006	**40**	**65**	**70**	**140**	**230**
			2007	**18**	**53**	**94**	**210**	**375**
5	468	Riffle	2005	6	22	55	160	360
			2006	48	65	75	200	400
			2007	6	45	85	190	325
5a	533	Rock weir pool	**2007**	**28**	**140**	**250**	**450**	**700**
6	594	Riffle	2005	20	40	60	250	450
			2007	**14**	**95**	**140**	**350**	**650**
6a	703	Rock weir pool	**2007**	**32**	**115**	**175**	**325**	**500**
7	724	Riffle	2005	35	90	150	375	750
			2007	**28**	**65**	**125**	**325**	**600**
8	835	Riffle	2005	20	50	65	190	310
			2007	25	55	82	180	280
9	892	Run	2005	20	45	70	120	350
			2007	4	18	35	125	225
10	1,004	Riffle	2005	15	32	50	100	160
			2007	3	12	23	80	160
11	1,308	Pool	2005	5	20	40	200	320
			2006	25	60	75	150	240
			2007	3	15	35	130	350
12	1,524	Head of pool	**2005**	**27**	**47**	**70**	**170**	**270**
			2007	**3**	**10**	**28**	**140**	**255**
13	1,604	Pool	**2005**	**9**	**30**	**60**	**180**	**350**
			2006	**20**	**55**	**85**	**190**	**275**
			2007	**6**	**18**	**35**	**100**	**200**
14	1,654	Head of pool	**2005**	**7**	**30**	**50**	**150**	**310**
			2007	**3**	**10**	**23**	**80**	**150**
15	1,630	Riffle	2005	8	48	90	200	350
			2007	3	15	30	95	200

[4] Column figures represent the percent of the pebbles sampled that were equal to or smaller in size to the percentiles listed.

Table 6. Pebble count summary. Bolded values were taken post-treatment. Dominant particle-size class underlined.

Transect	Station	Flow type	Year	Particle-size class				
				Sands	Gravels	Cobble	Boulder	Bedrock
1	0	Riffle	2005	2	42	38	17	1
			2006	6	39	44	11	0
			2007	1	24	52	23	0
2	100	Riffle	2005	0	28	54	17	1
			2006	4	28	45	22	0
			2007	0	27	48	25	0
3	207	Riffle	2005	3	49	39	9	0
			2006	**0**	**27**	**65**	**8**	**0**
			2007	**0**	**29**	**47**	**24**	**0**
4	270	Riffle	2005	6	29	51	14	0
			2006	**0**	**38**	**56**	**6**	**0**
			2007	**3**	**29**	**49**	**19**	**0**
5	468	Riffle	2005	1	51	37	11	0
			2006	0	30	51	19	0
			2007	1	39	49	12	0
5a	533	Rock weir pool	**2007**	**0**	**21**	**29**	**50**	**0**
6	594	Riffle	2005	2	43	36	19	0
			2006	0	54	40	6	0
		Rock weir pool	**2007**	**2**	**20**	**42**	**32**	**0**
6a	703	Rock weir pool	**2007**	**0**	**22**	**42**	**36**	**0**
7	724	Riffle	2005	0	24	41	36	0
			2006	0	28	53	19	0
			2007	0	29	41	30	0
8	835	Riffle	2005	3	33	53	11	0
			2006	3	10	66	21	0
			2007	1	34	56	9	0
9	892	Run	2005	0	35	55	10	0
			2006	6	38	54	2	0
			2007	8	55	31	6	0
10	1,004	Riffle	2005	0	55	41	4	0
			2007	8	64	27	1	0
11	1,308	Pool	2005	5	48	33	14	0
			2006	6	25	63	6	0
			2007	7	56	28	9	0
12	1,524	Head of pool	**2005**	**0**	**43**	**48**	**9**	**0**
			2007	**12**	**51**	**29**	**8**	**0**
13	1,604	Pool	**2005**	**1**	**47**	**42**	**10**	**0**
			2006	**9**	**27**	**56**	**9**	**0**
			2007	**6**	**57**	**33**	**4**	**0**
14	1,654	Head of pool	**2005**	**3**	**50**	**38**	**9**	**0**
			2007	**8**	**63**	**26**	**3**	**0**
15	1,630	Riffle	2005	4	36	48	13	0
			2007	12	49	36	3	0

Table 7. Channel dimensions at transects.

Transect	Year	Treatment	Mean depth	Thalweg depth	Cross sectional area	Width to depth ratio
1	2005		4.34	4.83	182	9.7
	2006		4.46	5.11	187	9.4
	2007		4.39	4.93	184	9.6
2	2004		3.33	2.9	123	11.1
	2005		3.31	3.1	122	11.2
	2006		3.22	4.65	119	11.5
	2007		3.15	4.83	117	11.7
3	2004		2.16	4.04	158	33.8
	2005Before		2.17	4.09	158	33.6
	2005After	Keystones	3.67	4.75	62	4.6
	2006		3.44	4.91	89	7.6
	2007		3.27	4.86	95	8.9
4	2005Before		2.57	5.5	296	44.7
	2005After	Keystones	4.3	5.0	86	4.7
	2006		4.01	5.01	167	7.8
	2007		3.96	5.14	143	7.0
5	2004		3.9	5.69	129	8.5
	2005		3.97	5.23	131	8.3
	2006		4.07	5.18	134	8.1
	2007		3.79	5.10	125	8.7
5a	2006After	Rock weir	3.44	5.01	65	5.5
	2007		4.08	5.57	77	4.7
6	2004		3.73	4.96	131	9.4
	2005		3.69	5.02	129	9.5
	2006Before		3.41	4.62	119	10.3
	2006After	Rock weir	3.32	5.59	120	10.8
	2007		3.48	5.81	125	10.3
6a	2006After	Rock weir	2.78	4.65	67	8.6
	2007		3.35	4.43	80	7.2
7	2004	Logs	4.65	6.28	288	13.3
	2005		4.64	5.92	288	13.4
	2006		4.85	5.93	301	12.8
	2007		4.75	6.21	295	13.1
8	2004		3.23	5.16	284	27.2
	2005		3.21	5.04	282	27.4
	2006		3.38	4.54	297	26.0
	2007		3.34	5.15	294	26.3
9	2004		3.81	5.51	263	18.1
	2005		3.79	5.60	262	18.2
	2007		4.08	5.54	282	16.9
10	2004		4.05	4.73	101	6.2
	2005		3.97	4.61	99	6.3
	2006		3.95	4.58	99	6.3
	2007		3.94	4.31	99	6.3
11	2004		4.11	5.68	169	10.0
	2005		4.09	5.51	168	10.0
	2006		4.10	5.36	168	10.0
	2007		4.07	5.44	167	10.1
12	2004	Log def.	2.36	3.97	111	19.9

Table 7. Channel dimensions at transects (con't).

Transect	Year	Treatment	Mean depth	Thalweg depth	Cross sectional area	Width to depth ratio
12 (cont.)	2005		2.88	4.26	135	16.3
	2006		2.79	4.17	131	17.2
	2007		2.96	4.36	139	15.8
12a	2007After	Rock weir	4.52	7.08	137	6.6
13	2004	Log def.	4.91	6.27	137	5.7
	2005		4.95	6.66	139	5.7
	2006		4.90	6.75	142	5.9
	2007		5.01	6.87	145	5.8
14	2004	Log def.	4.88	6.62	171	7.2
	2005		4.24	5.49	148	8.3
	2006		4.06	5.07	142	8.6
	2007		4.63	5.86	162	7.6
14a	2007After	Rock weir	2.35	6.04	68	12.3
15	2004		3.8	4.75	144	10.0
	2005		3.9	4.5	148	9.7
	2006		3.85	4.75	146	9.9
	2007		3.85	4.43	146	9.9
16	2007After	Rock weir	3.64	6.45	95	7.1
17	2007		3.21	4.69	144	14.0

Table 8. Thalweg depths in feet at transects with treatments (B=before treatment; A=after treatment; KS=keystones; W=rock weir; Logs=logs with attached rootwads; LD=log deflectors).

	Transect No. and Treatment Type											
	3	4	5a	6	6a	7	12	12a	13	14	14a	16
Year	KS	KS	W	W	W	Logs	LD	W	LD	LD	W	W
2004B	4.04			4.96		6.28						
2004A							3.97		6.27	6.62		
2005B	4.09	5.50		5.02		5.92						
2005A	4.75	5.0					4.26		6.66	5.49		
2006B				4.62		5.93						
2006A	4.91	5.01	5.01	5.59	4.65		4.17		6.75	5.07		
2007A	.4.86	5.14	5.57	5.81	4.43	6.21	4.36	7.08	6.87	5.86	6.04	6.45

Table 9. Mean depths in feet at transects with treatments (B=before treatment; A=after treatment; KS=keystones; W=rock weir; Logs=logs with attached rootwads; LD=log deflectors).

	Transect No. and Treatment Type											
	3	4	5a	6	6a	7	12	12a	13	14	14a	16
Year	KS	KS	W	W	W	Logs	LD	W	LD	LD	W	W
2004B	2.16			3.73		4.65						
2004A							2.36		4.91	4.88		
2005B	2.17	2.57		3.69		4.64						
2005A	3.67	4.30					2.88		4.95	4.24		
2006B				3.41		4.85						
2006A	3.44	4.01	3.44	3.32	2.78		2.79		4.90	4.06		
2007A	3.27	3.96	4.08	3.48	3.35	4.75	2.96	4.52	5.01	4.63	2.35	3.64

Table 10. Fish species occurrence and abundance determined by one-run electrofishing. Bolded numbers represent post-restoration samples from treated reach.

Transects	Date	Length (ft.)	Area (ft.^{2})	Fish species abundance[5]							
				Brook trout[6]				Other fish species[7]			
				Small	Mid	Legal	All	BND	CCB	SCL	WHS
2-4	7/30/04	160	3,979	5.7	5.4	0.2	11.3	3.4	0.5	4.8	0.2
2-3	8/9/05	107	4,280	4.0	2.1	0	6.1	2.3	0	1.5	0
1-3	8/18/06	207	6,000	3.4	2.5	0.6	6.6	2.2	0.4	1.5	0
3-Bridge	**7/16/07**	**100**	**1,300**	**0**	**8.3**	**0.7**	**9.0**	**0**	**0**	**2.8**	**0**
7-8	7/30/04	111	3,750	3.6	1.2	0	4.8	4.5	1.9	4.5	0
7-8	8/9/05	111	4,329	6.2	5.4	0.2	11.8	2.9	0.2	2.5	0
7-8	8/18/06	111	3,775	7.4	1.9	0.2	9.5	6.4	1.4	1.9	0
5-6	**7/16/07**	**277**	**4,986**	**1.4**	**3.2**	**0.4**	**5.1**	**2.0**	**1.3**	**0**	**0**
7-8	**7/16/07**	**100**	**2,900**	**1.6**	**5.0**	**0**	**6.5**	**5.6**	**0.9**	**1.6**	**0.3**
12-14	**8/9/05**	**130**	**4,030**	**3.8**	**5.1**	**0.2**	**9.5**	**3.6**	**0.2**	**1.8**	**0**
12-14	**8/18/06**	**130**	**2,680**				**6.9**				
12-13	**7/16/07**	**100**	**2,060**	**4.8**	**3.9**	**0**	**8.7**	**4.8**	**0.4**	**1.7**	**0**

Table 11. Fish species occurrence, South Bog Stream.

Common name	Scientific name
Brook trout	*Salvelinus fontinalis*
Blacknose dace	*Rhinichthys atratulus*
Creek chub	*Semotilus corporalis*
Pearl dace	*Semotilus margarita*
Slimy sculpin	*Cottus cognatus*
White sucker	*Catostomus commersoni*

[5] Number per 100 yd.^{2}

[6] Small = <3.5" (young of year); mid = 3.5 to 6"; legal = 6" and longer.

[7] BND = blacknose dace; CCB = creek chub; SCL = slimy sculpin; WHS = white sucker.

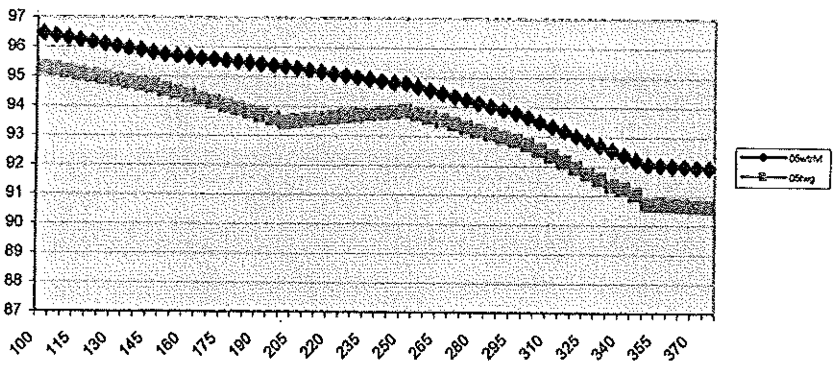
Table 12. South Bog Stream invertebrate sampling.

Order	Family	Year sampled: 2003	2004	2006
Coleoptera	Hydrophilidae	0	1	0
Diptera	Blephariceridae	0	2	3
Diptera	Chironomidae	1	0	1
Diptera	Simuliidae	7	0	6
Diptera	Tabanidae	1	1	0
Diptera	Tipulidae	0	1	2
Ephemeroptera	Baetidae	14	15	5
Ephemeroptera	Baetiscidae	0	0	6
Ephemeroptera	Ephemerellidae	6	1	5
Ephemeroptera	Ephemeridae	16	0	2
Ephemeroptera	Heptageniidae	8	11	23
Ephemeroptera	Isonychiidae	0	0	2
Ephemeroptera	Leptophlebiidae	8	2	0
Megaloptera	Corydalidae	0	1	0
Megaloptera	Sialidae	0	0	2
Odonata	Cordulegastridae	9	1	0
Odonata	Gomphidae	0	0	3
Odonata	Lestidae	1	0	0
Plecoptera	Capniidae	1	0	0
Plecoptera	Chloroperlidae	0	0	2
Plecoptera	Peltoperlidae	2	0	5
Plecoptera	Perlidae	0	0	9
Plecoptera	Pteronarcydae	10	6	0
Trichoptera	Brachycentridae	0	1	0
Trichoptera	Glossosomatidae	0	2	4
Trichoptera	Hydropsychidae	2	1	1
Trichoptera	Limnephilidae	2	14	0
Trichoptera	Philopotamidae	1	4	30
Trichoptera	Phryganeidae	0	2	0
Trichoptera	Polycentropodidae	3	0	0

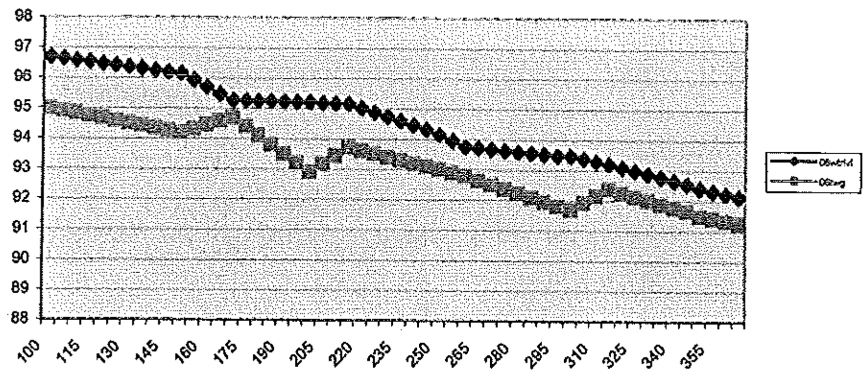
Appendix A

Longitudinal profiles of upper reach

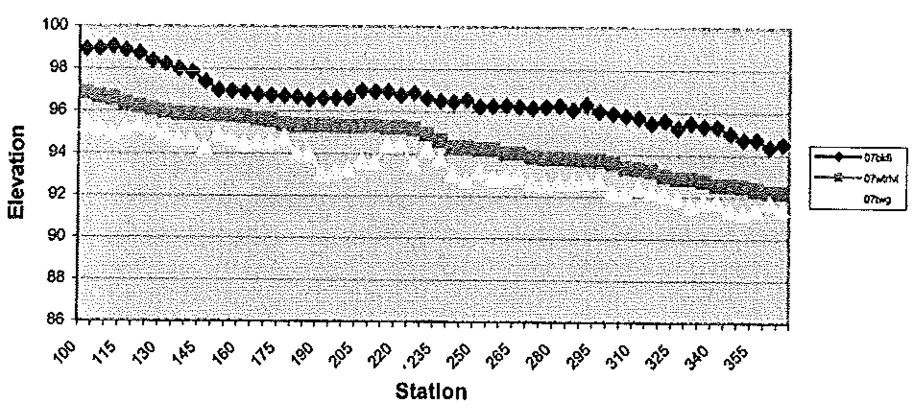
2005 Longitudinal Profile



2006 Longitudinal Profile

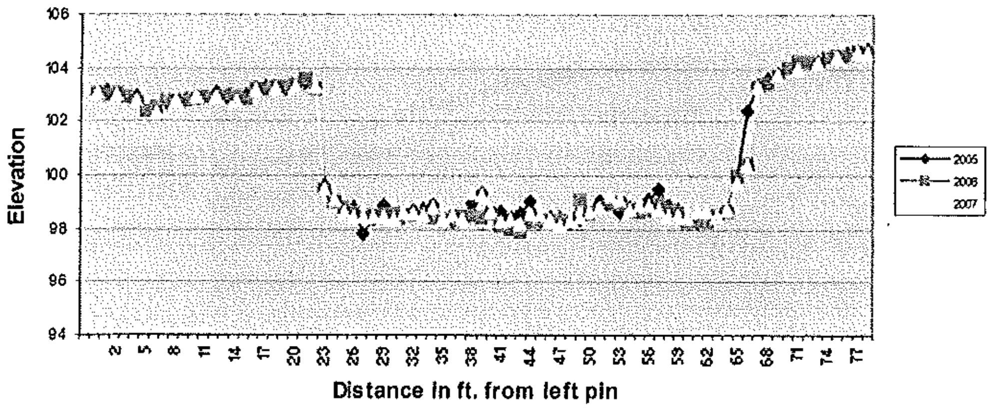


2007 Longitudinal Profile

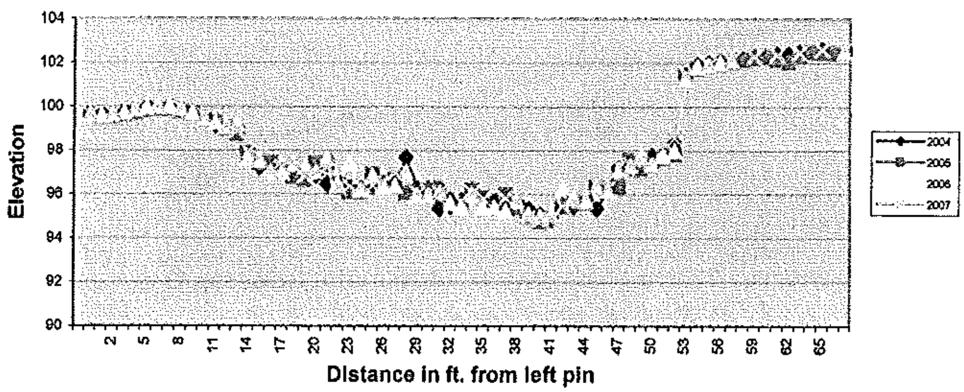


Appendix B
Transect profiles

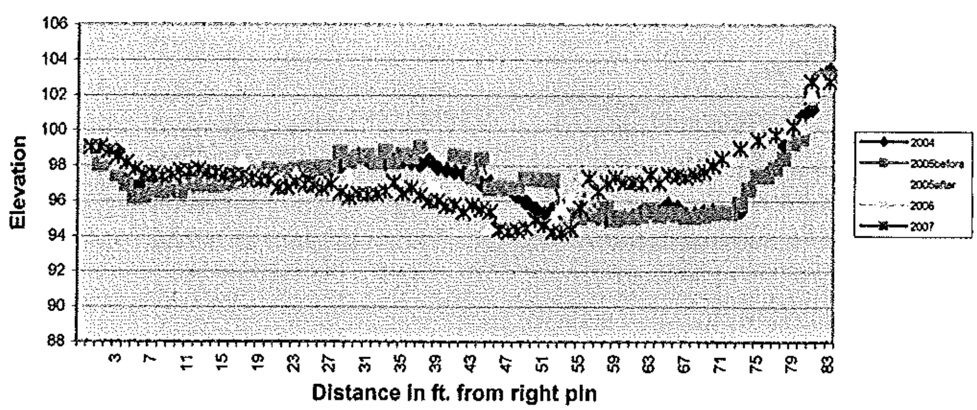
Transect 1, Station 0 (Riffle)
Control, Upper Project 2005



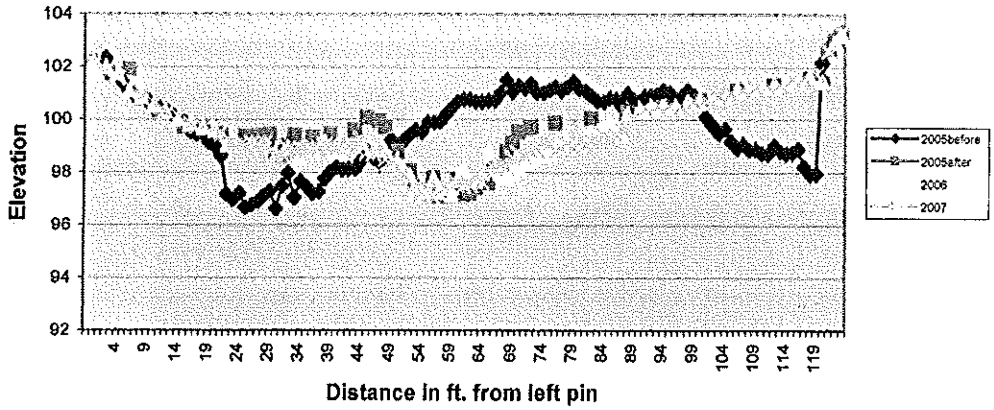
Transect 2, Station 100 (Riffle)
Control, Upper Project 2005



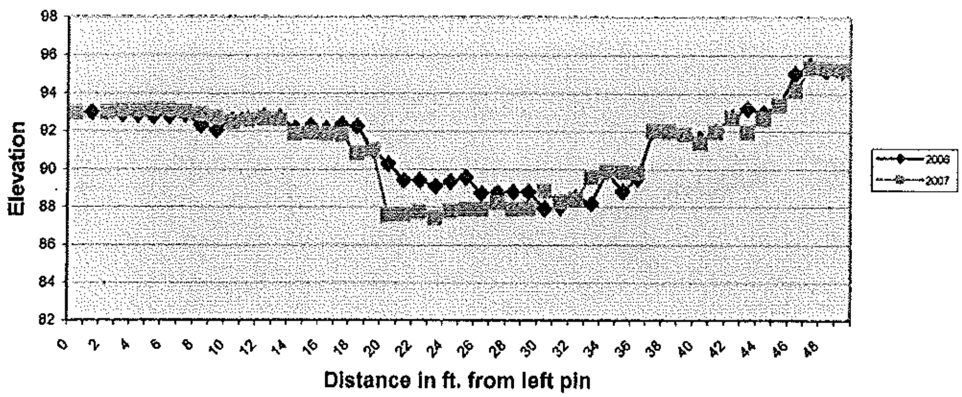
Transect 3, Station 207 (Riffle)
Upper Project 2005



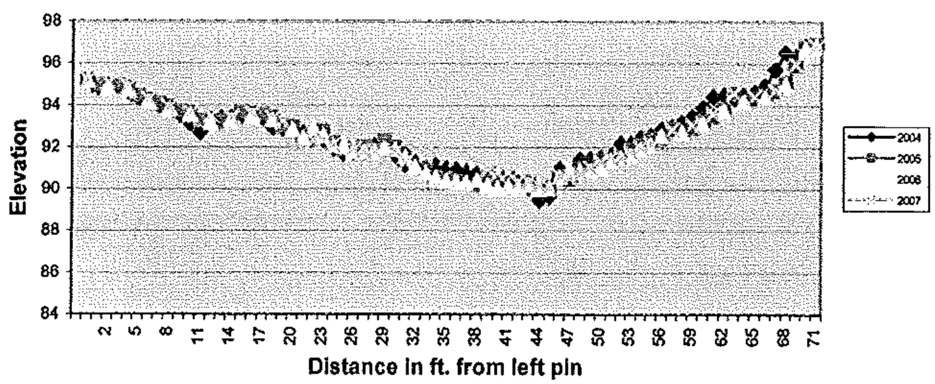
Transect 4, Station 270 (Riffle)
Upper Project 2005



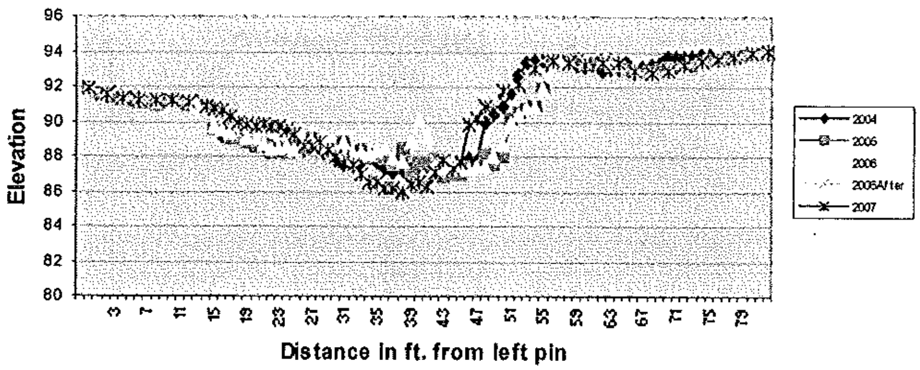
Transect 5A, Station 533
Pool of Weir 1, Middle Project 2006



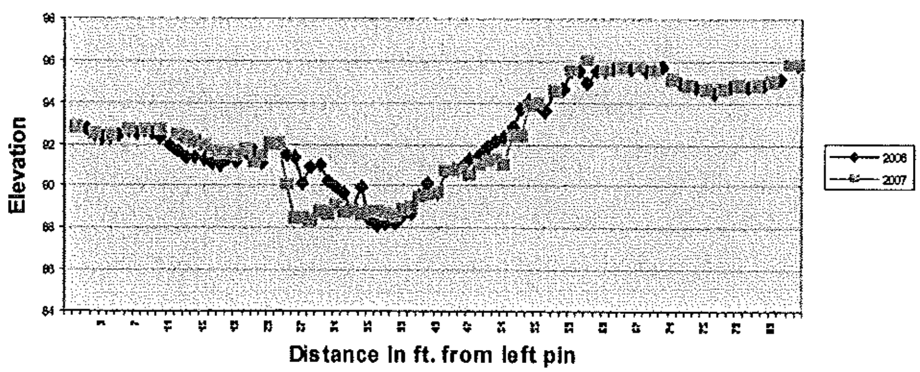
Transect 5, Station 468 (riffle)
Control below bridge, Middle Project 2006



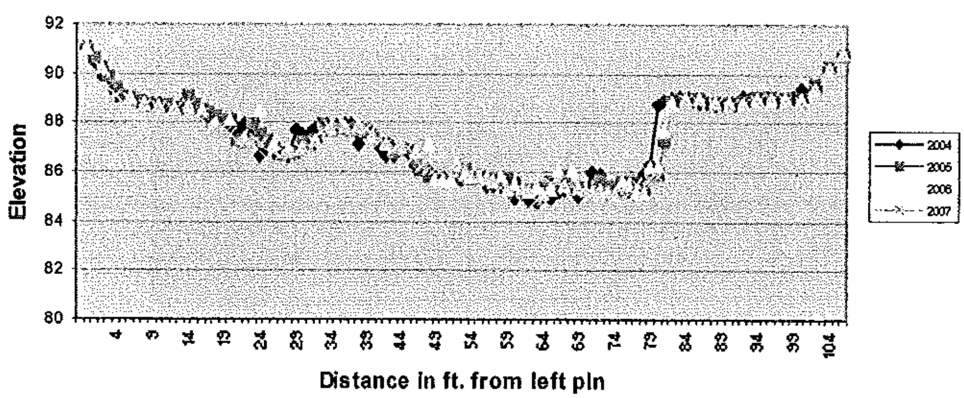
Transect 6 Station 604
Weir 2, Middle Project 2006



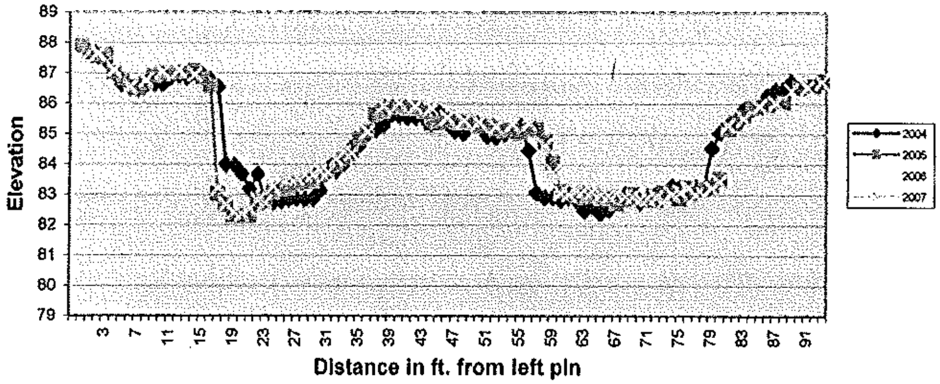
Transect 6A, Station 703
Weir 3, Middle Project 2006



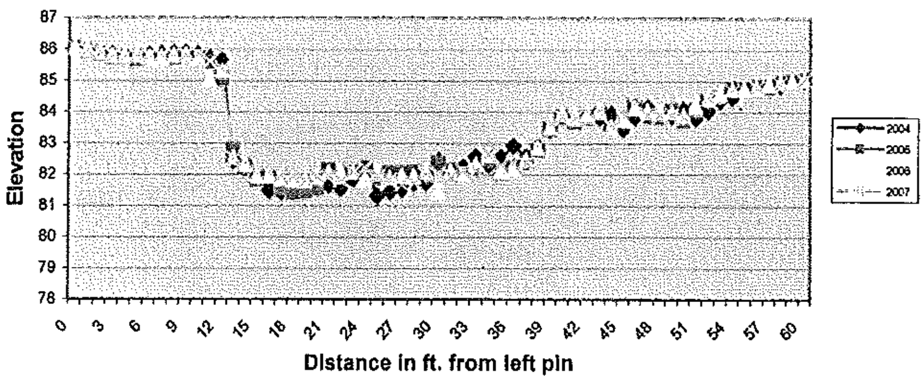
Transect 7, Station 724 (riffle)
Below Weir No. 3, Middle Project 2006



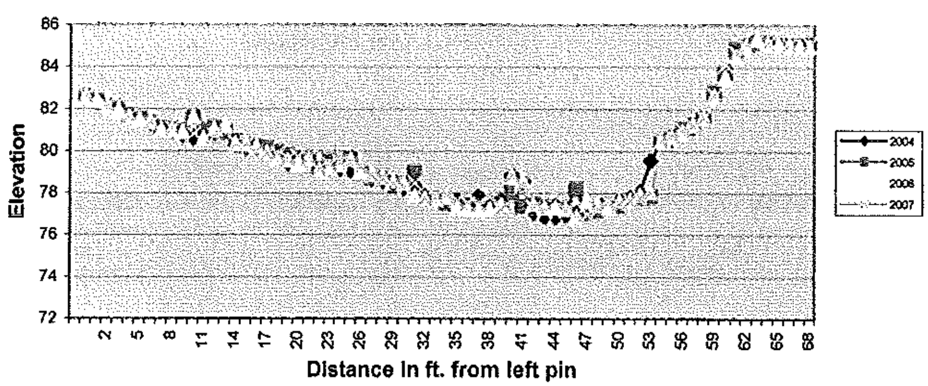
Transect 9, Station 892 (run)
Control, Split Channel below Middle Project



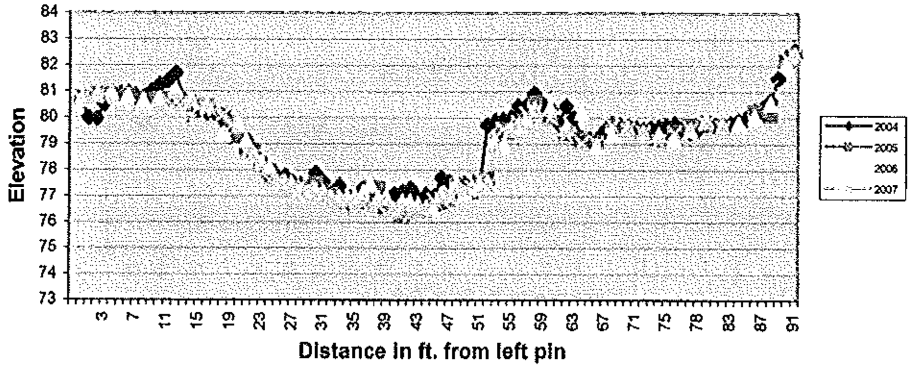
Transect 10, Station 1,004
Control, Below Middle Project



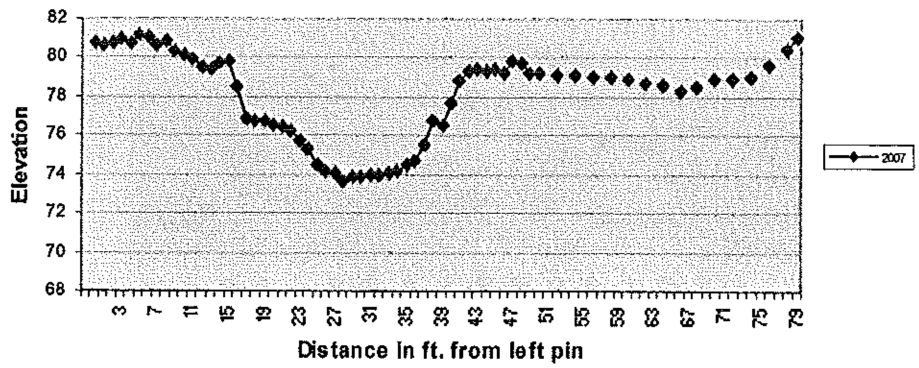
Transect 11, Station 1,308 (Riffle)
Control, Upstream of Lower Project 2004



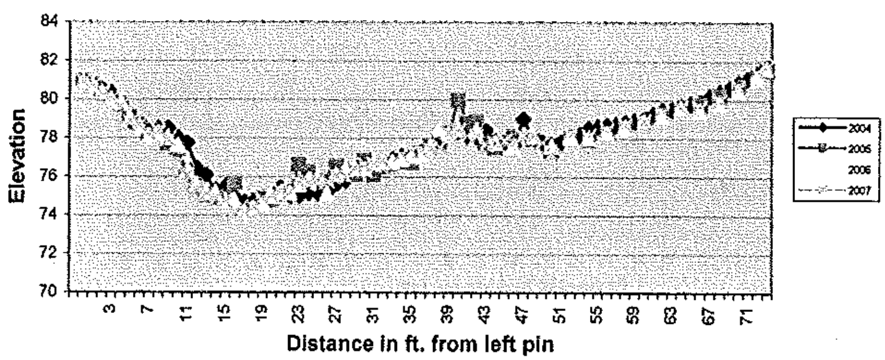
Transect 12, Station 1,524 (Riffle)
Below 1st pair of log deflectors, Lower Project 2004



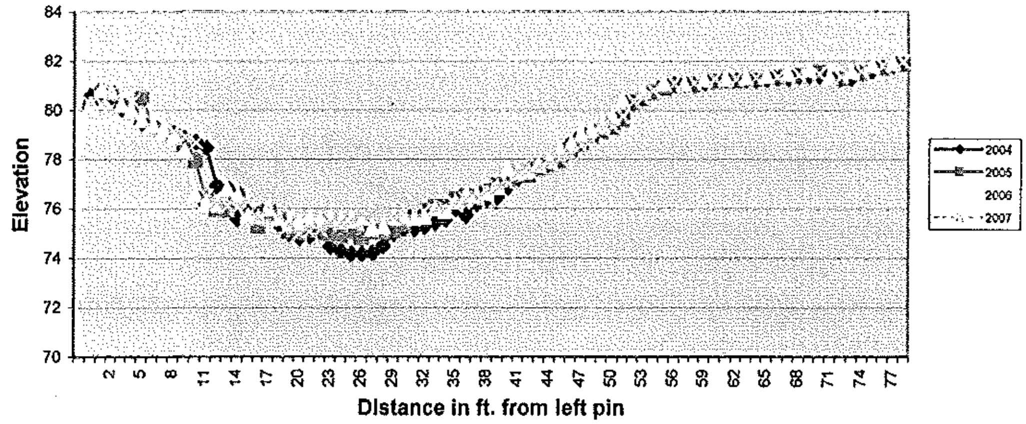
Transect 12A, Station 1,544
Midpool, rock weir 1 constructed 2007



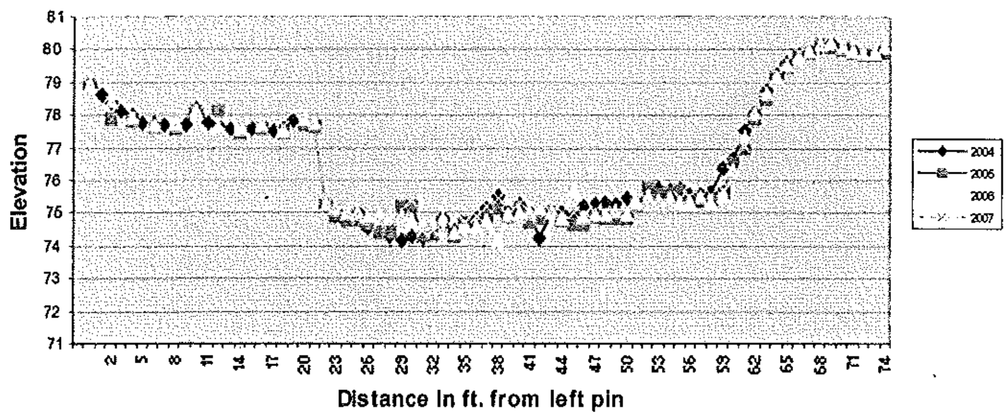
Transect 13, Station 1,604 (Pool)
Below 2nd pair of log deflectors, Lower Project 2004



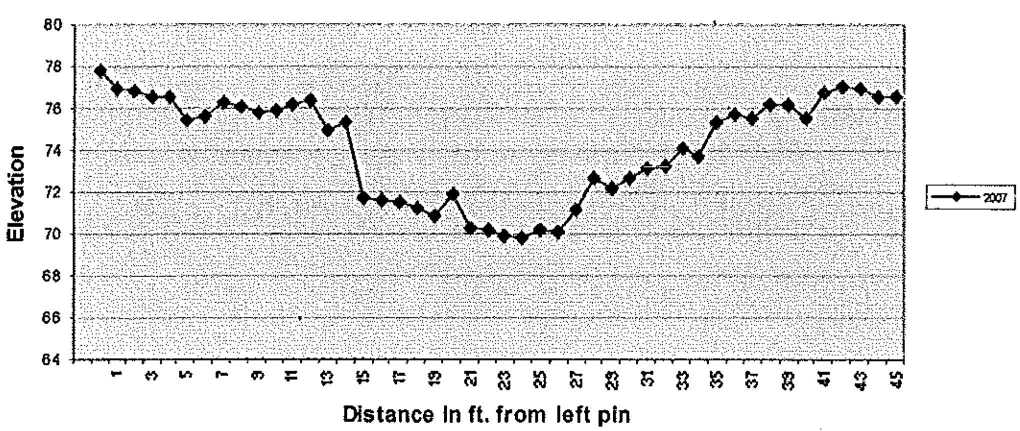
Transect 14, Station 1,654 (Head of Pool)
Between 4th and 5th pair of log deflectors, Lower Project 2004



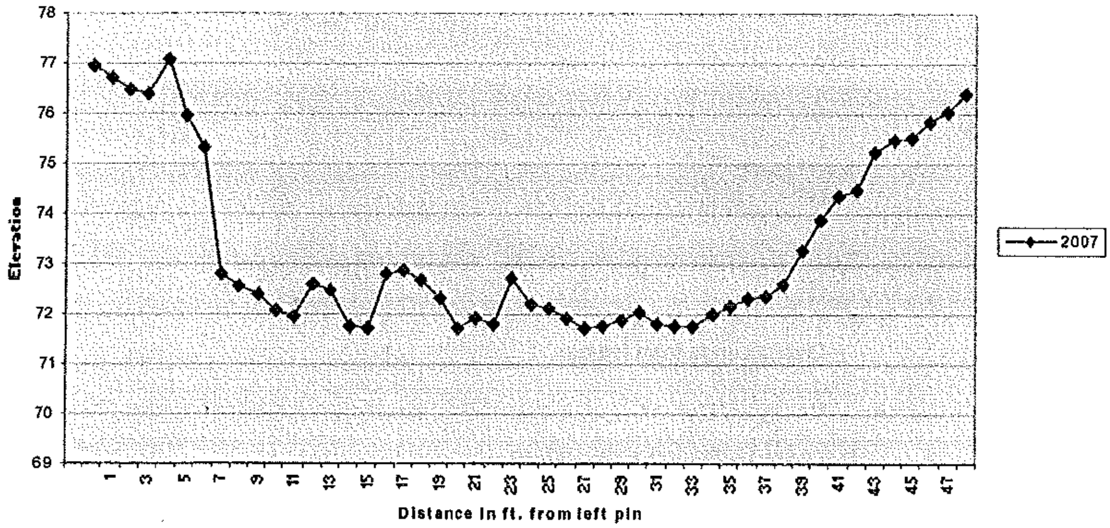
Transect 15, Station 1,730 (Riffle)
Below log deflectors (Control) Lower Project



Transect 16 Station 1,820
Mid pool, rock weir No. 3 constructed 2007

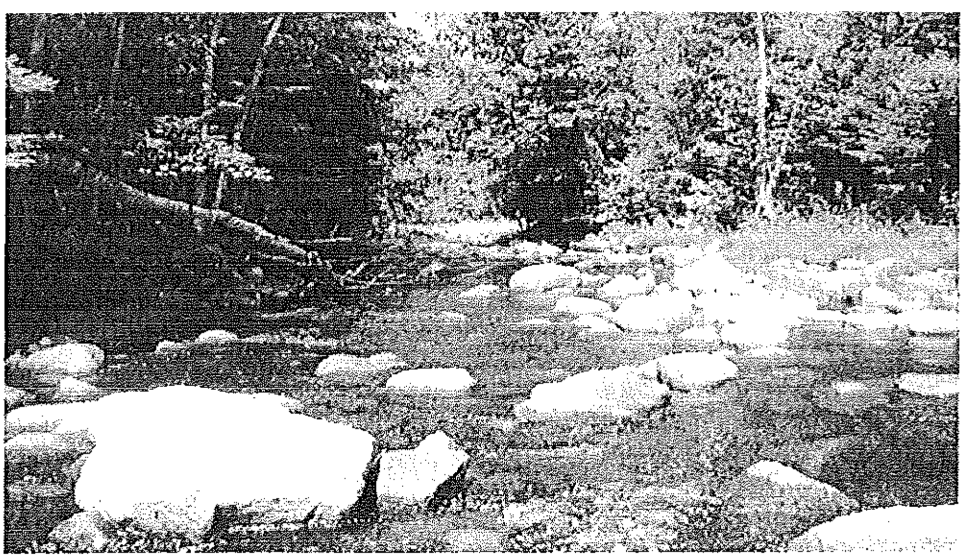


South Bog Stream, Rangeley Plt.
Transect 17 Station1,877 (Riffle)
Control



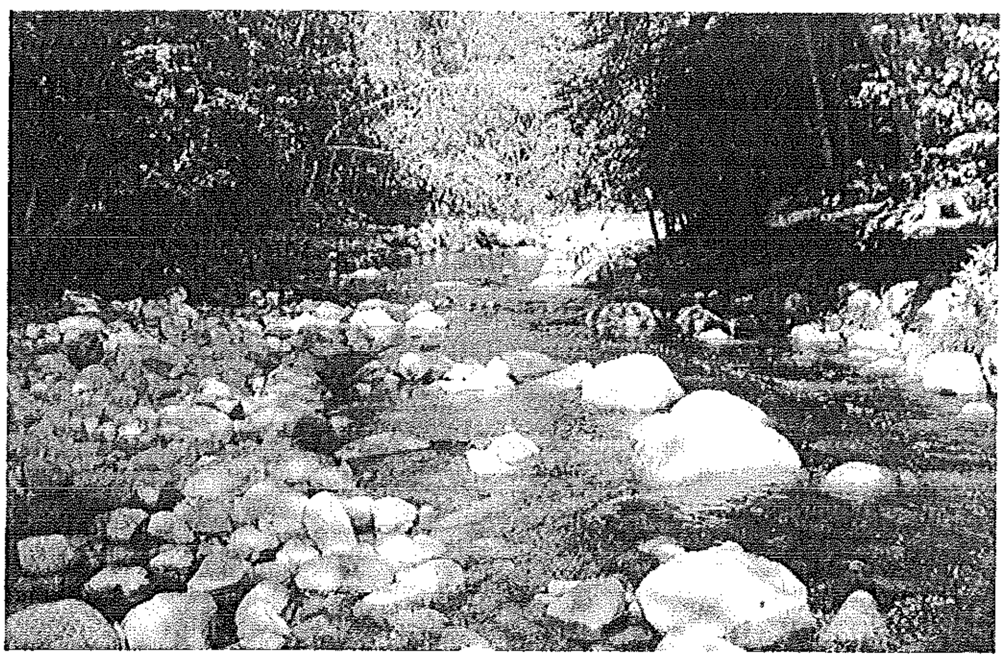
Appendix C
Photos of Transects

Transect 1 (control) looking upstream, 2007.

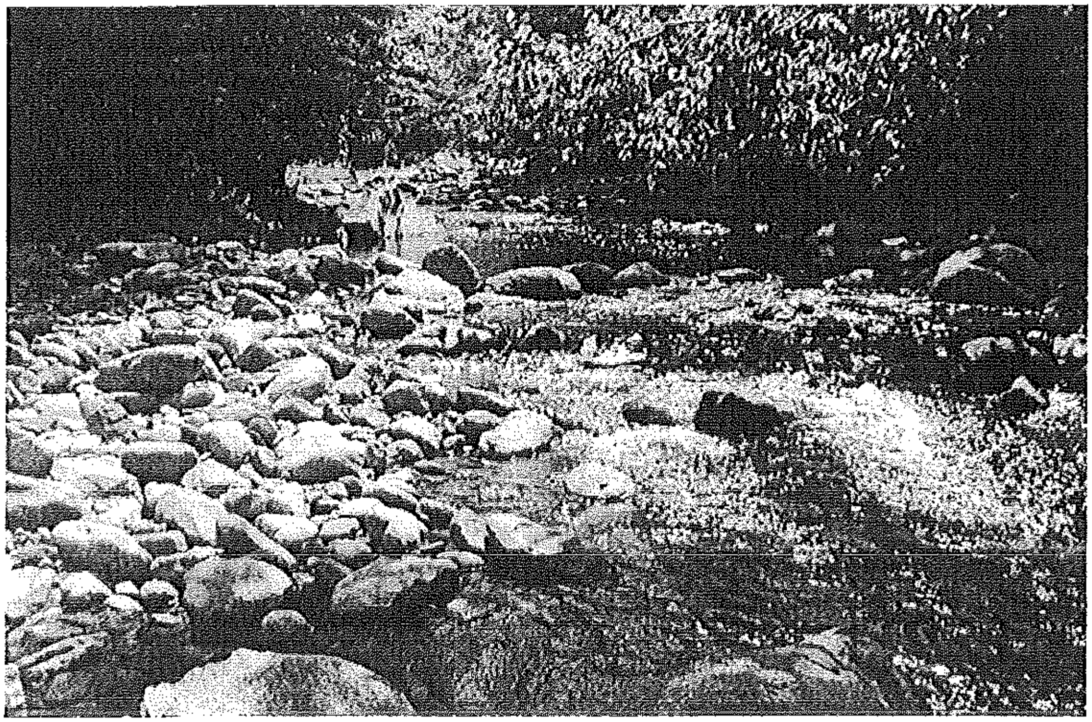


Transect 1 (control) looking downstream, 2007.

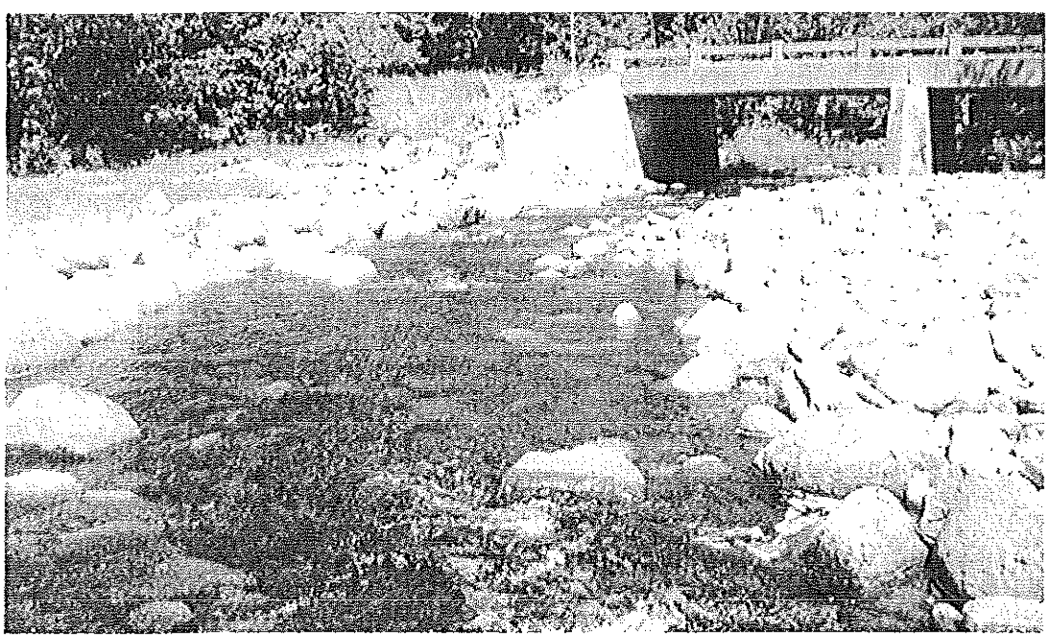
Transect 2 (control) looking upstream, 2007



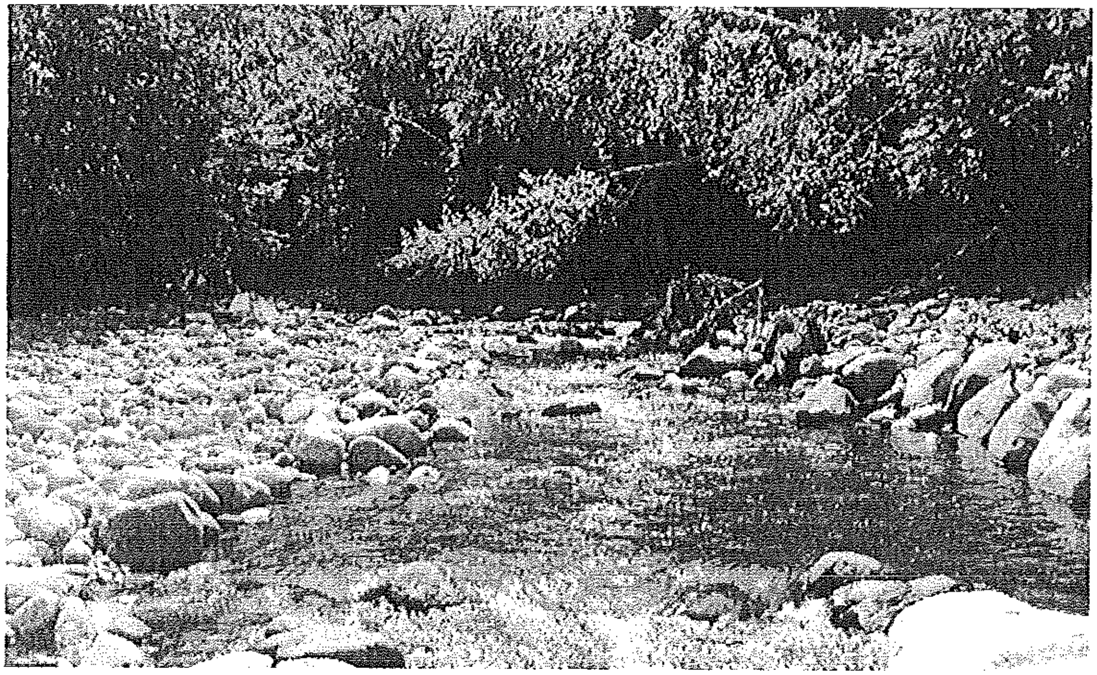
Transect 2 (control) looking downstream, 2007. Upper project area visible in distance.



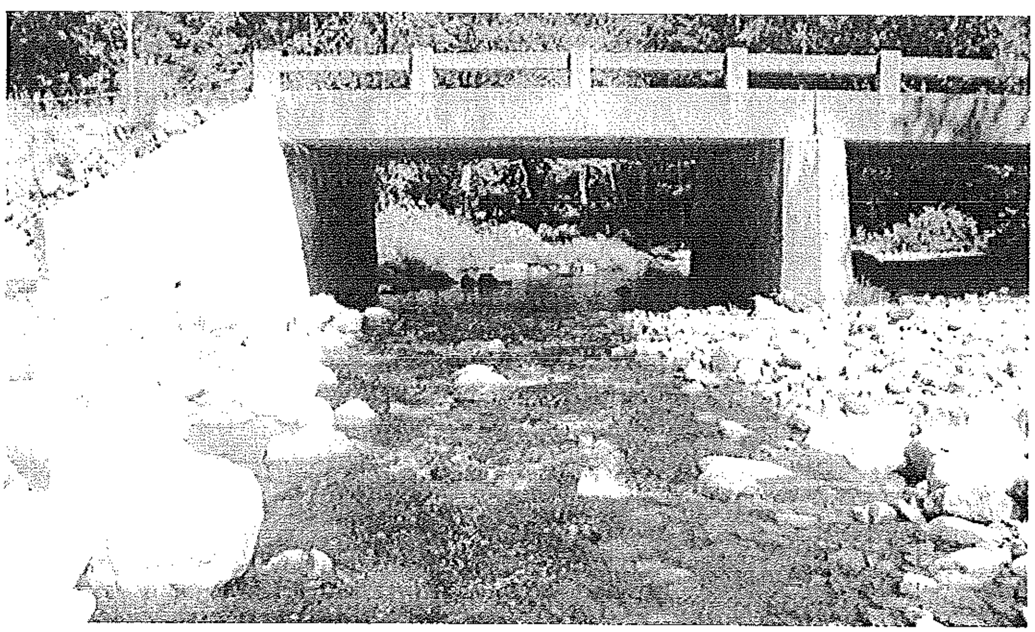
Transect 3 looking upstream, 2007, showing constructed pool and beginning of riffle/pool sequence.



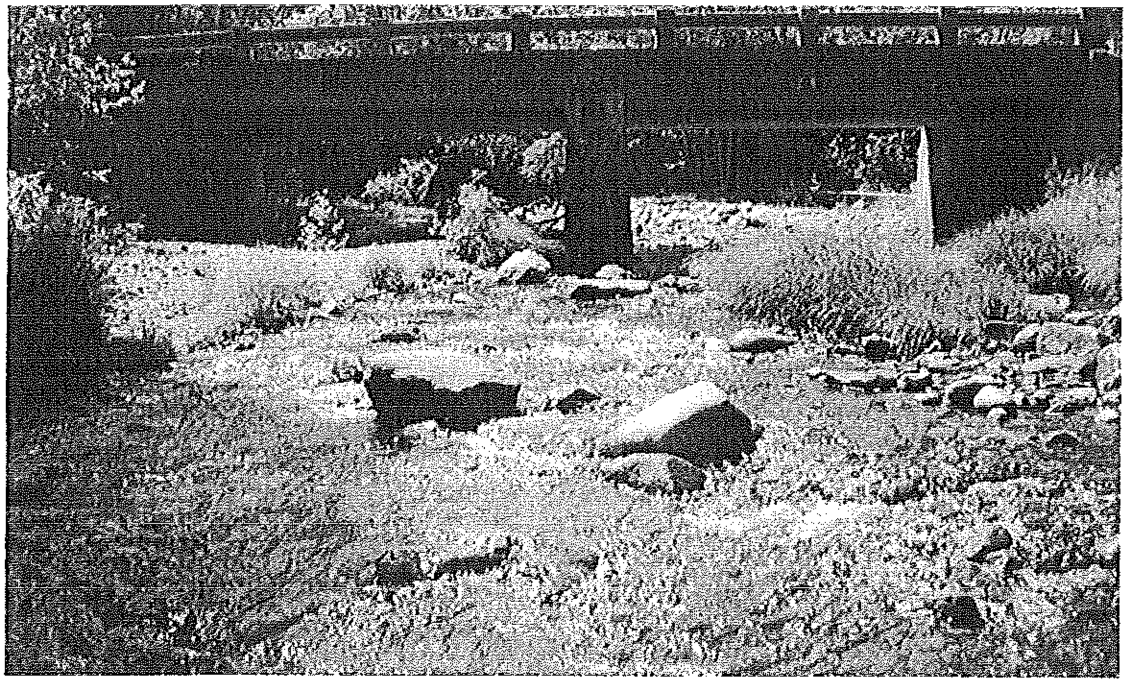
Transect 3 looking downstream, 2007, showing riffle/pool sequence which terminates at bridge.



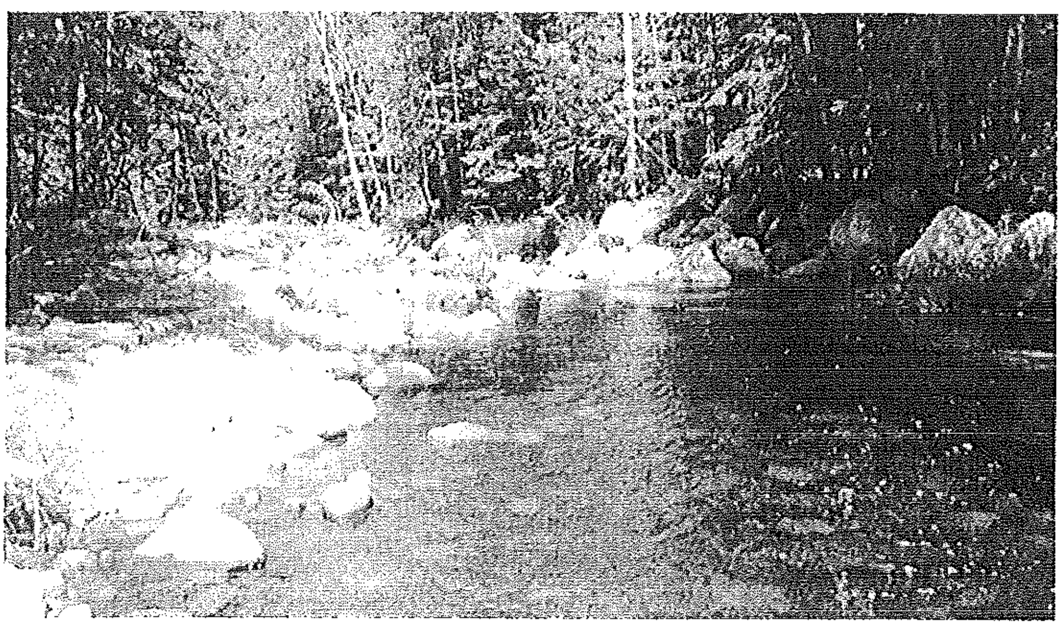
Transect 4 looking upstream, 2007, showing riffle/pool sequence.



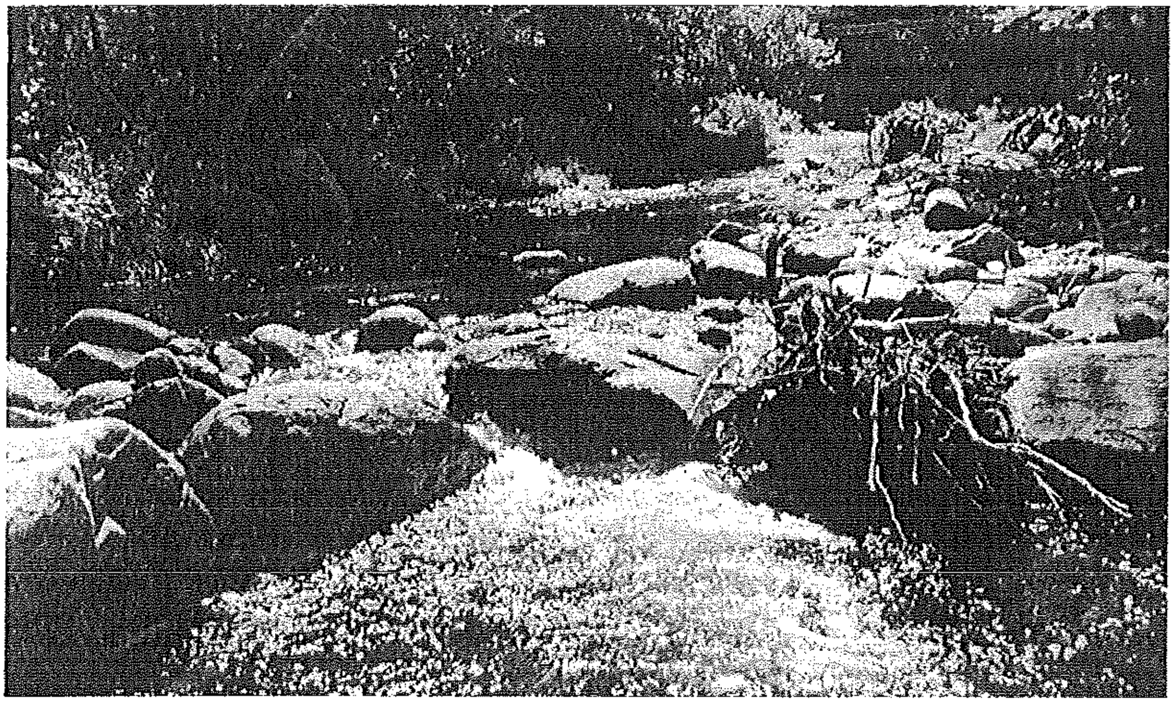
Transect 4 looking downstream, 2007, showing lower end of riffle/pool sequence.



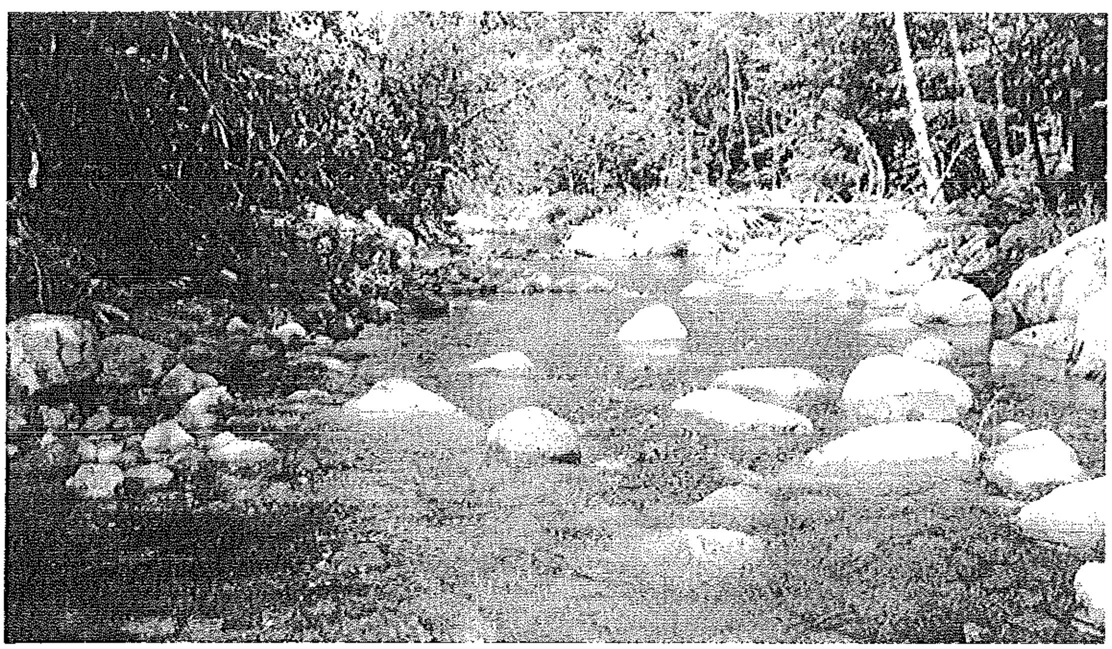
Transect 5 (control) looking upstream, 2007.



Transect 5 (control) looking downstream, 2007. Two logs are on left bank; upper rock vein visible in distance.

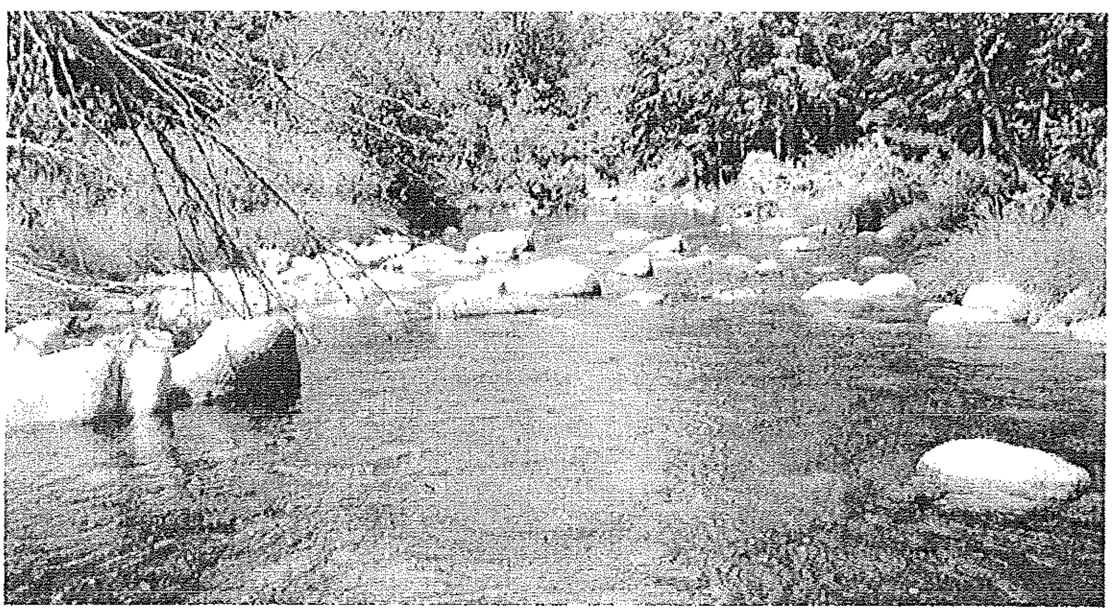


Transect 5a looking upstream, 2007, showing rock weir No. 1., associated root wad, and pool.

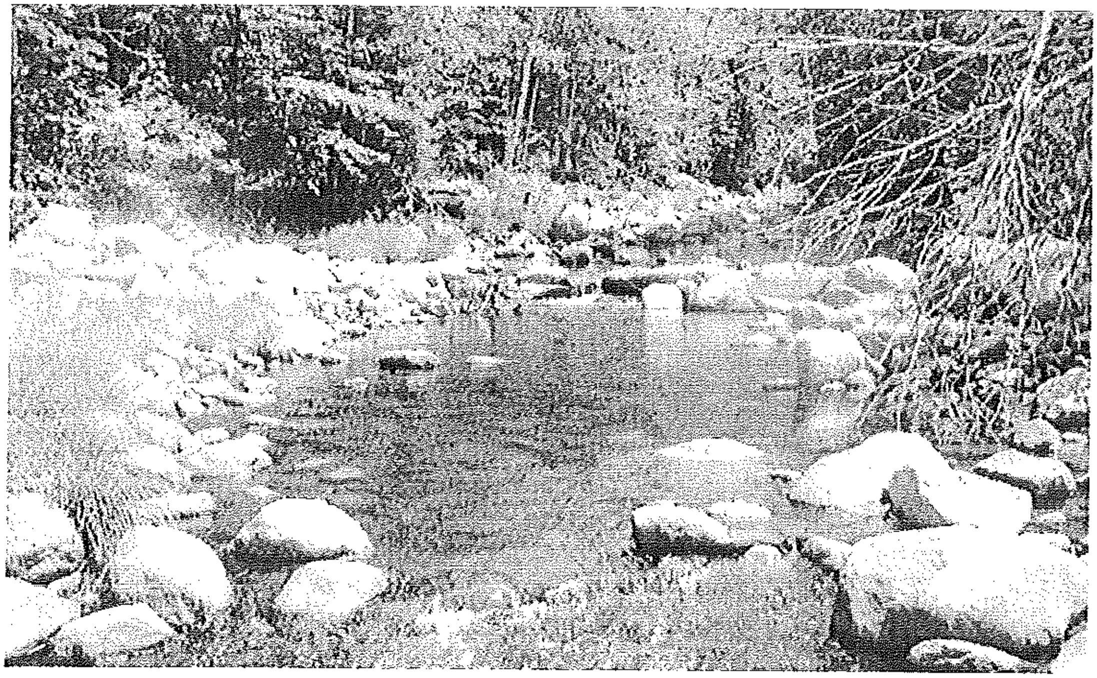


Transect 5a, looking downstream, 2007. Rock weir No. 2 is visible in distance.

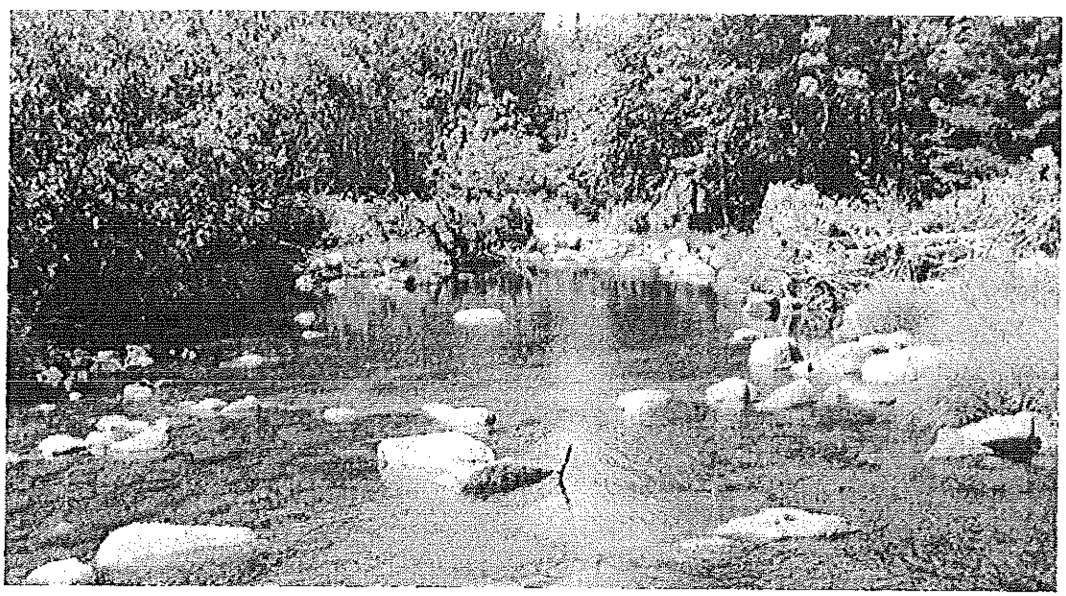
Transect 6a looking upstream. Apex of rock weir No. 2 in immediate foreground.



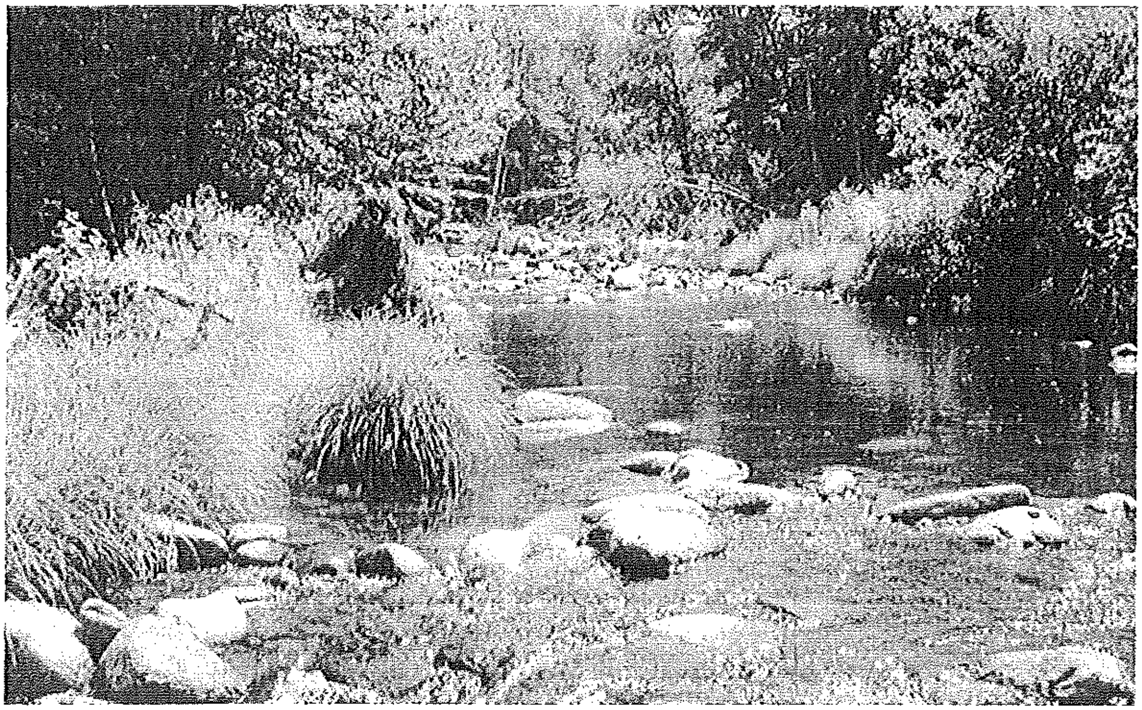
Transect 6a looking downstream. Root wads of downstream logs visible in distance.



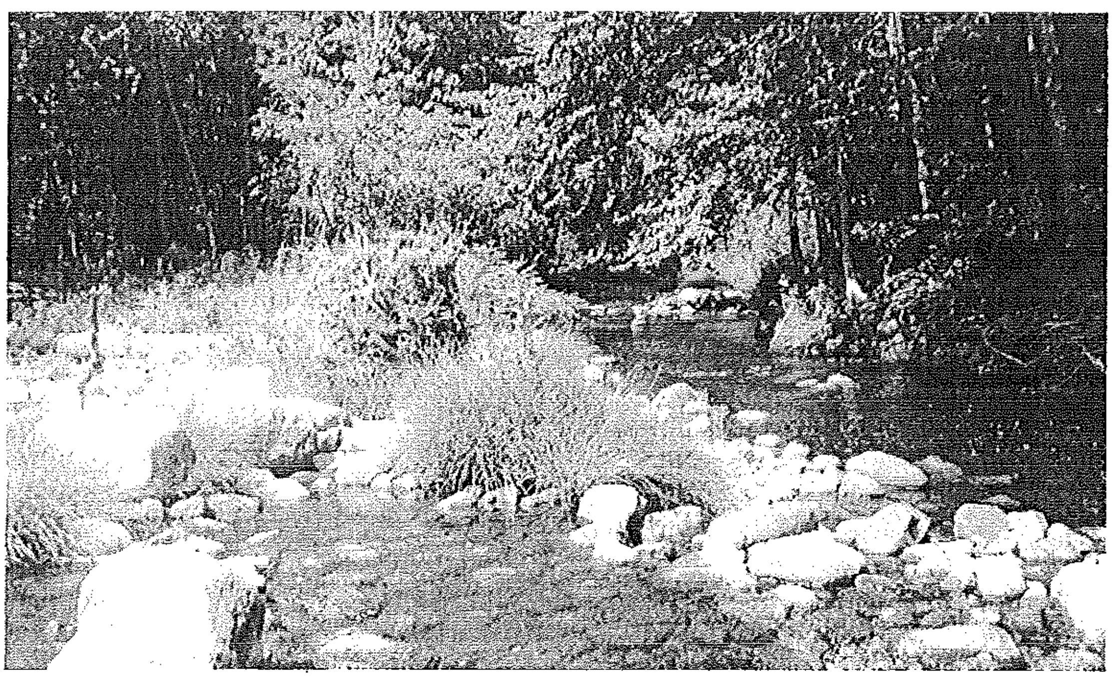
Transect 7 looking upstream, 2007. Rock weir No. 3 visible in distance.



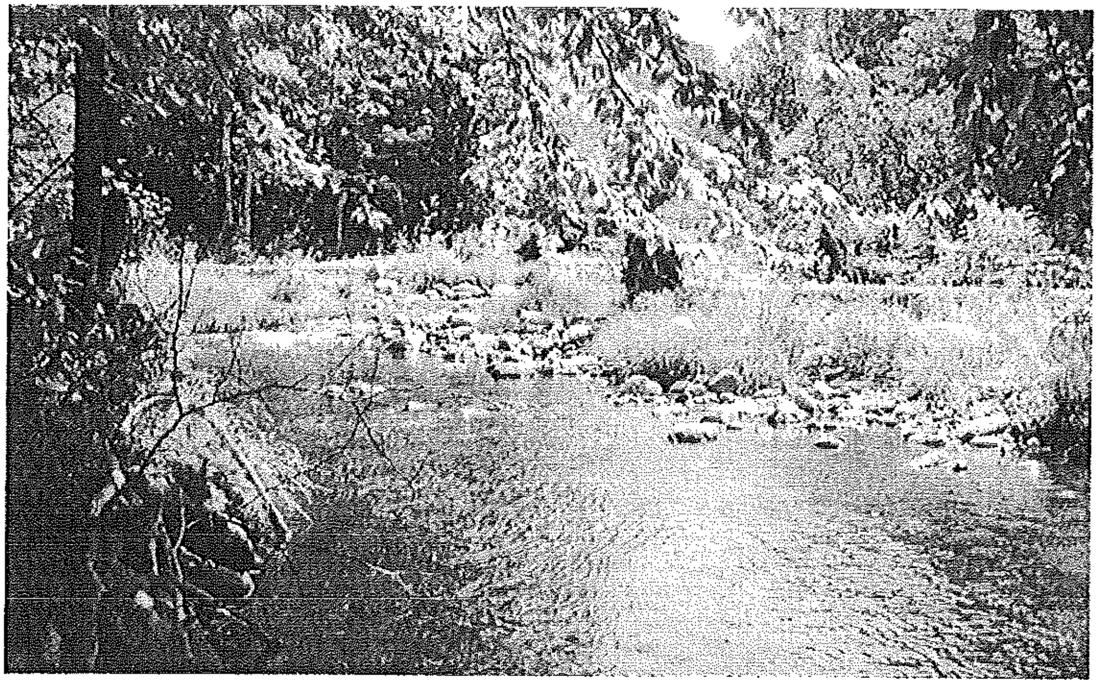
Transect 7 looking downstream, 2007. Split channel with island (mid photo) in distance.



Transect 8 looking upstream, 2007. Photo taken from main channel, root wads visible on left.



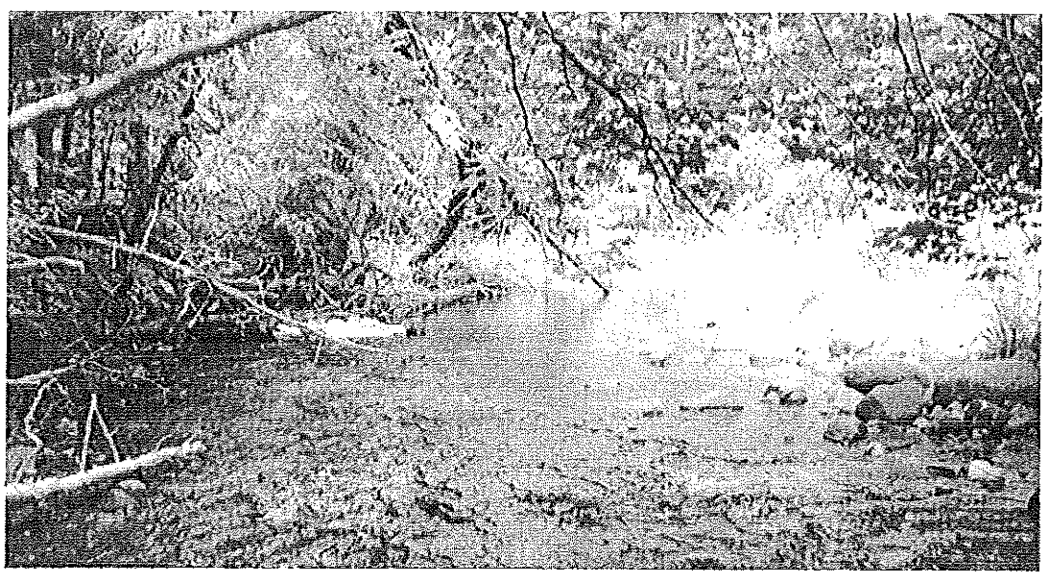
Transect 8 looking downstream, 2007. Main channel on right; logs on island at left.



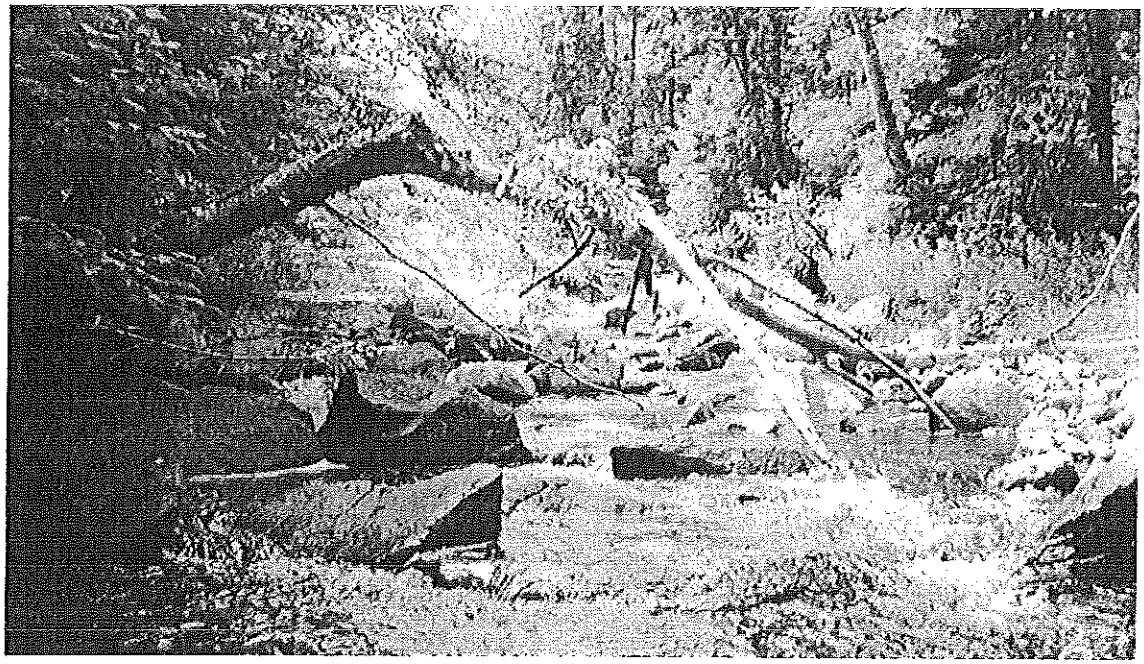
Transect 9 looking upstream, 2007. Logs on shore visible on left; logs on island visible on right.

Transect 9 looking downstream, 2007. Side channel reenters main stem at foot of island on left.

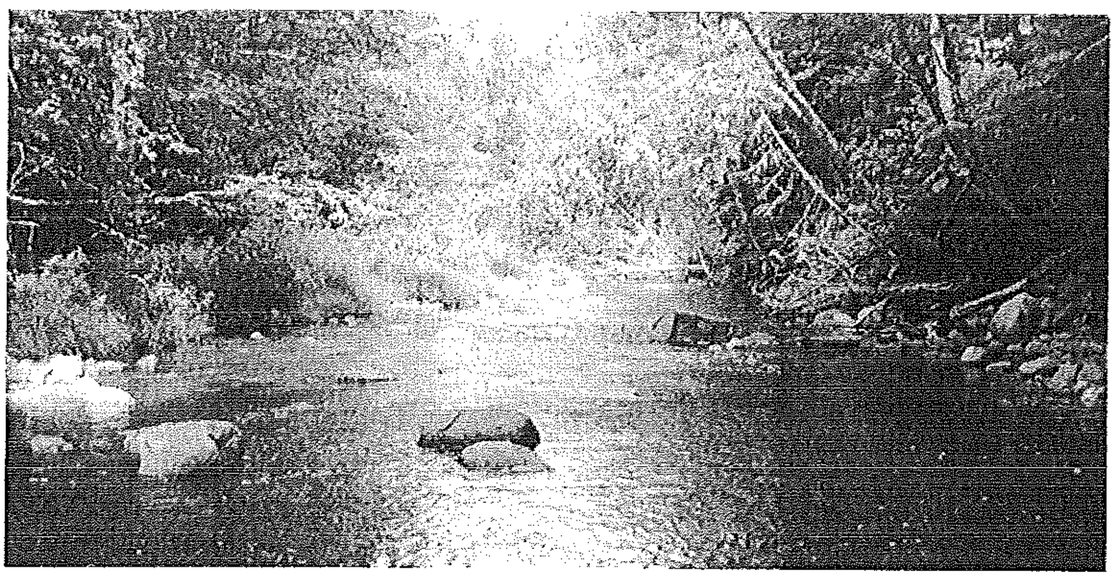
Transect 10 (control) looking upstream, August 2007. Side channel (arrow) visible at right of photo.



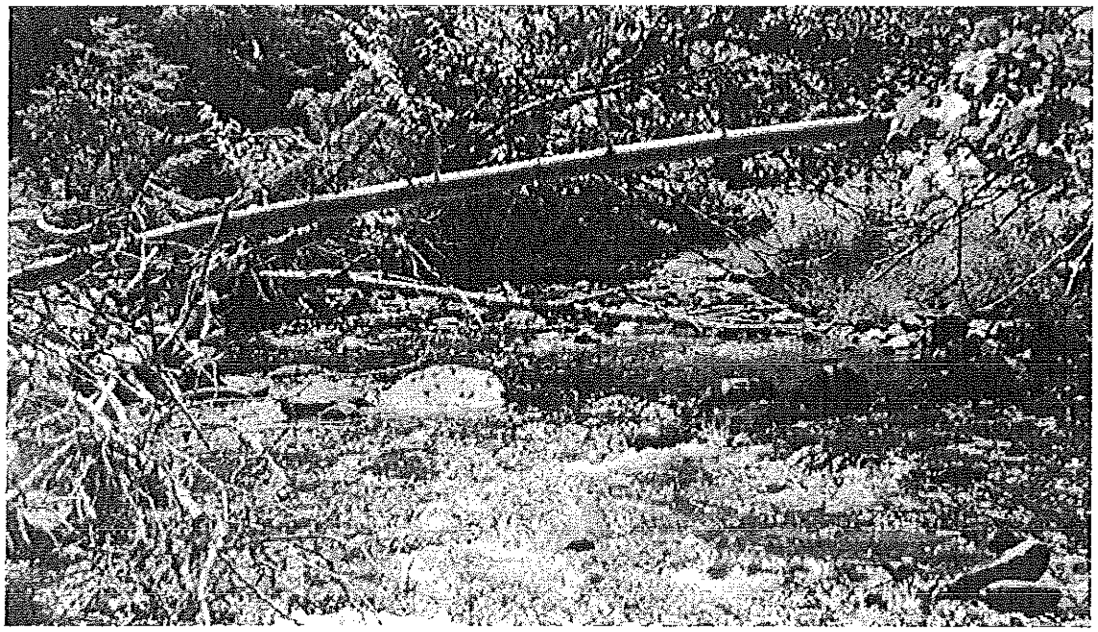
Transect 10 (control) looking downstream, August 2007.



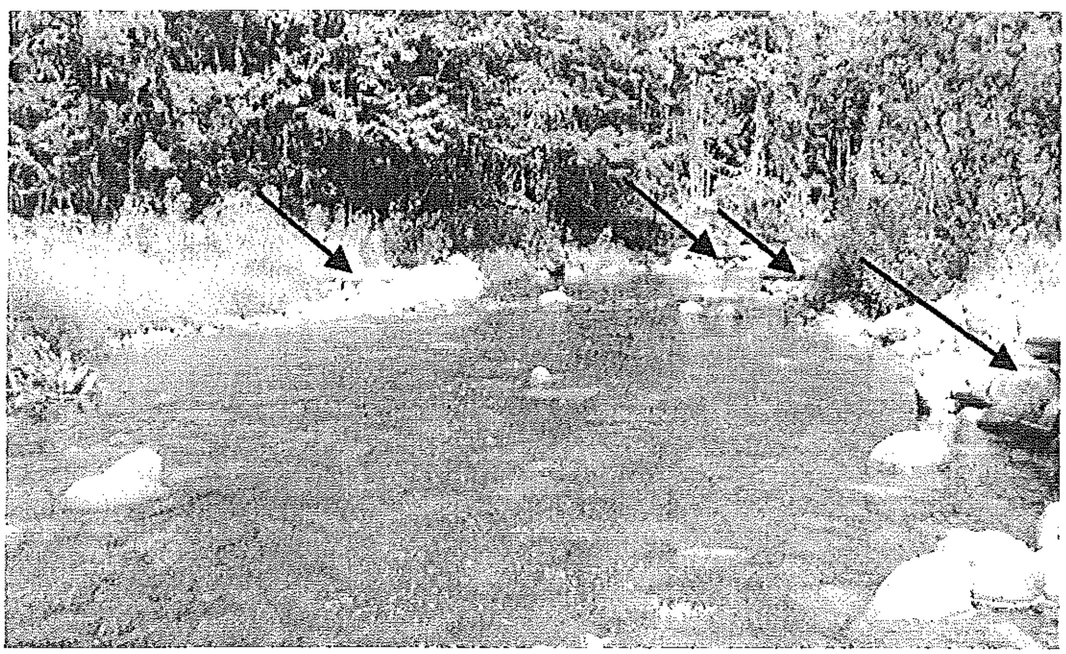
Transect 11 (control) looking upstream, August 2007. The presence of boulders and woody debris in this reach provides habitat complexity for brook trout.



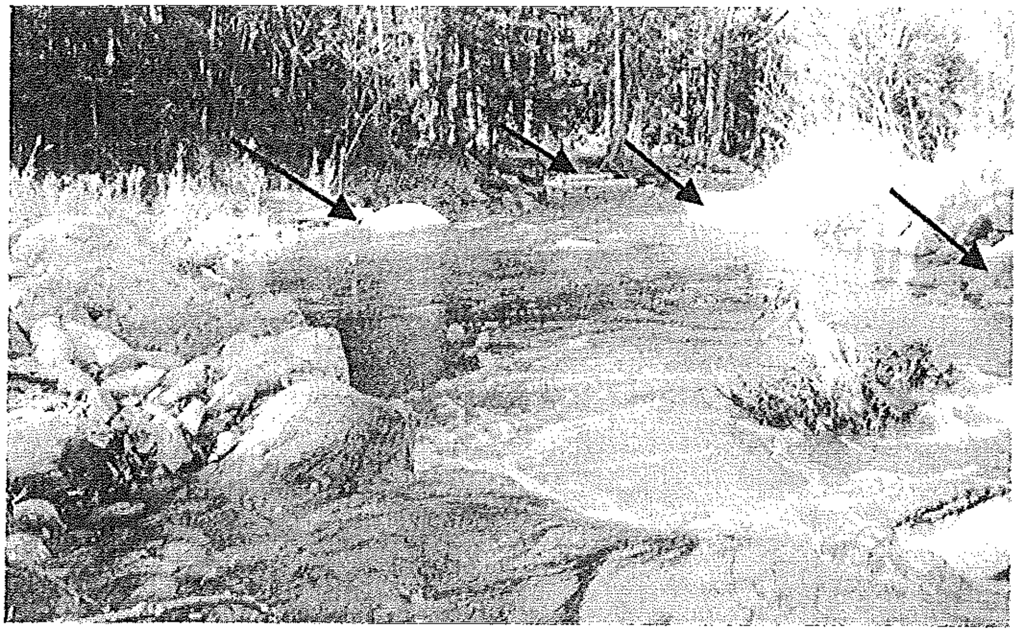
Transect 11 (control) looking downstream, August 2007.



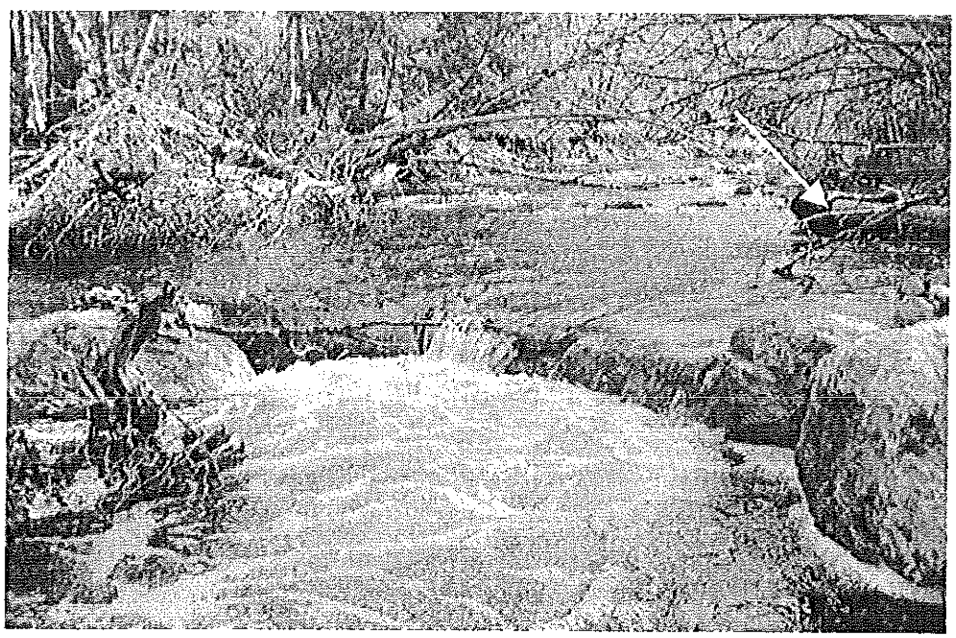
Transect 12 (control) looking upstream, August 2007.



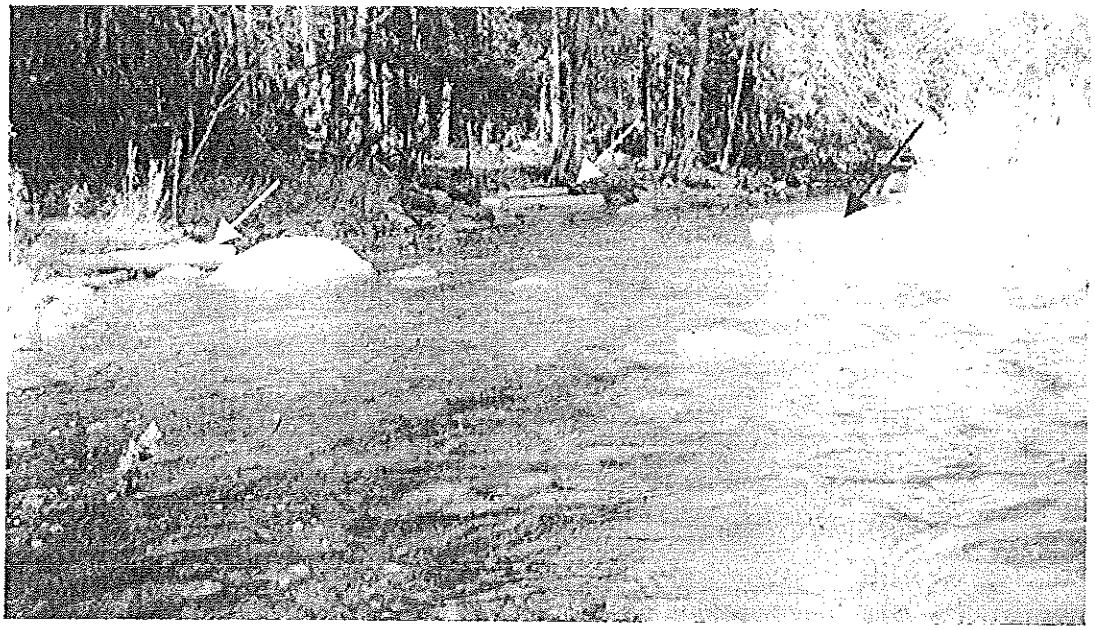
Transect 12 (control) looking downstream into lower treatment area, August 2007. Four log deflectors, highlighted by arrows, are visible.



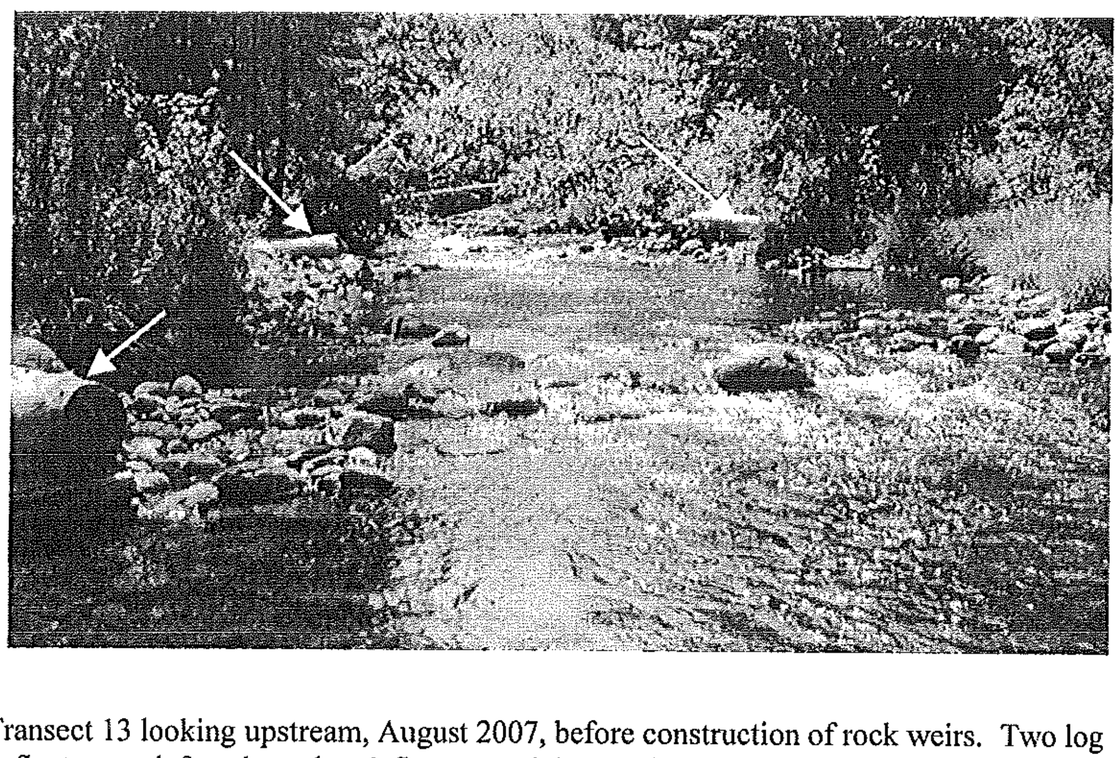
Transect 12 looking downstream after construction of rock weir no. 1, October 2007. Wing of rock weir is at left; pool and root wad visible immediately downstream of weir. Four log deflectors (highlighted by arrows) are visible downstream. The left log deflector of the second pair was removed in order to construct this weir.



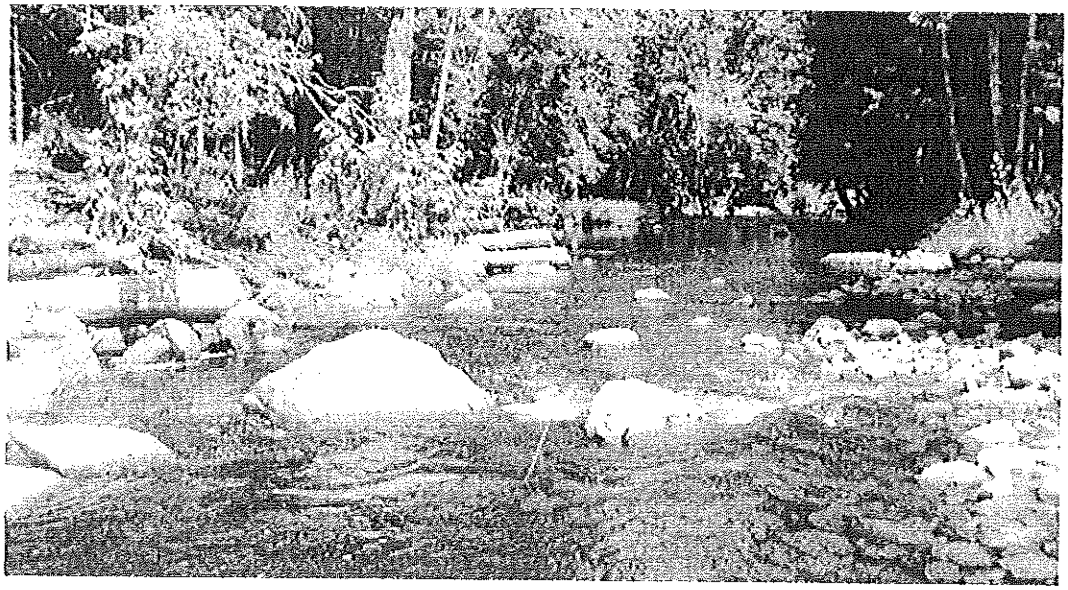
Transect 12a looking upstream, October 2007, showing same rock weir as in previous photo. One of the upper-most pair of log deflectors (arrow) is visible at the right of the photo; the other is obscured by woody debris.



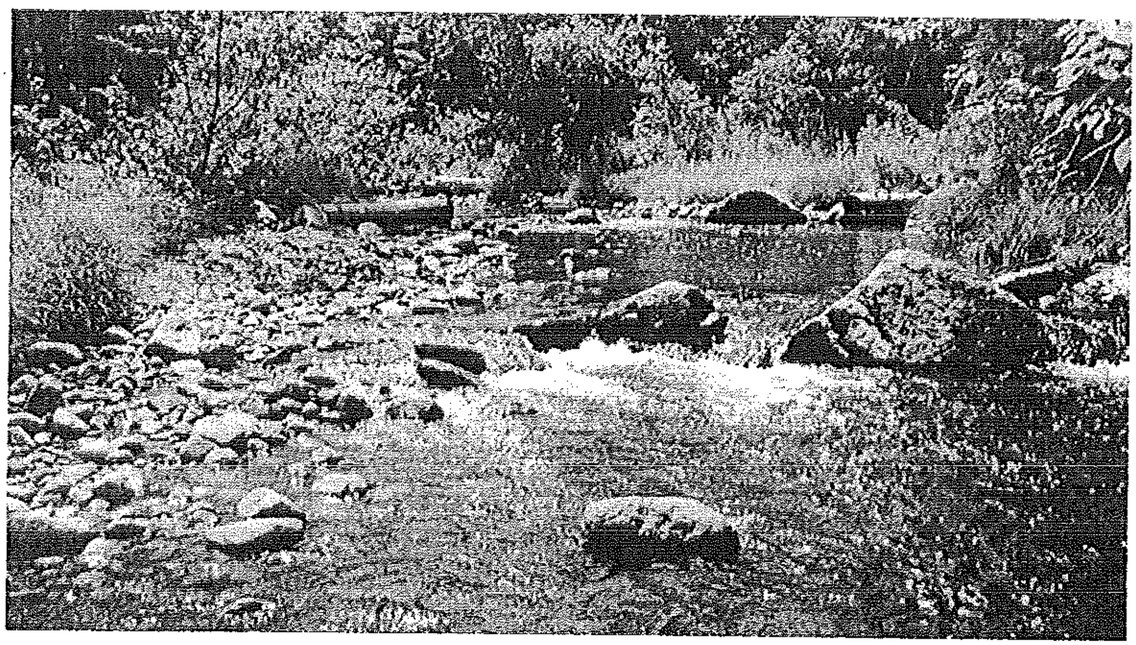
Transect 12a looking downstream from Weir 1, October 2007.



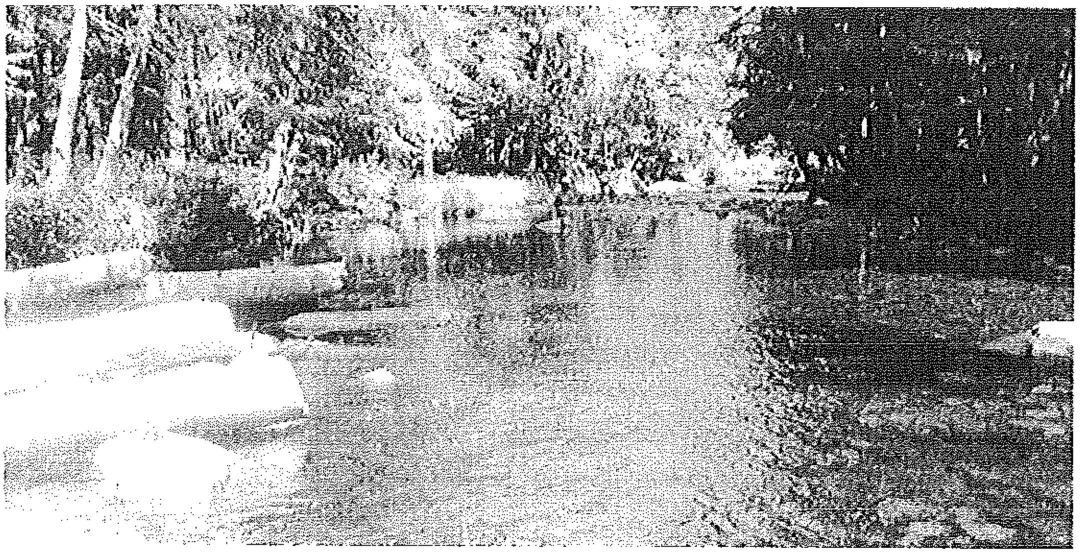
Transect 13 looking upstream, August 2007, before construction of rock weirs. Two log deflectors on left and one log deflector on right are visible.



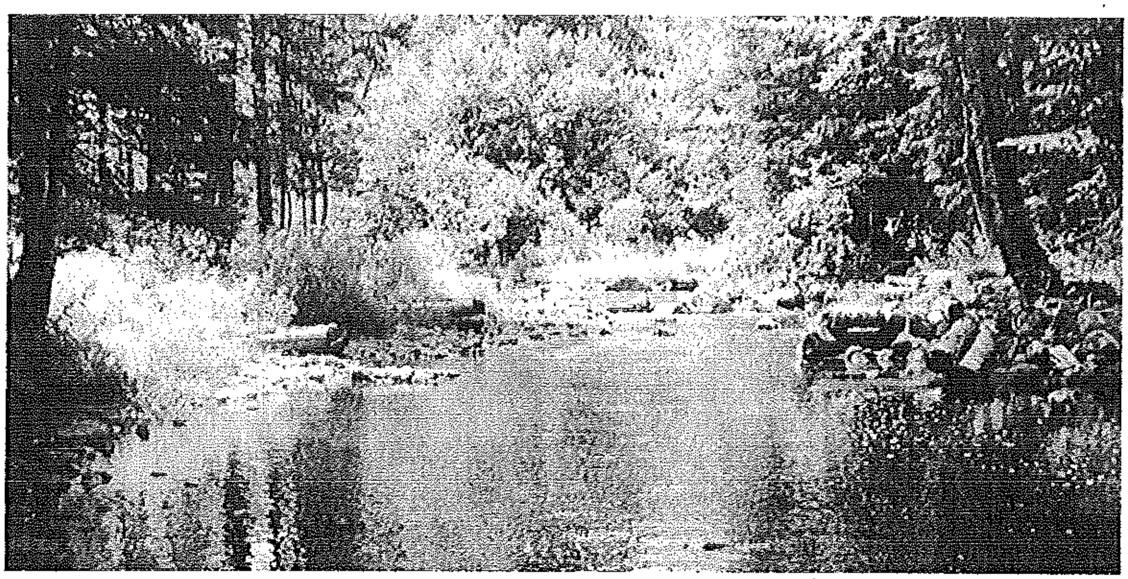
Transect 13 looking downstream, August 2007. Two log deflectors on left and one log deflector on right are visible; the furthest log deflectors represent the lower end of the project area.



Transect 14 looking upstream, August 2007. Log deflectors visible on both sides of stream.

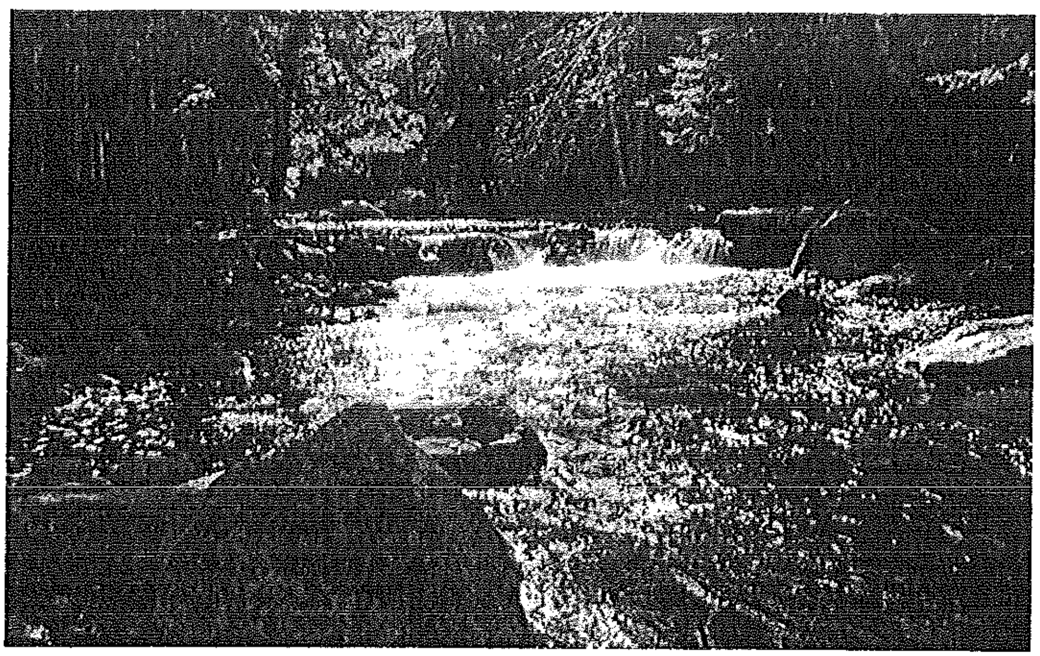


Transect 14 looking downstream, August 2007. Lowermost log deflectors showing ice damage to structure on left.

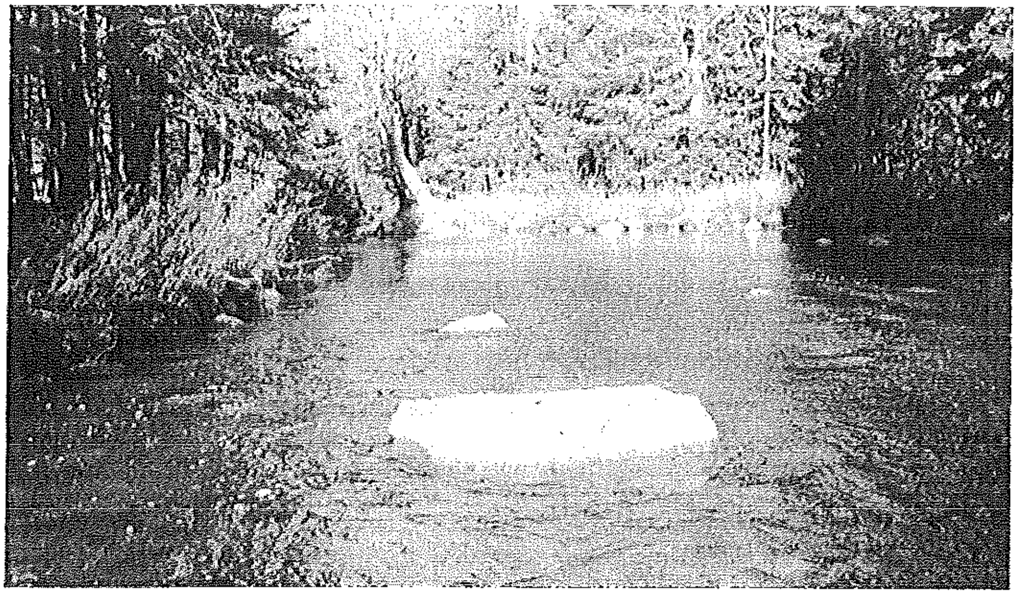


Transect 15 looking upstream, August 2007, prior to construction of Weir No. 2. Several log deflectors, including ice-damaged structure on right, are visible.

Transect 15 looking downstream, August 2007.

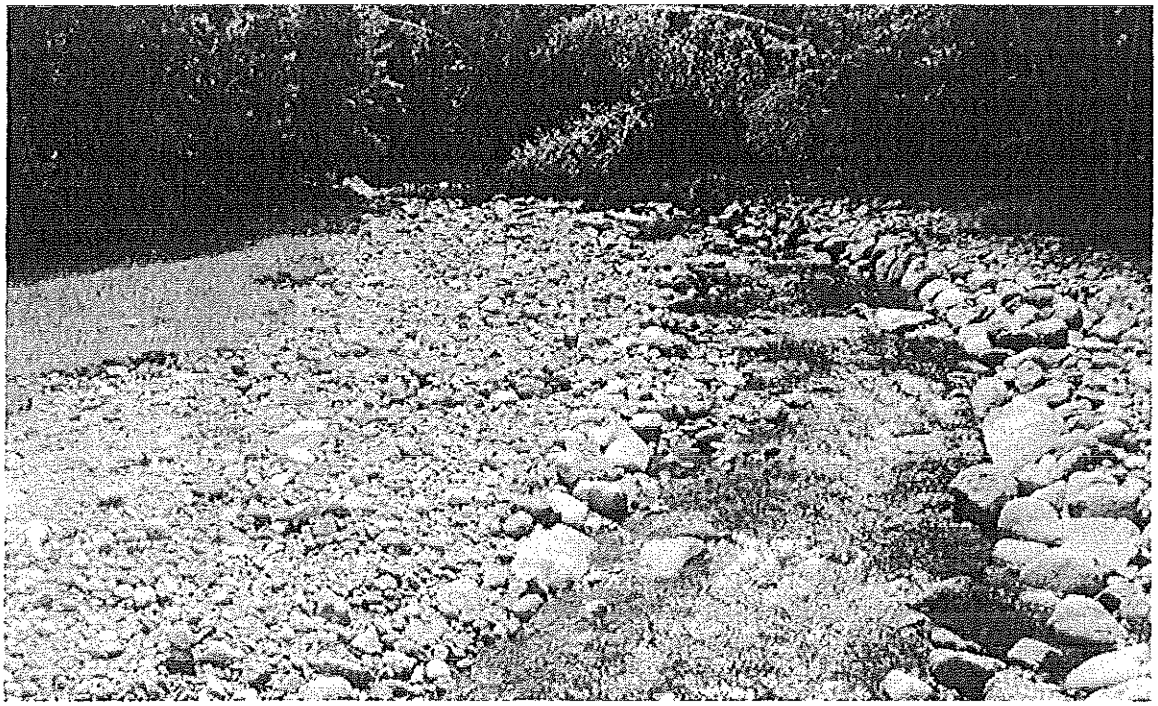


Transect 16 looking upstream at Weir No. 2 in distance, October 2007.

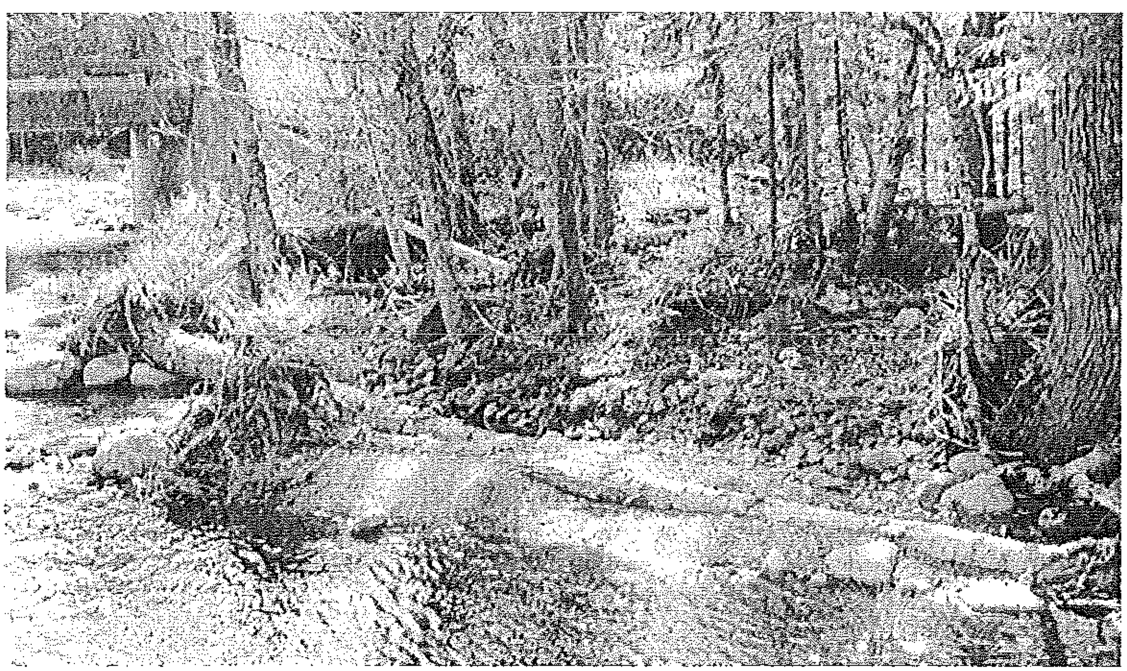


Transect 17 looking downstream, October 2007.

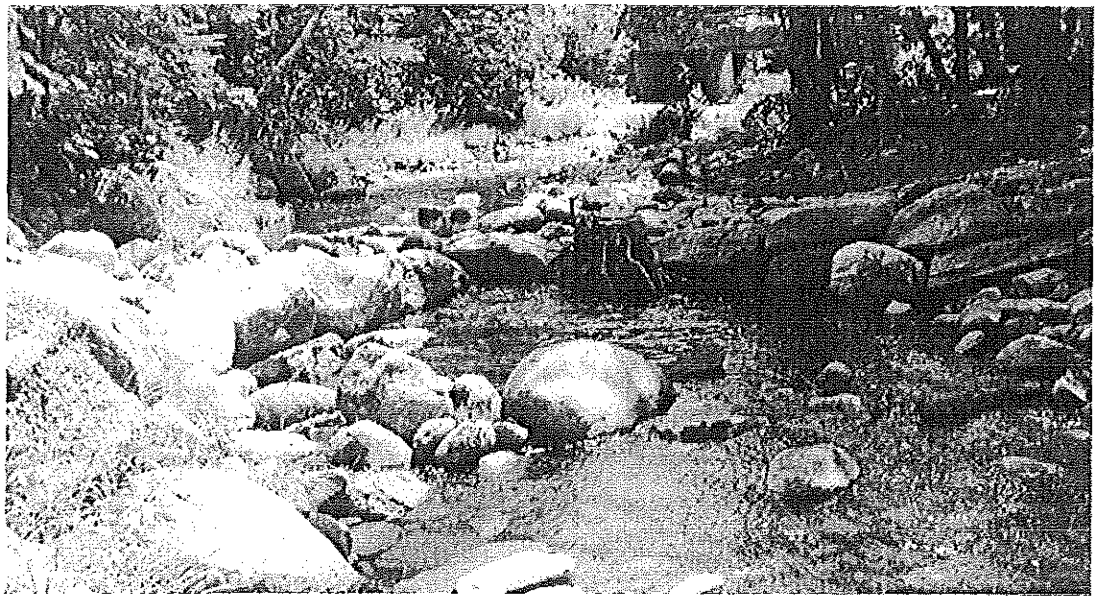
Appendix D
Photos of Structures



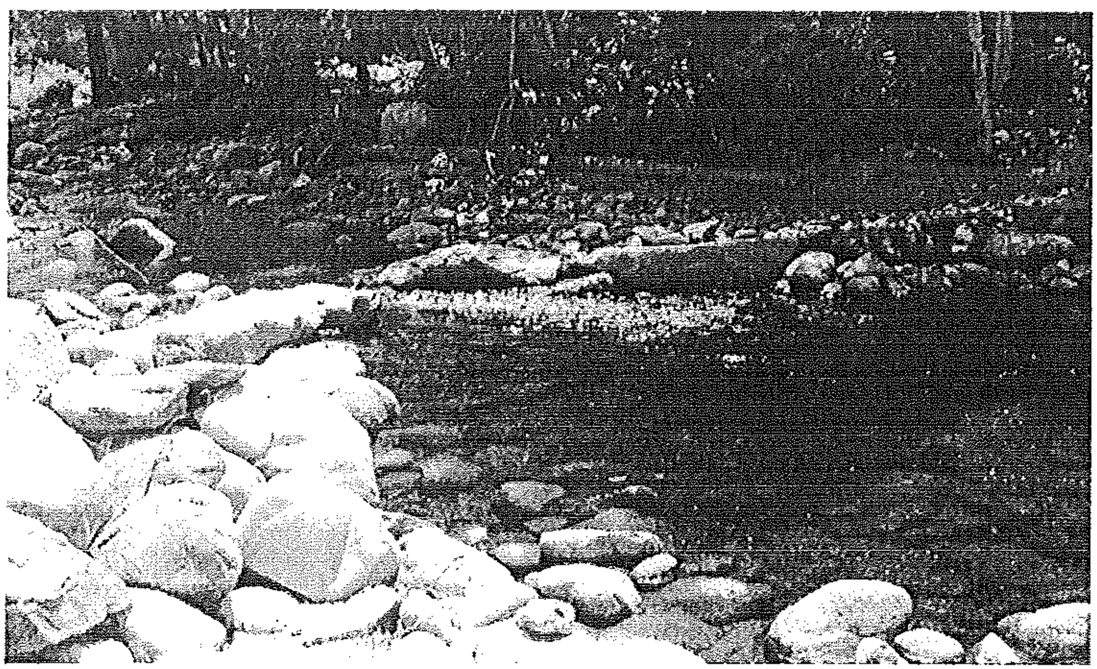
Keystone riffle/pool sequence upstream of South Shore Drive bridge (Upper Project), August 2007.



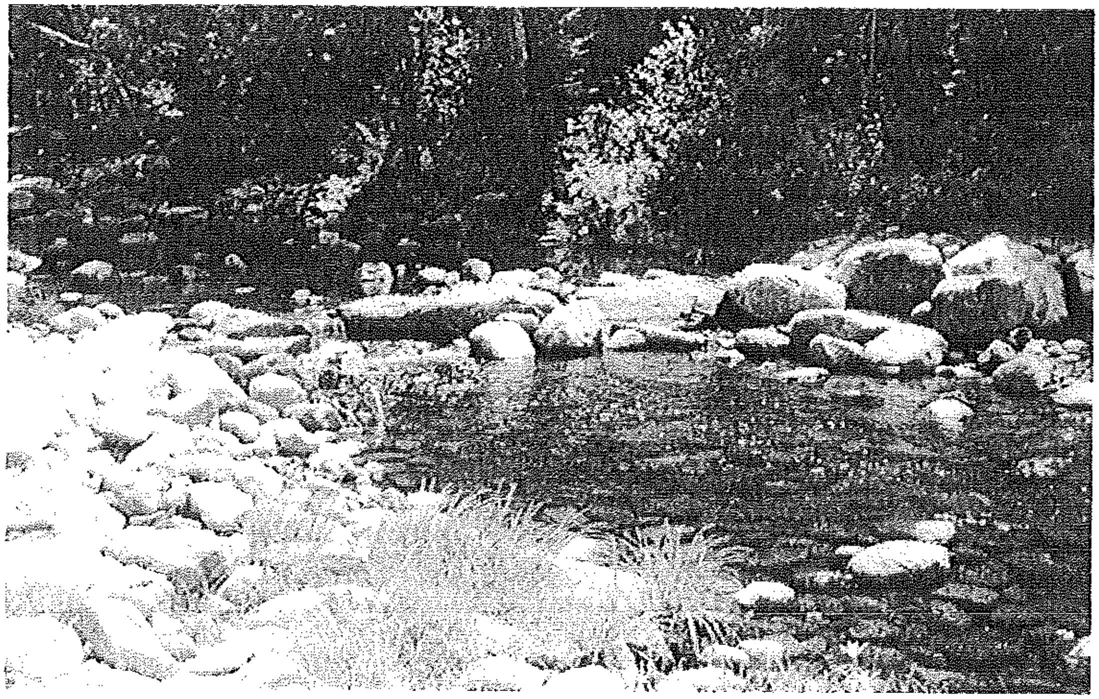
Logs placed downstream of bridge (Middle Project) with trapped sediment, October 2007.



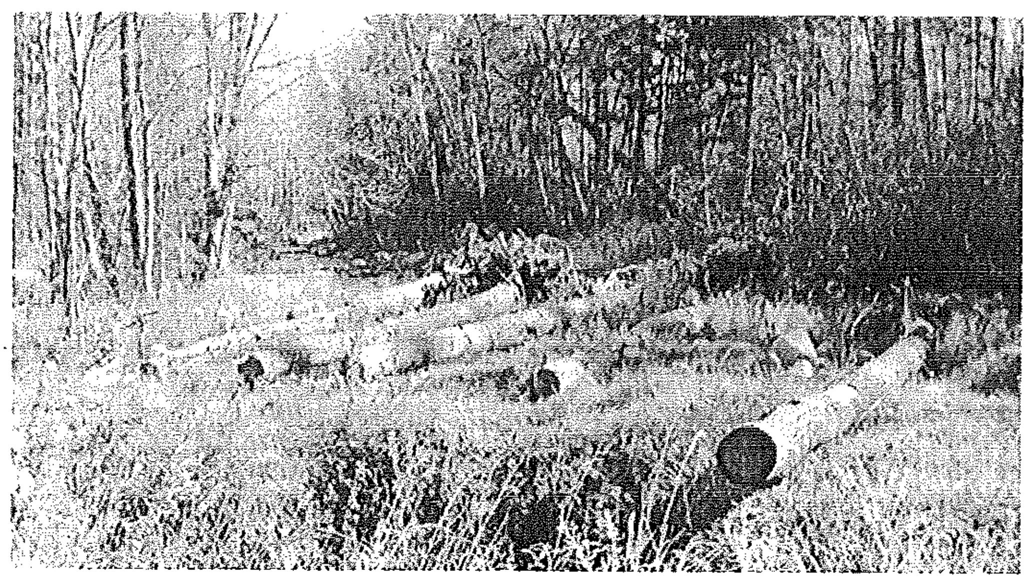
Weir No. 1 and associated root wad, Middle Project, August 2007, one year after construction.



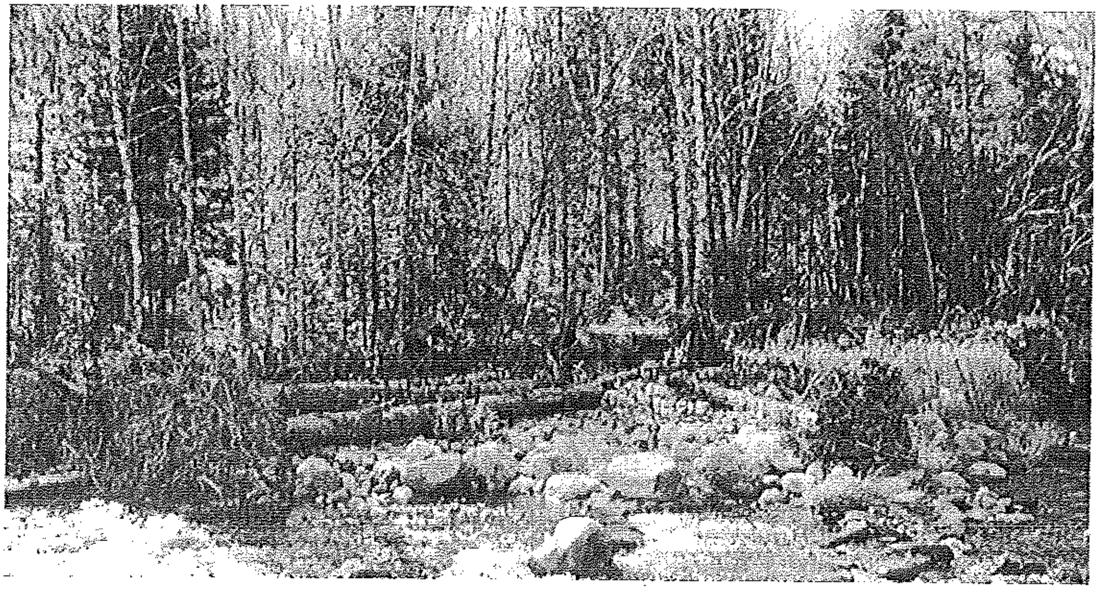
Weir No. 2, Middle Project, August 2007, one year after construction.



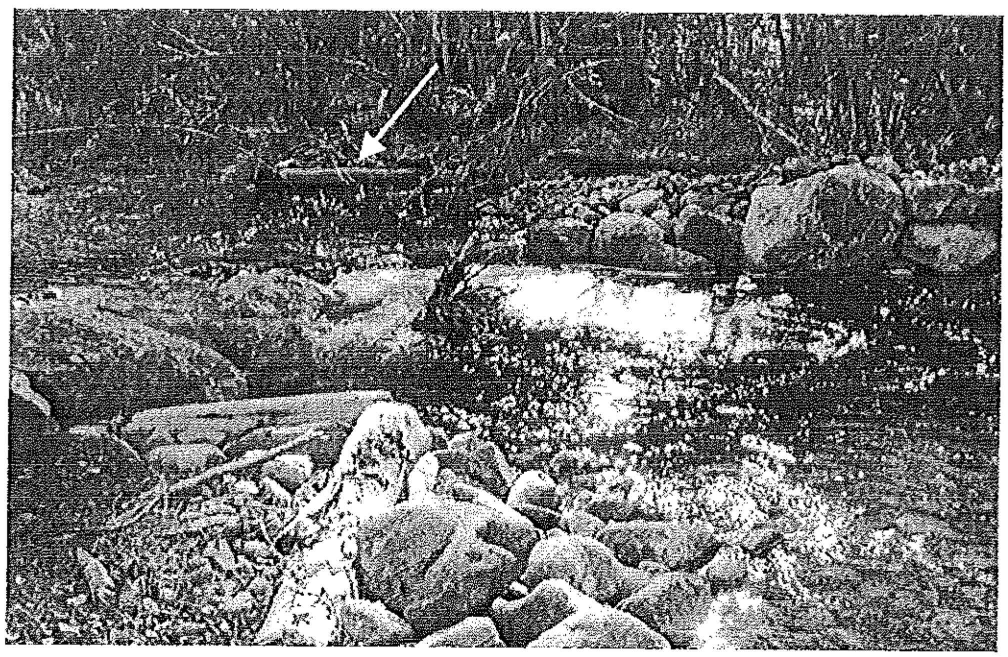
Weir No. 3, Middle Project, August 2007, one year after construction.



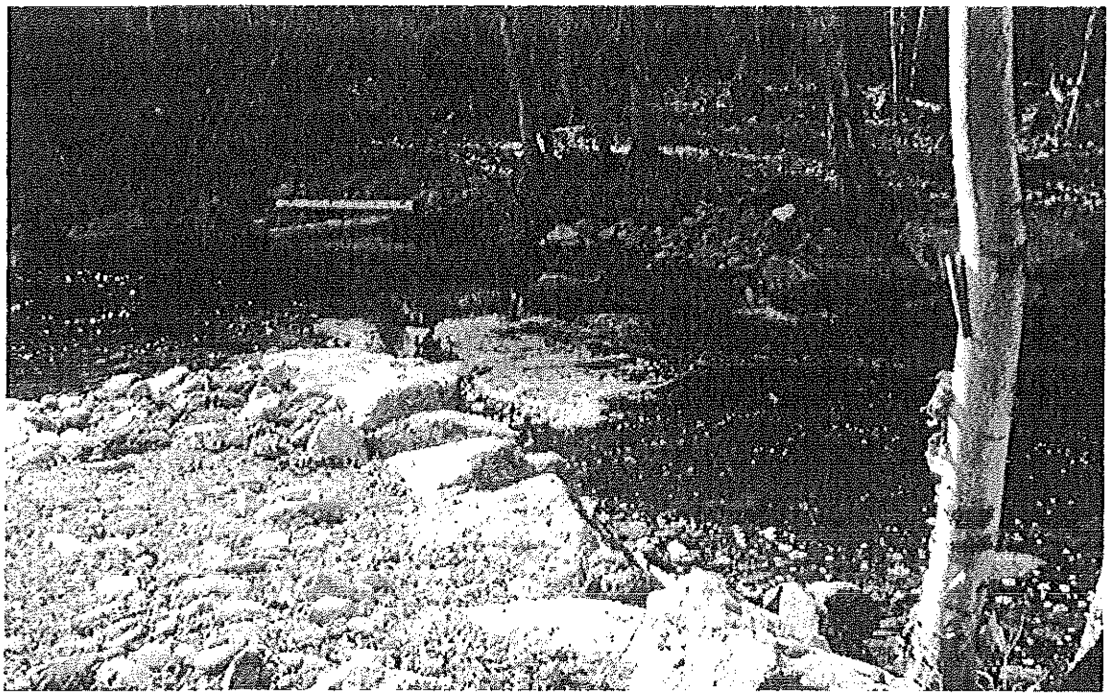
Cabled logs with attached root wads, Middle Project, east shore, October 2007, 14 months after construction. Little sediment has been trapped by these logs to date.



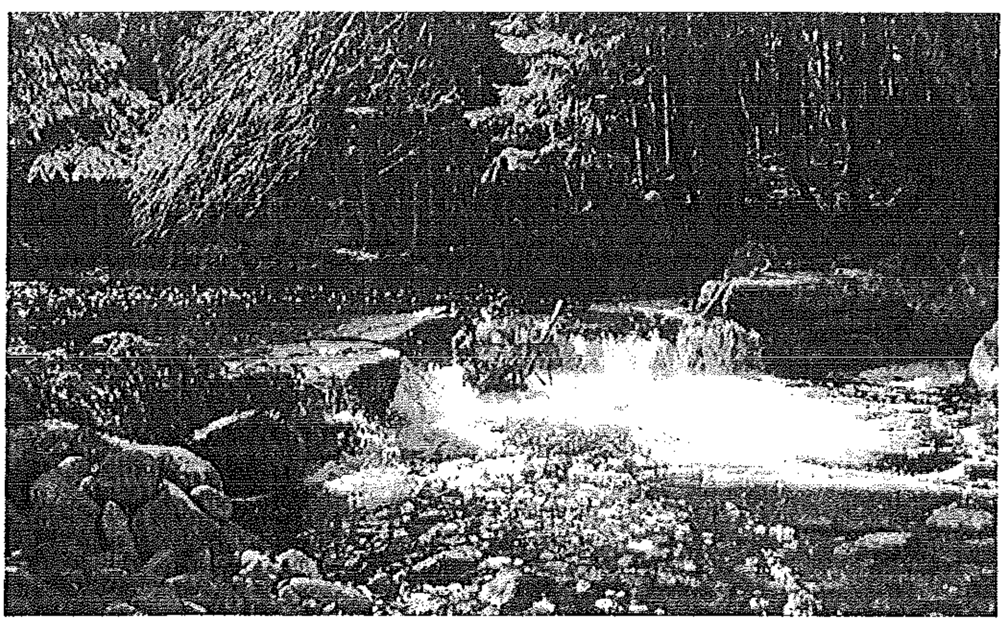
Cabled logs with attached root wads, Middle Project, west shore, October 2007, 14 months after construction (approximately across the stream from those in previous photo). Little sediment has been trapped by these logs to date.



Weir No. 1, Lower Project, was constructed proximate to the second pair of log deflectors, and the river-right deflector was removed to accommodate the weir; the river-left log deflector is visible in the foreground of the photograph; river-left log deflector of first pair is highlighted by arrow.



Rock weir No. 2, Lower Project, October 2007, two months after construction. The river-left log deflector of the lower-most pair (which suffered ice damage) was removed to construct this weir.



Rock weir No. 3, Lower Project, October 2007 (two months after construction).

COOPERATIVE

STATE SPORT FISH RESTORATION FEDERAL

PROJECT

This report has been funded in part by the Federal Aid in Sport Fish Restoration Program. This is a cooperative effort involving federal and state government agencies. The program is designed to increase sport fishing and boating opportunities through the wise investment of anglers' and boaters' tax dollars in state sport fishery projects. This program which was funded in 1950 was named the Dingell-Johnson Act in recognition of the congressmen who spearheaded this effort. In 1984 this act was amended through the Wallop-Breaux Amendment (also named for the congressional sponsors) and provided a threefold increase in Federal monies for sportfish restoration, aquatic education and motorboat access.

The Program is an outstanding example of a "user pays-user benefits", or "user fee" program. In this case, anglers and boaters are the users. Briefly, anglers and boaters are responsible for payment of fishing tackle excise taxes, motorboat fuel taxes, and import duties on tackle and boats. These monies are collected by the sport fishing industry, deposited in the Department of Treasury, and are allocated the year following collection to state fishery agencies for sport fisheries and boating access projects. Generally, each project must be evaluated and approved by the U.S. Fish and Wildlife Service (USFWS). The benefits provided by these projects to users complete the cycle between "user pays — user benefits".

Maine Department of Inland Fisheries and Wildlife
284 State Street, Station #41, Augusta, ME 04333