ROSS LAKE TRIBUTARY STREAM CATALOG

TABLE OF CONTENTS

SECTION 1

INTRODUCTION

1. BACKGROUND AND PROJECT OBJECTIVES

A survey of tributaries to Ross Lake was conducted during Spring and Summer 1989 to help evaluate the effects that lake level fluctuation has on rainbow trout spawning. During most years, Ross Lake reaches a low water elevation of 1500-1520 feet during the spring and then rises during May and June to an elevation of around 1602 feet. The rising water level in the lake coincides with late spring runoff of snow, and also overlaps part or all of the spawning season for resident rainbow trout.

Low lake levels in spring expose a section of each tributary stream or river, between El 1520 and El 1602. Stream reaches within this area are called the "drawdown reach" because they are alternately exposed by lake drawdown, then inundated as the lake level rises.

The simultaneous occurrence of trout spawning and lake level rising, in most tributary streams during most years, results in the following: trout have access to and spawn in drawdown reaches of streams, and these trout redds are subsequently submerged as the lake level rises. Some tributary streams have steep gradients and/or waterfalls within the drawdown reach, and these steep stream sections may be barriers to migrating trout during the spawning season. The tributary survey was designed to accomplish the following objectives:

- Measure, describe, and evaluate spawning habitat within the drawdown reach of each tributary stream.
- Compare the amount and quality of spawning habitat in the drawdown reach with the amount of spawning habitat available above the maximum water surface level of Ross Lake.
- Locate, measure, and describe each barrier to upstream trout migration within the drawdown reach of each tributary, and evaluate the severity of the barrier.

2. PREVIOUS SURVEYS

Two major surveys of Ross Lake tributary streams and trout populations have been completed in the last 20 years, and a wealth of information on Ross Lake fisheries is available. The first major survey was compiled by the International Skagit-Ross Fishery Committee for the City of Seattle, Department of Lighting (City of Seattle, 1972, 1973, 1974) and the second comprehensive work was completed by Jim Johnston of the Washington Department of

Wildlife (Johnston, 1989). These two reports contain a tremendous amount of data and many observations related to trout populations in and around Ross Lake. Additional analysis of resident fish populations is contained in a 1988 report prepared for Seattle City Light (Envirosphere et. al., 1988). Reports by City of Seattle (1974) and Johnston (1989) are essential reading for a thorough understanding of Ross Lake fisheries.

3. COMPANION SURVEYS AND INFORMATION

This catalog describes physical measurements and data related to trout habitat in the drawdown reach and above Ross Lake's full pool level, with special emphasis on trout spawning habitat in the drawdown reach of each tributary stream. It is part of a comprehensive study designed to increase knowledge of Ross Lake fisheries as well as obtaining additional information on fisheries in Diablo and Gorge Lakes. Other relevent reports and studies funded by Seattle City Light at the same time this stream catalog was prepared are available at Seattle City Light's Environmental Affairs Division as follows:

- Videotape surveys of drawdown reach of each trout stream draining into Ross Lake, from ground level and from the air.
- Videotape survey of each tributary stream above Ross Lake, to the upper end of habitat available to trout from Ross Lake.
- Diablo and Gorge Lakes Tributary Stream Catalog
- Resident Fisheries Study for Ross, Diablo, and Gorge Lakes.

SECTION 2

SURVEYING METHODS

1. IDENTIFICATION OF SPAWNING STREAMS

Tributary streams to Ross Lake range in size from small trickles to large rivers. The first task of the survey was to identify which streams could support trout spawning, and concentrate on these streams. The drawdown reach and upper tributary habitat in the following streams was not surveyed, for the reason(s) indicated below:

Stream	Reasons the Stream Was Not Surveyed	Reference
Happy Creek	Stream has been diverted to a waterfall entering Ross Lake, not accessible to Ross Lake trout	
Hidden Hand Creek	Too small and steep to provide trout habitat	
Howlett Creek	Small tributary entering Ross Lake in Canada, approximately the size of May Creek.	
Lillian Creek	Too small and steep to provide trout habitat	
Lone Tree Creek	Too small and steep to provide trout habitat	
May Creek	Too small and steep to provide trout habitat	City of Seattle 1974
Skymo Creek	Too steep to provide trout habitat	City of Seattle 1974
Unnamed tributaries	Too steep and small to provide trout habitat	USGS Topographic Maps

The streams listed above were considered to be important sources of water and/or food for trout living in Ross Lake; however, the streams would not directly support trout spawning or rearing. Also, there were no potential fisheries enhancement projects associated with the streams listed above, and they were not considered further during the 1989 survey.

All Ross Lake tributaries that support stream spawning trout were surveyed during spring and summer 1989, and the results of these surveys are

compiled in this catalog. The tributaries listed below are all known to support spawning trout (City of Seattle 1974, Johnston 1989) or have some potential for spawning trout:

Arctic Creek
Big Beaver Creek and Tributaries
Devils Creek
Dry Creek
Hozomeen Creek
Lightning Creek and Tributaries
Little Beaver Creek and Tributaries
No Name Creek
Pierce Creek
Roland Creek
Ruby Creek and Tributaries
Silver Creek
Skagit River and Tributaries

All trout spawning tributaries listed above were surveyed in a similar manner. First, the drawdown reach of the tributary was surveyed when the Ross Lake water surface was at a "normal" low elevation of 1515'-1520'. The Drawdown Reach Survey extended from Ross Lake's low pool elevation to El 1602, which is the full pool level for Ross Lake. After the Drawdown Reach Survey was completed, an Upper Tributary Survey was done to quantify trout habitat above Ross Lake and evaluate fish passage barriers. The Drawdown Reach and Upper Tributary Surveys are described below.

2. DRAWDOWN REACH SURVEY

The Drawdown Reach Survey for each tributary consisted of the following:

- Measurements of stream flow, length, gradient, width, depth, and other physical data within the drawdown reach.
- Estimation of the amount of spawning habitat available to trout, along with observations related to spawning habitat quality.
- Measurement, classification, and evaluation of barriers or potential barriers to trout migrations.
- Videotape and 35mm photos.

Physical measurements of each tributary were used to generate a stream profile for each drawdown reach, and also to calculate the amount of spawning habitat below Ross Lake's full pool level. These data are summarized on the stream profile drawing for each tributary.

Fish passage barriers were identified in the drawdown reach and classified according to a system suggested by Powers and Orsborn (1985). The classification system requires an evaluation of flow patterns, site geometry

and topography, bed slope, depth, turbulence, longitudinal profile, water velocity, stream discharge, and other variables that affect fish passage. After observation and measurement of these data, the classification system assigns a difficulty rating to each barrier, which is a measure of the relative difficulty of fish passage. A detailed description of this classification system is presented in Appendix A.

For barriers within the drawdown reaches of Ross Lake tributaries, there was a good relationship between trout passage and the product of "Difficulty Rating" X "Barrier Height." Barriers where the Difficulty Rating X Barrier Height was 6 or less were considered passable by most trout and were not perceived to be a fish passage problem. For instance, a 1.5-foot-high waterfall on Pierce Creek had a Difficulty Rating of 1, the product of Difficulty Rating X Barrier Height was 1 X 1.5 = 1.5, and it was judged that this short drop over in-stream logs would not create any difficulty for trout passage.

Barriers where the Difficulty Rating x Barrier Height ranged from 7 to 50 were considered partial or total barriers, depending on stream flow and other variables. As an example, a 4-foot-high turbulent cascade on Pierce Creek had a Difficulty Rating (4) x Barrier Height (8 feet) = 32 total rating. This cascade was considered a total barrier to trout as observed at 35 cubic feet per second (cfs) stream flow, but it was noted that the probability of fish passage would increase as flow decreased.

Any barrier with a total rating greater than 50 was considered a total barrier to fish passage at all flows.

Forms used to collect stream habitat, spawning habitat, and barrier data for Pierce Creek have been duplicated for this section to illustrate the type of data collected during the Drawdown Reach Survey. Data collected during the Drawdown Reach Survey are summarized in each description of tributary streams, and the descriptions are accompanied by a representative number of photographs.

RESIDENT FISH STUDY

SEATTLE CITY LIGHT

DATE: 4/25/89

OBSERVERS: PDT, DTH

STREAM NAME: Pierce Creek

LOCATION OF STREAM MOUTH: R13E T38N S.14

STREAM CATALOG NO. _____

STATION NO.: 1

STATION DISTANCE ABOVE MOUTH: 0 FEET

ELEVATION OF STATION: 1517 FEET

HABITAT DESCRIPTION WITHIN 50 FEET UPSTREAM AND 50 FEET DOWNSTREAM:

AVERAGE WATER WIDTH: 10 FEET

WIDTH RANGE: 8 FEET TO 15 FEET

AVERAGE WATER DEPTH: 1.0 FEET

DEPTH RANGE: 0.5 FEET TO 1.5 FEET

AVERAGE POOL DEPTH: 1.0 FEET

HABITAT PERCENTAGE: POOL: 0 RIFFLE: 90 SPAWN: 10

OVERALL BOTTOM COMP. (%): B 3 R 60 G 35 S 2

SPAWNING SUBSTRATE: there are small, isolated pockets suitable for trout spawning on the edges of the stream. Water is fast and turbulent.

	NONE	FEW	COMMON	ABUNDANT	
AQUATIC PLANTS:	X				
AQUATIC INSECTS:		X			mayflies
FISH:	X				
COVER:		X			

IN-STREAM AND BANK COVER: there is a small amount of cover provided by logs and other organic debris, also small bits of cover behind rocks.

35MM PHOTOS: ROLL: 2 PICTURES: 22

VIDEOTAPE: _____

RESIDENT FISH STUDY

SEATTLE CITY LIGHT

DATE: 4/25/89

OBSERVERS: PDT, DTH

STREAM NAME: Pierce Creek

LOCATION OF STREAM MOUTH: R13E T38N S. 14

STREAM CATALOG NO.

TRIBUTARY TO: BIG BEAVER / ROSS LAKE

FLOW CALCULATION:

TOTAL WIDTH: 8.5'

FLOW = W*D*V = 35 CFS

	D (FT)	V (FT/S)
1/4 W	1.2	3.5
1/2 W	1.3	2.7
3/4 W	1.2	4.3
AVG	1.2	3.5

LAKE ELEVATION AT TIME OF SURVEY: 1515 FEET

STATION	DIST. ABOVE MOUTH (FT)	DIST. TO NEXT STA. (FT)	COMPASS BEARING	GRADIENT TO NEXT STA. (%)	ELEVATION OF STATION	STA. TYPE B=BARRIER H=HABITAT
1	0	250	282°	5%	1517	H
2	250	400	276°	5%	1529	H
3	650	272	272°	5.5%	1549	H
4	922	160	244°	6.0%	1564	B
5	1082	211	204°	4.0%	1574	H
6	1293				1582	B
7					1590	TOP OF STA. 6 BARRIER
8						
9						
10						

NOTES:

RESIDENT FISH STUDY

SEATTLE CITY LIGHT

DATE: 4/25/89

OBSERVERS: PDT, DTH

STREAM NAME: Pierce Creek

LOCATION OF STREAM MOUTH: R13E T38N S.14

STREAM CATALOG NO. _____

STATION NO.: 2

STATION DISTANCE ABOVE MOUTH: 250 FEET

ELEVATION OF STATION: 1529 FEET

HABITAT DESCRIPTION WITHIN 50 FEET UPSTREAM AND 50 FEET DOWNSTREAM:

AVERAGE WATER WIDTH: 10 FEET — WIDTH RANGE: 8 FEET TO 15 FEET

AVERAGE WATER DEPTH: 1.0 FEET — DEPTH RANGE: 0.5 FEET TO 1.5 FEET

AVERAGE POOL DEPTH: 1.0 FEET — there are no pools except pocket water in rubble/boulder riffles.

HABITAT PERCENTAGE: POOL: 0 RIFFLE: 100 SPAWN: 0

OVERALL BOTTOM COMP. (%): B 5 R 90 G 5 S 0

SPAWNING SUBSTRATE: No spawning substrate, almost all boulder/rubble.

	NONE	FEW	COMMON	ABUNDANT
AQUATIC PLANTS:	X			
AQUATIC INSECTS:		X		
FISH:	X			
COVER:		X		

IN-STREAM AND BANK COVER: Boulders and rubble, very little large organic debris available for cover.

35MM PHOTOS: ROLL: 2 PICTURES: 23, 24

VIDEOTAPE: _____

Water velocity is 4-5 ft/sec, but there are enough small resting places to allow fish passage.

RESIDENT FISH STUDY

SEATTLE CITY LIGHT

DATE: 4/25/89

OBSERVERS: PDT, DTH

STREAM NAME: Pierce Creek

LOCATION OF STREAM MOUTH: R13E T38N S.14

STREAM CATALOG NO. _____

STATION NO.: 3

STATION DISTANCE ABOVE MOUTH: 650 FEET

ELEVATION OF STATION: 1549 FEET

HABITAT DESCRIPTION WITHIN 50 FEET UPSTREAM AND 50 FEET DOWNSTREAM:

AVERAGE WATER WIDTH: 10 FEET

WIDTH RANGE: 8 FEET TO 15 FEET

AVERAGE WATER DEPTH: 1.0 FEET

DEPTH RANGE: 0.5 FEET TO 1.5 FEET

AVERAGE POOL DEPTH: 1.5 FEET

HABITAT PERCENTAGE: POOL: 0 RIFFLE: 90 SPAWN: 10

OVERALL BOTTOM COMP. (%): B 10 R 78 G 10 S 2

SPAWNING SUBSTRATE: Small but good pockets of spawning gravel, mostly along banks where velocity is 1.0-2.0 ft/s, depth is 6" - 1.0', there is some good spawning habitat available here.

	NONE	FEW	COMMON	ABUNDANT
AQUATIC PLANTS:	X			
AQUATIC INSECTS:		X		
FISH:	X			
COVER:		X		

IN-STREAM AND BANK COVER: Small amount of logs and other organic debris, plus pocket water cover provided by boulders.

35MM PHOTOS: ROLL: 3 PICTURES: 1, 2, 3

VIDEOTAPE: _____

RESIDENT FISH STUDY

SEATTLE CITY LIGHT

DATE: 4/25/89

OBSERVERS: PDT, DTH

STREAM NAME: Pierce Creek

LOCATION OF STREAM MOUTH: R13E T38N S.14

STREAM CATALOG NO.

STATION NO.: 4

STATION DISTANCE ABOVE MOUTH: 922 FEET

ELEVATION OF STATION: 1564 FEET

DESCRIPTION OF BARRIER TO UPSTREAM MIGRATION OF TROUT:

CLASS: Multiple Falls

TYPE: 1 A I

DEGREE OF DIFFICULTY: 1

VERTICAL DROP OF BARRIER: 1.5 FEET

HORIZONTAL DISTANCE OF BARRIER: 0 FEET

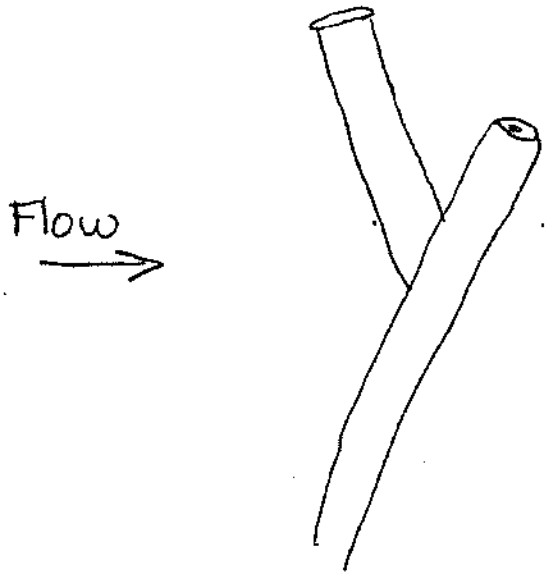
GRADIENT OF BARRIER: — PERCENT

STREAM FLOW AT OBSERVATION: 35 CFS

PARTIAL OR TOTAL BARRIER TO TROUT: This small drop over some large organic debris should not present any difficulty to trout passage.

EFFECT OF FLOW ON BARRIER: Insignificant barrier regardless of flow.

SKETCH:



1-1.5' drop over log. There were about 4 of these small drops between the mouth of Pierce Creek and #1602'. All were passable at most flows with drops of 1-2 feet and difficulty of 1 or 2.

35MM PHOTOS: ROLL: 3 PICTURES: 4,5

VIDEOTAPE:

RESIDENT FISH STUDY

SEATTLE CITY LIGHT

DATE: 4/25/89

OBSERVERS: PDT, DTH

STREAM NAME: Pierce Creek

LOCATION OF STREAM MOUTH: R13E T38N S.14

STREAM CATALOG NO.

STATION NO.: 5

STATION DISTANCE ABOVE MOUTH: 1082 FEET

ELEVATION OF STATION: 1574 FEET

HABITAT DESCRIPTION WITHIN 50 FEET UPSTREAM AND 50 FEET DOWNSTREAM:

AVERAGE WATER WIDTH: 12 FEET

WIDTH RANGE: 8 FEET TO 20 FEET

AVERAGE WATER DEPTH: 2.0 FEET

DEPTH RANGE: 0.5 FEET TO 4 FEET

AVERAGE POOL DEPTH: 4 FEET

HABITAT PERCENTAGE: POOL: 30 RIFFLE: 55 SPAWN: 15

OVERALL BOTTOM COMP. (%): B 30 R 30 G 20 S 20

SPAWNING SUBSTRATE: Several good spots with depths of 0.5 - 1.0 ft, velocity = 1-2 ft/s. There are several small areas about 8'X10' in size that look ideal for trout spawning.

	NONE	FEW	COMMON	ABUNDANT
AQUATIC PLANTS:	X			
AQUATIC INSECTS:		X		
FISH:	X			
COVER:		X		

IN-STREAM AND BANK COVER: large organic debris and rubble/boulders provide cover.

35MM PHOTOS: ROLL: 3 PICTURES: 6, 7

VIDEOTAPE:

There is a small drop 20' upstream (1-1.5' vertical) which should not be a barrier.

RESIDENT FISH STUDY

SEATTLE CITY LIGHT

DATE: 4/25/89

OBSERVERS: PDT, DTH

STREAM NAME: Pierce Creek

LOCATION OF STREAM MOUTH: R13E T38N S.14

STREAM CATALOG NO.

STATION NO.: 6

STATION DISTANCE ABOVE MOUTH: 1293 FEET

ELEVATION OF STATION: 1586 FEET

DESCRIPTION OF BARRIER TO UPSTREAM MIGRATION OF TROUT:

CLASS: Complex chute

TYPE: IC2

DEGREE OF DIFFICULTY: 4

STREAM FLOW AT OBSERVATION: 35 CFS

VERTICAL DROP OF BARRIER: 8 FEET

HORIZONTAL DISTANCE OF BARRIER: 55 FEET

GRADIENT OF BARRIER: 14 PERCENT

PARTIAL OR TOTAL BARRIER TO TROUT: Total barrier to trout because of velocity barrier immediately upstream of 3' high falls.

EFFECT OF FLOW ON BARRIER: less flow would yeild slightly better passage. More flow would mean worse passage.

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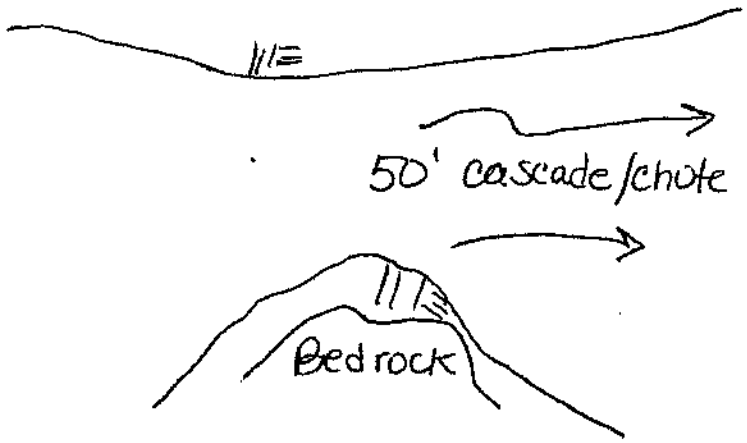

looks like there are lots more barriers upstream

Stream habitat above 1602 looks like steep, bedrock gradient with numerous passage barriers 4-8' high.

35MM PHOTOS: ROLL: 3 PICTURES: 8, 9, 10 (upstream of Sta. 6)

IDEOTAPE:

3. UPPER TRIBUTARY SURVEY

The Upper Tributary Survey consisted of the following:

- o Calculation of the amount of trout spawning habitat available above the drawdown reach in each tributary stream.
- o Quality of trout spawning habitat above the drawdown reach was described based on a combination of historical information, videotape observations and on-site evaluations during 1989 surveys.
- o Evaluation of barriers to trout migration in tributary sections above El 1602.

The method used for calculating available trout spawning habitat was as follows:

1. Tributary streams were divided into sections based on consideration of stream lengths and gradients measured using USGS topographic maps.
2. Watershed areas for each stream section were measured from USGS maps.
3. Flow and width for each tributary section were calculated using regressions for flow and width vs. watershed area. These regressions were generated using data from our detailed surveys of streams within the drawdown reach of Ross Lake.
4. Percent spawning in each section of tributary was estimated based on the following criteria developed from spawning habitat data collected in the drawdown reach of Ross Lake tributaries.

   Streamflow more than 1,000 cfs (main Skagit River near Ross Lake): No spawning habitat.

   Stream flow more than 50 cfs but less than 1,000 cfs:

   0-2% gradient = 2% spawning habitat
   Greater than 2% gradient = 0% spawning habitat

   Stream flow less than 50 cfs:

   0-5% gradient = 10% spawning habitat
   5-10% gradient = 5% spawning habitat
   Greater than 10% gradient = 0% spawning habitat

A table summarizing measurements and calculations described in this section has been included in each tributary stream description.

Any section of tributary stream with a calculated gradient of 15% or more was considered an impassible barrier to trout migration. In some streams (e.g., Lightning Creek, Little Beaver Creek), there was a substantial amount of good spawning habitat above in-stream barriers to migrating trout.

When a barrier was encountered below a substantial amount of spawning habitat, and it was considered possible to alter the barrier to provide fish passage, the spawning habitat area upstream of the barrier was also calculated.

ARCTIC CREEK

Spawning Habitat

In the drawdown reach of Arctic Creek, there are a few small pockets of suitable spawning habitat along the edges of the streambank. Most of the stream substrate is too large and the streambed is too steep in this section (3-4%) to provide substantial spawning habitat (Photos 1-4).

Above El 1602 in Arctic Creek, the stream becomes a series of large waterfalls and there is no trout spawning habitat (Table 1).

Fish Passage Barriers

As shown in Figure 1, a waterfall at El 1558 (Photo 5) with a vertical drop of over 100 feet is a total barrier to trout migration in Arctic Creek even at full pool (El 1602). Above the waterfall, Arctic Creek's steep rapids and waterfalls would continue to hinder passage for migrating trout. It was not considered feasible to alter these barriers to improve fish passage.

Spawning Activity

Historical studies did not conclude that any trout spawning occurred in Arctic Creek (City of Seattle, 1974). Although Johnston (1989) indicates that the mouth of Arctic Creek is used for spawning to some extent, there were no observations of trout spawning activity during 1989 spawning surveys, on the following dates in Arctic Creek: June 15, June 28, and July 19. On these same dates in 1989, trout were observed spawning in other Ross Lake tributaries.

Photo 1. Arctic Creek at elevation 1518'. Flow = 80cfs on 4/27/89. This riffle area has only a small amount of good trout spawning habitat. The stream gradient is 1.5%.

Photo 2. Arctic Creek at elevation 1522'. Flow = 80cfs on 4/27/89. Streambed gradient is 3.0% with some spawning habitat available. Some areas with good gravel substrates are too shallow (<0.5 ft.).

Photo 3. Arctic Creek at elevation 1533'. Flow = 80cfs on 4/27/89. Small pockets of suitable spawning habitat are along the stream edge, but overall this stretch is too steep (3.0% gradient) and fast for trout spawning.

Photo 4. Arctic Creek at elevation 1548'. Flow = 80cfs on 4/27/89. Streambed gradient is 4.0% and substrates are too large for good spawning habitat at this location.

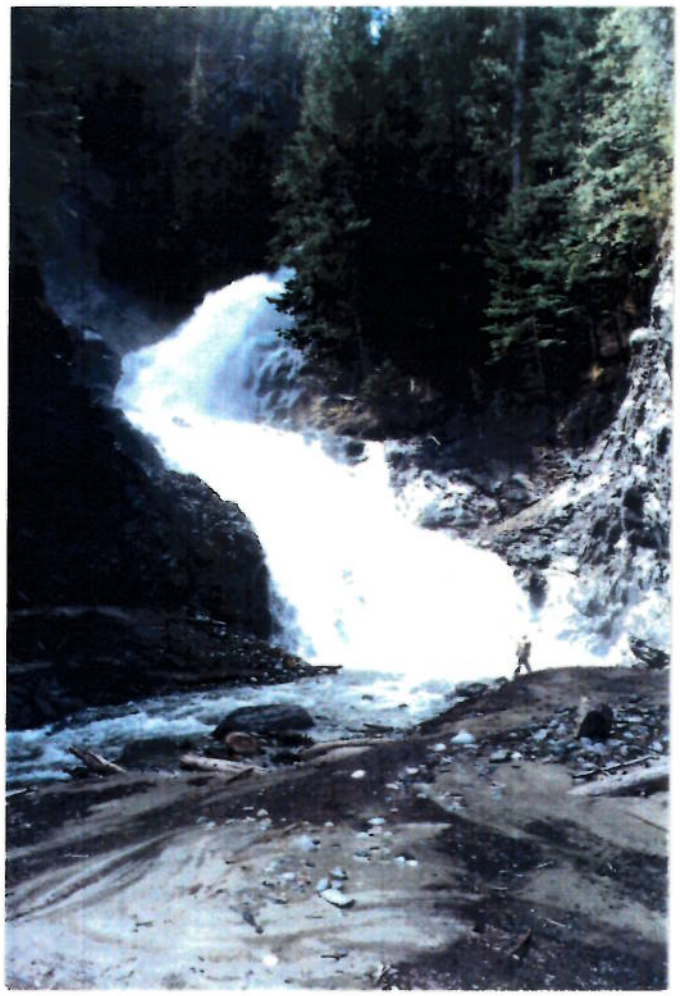

Photo 5. Arctic Creek at elevation 1558'. Flow = 80cfs on 4/27/89. This type IIC2 waterfall has a degree of difficulty rating of 5 and is a total barrier to trout at all flows. Full pool elevation 1602' is at about the middle of the photo.

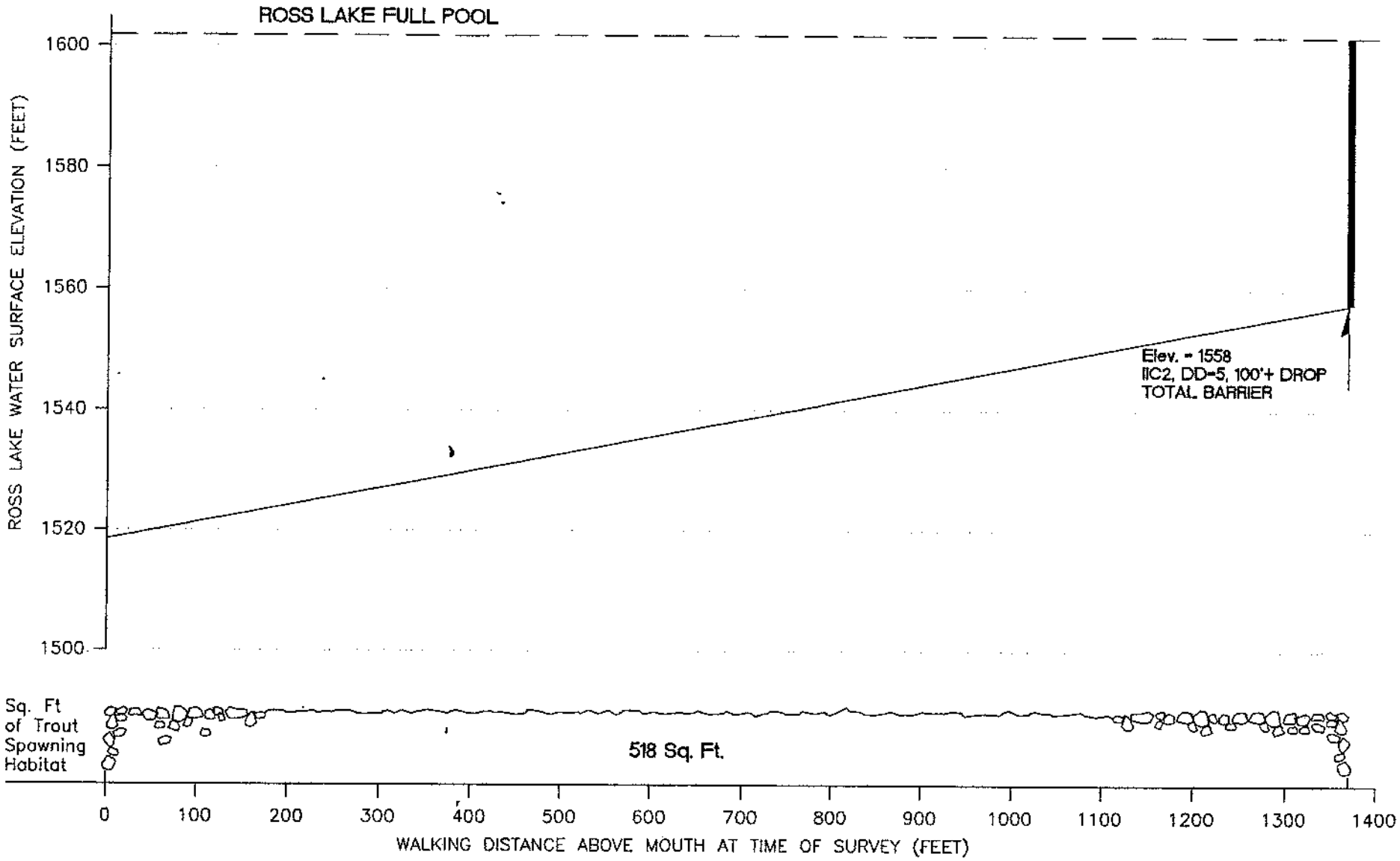

Figure 1: Stream profile showing trout spawning habitat and barriers in the drawdown reach of ARCTIC CREEK

VAA00397

TABLE 1. ROSS LAKE TRIBUTARIES TROUT SPAWNING HABITAT AND MIGRATION BARRIERS

TRIBUTARY NAME	DISTANCE (FT) FROM	TO	HABITAT NOTES	WATERSHED AREA (SQ MI)	CFS (CALC)	WIDTH (CALC)	PERCENT GRADIENT[4]	PERCENT SPAWNING	SPAWNING AREA(SQ FT)
ARCTIC CREEK	0	600	BARRIER	12.87	57	20	33%	0%	0
	600	29040	BARRIER	6.37	29	14	33%	0%	0

HABITAT NOTES:

1. "SPAWNING" INDICATES THIS SECTION OF STREAM HAD SUITABLE SPAWNING HABITAT FOR TROUT.
2. "PASSAGE" DENOTES STREAM SECTIONS THAT ALLOWED FISH PASSAGE BUT WERE CONSIDERED TOO STEEP FOR SPAWNING HABITAT
3. "BARRIER" IDENTIFIES STREAM REACHES OR INDIVIDUAL LOCATIONS THAT WERE BARRIERS TO TROUT MIGRATION.
4. "PERCENT SPAWNING" IS THE ESIMATED PERCENTAGE OF STREAM BOTTOM AREA THAT IS SUITABLE FOR SPAWNING TROUT, IN ANY GIVEN STREAM SECTION.

BIG BEAVER CREEK AND TRIBUTARIES

Spawning Habitat

There is no suitable trout spawning habitat within the drawdown reach of Big Beaver Creek. The drawdown reach has primarily boulder and rubble substrates with multiple falls (Photos 6 & 8).

Spawning habitat is abundant above El 1602 (Table 2). Substrates are excellent for spawning (Johnston 1989) and streambed gradient is one to three percent. This section of stream is a meandering, often braided channel with riffle and pool habitats. The helicopter survey and videotape verified that about 9 miles of Big Beaver Creek were accessible to trout from Ross Lake, once the barriers below El 1602 were flooded (City of Seattle 1973). Johnston's 1989 report states that Big Beaver Creek above the drawdown reach contains excellent gravel bars and probably more near perfect spawning habitat than in all other American tributaries combined. It was estimated that the total amount of spawning habitat in Big Beaver Creek was 36,000 square feet, below the confluence of Big Beaver Creek and McMillan Creek. A short stretch of McMillan Creek appeared to be accessible to trout from Ross Lake, but its steep gradient (5%) indicated that spawning habitat would be insignificant.

Fish Passage Barriers

A multiple falls at EL 1516 (Photo 7) and a complex chute at El 1563 (Photos 9 & 10) are both total barriers to trout migration with respective heights of 39-feet and 34-feet as indicated on the stream profile (Figure 2). The fish passage barrier reported by Johnston (1989) at El 1587 is actually part of a larger series of bedrock chutes that extends from El 1563 to El 1587.

When Ross Lake is at full pool (El 1602), the first migration barrier is at El 1725 (City of Seattle, 1973), near the confluence of Big Beaver and McMillan Creeks. The helicopter survey and videotape of trout habitat above this point showed a long series of cascades and whitewater, with numerous barriers to trout migration. The limited amount of spawning habitat above the barriers, and the overall steep gradient of both streams, resulted in the conclusion that barrier removal in upper Big Beaver Creek (Above El 1725) or McMillan Creek would not be beneficial to Ross Lake trout.

Spawning Activity

Studies conducted for City of Seattle, Department of Lighting from 1971-1973 provided no evidence of rainbow trout spawning in Big Beaver Creek, however, they did find that Ross Lake rainbow trout do enter the stream (City of Seattle, 1974). Johnston (1989) observed approximately 200 rainbow trout above El 1625 in Big Beaver Creek during 1971 and believed they were able to ascend the barriers at the mouth during the peak spawning period, depending on lake level. During 1986 surveys, hundreds of 10-15-inch fish were observed in Beaver Creek. These fish probably gained access to the creek after mid-July

when Ross Lake levels were high and stream flows were low. These are probably not spawning fish, but feeding run fish (Johnston, 1989).

During our surveys on June 16, June 28, and July 19, 1989, no spawning fish were observed near the mouth of Big Beaver Creek or within 200 feet upstream of the mouth.

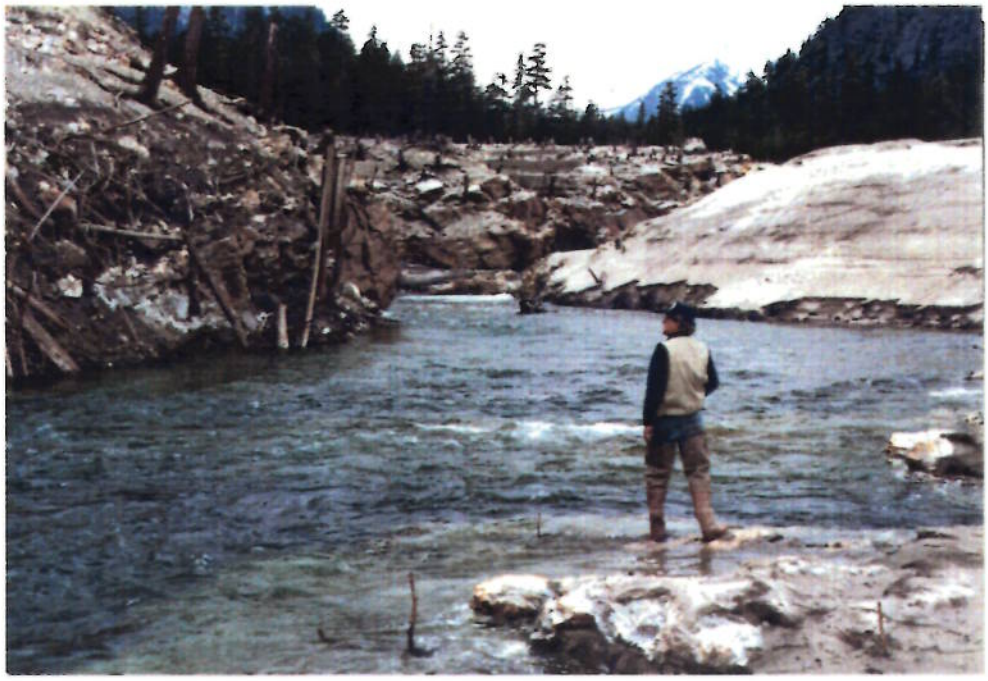

Photo 6. Big Beaver Creek at Elevation 1515'. Flow = 450cfs on 4/25/89. At this station, a large pool merges into the lake. No spawning substrate is present.

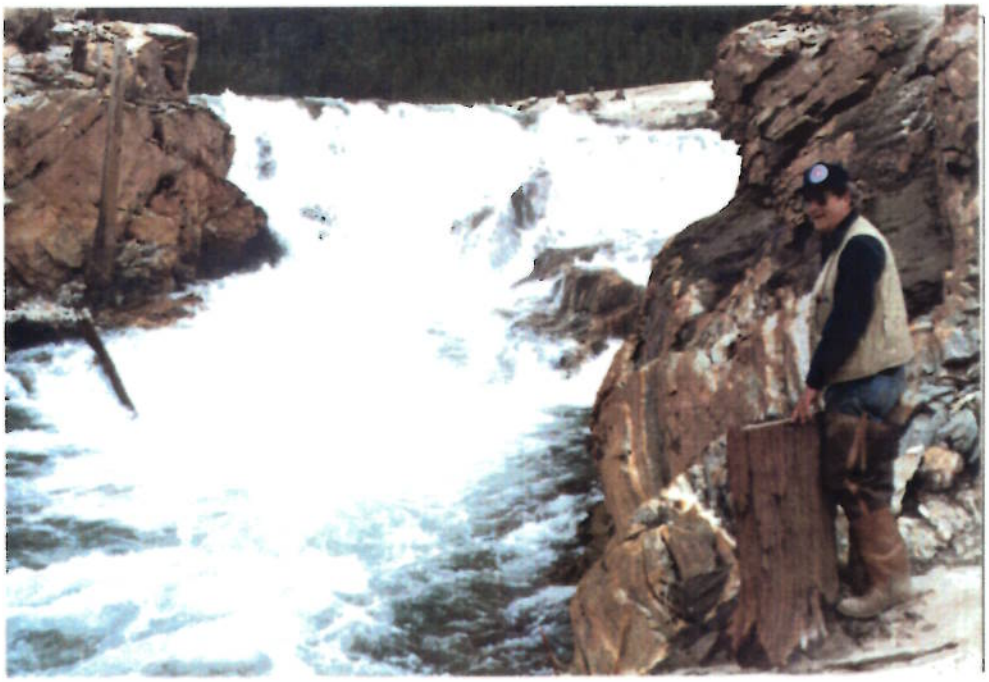

Photo 7. Big Beaver Creek at elevation 1516'. Flow = 450cfs on 4/25/89. This multiple falls is a total barrier at all flows due to the extreme height that fish would be required to jump. It is a type IID1 with a degree of difficulty rating 6, and has a 39 foot vertical drop.

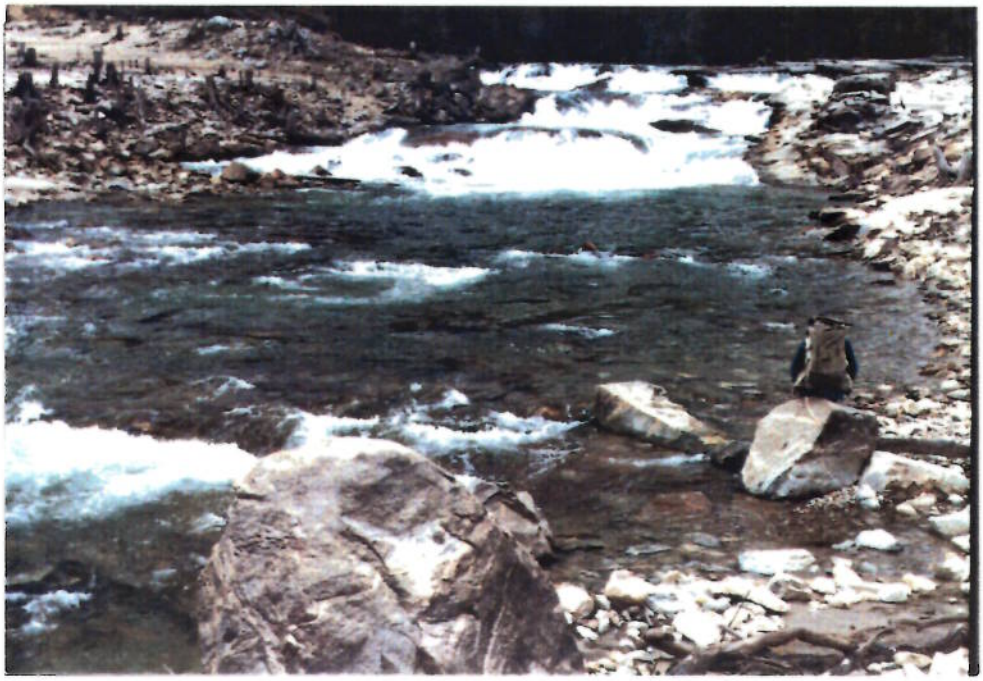

Photo 8. Big Beaver Creek at elevation 1563'. Flow = 450cfs on 4/25/89. Between barriers in the drawdown reach, Big Beaver Creek is a high velocity riffle, with mostly bedrock and boulder substrates. There is no spawning habitat in this section.

Photo 9. Big Beaver Creek at elevation 1563'-1597'. Flow = 450cfs. This complex chute is a total barrier to trout at all flows. It is a type IIB1 with a degree of difficulty 3 and a vertical drop of 34 feet.

Photo 10. Big Beaver Creek at elevation 1563'-1597'. Flow = 450cfs on 4/25/89. Total cascade length is approximately 180 feet with an average slope of 10%.

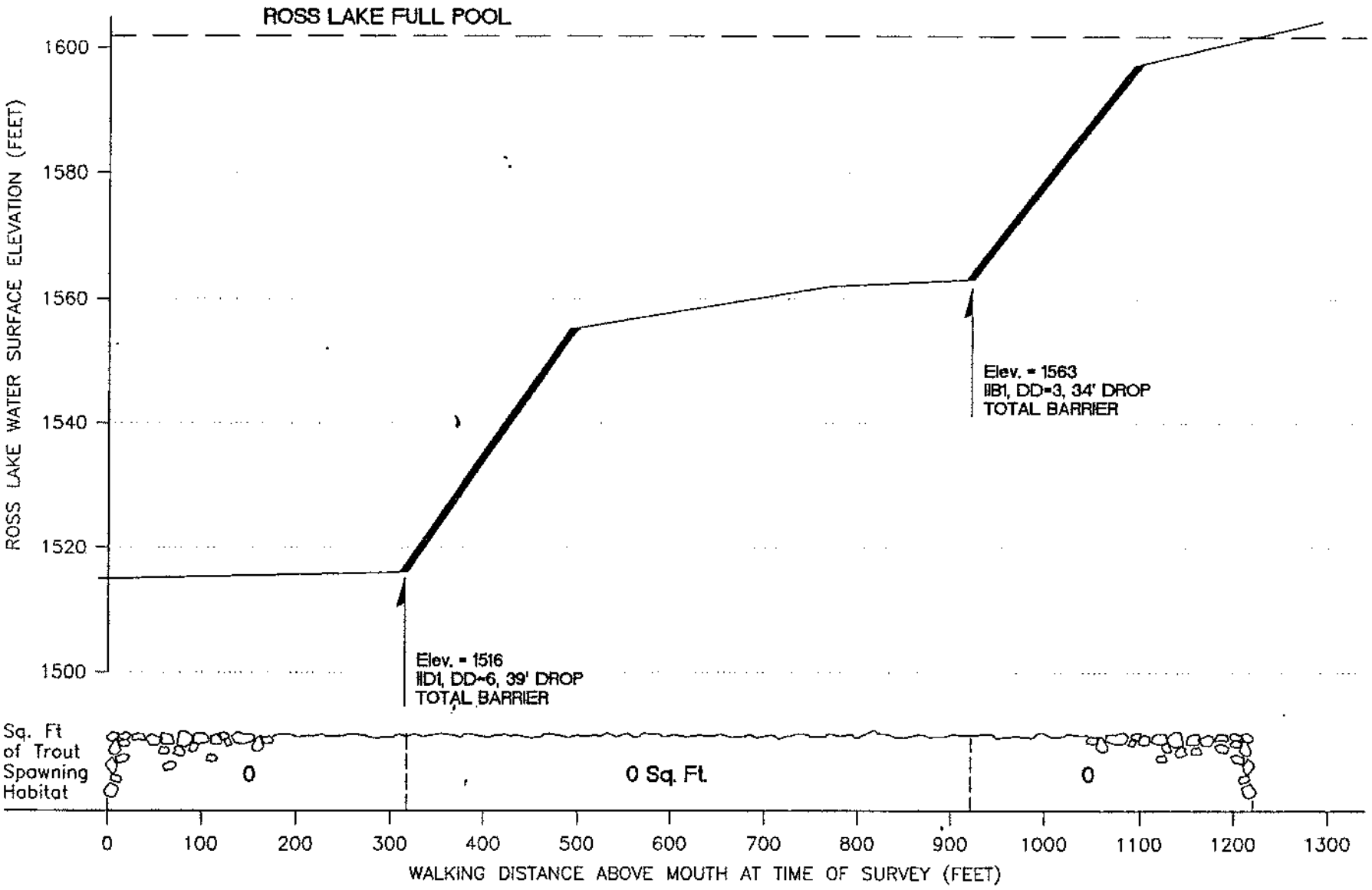

Figure 2: Stream profile showing trout spawning habitat and barriers in the drawdown reach of BIG BEAVER CREEK

VAA00285

TABLE 2. ROSS LAKE TRIBUTARIES TROUT SPAWNING HABITAT AND MIGRATION BARRIERS

TRIBUTARY NAME	DISTANCE (FT) FROM	TO	HABITAT NOTES	WATERSHED AREA (SQ MI)	CFS (CALC)	WIDTH (CALC)	PERCENT GRADIENT	PERCENT SPAWNING[4]	SPAWNING AREA(SQ FT)
BIG BEAVER CREEK	0	24000	SPAWNING	54.18	234	45	1%	2%	21444
	24000	44000	SPAWNING	38.73	168	37	1%	2%	14828
	44000	44000	BARRIER	-	-	-	-	-	0
	44000	98680	PASSAGE	19.00	83	25	3%	0%	0
	98680	109240	SPAWNING	3.55	16	10	7%	5%	5184
MCMILLAN BIG BEAV		4500	PASSAGE	12.71	56	20	3%	0%	0
	4500	14000	SPAWNING	10.00	44	17	5%	5%	8295
	14000	31000	SPAWNING	4.57	21	11	3%	10%	19209
	31000	33000	BARRIER	0.66	3	4	20%	0%	0

HABITAT NOTES:

1. "SPAWNING" INDICATES THIS SECTION OF STREAM HAD SUITABLE SPAWNING HABITAT FOR TROUT.
2. "PASSAGE" DENOTES STREAM SECTIONS THAT ALLOWED FISH PASSAGE BUT WERE CONSIDERED TOO STEEP FOR SPAWNING HABITAT
3. "BARRIER" IDENTIFIES STREAM REACHES OR INDIVIDUAL LOCATIONS THAT WERE BARRIERS TO TROUT MIGRATION.
4. "PERCENT SPAWNING" IS THE ESIMATED PERCENTAGE OF STREAM BOTTOM AREA THAT IS SUITABLE FOR SPAWNING TROUT, IN ANY GIVEN STREAM SECTION.

DEVILS CREEK

Spawning Habitat

Devils Creek has almost no trout spawning habitat in the drawdown reach due to numerous barriers and large streambed substrates (Photo 16).

Above El 1602, streambed gradient is 4-5% overall and the stream is confined in a narrow bedrock canyon. Several barriers to trout migration exist in the lower 500 feet of Devils Creek, and there appears to be some suitable spawning habitat between these barriers (Table 3).

Fish Passage Barriers

At El 1540 a series of high velocity chutes and falls was considered a total barrier to trout migration (Photo 11). Overall this series of barriers is approximately 20-feet-high with rapids between barriers ranging from 4 to 6 feet in height (Figure 3). A multiple falls or chute at El 1561 may delay trout migration but should not be a barrier (Photos 12 & 13). The turbulent cascade found at El 1564 is characteristic of Devil's Creek in this reach (Photos 14 & 15). It should only temporarily delay some trout during spawning migration.

The lowermost 3 miles of Devils Creek, above Ross Lake full pool, flows through a narrow bedrock canyon with tall cliffs on either side of the stream. Overall stream gradient in this reach is 4-5% and there are numerous total barriers to trout migration above the drawdown reach.

The first barrier to trout migration is a 12-foot high chute/waterfall formed by bedrock and massive boulders, about 300-feet upstream from Ross Lake full pool. About 100-feet above this first barrier is an 8-foot high bedrock chute, followed by a 7-foot high waterfall after another 100 feet of stream. All of these barriers were total blocks to trout migration at all flows. Resident rainbow trout were caught upstream of these barriers.

Only the lowermost 500 feet of Devils Creek was surveyed in detail, with 3 total barriers identified. Stream gradient above these barriers increases, and stream characteristics (bedrock channel, narrow canyon) remain the same. It was concluded that there are many barriers to trout migration in the lowermost 3 miles of Devils Creek, all barriers are inaccessible due to the steep canyon walls, and it would be impractical to try to remove barriers in Devils Creek.

Spawning Activity

Studies conducted by the Fisheries Research Institute of the University of Washington (FRI) found newly emergent fry at the shoreline of Ross Lake near the inlet of Devils Creek indicating that some shoreline trout spawning may occur there (City of Seattle, 1972).

During surveys on June 15, June 18, and July 19, 1989, a few rainbow trout ranging from 4 to 12 inches were observed in the mouth of Devil's Creek. No spawning activity or redds were seen.

Photo 11. Devils Creek at elevation 1540'. Flow = 100cfs on 4/28/89. This photo was taken from a vertical cliff looking straight down on Devils Creek. This series of high velocity chutes/falls was judged to be a total barrier to trout. Overall, the series of barriers is approximately 20 feet high with a series of 4-6 foot vertical drops. Degree of difficulty rating is 3 and the barrier is type IIB1.

Photo 12. Devils Creek at the bottom of the barrier, elevation 1561'. Flow = 100cfs (estimated) on 4/28/89. Devils Creek is in an inaccessible canyon with vertical bedrock walls in this reach.

Photo 13. Devils Creek at elevation 1561'. Flow = 100cfs (estimated) on 4/28/89. This multiple falls or chute may delay trout migration but should not be a barrier. It is a type IIC1 barrier with a 3 foot vertical drop.

Photo 14. Devils Creek at elevation 1564'. Flow = 100cfs (estimated) on 4/28/89. Turbulent cascade characteristic of Devils Creek in this reach. This type IIB2 barrier has a degree of difficulty rating of 4, and should only temporarily delay some trout.

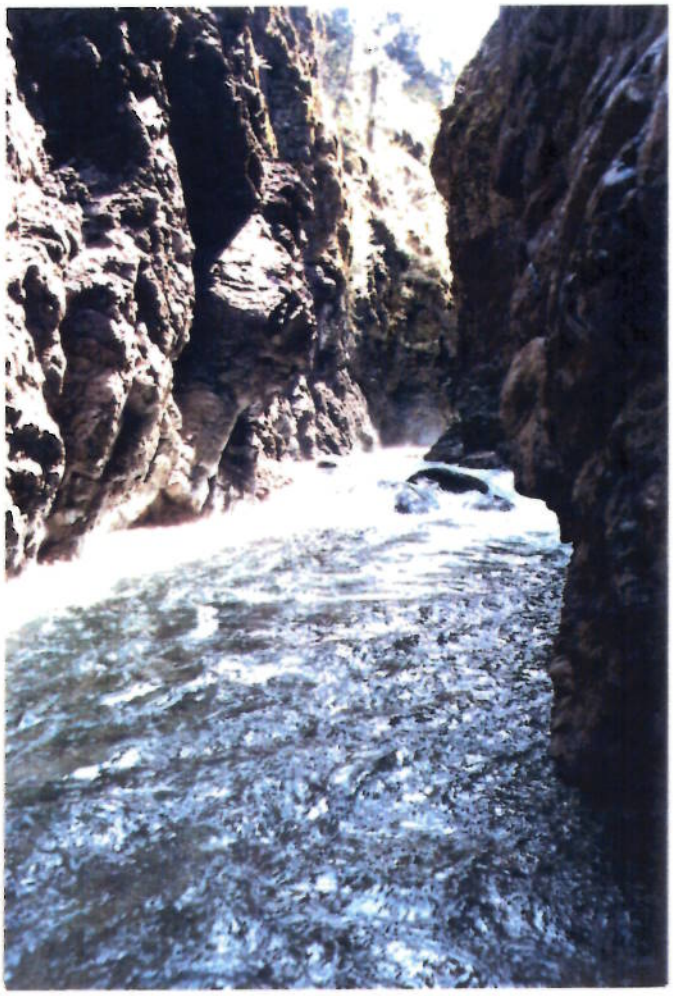

Photo 15. Devils Creek above the barrier cascade at elevation 1564'. Flow = 100cfs on 4/28/89. The vertical canyon walls made a detailed survey difficult within the drawdown reach.

Photo 16. Devils Creek at elevation 1567'. Flow = 100cfs (estimated) on 4/28/89. Substrates are too large to be suitable for trout spawning in this pool and riffle habitat.

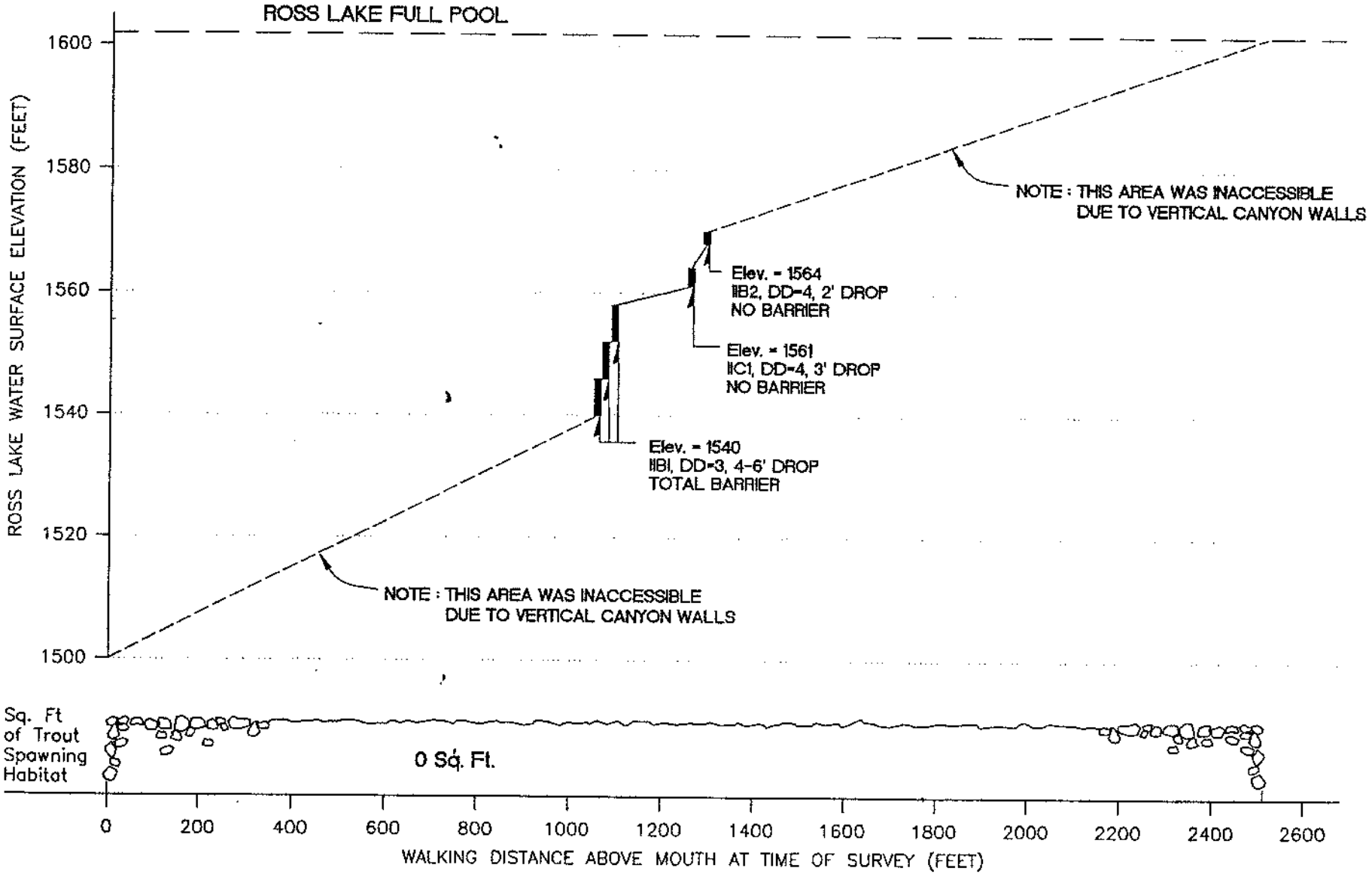

Figure 3: Stream profile showing trout spawning habitat and barriers in the drawdown reach of DEVILS CREEK

VAA00535

TABLE 3. ROSS LAKE TRIBUTARIES TROUT SPAWNING HABITAT AND MIGRATION BARRIERS

TRIBUTARY NAME	DISTANCE (FT) FROM	TO	HABITAT NOTES	WATERSHED AREA (SQ MI)	CFS (CALC)	WIDTH (CALC)	PERCENT GRADIENT	PERCENT[4] SPAWNING	SPAWNING AREA(SQ FT)
DEVILS CREEK	0	300	PASSAGE	31.75	138	33	4%	0%	0
	300	10000	BARRIER	30.75	130	32	4%	0%	0
	10000	24000	PASSAGE ?	26.00	114	30	5%	0%	0
	24000	30000	PASSAGE ?	20.50	90	26	4%	0%	0
	30000	45000	PASSAGE ?	13.00	57	20	5%	0%	0
	45000	46400	BARRIER	7.25	32	15	36%	0%	0

HABITAT NOTES:

1. "SPAWNING" INDICATES THIS SECTION OF STREAM HAD SUITABLE SPAWNING HABITAT FOR TROUT.
2. "PASSAGE" DENOTES STREAM SECTIONS THAT ALLOWED FISH PASSAGE BUT WERE CONSIDERED TOO STEEP FOR SPAWNING HABITAT
3. "BARRIER" IDENTIFIES STREAM REACHES OR INDIVIDUAL LOCATIONS THAT WERE BARRIERS TO TROUT MIGRATION.
4. "PERCENT SPAWNING" IS THE ESIMATED PERCENTAGE OF STREAM BOTTOM AREA THAT IS SUITABLE FOR SPAWNING TROUT, IN ANY GIVEN STREAM SECTION.

DRY CREEK

Spawning Habitat

Almost all of the good spawning habitat in Dry Creek is in the drawdown reach, rather than in Dry Creek above El 1602. Stream gradient in the drawdown reach varies from 2% to 7% and small areas suitable for trout spawning were observed and recorded throughout the drawdown reach (Photos 17, 20 and 21).

Immediately upstream from El 1602, at the top of the 8-foot-high log debris barrier in Dry Creek, there is a short section of stream with habitat suitable for spawning trout. Spawning habitat is created by gravel accumulated behind the log debris barrier, and only extends about 100 feet up the stream. Above this short section of stream, Dry creek gains altitude rapidly and there was only 100 square feet of spawning habitat before barriers stopped trout migration. The only spawning habitat above the drawdown reach was the lowermost 500 feet of stream, where the 10% gradient limited spawning habitat to pool tailouts and stream edges.

Fish Passage Barriers

Two small waterfalls created by log debris were observed at El 1516 and El 1522, with heights of 3-feet and 2.5-feet respectively (Photos 18 and 19). Neither of these small waterfalls was considered a barrier to upstream migration of trout, as shown on the stream profile (Figure 4).

An 8-foot-high log debris pile creates a series of cascades and waterfalls from El 1594 to El 1602 in Dry Creek (Photos 22, 23, 24). This log pile was considered a total barrier to trout migration, and at all flows is at least a long and severe delay for any fish attempting to pass over the barrier. Historically, this log pile floats and disperses as the lake water comes up to full pool, and a new log pile returns and creates a similar barrier every year.

Above El 1602 fish passage would become increasingly difficult as the gradient of Dry Creek increases up the hillside. Spawning habitat was non-existent more than 500 feet upstream from Ross Lake, as the stream gradient increased to 14% and whitewater cascades became dominant. About 1,200 feet above Ross Lake full pool, a 6-foot high chute/falls and 10-foot high boulder cascade formed an impassable series of barriers to Ross Lake trout. One resident trout was seen above these barriers. Barrier removal for fisheries enhancement was considered impractical in Dry Creek above Ross Lake full pool, due to the steep stream gradient and lack of spawning habitat in the upper reaches.

Spawning Activity

Surveys conducted between 1970-1972 indicate that spawning occurs in the mouth and lower 1/4 mile of Dry Creek and that shoreline spawning in the area around the creek inlet may also occur. This was determined by the observation of both fry and ripe fish in these areas (City of Seattle, 1973).

Several redds and spawning pairs of trout were observed at the mouth of Dry Creek June 28, 1989, however, there was no evidence of significant spawning activity during surveys on June 15 or July 19, 1989.

Photo 17. Dry Creek at elevation 1514'. Flow = 16cfs on 4/24/89. 2% gradient, good spawning habitat typical of drawdown reach. Stream bottom composed mostly of 1-3 inch gravel.

Photo 18. Dry Creek at elevation 1516'. Flow = 16cfs on 4/24/89. 3 foot high waterfall created by in-stream wood debris. Barrier type IA2, difficulty rating 2, no barrier to trout migration.

Photo 19. Dry Creek at elevation 1522'. Flow = 16cfs on 4/24/89. 2.5 foot high waterfall caused by in-stream wood debris. Barrier type IA1, difficulty rating 1, no barrier to trout migration.

Photo 20. Dry Creek at elevation 1540'. Flow = 16cfs on 4/24/89. Stream gradient approximately 5%, mostly riffle habitat with gravel and rubble stream bottom. Small, isolated pockets suitable for trout spawning. The entire channel is unstable and probably moves during high flows.

Photo 21. Dry Creek at elevation 1578'. Flow = 16cfs on 4/24/89. Small, isolated pockets suitable for trout spawning in boulder/rubble/gravel streambed. Stream gradient is 5%, very little in-stream cover other than occasional shallow pools and stumps. 8 foot high log debris pile is visible at tree-line.

Photo 22. Dry Creek at elevation 1594'. Flow = 16cfs on 4/24/89. 8 foot high fish passage barrier created by log debris pile from shore drift. Barrier type ID2, difficulty rating 6, probably a total barrier at this flow.

Photo 23. Dry Creek at elevation 1594'. Flow = 16cfs on 4/24/89. Close-up of log debris barrier showing multiple and complex chutes and falls within the barrier. Total height of barrier is 8 feet and it shifts each year as Ross Lake fills and then recedes. Total barrier to trout migration until Ross Lake reaches an elevation of about 1598'.

Photo 24. Dry Creek at Elevation 1604'. Flow = 16cfs on 4/24/89. Gravel accumulation immediately above 8 foot high log debris barrier creates a 100 foot length of good spawning habitat in Dry Creek. Above this aggraded section of stream, Dry Creek gradient steepens to 15%+ and spawning habitat is scarce.

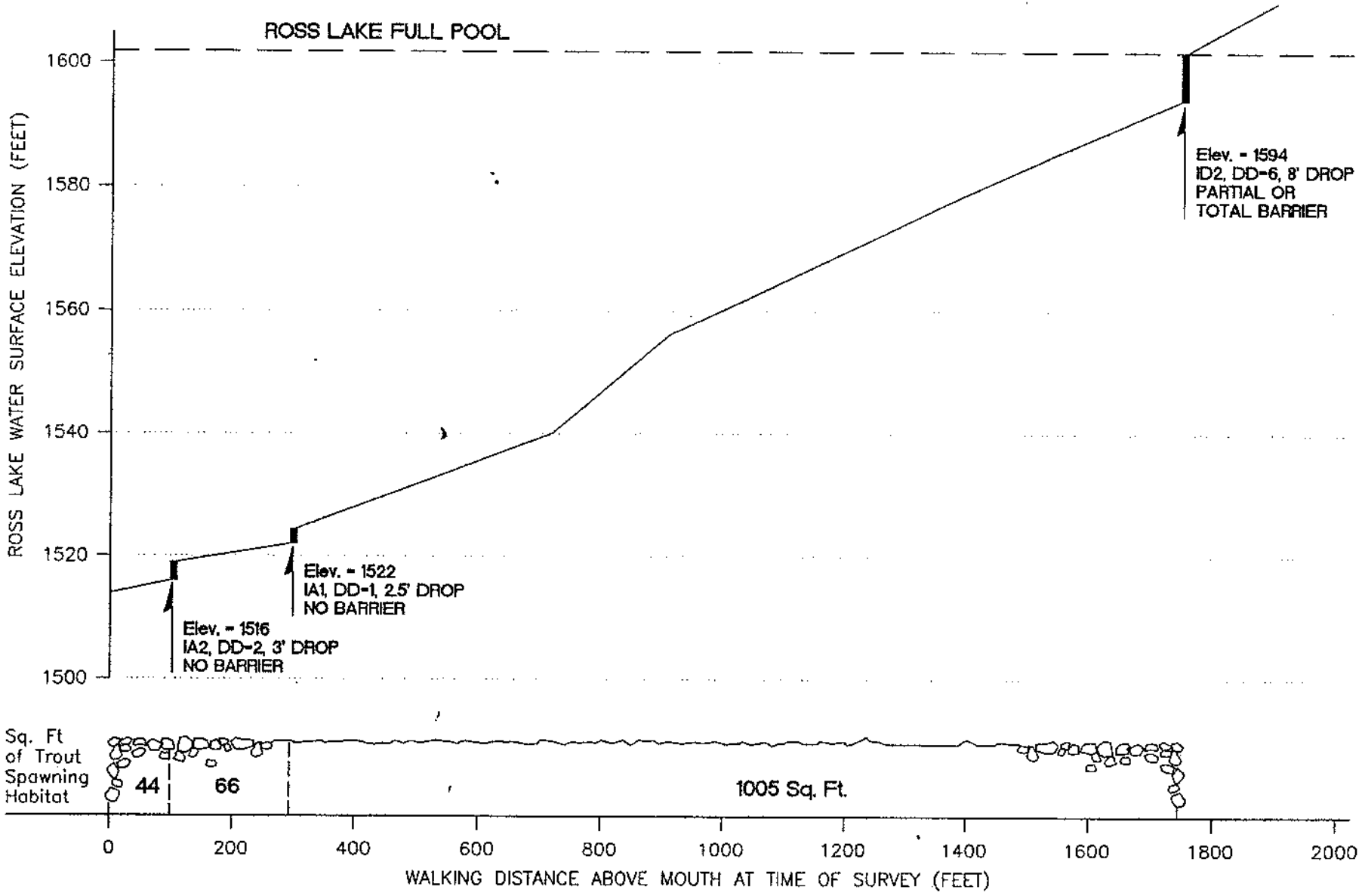

Figure 4: Stream profile showing trout spawning habitat and barriers in the drawdown reach of DRY CREEK

VAA00264

TABLE 4. ROSS LAKE TRIBUTARIES TROUT SPAWNING HABITAT AND MIGRATION BARRIERS

TRIBUTARY NAME	DISTANCE (FT) FROM	TO	HABITAT NOTES	WATERSHED AREA (SQ MI)	CFS (CALC)	WIDTH (CALC)	PERCENT GRADIENT	PERCENT SPAWNING[4]	SPAWNING AREA(SQ FT)
DRY CREEK	0	500	SPAWNING	3.87	17	10	10%	2%	100
	500	2500	BARRIER	3.62	16	10	17%	0%	0

HABITAT NOTES:

1. "SPAWNING" INDICATES THIS SECTION OF STREAM HAD SUITABLE SPAWNING HABITAT FOR TROUT.
2. "PASSAGE" DENOTES STREAM SECTIONS THAT ALLOWED FISH PASSAGE BUT WERE CONSIDERED TOO STEEP FOR SPAWNING HABITAT
3. "BARRIER" IDENTIFIES STREAM REACHES OR INDIVIDUAL LOCATIONS THAT WERE BARRIERS TO TROUT MIGRATION.
4. "PERCENT SPAWNING" IS THE ESIMATED PERCENTAGE OF STREAM BOTTOM AREA THAT IS SUITABLE FOR SPAWNING TROUT, IN ANY GIVEN STREAM SECTION.

HOZOMEEN CREEK

Spawning Habitat

All of the good spawning habitat for Hozomeen Creek is in the drawdown reach just below full pool (Photo 28). Below El 1570 where gradient decreases, substrate is silt or sand (Photo 25, 26 and 27). Suitable spawning gravel predominates the streambed from El 1573 to passable barriers at El 1595 and depths and velocities in this section are also excellent for trout spawning (Photo 28). The streambed gradient in this section is from 1-3%.

As indicated in Table 5, streambed gradient increases dramatically above El 1602 to 22% over the first 900 feet and the stream is a series of impassable chutes, falls, and rapids for a distance of at least 1/2 mile.

Fish Passage Barriers

Log debris forms two small waterfalls at El 1595 (Photo 29) and El 1602 with vertical drops of 2.5 and 2 feet respectively. These should be passable to fish at most flows, as indicated in Figure 5.

As the gradient increases sharply above El 1602, trout migration would become more difficult. The first impassable barrier occurs at El 1625 (City of Seattle 1973), and this begins a 1/2-mile long sequence of impassable stream habitat. Alteration and/or removal of these barriers, in an effort to get Ross Lake trout to upstream spawning habitat, was considered impractical.

Spawning Activity

The City of Seattle (1973) report noted that spawning may occur along the lake shoreline in the vicinity of Hozomeen Creek. This was determined by observations of emergent fry.

Several redds and mating pairs were observed in Hozomeen Creek during the 1989 survey. Four redds were marked on 6/16/89. When observers returned on 7/19/89 all four redds were completely covered with 1-2 inches of silt. Egg survival is predicted to be low in these redds.

Photo 25. Hozomeen Creek at elevation 1555'. Flow = 15cfs on 5/16/89. Hozomeen Creek is a wide, shallow, silty creek in this reach and there is no suitable spawning habitat.

Photo 26. Hozomeen Creek at elevation 1564'. Flow = 15cfs on 5/16/89. Streambed gradient is 0.2% with lots of small, woody debris along the channel. Over one mile of this type of habitat existed in lower Hozomeen Creek.

Photo 27. Hozomeen Creek at elevation 1567'. Flow = 15cfs on 5/16/89. As streambed gradient decreases to 0.5% toward the mouth of Hozomeen Creek, spawning habitat completely disappears. The channel becomes wide and silty with lots of meanders through most of the drawdown reach.

Photo 28. Hozomeen Creek at elevation 1573'. Flow = 15cfs on 5/16/89. Spawning habitat appears to be excellent in this reach. Pools to 3 feet deep and some woody debris provide cover.

Photo 29. Hozomeen Creek at elevation 1595'. Flow = 15cfs on 5/16/89. Cascade barrier through debris. This type IB1 barrier was rated degree of difficulty 2. It should not be a problem for migrating trout as there are several routes through which fish could pass.

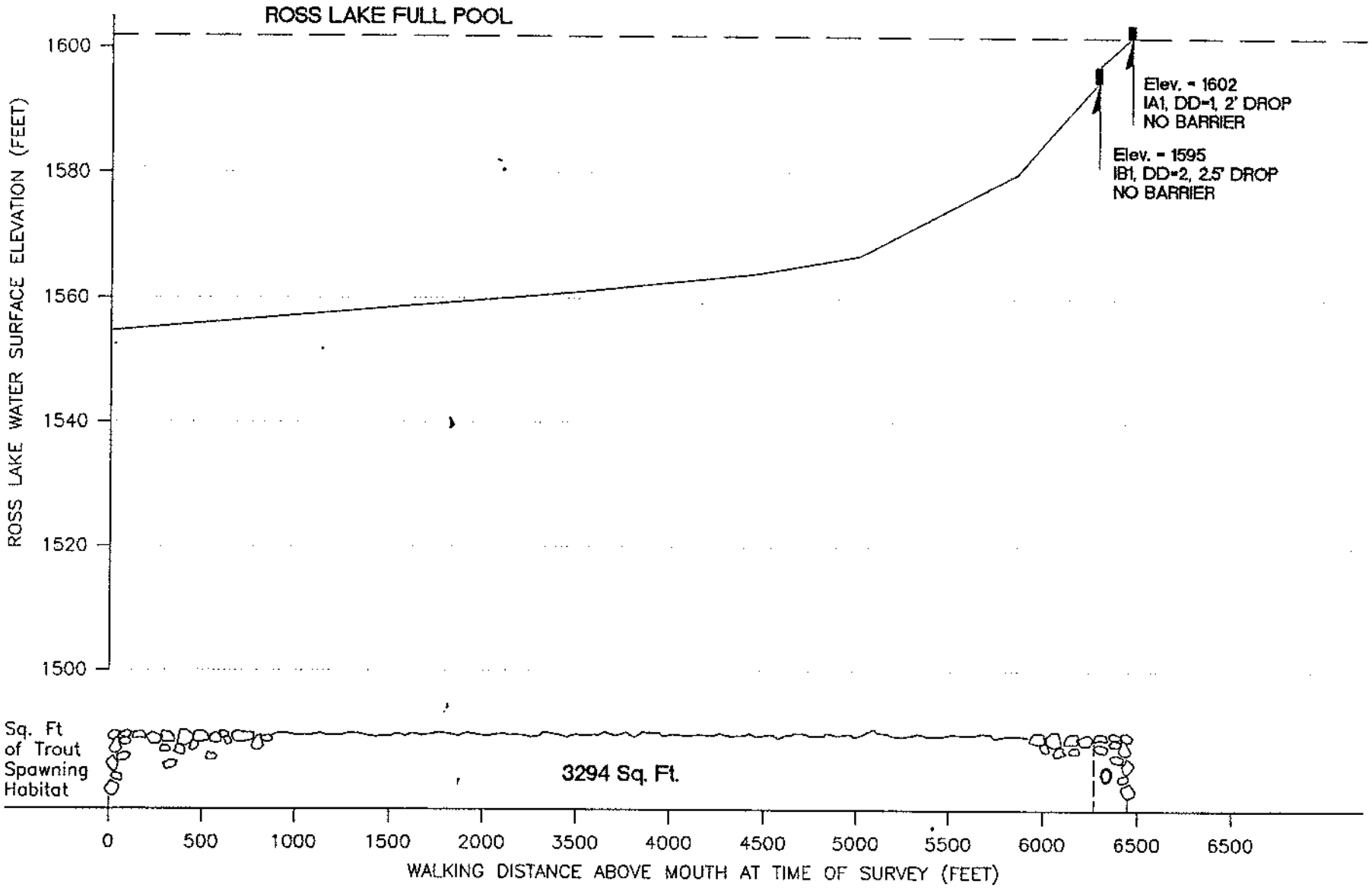

Figure 5: Stream profile showing trout spawning habitat and barriers in the drawdown reach of HOZOMEEN CREEK

VAA00399

TABLE 5. ROSS LAKE TRIBUTARIES TROUT SPAWNING HABITAT AND MIGRATION BARRIERS

TRIBUTARY NAME	DISTANCE (FT) FROM	TO	HABITAT NOTES	WATERSHED AREA (SQ MI)	CFS (CALC)	WIDTH (CALC)	PERCENT GRADIENT	PERCENT SPAWNING[4]	SPAWNING AREA(SQ FT)
HOZOMEEN CREEK	0	264	SPAWNING	6.87	31	14	10%	2%	74
	264	264	BARRIER	-	-	-	-	-	0
	264	900	BARRIER	4.50	28	12	22%	0%	0
	900	22968	PASSAGE	3.37	15	10	0%	0%	0

HABITAT NOTES:

1. "SPAWNING" INDICATES THIS SECTION OF STREAM HAD SUITABLE SPAWNING HABITAT FOR TROUT.
2. "PASSAGE" DENOTES STREAM SECTIONS THAT ALLOWED FISH PASSAGE BUT WERE CONSIDERED TOO STEEP FOR SPAWNING HABITAT
3. "BARRIER" IDENTIFIES STREAM REACHES OR INDIVIDUAL LOCATIONS THAT WERE BARRIERS TO TROUT MIGRATION.
4. "PERCENT SPAWNING" IS THE ESIMATED PERCENTAGE OF STREAM BOTTOM AREA THAT IS SUITABLE FOR SPAWNING TROUT, IN ANY GIVEN STREAM SECTION.

LIGHTNING CREEK AND TRIBUTARIES

Spawning Habitat

Lightning Creek has some good trout spawning habitat both above and below full pool (Photos 30 & 32). Stream gradient in the drawdown reach is between 0.5% and 3.0% (Photo 33). Some areas have suitable spawning gravel but velocities and depths may be too great (Photo 34). A section of excellent spawning habitat is available just below El 1602 and appears to have good velocities for spawning even when Ross Lake is at full pool.

Above El 1602 in Lightning Creek, there are several miles of good spawning habitat with the exception of barriers identified below (Table 6).

Fish Passage Barriers

A multiple falls/chute at El 1540 (Photo 34) is probably a delay for most fish but not a total barrier (Figure 6). Three total barriers occur at El 1550 (Photo 36), El 1558, and El 1566 with vertical drops of 7, 6, and 6 feet respectively. At El 1591 a 5-foot-high turbulent cascade is at least a partial barrier and possibly a total barrier depending on streamflow (Photo 37).

Above full pool, a 1,400-foot length of Lightning Creek is accessible to trout before a 13-foot high barrier would stop their spawning migration. This barrier was noted by City of Seattle (1973) and Johnston (1989); the barrier is formed by a landslide of massive boulders. The boulders have lodged in the stream channel to form a 6-foot high waterfall and 7-foot cascade that together make up the totally impassable barrier. The barrier was considered impassable at all flows.

At a distance of 2,300 feet above Ross Lake full pool, another barrier exists in Lightning Creek. Large boulders in the stream create a 6-foot high turbulent cascade that would probably stop all but the strongest fish.

Above the two barriers identified above, Lightning Creek is a moderate gradient (3%), relatively wide stream with excellent spawning areas for trout. If trout got over the two lower barriers, they would have access to about 2 miles of Lightning Creek before reaching a log jam barrier above the confluence with Three Fools Creek. A log jam 1,100 feet above the Three Fools Creek confluence forms a 6-foot high turbulent cascade that would be a total barrier to upstream movements of trout. Two other old, washed out log jams were also found nearby but did not create any barriers to trout migration. The City of Seattle (1973) and Johnston (1989) reported three log jam barriers in this vicinity but apparently two log jams have been removed by flood flows.

Trout were caught about 7,000 feet upstream from Ross Lake, upstream of the lower barriers and downstream of the Three Fools Creek confluence.

Spawning Activity

Studies conducted during 1972-1973 found that the lower 1/4-mile and mouth of Lightning Creek were important spawning sites for Ross Lake trout. Fry abundance sampling concluded that Lightning Creek above El 1602 produced a large number of fry, second only to Ruby Creek when comparing the tributaries within the United States (City of Seattle, 1974). In addition, rainbow trout may use the shoreline near the mouth of Lightning Creek for spawning (Johnston, 1989).

During the 1989 tributary mouth spawning surveys, a significant number of fish were observed in the mouth of Lightning Creek. On June 15 and June 28, 6 and 25-30 fish, respectively, were observed milling in the mouth of Lightning Creek. A subsequent survey conducted on July 19, 1989 revealed that at least 15 trout appeared to be spawning on a gravel bar just below El 1602 and at least 30 trout were in the vicinity.

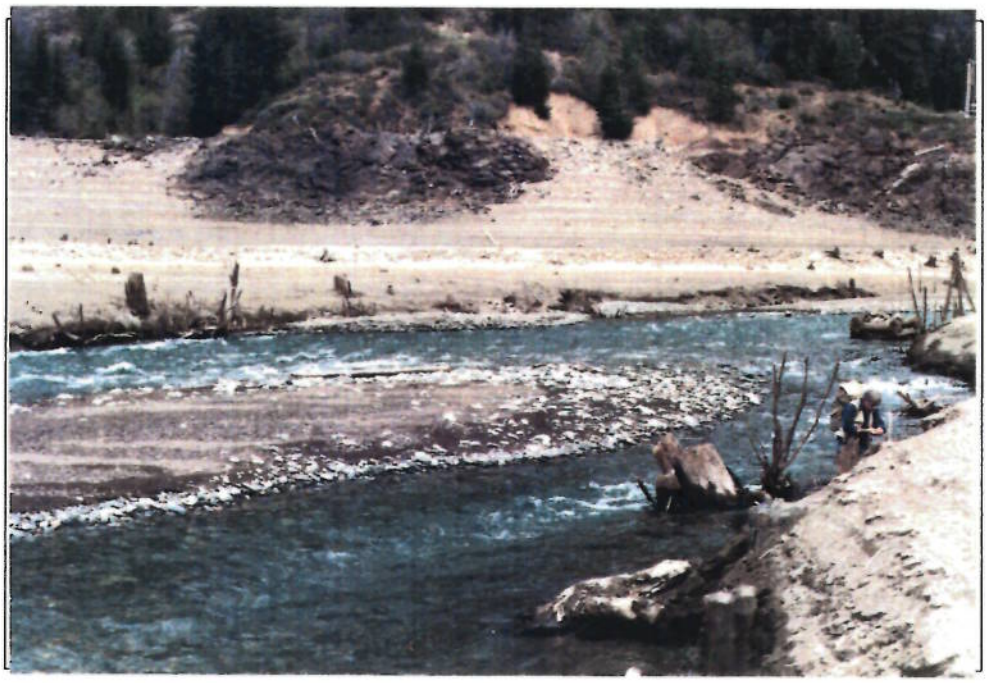

Photo 30. Lightning Creek at elevation 1524'. Flow = 480cfs on 4/26/89. Good trout spawning habitat at downstream end of pool tailouts. Streambed gradient 0.5%.

Photo 31. Lightning Creek at elevation 1526'. Flow = 480cfs on 4/26/89. This reach is too deep and fast for trout spawning and rubble substrates are too large.

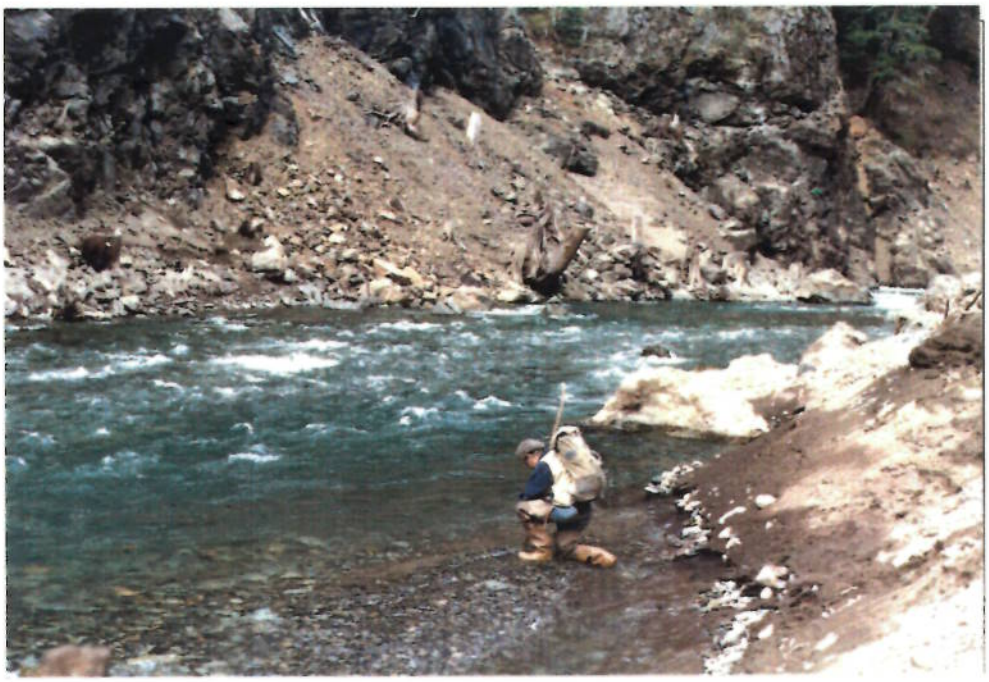

Photo 32. Lightning Creek at elevation 1529'. Flow = 480cfs on 4/26/89. In this reach, several areas approximately 10 feet x 30 feet in size have suitable spawning habitat, mostly along the edge of the stream or below large boulders.

Photo 33. Lightning Creek at elevation 1531'. Flow = 480cfs on 4/26/89. Streambed gradient is 3.0%. Substrates are boulder and rubble, too large for trout spawning.

Photo 34. Lightning Creek at elevation 1540'. Flow = 480cfs on 4/26/89. This multiple falls/chute is probably a delay for most fish, but not a total barrier. They should be able to jump the 3 foot falls on the left bank.

Photo 35. Lightning Creek at elevation 1542'. Flow = 480cfs on 4/26/89. There is no trout spawning habitat in this reach. However, it provides good cover and passage for migrating trout.

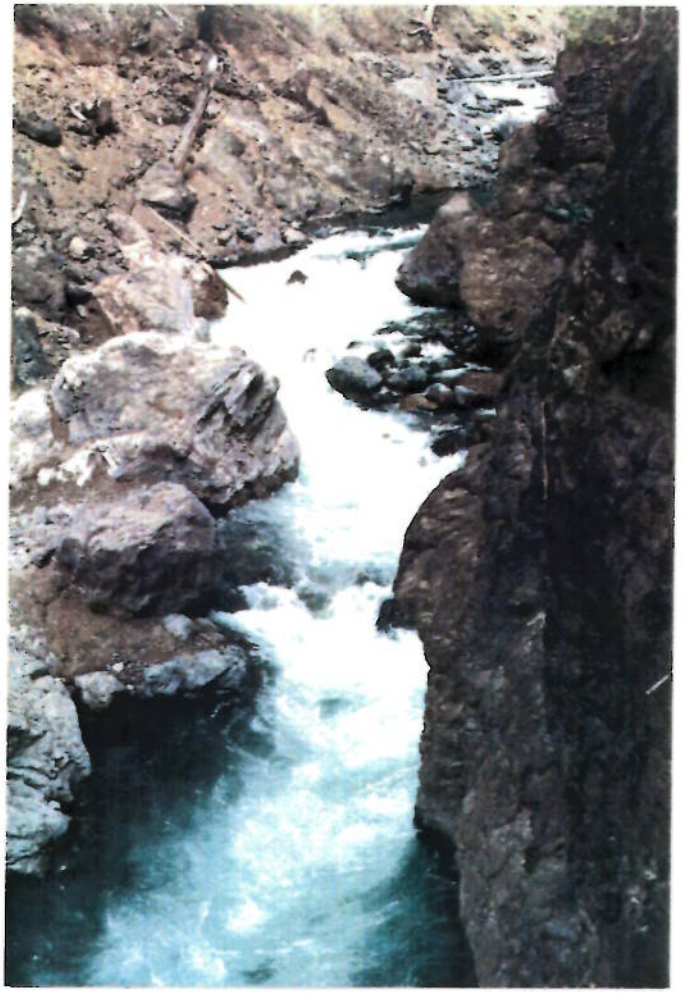

Photo 36. Lightning Creek at elevation 1550'. Flow = 480cfs on 4/26/89. This turbulent cascade type IIC1 barrier has a degree of difficulty rating of 4. It was judged to be a total migration barrier to trout until the pool filled to an elevation of 1556'.

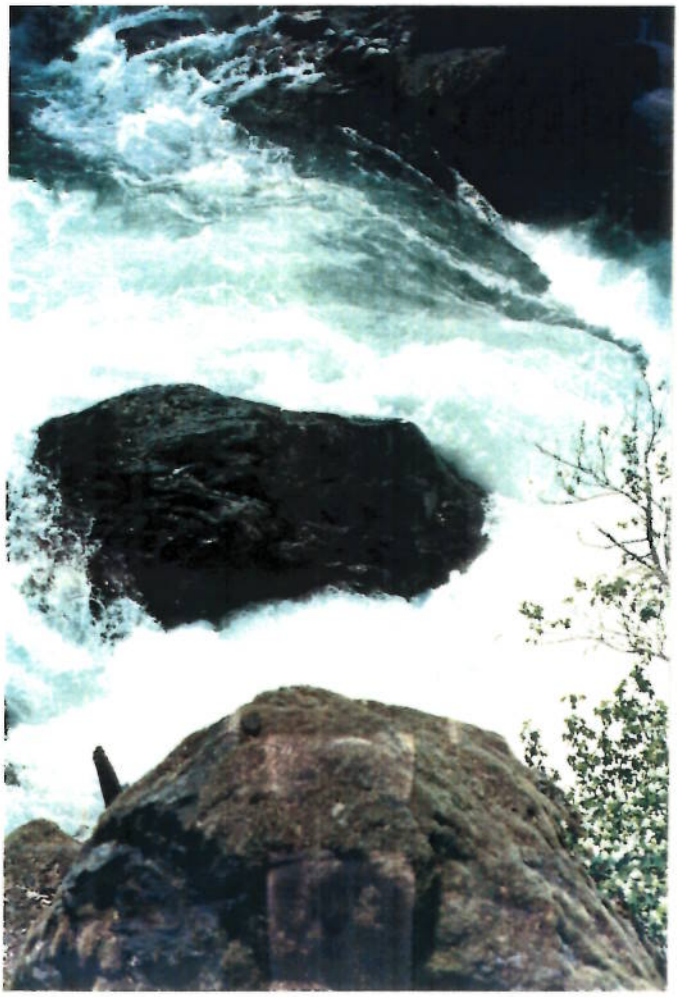

Photo 37. Lightning Creek at elevation 1591'. Flow = 450cfs on 5/15/89. A turbulent cascade type IIC1 with a degree of difficulty rating of 4. May be a total barrier although it appears that trout could swim around one side or the other to avoid it.

Photo 38. Lightning Creek at elevation 1602'. Flow = 450cfs on 5/15/89. Bedrock and boulders are the predominate substrates in this portion of Lightning Creek. There are no passage problems for trout in this reach, but trout spawning habitat is non-existent here.

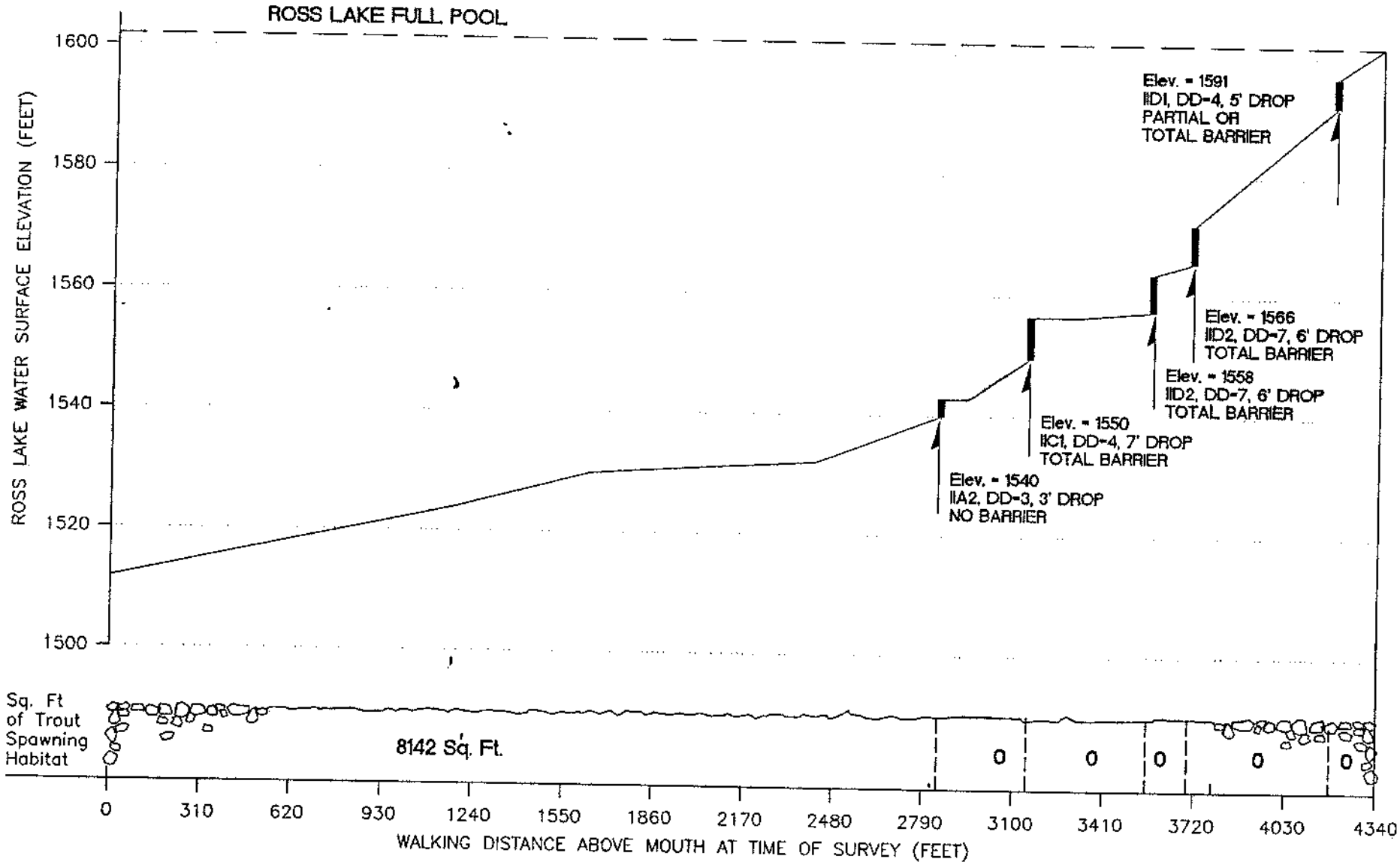

Figure 6: Stream profile showing trout spawning habitat and barriers in the drawdown reach of LIGHTNING CREEK

VAA00400

TABLE 6. ROSS LAKE TRIBUTARIES TROUT SPAWNING HABITAT AND MIGRATION BARRIERS

TRIBUTARY NAME	DISTANCE (FT) FROM	TO	HABITAT NOTES	WATERSHED AREA (SQ MI)	CFS (CALC)	WIDTH (CALC)	PERCENT GRADIENT	PERCENT SPAWNING[4]	SPAWNING AREA(SQ FT)
LIGHTNING CREEK	0	1400	PASSAGE	161.34	683	82	2%	2%	2240
	1400	1400	BARRIER	-	-	-	-	-	0
	1400	11000	SPAWNING	155.00	675	78	2%	2%	14976
	11000	11000	BARRIER	-	-	-	-	-	0
	11000	32000	SPAWNING	121.00	500	69	2%	2%	28980
	32000	35000	PASSAGE	99.10	423	62	5%	0%	0
	35000	57000	PASSAGE	82.83	355	57	4%	0%	0
	57000	60280	PASSAGE	64.90	279	49	8%	0%	0
	60280	70120	PASSAGE	56.66	244	46	4%	0%	0
	70120	106200	SPAWNING	27.82	121	31	1%	2%	22255
	106200	110300	BARRIER	2.58	12	8	15%	0%	0
THREE FOOLS LIGHT		17000	PASSAGE	48.93	211	42	4%	0%	0
	17000	33500	PASSAGE	33.06	144	34	9%	0%	0
	33500	35300	BARRIER	13.22	58	20	16%	0%	0
FREEZOUT	LIGHT	1500	BARRIER	13.03	58	20	19%	0%	0

HABITAT NOTES:

1. "SPAWNING" INDICATES THIS SECTION OF STREAM HAD SUITABLE SPAWNING HABITAT FOR TROUT.
2. "PASSAGE" DENOTES STREAM SECTIONS THAT ALLOWED FISH PASSAGE BUT WERE CONSIDERED TOO STEEP FOR SPAWNING HABITAT
3. "BARRIER" IDENTIFIES STREAM REACHES OR INDIVIDUAL LOCATIONS THAT WERE BARRIERS TO TROUT MIGRATION.
4. "PERCENT SPAWNING" IS THE ESIMATED PERCENTAGE OF STREAM BOTTOM AREA THAT IS SUITABLE FOR SPAWNING TROUT, IN ANY GIVEN STREAM SECTION.

LITTLE BEAVER CREEK AND TRIBUTARIES

Spawning Habitat

Little Beaver Creek has very little suitable spawning habitat in the drawdown reach. A few small pockets of spawning gravel exist in the alluvial fan between El 1518 and El 1523 (Photos 39-42) above which the stream becomes a long, fast, deep riffle with virtually no suitable spawning gravel (Photos 43-46).

From Ross Lake full pool El 1602 to about one mile upstream, there are a series of cascades and waterfalls in bedrock channel sections that make it impossible for trout to get to upstream spawning habitat. Habitat upstream of these barriers includes about 7 miles of low gradient habitat with an estimated 101,000 square feet of spawning habitat (Table 7).

Fish Passage Barriers

Our survey of the drawdown reach did not identify any definite barriers to trout migration below El 1602; however, the stream channel was not completely accessible due to the vertical canyon walls (Figure 7).

Numerous barriers to trout migration exist in the lower mile of Little Beaver Creek, above the confluence with Ross Lake full pool. The entire reach of one mile length is a steep (4.5%) gradient stream with bedrock streambed and banks. Vertical cliffs surround both sides of the stream and it is only accessible by foot in a few locations.

The 1989 survey identified at least seven barriers to trout migration in lower Little Beaver Creek, as shown below:

Stream Distance Above Ross Full Pool (Approximate) (ft)	Barrier Type	Barrier Height (ft)	Barrier Classification	Notes
1,000	Turbulent Cascade	7	IIB2	Total barrier
2,000	Turbulent Cascade	4	IB2	Partial barrier
3,500	Bedrock Chute	5	IIB2	Total barrier
4,000	Bedrock Chute	4	IIB2	Partial or total barrier
4,200	Bedrock Chute	4	IIB2	Partial or total barrier
5,000	Waterfall	12	IIA1	Total barrier
5,200	Chute/Falls	8	ID2	Total barrier

All barriers were created by irregularities in the bedrock stream channel. The inaccessible stream canyon made identification of all barriers extremely difficult, and there are undoubtedly more barriers in the lower mile of Little Beaver Creek than the seven listed above.

The entire mile of barriers described above would need to be bypassed for Ross Lake trout to have access to the estimated 101,000 square feet of spawning habitat above the barriers.

Trout fry were observed in Little Beaver Creek 6,000 feet upstream from Ross Lake; this confirms that a resident population exists above all barriers (City of Seattle 1973, Johnston 1989).

Spawning Activity

Sexually mature rainbow trout and newly emergent fry were observed in the early 1970s, in the vicinity of the mouth of Little Beaver Creek indicating that some shoreline spawning may occur (City of Seattle, 1973). Johnston's 1989 report indicates that spawning occurs at the mouth and lower 0.09 mile of the stream. No evidence was found of trout spawning in Little Beaver Creek during the 1989 survey conducted on June 15, June 28, and July 19.

Photo 39. Little Beaver Creek at elevation 1518'. Flow = 330cfs on 4/27/89. Streambed gradient is 1.0% with small patches of excellent spawning habitat. Channel is braided in this area.

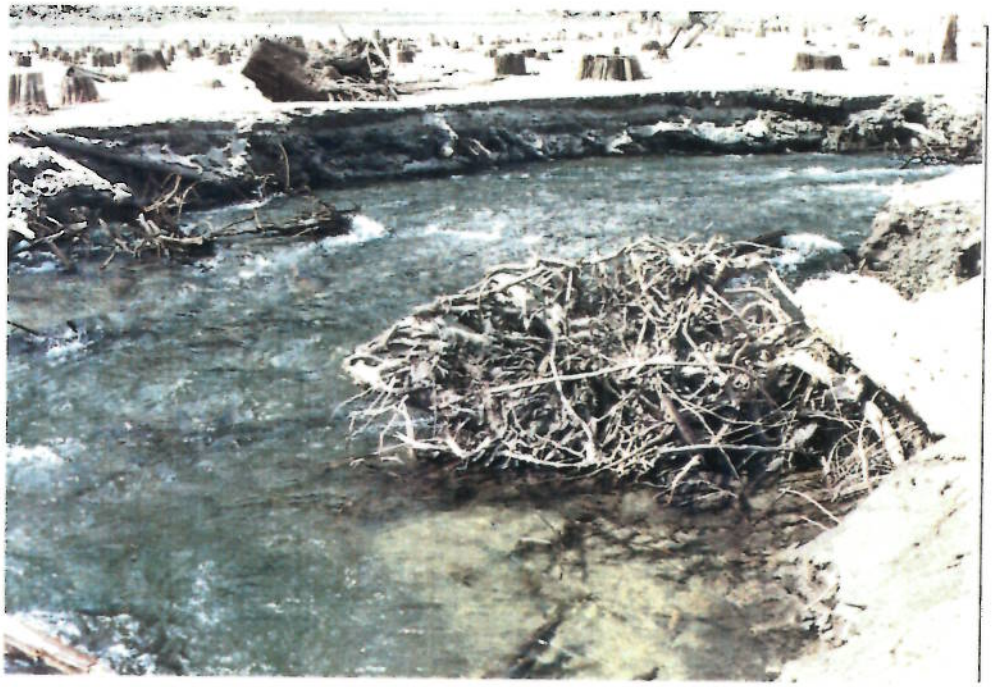

Photo 40. Little Beaver Creek at elevation 1518'. Flow = 330cfs on 4/27/89. Large organic debris provides good cover in this section of the creek.

Photo 41. Little Beaver Creek at elevation 1523'. Flow = 330cfs on 4/27/89. Braided channels spreading across the alluvial fan provide good spawning habitat. Streambed gradient is 0.5%.

Photo 42. Little Beaver Creek at elevation 1523'. Flow = 330cfs on 4/27/89. This location has in-stream cover provided by large organic debris, stumps, and 3 foot deep pools as well as some good spawning substrates.

Photo 43. Little Beaver Creek at elevation 1523'. Flow = 330cfs on 4/27/89. This long, fast, deep riffle has no spawning habitat but is not a problem for trout passage.

Photo 44. Little Beaver Creek at elevation 1530'. Flow = 330cfs on 4/27/89. This is a long, big riffle with rubble/boulder substrate too large for trout spawning but good for passage.

Photo 45. Little Beaver Creek at elevation 1538'. Flow = 330cfs on 4/27/89. This riffle provides good passage for trout migration but no spawning area. Streambed gradient is 1.0%.

Photo 46. Little Beaver Creek at elevation 1543'. Flow = 330cfs on 4/27/89. Substrates in this stream reach are too large for trout spawning.

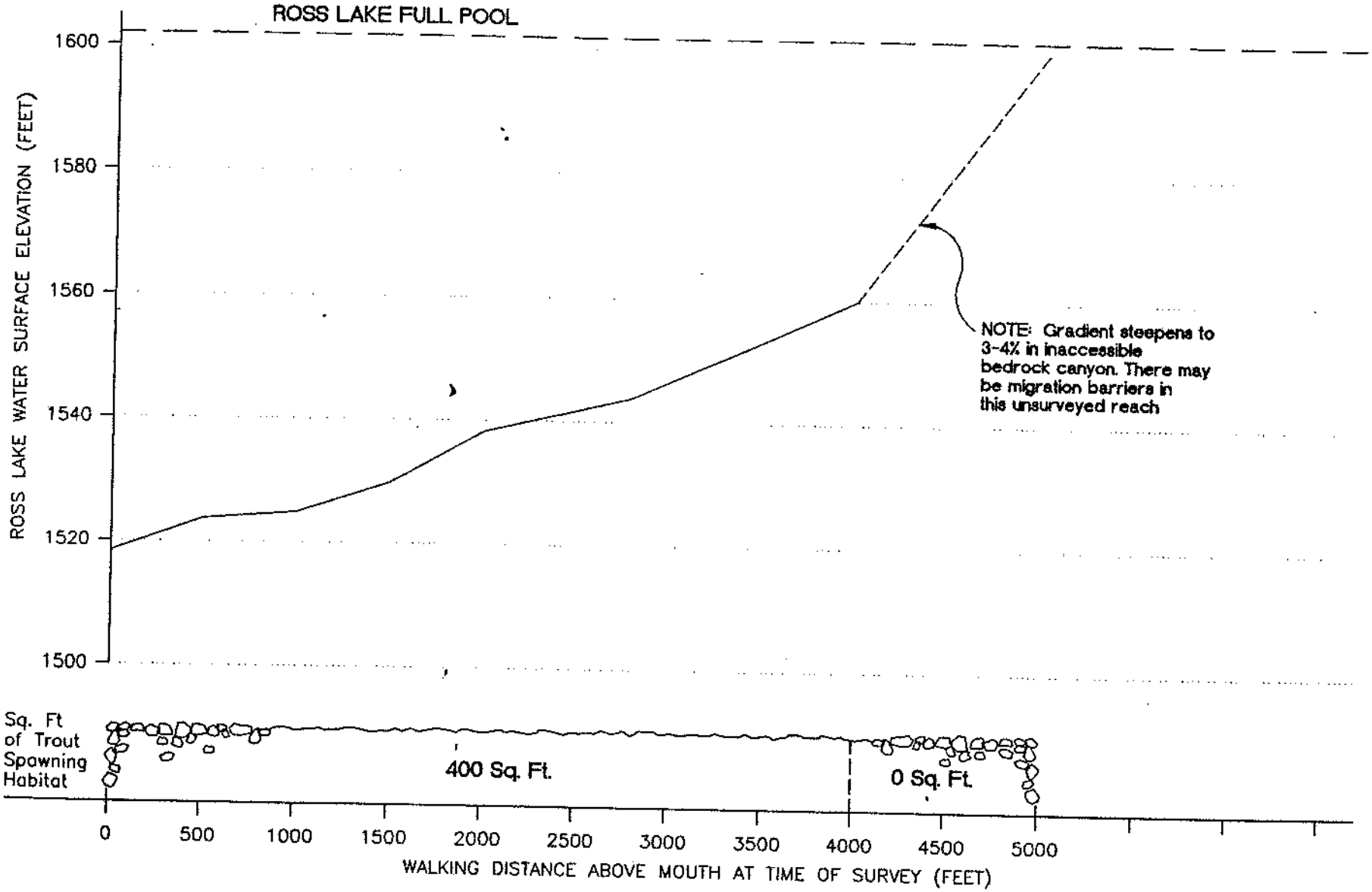

Figure 7: Stream profile showing trout spawning habitat and barriers in the drawdown reach of LITTLE BEAVER CREEK

TABLE 7. ROSS LAKE TRIBUTARIES TROUT SPAWNING HABITAT AND MIGRATION BARRIERS

TRIBUTARY NAME		DISTANCE (FT) FROM	TO	HABITAT NOTES	WATERSHED AREA (SQ MI)	CFS (CALC)	WIDTH (CALC)	PERCENT GRADIENT	PERCENT SPAWNING[4]	SPAWNING AREA(SQ FT)
LITTLE BEAVER CREEK		0	475	PASSAGE	49.50	214	42	3%	0%	0
		475	475	BARRIER	-	-	-	-	-	0
		475	7000	BARRIER	47.00	200	40	4%	0%	0
		7000	17000	SPAWNING	41.12	178	38	2%	2%	7665
		17000	46000	SPAWNING	24.12	105	28	1%	2%	16523
		46000	78000	SPAWNING	10.00	44	17	2%	10%	55880
		78000	98800	SPAWNING	3.75	17	10	3%	10%	21055
		98800	109360	BARRIER	2.00	9	7	18%	0%	0
	PERRY	LIL BEAV	2000	BARRIER	12.77	56	20	12%	0%	0
		2000	2800	BARRIER	12.11	54	19	25%	0%	0
	REDOUBT	LIL BEAV	1200	SPAWNING	10.27	46	18	7%	5%	1063
		1200	1700	BARRIER	9.82	44	17	32%	0%	0
	MIST	LIL BEAV	1500	SPAWNING	4.96	22	12	8%	5%	887
		1500	2200	SPAWNING	4.48	20	11	9%	5%	391
		2200	3400	BARRIER	4.06	18	11	33%	0%	0

HABITAT NOTES:

1. "SPAWNING" INDICATES THIS SECTION OF STREAM HAD SUITABLE SPAWNING HABITAT FOR TROUT.
2. "PASSAGE" DENOTES STREAM SECTIONS THAT ALLOWED FISH PASSAGE BUT WERE CONSIDERED TOO STEEP FOR SPAWNING HABITAT
3. "BARRIER" IDENTIFIES STREAM REACHES OR INDIVIDUAL LOCATIONS THAT WERE BARRIERS TO TROUT MIGRATION.
4. "PERCENT SPAWNING" IS THE ESIMATED PERCENTAGE OF STREAM BOTTOM AREA THAT IS SUITABLE FOR SPAWNING TROUT, IN ANY GIVEN STREAM SECTION.

NO NAME CREEK

Spawning Habitat

The only suitable trout spawning habitat to be found in No Name Creek is in the alluvial fan within the drawdown reach. (El 1518 to 1543). Streambed gradient is 1.5%, spawning size gravel is the predominant substrate and depths and velocities are good for spawning (Photos 47 & 48). At El 1543, the gradient increases to 11% and is mostly riffle habitat in a braided channel. The only available spawning habitat is found along the shallow stream edges (Photo 49). Between El 1543 and El 1602, there is virtually no spawning habitat due to numerous falls and steep gradient.

Above El 1602 the streambed gradient in No Name Creek is 20% and there is no trout spawning habitat available (Table 8).

Fish Passage Barriers

Two barriers at El 1543 (Photo 50) and El 1548 (Photo 51) would not present any passage problems to migrating trout in No Name Creek at any streamflow.

As shown on the stream profile (Figure 8), from El 1557 to above El 1602 there is a series of falls ranging in height from 5 to 25 feet. With the exception of the simple falls at El 1557 (Photo 52) which could be jumped by a trout able to leap 5 feet, all are impassable barriers at all flows (Photo 53).

Spawning Activity

City of Seattle reports (1973-74) did not indicate any evidence of spawning in No Name Creek. Johnston, (1989) states that trout spawning may occur in the mouth of No Name Creek.

Although there appears to be some good spawning habitat near the mouth of No Name Creek, we did not observe any trout or evidence of spawning in this creek on the following survey dates: June 15, June 28, and July 19, 1989.

Photo 47. No Name Creek at elevation 1518'. Flow = 45cfs on 4/27/89. Good spawning habitat becomes increasingly common as stream gradient lessens towards Ross Lake. Shallow pools, old stumps and large organic debris provide cover.

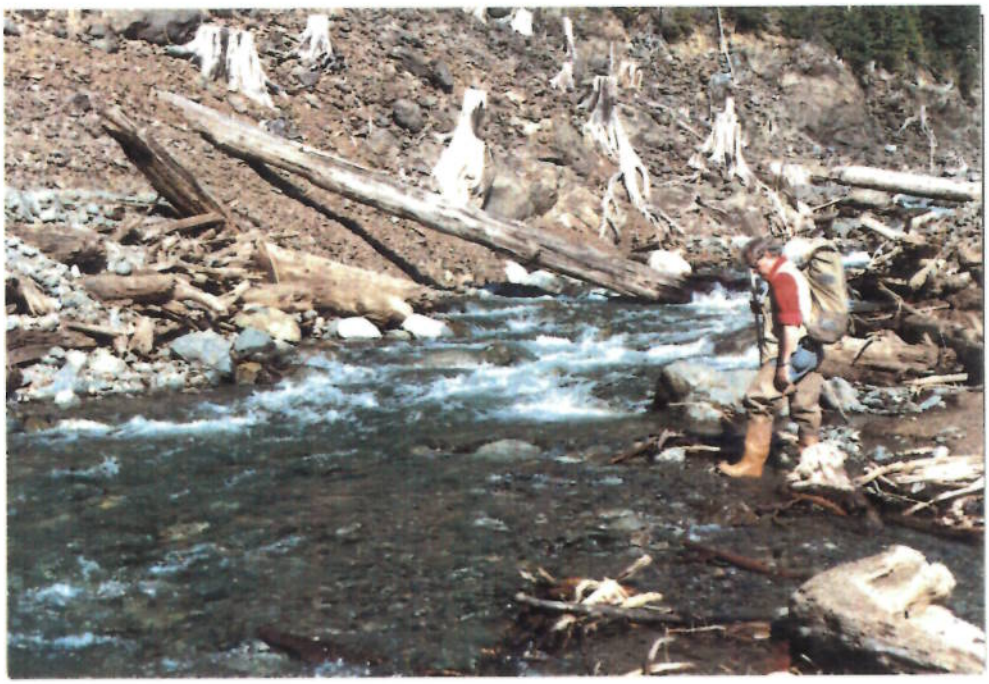

Photo 48. No Name Creek at elevation 1525'. Flow = 45cfs on 4/27/89. The alluvial fan has the only suitable spawning areas in this creek. Several areas within it appear to have excellent spawning conditions: gravel size is .25-2.0 inches, depth is 0.3-1.0 feet and velocity is 0.5-1.5 ft/sec. Stream gradient is 6.25% but steepens noticeably above this station.

Photo 49. No Name Creek at elevation 1543'. Flow = 45cfs on 4/27/89. This reach has a stream gradient of 11% and is mostly riffle with a braided channel. Spawning substrate is available only along shallow edge of stream (<0.5) which would be dry with a small decrease in flow.

Photo 50. No Name Creek at elevation 1543'. Flow = 45cfs on 4/27/89. A boulder cascade, type IB2 barrier, with a degree of difficulty rating of 3. Trout could get up the sides of this chute in several areas so it would not be a migration barrier. Passage would be easier at lower flows but could also be accomplished at higher flows.

Photo 51. No Name Creek at elevation 1548'. Flow = 45cfs on 4/27/89. This simple falls or chute would not be a barrier to trout migration at any flow. There are several areas where trout could leap 1-2 feet over the falls. The classification for this barrier is type IIA1, degree of difficulty rating 2.

Photo 52. No Name Creek at elevation 1557'. Flow = 45cfs on 4/27/89. This waterfall is a total barrier to trout at this flow, but with less flow, any trout able to leap 5 feet vertical could make it. Good hydraulics for jumping. Type IIA1, degree of difficulty rating 2.

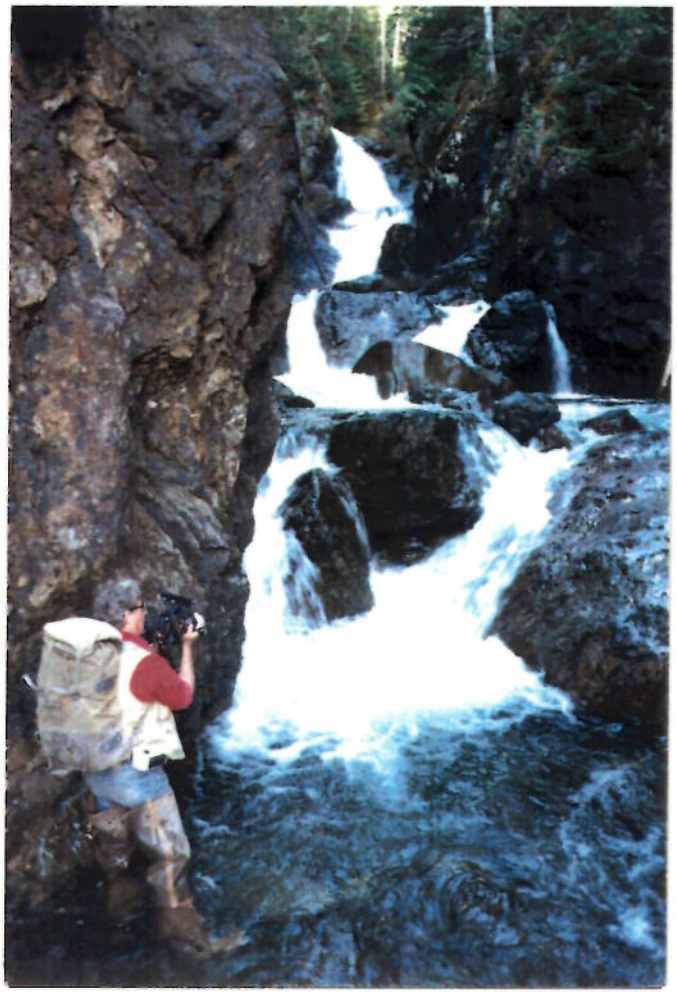

Photo 53. No Name Creek at elevation 1570'. Flow = 45cfs on 4/27/89. This series of chutes and falls are total barriers at all flows. They are all type IIC1, degree of difficulty rating 4 with vertical drops of 6-20 feet.

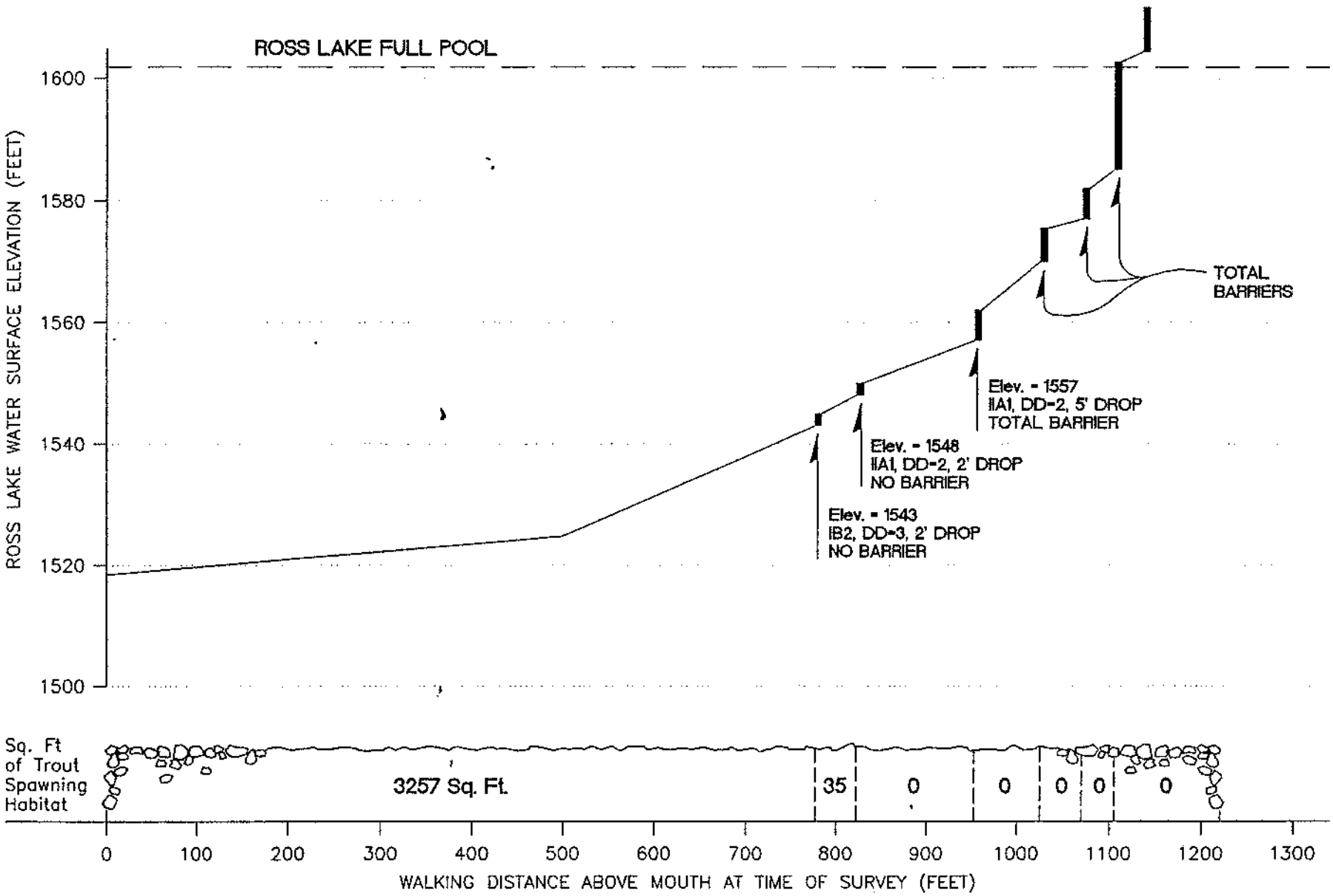

Figure 8: Stream profile showing trout spawning habitat and barriers in the drawdown reach of NO NAME CREEK

VAA00283

TABLE 8. ROSS LAKE TRIBUTARIES TROUT SPAWNING HABITAT AND MIGRATION BARRIERS

TRIBUTARY NAME	DISTANCE (FT) FROM	TO	HABITAT NOTES	WATERSHED AREA (SQ MI)	CFS (CALC)	WIDTH (CALC)	PERCENT GRADIENT	PERCENT SPAWNING[4]	SPAWNING AREA(SQ FT)
NONAME CREEK	0	1000	BARRIER	6.84	31	14	20%	0%	0

HABITAT NOTES:

1. "SPAWNING" INDICATES THIS SECTION OF STREAM HAD SUITABLE SPAWNING HABITAT FOR TROUT.
2. "PASSAGE" DENOTES STREAM SECTIONS THAT ALLOWED FISH PASSAGE BUT WERE CONSIDERED TOO STEEP FOR SPAWNING HABITAT
3. "BARRIER" IDENTIFIES STREAM REACHES OR INDIVIDUAL LOCATIONS THAT WERE BARRIERS TO TROUT MIGRATION.
4. "PERCENT SPAWNING" IS THE ESIMATED PERCENTAGE OF STREAM BOTTOM AREA THAT IS SUITABLE FOR SPAWNING TROUT, IN ANY GIVEN STREAM SECTION.

PIERCE CREEK

Spawning Habitat

Small, isolated pockets of good spawning habitat are available in the drawdown reach of Pierce Creek (Photos 53, 56, 58). These are found primarily along the banks where lower velocities can be found. The streambed gradient in this portion of Pierce Creek is 5% (Photos 54 & 55).

Streambed gradient of Pierce Creek above El 1602 is 33% and there is no suitable trout spawning habitat (Table 9).

Fish Passage Barriers

Figure 9 shows a small, multiple falls at El 1564 which is an insignificant barrier at any flow (Photo 57). This 1.5-foot drop should not present any difficulty to trout migration.

At El 1586, a complex chute presents a total barrier to trout migration (Photo 59). The combination of an 8-foot vertical drop and high velocities make it virtually impassable.

Above El 1602 there are numerous passage barriers 4-8 feet high and as mentioned previously, streambed gradient is very steep (Photo 60). The significant amount of spawning habitat in Pierce Creek above El 1602 indicated it would be impractical to attempt to modify or remove any trout migration barriers in Pierce Creek. Several 60-80 foot high waterfalls exist in Pierce Creek just upstream of the smaller falls shown in Photo 60.

Spawning Activity

In the mouth of Pierce Creek, sexually mature trout and emergent fry were found during the 1971-1973 survey indicating some spawning does take place in this vicinity (City of Seattle, 1974). Johnston's report (1989) supports this and states that spawning occurs in the mouth and lower 0.08 miles of Pierce Creek.

We found that some successful spawning does take place in the mouth of Pierce Creek. Redds and spawning trout were observed at El 1598 on June 16, 1989 and June 28, 1989 and tributary spawning success studies determined that trout fry successfully emerged from redds near the mouth of Pierce Creek.

Photo 54. Pierce Creek at elevation 1529'. Flow = 35cfs on 4/25/89. There is no spawning substrate in this boulder/rubble riffle. Water velocities are 4-5 ft/sec but there are enough small resting areas to provide fish passage.

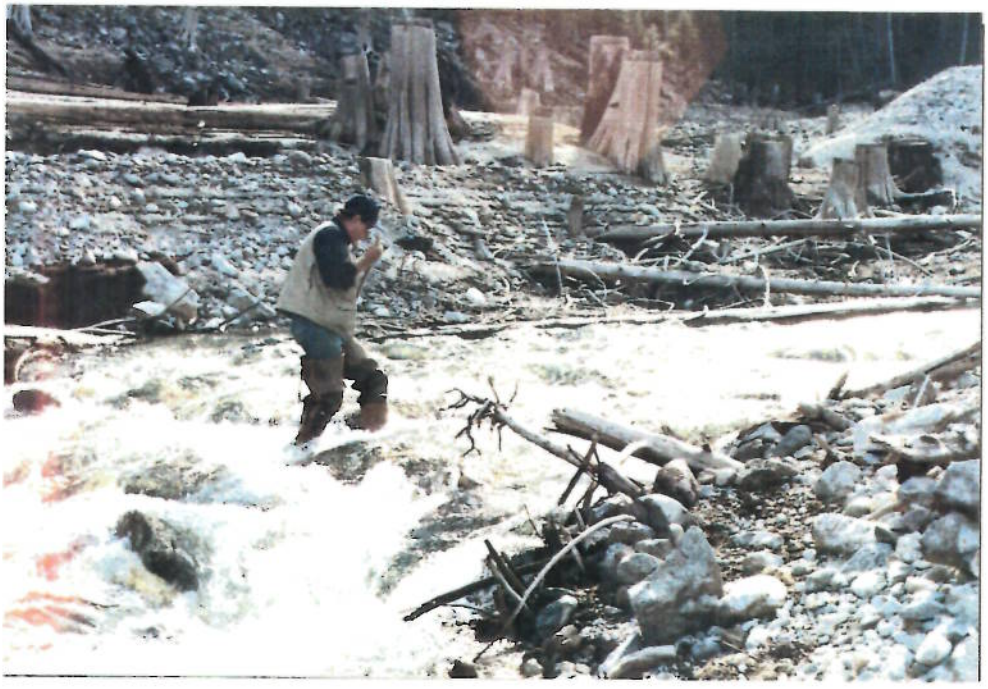

Photo 55. Pierce Creek at elevation 1549'. Flow = 35cfs on 4/25/89. Streambed gradient is 5.5%. Cover is provided by a small amount of large organic debris plus pockets of good cover from boulders.

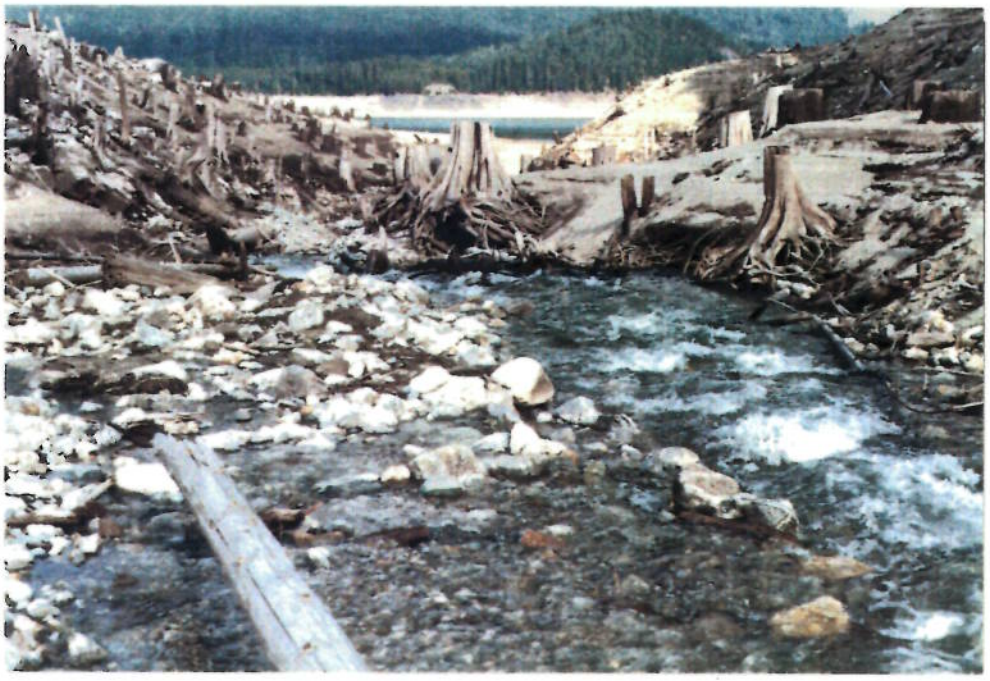

Photo 56. Pierce Creek at elevation 1549'. Flow = 35cfs on 4/25/89. Primarily riffle habitat with small, but good pockets of spawning gravel mostly along banks where velocity is 1.0-2.0 ft/sec and depth is 0.5-1.0 feet. Small amount of large organic debris plus small pockets of good cover from boulders.

Photo 57. Pierce Creek at elevation 1564'. Flow = 35cfs on 4/25/89. One of 4 small multiple falls between the mouth of Pierce Creek and elevation 1602'. This 1.0-1.5 foot drop over a log should not present any difficulty to trout passage regardless of flow. Barrier type IA1, degree of difficulty rating 1.

Photo 58. Pierce Creek at elevation 1574'. Flow = 35cfs on 4/25/89. Below pools there were several areas approximately 8 feet x 10 feet in size of good spawning habitat. Depth of 0.5-1.0 feet, velocities 1-2 ft/sec with good spawning gravel. A 1.0-1.5 foot drop located 20 feet upstream should not be a barrier.

Photo 59. Pierce Creek at elevation 1586'. Flow = 35cfs on 4/25/89. 3 foot high total barrier to trout due to high velocity immediately upstream of falls. Classified as a complex chute, this barrier is a type IC2 with a degree of difficulty rating of 4.

Photo 60. Pierce Creek at elevation 1602'. Flow = 35cfs on 4/25/89. This station is upstream of the barrier at elevation 1586'. Stream habitat above elevation 1602' was steep, bedrock gradient with numerous passage barriers 4-8 feet high.

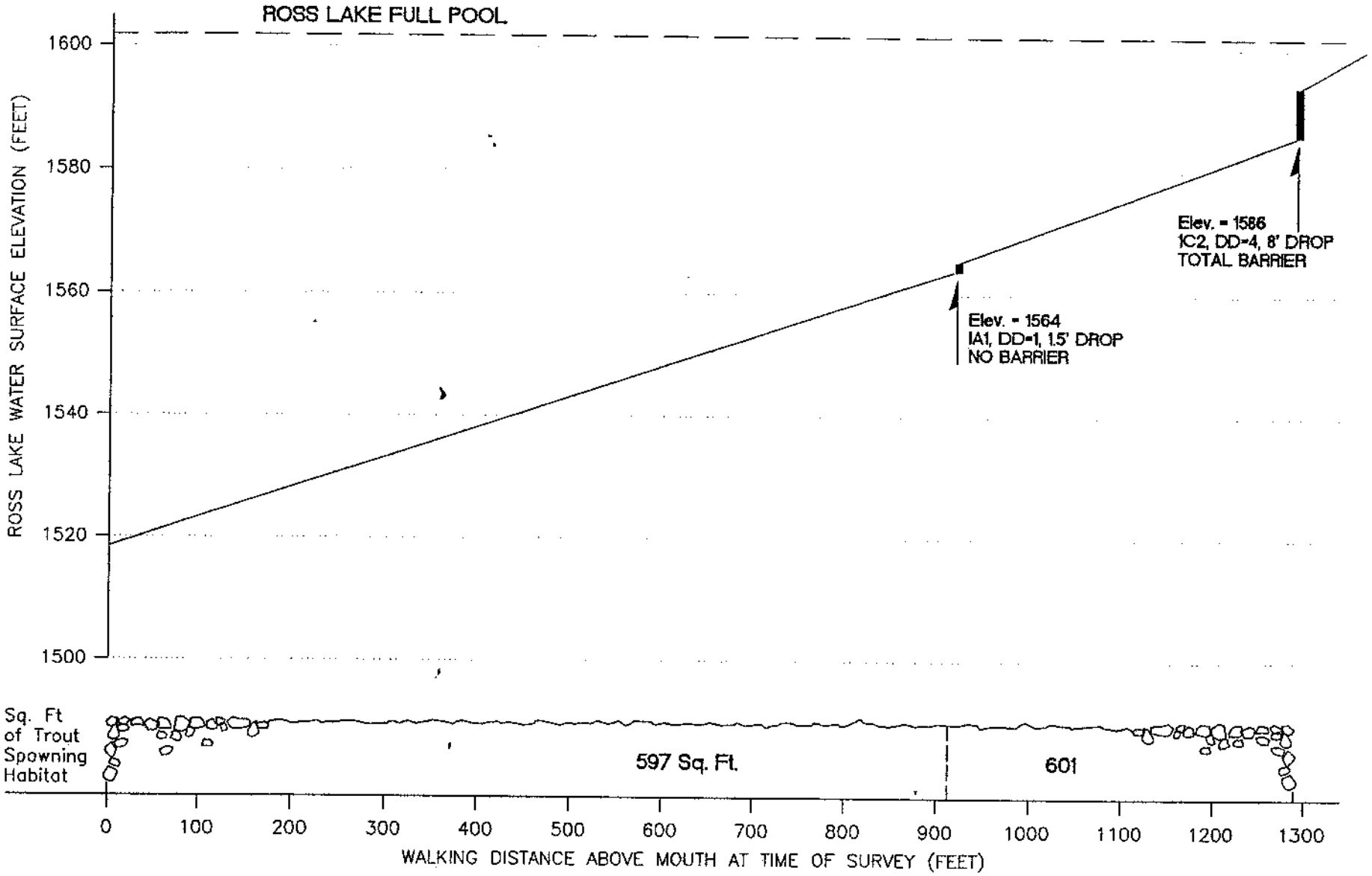

Figure 9: Stream profile showing trout spawning habitat and barriers in the drawdown reach of PIERCE CREEK

VAA00401

TABLE 9. ROSS LAKE TRIBUTARIES TROUT SPAWNING HABITAT AND MIGRATION BARRIERS

TRIBUTARY NAME	DISTANCE (FT) FROM	TO	HABITAT NOTES	WATERSHED AREA (SQ MI)	CFS (CALC)	WIDTH (CALC)	PERCENT GRADIENT	PERCENT SPAWNING[4]	SPAWNING AREA(SQ FT)
PIERCE CREEK	0	1200	BARRIER	2.90	13	9	33%	0%	0

HABITAT NOTES:

1. "SPAWNING" INDICATES THIS SECTION OF STREAM HAD SUITABLE SPAWNING HABITAT FOR TROUT.
2. "PASSAGE" DENOTES STREAM SECTIONS THAT ALLOWED FISH PASSAGE BUT WERE CONSIDERED TOO STEEP FOR SPAWNING HABITAT
3. "BARRIER" IDENTIFIES STREAM REACHES OR INDIVIDUAL LOCATIONS THAT WERE BARRIERS TO TROUT MIGRATION.
4. "PERCENT SPAWNING" IS THE ESTIMATED PERCENTAGE OF STREAM BOTTOM AREA THAT IS SUITABLE FOR SPAWNING TROUT, IN ANY GIVEN STREAM SECTION.

ROLAND CREEK

Spawning Habitat

The majority of suitable spawning habitat in Roland Creek is in the drawdown reach and this is of marginal quality, primarily along the stream edge and in pool tailouts (Photos 61, 63, 66 & 67). Streambed gradient is 6-7% and spawning substrates are somewhat angular and cemented by fines.

Roland Creek, above the drawdown reach, is a small, steep gradient stream with an estimated trout spawning area of 350 square feet accessible to Ross Lake fish (Table 10). The stream has an average gradient of 10% from Ross Lake full pool to a distance of 1,400 feet upstream. Streambed substrate is primarily boulders and rubble, with small amounts of gravel for spawning.

Fish Passage Barriers

As indicated on the Roland Creek stream profile (Figure 10), an unstable barrier (El 1559) created by stream erosion around old stumps may pose a temporary delay for some trout but should not be considered a passage problem (Photos 64 and 65).

At a distance of 1,400 feet upstream from Ross Lake (200 feet upstream from the trail crossing), a 6-foot high chute cascades over in-stream logs, and forms the first total barrier to trout migration. Stream gradient increases above this point, spawning habitat is scarce, and a 5-foot high chute over bedrock forms another total barrier 700 feet above the first barrier. Above this second barrier, overall stream gradient is 17% and there are multiple barriers to trout migration with almost no spawning habitat between the barriers. There were no reasonable enhancement projects identified for Roland Creek above El 1602.

Spawning Activity

During 1971-1973 spawning studies, the mouth and lower 0.3 miles of Roland Creek were determined to be used by trout for spawning. Sexually mature adults and newly emergent fry were observed (City of Seattle, 1974). According to Johnston (1989) 2,500 to 3,000 trout were observed migrating into Roland Creek during the June 1986 spawning season.

Although we did not observe as many fish in Roland Creek as Johnston (1989) reported, there does appear to be a substantial number of fish utilizing this creek for spawning. A survey conducted on June 15, 1989 noted three redds just above full pool. On June 28th, 40 or more fish were seen in the drawdown reach of Roland Creek.

Photo 61. Roland Creek at elevation 1516'. Flow = 5cfs on 4/26/89. Very small amount of spawning area along stream edge. Gravel is slightly angular, loose enough for spawning. Primarily riffle habitat with a 7.5% gradient.

Photo 62. Roland Creek at elevation 1543'. Flow = 5cfs on 4/26/89. Small pockets of spawning substrate along stream edge. Stream gradient of 6% mostly riffle habitat. Large organic debris provides some cover for fish.

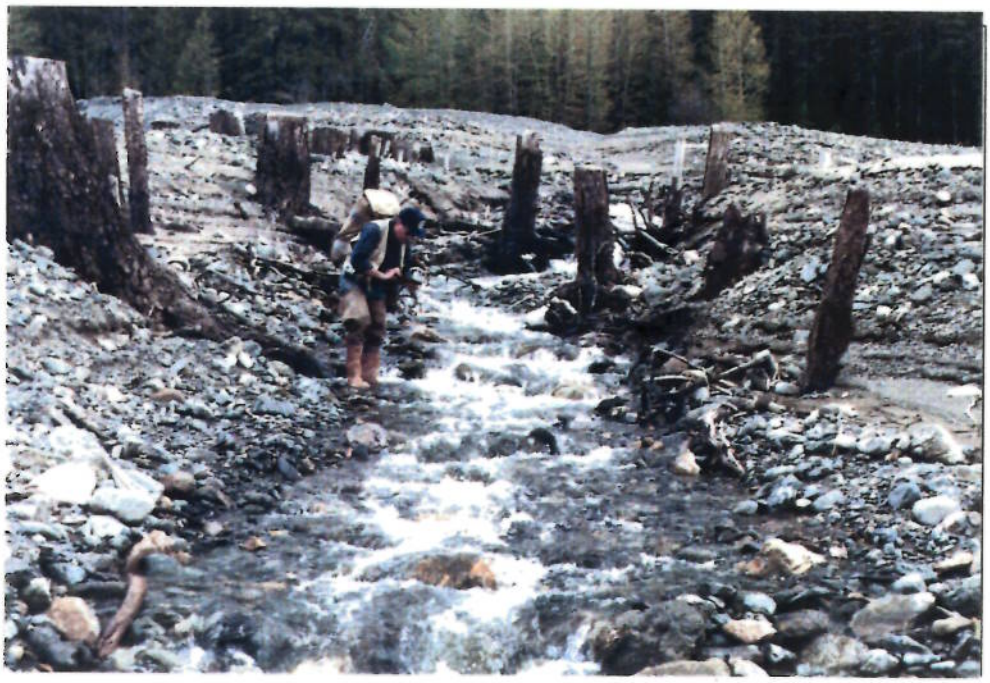

Photo 63. Roland Creek at elevation 1554'. Flow = 5cfs on 4/26/89. Stream gradient approximately 6%, riffle habitat with rubble and gravel substrate. Isolated pockets of marginal quality spawning habitat due to depth of <0.5 feet.

Photo 64. Roland Creek at elevation 1559'. Flow = 5cfs on 4/26/89. Two foot high multiple falls created by the stream eroding around old stumps. Roots hold back gravel. Barrier type IA2, Degree of difficulty rating 2.

Photo 65. Roland Creek at elevation 1559'. Flow 5cfs on 4/26/89. Close-up of small, unstable barrier. May temporarily slow down some trout, but should not be considered a barrier. Higher flows would reduce severity of barrier, lower flows would make it more difficult.

Photo 66. Roland Creek at elevation 1575'. Flow = 5cfs on 4/26/89. Stream gradient is approximately 7.5% in this mostly riffle habitat. Substrate is predominantly rubble with very small pockets of suitable spawning sized gravel along edges of creek where water turbulence is lessened. Sparse cover except for old stumps scattered along stream.

Photo 67. Roland Creek at elevation 1600'(+/-). Flow = 5cfs on 4/26/89. Shallow pool with some cover from turbulent water and rubble as well as large organic debris washed down from above.

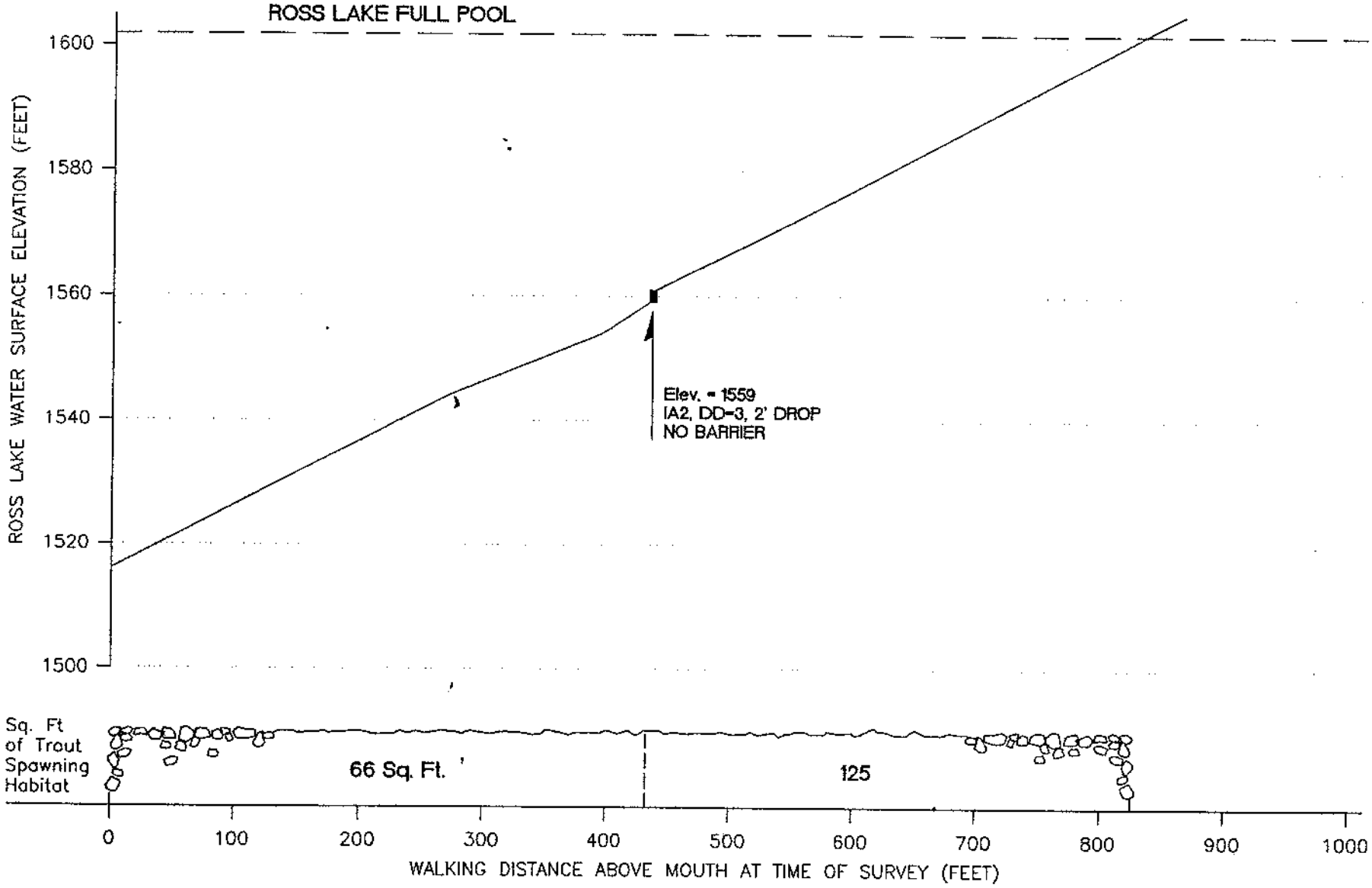

Figure 10: Stream profile showing trout spawning habitat and barriers in the drawdown reach of ROLAND CREEK

VAA00286

TABLE 10. ROSS LAKE TRIBUTARIES TROUT SPAWNING HABITAT AND MIGRATION BARRIERS

TRIBUTARY NAME	DISTANCE (FT) FROM	TO	HABITAT NOTES	WATERSHED AREA (SQ MI)	CFS (CALC)	WIDTH (CALC)	PERCENT GRADIENT	PERCENT SPAWNING[4]	SPAWNING AREA(SQ FT)
ROLAND CREEK	0	1400	SPAWNING	1.87	9	7	10%	5%	350
	1400	1400	BARRIER	-	-	-	-	-	0
	1800	13992	BARRIER	0.87	4	4	24%	0%	0

HABITAT NOTES:

1. "SPAWNING" INDICATES THIS SECTION OF STREAM HAD SUITABLE SPAWNING HABITAT FOR TROUT.
2. "PASSAGE" DENOTES STREAM SECTIONS THAT ALLOWED FISH PASSAGE BUT WERE CONSIDERED TOO STEEP FOR SPAWNING HABITAT
3. "BARRIER" IDENTIFIES STREAM REACHES OR INDIVIDUAL LOCATIONS THAT WERE BARRIERS TO TROUT MIGRATION.
4. "PERCENT SPAWNING" IS THE ESIMATED PERCENTAGE OF STREAM BOTTOM AREA THAT IS SUITABLE FOR SPAWNING TROUT, IN ANY GIVEN STREAM SECTION.

RUBY CREEK AND TRIBUTARIES

Spawning Habitat

Although Ruby Creek in the drawdown reach is generally too large to provide good trout spawning habitat, it does have some small pockets of suitable spawning habitat along edges of the main channel (Photo 72). With the exception of these isolated areas, water depths are 2-3 feet, velocities are about 3 feet per second and substrates are predominantly rubble (Photos 68 & 71).

As indicated in Table 11, the upper reaches of Ruby Creek provide abundant trout spawning habitat, particularly in Canyon Creek and Granite Creek (Photo 73) tributaries. Creeks in this drainage have gradients primarily in the 1-6% range and generally flows of less than 200 cfs.

The helicopter survey and videotape of the Ruby Creek drainage did not identify any barriers to migrating trout, except the inevitable series of cascades and high velocity chutes in upper reaches of the watershed. Therefore, it was assumed the migrating trout from Ross Lake had access to a total of 21 miles of streams for spawning in the Ruby Creek drainage (City of Seattle 1973). Accessible streams were as follows (City of Seattle 1973): Ruby Creek (3.4 miles), Canyon Creek (9.2 miles), Mill Creek (1.2 miles), Slate Creek (0.5 miles), North Fork Canyon Creek (0.6 miles) and Granite Creek (6.1 miles).

The total area of accessible spawning habitat in the Ruby Creek drainage was estimated to be 62,000 square feet (Table 11). Inaccessible stream areas were steep, small tributaries where trout spawning habitat was very limited. There were no barriers identified within the Ruby Creek drainage that would substantially increase spawning habitat for Ross Lake trout for a reasonable cost.

Fish Passage Barriers

There are no fish migration barriers in the drawdown reach of Ruby Creek (Figure 11). Some small, high gradient tributaries such as Lillian Creek (Photos 69 & 70) have barriers but probably do not provide any spawning or rearing habitat for trout so are not a concern for passage. Tributaries such as Canyon Creek and Granite Creek which do have good spawning habitat were accessible to trout for long distances and the only identified barriers were small, steep stream reaches near the upper limit of good trout spawning habitat.

There were no barriers identified within the Ruby Creek drainage where enhancement measures would substantially increase spawning habitat at a reasonable cost.

Spawning Activity

Studies from 1971-1973 have concluded that Ruby Creek is the most important American tributary in Ross Lake for the production of rainbow trout. Fry abundance in Ruby Creek above El 1602 was greater than in any other American tributary (City of Seattle 1974).

Johnston (1989) reported that rainbow trout spawn in the entire 3.4 miles of Ruby Creek in addition to Granite Creek and Canyon Creek.

During our tributary mouth spawning survey, June 16, 1989 trout were observed paired up in spawning areas at El 1596, but no active spawning was observed in the drawdown reach. There were no observations of trout spawning activity in Ruby Creek during additional surveys conducted on June 28 and July 19, 1989.

Photo 68. Ruby Creek at elevation 1515'. Flow = 600cfs on 4/25/89. This stretch of Ruby Creek is too big for trout spawning. Substrate is 3-12 inch rubble, water velocity is 3 ft/sec, depth is 2-3 feet.

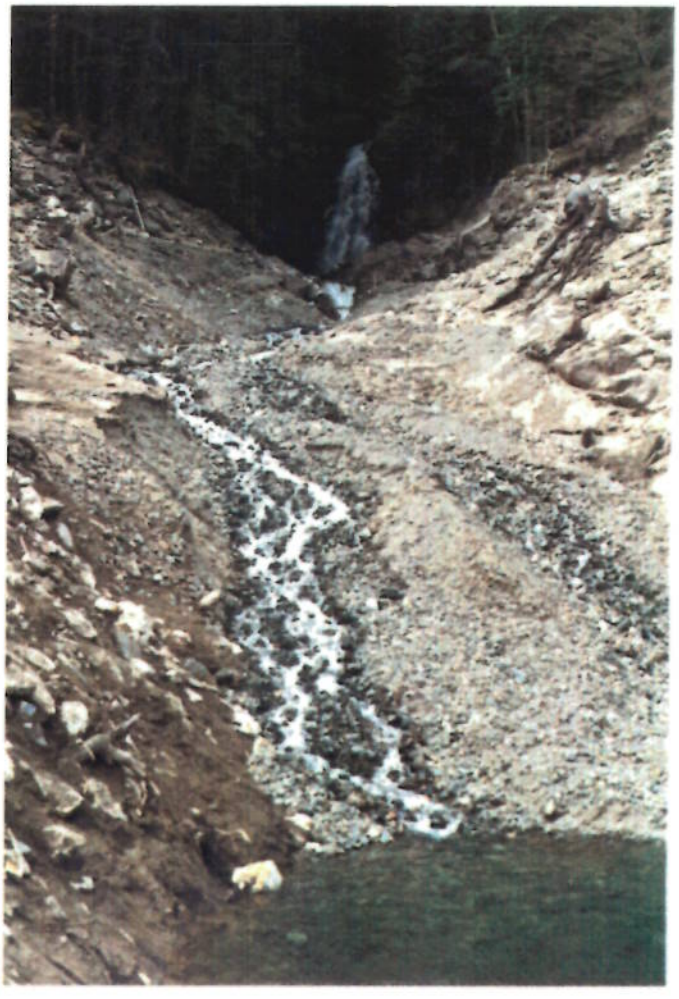

Photo 69. Lillian Creek tributary to Ruby at elevation 1515'. Flow = 2cfs on 4/25/89. Extreme gradient (29%) typical of small creeks entering Ruby Arm. There is no spawning or rearing habitat for trout.

Photo 70. Lillian Creek tributary to Ruby at elevation 1515'. Flow = 2cfs on 4/25/89. This turbulent cascade type IID2 has a degree of difficulty rating of 7 and is a total barrier at all flows. Just above 1602' elevation there is a 20 foot waterfall.

Photo 71. Ruby Creek at elevation 1522'. Flow = 600cfs on 4/25/89. Streambed gradient is 1%. This riffle is not suitable for trout spawning. Rubble and boulder are predominate substrates.

Photo 72. Ruby Creek at elevation 1531'. Flow = 600cfs on 4/25/89. There are small pockets of suitable spawning habitat along sides of main channel. Large rocks and rubble are predominate substrates.

Photo 73. Granite Creek tributary to Ruby Creek at elevation 1900'+. Flow = 300cfs on 5/18/89. There are small isolated pockets of spawning gravel in this portion of Granite Creek just above the confluence with Canyon Creek.

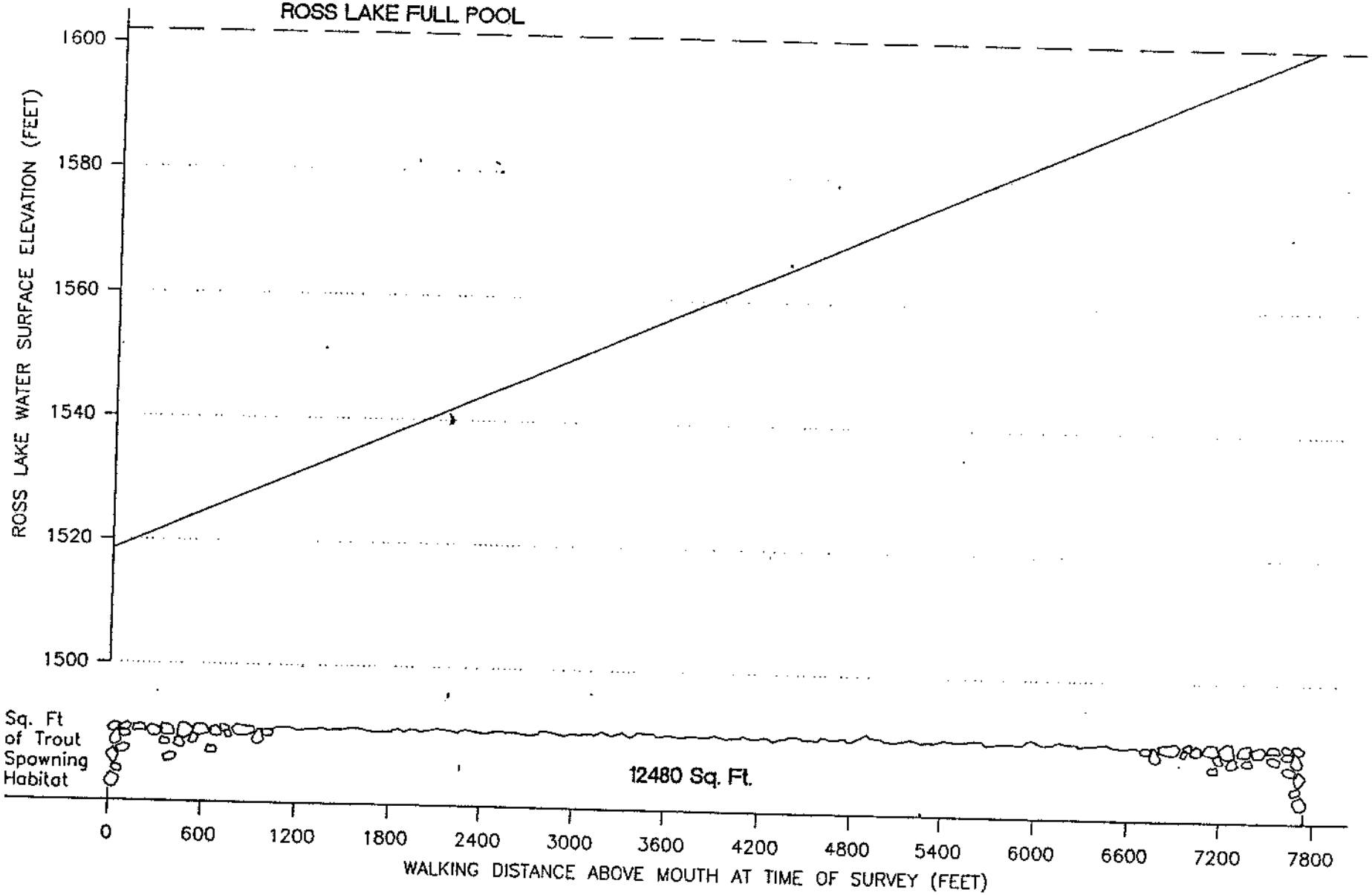

Figure 11: Stream profile showing trout spawning habitat and barriers in the drawdown reach of RUBY CREEK

TABLE 11. ROSS LAKE TRIBUTARIES TROUT SPAWNING HABITAT AND MIGRATION BARRIERS

TRIBUTARY NAME	DISTANCE (FT) FROM	TO	HABITAT NOTES	WATERSHED AREA (SQ MI)	CFS (CALC)	WIDTH (CALC)	PERCENT GRADIENT	PERCENT SPAWNING[4]	SPAWNING AREA(SQ FT)
RUBY CREEK	0	19000	SPAWNING	180.00	705	83	1%	2%	31709
PANTHER	RUBY CR	2500	PASSAGE	23.37	102	28	6%	0%	0
	2500	2500	BARRIER	-	-	-	-	-	0
	2500	19800	PASSAGE	19.95	88	26	7%	0%	0
	19800	37500	SPAWNING	13.91	61	21	2%	2%	7427
	37500	61000	SPAWNING	6.81	30	22	6%	5%	25620
	61000	62200	BARRIER	2.57	12	8	17%	0%	0
CRATER	RUBY CR	1500	BARRIER	12.82	57	20	24%	0%	0
CANYON	RUBY CR	7000	SPAWNING	57.30	247	46	2%	2%	6452
	7000	15000	SPAWNING	55.45	239	45	1%	2%	7241
	15000	34000	SPAWNING	51.90	224	44	2%	2%	16575
	34000	44000	PASSAGE	34.48	150	35	4%	0%	0
	44000	44000	BARRIER	-	-	-	-	-	0
	44000	51300	PASSAGE	19.18	84	25	7%	0%	0
	51300	52200	BARRIER	18.50	81	25	27%	0%	0
SLATE	CANYON	2500	PASSAGE	25.95	113	30	8%	0%	0
	2500	2500	BARRIER	-	-	-	-	-	0
	2500	6500	PASSAGE	24.33	106	29	5%	0%	0
	6500	16500	PASSAGE	23.26	102	28	4%	0%	0
	16500	17900	PASSAGE	12.66	56	20	14%	0%	0
	17900	28900	SPAWNING	9.18	41	17	5%	5%	9158
	28900	43900	SPAWNING	3.89	18	10	8%	5%	7748
	43900	44900	BARRIER	1.40	6	6	28%	0%	0
GRANITE	RUBY CR	18000	PASSAGE	52.38	226	44	3%	0%	0
	18000	23000	PASSAGE	44.95	195	40	4%	0%	0
	23000	26300	PASSAGE	42.27	183	39	6%	0%	0
	26300	34800	PASSAGE	38.45	167	37	5%	0%	0
	34800	34800	BARRIER	-	-	-	-	-	0
	34800	69000	SPAWNING	24.64	108	29	2%	2%	19719
	69000	71000	PASSAGE	12.94	57	20	6%	0%	0
	71000	83000	SPAWNING	8.41	37	16	3%	10%	19032
	83000	90000	SPAWNING	2.27	10	8	7%	5%	2680

HABITAT NOTES:

1. "SPAWNING" INDICATES THIS SECTION OF STREAM HAD SUITABLE SPAWNING HABITAT FOR TROUT.
2. "PASSAGE" DENOTES STREAM SECTIONS THAT ALLOWED FISH PASSAGE BUT WERE CONSIDERED TOO STEEP FOR SPAWNING HABITAT
3. "BARRIER" IDENTIFIES STREAM REACHES OR INDIVIDUAL LOCATIONS THAT WERE BARRIERS TO TROUT MIGRATION.
4. "PERCENT SPAWNING" IS THE ESIMATED PERCENTAGE OF STREAM BOTTOM AREA THAT IS SUITABLE FOR SPAWNING TROUT,

SILVER CREEK

Spawning Habitat

Portions of the drawdown reach of Silver Creek have some suitable spawning habitat primarily near the mouth and along the edges of braided channels (Photos 74 and 75). Streambed gradients range from 1-3.5% and substrates are rubble and gravel (Photos 76 and 77). The unstable channel may hamper spawning success even in the small amount of area where substrate, depth and velocity coincide to be suitable for spawning (Photos 78 and 79).

Above full pool, there is virtually no suitable spawning habitat as the streambed gradient steepens from 3% to 11% (Table 12). According to the City of Seattle (1973) Ross Lake trout have access to about 1/2-mile of Silver Creek before the stream gradient steepens to form a continuous series of cascades and waterfalls alternated with pool and rubble habitat.

Fish Passage Barriers

Fish passage is not a problem in the drawdown reach of Silver Creek. As indicated by the stream profile (Figure 12), there are no barriers to trout migration.

Above El 1602, the first migration barrier noted by the City of Seattle (1973) is at El 1784. This barrier begins a long and continuous series of barriers to trout migration in Silver Creek, with insignificant amounts of spawning habitat between or above the barriers. It was considered impractical to attempt to remove any barriers in Silver Creek.

Spawning Activity

Sexually mature trout and emergent fry were observed in the mouth of Silver Creek during City of Seattle 1971-1973 studies of trout spawning in Ross Lake tributary mouths. Johnston (1989) reported that spawning occurs in the mouth and lower 0.5 miles of Silver Creek.

At least three pairs of trout spawned just below full pool in Silver Creek in 1989; these were observed on June 15, 1989. When observers returned to the spawning site on June 28 and July 19 there was no further evidence of spawning and a 1/4-inch layer of silt had been deposited in the location of the previously observed redd.

Photo 74. Silver Creek at elevation 1553'. Flow = 84cfs on 5/16/89. There are relatively large areas of good spawning habitat near the mouth of Silver Creek. Streambed gradient is 1.0% and substrate size is good for spawning.

Photo 75. Silver Creek at elevation 1557'. Flow = 84cfs on 5/16/89. Isolated pockets of suitable spawning substrate along sides of braided channel. Unstable channel would hamper spawning success if large flows occurred during egg incubation period.

Photo 76. Silver Creek at elevation 1567'. Flow = 84cfs on 5/16/89. Rubble substrates in this reach are too large for trout spawning. Gradient here is 2.75%.

Photo 77. Silver Creek at elevation 1585'. Flow = 84cfs on 5/16/89. Streambed gradient 3.5% with very little suitable spawning gravel. Boulders and large organic debris provide some in-stream and bank cover.

Photo 78. Silver Creek at elevation 1598'. Flow = 84cfs on 5/16/89. Large organic debris, boulders and collapsed pieces of streambank provide adequate cover. Gradient is steep and channel is unstable.

Photo 79. Silver Creek at elevation 1598'. Flow = 84cfs on 5/16/89. Very small amount of area where substrate, depth and velocity coincide to be suitable for trout spawning.

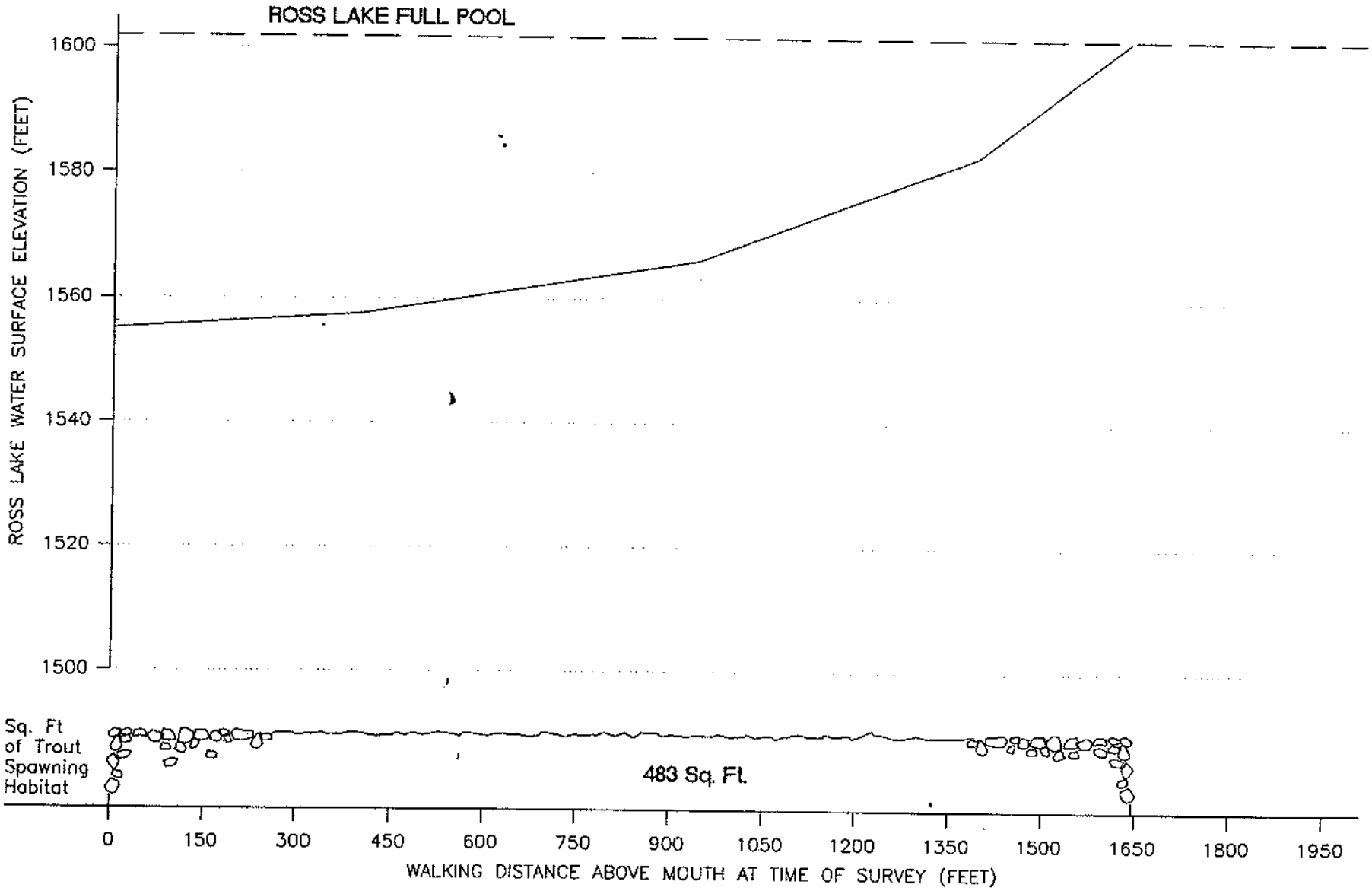

Figure 12: Stream profile showing trout spawning habitat and barriers in the drawdown reach of SILVER CREEK

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TABLE 12. ROSS LAKE TRIBUTARIES TROUT SPAWNING HABITAT AND MIGRATION BARRIERS

TRIBUTARY NAME	DISTANCE (FT) FROM	TO	HABITAT NOTES	WATERSHED AREA (SQ MI)	CFS (CALC)	WIDTH (CALC)	PERCENT GRADIENT	PERCENT SPAWNING[4]	SPAWNING AREA(SQ FT)
SILVER CREEK	0	1600	PASSAGE	14.63	65	22	3%	0%	0
	1600	2300	PASSAGE	14.10	62	21	11%	0%	0
	2300	2300	BARRIER	-	-	-	-	-	0
	2300	3400	BARRIER	13.69	60	21	18%	0%	0

HABITAT NOTES:

1. "SPAWNING" INDICATES THIS SECTION OF STREAM HAD SUITABLE SPAWNING HABITAT FOR TROUT.
2. "PASSAGE" DENOTES STREAM SECTIONS THAT ALLOWED FISH PASSAGE BUT WERE CONSIDERED TOO STEEP FOR SPAWNING HABITAT
3. "BARRIER" IDENTIFIES STREAM REACHES OR INDIVIDUAL LOCATIONS THAT WERE BARRIERS TO TROUT MIGRATION.
4. "PERCENT SPAWNING" IS THE ESIMATED PERCENTAGE OF STREAM BOTTOM AREA THAT IS SUITABLE FOR SPAWNING TROUT, IN ANY GIVEN STREAM SECTION.

SKAGIT RIVER AND TRIBUTARIES

Spawning Habitat

According to Johnston (1989) the Canadian Skagit River and its tributaries have more optimum fish spawning habitat than the combined U.S. tributaries of Ross Lake. Suitable spawning gravel is more abundant and streambed gradients are generally lower in the Canadian Skagit River System (Photos 81-87).

Our calculations of spawning habitat accessible to Ross Lake trout (Tables 1-12) also suggest that there is more available spawning habitat in the Canadian Skagit River system as shown in Table 13. U.S. tributaries have an estimated 101,000 square feet of suitable spawning habitat while Canadian tributaries are predicted to have 170,000 square feet or almost 2/3 of the total spawning habitat accessible to Ross Lake fish.

Fish Passage Barriers

An evaluation of streambed gradients from topographic maps indicate that most of the upper Skagit River is low gradient (0-3%) and that major tributaries important to spawning also have low gradients except approaching the headwaters of these creeks. Information obtained from the City of Seattle (1973) report indicates that there are no fish migration barriers on the Skagit River, Nepopekum Creek or Klesilkwa River.

Spawning Activity

Historical studies indicate that a substantial amount of trout spawning takes place in the upper Skagit River and its tributaries (City of Seattle, 1974).

There were no observations of trout spawning activity in the drawdown reach of the Skagit river during 1989 surveys. High turbidity and the large size of the Skagit River in this reach make observations of any spawning activity unlikely. This reach provides good passage to abundant upstream spawning habitat.

Photo 80. Skagit River at elevation 1555'. Flow = 1350cfs on 5/16/89. The Skagit River in the drawdown reach is large, silty and not suitable for trout spawning.

Photo 81. Nepopekum Creek tributary to the Skagit River, has a predicted June streamflow of 150cfs. There are virtually no suitable spawning substrates in this rubble/boulder channel. The streambed gradient is 2.0%.

Photo 82. The Skagit River above Ross Lake has some suitable trout spawning substrates, but most are too large. June streamflow is expected to be approximately 1100cfs in this reach and the streambed gradient is 1.0%.

Photo 83. The Klesilkwa River is one of the larger tributaries to the upper Skagit River. It's estimate of June streamflow is about 400cfs and the streambed gradient is 1.5%. There appears to be substantial spawning habitat in this portion of the river.

Photo 84. The Sumallo River tributary to Skagit River. It was estimated that June streamflow would be approximately 300cfs. Spawning habitat is present in this reach, but not abundant. Streambed gradient is 3.0%.

Photo 85. Snass Creek tributary to upper Skagit River. June streamflow is expected to be about 78cfs. Streambed gradient is 2.0%. This reach has some good trout spawning habitat.

Photo 86. Skaist River is a tributary near the headwaters of the Skagit River. It's predicted average June streamflow is 120cfs. This reach, just above the confluence, had a few areas of good spawning habitat. The streambed gradient is 1.5%.

Photo 87. The Skagit River above the Skaist River confluence appeared to have very little suitable spawning habitat. Substrates were primarily boulder and rubble. June flow for this reach is estimated at 225cfs. The streambed gradient is 3.5% in this reach of the Skagit.

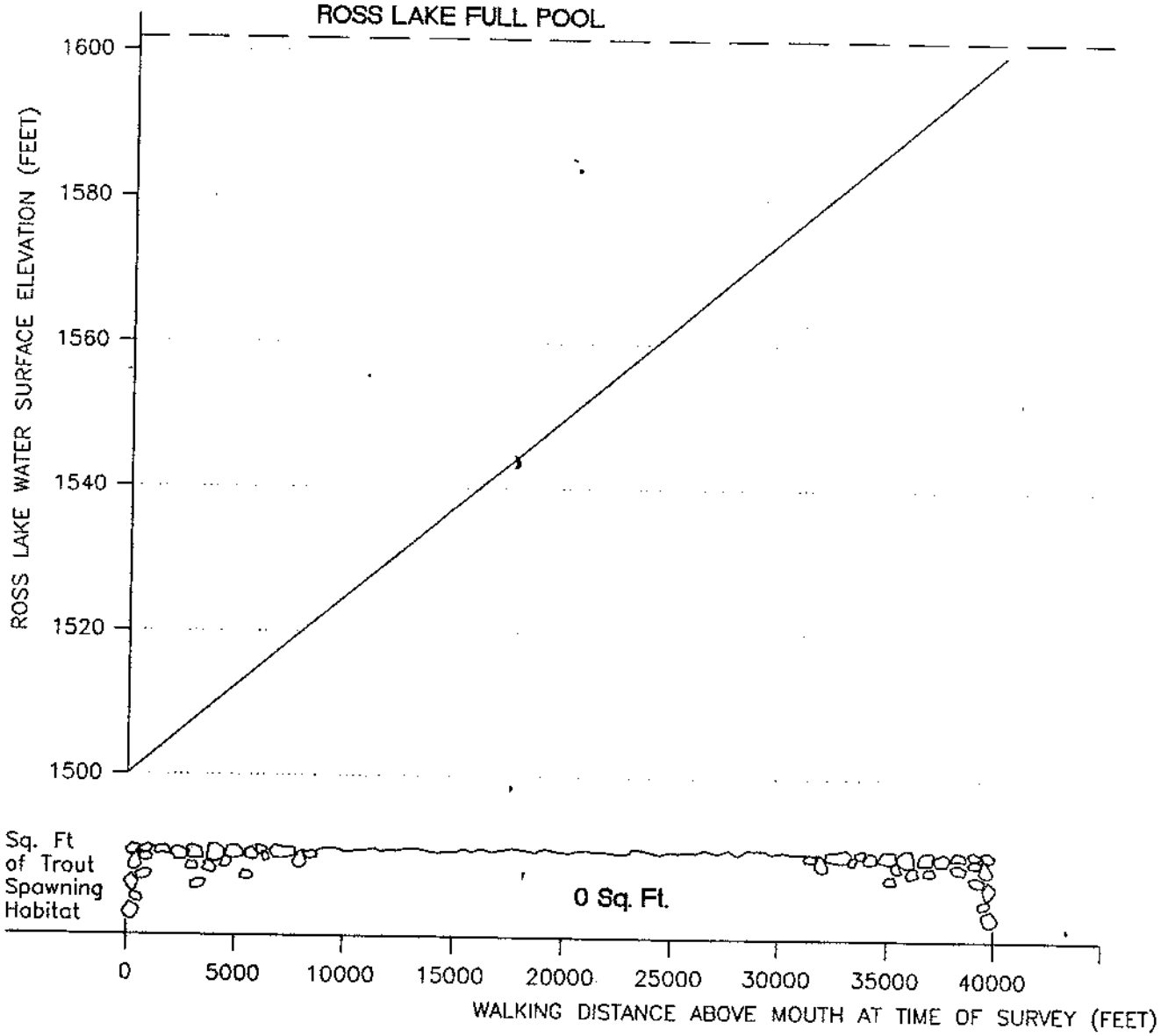

Figure 13: Stream profile showing trout spawning habitat and barriers in the drawdown reach of SKAGIT RIVER

VAA00536

TABLE 13. ROSS LAKE TRIBUTARIES TROUT SPAWNING HABITAT AND MIGRATION BARRIERS

TRIBUTARY NAME		DISTANCE (FT) FROM	TO	HABITAT NOTES	WATERSHED AREA (SQ MI)	CFS (CALC)	WIDTH (CALC)	PERCENT GRADIENT	PERCENT SPAWNING[4]	SPAWNING AREA(SQ FT)
SKAGIT RIVER		0	63000	SPAWNING	324.69	1358	121	0%	0%	0
		63000	102600	SPAWNING	246.37	1036	104	0%	0%	0
		102600	134280	PASSAGE	118.98	506	69	3%	0%	0
		134280	165960	PASSAGE	19.79	87	26	0%	0%	0
	KLESILKWA	SKAGIT	44880	SPAWNING	39.71	172	38	1%	2%	33738
		44880	68640	SPAWNING	10.21	45	18	8%	5%	20986
	SUMALLO	SKAGIT	55440	SPAWNING	74.00	318	53	0%	2%	58909
	GALENE	SKAGIT	21120	BARRIER	3.70	17	10	19%	0%	0
	NEPOPEKUM	SKAGIT	18480	PASSAGE	24.74	108	29	3%	0%	0
		18280	36960	PASSAGE	18.21	80	24	5%	0%	0
		36960	73920	SPAWNING	8.41	37	16	4%	10%	58618
		73920	79200	SPAWNING	0.94	4	5	9%	5%	1238
	MCNAUGHT	SKAGIT	23760	PASSAGE	12.07	53	19	8%	0%	0
		23760	35904	BARRIER	3.72	17	10	16%	0%	0
	ST. ALICE	SKAGIT	10560	BARRIER	11.70	52	19	9%	0%	0
		10560	39600	PASSAGE	4.95	22	12	12%	0%	0
	MARMOT	SKAGIT	10560	BARRIER	3.11	14	9	19%	0%	0
		10560	23760	BARRIER	1.11	5	5	15%	0%	0
	TWENTYSIX	SKAGIT	13200	BARRIER	7.20	32	15	15%	0%	0
		13200	33000	BARRIER	2.70	12	8	15%	0%	0
	SKAIST	SKAGIT	21120	PASSAGE	32.27	140	33	5%	0%	0
		21120	39600	PASSAGE	10.27	46	18	11%	0%	0
	SNASS	SKAGIT	31680	PASSAGE	16.00	70	23	8%	0%	0

HABITAT NOTES:

1. "SPAWNING" INDICATES THIS SECTION OF STREAM HAD SUITABLE SPAWNING HABITAT FOR TROUT.
2. "PASSAGE" DENOTES STREAM SECTIONS THAT ALLOWED FISH PASSAGE BUT WERE CONSIDERED TOO STEEP FOR SPAWNING HABITAT
3. "BARRIER" IDENTIFIES STREAM REACHES OR INDIVIDUAL LOCATIONS THAT WERE BARRIERS TO TROUT MIGRATION.
4. "PERCENT SPAWNING" IS THE ESIMATED PERCENTAGE OF STREAM BOTTOM AREA THAT IS SUITABLE FOR SPAWNING TROUT, IN ANY GIVEN STREAM SECTION.

SECTION 4

SPAWNING HABITAT SUMMARY

Information obtained during spawning habitat surveys conducted in the drawdown and upper reaches of Ross Lake tributaries provided a basis for categorizing the tributaries. The 13 tributaries examined fall into three categories:

1. Tributaries in which the amount of trout spawning habitat remains relatively unchanged as Ross Lake water surface elevation increases. This category included Devils Creek, Little Beaver Creek, Roland Creek, Ruby Creek, Silver Creek, and the Skagit River.

2. Tributaries that have a substantial decrease in trout spawning habitat as Ross Lake water surface elevation increases. Arctic Creek, Dry Creek, Hozomeen Creek, No Name Creek, and Pierce Creek were in this group.

3. Tributaries that have a substantial increase in trout spawning habitat as the Ross Lake water surface increases to El 1602. This category included Big Beaver and Lightning Creeks.

Figure 14 shows how spawning habitat in each of the 13 tributaries is affected by an increase in Ross Lake water surface elevation. A discussion for each category of streams follows:

1. Devils Creek, Little Beaver Creek, Roland Creek, Ruby Creek, Silver Creek, Skagit River

These streams have relatively little change in available spawning habitat as Ross Lake water surface elevation changes (Fig. 14). Devil's Creek has little spawning habitat and numerous trout migration barriers for much of its length. The trout migration barrier of most interest on Little Beaver Creek is above El 1602, and there is little spawning habitat for trout within the drawdown reach. The other tributaries in this category have no barriers to prevent trout migration so the only effect Ross Lake has on spawning habitat is inundation of spawning habitat in the drawdown reaches.

2. Arctic Creek, Dry Creek, Hozomeen Creek, No Name Creek, and Pierce Creek

Prior to construction of Ross Lake, all these streams probably had excellent spawning areas on large alluvial fans near their confluence with the Skagit River. Ross Lake filling in the spring and early summer of each year now covers most of the alluvial fans of these streams and inundates almost all of the spawning habitat in these five tributaries. In these tributaries, spawning habitat upstream of Ross Lake full pool only adds up to a tiny fraction (0.06%) of the total spawning habitat available to Ross Lake trout.

Although only a small percentage of total Ross Lake trout spawning habitat is lost in these streams, it is probable that each stream's spawning trout population is greatly reduced over historic levels.

The value of these lost populations (individual genetic strains?) of trout is unknown but must be compared with the value of an overall gain in total spawning habitat as Ross Lake fills to El 1602 (Figures 14 and 15).

3. Big Beaver Creek, Lightning Creek

Lightning Creek and Big Beaver Creek have barriers that prevent trout migration to upstream spawning areas until Ross Lake reaches El 1596 and El 1597 respectively (Fig. 14). When Ross Lake water submerges barriers on Big Beaver and Lightning Creeks, a large amount of excellent spawning habitat is made available to trout (Figures 14 and 15).

A graph was developed to show how the total amount of spawning habitat available to Ross Lake trout changes with water surface elevation (Figure 15). The graph shows the amount of habitat that probably existed prior to construction of Ross Lake; this would be equal to the amount of habitat available at a Ross Lake elevation of 1300 feet (Figure 15).

As water surface elevation increases above 1,300 feet, total spawning habitat available decreases due to inundation of spawning habitat near the mouths of Ross Lake tributaries (Figure 15). However, once Ross Lake water levels increase to El 1596-1597 and the barriers at Lightning Creek and Big Beaver Creek are submerged, a large amount of excellent spawning habitat is made available to trout. Overall, there appears to be about the same amount of total available spawning habitat once Ross Lake reaches full pool, compared to the amount of habitat that probably existed before Ross Lake was built (Figure 15).

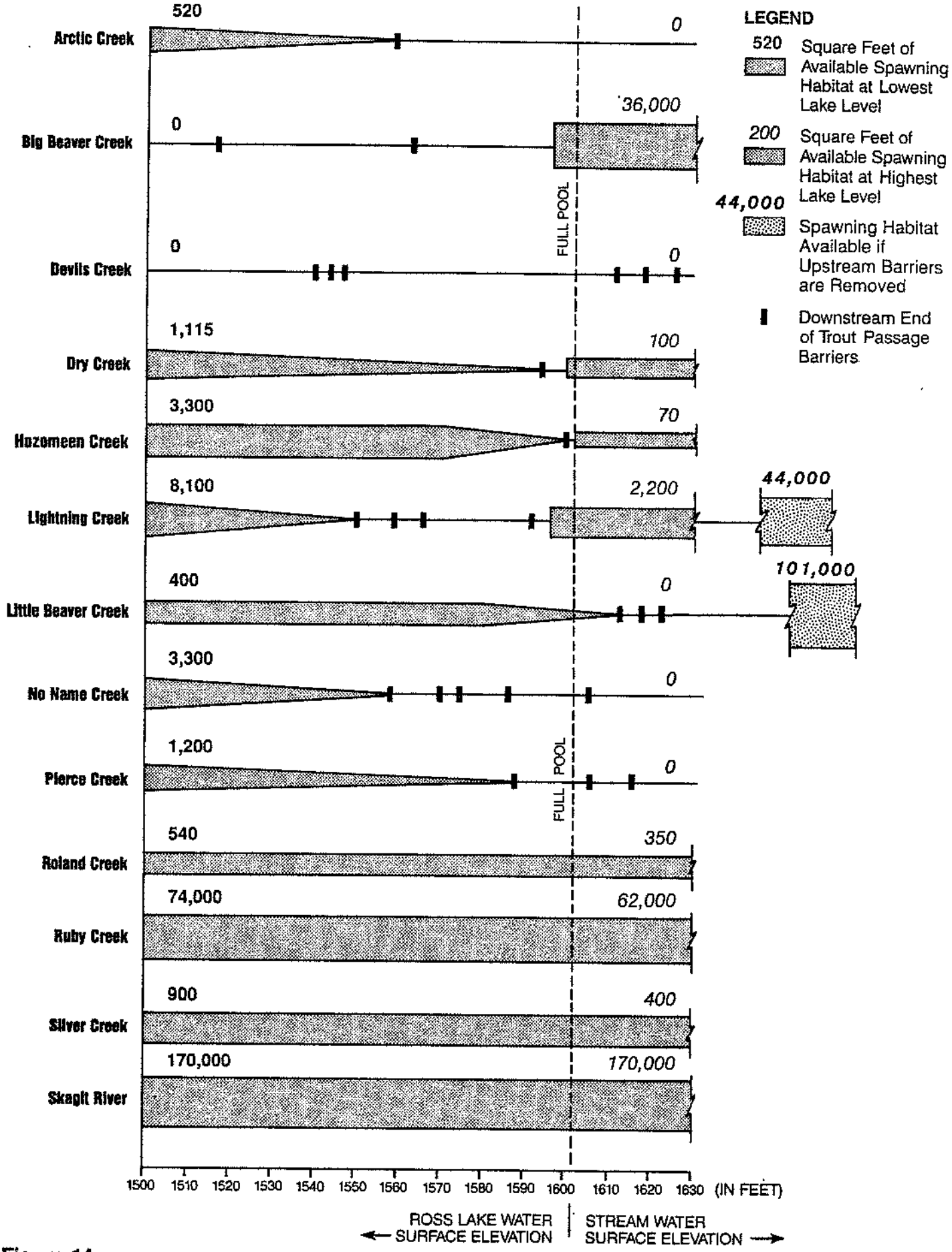

Figure 14.
Spawning habitat available to Ross Lake Trout vs. water surface elevation of Ross Lake.

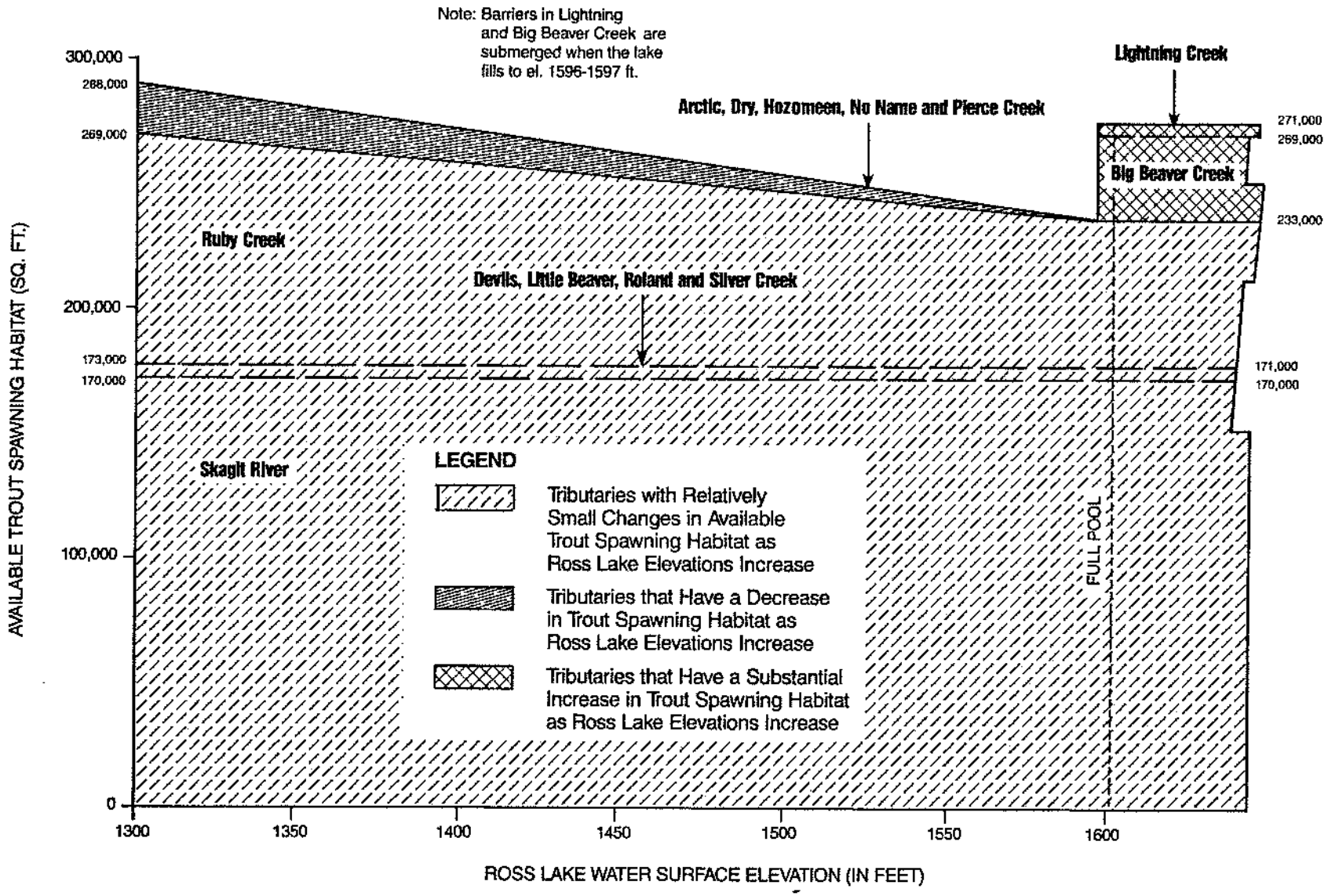

Figure 15.
Total amount of trout spawning habitat available to Ross Lake trout, assuming Ross Lake water elevation could vary from 1300 feet (hypothetical small lake) to 1602 feet (full pool).

SECTION 5

TROUT MIGRATION BARRIER SUMMARY

The overall goals of identifying and studying barriers in Ross Lake tributaries were:

- Identify and classify barriers within the drawdown reach, and summarize the effect of Ross Lake water surface fluctuations on available spawning habitat.
- Identify and classify barriers to trout migration in all streams to locate the upstream limit of trout migrations.
- Where it was considered feasible to alter or remove a barrier to provide access to upstream habitat, estimate the amount of habitat that could be gained by removal of the barrier.

These goals were accomplished using a review of available information (Johnston 1989, City of Seattle 1972, 1973, 1974) and on-site surveys.

BARRIERS WITHIN THE DRAWDOWN REACH

Barriers on Big Beaver, Dry, Hozomeen and Lightning Creeks all blocked trout access to upstream spawning habitat until Ross Lake water elevations approached full pool (Figure 14). There would be two ways to rectify the effects of these barriers on trout spawning populations:

1. Remove the log debris barriers on Dry and Hozomeen Creeks and alter the bedrock barriers on Big Beaver and Lightning Creeks to provide fish passage.
2. Change Skagit Project operations so Ross Lake attains full pool elevation by the beginning of the spawning season and submerges the barriers.

There are advantages and disadvantages of each of these enhancement measures; these pros and cons are listed in Table 14. A detailed estimate of the cost of barrier removal or alteration is presented in the Ross Lake Fisheries Enhancement section of the Resident Fisheries Study for Ross, Diablo, and Gorge Lakes.

Drawdown reach barriers on Arctic, Devils, No Name, and Pierce Creeks were identified, but there were no significant amounts of useable spawning habitat above these barriers (Figure 14). Removal, alteration, or flooding of these barriers would not benefit trout populations in these streams. In fact, the most beneficial action for spawning trout in Arctic, Dry, Hozomeen, No Name, and Pierce Creeks would be to hold Ross Lake water surface elevations below 1,500 feet until rainbow trout fry emerged in August.

BARRIERS ABOVE THE DRAWDOWN REACH

Barrier removal or alteration above El 1602 was considered impractical in the following streams: Arctic, Devils, Dry, Hozomeen, No Name, Pierce and Roland Creeks. The primary reasons why it would not be advisable to remove barriers in these streams were:

- Streams were extremely steep immediately above El 1602, and multiple large barriers would need to be removed (Arctic, No Name, Pierce).
- Spawning habitat upstream of El 1602 was very limited compared to other streams (Arctic, Dry, Hozomeen, Roland).
- A long sequence of barriers interspersed with relatively short sections of spawning habitat made barrier removal impractical (Devils).

All streams surveyed eventually had some barrier to upstream trout migrations. In some streams, these barriers were far enough upstream of Ross Lake that it is doubtful that meaningful numbers of spawning Ross Lake trout ever encountered these barriers. The approximate location of barriers of this type for Big Beaver Creek and tributaries, Ruby Creek and tributaries, and the Skagit River and tributaries were documented by the City of Seattle (1972-1974) or are known to exist at the upper reaches of primary and secondary streams. Above El 1602, there were no barriers identified in the Big Beaver Creek, Ruby Creek, or Skagit River drainages that could be removed to improve Ross Lake fisheries.

The lowermost barrier on Silver Creek was about 1/2-mile upstream of El 1602 (City of Seattle 1973). Above this barrier, Silver Creek becomes an increasingly steep series of cascades and waterfalls, and spawning habitat was very limited (Table 12). There were no reasonable enhancement possibilities identified in Silver Creek.

Lightning Creek and Little Beaver Creek were the only streams surveyed where barrier removal above El 1602 would provide Ross Lake spawning trout with large areas of additional spawning habitat.

The first two barriers in Lightning Creek consisted of a 13-foot high cascade/waterfall 1,400 feet upstream from Ross Lake full pool, and a 6-foot high turbulent cascade 2,300 feet upstream from Ross Lake. Removal of these two barriers would give Ross Lake trout access to an additional 2 miles of stream habitat with an estimated spawning area of 15,000 square feet (Table 6).

One log jam forms another impassable barrier in Lightning Creek, about 2-1/4-miles upstream from Ross lake. Removal of this log jam would make an additional 4 miles of Lightning Creek available to Ross Lake trout, with an estimated spawning habitat area of 29,000 square feet (Table 6).

The numerous trout migration barriers in Little Beaver Creek would be much more difficult to remove than barriers in Lightning Creek, because of

the inaccessible nature of the bedrock canyon along the lower mile of Little Beaver Creek. It was considered impossible to remove all barriers by rock excavation (blasting) or fish ladder construction. The only technically feasible option would be to construct a 1-mile long fishway tunnel to bypass the entire length of barriers in Little Beaver Creek. Bypassing all barriers would provide trout with an estimated 101,000 square feet of spawning habitat in Little Beaver Creek (Table 7).

A detailed estimate of the cost of barrier removal for Lightning Creek and Little Beaver Creek is included in the Ross Lake Fisheries Enhancement section of the Resident Fisheries Study for Ross, Diablo, and Gorge Lakes.

TABLE 14

ADVANTAGES AND DISADVANTAGES OF REMOVING, ALTERING, OR SUBMERGING TROUT MIGRATION BARRIERS WITHIN THE DRAWDOWN REACH OF ROSS LAKE TRIBUTARIES

ENHANCEMENT MEASURE			
REMOVE OR ALTER BARRIERS		FLOOD BARRIERS WITH ROSS LAKE	
Advantages	Disadvantages	Advantages	Disadvantages
Provides access to upstream spawning habitat as follows: Big Beaver Creek 36,000 SF[1] Dry Creek 100 SF Hozomeen Creek 70 SF Lightning Creek 2,200 SF	Alteration of bedrock barriers on Big Beaver and Lightning Creeks would be relatively expensive.	Provides access to upstream spawning habitat as follows: Big Beaver Creek 36,000 SF Dry Creek 100 SF Hozomeen Creek 70 SF Lightning Creek 2,200 SF	Guarantees that most spawning habitat in Arctic, Dry, Hozomeen, No Name, and Pierce Creeks would be submerged prior to spawning season. Any production currently from these areas would be lost.
	Removal of the Dry Creek barrier would need to be done each year and may adversely affect upstream spawning gravels.		Would require Seattle City Light to alter Skagit Project operations to fill pool earlier. Uncertain weather may make it difficult to always obtain El 1602 by a specific date.
Removal of the barrier in Hozomeen Creek would be straightforward and inexpensive.	Removal of natural (bedrock) barriers may be contrary to direction for the preservation of natural features and ecosystem management in Ross Lake National Recreation area.		Earlier fill poses increased risk of spill and impacts to down stream fishery.[2] Loss of power generation during early fill means loss of revenue during that time period.
Trout would have access to upstream areas regardless of runoff and weather.			

(1) SF = Square feet of available spawning habitat

(2) A study of the benefits and costs of early refill is in progress.

SECTION 6

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APPENDIX A

CLASSIFICATION OF BARRIERS

To facilitate analyses and subsequent generation of solutions to fish passage problems a classification system needs to be introduced to define the parameters involved in the analysis. The objective of this chapter is to develop a systematic method for classifying barriers based on the conditions that affect fish passage success. Barrier classification sheets will be developed to enable fisheries personnel to make use of the classification system in fisheries enhancement programs, both to catalog waterfall and culvert barriers, and to design their modifications.

Evidence of classification for waterfalls in the literature was found only in terms of the site geomorphology (or origin of formation) (Fairbrige, 1968). No classification of waterfalls could be found in the literature that correlated site hydraulics or fish passage success to geometry. Pryce-Tannatt (1937) noted, "Obstructions are many and varied. It would be useless to attempt to classify them beyond distinguishing between the comparatively mild, the definitely difficult, and the completely impossible." Dane (1978) suggests a classification of obstructions for culvert barriers based on blockage as follows:

1. Total--impassable to all fish all of the time,
2. Partial--impassable to some fish all of the time, and
3. Temporary--impassable to all fish some of the time.

The classification system developed for this study will analyze the site geometry and hydraulics, and how they interrelate to fish passage success. Because waterfalls in nature consist of such a wide range of

geologic and hydrologic combinations, a classification system for waterfalls should include several components, each of which describes waterfalls differently.

The classification system proposed here consists of four components: (1) class, (2) type, (3) magnitude and (4) discharge, extending from general to specific (Table 4). Class describes the flow patterns, number and characteristics of fish passage routes and site geometry in plan view. The class is determined by observing the characteristics in Table 4. Type describes the bed slopes, pool depths and geometry of the barrier in longitudinal profile, and therefore requires an engineering survey of the barrier site. Magnitude describes the elevation differences, water velocities and slope lengths the fish must negotiate. Because the class, type and magnitude of the barrier will vary with discharge, the fourth item for classification will be to accurately estimate or measure the discharge at the time of observation.

Also, a degree of passage difficulty rating will be applied, based on a range from 1 to 10, one being the least difficult to pass and ten the most difficult. This is a subjective comparative rating of barrier class characteristics in reference to fish passage difficulty which is independent of barrier height and velocity. The rating is based on the following assumptions:

1. The differential elevation and water velocities are within the swimming and leaping capabilities of the species in question.
2. At higher swimming speeds (>9 fps) leaping is more energetically efficient that swimming (Blake, 1983).
3. Fish will be attracted to the area of highest momentum (flow x velocity) when migrating upstream; therefore if multiple paths are present the fish may try to ascend the one with the highest attraction which will be created by the highest combination of drop, velocity, and discharge.

4. Turbulent flow (or white water) with surges, boils and eddies make it difficult for fish to orientate themselves and make full use of their swimming power.

Table 4. Characteristics of barrier classification components.

Classification Component	Characteristics
Class	Site geometry in plan view. Flow patterns Number of fish passage routes. Characteristics of fish passage routes.
Type	Site geometry in profile. Bed slopes Pool depths
Magnitude	Elevation drops Water velocities Slope lengths
Discharge	The flow rate at which the class, type and/or magnitude were measured.

Class

Waterfall barriers in nature are usually found in three forms; falls, chutes and cascades. From the author's field observations of many barriers, it appears that fall barriers are found either as single or multiple falls, chutes as either simple or complex, and cascades as boulder cascades or turbulent cascades. Combinations of falls and chutes will be denoted as compound barriers. These barrier classes and their characteristics are shown in Table 5 with their corresponding rating for degree of passage difficulty.

A single fall has the lowest degree of difficulty rating (DDR) because the fish has only one route to choose, and it leaps to pass. To determine the actual value of the DDR of 1 to 3, the upstream and downstream conditions must be analyzed. This will be done when barriers are classified by type. Multiple falls (falls in parallel) have a higher DDR than single falls because the fish has several routes from which to choose, and most likely will be attracted to the fall with the highest flow momentum (Stuart, 1964). Simple chutes have a slightly higher DDR than single falls because at high swimming speeds (>9 fps) leaping is more energetically efficient than swimming. Complex chutes have a higher DDR than simple chutes because the fish's propulsive power is reduced in white water. Boulder cascades have a slightly higher DDR than multiple falls because the fish have problems getting oriented to leap due to the turbulent resting areas. This analysis can be continued, comparing each barrier class based on the four original assumptions, for the degree of difficulty rating system.

Type

To classify barriers by type, conceptual models will be used which show the geometric and hydraulic relationships that are critical to fish passage success. Figures 14 and 15 show conceptual models and the notation used in profile view of a fall and chute respectively. These figures are not comprehensive for natural conditions, but the geometric dimensions apply and can fit any situation. Cascades are not included here because to determine the type of barrier requires measurements of bed slopes and pool depths. If these measurements could be made in a cascading reach, then a

cascade would simply consist of a series of falls and/or chutes and there would be several different types for one barrier class (i.e. several falls and/or chutes within a cascade).

Table 5. Subjective comparative rating of barrier class characteristics in reference to fish passage difficulty, independent of barrier height and velocity. Assumes passage success by strongest fish.

Class	Characteristics	Degree of Difficulty Range
Single falls	Entire stream flows through a single opening offering one path for fish passage.	1-3
Multiple falls	Flow divides through two or more channels offering the fish with several passage routes of varying difficulty.	3-5
Simple chute	Unvarying cross sections and constant bottom slope (steep), with supercritical flow at all stages	2-4
Complex chute	Varying cross sections, several changes in bed slope and/or curved alignment in plan view. White water at all stages.	4-6
Boulder cascades	Large instream boulders which constrict the flow creating large head losses from upstream to downstream sides of boulders. Intermediate resting areas in very turbulent pools.	5-7
Turbulent cascades	Large instream roughness elements or jutting rocks which churn the flow into surges, boils, eddies, and vortices. No good resting areas.	7-10
Compound	Combinations of single falls and/or simple chutes (e.g., culvert with high velocity and outfall drop)	3-7

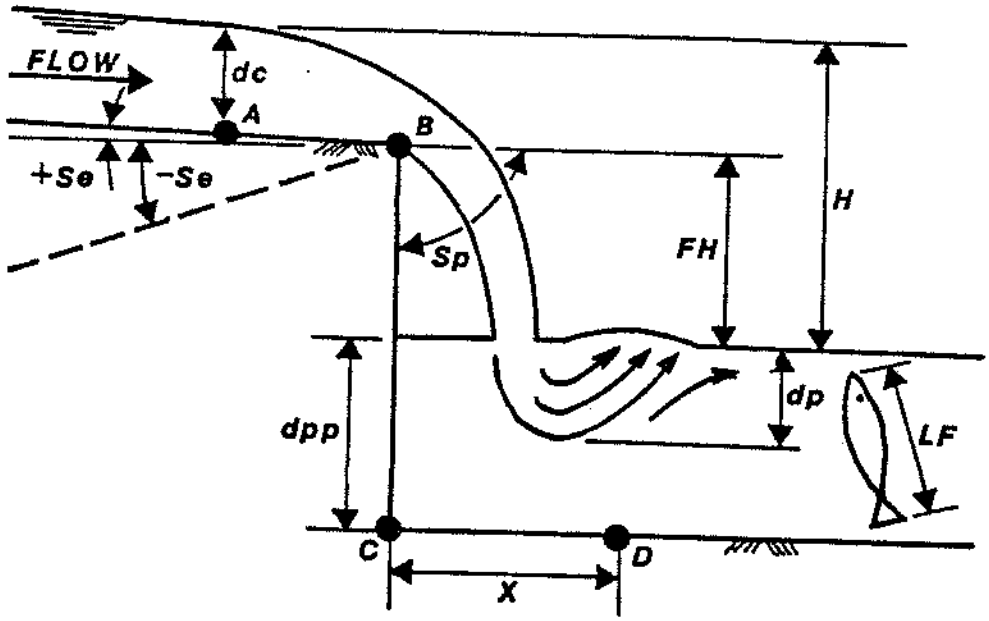

Figure 14. Conceptual model of a fall, where: A = point on fish exit bed slope where critical depth occurs; B = elevation of crest; C = furthest point upstream on bed of plunge pool; D = point just downstream of falling water (or standing wave) on bed of plunge pool; Se = fish exit slope; Sp = fish passage slope; dc = critical depth (point A); dpp = depth in the plunge pool; dp = depth the falling water plunges; X = horizontal distance from the crest (point B) to standing wave (point D); FH = fall height; H = change in water surface elevation; and LF = length of fish.

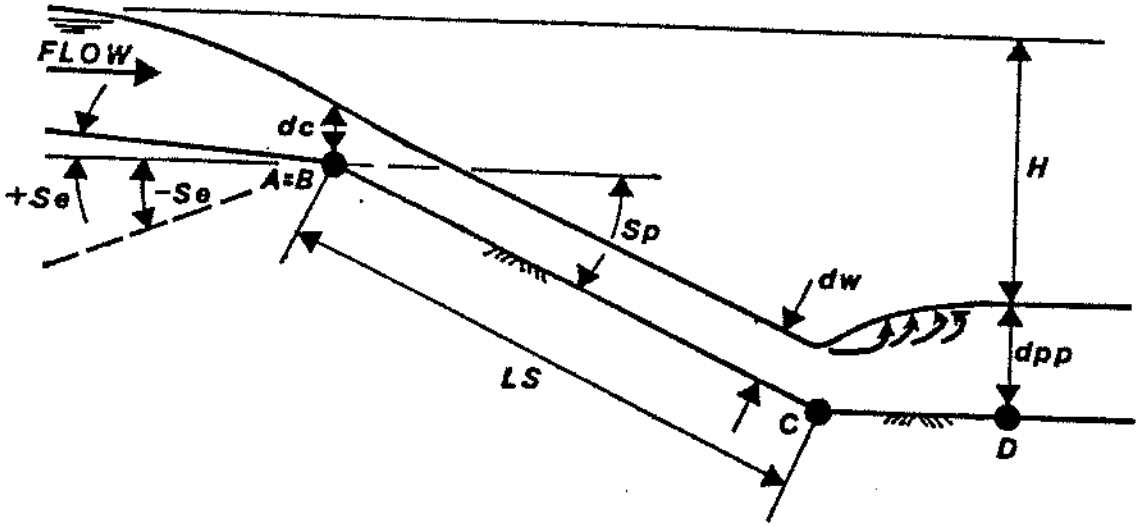

Figure 15. Conceptual model of a chute, where: A = point on fish exit bed slope where critical depth occurs; B = elevation of crest; C = furthest point upstream on bed of plunge pool; D = point just downstream of standing wave (or hydraulic jump) on bed of plunge pool; Se = fish exit slope; Sp = fish passage slope; LS = length of slope; dc = critical depth (point A); dw = depth of water; dpp = depth in the plunge pool; and H = change in water surface elevation.

The conceptual models in Figures 14 and 15 consist of three zones: (1) the fish exit zone (point A to point B in Figure 16); (2) the fish passage zone (point B to point C in Figure 17); and (3) the fish entrance zone (point C to point D in Figure 18). The notation used to denote the barrier type is given in these figures, and follows outlining logic from upstream to downstream. The type of barrier[1] will be determined by measuring the exit slope, passage slope and plunge pool depth, and selecting three characters from the notation, one each from the exit zone, passage zone and entrance zone (e.g. IIB2, would denote a chute barrier with a positive exit slope and a shallow plunge pool). From Figures 16, 17 and 18 it can be seen that there could be any of four different combinations of entrance and exit conditions for each of four passage zones; and thus 16 different types of barriers can exist according to this classification. These models are shown in Figure 19, along with the corresponding degree of passage difficulty rating. The similarities with culvert flow and geometry are denoted by dotted lines.

Magnitude and Discharge

To complete the classification, estimates of differential elevations, water velocities, length of slopes, etc., should be included, along with estimates of the discharge at the time of observation and migration season flows. These two components along with the barrier class and type then can be combined together to give the final barrier classification. A sample barrier classification sheet is shown in Fig. 20. This sheet can be used in the field to classify barriers and will be helpful in assessing design modifications.

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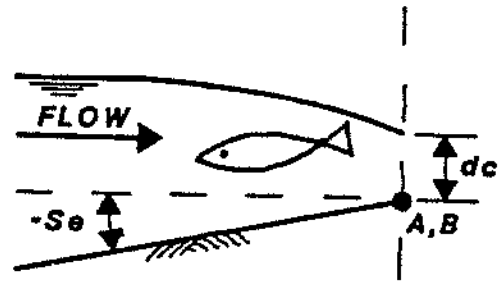
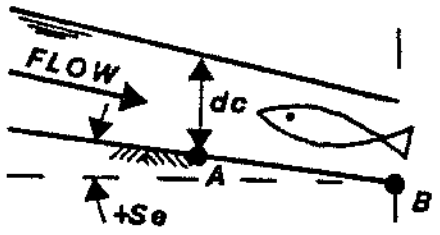
[1] In profile, but one must consider the flow pattern in plan view because it can cause disorientation of the fish.

FISH EXIT/WATER INLET SLOPE POSITION

NOTATION



I
(Good)

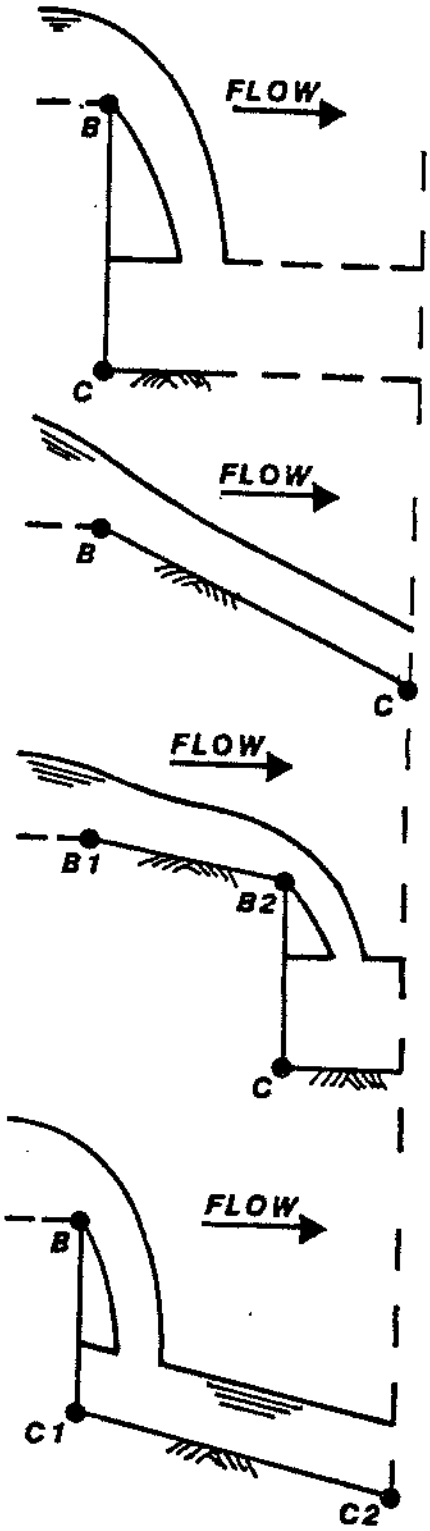


II
(Poor)

Figure 16. Fish exit zone notation, where: I = negative or nonsustaining slope at the fish exit (or water inlet). Good conditions for fish, reduced velocities, increased water depth therefore good resting areas. II = positive or sustaining slope at the fish exit (or water inlet). Poor conditions for fish, increased velocities, decreased depths and therefore poor resting areas.

FISH PASSAGE/WATER TRANSITION ZONE

NOTATION



A (fall)
(simple)

B (chute)
(simple)

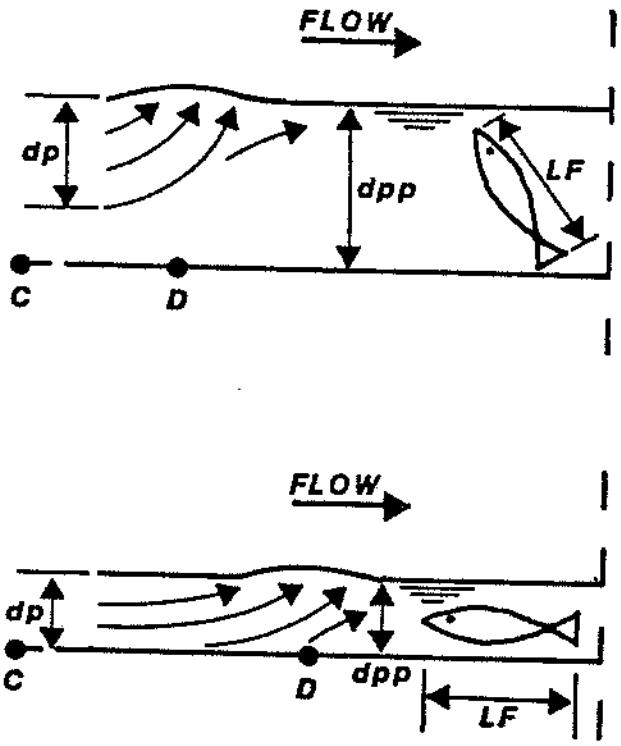
C (chute/fall)
(compound)

D (fall/chute)
(compound)

Figure 17. Fish passage zone notation.

FISH ENTRANCE/WATER EXIT ZONE

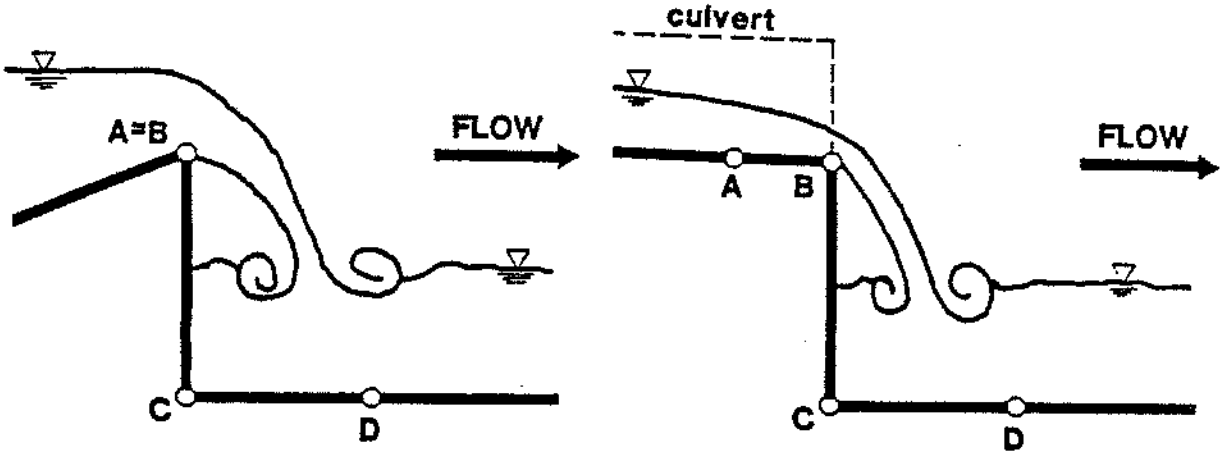
NOTATION



1
(Good)

2
(Poor)

Figure 18. Fish entrance zone notation, where: 1 = deep plunge pool. Good conditions for fish, sufficient depth allows dissipation of falling water energy and standing wave to develop. Good leaping conditions. 2 = shallow plunge pool. Poor conditions for fish, falling water strikes bed of plunge pool, creates turbulence and moves standing wave downstream. Poor leaping conditions.



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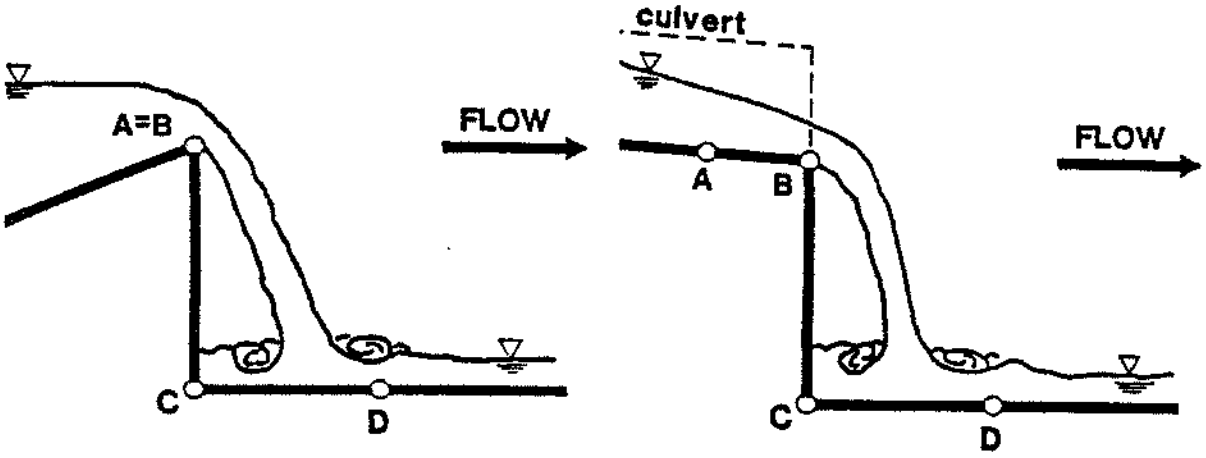
DEGREE OF DIFFICULTY: 1

TYPE: II A 1
DEGREE OF DIFFICULTY: 2



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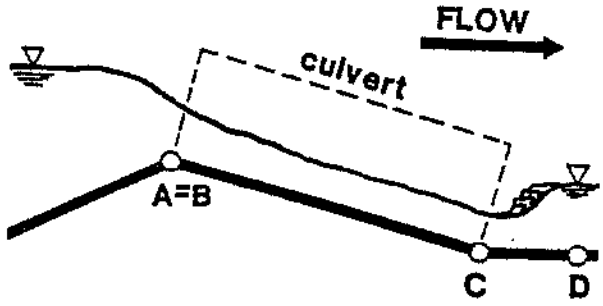
DEGREE OF DIFFICULTY: 2

TYPE: II A 2
DEGREE OF DIFFICULTY: 3

Figure 19. Conceptual models of barrier types with the corresponding degree of difficulty rating.



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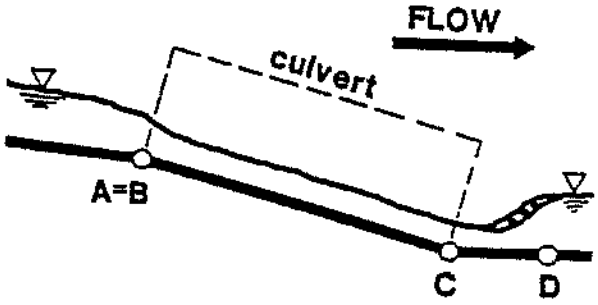

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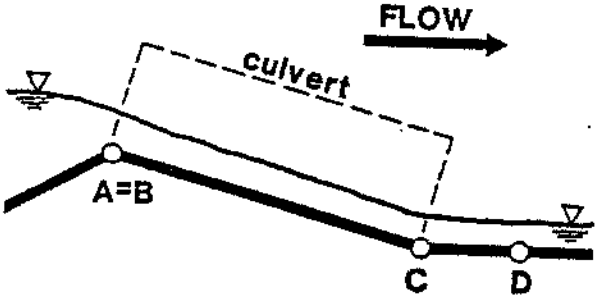
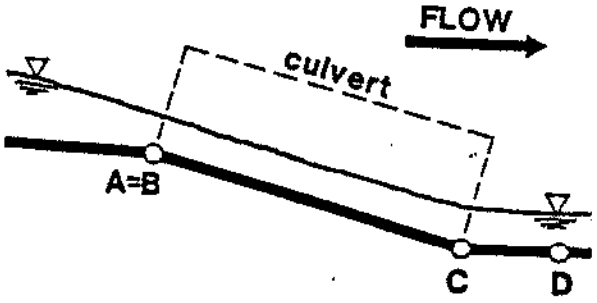


TYPE: I B 2
DEGREE OF DIFFICULTY: 3



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DEGREE OF DIFFICULTY: 4

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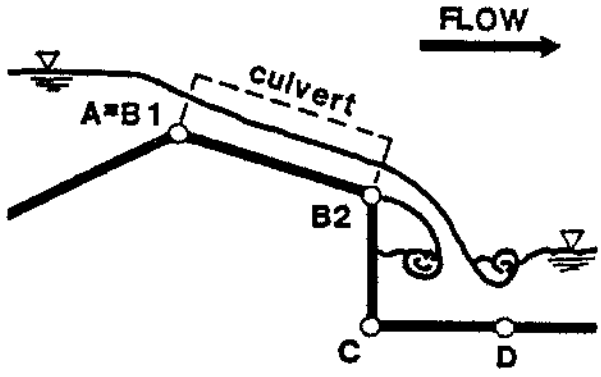
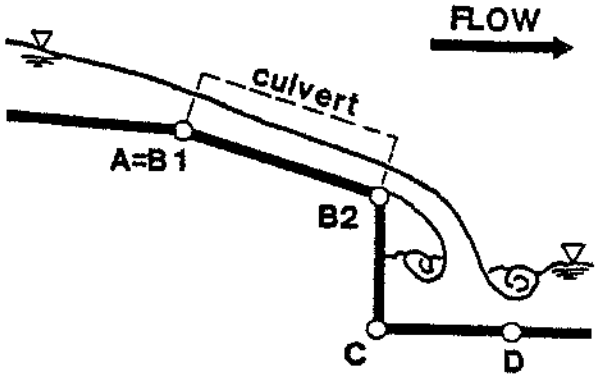
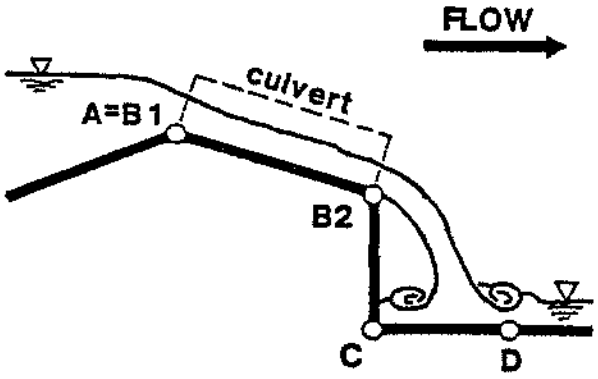


TYPE: I C 1
DEGREE OF DIFFICULTY: 3



TYPE: II C 1
DEGREE OF DIFFICULTY: 4



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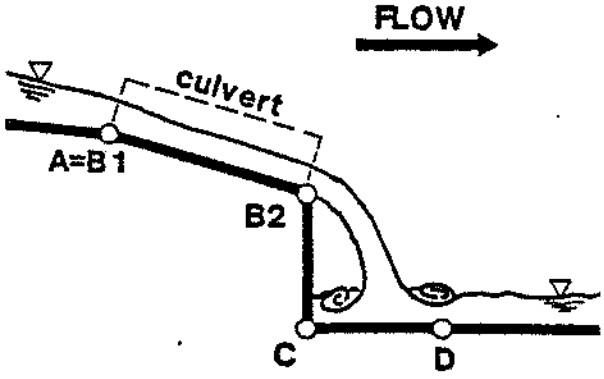

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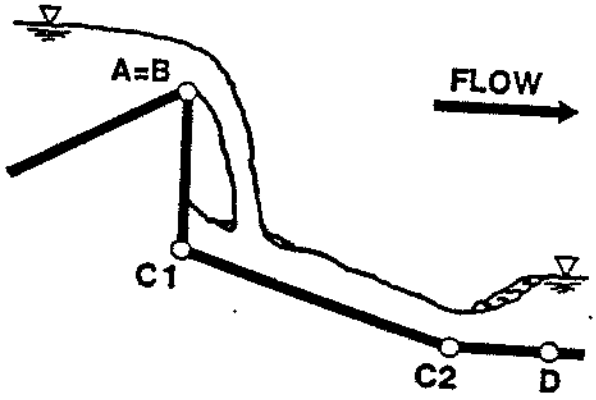
Figure 19. (Cont.)



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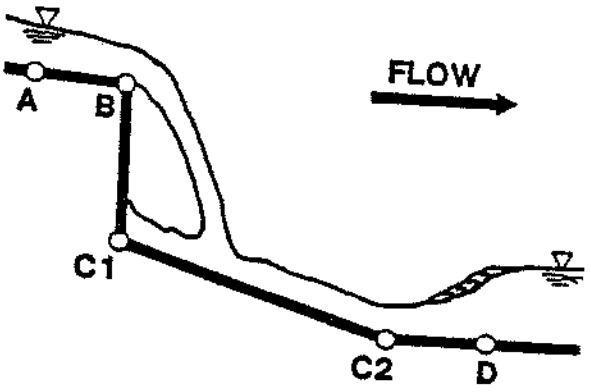
DEGREE OF DIFFICULTY: 5



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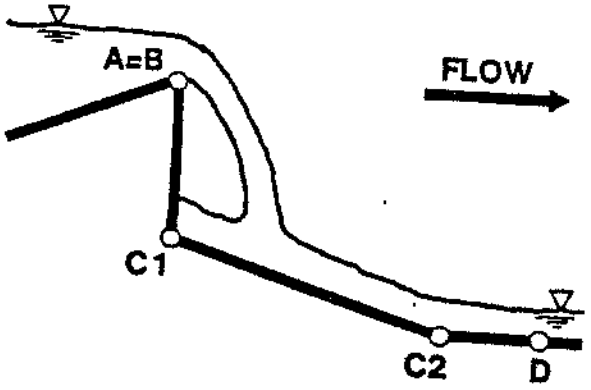

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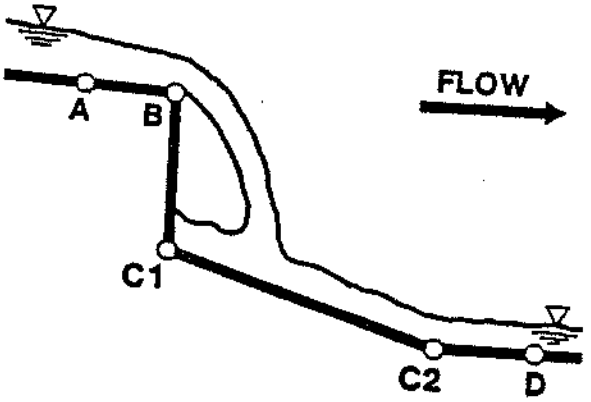

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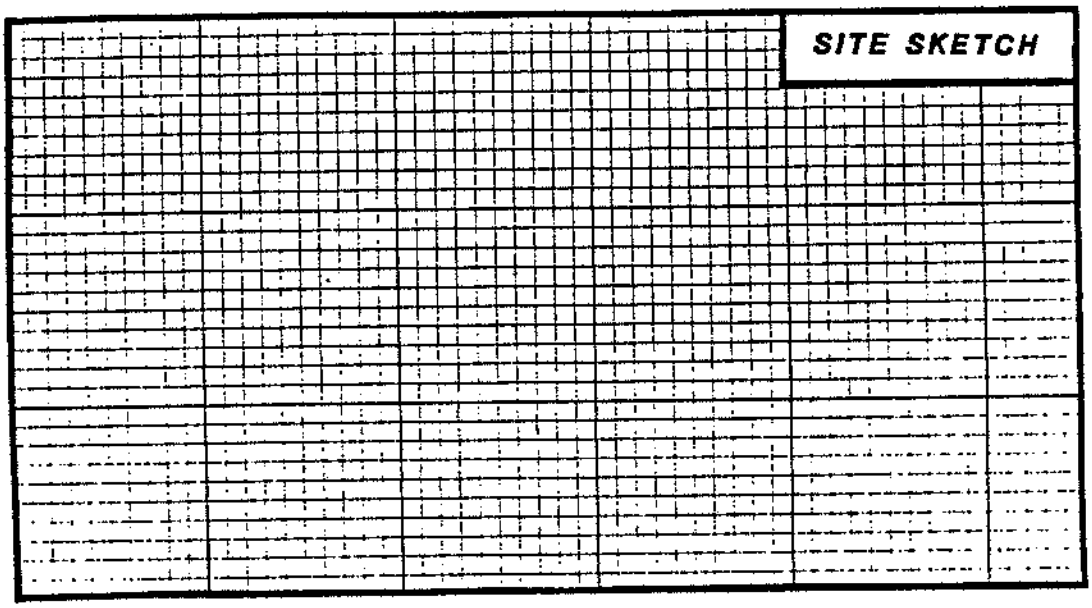
Figure 19. (Cont.)

SITE: **DATE:**

LOCATION:



CLASS:

TYPE:

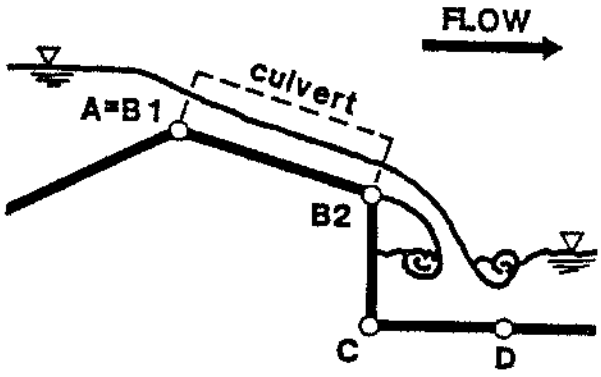
DEGREE OF DIFFICULTY:

MAGNITUDE:

DISCHARGE:

COMMENTS:

Figure 20. Sample barrier classification sheet.



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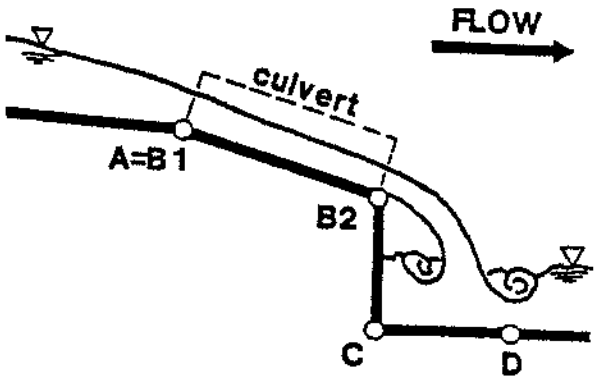

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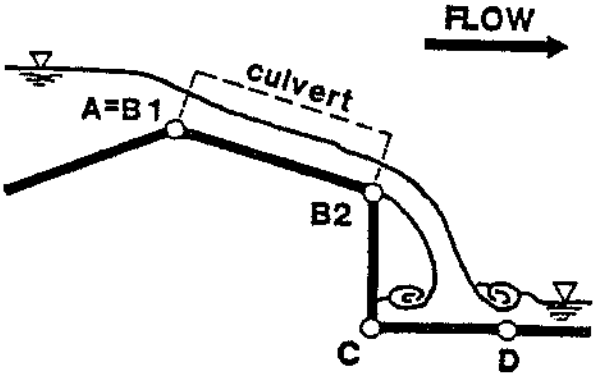

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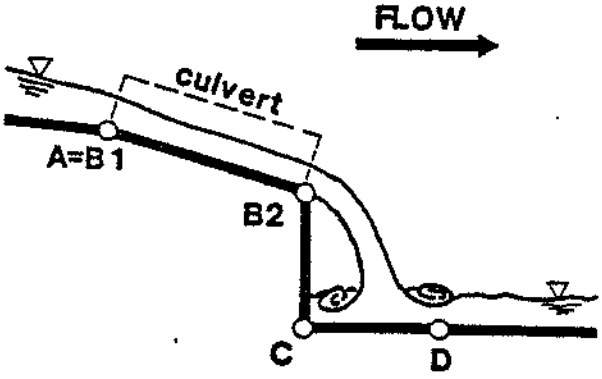

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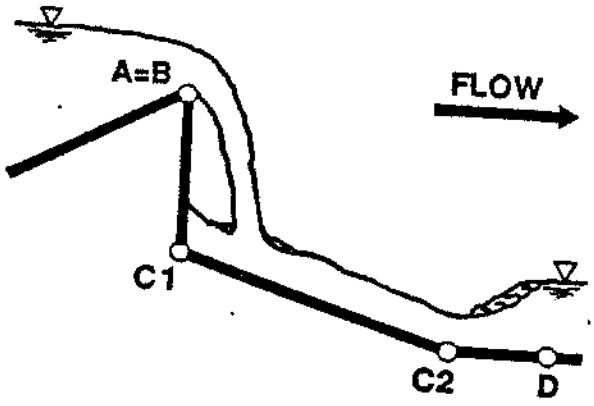

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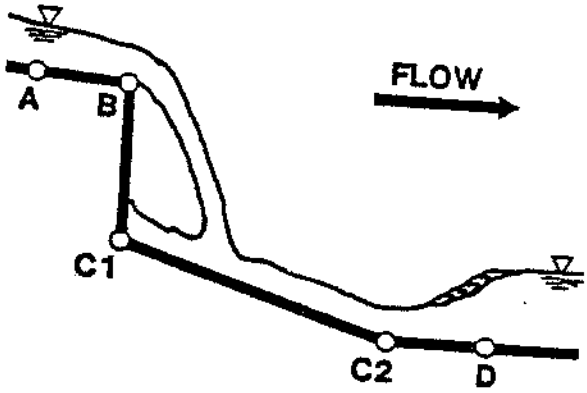

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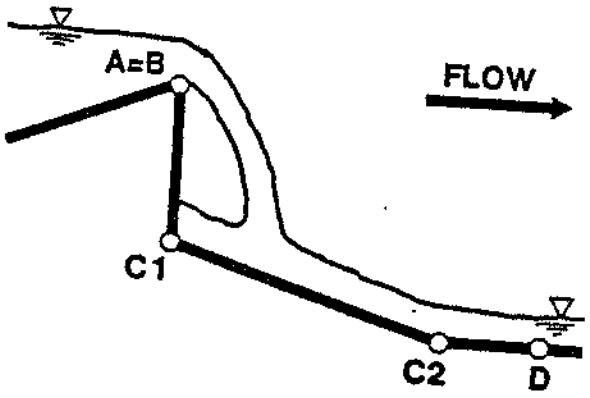

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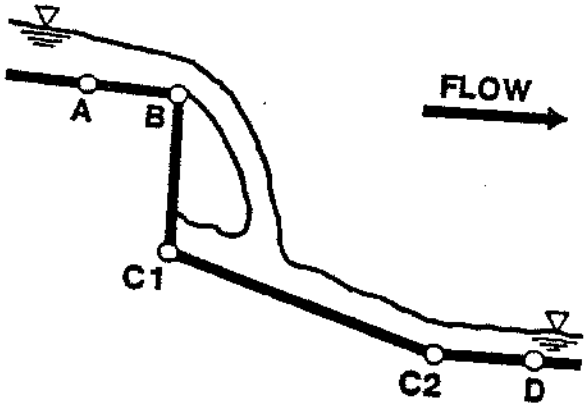

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Figure 19. (Cont.)