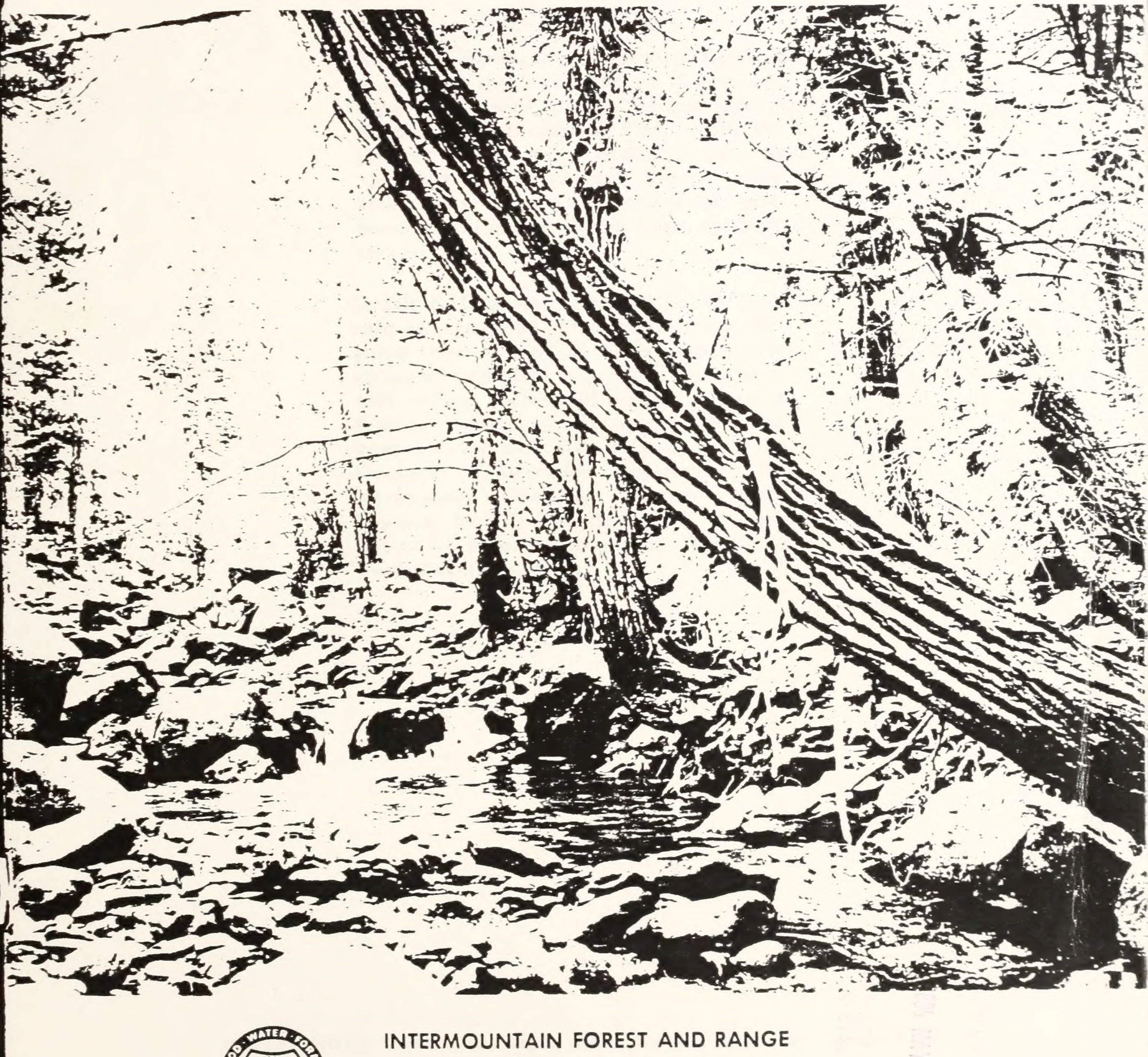
A TECHNIQUE FOR SAMPLING GENERAL FISH HABITAT CHARACTERISTICS OF STREAMS

ROSCOE B. HERRINGTON and DONALD K. DUNHAM



INTERMOUNTAIN FOREST AND RANGE
EXPERIMENT STATION
Ogden, Utah

THE AUTHORS

Roscoe B. Herrington is Recreation Resource Analyst at the Intermountain Forest and Range Experiment Station and has been in charge of the Recreation Planning Project since 1963. Prior to his present position, he conducted research covering inventory, marketing and production economics of the timber resources in Colorado, Idaho, Utah, and Montana.

Donald K. Dunham is Regional Fishery Biologist headquartered in the Intermountain Regional Office of the U.S. Forest Service. He graduated from the University of Montana in 1951 with a Bachelor of Science Degree in Wildlife Technology, following which he worked 5 years as a Fishery Biologist for the Wisconsin Conservation Department. He subsequently served as Research Fishery Biologist for the Department of Interior's Bureau of Sport Fisheries and Wildlife in North Dakota and Utah.

COVER PHOTO: Lower Sheep Creek, Ashley National Forest, near Manila, Utah.

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by

Roscoe B. Herrington
and
Donald K. Dunham

INTERMOUNTAIN FOREST AND RANGE
EXPERIMENT STATION
Forest Service
U.S. Department of Agriculture
Ogden, Utah 84401
Joseph F. Pechanec, Director

(The investigations reported in this paper were conducted by the U.S. Forest Service's Intermountain Forest and Range Experiment Station and Intermountain Region in cooperation with Utah State University.)

CONTENTS

INTRODUCTION

Sport fishing represents the major recreation value of many western streams — particularly the smaller ones. The ability of any stream to produce fish — and thus provide a fishing opportunity — is strongly related to the condition of the fish habitat. In spite of their obvious importance, habitat conditions of most western streams remain unknown. This lack of knowledge is partly due to the difficulty of determining which element of the habitat may be limiting and partly due to the expense of collecting habitat information.

A common procedure for observing and measuring the fish habitat is to have an experienced biologist walk along sections of each stream and record his evaluations. Experienced biologists, however, are usually in short supply. This process could well be expedited if personnel with minimal training could make objective measurements, which then could be evaluated by the biologists.

It is not practical to completely measure the varying elements of all streams. This paper describes a sampling technique for taking measurements along selected transects across streams. When tested on three streams, the results provided acceptably precise estimates of stream length and width, surface area, pool area, riffle area, depth, and streambed composition, as well as of the stability and vegetative cover of the streambanks.

Such data will permit land managers and fisheries biologists to evaluate the fishery potential of selected streams and to diagnose basic deficiencies in fish habitat. Although additional information would be essential for detailed planning, decisions seldom can be delayed until complete biological survey data become available. The data obtained from the technique reported here can help the land manager make effective interim plans and avoid costly mistakes particularly in recreation developments.

In addition, the data are sufficiently definitive and descriptive so that they could be used as a benchmark to determine the magnitude of future changes that may occur. The impact of destructive floods, for example, could be better determined from measurements made before the flood rather than afterward. Changes in streambed sedimentation might indicate the impact of management actions involving road location or livestock movement. This would require that some transects be established with permanent markers so that remeasurement could be made as needed.

A cost analysis of this study provides guides for estimating expenses of similar surveys using this technique in mountainous areas where road systems are limited. Expenditures for salaries, subsistence, vehicles, and horses totaled $1,652; thus the average cost per transect was $6.43. The average cost per mile was $18.93 (87.25 miles of stream were surveyed). On the average, a two-man crew measured 11.2 transects per day, or 2.8 miles of stream per day.

Boundaries for the three drainages sampled were selected to coincide with those of existing working compartments for timber, forage, and other resources. This was done to facilitate the use of the data by fishery biologists, foresters, hydrologists, highway planners, and other land managers. Wherever possible, natural drainage separations — ridgelines, divides, and saddles—should be used as boundaries.

STUDY AREA

Three stream drainages were sampled within the Wasatch National Forest in northeastern Utah: Henry's Fork, Main Fork of the Bear River, and Hayden Fork (fig. 1). These are representative of the headwaters portions of the larger drainages on the north slope of the Uinta Mountains.

The mountains are composed primarily of quartzites and other sedimentary rocks and have been heavily glaciated, although no glaciers are now present. Elevations range from about 6,000 to over 13,000 feet. Much of the area is above timberline (11,000 feet), below which the forest is interspersed with numerous alpine meadows. The predominant tree cover is lodgepole pine (*Pinus contorta*) with lesser amounts of Engelmann spruce (*Picea engelmannii*), Douglas-fir (*Pseudotsuga menziesii*), subalpine fir, (*Abies lasiocarpa*), and aspen (*Populus tremuloides*). Extensive areas of sagebrush (*Artemisia tridentata*) are found on the drier sites at the lower elevations.

Hayden Fork and Main Fork of the Bear River drain into the Great Salt Lake. Henry's Fork drains into the Green River — a tributary of the Colorado River — near Manila, Utah.

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[1] *Hutchison, S. Blair, John H. Wikstrom, Roscoe Burwell Herrington, and Robert E. Benson. Timber management issues on Utah's North Slope. U.S. Forest Serv. Res. Pap. INT-23, 23 pp., illus., 1965.*

Figure 1.—Sketch shows location of the three stream drainages measured during this study.

SELECTION OF THE SAMPLE TRANSECTS

Sample points were plotted on a map (scale: 2 inches/miles). Aerial photos (scale: 1/20,000) were used to determine what tributaries or portions of the main streams were dry. This was necessary because most maps don't distinguish between dry, intermittent, and flowing streams. Dry streambeds were eliminated from consideration as sample points. If there was any doubt as to whether a channel contained flowing water, the channel was included in the sample.

The beginning and end points of each flowing channel were identified on photos and then plotted on the map. The beginning point was defined as the origin, such as a lake or a stream, or as the point above which the streambed was obviously dry. The end of a stream was defined as the point where it drained into another stream or reached the drainage unit boundary. These decisions were based on aerial photo interpretation.

In some instances, inspection of the photos revealed flowing streams that were not shown on the map. Such channels were sketched as accurately as possible on the map.

Sample points were then selected and marked at ¼-mile intervals along the channels shown on the corrected map. The points were numbered as shown in figure 2. Dividers were used to measure the distance between these points. Each point was then located on the appropriate aerial photo and marked with the same number used on the map.[2]

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[2] *The map, rather than the aerial photos, was used for selecting the sample transects, because differences in scale between individual photos would have made equal spacing of the sample points difficult and time consuming to do on photos.*

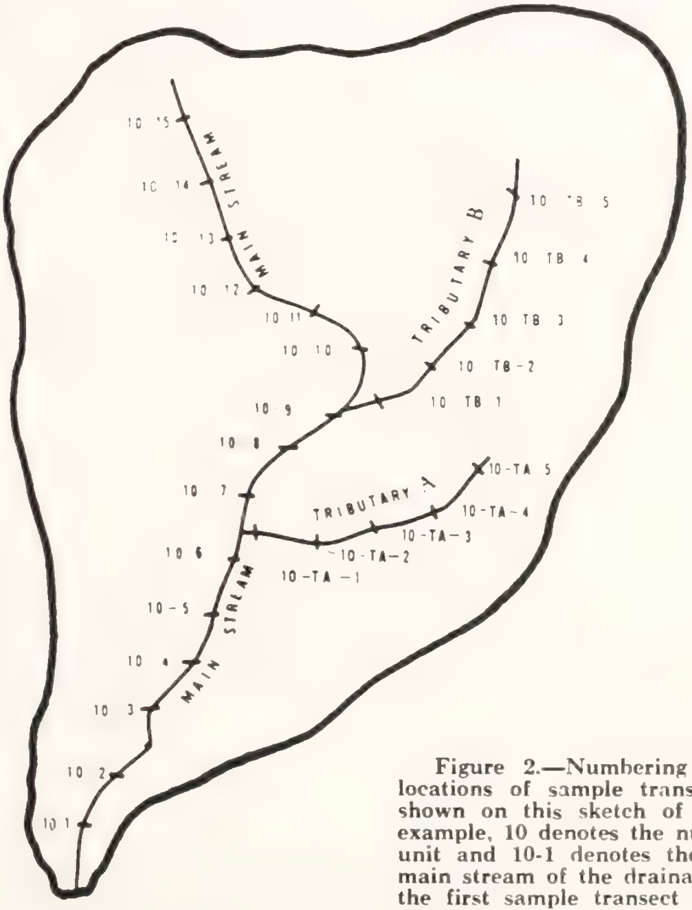

Figure 2.—Numbering system used to identify the locations of sample transects within drainage units is shown on this sketch of a hypothetical drainage. For example, 10 denotes the number assigned to the drainage unit and 10-1 denotes the first sample transect on the main stream of the drainage unit, while 10-TA-1 denotes the first sample transect on Tributary A in the drainage unit.

LOCATING SAMPLE POINTS IN THE FIELD

The field crew located points on streambanks that coincided approximately with the sample points marked on the aerial photos.[3] After initial training, field crews easily located each point within ± 200 feet by comparing photo images with ground details. Possible bias on the part of the field crew in locating the sample point was eliminated by having the crews establish transects exactly one hundred feet upstream from the point first identified on the ground.[4]

CHARACTERISTICS MEASURED

Measurements were taken only on those portions of stream channels averaging more than 4 feet wide. Altogether 290 potential transects were located and inspected in the field. Of these, however, only 257 actually were measured because 19 occurred at points where the channel was either dry or too narrow and 14 fell in extensive beaver pond areas, where wading was hazardous.

Measurements were made along a transect across the stream at a 90-degree angle to its centerline (fig. 3). If more than one channel was found, the transect was extended to the bank of the second channel. This process was repeated until all channels of a stream had been crossed. All measurements were recorded on the form shown in figure 4.

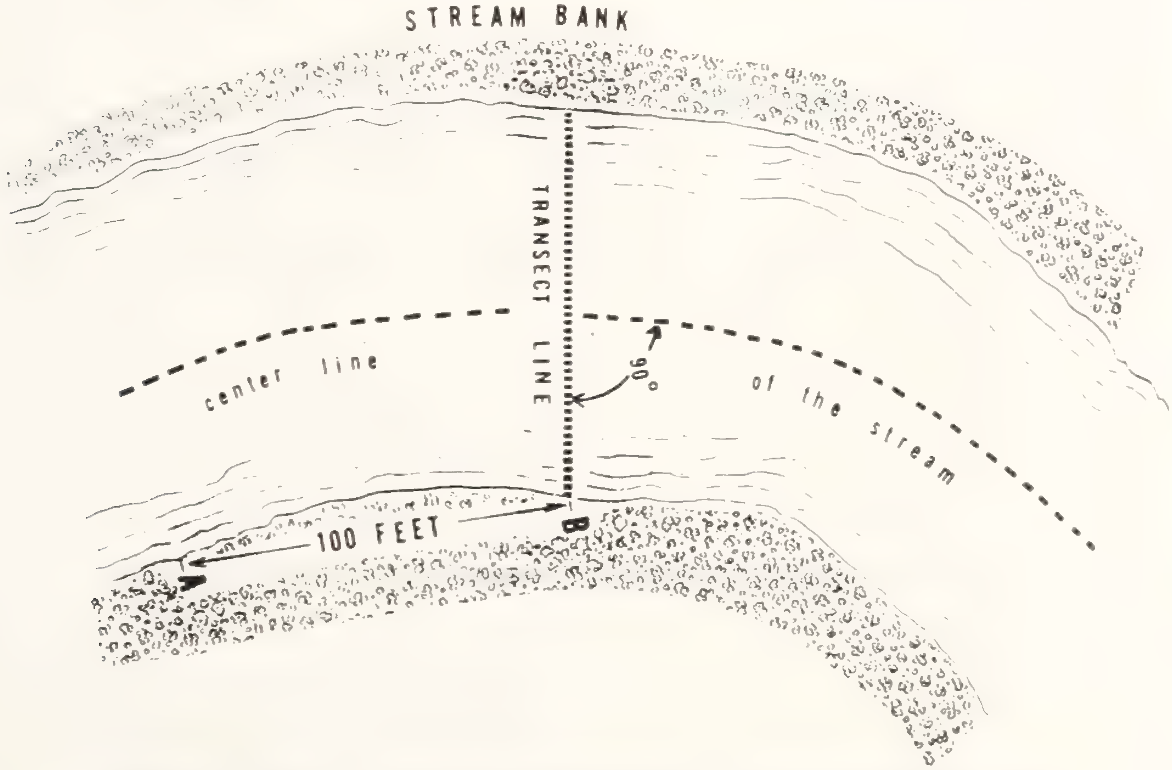

Figure 3.—Point A in above drawing represents the point identified by the field crew as approximating the location of the sample point shown on aerial photo. Point B was then established 100 feet upstream as one end of transect.

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[3] *Although it is possible technically to locate exact points, such refinement is not necessary; if points are to be established as permanent samples, greater precision in matching field points with those marked on the photos would be required. In addition it would be necessary to identify the exact sample point by using reference stakes or tree blazes.*

[4] *This was done in an effort to minimize the possibility that field crews might allow local conditions to influence the establishment of sample points, based on the assumption that they could not see (and thus prejudge) conditions one hundred feet away.*

WIDTH

The width of the water surface was measured to the nearest foot. Protruding rocks, stumps, or logs were included as part of the total width. Whether the channel was at high- or low-water stage at the time of sampling was noted on the form.[3]

DEPTH

Depth was measured to the nearest inch at three points along each transect at intervals of one-quarter, one-half, and three-quarters of the distance across each channel. For example, if channel width was 20 feet, depth measurements were made at 5, 10, and 15 feet from one bank. The three depth readings and their average were recorded on the form.

POOLS AND RIFFLES

Two classes of water surface were recognized — pools and riffles. In general, those parts of the channel where the water flowed more slowly and was deeper than in surrounding portions were called pools. Conversely, the faster moving, more shallow portions were called riffles. Pools and riffles usually were intermixed along a single transect.

Recognition of pool area is somewhat subjective; thus the field crews needed training to make comparable estimates. The obvious pool situations, such as impoundments behind beaver dams or other obstructions, were easily recognized. Other pools, such as the small

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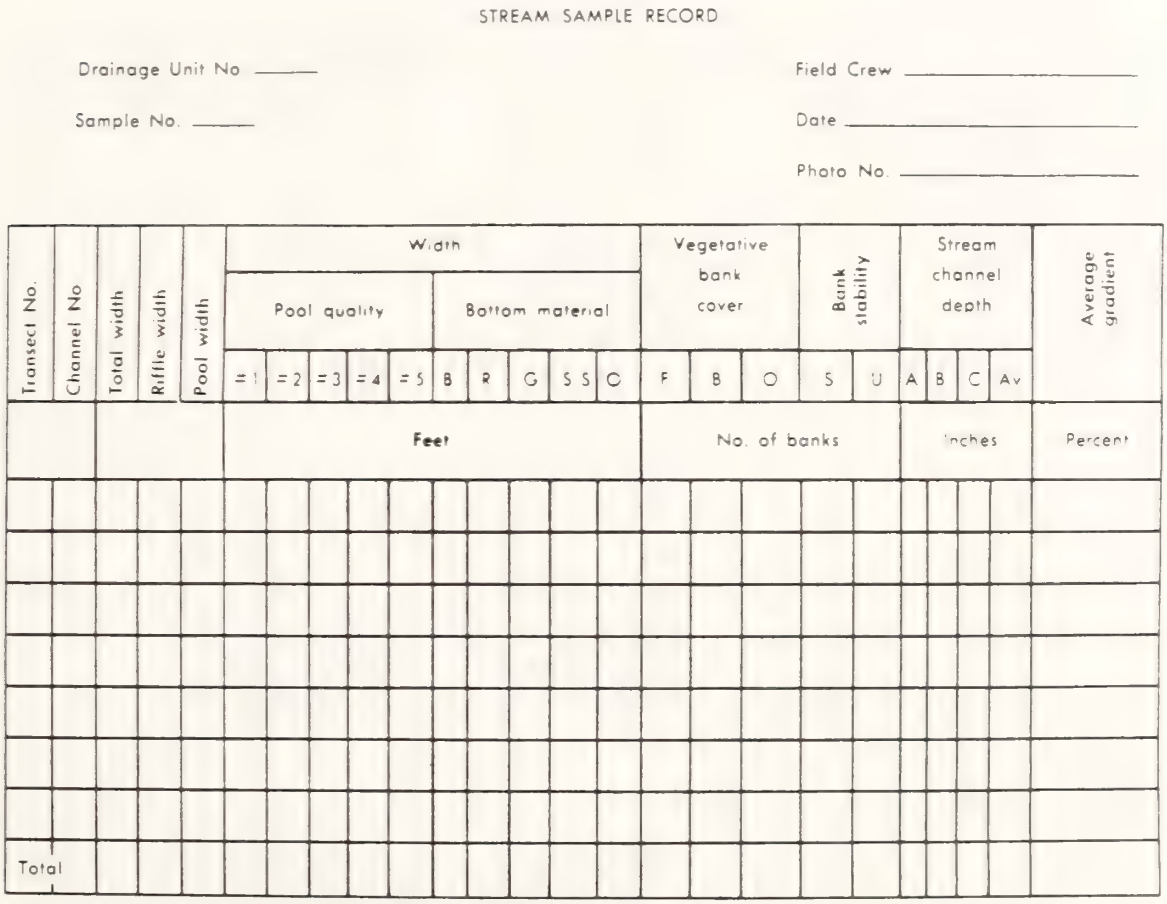
[3] *The high-water mark was identified by debris, water marks on vegetation and rocks, or any other evidence that the water level had been higher than was found during the visit to the sample. If no such evidence was found, the water level was noted as being at the high-water stage.*



STREAM SAMPLE RECORD

Drainage Unit No ______

Sample No. ______

Field Crew ______

Date ______

Photo No. ______

Transect No.	Channel No	Total width	Riffle width	Pool width	Width										Vegetative bank cover			Bank stability		Stream channel depth				Average gradient
					Pool quality					Bottom material														
					=1	=2	=3	=4	=5	B	R	G	SS	C	F	B	O	S	U	A	B	C	Av	
					Feet										No. of banks					Inches				Percent
Total																								

Figure 4.—Shown above is the record form used in the study.

ones formed in eddies below protruding rocks, were less evident. Fortunately, these smaller pools comprised only a small part of the total pool area.

Five pool-quality classes were designed on the basis of pool size, water depth, and fish shelter, see guide, page 7. The deeper and larger pools with abundant shelter were considered better fish habitat than the smaller, shallower, and more exposed pools.

The width of each pool along the transect was measured to the nearest foot and was recorded according to quality classes (fig. 5).

Riffles, in effect, were defined as all water surface areas not designated as pools. Therefore, the sum of all pool widths was subtracted from the width of the channel to determine riffle width for that channel.

BOTTOM COMPOSITION

Five types of bottom material were defined as follows:

Boulder--Rocks over 12 inches in diameter

Rubble—Rocks 3 to 11.9 inches in diameter

Gravel—Rocks 0.1 to 2.9 inches in diameter

Sand-silt—Particles less than 0.1 inch in diameter

Other—Other matter (sunken logs or other debris)

Bottom material was not always visible because of suspended silt, shadows, or water depth. Classification in such cases was based largely on the "feel" of the bottom as a field-

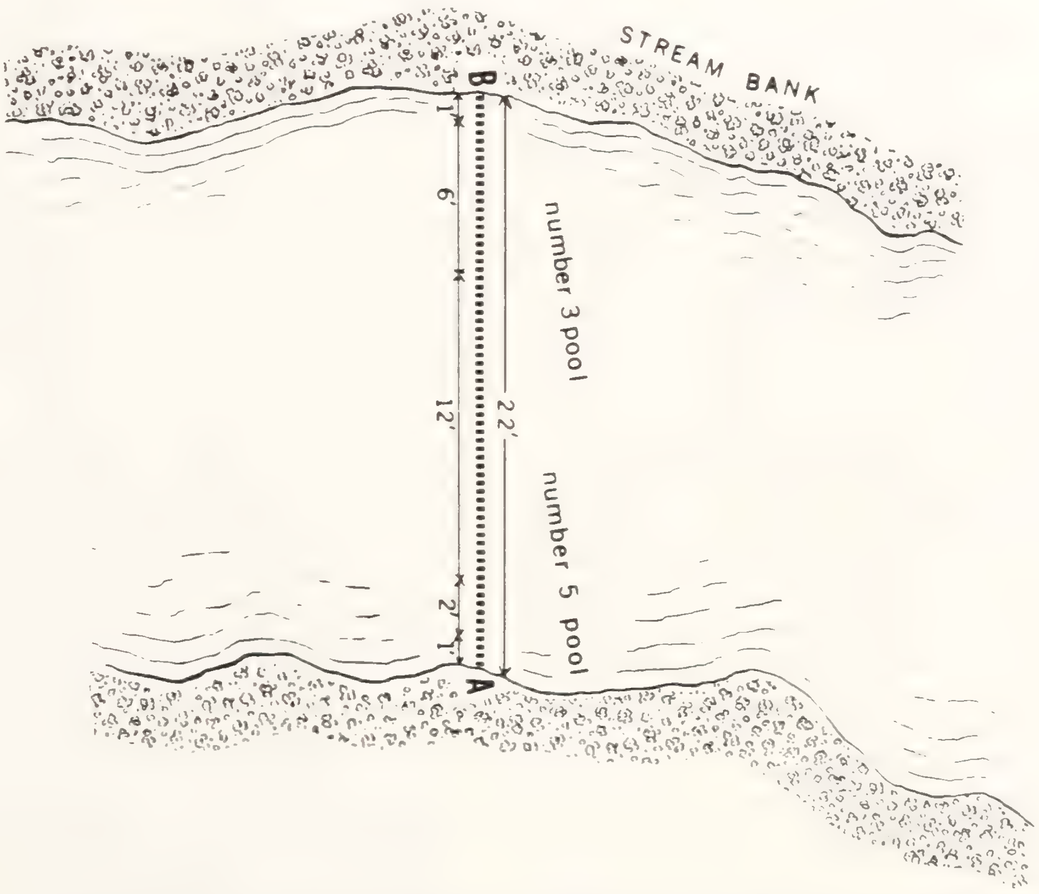


Figure 5.—This hypothetical transect shows the type pool and riffle data that were recorded. One pool, of number three quality, is 6 feet wide along the transect. The second pool, of number five quality, is 2 feet wide along the transect. The remainder of the total transect length — 14 feet — is recorded as riffle area.

Pool quality recognition guide

Pool			
Quality class no.	Length or Width	Depth	Shelter[1]
1	Greater than a.c.w.[2]	2′ or deeper	Abundant[3]
	Greater than a.c.w.	3′ or deeper	Exposed[4]
2	Greater than a.c.w.	2′ or deeper	Exposed
	Greater than a.c.w.	<2′	Intermediate[5]
	Greater than a.c.w.	<2′	Abundant
3	Equal to a.c.w.	<2′	Intermediate
	Equal to a.c.w.	<2′	Abundant
4	Equal to a.c.w.	Shallow[6]	Exposed
	Less than a.c.w.	Shallow	Abundant
	Less than a.c.w.	Shallow	Intermediate
	Less than a.c.w.	<2′	Intermediate
	Less than a.c.w.	2′ or deeper	Abundant
5	Less than a.c.w.	Shallow	Exposed

[1] *Logs, stumps, boulders, and vegetation in or overhanging pool, or overhanging banks.*
[2] *Average channel width.*
[3] *More than ½ perimeter of pool has cover*
[4] *Less than ¼ of pool perimeter has cover*
[5] *¼ to ½ perimeter of pool has cover*
[6] *Approximately equal to average stream depth*

worker waded along the transect. Therefore, it was impractical to detect any bottom type less than 1 foot long. The combined lineal footage of each type of bottom material was measured and recorded to the nearest foot for each channel. Width of the stream bottom was considered equal to the width of the stream surface.

BANK STABILITY

Bank conditions at each end of a transect were rated either as "stable" or as "unstable." (1) An "unstable" rating was given if there was any evidence of soil sloughing within the past year. (2) The number of stable banks for each transect was recorded as 0, 1, or 2. (3) On multiple channels, only the two outermost banks were rated.

STREAMSIDE VEGETATION

Three types of streamside vegetation were recognized: "forest," "brush," and "open." Forest was defined as stands of trees. Other woody vegetation was defined as "brush," and banks without woody types of vegetation were rated as "open." Recognition of these three vegetation types was largely based on subjective judgment; no specific measurements were made. The field crews estimated which type predominated over an area approximately two hundred feet square at each end of the transect above the high-water mark. In making their judgment, the field crews used aerial photos along with visual estimation of ground cover.

CHANNEL GRADIENT

Two gradient readings were taken using a hand level: one reading one hundred feet upstream from the sample point and the other one hundred feet downstream. The average of these two readings (ignoring the minus sign of the downstream reading) was recorded as the gradient of the sample point.

STREAM LENGTH

On the aerial photos, the field crew identified and marked either (1) the origin of the stream (at a lake or spring) or (2) the point at which the average stream width became less than 4 feet — whichever was encountered first while working upstream. This point often was downstream of the stream's beginning point — originally marked as a correction

on the map. This new point was transferred to the corrected map.

The length of the stream in miles then was measured on the corrected map by using dividers set at map scale to measure ¼-mile distances. However, such direct map measurements underestimate the true stream length because of the extra distance involved in the meandering course followed by most streams. It is possible, of course, to measure the true stream length in the field, but this would require a great deal of time. Because overhanging trees obscure the stream channel in many places, complete measurement on aerial photos is not possible either.

As an alternative, the amount of meander was estimated for the stream by measuring the meander distance of selected segments of stream channel that were visible on the aerial photos. Four or five segments approximately one-fourth of a mile long were measured for each main channel and four or five for the tributaries of that channel.

A "meander factor" was calculated for each sample segment using the procedures described by Herrington and Tocher.[6] The meander factors for the sample segments were then averaged together. An average meander factor for each stream and its tributaries then was calculated. This factor expresses the number of units of meander distance that are associated with one unit of straight line distance. In this study, factors ranged from 1.1 to more than 2.1 for individual stream segments sampled.

These average meander factors for the stream were used to adjust the stream lengths determined from the corrected map. For example, one stream that had measured 8.6 miles on the corrected map was found to have an average meander factor of 1.47. Thus, the adjusted length of this stream was calculated as being 12.64 miles (8.6 miles × 1.47).

PRECISION OF RESULTS

The stream characteristics recorded at each sample transect can be used either singly as a description of the stream at that particular point or in combination with other samples to obtain an estimate of the stream as an entity. Composite estimates require that numerical values for specific characteristics of all samples be totaled to derive a mean or average value per transect or be expressed as a percent of all transects having any particular characteristic.

Table 1 summarizes the general characteristics estimated for the three drainages included in this study. Width, depth, and gradient of each stream were calculated as the average value per transect. The data for bank stability and vegetation type were expressed as proportions of all banks rated. Data on pool area, riffle area, pool class quality, and bottom material were expressed as proportions of the stream's total surface area.

The reduction of a large number of individual measurements to a single figure facilitates comparison between streams in terms of a specific characteristic. For example, the Main Fork of the Bear River was found to have a much lower proportion of its surface area in pool situations than Henry's Fork and Hayden Fork. However, such composite estimates always are associated with a certain amount of error because they are obtained from samples rather than a complete measurement of an entire stream. For this reason, any estimate is expected to approximate the actual situation rather than indicate precisely its magnitude. Therefore, the utility of the estimates depends on the amount of error associated with them.

The standard error of the estimate was calculated for selected stream characteristics to indicate how large an error was associated with the estimates for the three streams. One

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[6] *Herrington, Roscoe B., and S. Ross Tocher. Aerial photo techniques for a recreation inventory of mountain lakes and streams. U.S. Forest Serv. Res. Pap. INT-37, 21 pp., illus., 1967.*

Table 1. — Summary of stream drainage characteristics

		Main Fork	Henry's Fork			Hayden Fork			Total
		of Bear River[1]	Main channel	Tributary channels	Total	Main channel	Tributary channels	Total	all streams
Number of transects		50	68	51	119	45	43	88	257
Adjusted stream length	miles	15.30	22.75	17.70	40.45	13.50	18.00	31.50	87.25
Average width	feet	43	28	10	20	26	12	19	24
Surface area	acres	79.7	77.2	21.5	98.7	42.5	26.2	68.7	247.1
Riffle area	percent	89.7	80.6	66.2	77.5	72.5	82.8	75.6	81.3
Pool area	percent	10.3	19.4	33.8	22.5	27.5	17.2	24.4	18.7
Proportion of pool area by pool quality class[2]									
Class 1	percent	28.8	43.7	11.9	33.3	58.8	52.9	57.6	40.9
Class 2	percent	11.8	9.3	70.6	29.3	13.0	0	10.2	19.3
Class 3	percent	7.0	18.9	4.5	14.2	14.2	14.9	14.4	12.8
Class 4	percent	25.8	14.2	6.8	11.8	8.7	20.7	11.2	14.3
Class 5	percent	26.6	13.9	6.2	11.4	5.3	11.5	6.6	12.7
Proportion of bottom area by material class[3]									
Boulder	percent	42.4	49.4	70.3	53.9	32.7	25.3	30.5	43.6
Rubble	percent	44.2	39.6	17.2	34.7	48.4	45.6	47.5	41.5
Gravel	percent	8.6	3.8	5.7	4.2	14.6	15.6	14.9	8.6
Sand-Silt	percent	4.7	7.2	5.5	6.9	4.3	11.9	6.6	6.0
Other	percent	.1	0	1.3	.3	0	1.6	.5	.3
Proportion of stream banks by vegetative types[4]									
Forest	percent	43.0	24.3	12.9	19.3	8.9	44.2	26.1	26.3
Brush	percent	12.0	54.4	77.5	64.3	27.8	9.3	18.8	38.5
Other	percent	45.0	21.3	9.8	16.4	63.3	46.5	55.1	35.2
Proportion of stable banks	percent	96	93	98	95	90	96	93	95
Average depth	inches	13.6	10.5	5.1	8.2	10.5	7.5	9.0	9.5
Average gradient	percent	3.4	2.9	6.6	4.5	2.8	7.2	4.9	4.4

[1] *No tributary channels existed.*
[2] *See "Pool quality recognition guide," page 7.*
[3] *See page 6 for definition of class.*
[4] *See page 7 for definition of types.*

set of samples was taken for the main channel and a second set for all tributary channels for each drainage. Computations of precision were then made for (1) the main channel, (2) the tributary channels, and (3) the total drainage (1 and 2 combined). Because tributaries generally were smaller and steeper than the main channels, they were expected to have different characteristics.

Limits of accuracy for proportions of bank stability and vegetation types were easy to compute because they constituted a binomial distribution. The following formulas were used to calculate the confidence intervals.[7]

$$CI_{66} = \bar{p} \pm S_{\bar{p}}$$

where

$CI_{66} =$ the confidence interval that has a 66-percent probability of containing the true value of the stream characteristic described.

$$\bar{p} = \frac{\text{number of samples in class/type}}{\text{total number of samples}}$$

$$S_{\bar{p}} = \sqrt{\frac{\bar{p}\,(1 - \bar{p})}{n - 1}}$$

For example, the proportion of unstable banks ranged from 4 percent on the Main Fork of the Bear River to 10 percent on Hayden Fork, excluding tributaries (table 2). Computations

Table 2. — **Precision of bank stability estimates**

Channels	**Number of samples (n)**	**Percent unstable banks ($\bar{p}$)**	**Standard error ($S_{\bar{p}}$)**	**Confidence interval (66% level)**
		— Percent —		
		HENRY'S FORK		
Main	136	7.4	±2	5-9
Trib.	102	2.0	±1	1-3
	238	5.0	±1	4-6
		MAIN FORK OF BEAR RIVER		
Main	100	4.0	±2	2-6
Trib.	...	...	...	...
	100	4.0	±2	2-6
		HAYDEN FORK		
Main	90	10.0	±3	7-13
Trib.	86	3.5	±2	2-6
	176	6.8	±2	5-9
All drainages	514	5.4	±1	4-6

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[7] *Freese, Frank. Elementary Forest Sampling. pp. 62-63. USDA Handbook 232. Wash., D.C. 1962.*

indicated that we could be 66-percent certain that the true proportion lies between the confidence intervals shown in table 2. Confidence intervals for streambank cover would be of about the same magnitude although they were not calculated.

Some difficulty was encountered in computing confidence intervals for continuous variables. Pool data, for example, resembled a Poisson distribution rather than a normal distribution because a large number of the transects failed to intersect any pool area. In order to use computational procedures designed for normally distributed populations, four successive transects were grouped together and treated as a single sample.

Although this cluster approach reduced the number of samples, the estimates derived still fell within acceptable limits of precision (see table 3). Confidence intervals were computed as follows:

$$CI_{66} = \bar{p} \pm S_{\bar{p}}$$

where

CI_{66} = The confidence interval that has a 66-percent probability of containing the true value of the stream characteristic measured.

$$\bar{p} = \frac{\text{average pool width}}{\text{average stream width}} = \frac{\bar{y}}{\bar{x}}$$

$$S_{\bar{p}} = \sqrt{\frac{1}{\bar{x}^2}\left(\frac{S_y^2 + \bar{p}^2 S_x^2 - 2\bar{p}S_{xy}}{n}\right)}$$

Ibid., pp. 67-68.

Table 3. — **Precision of pool estimates**

Channels	Number of samples (n)	Percent of stream area in pool ($\bar{p}$)	Standard error ($S_{\bar{p}}$)	Confidence range (66% level)
		— *Percent* —		
		HENRY'S FORK		
Main	17	19.4	3.5	16-23
Trib.	13	33.3	11.1	22-44
	30	22.4	5.4	17-28
		MAIN FORK OF BEAR RIVER		
Main	13	10.6	2.6	8-13
Trib.		..	....	....
	13	10.6	2.6	8-13
		HAYDEN FORK		
Main	11	27.2	8.1	19-35
Trib.	11	17.3	5.2	12-22
	22	24.2	5.5	19-30

Although the estimates of total pool area were adequate, estimates of pool area by quality strata naturally would be less precise because of the greater amount of variation between samples. Consequently, such estimates could be considered as only being indicative of the amount of pool area by quality classes.

DISCUSSION

Although the procedures tested in this study provided good results, better results undoubtedly could be achieved by adopting several modifications.

We recommend that a minimum of five transects be measured at each sample point instead of a single transect. This would have these advantages: (1) reduced variation between samples, particularly in the quantity of pool area; and (2) reduced number of samples required to adequately describe a drainage. Such reduction in number of samples means that the distance between samples along the channels could be increased from one-fourth mile to as much as 1-mile intervals.

Regardless of the length of the stream being surveyed, at least 15 samples — preferably 30 — are required. Thus, the actual interval between sampling points depends on the length of the stream. In general, the 1-mile interval would be adequate for streams that are 15-30 miles long. Closer spacing would be necessary on shorter streams to obtain sufficient samples for maintaining acceptable limits of precision.

Procedures for measuring and recording stream characteristics would remain unchanged, except that stream gradients would have to be measured only for the first and fifth transects rather than for all five. When calculating the average value of any specific characteristic for a channel, the estimate would be based on five transects rather than on one.

It usually took about 15 minutes to measure a single transect and another 15 minutes to walk one-fourth mile to the next sample point. This meant it took approximately 2 hours to measure the four transects in a mile of stream. We estimate that a five-transect sample could be measured in about 45 minutes to an hour. Since the travel time on foot would be the same, time requirements per mile of stream could be reduced slightly.

The time saved would be greater on streams that are paralleled by nearby roads that could be used for auto travel between sampling points located at 1-mile intervals. Auto travel between sample points located at ¼-mile intervals proved impractical on the streams measured in this study because the roads usually were located so that the round-trip walk from auto to sample point was almost as far as the one-fourth mile from one sample point to the next.

Procedures also might need to be modified for larger streams. The streams examined in this study seldom exceeded one hundred feet between banks, and data usually could be obtained by fieldworkers using waders. For larger streams, however, it may be necessary to use boats. Sampling of bottom composition also would require changed procedures on larger streams.

Headquarters for the Intermountain Forest and Range Experiment Station are in Ogden, Utah. Project headquarters are also at:

- Boise, Idaho
- Bozeman, Montana (in cooperation with Montana State University)
- Logan, Utah (in cooperation with Utah State University)
- Missoula, Montana (in cooperation with University of Montana)
- Moscow, Idaho (in cooperation with the University of Idaho)
- Provo, Utah (in cooperation with Brigham Young University)

FOREST SERVICE CREED

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