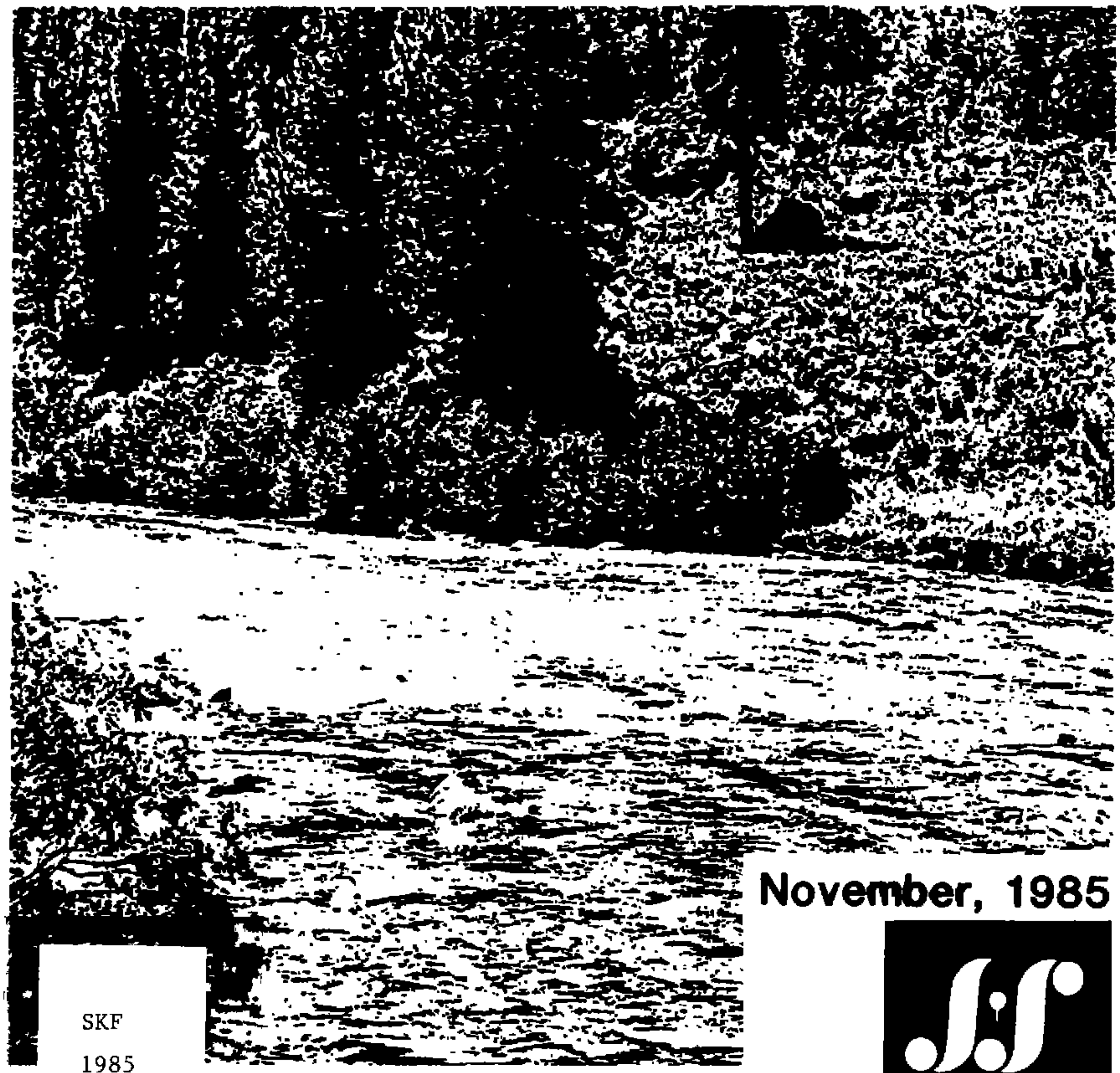
FINAL REPORT

Salmon and Steelhead Fry Trapping and Stranding in Potholes on the Skagit River, 1984



November, 1985

JONES & STOKES ASSOCIATES, INC.
environmental planning • natural resource sciences

FINAL REPORT

SALMON AND STEELHEAD FRY TRAPPING AND STRANDING IN POTHOLES ON THE SKAGIT RIVER, 1984

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EXECUTIVE SUMMARY

Background

The City of Seattle, Department of Lighting (SCL), is in the process of relicensing its Skagit River Project (Project No. 553) under the Federal Energy Regulatory Commission (FERC). As a part of that process, in 1984 SCL initiated a study of salmonid fry stranding in potholes. The potholes study was initiated because of concern expressed by the Washington Department of Fisheries (WDF) that salmon fry were being trapped or stranded (killed) in potholes when river level dropped as a result of SCL's operations at Gorge Powerhouse. Potholes are depressions in the substrate created by hydraulic pressure; the depressions hold water and possibly trap and strand fish. Depending on the substrate type and other factors, such as bank storage (water retained in gravel bars and river banks), most potholes retain water for some time after the river level has dropped.

With agreement from the Skagit River Standing Committee, SCL prepared and implemented a study plan to conduct salmonid fry stranding tests during March through April, 1984. At the request of WDF, no salmon fry stranding downramping tests were conducted after April 8, 1984. It was also agreed by the Skagit River Standing Committee that tests for steelhead fry would be conducted August through October, 1984.

Study Objectives and Tasks

The salmon and steelhead fry stranding studies were oriented toward determining the susceptibility of salmonids to pothole stranding and identifying those factors that appear to influence pothole stranding.

Specific study objectives included:

- Test time susceptibility of salmon and steelhead trout fry to stranding or trapping in potholes in the Skagit River from Newhalem to Rockport.
- Document the physical characteristics of potholes that could potentially impact fry.

The study area for this project was located on the Skagit River in Whatcom and Skagit Counties, Washington. This study was conducted on the river between the SCL's Gorge Powerhouse (RM 94.5) and Rockport, Washington (RM 67.5).

During the spring, 11 pothole study areas from RM 67.5 to RM 82.6 were given descriptive names (Rockport, Wayne's Swim, Tin Shack, Bad Spot, Eagle Bar, Forbidden Bar, Stump Haven, Hooper's Slough, Inaccessible Island, Fungus Bar, Bacon Creek). An additional 16 study areas were added during the fall.

In January and February, 1984, SCL personnel developed a study design and methodology to achieve the objectives set forth. It was judged that the objectives could be best met by: 1) carrying out pre-test reconnaissance surveys to locate, mark, and characterize the potholes located between Rockport and Newhalem; 2) conducting a series of field surveys following downramping at Gorge Powerhouse to record the amount of fry trapping and stranding and physical conditions (e.g., water temperature, depth, width, etc.) of each marked pothole; and 3) compiling and analyzing data gathered during the spring and fall surveys.

Surveys were conducted by placing observers on all study areas. Observers were responsible for recording data at each pothole study area. The number of trapped (live) and/or stranded (dead) fry was recorded for each pothole during every round of observations. Date and time of day of each pothole observation was noted for comparison of pothole hydraulics with the flow record based on USGS gaging stations at Newhalem and Marblemount. Maximum depth, average depth, average length, and average width of the pothole were recorded during each round of observations. Pothole water temperatures (^{o}F) were recorded to assess potential mortality due to rising water temperatures on sunny days.

Test flows from the Gorge Powerhouse covered a wide range of flow conditions. Further, agreed to by the Skagit River Standing Committee, all downramping was completed at least 6-1/2 hours before sunrise during the spring tests.

Personnel from SCL provided SCL power control with proposed downramping target times and flows. Upper limit test flows were held constant for approximately 10 hours. Target lower limit test flow was 2,300 cfs during the spring surveys and 1,400 cfs during the fall survey.

Data Compilation and Analysis

Field data were entered in the University of Washington Cyber computer system. Data were were entered chronologically by pothole area (river mile) and pothole number. FORTRAN programs were developed for the purpose of: 1) data checking; 2) integrating river flow data into pothole records; 3) preparing mortality files defined by site, date, and pothole; and 4) compiling a master data file consisting of one observation per pothole per day and providing consistent cover and substrate codes for each pothole as well as high and low flows for each day.

Data were analyzed to determine the following:

- General factor analysis to investigate the associations between a number of variables in the data set.
- Multiple regression of fry trapping and stranding vs. recorded flows at the Newhalem and Marblemount gages and modeled flows at Rockport.
- Pair-wise multiple regression analysis of flow history (for 24 and 72 hours preceeding each downramping event) vs. fry trapping.
- Forward stepwise and linear regression of amplitude for previous 24 hours vs. fry trapping and stranding.
- Determination of the relationship of cover and substrate to fry trapping and stranding.
- Multiple regression of river flows at Newhalem, Marblemount, and Rockport to the lowest maximum pothole depth of the day.
- Regression of fry trapping during spring and fall with date and flow.
- Regression of ramping rate of each test vs. trapping and stranding for the entire river.
- Determination of flows at which surveyed potholes connect and disconnect from the river as a result of downramping and flow releases at the Gorge Powerhouse and tributary inflow.
- Determination of the number of dry potholes at Marblemount and Rockport gaging locations.
- A regression of ramping rate of each test vs. fry trapping and stranding.
- A cursory examination of the timing of downramping vs. steelhead fry trapping.

Study Results

Potholes from Rockport to Gorge Powerhouse were surveyed during the spring, in the summer-fall period, and again in November, 1984. During the spring, 130 potholes were surveyed, of which 17 were considered as high flow (those potholes observed to stay disconnected from the river except under very high flow conditions). During the fall, 242 potholes were surveyed (of which 21 were high flow). In November, with discharges of 7,000 cfs from Gorge Powerhouse, an additional 140 high flow potholes were located.

Of the 113 potholes (excluding the 17 high flow potholes) surveyed during the spring, 95 (84 percent) trapped fry, while 33 (29 percent) stranded fry. During the fall, 99 (45 percent) of the 221 potholes (excluding 21 high flow potholes) surveyed trapped fry, while 39 (18 percent) stranded fry. No fry were observed trapped or stranded in high flow potholes surveyed during November; however, it is assumed that at flows of approximately 11,000 cfs at Rockport during February through August, fry would be vulnerable to trapping and stranding in those potholes.

Fry Trapping and Stranding

Spring. During the spring, a total of 17,538 fry (a number of which may have been repeatedly trapped) were observed trapped during the testing period form March 11 through May 18, 1985. One study area (Stump Haven [RM 72.2]) trapped 30 percent of all trapped fry observed, with one deep pothole trapping 19 percent of all fry trapped during the entire testing period. Of those fry trapped, 315 were stranded (killed); approximately 2 percent of the fry trapped. Only a few potholes (33 of 113 potholes) accounted for stranding.

Trapping of salmon fry was most prevalent between March 31 and April 28, with number of fry trapped decreasing significantly during May. The number of fry trapped was less on the second day of paired tests (7,496 fry trapped on the first day vs. 3,165 fry trapped on the second day of paired tests). Fry stranding throughout the test period did not follow the same temporal trend established with trapping.

No mortality caused by high water temperatures was observed during the spring. A predominance of potholes (75 percent) had some cover (e.g., overhead vegetation) while only 25 percent had no cover.

One common chacteristic of fry stranding was that mortality often occurred on the fringes of potholes even though sufficient water was maintained in other portions of the pothole to sustain remaining fry. Of 1,380 observations of potholes made during the spring survey period, on only 17 occasions were all fry observed to be stranded.

Fall. During the fall, 3,578 fry were trapped during testing carried out from August 22 through September 28, of which 426 were stranded. In addition, during a reconnaissance survey on August 15, an additional 3,120 fry were observed trapped, of which 508 were stranded. Approximately 70 percent of all stranding occurred in single potholes at two areas.

During the fall, over 81 percent of all fry trapped were observed during the three earliest test dates. Stranded fry were temporally distributed in a pattern similar to the observed trapping. As with spring, the greatest number of fry trapped were on the first day of paired tests.

Of the fry stranded, a majority were killed in potholes with sand substrate as compared with other substrates (silt, pea gravel, gravel, and cobble) and a majority of both trapped and stranded fry were found in potholes having cover of some kind (logs, vegetation).

As with salmon fry observed during the spring, steelhead fry also became stranded on the shallow fringes of draining potholes.

During the fall surveys, 69 fry were killed by high water temperatures in two high flow potholes which depended on under-gravel recharge of water.

Analyses of River Flow

Analyses of river flow to fry trapping and stranding were carried out. Included in the evaluation were relationships of trapping and stranding to minimum test flows, average daily discharge for 24- and 72-hour periods prior to the test, mean and maximum downramp amplitude during the 24 and 72 hours prior to each test and ramping rate.

No strong relationship were found with any of the statistical analyses conducted of fry trapping and stranding. The lack of statistically significant relationships appeared to be caused by a variety of confounding effects, among them the apparent decreased vulnerability of fry to trapping with time and the influence of running back-to-back tests (i.e., fry trapping and stranding was generally less on the second day of the 2-day tests.

Spring. No strong relationship was found with any of the statistical analyses conducted of fry trapping and stranding. A weak relationship showed a trend that fewer fry were trapped as minimum test flows increased, however, that trend did not hold for stranding. Additionally, a logistic regression model showed Newhalem and Rockport flows to be more strongly associated with stranding than were Rockport flows; however, the relationship was also weak. This, in part, was due to the changes in testing procedures after April 8 as requested by WDF.

Results of analysis of the relationship of average daily discharge (for the 24- and 72-hour period prior to each test), maximum downramp amplitude (for 24- and 72-hours prior to each test) and ramping rate showed no significant relationship to trapping or stranding.

Fall. As with the spring results, no strong relationships were found with any of the analyses of flow to fry trapping and stranding.

A linear regression of downramp rates (cfs per hour) to trapping and stranding yielded a negative relationship, probably because the greatest number of fry trapped and stranded occurred on a day with the lowest downramp rate.

A cursory examination of the relationship of the timing of downramping to the incidence of steelhead trapping showed that a trend of greater numbers of fry trapped during daylight hours may be apparent; however, since only one daylight downramp was conducted as a part of this study, these cursory results cannot be considered conclusive.

Pothole Connectivity

Field data collected during the spring and fall seasons included information on the flows at which potholes became connected and disconnected from the river. Connecting flow information was not available for a large number of potholes (data were available on 2 of 9 potholes assigned to the Newhalem gage, 15 of 60 potholes assigned to the Marblemount gage, and 113 of 185 potholes assigned to the Rockport gage). The information that is available indicates potholes connecting at flows ranging from 1,500 to 2,000 cfs at Newhalem, 2,000 to >4,000 cfs at Marblemount, and 3,000 to >7,500 cfs at Rockport.

The data available suggest that during the spring at potholes assigned to the Rockport gage, a majority of the fry mortality occurred in potholes connecting at flows of 5,500 cfs and greater. No mortality data were available in the spring for potholes assigned to the Marblemount or Newhalem gages.

For the fall period, data indicate that a majority of the fry mortality occurred in potholes connecting in the 2,500 to 3,500 cfs range at Marblemount and in the 5,500 to 6,500 cfs range at Rockport.

Dry Potholes vs River Flow

Based on a limited sample of observations, numbers of dry potholes in areas assigned to the Marblemount and Rockport gages by flow increment were determined. Flow data indicated that 35 of the 60 potholes (58 percent) assigned to Marblemount became dry between 2,000 and 3,500 cfs. Flow data for the remaining 25 potholes were not available.

Based on flow data for potholes assigned to Rockport, 68 percent of the potholes became dry at flows ranging from 3,500 to 9,500 cfs. The wider range of flows for the pothole areas assigned to Rockport is due to the greater number of high flow potholes in the lower reach of the river. Flow data for the remaining 32 percent of the potholes were not available.

Discussion

Spring

Of the 17,538 fry trapped during the spring, only 2 percent became stranded (mortality). This figure was low when compared with the results of other fry stranding studies conducted on the Cowlitz River, where in 2-days time over 7,200 fry were stranded (primarily on gravel bars) during downramping.

Several factors may be influencing the low number of fry stranded on the Skagit: 1) storage of water in river banks and bars (termed bank storage) may have a significant bearing on how long water is sustained in potholes following a downramping event, 2) the duration of the minimum flow of the downramping event, and 3) the elevation of the potholes trapping fry relative to elevation of the river during the minimum flow of the event. All of these factors may be working in concert; and in many cases, the influences may vary from site to site on the river.

A majority of the potholes surveyed during the spring were located in the lower 5 miles of the study area from Rockport to Illabot Slough; however, fewer potholes in the lower river trapped fry than did potholes on the rest of the river. A number of factors may account for this difference: 1) habitat in many of the potholes in the lower river were less preferred by fry; and 2) potholes, although containing water, were not connected to the river except during very high river flows and, therefore, were not "available" to fry.

Temporal distribution patterns were different for trapped and stranded fry during the spring surveys. There was no apparent relationship between numbers of fry trapped and timing of test dates, although 88 percent of all observed fry were trapped between March 11 and April 28. The lower numbers of fry trapped during the first two test dates may have been a result of less observational effort. Chinook salmon are known to have an extended fry emergence period, a situation which was evident during this study.

Of interest was the finding that generally less trapping and stranding occurred on the second day of "paired" test dates. During all paired tests, flow releases from Gorge Powerhouse were nearly the same. Any difference in downstream flow conditions would result from change in tributary inflow. On most occasions, tributary inflow was relatively unchanged during the second day.

Several reasons may account for this trend: 1) fry may not have sufficient time to reinhabit pothole areas between tests, 2) fry may "learn" or become accustomed to the flow fluctuations and therefore do not reoccupy pothole habitat immediately following the first day of tests, and 3) fry may be territorial and flow fluctuations may disrupt their normal patterns of territoriality resulting in fewer fish on the second day. Field studies carried out during 1985 will better define the movement of fry in pothole areas.

No strong relationship was found with any of the analyses conducted of flow to fry trapping and stranding. A majority of the flow and trapping/stranding relationships appeared to be confounded by a variety of factors such as the age or size of fry (which influenced the likelihood of trapping and stranding), lack of continuous testing during the spring survey period (no tests were run from April 14 through May 18, 1934) and the size, species composition, and location of the fry population at risk in the river.

Although no statistical relationship of flows to trapping and stranding were clearly evident, there is indication that flow history prior to a downramping event is an important testing condition that should be analyzed during 1985 studies.

Fall. During the fall surveys, 3,578 fry were trapped and 315 stranded, a majority of those being emerged steelhead. The most important trapping areas for fry were Big Eddy (RM 77.5), which accounted for 27 percent of trapping; Wayne's Swim (RM 68.1) accounted for 19 percent of trapping; and Stump Haven (RM 72.2) 11 percent.

Several factors could account for the lower numbers of both trapping and stranding: 1) less wetted fry habitat (and therefore fewer potholes) was available due to seasonally declining river flows; 2) as fry became larger, they were better able to avoid trapping; and 3) as they became larger, steelhead fry were attracted to different types of habitat. In all likelihood, all of those factors had a bearing on the difference in trapping and stranding.

Temporal distribution patterns for both trapped and stranded steelhead fry during the fall surveys were markedly more evident than were observed for salmon fry during the spring survey. Over 80 percent of all trapped and stranded fry were observed during the first three test dates in a declining manner. Data collected during the reconnaissance survey 1 week prior to the first test date also corroborated the results. The decline in the numbers of steelhead fry trapped and stranded during the study is probably associated with the increased size of fry. In all likelihood, by late September a majority of the steelhead fry either no longer occupied the pothole habitat or were able to avoid trapping by moving away from potholes as the river levels dropped.

As was also observed during spring surveys, fewer fry were generally observed during the second day of paired test dates for the same reasons given for spring. During steelhead fry stranding conducted by Crumley (unpublished Skagit Standing Committee minutes, January 10, 1984) in 1983, it was noted that the first test stranded relatively many fry as compared to following tests. He noted that steelhead may have an increased adaptability to flow fluctuations based on their nonmigratory behavior.

Flow records at Gorge Powerhouse indicate that the average daily discharges for the 72 hours prior to the test days (2,822 cfs) were 1,505 cfs less than occurred during the reconnaissance survey (4,327 cfs) (Appendix G). That reduction occurred because the Interim Flow Agreement requires that after August 20, maximum flows at the Gorge Powerhouse be no greater than 4,200 cfs. That reduction in regulated flows, coupled with a seasonal reduction in tributary inflow, probably altered the amount and type of habitat available to fry.

That required reduction in flow may very well have had a significant bearing on stranding observations during the first two tests on August 22 and 23, just 2 and 3 days after the 4,200 cfs maximum flow was initiated. On August 22, 142 (33 percent of all fry stranded during the surveys) were found stranded in one pothole at Forbidden Bar (RM 70.5). That pothole was isolated from the river but was sustained by water passing through the gravel bar. No mortality was reported at that site during the rest of the survey.

A significant number of the fry stranded in the fall (508 fry, 46 percent) of all fry were killed during the reconnaissance survey prior to the drop to maximum flow requirements. As a result, many fish were stranded in higher flow potholes, potholes that were no longer available as habitat after August 20.

Pothole Connectivity

Preliminary information on the flows at which potholes connect to the river indicates that potholes with connecting flows greater than 5,500 cfs at Rockport constituted a majority of the spring fry stranding; however, this preliminary conclusion is based on data which omits 72 spring potholes for which there is no calculated connectivity. These data suggest that during the spring, fry occupy the high potholes areas (probably to gain refuge) during high river flow conditions. Fry occupying those potholes would be vulnerable to trapping when flow levels declined.

No connecting flow information during the spring was available for potholes assigned to the Marblemount gage; however, data for fall surveys showed a majority of the fry stranding occurred in potholes connecting at 2,500 to 3,500 cfs. Once again, those data are preliminary.

River flows during the fall were lower than those during the spring because of lower tributary inflow and an Interim Flow Agreement requirement limiting the maximum discharge at Gorge Powerhouse to 4,200 cfs after August 20. As a result, potholes that were continually flooded during the spring became dry during the lower fall flows. This is reflected in the fact that in potholes assigned to the Rockport gage, seven fry were stranded during the spring in potholes having connecting flows <6,000 cfs, while in the fall, 232 fry were stranded in potholes connected at <6,000 cfs.

1. INTRODUCTION

Background

As a part of relicensing for the City of Seattle's Skagit River Project (Project No. 553), in September, 1978, the Federal Energy Regulatory Commission (FERC) issued an order to initiate proceedings which would address the effect of the project's (Ross, Diablo, and Gorge Dams) flow regime on the fish resources of the Skagit River. In February, 1981, the City of Seattle, Washington Departments of Fisheries and Game, National Marine Fisheries Service, and Skagit System Cooperative Indian Tribes established an interim agreement which set out conditions of flow regulation and performance of fishery studies (U. S. Federal Regulatory Commission 1981).

As a part of that agreement, the Skagit River Standing Committee was formed to coordinate fish protection needs and research studies during the period of FERC relicensing. The Standing Committee consists of representatives from the National Marine Fisheries Service, U. S. Fish and Wildlife, the National Park Service, U. S. Forest Service, the Washington Departments of Fisheries and Game, the Skagit System Cooperative Indian Tribes, and Seattle City Light (SCL).

Section 3 of the Interim Agreement defined seven subject areas of fisheries study to be undertaken by SCL over a 2-year period (Appendix A). This pothole stranding study was not identified in the interim agreement but was instead reported in December, 1983, as a concern by the Washington Department of Fisheries (WDF). The WDF reported on salmon fry stranding in potholes observed during gravel bar stranding studies the Department was conducting during 1983 on the Skagit River. Potholes, by definition, are depressions in the substrate created by hydraulic pressure; the depressions hold water and possibly trap or strand fish as a result of reduced river flows. Potholes are a natural phenomena which occur in both regulated and unregulated rivers.

As a result of their observations, the WDF requested that SCL provide flow releases at Gorge Dam sufficient to maintain a minimum discharge of 3,900 cubic feet per second (cfs) at the Marblemount U. S. Geological Survey (USGS) flow gage from February through May. It was judged by WDF that such flows would adequately prevent major salmon fry stranding in potholes (Washington Department of Fisheries 1983a); however, the Skagit River Standing Committee concluded that more information was needed to determine the extent of fry stranding and to establish any flow requirements.

In response to the WDF request, SCL proposed to conduct a series of tests during the spring, summer, and fall of 1984 to determine the magnitude of pothole stranding as a basis for establishing flow requirements necessary to protect the juvenile salmonids.

With agreement from the Skagit River Standing Committee, SCL prepared and implemented a study plan to conduct salmonid fry stranding tests from March through May, 1984. However, due to concerns about potentially large fry mortalities, WDF cancelled further salmon fry stranding tests after April 8, 1984. It was agreed by the Skagit River Standing Committee that tests for steelhead fry would be conducted August through October, 1984 (Seattle City Light 1984a).

This report presents the results of both the salmon (March through May, 1984) and steelhead (August and September, 1984) fry stranding surveys.

Study Objectives and Tasks

The salmon and steelhead fry stranding studies were oriented toward determining the susceptibility of salmonids to pothole stranding and identifying those factors that appear to influence pothole stranding.

Specific study objectives included:

- Test the susceptibility of salmon and steelhead trout fry to stranding or trapping in potholes in the Skagit River from Newhalem to Rockport.
- Document the physical characteristics of potholes that could potentially impact fry.

To achieve the study objectives, a study plan was developed which included the following tasks:

- Conduct reconnaissance surveys to locate, mark, and characterize potholes visible at Gorge Dam flows between 1,200 and 7,200 cfs.
- Conduct fry stranding and trapping surveys of marked potholes in replicated fashion.
- Compile and analyze 1984 salmon and steelhead stranding data.

A more detailed discussion of the study tasks is presented in the STUDY METHODOLOGY section of this report.

2. DESCRIPTION OF THE STUDY AREA

Location

The study area for this project was located on the Skagit River in Whatcom and Skagit Counties, Washington (Figure 2-1). The Skagit River, which is the largest river flowing into Puget Sound, originates in British Columbia, Canada, and flows south across the international boundary through Ross, Diablo, and Gorge Reservoirs (operated by Seattle City Light) and thence for 94 river miles (RM) west to Puget Sound near Mount Vernon, Washington.

This study was conducted on the Skagit River between the Seattle City Light's Gorge Powerhouse (RM 94.2) and Rockport, Washington (RM 67.5) (Figure 2-1). Key geographical points within the study area include the communities of Rockport at the western end of the study area; Marblemount (RM 77); and Newhalem, a Seattle City Light community located at the upper end of the study area at RM 94.

The Skagit River study area is bounded by State Highway 20 along its northern bank and the Rockport-Cascade Road along portions of its southern bank from Rockport northeast to Marblemount.

Physical Characteristics

The Skagit River from Rockport to Newhalem is characterized by a variety of river environments ranging from a broad, braided plain over 1,200 feet in width just upriver of Rockport to a confined, well-defined channel 300-500 feet wide near Newhalem (Washington Department of Fisheries 1975).

Rockport to Illabot Creek

This short reach of the study area (4.1 river miles) contains a broad floodplain, side channels, sloughs, and extensive gravel and sand bars. The gradient (7 feet per mile) from Illabot Creek (RM 71.6) to Rockport (RM 67.5) is considerably less than in the upper river (Figure 2-2). The most significant tributary along this reach is Illabot Creek (RM 71.6).

Because of the extensive gravel bars, side channels, and sloughs, potholes are common, occurring in clusters and groups -- particularly from the Rockport Steelhead Park to the Skagit Bald Eagle Natural Area located approximately 1 mile upriver of

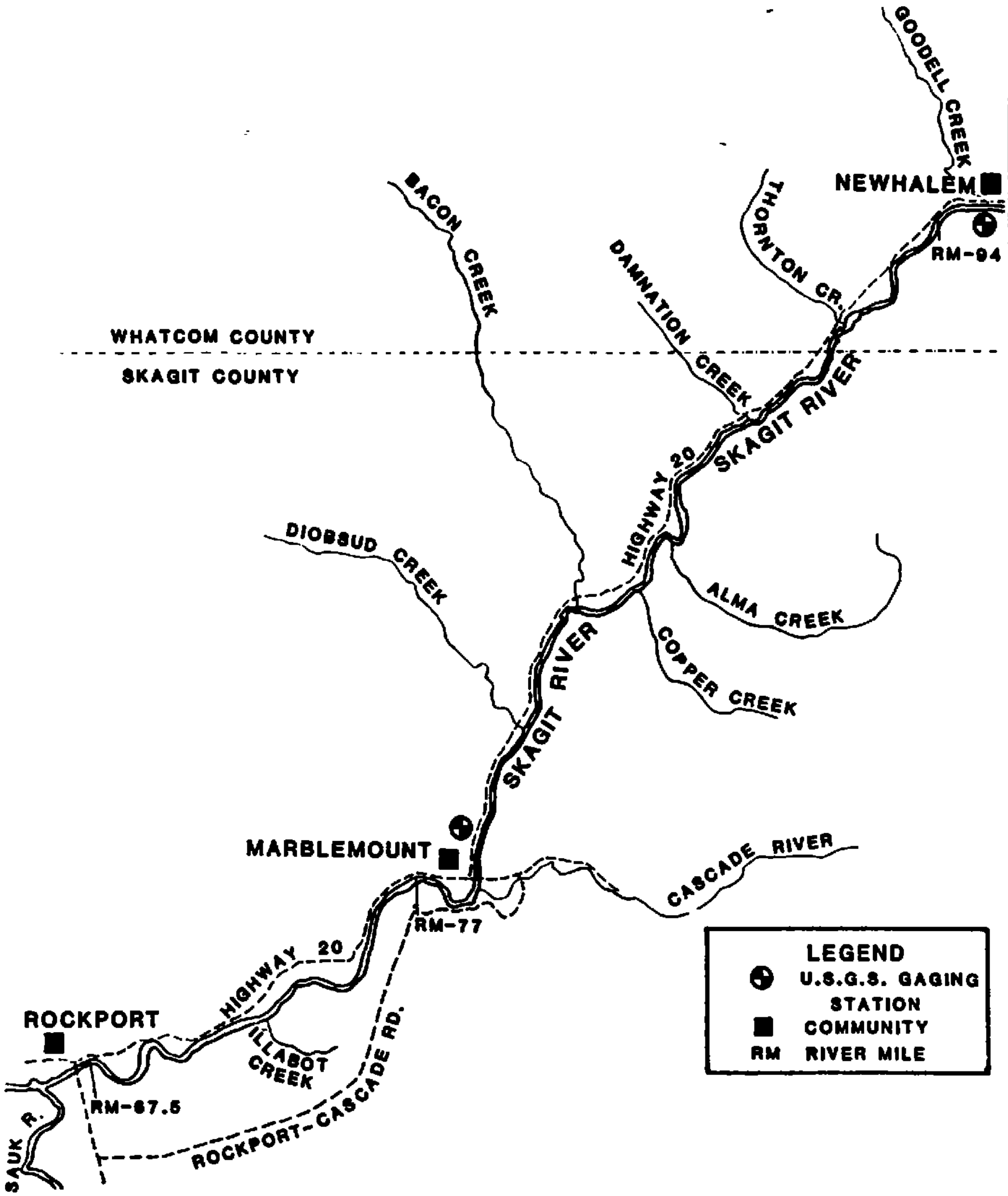


FIGURE 2-1. SALMONID FRY STRANDING STUDY AREA, SKAGIT RIVER, WASHINGTON

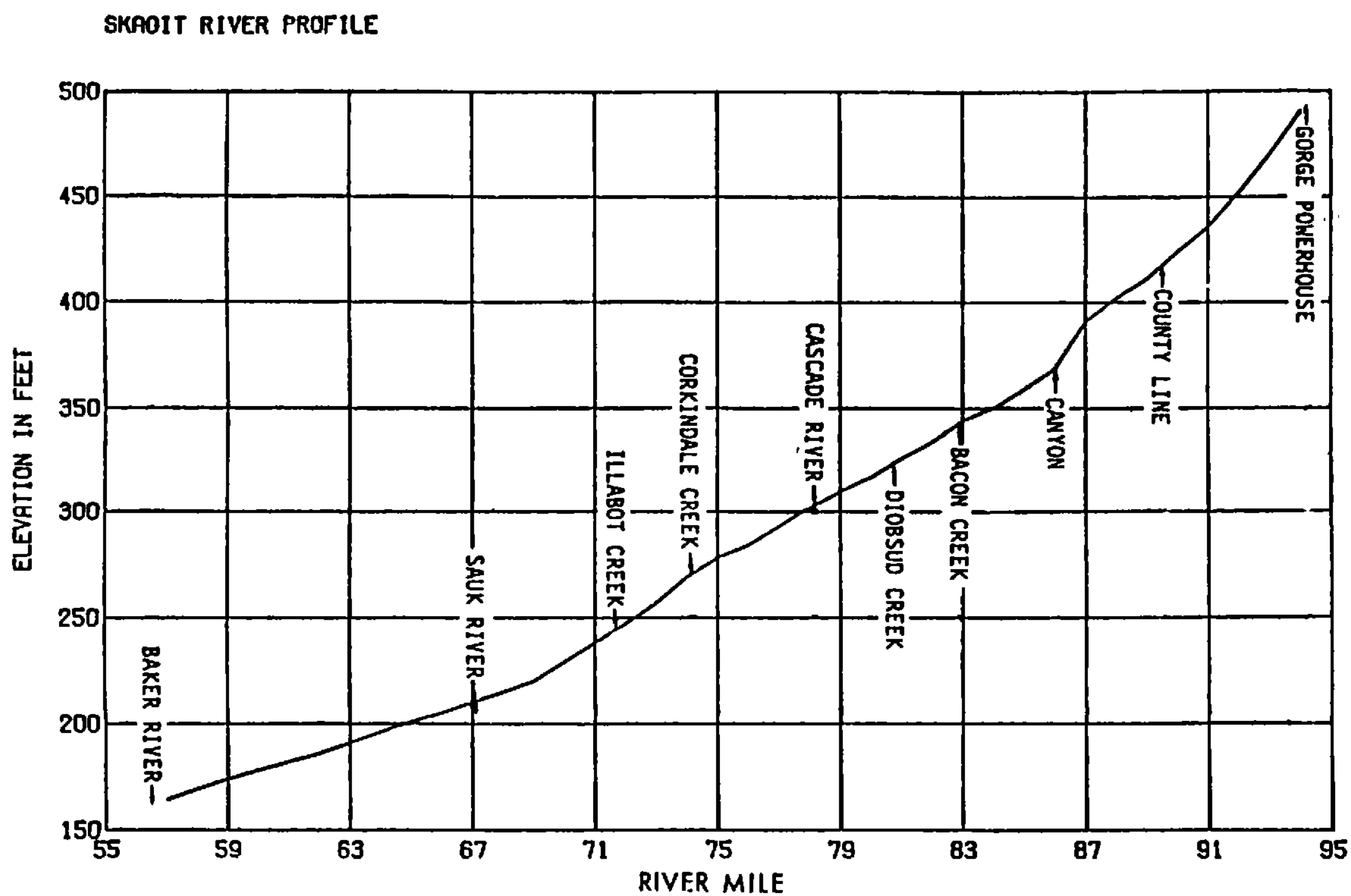


FIGURE 2-2. SKAGIT RIVER PROFILE ILLUSTRATING RIVER MILES AND LOCATIONS OF MAJOR TRIBUTARIES (MODIFIED FROM CRUMLEY AND STOBER 1984)

Rockport. During surveys for this study, 146 potholes were located from Rockport to Illabot Creek.

Illabot Creek to Bacon Creek

This 10 mile reach of river has a moderate gradient dropping 100 feet (10 feet per mile) from an elevation of 340 feet near Bacon Creek to 240 feet near Illabot Creek (Figure 2-2). The portion of this reach from Illabot Creek (RM 71.4) to RM 73.1 is characterized by a large number of side channels, sloughs, and gravel and sand bars. Upriver from RM 73.1 to Bacon Creek (RM 82.9), the river channel is more confined but also includes gravel bar and side channel areas at RM 76.3, RM 77.5 (Big Eddy), RM 77.7 (Marblemount Slough), RM 78.5, RM 82.6, and at the mouth of Bacon Creek. The Cascade River (RM 78.1) is the most significant tributary found within this reach of the Skagit River.

During this study, 173 potholes were located within this reach.

Bacon Creek to Newhalem

The reach of the Skagit River from Newhalem to Bacon Creek (RM 83) is characterized by a moderate gradient dropping about 150 feet in 12 miles (elevation of 490-340 feet) or 12 feet per mile (Figure 2-2). Mid-portions of the reach from RM 85-89 contain steep valley walls and large rock formations on both sides of the river, whereas the lower portion (RM 83-85) of the reach has a wider, though constricted, channel. Significant tributaries (those of greatest length and known to support anadromous fish) within this reach include Newhalem Creek (RM 93.3), Goodell Creek (RM 92.9), Thornton Creek (RM 90.1), Alma Creek (RM 85.2), and Bacon Creek (RM 82.9). The drainage area for the Skagit River above Bacon Creek has been calculated to be 3,339 km^2 (1,289 square miles) (USGS 1983).

Areas of gravel bars and side sloughs in this reach occur just downstream of Alma Creek (RM 84.3), downstream of Damnation Creek (RM 87), near Sky Creek (RM 88), at the County Line Ponds (RM 89), and at the three islands near Thornton Creek (RM 90).

From Bacon Creek to Alma Creek, 11 potholes were surveyed during this study.

A detailed description of channel configuration for portions of the Skagit River from Newhalem to Rockport is found in Crumley and Stober (1984). The WDF stream catalog (1975) provides descriptions and locations of tributaries in the study area.

Hydrology

Overview

This study was confined to the Skagit River from the Gorge Powerhouse to the confluence with the Sauk River at Rockport (RM 67.5), a portion of the river most affected by flows regulated by the Skagit River Project (Seattle City Light Project No. 553) located upstream of Newhalem. During the late winter and late summer-early fall periods when tributary inflow is decreased, river flows in the upper Skagit River are almost exclusively regulated by discharge from Gorge Powerhouse. During the remainder of the year, tributary inflow exerts a major influence on mainstem discharge. Freshets and snowmelt cause erratic streamflow conditions in both the tributaries and the mainstem. Such conditions have been observed, on occasion, to more than triple the regulated flow.

As previously mentioned, several tributaries enter the upper Skagit River between Newhalem and Rockport (Figure 2-1). The Cascade River (RM 78.1), located downstream of Marblemount, is the major tributary with a mean average discharge of 1,040 cfs (USGS 1983). Similar to the other larger tributaries in the upper Skagit River, flows are generally greater from May through July and October through January.

Based on gaged flows, mean average discharge of the Skagit River increases from 4,464 cfs at Newhalem to 5,939 cfs at Marblemount as a result of tributary inflow (USGS 1983). The mean average discharge at Rockport is unknown due to the absence of a gaging station. However, an estimate of 7,326 cfs can be calculated by applying the river flow model developed for this study and described in Appendix C of this report.

Flow Characteristics

Coupled with changes in tributary inflow, daily flow fluctuations in the upper Skagit River are generally a function of daily and seasonal power demand characterized by greater discharge during daylight and evening hours and lower discharge during late evening and early morning hours. Typically, flows at Newhalem are increased between 0600 and 0800 hours to a level not to exceed the Interim Flow Agreement maximum flow for that month (Appendix A). Flows are generally decreased from mid-day until 2200-2400 hours when downramping occurs resulting in a minimum allowable discharge. Downramping is defined here as that phase of the hydroelectric operational cycle when discharge from Gorge Powerhouse declines due to lower electrical demand. The result of this type of power generation regime is to cause both short-term (daily) and long-term (seasonal) fluctuations of river stage which are not commonly found in unregulated rivers. Figures 2-3 and 2-4 compare the short-term river fluctuations of the Skagit River (regulated) and the unregulated Cascade River. It should be noted that the Skagit River flow fluctuations shown as Figure 2-3 were measured in 1975, prior to implementation of the Interim

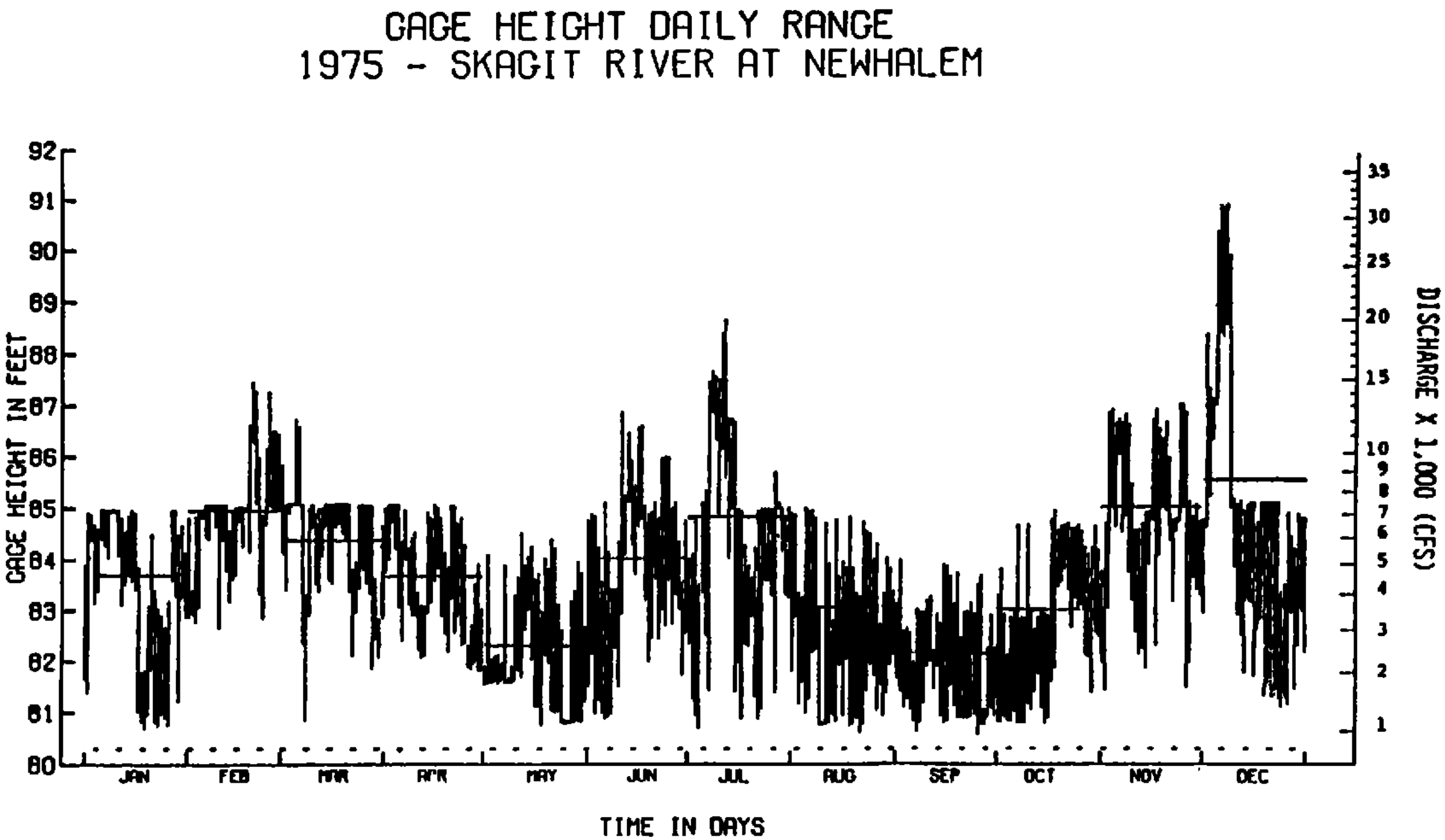


FIGURE 2-3. DAILY RANGE OF FLOW FLUCTUATIONS IN FEET AND CFS FOR SKAGIT RIVER AT NEWHALEM (USGS) FOR 1975 (PRIOR TO THE INTERIM FLOW AGREEMENT). THE MEAN DAILY DISCHARGES AND THE MEAN MONTHLY DISCHARGES ARE ALSO SHOWN (FROM GRAYBILL ET AL. 1979).

1975 - CASCADE RIVER

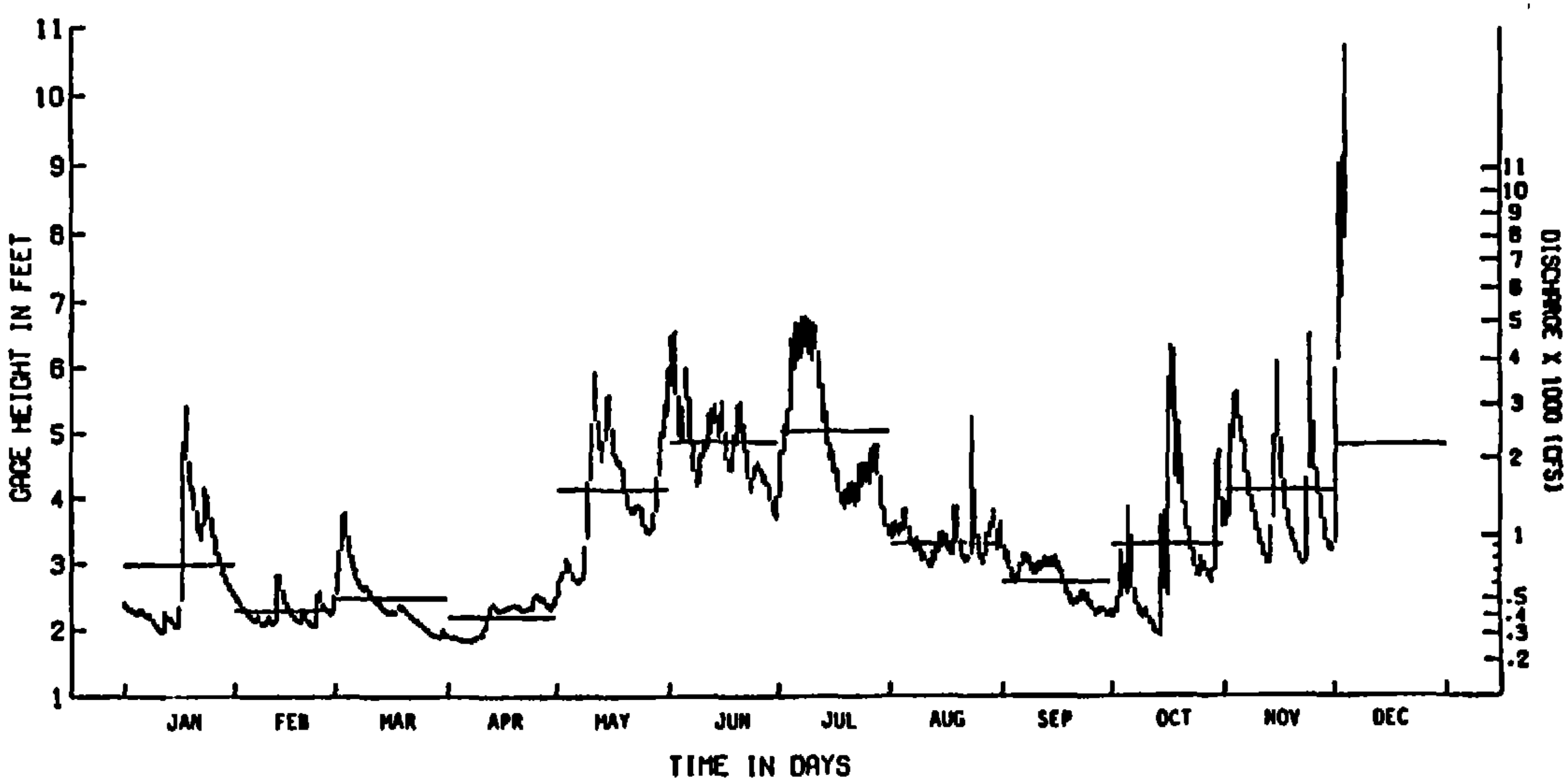


FIGURE 2-4. DAILY RANGE OF FLOW FLUCTUATIONS IN FEET AND CFS FOR CASCADE RIVER (USGS) FOR JANUARY THROUGH NOVEMBER, 1975. THE MEAN DAILY DISCHARGES FOR THIS PERIOD AND THE MEAN MONTHLY DISCHARGES FOR THE YEAR ARE ALSO SHOWN (FROM GRAYBILL ET AL. 1979).

Flow Agreement. Daily flow fluctuations have been reduced as a result of the adherence to the flow regime outlined in the Interim Flow Agreement. Daily flow fluctuation in the Skagit River often reaches 3,000 cfs throughout the year. The magnitude of Skagit River daily fluctuation is larger than observed for the Cascade River, where daily flow fluctuation rarely exceeds 2,000 cfs.

Longer-term flow patterns in the Skagit River are discussed at length by Graybill et. al (1979). Natural high flow conditions typical for late spring-early summer are reduced as a result of flow management. Conversely, flows which occur during the rest of the year generally augment 'natural' flows (Figure 2-5). Average regulated monthly flows are generally highest in June and July and lowest in February, March, September, and October.

Presently, minimum and maximum discharge, downramping rate, and flow fluctuation are regulated by an Interim Flow Agreement (FERC No. EL-78-36) between several state and federal agencies, the Skagit River Tribes, and the City of Seattle. This agreement also mandates the collection of data for fishery resource studies, including the present study.

Fish Resources

Overview

Five species of Pacific salmon and steelhead trout inhabit the upper Skagit River below Newhalem. Chinook, chum, and pink salmon are known to be mainstem spawners while coho salmon prefer the streams tributary to the Skagit River. Sockeye salmon spawning is limited to the Baker River (located downstream of the study area). Steelhead spawn both in the mainstem and tributaries of the upper Skagit River. Detailed salmonid life history information pertaining to Skagit River stocks is presented in Graybill et al. (1979). Escapement data for the above species can be found in annual Washington Department of Fisheries and Washington Department of Game (WDG) progress reports. Additional baseline information dealing with juvenile and adult steelhead stocks in the Skagit River was collected by WDG beginning in 1977 (Phillips et al. 1980).

Chinook, coho, chum, and steelhead fry were judged to represent the species most likely to be subject to stranding during the time period of this study. Pink salmon fry, though present in the river during even years, were rarely observed. This may be due to immediate downstream migration after emergence (Scott and Crossman 1973). Sockeye fry were never observed due to their confinement to lake environments. Chinook, coho, and chum fry made up the bulk of the fry observed during the spring surveys (March 11 through May 18, 1984). Only coho salmon and steelhead trout fry were present during fall surveys (August 15 through September 28, 1984). Figure 2-6 indicates those months

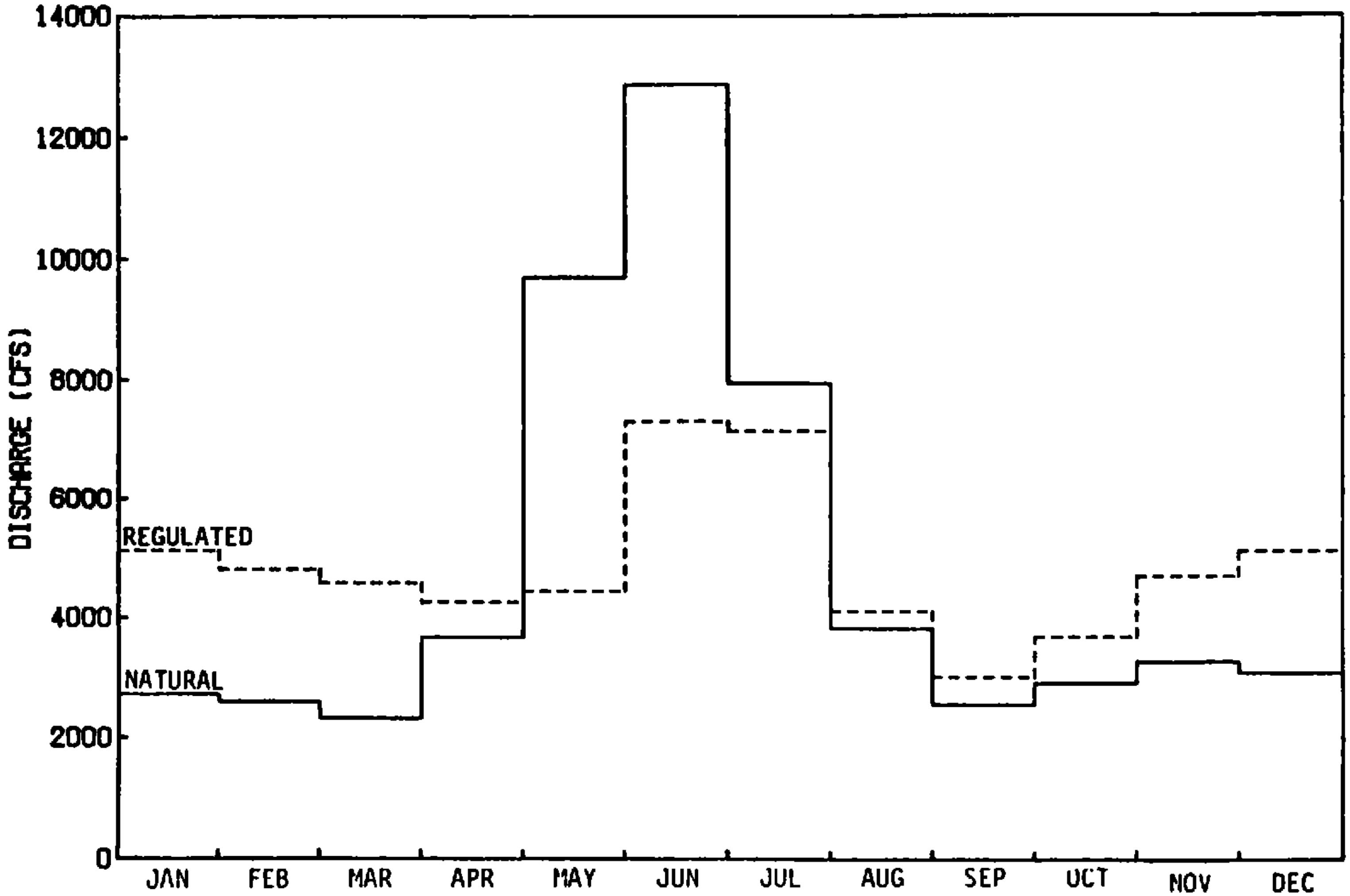


FIGURE 2-5. LONG-TERM NATURAL AND REGULATED STREAMFLOW PATTERNS FOR SKAGIT RIVER AT NEWHALEM (1954-1975) (SCL AND USGS) (FROM GRAYBILL ET AL. 1979)

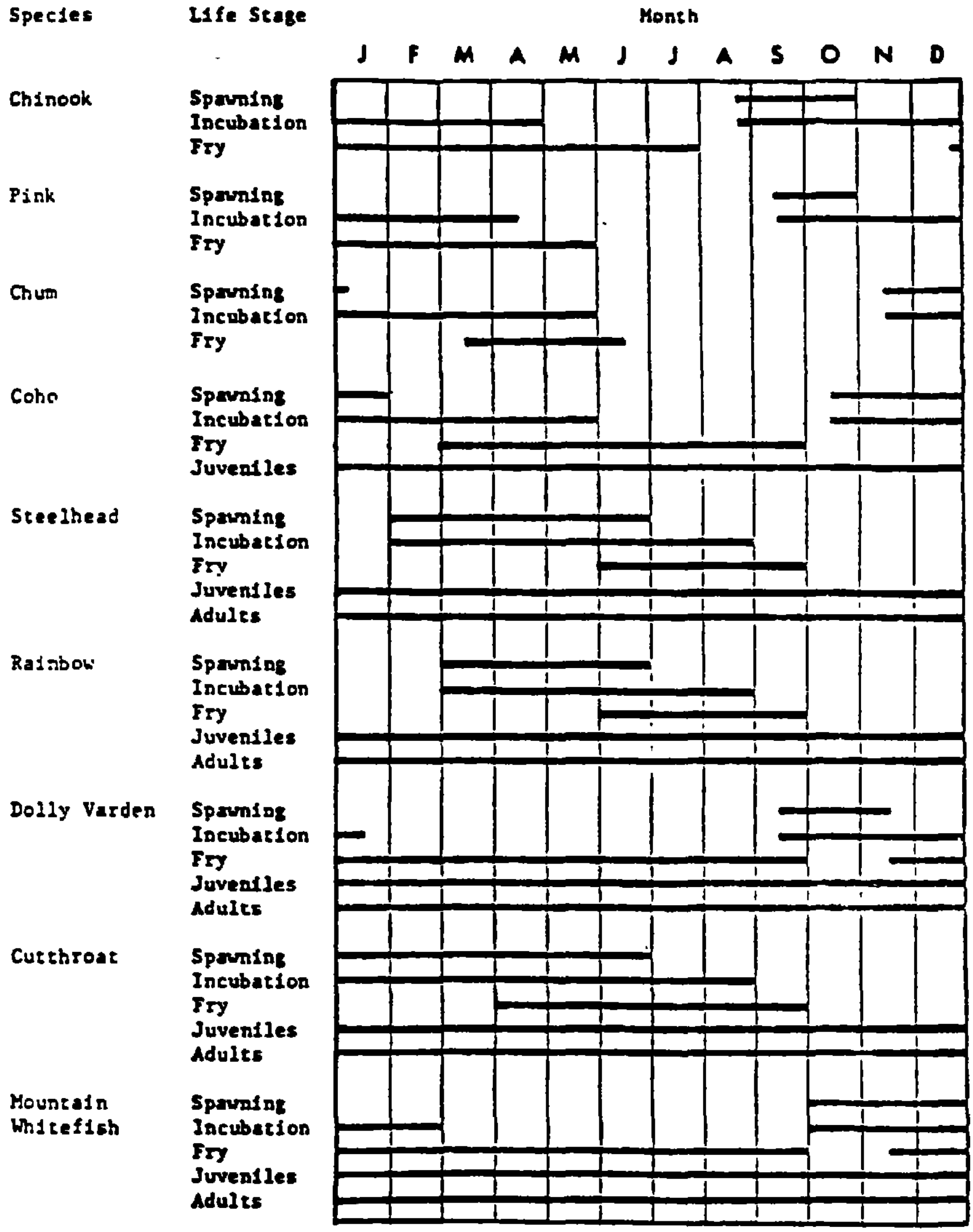


FIGURE 2-6. TIMING OF LIFE STAGES OF SALMONIDS IN THE SKAGIT RIVER (FROM CRUMLEY AND STOBER 1984)

of the year when fry occur in the Skagit River. The following life history information for chinook, chum, and coho salmon and steelhead trout has been condensed from Graybill et al. (1979).

Chinook Salmon. Chinook salmon spawning is generally greatest during September; observational data define the range of spawning from late August through October. Preferred depths and velocities of chinook spawners range from 1.7 to 4.2 feet and 1.8 to 3.7 feet per second, respectively. Peak chinook emergence in the Skagit River occurs from January through March, with peak abundance of fry observed in February and March. Chinook fry tend to inhabit the shallow, quiet waters at the edges of the river during the rearing phase; emigration generally occurs from April through July. By late July, nearly all of the fry are absent from the upper Skagit.

Chum Salmon. During 1976, greatest numbers of spawning chum salmon were observed from November through December, with peak spawning noted during early December. Depth and velocity measurements indicate that chum salmon prefer shallower water with lower velocities compared with chinook salmon; chum salmon prefer depths of 1.4 to 4.4 feet and velocities of 0.2 to 3.0 feet per second. This may account for the observed preference of chum salmon to use side channels for spawning. Chum salmon fry emerge in March with peak numbers noted in April and May. A limited feeding and rearing stage has been observed with emigration occurring soon after emergence. By June, most of the fry have left the upper Skagit River.

Coho Salmon. Coho salmon spawning occurs predominantly in the tributary streams of the upper Skagit River with at least 75 percent of total spawning observed in tributaries. The timing of coho spawning ranges from mid-October through January. Although fry generally begin to emerge as early as February, significant numbers are not present in the mainstem until April. Peak abundance is generally observed from June through August; however, large numbers of juveniles are present in the upper Skagit River throughout much of the year due to their extended freshwater rearing phase. Younger fry prefer similar habitat to chinook fry; shallow, quiet waters along the river bank and backwater areas are prime rearing areas. As the fry become larger, they tend to seek deeper pool areas with cover. Emigration of Age 1+ cohorts occurs during the spring.

Steelhead Trout. Over 80 percent of total steelhead trout spawning occurs in tributaries of the upper Skagit River (Phillips et al. 1980). Preferred water depths and velocities by steelhead are less than those preferred by chinook salmon; depth and velocity values of 0.9 to 2.9 feet and 1.5 to 3.0 feet per second were calculated, respectively. Greatest spawning activity is observed in April and May. Steelhead emerge later than the salmon species, primarily due to their late winter-early spring spawning season. Emergence may begin as early as June with peak abundance occurring in August and September. Life history similarities between steelhead trout and coho salmon are evident: 1) the majority of spawning occurs in the tributaries; 2) greater numbers of fry emerge in the tributaries, thus causing a delayed appearance of larger numbers in the mainstem; and 3) relatively large numbers of fry and/or juveniles are present in the river throughout the year. Younger fry inhabit the shallow, nearshore region along gravel bars while older juveniles prefer deeper waters.

3. STUDY METHODOLOGY

Introduction

In January and February, 1984, SCL/EAD personnel developed a study design and methodology to achieve the objectives of the study outlined in the INTRODUCTION. It was judged that the objectives could be best met by: 1) carrying out pre-test reconnaissance surveys to locate, mark, and characterize the potholes located between Rockport and Newhalem; 2) conducting a series of field surveys following downramping at Gorge Powerhouse to record the incidence of trapped and stranded fry in identified potholes along with measurements of the physical conditions (e.g., water temperature, depth, width, etc.) of each marked pothole; and 3) compiling and analyzing data gathered during the spring and summer-fall surveys.

Fry were considered to be trapped if they were observed alive in potholes disconnected from the river after the occurrence of a downramp event. Dead fry were labeled as stranded only if their demise was the ultimate result of being trapped in the potholes. Such mortality was generally a result of dewatered potholes and rarely a result of lethal water temperatures.

Reconnaissance of Potholes

Spring Reconnaissance

Prior to the spring fry stranding surveys, reconnaissance surveys were conducted for the purpose of identifying the abundance and distribution of all potential potholes. Personnel from SCL/EAD and Shapiro and Associates (SA) surveyed the Rockport-Marblemount section on March 10 and the Marblemount-Bacon Creek and Alma Creek-Newhalem sections on March 11.

Both sides of the river were accessed by jet boat as were side channels, sloughs, and islands. All areas potentially possessing potholes (e.g., gravel bars and sloughs) were checked on foot. When a pothole was located, it was assigned to a study area, flagged with red surveyor's tape, numbered, and the location of the pothole marked on a map. Observational data such as number of trapped and/or stranded fry, pothole dimensions, substrate and cover types, water temperature, weather conditions, and presence of seepage flow were noted along with the time of day and location. River mileage (RM) was determined for each study area as an identification marker in both the field and data files. The identifying mileage marker was measured at the center of each study area. Access maps were developed to assist future field observers in locating the study areas during field testing.

Mean daily discharge from Gorge Powerhouse for the week previous to March 10 ranged from 4,030 to 6,370 cfs. Normal operational weekend flows on March 9 and 10 facilitated the reconnaissance survey; flows were reduced from 7,119 cfs to 5,466 beginning at 2300 hours, March 9 and further reduced to 5,162 cfs at 1200 hours, March 10. On March 11, a downramp event was carried out; flows were dropped to 2,348 cfs until 1500 hours when discharge was increased to the initial operating level.

Summer Reconnaissance

On August 15 and 16, 1984, reconnaissance surveys were conducted prior to the summer stranding surveys by personnel from SCL/EAD, Jones & Stokes Associates (JSA), and Gaia Northwest, Inc. in the same manner as previously described. The purposes of the summer reconnaissance survey were: 1) to relocate and remark as necessary those potholes studied during the spring survey, 2) locate new potholes not previously identified during the spring surveys, and 3) set rebar (with measuring tape attached) at the deepest point of each pothole to be used as a depth gage and pothole marker. On August 15, the river section between Marblemount and Rockport was surveyed. The remaining section upstream from Marblemount to Alma Creek was surveyed on August 16.

River flow typically declines to the lowest levels during later summer-early fall. Therefore, for the purpose of exposing potential lower flow potholes, discharge from Gorge Powerhouse was reduced from 5,751 cfs to 1,400 cfs, the minimum allowable discharge, before midnight on August 14, 1984. Discharge from Gorge Powerhouse remained at 1,400 cfs until 1030, August 15, when flows were increased to normal operating conditions. Discharge was again reduced to 1,400 cfs for the survey on August 16. Gaged discharge at Marblemount declined from 6,475 to 2,600 cfs on August 15 as a result of downramping from Gorge Powerhouse, with similar flow conditions noted for August 16. For the week prior to the reconnaissance surveys, mean daily discharge at Gorge Powerhouse ranged from 3,360 to 4,920 cfs. The minimum sustained flow recorded for the week, 2,993 cfs, occurred on August 11 over a 12-hour time period. Maximum sustained flow during the same period occurred during August 14 over a 12-hour time period and ranged from 5,523 to 5,751 cfs. Sustained minimum and maximum flows recorded at Marblemount during the associated time periods were 4,550 cfs and 6,475 cfs, respectively.

High Flow Pothole Reconnaissance

High flow reconnaissance surveys were conducted during November 7 and 8, 1984 by SCL/EAD and JSA personnel. The Rockport-Bacon Creek section was covered by jet boat while the upper Bacon Creek-Newhalem section was surveyed on foot due to mechanical problems with a second jet boat. The purpose of the November pothole reconnaissance survey was to identify high flow potholes (those potholes associated with very high river flows) located along the upper portions of gravel bars and river banks. Similar to the summer reconnaissance survey, staff gages were set at the deepest point of each pothole and physical characteristics of each pothole were noted. Discharge from Gorge Powerhouse varied from 6,900 to 7,200 cfs on November 7 and from 6,900 to 7,150 cfs on November 8.

Fish Stranding Surveys

Experimental Design

The study design and methodology followed throughout the spring and summer surveys was developed by SCL/EAD personnel. A search of the literature indicated that on other rivers no comparable studies have been performed. Potential field techniques and ideas were included from stranding observations previously completed on the Skagit, Cowlitz, and Columbia Rivers by the Washington Department of Fisheries (1970, 1974, 1976, 1977), the University of Washington, Fisheries Research Institute (1984), and Graybill et al. (1979). The study design emphasized the need for determining mortality relationships over the entire operational flow range, including extreme conditions. It was felt that this approach would best determine the significance of fry mortality resulting from SCL operations.

In order to determine such a correlation, the spring surveys included six downramp tests from March 11 through April 8, 1984. However, from April 8 through May 12, 1984, all downramping tests were curtailed at the insistence of the Washington Department of Fisheries. Field studies during that curtailment period were limited to observations of stranding and trapping coincident with regular SCL Gorge Powerhouse operations during that time. No such curtailment occurred during the fall surveys, and 12 downramping tests were carried out.

Survey Techniques

Surveys were conducted by placing observers on all study areas before daylight in order to minimize the potential bias due to removal of fish by predators and scavengers prior to the field observations. Between 10 and 15 observers were present over selected study areas during all field tests. Prior to field surveys, time was spent training field observers regarding the locations of potholes, the field methodology to use in measuring pothole characteristics, and observing fry. Observer teams were supplied with yardsticks, thermometers (°F), clipboards, field forms, hip boots, and pothole location maps.

Field personnel were split into three groups for logistical purposes and transported to selected study areas in three vehicles. In addition to the land-based crew, a boat crew consisting of two to four personnel was sometimes used to access otherwise inaccessible study areas. Initially, two or three observers were placed at each study area to become familiar with the characteristics of that area. Personnel were shifted to new areas for later tests leaving at least one familiar observer at each site. After the third test, single observers were assigned to familiar study areas. When personnel unfamiliar with particular study areas were employed, they were oriented to their assigned areas by experienced observers.

During the fall surveys, observers were responsible for completing the field form shown as Figure 3-1. A similar form was used for the spring survey with most of the same type of information collected. The newer form was developed to aid in keypunching of data for computer analysis. All data recorded on the older forms were transcribed to the new forms prior to keypunching.

In the fall, each field form contained information for an individual pothole. Observers carried a number of data forms equal to the number of potholes for each study area during all test dates. In addition to general notes on weather conditions and comments, the following variables were recorded during each round of observations. The number of trapped (live) and/or stranded (dead) fry was recorded for each pothole during every round of observations. The maximum number of trapped fry recorded for a pothole during the entire test day was used as the number of trapped fry for that day. Numbers of stranded fry were added over all observations for the day. Date and time of day of each pothole observation was noted for comparison of pothole hydraulics with the flow record based on USGS gaging stations at Newhalem and Marblemount. Maximum depth, average depth, average length, and average width of the pothole were recorded during each round of observations; these variables were included to calculate pothole volume and to gain information on hydraulic response of potholes to changes in river discharge. Pothole water temperatures (^{o}F) were recorded during each round of observations to assess potential mortality due to rising water temperature on sunny days.

River temperature was also recorded for comparison with pothole temperatures to aid in evaluating to what extent potholes are recharged with fresh river water during an increasing river discharge. The presence or absence of seepage flow through the gravel was also noted to further assess pothole hydraulics. Observers were also responsible for recording cover and substrate types of all potholes. Cover and substrate codes were established to aid in regression analyses against trapped and stranded number of fry.

During the fall and high flow pothole surveys, river staff gages were installed at the major pothole areas. These gages were surveyed against 'permanent' benchmarks which were also installed at major pothole areas. Most of the benchmarks consisted of a spike which was driven into the largest tree

Site No. and Name Collectors(s) Date

Observed from ____hrs. to ____hrs. Weather________________River Temp. ____°____

L-120-60(7-84)

PH #	TIME	RMPT FLOW	HARD FLOW	MEAN FLOW	AMPL FLUCT	DWNRP TIME	MAX DEPTH	AVE DEPTH	LENGTH	WIDTH	VOL	TEMP	COV.	SUBST 1°/2°	FRY TRAP	FRY STRND	ADJ TRAP	SEEPAGE	RIVER GAGE	STAFF GAGE (Ft)	

CODES: COV. - 0-root wad, 1-roots, 2-sticks, limbs, 3-logs, 4-boulder/rock, 5-submerged veg., 6-overhanging veg., 7-no cover
SUBST. - 1-silt, 2-sand, 3-pea gravel, 4-gravel (1/2-4"), 5-cobble (over 4")

PROFILE, X-SECTION, SKETCH, and/or GENERAL DESCRIPTION: (use back of sheet)

FIGURE 3-1. FIELD DATA FORM FOR POTHOLE SURVEYS, FALL, 1984, SKAGIT RIVER nearby. Locations of all river gages and benchmarks are shown in the pothole area maps (Appendix B). River gages were read at least once during each round of pothole observations. Also, staff gages were installed in all identified potholes to further aid in determining hydraulic response of potholes to changing river discharge. Pothole staff gages consisted of 3/8 inch rebar to which were attached yardsticks or plastic tape marked in one-hundredth foot gradations. Pothole gage measurements were recorded during every round of observations.

Spring Pothole Surveys. Surveys of pothole areas were conducted on 14 days during the period from March 11 through May 18, 1984. The surveys were carried out at gravel bar and slough areas identified during the March 9 and 10 reconnaissance surveys. In order to facilitate data compilation, the survey areas were given names: Rockport Bar (RM 67.5), Wayne's Swim (RM 68.1), Tin Shack (RM 68.3), Bad Spot (RM 70.0), Eagle Bar (RM 70.1), Forbidden Bar (RM 70.5), Hooper's Slough (RM 72.7), and Big Eddy (RM 77.5). A number of pothole areas were added to or deleted from the survey based on early fry trapping and stranding results. For example, Big Eddy (RM 77.5) was dropped from the survey when no fry trapping or stranding was observed. Additionally, four pothole survey areas: Stump Haven (RM 72.2), Inaccessible Island (RM 73.1), Fungus Bar (RM 78.5), and Bacon Creek (RM 82.6) were added, bringing the total of survey areas to 11. With the exception of Inaccessible Island and Bacon Creek, all study areas were surveyed during the downramping events of April 1, 7, 8, 21, 28 and May 3, 4, 11, 12, 17, 18, 1984 (Table 3-1). Inaccessible Island was surveyed only when a boat was available.

Fall Pothole Surveys. The low flow reconnaissance surveys of August 15 and 16 revealed pothole areas in addition to those surveyed during the spring. Rick's Surprise (RM 73.0), Carnage Bar (RM 73.3), Big Eddy (RM 77.5), Marblemount Slough (RM 78.2), Oink Bar (RM 82.9), and Driftwood Bar (RM 83.0) were land accessible; observers were assigned to these areas during most of the downramping tests (Table 3-2). The 'boat accessible only' areas were sampled on those dates when a jet boat was available. A total of 17 land-accessible areas were surveyed over 12 test dates with an additional 10 boat-accessible areas which were surveyed over five test dates. The fall surveys were conducted over 12 test dates grouped into six replicated (2-day) tests. Each pair of tests received the same discharge from Gorge Powerhouse with similar downramp times.

Test Flow Conditions

Test flows from the Gorge Powerhouse covered a wide range of flow conditions. Further, as required in the Interim Flow Agreement, downramping was usually completed at least 6.5 hours before dawn at Gorge Powerhouse. Due to the lag time from Gorge Powerhouse to Rockport, the effects of downramping at the lower end of the study area extended 1/2 hour to 3 hours into the morning daylight hours on 6 of the 12 tests during the fall

Table 3-1. Sampling Frequency During the Spring Fish Stranding Study, 1984

STUDY AREA	SPRING SURVEY DATES 3-11	3-24	3-31	4-1	4-7	4-8	4-21	4-28	5-3	5-4	5-11	5-12	5-17	5-18
Rockport (RM 67.5)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Wayne's Swim (RM 68.1)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Tin Shack (RM 68.3)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Bad Spot (RM 70.0)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Eagle Bar (RM 70.1)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Forbidden Bar (RM 70.5)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Stump Haven (RM 72.2)	-	-	x	-	x	x	x	x	x	x	x	x	x	x
Rooper's Slough (RM 72.7)	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Inaccessible Island (RM 73.1)	-	-	a	-	a	a	-	a	a	-	-	-	-	-
Fungus Bar (RM 78.5)	-	x	x	x	x	x	x	x	x	x	x	x	x	x
Bacon Creek (RM 82.6)	-	-	x	x	x	x	-	x	x	-	x	-	x	-

- = No observations.
a = Single observation per pothole/day.
x = More than two observations per pothole/day.

Table 3-2. Sampling Frequency During the Fall Fish Stranding Study, 1984

STUDY AREA	FALL SURVEY DATES													
	8-15*	8-16*	8-22	8-23	8-31	9-1	9-6	9-7	9-13	9-14	9-20	9-21	9-27	9-28
Rockport (RM 67.5)**	-	-	x	x	x	x	x	x	x	x	x	x	x	x
Wayne's Swim (RM 68.1)**	-	-	x	x	x	x	x	x	x	x	x	x	x	x
Tin Shack (RM 68.3)**	-	-	x	x	x	x	x	x	x	x	x	x	x	x
Bad Spot (RM 70.0)**	a	-	x	x	x	x	x	x	x	x	x	x	x	x
Eagle Bar (RM 70.1)**	a	-	x	-	x	x	x	x	x	x	x	x	x	x
Forbidden Bar (RM 70.5)**	a	-	x	x	x	x	x	x	x	x	x	x	x	x
Stump Haven (RM 72.2)**	a	-	x	x	x	x	x	x	-	-	x	x	x	x
Model Pothole (RM 72.6)	a	-	-	a	-	-	a	-	-	-	a	a	a	-
Hooper's Slough (RM 72.7)**	a	-	a	x	x	x	x	x	x	x	x	x	x	x
Rick's Surprise (RM 73.0)	a	-	-	a	-	a	-	x	x	x	x	x	x	x
Inaccessible Island (RM 73.1)**	a	-	a	a	-	a	-	x	x	x	x	x	x	x
Carnage Bar (RM 73.3)	a	-	-	x	x	x	x	x	x	x	x	x	x	x
Dry Bar (RM 74.2)	a	-	-	a	-	-	a	-	-	-	-	-	a	-
North O'Brians Ferry (RM 76.0)	a	-	-	a	-	-	-	-	-	-	-	-	a	-
Seclusion Island (RM 76.3)	a	-	-	a	-	-	a	-	-	-	a	a	a	-
Big Eddy (RM 77.5)	a	-	a	a	x	x	x	x	x	x	x	x	x	x
Marblemount Slough (RM 78.2)	a	-	-	x	x	x	-	a	x	x	x	x	x	-
Fungus Bar (RM 78.5)**	-	a	x	x	x	x	x	x	x	x	x	x	x	x
Sam's Bar (RM 82.0)	-	a	-	a	-	-	-	a	-	-	-	-	a	-
Maple Bar (RM 82.5)	-	a	-	-	-	-	-	a	-	-	-	-	a	-
Bacon Creek (RM 82.6)**	-	a	a	x	x	x	a	x	x	x	x	x	x	x
Face Bar (RM 82.7)	-	a	-	a	-	-	-	a	-	-	-	-	a	-
Oink Bar (RM 82.9)	-	a	-	a	a	-	a	x	x	x	x	x	x	x
Driftwood Bar (RM 83.0)	-	a	-	a	a	-	a	x	x	x	x	x	x	x
Minibar (RM 83.3)	-	a	-	a	-	-	-	a	-	-	-	-	a	-
Flower Pothole (RM 83.5)	-	a	-	a	-	-	-	a	-	-	-	-	a	-
Copper Creek (RM 84.0)	-	a	-	a	-	-	-	a	-	-	-	-	a	-

\- = No observations.
a = Single observation per pothole/day.
x = More than two observations per pothole/day.
* = Reconnaissance survey only.
** = Areas where observations were also made during the spring, 1984.

study. However, on September 27 and 28, downramping at Gorge Powerhouse ended at 0420 in order to test the effects of "daylight" downramping.

Personnel from SCL/EAD provided SCL power control with proposed downramping target times and flows. Upper limit test flows were generally held constant during the late afternoon and evening hours prior to the downramp event. Downramping was generally begun between 2000 and 2330 hours at Gorge Powerhouse and completed within 2 hours; downramp ending times varied from 2215 to 0230 hours. The minimum test flows were usually held constant throughout the morning hours of each test day. Lower test flows were generally targeted around the minimum flows as specified in the Interim Flow Agreement; minimum discharge was 2,300 cfs during the spring surveys and 1,400 cfs during the fall surveys (Table 3-3). Downramp rate was always less than 2,000 cfs per hour (Table 3-3). Appendix G presents monthly flow histories at the Gorge Powerhouse for March through November, 1984.

It should be noted that no spring test downramp events were conducted for the test dates between April 14 and May 18, 1984, by request from the Washington Department of Fisheries. This request was made to SCL on April 11, 1984, based on WDF's contention that the low flows would potentially cause water temperatures to rise to lethal levels in the exposed potholes and that high fry mortality would result. It was SCL's opinion that the low flows that occurred during the test downramp event would likely occur anyway as a result of normal power operations, irregardless of the testing events. As a result of discussions during the April 25, 1984, Skagit River Standing Committee meeting, it was agreed that no additional downramping tests be carried out during the spring but that observers could be in the field collecting data during normal Gorge Powerhouse operations.

Data Compilation and Analysis

Data Compilation

Field data forms from the spring and fall surveys were reviewed visually to identify any inconsistencies or missing values in the data. In order to facilitate data input in the computer, as well as to adjust for changes in data collection format, data from spring survey forms were transferred to the standardized fall survey forms (Figure 3-1). In addition, pothole water depths measured in standard inches during the spring surveys were converted to the one-hundredth foot surveyors gradations used during the fall surveys.

Once all data adjustments were completed, a computer data input format was developed and data from the field forms were keypunched directly into the University of Washington Cyber computer system. Data were entered chronologically by pothole area (river mile) and pothole number. Each data record

Table 3-3. Discharge Rates and Downramp Times at Gorge Powerhouse During Fish Stranding Surveys, 1984

TEST DATE	DOWNRAMPING TIME BEGIN	DOWNRAMPING TIME END	DISCHARGE (CFS) BEGIN	DISCHARGE (CFS) END	OVERALL DOWNRAMP RATE (CFS/HOUR)	DOWNRAMP RATE DURING FIRST HOUR*
3-11	2200	0100	5162	2359	934.3	478.0
3-24	2200	0030	5854	2315	1415.6	1578.0
3-31	2215	0030	4514	2304	982.2	1081.0
4-1	2145	2345	4514	2304	1105.0	1222.0
4-7	2000	2345	6190	2337	1027.5	1180.0
4-8	2130	0000	5637	2304	1333.2	1361.0
4-21	--	--		2029	--	--
4-28	--	--		2418	--	--
5-3	--	--		3610	--	--
5-4	--	--		3565	--	--
5-11	--	--		1880	--	--
5-12	--	--		1700	--	--
5-17	2115	2215	4208	3357	851.0	851.0
5-18	2115	2215	4140	3201	939.0	939.0
8-15**	2145	0030	5561	1441	1498.2	1489.0
8-16	2145	0100	6442	1441	1538.8	2071.0
8-22	2145	2315	2730	1660	713.3	980.0
8-23	2200	2300	2718	1650	1068.0	1058.0
8-31	2215	0030	4259	1441	1252.4	1457.0
9-1	2030	2315	4242	1450	1015.3	1644.0
9-6	2330	0200	3565	1477	835.0	1327.0
9-7	2200	0015	3565	1459	936.0	1135.0
9-13	0030	0230	3565	1414	1075.5	1171.0
9-14	0015	0215	3550	1423	1063.5	1367.0
9-20	0000	0130	3580	1432	1432.0	1850.0
9-21	2315	0100	3590	1441	1228.0	1880.0
9-27	0245	0430	3700	1423	1301.1	1473.0
9-28	0300	0430	3550	1432	1412.0	1540.0

* - The maximum hourly downramp rate is 2,000 cfs/hour as required under the Interim Flow Agreement.

** - Reconnaissance survey; no formal field tests conducted.

contained two 80-column card images, which included 43 separate descriptive items. A copy of the data form and description of parameters is presented in Appendix D. All data, including those collected during reconnaissance surveys and high flow pothole surveys (except for a stretch of the river from Alma Creek to Newhalem), were entered into the complete data file.

River flow data from USGS gages at Newhalem and Marblemount, plus a predicted flow at Rockport, were entered for each pothole field observation. Additional flow data were also entered for the 3 days preceeding each field observation.

Quality Control

Data entered into the Cyber computer were reviewed and checked by the following methods:

- Checks built into FORTRAN programs developed for data compilation and locating incorrect values, such as dates within the data files.
- Use of BMDP package programs which display the maximum, minimum, and frequency distribution of each variable to check for any out-of-range or invalid values.
- Visually checking both character and numeric variables in summaries of each pothole area.

Additionally, incorrect variables were also identified when data were summarized for the Master Data Set.

Programming

FORTRAN programming was an important element of the study. Programs were developed for the purposes of: 1) data checking; 2) integrating river flow data into pothole records; 3) preparing mortality files defined by site, date, and pothole; 4) compiling a master data file consisting of one observation per pothole per day; and 5) providing consistent cover and substrate codes for each pothole as well as high and low flows for each day.

Data Analysis

The mortality files and master data files were utilized to prepare summary accounts of measured parameters and to carry out statistical analyses of those parameters. Data in both files were subjected to the following analyses:

- General factor analysis to investigate the associations between a number of variables in the data set. This analysis served as an exploratory tool, highlighting variables and relationships which merited further testing.

- Multiple regression analysis and logistic regression analysis of fry trapping and stranding vs. flows at the Newhalem and Marblemount gages and modeled flows at Rockport. This analysis was to determine the relationship of flows at various gaging stations to trapping and stranding results.

- Multiple regression analysis of flow history (for 24 hours and 72 hours preceeding each downramp event) vs. fry trapping. Flow history consisted of five variables: mean daily flow for the 24 hours prior to the test, maximum downward amplitude for the 24 hours prior to the test, mean downward amplitude for the 72 hours preceeding the test, mean daily flow for the previous 72 hours, and the maximum daily downward amplitude for the previous 72 hours.

- Linear regression of amplitude for previous 24 hours vs. fry trapping and stranding. Two definitions of amplitude were presented and subsequently tested: 1) amplitude 1 was defined as the difference between the discharge at Gorge Powerhouse immediately preceeding downramping and the resultant lower test flow after downramping; 2) amplitude 2 was defined as the difference between the maximum discharge measured at Gorge Powerhouse within 24 hours prior to downramping and the resultant lower test flow after downramping. It was felt that this approach would help to determine whether trapping or stranding was more a function of actual downramping or of flow history prior to downramping.

- Determination of the relationship of cover and substrate to fry trapped and stranded. This analysis was to determine whether cover or substrate type affect fry trapping and/or stranding.

- Multiple regression analysis of river flows at Newhalem, Marblemount, and Rockport to the lowest maximum pothole depth of the day.

- Regression of fry trapping during spring and fall with date and flow. The intent of this analysis was to determine any relationship of incidence of trapping to calendar date. Dates were 'adjusted' by Marblemount flow in order to alleviate possible seasonal confounding of flow by date.

- Regression of ramping rate of each test vs. trapping and stranding for the entire river.

- Determination of flows at which surveyed potholes connect and disconnect from the river as a result of downramping and flow releases at the Gorge Powerhouse.

- Determination of the number of dry potholes based on 24 hours maximum amplitude at Marblemount and Rockport gaging locations.

- A regression of ramping rate of each test vs. fry trapping and stranding.

- A cursory examination of the timing of downramping vs. steelhead fry trapping.

Standard statistical programs from the BMDP and SPSS packages were used to conduct a majority of the analyses.

River Flow Analyses

River flow data from existing USGS gaging stations at Newhalem and Marblemount were assigned to 19 of the 32 pothole areas between Rockport and Newhalem. The Newhalem flows were assigned to four pothole areas and the Marblemount flows assigned to 15 pothole areas. Because of significant tributary inflow to the Skagit River between the Cascade River and Rockport, as well as differential lag in the river response downstream to an event at the powerhouse, it was determined that gaged river flows at Marblemount could not be assigned to the 13 remaining areas near Rockport without significant error in analysis.

In order to provide for a more accurate analysis of flows in the Rockport area, a flow model was developed utilizing data from the Newhalem and Marblemount gaging stations for calibration, employing a Gaussian filter and assuming that the tributary inflow between Marblemount and Rockport is 0.94 of the runoff between Newhalem and Marblemount (Crumley and Stober 1984). The model predicted both. The Gaussian filter was tested between the gaged Newhalem and Marblemount stations and then applied to the flow between Marblemount and Rockport. Appendix C explains in detail the development, assumptions, and outcome of the model.

River flow data for all test dates were entered into a computer file. Flow data from USGS 1984 flow records were entered in 15-minute increments beginning at midnight of each test day and continuing to midnight of the following day. Flow data for paired tests were entered for the entire 2-day period. These data were for two gaged locations and one modeled location on the river -- Newhalem, Marblemount, and Rockport (modeled flows since there is no gaging station at Rockport). The flow data in 15-minute increments were tied to a comparable field observation time at each pothole area. For example, if a field observer noted water beginning to enter pothole number 15 at Stump Haven at 0815, the flow records would indicate the gaged flow of that same time at Newhalem, Marblemount, or modeled flow at Rockport. Adjustments were made to account for lag time between the three gaging sites.

Without the benefit of either gaging stations at each area or a sophisticated hydraulic model of the river, an exact river flow at each study area at a particular time could not be achieved because of: 1) the effects of tributary inflow between each study area and the nearest gaging station, and 2) the distance and lag time between a gaging station and a particular study area. This method, however, could give a reasonable estimate of flow conditions at those study areas closest to gaging stations with less accuracy at those areas further downstream.

The detailed gaged flow records at the Gorge Powerhouse and from Marblemount provided information on average daily discharge, downramp amplitudes, minimum test flows, and ramping rates. Information on connecting flows at each pothole were derived from the 15-minute interval flow records.

4. STUDY RESULTS

Pothole Distribution and Characteristics

Potholes from Rockport (RM 67.5) to Gorge Powerhouse were surveyed during the spring, in the summer-fall period, and again in November, 1984. Table 4-1 shows the number of potholes surveyed by pothole area and river mile.

The general locations of pothole areas on the river from Rockport (RM 67.5) to Alma Creek (RM 84.0) are shown on the Pothole Index Map in Appendix B. Appendix B also includes detailed maps showing the locations of potholes at each area.

Pothole areas could be generally characterized by two descriptive classifications: 1) side channels/sloughs to the Skagit River, and 2) gravel bars. Because of the dynamic nature of the river, it was not unusual for areas to have a mix of characteristics from both classifications thereby confounding attempts to standardize pothole summary information for statistical analysis.

Pothole areas considered as side channels/sloughs were those where potholes were found in a linear pattern within or immediately adjacent to a definable channel that received water from the main river at certain flows. Examples of areas considered as side channels/sloughs included Stump Haven (RM 72.2), Hooper's Slough (RM 72.7), Inaccessible Island (RM 73.1), and Bacon Creek (RM 82.6).

Pothole areas characterized as gravel bars were those where potholes were more randomly scattered over gravel areas and were often created by log debris. Examples of areas considered as gravel bars included Bad Spot (RM 70.0), Model Pothole (RM 72.6), and Oink Bar (RM 82.9).

Substrate type was determined for all potholes surveyed during the spring and fall. Figure 4-1 indicates the substrate types for all 242 potholes (the 130 potholes common to both spring and fall plus 112 additional potholes identified during the fall surveys). Sand (31 percent of all potholes) and gravel (30 percent) were predominate substrate types, with silt (24 percent), cobble (11 percent), and pea gravel (5 percent) constituting the remainder.

Spring Surveys

Pothole surveys during the spring generally were conducted on the lower 15 miles of the study area from Rockport (RM 67.5)

Table 4-1. Potholes Surveyed and Reconnaissanced Spring, Fall, and November, 1984

STUDY AREA	TOTAL NUMBER OF POTHOLES SURVEYED SPRING, 1984*	TOTAL NUMBER OF POTHOLES SURVEYED FALL, 1984*	POTHOLES RECONNAISSANCED ONLY DURING NOVEMBER, 1984**
Rockport (RM 67.5)	8	31	2
Wayne's Swim (RM 68.1)	12 (1)	20 (1)	2
Tin Shack (RM 68.3)	17 (7)	17 (5)	3
Bad Spot (RM 70.0)	17 (9)	20 (12)	2
Eagle Bar (RM 70.1)	11	18	4
Forbidden Bar (RM 70.5)	9	6	3
J. R. Bar (RM 71.1)	-	-	6
Beaver Island (RM 71.4)	-	-	2
Stump Haven (RM 72.2)	20	28	6
Model Pothole (RM 72.6)	-	4	1
Hooper's Slough (RM 72.7)	10	12	1
Rick's Surprise (RM 73.0)	-	4	0
Inaccessible Island (RM 73.1)	12	14	4
Carnage Bar (RM 73.3)	-	2	0
Power Bar (RM 74.0)	-	-	4
Dry Bar (RM 74.2)	-	3	1
North O'Brians Ferry (RM 76.0)	-	3	0
Seclusion Island (RM 76.3)**	-	2 (2)	6
Big Eddy (RM 77.5)	-	9	5
Teflon Bar (RM 77.7)	-	-	2
Marblemount Slough (RM 78.2)	-	2	4
Rainier Bar (RM 78.3)	-	-	1
Fungus Bar (RM 78.5)	10	15 (1)	4
Sam's Bar (RM 82.0)	-	1	0
Maple Bar (RM 82.5)	-	4	0
Bacon Creek (RM 82.6)	4	9	8
Face Bar (RM 82.7)	-	3	0
Oink Bar (RM 82.9)	-	6	1
Driftwood Bar (RM 83.0)	-	3	1
Minibar (RM 83.3)	-	3	0
Flower Pothole (RM 83.5)	-	1	0
Copper Creek (RM 84.0)	-	2	0
Alma Creek to Goodell Creek (RM 85.0 to RM 92.8)**	-	-	67
	130 (17)	242 (21)	140

- Not surveyed.
( ) Indicates the number of high flow potholes surveyed. High flow potholes are those known to stay disconnected from the river during the duration of the study.
* Total number includes high flow potholes surveyed during spring and fall 1984.
** See Appendix E for detailed description of these potholes.

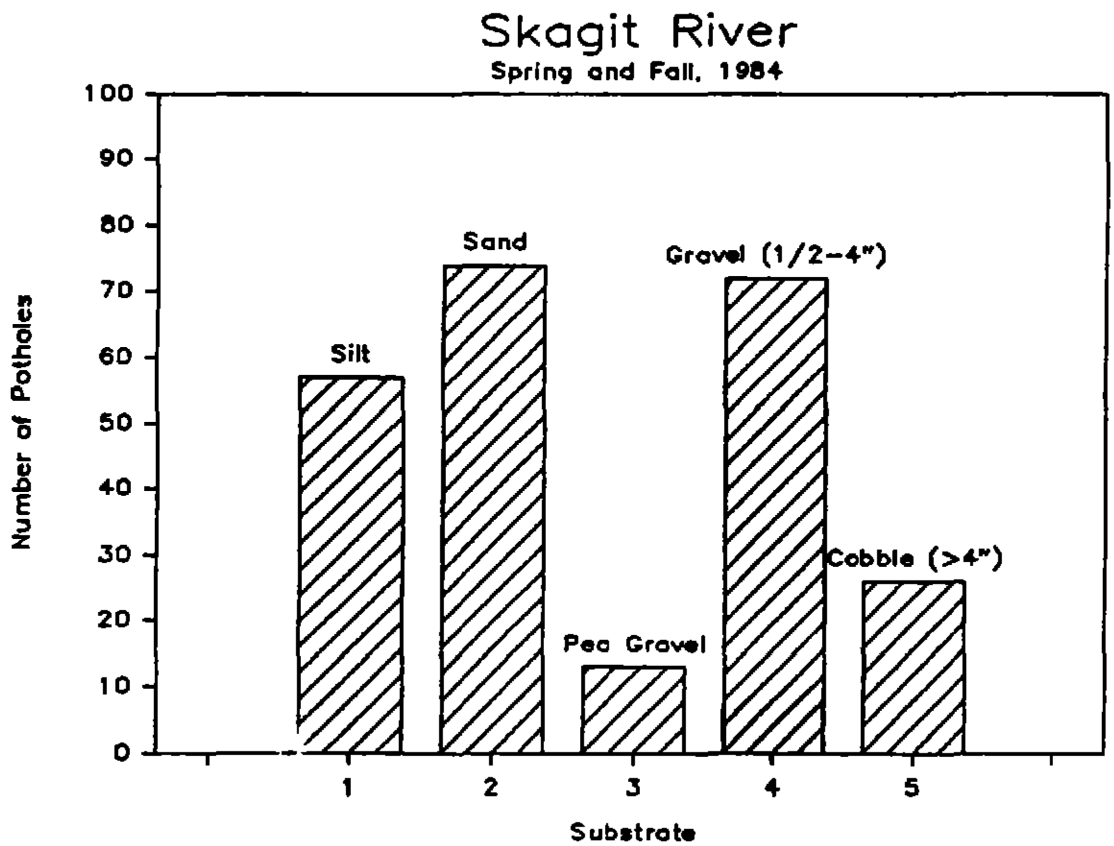


FIGURE 4-1. PRIMARY SUBSTRATE TYPES OF POTHOLES SURVEYED SPRING AND FALL, 1984, SKAGIT RIVER

to Bacon Creek (RM 82.6). A total of 130 potholes were regularly surveyed, of which 104 (80 percent) were located between Rockport and Illabot Slough, a distance of approximately 5.2 miles (Table 4-1). On test dates when a jet boat was available, that portion of the river upstream of Bacon Creek was surveyed. A number of potentially important pothole areas were identified and surveyed; Agg Pond Bar (RM 91.3) was surveyed on three occasions with no stranding observed.

Of the 130 potholes regularly surveyed, 17 were determined to be high flow potholes, those potholes which were observed to be disconnected from the river during the test periods. For the purpose of data analysis, those 17 potholes were evaluated separately.

Table 4-2 summarizes the potholes at each study area and the number of potholes found to trap and strand fry. Of the 113 potholes (excluding the 17 high flow potholes) surveyed during the spring, 95 (84 percent) trapped fry while 33 (29 percent) stranded fry. Within pothole study areas, percentages of potholes trapping fry ranged from 50-100 percent, while percentages of potholes stranding fry ranged from 0-63 percent. Figure 4-2 indicates that there was no apparent linear relationship between the total number of potholes, number of potholes trapping fry, or number of potholes stranding fry by study area with river mile. However, with the exception of two areas: Stump Haven and Fungus Bar, there appears to be a relationship between total number of potholes by study area and number of potholes trapping and stranding fry.

Fall Surveys

Numbers of potholes and study areas in the fall period were greatly increased over those surveyed in the spring. A total of 242 potholes were surveyed between Rockport (RM 67.5) and Copper Creek (RM 84.0), of which 176 (73 percent) were located between Rockport and Illabot Slough (5.2 miles). Of the 242 potholes surveyed, 21 were high flow potholes and analyzed separately in this report.

Table 4-3 summarizes the potholes at each study area and the number of potholes observed to trap and strand fry. Of the 221 potholes (excluding the 21 high flow potholes) surveyed during the fall, 99 (45 percent) trapped fry while 39 (18 percent) stranded fry. Within study areas, percentages of potholes which trapped fry and stranded fry varied from 0-100 percent. Figures 4-3 and 4-4 indicate the relationships of potholes that trapped and stranded fry during the fall by river mile. The total number of potholes by study area decreased moving upriver, probably due to the increase in gradient and narrower river channel and floodplain. There was a general tendency of increased numbers of potholes which trapped and stranded fry with increased numbers of potholes by study area, though not as pronounced as was observed for the spring survey.

Table 4-2. Summary of Potholes With Trapped and Stranded Fry by Area, Spring 1984*

STUDY AREA	TOTAL NUMBER OF POTHOLES	NUMBER OF POTHOLES WITH TRAPPED FRY	PERCENT OF POTHOLES TRAPPING FRY	NUMBER OF POTHOLES WITH STRANDED FRY	PERCENT OF POTHOLES STRANDING FRY
Rockport (RM 67.5)	8	6	75	4	50
Wayne's Swim (RM 68.1)	11	8	73	2	18
Tin Shack (RM 68.3)	10	5	50	3	30
Bad Spot (RM 70.0)	8	7	88	5	63
Eagle Bar (RM 70.1)	11	11	100	6	55
Forbidden Bar (RM 70.5)	9	8	89	3	33
Stump Haven (RM 72.2)	20	16	80	2	10
Hooper's Slough (RM 72.7)	10	9	90	3	30
Inaccessible Island (RM 73.1)	12	12	100	3	25
Fungus Bar (RM 78.5)	10	9	90	0	0
Bacon Creek (RM 82.6)	4	4	100	2	50
TOTALS	113	95	-	33	-
PERCENTAGE			84		29

* Excludes high flow potholes (those potholes never observed connected to the Skagit River during the test period).

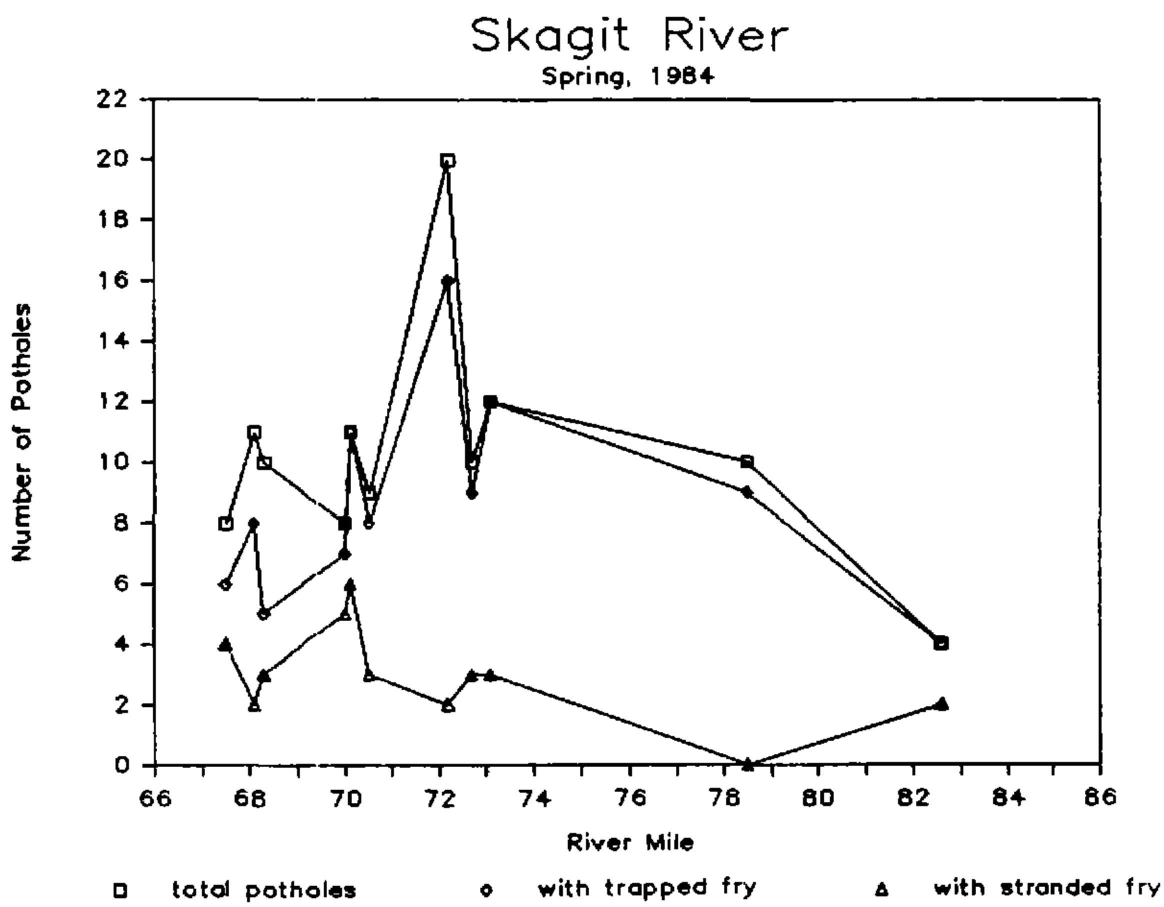


FIGURE 4-2. RELATIONSHIP OF THE TOTAL NUMBER OF POTHOLES BY STUDY AREA (RIVER MILE) TO POTHOLES THAT TRAPPED AND STRANDED FRY, SPRING, 1984, SKAGIT RIVER

Table 4-3. Summary of Potholes With Trapped and Stranded Fry by Area, Fall 1984*, **

STUDY AREA	TOTAL NUMBER OF POTHOLES	NUMBER OF POTHOLES WITH TRAPPED FRY	PERCENT OF POTHOLES TRAPPING FRY	NUMBER OF POTHOLES WITH STRANDED FRY	PERCENT OF POTHOLES STRANDING FRY
Rockport (RM 67.5)	31	7	23	3	10
Wayne's Swim (RM 68.1)	19	13	68	3	16
Tin Shack (RM 68.3)	12	3	25	1	8
Bad Spot (RM 70.0)	8	5	63	2	25
Eagle Bar (RM 70.1)	18	3	17	2	11
Forbidden Bar (RM 70.5)	6	3	50	1	17
Stump Haven (RM 72.2)	28	20	71	9	32
Model Pothole (RM 72.6)	4	2	50	0	0
Booper's Slough (RM 72.7)	12	9	75	2	17
Rick's Surprise (RM 73.0)	4	2	50	0	0
Inaccessible Island (RM 73.1)	14	3	21	0	0
Carnage Bar (RM 73.3)	2	2	100	2	100
Dry Bar (RM 74.2)	3	0	0	0	0
North O'Brians Ferry (RM 76.0)	3	0	0	0	0
Seclusion Island (RM 76.3)	***	***	***	***	***
Big Eddy (RM 77.5)	9	8	89	7	78
Marblemount Slough (RM 78.2)	2	1	50	0	0
Fungus Bar (RM 78.5)	14	5	36	2	0
Sam's Bar (RM 82.0)	1	0	0	0	22
Maple Bar (RM 82.5)	4	0	0	0	33
Bacon Creek (RM 82.6)	9	5	56	2	33
Face Bar (RM 82.7)	3	1	33	1	0
Oink Bar (RM 82.9)	6	5	83	2	0
Driftwood Bar (RM 83.0)	3	0	0	0	0
Minibar (RM 83.3)	3	1	33	0	0
Flower Pothole (RM 83.5)	1	0	0	0	0
Copper Creek (RM 84.0)	2	1	50	0	0
TOTALS	221	99	-	39	-
PERCENTAGE			45		18

* Excludes high flow potholes (those potholes never observed connected to the Skagit River during the test period).
** Excludes results of 8/15 reconnaissance survey.
*** All potholes tested were high flow potholes.

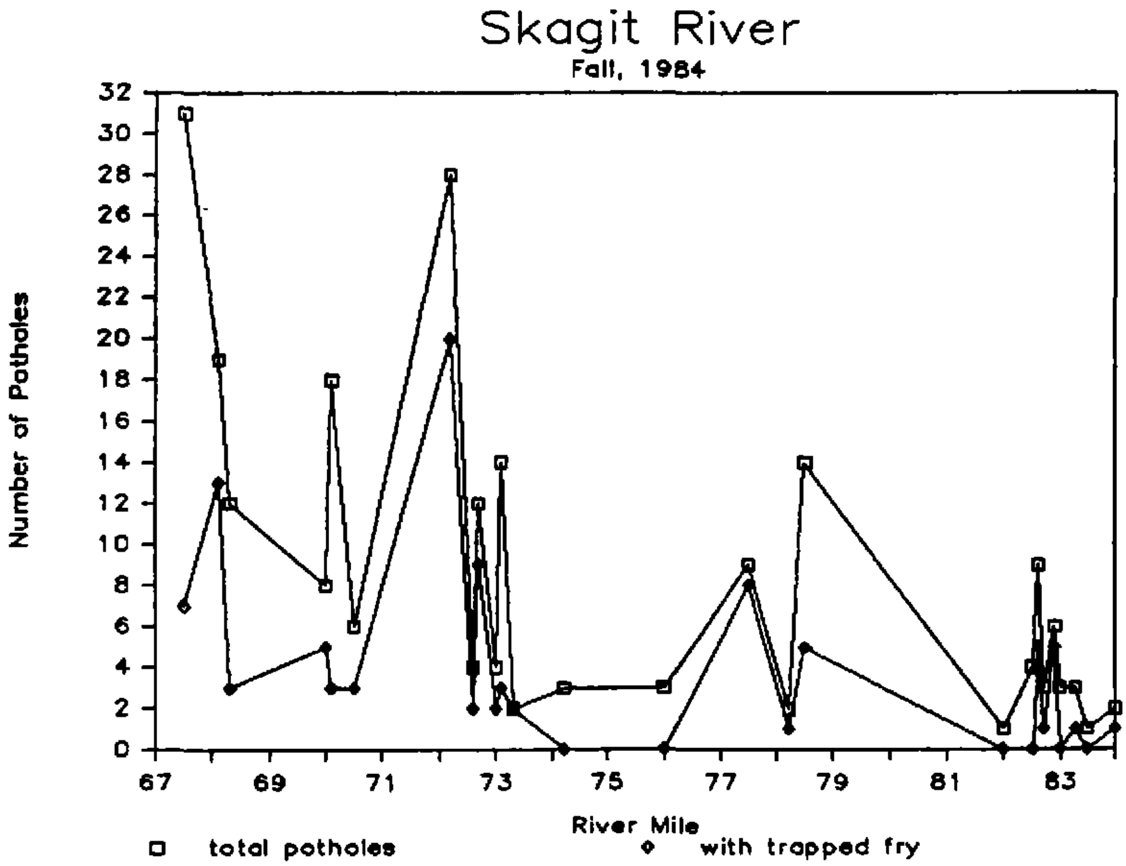


FIGURE 4-3.

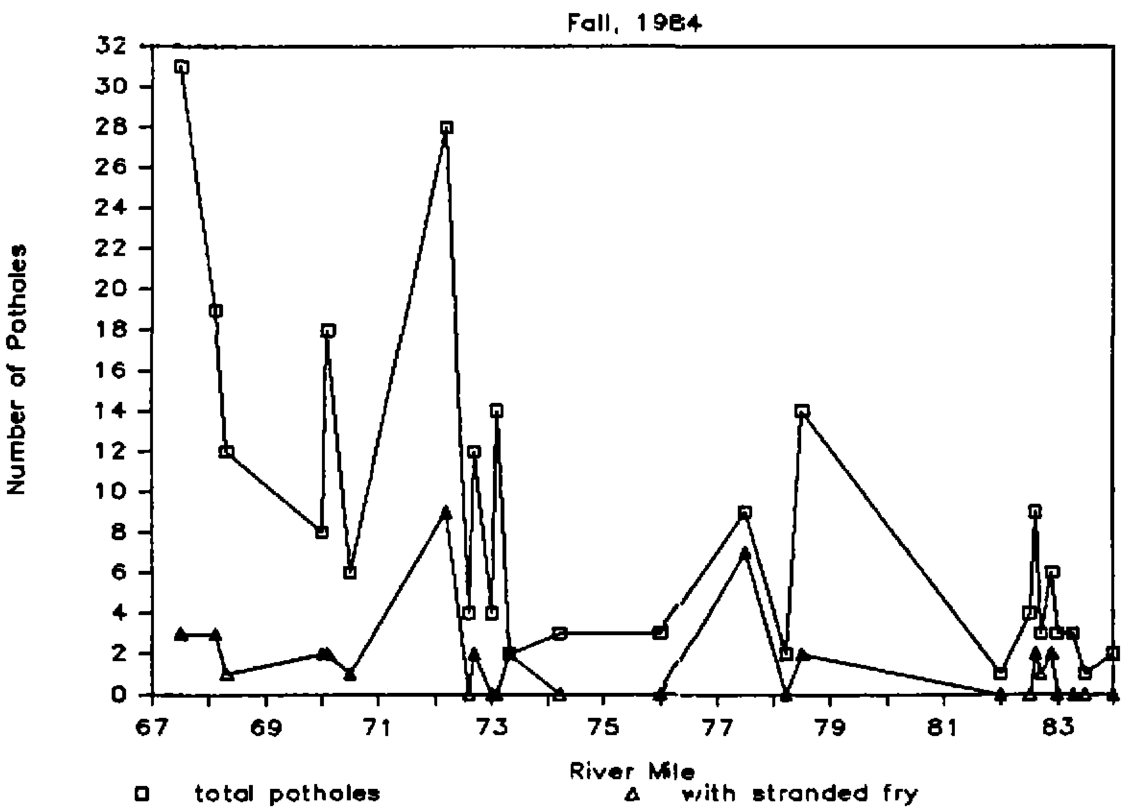


FIGURE 4-4.

FIGURES 4-3 and 4-4. RELATIONSHIPS OF THE TOTAL NUMBERS OF POTHOLES BY STUDY AREA (RIVER MILE) TO POTHOLES THAT TRAPPED FRY AND STRANDED FRY, FALL, 1984, SKAGIT RIVER

November High Flow Pothole Reconnaissance

During November, 1984, reconnaissance surveys were conducted to identify potholes occurring at very high river flows. The reconnaissance covered the lower river from Rockport to Bacon Creek and the upper river from Alma Creek to Newhalem. A total of 140 high flow potholes were observed. No potholes were found between Alma Creek and Damnation Creek. Table 4-1 indicates the number and location of high flow potholes. Maps in Appendix B and the table in Appendix E provide detailed locations and information regarding the high flow potholes. Because these potholes were surveyed only in November, no fry trapping or stranding data were collected and no statistical analyses applied. Figure 4-5 indicates the substrate types for 140 high flow potholes surveyed during November. Silt was the more common substrate (40 percent of all potholes), followed by sand (31 percent), cobble (27 percent), and pea gravel and gravel (each approximately 1 percent).

On the 25 miles of river surveyed for high flow potholes, 67 (48 percent) of the 140 potholes located occurred in the upper river from Alma Creek to Goodell Creek (7.8 miles). The remaining 73 potholes were scattered from Rockport to Driftwood Bar (RM 83.0), a distance of 15.5 miles.

Fry Trapping and Stranding

The focus of the data analysis was to determine the relationship of a number of physical and spatial variables to fry trapping and stranding. The relationship of trapping with these variables was treated directly, with trapping itself as the independent variable. Numbers of fish stranded is meaningful only as a proportion of fish originally trapped, i.e., the number of fish who die out of the number of fish at risk. For that reason all relationships of stranding to flow and pothole conditions were treated as conditional probabilities, modeling the logistic transform of the ratio of stranding to trapping as a function of the variables of interest.

The variables investigated were river mile; julian date; the maximum depth of a pothole at its deepest point for any given day; the length and width of the pothole; the maximum pothole temperature; the river gage reading; the flow code, which is an integral code related to river mile and assigned to either Newhalem, Marblemount, or Rockport; the flow at which each pothole becomes connected to the river; the flow at which each pothole becomes disconnected from the river; the maximum flow at Newhalem just prior to downramping; the maximum flow for 24 and 72 hours prior to a test; the minimum flow at Newhalem throughout the day; the number of times the pothole was observed to be dry throughout the day; the area and the volume of the pothole; and the number of fry trapped and stranded.

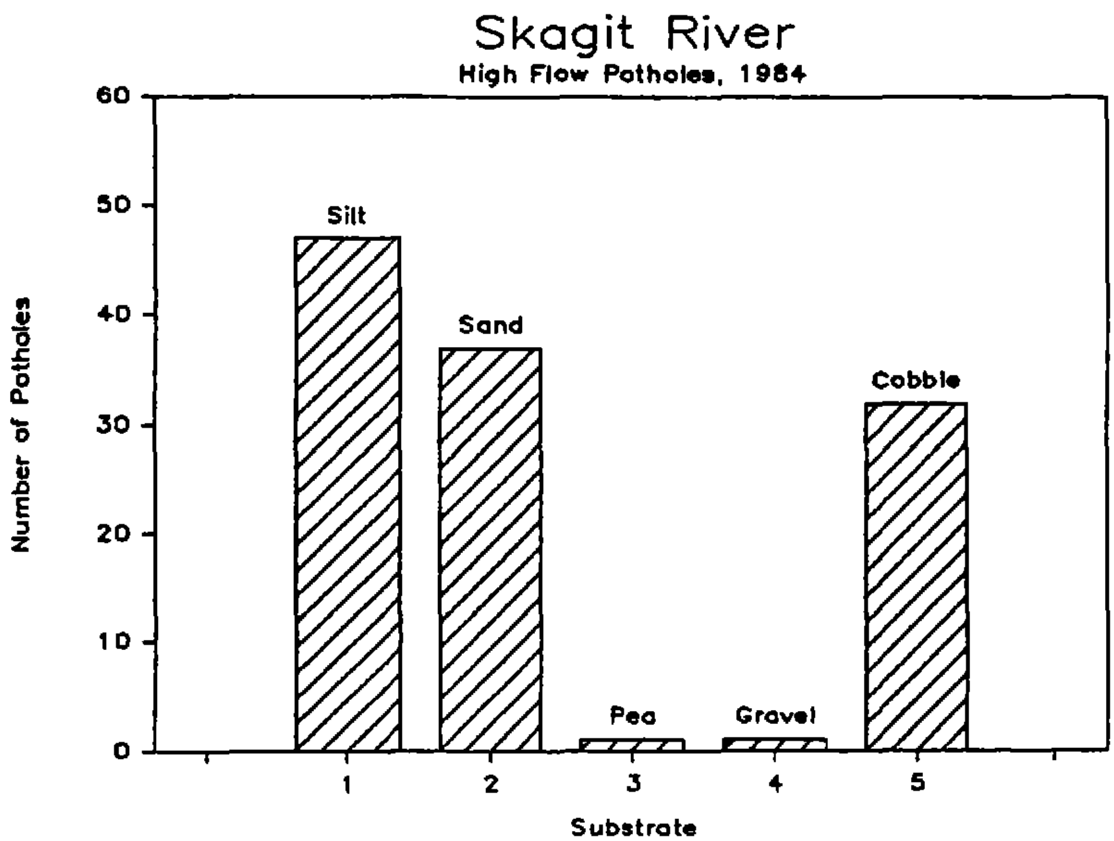


FIGURE 4-5. PRIMARY SUBSTRATE TYPES OF HIGH FLOW POTHOLES SURVEYED IN NOVEMBER, 1984, SKAGIT RIVER

Regressions of trapping and stranding/trapping on river flows, downramp amplitudes, and flow history have been done in two ways: once on the full data set, including both spring and fall, and again with spring and fall data separated. The seasonal analyses are presented herein while a discussion of the results of the full data set analyses is provided in Appendix F. In most cases, results differed when data was broken down by season. Regression effects which had been significant on the entire data set often were not significant when the smaller seasonal data sets were run or were replaced by other effects. Such changes in regression effect can have four possible interpretations: 1) the strengths of the effects of flows, amplitudes, and flow history did, in fact, change by season as reflected by the varying regression results; 2) regression results, which were weak due to large variation in the data for flows, amplitudes, or differing sample sizes; 3) severe confounding between the main effects and time changes over the seasons; and 4) all three of the above conditions were in effect.

Using the entire data set, an exploratory analysis was conducted to investigate possible inter-relationships among the range of variables (65 correlations). The output was a covariance matrix, showing pairwise covariance of all variables. This analysis was run on the entire data set (4,314 cases) and again on a set of data for which data having missing values for one or more of the aforementioned variables were excluded (50 cases).

Of the 65 variables analyzed, 48 showed a correlation coefficient of greater than .279 or less than -.279 (the range considered statistically significant at the .05 level). A number of the correlations were superfluous (e.g., length-to-area or area-to-volume relationship of potholes); however, the correlations did serve as a cross check on the validity of the value of the variables.

Of greatest interest was the correlation coefficient run to compare fry stranding with fry trapping. This analysis included all non-zero trapping and stranding results (682 cases). A non-significant correlation coefficient of .0074 was observed, with the conclusion that stranding does not increase as trapping increases.

A statistical summary of the multivariate analysis is presented in Appendix F of this report. Additional results of the statistical analyses are included in appropriate sections of this RESULTS section.

Spring Surveys

Trapping and Stranding by Area (River Mile). A summary of the number of fry trapped during the spring in potholes in the study areas is shown in Table 4-4. A total of 17,538 fry were trapped during the entire testing period from March 11 through May 18, 1985. One study area, Stump Haven (RM 72.2) trapped 30

Table 4-4. Summary of Fry Trapped and Stranded by Area, Spring 1984*

STUDY AREA	NUMBER OF TEST DATES	TOTAL NUMBER OF TRAPPED FRY	TOTAL NUMBER OF STRANDED FRY	PERCENT OF TRAPPED FRY STRANDED
Rockport (RM 67.5)	14	126	45	36
Wayne's Swim (RM 68.1)	14	1,837	15	1
Tin Shack (RM 68.3)	14	90	8	9
Bad Spot (RM 70.0)	14	1,042	88	8
Eagle Bar (RM 70.1)	14	1,604	44	3
Forbidden Bar (RM 70.5)	14	1,663	9	1
Stump Haven (RM 72.2)	11	5,304	54	1
Hooper's Slough (RM 72.7)	14	1,750	7	<1
Inaccessible Island (RM 73.1)	5	847	11	1
Fungus Bar (RM 78.5)	13	1,364	0	0
Bacon Creek (RM 82.6)	8	1,911	34	2
TOTALS		17,538	315	-
PERCENTAGE				2

* Excludes high flow potholes (those potholes never observed connected to the Skagit River during test dates).

percent of all trapped fry observed during the testing period, with one pothole trapping 63 percent (3,351 fry) of all fry trapped at that area.

Of the 11 pothole areas studied, six areas contributed to 78 percent of all trapping. All six areas are side sloughs and side channels to the river that have potholes occurring in a linear pattern.

A summary of fry stranding during the spring is presented in Table 4-4. A total of 315 fry were stranded, with 84 percent of all stranding occurring in 5 of the 11 areas studied. The areas of greatest stranding did not correspond with the areas of greatest trapping. For example, although 126 fry were observed trapped in potholes at Rockport (RM 67.5), 45 fry (36 percent) were stranded, while at Stump Haven (RM 72.2) 54 fry of 5,304 trapped (1 percent) became stranded.

Figure 4-6 indicates a negligible relationship between the number of potholes surveyed that contained trapped fry to the number of stranded fry by study area (river mile).

One common pattern of stranding between study areas was that only a few potholes accounted for a majority of the stranding. Two potholes at Bad Spot (RM 70.0) were responsible for 85 percent of the stranding at that site (Potholes 13 and 14). Stump Haven (RM 72.2), Rockport Bar (RM 67.5), and Eagle Bar (RM 70.1) are sites with large backwater areas or side channels. Ninety-three percent of all stranding at Stump Haven occurred in a large pothole (Number 15) located at the upstream end of the side channel. Rockport Bar has a relatively gradual slope which includes a number of potholes clustered near the upstream end of the slough. Nearly half of the stranding for the area (44 percent) occurred in two potholes (Potholes 1 and 3A) located near the back slough. A number of potholes are also clustered around the downstream opening into the slough, with one of those potholes (Pothole 6) accounting for 53 percent of the spring stranding mortality at that pothole area. Stranding at Eagle Bar occurred mainly in two potholes (77 percent) associated with the upper reach of the slough running through Eagle Bar (Potholes 3 and 5A).

With the exception of the Bacon Creek area (RM 82.6), the pothole areas associated with greatest spring mortality were all located between Marblemount and Rockport on the lower reach of the study area. At the Bacon Creek pothole area (located 0.3 mile downstream of the confluence of Bacon Creek and the Skagit River), two potholes located in a side channel (Potholes 1 and 2) were responsible for all of the observed stranded fry in the area. No mortality was found on Fungus Bar (RM 78.5), the only other regularly surveyed study area located upstream from Marblemount.

<u>High Flow Potholes</u>. Those high flow potholes identified during the spring as having trapped and stranded fry were

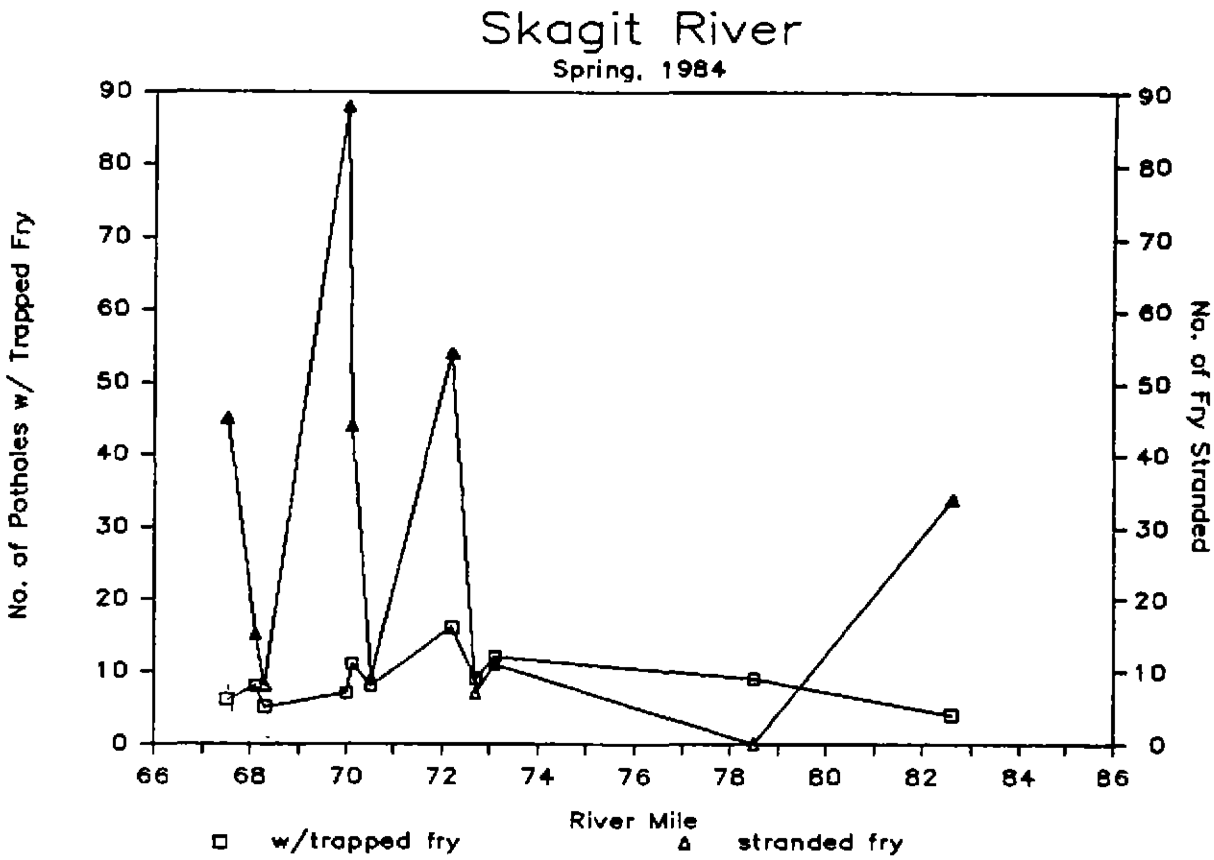


FIGURE 4-6. RELATIONSHIP OF THE NUMBER OF POTHOLES CONTAINING TRAPPED FRY TO THE NUMBER OF STRANDED FRY BY STUDY AREA (RIVER MILE), SPRING, 1984, SKAGIT RIVER

evaluated separately from the data previously presented. Two study areas, Tin Shack (RM 68.3) and Bad Spot (RM 70.0), had 14 high flow potholes with trapped and stranded fry (Table 4-5). The fry observed in those potholes were not included in the summary information shown in Table 4-4 since those fry were trapped for the duration of the study. The number of fry observed in those potholes varied from one test to another due to such factors as changes in weather and light conditions, color of the water, and movement of fry within the potholes.

It should be noted that Wayne's Swim, Pothole Number 8, was not a high flow pothole but was removed from the main analysis of potholes to be analyzed because of its large size and depth. A large number of fry continually occupied the pothole, probably because of the extremely large amount of cover present (see Pothole Area Maps - Appendix B).

Trapping and Stranding by Date. Figure 4-7 indicates the percent of total fry trapped and stranded by test date during the spring, 1984. A summary of trapping and stranding for each study area by test date is presented in Tables 4-6 and 4-7. Numbers of fry trapped and stranded by study area varied greatly between test dates. However, those study areas previously described as being associated with greater overall trapping and stranding generally showed greater trapping and stranding over more test dates. Stump Haven showed greatest daily trapping over more test dates than any other study area (36 percent). Similarly, stranding occurred at Bad Spot over more test dates than at any other study area (29 percent).

Trapping of fry was most prevalent between March 31 and April 28, with the number of fry trapped decreasing significantly during May. One common relationship occurring throughout the test period was that the number of fry trapped was less on the second day when tests were conducted on consecutive days. Those "paired" tests were conducted on five occasions throughout the study. A number of factors probably influence the number of fry trapped over time: 1) river flows prior to the test, 2) the minimum test flow, 3) downramp amplitude, 4) number of fry utilizing the test areas, and 4) the age and size of the fry. Relationships of several of these factors will be discussed in later sections of this report.

River flow at Marblemount and date were included together in a regression analysis against trapping. The Marblemount flow was used since it was most strongly related to trapping. Both flow ($t = -3.94$; $p < .001$) and date ($t = -4.05$; $p < .001$) were found to be significantly related to trapping, although the relationship was not a linear one (F value of 33.7; $p < .001$; $R^2 = .125$), as exhibited by a strong fanning pattern of the residuals (Appendix F).

Stranding of fry throughout the test period did not follow the same temporal trend established with trapping. The greatest number of stranded fry (94) for any one test were observed on the

Table 4-5. High Flow Potholes Surveyed Over 14 Test Dates, Spring 1984*

STUDY AREA	POTHOLE	MAX. NO. OF TRAPPED FRY OBSERVED	TOTAL STRANDING
Wayne's Swim (RM 68.1)	008	0	0
Tin Shack (RM 68.3)	002	150	0
	005	50	1
	006	30	0
	06B	25	0
	06C	0	0
	11A	30	0
	11B	50	0
Bad Spot (RM 70.0)	001	200	3
	002	300	2
	003	100	0
	007	12	0
	008	7	0
	009	12	0
	015	200	0
	016	0	0
	017	30	4

* High flow potholes are those known to stay disconnected from river flow during the duration of the study.

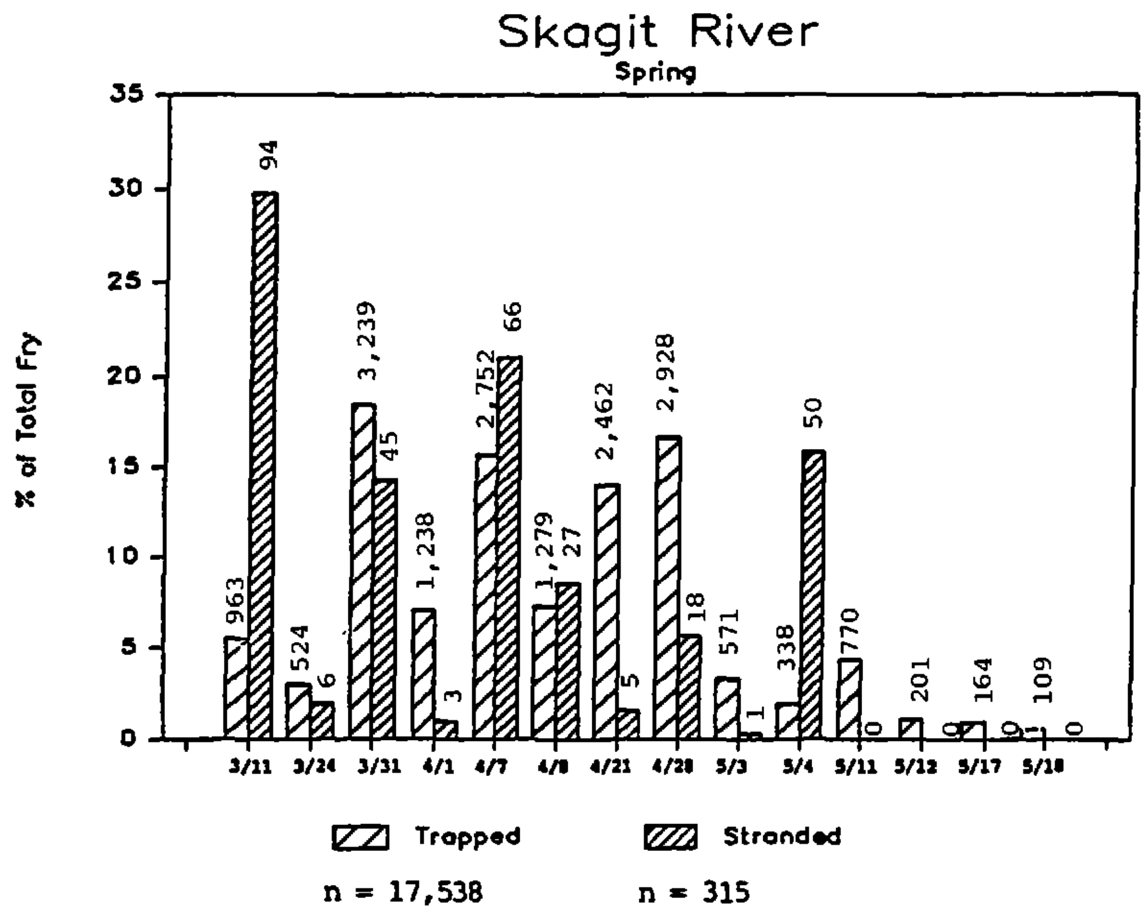


FIGURE 4-7. PERCENT OF TOTAL FRY TRAPPED AND STRANDED BY TEST DATE, SPRING, 1984, SKAGIT RIVER

Table 4-6. Fry Trapped by Test Date at Each Study Area (River Mile), Spring, 1984, Skagit River

STUDY AREA	TEST DATE 3-11	3-24	3-31	4-1	4-7	4-8	4-21	4-28	5-3	5-4	5-11	5-12	5-17	5-18	TOTAL
Rockport (RM 67.5)	25	39	28	0	30	4	0	0	0	0	0	0	0	0	126
Wayne's Swim (RM 68.1)	60	7	141	120	411	284	243	565	0	0	6	0	0	0	1,837
Tin Shack (RM 68.3)	2	38	20	7	4	12	2	1	0	0	2	2	0	0	90
Bad Spot (RM 70.0)	294	76	72	23	200	69	78	102	50	35	17	4	6	16	1,042
Eagle Bar (RM 70.1)	61	217	635	315	90	131	101	51	0	0	0	0	1	2	1,604
Forbidden Bar (RM 70.5)	85	34	105	30	62	253	186	172	160	178	180	85	122	11	1,663
Stump Haven (RM 72.2)	-	-	786	-	1,262	98	1,738	1,211	0	52	82	0	22	53	5,304
Hooper's Slough (RM 72.7)	436	100	61	45	175	168	102	316	69	7	184	85	1	1	1,750
Inaccessible Island (RM 73.1)	-	-	407	-	158	121	-	129	32	-	-	-	-	-	847
Fungus Bar (RM 78.5)	-	13	278	358	141	119	12	112	85	66	129	25	0	26	1,364
Bacon Creek (RM 82.6)	-	-	706	340	219	20	-	269	175	-	170	-	12	-	1,911
TOTALS	963	524	3,239	1,238	2,752	1,279	2,462	2,928	571	338	770	201	164	109	17,538

- No observations on that day.

Table 4-7. Fry Stranded by Test Date at Each Study Area (River Mile), Spring, 1984, Skagit River

STUDY AREA	TEST DATE 3-11	3-24	3-31	4-1	4-7	4-8	4-21	4-28	5-3	5-4	5-11	5-12	5-17	5-18	TOTAL
Rockport (RM 67.5)	10	0	15	0	16	4	0	0	0	0	0	0	0	0	45
Wayne's Swim (RM 68.1)	0	0	6	0	6	3	0	0	0	0	0	0	0	0	15
Tin Shack (RM 68.3)	0	5	3	0	0	0	0	0	0	0	0	0	0	0	8
Bad Spot (RM 70.0)	49	0	15	0	20	0	4	0	0	0	0	0	0	0	88
Eagle Bar (RM 70.1)	35	1	0	0	2	6	0	0	0	0	0	0	0	0	44
Forbidden Bar (RM 70.5)	0	0	0	0	0	9	0	0	0	0	0	0	0	0	9
Stump Haven (RM 72.2)	-	-	4	-	0	0	0	0	0	50	0	0	0	0	54
Hooper's Slough (RM 72.7)	0	0	0	3	2	1	1	0	0	0	0	0	0	0	7
Inaccessible Island (RM 73.1)	-	-	0	-	10	0	-	0	1	-	-	-	-	-	11
Fungus Bar (RM 78.5)	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bacon Creek (RM 82.6)	-	-	2	0	10	4	-	18	0	-	0	-	0	-	34
TOTALS	94	6	45	3	66	27	5	18	1	50	0	0	0	0	315

- No observations on that day.

first test date, March 11, 1984, with other stranding peaks occurring on March 31, April 7, and May 4, 1984. As with trapping, stranding of fry tended to be lower on the second day of paired tests. The one exception was on May 4 when stranding was greater on the second day of the 2-day tests. No stranded fry were observed during observations conducted after May 4.

Trapping and Stranding by Substrate Type. Figure 4-8 indicates the primary substrate type in those potholes trapping and stranding fry during the spring. Potholes with sand (38 percent of all potholes trapping fry) and gravel (28 percent) substrates trapped more fry than did potholes with silt (17 percent), cobble (12 percent), or pea gravel (5 percent). Potholes with gravel (35 percent of all potholes stranding fry) and silt (35 percent) stranded more fry than did potholes with sand (19 percent), cobble (8 percent), or pea gravel (5 percent). This result was confirmed through analyses of the data using a logistic regression analysis which showed a significant difference of the proportion of stranding to trapping among the various substrate types (Appendix F). Gravel and silt were associated with larger stranding proportions than any of the other substrate types.

Figure 4-9 indicates the number of fry trapped and stranded by substrate type. A predominance of fry were trapped in potholes with sand, followed by cobble and gravel. Of interest is the fact that although the number of potholes with cobble substrate (Figure 4-8) was less than silt or gravel, there were more fry trapped per pothole with cobble substrate than in potholes with other substrate types. More fry were stranded in potholes with silt substrate than with any other substrate type.

Trapping and Stranding by Cover Type. Figure 4-10 shows the primary cover type of potholes with trapped and stranded fry occurring during the spring. A predominance of potholes had cover (82 potholes or 75 percent) to those potholes without cover (27 potholes or 25 percent).

Figure 4-11 shows the relative number of fry trapped and stranded by cover type. Potholes with cover collectively trapped and stranded more fry than did potholes without cover. Additionally, more fry were trapped in potholes with overhead vegetation as the most common cover type. More fry were stranded in potholes containing root wads than with any other cover type.

Analyses of data for both spring and fall using a logistic regression analysis showed a significant difference of the proportion of stranding to trapping among the various cover types and also with the analysis of cover vs. no cover (Appendix F) of fry. In this analysis, cover had a positive effect on survivability (chi-square = 16.6; $p < .001$).

Pothole Temperatures. Figure 4-12 shows the frequency of maximum daily water temperatures observed in potholes during the

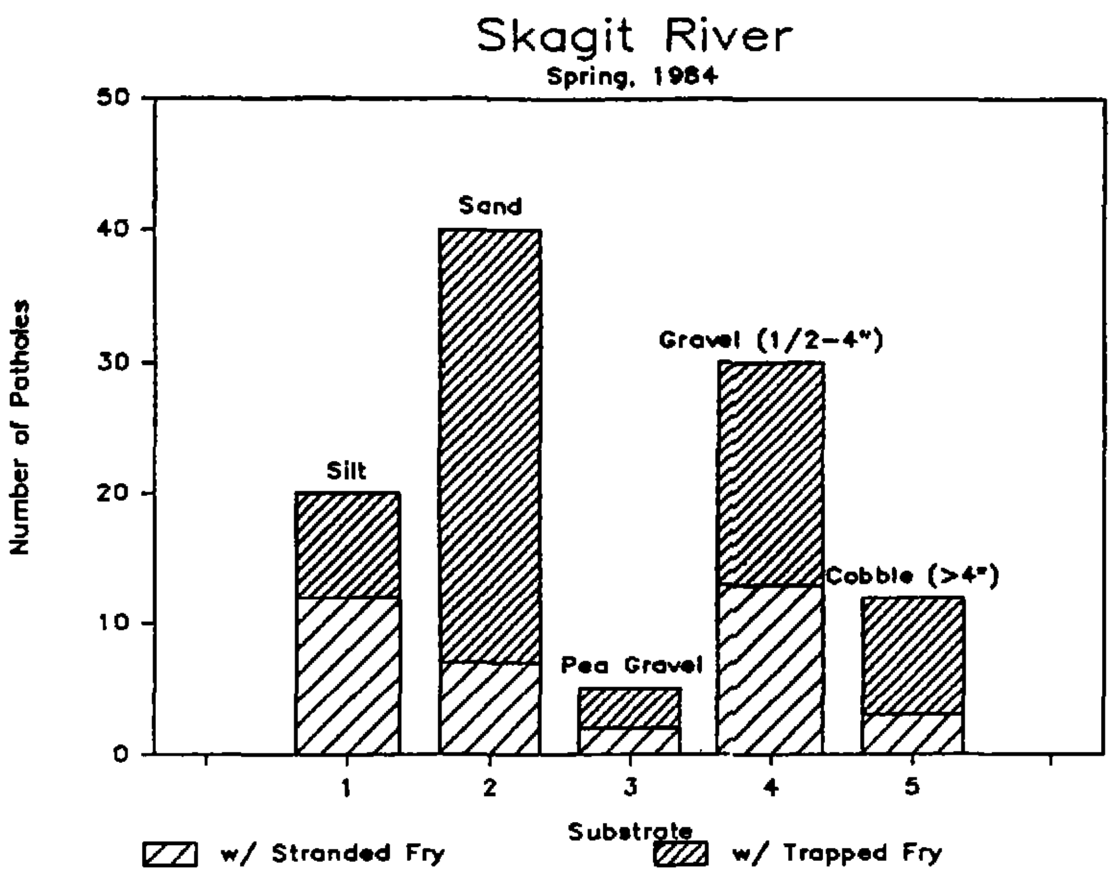


FIGURE 4-8. PRIMARY SUBSTRATE TYPES OF POTHOLES TRAPPING AND STRANDING FRY, SPRING, 1984, SKAGIT RIVER

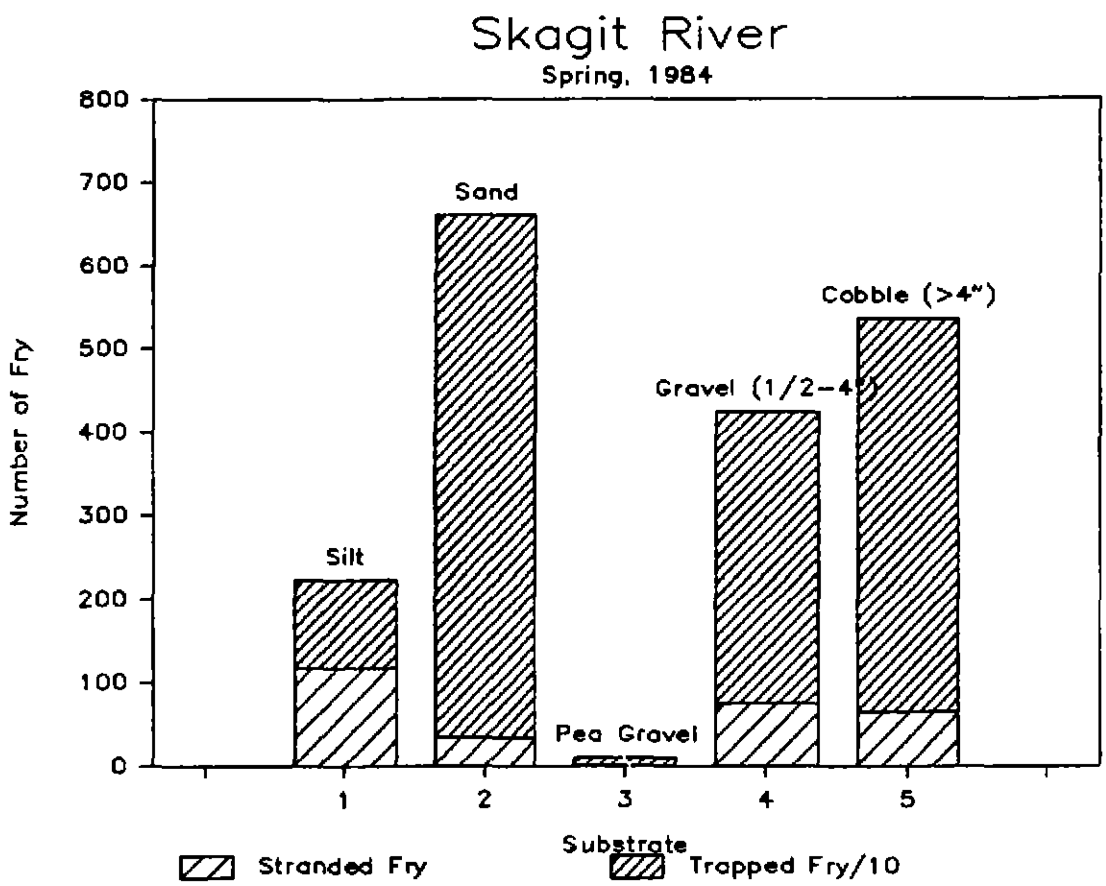
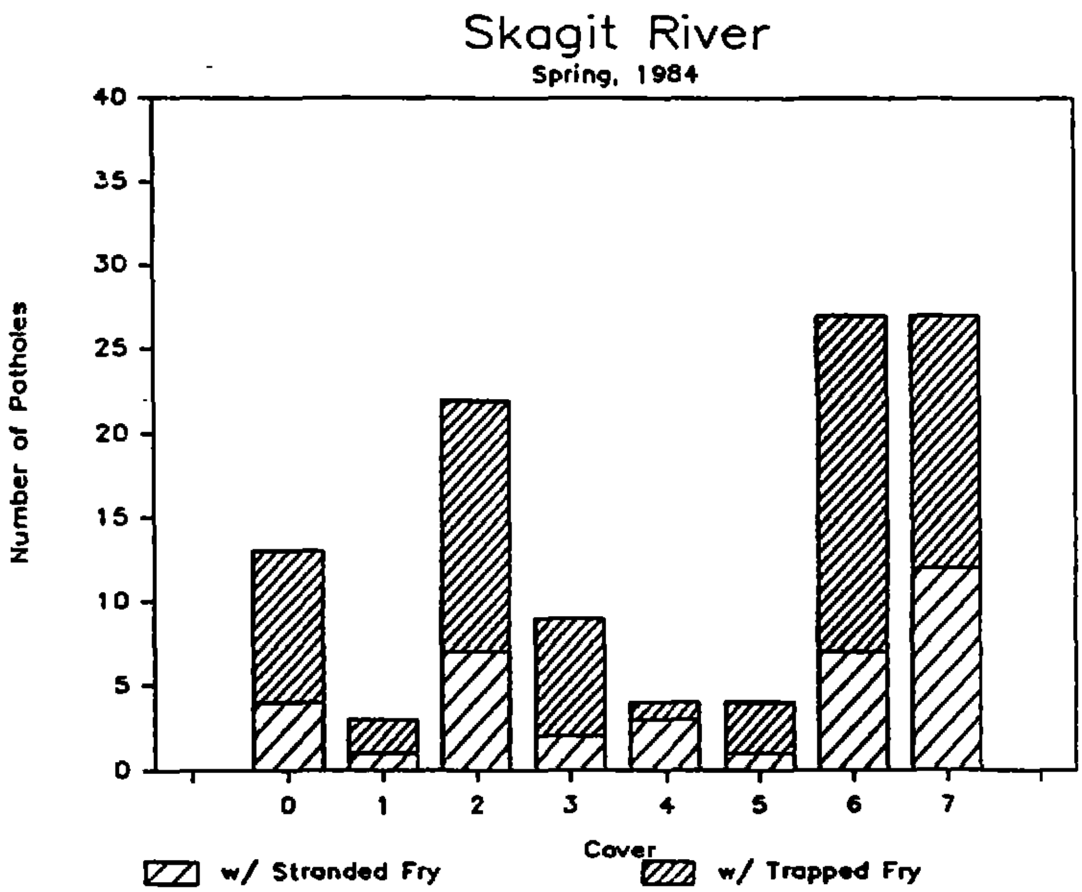


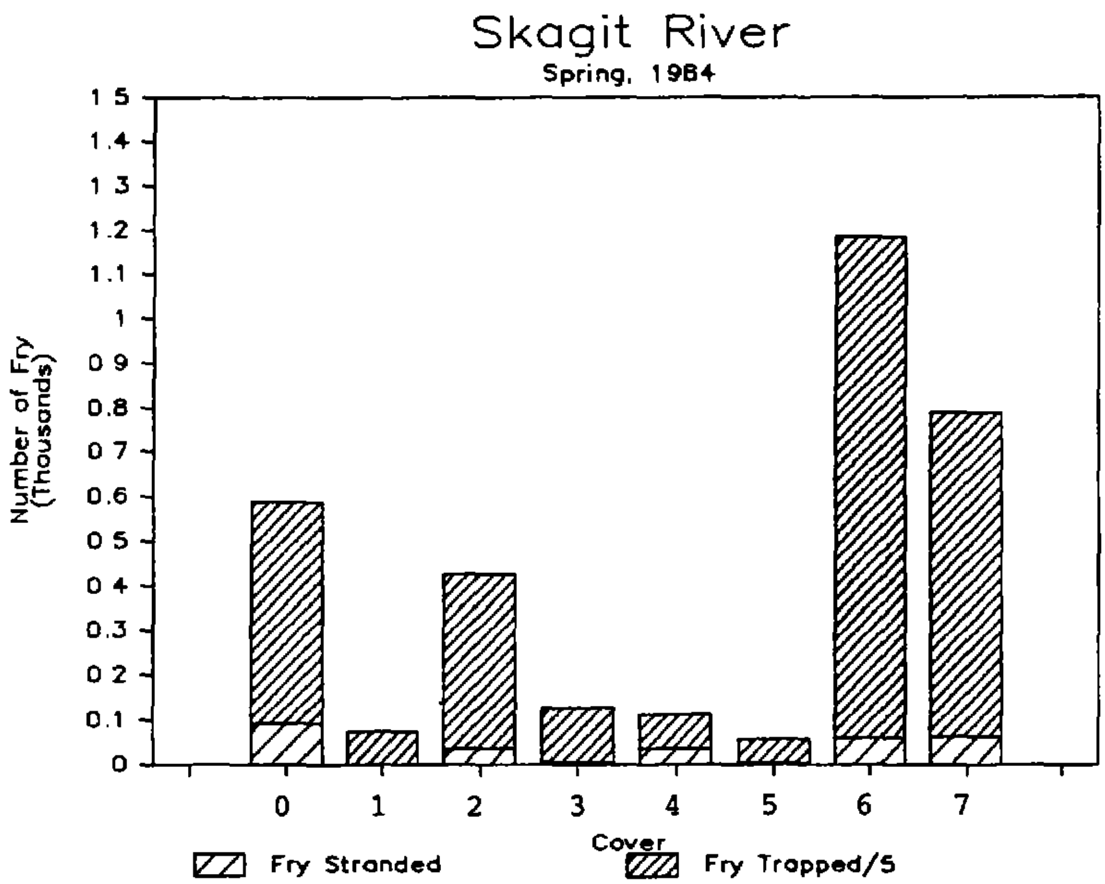
FIGURE 4-9. NUMBER OF FRY TRAPPED AND STRANDED BASED ON SUBSTRATE TYPE OF POTHOLES, SPRING, 1984, SKAGIT RIVER



Legend

0 - Root Wad
1 - Roots
2 - Sticks, Limbs
3 - Logs
4 - Boulders
5 - Submerged Vegetation
6 - Overhead Vegetation
7 - No Cover

FIGURE 4-10. PRIMARY COVER TYPES OF POTHOLES WITH TRAPPED AND STRANDED FRY, SPRING, 1984, SKAGIT RIVER



Legend

0 - Root Wad
1 - Roots
2 - Sticks, Limbs
3 - Logs
4 - Boulders
5 - Submerged Vegetation
6 - Overhead Vegetation
7 - No Cover

FIGURE 4-11. NUMBER OF FRY TRAPPED AND STRANDED BASED ON COVER TYPE OF POTHOLES, SPRING, 1984, SKAGIT RIVER

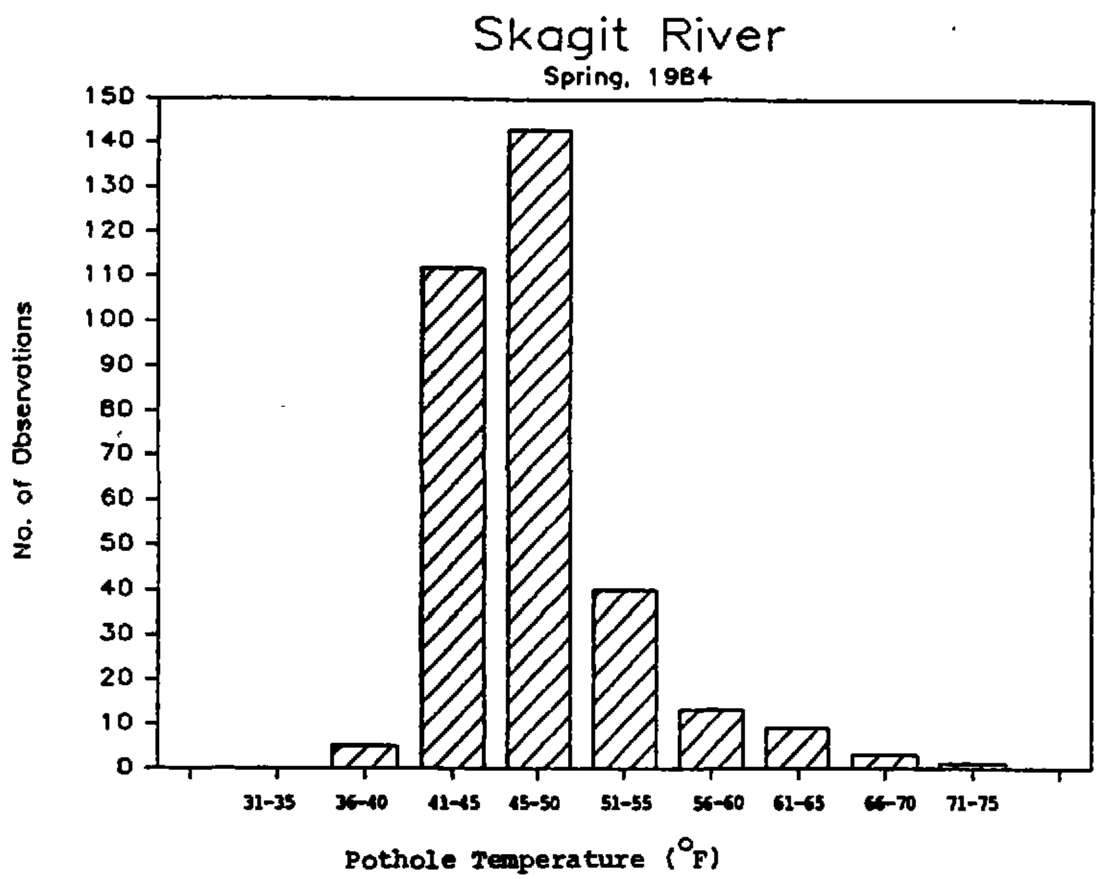


FIGURE 4-12. FREQUENCY OF OBSERVED POTHOLE TEMPERATURES DURING THE SPRING, 1984, SKAGIT RIVER

spring. No mortality associated with high water temperatures was observed.

Fall Surveys

Trapping and Stranding by Area (River Mile). Total numbers of fry trapped in potholes over the 26 fall study areas are summarized in Table 4-8. During the fall test period from August 22 through September 28, 1984, a total of 3,578 fry were trapped. The majority of the fry were newly emerged steelhead fry; however, coho salmon were also observed.

Big Eddy (RM 77.5), a study area characterized by flooding at relatively lower flows, trapped 27 percent of all fry trapped in the study. Big Eddy is unique in that no other major pothole area contained trapped fry in all surveyed potholes. With the exception of Oink Bar (RM 82.9), which trapped 10 percent of the total fry, a majority of trapping occurred downstream of Marblemount. Study areas located in the lower 5.2 river miles of the study reach accounted for 54 percent of all trapped fry. Wayne's Swim (RM 68.1), Stump Haven (RM 72.2), and Hooper's Slough (RM 72.7), responsible for most of the trapped fry in the lower section, are characterized by clusters of potholes around side channels and sloughs. Similar to Big Eddy, the above study areas included trapped fry in a majority of the surveyed potholes.

Fry stranding summarized over all study areas is also presented in Table 4-8; a total of 426 fry were observed to be stranded during the fall test period. The largest percentage of fry, 33 percent, were observed stranded at Forbidden Bar (RM 70.5). Within the Forbidden Bar study area, all stranding occurred in a single pothole (Pothole 2) located along side the upper reach of a high flow side channel on August 22, 1985. This particularly large stranding event was due to a combination of lower maximum allowable flows from the Gorge Powerhouse and declining natural flows. This pothole was never observed to be connected to the mainstem of the river during the remainder of the study.

Three of the five study areas which trapped the majority of fry were also responsible for 53 percent of total fry stranded. Similar to Forbidden Bar, nearly all stranding at Stump Haven was attributed to a single pothole located along the side channel (Pothole J). In contrast, stranding at Big Eddy was distributed over several potholes. Similar to the pattern exhibited with trapped fry, Oink Bar was the only study area upstream from Marblemount where stranding was observed to be high. Fourteen percent of all fall stranding occurred at Oink Bar, which is located directly on the downstream bank at the mouth of Bacon Creek. Fry stranded in this area may have newly emerged from Bacon Creek, known to be an important steelhead spawning and rearing area.

Table 4-8. Summary of Fry Trapped and Stranded by Area, Fall 1984*, **

STUDY AREA	NUMBER OF TEST DATES	TOTAL NUMBER OF TRAPPED FRY	TOTAL NUMBER OF STRANDED FRY	PERCENT OF TRAPPED FRY STRANDED
Rockport (RM 67.5)	12	54	11	20
Wayne's Swim (RM 68.1)	12	679	6	1
Tin Shack (RM 68.3)	12	30	3	10
Bad Spot (RM 70.0)	12	125	2	2
Eagle Bar (RM 70.1)	11	83	13	16
Forbidden Bar (RM 70.5)	12	235	142	60
Stump Haven (RM 72.2)	10	405	87	21
Model Pothole (RM 72.6)	4	35	0	0
Hooper's Slough (RM 72.7)	12	302	9	3
Rick's Surprise (RM 73.0)	10	22	0	0
Inaccessible Island (RM 73.1)	10	17	3	18
Carnage Bar (RM 73.3)	11	16	3	19
Dry Bar (RM 74.2)	3	0	0	0
North O'Brians Ferry (RM 76.0)	2	0	0	0
Seclusion Island (RM 76.3)	5	***	***	***
Big Eddy (RM 77.5)	12	960	79	8
Marblemount Slough (RM 78.2)	9	69	0	0
Fungus Bar (RM 78.5)	12	78	7	9
Sam's Bar (RM 82.0)	2	0	0	0
Maple Bar (RM 82.5)	2	0	0	0
Bacon Creek (RM 82.6)	12	86	2	2
Face Bar (RM 82.7)	3	7	1	14
Oink Bar (RM 82.9)	10	366	58	16
Driftwood Bar (RM 83.0)	10	0	0	0
Minibar (RM 83.3)	4	3	0	0
Flower Pothole (RM 83.5)	3	0	0	0
Copper Creek (RM 84.0)	3	6	0	0
TOTALS		3,578	426	-
PERCENTAGE				12

* Excludes high flow potholes.
** Excludes 8/15/84 reconnaissance survey.
*** All potholes tested were high flow potholes.

Figure 4-13 indicates that there is no clear relationship between the number of potholes containing trapped fry and the number of stranded fry for a particular area. For example, while Forbidden Bar stranded the most fry by area, only three potholes contained trapped fry. Also, Wayne's Swim, with 13 potholes containing trapped fry, accounted for only 1 percent of total stranded fry.

Trapping and Stranding During the Reconnaissance Survey. A summary of trapping and stranding observed during the reconnaissance survey of August 15 and 16, 1984, is presented in Table 4-9. A total of 3,120 trapped fry were observed over 18 study areas. Generally, numbers of fry stranded per area were higher than were later observed during the fall surveys. Although 50 percent of all trapped fry were observed at Forbidden Bar, Hooper's Slough, and Stump Haven, all major study areas had more trapped fry than observed during the surveys.

For the week prior to the August 15 downramp (5,751 to 1,400 cfs), average daily discharge at the Gorge Powerhouse ranged from 3,360 to 4,920 cfs. Minimum sustained flow over the same time period was gaged at 2,993 cfs on August 11. Apparently the magnitude of the downramp, along with previous high flow conditions, caused a major reduction in juvenile backwater and side channel habitat thereby concentrating fry in potholes associated with sloughs and side channels.

Numbers of fry stranded during the reconnaissance survey are also summarized in Table 4-9. A greater incidence of stranding was observed during the reconnaissance survey than was later observed during the fall survey. A total of 508 fry were stranded over the 18 study areas, with 69 percent of the total fry stranded in single potholes at Hooper's Slough (200 fry in Pothole 4) and Eagle Bar (150 fry in Pothole 8). In both cases, the potholes involved with stranding were located at the upper ends of sloughs which had become dewatered during the downramp event.

High Flow Potholes. Summary data for trapped and stranded fry in high flow potholes surveyed during the fall is presented in Table 4-10. As was mentioned previously, all data associated with high flow potholes were evaluated separately and were not included in other summary tables.

Twelve high flow potholes in three study areas contained trapped fry; of those potholes, mortality was observed in only four potholes. Single potholes in Bad Spot and Tin Shack accounted for 93 percent of the observed mortality. In both cases, mortality was due to high water temperature resulting from a combination of lower water levels, very warm air temperatures, and no tree canopy over the potholes. Most of the high flow potholes had relatively greater volumes and retained water throughout the fall surveys. Water quality conducive to fry survival was achieved by the recharge of fresh water through the gravel bars. This resulted in little observed mortality.

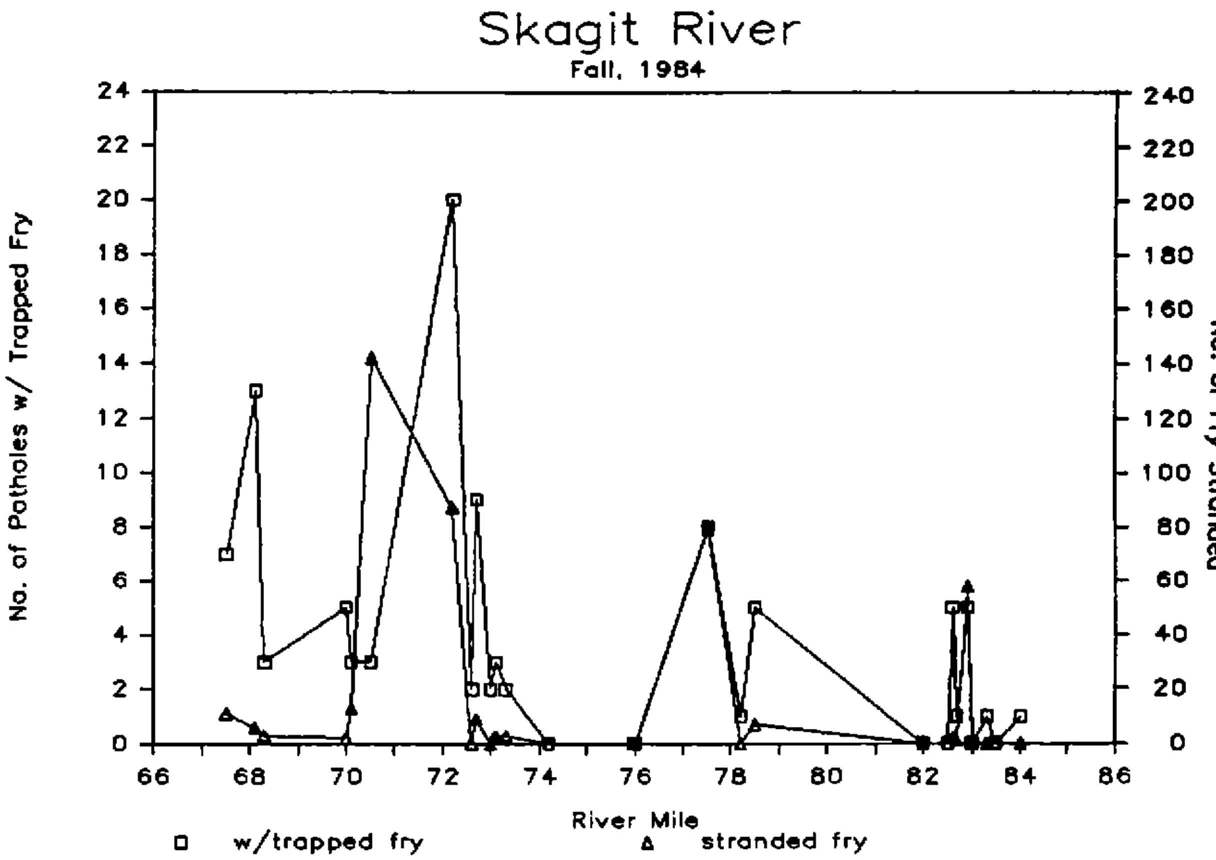


FIGURE 4-13. RELATIONSHIP OF THE NUMBER OF POTHOLES CONTAINING TRAPPED FRY TO NUMBERS OF STRANDED FRY BY STUDY AREA (RIVER MILE), FALL, 1984, SKAGIT RIVER

Table 4-9. Summary of Fry Trapped and Stranded by Study Area Observed During Reconnaissance Survey, August 15 and 16, 1984

STUDY AREA	NUMBER OF FRY TRAPPED*		NUMBER OF FRY STRANDED*		NO. OF POTHOLES W/FRY TRAPPED		NO. OF POTHOLES W/FRY STRANDED	
	8-15	8-16	8-15	8-16	8-15	8-16	8-15	8-16
Rockport (RM 67.5)	-	-	-	-	-	-	-	-
Wayne's Swim (RM 68.1)	-	-	-	-	-	-	-	-
Tin Shack (RM 68.3)	-	-	-	-	-	-	-	-
Bad Spot (RM 70.0)	107	-	65	-	4	-	1	-
Eagle Bar (RM 70.1)	300	-	150	-	1	-	1	-
Forbidden Bar (RM 70.5)	621	-	0	-	4	-	0	-
Stump Haven (RM 72.2)	427	-	22	-	9	-	2	-
Model Pothole (RM 72.6)	205	-	0	-	3	-	0	-
Hooper's Slough (RM 72.7)	510	-	200	-	6	-	1	-
Rick's Surprise (RM 73.0)	82	-	0	-	4	-	0	-
Inaccessible Island (RM 73.1)	206	-	3	-	11	-	2	-
Carnage Bar (RM 73.3)	37	-	36	-	2	-	2	-
Dry Bar (RM 74.2)	-	-	-	-	-	-	-	-
North O'Brians Ferry (RM 76.0)	-	-	-	-	-	-	-	-
Seclusion Island (RM 76.3)**								
Big Eddy (RM 77.5)	287	-	31	-	5	-	2	-
Marblemount Slough (RM 78.2)	150	-	0	-	1	-	0	-
Fungus Bar (RM 78.5)	-	42	-	0	-	3	-	0
Sam's Bar (RM 82.0)	-	-	-	-	-	-	-	-
Maple Bar (RM 82.5)	-	8	-	0	-	1	-	0
Bacon Creek (RM 82.6)	-	5	-	0	-	3	-	0
Face Bar (RM 82.7)	-	26	-	0	-	2	-	0
Oink Bar (RM 82.9)	-	101	-	-	-	4	-	0
Driftwood Bar (RM 83.0)	-	-	-	-	-	-	-	-
Minibar (RM 83.3)	-	5	-	0	-	1	-	0
Flower Pothole (RM 83.5)	-	1	-	0	-	1	-	0
Copper Creek (RM 84.0)		-	-	-	-	-	-	-
TOTALS	2,932	188	507	0	50	15	11	0

* Excludes fry trapped or stranded in high flow potholes.
\- Not surveyed on that date.
** High flow potholes.

Table 4-10. High Flow Potholes Surveyed Over 12 Test Dates, Fall 1984*

STUDY AREA	POTHOLE	MAX. NO. OF TRAPPED FRY OBSERVED	TOTAL STRANDING**
Wayne's Swim (RM 68.1)	008	500	2
Tin Shack (RM 68.3)	002	200	0
	005	26	27***
	006	1	0
	11A	0	0
	11B	0	0
Bad Spot (RM 70.0)	001	550	0
	01A	370	3
	01B	300	0
	01C	0	0
	002	52	0
	003	42	42***
	007	150	0
	008	0	0
	009	95	0
	015	47	0
	016	0	0
	017	0	0
Seclusion Island (RM 76.3)	00A	1	0
	00B	6	0
Fungus Bar (RM 78.5)	00F	26	0

* High flow potholes were those observed to stay disconnected from river flow during all test dates.
** Does not include August 15, 1984 reconnaissance survey. Only pothole with 8/15 stranding was Bad Spot 003 with 25 stranded fry.
*** High temperature mortality.

Note: A total of 21 high flow potholes were surveyed during the fall, 1984. Of those, 12 contained trapped or stranded fry.

Trapping and Stranding by Date. The temporal distribution of fry trapped and stranded over the entire study area is shown in Figure 4-14. A summary table with numbers of fry trapped and stranded by study area and date is presented in Tables 4-11 and 4-12.

Similar to the spring survey, those study areas which trapped fry over more test dates were those with greater overall trapping. Big Eddy and Wayne's Swim were implicated in greater trapping over more test dates than any other study areas. Stranding over time was not limited to any specific area on the river but was spread over several study areas.

Regression analysis of numbers of trapped fry against date and river discharge showed that both flow ($t = 2.28$; $p < .02$) and date ($t = 8.99$; $p < .001$) were significantly related to trapping. As was observed for the spring data, the fit was not linear (F value of 50.9; $p < .001$; $R^2 = .160$).

Over 81 percent of all fry trapped were observed during the three earliest test dates of August 22, 23, and 31, 1984. It is important to note that peak steelhead fry emergence probably occurred immediately prior to and during this time period; previous studies have shown peak steelhead fry emergence occurring in mid-July and August in the Skagit River basin (Graybill et al. 1979). Also during this time, a steadily declining tributary inflow resulted in declining mainstem discharge as the fall survey progressed. Midway through the season, trapping declined to less than 100 fry per test date.

Stranded fry were temporally distributed in a pattern similar to that observed for trapped fry. During the August 22, 23, and 31, 1984 test dates, 83 percent of overall stranding occurred. Incidence of stranding declined to very low levels after the second week of the fall survey; 9 percent of all stranding was observed during the last 4 weeks of surveys.

Common to both spring and fall trapping and stranding was the occurrence of larger numbers of fry during the first day of most "paired" tests. The exception during the fall survey was the paired test occurring on September 6 and 7 during which heavy rainfall on September 6 substantially increased tributary inflow thereby reducing the effect of downramping during both test dates.

Trapping and Stranding by Substrate Type. Numbers of potholes are presented by primary substrate type for those potholes which contained trapped and stranded fry during fall surveys (Figure 4-15). No apparent relationship exists between potholes with trapping or stranding and substrate type. However, fewer potholes involved with trapping were primarily composed of pea gravel (4 percent) and cobble (10 percent). Likewise, fewer potholes responsible for stranding were primarily composed of pea gravel (8 percent) and cobble (10 percent). Potholes with

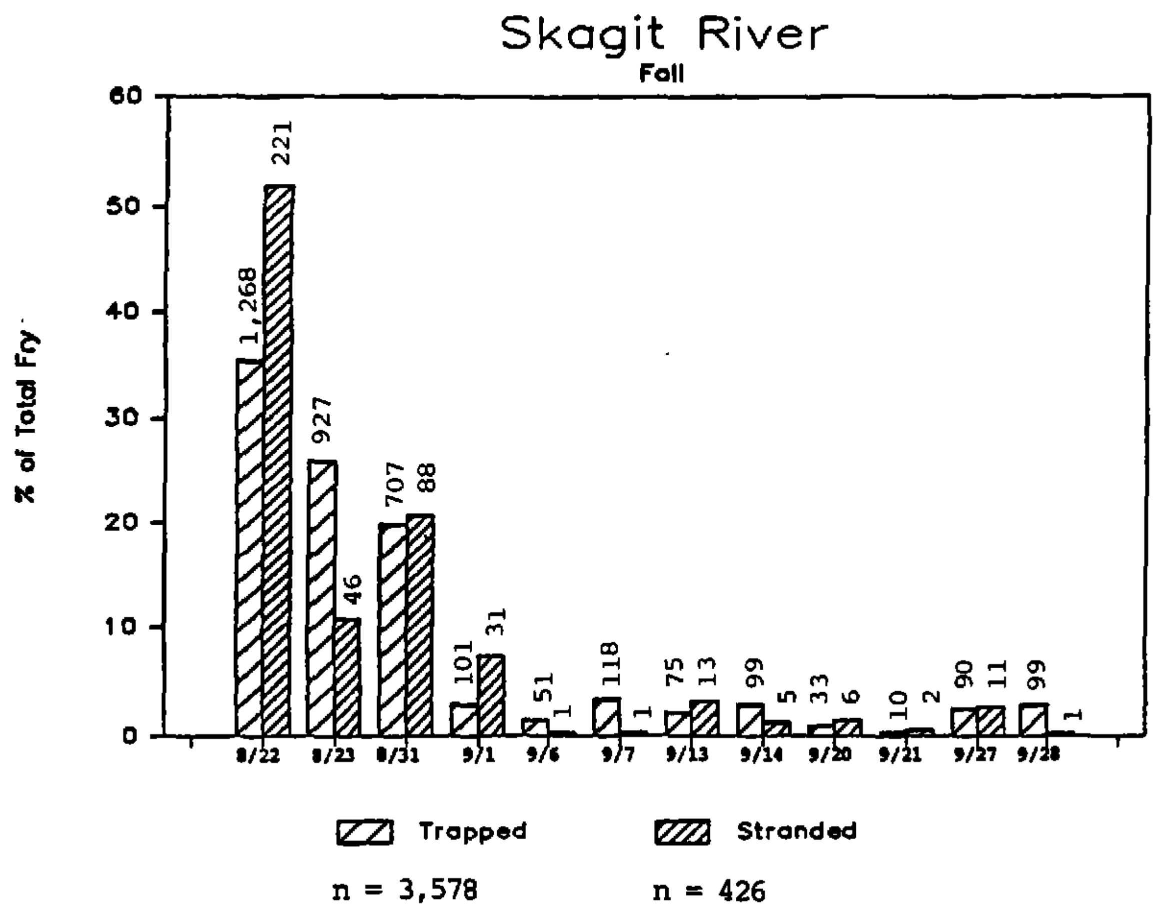


FIGURE 4-14. PERCENT OF TOTAL FRY TRAPPED AND STRANDED BY TEST DATE, FALL, 1984, SKAGIT RIVER

Table 4-11. Fry Trapped by Test Date at Each Study Area (River Mile), Fall, 1984, Skagit River

	TEST DATE												
STUDY AREA	8-22	8-23	8-31	9-1	9-6	9-7	9-13	9-14	9-20	9-21	9-27	9-28	TOTAL
Rockport (RM 67.5)	0	5	15	10	0	0	0	0	10	0	6	8	54
Wayne's Swim (RM 68.1)	154	273	58	14	1	4	3	64	11	2	28	67	679
Tin Shack (RM 68.3)	2	5	4	1	0	0	1	5	0	0	9	3	30
Bad Spot (RM 70.0)	67	48	0	1	1	0	1	1	2	0	1	3	125
Eagle Bar (RM 70.1)	0	-	8	19	3	1	34	2	0	0	16	0	83
Forbidden Bar (RM 70.5)	217	15	0	0	0	0	0	0	0	0	0	3	235
Stump Haven (RM 72.2)	240	60	63	8	11	15	-	-	0	2	6	0	405
Model Pothole (RM 72.6)	-	0	-	-	30	-	-	-	-	-	5	-	35
Hooper's Slough (RM 72.7)	135	56	16	3	4	33	9	12	3	0	16	15	302
Rick's Surprise (RM 73.0)	-	16	5	0	-	1	0	0	0	0	0	0	22
Inaccessible Island (RM 73.1)	3	11	-	3	0	0	0	0	0	0	0	0	17
Carnage Bar (RM 73.3)	-	0	7	6	0	0	0	0	0	3	0	0	16
Dry Bar (RM 74.2)	-	0	-	-	0	-	-	-	-	-	0	-	0
North O'Brians Ferry (RM 76.0)	-	0	-	-	-	-	-	-	-	-	0	-	0
Seclusion Island (RM 76.3)*	N/A												
Big Eddy (RM 77.5)	411	244	190	26	0	55	15	9	5	3	2	0	960
Marblemount Slough (RM 78.2)	-	50	5	5	-	5	1	0	2	0	1	-	69
Fungus Bar (RM 78.5)	15	57	5	1	0	0	0	0	0	0	0	0	78
Sam's Bar (RM 82.0)	-	-	-	-	-	0	-	-	-	-	0	-	0
Maple Bar (RM 82.5)	-	-	-	-	-	0	-	-	-	-	0	-	0
Bacon Creek (RM 82.6)	21	60	0	4	1	0	0	0	0	0	0	0	86
Face Bar (RM 82.7)	-	5	-	-	-	2	-	-	-	-	0	-	7
Oink Bar (RM 82.9)	-	16	331	-	0	2	11	6	0	0	0	0	366
Driftwood Bar (RM 83.0)	-	0	0	-	0	0	0	0	0	0	0	0	0
Minibar (RM 83.3)	3	0	-	-	-	0	-	-	-	-	0	-	3
Flower Pothole (RM 83.5)	-	0	-	-	-	0	-	-	-	-	0	-	0
Copper Creek (RM 84.0)	-	6	-	-	-	0	-	-	0	0	0	0	6
TOTALS	1,268	927	707	101	51	118	75	99	33	10	90	99	3,578

- No observations on that day.

* High flow pothole area only.

Table 4-12. Fry Stranded by Test Date at Each Study Area (River Mile), Fall, 1984, Skagit River

	TEST DATE												
STUDY AREA	8-22	8-23	8-31	9-1	9-6	9-7	9-13	9-14	9-20	9-21	9-27	9-28	TOTAL
Rockport (RM 67.5)	0	0	2	7	0	0	0	0	2	0	0	0	11
Wayne's Swim (RM 68.1)	0	0	0	2	0	0	0	1	1	1	0	1	6
Tin Shack (RM 68.3)	0	0	2	1	0	0	0	0	0	0	0	0	3
Bad Spot (RM 70.0)	1	0	0	0	1	0	0	0	0	0	0	0	2
Eagle Bar (RM 70.1)	0	-	1	0	0	0	5	1	0	0	6	0	13
Forbidden Bar (RM 70.5)	142	0	0	0	0	0	0	0	0	0	0	0	142
Stump Haven (RM 72.2)	76	0	2	2	0	1	-	-	0	1	5	0	87
Model Pothole (RM 72.6)	-	0	-	-	0	-	-	-	-	-	0	-	0
Hooper's Slough (RM 72.7)	0	0	5	0	0	0	2	0	2	0	0	0	9
Rick's Surprise (RM 73.0)	-	0	0	0	-	0	0	0	0	0	0	0	0
Inaccessible Island (RM 73.1)	0	0	-	3	0	0	0	0	0	0	0	0	3
Carnage Bar (RM 73.3)	-	0	2	1	0	0	0	0	0	0	0	0	3
Dry Bar (RM 74.2)	-	0	-	-	0	-	-	-	-	-	0	-	0
North O'Brians Ferry (RM 76.0)	-	0	-	-	-	-	-	-	-	-	0	-	0
Seclusion Island (RM 76.3)*	----------	----------	----------	----------	----------	----------	N/A	----------	----------	----------	----------	----------	----------
Big Eddy (RM 77.5)	1	35	22	14	0	0	6	0	1	0	0	0	79
Marblemount Slough (RM 78.2)	-	0	0	0	-	0	0	0	0	0	0	-	0
Fungus Bar (RM 78.5)	0	6	1	0	0	0	0	0	0	0	0	0	7
Sam's Bar (RM 82.0)	-	-	-	-	-	0	-	-	-	-	0	-	0
Maple Bar (RM 82.5)	-	-	-	-	-	0	-	-	-	-	0	-	0
Bacon Creek (RM 82.6)	1	0	0	1	0	0	0	0	0	0	0	0	2
Face Bar (RM 82.7)	-	1	-	-	-	0	-	-	-	-	0	-	1
Oink Bar (RM 82.9)	-	4	51	-	0	0	0	3	0	0	0	0	58
Driftwood Bar (RM 83.0)	-	0	0	-	0	0	0	0	0	0	0	0	0
Minibar (RM 83.3)	0	0	-	-	-	0	-	-	-	-	0	-	0
Flower Pothole (RM 83.5)	-	0	-	-	-	0	-	-	-	-	0	-	0
Copper Creek (RM 84.0)	-	0	-	-	-	0	-	-	-	-	0	-	0
TOTALS	221	46	88	31	1	1	13	5	6	2	11	1	426

\- No observations on that day.
* High flow pothole area only.

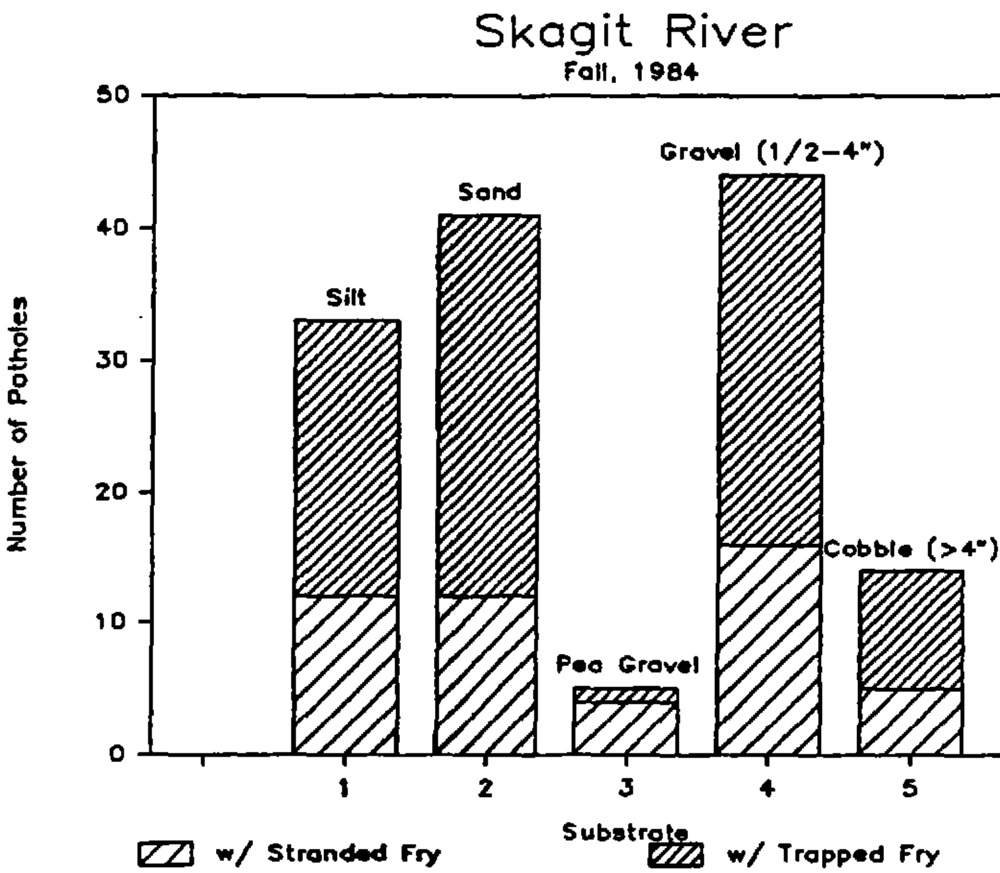


FIGURE 4-15. PRIMARY SUBSTRATE TYPES OF POTHOLES TRAPPING AND STRANDING FRY, FALL, 1984, SKAGIT RIVER

trapping and stranding were distributed fairly evenly among the remaining substrate types: silt, sand, and gravel.

Figure 4-16 indicates the number of fry trapped and stranded based on substrate. Of interest is the fact that more fry were trapped and stranded in potholes with sand substrate. This indicates that more fry were found in potholes having sand substrate than in any other.

A logistic regression of these data indicated a significant relationship to the proportion of stranded to trapped fry. The highest proportion of stranding was associated with silt and gravel; the lowest proportion with cobble and sand.

Trapping and Stranding by Cover Type. Numbers of potholes containing trapped and stranded fry during the fall surveys are shown by primary cover type in Figure 4-17. As was apparent during the spring surveys, the majority of potholes with trapped fry were associated with some type of cover (77 percent); predominant cover types were root wads, sticks, logs, and overhanging vegetation. However, 27 percent of those potholes which stranded fry had some type of associated cover with the predominant cover types being the same as those observed for potholes with trapped fry.

Figure 4-18 shows the number of fry trapped and stranded by cover type. More fry utilized potholes with sticks and limbs as cover than any other cover type. Additionally, more fry were stranded in potholes with sticks and limbs than were observed for any other cover type.

A logistic regression of these data showed a significant relationship of cover to the proportion of stranded to trapped fry. Cover, as a whole, had a positive effect on survivability (chi-square 16.6; $p < .001$) (Appendix F).

Pothole Temperatures. Figure 4-19 shows the frequency of maximum daily water temperatures for all potholes observed during the fall surveys. The predominance of observed water temperatures ranged from 51 to 65°F. No observed mortality was due to high water temperatures other than that mentioned previously for the two high flow potholes at Bad Spot and Tin Shack (Table 4-10).

Analyses of River Flow to Fry Trapping and Stranding

From the outset of the study, it was clear that the flow discharges from the Gorge Powerhouse, in concert with tributary inflows from Newhalem to Rockport, had a direct influence on the flooding and dewatering of potholes and on the trapping and stranding of fry.

Because it was not known which flow variables were of greatest importance to fry trapping and stranding, a number of

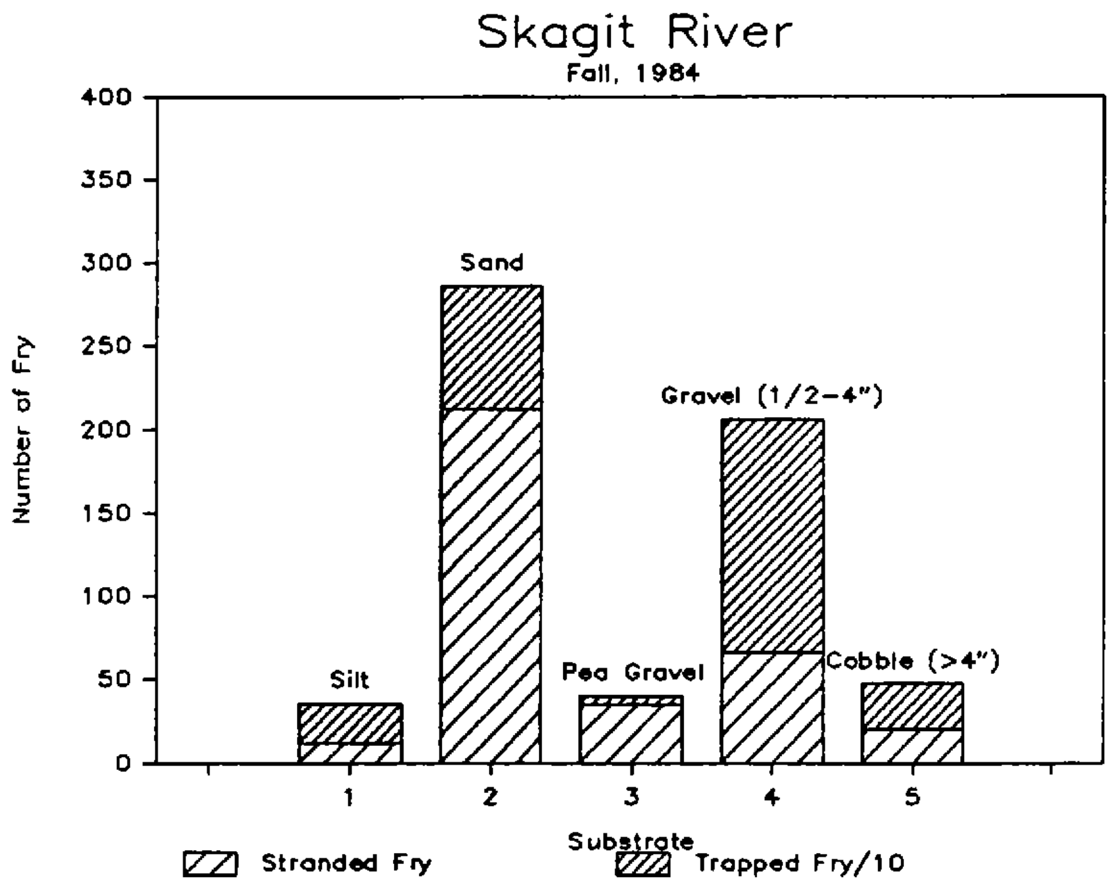


FIGURE 4-16. NUMBER OF FRY TRAPPED AND STRANDED BASED ON SUBSTRATE TYPE OF POTHOLES, FALL, 1984, SKAGIT RIVER

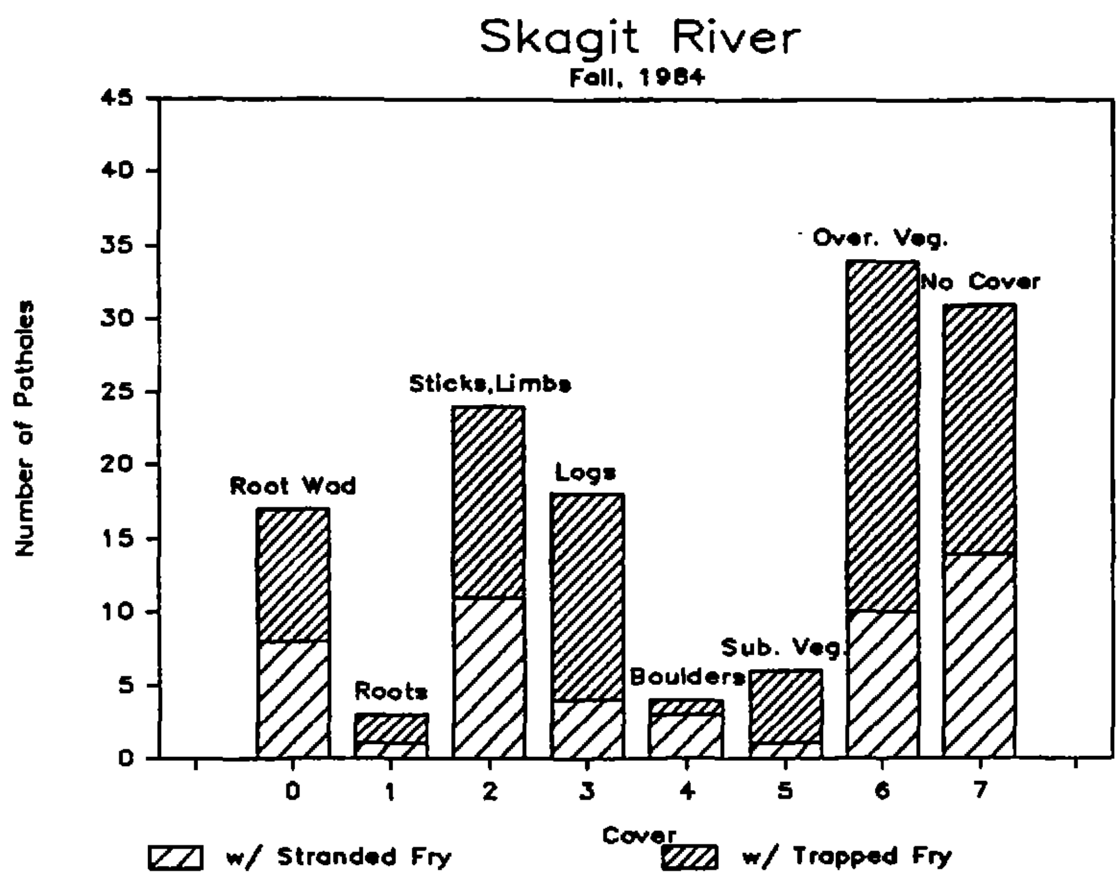
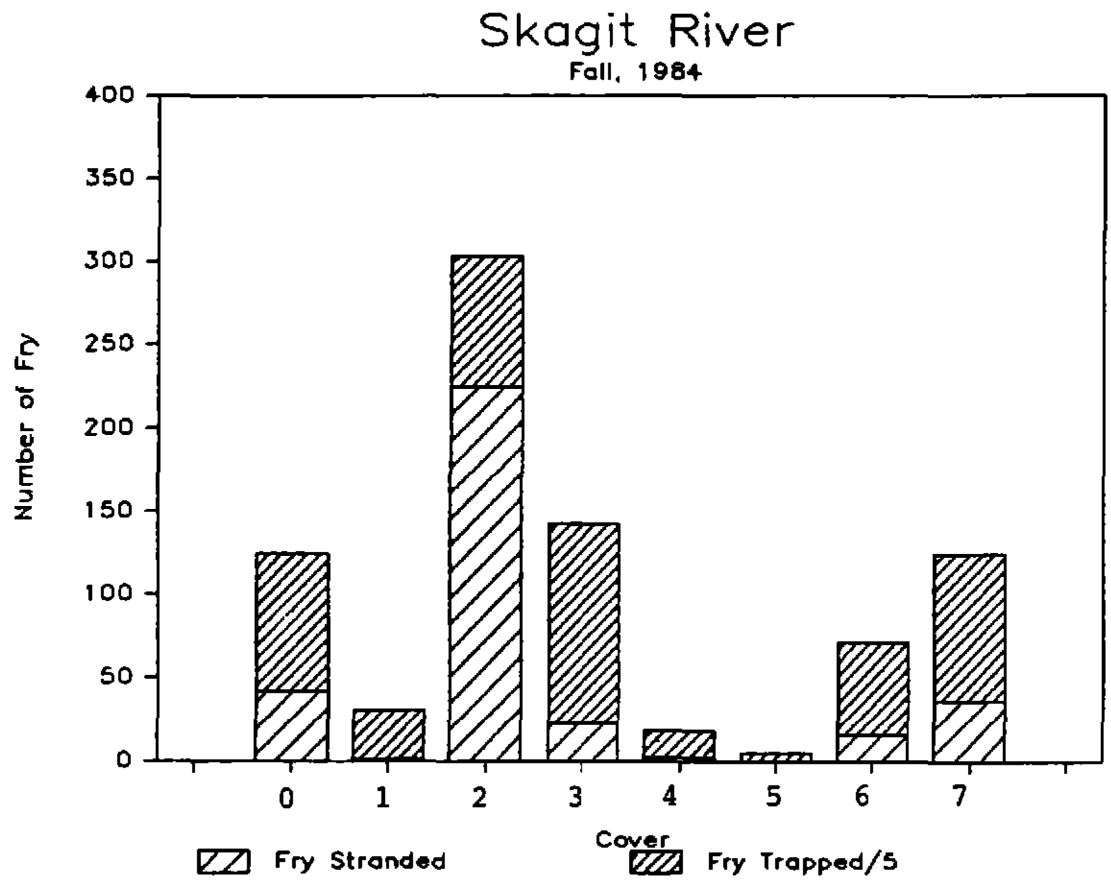


FIGURE 4-17. PRIMARY COVER TYPES OF POTHOLES WITH TRAPPED AND STRANDED FRY, FALL, 1984, SKAGIT RIVER



Legend

0 - Root Wad
1 - Roots
2 - Sticks, Limbs
3 - Logs
4 - Boulders
5 - Submerged Vegetation
6 - Overhead Vegetation
7 - No Cover

FIGURE 4-18. NUMBER OF FRY TRAPPED AND STRANDED BASED ON COVER TYPE OF POTHOLES, FALL, 1984, SKAGIT RIVER

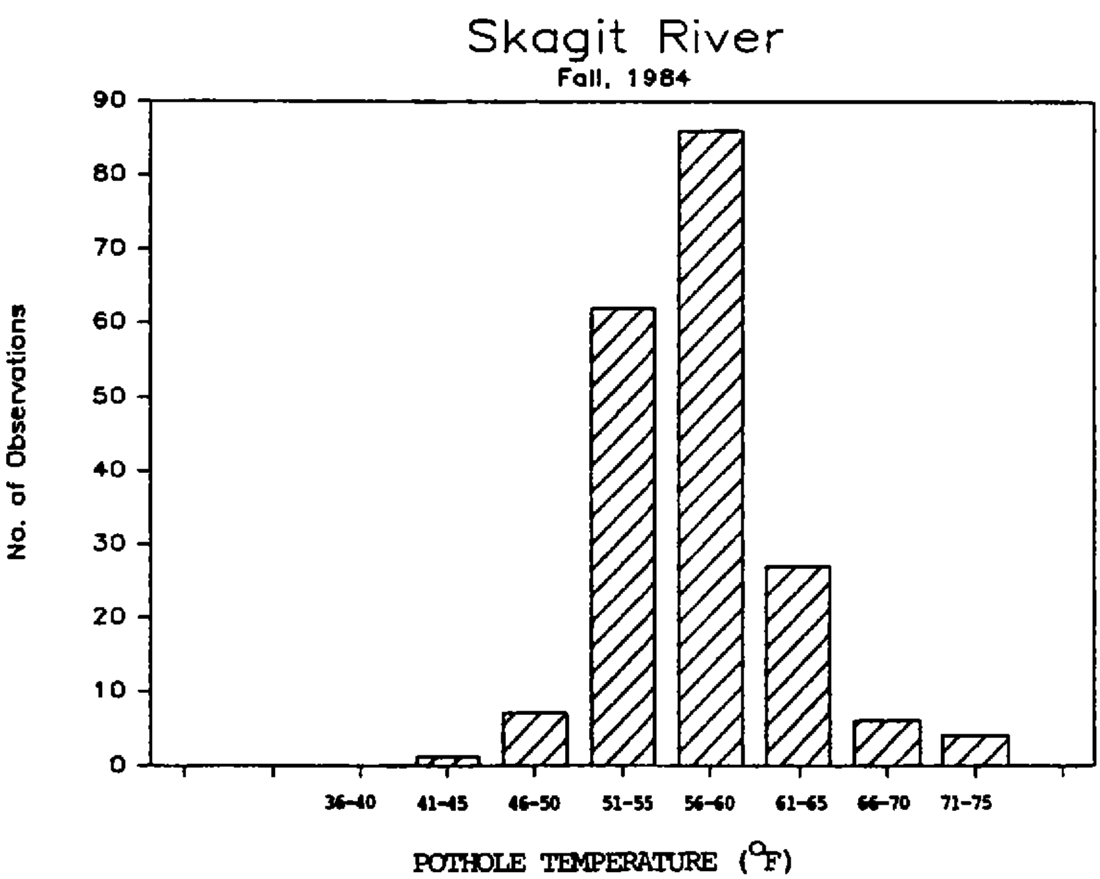


FIGURE 4-19. FREQUENCY OF OBSERVED POTHOLE TEMPERATURES DURING THE FALL, 1984, SKAGIT RIVER

statistical analyses were initiated. These included determining the relationships of trapping and stranding to:

- minimum test flows,
- average daily discharge,
- mean and maximum daily downramp amplitude during the 24 hours and 72 hours prior to each test, and
- ramping rate.

Spring Study

Overview of Test Flow Conditions. Spring tests were carried out during March, April, and May, 1984. The daily flows during those months and the daily flow amplitude for 1984 is presented in Appendix G (R. W. Beck 1984). Also shown in Appendix G are the average daily discharge, average downramp amplitudes, and maximum downramp amplitudes for the 24- and 72-hour periods prior to each test. The relationship of those flow factors to fry trapping and stranding are discussed in the following paragraphs.

Relationship of Minimum Test Flows to Fry Trapping and Stranding. Figure 4-20 shows the relationships of minimum test flows as recorded at Marblemount and Rockport to numbers of fry trapped and stranded during the spring. Because a majority of the tests had minimum flows at the lower end of the range (3,200 to 3,500 cfs at Marblemount), the sample size at the upper end of the flow spectrum was limited. The figures do show a trend that fewer fish were trapped as the minimum test flows increased; however, that trend does not hold for stranded fry.

A multivariate regression analysis of minimum flows at Newhalem, Marblemount, and Rockport to trapping showed that the Marblemount flow was most strongly associated with trapping ($t = 3.48$; $p < .001$). The inclusion of the Marblemount flow into the equation precluded any other flow variable; however, it is apparent that a strong linear relationship does not exist ($R^2 = 0.026$). Figure 4-21 presents the line of best fit and the 95 percent confidence interval from simple linear regression analysis using Marblemount flow only.

A logistic regression model was employed in an attempt to relate flow at the three gage stations to stranding. The flows at Newhalem and Rockport were found to be most closely associated with stranding (F's-to-enter 65.20 and 44.58, respectively). The values of these coefficients reflect the effect of flows on the survival of the fry (coefficient/standard errors -5.409 and -5.659, respectively). The negative value of the coefficients indicates that survivability decreases as flow decreases.

Relationship of Previous 24- and 72-Hour Average Discharge to Fry Trapping and Stranding. Figure 4-22 indicates the relationship of fry trapping and stranding to average discharge

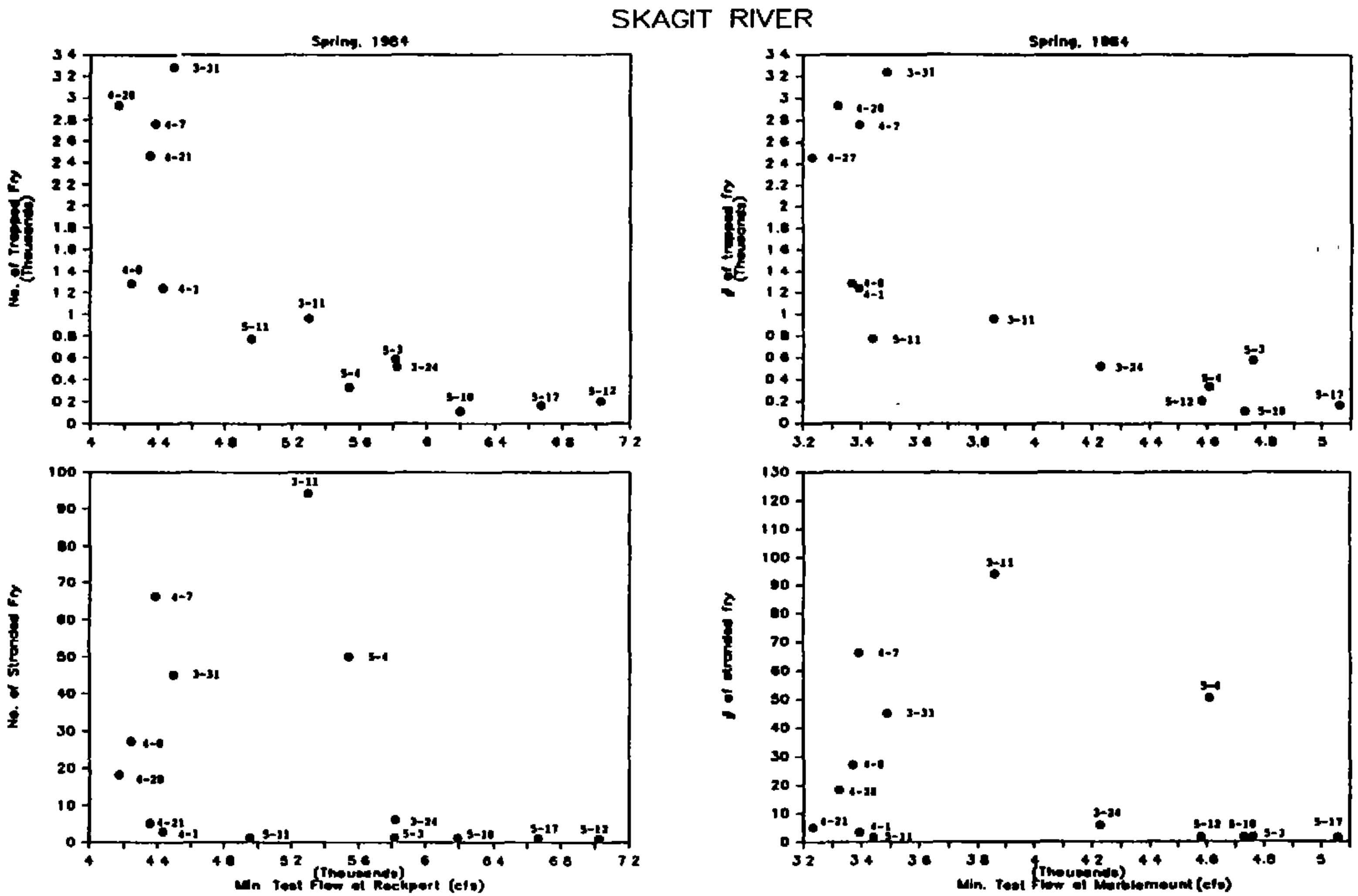


FIGURE 4-20. RELATIONSHIPS OF MINIMUM TEST FLOWS AT ROCKPORT AND MARBLEMOUNT TO NUMBERS OF FRY TRAPPED AND STRANDED, SPRING, 1984, SKAGIT RIVER

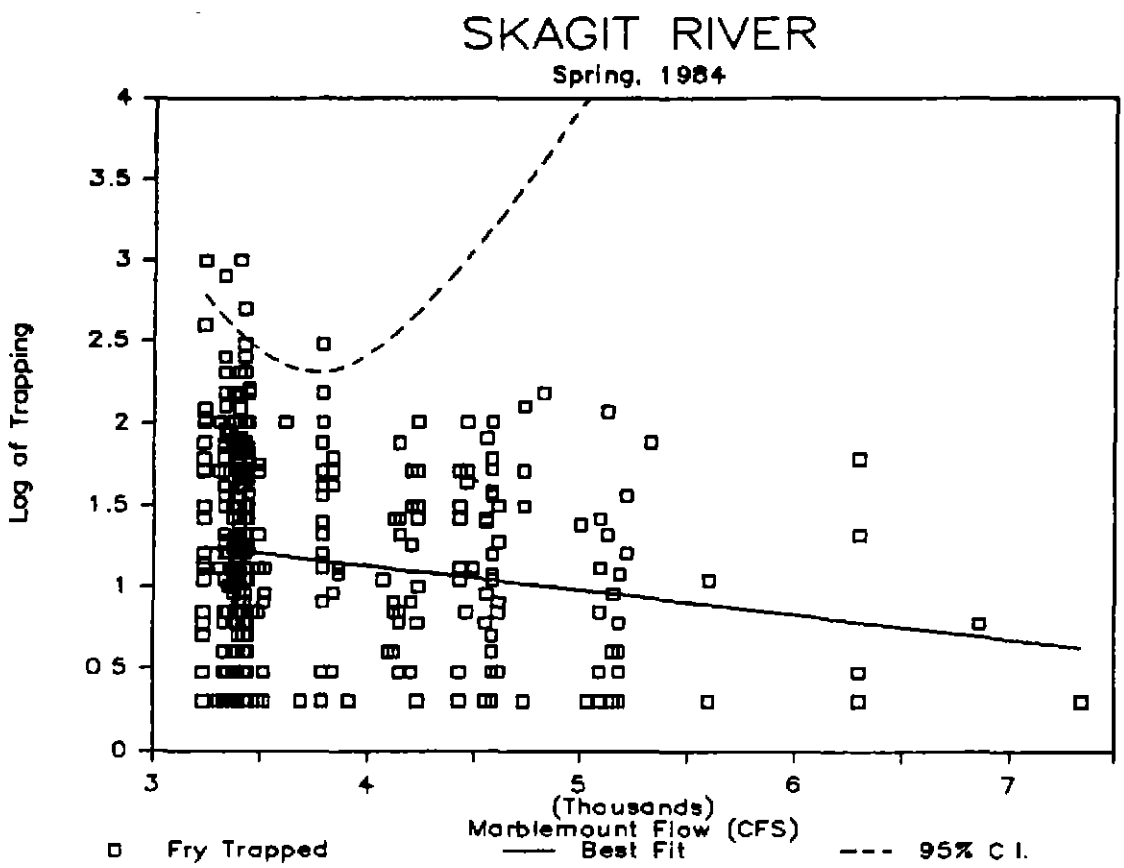


FIGURE 4-21. RELATIONSHIP OF MINIMUM OBSERVED FLOW AT MARBLEMOUNT BY POTHOLE TO NUMBERS OF FRY TRAPPED (LOG RELATIONSHIP), SPRING, 1984, SKAGIT RIVER

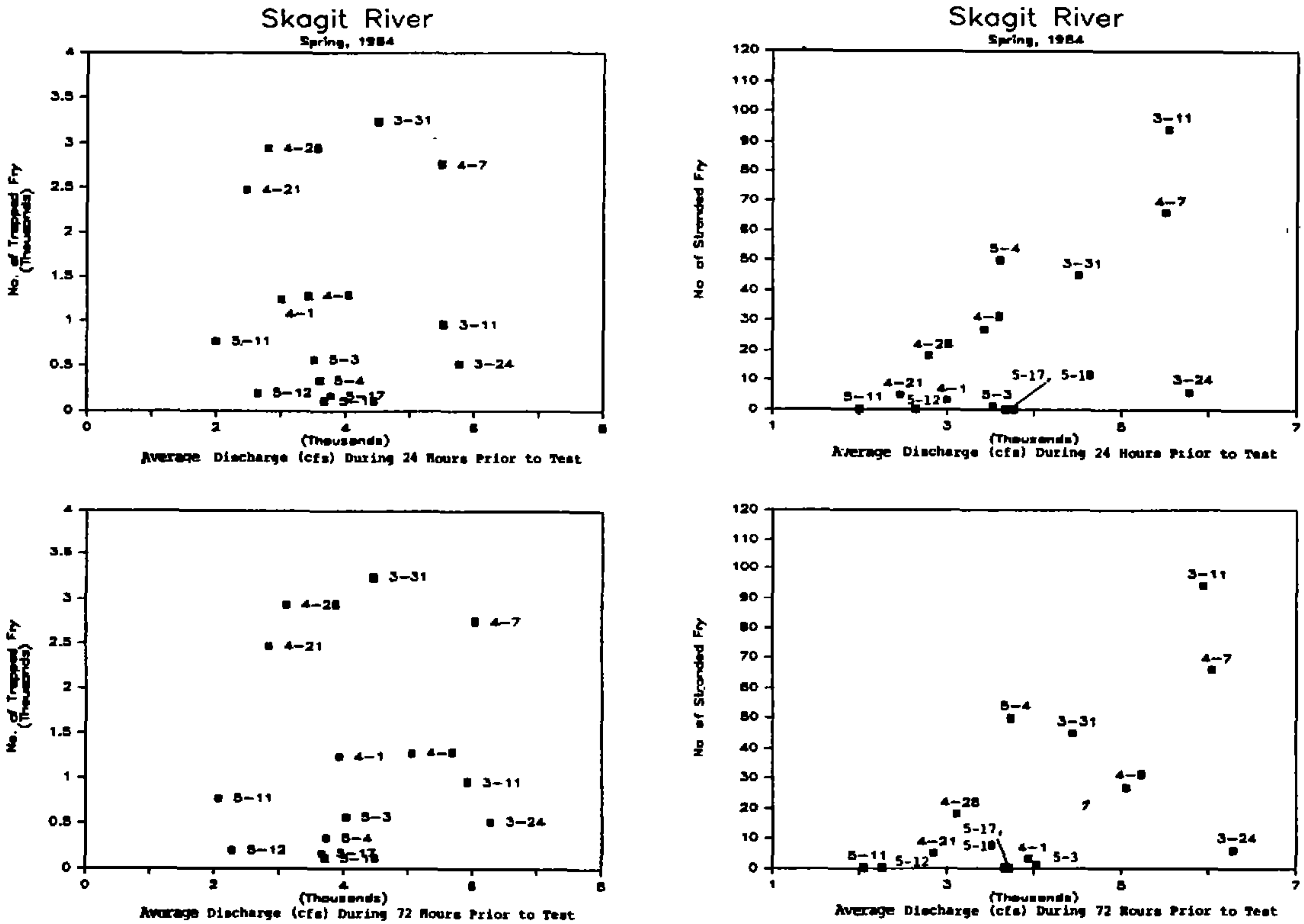


FIGURE 4-22. RELATIONSHIP OF FRY TRAPPING AND STRANDING TO AVERAGE DISCHARGE DURING 24 AND 72 HOURS PRIOR TO TEST, SPRING, 1984, SKAGIT RIVER

during the 24 and 72 hours prior to each test. There appears to be a trend exhibiting greater numbers of both trapped and stranded fry during downramp events with greater average daily discharge as measured during the 72-hour period prior to downramping. This relationship is confounded by the temporal vulnerability of fry to trapping and stranding as is evident by the reduced values of fry trapping and stranding in the 3,500 to 4,000 cfs range (Figure 4-22). These values are from later test dates when fewer numbers of fry were observed. Accordingly, the statistical regression of the mean daily discharge for both 24- and 72-hour periods prior to the test showed no statistical significance (Appendix F).

A general parallel trend of fry trapping and stranding is an indication that flow history prior to each test may be a factor that warrants further evaluation during future studies.

Relationship of Maximum Downramp Amplitude to Fry Trapping and Stranding. The relationship of maximum downramp amplitude for 24 and 72 hours prior to each test was explored. Figure 4-23 shows those relationships. For both variables, no significant relationships were noted when regressed against trapping. A significant relationship was apparent between maximum downramp amplitude during the previous 24-hour period and stranding, as determined by logistic regression analysis ($p < 0.001$). A very small negative coefficient was associated with the variable which indicates a decreasing probability of survival with decreasing maximum downramp amplitude (Appendix F). This counterintuitive result may be due to the inclusion in the analysis of the later test dates during which very few fish were trapped suggesting that the vulnerability of fry to trapping had declined.

Relationship of Ramping Rate to Trapping and Stranding. A linear regression of downramp rates (cfs per hour) to trapping was explored. The analysis was first conducted for all dates during the spring. The regression equation generated a slope of 0.05 and $r = 0.25$, indicating a very weak relationship. When all dates of zero downramping were removed (April 21 through May 12), a weak relationship was still evident (slope = 0.20, $r = 0.04$) indicating that variables other than downramping rate appear to be more important relative to trapping.

A similar exercise was conducted for stranded fry. With all dates included, the slope was 0.001 and $r = 0.24$. With all dates of zero fry stranding removed, a negative relationship was apparent (slope = -0.04, $r = -0.22$). The analyses involving the examination of ramping rate on fry trapping and stranding were conducted in a cursory fashion. Ramping rate was not targeted as a test variable during the studies, thus, only a small range of ramping rates were available to be analyzed. It should also be noted that these analyses were simple linear regressions. No attempt was made to standardize the data by date (e.g., the number of potholes on which observations were made varied among test dates) which may explain the changes in magnitude and sign of the slopes and coefficients of the equations. In effect,

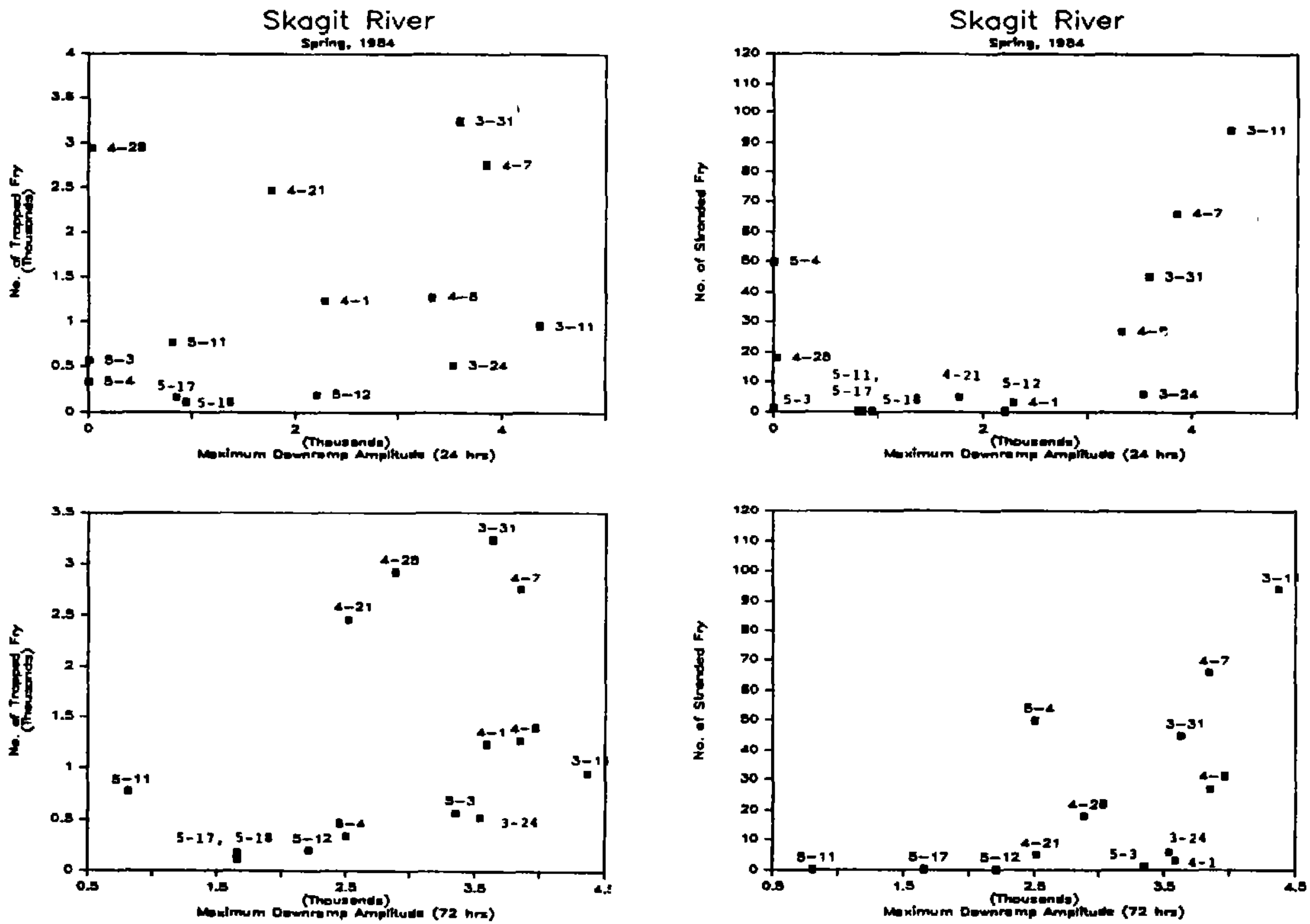


FIGURE 4-23. RELATIONSHIP OF MAXIMUM DOWNRAMP AMPLITUDE (cfs) DURING PREVIOUS 24 AND 72 HOUR PERIODS PRIOR TO TESTS AND NUMBERS OF TRAPPED AND STRANDED FRY, SPRING, 1984, SKAGIT RIVER

other variables are more important in determining trapping and stranding given the small range of ramping rates. These results again indicates the importance of considering flow history for at least 24 hours prior to initiation of a test event.

Fall Study

Overview of Test Flow Conditions. Fall tests were carried out during August and September, 1984. The daily flows during those months and the daily flow amplitude for 1984 is presented in Appendix G (R. W. Beck 1984). Also shown in Appendix G are the computed average daily discharge, average downramp amplitudes, and maximum downramp amplitudes for the 24- and 72-hour periods prior to each test.

Relationship of Minimum Test Flows to Fry Trapping and Stranding. Figure 4-24 shows the relationships of minimum test flows as recorded at Marblemount and Rockport to numbers of fry trapped and stranded during the fall. Because a majority of the tests had minimum flows at the lower end of the range (2,300 to 2,700 cfs at Marblemount), a large range of fry observations are located within a small range of flow conditions. At the high end of the flow range (3,900 cfs at Marblemount) the minimum flow of 3,860 cfs occurred as a result of heavy rainfall on September 6, which curtailed much of the field observations and reduced the numbers of trapped and stranded fry. This particular test was an example of how tributary inflow greatly confounded the results of the test even though flows from Gorge Powerhouse at the end of the downramp event were similar to previous tests (1,450 cfs).

The fall data were analyzed in the same manner as the spring data. For fall, neither Marblemount nor Rockport flows were significantly related to trapping. However, Newhalem flows showed a strong enough association with trapping to be considered significant ($t = 4.91$; $p < .001$) although the linear fit was poor ($R^2 = 0.09$). Figure 4-25 shows the line of best fit of trapping relative to Newhalem flow. The results shown in the figure run counter to the expected relationship of fry trapping to minimum test flows (that fry trapping would decrease as minimum test flows increase). The influence of fry age and size over time (and perhaps changes in habitat preference with age) appears to affect the outcome.

A logistic regression analysis showed that none of the three flows was siginificantly related to stranding.

Relationship of Previous 24- and 72-Hour Average Discharge to Fry Trapping and Stranding. Figure 4-26 shows the relationship of fry trapping and stranding to average daily discharge during the 24- and 72-hour period prior to each test. As with the spring period, a general parallel trend of fry trapping and stranding does appear for both time periods, an indication that flow history prior to each test may be an important factor to evaluate during 1985 steelhead studies. However, the statistical regression of the mean daily discharge

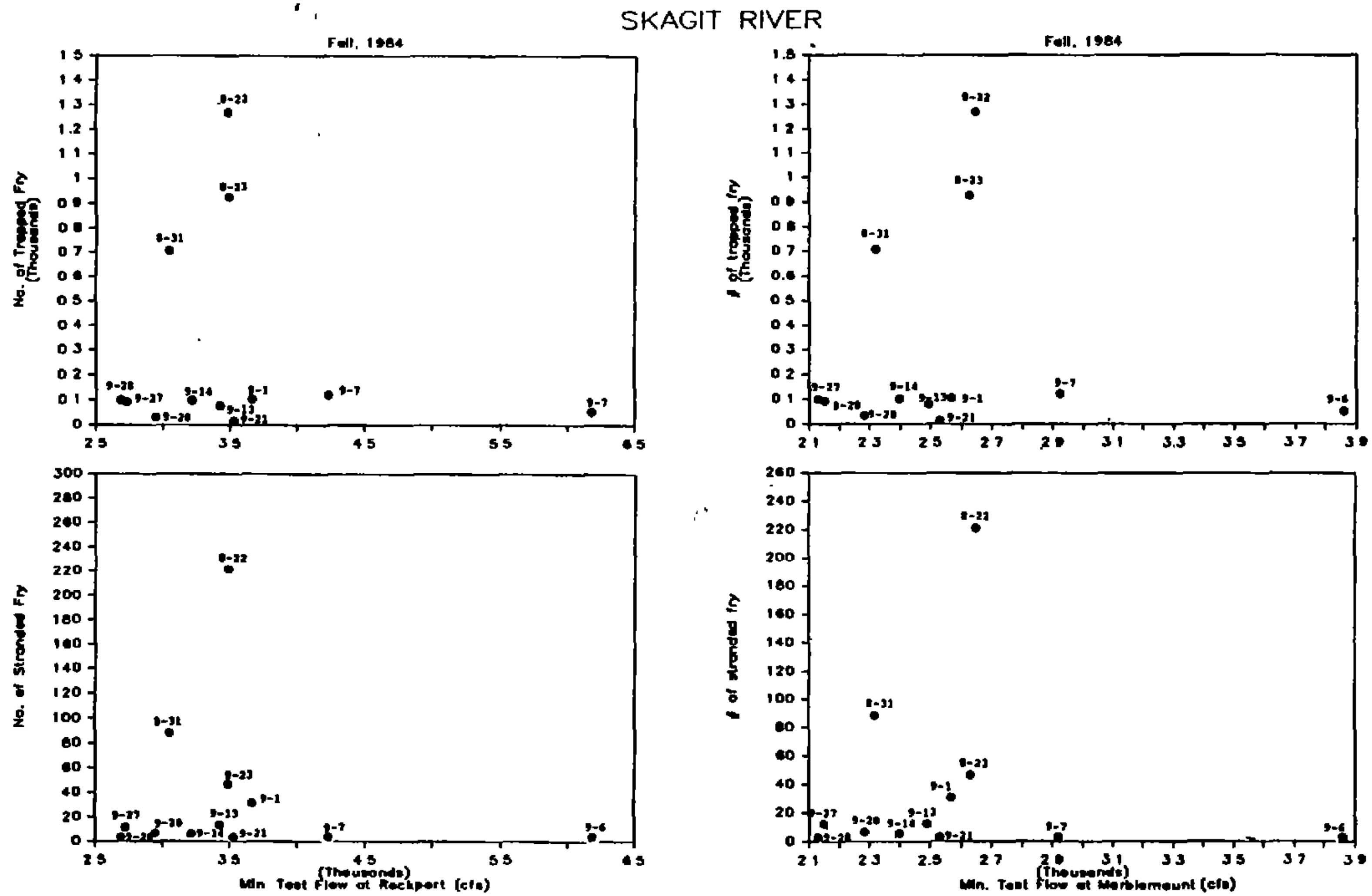


FIGURE 2-24. RELATIONSHIP OF MINIMUM TEST FLOWS AT ROCKPORT AND MARBLEMOUNT TO NUMBERS OF FRY TRAPPED AND STRANDED, FALL, 1984, SKAGIT RIVER

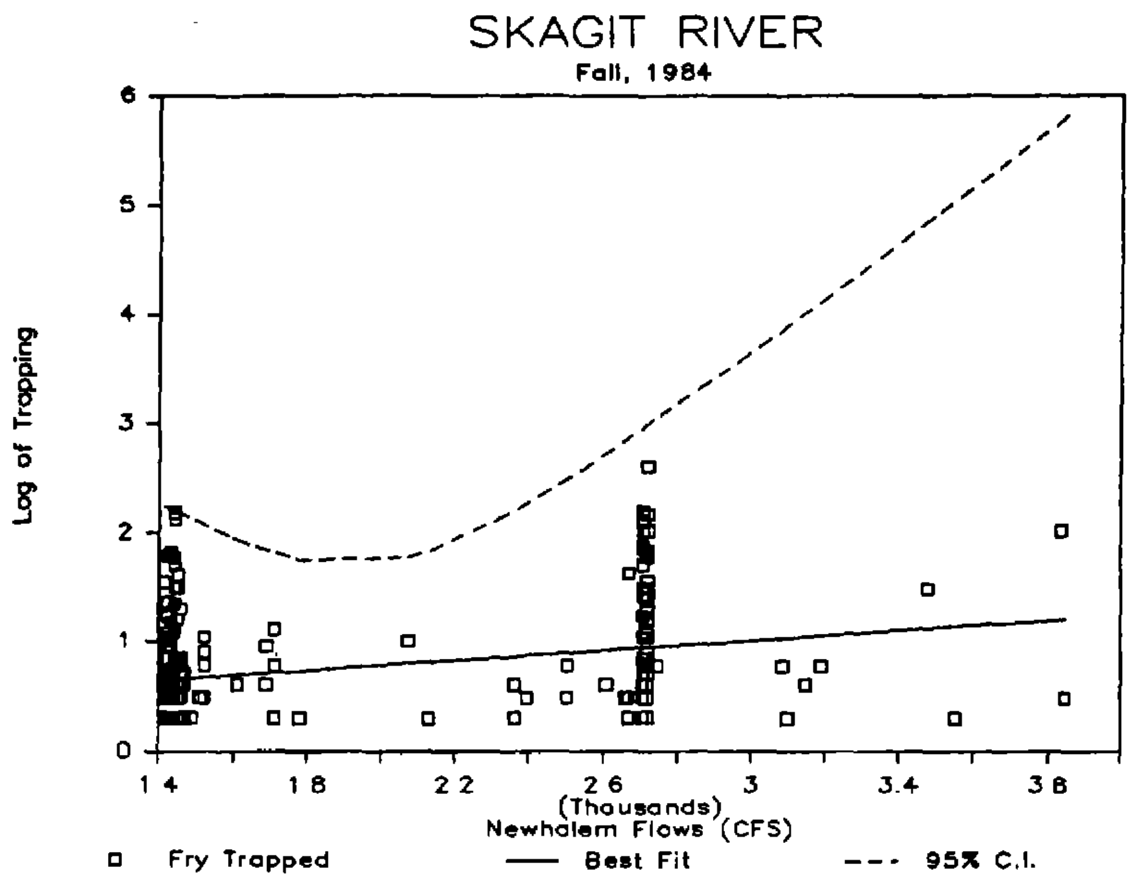


FIGURE 4-25. RELATIONSHIP OF MINIMUM OBSERVED FLOW AT NEWHALEM BY POTHOLE TO NUMBER OF FRY TRAPPED (LOG RELATIONSHIP), FALL, 1984, SKAGIT RIVER

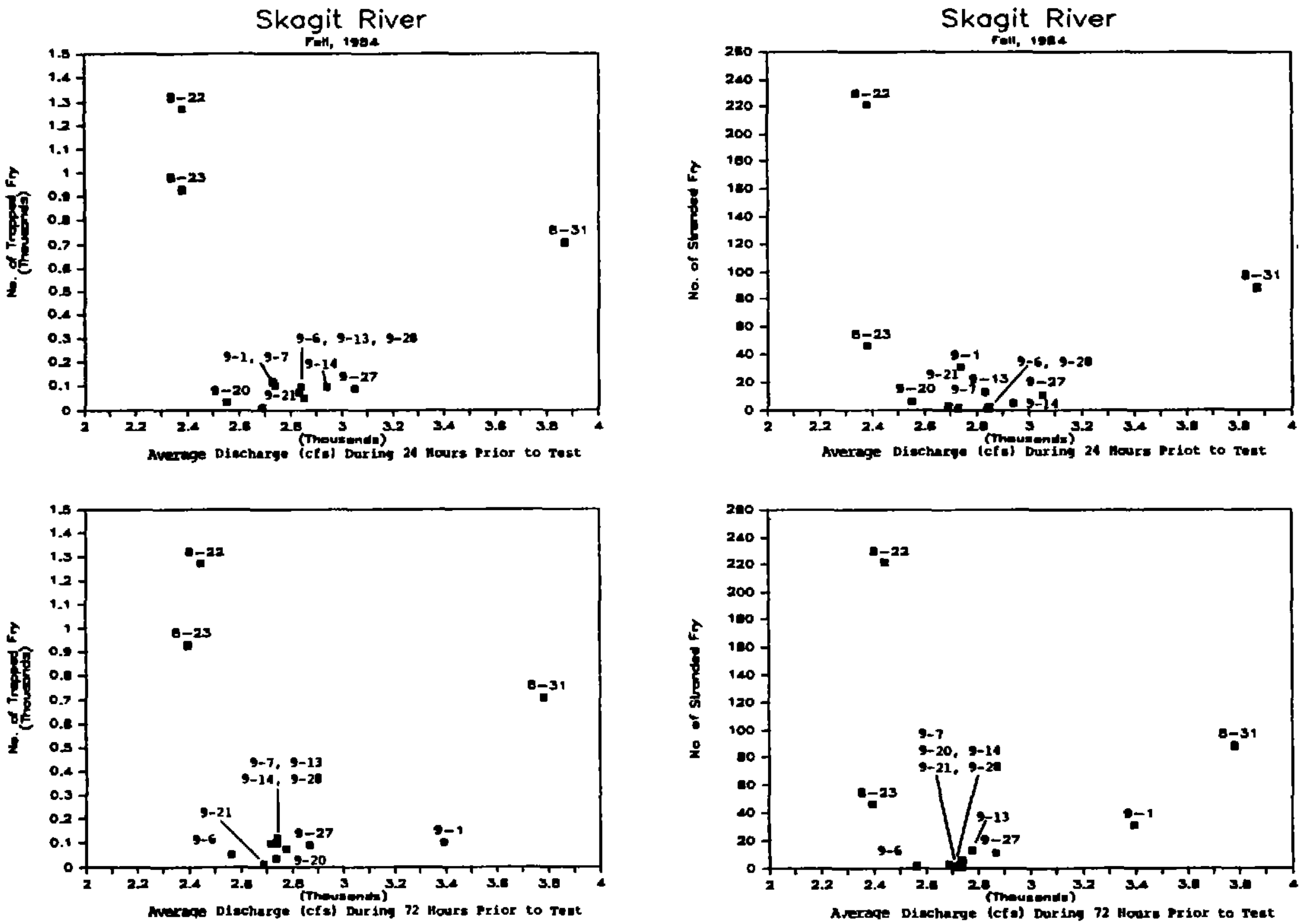


FIGURE 4-26. RELATIONSHIP OF FRY TRAPPING AND STRANDING TO AVERAGE DISCHARGE DURING 24 AND 72 HOURS PRIOR TO TEST, FALL, 1984, SKAGIT RIVER

for both 24- and 72-hour periods prior to the test showed no statistical significance for either trapping or stranding analyses. The reason for the lack of statistically significant results appears to be large variations in the data unexplained by the relationship investigated (Appendix F).

Relationship of Maximum Downramp Amplitude to Fry Trapping and Stranding. Figure 4-27 shows the relationships between maximum downramp amplitude during 24 and 72 hours prior to each test. The significance of the graph is limited by the fact that a majority of the tests had similar 24-hour (2,100 to 2,300 cfs) and 72 hour (2,100 to 2,400 cfs) amplitudes and that paired tests (2-day back-to-back) were included (on virtually all occasions, trapping was less on the second day of a 2-day test).

The regression analysis and logistic regression analysis (Appendix F) indicated that neither the previous 24-hour nor the previous 72-hour maximum downramp amplitudes had a significant association with trapping or stranding.

Relationship of Ramping Rate to Trapping and Stranding. A linear regression of downramp rates (cfs per hour) to trapping was evaluated. As with the spring analysis, the regression was conducted on all dates. The regression equation showed a negative slope of -0.22 and an $r = -0.42$. This negative relationship may have appeared because the greatest number of fry (1,268) were trapped on a day with the lowest downramp rate (713 cfs) but on the first test day of the fall studies. However, as with the spring data, other confounding variables are more important when considering the relatively small range of ramping rates examined.

A similar negative relationship occurred when stranding was analyzed (slope of -0.14 and $r = -0.49$), indicating that factors similar to the effects on trapping are involved.

Relationship of Downramp Time to Trapping. A cursory examination was made of the relationship of the timing of downramping to the incidence of steelhead trapping. Figure 4-28 shows the number of fry trapped by downramp ending time at Rockport. Numbers of fry trapped are summed over those study areas located furthest downstream and most likely affected by the downramp lag: Rockport, Wayne's Swim, Tin Shack, Bad Spot, Eagle Bar, and Forbidden Bar. The major effects of downramping were concluded by daybreak over the remaining upstream study areas. The downramp ending time at Rockport was calculated by adding 6.5 hours onto the downramp ending time at Gorge Powerhouse. This analysis has several limitations which should be noted. For example, the temporal distribution of trapped fry as shown in Figure 4-28 clearly shows that greater numbers of fry were at risk of being trapped during the first three sampling dates, August 22, 23, and 31, 1984. Also, on September 6, very high tributary inflow had a major dampening effect on downramp amplitude resulting in fewer number of fry trapped throughout the study area. If the results from those four dates are excluded,

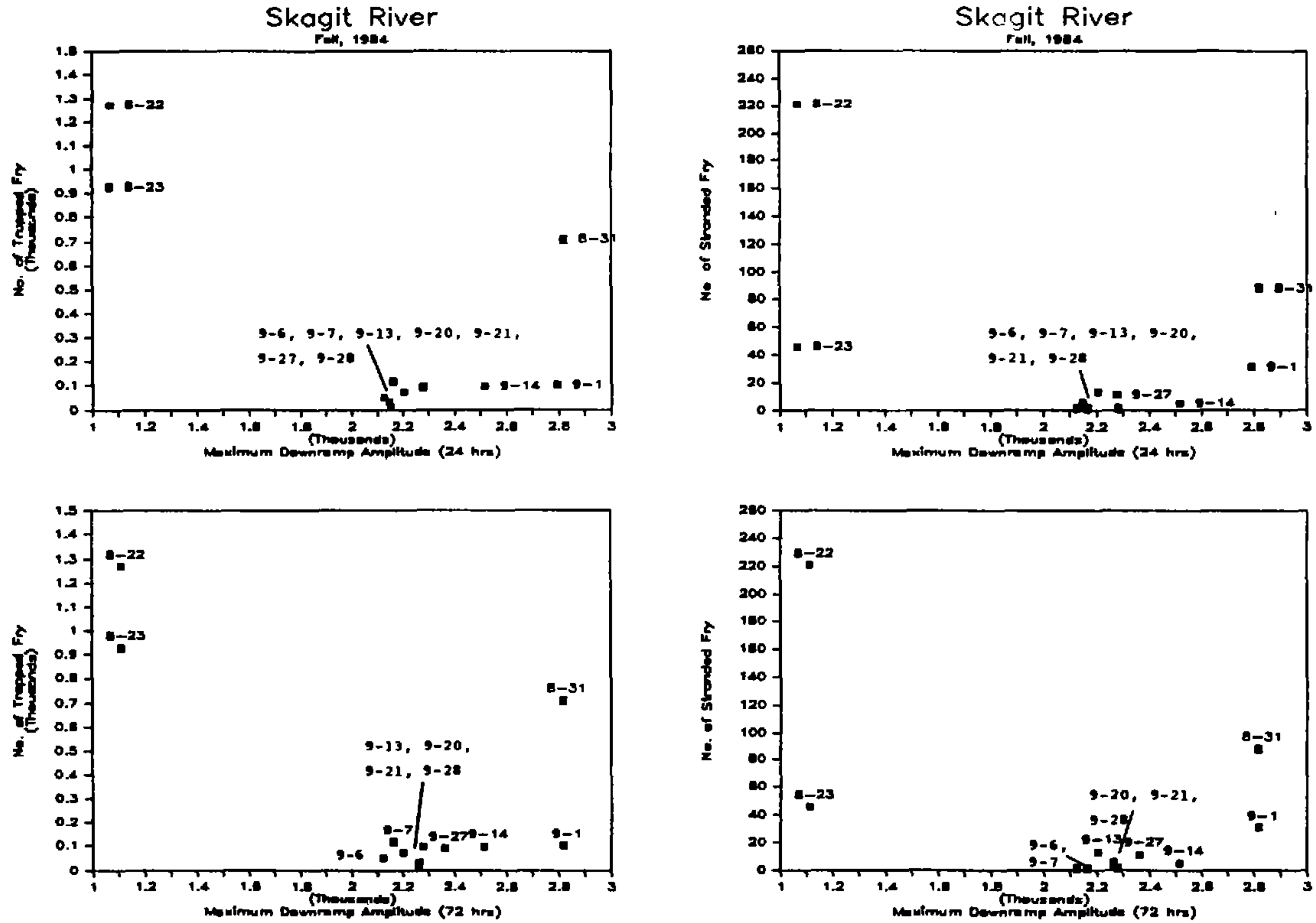


FIGURE 4-27. RELATIONSHIP OF MAXIMUM DOWNRAMP AMPLITUDE (cfs) DURING PREVIOUS 24 AND 72 HOUR PERIODS PRIOR TO TESTS AND NUMBERS OF TRAPPED AND STRANDED FRY, FALL, 1984, SKAGIT RIVER

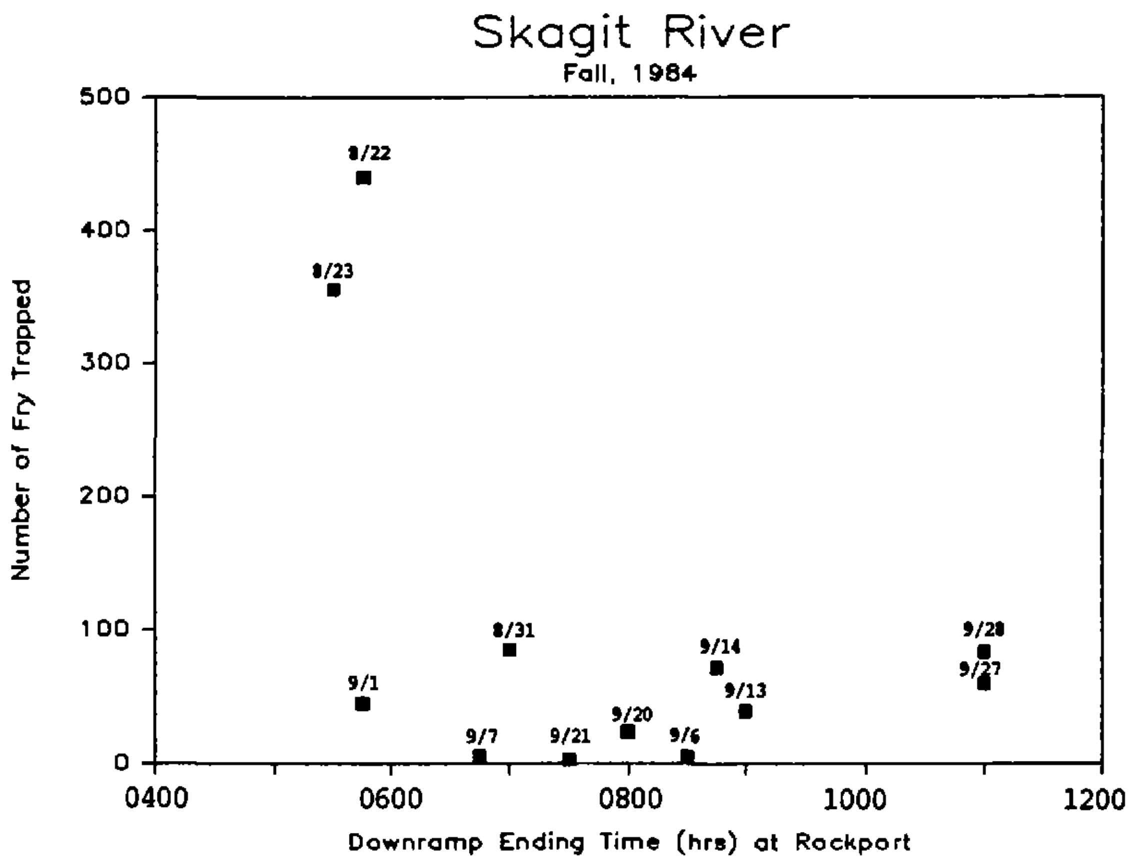


FIGURE 4-28. RELATIONSHIP OF DOWNRAMP ENDING TIME TO NUMBER OF FRY TRAPPED AT SIX STUDY AREAS LOCATED BETWEEN RM 67.5 and 70.5, FALL, 1984, SKAGIT RIVER

then a trend of increasing numbers of trapped fry by daylight downramp may be apparent. Of interest is the appearance of greater numbers of fry trapped during the last two test dates, September 27 and 28 when downramping was conducted later than all previous test dates. However, these cursory results cannot be considered conclusive since only one paired daylight downramp event was conducted. Further, the singular effect of downramp time cannot be distinguished from the effects of other confounding variables.

Pothole Connectivity

Field data collected during the spring and fall seasons included information on the flows at which potholes became connected and disconnected from the river. Those field observations also included records of when each pothole was observed dry (without measurable water in the pothole) and the drainage of potholes during the course of each test day.

A computer program was developed to summarize the pothole connectivity. This summary is presented as Appendix I. Appendix I includes a record of pothole area; pothole number; the connectivity flow (if available) for each pothole; the river flow gage assignment (Newhalem, Marblemount, or Rockport); the average number of fry trapped per day for spring and fall; the total number of fry stranded during spring and fall; the number of observations the pothole was observed connected and disconnected; the river flow when each pothole was observed dry and the number of observations each pothole was observed dry.

The following section of this RESULTS section includes analyses of river flow and pothole depth, pothole connectivity, and dry potholes vs. river flow.

Relationship of River Flow to Minimum Pothole Depth

Since the most numerous fry strandings were observed to be related to the draining of potholes, the association between river flows and drainage, as observed through lowest measured pothole depth of the day was measured with a linear regression model against the flows at the assigned gage stations (Newhalem, Marblemount, and Rockport). The regression gave an F value of 9.93, $p = <.001$ and $R^2 = 0.03$.

The flow at Marblemount was found to be significantly related to the depth of potholes in the study areas assigned to that gaging station. Similarly, the flow at Rockport was even more significantly related to minimum pothole depths at areas assigned to that gaging station than was the Marblemount flow (Appendix F).

This exercise served as a check on the validity of assigning pothole areas to one of the three river gage stations. It also gave credence to the Rockport flow model (Appendix C).

Pothole Connectivity

Field data collected during the spring surveys included observations of flows at which potholes connected and disconnected from the river. In the computer records, the time of these observations were associated with the river flow at that same time at either Rockport, Marblemount, or Newhalem. Appendix I indicates the pothole study areas and the assigned gage station.

Table 4-13 shows the relationship of pothole connecting at Newhalem, Marblemount, and Rockport to the number of fry trapped per day and the total number of fry stranded.

The connecting flow information used to develop Table 4-13 and as shown in Appendix I consisted of the average of the maximum river flow at which the pothole was observed disconnected and the lowest river flow at which the pothole was observed connected to the river. If flow records showed no minimum connecting flow, then the maximum disconnecting flow was used. If no disconnecting flow data were available, then no connectivity information was shown because disconnect flows alone were judged to be a more accurate representation of pothole connectivity.

The connecting and disconnecting flow information for each pothole was gathered during the field observations. Observers noted whether the pothole was connected or disconnected from the river and the time of the observation. During most observations, the potholes were either completely connected to or disconnected from the river. Occasionally, observations were made just as flows from the river were just entering potholes or while surface water from the pothole was still draining as river flows declined. In such rare cases, accurate connect and disconnect information for the pothole could be achieved.

For most potholes, however, the connectivity information was more limited and usually consisted of several observations of the pothole completely disconnected or completely connected to the river. For example, observations at Pothole No. 10 at Bad Spot showed the pothole was connected to the river at flows of 4,629 cfs (minimum connecting flow) on April 8 and 6,908 cfs on May 11 and was disconnected at flows of 3,805 cfs (maximum disconnect flow) on September 27and 3,665 cfs on September 28. Based on those records, it was clear that the connectivity flow of Pothole No. 10 lay between 3,805 and 4,629 cfs. In this case, the connecting flow was the average of the two flows or 4,217 cfs.

Table 4-13 shows that connecting flow information (both connecting and disconnecting observations) was not available for a large number of potholes, particularly for the Marblemount gage (connecting flow information available on 15 of 60 potholes surveyed) and Rockport gage (flow information on 113 of 185 potholes). The information that is available indicates potholes connecting at flows ranging from 1,500 to >2,000 cfs at Newhalem,

Table 4-13. Relationship of Pothole Connecting Flows at Newhalem, Marblemount, and Rockport to Number of Fry Trapped/Test Day and Total Number of Fry Stranded, Skagit River

FLOW (cfs)	NO. OF POTHOLES	AVG. NO. OF FRY TRAPPED/TEST DAY* SPRING**	FALL	TOTAL NO. OF FRY STRANDED * SPRING	FALL
NEWHALEM (9 Potholes)					
1500-2000	2	0.00	0.00	0	0
>2000	5	0.00	0.75	0	0
Unknown	2	0.00	0.00	0	0
MARBLEMOUNT (60 Potholes)					
2000-2500	1	0.00	12.17	0	0
2500-3000	3	0.00	2.37	0	57
3000-3500	5	0.00	4.52	0	56
3500-4000	1	0.00	4.54	0	7
>4000	5	0.00	0.69	0	0
Unknown	45	3.57	3.51	34	97
ROCKPORT (185 Potholes)					
3000-3500	3	2.42	2.04	0	1
3500-4000	6	0.00	0.64	0	0
4000-4500	20	1.22	1.80	0	21
4500-5000	9	3.51	6.93	0	9
5000-5500	4	3.35	0.86	0	1
5500-6000	7	8.94	3.70	7	200
6000-6500	16	11.13	0.82	65	68
6500-7000	4	13.64	0.00	4	0
7000-7500	1	2.40	0.00	4	0
>7500	43	2.45	7.08	62	179
Unknown	72	4.43	3.69	149	312

* Includes trapping and stranding in high flow potholes and during 8/15 reconnaissance survey. Figures do not include November high flow potholes.

** Note: Zeros at Marblemount in spring resulted from the fact no connecting flow information was available at sites assigned to Marblemount gage.

2,000 to >4,000 cfs at Marblemount, and 3,000 to >7,500 cfs at Rockport.

The data suggest that at pothole areas assigned to the Rockport gage, a majority of the mortality during the spring occurred in potholes connecting at higher flows (6,000 cfs and greater). However, of the sample, a majority of the observations are in potholes with unknown connecting flows.

For the fall period, more complete information was available on connectivity for potholes assigned to both Marblemount and Rockport. Data in Table 4-13 indicates that a majority of the fry mortality occurred in the 2,500 to 3,500 cfs range at areas assigned to Marblemount and in the 5,500 to 6,500 cfs range at pothole areas assigned to Rockport. Additionally, 37 percent of the known mortality in the fall was attributed to potholes connecting at flows >7,500 cfs (Table 4-13).

Dry Potholes vs. River Flow

A computer analysis was carried out to determine the number of potholes observed dry at various river flows. Figures 4-29 and 4-30 indicate the number of dry potholes in areas assigned to the Marblemount and Rockport gages.

Dry potholes were determined from spring and fall field observations. A dry pothole was defined as a pothole having no measurable water depth during the test day. Observations of dry potholes recorded during each test day were compared with the corresponding flow record for that day to determine the "dry" flow.

Figure 4-29 indicates that 35 of the 60 potholes (58 percent) assigned to Marblemount become dry between 2,000 and 3,500 cfs. Flow data for the remaining 25 potholes were not available. In contrast, Figure 4-30 shows that the number of dry potholes located between RM 67.5 and 73.1, and assigned to the Rockport gage, varies widely between 2,500 and 9,500 cfs. This may be a result of the presence of greater number of identified high flow potholes in the lower reach of the river. Dry potholes were observed over a greater range of flows in areas such as Rockport, Bad Spot, Eagle Bar, and Tin Shack than were observed in upper river pothole areas (Appendix I). For example, potholes were observed to dry at flows ranging to 7,200 cfs at Rockport, Bad Spot, and Eagle Bar. Higher flow potholes in upstream pothole areas such as Big Eddy, Fungus Bar, and Oink Bar were observed to dry at flows <3,800 cfs as measured at Marblemount.

Appendix I more concisely shows the sum of observations of dry potholes at each site, both spring and fall. This indicates those potholes that were dry during the tests.

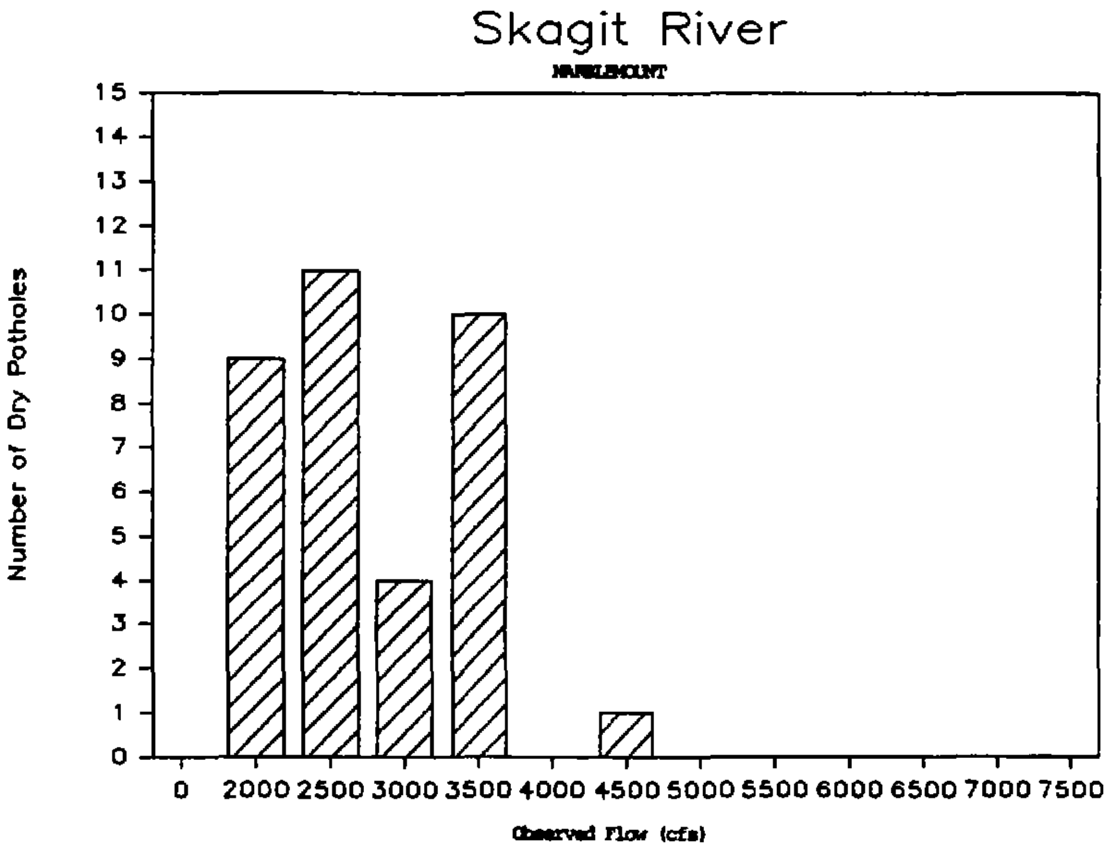


FIGURE 4-29. NUMBER OF DRY POTHOLES BETWEEN RM 73.3-82.9 (POTHOLES ASSIGNED TO THE MARBLEMOUNT GAGE ONLY) OBSERVED AT INCREMENTAL FLOWS OF 500 CFS

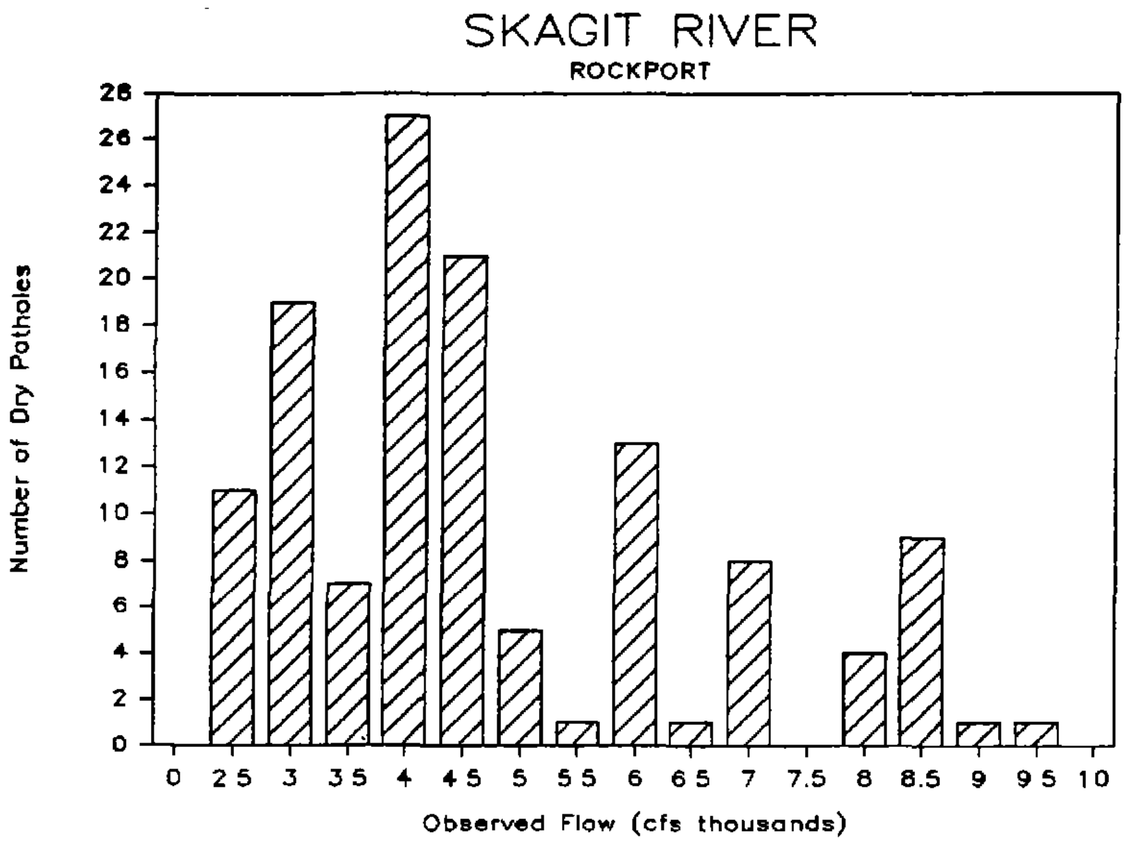


FIGURE 4-30. NUMBER OF DRY POTHOLES BETWEEN RM 67.5-73.1 (POTHOLES ASSIGNED TO THE ROCKPORT GAGE ONLY) OBSERVED AT INCREMENTAL FLOWS OF 500 CFS

5. DISCUSSION

Locations and Characteristics of Potholes Trapping and Stranding Fry

Spring

Of the 17,538 fry observed trapped (some repeated observations of fry may have occurred) during the spring, 30 percent of the trapping occurred at Stump Haven (RM 72.2), a side channel/slough area characterized by clusters of potholes at the upstream end of the slough and a series of potholes lying in a linear pattern along the remainder of the area. This characteristic was common of a majority of the areas that trapped fry during the spring. During stranding studies on the Cowlitz River, Bauersfeld (1978) found side channel and gravel bar stranding to be significant, particularly when downramping was conducted at the lower range of river flows (5,500 to 2,300 cfs reduction).

In some areas (Rockport, Stump Haven, Hooper's Slough, Fungus Bar, and Bacon Creek), potholes located at the top of the slough areas accounted for most of the trapping, while in other areas (e.g., Forbidden Bar) trapping was located at the lower end of sloughs. Studies by Hartman (1965), Stein et al. (1972), and Lister and Genoe (1970) indicated the preference of coho and chinook fry to occupy backwater eddies near shore and stream margins in association with bank cover. The limited swimming ability due to size of newly emerged fry appear to also cause fry to seek out protected areas (Everest and Chapman 1972). All of the areas, previously mentioned provide quiet water refuge for fry.

A majority of the potholes surveyed during the spring were located in the lower portion of the study area from Rockport to Illabot Slough; however, fewer potholes in the lower river trapped fry than did potholes on the rest of the river. Several factors may account for this difference: 1) habitat in many of the potholes in the lower river were less preferred by fry and 2) potholes (e.g., Tin Shack [RM 68.3]), although containing water, were not connected to the river except during very high river flows and therefore were not "available" to fry.

No fry population estimates in the river were made as a part of the study, so the relationship of fry abundance in the river to the number of fry trapped in potholes could not be determined. Additionally, no species compositions of trapped or stranded fry were made. Species composition (particularly as related to the timing of emergence) of the fry could have a significant effect on trapping and stranding results. Woodin et al. (1984) found that, based on electrofishing results during 1980 through 1983, the Marblemount area supported the greatest abundance of salmon fry; however, it is believed that more fry utilize the area near Rockport than further upriver (Kurko pers. comm.). Fungus Bar, the study area closest to previous electrofishing surveys, trapped 1,364 fry but with no observed stranding. Stober et al. (1981) theorized that site-specific variances in fry abundance are related to the spawning ground distribution of adults and the dispersal characteristics of the fry.

Results showed that there was no clear relationship of number of fry stranded to those trapped. For example, 45 fry were stranded of 126 fry trapped (36 percent) at Rockport, while at the rest of the areas only 2 percent of the fish trapped were stranded. In those areas of greatest stranding (Rockport, Bad Spot, Stump Haven, and Bacon Creek), potholes with stranded fry were most often located at the upstream end of each area. Additionally, one other common pattern of stranding between study areas was that only a few potholes accounted for a majority of the stranding. Two potholes at Bad Spot accounted for 85 percent of the stranding, 93 percent of stranding at Stump Haven occurred in one broad shallow pothole, 77 percent of stranding occurred in two potholes at Eagle Bar, and one pothole at Rockport resulted in 53 percent of the stranding at that site.

The percent of stranding for this study (315 fry) observed relative to the number of fry trapped (17,538) was surprisingly low. Only 2 percent of the trapped fish became stranded during 14 test days from March through May. During chinook salmon fry stranding studies on the Cowlitz River, Bauersfeld (1978) reported stranding 42 chinook and coho fry in side channels and gravel bars during one 3,900 cfs (9,400 to 5,500 cfs reduction) downramping event and 899 salmonids on the next day downramping of 3,200 cfs (5,500 to 2,300 cfs reduction). His estimate for total side channel loses on the second day alone were 6,329 chinook and coho fry.

An interesting note regarding fry mortality at Stump Haven and Bad Spot was that on several occasions, fry were observed stranded on the fringes of potholes that were only partially drained.

According to Scott and Crossman (1975), young salmonid fry have an affinity to shallow fringes and to substrate rather than to the deeper water column occupied by larger fish. During field surveys, fry were often observed to seek out cover afforded by large substrate such as cobble. If such substrate became exposed due to partial pothole drainages, those associated fry would become stranded. Similar observations of stranding on the Skagit River were made by Thompson (1970) and Phinney (1974).

Analyses of data for this study showed that fry were more often found trapped in potholes that had some sort of cover (75 percent) (e.g., overhead vegetation, logs, etc.) vs. potholes without cover (25 percent); however, this result was not surprising since a majority (75 percent) of the potholes studied had some kind of cover. Bustard and Narver (1975) found that coho fry became more closely associated with cover and lower water velocities at low water temperatures (4°C or less) and that few fish were found more than 1 meter (~33 inches) away from cover. These observations were similar to those made by Hartman (1965).

Results of this study showed some differences in trapping and stranding of salmon fry by substrate and cover type. While more fry were trapped in potholes with sand, more fry were trapped in potholes having silt substrate. Additionally, more fry were trapped and stranded in potholes with cover than with potholes without cover. Previous studies by Lister and Genoe (1970) showed chinook and coho salmon fry to have a preference for habitat with cover. Everest and Chapman (1972) reported that Age 0 chinook prefer water velocities of <0.15 m/sec and water depths of 0.15-0.3 m with silt substrate.

Several factors may be influencing the pothole stranding of fry on the Skagit: 1) storage of water in river banks and bars (termed bank storage) may have a significant bearing on how long water is sustained in potholes following a downramping event, 2) the duration of the minimum flow of the downramping event, and 3) the elevation of the potholes trapping fry relative to elevation of the river during the minimum flow of the event. All of these factors may be working in concert. In many cases, the influences may vary from site to site on the river, e.g., bank storage may be more prevalent in an area of massive gravel and cobble than on a broad flat sand bar area. These factors should be considered in future pothole studies.

Mortality of fry due to high water temperatures was not a factor during the spring. This is not surprising given the fact that 75 percent of all potholes with trapped fry had some kind of cover. Bauersfeld (1978) reported fry mortality due to high water temperatures in potholes on the Cowlitz River. However, during that study, many of the fry were trapped in the potholes for nearly 24 hours and were not shaded.

Whether a pothole is on the north or south side of the river may, in some cases, be a more important factor in pothole water temperature than the presence of overhead vegetation. For example, potholes along the north bank may not be shaded from the sun by overhead vegetation, whereas potholes on the south bank could be shaded even though overhead cover does not exist.

Fall

During the fall surveys, 3,578 fry were trapped, a majority of those being emerged steelhead. The most important trapping areas for fry were Big Eddy (RM 77.5), which accounted for 27 percent of trapping; Wayne's Swim (RM 68.1) accounted for 19 percent of trapping and Stump Haven (RM 72.2) 11 percent.

It should be noted here that during the initial reconnaissance survey conducted on August 15 and 16, a large number of fry (3,120) were observed trapped in potholes at Forbidden Bar (RM 70.5), Hooper's Slough (RM 72.7), Stump Haven (RM 72.2), and Eagle Bar (RM 70.1). With the addition of the August reconnaissance survey results, Big Eddy remained the most important area (1,247 fry), with Forbidden Bar (856 fry), Stump Haven (832 fry), and Hooper's Slough (821 fry) next in the order of importance.

As with the spring surveys, the common feature of areas trapping steelhead fry was that most were side channel/sloughs with linear patterns of potholes.

The most significant areas for fry stranding in the fall (including results of the reconnaissance survey) were Hooper's Slough (209 fry), Forbidden Bar (142 fry), Big Eddy (110 fry), and Stump Haven (109 fry). Once again, a majority of the potholes in these areas were located in side channel/slough areas. Everest and Chapman (1970) reported that Age 0 steelhead prefer rubble substrate in water velocities of 0.15 m/sec and depths of 0.15 m and that as fish become larger they moved into faster, deeper water. Bustard and Narver (1975) also found that Age 0 steelhead preferred shallow water, often less than 0.15 m in depth. Mortality at Hooper's Slough and Eagle Bar was in long, linear potholes with sand substrates. During tests after the reconnaissance survey, stranding at both Hooper's Slough (9 fry) and Eagle Bar (13 fry) was extremely low.

Several factors could account for the lower numbers of both trapping and stranding: 1) less wetted habitat (and therefore potholes) was available due to seasonally declining river flows; 2) as fry became larger, they were better able to avoid trapping; and 3) as they became larger, steelhead fry were attracted to different types of habitat. In all likelihood, all of those factors had a bearing on the difference between trapping and stranding. The amount of available wetted habitat was determined, in part, by the maximum discharge requirement of 4,200 cfs (as measured at Gorge Powerhouse) set forth in the Interim Flow Agreement. That factor is discussed in a later section of this discussion.

Comparisons of Spring and Fall Trapping and Stranding

Figure 5-1 compares the locations and numbers of fry trapped spring and fall. Aside from the difference at Big Eddy (RM 77.5), there was a comparable trend of trapping along the river both spring and fall.

Figure 5-2 indicates the spring and fall stranding by area (river mile). Peaks of steelhead stranding at Forbidden Bar and Big Eddy were the major differences in stranding locations between the surveys. Fry trapping and stranding were compared in potholes common to both spring and fall surveys (Figures 5-3 and 5-4). Of the 90 common potholes, only 41 trapped fry both spring

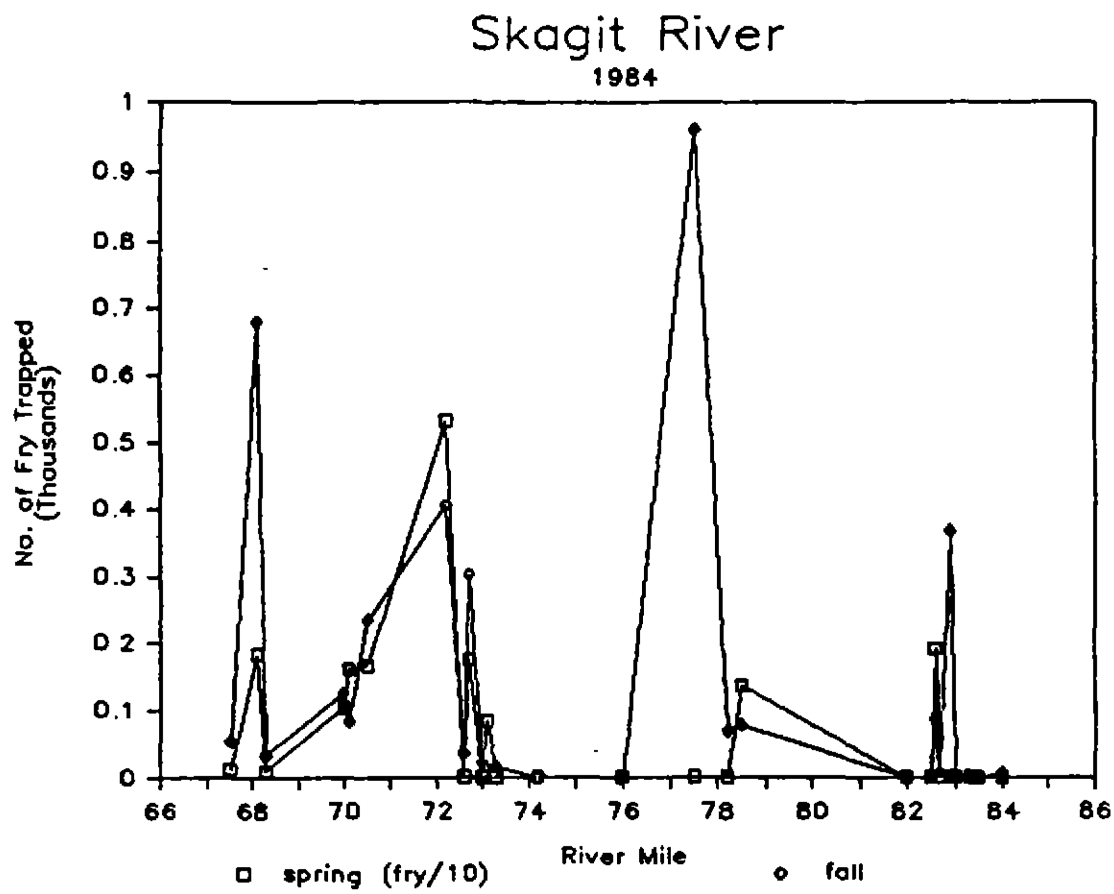


FIGURE 5-1.

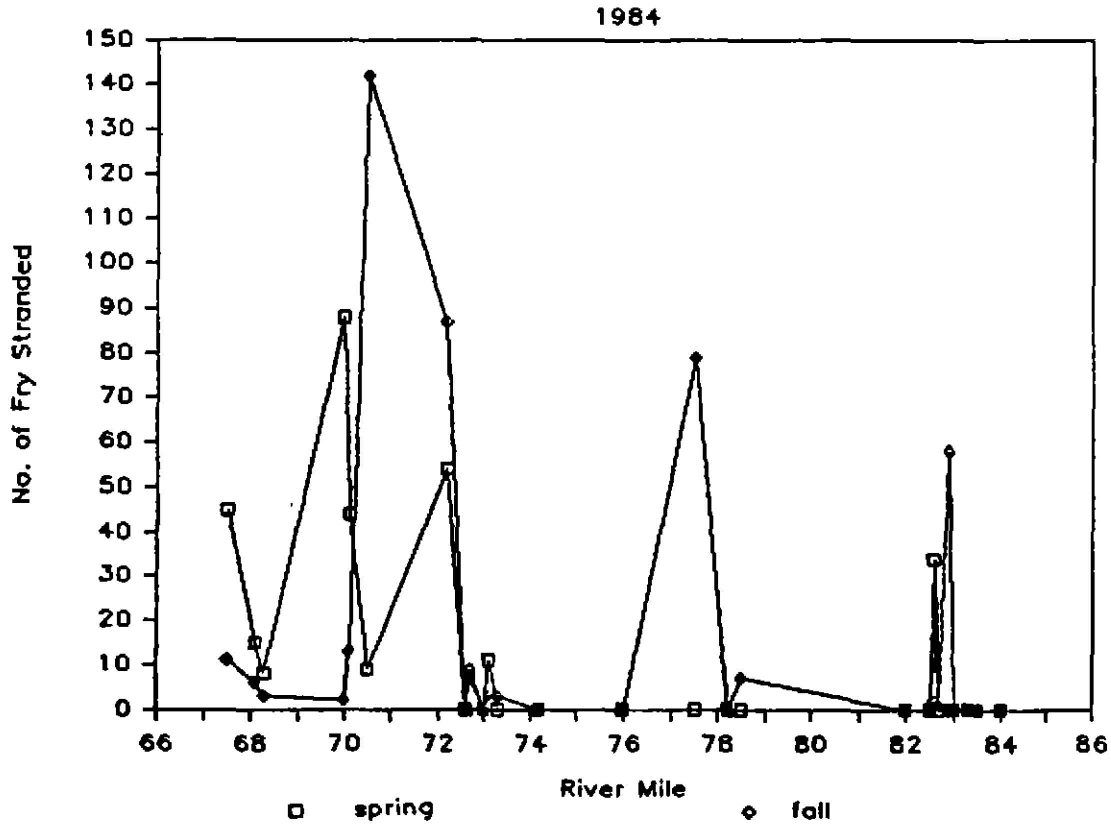


FIGURE 5-2.

FIGURES 5-1 and 5-2. COMPARISONS OF SPRING AND FALL, 1984, FRY TRAPPING AND FRY STRANDING BY STUDY AREA (RIVER MILE), SKAGIT RIVER

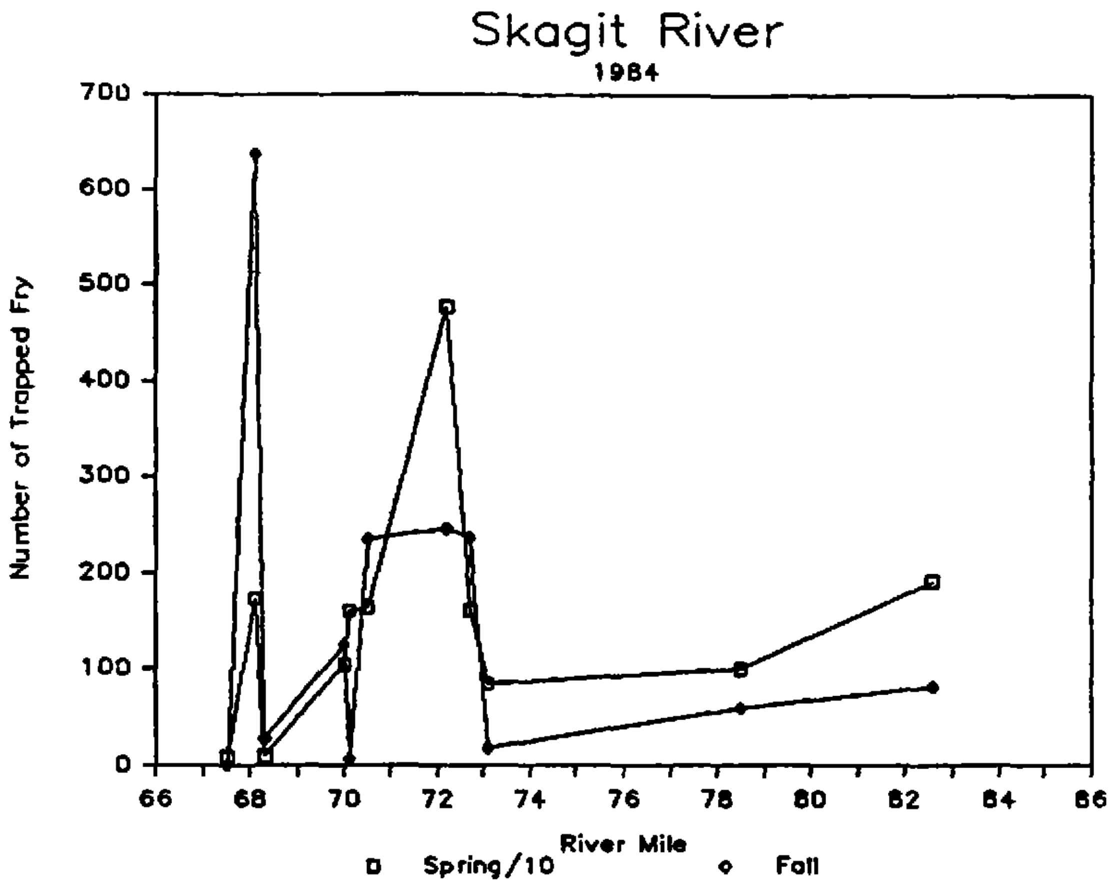


FIGURE 5-3.

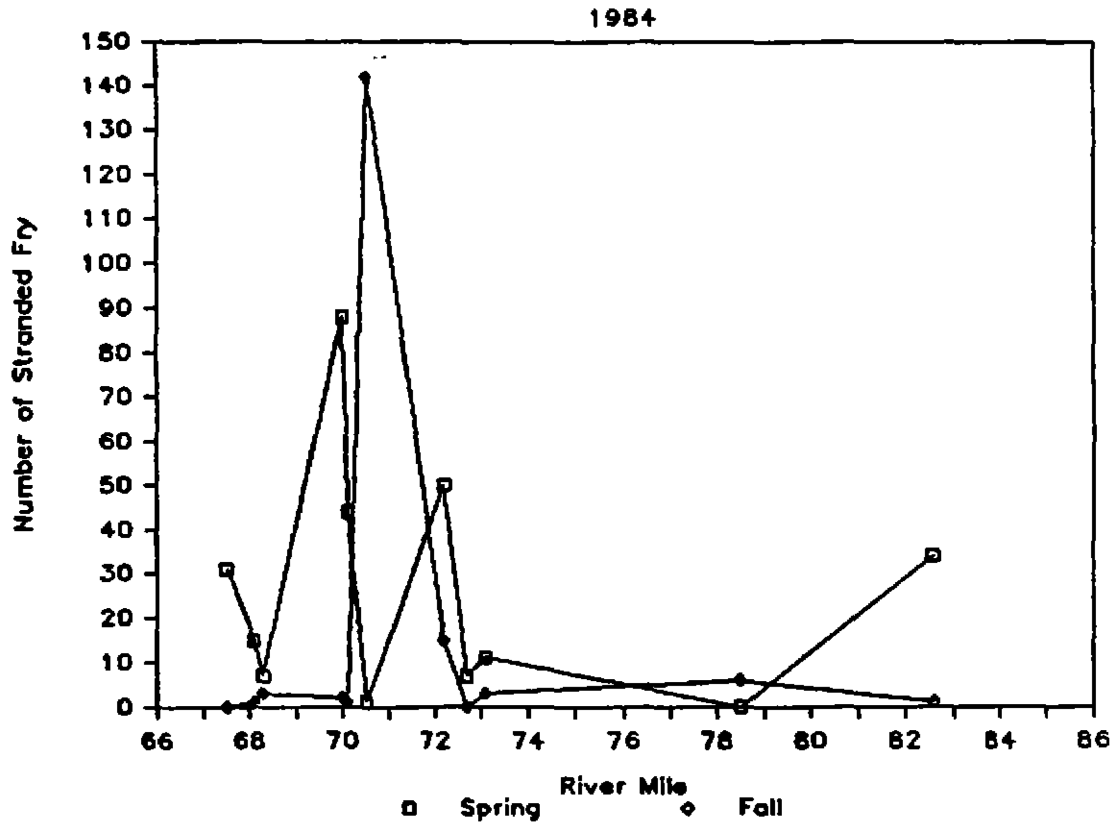


FIGURE 5-4.

FIGURES 5-3 and 5-4. COMPARISONS OF FRY TRAPPING AND FRY STRANDING BY STUDY AREA (RIVER MILE) IN POTHOLES COMMON TO BOTH SPRING AND FALL SURVEYS, 1984, SKAGIT RIVER and fall, while just five potholes stranded fry during both seasons (Appendix H). Review of water depths of the other 49 common potholes indicated that 52 percent of the potholes that trapped fish in the spring were dry during the fall. This suggests that even between tests during the fall, river flows may not have been sufficient to flood those potholes and provide habitat for steelhead fry. This finding is not surprising since: 1) tributary inflow to the Skagit River was lower during August and September than it was during the spring, and 2) per the Interim Flow Agreement (Appendix A), the maximum allowable flow at Gorge Powerhouse is 4,200 cfs. The difference of spring and fall flow conditions will likely vary from year to year due to variability in tributary inflow and weather conditions.

High Flow Potholes

During both the spring and the fall survey periods, a number of potholes were found that were continually dry or contained fry and a sufficient amount of water to sustain the fish throughout the spring, summer, and fall. Those potholes located at Wayne's Swim (RM 68.1), Tin Shack (RM 68.3), Bad Spot (RM 70.0), Seclusion Island (RM 76.3), and Fungus Bar (RM 78.5) were observed to connect to the river only during very high river flows.

High flow observations (9,750 cfs at Marblemount, 11,900 cfs at Rockport) made during November, 1984, provided information on flows at which these potholes connect to the river. All areas are similar in that the potholes are located on cobble bars through which river water continually flows. These potholes were deep enough and with sufficient cover to sustain fish populations even though never directly connected to the river during the testing periods.

Observations at the potholes in November indicated that even with a 9,750 cfs flow at Marblemount, many of the potholes were not connected to the river. In most cases, streams of water flowed through the gravel bars to the potholes with water in turn flowing from those potholes to others on the gravel bar (sometimes located 50 to 100 yards away).

Because fry in these potholes were "residents" and were not affected by test flows, data gathered on these potholes were treated separately. During the fall at Wayne's Swim, a very deep and large pothole that did frequently connect to the river (Pothole 8), but always contained water, was also treated separately.

It is believed that the fry were washed into the high flow potholes during extremely high water events (probably greater than 11,000 cfs at Rockport) during the winter of 1983-1984. It is assumed that equally high flows would be necessary to release these fry into the river.

The number of fry observed in these potholes varied during the surveys, but an average of 352 fry in 14 potholes were counted during the spring and 565 fry in 11 potholes (excluding Wayne's Swim No. 8) during the fall.

In addition to the high flow potholes that were a normal part of the spring and fall testing, 140 additional high flow potholes were located during reconnaissance surveys in November, 1984. Those potholes become connected to the river only at very high flows (>9,000 cfs at Rockport) and could cause fry trapping and stranding during high winter flows and during snow runoff conditions.

Trapping and Stranding by Date

Spring

Temporal distribution patterns were different for trapped and stranded fry during the spring surveys. There was no apparent relationship between numbers of fry trapped and timing of test dates, although 88 percent of all observed fry were trapped between March 11 and April 28. The lower numbers of fry trapped during the first two test dates (Figure 4-8) may have been a result of less observational effort; only seven and eight of the eventual 11 study areas were sampled on March 11 and 24, respectively. The implication that greater numbers of trapped fry would have been observed on those dates is further strengthened by the observation that two study areas, Bad Spot and Booper's Slough, contained more trapped fry on those dates than were observed on the remainder of the test dates. Fry stranding was also observed over an extended period during the spring; however, with the exception of May 4, a declining trend was apparent. The largest number of fry stranded (94 fry) occurred on the first date. Had all areas been sampled during the first two dates, it is conceivable that more stranding would have been observed. However, fewer numbers of stranded fry were observed on March 24 than were observed on subsequent dates at study areas common to all test dates. These apparent contrasting results are largely due to the extended fry emergence period known for chinook salmon. Phinney (1974), Orrell (1976), and Graybill et al. (1978) reported on chinook fry length distributions over the spring and concluded that prolonged emergence resulted from stock overlaps in habitat use; spring, summer, and fall chinook runs all occur in the Skagit River. Chinook fry emergence above the Cascade River began as early as January and extended into May for the years covered in the reports cited. This pattern fits well to the fry abundance data summarized by date in Tables 4-6 and 4-7. In general, fewer fry were trapped later in the survey period than earlier.

Of interest was the finding that generally less trapping and stranding occurred on the second day of "paired" test dates. Several reasons may account for this trend: 1) fry may not have sufficient time to reinhabit pothole areas between tests, 2) fry may "learn" or become accustomed to the flow fluctuations and therefore do not reoccupy pothole habitat immediately following the first day of tests, and 3) fry may be territorial and flow fluctuations may disrupt their normal patterns of territoriality resulting in fewer fish on the second day. Field studies carried out by R. W. Beck and Associates, Inc. during 1985 will better define the movement of fry in pothole areas and help to provide an answer for this phenomenon.

Fall

Temporal distribution patterns for both trapped and stranded steelhead fry during the fall surveys were markedly more evident than were observed for salmon fry during the spring survey. Over 80 percent of all trapped and stranded fry were observed during the first three test dates in a declining manner. Data collected during the reconnaissance survey 1 week prior to the first test date also corroborated this pattern. This relatively sharp peak of fry abundance in potholes is consistent with the timing of steelhead abundance previously reported in the Skagit River (Graybill et al. 1979).

The decline in the number of steelhead fry trapped and stranded during the study is probably associated with the increased size of the fry. Bustard and Narver (1975) noted that steelhead fry move into deeper water as they increase in size. In all likelihood, by late September a majority of the steelhead fry either no longer occupied the pothole habitat or were able to avoid trapping by moving away from potholes as the river levels dropped.

As was also observed during spring survey, fewer fry were generally observed during the second day of paired test dates for the same reasons given for spring. During steelhead fry stranding conducted by Crumley (unpublished Skagit Standing Committee minutes, January 10, 1984) in 1983, it was noted that the first test stranded relatively more fry as compared to following tests. He noted that steelhead may have an increased adaptability to flow fluctuations based on this nonmigratory behavior.

Flow records at Gorge Powerhouse indicate that the average daily discharges for the 72 hours prior to the test days (2,822 cfs) were 1,505 cfs less than occurred during the reconnaissance survey (4,327 cfs) (Appendix G). That reduction occurred because the Interim Flow Agreement requires that after August 20, maximum flows at the Gorge Powerhouse be no greater than 4,200 cfs. That reduction in maximum regulated flow, coupled with a seasonal reduction in tributary inflow, reduced the amount of wetted habitat available to fry. This reduction in habitat was partly explained when potholes common in both the spring and fall surveys were compared.

That required reduction in maximum flow may very well have had a significant bearing on stranding observations during the first two tests on August 22 and 23, just 2 and 3 days after the

4,200 cfs maximum flow was initiated. On August 22, 142 (33 percent of all fry stranded during the surveys) were found stranded in one pothole at Forbidden Bar (RM 70.5). That pothole became isolated from the river but was sustained by water passing through the gravel bar. Flows at which that pothole connected to the river were estimated to be 6,470 cfs at Marblemount, approximately 2,200 cfs greater than the maximum allowable flow from the Gorge Powerhouse. No mortality was reported at that site during the rest of the survey.

At Stump Haven (RM 72.2), 76 fry were observed stranded on August 22. Estimated connecting flow for that side channel is 5,400 cfs (Marblemount). Throughout the remainder of the survey, 11 additional fry were stranded at that site. Additionally at Big Eddy (RM 77.5), which was surveyed only in the fall (and observed to be flooded most of the time during the spring), the connecting flow was approximately 3,300 cfs (Marblemount). Based on these preliminary results, it is suggested that any 1985 season steelhead fry studies take into consideration the influence of the Interim Flow Agreement maximum flow requirements.

Analyses of River Flow to Fry Trapping and Stranding

The analyses of flow conditions (minimum test flows, average daily discharge, mean and maximum daily downramp amplitude during the 24 and 72 hours prior to each test, and ramping rate) were affected by a number of factors that caused no strong relationships to appear in any of the results, but there were some hints of what may be important to evaluate during 1985 studies.

One of the most significant factors at work was that of the population of fry in the river during the time of the tests. Due to the difficulty in conducting such surveys, no population surveys in the river were conducted prior to each test. As a result, there was no clear indication of the number of fish that were at risk of being trapped. Additionally, as mentioned previously, populations of fry vary over time and in different parts of the river which influence the risk of trapping. Other biological factors such as preference of cover, substrate and velocity conditions, and age and size of the fry are also important.

Results showed that on the second day of paired downramp tests the incidence of trapping and stranding was significantly less than during the first day. This particular factor also influenced the relationship of each of the flow analyses to trapping and stranding.

The downramp tests conducted during the spring (except for those after April 8) and fall had ending discharges set at ~2,300 cfs and ~1,450 cfs, respectively. This resulted in observations at similar flows with few other flow conditions for comparison.

Additionally, during the fall, all tests from September 6 to the end of the study began at ~3,550 cfs and ended at ~1,450 cfs. These standardized tests resulted in excellent temporal data on fry trapping and stranding (Figures 4-7 and 4-14) but provided limited data for comparing the effects of varying discharge conditions on trapping and stranding.

Another influencing factor was that not all study areas were sampled equally throughout the tests. During the spring, four areas were not surveyed on the first test day and three areas were missed on the second test. During the fall, a number of sites were not surveyed on each test date. This resulted in an unequal set of data for each test day, which made analysis and interpretation difficult.

Given all of these factors, a number of preliminary conclusions can be drawn from the data.

<u>Spring</u>

No strong relationships were found with any of the analyses of flow to fry trapping and stranding conducted. One weak relationship showed flows at Newhalem and Rockport to be most closely associated with stranding and that the odds of survivability of fry decreased with decreased flows.

A majority of the flow and trapping/stranding relationships appeared to be confounded by a variety of factors such as the age and size of fry (which influenced the likelihood of trapping and stranding), lack of continuous testing during the spring survey period (no tests were run from April 14 through May 18, 1984) and the size, species composition, and location of the fry population at risk in the river.

A multivariate regression analysis of minimum flows at Newhalem, Marblemount, and Rockport to trapping showed gaged flow at Marblemount to be more strongly associated with trapping (Figure 4-21). A decrease in trapping was associated with increased river flows; however, a linear relationship did not exist. Similarly, neither analyses of average discharge or maximum downramp amplitude for 24 and 72 hours prior to the test events showed any statistical significance.

Although no statistical relationships of flows to trapping and stranding were clearly evident, there is indication that flow history prior to a downramping event is an important testing condition.

No clear picture of the relationship of minimum test flow or ramping rate per hour was evident, in part due to the changes in testing procedures after April 8. A regression analysis of ramping rate per hour showed a negative relationship because the greatest number of fry stranded occurred on the day with the smallest downramp rate.

In order to achieve a statistical relationship of flow conditions to trapping and stranding in 1985 field studies, a study design must be established at the outset that will allow for a meaningful analysis. A number of downramp minimum flows must be considered and the results applied to variables such as tributary inflow and the population of fry in the river at the time of the tests.

Fall

As with the spring results, no strong relationships were found with any of the analyses of flow to fry trapping and stranding conducted. Graphically, the relationship of maximum downramp amplitude for 72 hours prior to each test showed the greater the downramp amplitude the greater the incidence of fry trapping; however, statistical analyses showed no significance. The relationship was clouded by the high number of trapped and stranded fry during the first two dates, August 22 and 23, tests dates with the smallest downramp amplitude during the previous 72 hours.

When the flow history (Appendix G) prior to the first two tests was evaluated, it was noted that flow discharges from Gorge Powerhouse for 6 days prior to the tests had ranged from approximately 2,800 cfs to 1,800 cfs with an average daily discharge of about 2,400 cfs. Because the flow discharge from Gorge Powerhouse for 72 hours prior to the downramp test was low, the magnitude of the downramp event on August 22 and 23 was only 1,114 cfs, the smallest magnitude for any of the test events. Therefore, the number of trapped and stranded fish observed on August 22 and 23 was probably more a function of the overall abundance of fry in the river rather than a function of the downramp amplitude. Since no fry population surveys were conducted during the study, this conclusion is only conjecture.

No clear picture of the relationship of either minimum test flow, average discharge for 24 or 72 hours prior to the test or average downramp amplitude for the 24 hours prior to the test events showed any statistical significance.

An evaluation of downramp ending time to the number of fry trapped during the fall showed a trend of increased numbers of trapped fry the later into daylight the downramp was concluded at Rockport. No statistical analysis was conducted on the data; however, Figure 4-28 does show an upward trend, but only if four dates (August 22, 23, 31, and September 6) are excluded from the analysis. In steelhead fry stranding analyses conducted by Crumley during 1983 (unpublished Skagit Standing Committee minutes, January 10, 1984), no correlations were found to the variables of night/day downramping and trapping. Since only one "daylight" downramp was conducted as a part of this study, these cursory results cannot be considered conclusive.

Pothole Connectivity

Flow connectivity information for the pothole areas indicates a number of unknown connecting flows for 119 of 254 potholes sampled. Connectivity flow information that is available represents an average of the maximum river flow at which the pothole was observed disconnected and the lowest river flow at which the pothole was observed connected to the river. In many cases, both connecting and disconnecting flow information was not available; for those cases, a maximum disconnecting flow alone was used. If no maximum disconnecting flow was available, then no connectivity flow information was shown (i.e., if there was only one observation of connectivity at a pothole, it was not used). Ideally, the flow at which an individual pothole connects is between the connect and disconnect flow; however, a number of factors such as bank storage, drainage from other potholes, or other parts of a site caused by hydraulic gradient, lag time from the nearest gaging station, and tributary inflow between the nearest gaging station and the actual site all affect the connectivity flow.

Given the connectivity information that is available, preliminary indications are that potholes connecting at flows greater than 5,500 cfs at Rockport constituted a majority of the spring stranding; however, this preliminary conclusion is based on data which omits 72 spring potholes for which there is no calculated connectivity flow. This indicates that fry occupy the high pothole areas (probably to gain refuge) during high river flow conditions. Fry would be vulnerable in those high flow areas due to the likelihood that any flow fluctuations would most likely be downward than upward as tributary flow decreases.

No connecting flow information during the spring was available for potholes assigned to the Marblemount gage; however, data for fall surveys showed a majority of the fry stranding occurred in potholes connecting at 2,500 to 3,500 cfs. Once again, those data are preliminary.

River flows during the fall were lower than those during the spring because of lower tributary inflow and an Interim Flow Agreement requirement limiting the maximum discharge at Gorge Powerhouse to 4,200 cfs after August 20. As a result, many of the potholes that were continually flooded during the spring became exposed during the lower fall flows. This is reflected in the fact that in potholes assigned to the Rockport gage, seven fry were stranded during the spring in potholes having connecting flows <6,000 cfs, while in the fall, 232 fry were stranded in potholes connected at <6,000 cfs.

Preliminary analyses of the flows at which potholes were observed dry indicates that 35 of 60 potholes (58 percent) assigned to Marblemount were dry between 2,000 and 3,500 cfs, while those potholes assigned to the Rockport gage covered a much wider range of flows, varying from 2,500 to 9,500 cfs. Of the

128 Rockport assigned potholes with dry flow observations, 90 (70 percent) were observed dry at river flows of <5,000 cfs.

Forty six percent (508 fry) of all fry stranded in the fall were killed during the reconnaissance survey prior to the Interim Flow Agreement drop in river flows. Indications are that many of the potholes that were regularly flooded prior to the flow drop became disconnected from the river and were no longer available as habitat for fry during September.

6. CONCLUSIONS

Pothole Distribution and Characteristics

A total of 382 (including 140 high flow potholes reconnaissanced during November) potholes were found over all Gorge Powerhouse operational flows (1,450 to 7,000 cfs) between Rockport (RM 67.5) Newhalem (RM 94.0); the majority of potholes were located between Rockport and Illabot Slough. Predominant substrate type of potholes was sand (31 percent) and gravel (30 percent).

Fry Trapping and Stranding

A total of 17,538 trapped fry and 315 stranded fry were observed in 84 and 29 percent, respectively, of all 130 potholes surveyed during the spring, 1984. An additional 3,120 steelhead fry were observed trapped and 507 fry observed stranded during a 2-day reconnaissance survey on August 15 and 16.

A total of 3,578 trapped fry and 426 stranded fry were observed in 45 and 18 percent, respectively, of all 221 potholes surveyed during the fall, 1984.

Common to both spring and fall was that, while trapping was distributed over a wide range of potholes, stranding was limited to relatively few potholes.

Fry Trapping and Stranding by Area

The majority of fry trapping and stranding was observed between Rockport and Marblemount during both spring and fall surveys. During spring, 30 percent of all observed fry were trapped at Stump Haven (RM 72.2), while stranding was distributed over many study areas. During fall, Big Eddy (RM 77.5) trapped 27 percent of all observed fry, with 54 percent of all fry trapped at nine study areas in the lower 5.2 river miles of the study reach. Highest percentages of fall stranding occurred at Forbidden Bar (33 percent), Stump Haven (20 percent), and Big Eddy (19 percent), all of which are located between Rockport and Marblemount.

Fry Trapping and Stranding by Date

During the spring survey, no apparent relationship was observed between trapping or stranding and date; however, numbers of trapped and stranded fry declined in May. This is consistent with previous reports of an extended chinook fry emergence period between January and May in the Skagit River. A temporal fry distributional relationship was apparent during the fall survey. Higher numbers of trapped and stranded fry were observed during the first paired test dates in August, with a marked declining trend through September.

Fry Trapping and Stranding by Substrate Type

The majority of trapped fry were found in potholes with primarily sand and gravel substrates during spring and fall surveys. Stranding was distributed over several substrate types in spring but was largely associated with sand substrate during fall.

Fry Trapping and Stranding by Cover Type

Trapped and stranded fry were more frequently observed in potholes with some cover type as opposed to no cover for both spring and fall surveys. Overhead vegetaton was the most common cover type associated with spring trapping, while fall trapping was higher in potholes with sticks and limbs as the primary cover type. Stranding was more frequently observed in potholes with root wads during the spring and sticks and limbs during the fall.

Pothole Temperatures

No observed mortality was associated with high water temperatures during the spring. During the fall, mortality due to high water temperatures was observed in two high flow potholes not connected to the river.

Relationship of Minimum Test Flows to Fry Trapping and Stranding

A trend was noted that fewer fish were trapped as minimum test flows increased during the spring but not during the fall. No apparent trend was evident for numbers of stranded fry by minimum test flow during either spring or fall.

Multivariate regression analysis of minimum flows at Newhalem, Marblemount, and Rockport to trapping yielded generally inconclusive results for both spring and fall due to the confounding effect of other flow variables. However, Marblemount flow and Newhalem flow during the spring and fall, respectively, were most strongly related to trapping. The logistic regression model resulted in stronger associations between Newhalem and Rockport flows and stranding in the spring. None of the three flows were significantly related to stranding in the fall.

Relationship of Average Daily Discharge to Fry Trapping and Stranding

No significant relationships were apparent for trapping and stranding by previous 24- and 72-hour average daily discharge for spring or fall.

Relationship of Maximum Downramp Amplitude to Fry Trapping and Stranding

The regression analysis of maximum downramp amplitude for 24 and 72 hours prior to each test and trapping during the spring resulted in the absence of any significant relationships. The logistic regression analysis of maximum downramp amplitude and stranding yielded an apparent significant relationship for the previous 24-hour variable. However, this result must be regarded as inconclusive due to the confounding effects of date and decreased vulnerability of fry to trapping as the season progressed.

No significant relationships were present between the previous 24-hour or the previous 72-hour maximum downramp amplitudes with trapping or stranding during the fall.

Relationship of Ramping Rate to Trapping and Stranding

Generally, regression analysis between ramping rate and trapping or stranding yielded inconclusive results. A weak relationship was apparent for ramping rate by spring trapping.

Relationship of River Flow to Minimum Pothole Depth

A significant positive relationship was determined for minimum pothole depth by river flow at the assigned gage stations. Rockport flows were more significantly related to associated pothole depths than were Marblemount flows.

This exercise served as a check on the validity of 1) assigning pothole areas to one of the three river gage stations and 2) Rockport flow model.

Relationship of Downramp Time to Trapping

A trend of greater numbers of fry trapped during daylight hours may be apparent. However, the singular effect of downramp time could not be distinguished from the effects of other confounding variables since only one paired daylight downramp event was conducted.

Connectivity

Pothole connecting flows at areas assigned to Newhalem, Marblemount, and Rockport ranged from 1,500 to >2,000 cfs, 2,000 to >4,000 cfs, and 3,000 to >7,500 cfs, respectively.

Based on limited information on pothole connectivity, indications are that potholes with connecting flows greater than 6,000 cfs at Rockport constituted a majority of the fry trapping and stranding during the spring.

During the fall, when river flows were lower, potholes with connecting flows between 2,500 and 3,500 cfs at Marblemount and between 5,500 and 6,500 cfs at Rockport constituted the greatest number of fry trapping and stranding.

Dry Potholes vs River Flow

Based on a limited sample of observations, numbers of dry potholes in areas assigned to the Marblemount and Rockport gages by flow increment were determined. For pothole areas assigned to Marblemount, 35 of 60 potholes, for which there was information, became dry between 2,000 and 3,500 cfs. In contrast, for potholes assigned to Rockport, potholes became dry between 2,500 and 9,500 cfs. The wider range of flows for the pothole areas assigned to Rockport is a result of the presence of greater numbers of high flow potholes in the lower reach of the river.

ACKNOWLEDGEMENTS

This study was initiated, managed, and funded by City of Seattle, Department of Lighting, Environmental Affairs Division. Seattle City Light (SCL) personnel included:

Mr. Keith Kurko, Project Supervisor
Mr. Wayne Wright, Project Leader
Ms. Cindy Monk, Project Assistant
Mr. Rick Rutz, Field Assistant

Spring, 1984, field surveys were carried out by Shapiro and Associates, Inc. under the supervision of SCL personnel.

The fall, 1984, surveys and this report were the responsibilities of Jones & Stokes Associates, Inc. Project personnel included the following:

Mr. Jonathan Ives, Project Manager
Mr. Thomas Keegan, Fish Biologist
Ms. Mary Pat Larsen, Biostatistics/Computer Programming
Mr. Alex Cudkowicz, Data Entry
Dr. Larry Larsen, River Flow Modeling
Ms. Gail Hustedde, Graphics
Ms. Carole Marino, Word Processing

Gaia Northwest, Inc., under the leadership of Dr. Percy Washington, provided excellent field assistance and analysis of biological factors affecting trapping and stranding susceptibility.

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Field observers during the spring and fall were responsible for the countless hours of data collection at the pothole areas. Their efforts and interest in this project were most appreciated.

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APPENDIX A

INTERIM AGREEMENT

CERTIFICATION OF SERVICE

I hereby certify that I have this day served the attached documents designated Submission of Offer of Settlement, Offer of Settlement, and proposed Order Approving Offer of Settlement upon all parties of record in this proceeding in accordance with the requirements of §1.17 of the Rules of Practice and Procedure.

Dated at Seattle, Washington this 27th day of February, 1981.

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UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

The City of Seattle,	)	Project No. 553
	)	
Washington	)	Docket No. EL 78-36
	)	
	)	

SUBMISSION OF OFFER OF SETTLEMENT

Pursuant to Section 1.18 of the Commission's Rules of Practice and Procedure, the below listed parties submit the attached Offer of Settlement.

EXPLANATORY STATEMENT

On September 7, 1978, the Commission issued an order under Article 37 of the license for Project No. 553 to initiate proceedings which would address the effect of the Project's flow regime on the fishery resources of the Skagit River. The Project consists of three dams (Ross, Diablo, and Gorge) located on the Skagit River; the affected fishery resource is located below the lower-most of the three dams (Gorge).

On July 20, 1979, at the request of the Commission staff, a Settlement Conference in this proceeding was held in Seattle. Commencing on July 29, 1979, certain parties to the proceeding entered into negotiations relating to flow levels and flow fluctuations from Project No. 553, and their effect on the Skagit River fishery resource. Over the course of several months, these parties reached agreement on a general framework for an interim (two year) settlement of flow and fishery issues. Several draft settlements were circulated for comment.

On July 24, 1980, the Commission staff again met with the parties in Seattle to discuss the status of the negotiations. At the July 24 meeting, most of the parties were able to reach general agreement on the resolution of the remaining areas of dispute. This Offer of Settlement reflects and arises out of the July 24, 1980, discussions among these parties.

On this "interim" basis, the Settlement Agreement would establish various conditions of flow regulation, including levels of minimum flow and constraints on maximum flows and flow fluctuations. Additionally, the Settlement Agreement would require the performance of flow-related fishery studies over an approximate two-year period. The flow regulation conditions and fishery studies are intended to lead to a long-term resolution of these issues through (1) improved consideration of fishery impacts and power planning and management, and (2) the addition of appropriate conditions in the license for Project No. 553.

It should be noted that at the conclusion of the approximate two-year study period, the City has agreed to continue the above flow regulations until a permanent resolution is reached under certain circumstances.

The below listed parties believe that there is substantial agreement on the terms of the Offer of Settlement at the present time, and that its submission is an appropriate course of action to minimize further delay in this proceeding. Accordingly, these parties recommend that the Commission approve the Agreement as proposed.

REFERENCES

No testimony or exhibits have yet been filed in this proceeding. The record consists of the petitions of the various parties and responses of the City.

CONCLUSION

The below listed parties respectfully request that this Offer of Settlement be considered and approved in accordance with Section 1.18 of the Rules of Practice and Procedure.

DATED this 27th day of February, 1981.

Respectfully submitted,

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PROPOSED ORDER

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

The City of Seattle, Washington	)	Project No. 553
	)	Docket No. EL78-36

ORDER APPROVING OFFER OF SETTLEMENT

On February 27, 1981, the City of Seattle, the State of Washington Departments of Fisheries and Game, National Marine Fisheries Service, and Skagit System Indian Tribes, all parties to the above titled proceedings, filed with the Federal Energy Regulatory Commission an Offer of Settlement. The Commission finds that the Offer of Settlement is in the public interest and accepts it, as hereinafter ordered.

The proposed settlement provides for and establishes various conditions of flow regulation downstream of the City's licensed Project No. 553 on the Skagit River, Washington, including levels of minimum flow and constraints on maximum flows and flow fluctuations. The settlement also requires performance of flow-related fisheries studies over an approximate two-year period. It is hoped the flow regulations and fisheries studies will lead to a long-term resolution of these issues through improved consideration of fisheries impacts and power planning and management, and the addition of appropriate conditions in the license for Project No. 553.

Upon review of the foregoing, the Commission finds that the Offer of Settlement represents a reasonable resolution of the issues raised in this phase of the proceeding; accordingly, the proposed settlement shall be incorporated herein by reference and shall be approved and adopted.

The Commission finds:

(1) The Offer of Settlement submitted by the above parties on February 27, 1981, should be approved and made effective as hereinafter ordered.

(2) The Commission orders:

(A) The Offer of Settlement certified to the Commission in this proceeding is hereby accepted, incorporated herein by reference and approved.

(B) The Commission's approval of this settlement shall not constitute approval of or a precedent regarding any other principle or issue in this or any other proceeding.

By the Commission.

UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

The City of Seattle, Washington	)	Project No. 553 Docket No. EL 78-36

SUPPLEMENTAL EXPLANATORY STATEMENT OF THE NATIONAL MARINE FISHERIES SERVICE AND THE SKAGIT SYSTEM TRIBES

While the undersigned concur in the Explanatory Statement contained in the Submission of Offer of Settlement they are offering this supplemental statement in order to clarify their position on one matter.

By submitting the Offer of Settlement in this docket the National Marine Fisheries Service and the three Skagit System Indian tribes do not waive any rights under the Federal Power Act, the National Environmental Policy Act or other laws which they may have with respect to the relicensing of Project No. 553 or other proceedings before this or other agencies or courts. Specifically, the tribes and the National Marine Fisheries Service reserve the right to challenge relicensing of the Ross Project should it occur prior to completion of investigation into downstream fisheries effects of the Ross Project.

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UNITED STATES OF AMERICA
FEDERAL ENERGY REGULATORY COMMISSION

The City of Seattle, Washington	)	Project No. 553 Docket No. EL 78-36

OFFER OF SETTLEMENT

UNDERSTANDINGS

On September 7, 1978, the Commission issued an order under Article 37 of the license for Project 553 to undertake proceedings to examine the effect of the project's flow regime on the Skagit River's fisheries resource. Commencing on July 29, 1979, following earlier discussions and a meeting with the Commission staff on July 20, 1979, certain parties to this proceeding entered into specific negotiations to resolve issues relating to the flow levels and flow fluctuations from Project No. 553, and their effect on the anadromous fish resource of the Skagit River. On July 24, 1980, the Commission staff again met with the parties to discuss the status of the negotiations and disputed issues.

Based on these negotiations, the parties have agreed to an interim agreement which sets out various conditions of flow regulation and requires the performance of related fishery studies.

The flow regulation conditions and fishery studies are intended to lead to a long-term resolution of these issues, through (1) improved consideration of fishery impacts in power planning and management and (2) the imposition of appropriate conditions in the license for Project No. 553.

Neither this agreement, nor its approval by the Commission, shall constitute approval of, or precedent regarding, any principle or issue in this or any other proceeding.

AGREEMENT

The City shall provide interim flow regulation and cooperate in the conduct of studies in the Skagit River in accordance with this agreement, which shall become effective as of the date of its approval by the Commission, except insofar as the parties agree on an earlier commencement of studies.

ARTICLE I - FLOW REGULATION

Section 1 - Minimum Flows

A. Subject to the exception for Insufficient Water Months in Section 3 below, the City shall maintain at least the instantaneous minimum flows at Newhalem set forth in the first column below:

Time Period	Sufficient Month Minimum Flow, Newhalem (cfs)	Anticipated Minimum Flow, Marblemount (cfs)
March	2300	3200
April 1-15	2300	3700
April 16-30	2000	3400
May	1700	3300
June	1000	3200
July	1325	2000
August 1-10	1325	2000
August 11-31	1400	2000
September	1400	2000
October	1200	2000
November	1800	3000
December	1800	3000
January	1900	3000
February	2300	3000

It is anticipated that such flows, together with expected sidestream inflows, will result in the flows set forth in the second column above. This expected correlation does not, however, constitute a condition precedent to maintaining the Sufficient Month Minimum Flow at Newhalem set out above.

B. Notwithstanding the above minimum flow schedule, the City shall undertake all reasonable means to supplement said minimum flows during the July 1 to August 10 time period in accordance with Exhibit A attached hereto, to the extent that high spring flows have resulted in steelhead spawning at high stages of the river.[1/]

C. The City shall give both oral and written notice to all parties (including FERC staff) as far in advance as possible of (1) its expected inability to meet minimum flows, and (2) the particular actions planned to meet or approach these flow levels. Quarterly, the City shall provide all parties with a written report documenting (1) the extent of its

[1/] For purposes of this Agreement, 'all reasonable means' includes efforts to arrange power exchanges within the Pacific Northwest and to modify operations at the Boundary Project, upon consideration of system requirements.

compliance with the minimum flow levels, and (2) the actions were actually taken to meet or approach the minimum flow levels. This report may be incorporated into the quarterly report provided under Section 7.

Section 2 - Maximum Flows

A. The City shall undertake all reasonable means to limit maximum flows at Newhalem (Gauge #12178000) in accordance with the Target Maximum Flows and Preferred Fisheries Flows set forth below.

Time Period	Target Maximum Flows (cfs)	Preferred Fisheries Flows (cfs)
August 20 - October 15 (even years)	4200	4200
August 20 - September 21 (odd years)	4200	4200
September 22 - October 31 (odd years)	4200	3200
November 22 - December 31	7000	5000
All other months	No Limit	No Limit

The Preferred Fisheries Flows set forth in the second column above are best current prediction of those which may maximize the productivity of the fisheries resources. It is expected that the goals set forth through October 1 can generally be achieved by reasonable means, but that achievement of the October 1 - December 31 Target Maximum Flows (and especially the Preferred Fisheries Flows) frequently will not be so accomplished because of load and flow conditions. It is recognized that inflows between Gorge powerhouse and the Newhalem gauge, namely Ladder Creek, will increase the maximum flows at Newhalem to some extent beyond the City's control. This expected correlation does not, however, constitute a condition procedent to maintaining the maximum flows set out in this section.

At the conclusion of the August 20 - October 31 and November 22 - December 31 time period noted above, the City shall provide all parties with a written report documenting (1) the extent of its compliance with the target maximum flow levels noted above, and (2) the actions which were considered and actually taken to limit maximum flow levels. This report may be incorporated into the quarterly report provided under Section 7.

Section 3 - Insufficient Water Months Provision

A. During Insufficient Water Months, the flows specified in Section 1.A may be adjusted by the City on an incremental basis according to the Minimum Flow Decision Rule as set forth in Exhibit B attached hereto. Insufficient water months shall occur when both of the following two conditions are met: (1) when the Predicted Combined Basin Runoff is less than 95% of Normal Runoff, as set forth in Section 3.C[2/], and (2) when the City (a) requests and takes delivery of power[3/] as stated in Section 9 of the Pacific Northwest Coordination Agreement, or (b) requests and takes delivery of purchased power from any source, or (c) attempts to obtain power as described in (a) or (b), but no purchase or interchange power is available at a reasonable price (this last provision (c) must be documented).

[2/] It is the general position of the National Marine Fisheries Service, the Department of the Interior, the Washington Departments of Fisheries and Game, and the Skagit System Indian Tribes that the use of a 95% threshold in this subsection, coupled with the calculations in subsections 3B, 3D and 3E, can result in the determination of an "insufficient water month" absent an actual water insufficiency. These parties would prefer to see a threshold for reduction in minimum flows at a point somewhat lower than 95%. However, for three reasons, these parties are willing to accept the use of a 95% threshold: (1) the fact that the threshold would apply to an interim basis only, and would be subject to evaluation during the interim period; (2) that the City will be incorporating the minimum flows under the Agreement into calculations of power planning and management curves; and (3) that the City will consider and act upon one or more of four possible alternatives as soon as the Predicted Combined Basin Runoff is less than 95% of Normal Runoff — (a) utilize excess water and capability at the Boundary Project, (b) overdraft Ross Reservoir to some extent, (c) obtain power through interchange under the Northwest Power Coordination Agreement, (d) purchase outside power at a reasonable price.

[3/] For the purposes of this Agreement, "power" signifies both energy and capacity.

B. The Predicted Combined Basin Water Volume shall be determined by the following procedure:4/

1. If Ross Reservoir storage is greater than the Pacific Northwest Coordination Agreement Energy Content Curve (E.C.C.), as and if adjusted, at the beginning of the month, the volume by which Ross Reservoir storage exceeds the E.C.C. is added to predicted Skagit basin runoff above Ross Dam (Runoff Prediction) to obtain a predicted combined basin water volume.

2. If Ross Reservoir storage is less than E.C.C., as and if adjusted, at the beginning of the month, the volume by which Ross Reservoir storage is below the E.C.C. is subtracted from predicted Skagit basin (Runoff Prediction) to obtain a predicted combined water volume.

3. For purposes of this subsection, "Ross Reservoir storage" includes all foreign storage in Ross Reservoir. "Energy Content Curve" refers to the Variable Energy Content Curve rather than the Base E.C.C. as it becomes available (approximately March 1 of each year).

C. Data relating to the Normal Runoff for the Skagit Basin above Ross Dam and Insufficient Threshold, for the purpose of this agreement, are set out in the table below:

Date	Normal Runoff (SFD)	Insufficient Threshold [95% of Normal Runoff (SFD)]
Oct. 1	1,226,765	1,165,427
Nov. 1	1,171,430	1,112,859
Dec. 1	1,105,820	1,050,529
Jan. 1	1,036,752	984,914
Feb. 1	980,735	931,698
Mar. 1	930,167	883,659
Apr. 1	875,886	832,092
May 1	773,016	734,365
June 1	526,969	500,621
July 1	255,697	242,912
Aug. 1	105,856	100,563
Sept. 1	41,531	39,454

1 SFD = 1.98 AC-FT

4/ In accordance with footnote 2/, the National Marine Fisheries Service, the Department of the Interior, the Washington Departments of Fisheries and Game, and the Skagit System Indian Tribes wish to note their general position that the Energy Content Curve and Runoff Prediction as used in this subsection may not reflect actual water insufficiencies. This is because both the E.C.C. and Runoff Prediction generally derive from conservative (i.e., "worst case") analyses of power planning needs.

D. Skagit basin runoff prediction above Ross Dam (Runoff Prediction) shall be made in the following manner: Runoff Predictions for the months of October, November, December, and January are the historical average runoff conditions (over all years of record) and are as indicated in the above table. Runoff Predictions for the months of February, March, April, and May shall be made by adding snowpack volume (obtained by surveys) to historical average precipitation (over all years of record). The June, July, August, and September Runoff Predictions shall be made by adding historical average residual snow melt, which has not run off, to historical average precipitation. All Runoff Predictions shall be made through the end of the water year (September 30).

E. To determine Insufficient Month Minimum Flows by use of Exhibit B, the predicted Combined Basin Water Volume shall be divided by the Normal Runoff for the particular time of year. The resulting ratio shall be used to obtain the Percent of Minimum Flow Committed by use of Exhibit B. The percent of Minimum Flow Committed shall be multiplied by the applicable Sufficient Month Minimum Flow for the month from the table in Section 1.A to obtain an Insufficient Month Minimum Flow. If the ratio of the Predicted Combined Basin Water Volume to Normal Runoff is equal to or greater than 95%, the full requirement of Section 1 shall apply.

F. The above procedure will be followed unless the calculated Insufficient Month Minimum Flow is less than 1000 cfs, in which case the Insufficient Month Minimum Flow for the month shall nevertheless be 1000 cfs. If at any time during an Insufficient Water Month the Predicted Combined Basin Water Volume exceeds the Insufficient Threshold, the Sufficient Month Minimum Flow will apply.

G. Notification of the amount of any insufficiency will be given by the City to the other parties as soon as information indicating possible insufficiency is available, and no later than seven calendar days after the start of each month, unless inclement weather prohibits the timely performance of snow surveys. In the latter case, insufficiency notification will be issued within four days after the survey data are available.

H. If in a pink salmon cycle (odd year) it appears that the month of September will be insufficient, the City shall nevertheless consider conserving storage from the period August 15-20 to achieve the Sufficient Month Minimum Flow of 1400 cfs during the peak pink salmon spawning period of September 22 - October 30. Under no circumstances, however, shall such storage conservation result in a flow of less than 1000 cfs at Newhalem.

Section 4 - Emergency Conditions

Notwithstanding the provisions of Section 3 in an Insufficient Water Month, if the Washington Departments of Fisheries or Game determine that conditions pose a critical threat to the fishery resource, the City shall use all reasonable means to supplement the Insufficient Month Minimum Flows determined under Section 3. Under such conditions, the City shall notify all parties and shall consult with them on a weekly basis.

Nothing in this agreement shall constrain the City from taking action to respond to emergency conditions, including mechanical failure, transmission line failure, floods, landslides, or acts of God. At the conclusion of the emergency conditions, the City will return to an operation schedule in compliance with the terms of this Agreement.

Section 5 - Flow Fluctuations and Ramping Rates

Downramp rates at Gorge at various flow levels shall follow the curve in Exhibit C within a band width of ± 100 cfs/hours. Upramp rates shall not exceed 2,000 cfs/hour. In meeting the flow requirements of this article, the City shall use all reasonable means to minimize the frequency and range of daily and periodic flow fluctuations.

The City shall provide a quarterly report to all parties (including FERC staff) on (1) available technology and other means to control flow fluctuations (including computer technology and software); (2) the means planned to minimize flow fluctuations for the following quarter; and (3) the actual restrictions of flow fluctuations and the means used to achieve these restrictions in the preceding quarter. This report may be incorporated into the quarterly report provided under Section 7.

Section 6 - Standing Committee and City Contract

A Standing Committee, composed of one representative each from the City, the Washington Department of Fisheries, the Washington Department of Game, the Skagit System Indian Tribes, the Fish and Wildlife Service, the National Marine Fisheries Service, the National Park Service, and the U.S. Forest Service shall be established for such consultation and meetings among the parties as may be appropriate under this Agreement. Meetings of the Standing Committee shall be open to all parties and additional representatives for purposes of open discussion and observation.

Within two weeks of the Commission's approval of this Agreement, each party shall designate, in writing, a contact person or persons for ~~parties to the Agreement~~. The designated contact person(s) will be responsible for coordinating that party's prompt response to questions, requests for information, follow-up to quarterly compliance reports, etc.

THE STANDING COMMITTEE

Section 7 - Periodic Reports

The City shall provide all parties with quarterly reports of its performance and compliance with the operational requirements of this Agreement, including documentation of actual flow levels and flow fluctuations, and actual operating curves generated under this Agreement. Reports required in Sections 1 and 2 may be incorporated into the quarterly report to avoid unnecessary duplication.

The City shall also provide the National Marine Fisheries Service and the Skagit System Indian Tribes with copies of the following documents, as they become available: (1) the weekly report to the Northwest Power Pool; (2) the daily reports entitled "Power System Generation and Load Data Logs (on a weekly basis); (3) the monthly Interchange Summaries; and (4) the monthly Inflow Forecasts.

Section 8 - Use of Flow Regulation Conditions

The interim flow regulation conditions in this Article shall be used by the City as requirements for purposes of power planning and management, including their submission as planning and management requirements in accordance with Section 6 of the Pacific Northwest Coordination Agreement, (e.g., through the use of the Sufficient Month Minimum Flow at Newhalem set forth in the first column in Section 1.A, without reduction, in calculations of the Energy Content Curve).

ARTICLE II - STUDIES

Section 1 - In General

For a period of approximately two years, all parties shall cooperate in the conduct of studies of the Skagit River fishery resources, as set out in Sections 2 through 8 below. The purpose of these studies is to provide improved data on the effect of flow regulation on the fishery resource, and, thus, to facilitate a permanent settlement of this proceeding.

Section 2 - Staffing and Funding

The City will fund the study effort, including one full-time biologist each for the Washington Departments of Fisheries and Game, as required. In addition, the Skagit System Indian Tribes, the Fish and Wildlife Service, the National Marine Fisheries Service, and the Washington Departments of Fisheries and Game will each provide a part-time individual for field data collection, as study requirements dictate. During the course of studies, any party may have an observer(s) present, who will be accorded full cooperation and access by the individual or group performing the studies.

Section 3 - Areas of Study

At a minimum, the following areas will be the subject of studies over a two-year period:

A. The comparative extent of fry stranding for steelhead trout, pink salmon, chum salmon, and summer/fall chinook salmon, using at least four downramp rates at representative points between 1,500 and 200 cfs/hour (e.g., 1,500; 1,000; 500; and 200 cfs/hour) at a mutually agreeable period of time as flow conditions and species availability permit. Additional ramp rates may be undertaken if deemed necessary by the Standing Committee.

B. The period of steelhead spawning and incubation, and the relationship between spawning flow and redd depth distribution for steelhead.

C. Flow fluctuation impacts upon spawning area, spawning behavior, egg incubation, and fry emergence for steelhead, chum, summer/fall chinook, and pink salmon.

D. Evaluation of the relationship between flow regulation and adult salmon production.

E. An Instream Flow Group (IFG) assessment, unless the Standing Committee determines that it is duplicative or irrelevant.

F. An analysis of the effects of minimum flows, maximum flows, and reduced ramping rates on power operations, costs, and Ross Lake recreational factors.

G. A detailed evaluation of the relative availability of longer range alternatives for meeting specific fish flow requirements, including load management, conservation, and resources.

Section 4 - Decision-Making

A written and detailed study outline (including an individual work plan for each study) will be prepared for each year of study. All aspects of study planning, implementation, and coordination with other ongoing studies shall be subject to the unanimous agreement of the Standing Committee, which shall meet as frequently as study requirements dictate.

Section 5 - Permits and Approvals

All parties, particularly the Washington Departments of Fisheries and Game, will cooperate with and assist the City in obtaining the necessary permits and approvals for conducting studies.

Section 6 - Reports

The City will prepare a draft study report in cooperation with all parties promptly at the conclusion of each phase of study. Data interpretation and report writing will be a cooperative

PRELIMINARY

effort among all parties to this ~~agreement~~, and a final report will be subject to the agreement of the Study Committee described in Section 4. In the event that unanimous agreement cannot be reached by the Committee, the report will reflect both majority and minority views.

Section 6 - Data Access

All parties will have open mutual access to all relevant data, reports, information, etc., pertaining to fisheries, stream flow, or power generation on the Skagit River.

ARTICLE III - AMENDING PROCEDURE

The City has agreed to the flow restrictions set forth in Article I, based on its present best judgment that such restrictions are workable. The development of unexpected, severe operational impacts during the course of this agreement could prove this present judgment wrong. Similarly, preliminary biologic study results may disclose impacts on the fisheries resource that are unforeseen at this time. Accordingly, in the event of severe, unanticipated impacts, including impacts on recreational factors on Ross Lake, any party may request a change in the parameters of the agreement. Should agreement on the relevant issue not be reached after discussion among the parties, the complaining party may petition the Commission for resolution.

ARTICLE IV - FURTHER PROCEEDINGS

At the conclusion of the approximate two-year study period contemplated by Article II of this Agreement, any party may petition the Commission to convene a hearing in this or other proceeding, either for the purpose of conducting further studies or for the purpose of achieving a permanent resolution of issues. Until a permanent resolution is achieved, the City shall nevertheless continue to provide the flow regulations set forth in Article I unless otherwise agreed by the parties, unless resolved under Article III, or unless a specific disputed flow restriction under Article III has remained unresolved for a period of six months after a petition to the Commission.

EXHIBIT A

STEELHEAD INCUBATION FLOW GUIDELINE

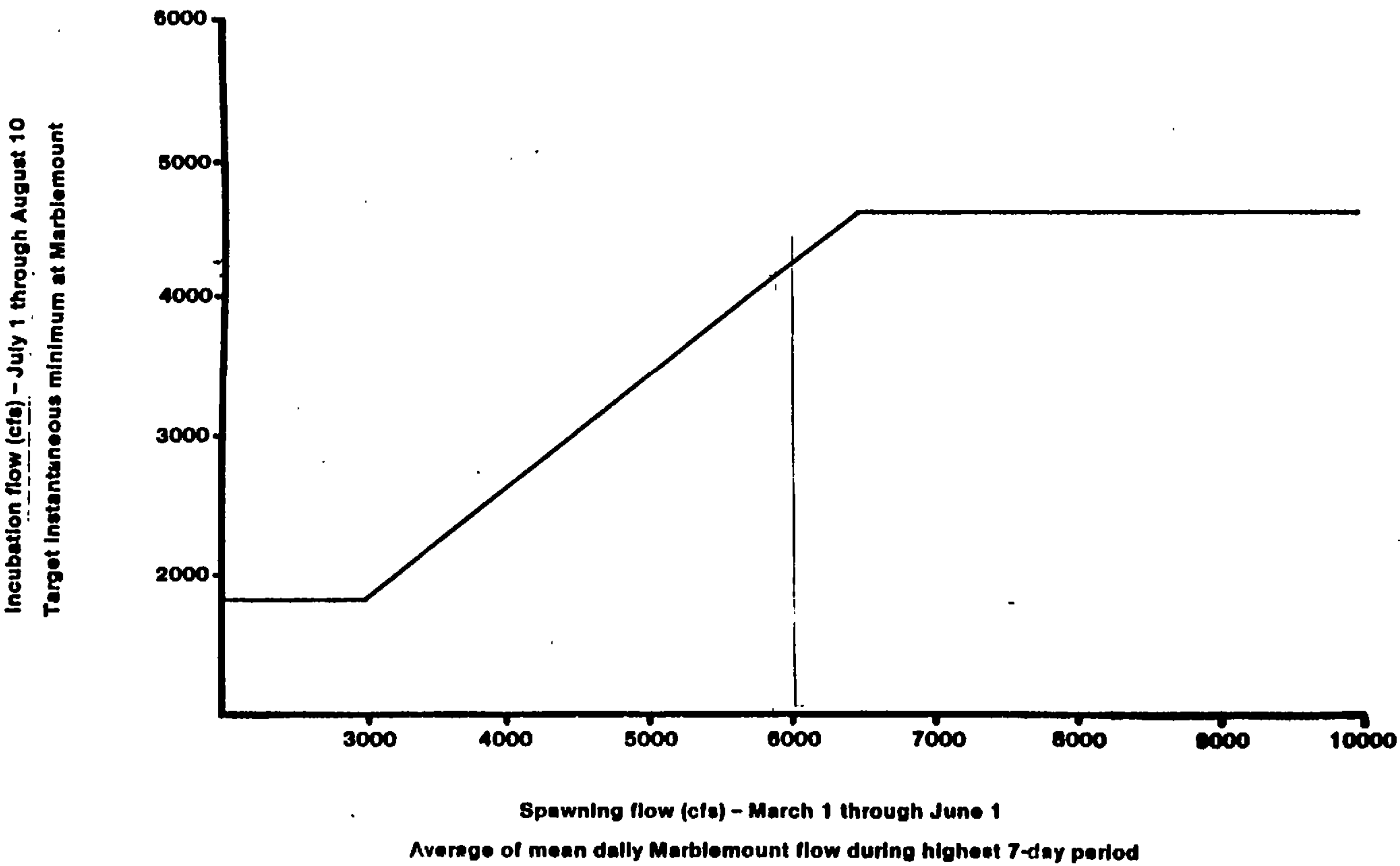
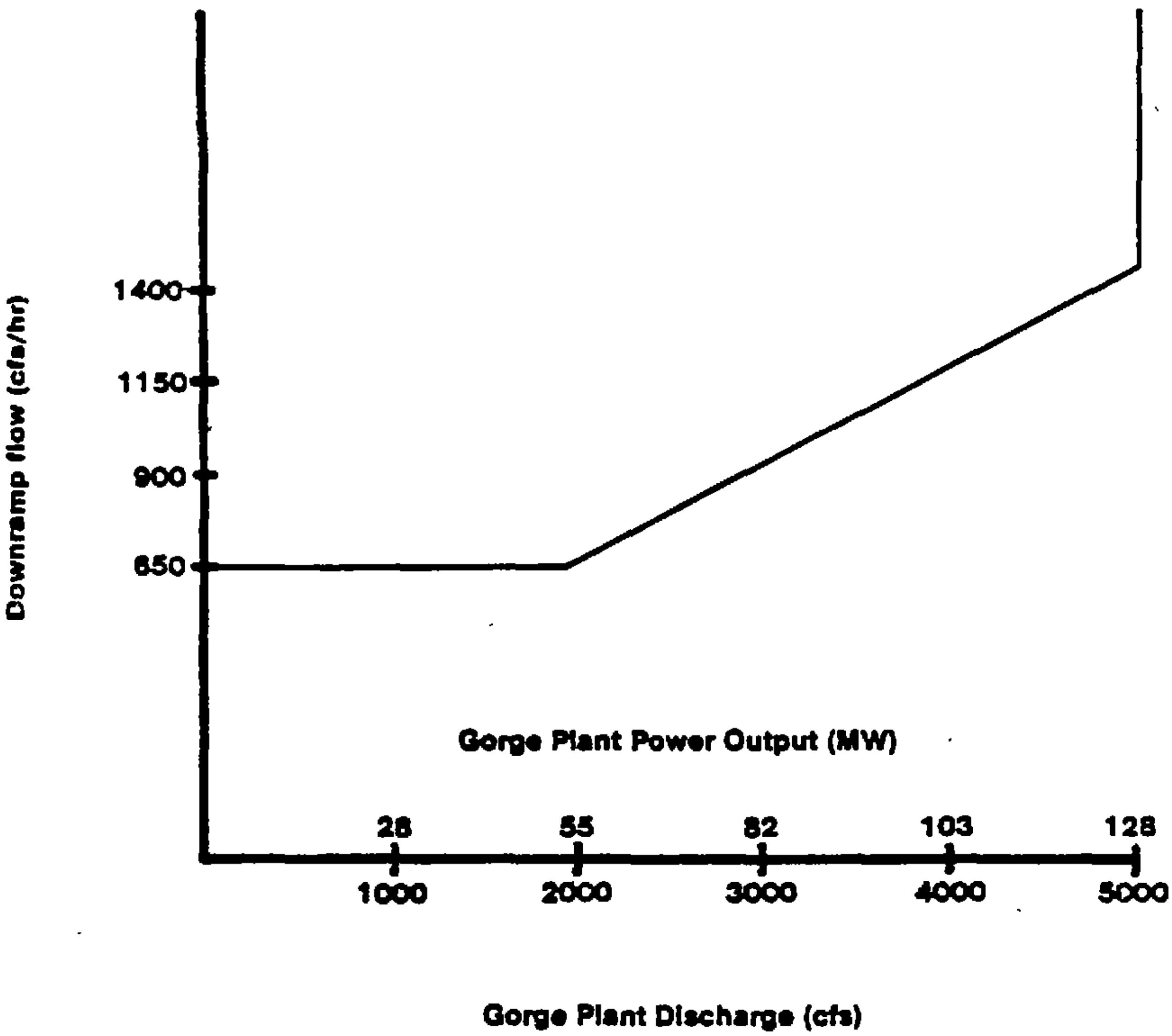


EXHIBIT C

OPERATIONAL DOWNRAMP



POWER CONTROL CE

Gage Height in feet	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
	Discharge in Cubic Feet per Second									
480.5	830	837	844	851	858	865	872	879	886	893
.6	900	907	914	921	928	935	942	949	956	963
.7	970	977	984	991	998	1005	1012	1019	1026	1033
.8	1040	1048	1056	1064	1072	1080	1088	1096	1104	1112
.9	1120	1128	1136	1144	1152	1160	1168	1176	1184	1192
481.0	1200	1208	1216	1224	1232	1240	1248	1256	1264	1272
.1	1280	1288	1296	1304	1312	1320	1328	1336	1344	1352
.2	1360	1369	1378	1387	1396	1405	1414	1423	1432	1441
.3	1450	1459	1468	1477	1486	1495	1504	1513	1522	1531
.4	1540	1549	1558	1567	1576	1585	1594	1603	1612	1621
.5	1630	1640	1650	1660	1670	1680	1690	1700	1710	1720
.6	1730	1740	1750	1760	1770	1780	1790	1800	1810	1820
.7	1830	1840	1850	1860	1870	1880	1890	1900	1910	1920
.8	1930	1941	1952	1963	1974	1985	1996	2007	2018	2029
.9	2040	2051	2062	2073	2084	2095	2106	2117	2128	2139
482.0	2150	2161	2172	2183	2194	2205	2216	2227	2238	2249
.1	2260	2271	2282	2293	2304	2315	2326	2337	2348	2359
.2	2370	2382	2394	2406	2418	2430	2442	2454	2466	2478
.3	2490	2502	2514	2526	2538	2550	2562	2574	2586	2598
.4	2610	2622	2634	2646	2658	2670	2682	2694	2706	2718
.5	2730	2742	2754	2766	2778	2790	2802	2814	2826	2838
.6	2850	2863	2876	2889	2902	2915	2928	2941	2954	2967
.7	2980	2993	3006	3019	3032	3045	3058	3071	3084	3097
.8	3110	3123	3136	3149	3162	3175	3188	3201	3214	3227
.9	3240	3253	3266	3279	3292	3305	3318	3331	3344	3357
483.0	3370	3385	3400	3415	3430	3445	3460	3475	3490	3505
.1	3520	3535	3550	3565	3580	3595	3610	3625	3640	3655
.2	3670	3685	3700	3715	3730	3745	3760	3775	3790	3805
.3	3820	3835	3850	3865	3880	3895	3910	3925	3940	3955
.4	3970	3987	4004	4021	4038	4055	4072	4089	4106	4123
.5	4140	4157	4174	4191	4208	4225	4242	4259	4276	4293
.6	4310	4327	4344	4361	4378	4395	4412	4429	4446	4463
.7	4480	4497	4514	4531	4548	4565	4582	4599	4616	4633
.8	4650	4667	4684	4701	4718	4735	4752	4769	4786	4803
.9	4820	4839	4858	4877	4896	4915	4934	4953	4972	4991
484.0	5010	5029	5048	5067	5086	5105	5124	5143	5162	5181
.1	5200	5219	5238	5257	5276	5295	5314	5333	5352	5371
.2	5390	5409	5428	5447	5466	5485	5504	5523	5542	5561
.3	5580	5599	5618	5637	5656	5675	5694	5713	5732	5751
.4	5770	5791	5812	5833	5854	5875	5896	5917	5938	5959
.5	5980	6001	6022	6043	6064	6085	6106	6127	6148	6169
.6	6190	6211	6232	6253	6274	6295	6316	6337	6358	6379
.7	6400	6421	6442	6463	6484	6505	6526	6547	6568	6589
.8	6610	6631	6652	6673	6694	6715	6736	6757	6778	6799
.9	6820	6843	6866	6889	6912	6935	6958	6981	7004	7027
485.0	7050	7073	7096	7119	7142	7165	7188	7211	7234	7257
.1	7280	7303	7326	7349	7372	7395	7418	7441	7462	7487
.2	7510	7533	7556	7579	7602	7625	7648	7671	7694	7717
.3	7740	7763	7786	7809	7832	7855	7878	7901	7924	7947
.4	7970	7995	8020	8045	8070	8095	8120	8145	8170	8195
.5	8220	8245	8270	8295	8320	8345	8370	8395	8420	8445
.6	8470	8495	8520	8545	8570	8595	8620	8645	8670	8695
.7	8720	8745	8770	8795	8820	8845	8870	8895	8920	8945
.8	8970	8995	9020	9045	9070	9095	9120	9145	9170	[illegible]

Rating Table (Cont'd)

Gage Height in Feet	Discharge in Cubic Feet per Second .00	.01	.02	.03	.04	.05	.06	.07	.08	.09
486.0	9520	9550	9580	9610	9640	9670	9700	9730	9760	9780
.1	9820	9850	9880	9910	9940	9970	10000	10030	10060	10090
.2	10120	10150	10180	10210	10240	10270	10300	10330	10360	10390
.3	10420	10450	10480	10510	10540	10570	10600	10630	10660	10690
.4	10720	10750	10780	10810	10840	10870	10900	10930	10960	10990
.5	11020	11055	11090	11125	11160	11195	11230	11265	11300	11335
.6	11370	11405	11440	11475	11520	11545	11580	11615	11650	11685
.7	11720	11755	11790	11825	11860	11895	11930	11965	12000	12035
.8	12070	12105	12140	12175	12210	12245	12280	12315	12350	12385
.9	12420	12455	12490	12525	12560	12595	12630	12665	12700	12735
487.0	12770	12805	12840	12875	12910	12945	12980	13015	13050	13085
.1	13120	13160	13200	13240	13280	13320	13360	13400	13440	13480
.2	13520	13560	13600	13640	13680	13720	13760	13800	13840	13880
.3	13920	13960	14000	14040	14080	14120	14160	14200	14240	14280
.4	14320	14360	14400	14440	14480	14520	14560	14600	14640	14680
.5	14720	14760	14800	14840	14880	14920	14960	15000	15040	15080
.6	15120	15160	15200	15240	15280	15320	15360	15400	15440	15480
.7	15520	15560	15600	15640	15680	15720	15760	15800	15840	15880
.8	15920	15960	16000	16040	16080	16120	16160	16200	16240	16280
.9	16320	16365	16410	16455	16500	16545	16590	16635	16680	16725
488.0	16770	16815	16860	16905	16950	16995	17040	17085	17130	17175
.1	17220	17265	17310	17355	17400	17445	17490	17535	17580	17625
.2	17670	17715	17760	17805	17850	17895	17940	17985	18035	18075
.3	18120	18165	18210	18255	18300	18345	18390	18435	18480	18525
.4	18570	18615	18660	18705	18750	18795	18840	18885	18930	18975
.5	19020	19065	19110	19155	19200	19245	19290	19335	19380	19425
.6	19470	19515	19560	19605	19650	19695	19740	19785	19830	19875
.7	19920	19965	20010	20055	20100	20145	20190	20235	20280	20325
.8	20370	20415	20460	20505	20550	20595	20640	20685	20730	20775
.9	20820	20865	20910	20955	21000	21045	21090	21135	21180	21225
489.0	21270	21315	21360	21405	21450	21495	21540	21585	21630	21675
.1	21720	21770	21820	21870	21920	21970	22020	22070	22120	22170
.2	22220	22270	22320	22370	22420	22470	22520	22570	22620	22670
.3	22720	22770	22820	22870	22920	22970	23020	23070	23120	23170
.4	23220	23270	23320	23370	23420	23470	23520	23570	23620	23670
.5	23720	23770	23820	23870	23920	23970	24020	24070	24120	24170
.6	24220	24270	24320	24370	24420	24470	24520	24570	24620	24670
.7	24720	24770	24820	24870	24920	24970	25020	25070	25120	25170
.8	25220	25270	25320	25370	25420	25470	25520	25570	25620	25670
.9	25720	25770	25820	25870	25920	25970	26020	26070	26120	26170
490.0	26220	26270	26320	26370	26420	26470	26520	26570	26620	26670
.1	26720	26770	26820	26870	26920	26970	27020	27070	27120	27170
.2	27220	27270	27320	27370	27420	27470	27520	27570	27620	27670
.3	27720	27775	27830	27885	27940	27995	28050	28105	28160	28215
.4	28270	28325	28380	28435	28490	28545	28600	28655	28710	28765
.5	28820	28875	28930	28985	29040	29095	29150	29205	29260	29315
.6	29370	29425	29480	29535	29590	29645	29700	29755	29810	29865
.7	29920	30030	30085	30140	30195	30250	30305	30360	30415	30470
.8	30525	30580	30635	30690	30745	30800	30855	30910	30965	31020
.9	31075	31130	31185	31240	31295	31350	31405	31460	31515	31570

APPENDIX B

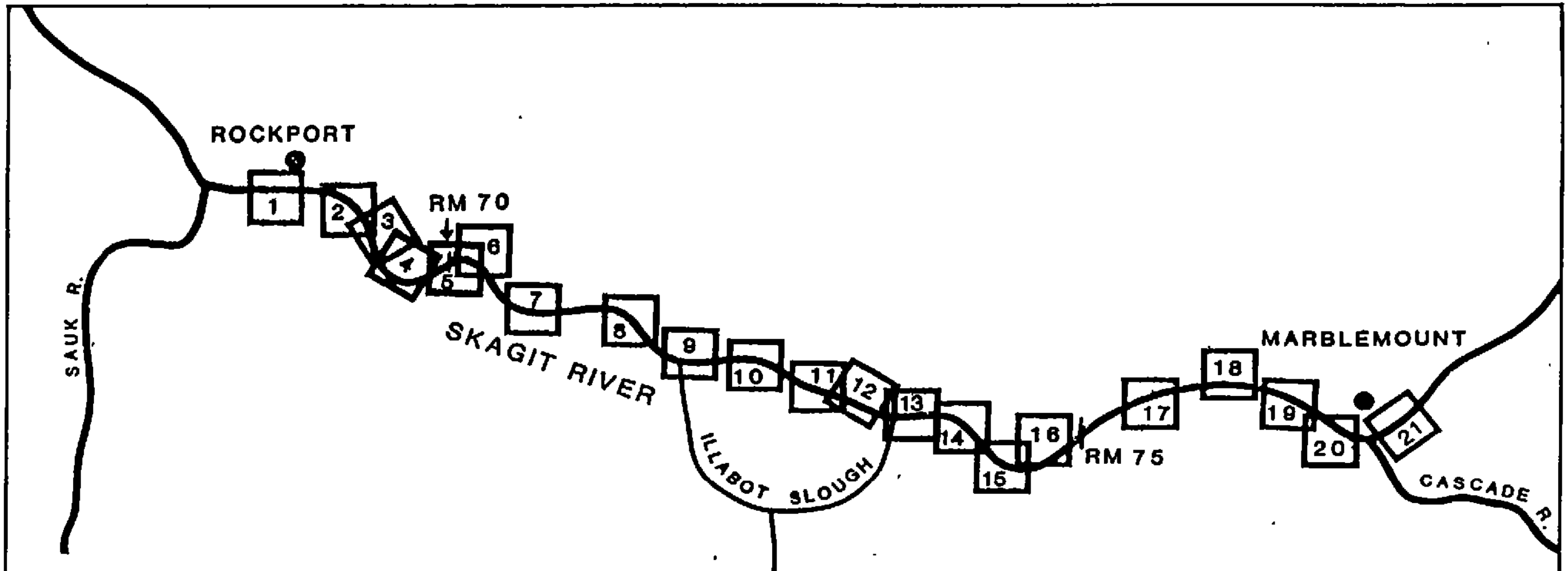
- B-1 Pothole Maps
- B-2 Access Maps to Pothole Areas

Appendix B

POTHOLE AREA MAPS AND POTHOLE AREA ACCESS MAPS

A series of 31 maps representing the 33 pothole areas located within the study area from Rockport (RM 67.5) to Alma Creek (RM 85.0) are presented in order of increasing river mileage. All potholes studied during the spring and fall surveys, as well as the high flow potholes surveyed in November, are included with the exception of seven potholes surveyed in the spring that were deleted from the fall studies. Those potholes were excluded from the fall survey because of changes in the physical structure of the potholes. In the fall, four potholes that were surveyed in the spring had become indistinguishable from nearby sloughs while the other three potholes had been eliminated due to the scouring effect of high river flows.

A series of pothole area access maps have also been developed as an aid for locating the pothole areas in the field. Names of roads, mileage from nearby towns, and other prominent landmarks have been included for those areas which are land accessible. It should be noted that there are a number of areas which are boat accessible only. For those areas, river mileages, as well as prominent landmarks, are provided.



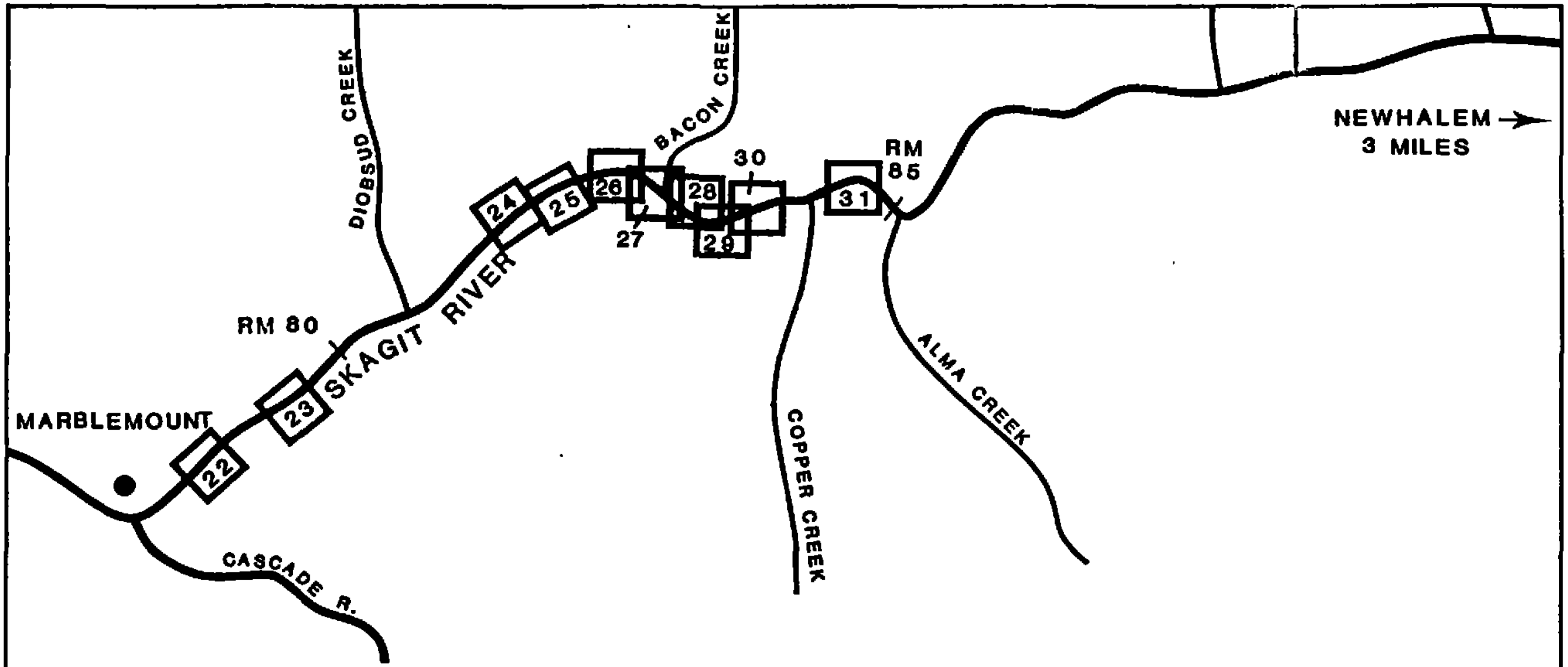
1 ROCKPORT BAR
2 WAYNE'S SWIM
3 LOWER TIN SHACK
4 UPPER TIN SHACK
5 BAD SPOT
6 EAGLE BAR
7 FORBIDDEN BAR
8 J.R. BAR
9 BEAVER ISLAND
10 STUMP HAVEN
11 MODEL POTHOLE
12 HOOPER'S SLOUGH
13 RICK'S SURPRISE & INACCESSIBLE ISLAND
14 CARNAGE
15 POWER BAR
16 DRY BAR
17 NORTH O'BRIAN'S FERRY
18 SECLUSION ISLAND
19 BIG EDDY
20 TEFLON BAR
21 MARBLEMOUNT SLOUGH

LEGEND FOR POTHOLE MAPS

- 10 POTHOLE LOCATION
- ⊕ NEW RIVER GAUGE
- + OLD RIVER GAUGE
- ▲ BENCHMARK
- LOGS AND DEBRIS
- * HIGHFLOW POTHOLE

SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

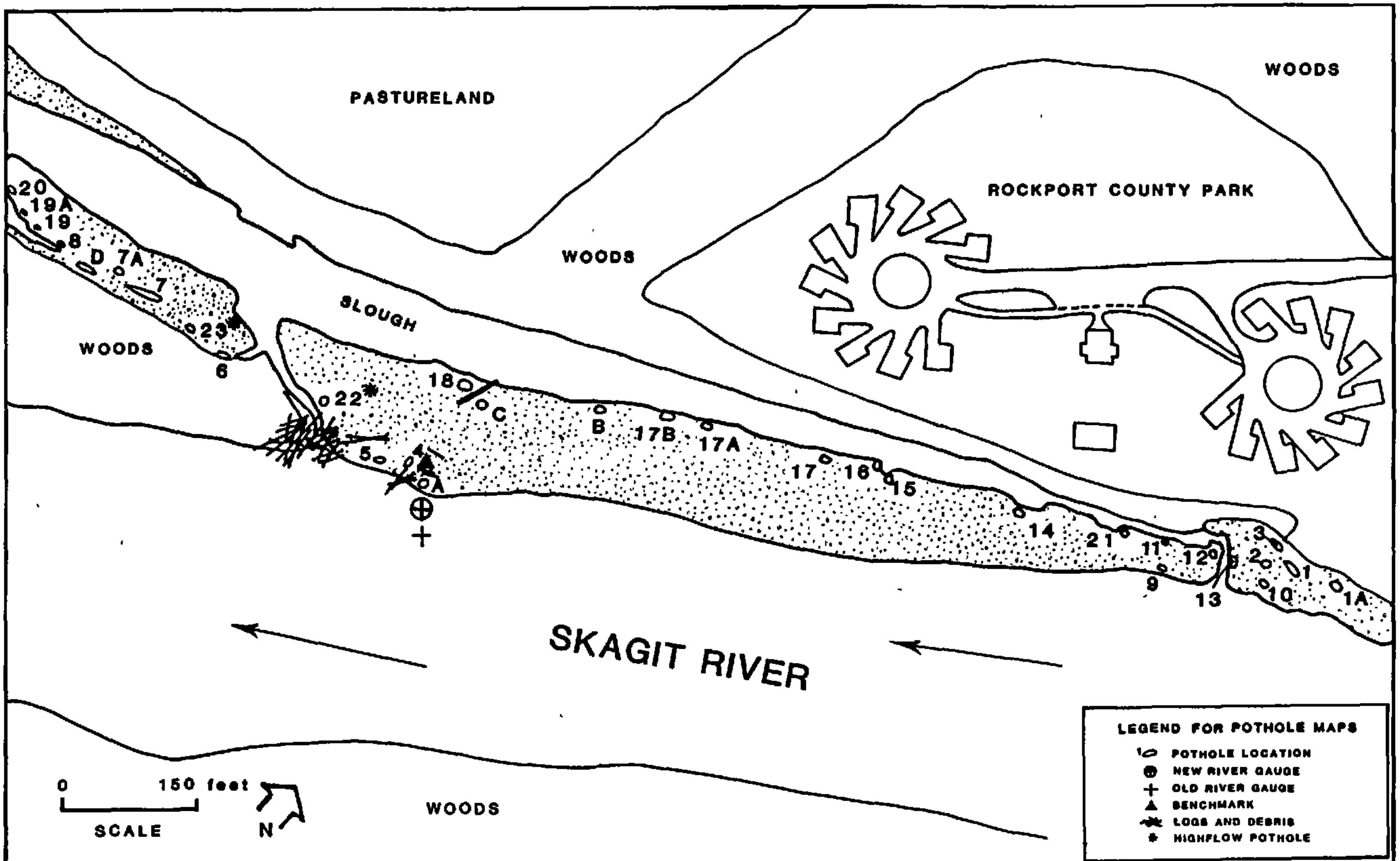
POTHOLE MAP INDEX
(MAPS 1 -21)



22 RAINIER BAR
23 FUNGUS BAR
24 SAM'S BAR
25 MAPLE BAR
26 BACON CREEK
27 FACE BAR & OINK BAR
28 DRIFTWOOD BAR
29 MINIBAR
30 FLOWER POTHOLE
31 COPPER CREEK

SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

POTHOLE MAP INDEX
(MAPS 21-31)



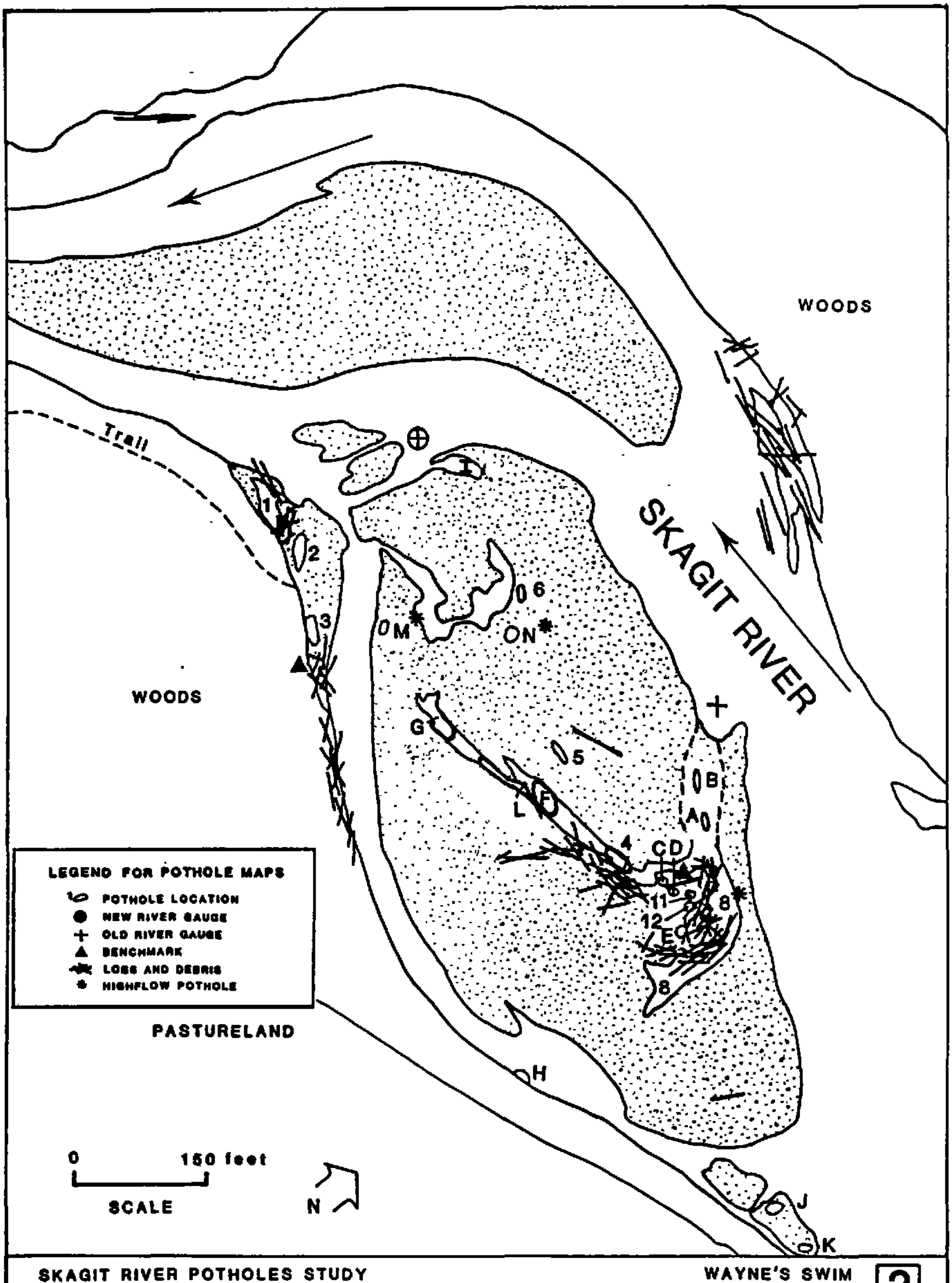
SKAGIT RIVER POTHOLES STUDY

JONES & STOKES ASSOCIATES, INC.

ROCKPORT BAR

RM-67.5

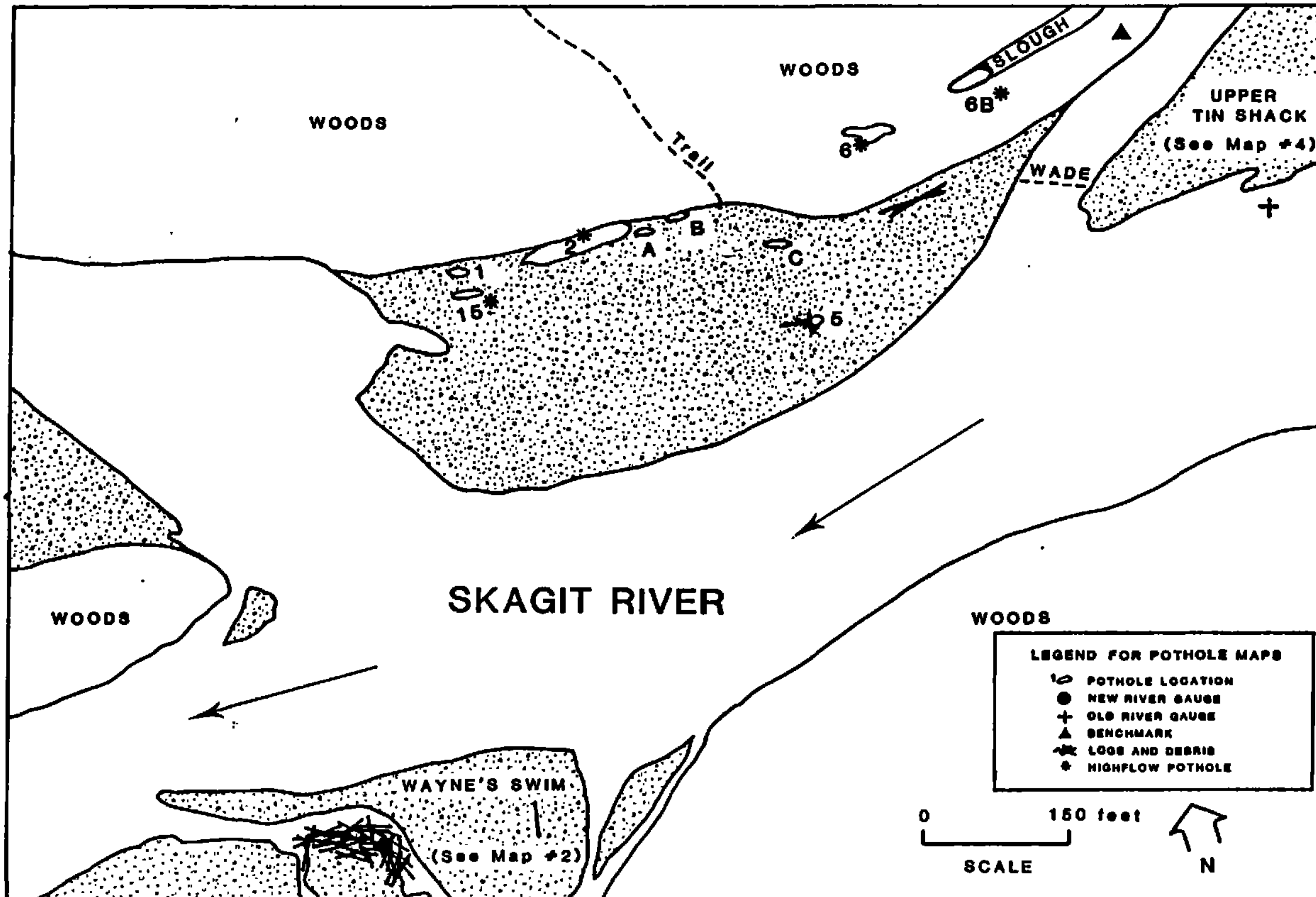
1



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

WAYNE'S SWIM
RM-68.1

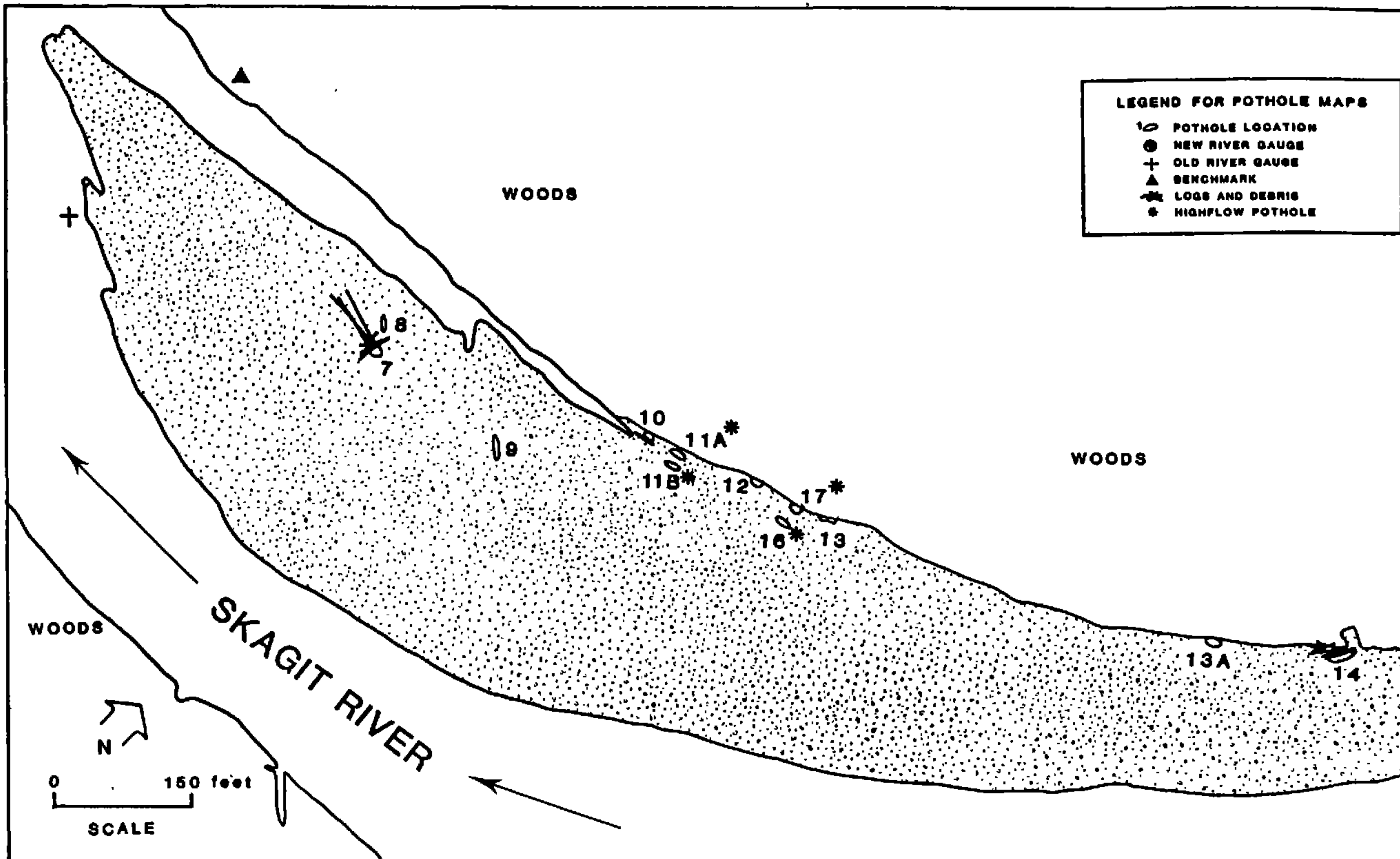
2



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

LOWER TIN SHACK
RM-68.3

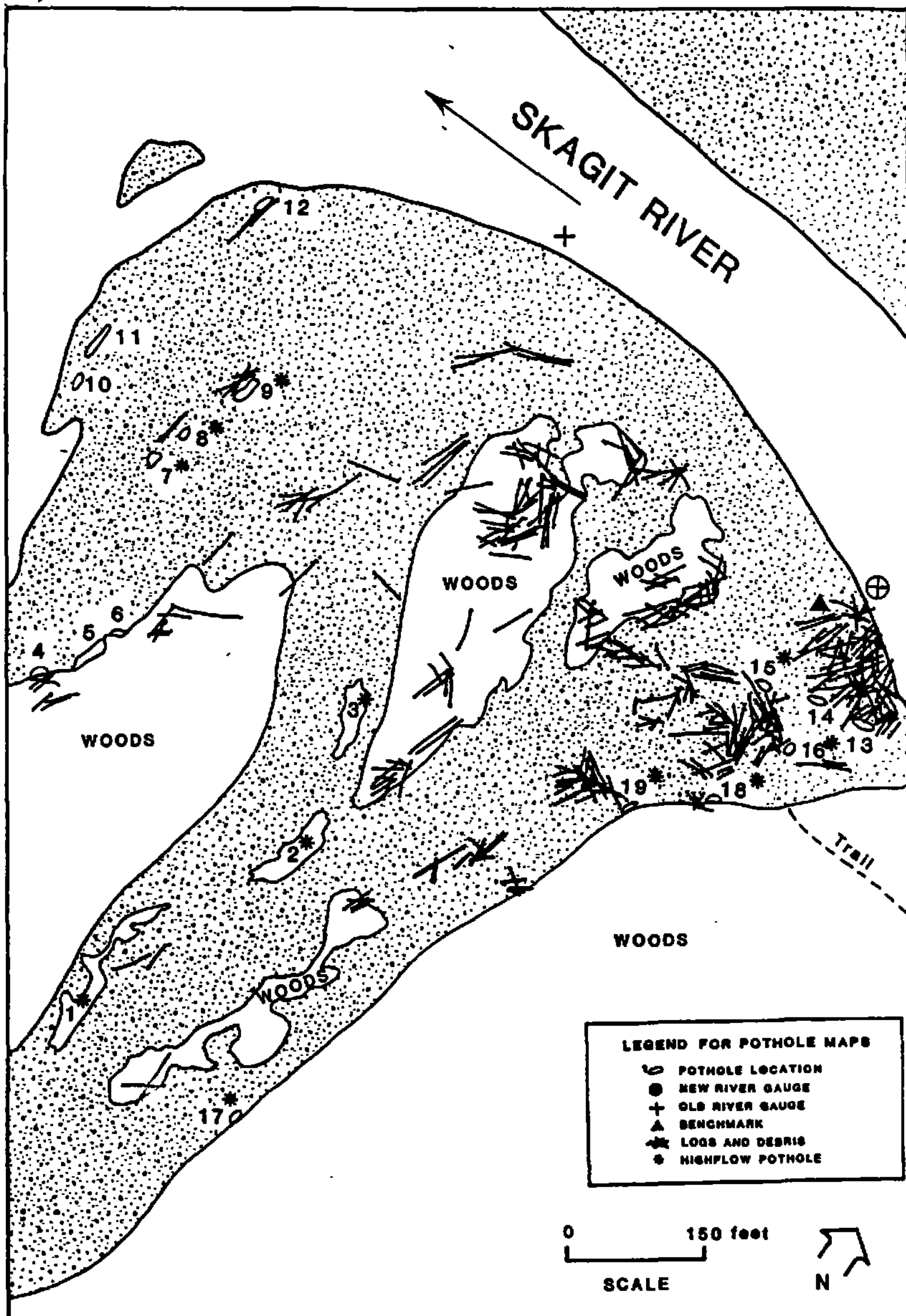
3



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

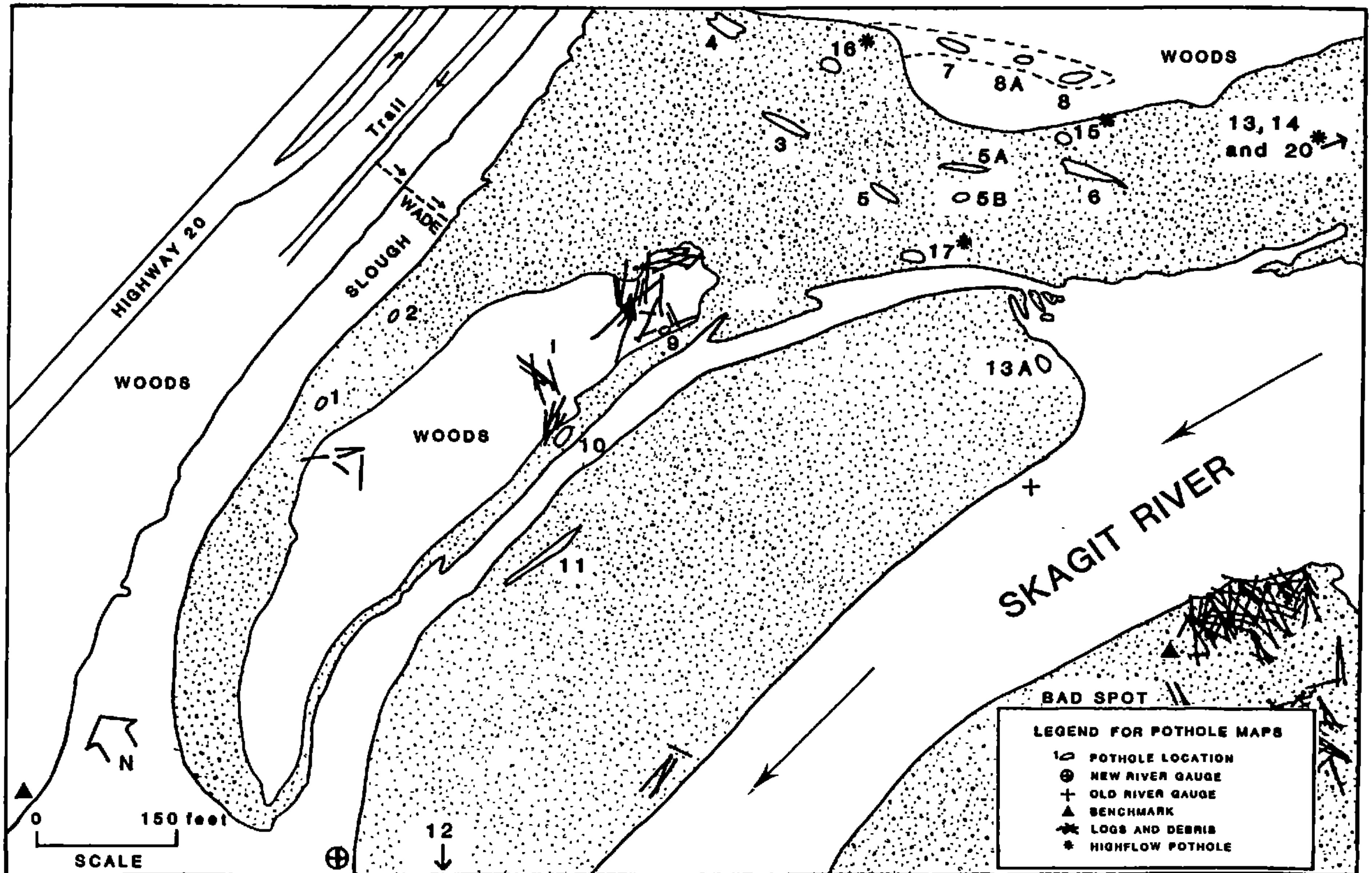
UPPER TIN SHACK
RM-68.3

4



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

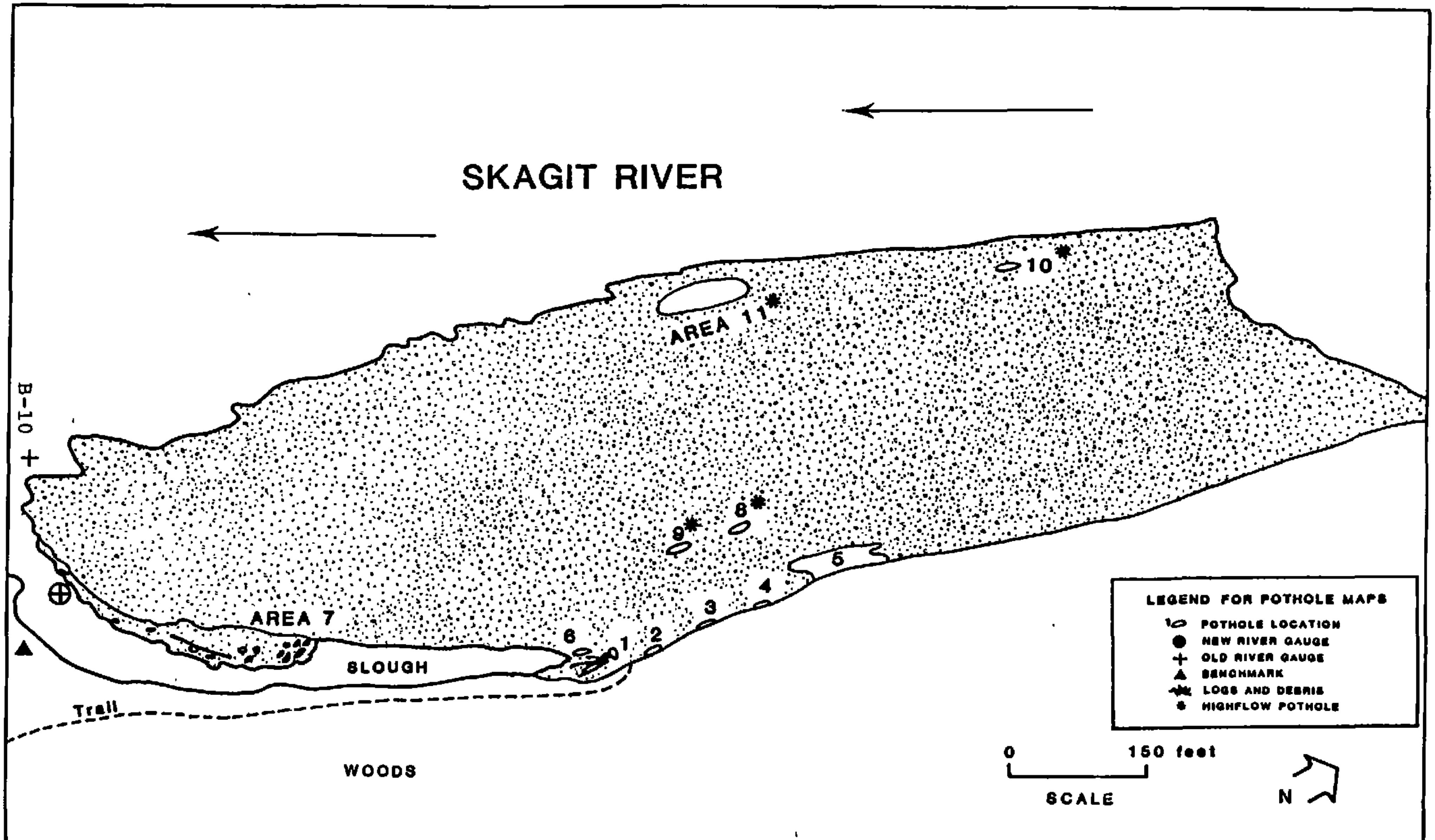
BAD SPOT
RM-70.0
5



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

EAGLE BAR
RM-70.1

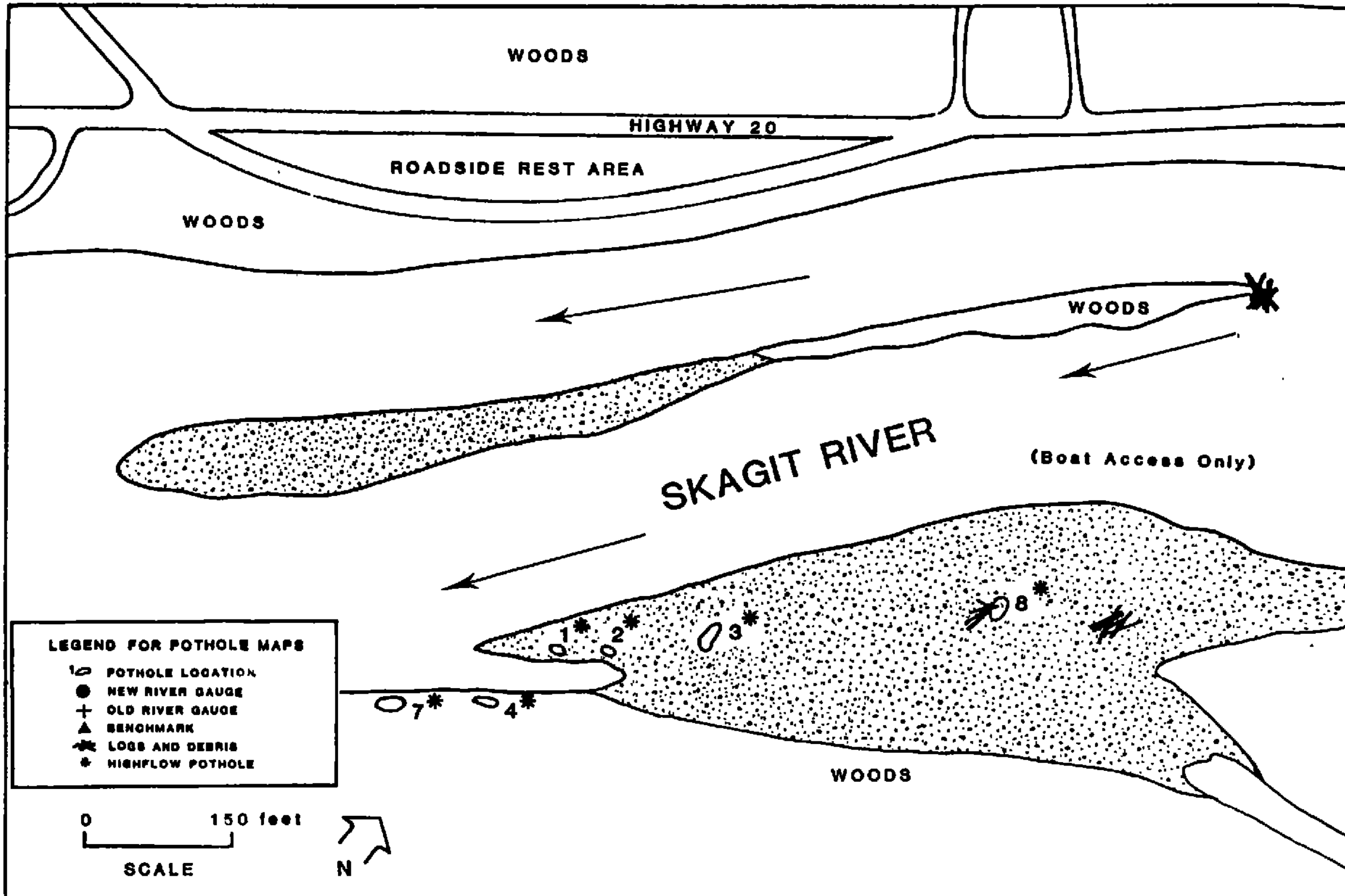
6



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

FORBIDDEN BAR
RM-70.5

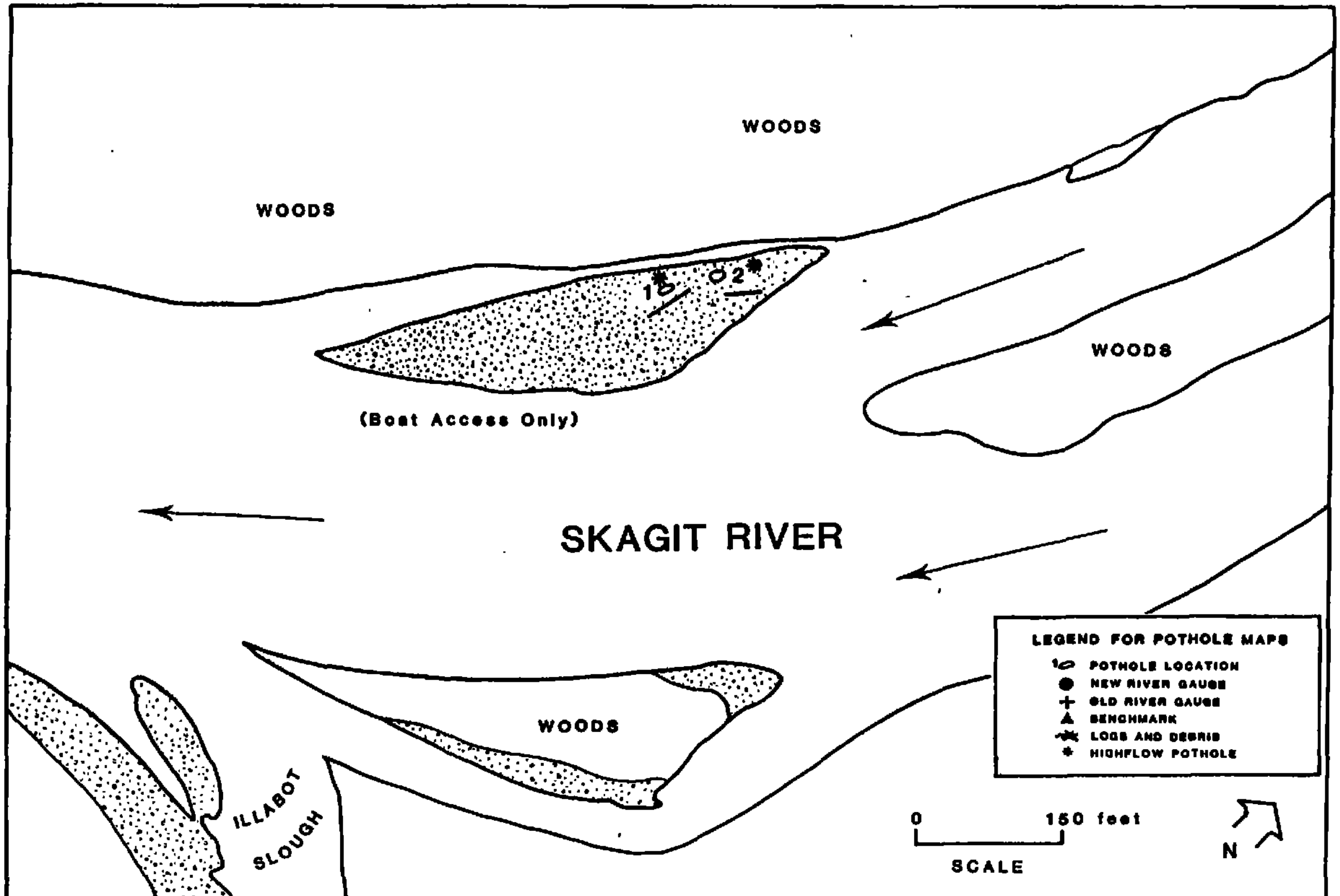
7



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

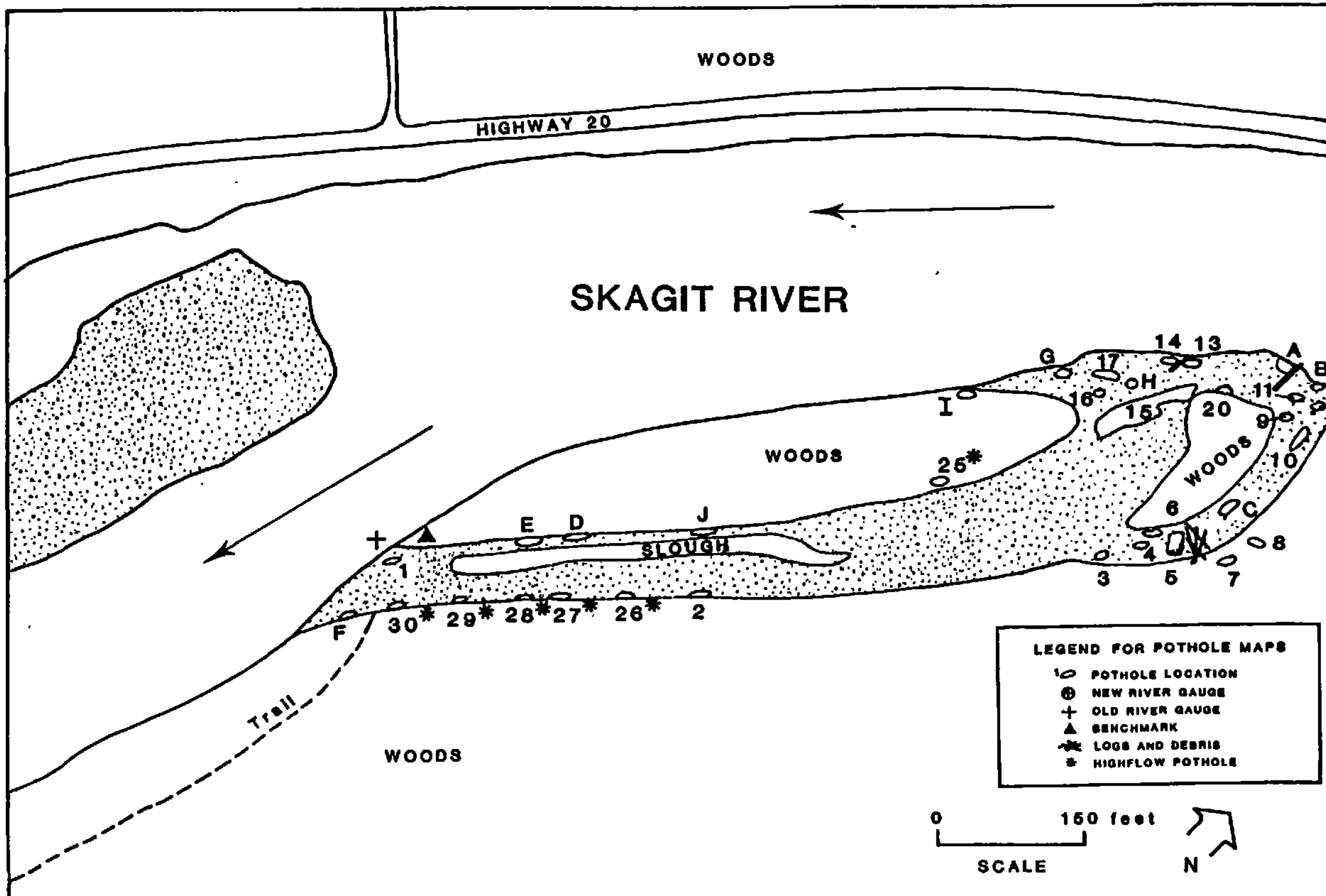
J.R. BAR
RM-71.1

8



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

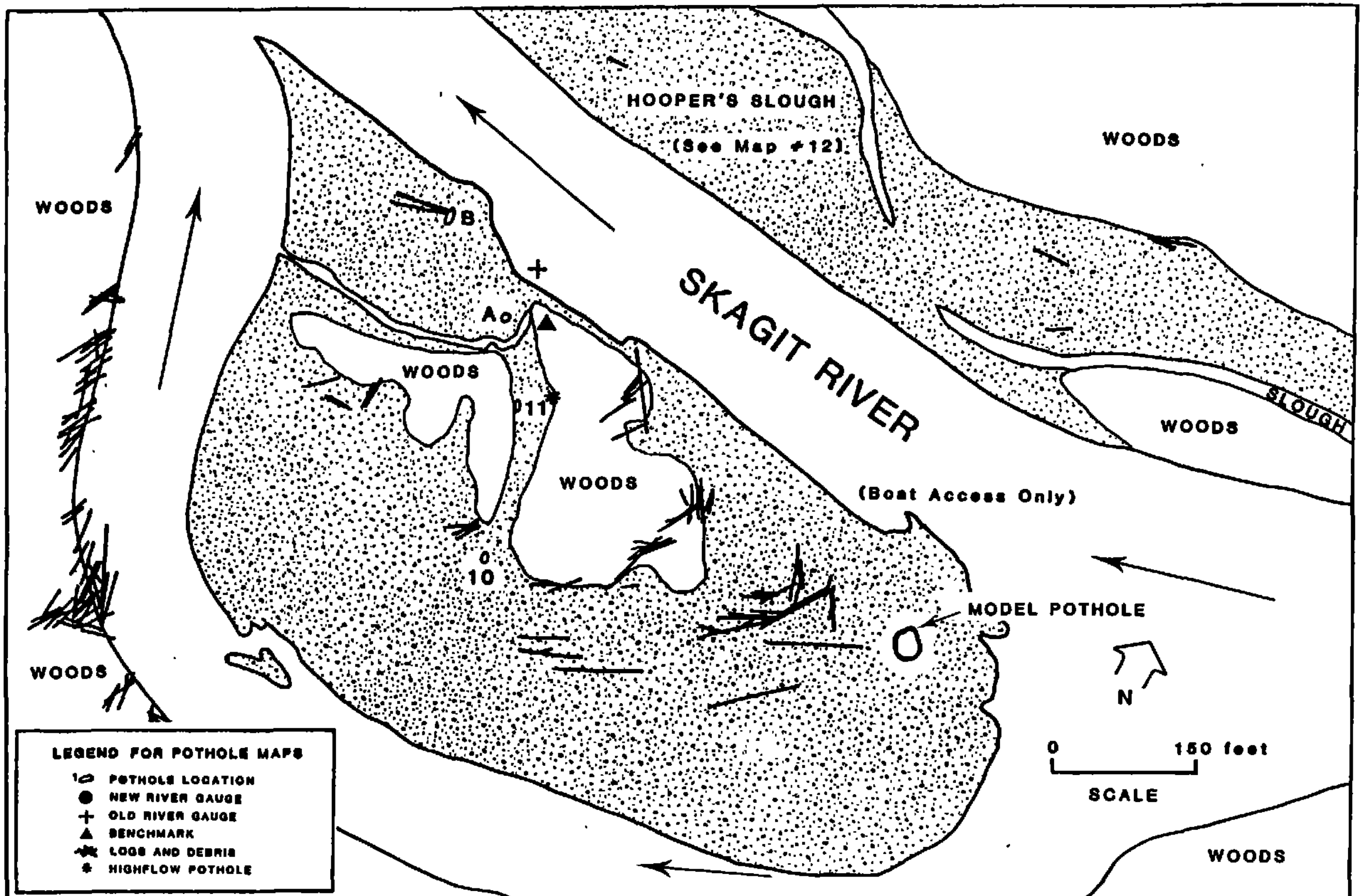
BEAVER ISLAND 9
RM-71.4



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

STUMP HAVEN
RM-72.2

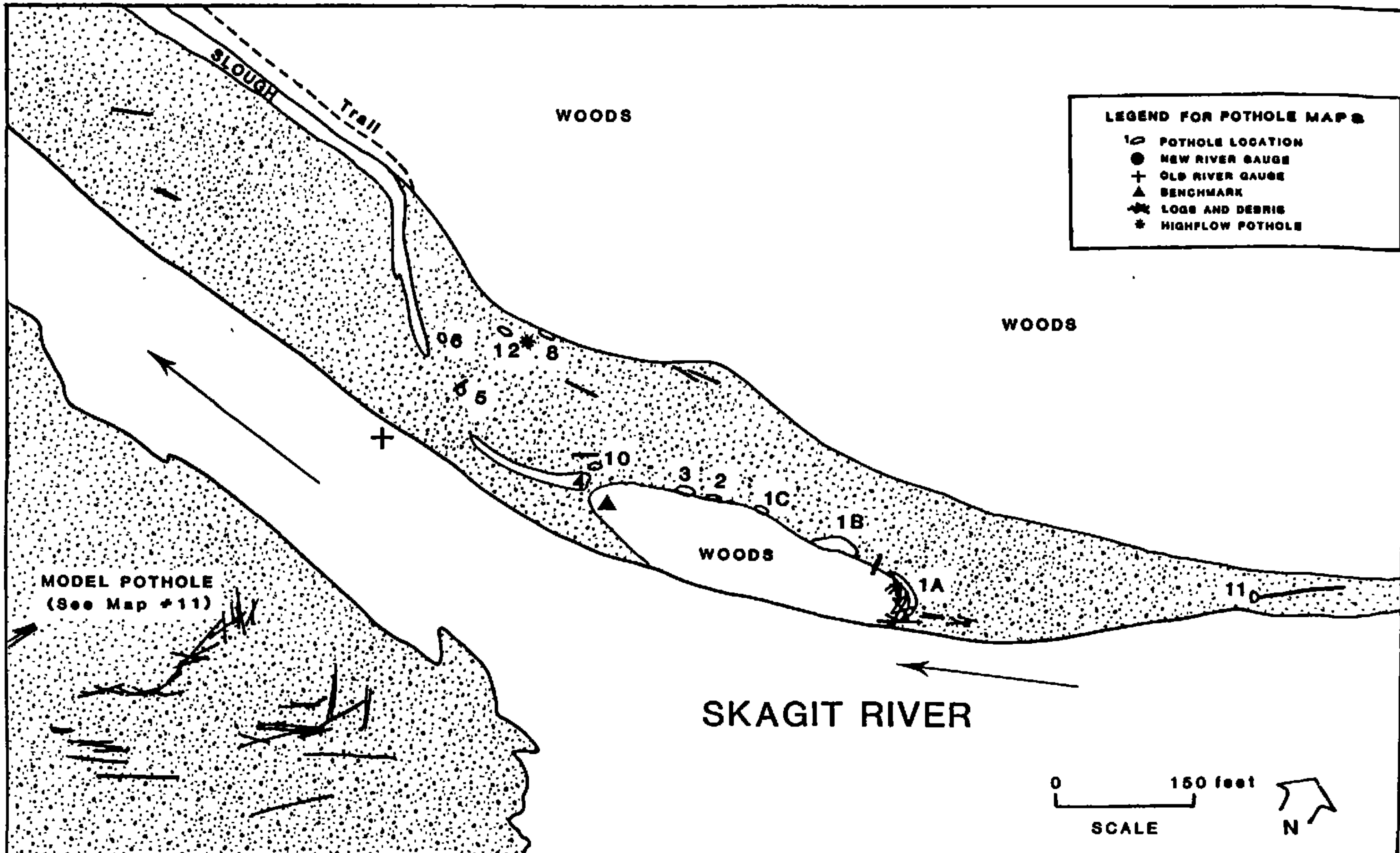
10



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

MODEL POTHOLE
RM-72.6

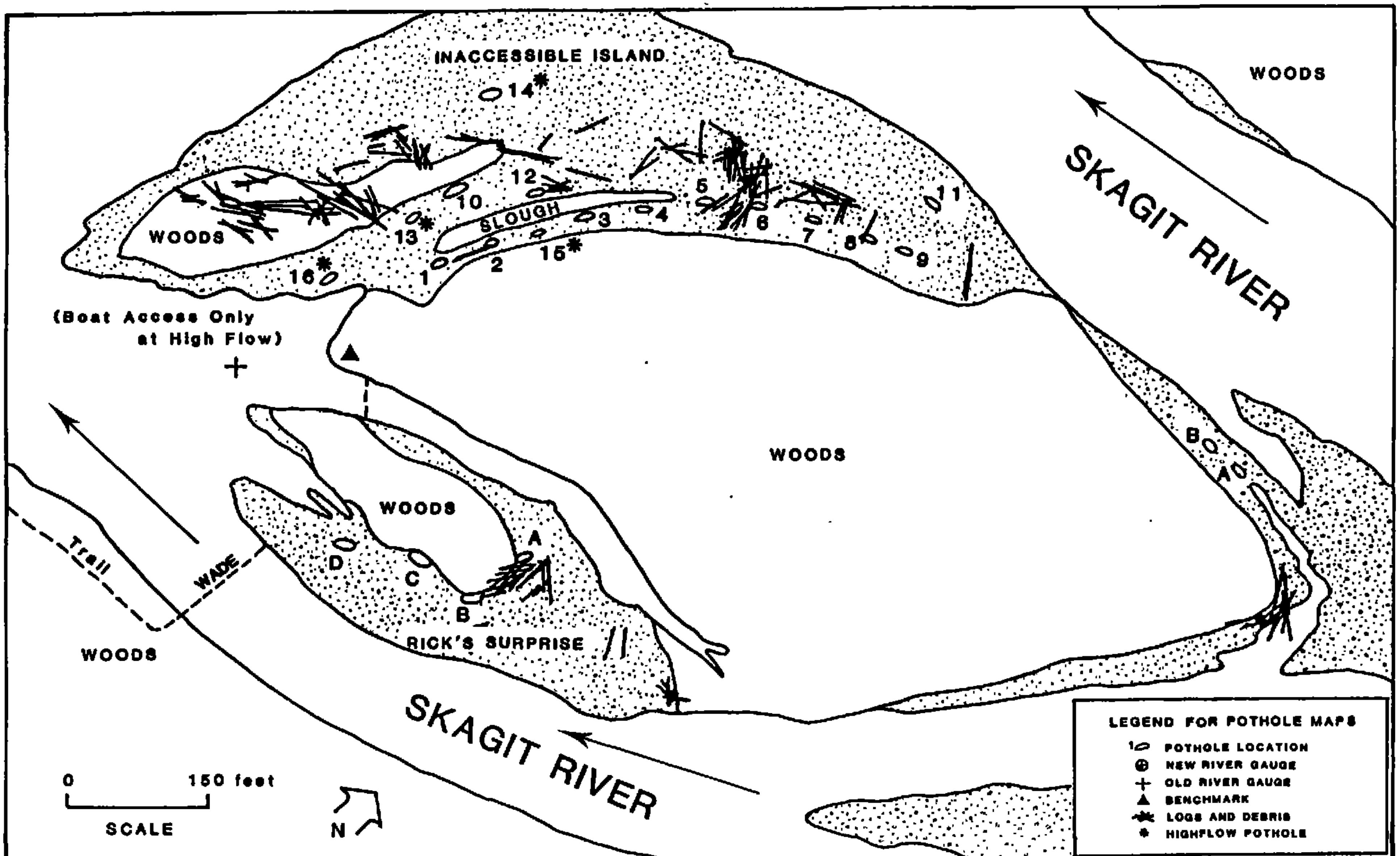
11



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

HOOPER'S SLOUGH
RM-72.7

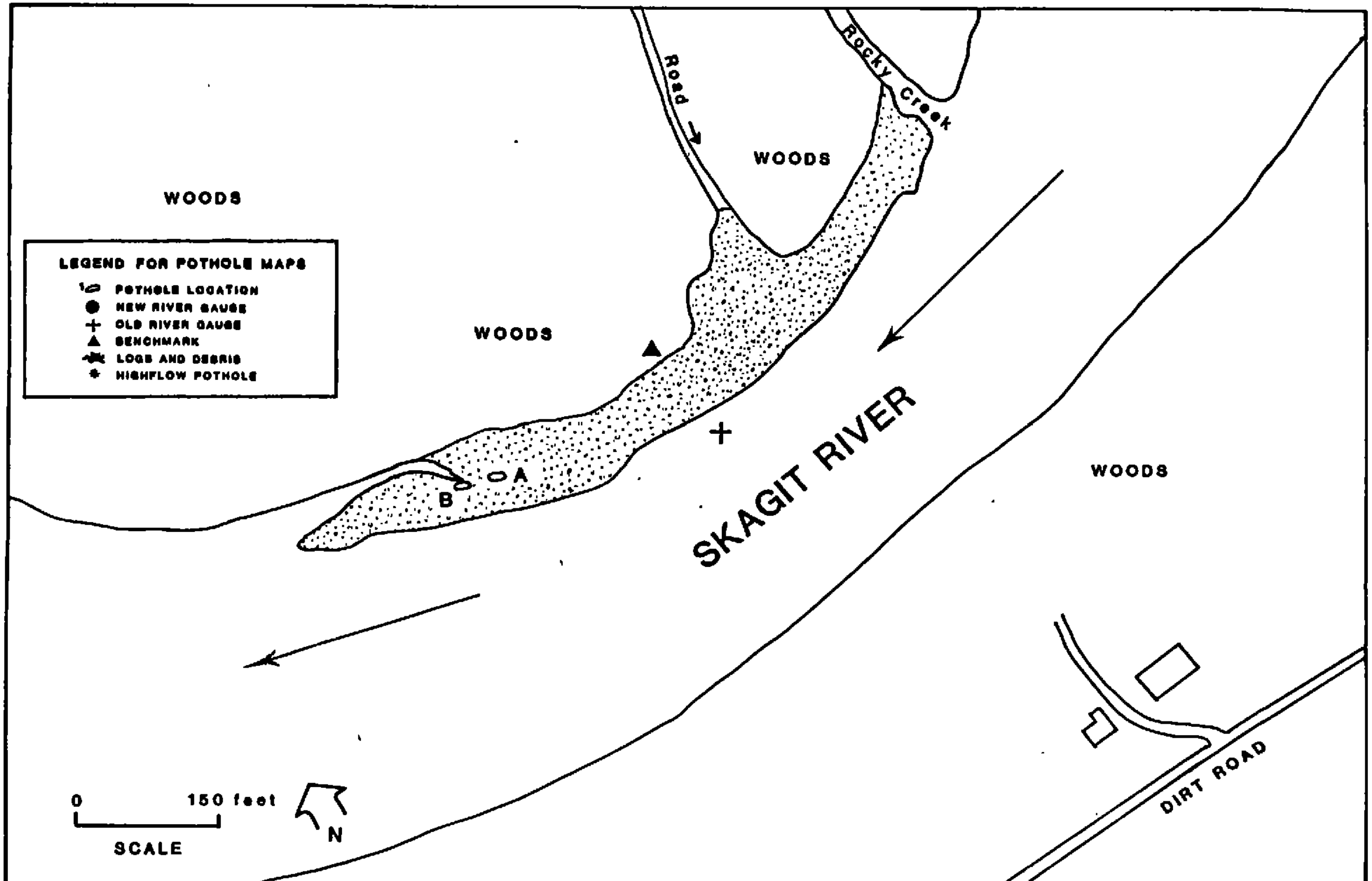
12



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

RICK'S SURPRISE & INACCESSIBLE ISLAND
RM-73.0 RM-73.1

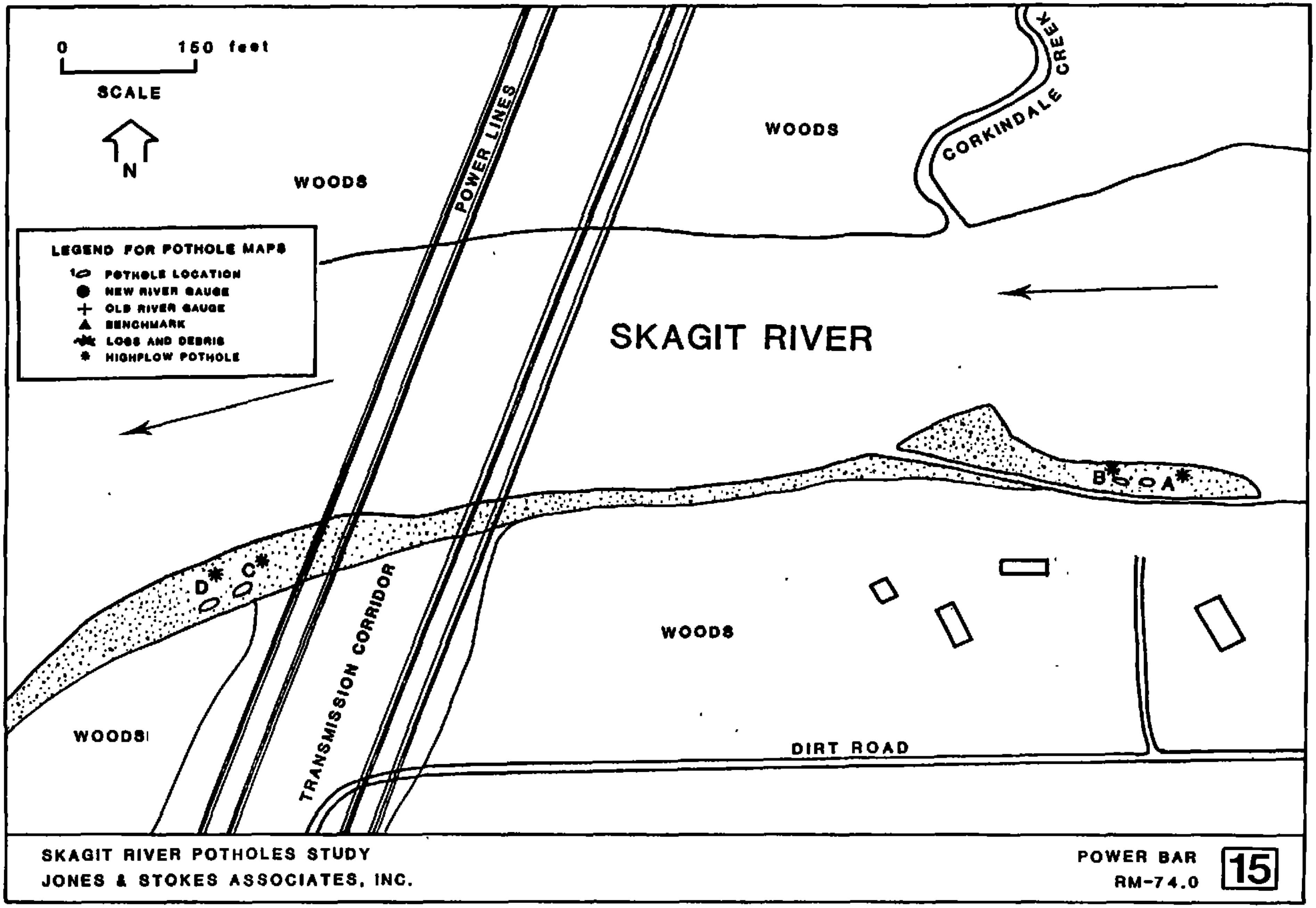
13

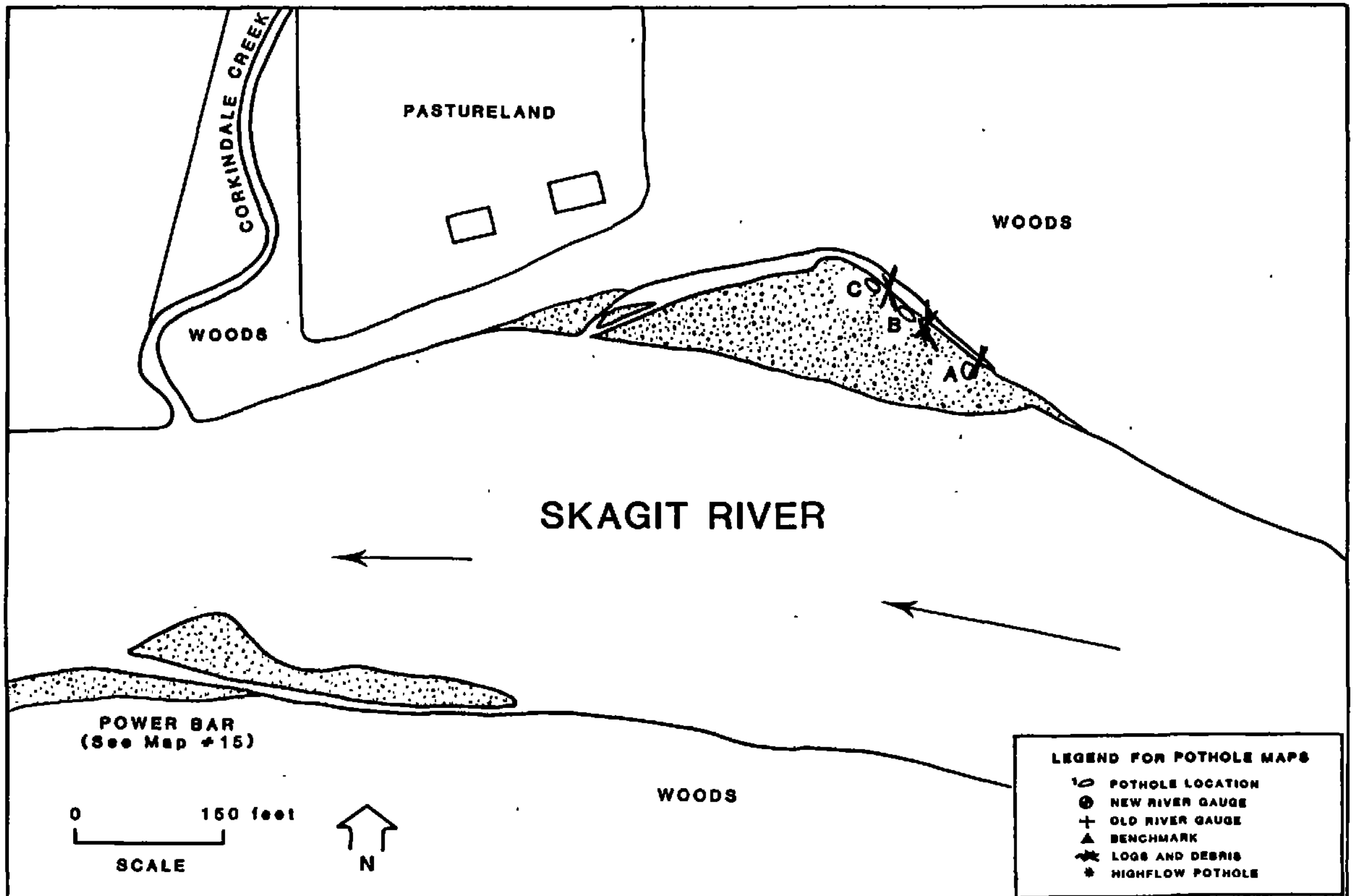


SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

CARNAGE
RM-73.3

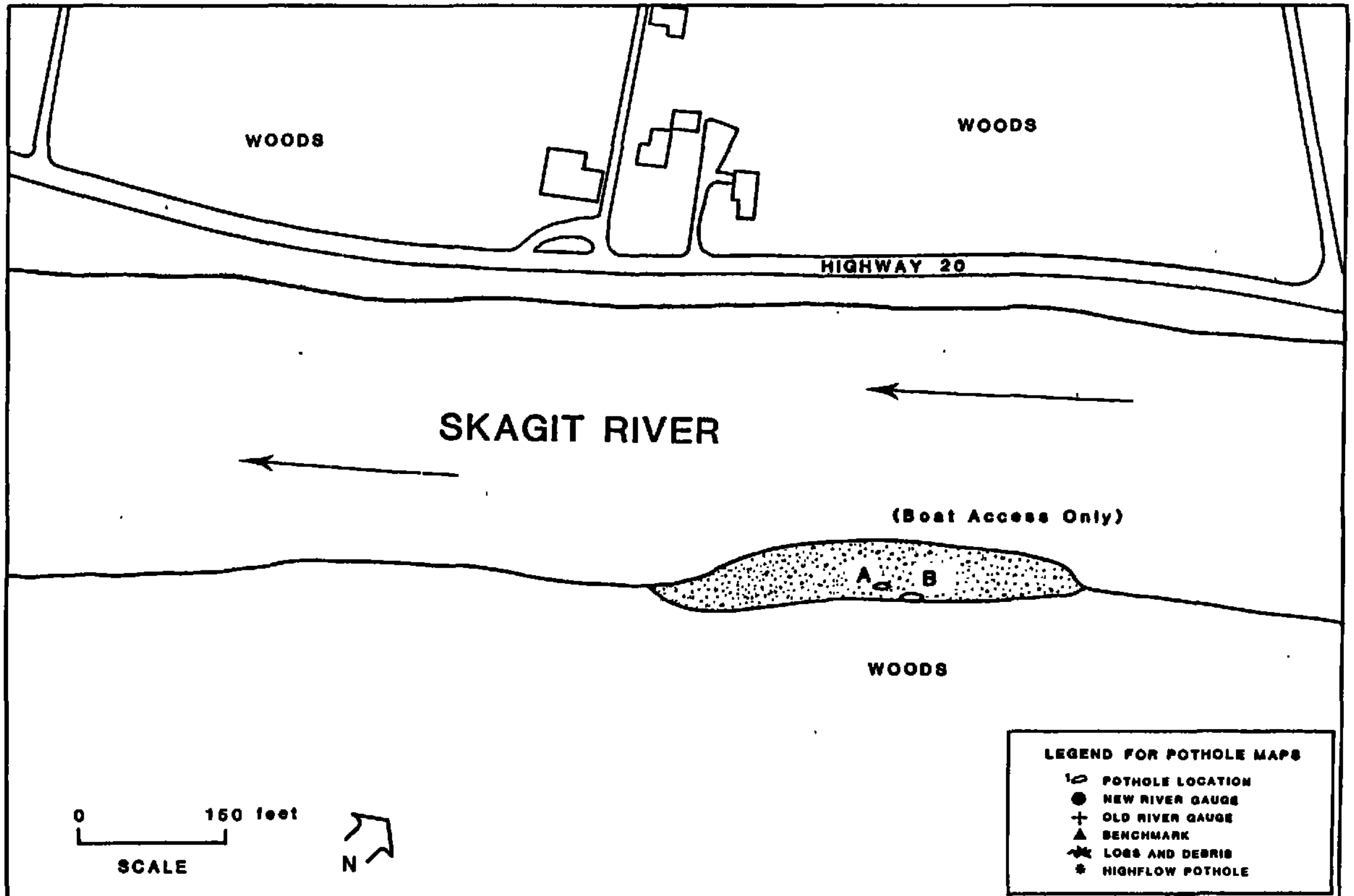
14


0 150 feet
SCALE
N
LEGEND FOR POTHOLE MAPS
POTHOLE LOCATION
NEW RIVER GAUGE
OLD RIVER GAUGE
BENCHMARK
LOGS AND DEBRIS
HIGHFLOW POTHOLE
WOODS
POWER LINES
WOODS
CORKINDALE CREEK
SKAGIT RIVER
B A
D C
TRANSMISSION CORRIDOR
WOODS
WOODS
DIRT ROAD
SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.
POWER BAR
RM-74.0
15



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

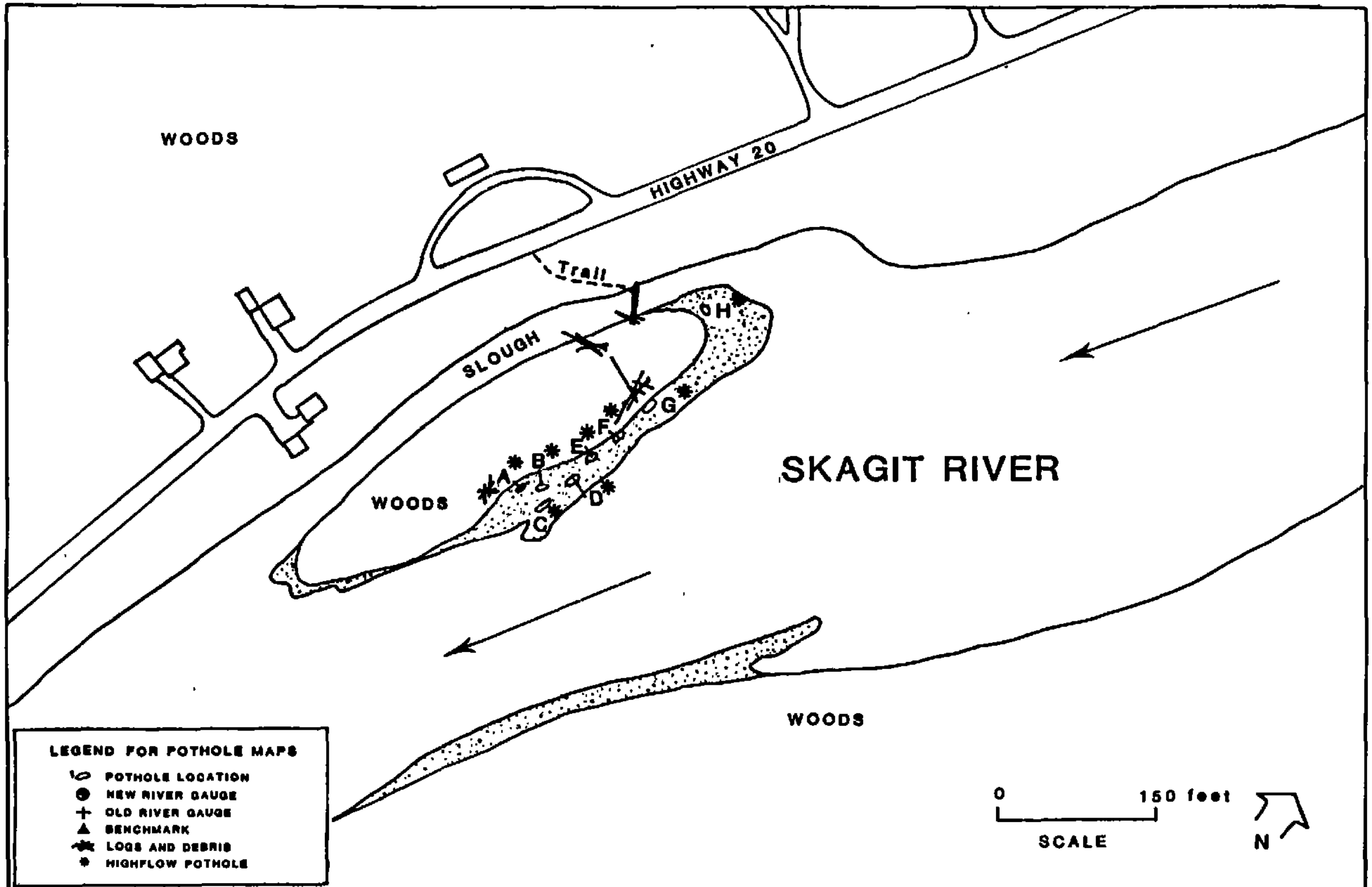
DRY BAR
RM-74.2
16



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

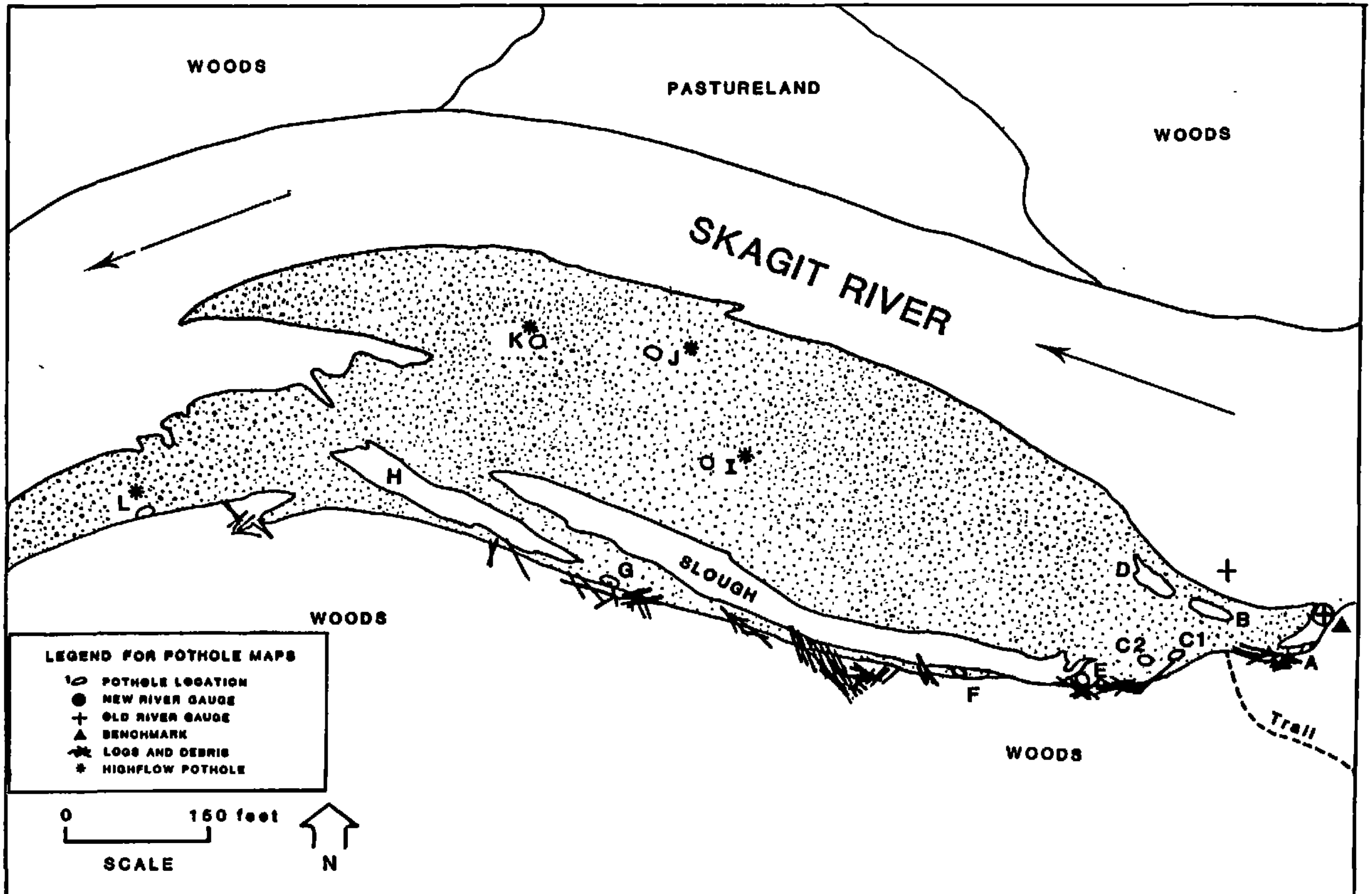
NORTH O'BRIAN'S FERRY
RM-76.0

17



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

SECLUSION ISLAND
RM-76.3
18



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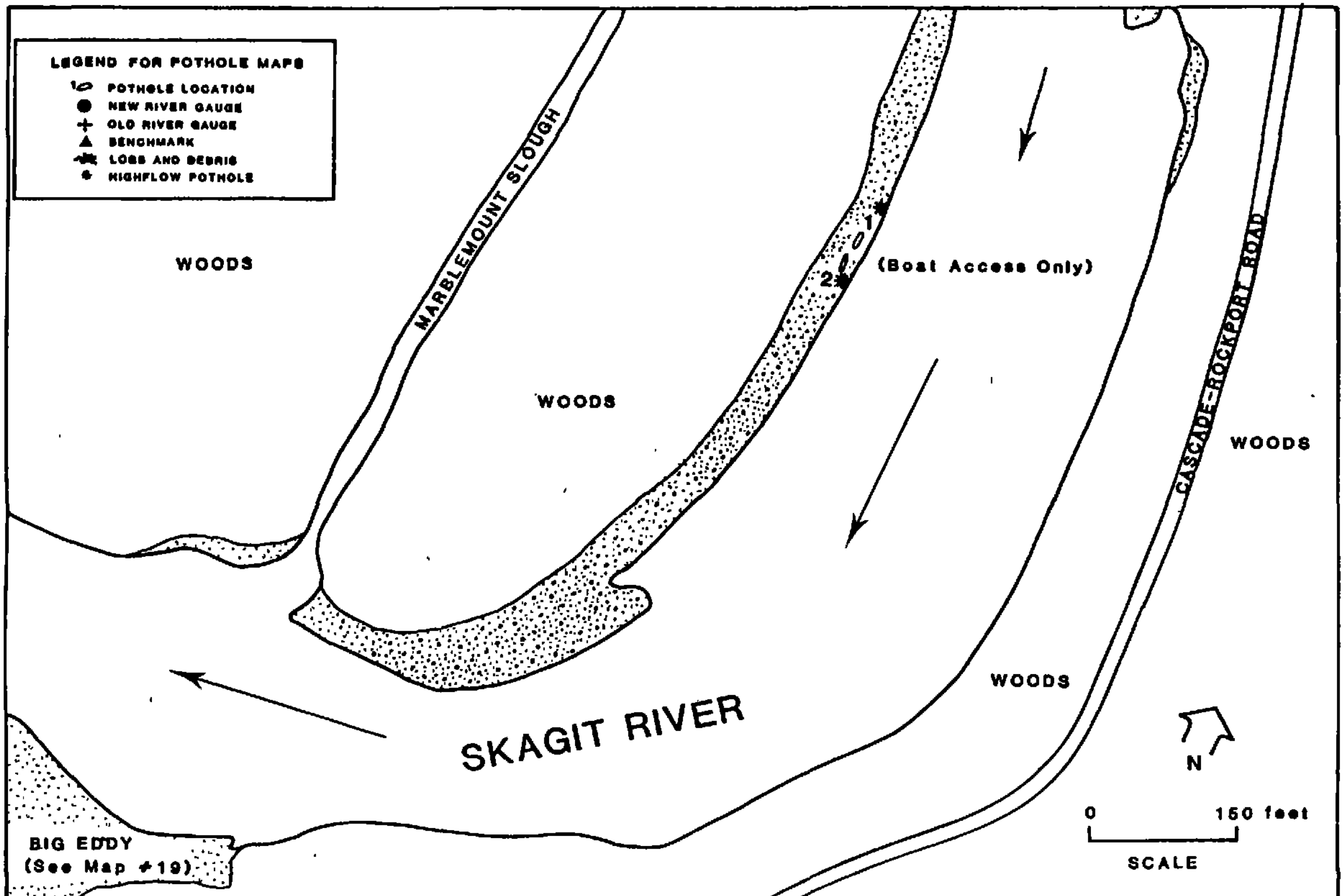
JONES & STOKES ASSOCIATES, INC.

BIG EDDY
RM-77.5

19



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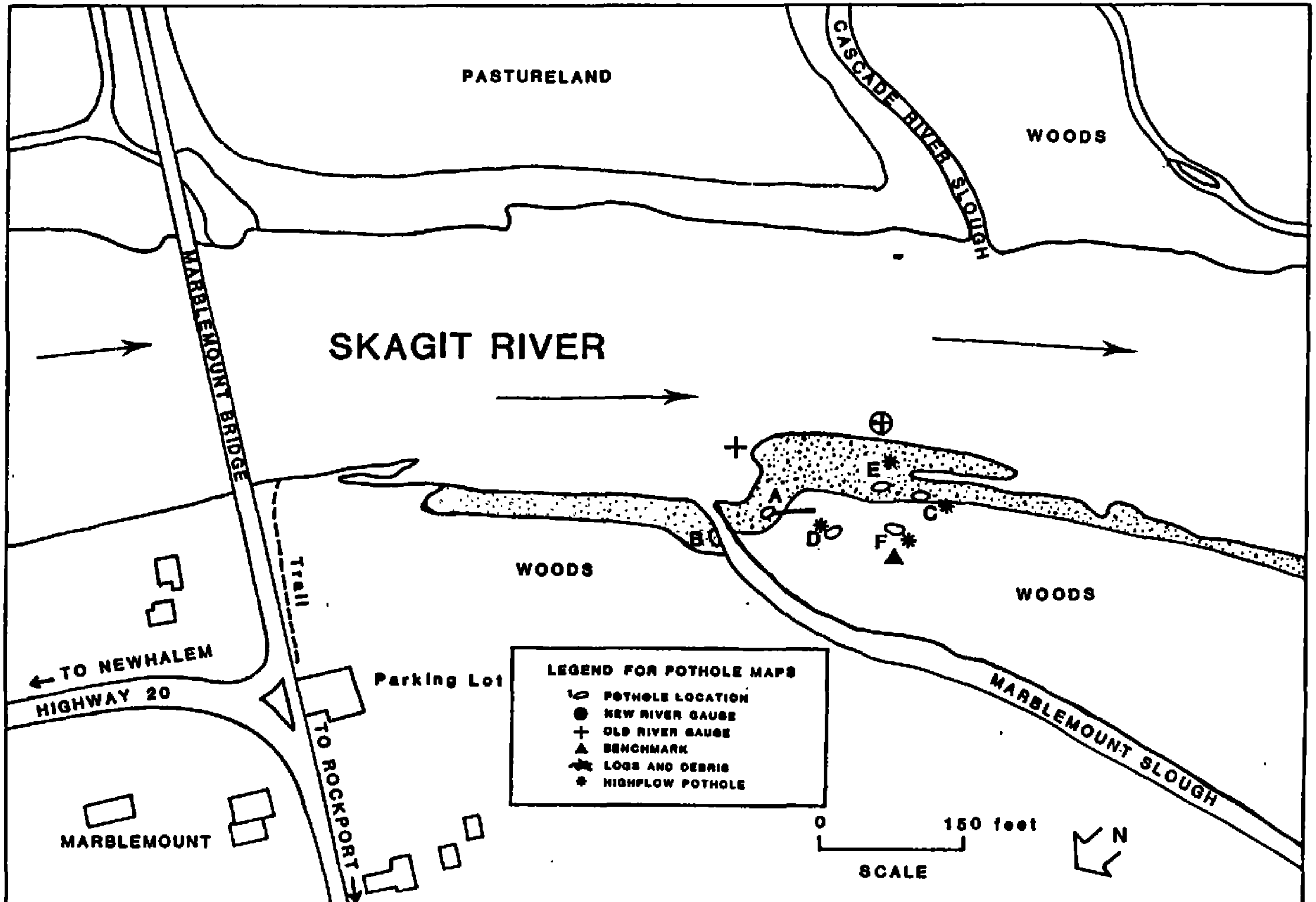
JONES & STOKES ASSOCIATES, INC.

TEFLON BAR
RM-77.7

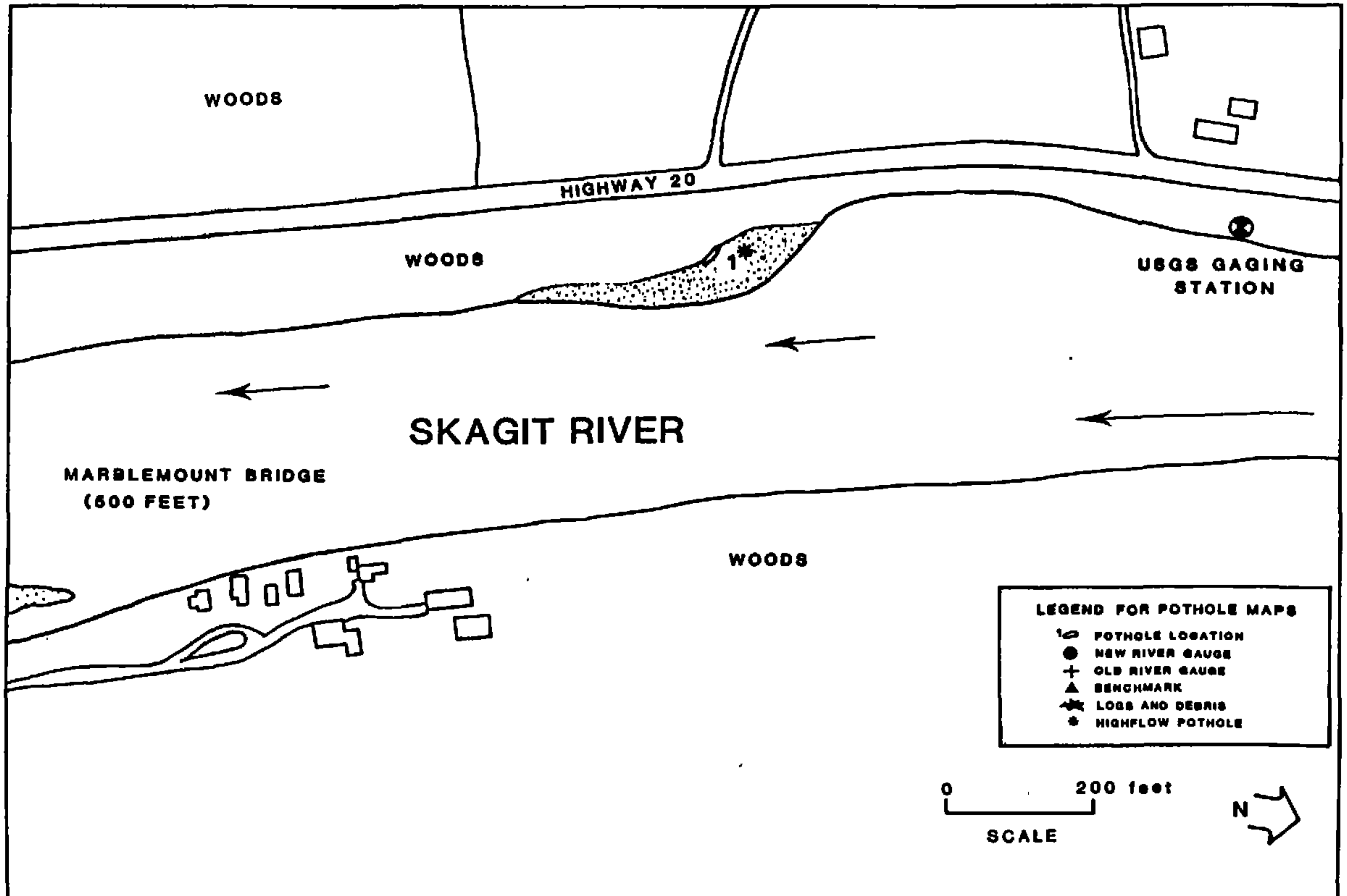
20



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

MARBLEMOUNT SLOUGH
RM-78.2

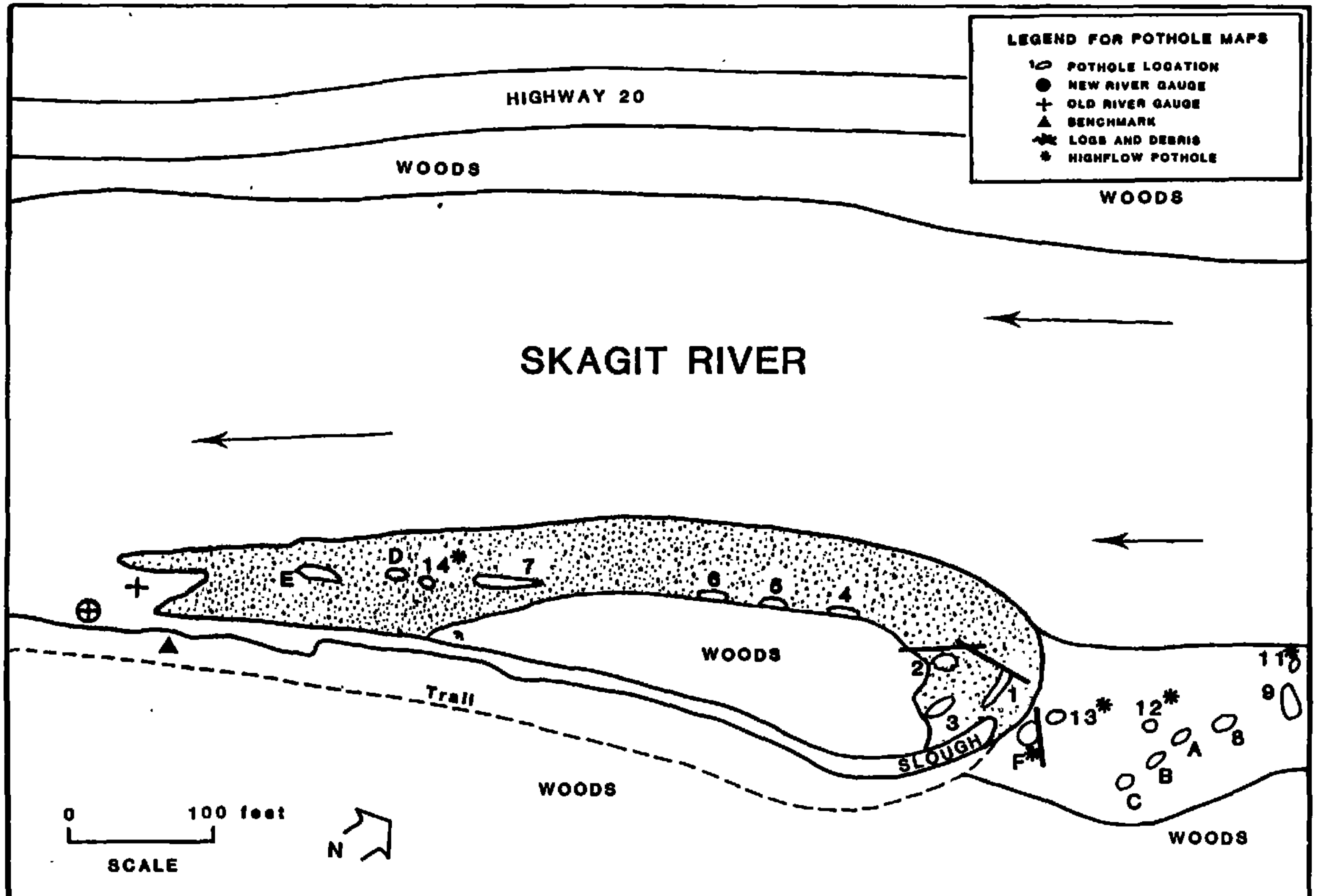
21



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

RAINIER BAR
RM- 78.3

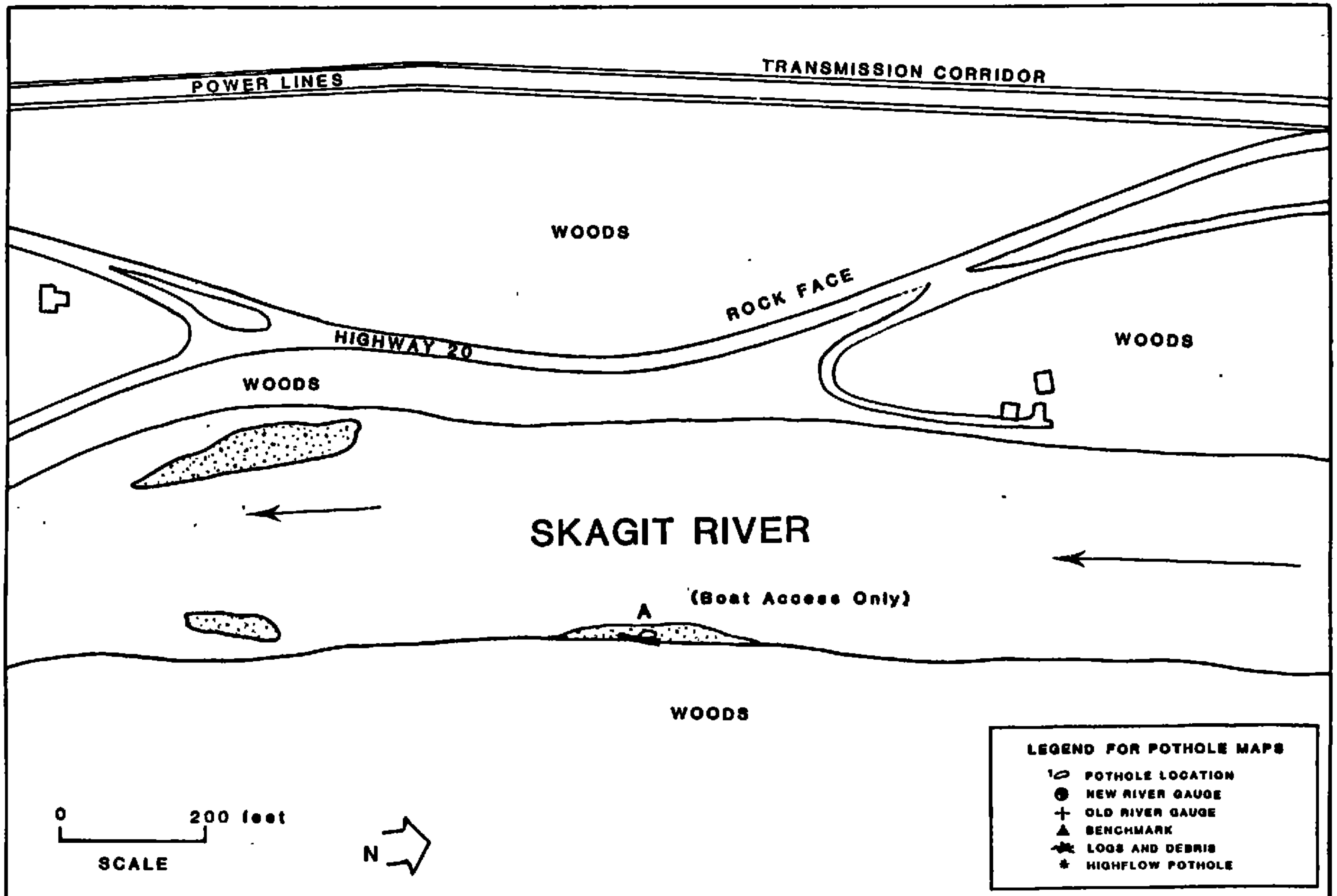
22



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

FUNGUS BAR
RM-78.5

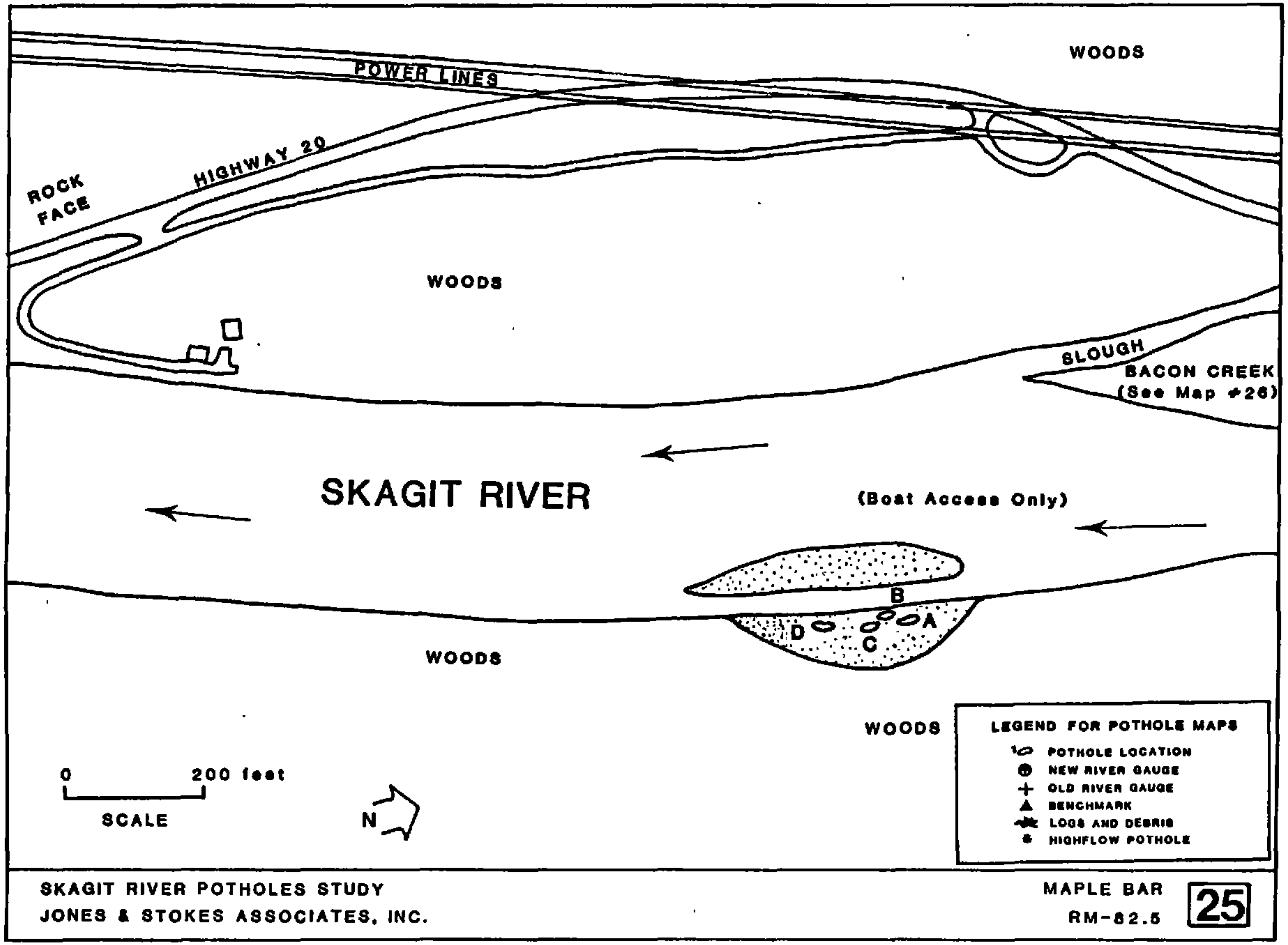
23



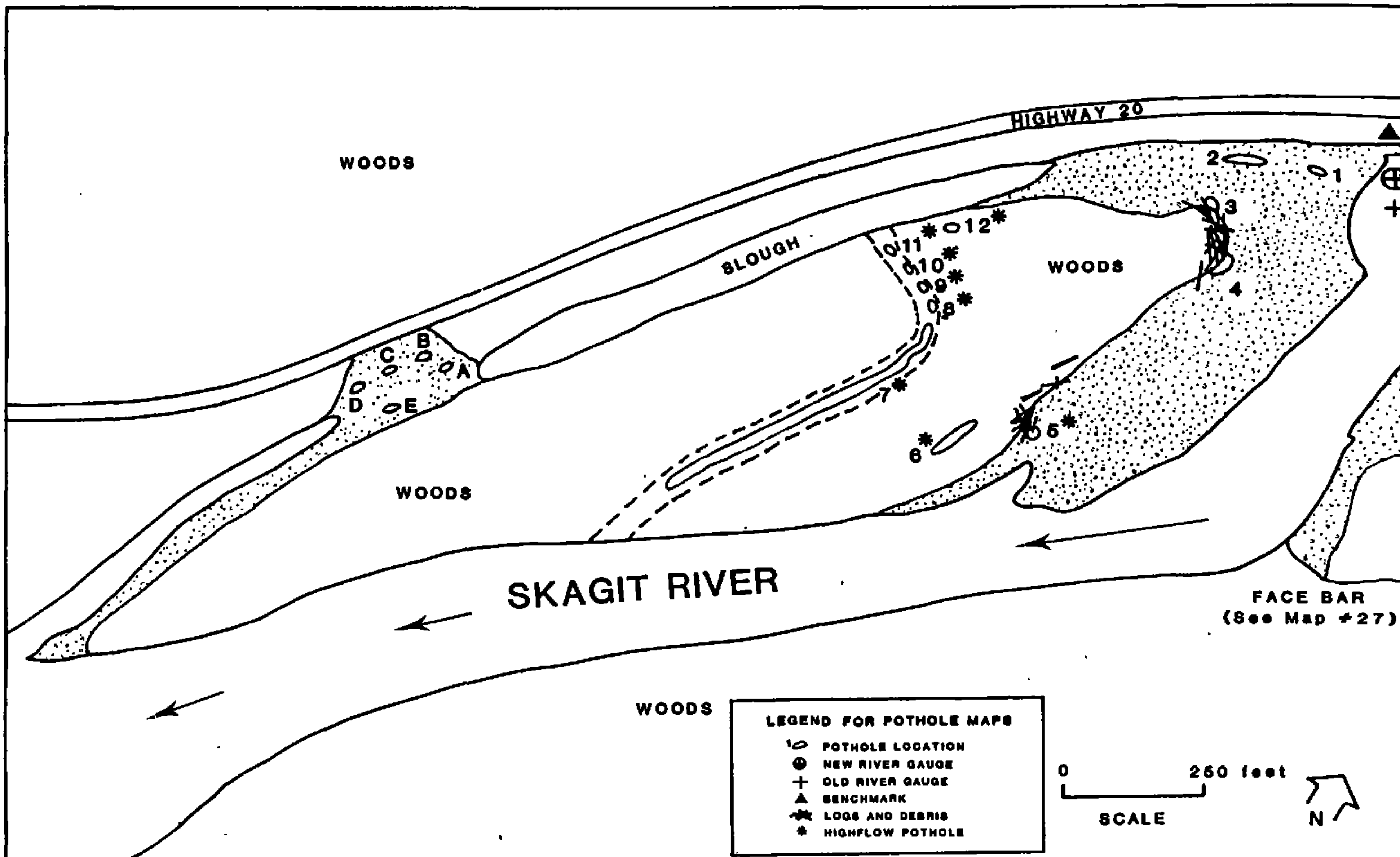
SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

SAM'S BAR
RM- 82.0

24



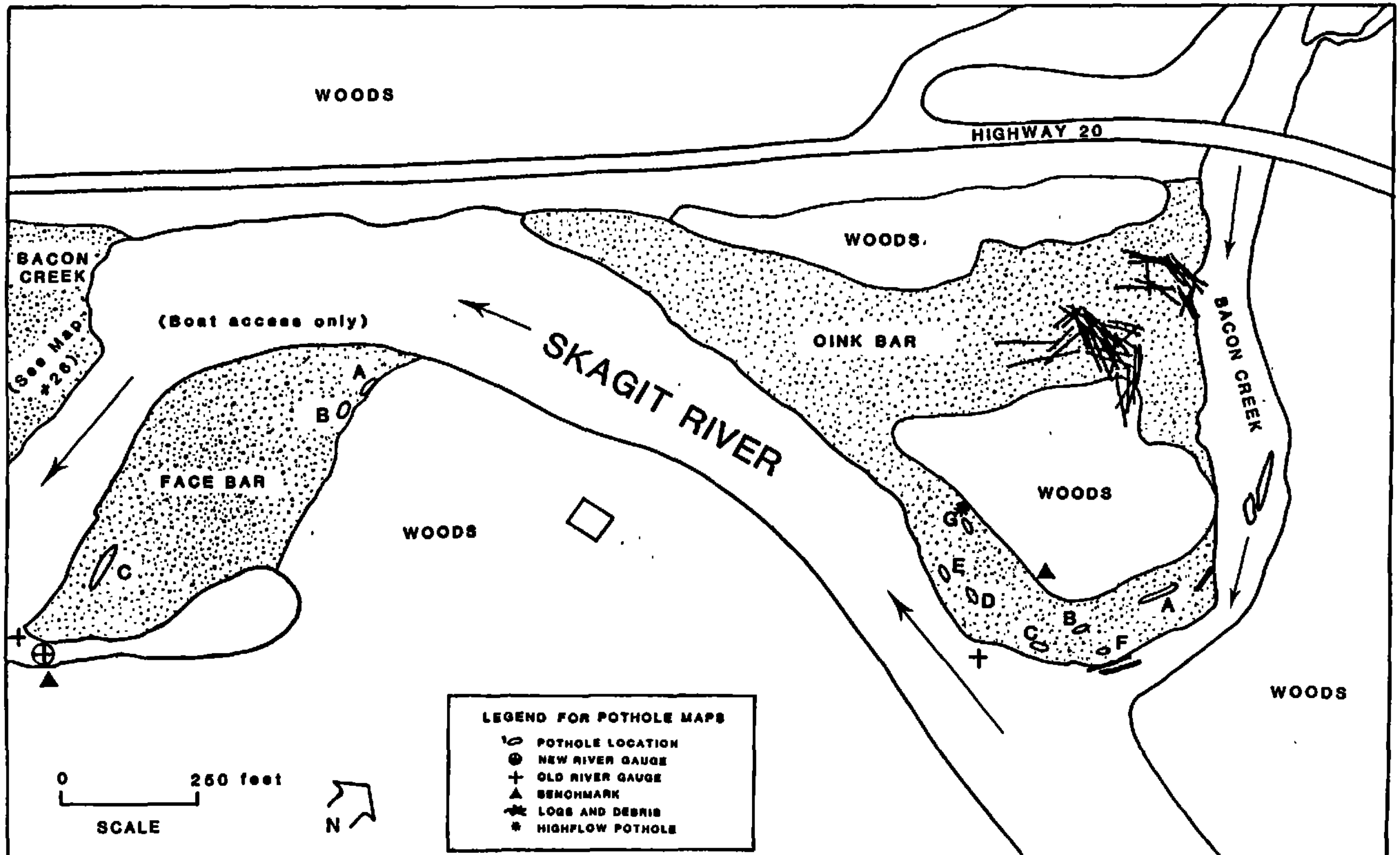
WOODS
POWER LINES
HIGHWAY 20
ROCK FACE
WOODS
SLOUGH
BACON CREEK (See Map #26)
SKAGIT RIVER
(Boat Access Only)
B
A
D
C
WOODS
WOODS
LEGEND FOR POTHOLE MAPS
POTHOLE LOCATION
NEW RIVER GAUGE
OLD RIVER GAUGE
BENCHMARK
LOGS AND DEBRIS
HIGHFLOW POTHOLE
0 200 feet
SCALE
N
SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.
MAPLE BAR
RM-82.5
25



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

BACON CREEK
RM-82.6

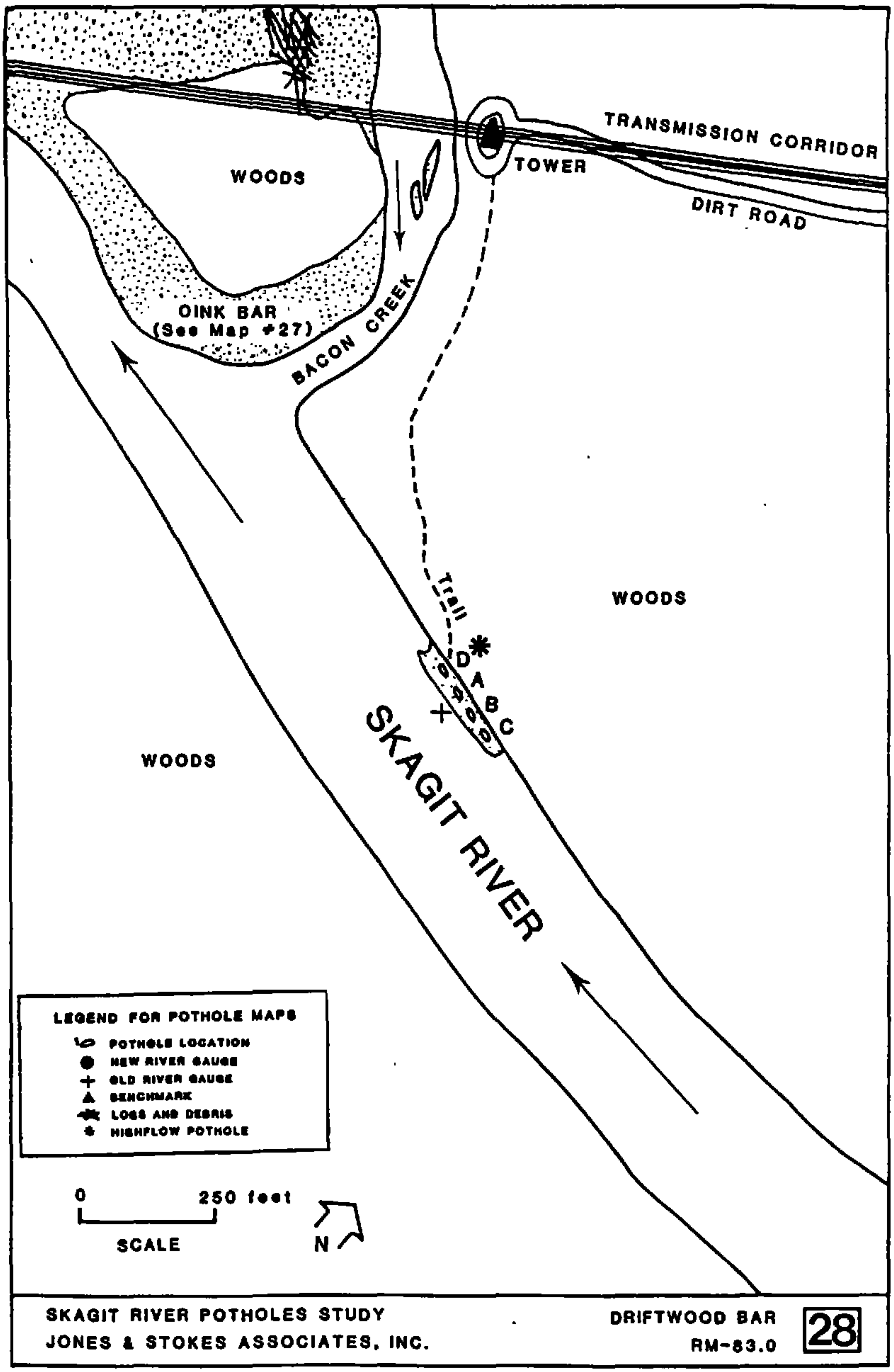
26

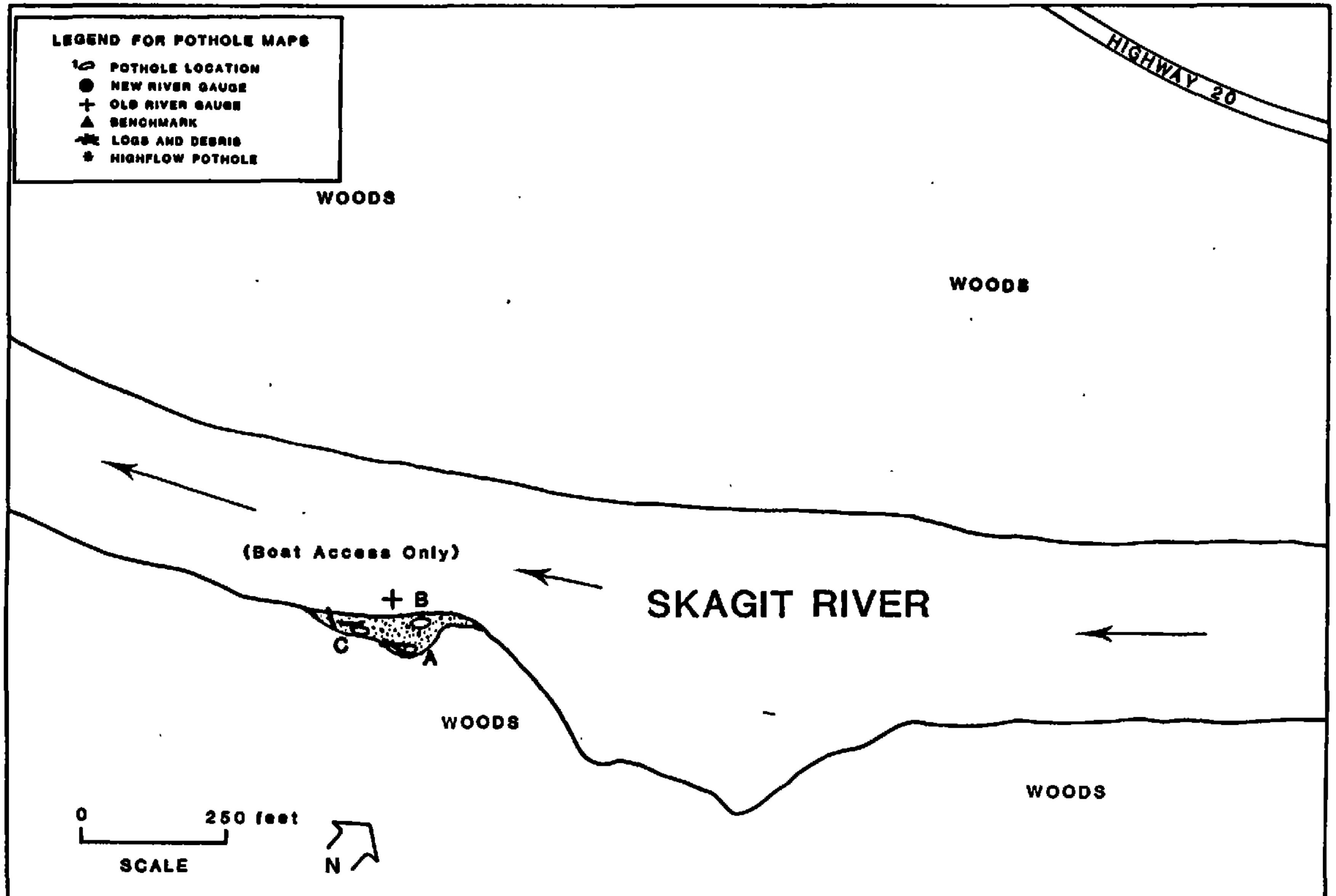


SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

FACE BAR & OINK BAR
RM-82.7 RM-82.9

27

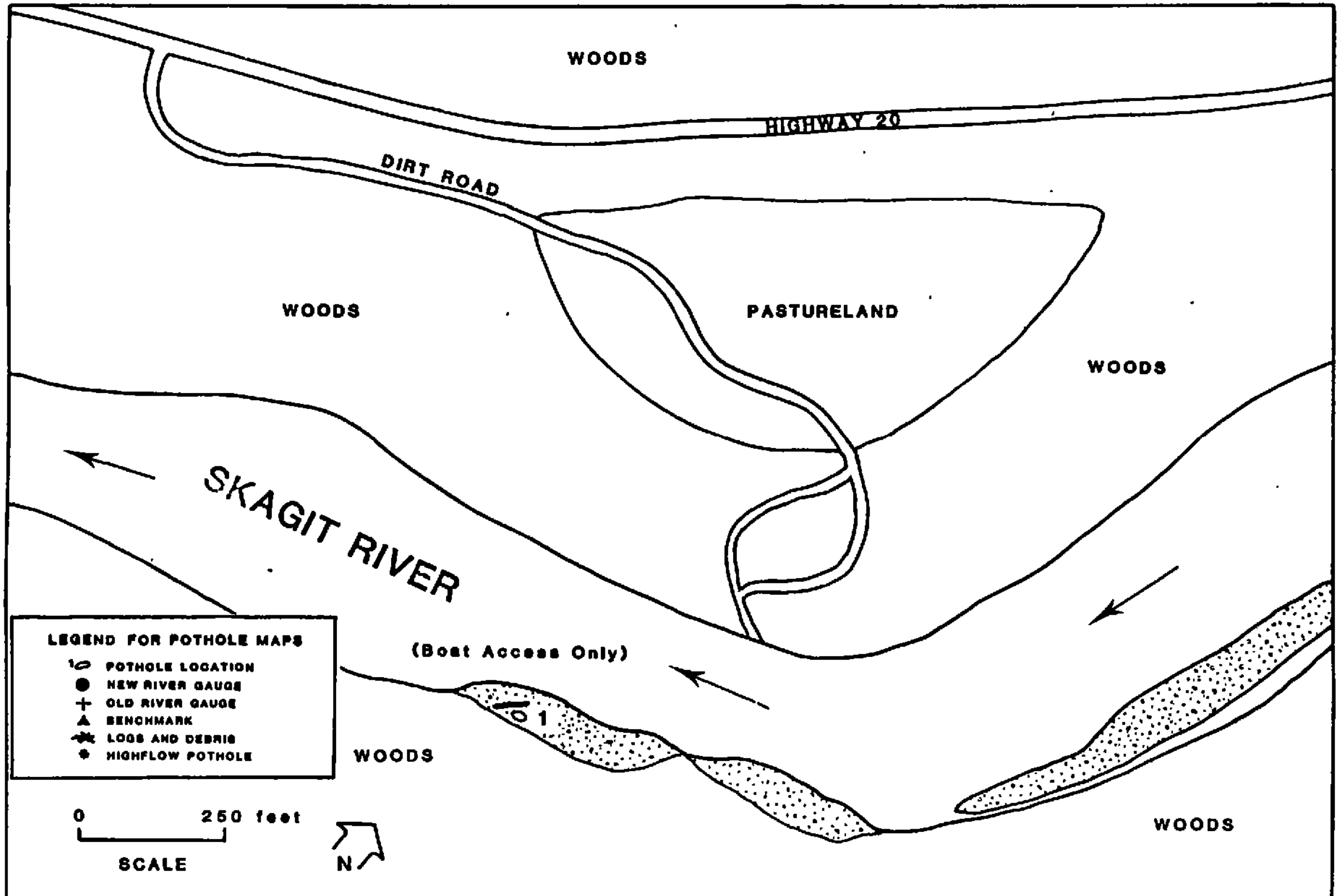

TRANSMISSION CORRIDOR
TOWER
DIRT ROAD
WOODS
OINK BAR
(See Map #27)
BACON CREEK
Trail
D
A
B
C
WOODS
WOODS
SKAGIT RIVER
LEGEND FOR POTHOLE MAPS
POTHOLE LOCATION
NEW RIVER GAUGE
OLD RIVER GAUGE
BENCHMARK
LOGS AND DEBRIS
HIGHFLOW POTHOLE
0
250 feet
SCALE
N
SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.
DRIFTWOOD BAR
RM-83.0
28



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

MINIBAR
RM- 83.3

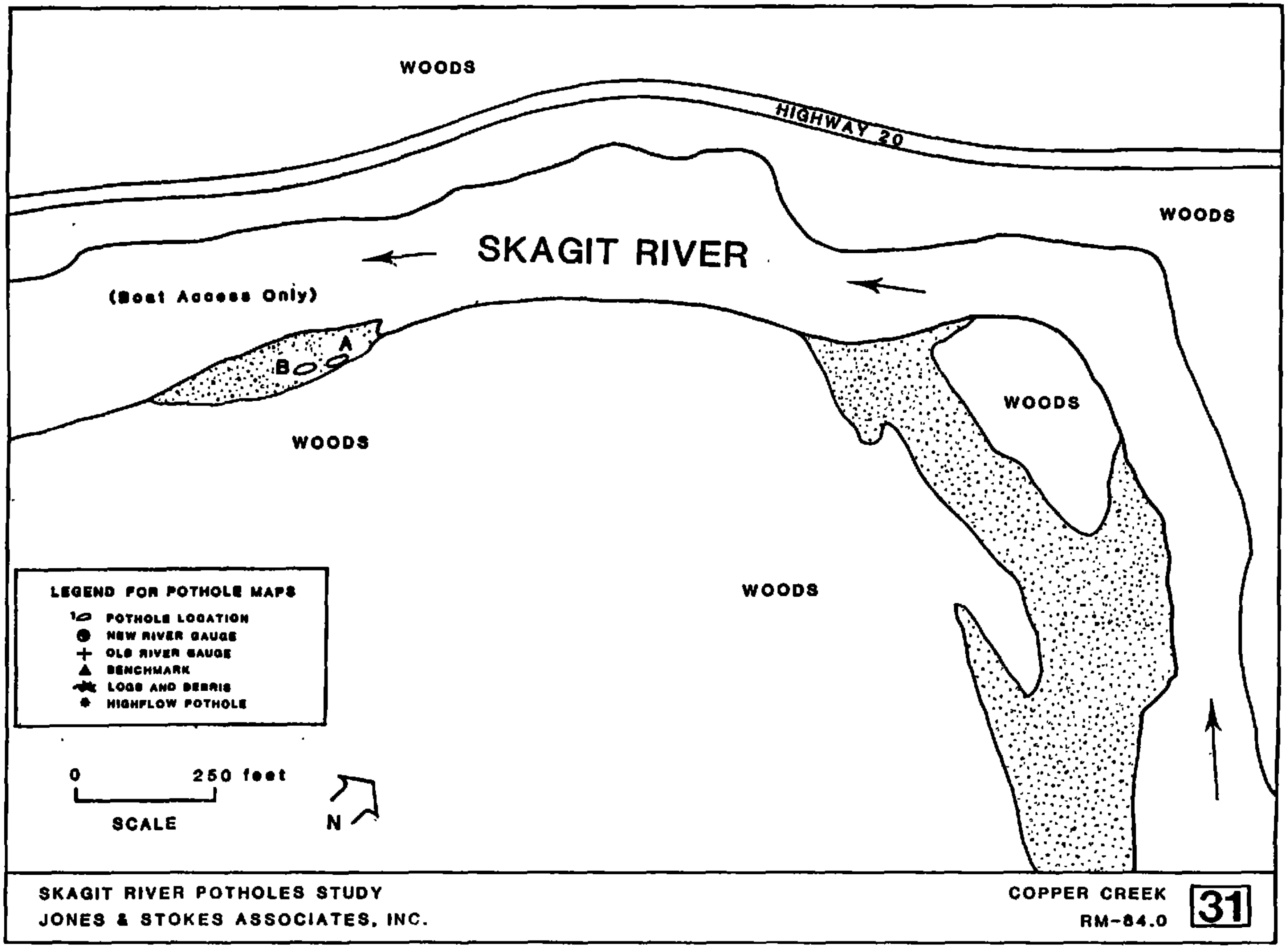
29

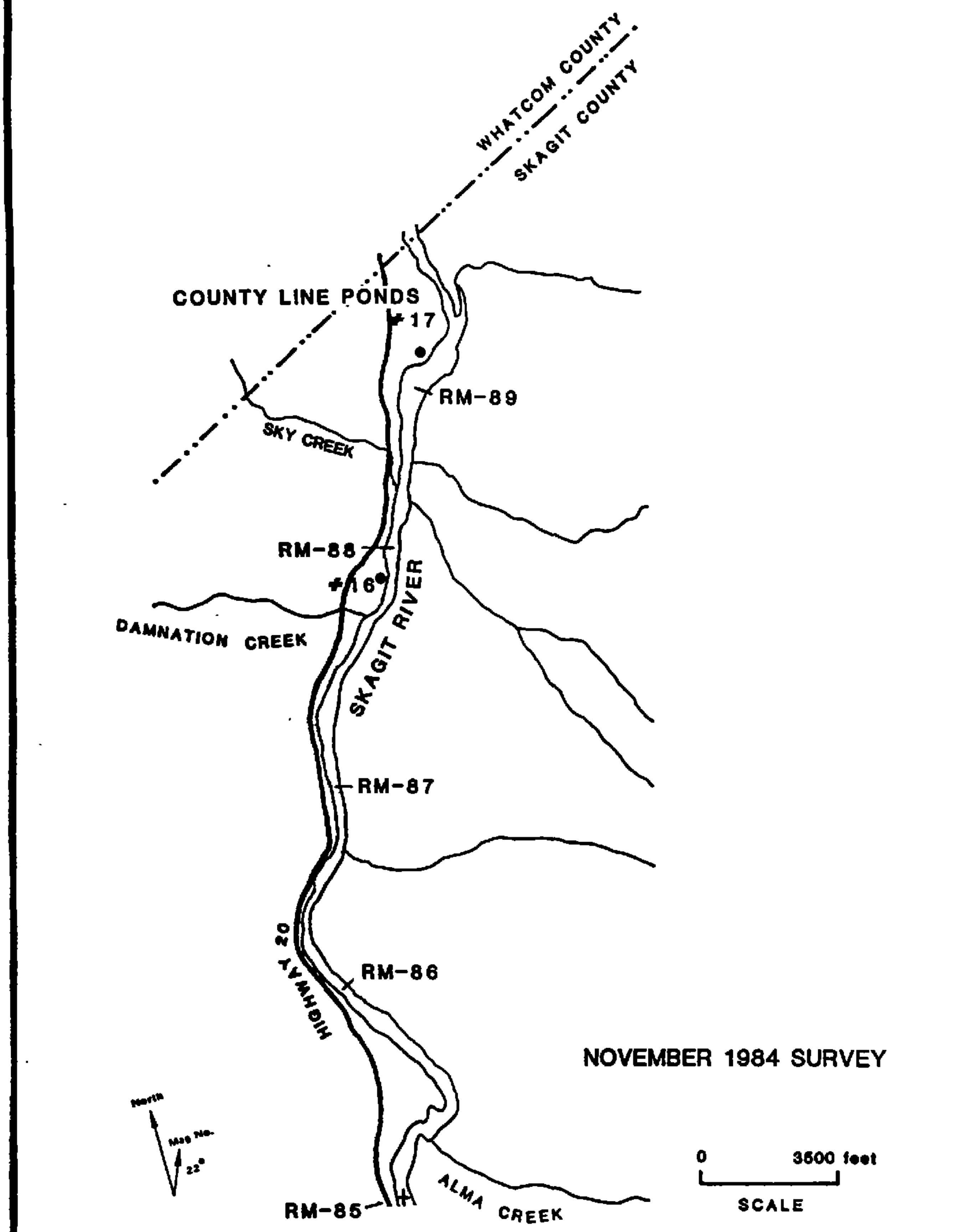


SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

FLOWER POTHOLE
RM-83.5

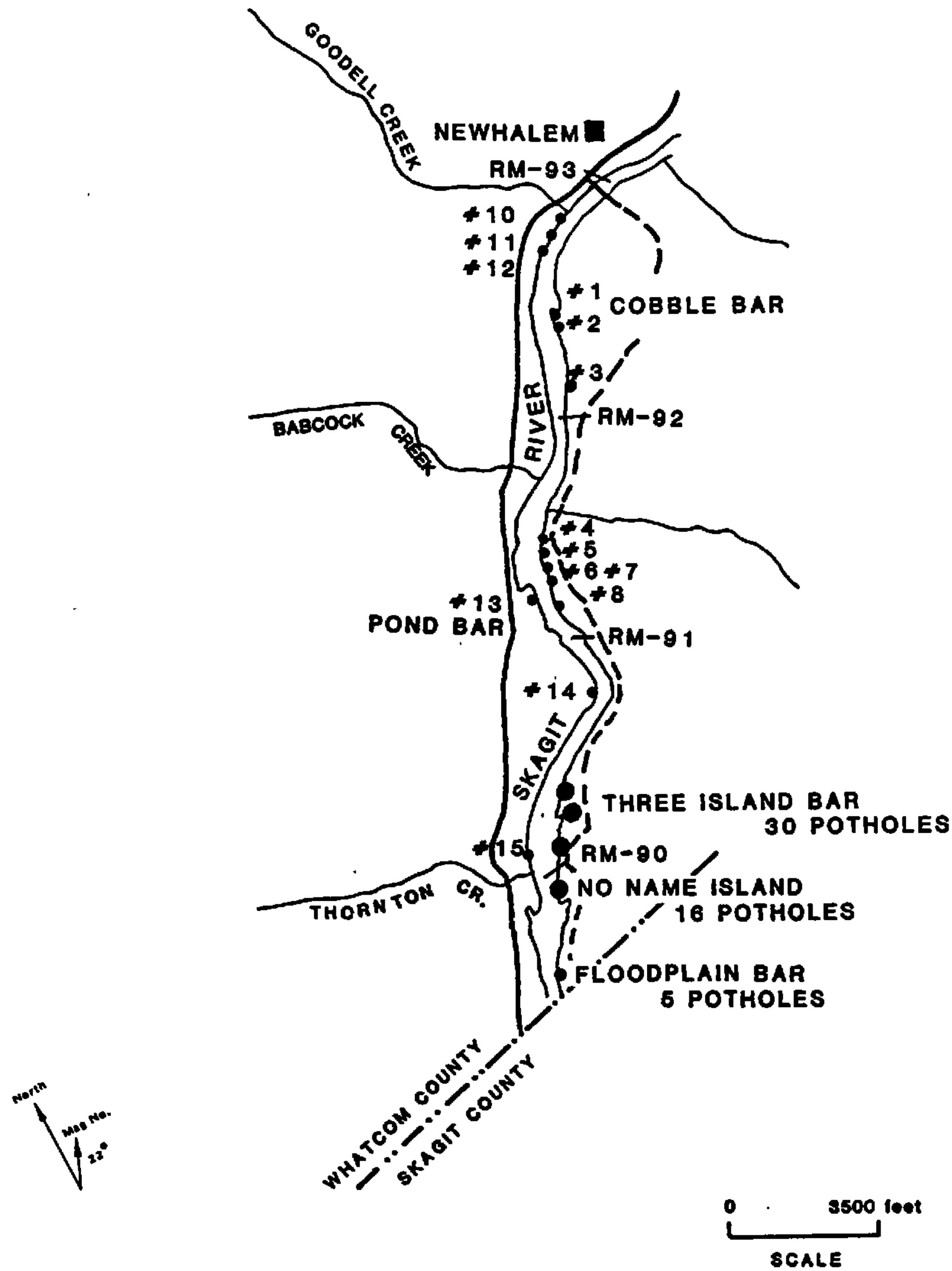
30


WOODS
HIGHWAY 20
WOODS
SKAGIT RIVER
(Boat Access Only)
A
B
WOODS
WOODS
WOODS
LEGEND FOR POTHOLE MAPS
POTHOLE LOCATION
NEW RIVER GAUGE
OLD RIVER GAUGE
BENCHMARK
LOGS AND DEBRIS
HIGHFLOW POTHOLE
0
250 feet
SCALE
N
SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.
COPPER CREEK
RM-84.0
31



SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

POTHOLE MAP INDEX
HIGHFLOW POTHOLES

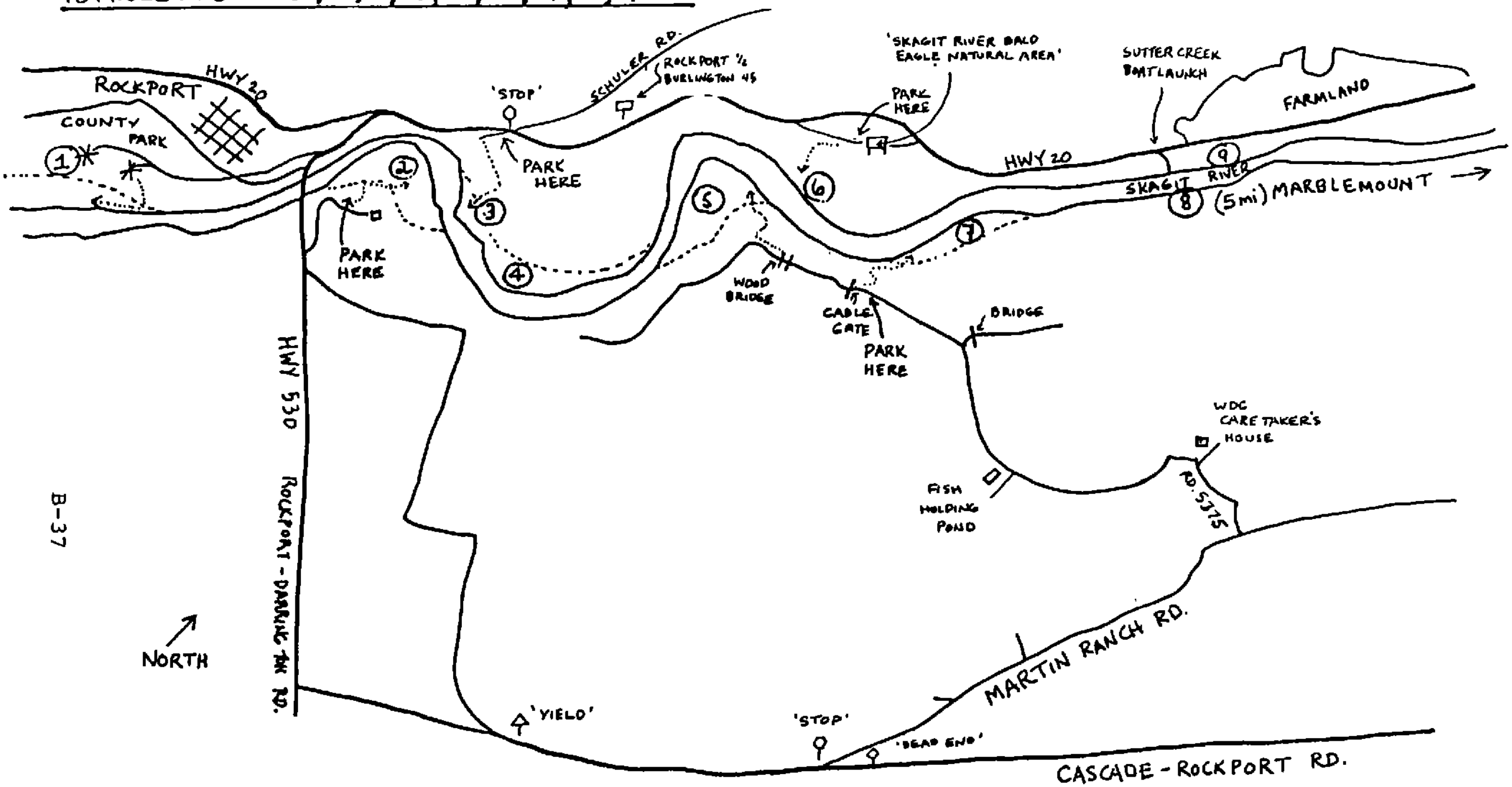


SKAGIT RIVER POTHOLES STUDY
JONES & STOKES ASSOCIATES, INC.

POTHOLE MAP INDEX
HIGHFLOW POTHOLES

ACCESS MAP A

POTHOLE AREAS 1, 2, 3, 4, 5, 6, 7, 8, 9

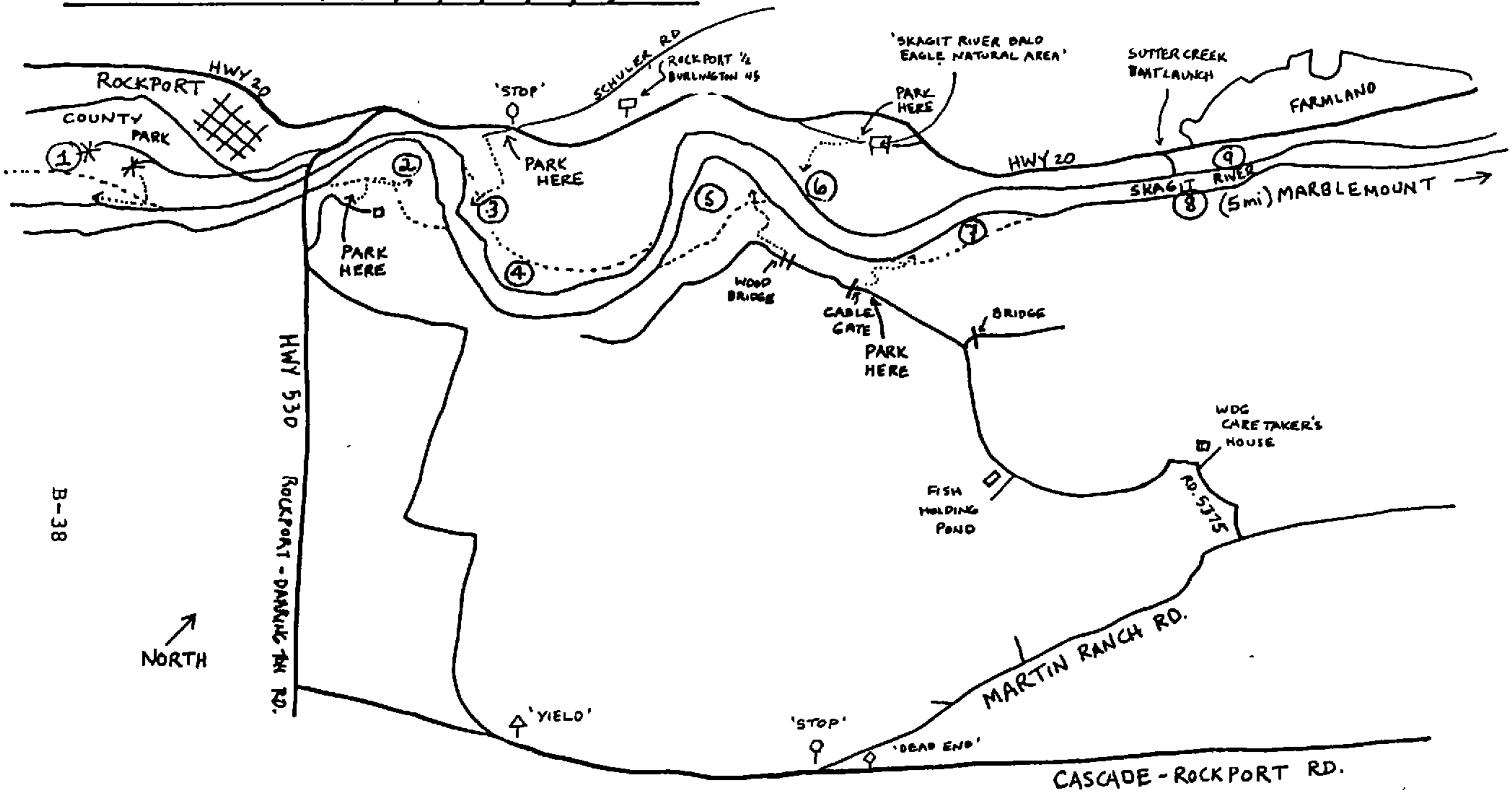


1 ROCKPORT BAR ACCESS (RM 67.5) (21 miles from Newhalem - 2 minute walk from car)

Go to Rockport County Park. 7.7 miles from Marblemount sign ("Rockport 7 - Burlington 45"). Park in the RV camping spots at west end of park. Cross to the bar just below the first camp spot. All the potholes are downstream of the crossing point.

ACCESS MAP A

POTHOLE AREAS 1, 2, 3, 4, 5, 6, 7, 8, 9



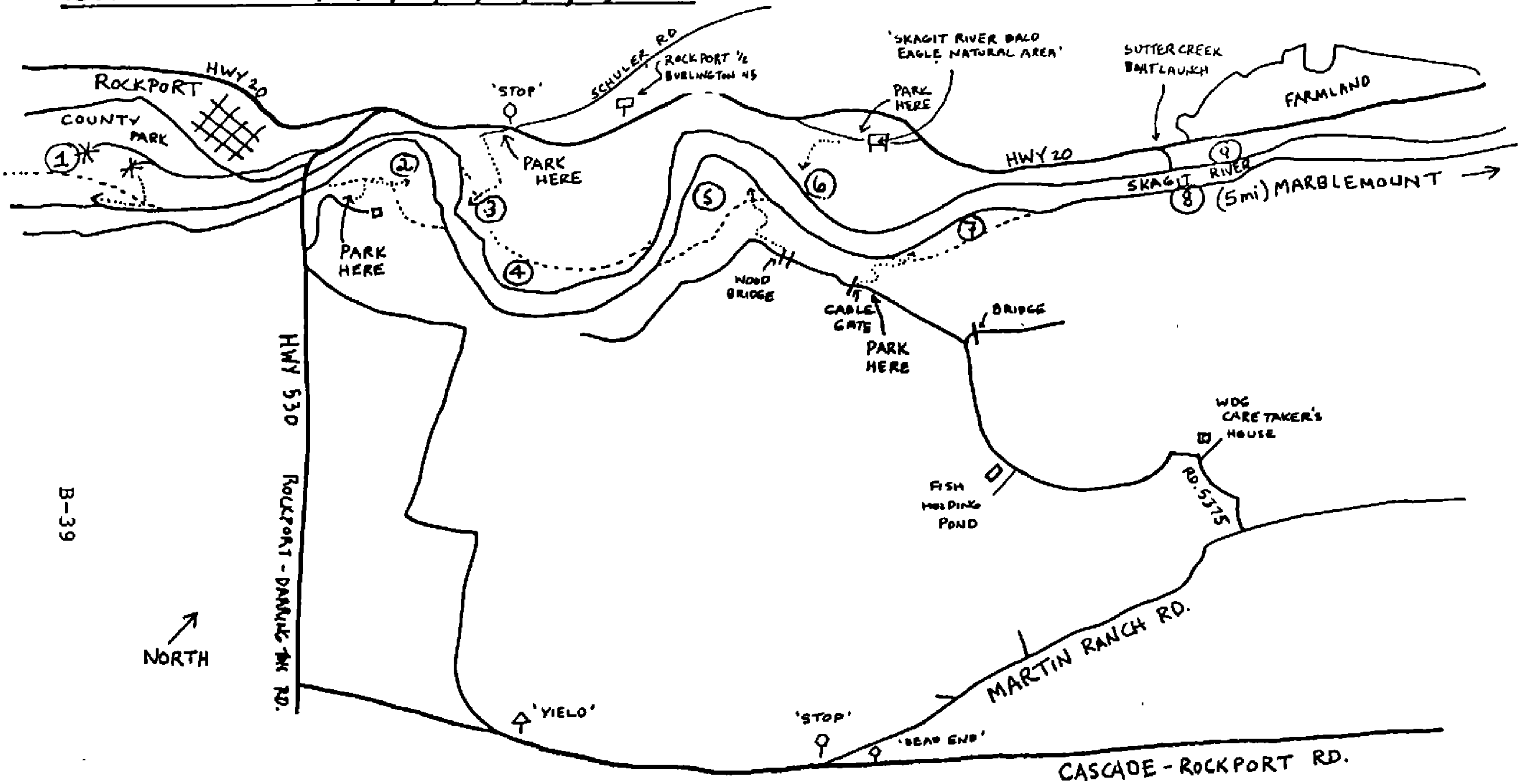
2 WAYNE'S SWIM (RM 68.1) (23 miles from Newhalem - 5 minute walk from car)

Travel to Marblemount, then head west to Rockport (21 miles). Cross Darrington-Rockport bridge. Make a sharp left at the first turn past the bridge. Drive down gravel driveway to place where you can pull off to the left and park in front of an old white VW bus. Walk to the right and behind the bus toward the river. Follow path for 5 minutes to shoreline then go upstream (to the right) following orange flags to a large maple tree with yellow flag. Drop down to the river at that point. You will access the bar between Potholes #2 and #3.

NOTE: The residents of the home at the end of the driveway should be consulted prior to using this access route.

ACCESS MAP A

POTHOLE AREAS 1, 2, 3, 4, 5, 6, 7, 8, 9

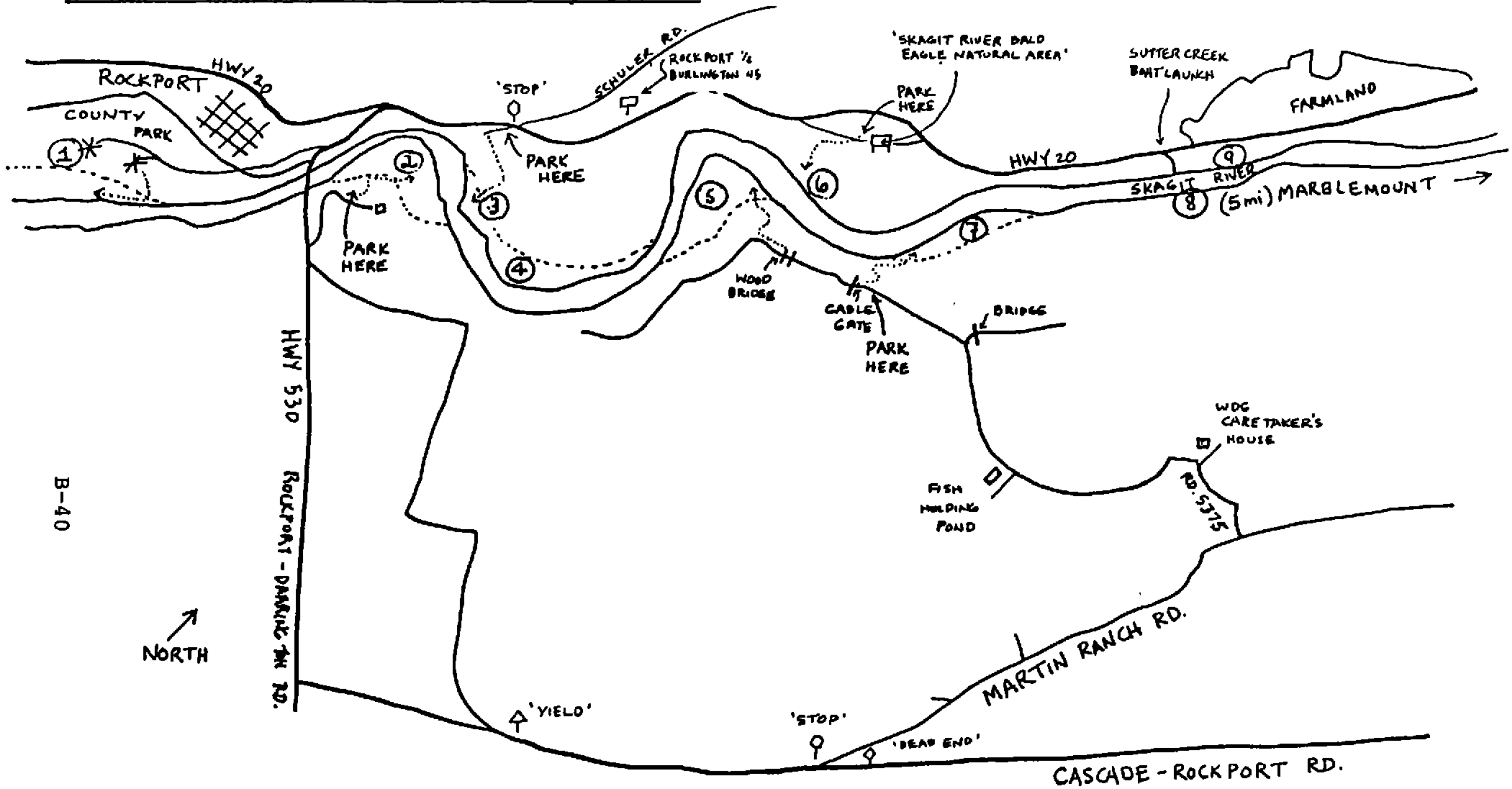


3 LOWER TIN SHACK (RM 68.3) (20.5 miles from Newhalem - 20 minute walk from car)

Travel to Marblemount. Turn west and go 6.5 miles west of the Marblemount sign that says "Rockport 7 - Burlington 45" on your right. Just past the sign "Rockport 1/2 mile" is Schuler Road and a stop sign on the right. Pull over to the left and park at the head of gravel road. Walk down old road grade. Cross over wood fence and continue out into the field. Head west across the field toward the woods. Walk along the edge of the pasture to a place where a yellow flag marks the trailhead through the woods. Go into the woods and follow flagging across a narrow waterway onto the gravel bar. You access the bar on Lower Tin Shack. Walking access time from Highway 20 is 20 minutes.

ACCESS MAP A

POTHOLE AREAS 1, 2, 3, 4, 5, 6, 7, 8, 9

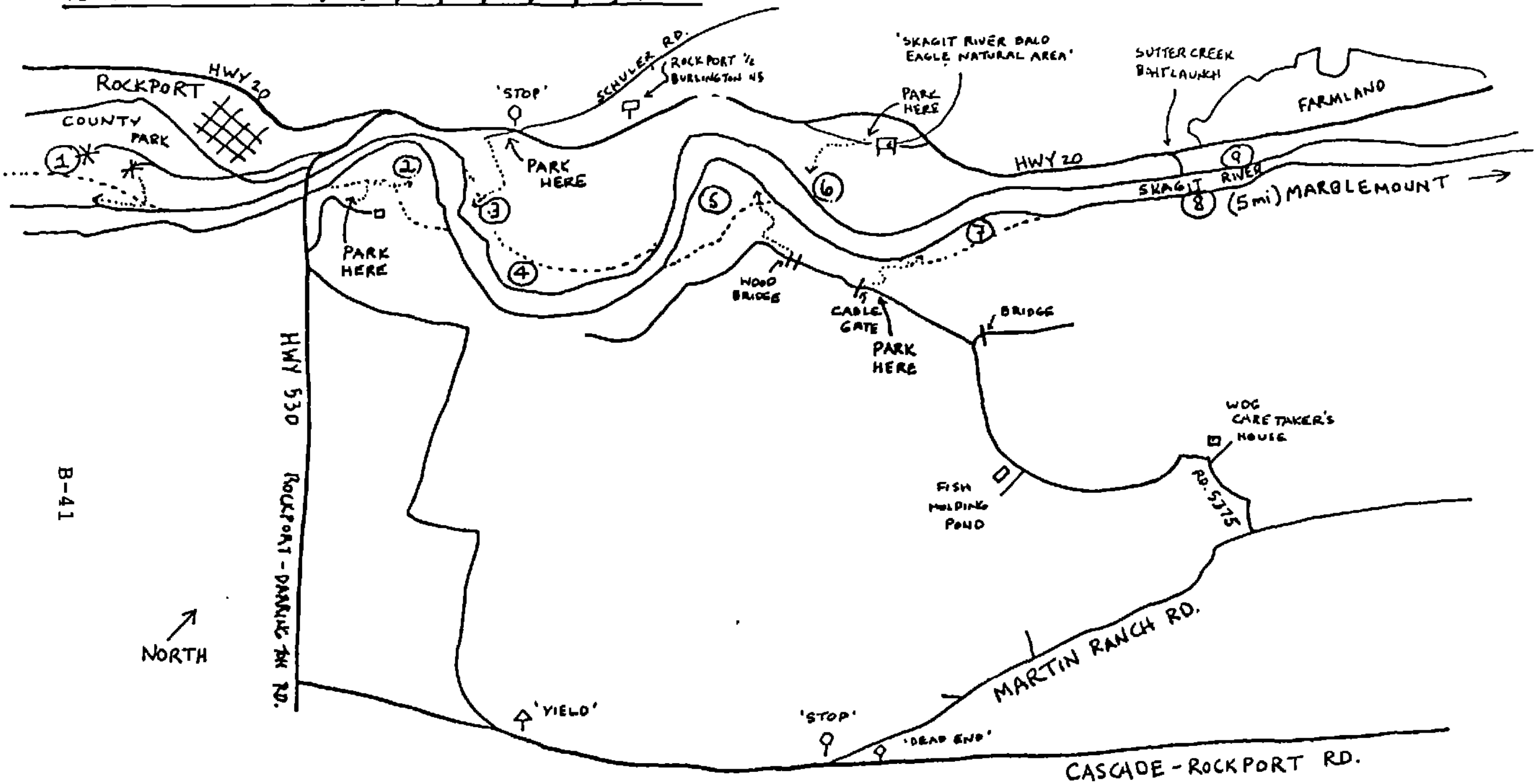


4 UPPER TIN SHACK (RM 68.3)

Walk upriver from the LOWER TIN SHACK area and wade to the UPPER TIN SHACK gravel bar. Potholes 7 through 17 occur along the bar.

ACCESS MAP A

POTHOLE AREAS 1, 2, 3, 4, 5, 6, 7, 8, 9

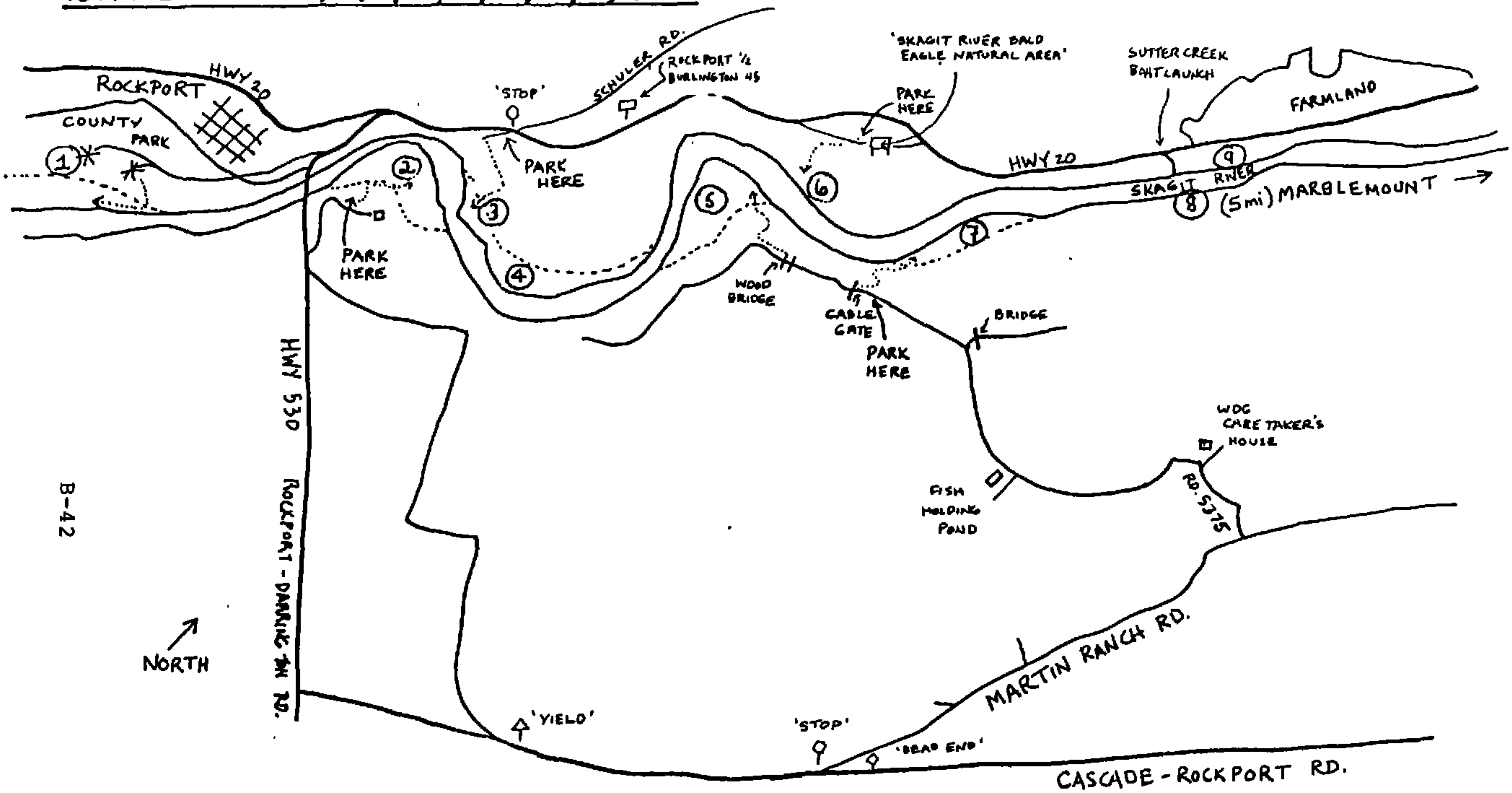


5 BAD SPOT (RM 70.0) (25 miles from Newhalem - 6 minute walk from car)

Travel to Marblemount. Go east across Marblemount bridge for 0.25 mile to the Cascade-Rockport Road. Turn right and cross the Cascade River bridge. Go southwest for 9.3 miles to Martin Ranch Road and take the hairpin turn to the right with DEAD END sign. Follow this road for 1.4 miles, then turn left on Road 5375. This is the WDG driveway that passes Barnaby Slough to the north. Take the road left and behind the caretaker's house. Go past the slough all the way to the "cable/drum" gate, 1 mile from house. Shove the drum out of the way, drop the cable and drive over it, then close it again and drive to the old wood bridge (0.3 mile from gate). DO NOT DRIVE ACROSS THE BRIDGE! Park and walk across. Continue on that old road grade across a narrow waterway until you see flags on the right of the path (4 minute walk). Turn right and follow flagged shrubby path along a fence line north to the river for 2 minutes. You will access the pothole area at the east and near Pothole #16.

ACCESS MAP A

POTHOLE AREAS 1, 2, 3, 4, 5, 6, 7, 8, 9

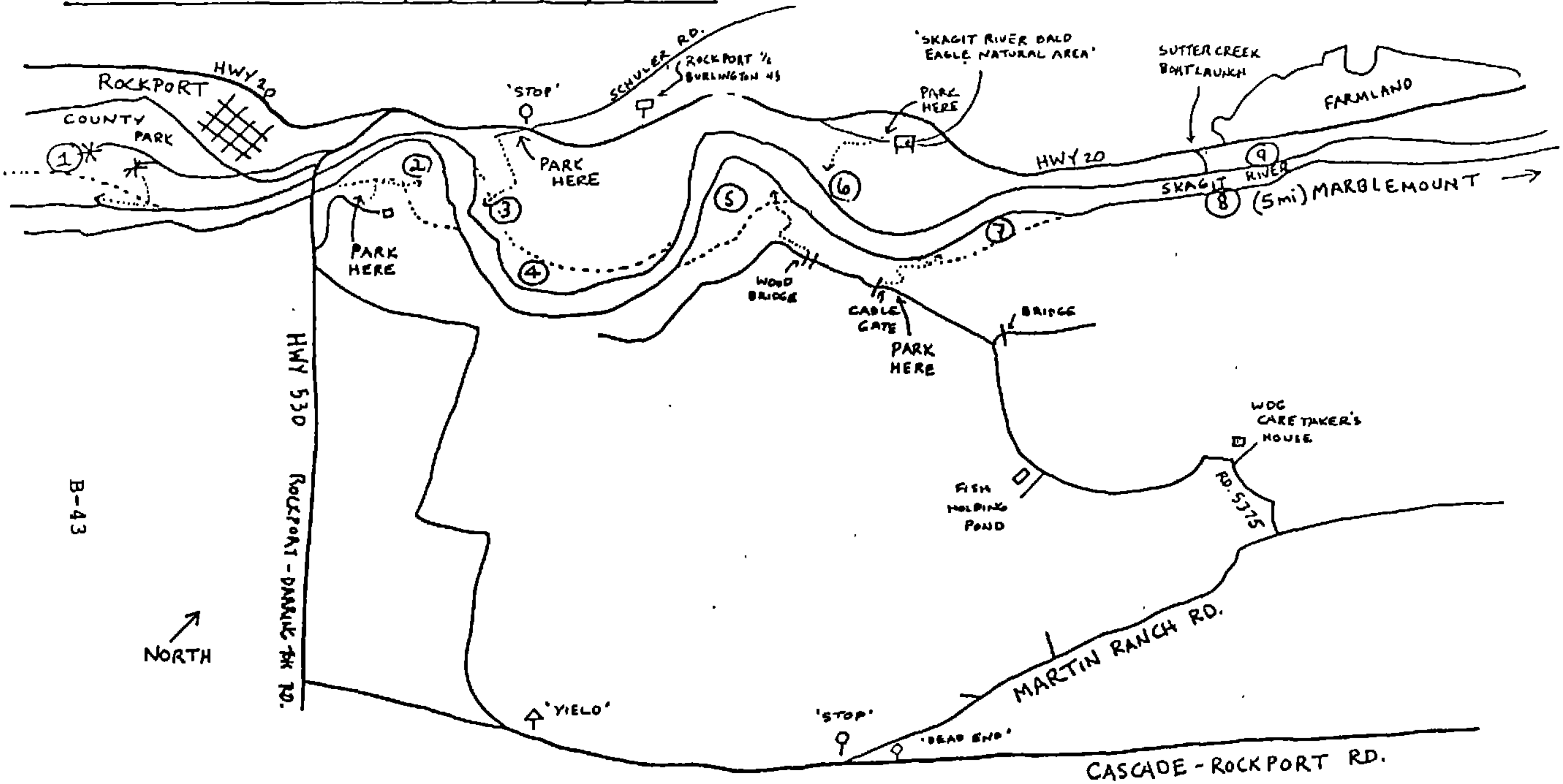


6 EAGLE BAR (RM 70.1) (5 minutes access from Highway 20)

Travel to Marblemount. Drive 5.8 miles west from Marblemount sign ("Rockport 7 - Burlington 45"). There will be a gravel road on the left which parallels the river for about 0.2 miles. Park near the "Skagit River Bald Eagle Natural Area" sign on the south side of Highway 20. Walk along the gravel/dirt road by the water channel for about 5 minutes to a 12-foot boulder on the left side of the road. Turn left there and follow the narrow trail to the river side channel. Cross the water onto the gravel bar. Walk toward the main river channel and upstream slightly to find Pothole #1. Boat access is required at very high flows.

ACCESS MAP A

POTHOLE AREAS 1, 2, 3, 4, 5, 6, 7, 8, 9

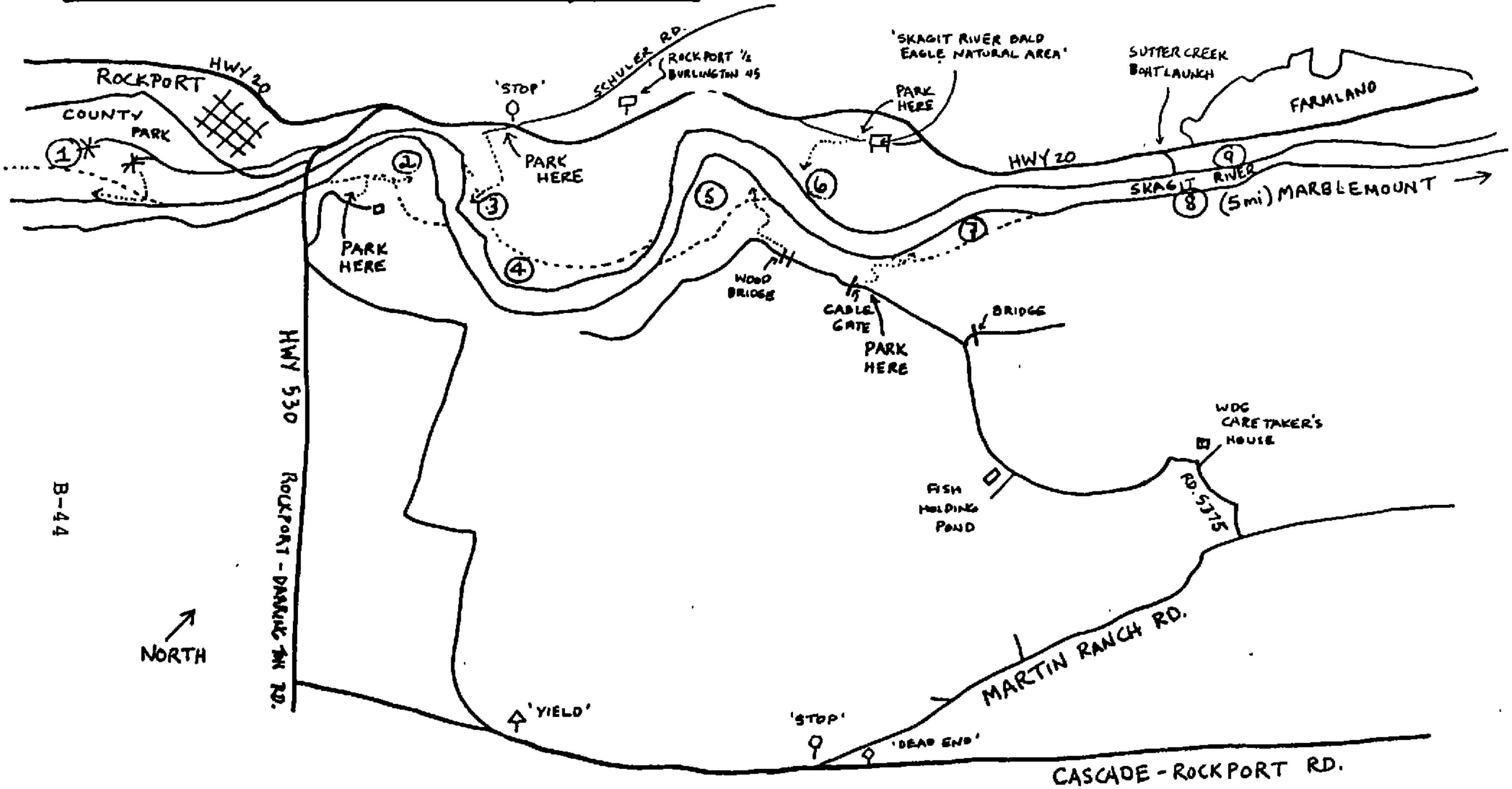


7 FORBIDDEN BAR (RM 70.5) (25 miles from Newhalem - 5 minute walk from car)

Travel to Marblemount. Access is from the south side of the Skagit River. Go east across Marblemount bridge for 0.25 mile to the Cascade-Rockport Road. Turn right and cross the Cascade River bridge. Go southwest for 9.3 miles to Martin Ranch Road, take the hairpin turn to the right with DEAD END sign. Follow this road for 1.4 miles, then turn left on Road 5375. This is the WDG driveway that passes Barnaby Slough to the north. Take the road left and behind the caretaker's house. Go past the slough all the way to the "cable/drum" gate, 1 mile from house. Park in the opening in the trees just before the "cable/drum" gate. There is a large maple tree with an orange flag. The trail starts just to the right of this tree. Head into the woods. The trail is easy to follow. It crosses a barbed wire fence (well flagged, but be careful!). Then follow the fence for awhile. Turn right and head out to a narrow but deep (mucky) channel, cross slightly upstream of the trail access. Head out toward the river. Follow shoreline along flagged trail to a large root wad on your left. Drop down to the river. Access will be at Pothole #1.

ACCESS MAP A

POTHOLE AREAS 1, 2, 3, 4, 5, 6, 7, 8, 9

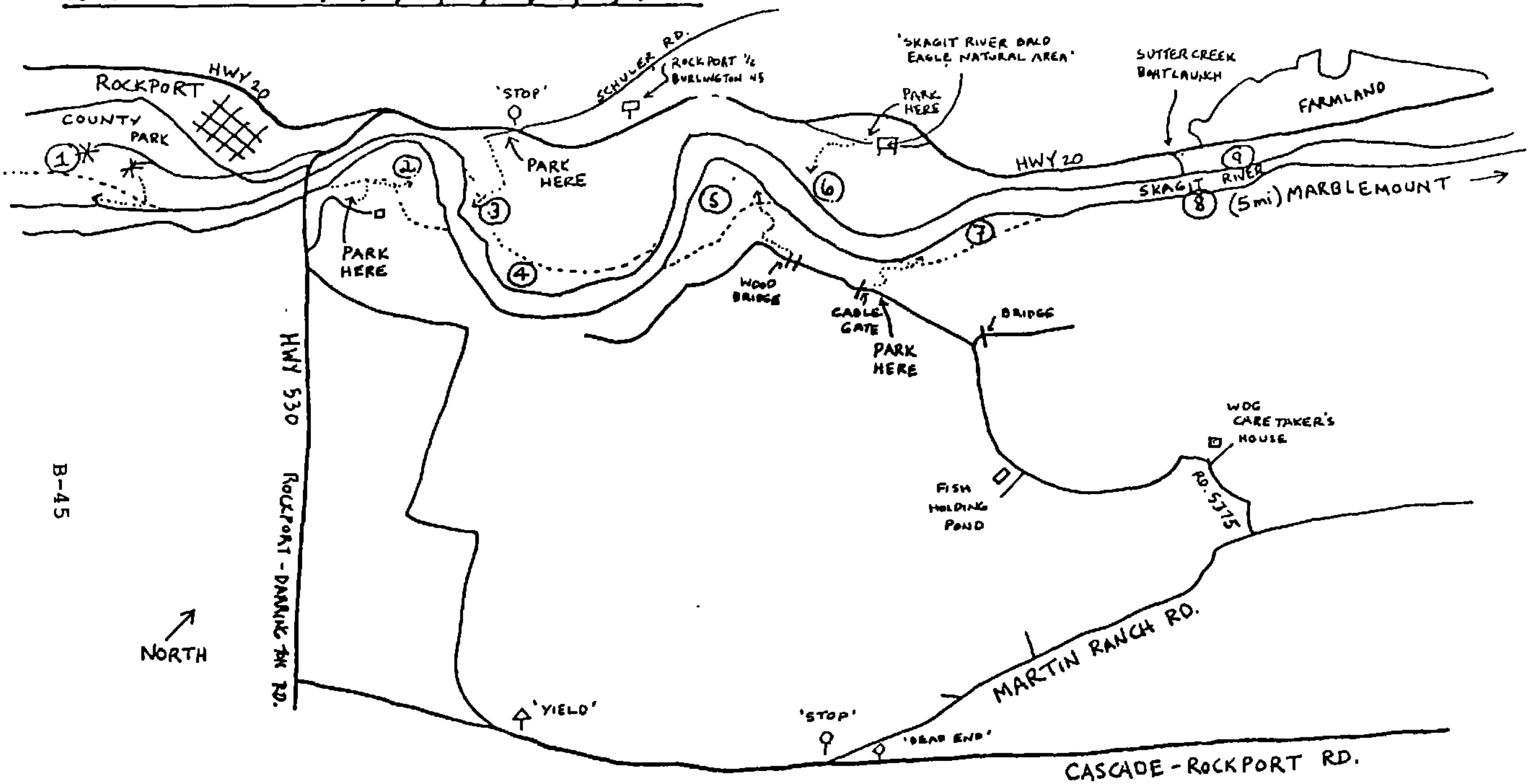


8 J. R. BAR (RM 71.1)

High flow pothole area surveyed only during 11/84. Boat access only; however, land access may be possible from the STUMP HAVEN parking area.

ACCESS MAP A

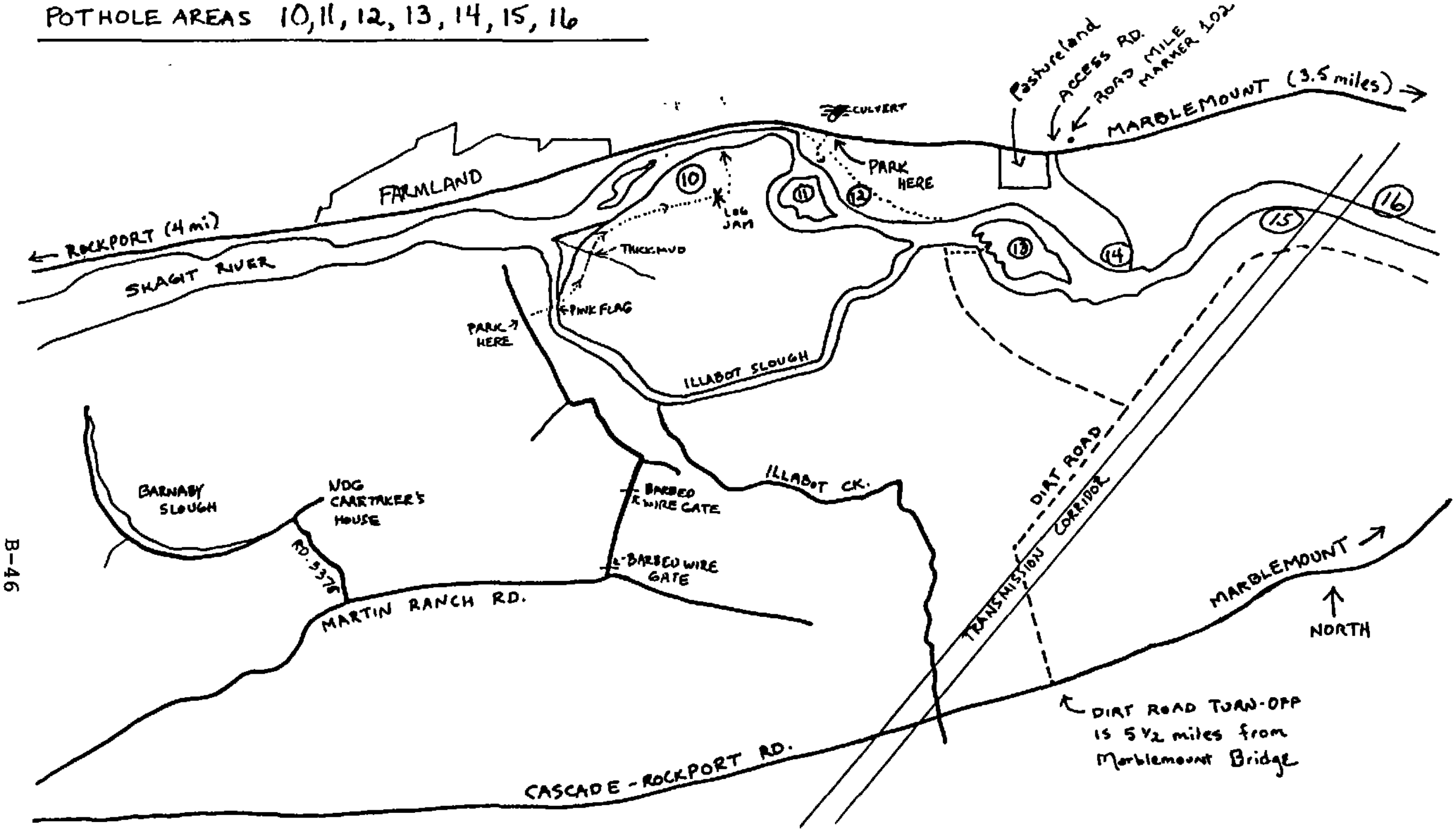
POTHOLE AREAS 1, 2, 3, 4, 5, 6, 7, 8, 9



9 BEAVER ISLAND (RM 71.4)

High flow pothole area surveyed only during 11/84. Boat access only.

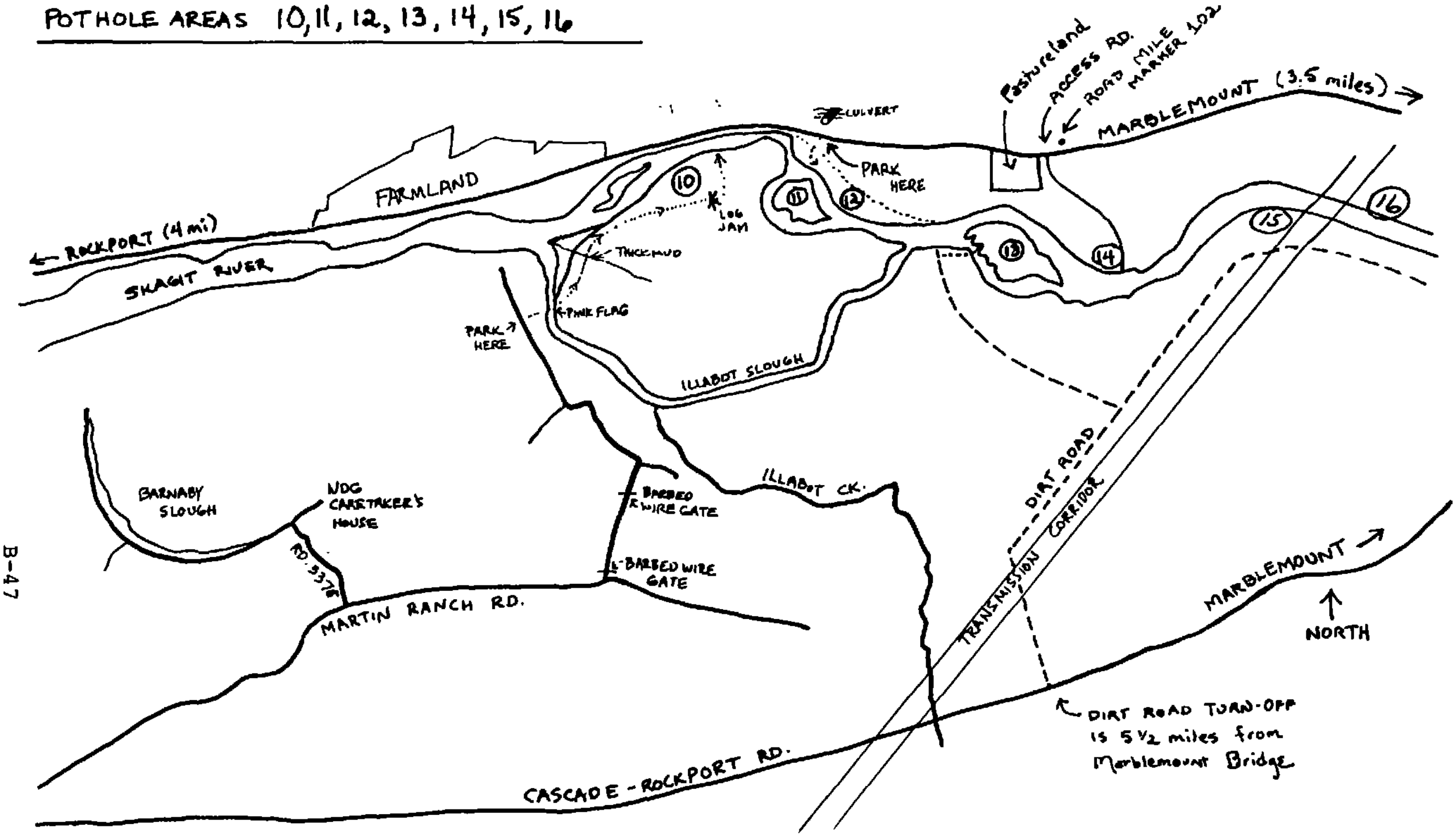
ACCESS MAP B
POTHOLE AREAS 10, 11, 12, 13, 14, 15, 16



10 STUMP HAVEN (RM 72.2) (8 miles from Rockport-Steelhead Park)

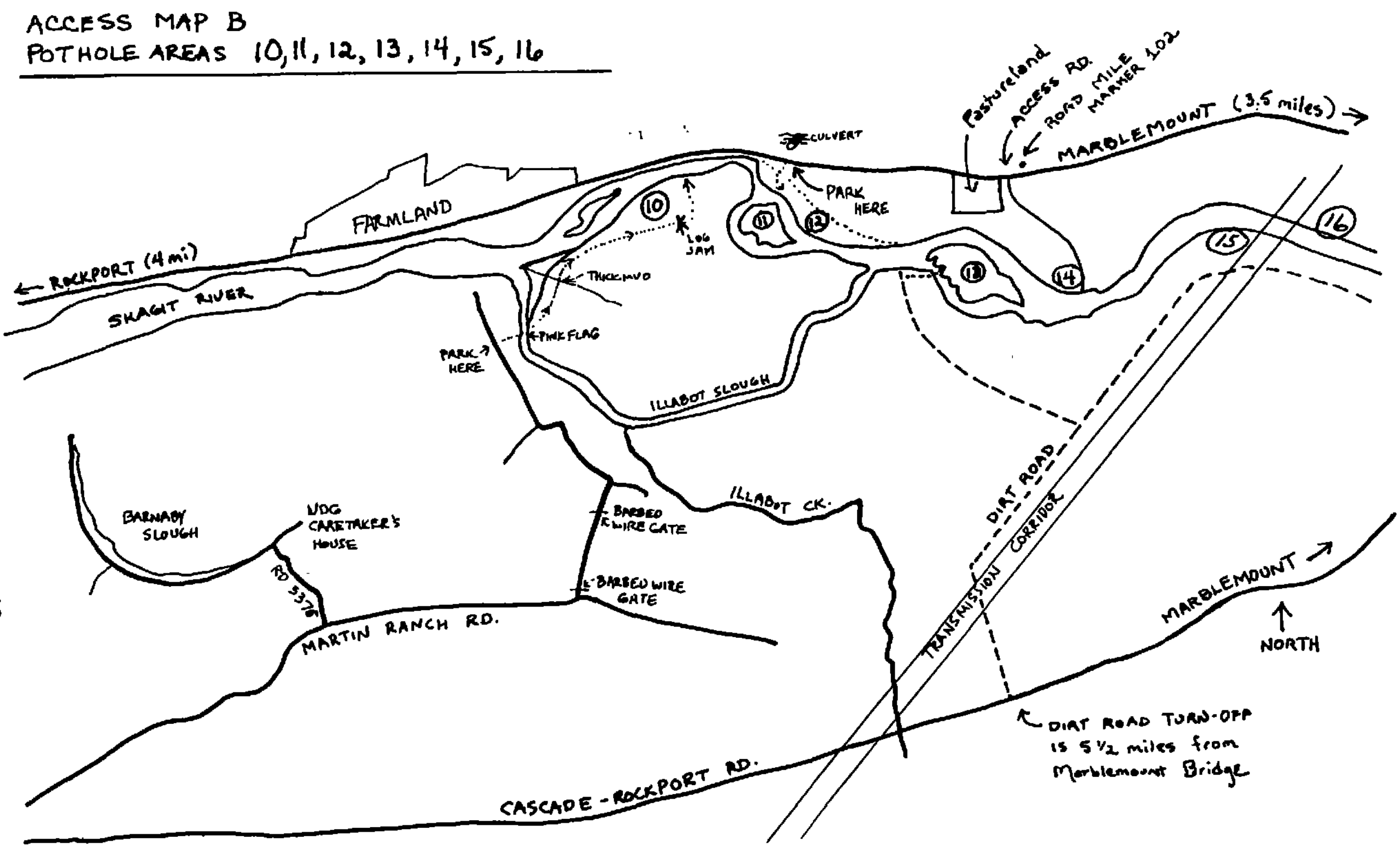
Cross Rockport-Darrington bridge over the Skagit heading south. Take the second left turn (2 miles) at Rockport-Cascade Road. Travel about 2.5 miles to Martin Ranch Road (DEAD END sign) and bear to the left. Proceed for 2.4 miles, past Road 5375, and stop at the first gated road on your left. This gate should be unlocked (owner, Fred Martin, lives in the mobile home at the end of the road if you need to get a key). Open the gate, drive in, then close the gate again, and go through another unlocked gate (also closed). At the fork in the road, take the left branch and drive about 0.5 miles along the creek and past pastures on the left. Stay to the right and drive through a pasture (roughly parallel to Illabot Slough). Park where the path narrows to a bushy foot trail. Some flagging is tied onto trees and a limb in the middle of the road at this point. Walk to flagging and drop down to bank. Cross the channel where the flagging is tied on the opposite bank of the slough. Proceed downstream (200 feet) to the flagged trail. Cross the small creek (thick mud) and follow the dried river bed back through woods to a log jam for about 15 minutes. Cross the log jam and enter the woods (approx. 50 feet). Follow flagging to the river. At the river bank, proceed upstream for 200 feet to a gravel bar/side channel. Pothole #1 is at the tree line of the island.

ACCESS MAP B
POTHOLE AREAS 10, 11, 12, 13, 14, 15, 16



11 MODEL POTHOLE (RM 72.6)

Boat access only.

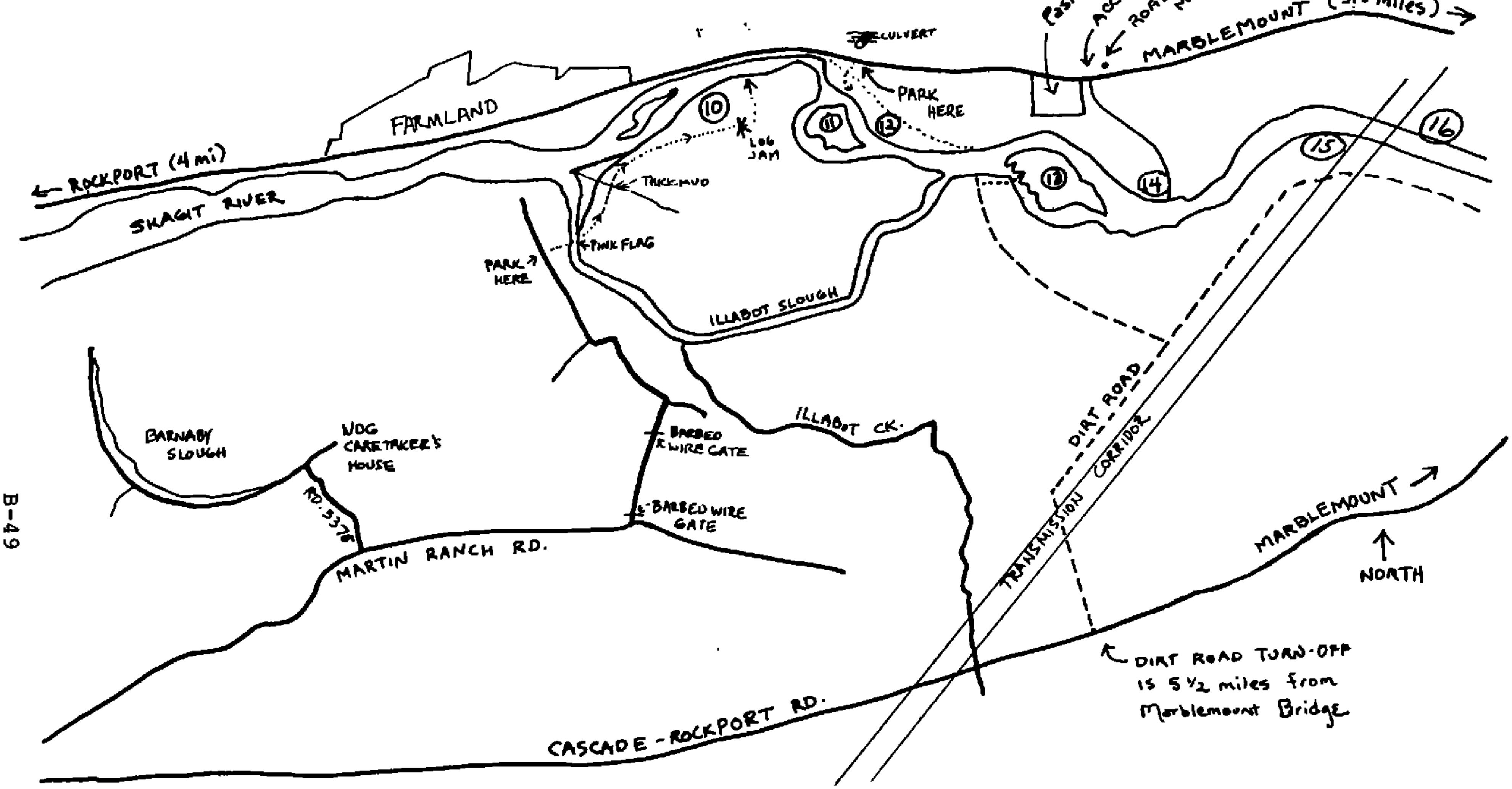


12 HOOPER'S SLOUGH (RM 72.7) (17.5 miles from Newhalem - 2 minute walk from car)

Travel to Marblemount. 3.5 miles west of Marblemount sign ("Rockport 7 - Burlington 45"), there will be a culvert on right side of Highway 20 and a concrete guardrail on left. Pull off just east of the guard rail. Go directly south down the bank toward the river. Cross a small channel with mud bottom and continue out toward the main river channel.

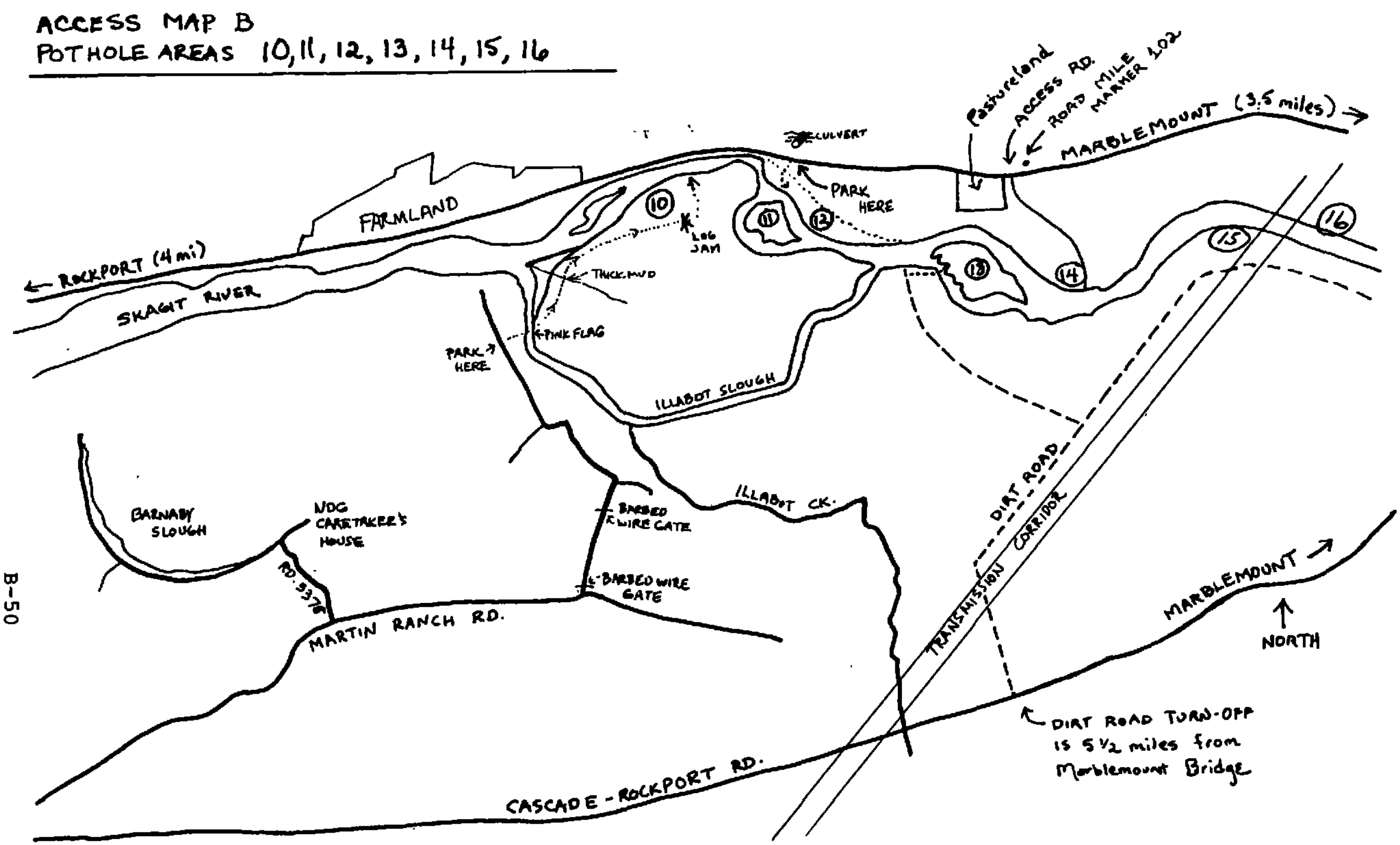
4.2 miles east of Rockport going east, pull over just past culvert crossing at first wide spot on the south side.

ACCESS MAP B
POTHOLE AREAS 10, 11, 12, 13, 14, 15, 16



13 RICK'S SURPRISE/INACCESSIBLE ISLAND (RM 73.0 and 73.1)

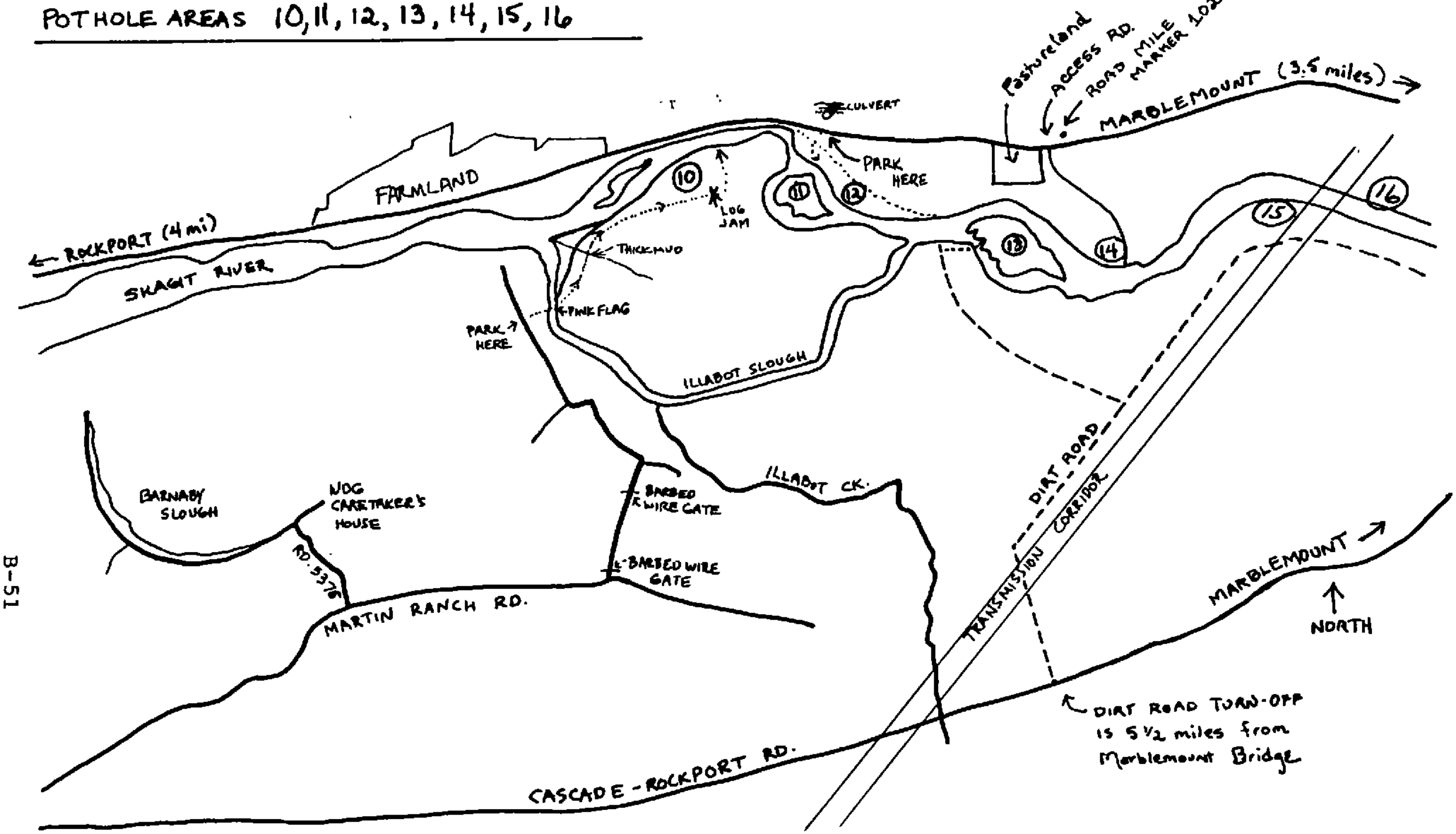
Travel to Marblemount. Go east across Marblemount bridge for 0.25 mile to the Cascade-Rockport Road. Turn right (south) and travel across Cascade River bridge. Continue for 5.5 miles. Turn right onto flagged gravel road -- this road will come to and travel with the transmission corridor. Follow this road for .8 miles and turn at the first left turn (flagged). Follow for another .8 miles until you come to an unpassable spot in the road. Park in the turnout and walk about 100 feet to the Skagit River. RICK'S SURPRISE and INACCESSIBLE ISLAND are to the right. Walk upstream to the riffle and cross over to RICK'S SURPRISE. INACCESSIBLE ISLAND is the next island over. During high flow conditions, the areas can only be accessed by boat.



14 CARNAGE BAR (RM 73.3)

Travel to Marblemount. Head west for 4.2 miles from the parking area across from the Log House Inn. Turn left onto a gravel road about 100 yards past mile marker 102. Veer left and follow the road to the river (0.5 miles). Park here. The pothole area is located about 200 yards downstream.

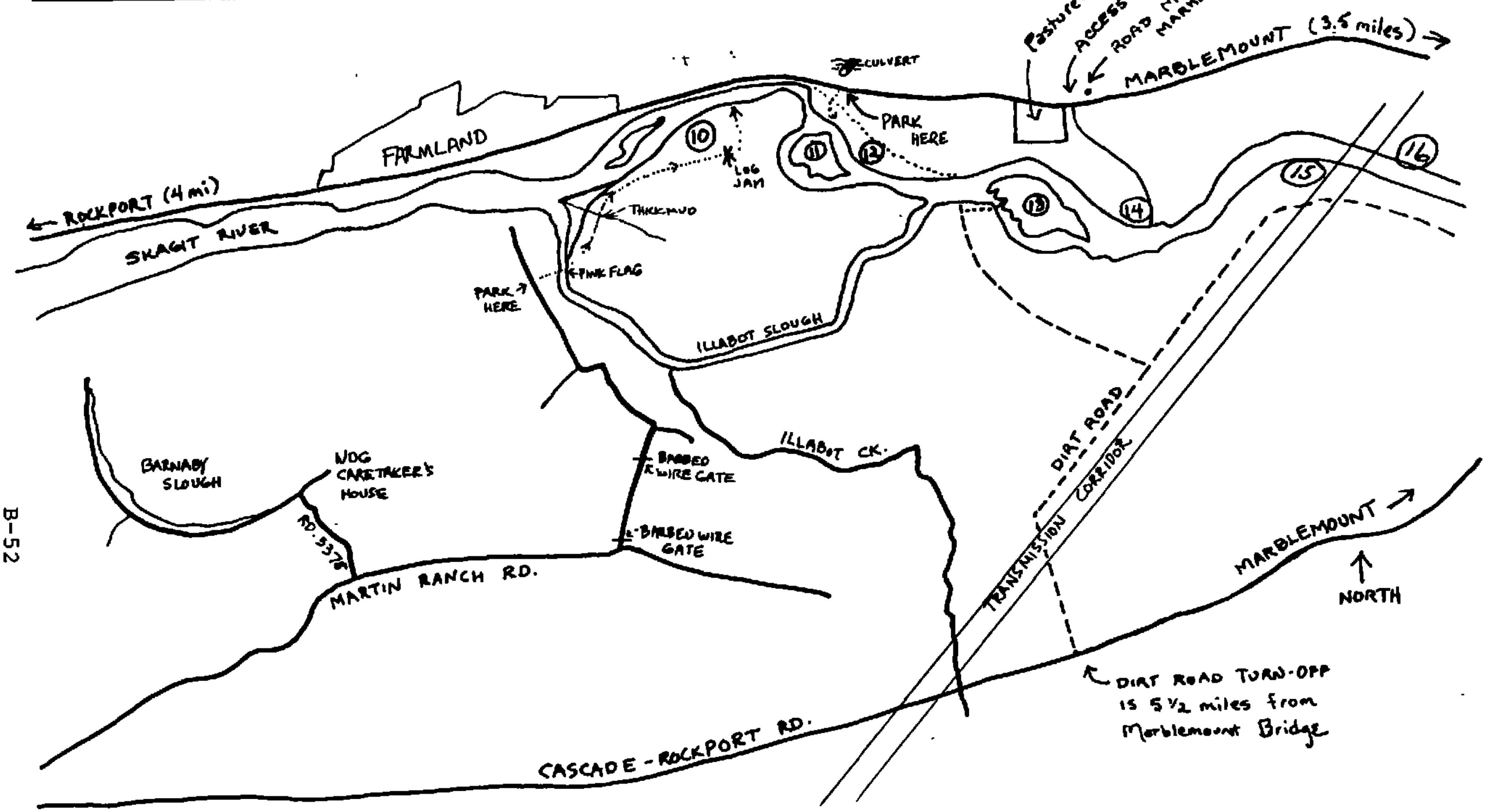
ACCESS MAP B
POTHOLE AREAS 10, 11, 12, 13, 14, 15, 16



15 POWER BAR (RM 74.0)

High flow pothole area surveyed only during 11/84. Travel to Marblemount. Go east across Marblemount bridge for 0.25 mile to the Cascade-Rockport Road and turn right (south) and travel across Cascade River bridge. Continue for 5.5 miles. Turn right onto dirt road under and then parallel to transmission corridor. Continue on road along transmission corridor until road begins to bear east away from corridor. Park at bend in road and walk to river along power lines. POWER BAR is just downstream of power lines.

ACCESS MAP B
POTHOLE AREAS 10, 11, 12, 13, 14, 15, 16

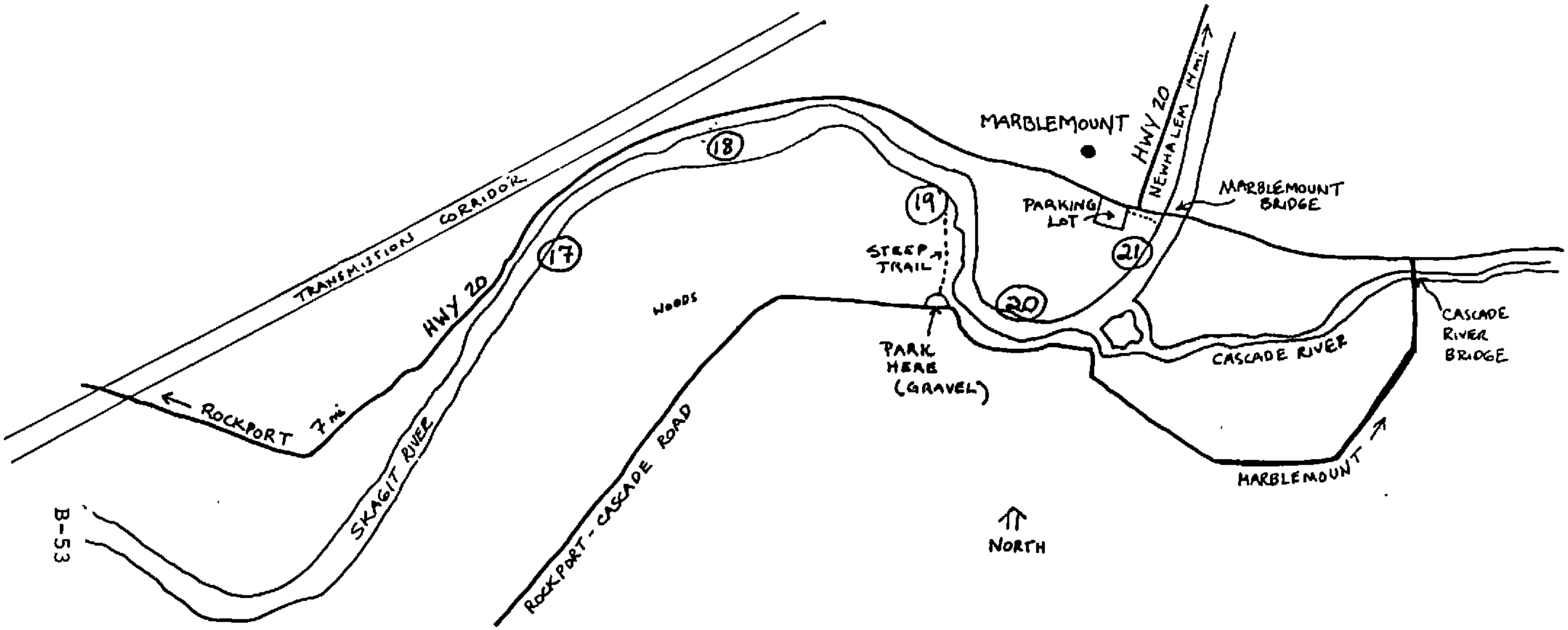


16 DRY BAR (RM 74.2)

DRY BAR was accessed only by boat; however, land access may be possible from the north side of the river where Corkindale Creek crosses Highway 20. From the log cabin at Marblemount, travel 2.3 miles west on Highway 20 to Corkindale Creek. Take private road on the left side of the highway (road follows edge of the forest/pasture area) to river. DRY BAR is just upstream at end of the road.

ACCESS MAP C

POTHOLE AREAS 17, 18, 19, 20, 21

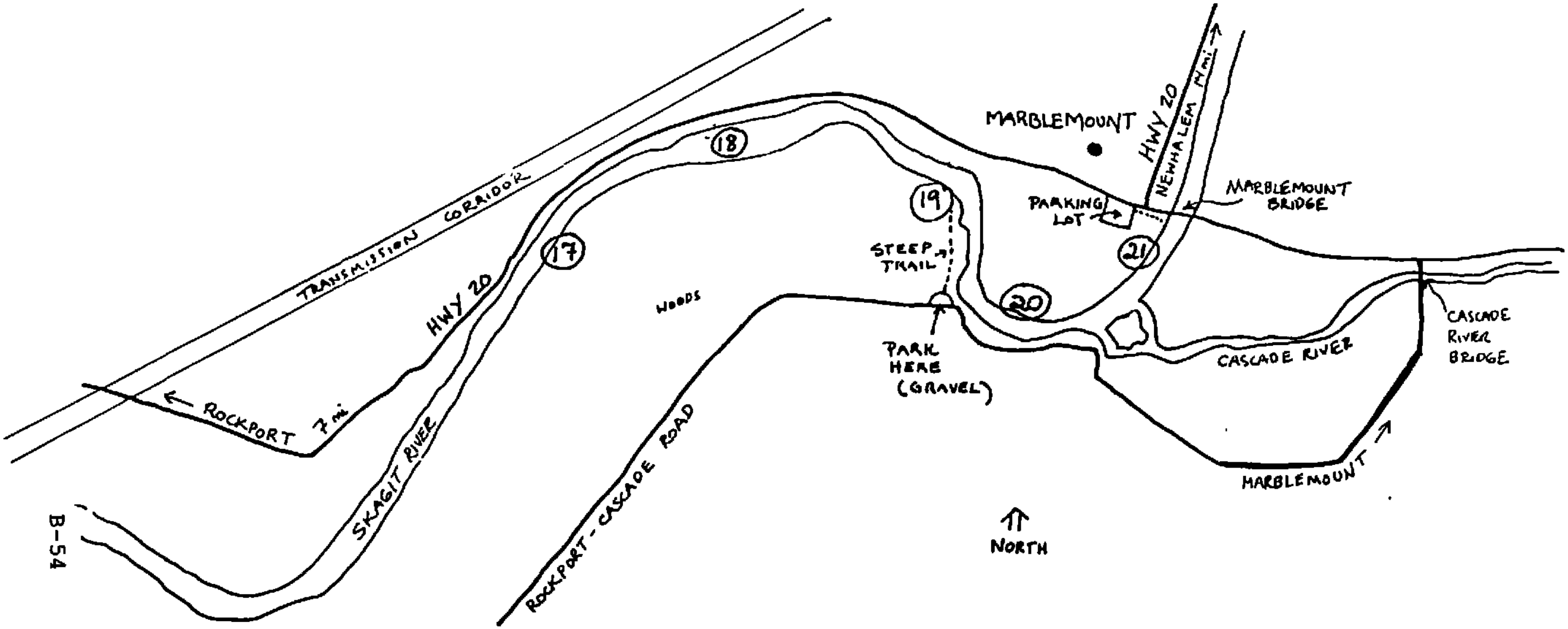


17 NORTH O'BRIAN'S FERRY (RM 76.0)

Boat access only.

ACCESS MAP C

POTHOLE AREAS 17, 18, 19, 20, 21

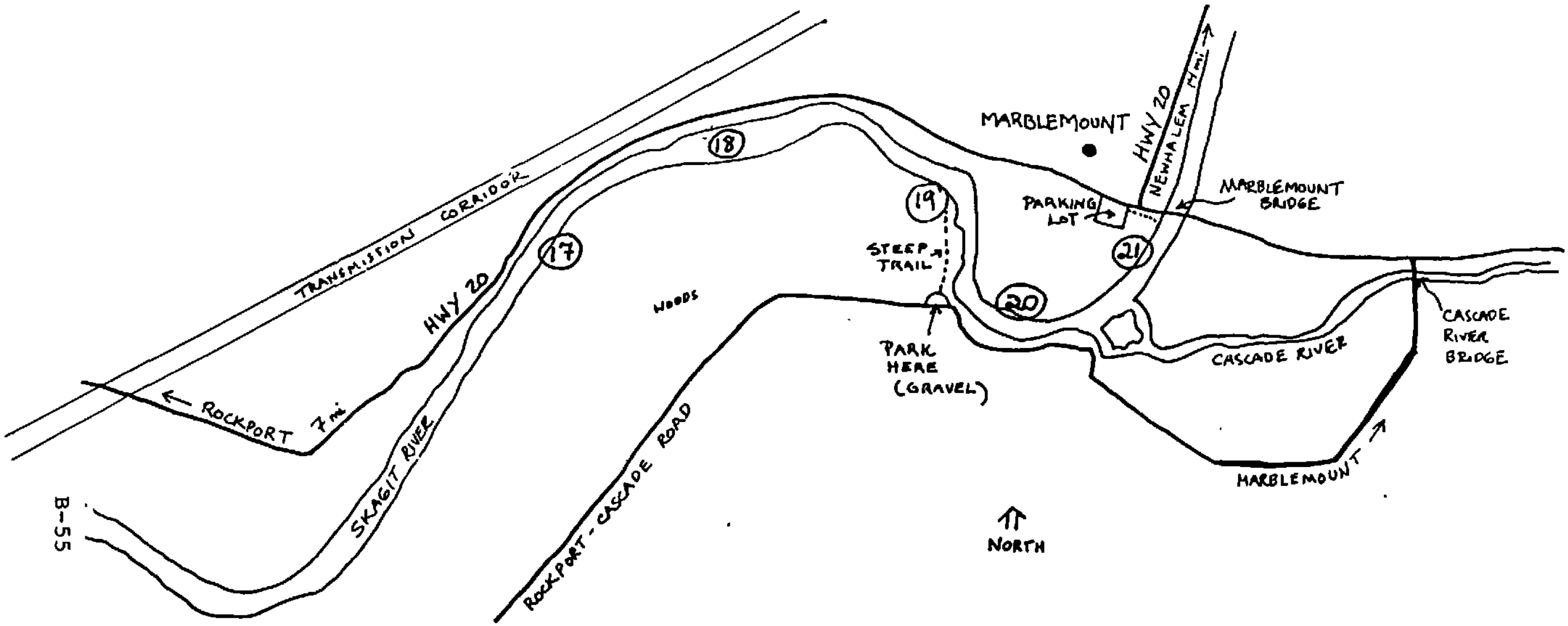


18 SECLUSION ISLAND (RM 76.3)

Travel to Marblemount. Head west for 1.25 miles from the parking area across from the Log House Inn. Just past mile marker 105 is a "Speed Zone Ahead" sign on the left side of the highway (river side). Park in front of the sign and walk down the trail (flagged) to where a fallen oak tree crosses the side channel of the river. At low flows you may be able to ford the channel; but at higher flows, cross over the tree. Head to the right and towards the main river channel for about 150 yards. The pothole area is located near a large pile of debris about 50 feet into the woods from the main river channel.

ACCESS MAP C

POTHOLE AREAS 17, 18, 19, 20, 21

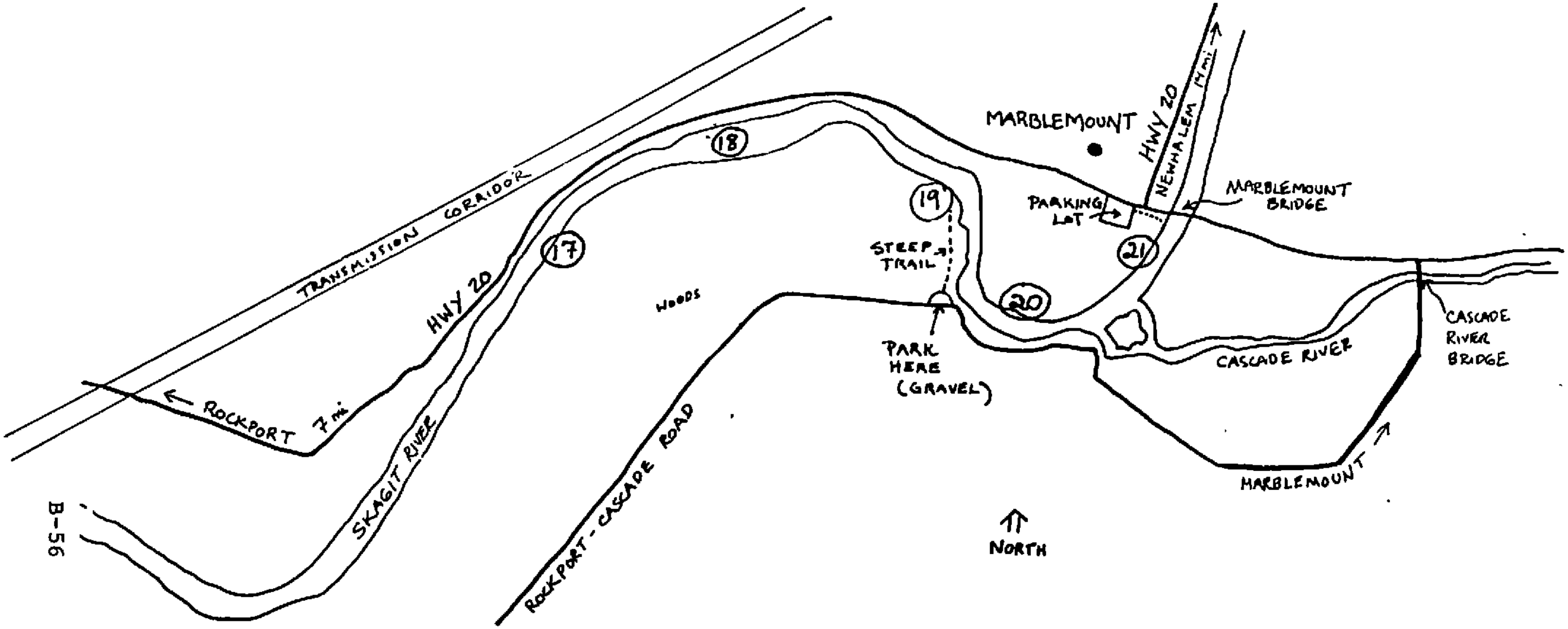


19 BIG EDDY (RM 77.5) (17.4 miles from Newhalem - 2 minute walk from car)

Travel to Marblemount. Access is from the south side of the Skagit River. Go east across Marblemount bridge for 0.25 mile to the Cascade-Rockport Road. Then go south across Cascade River bridge. Continue southwest on Cascade-Rockport Road for about 1.5 miles. There will be a pull-off on the right side of the road (beer cans, trash -- definitely a public spot!). Park there and take the path directly north toward the river. The trail goes down the steep bank to a small shack. The gravel bar is slightly downstream of the house across a side channel. Total access time from Cascade-Rockport Road is 3 minutes.

ACCESS MAP C

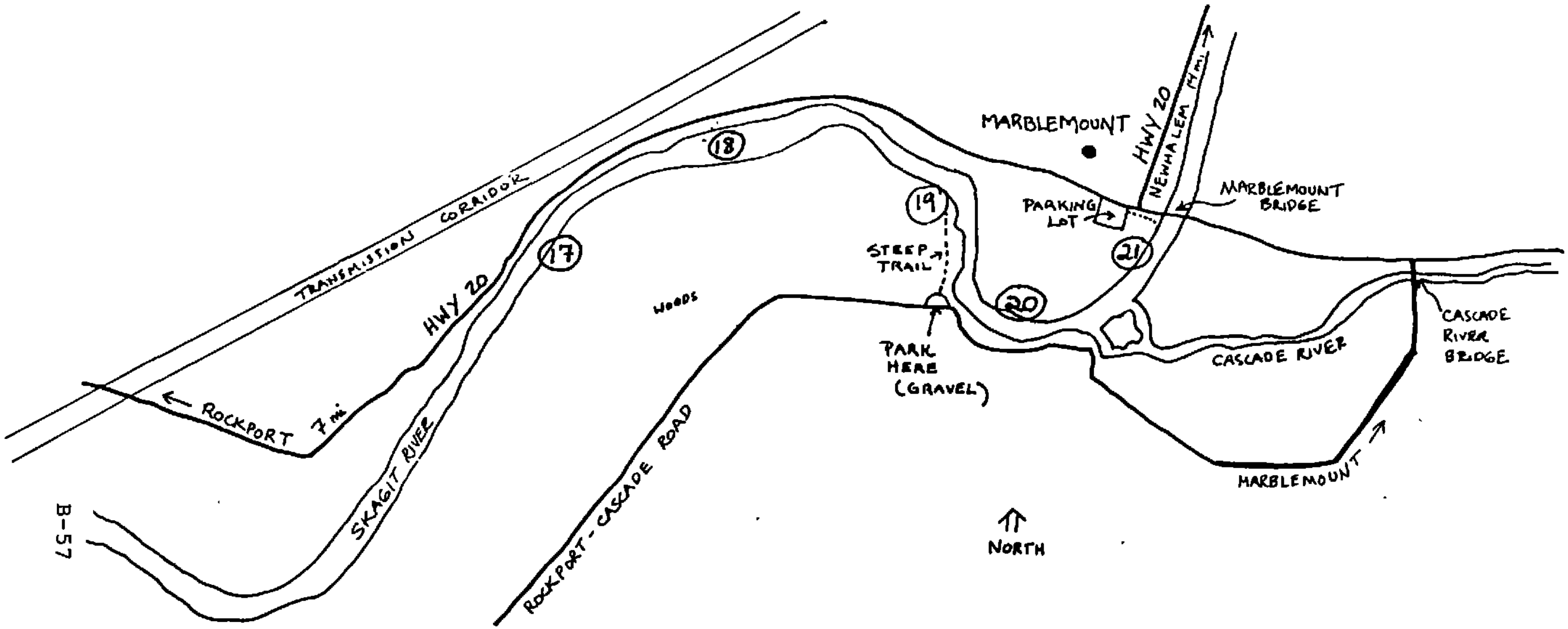
POTHOLE AREAS 17, 18, 19, 20, 21



20 TEFLON BAR (RM 77.7)

Boat access only.

ACCESS MAP C
POTHOLE AREAS 17, 18, 19, 20, 21

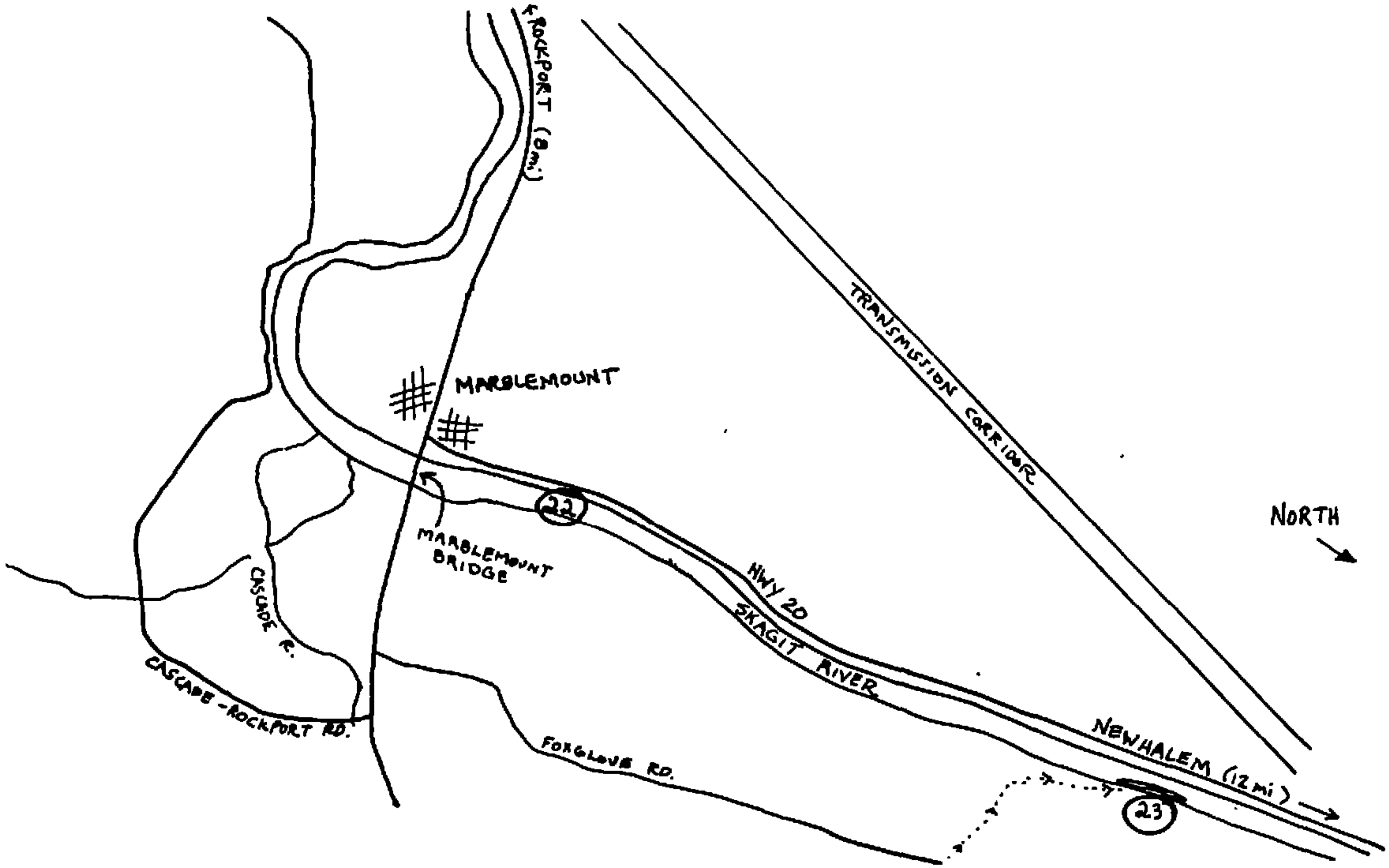


21 MARBLEMOUNT SLOUGH (RM 78.2)

Travel to Marblemount. Park across the highway from the Log House Inn. Walk east along the highway and follow the trail that leads to the right and under the Marblemount bridge until you reach the river. The pothole area is in a slough about 300 yards downstream from the bridge.

ACCESS MAP D

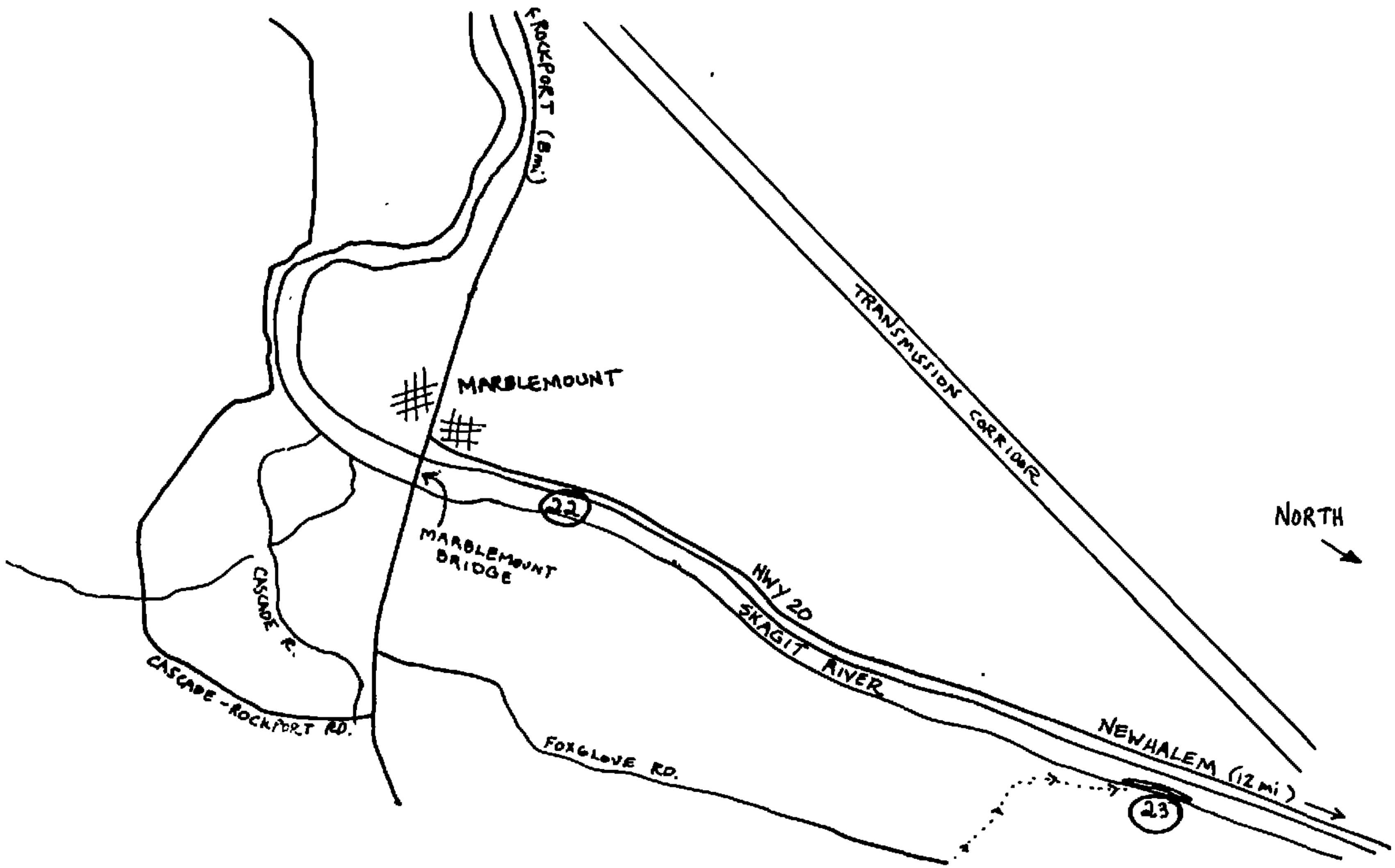
POTHOLE AREAS 22, 23



22 RAINIER BAR (RM 78.3)

RAINIER pothole is approximately 1,000 feet upriver of the Marblemount bridge off of Highway 20 and approximately 600 feet south of the USGS gaging station.

ACCESS MAP D
POTHOLE AREAS 22, 23



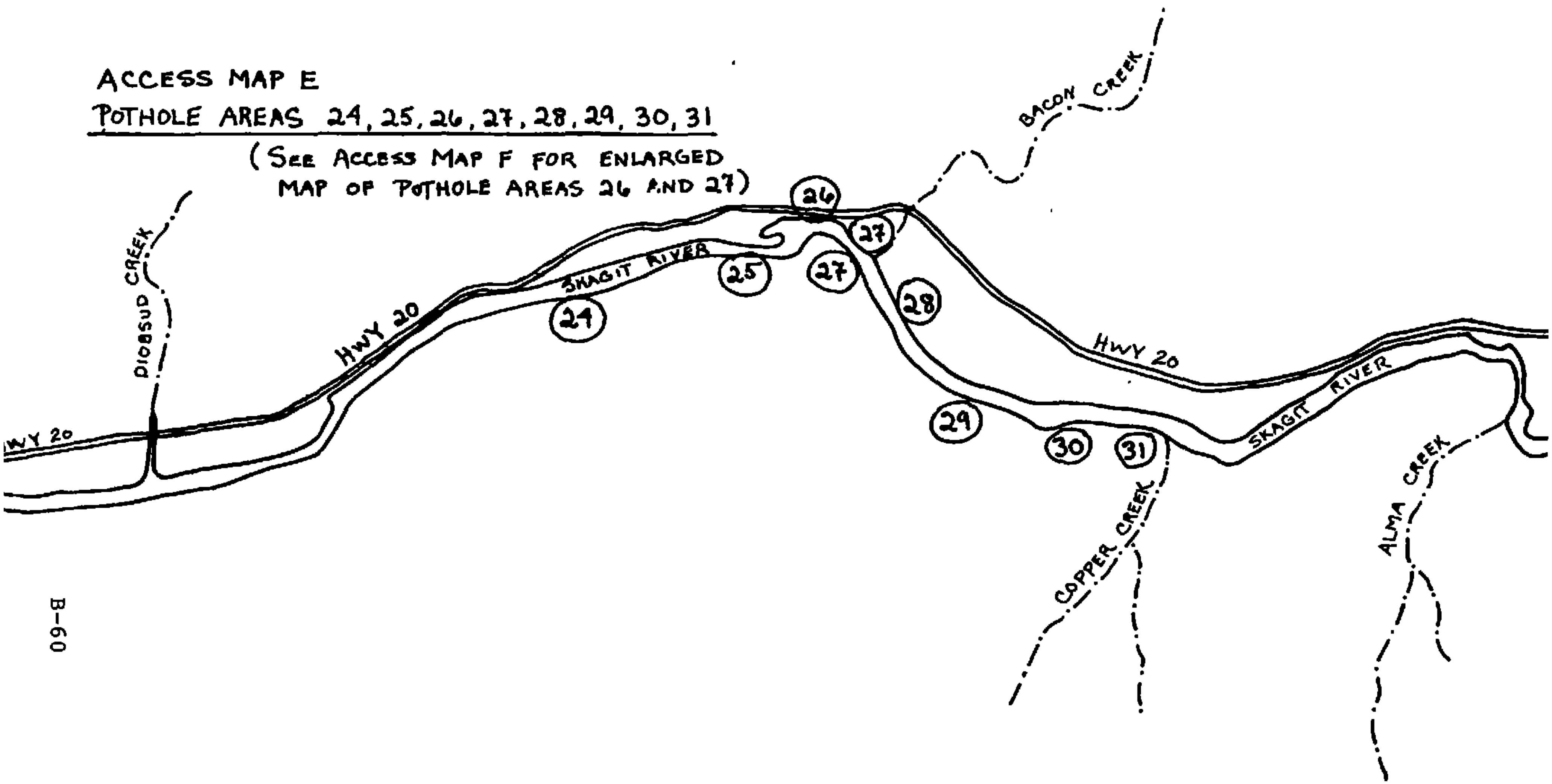
23 FUNGUS BAR (RM 78.5) (15.5 miles from Newhalem - 10 minute walk from car)

Travel to Marblemount. Go east across Marblemount bridge for about 0.25 mile. Turn left at Foxglove Road. Drive this dirt road for 1 mile to several downed trees across the road. Park here. Walk along the road for 300 yards as it curves toward the river. Follow the trail upstream along the river. The trailhead is flagged. Follow the trail all the way to the lower end of FUNGUS BAR. Cross a small channel to the bar.

ACCESS MAP E

POTHOLE AREAS 24, 25, 26, 27, 28, 29, 30, 31

(SEE ACCESS MAP F FOR ENLARGED MAP OF POTHOLE AREAS 26 AND 27)



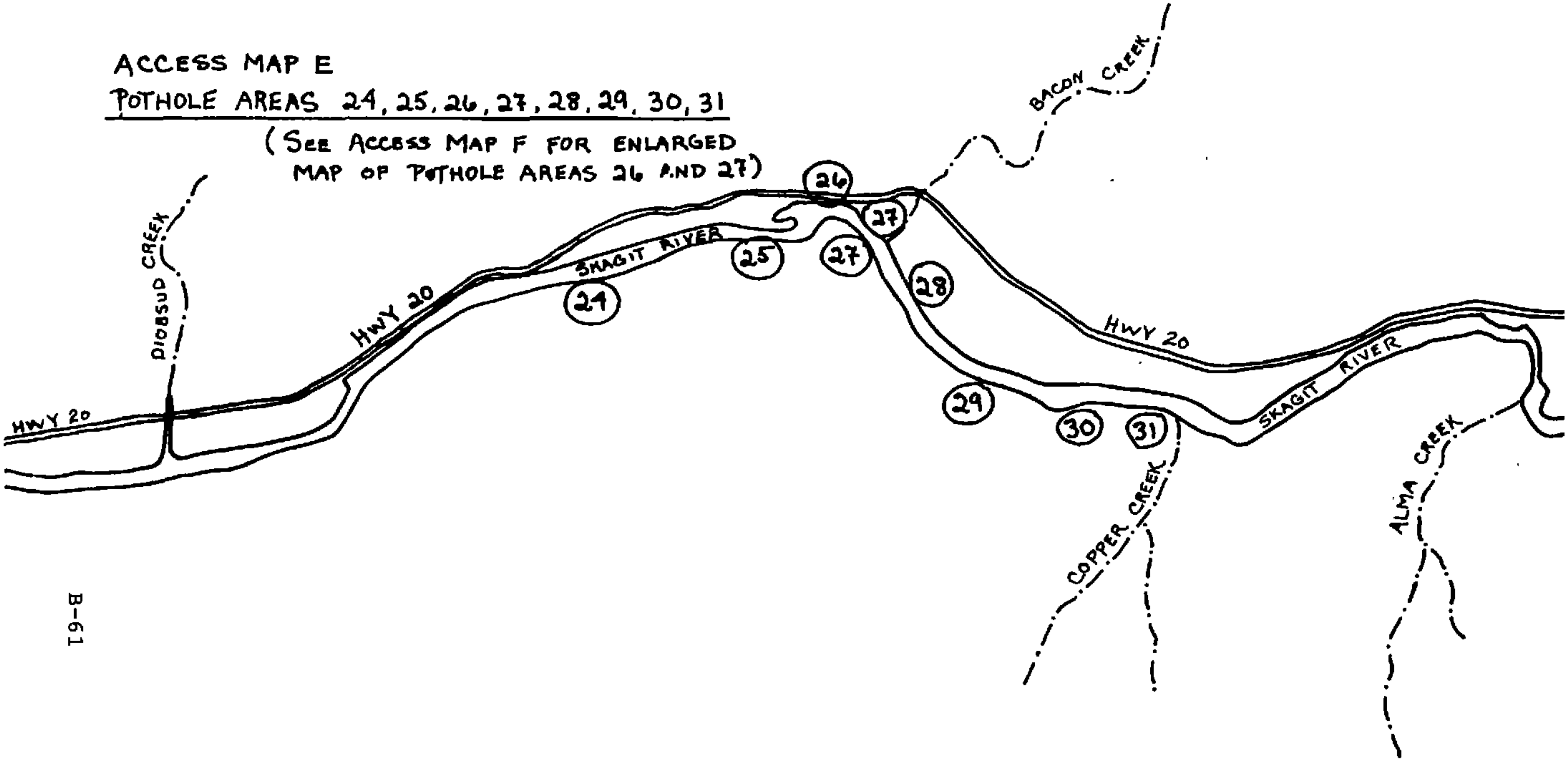
24 SAM'S BAR (RM 82.0)

Boat access only.

ACCESS MAP E

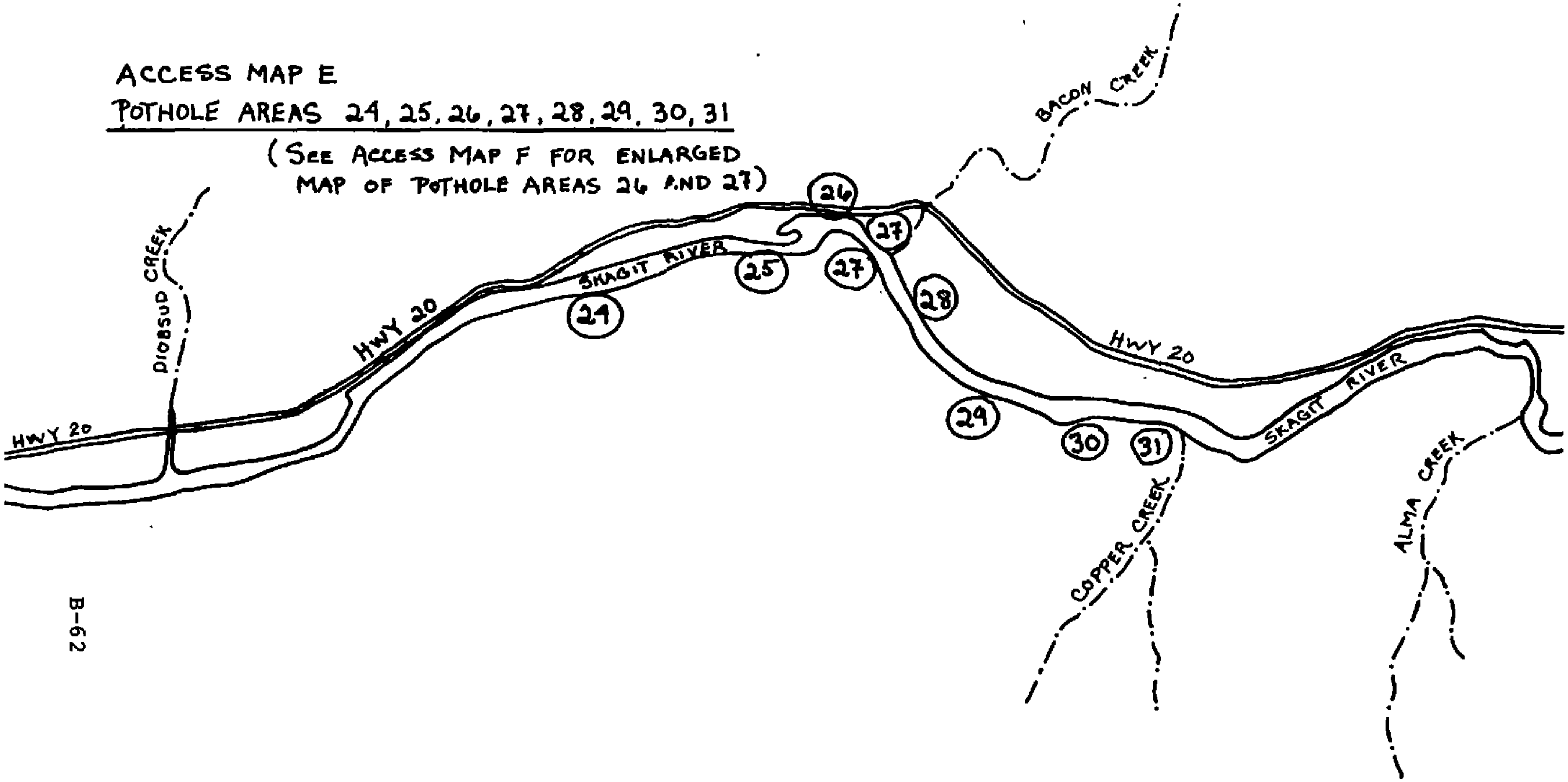
POTHOLE AREAS 24, 25, 26, 27, 28, 29, 30, 31

(SEE ACCESS MAP F FOR ENLARGED MAP OF POTHOLE AREAS 26 AND 27)



25 MAPLE BAR (RM 82.5)

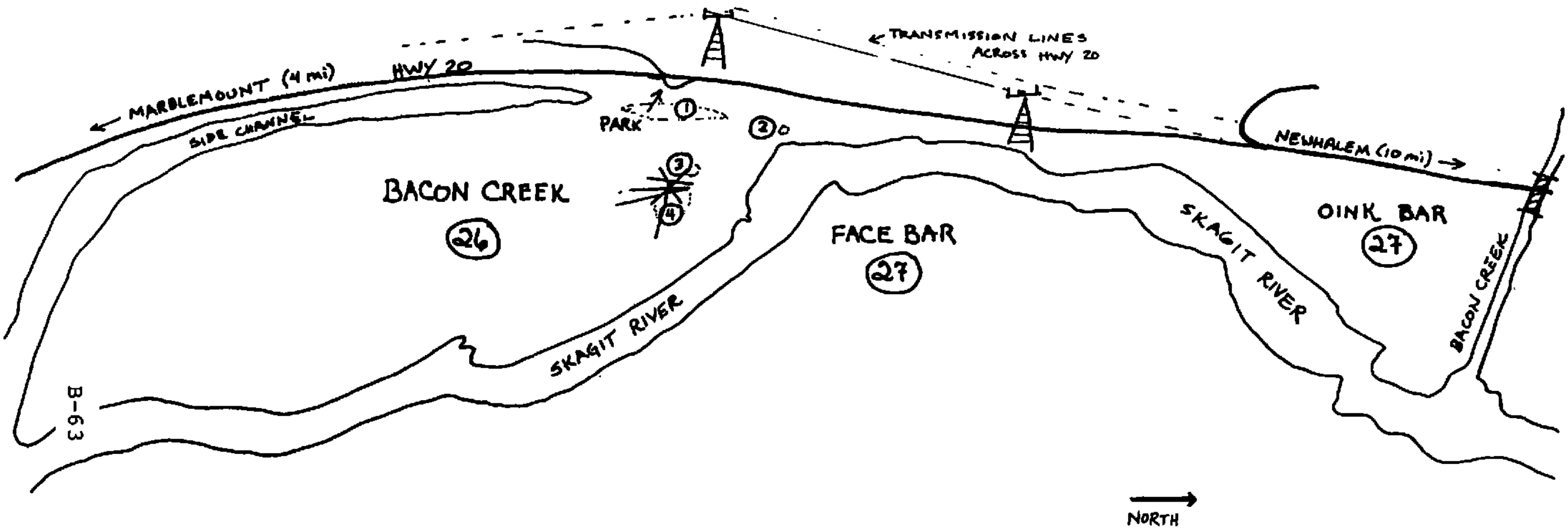
Boat access only.



26 BACON CREEK (RM 82.6)

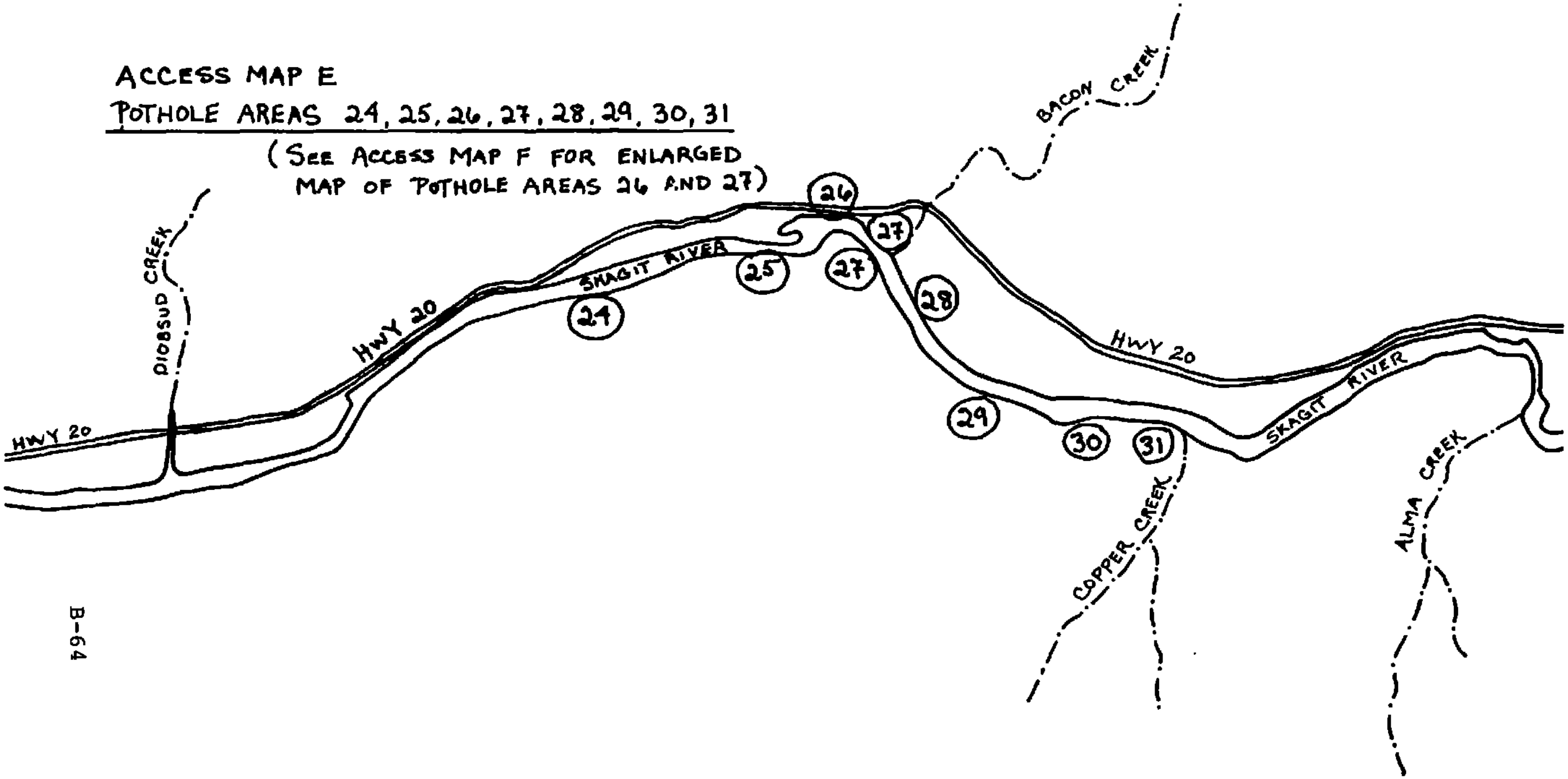
See Access Map F for detailed description.

ACCESS MAP F
POTHOLE AREAS 26, 27



26 BACON CREEK (RM 82.6) (10 miles from Newhalem - 1 minute walk from car)

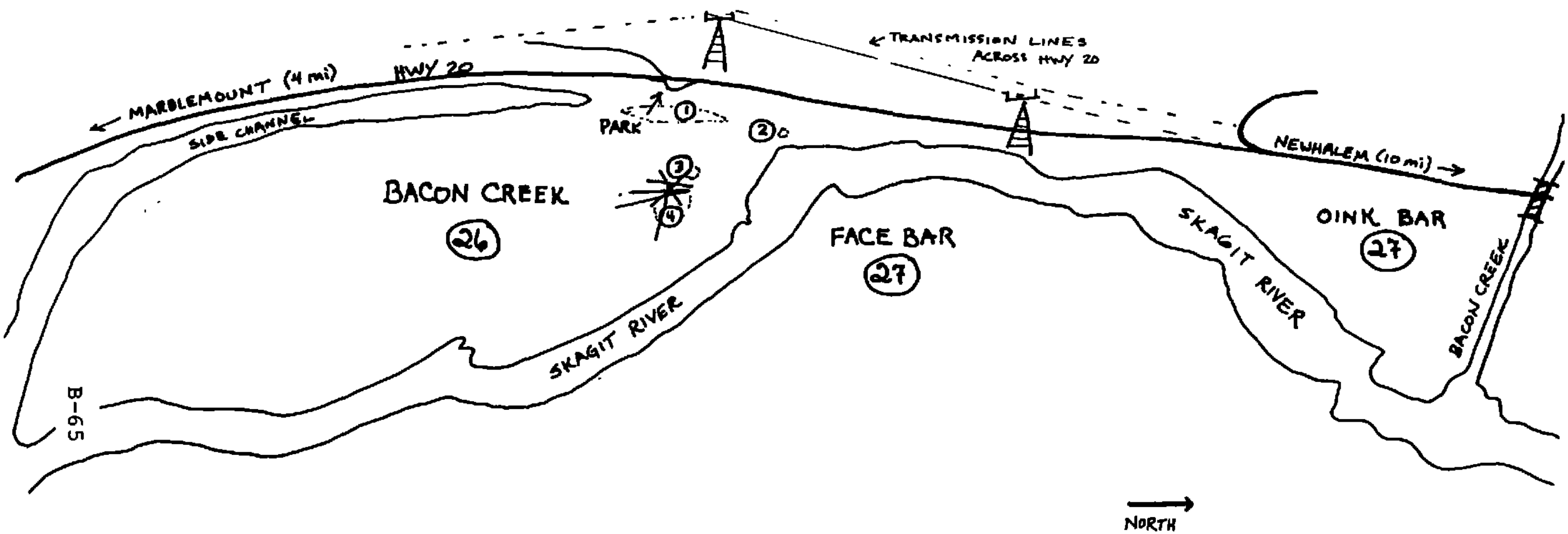
Head south for 10 miles on Highway 20 from Newhalem. Proceed 0.4 miles past the Bacon Creek bridge. There will be one transmission tower on each side of the road. Pull over on the gravel area, left hand side across from the tower. Walk directly down the riprap slope to the side channel. Pothole #1 is upstream of the parking spot at the base of the road embankment. Access from the south is 12 miles from Rockport or 4 miles from Marblemount. Go over Diobsud Creek bridge, then go to the transmission towers.



27 FACE BAR (RM 82.7)

Boat access only.

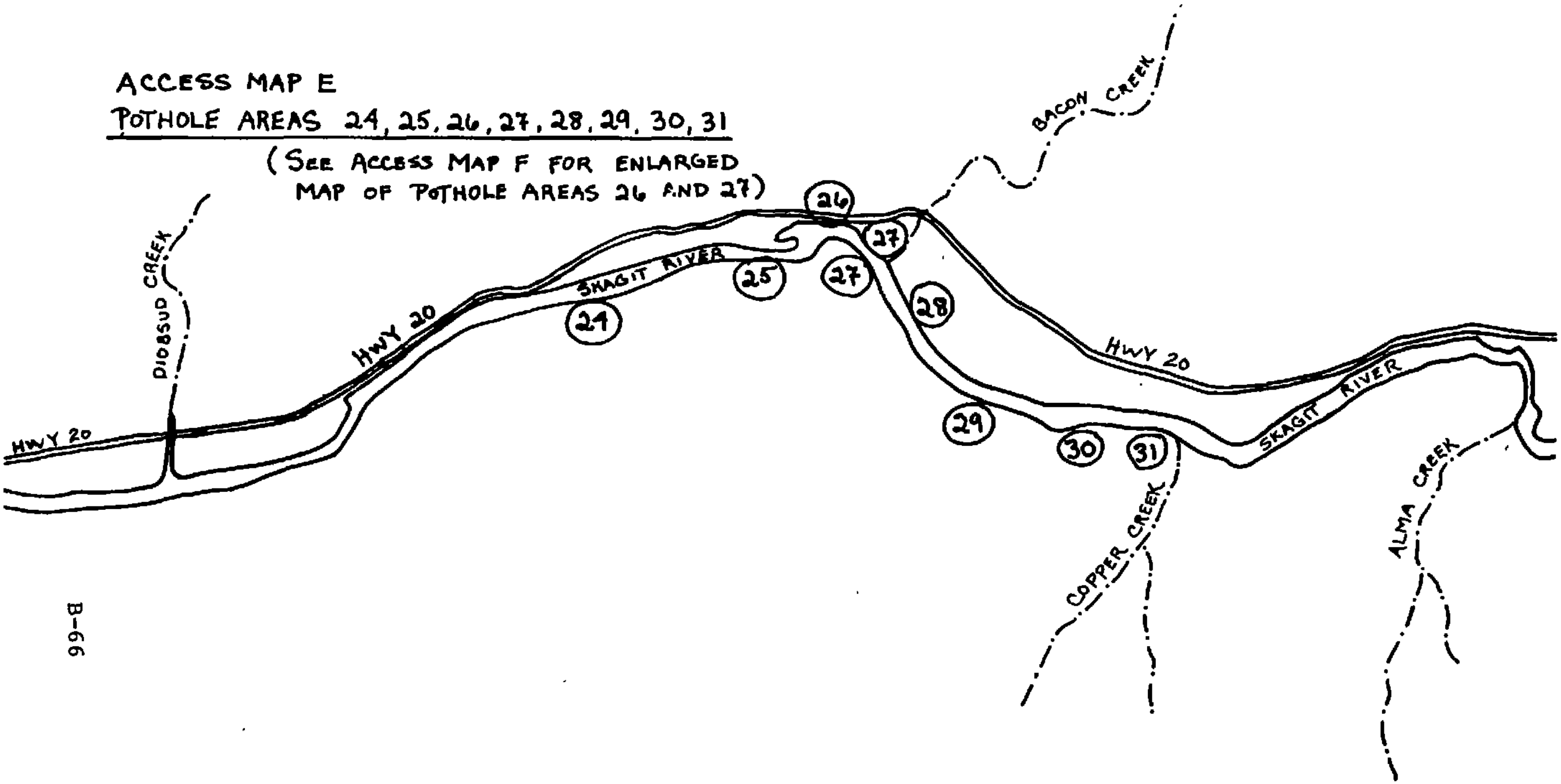
ACCESS MAP F
POTHOLE AREAS 26, 27



27 FACE BAR (RM 82.7); OINK BAR (RM 82.9)

Boat access only for FACE BAR.

OINK BAR is just downriver of the confluence of Bacon Creek and Skagit River. Head south from Newhalem on Highway 20 for 10 miles. Cross the Bacon Creek bridge and turn right at paved entrance to recreation area. Park and walk across the highway and down the bank to the mouth of Bacon Creek.



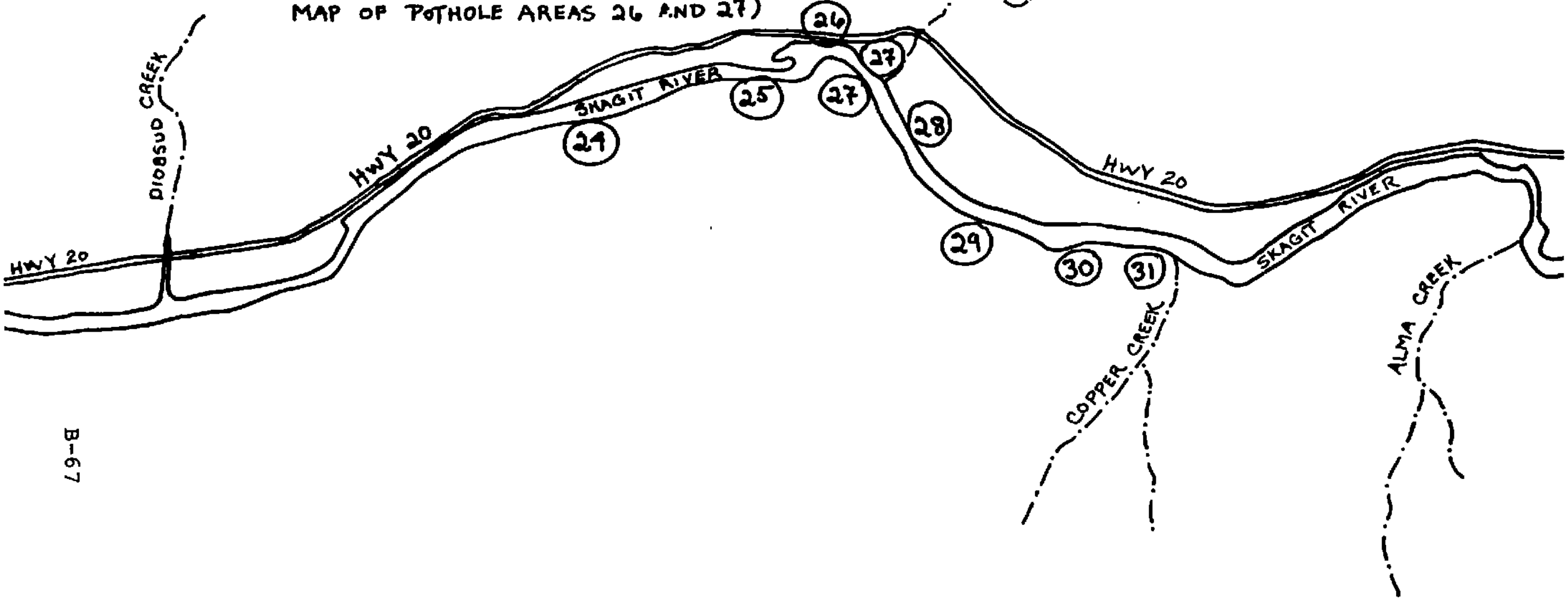
28 DRIFTWOOD BAR (RM 83.0)

Head south from Newhalem on Highway 20 for 10 miles. Turn left onto a gravel road .1 mile before the Bacon Creek bridge. This is the access road for the transmission corridor. Just before the locked gate (.1 mile), turn right onto another gravel road and follow it to the end (.1 mile). Bacon Creek is directly in front of you. Park here and follow the flagged trail downstream to the Skagit River. DRIFTWOOD BAR is located directly on the edge of the Skagit River about 250 yards upstream from the mouth of Bacon Creek.

ACCESS MAP E

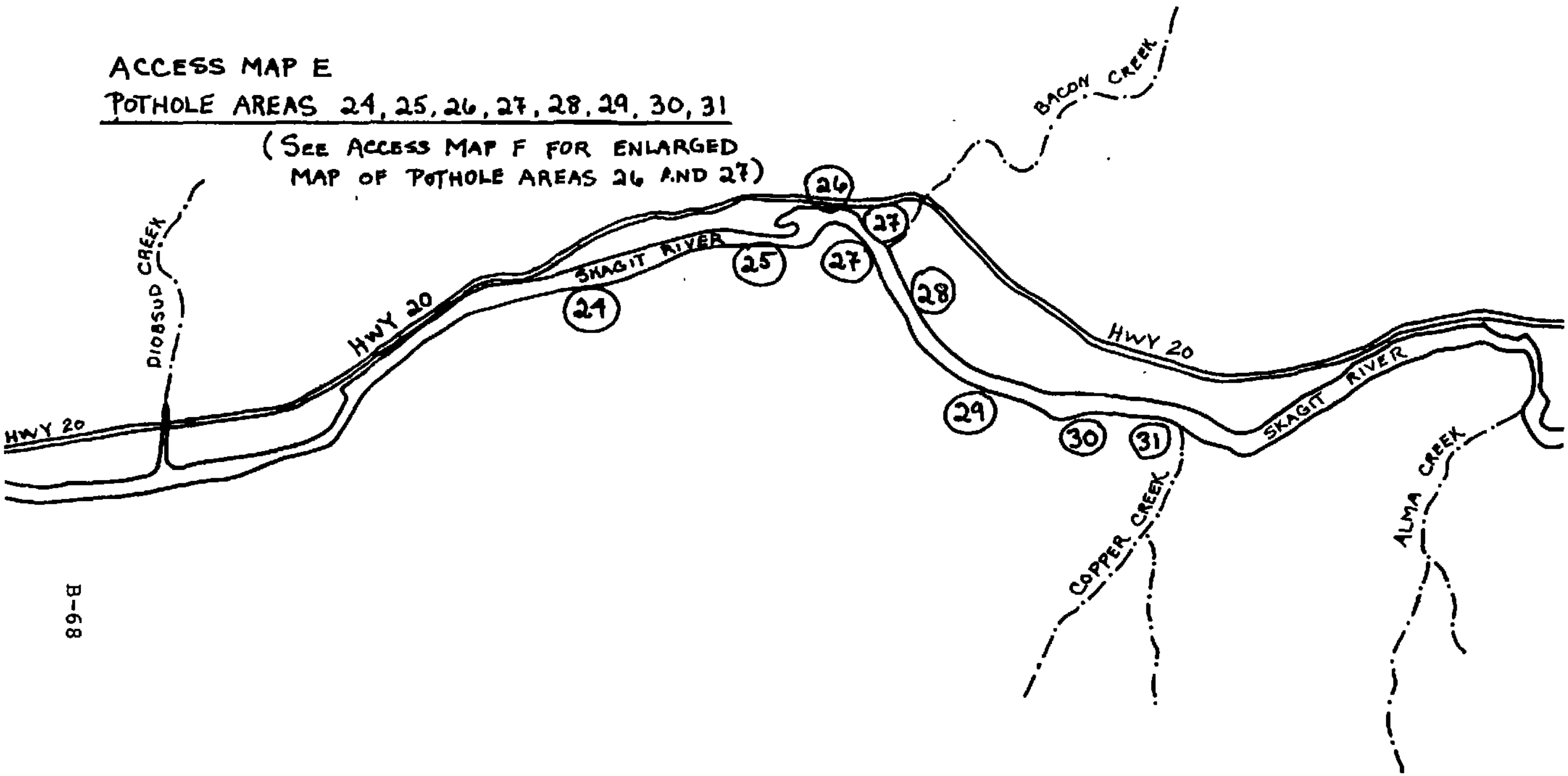
POTHOLE AREAS 24, 25, 26, 27, 28, 29, 30, 31

(SEE ACCESS MAP F FOR ENLARGED MAP OF POTHOLE AREAS 26 AND 27)



29 MINIBAR (RM 83.3)

Boat access only.



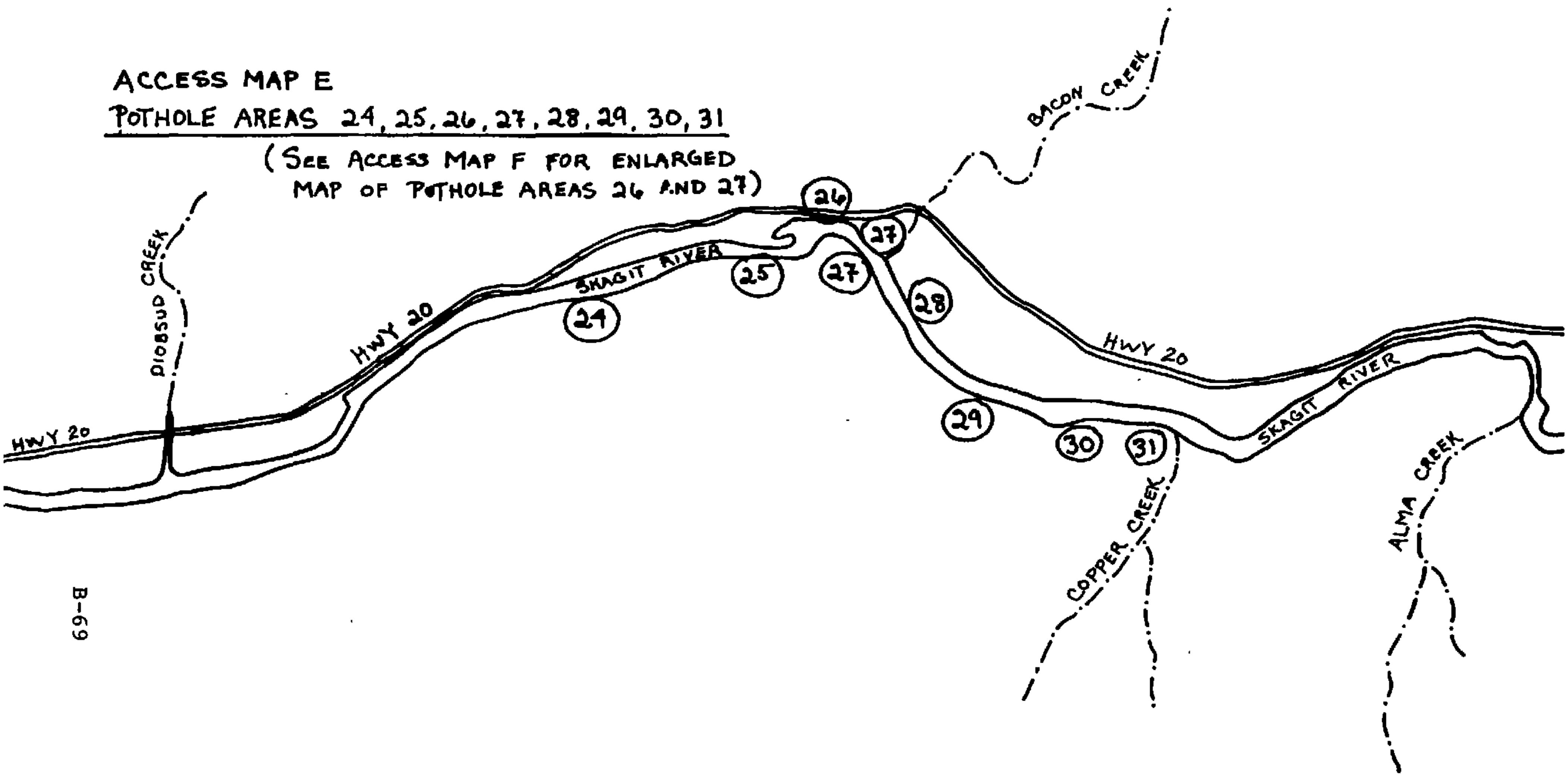
30 FLOWER POTHOLE (RM 83.5)

Boat access only.

ACCESS MAP E

POTHOLE AREAS 24, 25, 26, 27, 28, 29, 30, 31

(SEE ACCESS MAP F FOR ENLARGED MAP OF POTHOLE AREAS 26 AND 27)



31 COPPER CREEK (RM 84.0)

Boat access only.

APPENDIX C

Predictive Model for Skagit River Flows

APPENDIX C

A PREDICTIVE MODEL FOR SKAGIT RIVER FLOWS AND RIVER ELEVATIONS AT ROCKPORT, WASHINGTON.

River Flow

The discussion in this appendix concerns predictions of Skagit River flows. The purpose of the model is to predict river elevations at Rockport given the observed flows at (Newhalem) (Gorge Powerhouse) and Marblemount. Marblemount is located 14.5 rivermiles downstream of the powerhouse and Rockport an additional 10.8 rivermiles downstream of Marblemount. Between Newhalem and Rockport there is tributary inflow of water which is ungaged and uncertain as to its variation in time and magnitude. Based upon watershed area it has been estimated that the total tributary inflow is approximately 1.94 times the tributary inflow between Gorge Powerhouse and Marblemount (Wooden et al. 1984).

The flow data show that following a change in the regulated flow at the Gorge Powerhouse the changes in flow rates vary somewhat more slowly at Marblemount. This results because of the time it takes the water to drain from or fill sloughs, side channels, spaces around the rocks which make up the river bed and river banks, and also bank storage. It takes about two hours for any change in flow at the powerhouse to be seen in Marblemount flows. If there was no spreading in time of the shape of the flow vs time curve between Gorge Powerhouse and Marblemount then the difference of the powerhouse flow (displaced in time) and the Marblemount flow could be used to estimate the runoff between these two gaged locations. Because of the dispersion it is necessary to modify the flow record at the powerhouse before determining the tributary runoff.

Illustrated in Figures 1 and 2 are the Newhalem (powerhouse) flows, the Marblemount flows, and the differences between the flows. The Newhalem flow curve has been displaced in time by 2.25 hours which is the time it takes for the influence of diminished dam flow to reach Marblemount. The upper curve is the observed flow at Marblemount, the central curve is the observed flow at the dam, and the lower curve is the difference between the two flows. The difference between the two flows is due to tributary runoff, however as shown in the figures the simple differencing of the observed flows at Marblemount and Newhalem (Gorge Powerhouse) does not lead to a realistic estimate of the tributary runoff. The pulses in the tributary runoff curve result becauses of differences in the shapes of time histories of flow at the gaged stations and not real changes in tributary runoff. The tributary runoff curve could be smoothed by eye and values estimated manually, however such a process would be time consuming. Thus a procedure has been developed which gives better estimates of the tributary runoff than simple differencing and thereby automates the analysis.

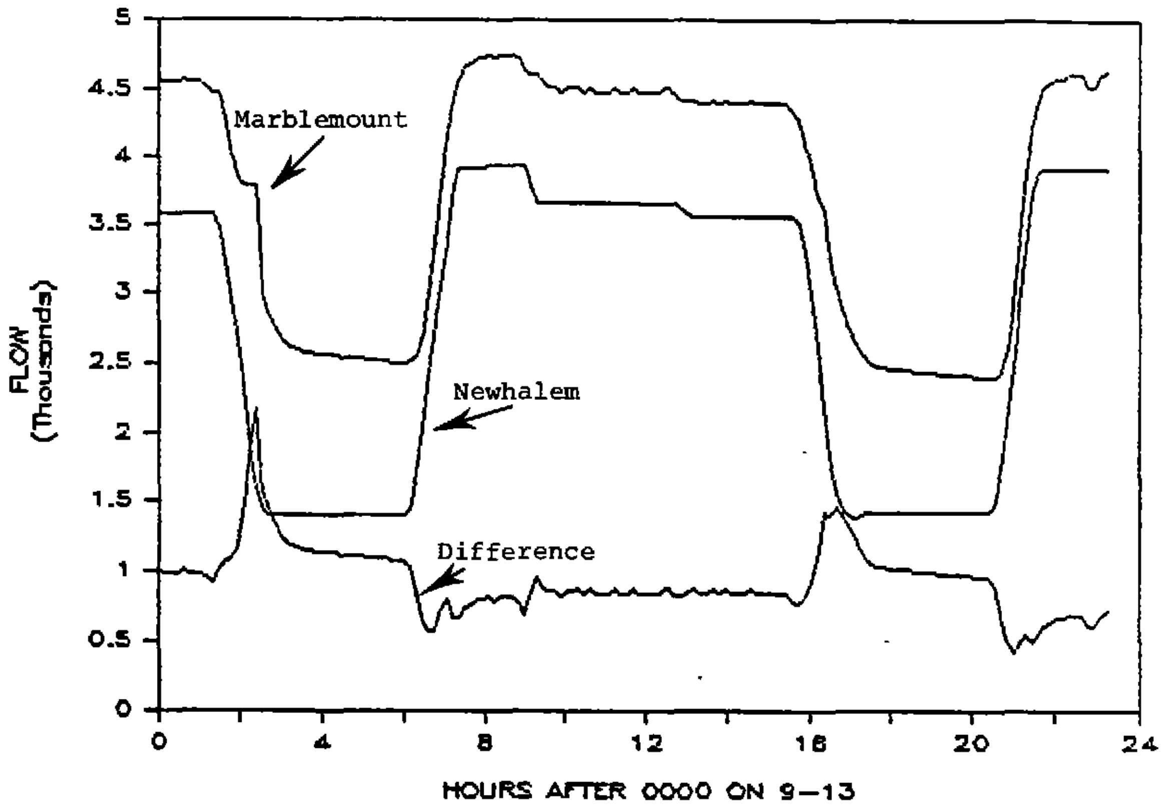


FIGURE 1.

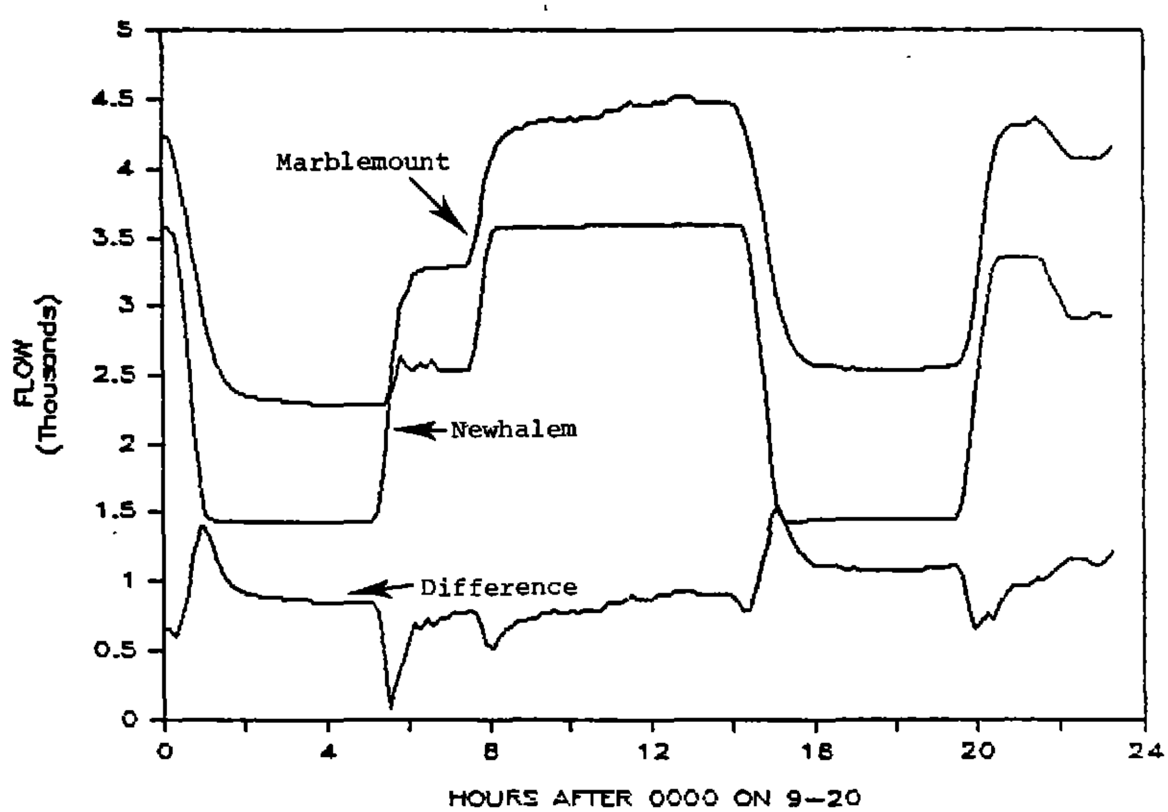


FIGURE 2.

FIGURES 1 and 2. NEWHALEM (GORGE POWERHOUSE) AND MARBLEMOUNT FLOWS AND DIFFERENCES BETWEEN FLOWS FOR SEPTEMBER 13 AND 20, 1984

The approach adopted to solve the problem of predicting the tributary runoff is based upon the following premises:

1) Time variations in runoff are small relative to the time variations in the regulated powerhouse flow. Downramping events at the powerhouse occur over time periods of 1 to 2 hours.

2) The river flow is primarily controlled by friction.

3) The same model used to explain the difference in the flow curves beteen Newhalem and Marblemount is used to predict the Rockport flow given the observed Marblemount flow.

4) The relation between flow and river elevation at Rockport is not known. Therefore the assumption is made that the river cross section is the same at both Rockport and Marblemount.

One way to proceed in solving the river flow problem would be set up a river flow model and then numerically integrate the equations. In general such a model would include both friction and the hydrodynamics of how a wave or impulse of water would change shape as it propagates down a river. The assumption that friction is the most important physical process reduces such a river flow model to a diffusive model. The solution to the equations would be a relationship expressing the flow downstream in terms of the history of the upstream flow. Instead of integrating a river flow model we have used the observations to determine a filter which is then extrapolated from the Newhalem to Marblemount observed flows to the Marblemount to Rockport flows. Because the model parameters are not based upon a physical model the procedure only can be effective when the stations are approximatly the same river distance apart.

The calculations discussed in this appendix were accomplished on a spread sheet program for a microcomputer. By adopting this approach it was possible to obtain flow estimates for all time periods of interest quickly. Certainly more sophisticated models could be developed, however there was neither the time nor the demonstrated necessity for more study. The estimates were compared with one set of observed river elevations obtained at Rockport. The comparison was extremely favorable with predicted and observed elevations agreeing to within a couple of inches of water level.

Analytic Details of the Flow Model

The river model is based upon the following expression:

$$M(t)= M(t-1) + N_m(t) + T(t) \qquad (1)$$

where $M(t)$ is the flow at Marblemount at time t, $N_m(t)$ is a modified flow at Newhalem, and $T(t)$ is the tributary runoff into the river at time t. The observed flow at Newhalem will be denoted by $N(t)$ in the equations which follow. The flow, $N_m(t)$, is determined by requiring the runoff estimate, $T(t)$, to be as smooth as possible. The observations of flows were made at 15 minute intervals. In the above formulas t is the present time and t-k is the time k 15 minute intervals preceeding the present time.

For the calculations discussed in this appendix $N_m(t)$ was determined by the equation:

$$N_m(t)= N(t-1) + c\sum_{K=1}^{LAG}(N(t-k)-N(t-k-1))\exp(-a(t-k)^2) \qquad (2)$$

where

$$c = 1/(\sum_{K=1}^{LAG}\exp(-a(k)^2)) \qquad (3)$$

The value of c is determined by the criteria that over a long period of time the average value of $N_m(t)$ must equal the average value of $N(t)$.

The exponential filter in (2) with a quadratic dependence on the time delay was found to fit the observations better than any other filter. Filters were tried with linear and cubic factors in the argument of the exponent and neither performed well. Unfortunately there was not time in this study to do a goodness-of-fit calculation. Parameter estimates were made by viewing graphic displays obtained using a range of parameter values. For the fall (low runoff) observations a value of a=.4 and 15 lags appeared to be optimum. For the spring (high runoff) observations a value of a=.6 appeared to fit the observations better.

Examples of the application of (1), (2), and (3) are shown in Figures 3 and 4. These are the same dates as the flows shown in Figures 1 and 2. The application of the filter before differencing to determine runoff yields estimates which are appreciably smoother in time than if the raw data is used.

In order to improve even further the runoff estimates the runoff calculations were smoothed with a 5 point running mean filter.

The runoff predictions for all observation periods are shown in Figures 5-22.

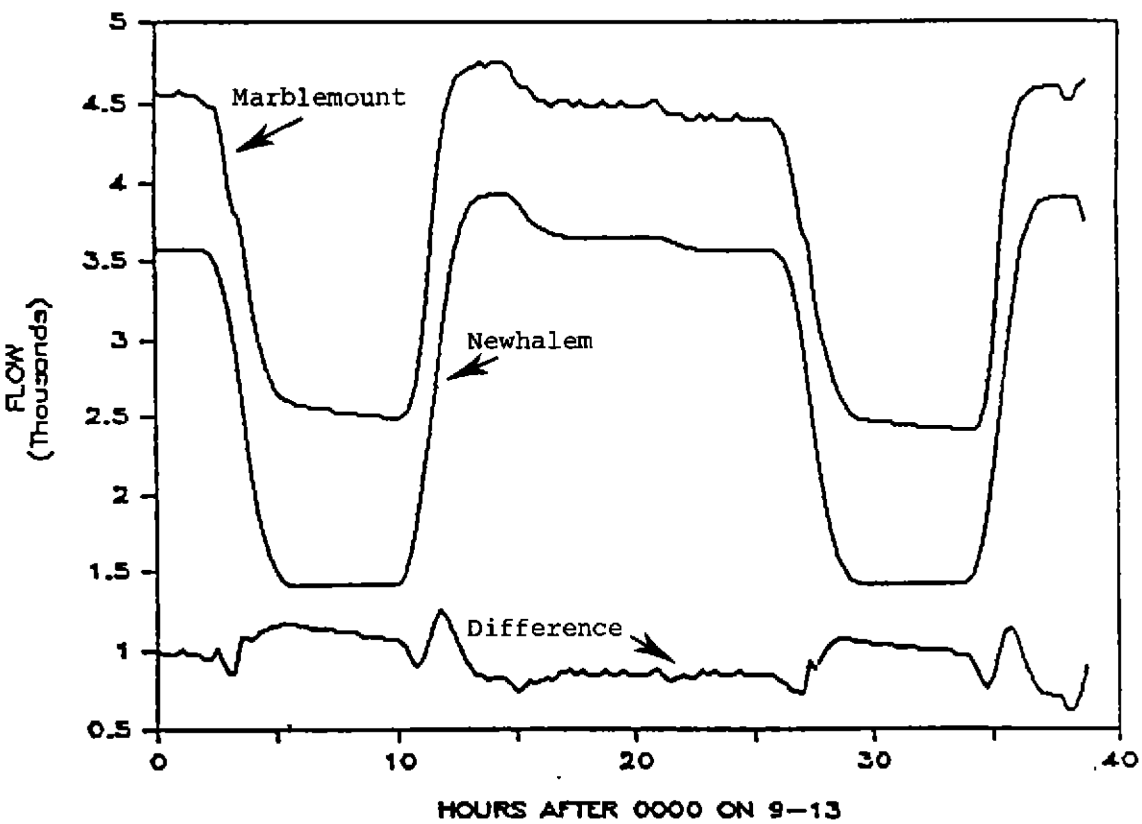


FIGURE 3.

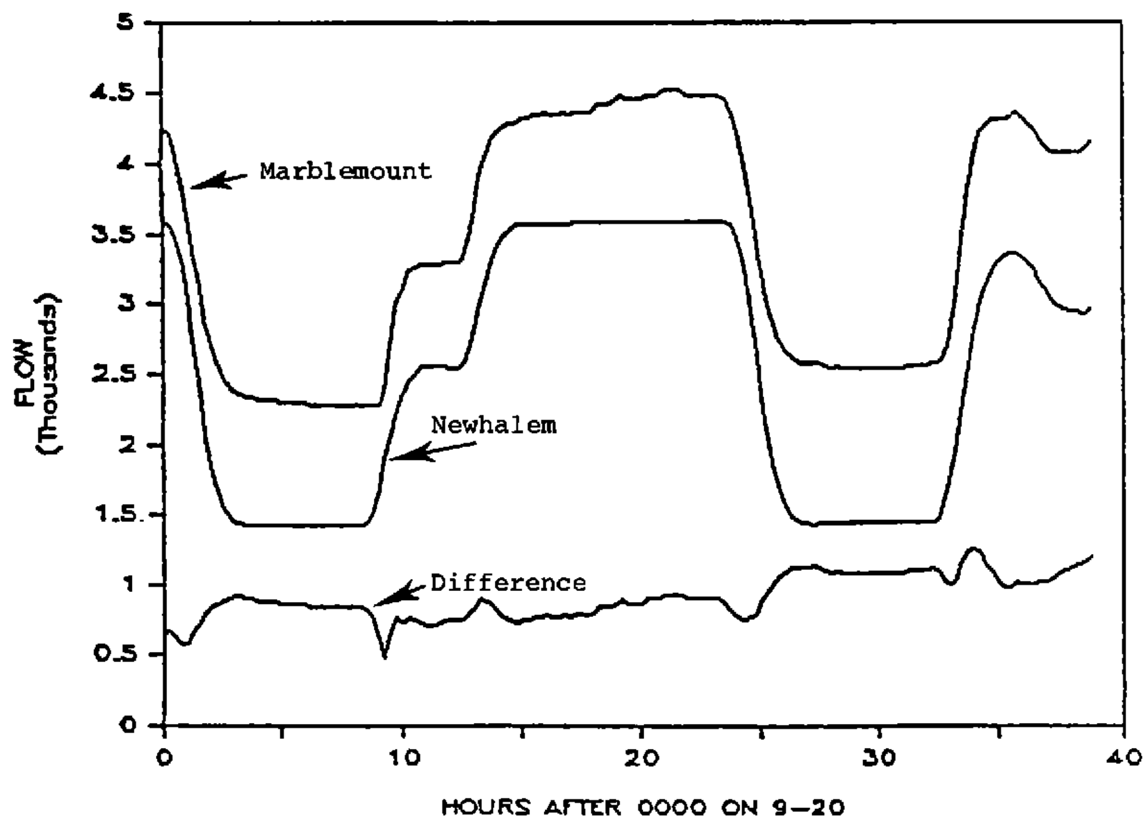


FIGURE 4.

FIGURES 3 and 4. NEWHALEM (GORGE POWERHOUSE) AND MARBLEMOUNT FLOWS AND DIFFERENCES BETWEEN FLOWS WITH EXPONENTIAL FILTERS APPLIED, SEPTEMBER 13 AND 20, 1984

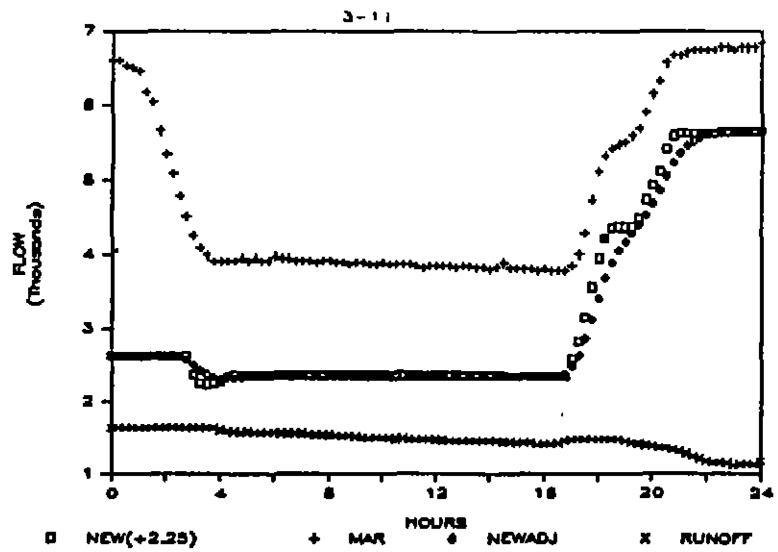


FIGURE 5.

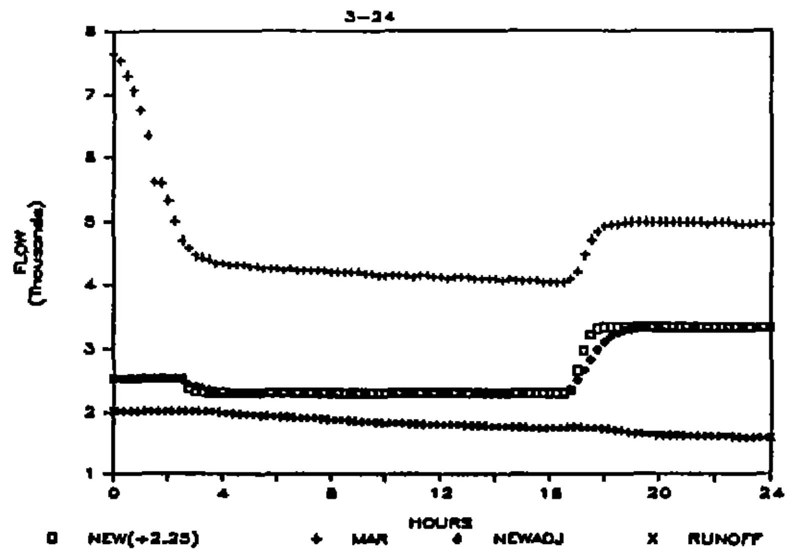


FIGURE 6.

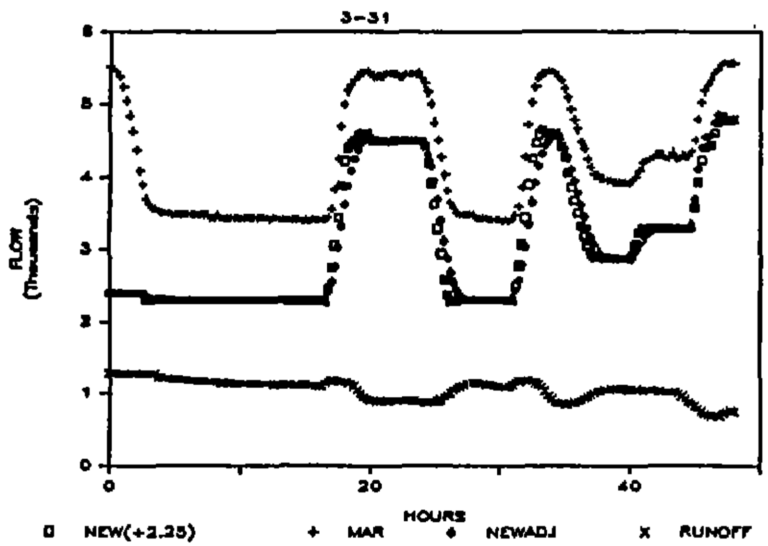


FIGURE 7.

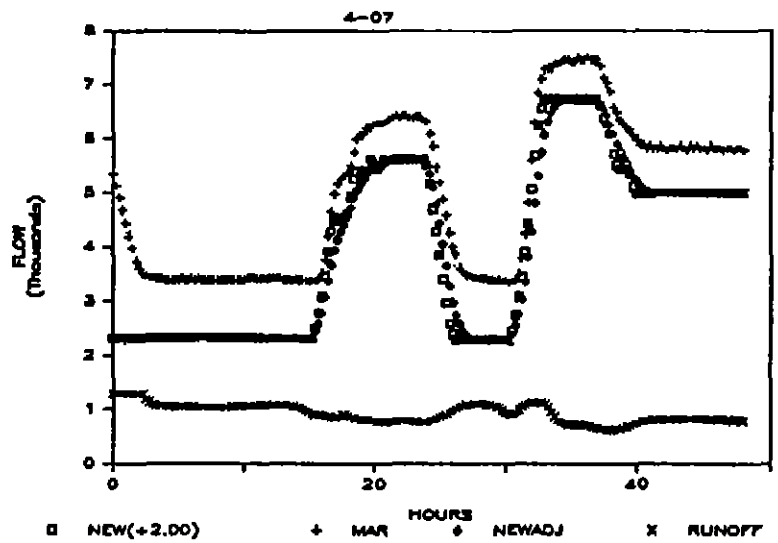


FIGURE 8.

FIGURES 5, 6, 7, and 8. RUNOFF PREDICTIONS FOR DOWNRAMP TEST DATES OF MARCH 11, 24, 31, 1984 AND APRIL 7, 1984

NOTE: Definitions of Abbreviations
New (+2.25) - Gaged flow at Newhalem plus 2.25 hours to account for lag time from Newhalem to Marblemount.
Mar - Gaged flow at Marblemount.
New adj - "Smoothed" Newhalem flow which is a predictive of what Newhalem flow looks like when it gets to Marblemount.

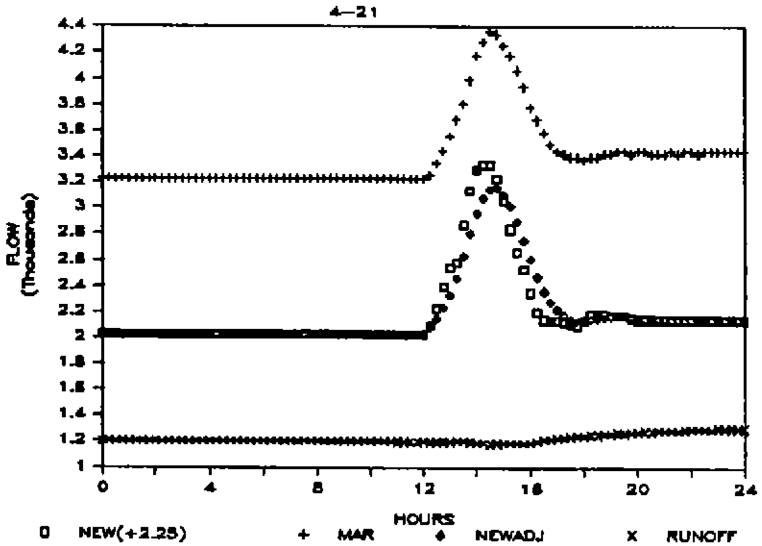


FIGURE 9.

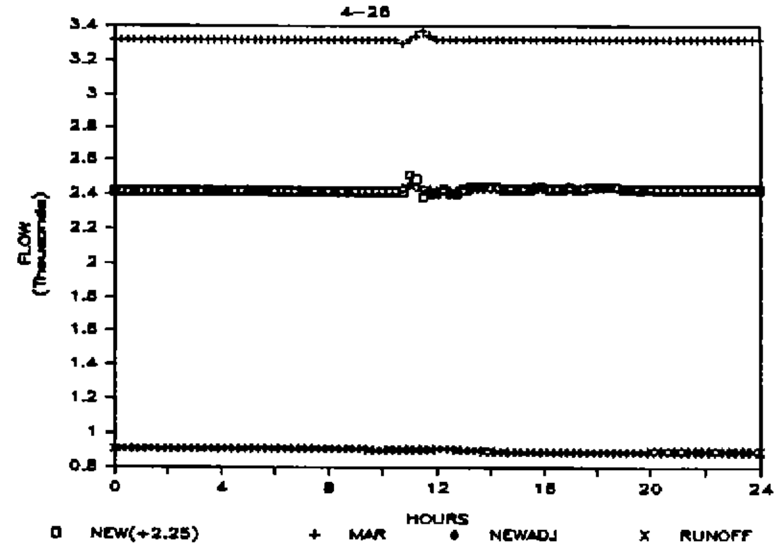


FIGURE 10.

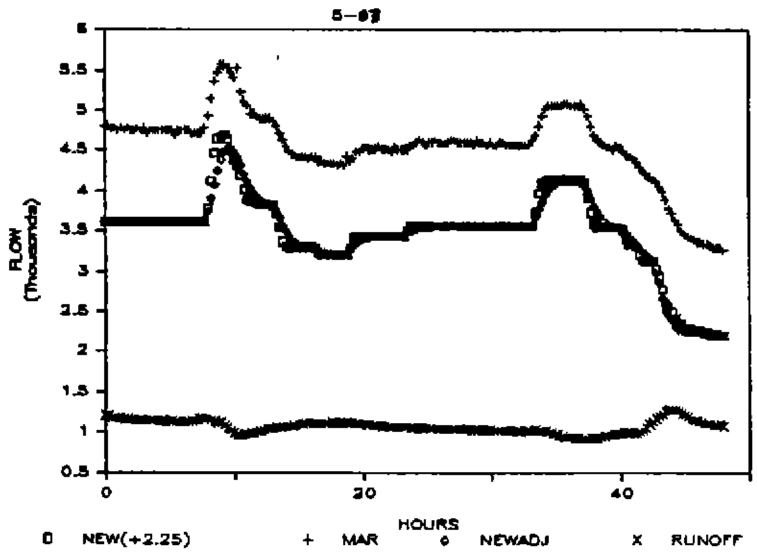


FIGURE 11.

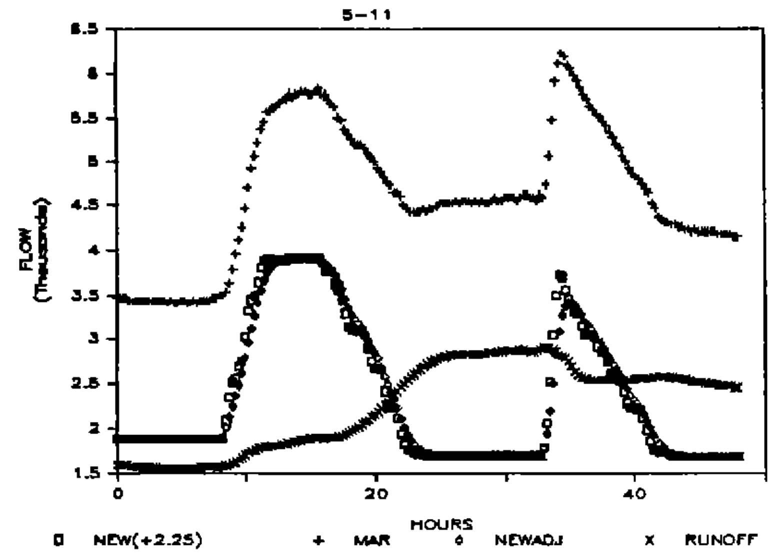


FIGURE 12.

FIGURES 9, 10, 11, and 12. RUNOFF PREDICTIONS FOR DOWNRAMP TEST DATES OF APRIL 21, 28, 1984 AND MAY 3 AND 11, 1984

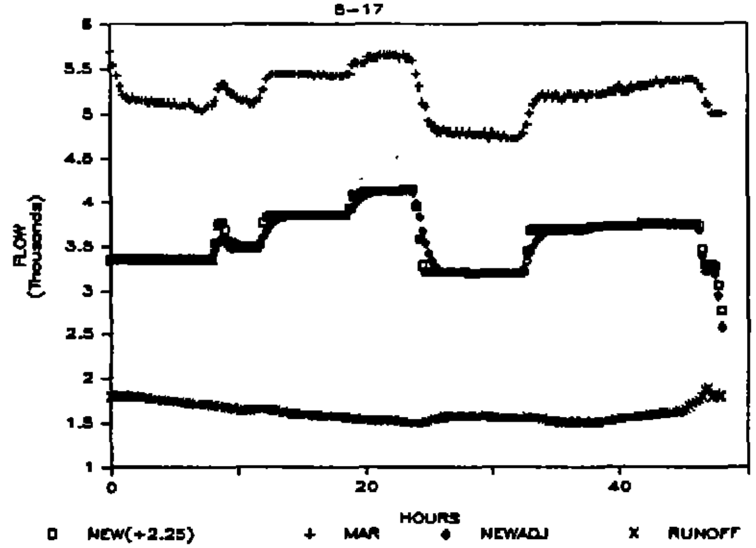


FIGURE 13.

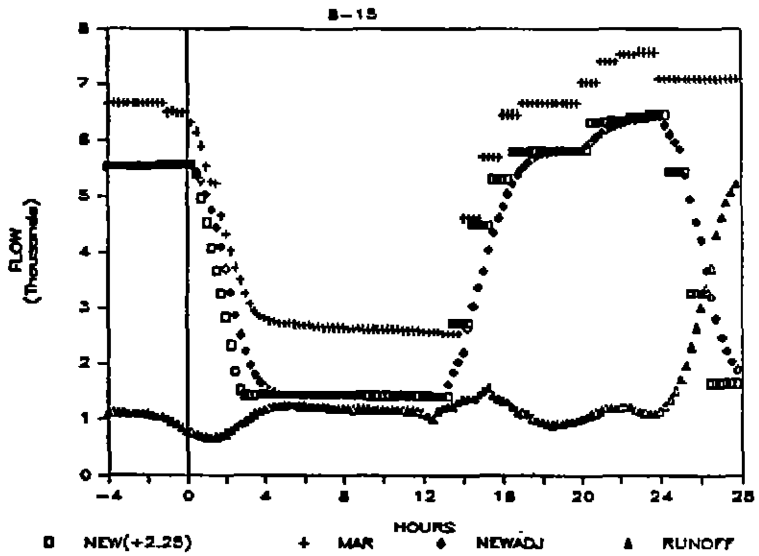


FIGURE 14.

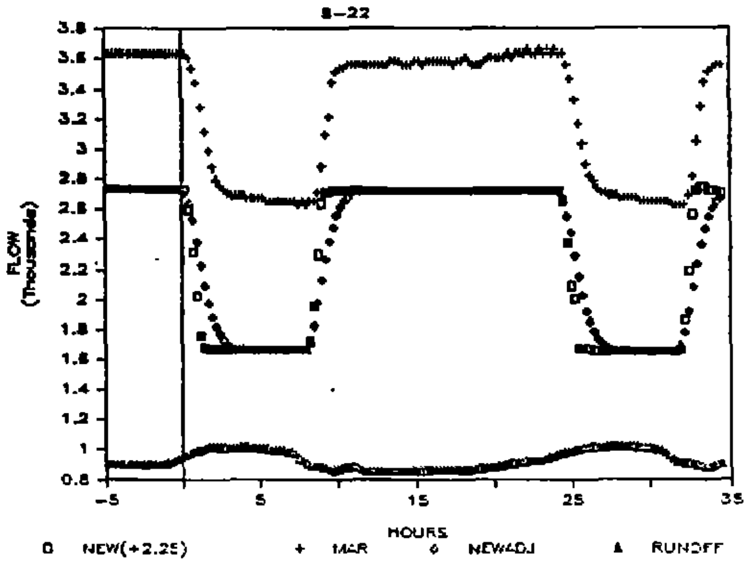


FIGURE 15.

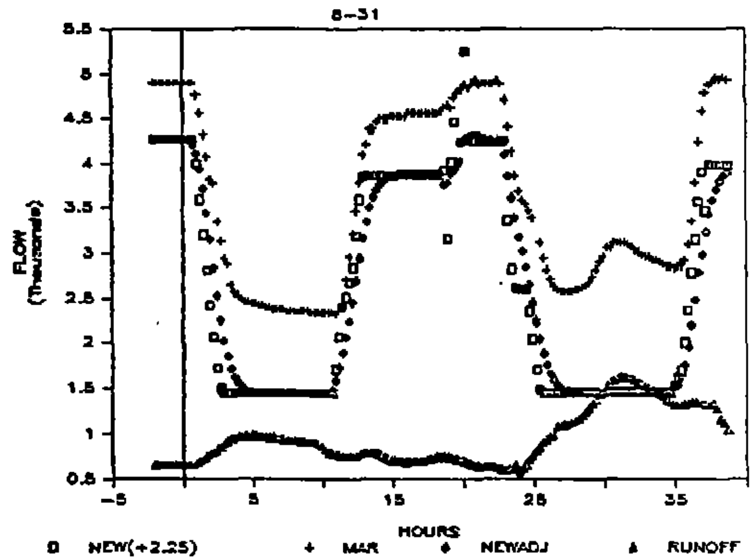


FIGURE 16.

FIGURES 13, 14, 15, and 16. RUNOFF PREDICTIONS FOR DOWNRAMP TEST DATES OF MAY 17, 1984, AUGUST 15, 22, AND 31, 1984

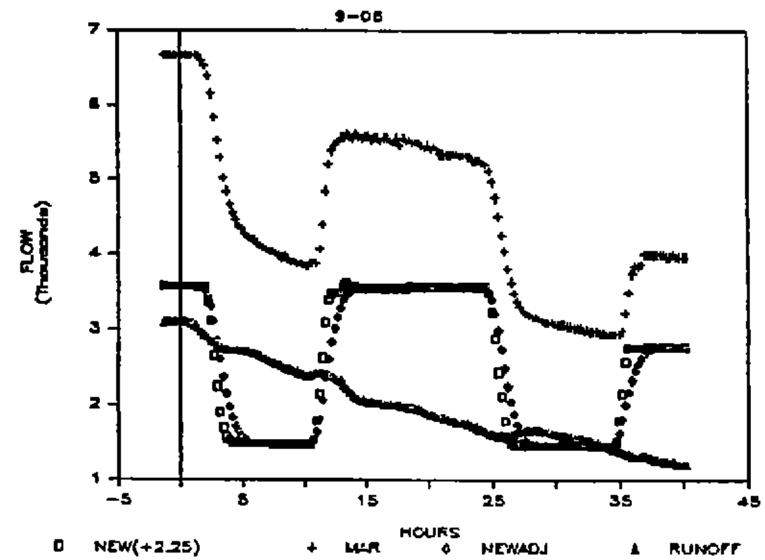


FIGURE 17.

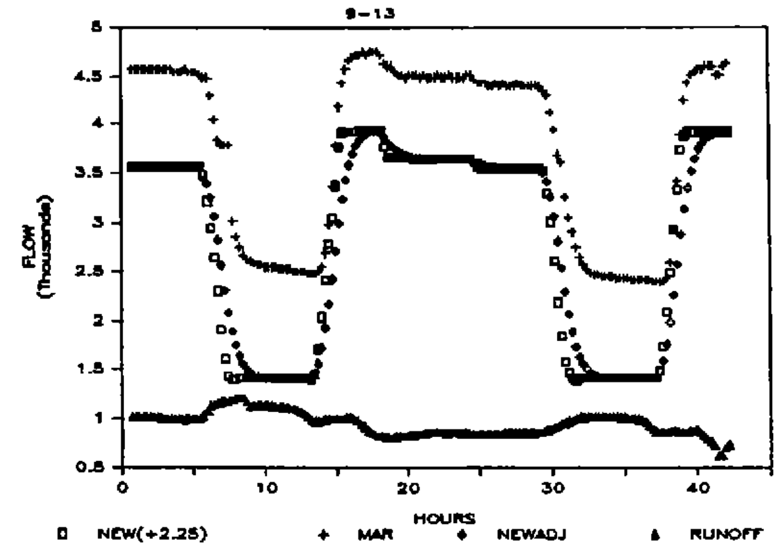


FIGURE 18.

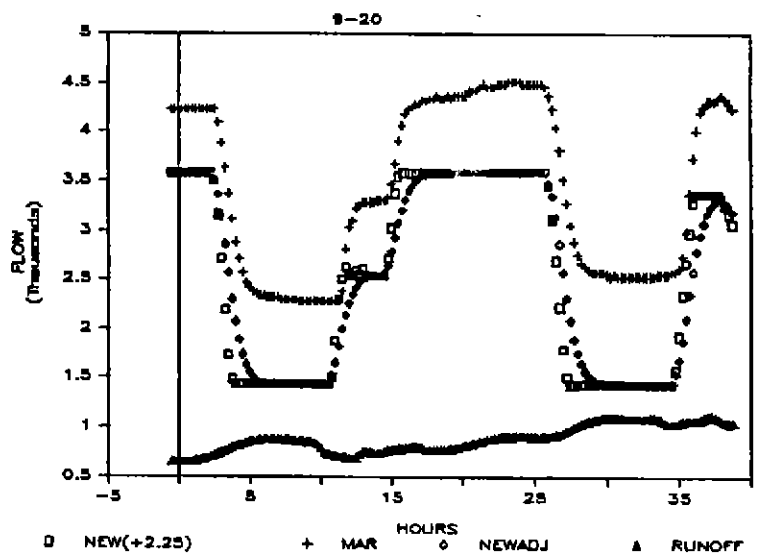


FIGURE 19.

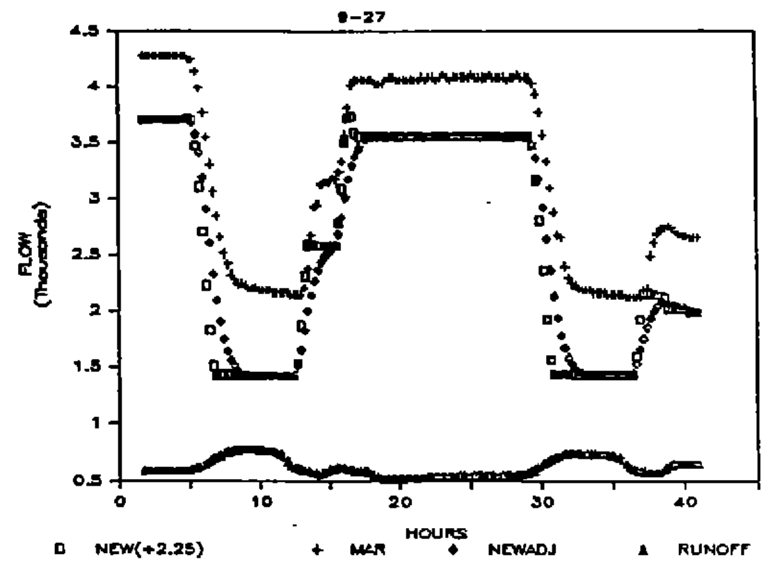


FIGURE 20.

FIGURES 17, 18, 19, and 20. RUNOFF PREDICTIONS FOR DOWNRAMP TEST DATES OF SEPTEMBER 6, 13, 20, AND 27, 1984

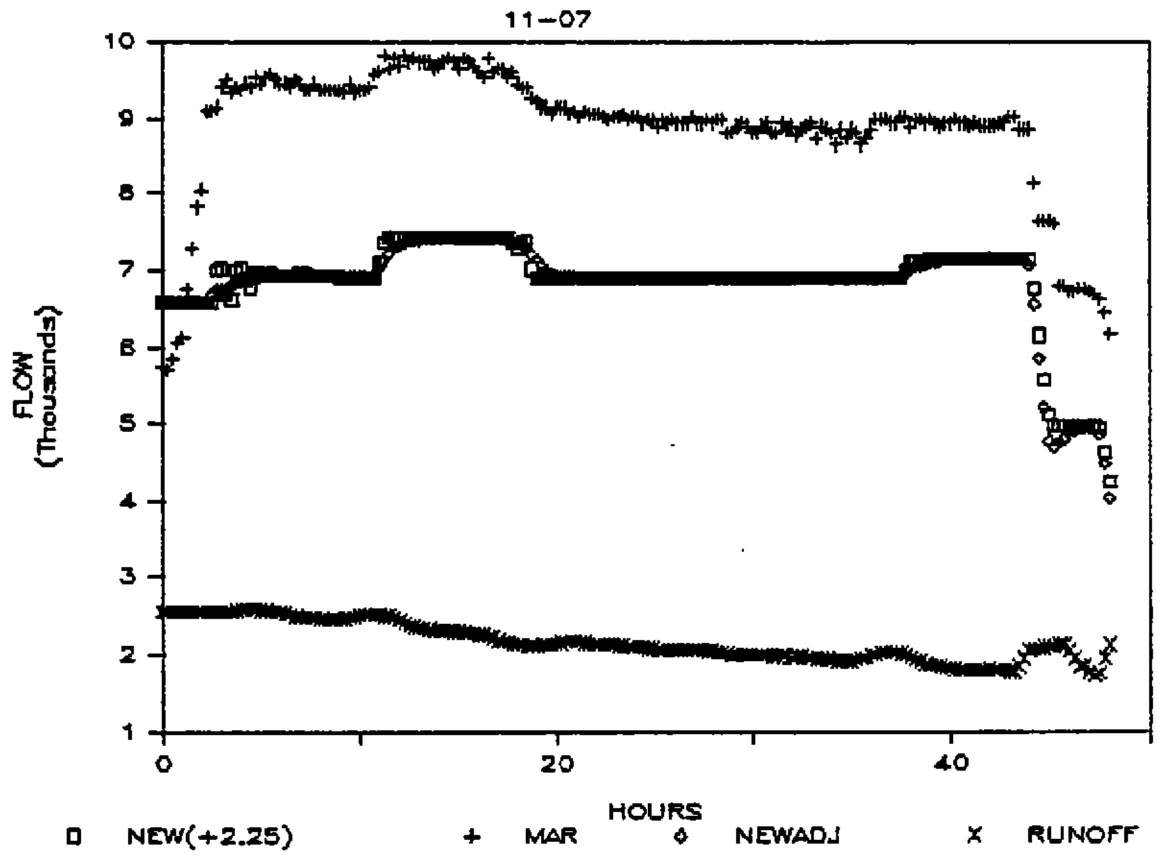


FIGURE 21.

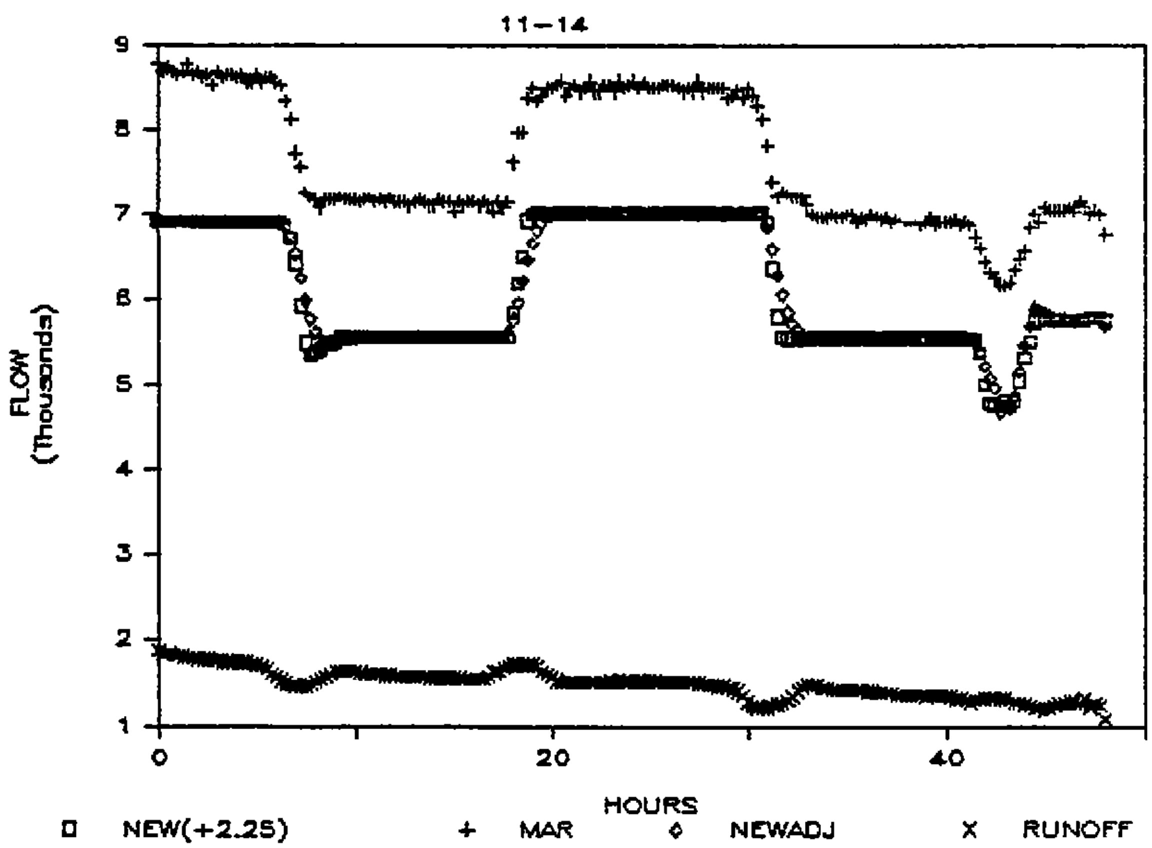


FIGURE 22.

FIGURES 21 and 22. RUNOFF PREDICTIONS FOR DOWNRAMP TEST DATES OF NOVEMBER 7, 8, 14, and 15, 1984

Rockport Flows

Predictions of Rockport flows were made by applying (1),(2), and (3) to the observed Marblemount flow. In this application the runoff is assumed known. It is the previously estimated runoff plus .94 of the runoff. This increment to the runoff is intended to account for additional inflow between Marblemount and Rockport. When the runoff is given (1) becomes a predicter for the Rockport flow R(t). That is, substitute R(t) for M(t) and M(t) for N(t) in equation (1).

The graphs showing the predicted Rockport flows do not show the displacement in time between Marblemount and Rockport flows. The displacement was incorporated when values were extracted from the estimates for inclusion in the master file of all data.

The predicted Rockport flows are shown in Figures 23-40.

River Elevations

Strandings of fish are related to potholes, the interconnectivity of potholes, and the depth of water in the potholes. These variables are related to river elevation. Therefore in order to carry out statistical tests a methodology is needed which relates river flow volumes to flow elevations at locations where potholes and fish stranding observations have been made.

Figure 41 shows the USGS evaluation [U.S. Geological Survey, Water Resources Division, Tacoma, Washington, Rating Table for the Skagit River at Marblemount, Washington] of the relationship between gage height and river flow at Marblemount. The observed relation between flow and river elevation can be fit to a function of the form

$$Q = 1210(1 + 0.5(y-1.4) + (y - 1.4)^{1.5}) \qquad (4)$$

where Q is the flow rate (cfs) and y is the river elevation in feet. The comparison of (4) with the observations is indicated in Figure 41.

Equation (4) can be inverted so that elevation can be determined as a function of flow rate. Let

$$x= y- 1.4, \qquad S= Q/1210 -1, \qquad z= x^{0.5} \qquad (5)$$

then (4) may be written

$$z^3 +0.5\, z^2 - S = 0 \qquad (6)$$

which has the solution

$$z= s_1 + s_2 - 1/6. \qquad (7)$$

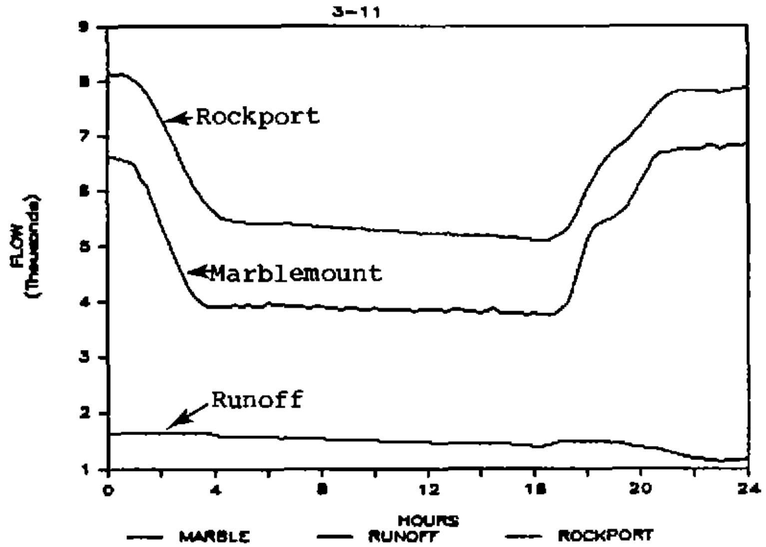


FIGURE 23.

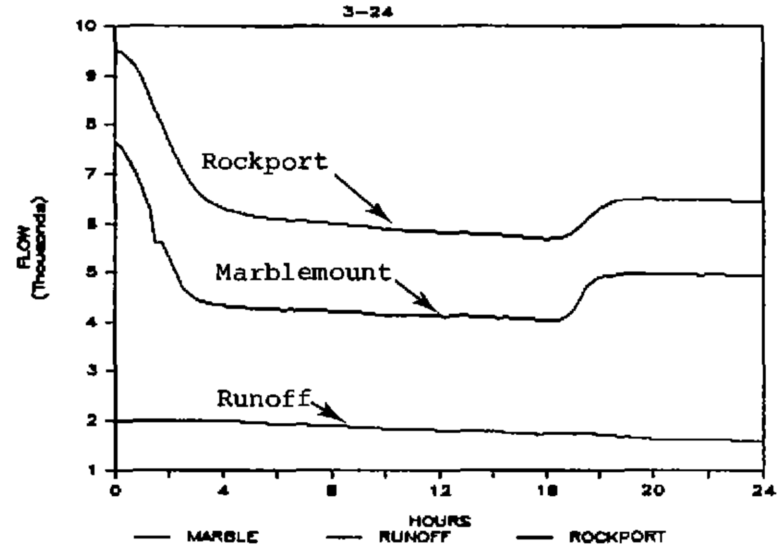


FIGURE 24.

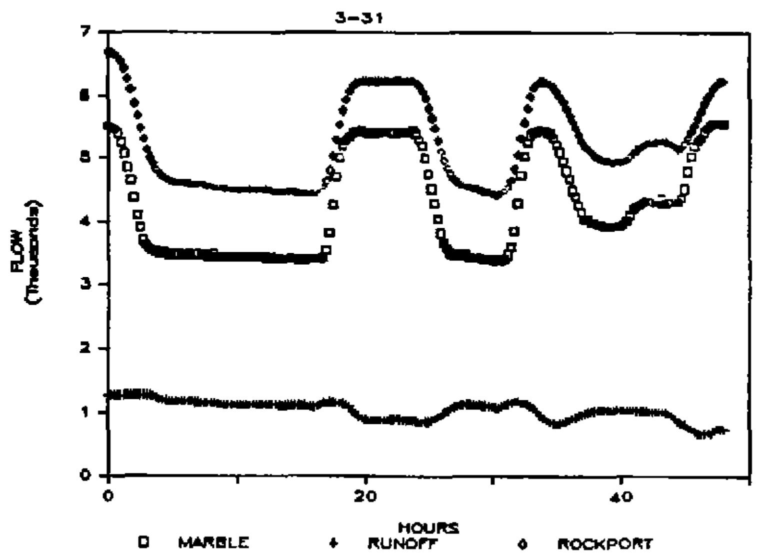


FIGURE 25.

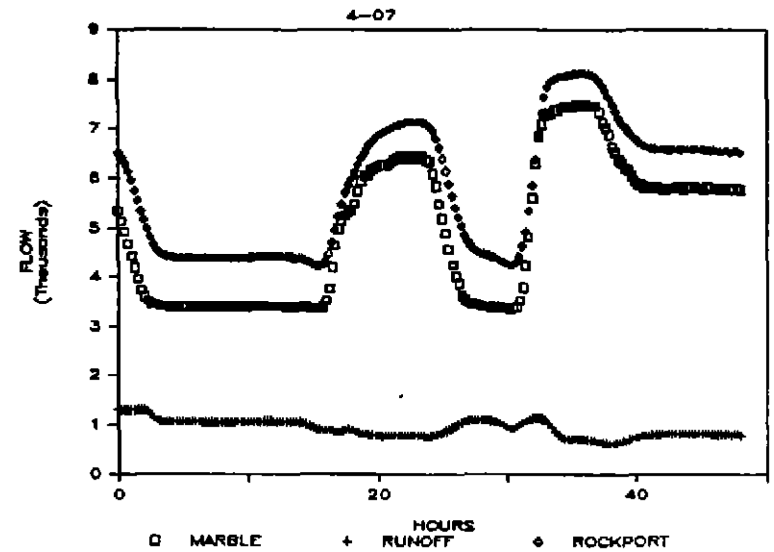


FIGURE 26.

FIGURES 23, 24, 25, and 26. PREDICTED FLOWS (MODELED) AT ROCKPORT FOR MARCH 11, 24, AND 31, 1984 AND APRIL 7, 1984

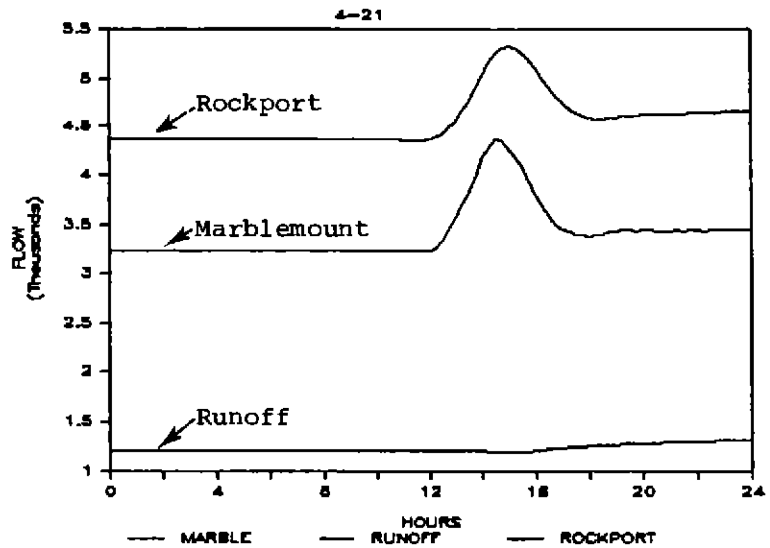


FIGURE 27.

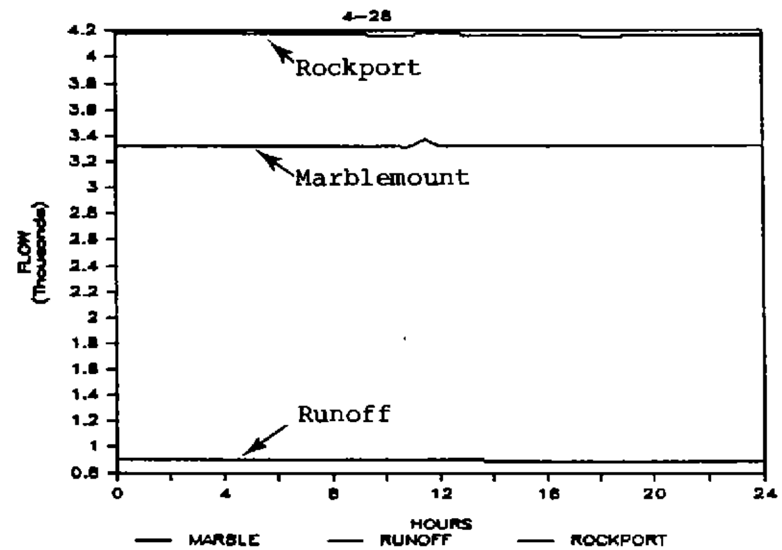


FIGURE 28.

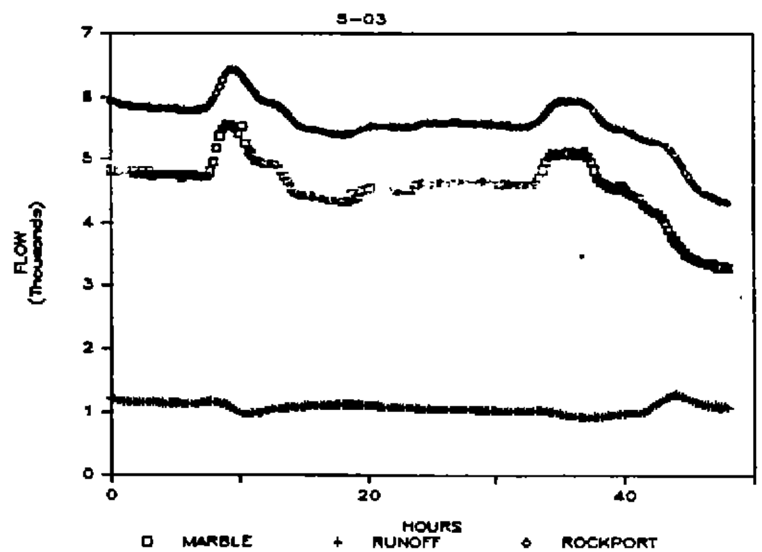


FIGURE 29.

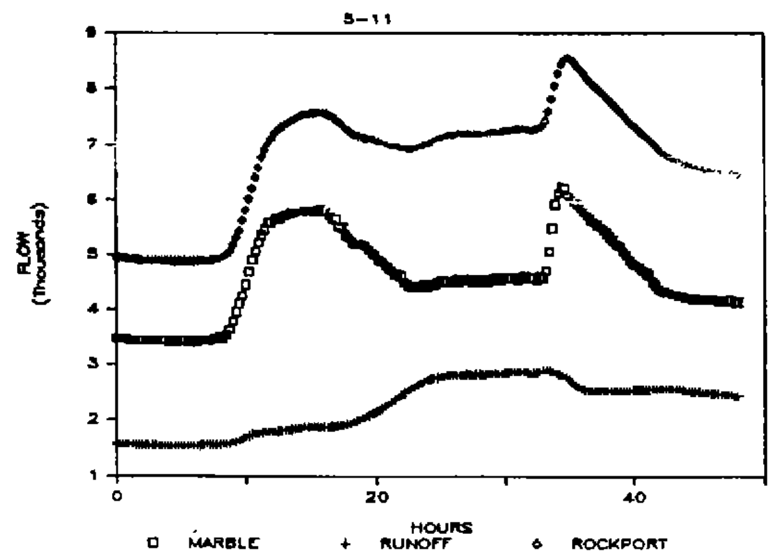


FIGURE 30.

FIGURES 27, 28, 29, and 30. PREDICTED FLOWS (MODELED) AT ROCKPORT FOR APRIL 21 AND 28, 1984 AND MAY 3 AND 11, 1984

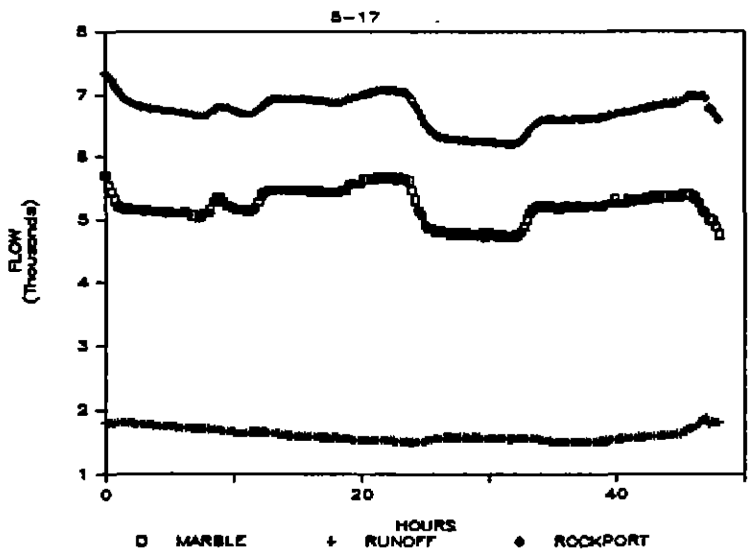


FIGURE 31.

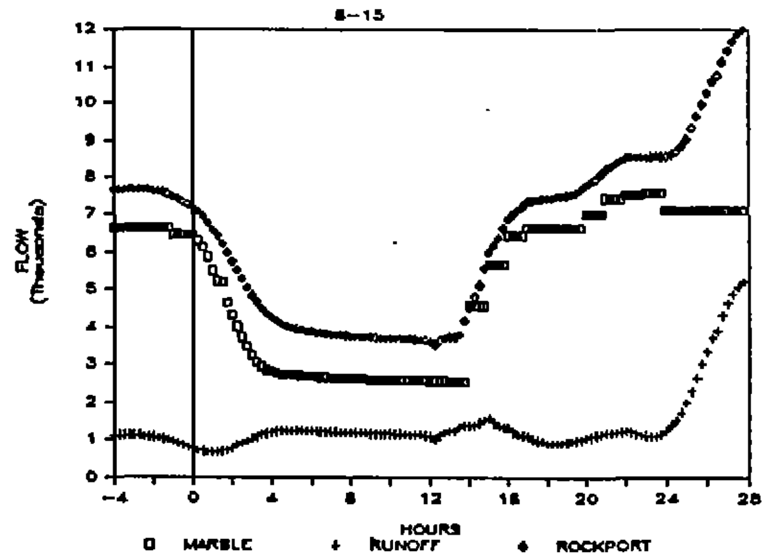


FIGURE 32.

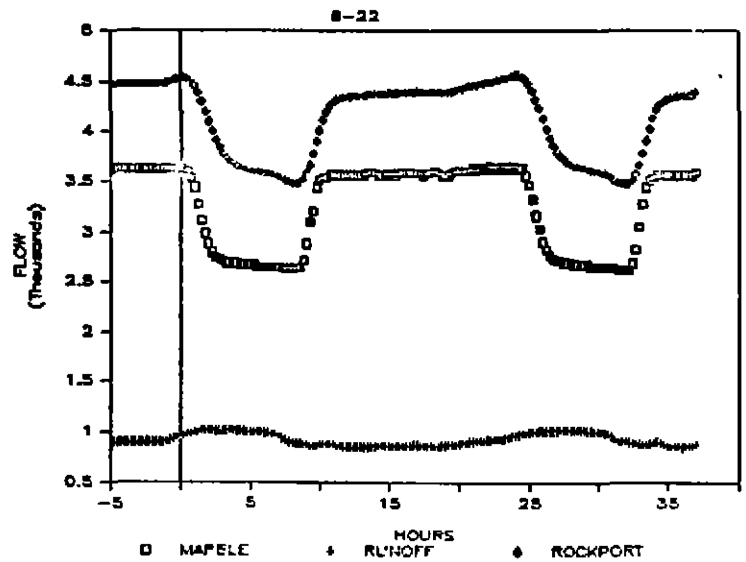


FIGURE 33.

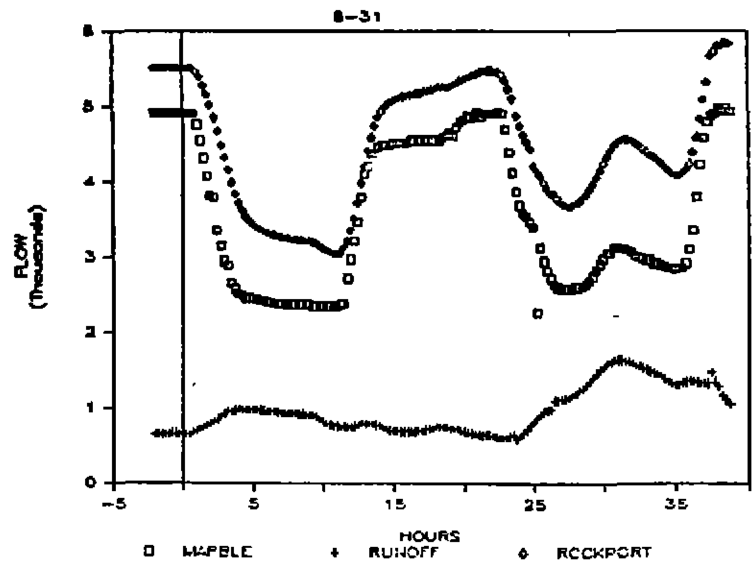


FIGURE 34.

FIGURES 31, 32, 33, and 34. PREDICTED FLOWS (MODELED) AT ROCKPORT FOR MAY 17, 1984, AUGUST 15, 22, AND 31, 1984

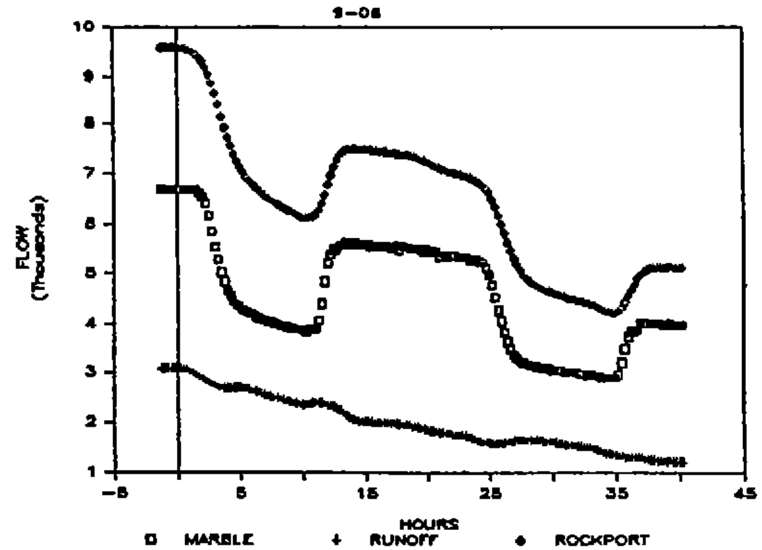


FIGURE 35.

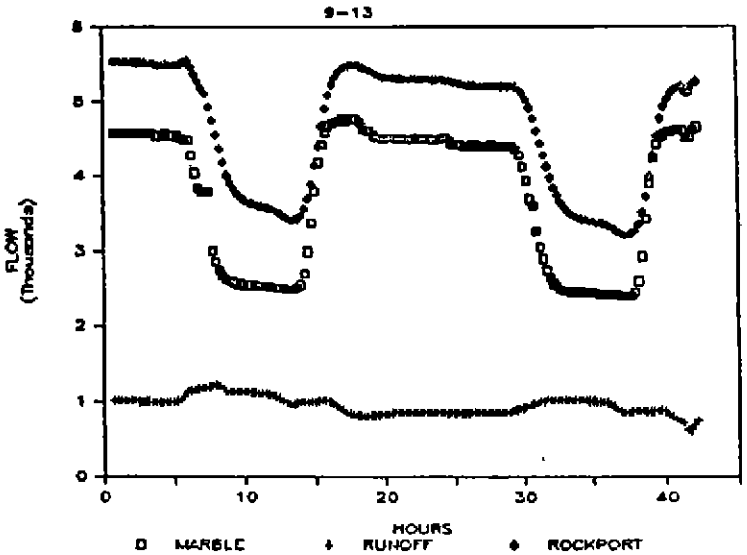


FIGURE 36.

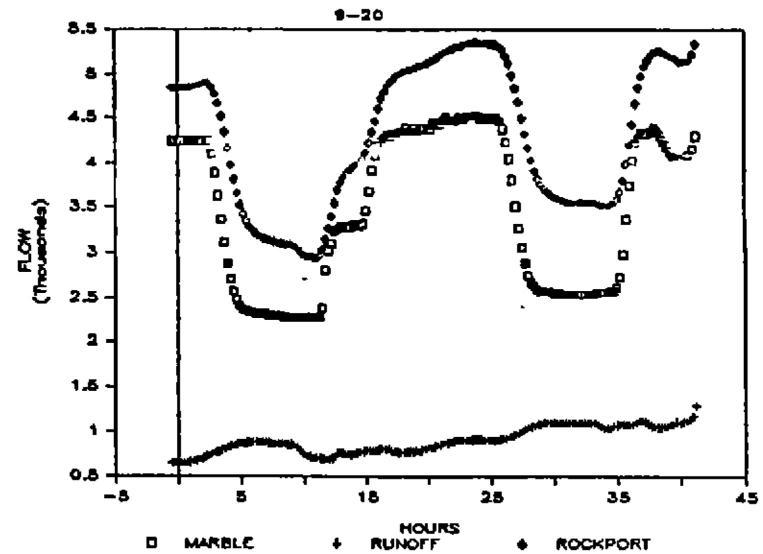


FIGURE 37.

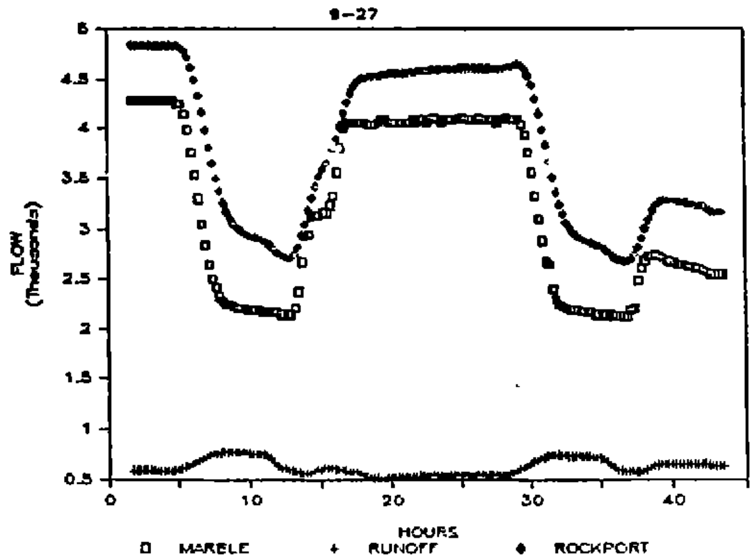


FIGURE 38.

FIGURES 35, 36, 37, and 38. PREDICTED FLOWS (MODELED) AT ROCKPORT FOR SEPTEMBER 8, 13, 20, AND 27, 1984

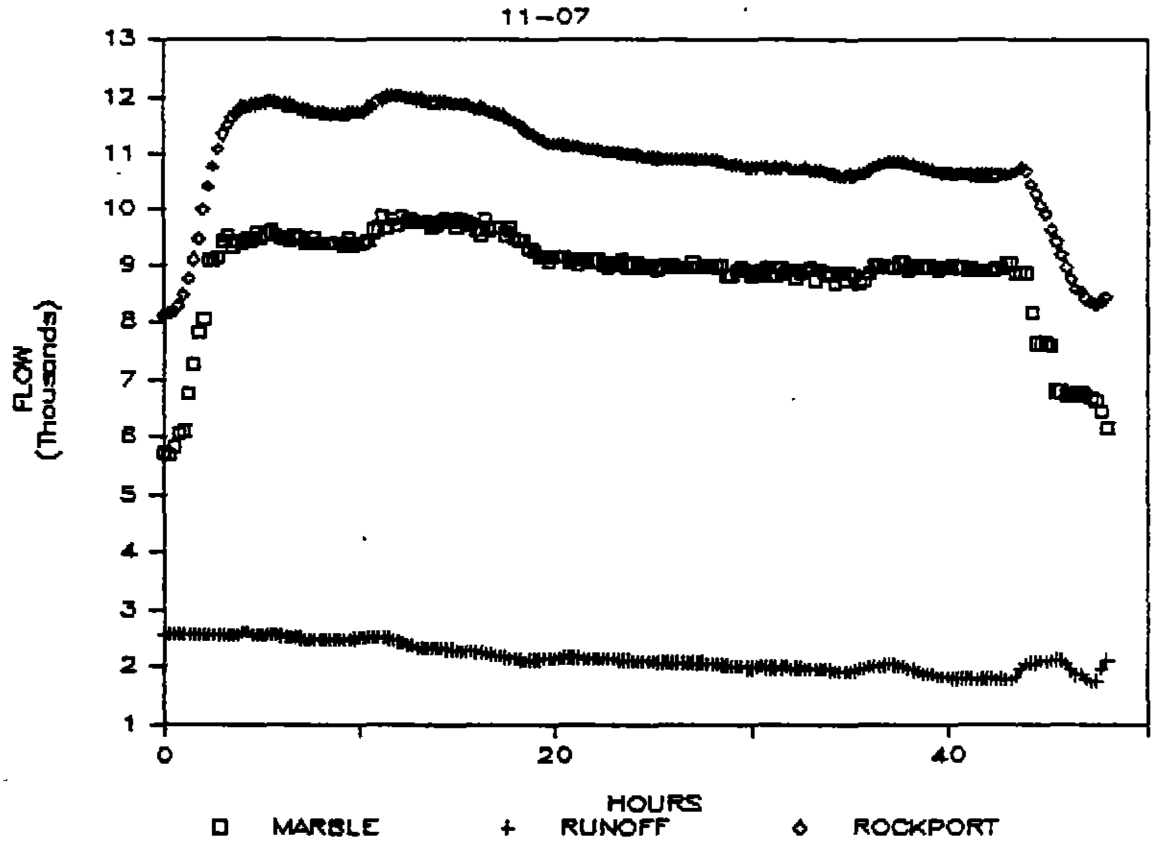


FIGURE 39.

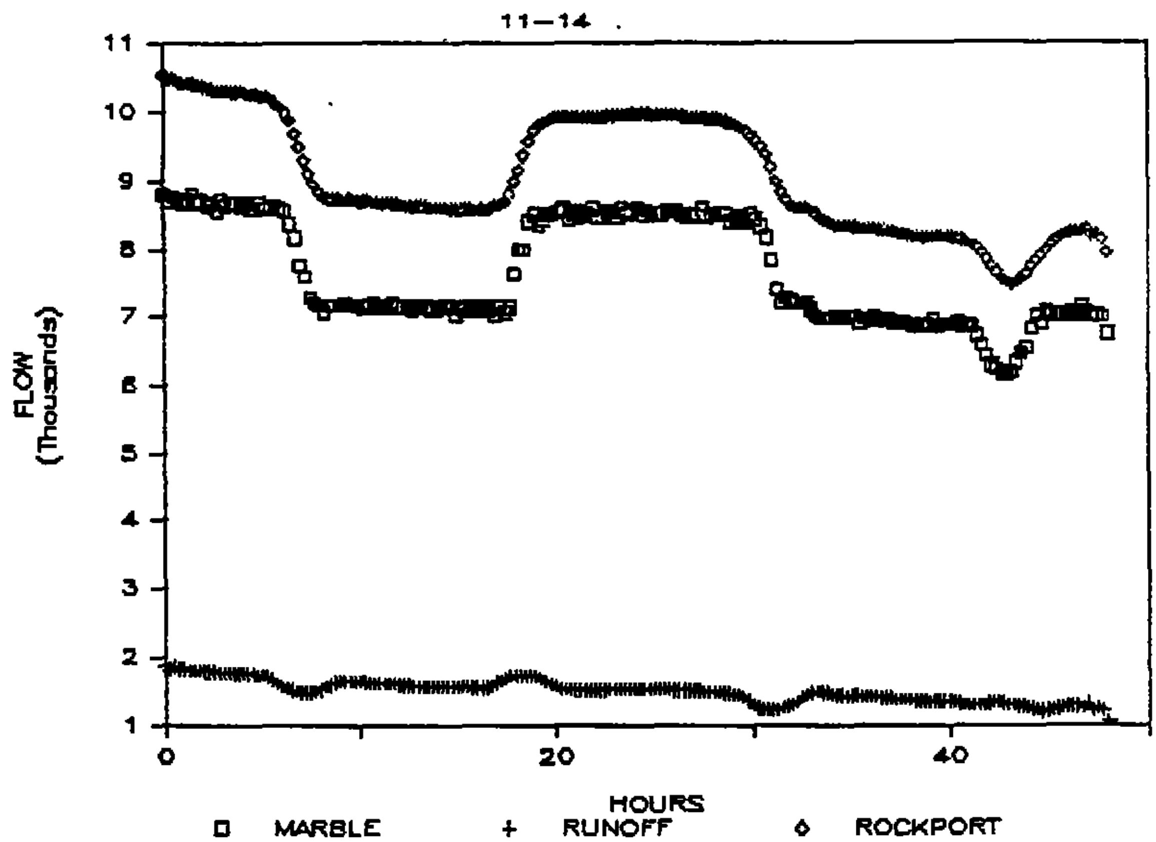
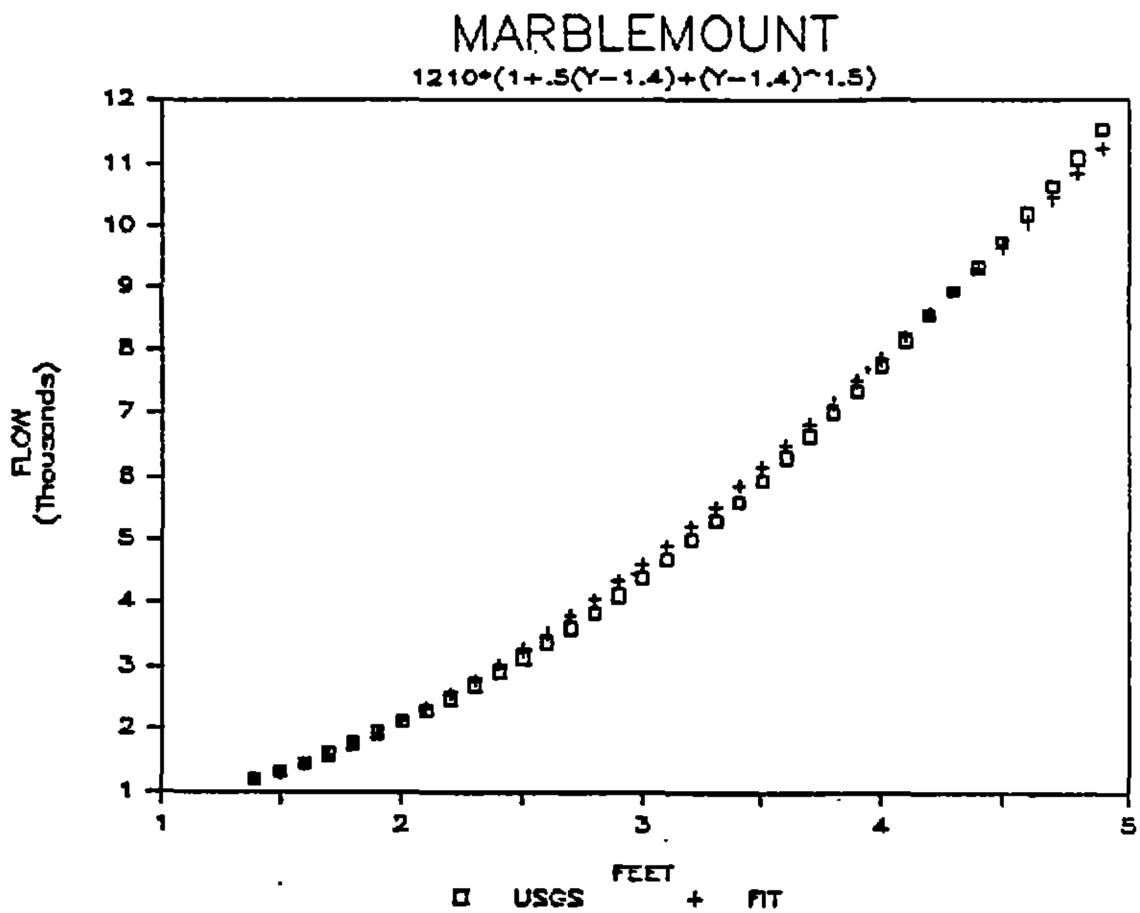


FIGURE 40.

FIGURES 39 and 40. PREDICTED FLOWS (MODELED) AT ROCKPORT FOR NOVEMBER 7, 8, 14, and 15, 1984



Source: USGS, Water Resources Division, Tacoma, Washington, Rating Table for the Skagit River at Marblemount

FIGURE 41. RELATIONSHIP BETWEEN GAGE HEIGHT AND RIVER FLOW AT MARBLEMOUNT BASED ON U.S.G.S. METHODOLOGY

In (7) the factors s_1 and s_2 are given by

$$s_1 = (r + (q^3 + r^2)^{0.5})^{1/3}$$

$$s_2 = (r - (q^3 + r^2)^{0.5})^{1/3} \qquad (8)$$

$$q = 1/36$$

$$r = 0.5S - 1/216$$

These equations have been incorporated into a FORTRAN program which is used to calculate river elevations given the flows.

Because there was no information on the shape of the river channel at Rockport, the same model (4)-(8) was used for both Marblemount and Rockport. River elevations for Marblemount and Rockport are shown in Figures 42-59.

On September 27, 1984 there were some sparse observations of the changes in flow elevation at Rockport as a result of a downramping at the powerhouse. To show the overall consistency of the calculations the observations and predictions are compared in Figure 60. Although all details are not exact, it does appear that both the range of water level change and the time dependence of water level change have been reproduced.

RIVER HEIGHTS

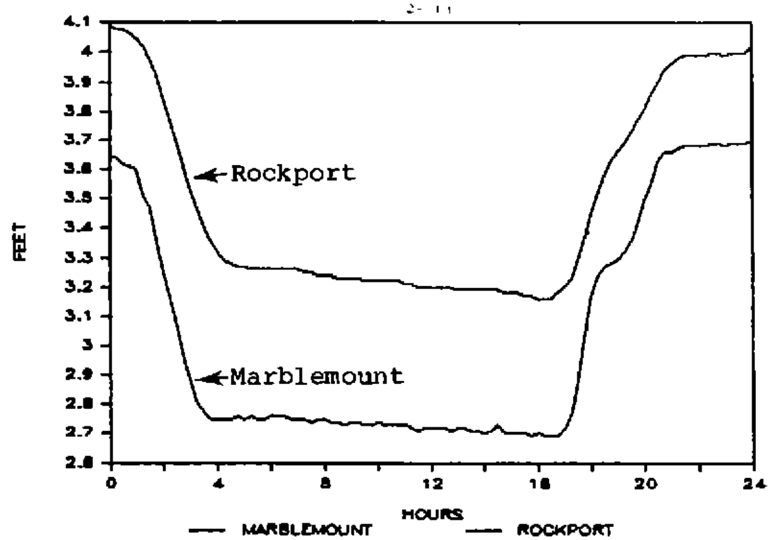


FIGURE 42.

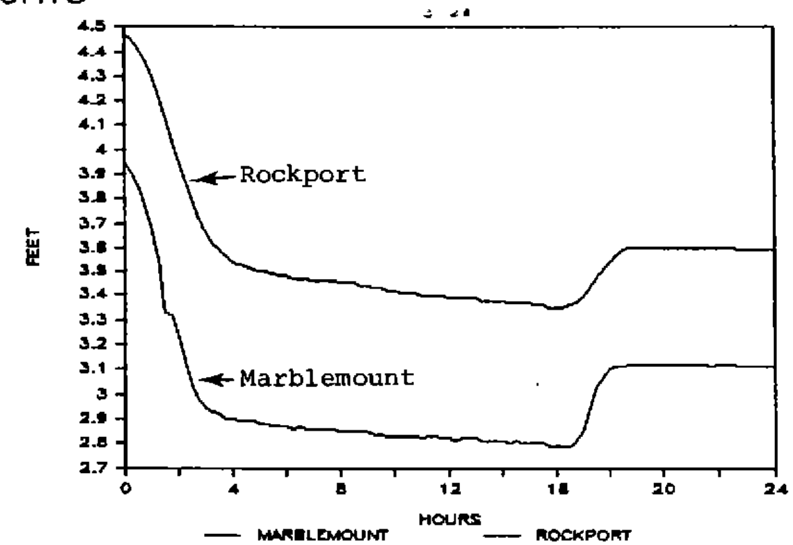


FIGURE 43.

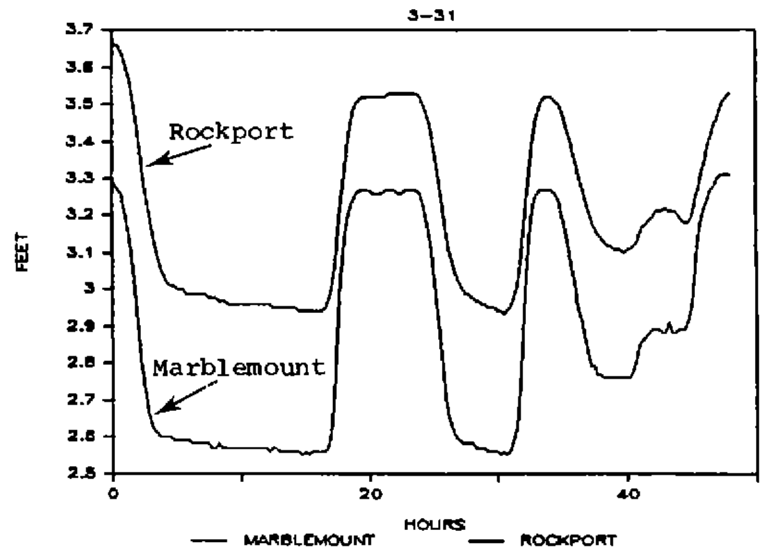


FIGURE 44.

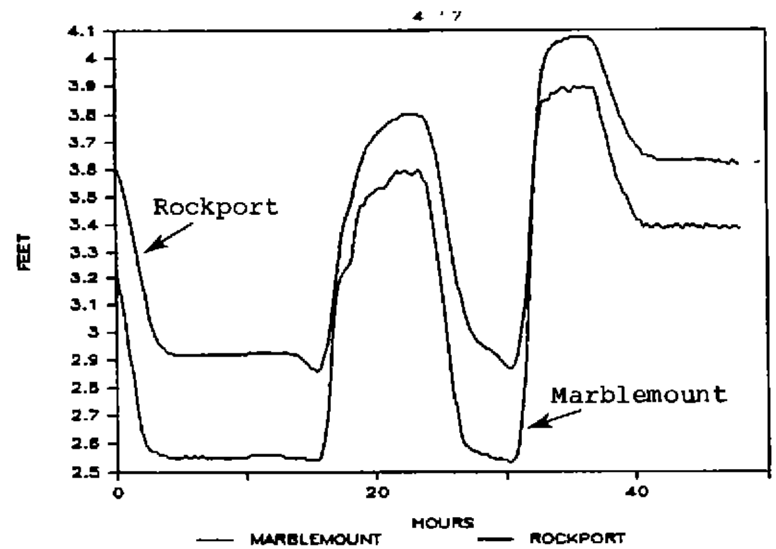


FIGURE 45.

FIGURES 42, 43, 44, and 45. RIVER HEIGHTS AT MARBLEMOUNT AND ROCKPORT FOR TEST DATES MARCH 11, 24, 31, 1984 AND APRIL 7, 1984

RIVER HEIGHTS

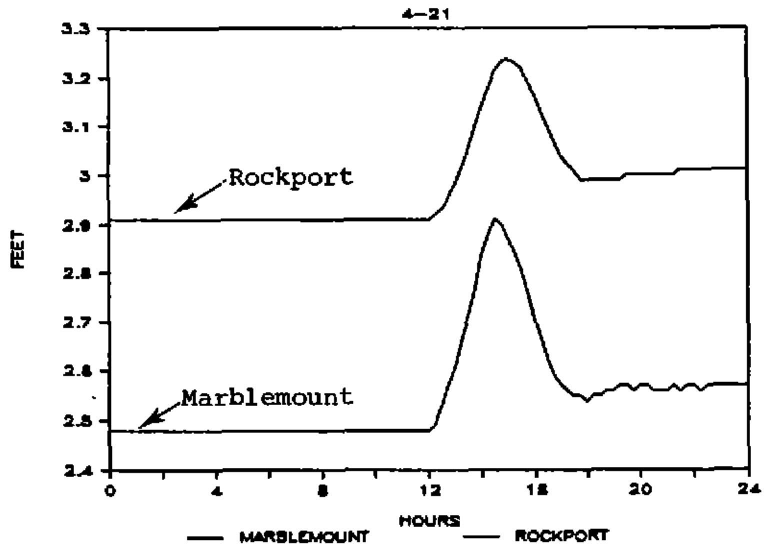


FIGURE 46.

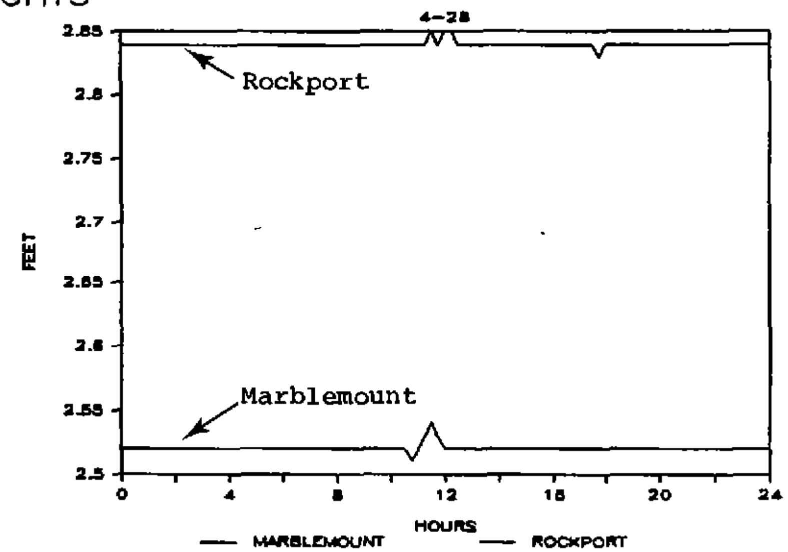


FIGURE 47.

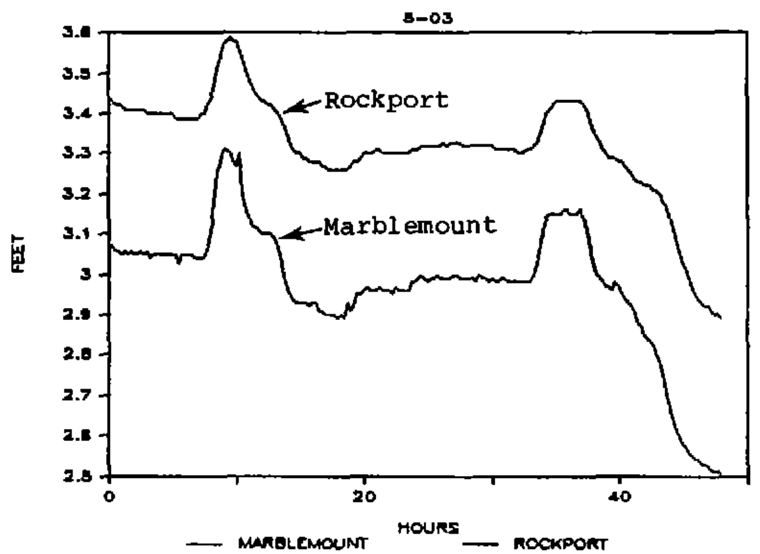


FIGURE 48.

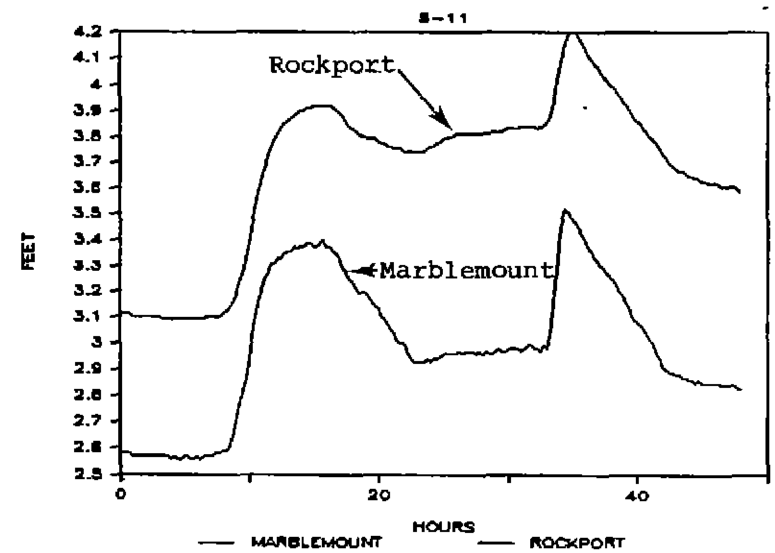


FIGURE 49.

FIGURES 46, 47, 48, and 49. RIVER HEIGHTS AT MARBLEMOUNT AND ROCKPORT FOR TEST DATES APRIL 21, 28, 1984 AND MAY 3 AND 11, 1984

RIVER HEIGHTS

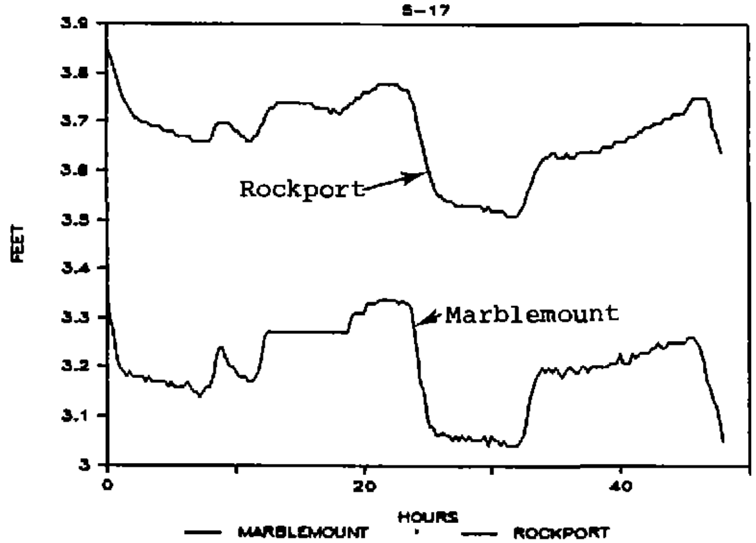


FIGURE 50.

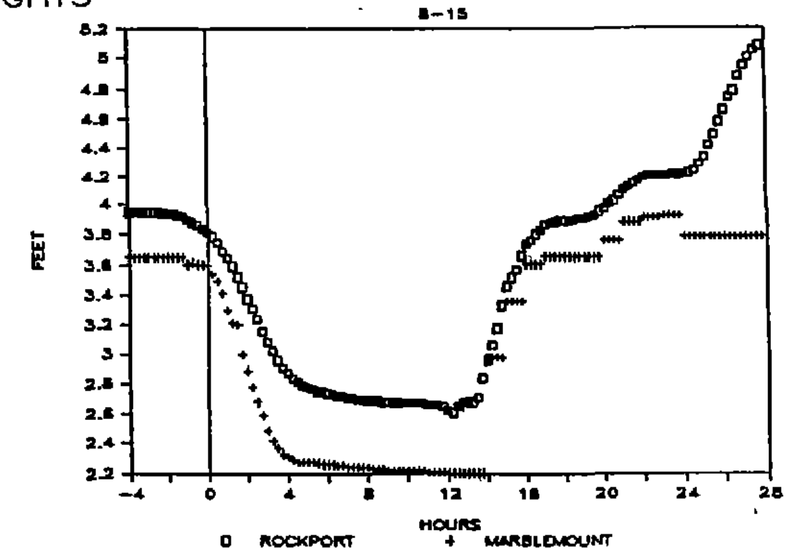


FIGURE 51.

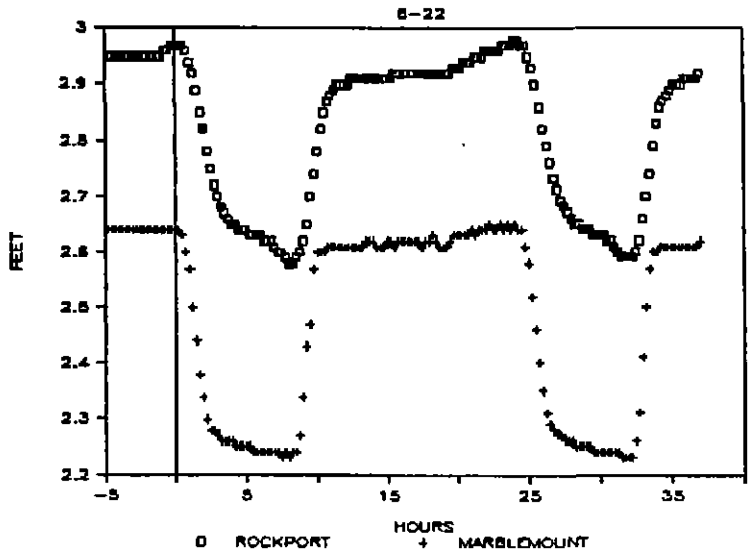


FIGURE 52.

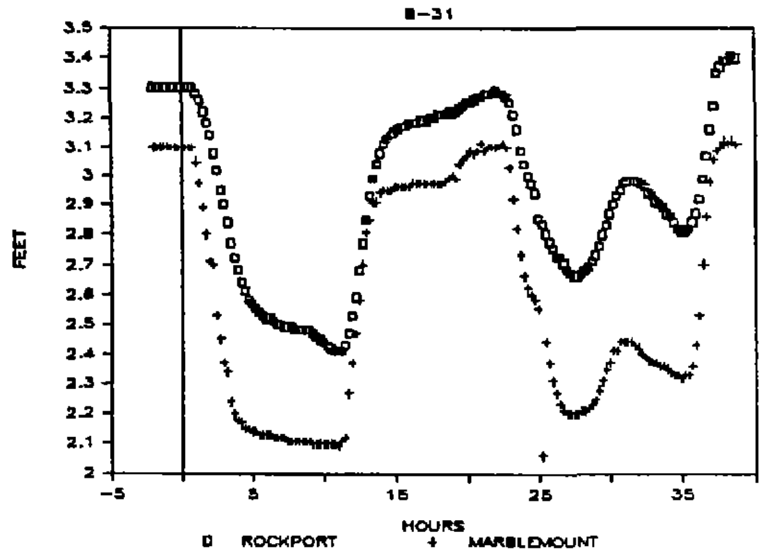


FIGURE 53.

FIGURES 50, 51, 52, and 53. RIVER HEIGHTS AT MARBLEMOUNT AND ROCKPORT FOR TEST DATES MAY 17, 1984, AUGUST 15, 22, AND 31, 1984

RIVER HEIGHTS

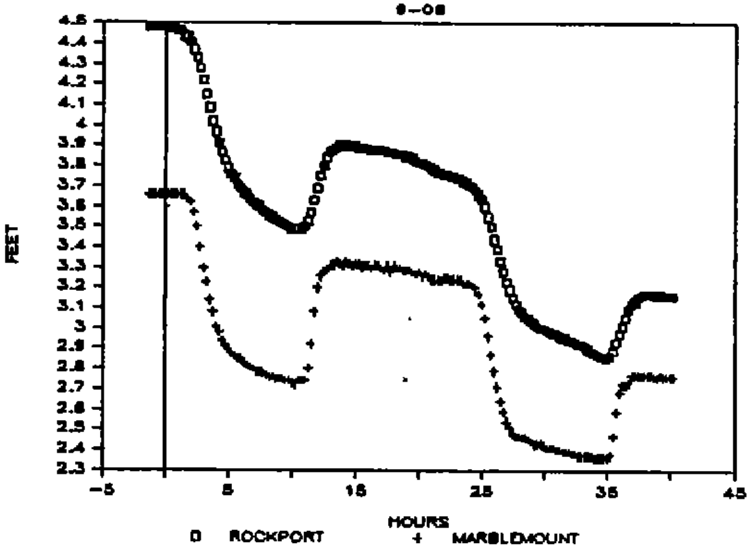


FIGURE 54.

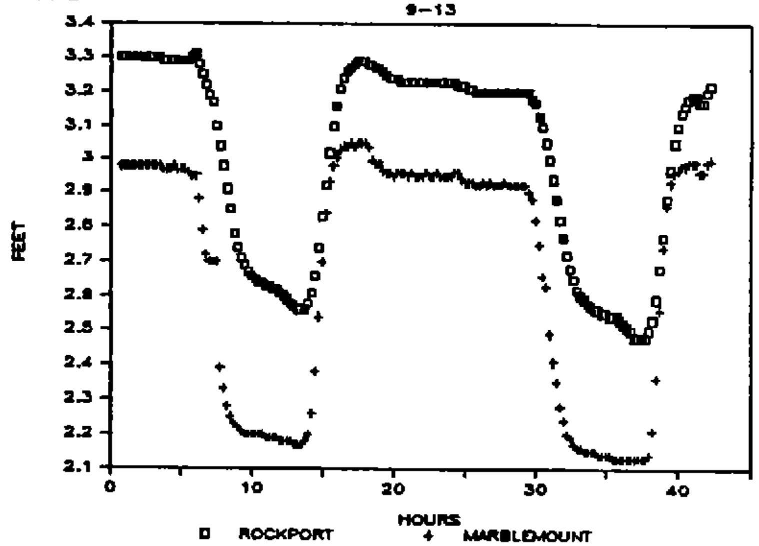


FIGURE 55.

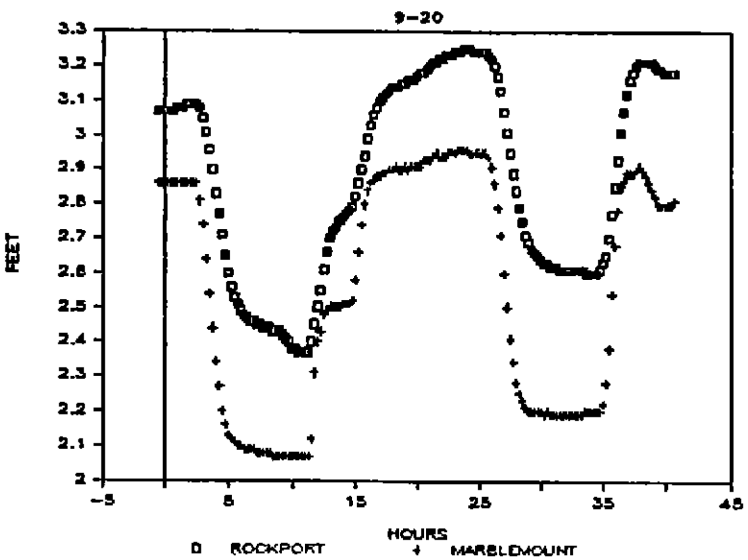


FIGURE 56.

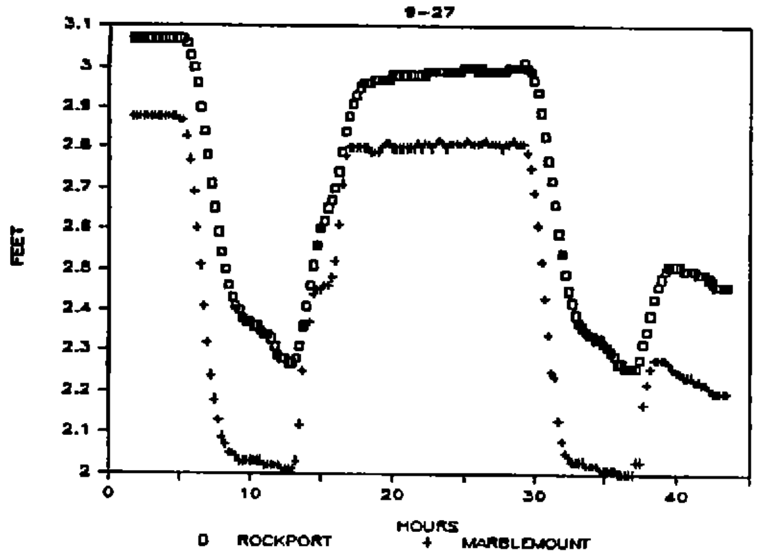


FIGURE 57.

FIGURES 54, 55, 56, and 57. RIVER HEIGHTS AT MARBLEMOUNT AND ROCKPORT FOR TEST DATES SEPTEMBER 8, 13, 20, AND 27, 1984

RIVER HEIGHTS

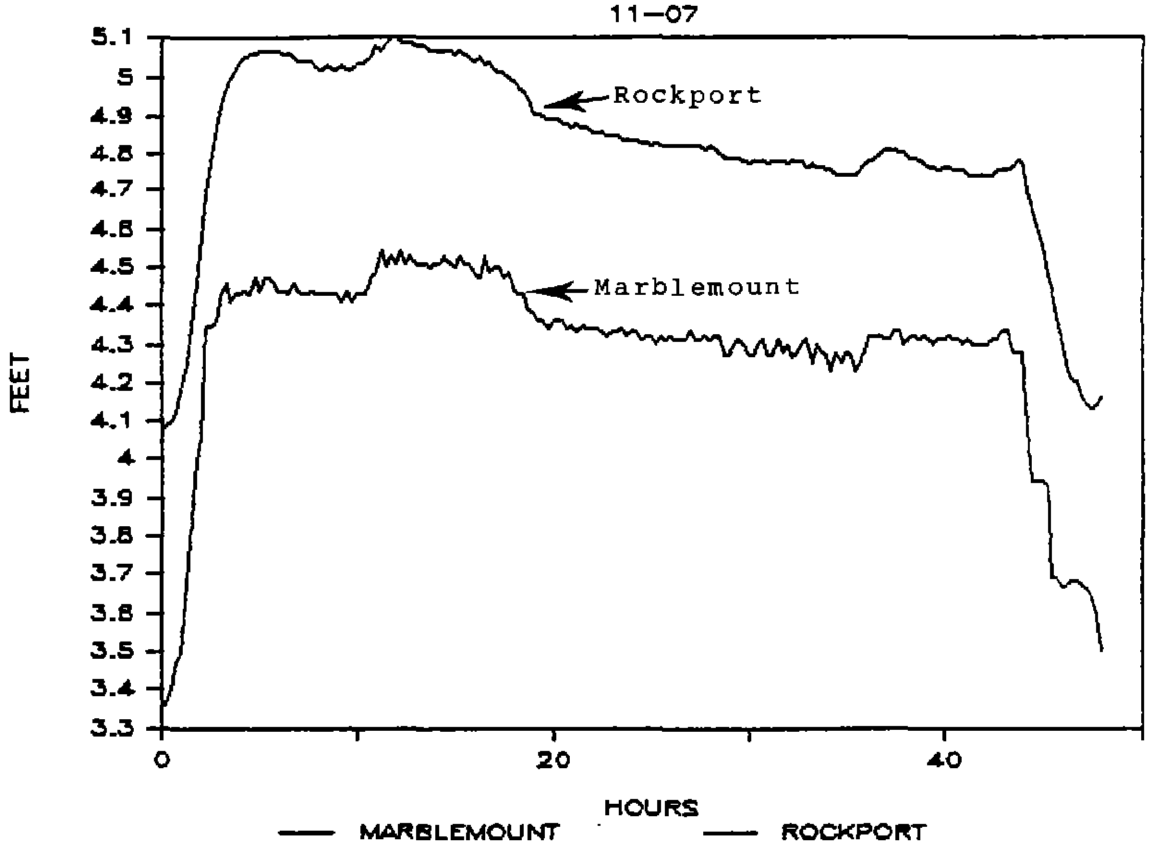


FIGURE 58.

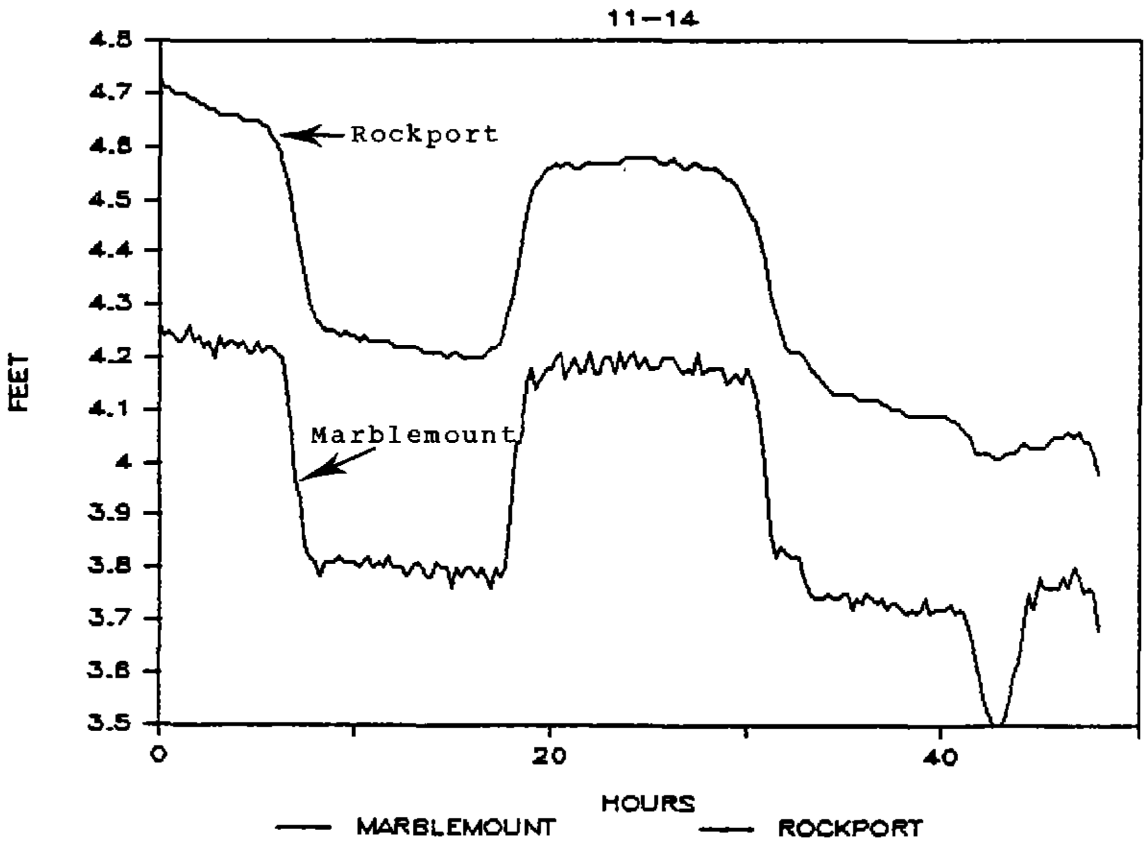


FIGURE 59.

FIGURES 58 and 59. RIVER HEIGHTS AT MARBLEMOUNT AND ROCKPORT FOR TEST DATES NOVEMBER 7, 8, 14, and 15, 1984

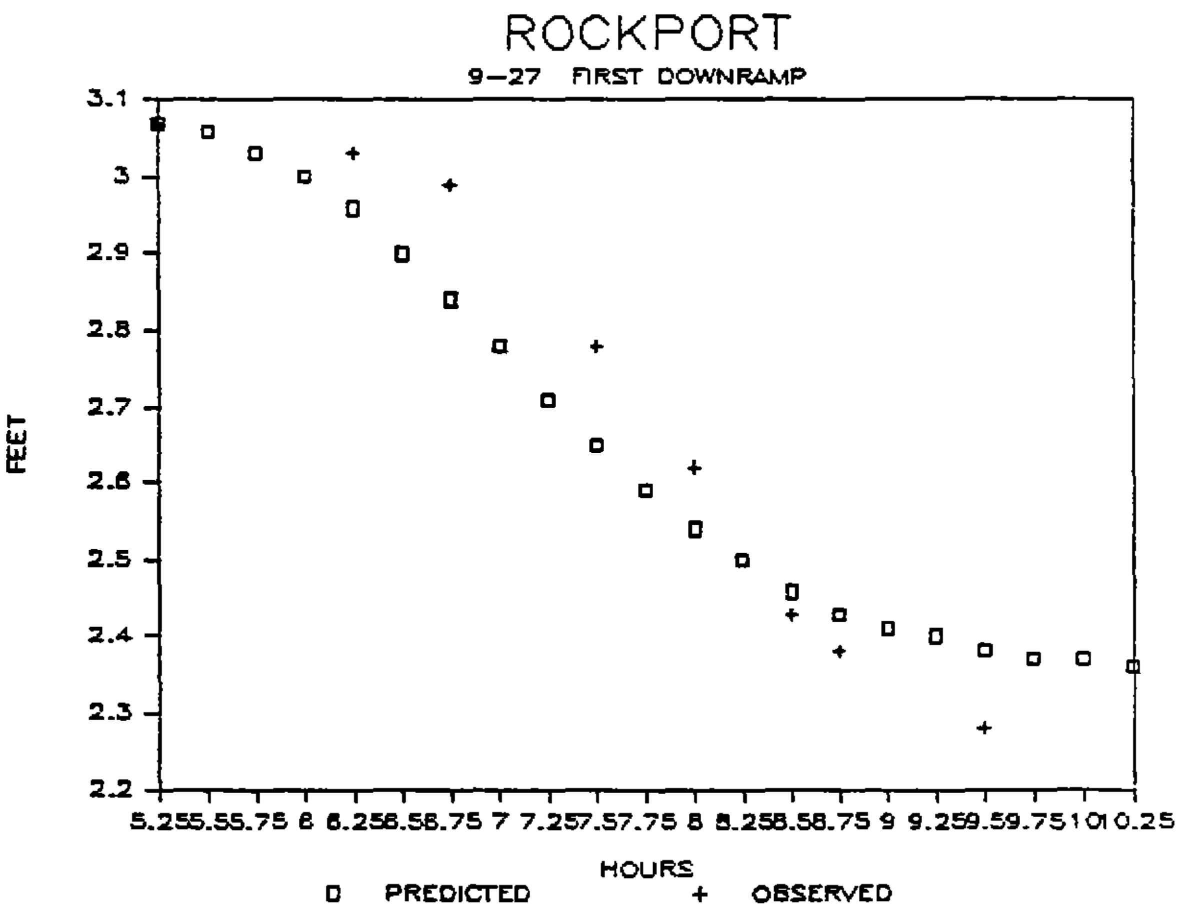


FIGURE 60. PREDICTED (MODELED) VERSUS OBSERVED SKAGIT RIVER FLOWS FOR SEPTEMBER 27, 1984 AT ROCKPORT, WASHINGTON

APPENDIX D

COMPUTER DATA ENTRY FORM

DATA FORM

Item #	Description	Eg/Column #
Card 1		
1	Pothole Site	W S 1 2
2	Pothole Number	1 3 B 3 4 5
3	River Mile	7 8 . 2 6 7 8 9
4	Date - Month	0 9 10 11
5	Date - Day	2 7 12 13
6	Date - Year	8 4 14 15
7	Time - Hours	0 9 16 17
8	Time - Min.	3 0 18 19
9	Maximum Depth	0 . 6 7 20 21 22 23
10	Average Depth	0 . 1 3 24 25 26 27
11	Connectivity 0 = not connected; 1 = connected; 2 = dry	1 28
12	Average Length	1 0 0 . 5 29 30 31 32 33
13	Average Width	3 7 . 3 34 35 36 37
14	Pothole Temperature	7 5 . 5 38 39 40 41

Item #	Description	Eg/Column #
15	Cover 1 0 = root wad; 1 = roots; 2 = sticks; 3 = logs; 4 = boulder, rocks; 5 = submerged vegetation; 6 = overhanging vegetation; 7 = no cover	$\overset{1}{42}$
16	Cover 2 (Categories same as Cover 1)	$\overset{2}{43}$
17	Substrate 1 1 = silt; 2 = sand; 3 = pea gravel; 4 = gravel (½-4") 5 = cobble (4" & up)	$\overset{1}{44}$
18	Substrate 2 (Categories same as Substrate 1)	$\overset{2}{45}$
19	Number of Fry Trapped	$\overset{1}{46}$ $\overset{0}{47}$ $\overset{0}{48}$ $\overset{0}{49}$
20	Number of Fry Stranded	$\overset{0}{50}$ $\overset{1}{51}$ $\overset{0}{52}$ $\overset{0}{53}$
21	Seepage 0 = no seepage; 1 = seepage	$\overset{0}{54}$
22	River Gage	$\overset{1}{55}$ $\overset{.}{56}$ $\overset{2}{57}$ $\overset{5}{58}$
23	Pothole Gage	$\overset{1}{59}$ $\overset{.}{60}$ $\overset{1}{61}$ $\overset{5}{62}$
24	River Temperature	$\overset{4}{63}$ $\overset{5}{64}$ $\overset{.}{65}$ $\overset{5}{66}$
25	Card Number	$\overset{1}{80}$

Item #	Description	Eg/Column #
Card 2		
26	Pothole Site	W S 1 2
27	Pothole Number	1 3 B 3 4 5
28	River Mile	7 8 . 2 6 7 8 9
29	Date - Month	0 9 10 11
30	- Day	2 7 12 13
31	Date - Year	8 4 14 15
32	Time - Hours	0 4 16 17
33	Time - Min.	1 0 18 19
34	Elevation at Marblemount	_ _ _ _ 2 . 2 4 20 21 22 23 24 25 26 27
35	Elevation at Rockport	_ _ _ _ 2 . 7 6 28 29 30 31 32 33 34 35
36	Flow at Newhalem	_ 1 4 4 1 . 36 37 38 39 40 41
37	Flow at Marblemount	_ 1 4 4 1 . 42 43 44 45 46 47
38	Flow at Rockport	_ 1 4 4 1 . 48 49 50 51 52 53
39	Trapping	_ _ 1 1 0 . 54 55 56 57 58 59
40	Stranding	_ _ 1 0 0 . 60 61 62 63 64 65

Item #	Description	Eg/Column #
41	Instantaneous Stranding	66 67 68 69 70 71: _ _ 1 2 0 .
42	Adjusted trap. (Max. #)	72 73 74 75 76 77 78 79: _ _ 1 0 0 . 0 0
43	Card Number	80: 2

APPENDIX E

Appendix E. High Flow Potholes Observed Between Alma Creek and Newhalem During the Reconnaissance Survey of November 7 and 8, 1984, with Gorge Powerhouse Discharge of Approximately 7,000 cfs

RIVER MILE	POTHOLE AREA	RIVER BANK	POTHOLE FIELD #	DEPTH (FT)	LENGTH (FT)	WIDTH (FT)	CONNECT.	COVER*	SUBSTRATE**	TEMP (°F)	REBAR***
88.0	Damnation Creek	West	16	0.40	18	12	Seepage	6	5	48	No
89.2	County Line Ponds	West	17	0.50	50	20	Yes	6	1	-	No
89.5	Flood Plain Bar	East	1	0.50	9	1	No	6	1	-	No
	Flood Plain Bar	East	2	0.42	3	2	No	6	1	-	No
	Flood Plain Bar	East	3	0.25	100	3	No	6	1	-	No
	Flood Plain Bar	East	4	0.50	6	4	No	6	1	-	No
	Flood Plain Bar	East	5	0.33	6	2	No	6	1	-	No
90.0	No Name Island	East	1	0.33	9	7	Yes	7	5	-	No
	No Name Island	East	2	0.17	2	2	No	6	1	-	No
	No Name Island	East	3	0.25	6	2	No	6	1	-	No
	No Name Island	East	4	1.00	10	6	No	6	1	-	No
	No Name Island	East	5	1.89	15	4	No	6	1	-	No
	No Name Island	East	6	0.33	5	4	Yes	6	1	-	No
	No Name Island	East	7	0.50	10	4	Yes	7	1	-	No
	No Name Island	East	8	0.42	26	3	No	6	1	-	No
	No Name Island	East	9	0.50	10	4	No	7	1	-	No
	No Name Island	East	10	0.25	24	1	No	6	1	-	No
	No Name Island	East	11	0.17	20	10	No	1	1	-	No
	No Name Island	East	12	0.25	10	2	No	1	1	-	No
	No Name Island	East	13	0.25	9	3	No	6	1	-	No
	No Name Island	East	14	0.26	20	5	Yes	7	5	-	No
	No Name Island	East	15	0.33	20	10	No	6	1	-	No
	No Name Island	East	16	0.50	15	2	No	6	1	-	No
90.2	Thornton Creek	West	15	0.30	20	10	Yes	6	2	47	No
90.5	Three Island Bar	East	1	1.32	12	10	Yes	3	5	-	Yes
	Three Island Bar	East	2	0.60	10	8	No	6	1	-	Yes
	Three Island Bar	East	3	1.68	30	12	No	6	2	-	Yes
	Three Island Bar	East	4	0.38	9	2	No	6	5	-	Yes
	Three Island Bar	East	5	0.62	12	5	No	6	5	-	Yes
	Three Island Bar	East	6	1.18	25	12	Yes	6	1	-	Yes
	Three Island Bar	East	7	0.51	20	20	Yes	6	1	-	Yes
	Three Island Bar	East	8	0.65	20	5	Yes	3	1	-	Yes
	Three Island Bar	East	9	0.90	30	12	Yes	6	1	-	Yes
	Three Island Bar	East	10	1.00	50	20	Yes	6	5	-	Yes
	Three Island Bar	East	11	0.50	8	8	Yes	6	2	-	Yes
	Three Island Bar	East	12	0.68	20	10	Yes	3	2	-	Yes
	Three Island Bar	East	13	1.25	15	15	No	6	1	-	Yes
	Three Island Bar	East	14	0.71	100	6	No	6	1	-	Yes
	Three Island Bar	East	15	0.30	15	4	No	6	1	-	Yes
	Three Island Bar	East	16	0.52	3	1	No	6	1	-	Yes
	Three Island Bar	East	17	1.44	175	25	No	6	5	-	Yes
	Three Island Bar	East	18	1.60	75	15	No	6	5	-	Yes
	Three Island Bar	East	19	0.64	150	8	No	6	2	-	Yes
	Three Island Bar	East	20	1.02	50	20	No	6	2	-	Yes
	Three Island Bar	East	21	1.00	100	20	Yes	6	1	-	Yes
	Three Island Bar	East	22	3.00	100	20	No	1	5	-	Yes
	Three Island Bar	East	23	1.50	200	50	No	3	1	-	Yes
	Three Island Bar	East	24	0.50	100	10	No	6	1	-	No

Appendix E. Continued

RIVER MILE	POTHOLE AREA	RIVER BANK	POTHOLE FIELD #	DEPTH (FT)	LENGTH (FT)	WIDTH (FT)	CONNECT.	COVER*	SUBSTRATE**	TEMP (°F)	REBAR***
	Three Island Bar	East	25	0.67	20	10	No	3	1	-	No
	Three Island Bar	East	26	1.00	100	80	NO	6	1	-	No
	Three Island Bar	East	27	0.75	80	10	No	6	1	-	No
	Three Island Bar	East	28	3.00	400	30	Yes	6	2	-	No
	Three Island Bar	East	29	0.42	12	10	No	6	5	-	No
	Three Island Bar	East	30	0.33	8	3	No	6	2	-	No
90.8	Boat Launch	West	14	0.30	9	6	Seepage	6	4	45	No
91.2	--	East	8	0.30	150	20	Seepage	6	5	-	No
91.3	Pond Bar	West	13	0.30	60	10	No	6	1	41	No
91.5	--	East	4	0.50	36	12	No	6	5	47	No
	--	East	5	0.50	48	18	No	6	5	47	No
	--	East	6	0.40	20	20	No	0	5	47	No
	--	East	7	0.40	80	15	Yes	6	1	47	No
92.1	--	East	3	0.40	15	6	Yes	6	2	48	No
92.5	Cobble Bar	East	1	0.50	33	5	No	6	2	45	No
	Cobble Bar	East	2	0.20	30	4	No	6	2	45	No
92.8	Goodell Creek	West	10	1.00	18	6	No	0	2	44	No
	Goodell Creek	West	11	0.20	10	10	Yes	6	2	47	No
	Goodell Creek	West	12	0.40	15	3	Yes	1	2	47	No

* Cover Codes: 0 = rootwad; 1 = roots; 2 = sticks, limbs; 3 = logs; 4 = boulders, rocks; 5 = submerged vegetation; 6 = overhanging vegetation; 7 = no cover.

** Substrate Codes: 1 = silt; 2 = sand; 3 = pea gravel; 4 = gravel (1/2 - 4"); 5 = cobble (>4").

*** Rebar set in pothole during reconnaissance survey.

APPENDIX F

STATISTICAL ANALYSES

APPENDIX F

SUMMARY OF RESULTS OF STATISTICAL ANALYSIS OF FRY TRAPPING AND STRANDING STUDY DATA

Introduction:

This section contains a detailed discussion of statistical analyses conducted on the Skagit River fry trapping and stranding study data. Variables thought to impact salmon and steelhead fry the most were those having to do with operations at Gorge Dam--river flow and ramping amplitude, as well as the physical characteristics of the potholes themselves. The relationship of trapping with these variables was treated directly, with trapping itself as the independent variable.

Numbers of fish stranded, however, is meaningful only as a proportion of fish originally trapped, i.e., the number of fish who die out of the number of fish at risk. For that reason all relationships of stranding to flow and pothole conditions were treated as conditional probabilities, modelling the <u>logistic transform</u> of the ratio of stranding to trapping as a function of the variables of interest. BMDPLR, (BMDP, 1981) or Biomedical Data Analysis Program for the Logistic Regression model, allows the entering of number at risk as COUNTS, and the number of "failures" as FCOUNTS. The logistic transform (Cox, 1977) then gives a linear model

$$L_i = \log(t_i/(1-t_i)) = B_0 + B_1 x \qquad (1)$$

where L_i is the logistic transform of t_i, the probability that a particular case (trapped fish) will <u>not</u> become a failure or stranded fish (BMDPLR models the probability of <u>success</u>). This proportion, t_i, is aggregated across all fish stranded within one pothole and is represented by the proportion of fish which survive over trapped fish in one pothole. As is evident from the extreme right hand side of equation (1), this transformation of the proportion can be modeled as a linear function of the independent variables. Because of the use of maximum likelihood or asymtotic covariance methods instead of least squares in arriving at parameter estimates, collinearity in the independent variables no longer poses a problem when modelling regressions. This model has the additional advantage of ability to incorporate categorical variables (i.e., cover, substrate types) as linear predictors.

Fall and Spring Breakdown:

Regressions of trapping and stranding/trapping on river flows, downramp amplitudes, and flow history have been done in two ways: once on the full data set, including both spring and fall, and again with spring and fall data separated. In most cases results differed when data was broken down by season. Regression effects which had been significant on the entire data set often were not significant when the smaller seasonal data sets were run or were replaced by other effects. Such changes in regression effect can have four possible interpretations: 1) the strengths of the effects of flows, amplitudes, and flow history did, in fact, change by season as reflected by the varying regression results, 2) regression results, which were weak due to large variation in the data (see R^2 values) for flows, amplitudes, and flow history, were unstable and subject to the influence of differing sample sizes, and 3) severe confounding between the main effects and time changed over the seasons, and 4) all three of the above conditions were in effect.

Multivariate Analysis:

Purpose:

A preliminary multivariate analysis was run to investigate the associations between a number of the variables in the data set. This analysis was to serve as an exploratory tool, highlighting variables and relationships which merited further testing.

Method:

A factor analysis was run on the following set of variables: river mile (RMILE), julian date (JULDAY), the minimum depth throughout the day of each pothole at its deepest point (MAXD), the length (LEN) and the width (WID) of the pothole, the maximum pothole temperature (PTEMP), the river gage reading (RGAGE), the flow code (FLOC) an integral code related to river mile, assigning a flow gage station (i.e., Newhalem, Rockport, and Marblemount) to each pothole, the river flows at the three stations (RFLON, RFLOM, and RFLOR), the flow at which connectivity occurs (CF) and the flow at which disconnectivity occurs (DF), the maximum flow at Newhalem just prior to downramping (MAXFLO1) and the maximum flow for the last 24 hours (MAXFLO2), the minimum flow at Newhalem throughout the day (MINFLO), the number of times the pothole was observed to be dry throughout the day (PRDRY), the area (AREA) and the volume (VOL) of the pothole (computed from LEN, WID, and MAXD), and the trapping (TRAP)[1] and stranding (STRAND)[2]. The output was a covariance matrix which gave the pairwise correlation between every pair of the above variables. This analysis was run first on the entire data set (4314 cases), then again on a set of data for which data having a missing value for one or more of the above variables were excluded (50 cases).

----

[1]One was added to this value for all non-missing cases in the data set. This was subtracted off in the analysis, except for when the logs were taken.
[2]See footnote for TRAP.

Results:

Since this is an exploratory analysis only, pairs of variables for which the correlation coefficient is more than .2 or less than -.2 are listed in the following table. Note that for 50 or more cases a correlation coefficient of greater than .279 or less than -.279 is considered statistically significant at the .05 level (Dixon and Massey, 1969).

Table 1

Variables	Full set (4314)	Reduced set (50)
RMILE-FLOC	-.874	-.871
RMILE-PTEMP		-.205
RMILE-RGAGE		-.205
RMILE-MAXFLO1	-.201	-.240
RMILE-MAXFLO2		-.205
RMILE-MINFLO	-.229	-.414
JULDAY-RGAGE		-.352
JULDAY-RTEMP		-.202
JULDAY-RFLON	-.225	-.486
JULDAY-RFLOM	-.220	-.754
JULDAY-RFLOR	-.202	-.586
MAXD-LEN	.503	.621
MAXD-WID	.585	.593
MAXD-TRAP		.376
MAXD-RFLON		.297
MAXD-PTEMP	.450	
MAXD-MAXFLO1		.233
MAXD-MAXFLO2		.243
MAXD-PRDRY	-.329	
MAXD-AREA	.411	.477
MAXD-VOL	.451	.518
LEN-WID	.762	.835
LEN-PTEMP	.302	
LEN-TRAP	.278	.344
LEN-AREA	.884	.918
LEN-VOL	.684	.890
WID-PTEMP	.428	
WID-TRAP	.280	.301
WID-AREA		.860
WID-VOLUME		.838
PTEMP-TRAP		.282
PTEMP-PRDRY	-.585	
TRAP-RFLOR		-.222
TRAP-MAXFLO1		-.237
TRAP-MINFLO		-.200
TRAP-AREA	.221	.283
TRAP-VOL		.274
RGAGE-RTEMP	.335	

Table 1

Variables	Full set (4314)	Reduced set (50)
RGAGE-FLOC		.331
RGAGE-RFLON		.295
RGAGE-RFLOM		.621
RGAGE-RFLOR		.695
RGAGE-MAXFLO1		.870
RGAGE-MINFLO		.854
FLOC-MAXFLO1	.245	.284
FLOC-MAXFLO2		-.215
FLOC-MINFLO	.281	.433
RFLON-RFLOM	.799	.488
RFLON-RFLOR	.698	.448
RFLON-MAXFLO1	.351	.419
RFLON-MAXFLO2		-.205
RFLON-MINFLO	.364	.463
RFLOM-RFLOR	.960	.926
RFLOM-MAXFLO1	.432	.728
RFLOM-MAXFLO2	.365	-.285
RFLOM-MINFLO	.526	.757
RFLOR-MAXFLO1	.463	.860
RFLOR-MAXFLO2	.323	
RFLOR-MINFLO	.527	.818
MAXFLO1-MAXFLO2	.728	
MAXFLO1-MINFLO	.818	.955
MAXFLO1-PRDRY	-.202	
MAXFLO2-MINFLO	.562	-.224
MINFLO-PRDRY	-.230	
AREA-VOL	.842	.990

Conclusion:

Of the above long list of correlations, some are obvious and redundant, such as that of FLOC with RMILE and RFLON with all other flow variables. Positive values for these correlations are, however, comforting to observe as they act as a cross check on the validity of the values of these variables. Of special interest, however, is the positive correlation of trapping with pothole size (i.e., LEN and WID) and pothole temperature, PTEMP. A separate correlation coefficient was run to compare STRAND with TRAP for non-zero values of TRAP (682 cases). A correlation coefficient of .0074 (not significant) was observed for this run. The conclusion is that stranding does not necessarily increase as trapping increases.

Limitations:

This analysis was done only on the extremes of the full data set or just the cases with no missing data. This analysis should be repeated on a subset of the variables which are present for most of the cases, thereby providing an intermediate sized data set on which to test the correlations. One suggestion is to run the factor analysis using only variables of greatest interest only on cases where TRAP = 0.

Connectivity of Potholes as a Result of Downramping and Flow Releases at the Gorge Powerhouse.

See text for discussion. These data did not lend themselves to a statistical model.

Multivariate Regression of Three Flows on Trapping and Stranding

Purpose:

This analysis was run to asses the effect of the magnitude of flows at three gage stations, Newhalem, Marblemount, and Rockport simultaneously first on trapping, then on stranding.

Trapping, Full Data Set:

Methods:

The relationship between trapping and the flows at the three stations (Newhalem, Marblemount, and Rockport) was investigated with a multiple regression of TRAP versus RFLON, RFLOM, and RFLOR simultaneously. There were 3486 cases in the analysis. Preliminary inspection of a normal probability plot of the residuals showed a marked skewed and curvilinear relationship, indicating that the linear fit was a poor one. This was corroborated by an extremely small R^2 of .0025 even though the regression was significant at F=2.95, p=.0314. Of the three flows, only RFLOR had a significantly non-zero coefficient (p=.04). Both the R^2 and p value of the F test were improved (to .0173 and F=3.98, p=.0078 respectively) by taking the log transform of TRAP (LTRP) and dropping the zero values of TRAP out of the data set. This left 709 cases. However, this time, none of the flow coefficients was significantly non-zero. The exclusion of zero TRAP values brought the normal probability plot of the residuals much closer to the ideal straight line. Investigation of the residuals plotted against the independent variable, however, still showed a fan shape that narrowed and inclined downward as flows increased. This fan shape as well as the low R^2 was an indication that the linear model still does not describe this relationship well.

Inspection of the covariance matrix of the three coefficients showed presence of strong multicollinearity. In order to investigate the extent of this as well as to determine whether the flows at one of the gage stations would be sufficient to describe the relationship, a forward stepwise multiple regression was run, allowing the model to choose the most significantly related flow. This approach, however, was not expected to correct the shape of the residual curve.

Results:

The forward stepwise regression procedure first calculates an F statistic individually for each independent variable. This F statistic, called an F-to-enter, measures the significance of the regression effect of the given independent variable on the dependent variable. When the value of this statistic is high, that is above the critical 0.1 probability level, the variable is considered related and included into the stepwise regression procedure.

While the original F's-to-enter of RFLON and RFLOM were high, (6.80 and 5.88, respectively, the p value for both $< .05$) RFLOM, the flow at Marblemount, was seen to have the highest F to enter (10.67, $p < .001$), making the fit more statistically significant although the R^2 of 0.0154 did not show an improvement in the fit.

TABLE 2

VARIABLES	COEFFICIENTS (S.E.)	T-VALUES	P
Intercept	0.703		
RFLOM	0.0000975 (.0000299)	3.27	< .001

The coefficient for RFLOM is small because flow values are on the order of 10^3. Inclusion of RFLOM into the equation precluded the presence of any other flow variable.

Conclusion:

While the flow at all three gage stations seems to be related to trapping, the flow at the Marblemount gage station is most strongly related. Because of their strong correlation with RFLOM, it was not possible to assess the effects of RFLON and RFLOR independently. Notice that the coefficient of the effect of RFLOM is positive. This would indicate that the greater the minimum flow at Marblemount the greater the trapping. This result which runs counter to intuition is perhaps due to a confounding effect with date. Large trapping events tended to occur in the beginning of the season when flows were high. This would be related more to the age of the fish than to the flows themselves. Later in this appendix is described a regression which was done on the relationship between trapping and flow at Marblemount, broken down by season, and adjusted for julian date. Here the coefficient of the flow became negative as would be expected.

Limitations:

A fan shape exhibited by residuals for the simple linear model indicated the inadequacy of this model to fully explain the relationship between trapping and flows. A more complete analysis should be run, including along with julian date (see Conclusion paragraph above), other variables such as pothole depth (MAXD), area (AREA), and flow history variables (see page 8 of this appendix). Some of the variables needed to explain trapping may not even be present in the 1984 fry stranding study data set.

Trapping, Spring Only:

Results:

The F's-to-enter of RFLON and RFLOM from a stepwise multiple regression on 449 cases are high, (6.36 and 10.32, respectively, the p value for both $< .05$) RFLOM, the flow at Marblemount, was seen to have the highest F to enter (12.11, $p < .001$), making the fit statistically significant although the R^2 of 0.0264 shows a pattern of large variances and departures from the fit.

TABLE 3

VARIABLES	COEFFICIENTS (S.E.)	T-VALUE	P
Intercept	1.726		
RFLOM	-0.0001493 (.0000429)	3.48	.001

Inclusion of RFLOM into the equation precluded the presence of any other flow variable.

Trapping, Fall Only:

Results:

Neither RFLOM nor RFLOR had a significant F-to-enter (RFLOM, 3.63, $p > .1$; RFLOR 0.59, $p > .9$) in a stepwise multiple regression on 233 cases. RFLON, the flow at Newhalem, was seen to have the highest F to enter (24.17, $p < .001$), making the fit statistically significant although the R^2 of 0.0947 shows a pattern of large variances and departures from the fit.

TABLE 4

VARIABLES	COEFFICIENTS (S.E.)	T-VALUE	P
Intercept	0.316		
RFLON	-0.0002326 (.0000473)	4.91	<.001

Inclusion of RFLON into the equation precluded the presence of any other flow variable.

Stranding, Full Data Set:

Method:

The relationship of stranding to river flow was investigated with stepwise logistic regression.

Results:

The logistic regression model was run on 682 cases (missing stranding values removed), with RFLON, RFLOM, and RFLOR as covariates. Like the stepwise multiple regression, the stepwise logistic regression computes F-to-enter values on all possible covariates. The covariate with the highest F-to-enter is entered, whereupon the F's-to-enter of the remaining variables are adjusted to take into account their correlation with the first. RFLOR was entered first, showing to be the most directly related to stranding as a proportion of trapping with an F-to-enter of 117.41. RFLOM was next in line with an F-to-enter of 56.38. RFLON was last with an F-to-enter of 3.57, not even significant at the 0.05 level (the degrees of freedom of these F's-to-enter is 1). RFLOM, however, when adjusted for correlation with RFLOR, achieved an F-to-enter of a mere 1.56. Therefore RFLON and RFLOM were not included in the equation. RFLQR achieved an improvement Chi-square of 137 ($p < .001$) when regressed on stranding/trapping. However the goodness of fit Chi-square, 4193 ($p < .001$) also remains high, indicating there is room for more variables in this equation. Parameters for a logistic regression are now related linearly to the logistic transform and not the proportion of stranding to trapping itself.

TABLE 5

TERM	COEFFICIENT	(S.E.)	COEFF/S.E.
RFLOR	0.001	(small)	11.172
Constant	0.041	(0.287)	0.141

Conclusion:

The risk of stranding, given trapping can be explained by any one of the three gage station flows. However, the association with the Rockport flow is the strongest. Once this flow is included in the equation, the inclusion of any other of the flows is redundant. Because BMDPLR measures the probability of <u>success</u> with the coefficient, in this case a positive coefficient means greater survivability with greater flow, which would be expected.

Limitations:

The model as it stands is far from saturation. Many other variables are needed to explain this risk. A more complete analysis should be run, including along with julian date (see Conclusion paragraph above), other variables such as pothole depth (MAXD), area (AREA), and flow history variables (see page 8 of this appendix). Some of the variables needed to explain stranding/trapping may not even be present in the 1984 fry stranding study data set.

Stranding, Spring Only:

Results:

The logistic regression model was run on 449 cases (missing stranding values removed), with RFLON, RFLOM, and RFLOR as covariates. RFLOR was entered first, showing to be the most directly related to stranding as a proportion of trapping with an F-to-enter of 65.20. RFLOM was next in line with an F-to-enter of 44.58. RFLON was last with an F-to-enter of 24.78, all three variables were significant at the 0.05 level (the degrees of freedom of these F's-to-enter is 1). All three variables, RFLON, RFLOM, and RFLOR, were entered into the equation. However the values of the coefficients were extremely small and did not show up on the printed output. No attempt was made to recover these values as the strength and direction of the association were considered of sufficient interest. This strength and direction is indicated by the size and the sign of the coefficient divided by the standard error. For the three variables, these values were: RFLON, -5.409, RFLOM, 1.747, RFLOR, -5.659. The coefficients of RFLON and RFLOR lead to the conclusion that the proportion of survivability goes down as does flow at Newhalem and Rockport. The opposite sign on the Marblemount coefficient reflects the high degree of correlation of Marblemount with Newhalem and Rockport (-.539 and -.853 respectively) leaving its role in this model a residual one only.

Stranding, Fall Only:

In the fall, none of the three variables, RFLON, RFLOM, nor RFLOR had a high enough F-to-enter to be included in the equation. These values were: RFLON, 1.35, RFLOM, 0.56, and RFLOR, 2.84. The regression was run on 233 cases.

Regression of Previous Day's Amplitude on Trapping and Stranding:

Purpose:

Two possible definitions of previous day's amplitude were presented: 1) flow prior to downramping minus minimum flow for the day (AMP1) and 2) maximum flow from the previous 24 hours minus minimum flow for the day (AMP2). The association between stranding and trapping and these two amplitudes was of interest.

Trapping, Full Data Set:

Methods:

The relationship of trapping to amplitude was investigated first with a forward stepwise regression, to determine which of the two amplitudes was most strongly related, and then with a simple linear regression, in order to examine the patterns of the residuals and assess the fit of the linear model.

Results:

The stepwise regression on 445 cases selected AMP2 as being the most strongly related to trapping ($F=9.76$, $p < .002$). The inclusion of AMP2 precluded AMP1, whose F to enter, 3.30, is below tolerance for entry into the equation. A simple linear regression, run on the same cases gave an intercept of .85 and a slope of .000114 ($T = 3.13$, 443 d.f, $p = .0019$).

Conclusion:

Only AMP2 has a statistically significant association with trapping.

Limitations:

Examination of the residuals showed the same fanning pattern seen in the regression of trapping versus flows. R^2 for this equation is .0216. The fanning pattern of the residuals as well as the low R^2 again indicate that the fit is inadequate.

<u>Trapping, Spring Only</u>:

No significant relationship was noted between trapping and AMP1 or AMP2 (276 cases).

<u>Trapping, Fall Only</u>:

No significant relationship was noted between trapping and AMP1 or AMP2 (169 cases).

<u>Stranding, Full Data Set</u>:

Methods:

As for the flows, the logistic regression model was used. BMDPLR is a stepwise regression program, and AMP1 and AMP2 were entered and/or removed from the equation on the basis of the improvement they made individually to the Chi-square. A variable was included only if the improvement in the fit was significant given the degrees of freedom that variable contributes. Variables highly correlated to variables with higher improvement Chi-squares will most probably not be selected.

Results:

As a result of applying the logistic regression model to 445 cases, only AMP2 was included in the equation with an F to enter of 12.95. AMP1, with an F to enter of 0.14, was not considered a strong enough influence to include in the equation. A parameter for AMP2 was too small to be printed as it was on the order of 10^{-4}. However, the coefficient divided by the standard error was 3.56, indicating a significant effect. Since the strength of association rather than the absolute size of the parameter is of interest, no attempt was made to recover this value.

Conclusion:

Only AMP2 had an association with stranding/trapping strong enough to be considered statistically significant.

Limitations:

The 563.41 goodness of fit Chi-square ($p < .001$, we must reject the null hypothesis that this model fits') indicates this fit comes far short of fully explaining the stranding to trapping ratio.

Stranding, Spring Only:

Results:

A stepwise logistic regression on 448 cases showed significant relationships with both AMP1 and AMP2 with F's-to-enter of 70.47 and 33.71 respectively. Again, coefficients were to small to be printed, but the coefficient divided by the standard error gives the following results: AMP1: -6.35, and AMP2 1.917. The minus sign on the coefficient of AMP1 again indicates an effect of decreasing probability of survival with decreased amplitude. This counterintuitive result can be explained by the confounding effect of time. Amplitudes decreased as vulnerability of fry decreased. Since AMP2 is highly correlated with AMP1 ($r = .808$) its effect in this model is residual only. With a goodness of fit Chi-square of 563.41, this model cannot be considered exhaustive.

Stranding, Fall Only:

Results:

A stepwise logistic regression run on 258 cases showed no significant effects with either AMP1 or AMP2.

Regression of Flow History on Trapping:

Trapping, Full Data Set:

Purpose:

The association between flow history and trapping was of interest. Flow history was broken down into five variables: mean daily flow for the 24 hours prior to the test (AVD24H), maximum downward amplitude for the 24 hours prior to the test (MXM24H), mean downward amplitude for the previous 72 hours (AVD72H), mean daily flow for the previous 72 hours (AVM72H), and the maximum daily downward amplitude for the previous 72 hours (MXM72H).

Methods:

This problem was approached in a similar manner to Task 2 and 3. A forward stepwise regression was run to eliminate superfluous or redundant variables. This was followed by a multiple regression on only the variables selected by the stepwise regression.

Results:

When a stepwise multiple regression was run on 589 cases, variables MXM72H and MXM24H were entered into the equation in that order with F's to remove of 22.54 and 11.23 respectively. F-to-enter values for the other three variables were too small to be entered once MXM72H and MXM24H were selected. The multiple regression on these variables only gave the following parameters:

TABLE 6

VARIABLE	COEFFICIENT		T-VALUE	P
Intercept	0.805			
MXM24H	-0.0000807	(.000024)	-3.351	(..001)
MXM72H	0.000152	(.000032)	4.748	(<.001)

The F value of the regression was 11.29 (2,586 d.f.), $p < .001$. The R^2 was 0.0371.

Conclusion:

Only the maximum daily downward amplitudes for the 24 and 72 hour periods before the test had a strong enough association with trapping to be considered statistically significant. Other variables were either redundant or not associated.

Limitations:

A fan shape exhibited by residuals for the multiple linear model indicated the inadequacy of this model to fully explain the relationship between trapping and flow history. A more complete analysis should be run, including along with julian date (see Conclusion paragraph above), other variables such as pothole depth (MAXD), area (AREA), and flow history variables (see page 8 of this appendix). Some of the variables needed to explain trapping may not even be present in the 1984 fry stranding study data set.

<u>Trapping, Spring Only</u>:

Results:

A stepwise multiple regression run on 397 cases showed no significant relationship with any of the five flow history variables.

Trapping, Fall Only:

Results:

A stepwise multiple regression run on 192 cases showed that only AVD72H (average downramp amplitude for the previous 72 hours) was significantly related to trapping. When adjusted by AVD72H whose F-to-enter was 40.39, the F's-to-enter of the other variables were all under 1.00. The model gives the following coefficients: intercept, 1.402, AVD72H, -.0003801 (s.e., .0000599), t = 6.36, p . .001. The R^2 for this model is 0.1753, a low value which shows widespread variation and departure from the model among the data values.

Number of Potholes Observed Dry at Observed Flows for Marblemount Assigned Potholes Only:

See text for discussion.

Cover and Substrate Matrix of Trapping and Stranding:

Purpose:

Of great interest is the survival rate of a fish already trapped in a pothole. Because the major killer of trapped fish was pothole drainage, cover and substrate types were thought to play a role in survival rate. The relationship between survival rate and cover and/or substrate was investigated for this study.

Method:

Raw totals of fish trapped but not stranded compared to fish stranded are shown plotted in the text for all types of cover and substrate. Although such graphs are good for illustrative purposes, a single episode of a large stranding in one particular cover or substrate category may have a great effect on the appearance of the graph. To keep track of the day to day pattern of stranding /trapping it is necessary to keep weights equal for each unit observation of a pothole per day. To do this two logistic regression models (see equation 1) were used, the first of which contained terms for spring/fall (FALSPR), cover (COV), and substrate (SUB), and the second of which contained a term to distinguish cover from no cover (CNC) in place of COV in the first model.

Coefficients for categorical variables from a logistic regression can provide an odds ratio, or a measure of survivability (the reciprocal of the risk) when a particular factor is present. An odds ratio greater than one indicates an increased survivability: an odds ratio less than one, an increased risk.

Types of pothole cover considered separately:

Results:

All three terms of the first model contributed highly significant improvement chi-sqares to the fit as is shown in the following table:

TABLE 7

TERM	DF	IMPR CHI-SQ	P-VALUE	GOF CHI-SQ	P-VALUE
constant				2281.6	< .001
FALSPR	1	562.5	< .001	1719.1	< .001
SUB	4	237.7	< .001	1481.4	< .001
COV	7	339.4	< .001	1142.0	< .001

For each effect of N levels (COV has 8 levels; SUB has 5, and FALSPR has 2) the BMDP logistic regression package made a contrast variable to identify pairwise differences beweeen the levels. The contrasts for the main effects (SUB, COV, and FALSPR) were set up as in Table 8:

TABLE 8

VARIABLE	NAME	CAT INDEX	DESIGN VARIABLES						
FALSPR	SPRING	1	-1						
	FALL	2	1						
COV	NO COVER	1	-1	-1	-1	-1	-1	-1	-1
	ROOT WAD	2	0	0	0	0	0	0	1
	ROOTS	3	0	0	0	0	0	1	0
	STICKS	4	0	0	0	0	1	0	0
	LOGS	5	0	0	0	1	0	0	0
	BOULDERS	6	0	0	1	0	0	0	0
	SUB VEG	7	0	1	0	0	0	0	0
	OVER VEG	8	1	0	0	0	0	0	0
SUB	SILT	1	-1	-1	-1	-1			
	SAND	2	0	0	0	1			
	PEA GRAVEL	3	0	0	1	0			
	GRAVEL	4	0	1	0	0			
	COBBLE	5	1	0	0	0			

There are 12 contrasts in this design. The first tests the difference between spring and fall (were proportionately more fish stranded in the spring or the fall?). The contrasts in the cover category compare all covers in turn with the "NO COVER" category. There are seven of these contrasts. Four substrate categories are compared in turn with SILT. Since BMDPLR gives coefficients in terms of probability of <u>success</u> comparing the factors pairwise in this way gives us a relative survival factor. Comparing "ROOT WAD" with "NO COVER", will tell us whether proportionately more fish were stranded in the presence of root wads, or in the absence of cover.

Resulting coefficients for the above contrasts are given in Table 9:

TABLE 9

TERM	COMPARISON	COEFFICIENT (S.E)	ODDS RATIO
FALSPR	FALL/SPRING	-0.955 (0.045)	.385
COV	OV VEG/NO COVER	0.142 (0.186)	1.15
	SB VEG/NO COVER	0.147 (0.464)	1.58
	BOULD/NO COVER	-1.594 (0.237)	.203
	LOGS/NO COVER	1.016 (0.231)	2.76
	STICKS/NO COVER	-1.534 (0.163)	.216
	ROOTS/NO COVER	2.530 (0.881)	12.5
	RT WAD/NO COVER	-0.703 (0.171)	.495
SUB	SAND/SILT	0.845 (0.130)	2.33
	P GRAV/SILT	0.841 (0.095)	2.32
	GRAV/SILT	-1.488 (0.194)	.226
	COBB/SILT	0.744 (0.090)	2.10
CONSTANT		2.910 (0.153)	

Conclusion:

All three terms included in the model have proven significantly related to the proportion of stranding to trapping or the survivability rate of fish in potholes. The survivablity rate was worse in the fall. Certain covers: overhanging vegetation (OV VEG), submerged vegetation (SB VEG), logs and roots seemed to decrease the risk of stranding. Of the substrate types, gravel (GRAV) and silt were associated with larger stranding proportions; sand, cobble, and pea gravel (because there were few potholes with this substrate) contributed to smaller strandings. These results resemble those shown in figures in the text, where proportions are taken in terms of numbers of potholes.

<u>Cover versus no cover</u>:

Results:

All three terms of this model, FALSPR, SUB, and CNC contributed highly significant improvement chi-sqares to the fit as is shown in the following table:

TABLE 10

TERM	DF	IMPR CHI-SQ	P-VALUE	GOF CHI-SQ	P-VALUE
constant				1418.6	< .001
FALSPR	1	562.5	< .001	856.1	< .001
SUB	4	237.7	< .001	618.4	< .001
CNC	1	16.6	< .001	601.7	< .001

For each effect of N levels (CNC has 2 levels; SUB has 5, and FALSPR has 2) the BMDP logistic regression package made a contrast variable to identify pairwise differences beween the levels. The contrasts for the main effects (SUB, CNC, and FALSPR) were set up as in Table 11:

TABLE 11

VARIABLE	NAME	CAT INDEX	DESIGN VARIABLES			
FALSPR	SPRING	1	-1			
	FALL	2	1			
CNC	NO COVER	1	-1			
	COVER	2	1			
SUB	SILT	1	-1	-1	-1	-1
	SAND	2	0	0	0	1
	PEA GRAVEL	3	0	0	1	0
	GRAVEL	4	0	1	0	0
	COBBLE	5	1	0	0	0

There are 6 contrasts in this design. The first tests the difference between spring and fall (were proportionately more fish stranded in the spring or the fall?). The contrasts in the cover category compares cover with no cover. Four substrate categories are compared in turn with SILT. Comparing the factors pairwise in this way gives us a relative survivability factor(the reciprocal of the relative risk). Comparing "COVER" with "NO COVER", will tell us whether proportionately more fish were stranded in the presence or in the absence of cover.

Resulting coefficients for the above contrasts are given in Table 12:

TABLE 12

TERM	COMPARISON	COEFFICIENT (S.E)	ODDS RATIO
FALSPR	FALL/SPRING	-1.036 (0.044)	.359
CNC	NO COVER/COVER	-0.232 (0.059)	.793
SUB	SAND/SILT	0.864 (0.105)	2.37
	P GRAV/SILT	1.018 (0.091)	2.77
	GRAV/SILT	-1.432 (0.176)	.239
	COBB/SILT	0.279 (0.077)	1.32
CONSTANT		2.658 (0.071)	

Conclusion:

All three terms included in the model have proven significantly related to the proportion of stranding to trapping or the survivability rate of fish in potholes. The survivablity rate was worse in the fall. As was expected, cover had a positive effect on survivability. Of the substrate types, gravel (GRAV) and silt were associated with larger stranding proportions; sand, cobble, and pea gravel (because fewer potholes have this substrate) contributed to smaller strandings. These results resemble those in figures shown in the text, where proportions are taken in terms of numbers of potholes.

Regression of Maximum Depth of Pothole as it Relates to River Flows at the Three Gage Stations:

Purpose:

As the most numerous strandings were observed to be related to the draining of potholes, the association between river flows and this drainage, as observed through lowest measured pothole depth of the day (MAXD) was measured with a linear regression model.

Method:

A multiple regression compared the minimum depth observed at the deepest point of the pothole for the day (MAXD) to flows at the closest of the three gage stations. By a method called "Dummy Regression" (Kleinbaum and Kupper, 1978). Variable Z1 was set to 0 for Marblemount and 1 for Newhalem. Dummy variable Z2 was set to 0 for Marblemount and 1 for Rockport. The variable FLOW was set equal to RFLOM. Newhalem flow (V1) was designated as 1*RFLON for the Newhalem sites (see list of sites assigned to Newhalem, Rockport, and Marblemount in text), and Rockport flow (V2) was designated as 1*RFLOR.

Results:

This model, run on 1610 cases, gave an F value of 9.93, $p <$ .001, and an R^2 of 0.03.

TABLE 13

VARIABLES	COEFFICIENTS (S.E.)	T-VALUES	P
Intercept	0.503		
Z1	-0.295 (0.645)	-0.457	.65
Z2	0.155 (0.137)	1.131	.26
V1	-0.0000145 (.000204)	-0.071	.94
V2*	-0.0000656 (.0000338)	-2.060	.04
FLOW*	0.0000831 (.0000142)	5.842	.00

Variables significant at the .05 level are indicated with a *. Flow is significantly different from zero. The significance of Z1, Z2, V1, and V2, are measured against the default coefficients, intercept and FLOW. The significance of V2, the flow at Rockport indicates an effect over and above that caused by the flow at Marblemount.

Conclusion:

The flow at Marblemount is significantly related to the depth of potholes in the areas assigned to it. The flow at Rockport is significantly more related to the depths of potholes assigned to it than is the Marblemount flow. As in previous regressions, a strong relationship exists, but examination of R^2 and residual plots show the fit does not fully explain the relationship.

Regression of Trapping on Julian Date and Flow:

Purpose:

The association between trapping and julian date is of interest because most of the trapping is thought to occur at a time when fry are just emerging.

Method:

A regression of trapping on julian date only may give a spurious result because of a confounding effect of date with flow, as julian date, which affects flow, also affects trapping. To avoid this problem it was necessary to adjust for flow in any regression which includes julian date by including flow in the equation also. The flow used in these equations was the minimum Marblemount flow for the day of observation only (RFLOM), as this flow was most strongly related to trapping (see the section on regression of flow versus trapping). These regressions were done separately for spring and fall data.

<u>Spring</u>:

Results:

Both flow and julian date were found to affect trapping ($t=-3.9$ and $t=-4.1$ respectively, $p < .001$ for both values). The F value for this fit was 33.7, $p < .001$ with an R^2 of .1252. The regression was done on 474 cases.

TABLE 14

VARIABLES	COEFFICIENTS (S.E.)	T-VALUES	P
Intercept	1.95		
JULDAY	-0.00653 (0.00161)	-4.051	<.001
RFLOM	-0.000191 (.0000486)	-3.94	<.001

Conclusion:

Both Marblemount flow and julian date tested significantly related to trapping.

Limitations:

Inspection of the graph of trapping versus julian date (see Fig. 5) shows a clear nonlinearity in the relationship. The residuals also exhibited a strong fanning pattern indicating the inadequate fit of the simple linear model.

<u>Fall</u>:

Results:

The F value for this fit was 50.9, $p < .001$ with an R^2 of .1601. The regression was done on 537 cases.

TABLE 10

VARIABLES	COEFFICIENTS (S.E.)	T-VALUES	P
Intercept	4.48		
JULDAY	-0.0160 (.00179)	-8.988	<.001
RFLOW	-0.838 (.0000368)	-2.276	.02

Conclusion:

Both Marblemount flow and julian date tested significantly related to trapping.

Limitations:

Inspection of the graph of trapping versus julian date (see Fig. 5) shows a clear nonlinearity in the relationship. The residuals also exhibited a strong fanning pattern indicating the inadequate fit of the simple linear model.

Remarks:

A subset of 23 potholes were never connected throughout the spring or the fall studies. These potholes always contained the same fish during successive observations. Therefore they were deleted from this analysis. The following potholes were involved:

BS--1, 1A, 1B, 1C, 2, 3, 7, 8, 9, 15, 16, 17
FB--F
SI--A, B
TS--2, 5, 6, 6B, 6C, 11A, 11B
WS--8

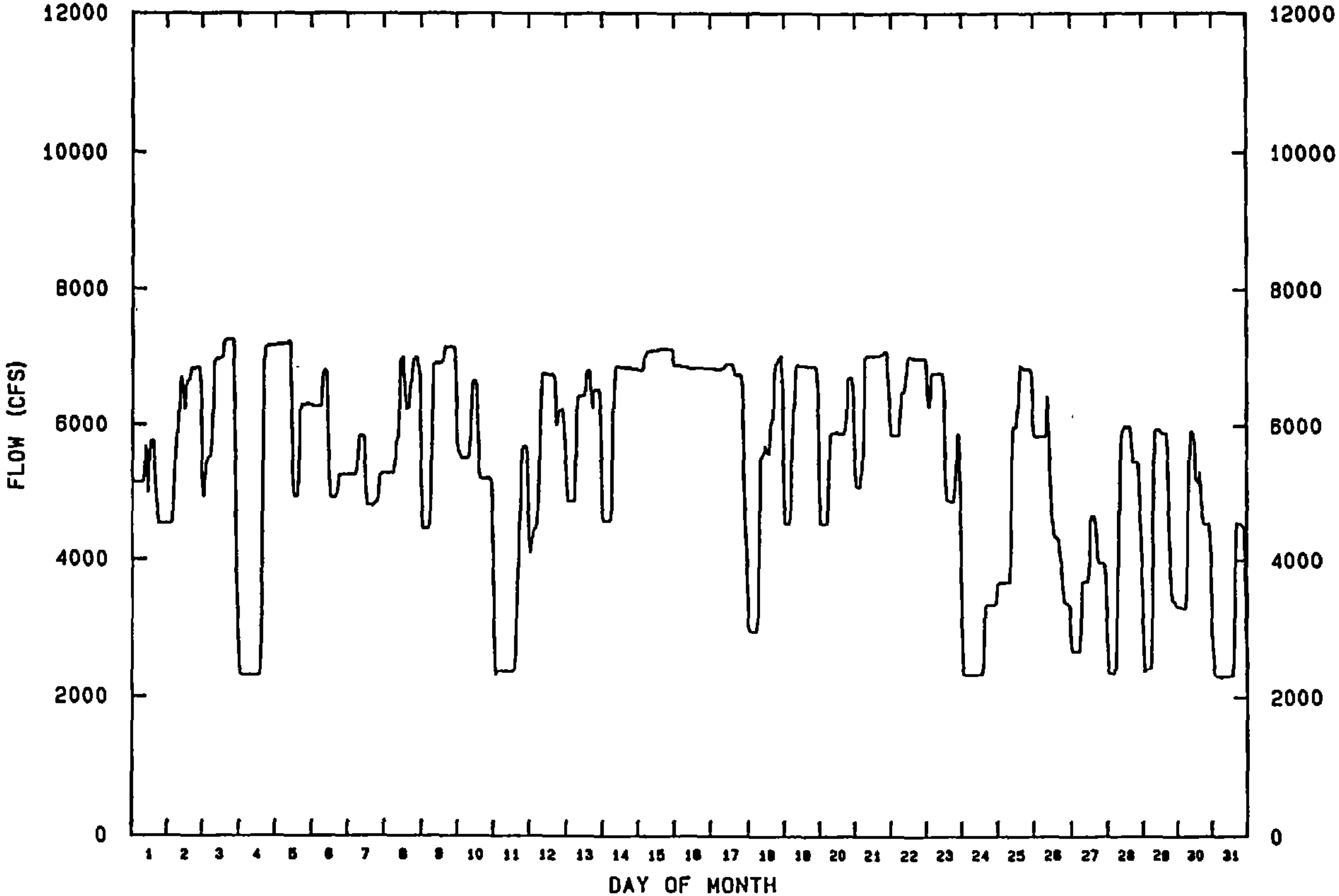
Tasks 0, 2, 3, and 4 were run with the BMDP package of statistical programs. Task 6 was run with MINITAB.

APPENDIX G

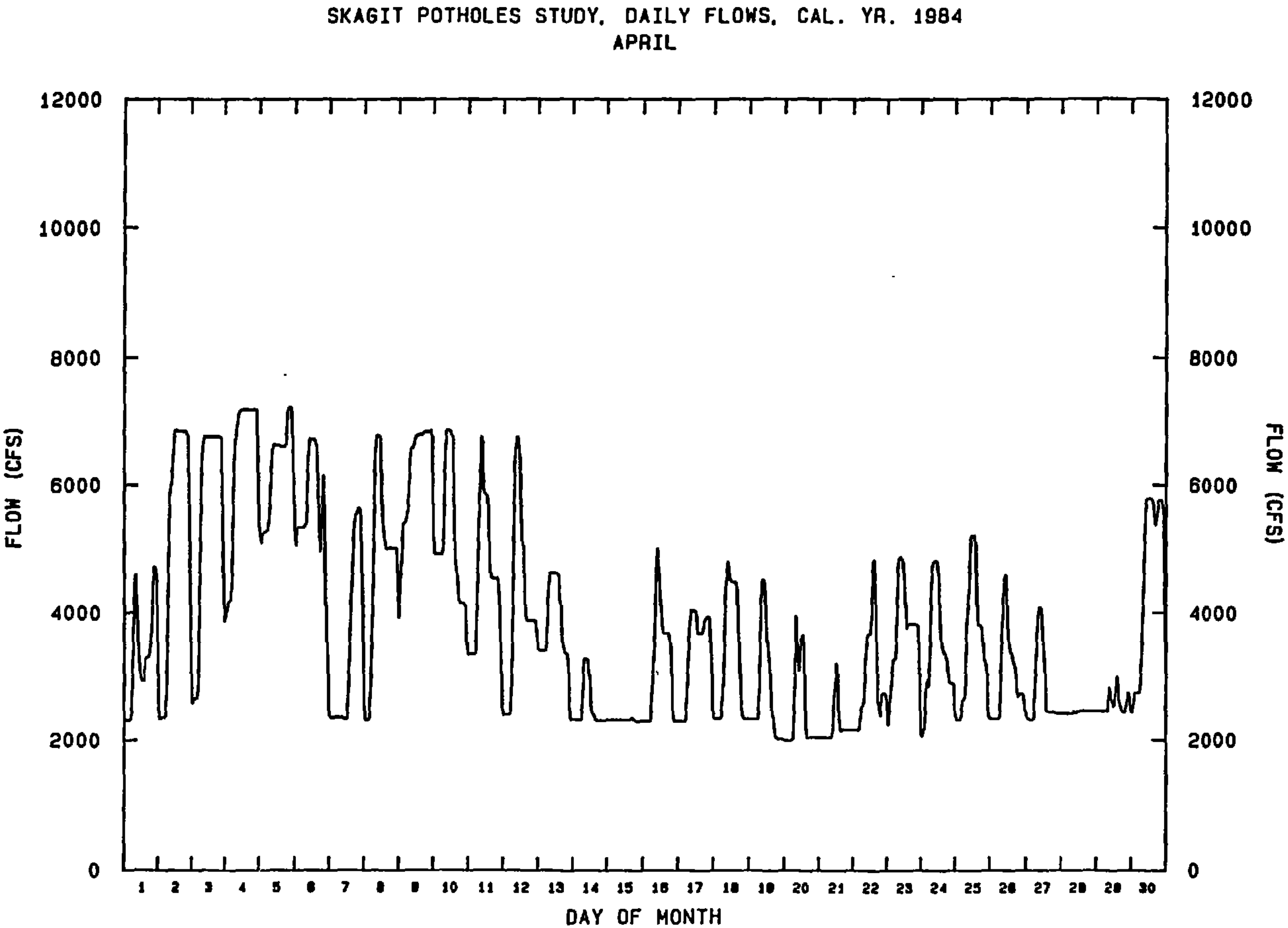
- DAILY FLOWS FROM GORGE POWERHOUSE, 1984
- 1984 DAILY FLOW AMPLITUDE

From: R. W. Beck, Inc. 1985

SKAGIT POTHOLES STUDY, DAILY FLOWS, CAL. YR. 1984
MARCH



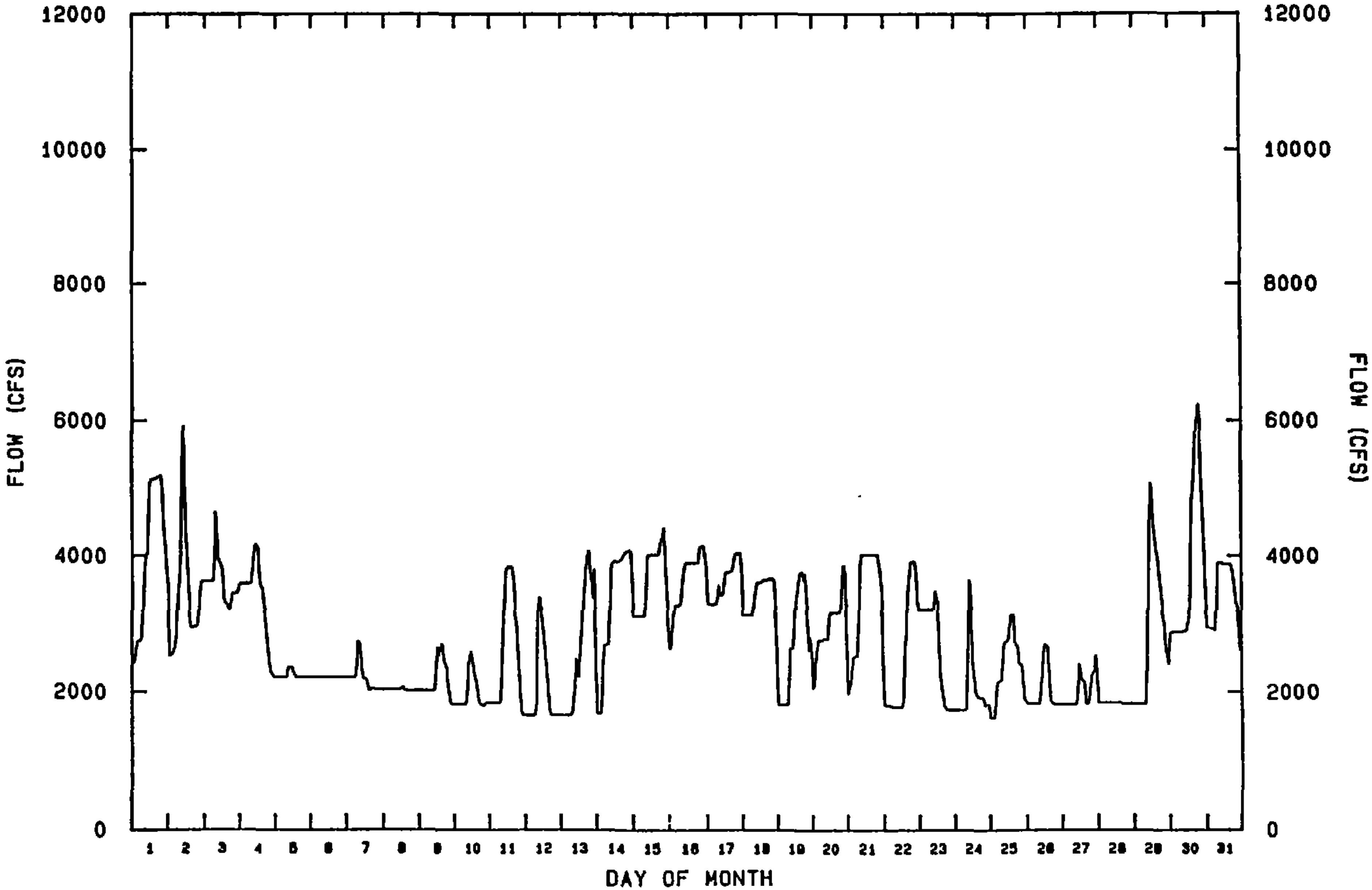
G-1



SKAGIT POTHOLES STUDY, DAILY FLOWS, CAL. YR. 1984
APRIL
12000
10000
8000
6000
4000
2000
0
FLOW (CFS)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
DAY OF MONTH

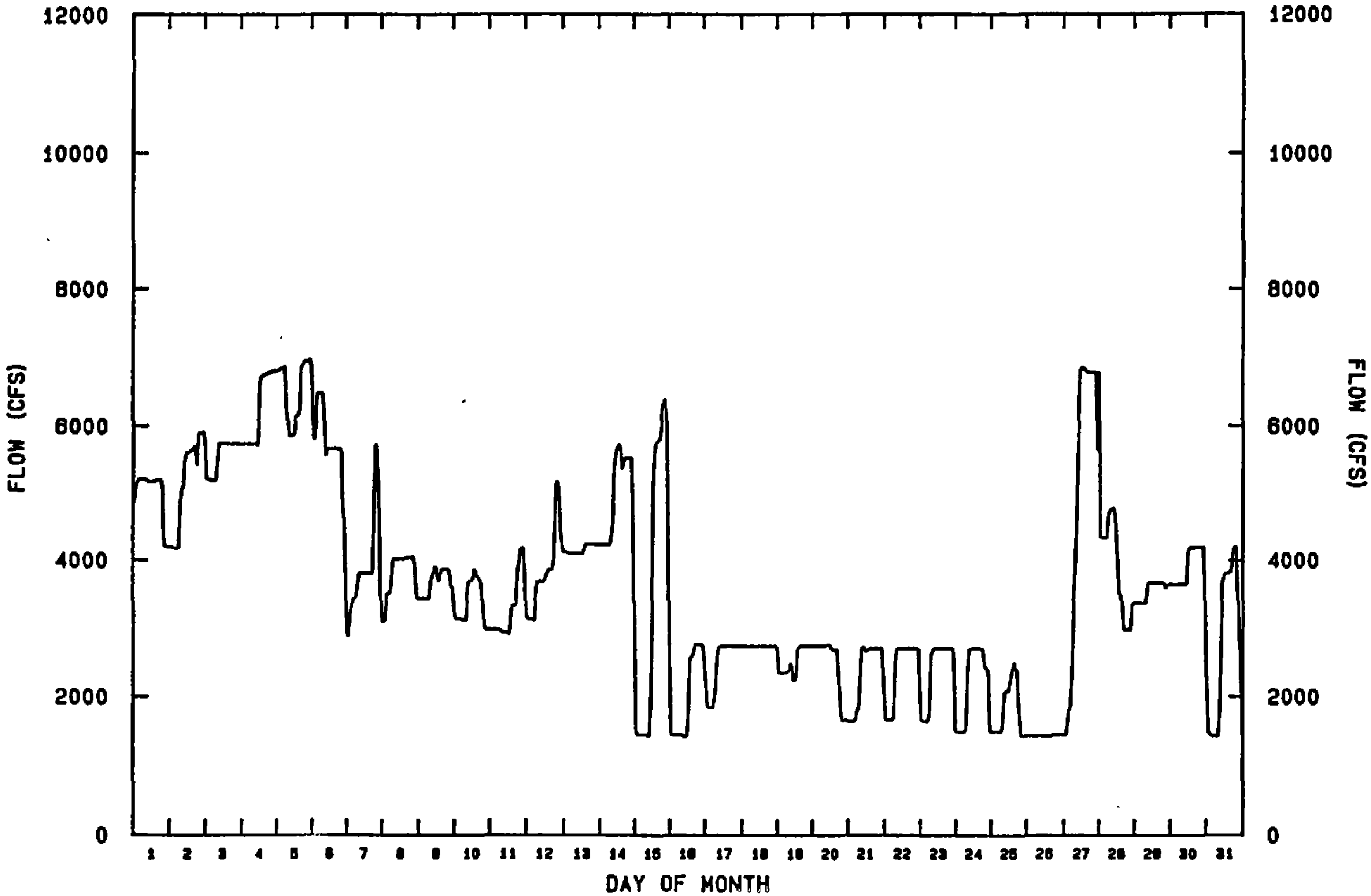
G-2

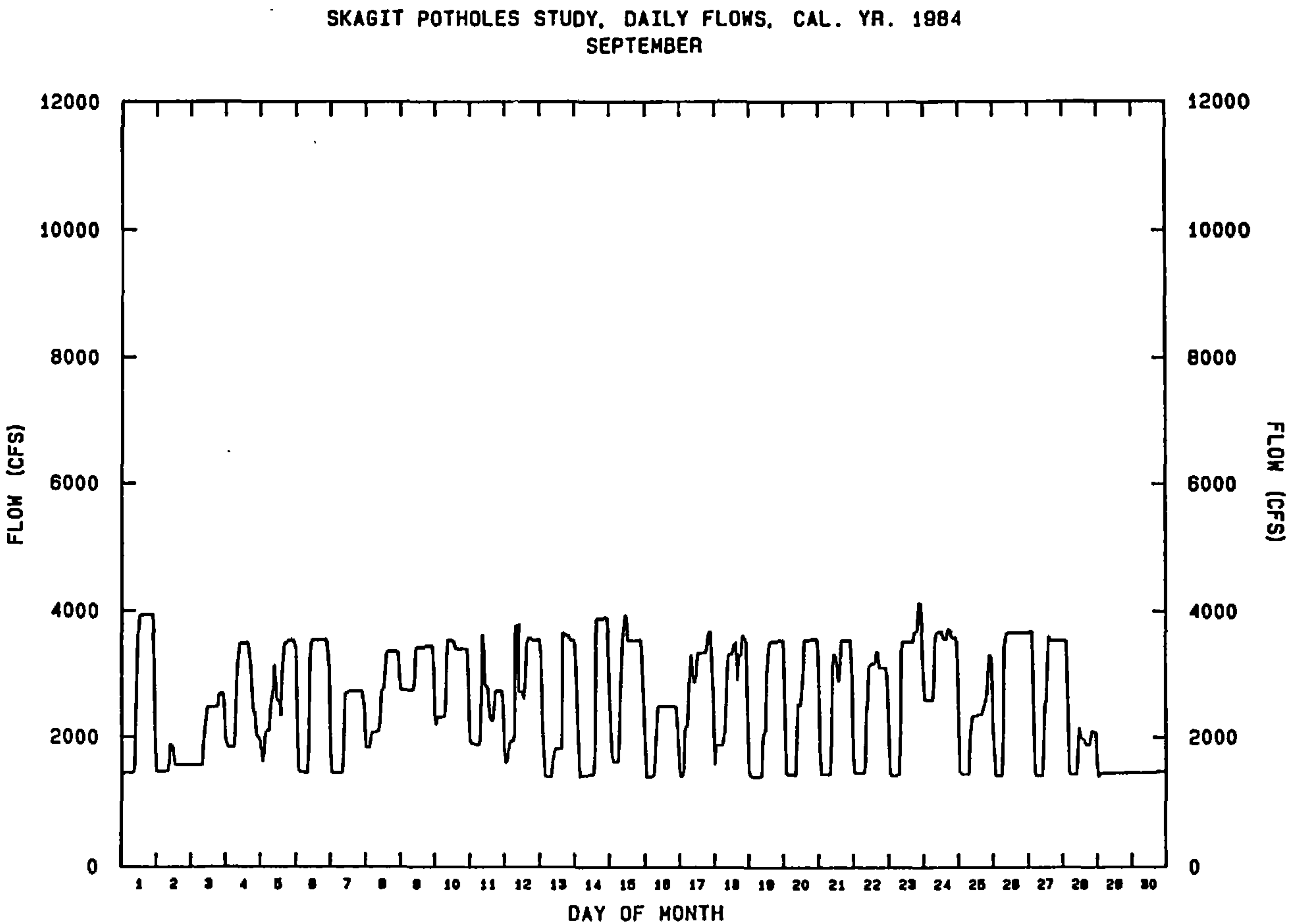
SKAGIT POTHOLES STUDY, DAILY FLOWS, CAL. YR. 1984
MAY



G-3

SKAGIT POTHOLES STUDY, DAILY FLOWS, CAL. YR. 1984
AUGUST




SKAGIT POTHOLES STUDY, DAILY FLOWS, CAL. YR. 1984
SEPTEMBER
FLOW (CFS)
FLOW (CFS)
12000
10000
8000
6000
4000
2000
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
DAY OF MONTH

Appendix G. Flow Conditions Prior to Test Dates

SPRING

DATE	24-HOUR PERIOD* AVERAGE DAILY DISCHARGE	24-HOUR PERIOD* AVERAGE DOWNRAMP AMPLITUDE	72-HOUR PERIOD* AVERAGE DAILY DISCHARGE	72-HOUR PERIOD* AVERAGE DOWNRAMP AMPLITUDE	72-HOUR PERIOD* MAXIMUM DOWNRAMP AMPLITUDE
3-11	5,530	4,372	5,933	2,851	4,372
3-24	5,780	3,539	6,280	1,827	3,539
3-31	4,510	3,592	4,450	3,262	3,633
4-1	3,010	2,295	3,937	2,816	3,592
4-7	5,500	3,853	6,040	2,750	3,853
4-8	3,420	3,333	5,060	3,148	3,853
4-21	2,470	1,776	2,843	2,085	2,518
4-28	2,800	36	3,110	1,739	2,885
5-3	3,530	10	4,040	1,955	3,352
5-4	3,610	10	3,733	841	2,504
5-11	2,010	814	2,060	343	814
5-12	2,650	2,210	2,270	1,072	2,210
5-17	3,780	851	3,667	1,165	1,662
5-18	3,680	952	3,720	1,155	1,662
FALL					
8-15**	4,920	4,328	4,327	1,801	4,328
8-16**	3,580	5,001	4,223	3,110	5,001
8-22	2,380	1,070	2,447	728	1,114
8-23	2,380	1,068	2,397	1,084	1,114
8-31	3,870	2,818	3,783	1,587	2,818
9-1	2,740	2,792	3,397	1,910	2,818
9-6	2,850	2,127	2,563	1,635	2,127
9-7	2,730	2,166	2,743	2,071	2,166
9-13	2,830	2,205	2,777	1,957	2,205
9-14	2,940	2,517	2,743	2,239	2,517
9-20	2,550	2,148	2,737	2,108	2,265
9-21	2,690	2,154	2,687	2,189	2,265
9-27	3,050	2,277	2,870	2,183	2,364
9-28	2,840	2,283	2,717	2,156	2,283

* For 24- and 72-hour period preceeding each test.
** Reconnaissance only. No formal field tests conducted.

SOURCE: USGS Primary Records, 1984, for flows at Gorge Powerhouse.

APPENDIX H

Appendix H. Trapping and Stranding in Potholes Common to Both Spring and Fall Surveys

AREA	POTHOLE NO.	SPRING TRAPPED	SPRING STRANDED	FALL TRAPPED	FALL STRANDED
Bacon Creek	1	373	13	0	0
	2	27	21	11	1
	3	2	0	0	0
	4	1,510	0	70	0
		1,912	34	81	1
Bad Spot	4	77	2	6	0
	5	469	0	65	0
	6	28	1	34	1
	10	3	0	0	0
	12	136	2	19	0
	13	214	14	0	0
	14	115	69	1	1
		1,042	88	125	2
Eagle Bar	1	19	2	3	0
	2	1	0	0	0
	3	10	9	0	0
	4	13	0	0	0
	5	1	1	3	1
	5A	177	25	0	0
	6	301	1	0	0
	7	73	6	0	0
	8	231	0	0	0
	10	560	0	0	0
	11	219	0	0	0
		1,065	44	6	1
Fungus Bar	1	66	0	5	0
	2	16	0	0	0
	4	495	0	45	0
	5	22	0	0	0
	6	79	0	0	0
	7	42	0	0	0
	8	147	0	0	0
	9	133	0	9	6
		1,000	0	59	6
Forbidden Bar	1	132	0	24	0
	2	527	0	148	142
	3	6	0	0	0
	5	970	0	63	0
	6	7	1	0	0
		1,642	1	235	142

Appendix H. (Continued)

AREA	POTHOLE NO.	SPRING TRAPPED	SPRING STRANDED	FALL TRAPPED	FALL STRANDED
Hooper's Slough	1A	290	0	55	0
	2	748	0	0	0
	3	23	3	32	0
	4	223	2	10	0
	5	209	0	110	0
	6	43	0	20	0
	9	67	0	10	0
	10	10	2	0	0
		1,613	7	237	0
Inaccessible Island	1	8	0	0	0
	2	45	0	6	0
	3	314	0	3	3
	4	21	0	0	0
	5	9	1	0	0
	6	92	0	0	0
	7	90	0	8	0
	8	68	0	0	0
	9	105	0	0	0
	10	2	0	0	0
	11	3	1	0	0
	12	90	9	0	0
		847	11	17	3
Rockport	1	8	6	0	0
	3	1	0	0	0
	4	10	1	0	0
	5	30	0	0	0
	6	38	24	0	0
		87	31	0	0
Stump Haven	2	191	0	25	0
	3	6	0	1	0
	4	266	0	21	0
	5	99	0	17	1
	6	75	0	2	0
	7	14	0	1	0
	8	350	0	60	0
	9	0	0	3	0
	10	260	0	7	0
	11	4	0	0	0
	12	50	0	0	0
	13	63	0	9	7
	14	12	0	2	1
	15	3,351	50	89	1
	16	9	0	0	0
	17	25	0	9	5
		4,775	50	246	15

Appendix H. (Continued)

AREA	POTHOLE NO.	SPRING TRAPPED	SPRING STRANDED	FALL TRAPPED	FALL STRANDED
Tin Shack	1	0	0	16	0
	7	37	0	8	0
	8	20	5	0	0
	9	6	0	3	3
	12	28	2	0	0
		91	7	27	3
Wayne's Swim	1	296	0	82	0
	2	400	0	228	0
	3	320	0	116	0
	4	492	0	146	0
	5	167	11	0	0
	I	0	0	6	1
	G	0	0	59	0
	11	44	0	0	0
	12	8	4	0	0
		1,727	15	637	1

APPENDIX I

APPENDIX I. SUMMARY OF FLOW CONNECTIVITY VARIABLES FOR POTHOLE AREAS

RIVER MILE	STUDY AREA	SITE 1	PH. # 2	C FLO 3	GAGE 4	TRAP S 5	TRAP F 6	STRAND S 7	STRAND F 8	9	10	11	12	DRY FLO 13	14	15
67.5	Rockport Bar	RP	1	6218	3	0.31	0.00	6	0	0	0	9	1	5270	150	240
		RP	2	0	3	0.00	0.00	0	0	0	0	0	1	4838	0	220
		RP	3	6948	3	0.04	0.00	0	0	0	1	8	0	4838	100	200
		RP	4	0	3	0.38	0.00	1	0	1	0	0	0	7209	320	260
		RP	5	0	3	1.20	0.00	0	0	4	0	0	0	7209	220	260
		RP	6	0	3	1.41	0.00	24	0	2	0	7	2	5348	150	230
		RP	7	6360	3	0.00	0.00	0	0	3	1	2	0	5606	120	230
		RP	8	4386	3	0.00	0.00	0	0	0	4	0	1	4427	0	100
		RP	9	0	3	0.00	0.00	0	0	0	4	0	2	3563	0	70
		RP	10	0	3	0.00	0.75	0	9	0	0	0	2	4612	0	210
		RP	11	4760	3	0.00	0.00	0	0	0	7	0	2	3058	0	40
		RP	12	3563	3	0.00	0.00	0	0	0	5	0	5	2948	0	20
		RP	13	3944	3	0.00	0.00	0	0	0	4	0	5	3004	0	20
		RP	14	0	3	0.00	0.50	0	0	0	10	0	1	0	0	0
		RP	15	5391	3	0.00	0.00	0	0	0	8	0	3	0	0	0
		RP	16	3612	3	0.00	0.09	0	0	0	7	0	4	0	0	0
		RP	17	4573	3	0.00	0.36	0	0	0	9	0	2	0	0	0
		RP	18	5652	3	0.00	0.00	0	0	0	8	0	1	2909	0	20
		RP	19	4366	3	0.00	0.33	0	1	0	7	0	2	3089	0	30
		RP	20	4458	3	0.00	0.73	0	0	0	4	0	4	3665	0	30
		RP	21	4760	3	0.00	0.00	0	0	0	2	0	2	4287	0	120
		RP	A	3370	3	0.00	2.20	0	1	0	4	0	6	0	0	0
		RP	B	0	3	0.00	0.00	0	0	0	0	0	0	6119	0	180
		RP	C	0	3	0.00	0.00	0	0	0	0	0	0	6120	0	170
		RP	D	0	3	0.00	0.00	0	0	2	0	3	0	0	230	190
		RP	1A	0	3	0.00	0.00	0	0	0	0	0	0	6175	0	210
		RP	3A	0	3	2.79	0.00	14	0	5	0	7	0	4176	40	0
		RP	7A	6153	3	0.00	0.00	0	0	0	0	0	1	4838	0	160
		RP	13A	3249	3	0.00	0.00	0	0	0	2	0	1	2757	0	20
		RP	17A	6697	3	0.00	0.00	0	0	0	1	0	0	4838	0	150
		RP	19A	0	3	0.00	0.00	0	0	0	0	0	0	4838	0	140
		RP	--	6119	3	0.00	0.00	0	0	0	1	0	0	0	0	160
68.1	Wayne's Swim	WS	1	5128	3	11.38	3.15	0	0	2	11	11	1	0	0	0
		WS	2	5857	3	15.38	8.77	0	0	5	11	9	1	0	0	0
		WS	3	5531	3	12.31	4.46	0	0	3	11	9	1	5222	10	0
		WS	4	4700	3	19.68	5.84	0	0	2	5	10	4	0	0	0
		WS	5	0	3	6.42	0.00	11	0	13	9	0	0	3100	0	40
		WS	6	4336	3	0.00	0.00	0	0	1	3	13	5	3327	0	60
		WS	8	4624	3	0.00	53.12	0	2	0	11	14	1	0	0	0
		WS	9	4542	3	9.17	0.00	0	0	2	0	10	0	0	0	0
		WS	11	5330	3	2.00	0.00	0	0	4	6	6	1	3224	0	50
		WS	12	6478	3	0.40	0.00	4	0	1	0	7	1	4363	10	310
		WS	A	4435	3	0.00	0.00	0	0	0	3	0	2	4242	0	210
		WS	B	4158	3	0.00	0.58	0	4	0	6	0	1	3293	0	120
		WS	C	4386	3	0.00	0.08	0	0	0	11	0	1	0	0	0
		WS	D	0	3	0.00	0.17	0	0	0	11	0	1	0	0	0
		WS	F	4366	3.	0.00	0.17	0	0	0	11	0	1	0	0	0
		WS	G	4653	3	0.00	2.57	0	0	2	11	9	1	0	20	0
		WS	H	4225	3	0.00	0.00	0	0	0	10	0	2	0	0	0
		WS	I	5203	3	0.00	0.29	0	1	0	4	14	3	2853	0	0
		WS	J	4302	3	0.00	0.67	0	1	0	8	0	2	0	0	20
		WS	K	4024	3	0.00	0.00	0	0	0	7	0	5	0	0	0
		WS	L	4146	3	0.00	0.18	0	0	0	9	0	2	0	0	0
		WS	E	0	3	0.00	1.67	0	0	0	11	0	1	0	0	0

APPENDIX I. (Continued)

RIVER MILE	STUDY AREA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
68.3	Tin Shack	TS	1	0	3	0.00	0.59	0	0	7	11	1	2	4889	130	0
		TS	2	0	3	12.68	28.61	0	0	12	12	1	2	0	0	0
		TS	3	0	3	0.07	0.00	1	0	7	0	0	0	7204	210	0
		TS	5	0	3	2.30	1.04	1	26	12	12	0	0	0	0	0
		TS	6	0	3	2.78	0.04	0	0	11	11	0	0	0	0	0
		TS	7	0	3	1.25	0.29	0	0	11	11	0	0	4497	20	0
		TS	8	0	3	0.83	0.00	5	0	4	0	0	0	7205	240	330
		TS	9	0	3	0.24	0.12	0	3	8	1	0	2	4888	150	310
		TS	10	0	3	0.00	0.00	0	0	10	1	0	2	4887	110	290
		TS	12	0	3	1.08	0.00	2	0	7	0	0	0	6175	170	300
		TS	13	0	3	0.00	0.00	0	0	0	0	0	0	8736	420	340
		TS	14	0	3	0.00	0.00	0	0	7	0	0	0	6137	180	290
		TS	A	0	3	0.00	0.00	0	0	0	12	0	2	0	0	0
		TS	B	0	3	0.00	0.23	0	0	0	10	0	0	0	0	0
		TS	C	0	3	0.00	0.00	0	0	13	12	0	0	0	0	0
		TS	13A	0	3	0.00	0.00	0	0	0	0	0	0	6137	0	330
		TS	6B	6538	3	6.41	0.00	0	0	14	13	7	2	0	0	30
		TS	6C	0	3	6.75	0.00	0	0	1	0	0	0	0	30	0
70.0	Bad Spot	BS	1	0	3	38.07	109.07	3	0	11	11	3	2	0	0	0
		BS	2	0	3	29.69	12.14	2	0	10	10	3	2	0	0	0
		BS	3	6283	3	25.18	5.96	0	67	9	10	3	2	0	0	0
		BS	4	0	3	2.66	0.62	2	0	8	8	4	2	3056	0	30
		BS	5	0	3	16.17	2.59	0	0	11	10	2	2	0	0	0
		BS	6	0	3	0.97	1.59	1	1	12	7	1	2	3108	0	30
		BS	7	0	3	0.55	10.76	0	0	13	10	0	1	0	0	0
		BS	8	0	3	0.31	0.00	0	0	13	1	0	1	3729	0	200
		BS	9	0	3	2.62	15.00	0	0	10	9	0	0	0	0	0
		BS	10	4217	3	0.10	0.00	0	0	5	8	8	3	2931	0	20
		BS	11	6175	3	0.00	0.00	0	0	1	1	8	2	4507	220	260
		BS	12	0	3	4.69	0.83	2	0	8	10	5	2	0	0	0
		BS	13	0	3	7.38	2.76	14	40	4	0	0	2	7207	250	270
		BS	14	0	3	3.97	0.03	69	1	12	1	0	2	5288	60	260
		BS	15	0	3	40.14	4.03	0	2	12	9	1	1	0	0	0
		BS	16	0	3	0.00	0.00	0	0	8	1	0	0	4498	130	260
		BS	17	7368	3	2.40	0.00	4	0	5	1	5	2	4887	40	220
		BS	1A	0	3	0.00	81.71	0	3	0	5	0	0	0	0	0
		BS	1B	0	3	0.00	67.17	0	0	0	5	0	0	0	0	0
		BS	1C	0	3	0.00	0.00	0	0	0	6	0	0	2843	0	10
70.1	Eagle Bar	EB	1	0	3	0.75	0.13	2	0	5	0	2	0	6119	240	450
		EB	2	0	3	0.04	0.00	0	0	7	1	3	0	4363	70	420
		EB	3	0	3	0.37	0.00	9	0	8	2	0	0	4507	210	420
		EB	4	0	3	0.50	0.00	0	0	11	8	2	2	2788	0	60
		EB	5	0	3	0.04	0.12	1	1	0	1	0	1	7205	400	380
		EB	6	0	3	12.04	0.00	1	0	12	2	0	0	4168	60	340
		EB	7	0	3	3.04	0.00	6	0	8	1	0	0	4546	200	430
		EB	8	0	3	9.24	11.54	0	150	11	3	0	0	4168	70	340
		EB	9	4094	3	0.00	0.00	0	0	0	9	0	2	3685	0	10
		EB	10	4225	3	24.35	0.00	0	0	3	10	7	2	0	0	0
		EB	11	0	3	10.43	0.00	0	0	3	0	5	1	4327	0	420
		EB	12	3565	3	0.00	0.00	0	0	0	3	0	6	3106	0	80
		EB	13	6270	3	0.00	0.00	0	0	0	1	0	0	4242	0	400
		EB	14	0	3	0.00	0.00	0	0	0	1	0	1	4302	0	330
		EB	5A	0	3	7.08	0.00	25	0	5	1	0	0	5288	240	430
		EB	8A	0	3	0.00	0.00	0	0	0	0	0	0	3559	0	300
		EB	13A	4225	3	0.00	7.70	0	12	0	6	0	4	0	0	0
		EB	5B	0	3	0.00	0.00	0	0	0	0	0	0	6341	0	430

APPENDIX I. (Continued)

RIVER MILE	STUDY AREA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
70.5	Forbidden Bar	FO	1	0	3	4.45	1.52	0	0	12	12	0	2	0	0	0
		FO	2	0	3	18.17	12.00	0	142	11	11	0	2	2853	0	10
		FO	3	0	3	0.21	0.00	0	0	4	0	0	2	7205	300	270
		FO	4	0	3	0.00	0.00	0	0	5	0	0	0	6376	160	270
		FO	5	0	3	34.64	16.54	0	0	11	12	0	0	0	0	0
		FO	6	6448	3	0.30	0.04	1	0	3	2	3	2	4331	10	170
		FO	7	6481	3	2.67	0.00	4	0	3	0	2	0	0	30	0
		FO	8	0	3	1.00	0.00	4	0	0	0	4	1	9288	0	10
		FO	9	0	3	0.29	0.00	0	0	1	0	2	0	9000	0	20
72.2	Stump Haven	SH	1	0	3	48.09	0.00	4	0	2	0	4	0	0	50	0
		SH	2	0	3	8.30	2.83	0	0	9	10	1	1	0	0	0
		SH	3	6353	3	0.26	0.04	0	0	6	11	4	1	0	0	0
		SH	4	0	3	11.57	0.91	0	0	7	10	3	1	0	0	0
		SH	5	0	3	4.50	1.68	0	1	7	10	4	1	0	0	0
		SH	6	6225	3	3.26	0.09	0	0	7	11	2	1	0	0	0
		SH	7	0	3	0.64	0.05	0	0	10	3	0	0	4095	0	100
		SH	8	0	3	15.22	3.91	0	0	10	10	0	1	0	0	0
		SH	9	0	3	0.00	0.57	0	0	4	4	5	1	4172	10	130
		SH	10	0	3	11.30	1.39	0	0	4	10	6	2	0	0	0
		SH	11	0	3	0.33	0.00	0	0	4	0	6	1	0	0	0
		SH	12	0	3	3.33	0.00	0	0	4	3	7	1	0	0	0
		SH	13	4909	3	2.74	0.39	0	7	4	7	7	3	3151	0	20
		SH	14	0	3	0.55	0.09	0	1	4	1	7	1	4838	0	160
		SH	15	6119	3	145.70	6.91	50	1	5	10	6	1	0	0	0
		SH	16	0	3	0.43	0.00	0	0	3	0	4	1	6137	0	200
		SH	17	0	3	1.14	0.41	0	5	3	8	7	2	0	0	0
		SH	18	0	3	0.00	0.00	0	0	1	0	2	0	0	0	0
		SH	19	6196	3	0.00	0.00	0	0	2	0	1	0	0	0	0
		SH	20	6181	3	0.00	0.00	0	0	3	1	0	0	4435	0	160
		SH	A	4516	3	0.00	0.08	0	0	0	3	0	5	3368	0	50
		SH	B	0	3	0.00	0.42	0	0	0	9	0	2	2804	0	10
		SH	C	0	3	0.00	0.20	0	2	0	0	0	1	6212	0	170
		SH	D	4386	3	0.00	17.92	0	1	0	8	0	2	3368	0	20
		SH	F	0	3	0.00	0.00	0	0	0	0	0	1	3368	0	160
		SH	G	0	3	0.00	0.17	0	21	0	8	0	2	4833	0	20
		SH	H	0	3	0.00	0.00	0	0	0	1	0	1	2832	0	150
		SH	I	0	3	0.00	0.18	0	0	0	5	0	5	3368	0	10
		SH	J	0	3	0.00	13.30	0	69	0	5	0	2	3724	0	20
		SH	K	3578	3	0.00	0.00	0	0	0	6	0	2	0	0	0
		SH	E	0	3	0.00	0.92	0	1	0	4	0	2	0	0	80
72.6	Model Pothole	MP	10	0	3	0.00	0.00	0	0	0	0	0	0	0	0	0
		MP	A	0	3	0.00	21.25	0	0	0	3	0	1	0	0	0
		MP	B	0	3	0.00	1.25	0	0	0	3	0	1	0	0	0
		MP	C	0	3	0.00	100.00	0	0	0	0	0	0	0	0	0
72.7	Hooper's Slough	HS	2	5531	3	25.79	0.00	0	0	7	1	3	2	4242	0	340
		HS	3	5551	3	0.79	1.10	3	0	5	11	4	2	4497	60	0
		HS	4	5596	3	7.96	11.11	2	200	7	7	3	2	3219	0	150
		HS	5	3370	3	7.25	3.93	0	0	9	4	2	10	0	0	0
		HS	6	0	3	1.48	1.10	0	0	11	12	0	1	0	0	0
		HS	7	0	3	10.21	0.00	0	0	6	0	0	0	4498	130	0
		HS	8	0	3	0.00	0.00	0	0	4	0	0	0	6341	200	380
		HS	9	0	3	4.19	0.63	0	0	7	1	3	1	0	0	0
		HS	10	5531	3	0.38	0.46	2	0	5	2	4	2	4264	0	300
		HS	11	0	3	0.00	2.85	0	8	0	8	0	4	0	0	0
		HS	1A	0	3	10.36	1.96	0	0	7	4	4	9	3197	0	10
		HS	1B	0	3	0.00	10.67	0	0	0	10	0	5	0	0	0
		HS	1C	4006	3	0.00	3.53	0	1	0	10	0	4	0	0	0

APPENDIX I. (Continued)

RIVER MILE	STUDY AREA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
73.0	Rick's Suprise	RS	A	0	3	0.00	2.70	0	0	0	10	0	0	0	0	0
		RS	B	0	3	0.00	6.50	0	0	0	10	0	0	0	0	0
		RS	C	0	3	0.00	1.00	0	0	0	2	0	0	4403	0	300
		RS	D	0	3	0.00	0.20	0	0	0	6	0	0	3224	0	160
73.1	Inaccessible Island	II	1	0	3	0.47	0.00	0	0	3	1	2	1	4586	0	300
		II	2	0	3	2.37	0.47	0	0	5	9	0	0	2843	0	40
		II	3	0	3	18.47	6.06	0	3	4	3	1	1	4586	0	220
		II	4	0	3	1.24	0.06	0	1	4	0	0	1	4366	10	340
		II	5	0	3	0.53	0.00	1	0	5	0	0	1	4586	0	310
		II	6	0	3	5.41	0.00	0	0	4	1	1	1	4336	0	250
		II	7	0	3	5.29	1.06	0	0	3	10	1	1	0	0	0
		II	8	0	3	4.00	0.06	0	0	3	1	2	1	4336	0	240
		II	9	0	3	6.56	0.19	0	0	3	1	2	1	4336	0	200
		II	10	0	3	0.12	0.59	0	0	5	2	0	1	4566	0	280
		II	11	0	3	0.19	0.13	1	2	1	0	1	1	4566	30	330
		II	12	0	3	6.00	1.33	9	0	3	2	0	1	3675	0	210
		II	A	3954	3	0.00	3.75	0	0	0	6	0	2	0	0	0
		II	B	4331	3	0.00	3.25	0	0	0	8	0	0	0	0	0
73.3	Carnage Bar	CB	A	0	2	0.00	2.85	0	36	0	2	0	1	2964	0	280
		CB	B	3098	2	0.00	1.23	0	3	0	4	0	5	2282	0	30
74.2	Dry Bar	RB	A	0	2	0.00	0.00	0	0	0	0	0	2	4068	0	30
		RB	B	0	2	0.00	0.00	0	0	0	1	0	2	2149	0	10
		RB	C	0	2	0.00	0.00	0	0	0	0	1	2	2149	0	10
76.0	North O'Briens Ferry	NF	A	0	2	0.00	0.00	0	0	0	1	0	0	2149	0	10
		NF	B	0	2	0.00	0.00	0	0	0	1	0	0	2149	0	10
		NF	C	0	2	0.00	0.00	0	0	0	0	0	0	2570	0	10
76.3	Seclusion Island	SI	A	0	2	0.00	5.86	0	0	0	3	0	1	2282	0	20
		SI	B	0	2	0.00	3.43	0	0	0	5	0	0	0	0	0
77.5	Big Eddy	BE	A	0	2	0.00	2.85	0	21	0	0	0	6	0	0	130
		BE	B	0	2	0.00	4.54	0	7	0	4	0	3	0	0	310
		BE	C	0	2	0.00	40.33	0	22	0	8	0	3	0	0	0
		BE	D	0	2	0.00	23.00	0	19	0	8	0	4	0	0	0
		BE	F	0	2	0.00	0.08	0	1	0	0	0	2	3562	0	400
		BE	G	3241	2	0.00	3.54	0	30	0	9	0	3	0	0	0
		BE	H	3241	2	0.00	14.70	0	1	0	7	0	3	0	0	0
		BE	E	0	2	0.00	0.46	0	2	0	4	0	4	2530	0	240
		BE	C2	0	2	0.00	15.27	0	7	0	7	0	4	0	0	0
78.2	Marblemount Slough	MS	A	0	2	0.00	19.91	0	0	0	5	0	3	0	0	0
		MS	B	0	2	0.00	0.00	0	0	0	7	0	3	0	0	0
78.5	Fungus Bar	FB	1	0	2	2.44	0.19	0	0	6	11	7	1	2282	0	90
		FB	2	0	2	0.59	0.00	0	0	10	1	1	1	3324	70	450
		FB	3	0	2	0.00	0.00	0	0	8	7	5	1	2530	0	230
		FB	4	0	2	18.33	2.48	0	0	7	13	6	1	0	0	0
		FB	5	0	2	0.81	0.00	0	0	10	0	2	1	3886	10	450
		FB	6	0	2	2.93	0.00	0	0	10	0	1	1	3886	80	460
		FB	7	0	2	1.56	0.00	0	0	7	4	4	1	3324	40	410
		FB	8	0	2	6.13	0.00	0	0	7	8	2	1	2282	0	130
		FB	9	0	2	5.54	0.79	0	6	9	8	0	1	2530	0	230
		FB	10	0	2	33.09	0.00	0	0	5	0	4	0	0	0	0
		FB	A	0	2	0.00	0.00	0	0	0	13	0	1	0	0	0
		FB	B	0	2	0.00	0.00	0	0	0	8	0	1	2530	0	210
		FB	C	0	2	0.00	1.92	0	0	0	12	0	1	0	0	0
		FB	D	0	2	0.00	0.00	0	0	0	8	0	2	2530	0	250
		FB	F	2244	2	0.00	12.17	0	0	0	9	0	3	0	0	0
		FB	E	3084	2	0.00	0.29	0	1	0	8	0	6	0	0	0
82.0	Sam's Bar	SP	A	2590	2	0.00	0.00	0	0	1	2	0	0	0	0	0
82.5	Maple Bar	MB	A	0	2	0.00	2.67	0	0	0	2	0	1	0	0	0
		MB	B	0	2	0.00	0.00	0	0	0	2	0	1	0	0	0
		MB	C	0	2	0.00	0.00	0	0	0	2	0	1	0	0	0
		MB	D	0	2	0.00	0.00	0	0	0	1	0	0	2570	0	10

APPENDIX I. (Continued)

RIVER MILE	STUDY AREA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
82.6	Bacon Creek	BC	1	0	2	16.95	0.00	13	0	5	1	1	1	3562	0	350
		BC	2	0	2	1.23	0.55	21	1	5	11	1	1	0	0	20
		BC	3	0	2	0.10	0.00	0	0	5	1	1	1	3586	0	290
		BC	4	0	2	68.59	3.32	0	0	5	12	1	0	0	0	0
		BC	A	0	2	0.00	0.00	0	0	0	1	0	1	3562	0	360
		BC	B	0	2	0.00	0.00	0	0	0	3	0	1	3562	0	310
		BC	C	0	2	0.00	0.31	0	0	0	11	0	1	0	0	0
		BC	D	0	2	0.00	0.08	0	0	0	7	0	2	2530	0	150
		BC	E	0	2	0.00	0.08	0	1	0	1	0	3	3562	0	240
82.7	Face Bar	JB	A	0	2	2.50	4.50	0	1	1	4	0	1	0	0	0
		JB	B	0	2	0.00	1.00	0	0	0	1	0	1	3278	10	30
		JB	C	0	2	0.00	0.00	0	0	1	1	0	1	3278	0	20
82.9	Oink Bar	OB	A	0	2	0.00	16.33	0	0	0	4	0	4	2530	0	250
		OB	B	0	2	0.00	15.58	0	0	0	6	0	5	0	0	80
		OB	C	2737	2	0.00	5.67	0	57	0	4	0	7	2282	0	120
		OB	D	0	2	0.00	0.25	0	1	0	6	0	3	2530	0	200
		OB	F	2803	2	0.00	1.44	0	0	0	1	0	8	0	0	0
		OB	E	0	2	0.00	0.00	0	0	0	6	0	5	0	0	60
83.0	Driftwood Bar	DB	A	1986	1	0.00	0.00	0	0	0	3	0	7	0	0	0
		DB	B	0	1	0.00	0.00	0	0	0	3	0	7	0	0	0
		DB	C	1725	1	0.00	0.00	0	0	0	5	0	6	0	0	0
83.3	Minibar	IB	A	0	1	0.00	2.00	0	0	0	4	0	0	0	0	0
		IB	B	0	1	0.00	0.00	0	0	0	2	0	0	0	0	0
		IB	C	0	1	0.00	0.00	0	0	0	1	0	1	4713	0	10
83.5	Flower Pothole	FP	A	0	1	0.00	0.25	0	0	0	4	0	0	0	0	0
84.0	Copper Creek	CC	A	0	1	0.00	1.50	0	0	0	4	0	0	0	0	0
		CC	B	0	1	0.00	0.00	0	0	0	1	0	0	0	0	0

Appendix I. Format Description

COLUMN	VARIABLE	DESCRIPTION
1	SITE	Code of pothole area (see attached sheet)
2	PH #	Pothole number at each area
3	C FLO	Connectivity flow (avg. of max. [DF] and min. CF)*
4	GAGE	Assigned gage location 1 = Newhalem 2 = Marblemount 3 = Rockport
5	TRAP S	Avg. # trapped/daily observation for spring
6	TRAP F	Avg. # trapped/daily observation for fall
7	STRAND S	Total # stranded - spring
8	STRAND F	Total # stranded - fall
9**		Sum of disconnect observations - spring
10**		Sum of disconnect observations - fall
11**		Sum of connect observations - spring
12**		Sum of connect observations - fall
13	DRY FLO	Maximum assigned flow when pothole dry
14		Sum of dry observations - spring
15		Sum of dry observations - fall

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* DF is the flow at which the pothole was observed disconnected from the river.
CF is the flow at which the pothole was observed connected to the river.
If the minimum (CF) was missing, then the maximum (DF) was used; if the maximum (DF) was missing, then the CFLO = 0.

**These variables represent sums of the last observation of the day and not the sum of all observations, i.e., the number of days during the spring and fall surveys when the pothole was observed connected or disconnected.

Skagit River Pothole Study Areas

STUDY AREA	CODE	RIVER MILE	POTHOLE MAP REF. NO.	RIVER GAGE ASSIGNMENT
Rockport Bar	RP	67.5	1	Rockport
Wayne's Swim	WS	68.1	2	Rockport
Tin Shack	TS	68.3	4,3	Rockport
Bad Spot	BS	70.0	5	Rockport
Eagle Bar	EB	70.1	6	Rockport
Forbidden Bar	FO	70.5	7	Rockport
J. R. Bar	JR	71.1	8	Rockport
Beaver Island	BI	71.4	9	Rockport
Stump Haven	SH	72.2	10	Rockport
Model Pothole	MP	72.6	11	Rockport
Hooper's Slough	HS	72.7	12	Rockport
Rick's Surprise	RS	73.0	13	Rockport
Inaccessible Island	II	73.1	13	Rockport
Carnage Bar	CB	73.3	14	Marblemount
Power Bar	PB	74.0	15	Marblemount
Dry Bar	RB	74.2	16	Marblemount
North O'Brians Ferry	NF	76.0	17	Marblemount
Seclusion Island	SI	76.3	18	Marblemount
Big Eddy	BE	77.5	19	Marblemount
Teflon Bar	TB	77.7	20	Marblemount
Marblemount Slough	MS	78.2	21	Marblemount
Rainier Pothole	RA	78.3	22	Marblemount
Fungus Bar	FB	78.5	23	Marblemount
Sam's Bar	SP	82.0	24	Maeblemount
Maple Bar	MB	82.5	25	Marblemount
Bacon Creek	BC	82.6	26	Marblemount
Face Bar	JB	82.7	27	Marblemount
Oink Bar	OB	82.9	27	Marblemount
Driftwood Bar	DB	83.0	28	Newhalem
Minibar	IB	83.3	29	Newhalem
Flower Pothole	FP	83.5	30	Newhalem
Copper Creek	CC	84.0	31	Newhalem