

# THE ENVIRONMENTAL EFFECT OF LOW-HEAD IMPOUNDMENT STRUCTURES WITH BOTTOM WATER OVERFLOWS ON TROUT STREAMS IN THE SOUTHERN APPALACHIANS

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## ABSTRACT

A study was made by the USDA, Soil Conservation Service in cooperation with the Georgia Game and Fish Commission and the USDA, Forest Service in the summer months of the years 1964-67. The purpose was to determine the extent of thermal pollution in the tailwater and the effect of this pollution on rainbow trout.

The study was made at a single-purpose, Public Law 566 floodwater-retarding structure on Hall Creek, which is a tributary of Hightower Creek in Towns County, Georgia. The conservation pool has 4.3 surface acres and is 17.5 feet deep. Normal streamflow is discharged through a bottom water overflow that extends down from the pool surface 10 feet. The structure contains 27 acre feet of stored water in the conservation pool; inflow is approximately 2.5 cfs at low flow during summer droughts and normal inflow is 5.7 cfs. The structure is located at 2,228 feet above mean sea level.

The instruments used in the study were two single-pen 7-day, clock-wound instruments and one double-pen 7-day, clock-wound instrument for taking both water and air temperature.

The single-pen instrument locations were 1,200 feet above the structure on the main stream and 2,700 feet below the structure for recording water temperature. The double-pen instrument was located immediately below the structure to record both air and water temperatures.

Tailwater temperatures varied from above structure water temperatures by as much as 9°F. The normal rise was 2° to 4°, with a random sample average of 3.0°F.

This paper presents the findings of a 4-year 1964-67 cooperative study of the effects a single-purpose floodwater retarding structure with a deep water overflow has upon a marginal trout stream when it has the limitations presented.

The study was made by the USDA Soil Conservation Service in cooperation with the Georgia Game and Fish Commission and the USDA Forest Service. The study was made on Hall Creek, a tributary of Hightower Creek, a feeder stream of TVA Lake Chatuge in Towns County, Georgia. Hall Creek watershed contains 1,314 acres with 1,280 acres in mixed hardwood – pine woodland. The remaining 34 acres is idle land formerly used for pastureland or cropland, which is reverting to woodland. Approximately 1,000 acres of the watershed is in the Chattahoochee National Forest administered by the United States Forest Service. The study structure site is 2,228 feet above mean sea level. The streamflow ranges from 2.5 cubic feet per second during dry periods to a normal flow of 5.7 cubic feet per second during most of the year. Much higher flows occur during and immediately after rains.

The surface area of the conservation pool is 4.3 acres, and the sediment storage volume in this pool in 1961 was 27 acre-feet. The conservation pool has been filling with silt at a somewhat faster rate than was expected because of timber cutting operations on the national forest. The principal spillway stands 17.5 feet above the old stream bed. The deep water overflow conduit is 1.5 feet by 2.0 feet extends down the principal spillway 10 feet from the water surface, and the water entrance opening is 7.5 feet above the flood plain. This size is sufficient to carry normal streamflow. Water is removed from the structure through 300 linear feet of reinforced concrete pipe which is 18 inches in diameter and located at about the level of the original streambed.

Instruments used in making the study were 7-day, clockwound, recording thermographs. The two single-pen instruments each have 20 linear feet of probe, and the double-pen instrument has one 20-foot probe and one 5-foot probe. The

single-pen instruments were used throughout the study and the double-pen instrument was added in 1966 to give on-site air temperature. Before 1966, air temperatures were obtained from the U. S. Department of Commerce's monthly weather bulletin; the station selected as a representative station was the Georgia Agricultural Experiment Station Branch at Blairsville, Georgia. Although the station at Helen, Georgia is closer to the study area, it is located across a mountain range. The Blairsville station is on the same side of the range, and the temperatures are more closely correlated with those in the study area. The least accurate part of the study is the rainfall data which also came from the Blairsville station. Rainfall during the winter is fairly uniform over a large area, while summer showers in the mountains are localized and vary greatly in intensity even within the shower area. As yet, it has not seemed feasible to place recording rain gauges in the watershed.

The first year of the study was 1964. One single pen thermograph was located 1,200 feet above the structure on the streambank. The cable, covered by soil and rocks, extended into the stream channel, and large rocks were arranged to maintain a current of water over the exposed probe. This prevented sanding-in or silt coverage and allowed for an accurate water temperature recording. The second single pen thermograph was located 60 feet below the structure, and the cable and probe were located as described for the first thermograph.

In 1965, the single pen thermographs were located at the same places as in 1964. There was one change in procedure in 1965. The stream crosses a county road approximately 1,100 feet below the structure site. At this point, the stream temperature was checked manually once each week when the thermograph charts were changed. This stream temperature reading was placed on the back of the chart which had been removed from the instrument immediately below the structure. From these manual readings, it was decided that a recording instrument should be placed as far down Hall Creek as possible to get more temperature data.

In 1966, the third year of the study, one thermograph was located at the same point, 1,200 feet above the structure. The thermograph below the structure was moved up toward the embankment 20 feet because of channel changes (40 feet below the structure). This was a double-pen instrument and was housed in a slatted enclosure according to U. S. Department of Commerce designs for weather stations. The five-foot probe was placed in the center of the enclosure, and the 20-foot cable and probe placed in the stream as previously described. A third single-pen instrument was located as far down Hall Creek as feasible, approximately 2,700 feet, and approximately 160 feet above the confluence of Hall Creek with Hightower Creek. The cable and probe were prepared as previously described. When this instrument was installed, the weekly reading at the road crossing was discontinued.

The 1967 study was the same as 1966 as to instrument locations and operations.

In the operation of the thermographs during the entire study, the following procedure was used:

- a. The thermograph charts were changed at weekly intervals, except in a few cases such as holidays.
- b. Air temperature was taken with a 1° graduated mercury thermometer for 3 minutes and this temperature was recorded on the back of the new chart to be installed.
- c. The thermometer was placed in the stream near the probe for 3 minutes and was read under the water. The water temperature was also recorded on the back of the chart to be installed.
- d. The watershed name, the structure number, or the creek name was written on the back of the chart, and the thermograph location, e.g. above the structure, below structure, down creek, was also written on the back.
- e. The complete date and time were placed on the back of the new chart.
- f. The recorded chart was removed from the thermograph, and the air and water temperatures put on this chart, as well as the date of removal and clock time.
- g. The instrument was key-wound, and the pen or pens inked.
- h. The new chart was installed and the chart time and temperature checked for accuracy of setting.

- i. The probe was checked for sand, silt, or leaf coverage, and was carefully replaced in the stream current.

The Georgia Game and Fish Commission removed the fish from Hall Creek on November 6, 1961, by an application of Rotenone; and the structure drain gate was closed immediately before the Rotenone was applied.

The U. S. Fish and Wildlife Service stocked the conservation pool with 1,204 rainbow trout (*Salmo gairdneri*) that weighed 70 pounds on December 6, 1961. There have been no controls as to season or size on fishing in the stream above the structure, in the conservation pool, or below the structure either by the landowners or by the Georgia Game and Fish Commission from the date of stocking until the present. In the summer of 1962, there was some fishing pressure that grew to comparatively high pressure by the spring of 1963. This fishing pressure was in the conservation pool and in the stream below the structure. There was only moderate fishing pressure in the stream above the structure. Examples of creel census of fishermen follows:

5/1/63 – Above structure – 8 trout (average size 9 inches, fishing time, 1 hour).  
In conservation pool – 4 trout (average size 13 inches, fishing time, 1 hour).  
Below structure – 3 trout (average size 8 inches, fishing time, 1 hour).

5/25/63 – Above structure – 6 trout (average size 12 inches, fishing time, 1 hour).  
In conservation pool – 8 trout, (average size 10 inches, fishing time, 1 hour).  
Below structure – 4 trout (average size, 7 inches, fishing time, 1 hour).

6/5/63 – Above structure – 5 trout (average size 10 inches, fishing time, 1 hour).  
In conservation pool – 7 trout (average size 15 inches, fishing time, 2 hours).  
Below structure – 2 trout (average size 8 inches, 1 hour fishing time).

The Georgia Game and Fish Commission, the USDA Forest Service, and the Soil Conservation Service made a population study above the structure on August 20, 1964. The segment studied was 500 linear feet of stream immediately above the structure. The method employed was the use of electrofishing gear. Salt blocks located upstream above the sample segment made the fishing more effective. The stream sample yielded 21 rainbow trout, the largest being 7.3 inches and weighing 58 grams. The smallest trout measured 3 inches and weighed 4 grams. There were seven creek chubs (*Semotilus atromaculatus*) in the sample area.

The consensus of the biologists was that there was good reproduction of rainbow trout. The variation in size was also good for such a small stream during the driest part of the year. The numbers and physical condition of the trout in the sample area were also very good.

There were six sample fishing trips between March 11, 1964, and July 14, 1964, above the structure where 28 rainbow trout (*Salmo gairdneri*, Richardson), ranging from 6 to 9 inches were taken in 12 hours of fishing.

Ten sample fishing trips between March 11, 1964, and July 14, 1964, were made in the conservation pool where 40 rainbow trout (*Salmo gairdneri* Richardson), ranging from 8 to 14 inches, were taken in 20 hours. On four occasions fishing below the structure between April 2 and May 25, 1964, 17 rainbow trout (*Salmo gairdneri* Richardson) were taken in a total of 7 hours fishing time. Most of these fish were 8 inches, two were 7 inches.

On August 14 - 17, 1967, the group cooperating in the study took another sample on Hall Creek. Again, those participating were the USDA Forest Service, the Georgia Game and Fish Commission, and the Soil Conservation Service.

On August 14, 1967, a number of temperature profile checks were made in the conservation pool on Hall Creek. These findings are recorded below: (All degrees Fahrenheit.)

Surface Water	74	75	75	75	74	74	75	72	74	73
2 Ft. Depth From Surface	70	70	70	70	70	69	69	69	68	69
4 Ft. Depth From Surface	68	68	68	68	69*	68	68	67	67	68
5 Ft. Depth From Surface				67						
6 Ft. Depth From Surface	67	66	66			67	67	66	66	67
7 Ft. Depth From Surface		66				67	67	66	66	67
8 Ft. Depth From Surface	66					66	66	66	66	66
9 Ft. Depth From Surface										
10 Ft. Depth From Surface	66					66	66	65	66	
11 Ft. Depth From Surface										
12 Ft. Depth From Surface	65					65			65	
13 Ft. Depth From Surface						65			65	
14 Ft. Depth From Surface	65									
15 Ft. Depth From Surface										

\*Three feet.

During these stratification studies, the stream-water was entering the conservation pool at 64°F and the air temperature was 71°F. The released water was 68°F at noon and was 65°F at midnight. From this sample, all released water warmed at least 1°.

Fish population samples were taken above the structure with electrofishing gear on August 15, 1967. The stream section studied started at the edge of the original conservation pool and extended upstream a distance of 500 linear feet. The stream averaged 10 feet wide and 3 inches deep. The air temperature at the time of sampling was 65°F and the water temperature was 60°F.

The following species of fish by length and weight were recovered: Nineteen creek chubs from 2.4 inches to 4.0 inches that weighed a total of 78 grams; two hornyheads (*Hybopsis biguttata*) 5.2 to 7.6 inches that weighed 114 grams; 35 rainbow trout from 2.4 to 3.7 inches that weighed 233 grams.

Below the Hall Creek structure, a 500 linear foot section of stream was sampled. The air temperature was 68°F, and the water temperature 64°F. The section was electrofished and the following was collected:

- 23 Mottled Sculpins (*Cottus bairdi* Girard) from 2.3 to 4.0 inches with a total weight of 190 grams.
- 4 Longnose dace, (*Rhinichthys Cataractae* (Valenciennes), 4.9 to 4.4 inches weighing 80 grams.
- 7 Alabama hog suckers (*Hypentelium etowanum* (Jordan), 8.5 to 7.0 inches weighing 634 grams.
- 10 Creek chub (*Hybopsis* species), 2.2 to 3.3 inches weighing 42 grams.
- 6 Redbreast sunfish (*Lepomis auritus* (Linnaeus), 4.3 to 5.2 inches with a total weight of 150 grams.
- 1 Largemouth bass (*Micropterus salmoides* (Lacepede), 10.5 inches weighing 274 grams.
- 3 Hornyhead chub (*Hybopsis biguttata* (Kirtland), 4.5 inches to 8.4 inches weighing 168 grams.
- 1 Bluegill (*Lepomis macrochirus* Rafinesque), 4.2 inches, weighing 20 grams.
- 1 shiner (*Notropis* species), 5.5 inches, weighing 24 grams.
- 1 Redhorse sucker (*Moxostoma* species), 6.5 inches, weighing 62 grams.
- 2 Stonerollers (*Camptostoma anomalum* (Rafinesque).
- 24 Yellow perch (*perca flavescens* (Mitchill), 3.4 to 6.0 inches total weight 210 grams.

*The hole approximately 20 feet by 30 feet immediately below the structure where the drainpipe discharges contained the following species of fish:*

- 2 Rainbow trout (*Salmo gairdners* Richardson), 3.5 inches to 9.2 inches and weighed 198 grams.

- 4 Alabama hog suckers (*Hypentelium etowanum* (Jordan), 5.5 to 8.3 inches with a total weight of 735 grams.
  - 2 Largemouth bass (*Micropterus salmoides* (Lacepede), 7.8 inches to 8.3 inches and weighted 237 grams.
  - 1 Longnose dace (*Rhinichthys cataractae* (Valenciennes), 3.5 inches, 8 grams.
  - 7 Redbreast (*Iepomis auritus* Linnaeus), 3.6 to 6 inches in length, total weight 206 grams.
  - 30 Sculpins (*Cottus bairdi* Girard), 2.0 inches to 4.0 inches, total weight of 328 grams.
  - 6 Creek chubs (*Erimyzon oblongus* Mitchill), total weight 42 grams.
- The Hall Creek Conservation Pool was drained and the following were recovered between the screen and drainpipe. This section of stream had previously had all fish removed with cresol before the structure was drained.
- 13 Rainbow trout (*Salmo gairdneri*). 4.2 inches to 16.4 inches, total weight 2,458 grams.
  - 400 Creek Chubs (*Erimyzon oblongus* (Mitchell) 2.2 to 9.0 inches, total weight 590 grams.
  - 400 Hornyheads (*Hybopsis biguttata* (Kirtland).
  - 1 Blue gill bream (*Lepomis macrochirus* (Rafinesque), 4.5 inches, total weight 21 grams.
  - 1 Redbreast (*Lepomis auritus* (Linnaeus), 3.6 inches, 14 grams.

Thermograph chart data were transferred to cross sectional paper. The data were then analyzed. Table No. 1 shows the calendar months and days for each of the study years. The stream water temperature before entering the conservation pool can be compared to the released water temperature below the structure. For 1966 and 1967, these temperatures can be compared to the stream temperature 3/4 mile below the structure. The data showed little variation in temperature between the inlet and discharged water early in the study period and late in the study period each year. The period of greatest variance is in July and August. The maximum discharge water temperature recorded during the study was 72°F. This temperature was reached June 13-24, 1964 for 56 hours. The 72°F temperature was reached twice in 1965 during the periods of August 7-18, for a total of 5 hours, and August 18-29, for a total of 2 hours. There were no 72°F temperatures recorded in either 1966 or 1967 in the discharge water.

To develop Table No. 2, equal size slips of paper were marked with calendar days from May 15 to October 23. These dated slips were placed in a box and mixed thoroughly by shaking. Then, 20 slips (a 12.4 percent sample) were removed; the dates were arranged in sequence. This is the first two columns of the table. Then from the temperature chart the 1200 Military Eastern Standard Time reading for these dates was made, comparing the inlet and discharge water temperatures for these dates each year of the study. This table shows the increase in discharge water temperatures over the inlet water temperatures. This difference varies from year to year, but the 4-year average variation is 3.0°F. This table shows the average rise in discharge water temperature. Conclusions from this study are:

- a. A principal spillway height of 17.5 feet and a deep water overflow extending down from the water surface a distance of 10 feet at an elevation of 2,228 feet above sea level with a normal flow of 2.5 to 5.7 cubic feet per second and a stored water volume of approximately 27 acre feet will warm the discharge water an average of 3°F during the summer months of the year.
- b. The daily water temperature varies as the average daily air temperature varies and the kind and extent of rainfall varies.
- c. An impounded structure acts as a fish barrier and prevents migration of warm water species into trout waters. This is especially true when the feeder stream temperatures go 66°F or more for much of the summer.
- d. The stream above and the conservation pool both grow trout. The number and size of the trout are in direct relation to the fish population, food supply, water area, and fishing pressure, (and possibly numbers and sizes stocked).

TABLE 1  
1964

Month	Date Begin	Date End	STREAM TEMPERATURE ABOVE STRUCTURE			STREAM TEMPERATURE IMMEDIATELY BELOW STRUCTURE					
			Maximum Temp.	Minimum Temp.	No. of Hours	At or Above °F	Maximum Temp.	Minimum Temp.	No. of Hours	At or Above °F	
May	5	11									
May	11	22	62°	52°	49	60°	64°	Below	64°	134	64°
May	22	June 2	66°	52°	138	60°	68°	62°	68°	116	65°
June	2	13									
June	13	24	67°	62°	32	66°	72°	68°	68°	75	70°
June	24	July 5	66°	60°	22	65°	71°	65°	65°	30	70°
July	5	16	68°	60°	7	65°	68°	66°	68°	107	68°
July	16	27	66°	62°	105	64°	68°	66°	66°	104	67°
July	27	Aug. 7	68°	63°	75	66°	71°	67°	67°	46	70°
Aug.	7	18	67°	59°	144	65°	71°	62°	62°	63	70°
Aug.	18	29	66°	62°	101	64°	68°	63°	68°	70	67°
Aug.	29	Sept. 9	66°	59°	44	64°	68°	66°	68°	175	67°
Sept.	9	20	66°	57°	64	63°	68°	63°	68°	133	66°

TABLE NO. 1 (Cont'd)  
1965

STREAM TEMPERATURE ABOVE STRUCTURE				STREAM TEMPERATURE IMMEDIATELY BELOW STRUCTURE						
Month	Date Begin	End	Maximum Temp.	Minimum Temp.	No. of Hours	At or Above °F	Maximum Temp.	Minimum Temp.	No. of Hours	At or Above °F
May	5	11	63°	60°	27	62°	65°	63°	61	64°
May	11	22	63°	55°	10	63°	66°	60°	14	65°
May	22	June 2	64°	60°	76	63°	67°	63°	114	65°
June	2	13	64°	57°	57	63°	67°	60°	64	65°
June	13	24	65°	62°	194	63°	69°	64°	49	68°
June	24	July 5	67°	64°	241	65°	71°	67°	183	69°
July	5	16	68°	63°	97	66°	71°	67°	96	70°
July	16	27	67°	61°	46	66°	71°	65°	43	70°
July	27	Aug. 7	68°	63°	100	66°	72°	67°	90	70°
Aug.	7	18	68°	66°	157	67°	72°	69°	3	71°
Aug.	18	29	65°	60°	17	65°	69°	62°	154	66°
Aug.	29	Sept. 9	67°	62°	53	66°	70°	66°	109	68°
Sept.	9	20	67°	58°	40	66°	70°	61°	76	68°
Sept.	20	28	63°	54°	29	62°	64°	57°	104	62°
Sept.	28	Oct. 8	61°	53°	56	59°	61°	52°	110	59°
Oct.	8	23								





TABLE NO. 1 (cont'd)  
1967

Month	Date Begin	Date End	STREAM TEMPERATURE ABOVE STREAM TEMPERATURE IMMEDIATELY STREAM TEMPERATURE 3/4 MILE BELOW STRUCTURE			STREAM TEMPERATURE IMMEDIATELY STREAM TEMPERATURE 3/4 MILE BELOW STRUCTURE							
			Maximum Temp.	Minimum Temp.	No. of Hours Above °F	Maximum Temp.	Minimum Temp.	No. of Hours Above °F					
May	5	11	61°	54°	5	61°	57°	6	60°	61°	56°	76	60°
May	11	22	64°	60°	24	69°	62°	62	66°	64°	61°	217	63°
May	22	June 2	64°	59°	69	69°	64°	103	66°	66°	63°	38	65°
June	2	13	64°	57°	10	65°	61°	174	63°	66°	58°	64	63°
June	24	July 5	64°	59°	67	67°	62°	44	66°	67°	62°	46	66°
July	5	16	64°	59°	166	64°	62°	107	66°	71°	66°	66	70°
July	16	27	64°	59°	102	67°	61°	43	65°	69°	60°	61	68°
July	27	Aug. 7	64°	59°	77	66°	60°	15	65°	66°	59°	11	65°
Aug.	7	18	64°	59°	11	61°	59°	113	60°	61°	58°	46	60°
Aug.	18	29											
Aug.	29	Sept. 9											
Sept.	9	20											
Sept.	20	28											
Sept.	28	Oct. 8											
Oct.	8	23											

Ended 9/6/67

TABLE 2

Temperature variation of random samples reflecting degrees fahrenheit difference between inlet and discharge water.

<i>Month</i>	<i>Day</i>	<i>Year</i> <i>1964</i>	<i>Year</i> <i>1965</i>	<i>Year</i> <i>1966</i>	<i>Year</i> <i>1967</i>
May	21	3	2.5		
June	2	3	3	9	4
June	15	3	3	3	3
June	28	4.5	2	1.5	3
July	10	5	3.5	2.5	1
July	19	3.5	3.5	3.5	2
July	28	1	3.5	4.5	2
August	3	3	4	5.5	2.5
August	11	5	5	3	1
August	16	3.5	3	2	3
August	22	1	2.5	4	1
August	28	3	3	6	1
September	5	4	2	3	2
September	12	2	3	5	
September	17	6	2	2	
September	21		3	4	
September	25		3.5	1	
October	4		3		
October	12		1		
October	21		1		
Average		3.4	2.9	3.7	2.1

Total Average 3.0°F

- e. The trout below the structure have been gradually displaced by warm water species. Yet, some few trout still occur below the structure.
- f. This study suggests that the deep water release should have been extended as close to the pond bottom as possible. A study will be run to test this possibility on Hiawassee River as soon as the structure with a deep water release is constructed.