Fishery Data Series No. 94-37

Annual Summary of Alaska Department of Fish and Game Instream Flow Reservation Applications

by

Christopher C. Estes

October 1994

Alaska Department of Fish and Game

Division of Sport Fish

FISHERY DATA SERIES NO. 94-37

ANNUAL SUMMARY OF ALASKA DEPARTMENT OF FISH AND GAME INSTREAM FLOW RESERVATION APPLICATIONS[1]

by

Christopher C. Estes

Alaska Department of Fish and Game
Division of Sport Fish
Anchorage, Alaska

October 1994

[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-9, Job No. H-1.

The Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

TABLE OF CONTENTS

LIST OF FIGURES

Figure | Page

LIST OF APPENDICES

Appendix | Page

LIST OF APPENDICES (Continued)

ABSTRACT

This report summarizes the principal instream flow activities of the Alaska Department of Fish and Game during the eighth year of its program.

Between July 1, 1993 and June 30, 1994, instream flow analyses were completed for five river reaches: Sagavanirktok River near Pump Station 3, Sagavanirktok River near Sagwon, Kuparuk River near Deadhorse, Situk River near Yakutat. Applications to acquire instream flow reservations were prepared based on these analyses and will soon be submitted to the Alaska Department of Natural Resources for adjudication.

Ten instream flow reservation requests filed by the Alaska Department of Fish and Game in previous years have been granted by the Alaska Department of Natural Resources.

Other applications from prior years are pending the completion of the adjudication process by the Alaska Department of Natural Resources.

A summary of instream flow related Alaskan legislation, regulations, and actions of other agencies and the private sector is also presented.

KEY WORDS: instream flow, flow reservation, water rights, adjudication, Water Use Act, statutes, Water Use Act Regulations, Tennant Method, Montana Method, Alaska, flushing flow, Sagavanirktok River, Kuparuk River, Power Creek, Situk River, water marketing, water exports.

INTRODUCTION

Alaska has abundant and diversified sport fisheries which are of considerable recreational importance to anglers and others. To date approximately 15,000 water bodies in Alaska have been formally identified as supporting anadromous and resident fish species (ADF&G 1993). Many others have yet to be investigated.

In 1992 an estimated 428,768 sport anglers took 1.8 million household trips and fished about 2.5 million days[1] to harvest 3.2 million fish (Mills 1993). These values represent significant increases over those noted in the late seventies and early eighties (Mills 1979, 1980, 1981a, 1981b, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993).

The continued production of Alaska's valuable fishery resources is, in part, dependent upon maintaining important habitat characteristics, including the quantity and quality of water within fish bearing waters. Private, government, and commercial developments resulting from increased population growth, urbanization, and resource development can contribute to water quantity (instream flow) and other habitat modifications that are detrimental to fish production. Examples of these developments and activities are hydroelectric facilities and operations, community and individual water supply facilities and operations, exportation of Alaskan water to other states and countries, recreational based water uses such as artificial snow making, mining facilities and operations, agriculture, aquaculture, fish processing facilities and operations, municipal growth, forestry, manufacturing, oil and gas facilities and operations, etc. The term, instream flow, is normally used to describe the quantity of water that flows past a given point within a stream channel during one second. It can also be used to refer to the volume of water in a lake or a physical attribute related to water quantity, such as water depth.

Fortunately, the Alaska Legislature recognized the importance of instream flow protection to the economic and social well-being of its citizens by amending the Water Use Act (Alaska Statute, AS, 46) in 1980. The amendments (AS 46.15.03 and AS 46.15.145) provided the opportunity for private individuals; in addition to state, federal, and local government agencies to legally acquire instream flow water rights in rivers, streams, and lakes for one or a combination of four types of uses:

1) protection of fish and wildlife habitat, migration, and propagation;

2) recreation and parks purposes;

3) navigation and transportation purposes; and

4) sanitary and water quality purposes.

---

[1] Any part of a day (24-hour period) that is fished by an individual is counted as one day fished.

Instream flow reservation requests can be quantified as rates of flow, surface water elevations, or water depths.

Regulations to implement the instream flow law were adopted by the Alaska Department of Natural Resources (DNR) in September 1983 and modified in 1990 and 1992. Additional regulation modifications relating to instream flows were approved in 1993. Forms required to apply for instream flows were first made available by the DNR in November 1983. Further information related to Alaska's instream flow water laws can be found in Harle and Estes (1993), Estes (1992), Harle (1988), Estes and Harle (1987), White (1981), and Curran and Dwight (1979).

The Fish and Game Act (AS 16) requires the Alaska Department of Fish and Game (ADF&G) to, among other responsibilities, "manage, protect, maintain, improve, and extend the fish, game and aquatic plant resources of the state in the interest of the economy and general well-being of the state" (AS 16.05.020). One of the AS 16 provisions enables the ADF&G to acquire water rights to further its objectives or purposes (AS 16.05.050). The Division of Sport Fish of the ADF&G initiated a program in 1986 to take advantage of the new opportunity to acquire instream flow water rights for sport fish resources by initiating an ongoing program in 1986.

To reserve instream flows, an application containing supporting data and analyses that substantiate the flows being requested must be submitted to the DNR for adjudication (the administrative determination of the validity and amount of a water right, including the settlement of conflicting claims among competing appropriators).

This report summarizes the eighth year of this program in which the primary objective was to estimate seasonal quantities of instream flows necessary to sustain sport fishery resources in four stream reaches. Included in the Discussion is a summary of other instream flow related activities by the private sector and other agencies.

METHODS

Study Design

Procedures were selected that complied with instream flow application instructions and requirements established by state law (AS 46.15.145), state regulations (11 AAC 93.141-146), instream flow application form instructions (Estes 1993), and the "*State of Alaska Instream Flow Handbook*" (DNR 1985).

Site Selection

River/stream reaches nominated for instream flow protection in 1994-5 were selected following procedures in the 1984 Departmental Instream Flow Work Plan (ADF&G 1984; Estes 1985), and as modified in 1986 (Instream Flow Committee 1986). The final selection of a site was made by the Statewide Instream Flow Coordinator in consultation with Regional Supervisors for each region of the Division of Sport Fish or designees. The choice of a site was based on the importance of a water body to the sport fishery resources, the likelihood for competing out-of-stream or diversionary water appropriations, whether existing hydrologic and biologic data for a stream reach were adequate for performing an instream flow analysis (including the subsequent preparation and submission of an application), and whether other state and federal statutory mechanisms would provide better and more cost effective protection than an instream flow water right acquired under Alaskan law.

Five reaches (Figure 1; Appendices A1-5) were selected for instream flow analyses and preparation of instream flow reservations in Fiscal Year 1994 (FY 94, July 1, 1993 to June 30, 1994): Sagavanirktok River (two reaches), Kuparuk River, Power Creek, and Situk River.

Stream reach boundaries for each FY 94 instream flow application were selected to insure that flow, habitat, and fish periodicity (seasonal use of habitat for passage, spawning, incubation, and rearing) characteristics within the reach were uniform throughout the study reach. Reaches were defined on U.S. Geological Survey (USGS) topographic maps with the assistance of ADF&G biologists and USGS hydrologists. Topography, watershed, and channel patterns, fish periodicity, USGS gage site descriptions and mean daily flow data were collectively analyzed.

Fish periodicity data for defining stream reaches and flow requirements were obtained and summarized from reviews of scientific literature, interviews with fishery and habitat biologists from the ADF&G and other agencies, the "*Catalog of Waters Important for Spawning, Rearing, or Migration of Anadromous Fishes*" (ADF&G 1993), and the Division of Sport Fish statewide harvest survey publication series (Mills 1979-1993). ADF&G biologists, responsible for the areas encompassing targeted instream flow reaches, reviewed and refined the syntheses of periodicity data. If discrepancies were discovered among data sources for species distribution and life phase occurrence within a reservation reach area, individuals responsible for data sources were consulted to reach a consensus as to which data to use. The final periodicity chart was based on these consultations.

Flow data and gage site descriptions used for delineating reach boundaries were obtained from USGS "*Water-Data*" Reports; and from interviews with ADF&G biologists, USGS hydrologists, DNR Division of Geological and Geophysical Survey hydrologists, DNR land and Water Management Division resource specialists, and other resource specialists that are known to have data pertinent to the reservation. Alaska water laws and regulations required that stream reach boundaries encompassed a stream reach with homogeneous flow and biologic characteristics. Boundaries were first determined by evaluating watershed and channel characteristics upstream and downstream of a stream gage or discharge site. Seasonal fish distribution and species periodicity were used to refine reach boundaries that were hydrologically defined. The resulting selection of boundaries were then refined based upon reviews by USGS hydrologic personnel and ADF&G regional biologists.

Instream Flow Analysis

An applicant's choice and use of a specific method for quantifying instream flow requirements is not restricted by existing Alaska water laws, regulations, or a set of established standards (DNR 1985, Estes and Harle 1987). However, the rationale for the selection of a method or methods

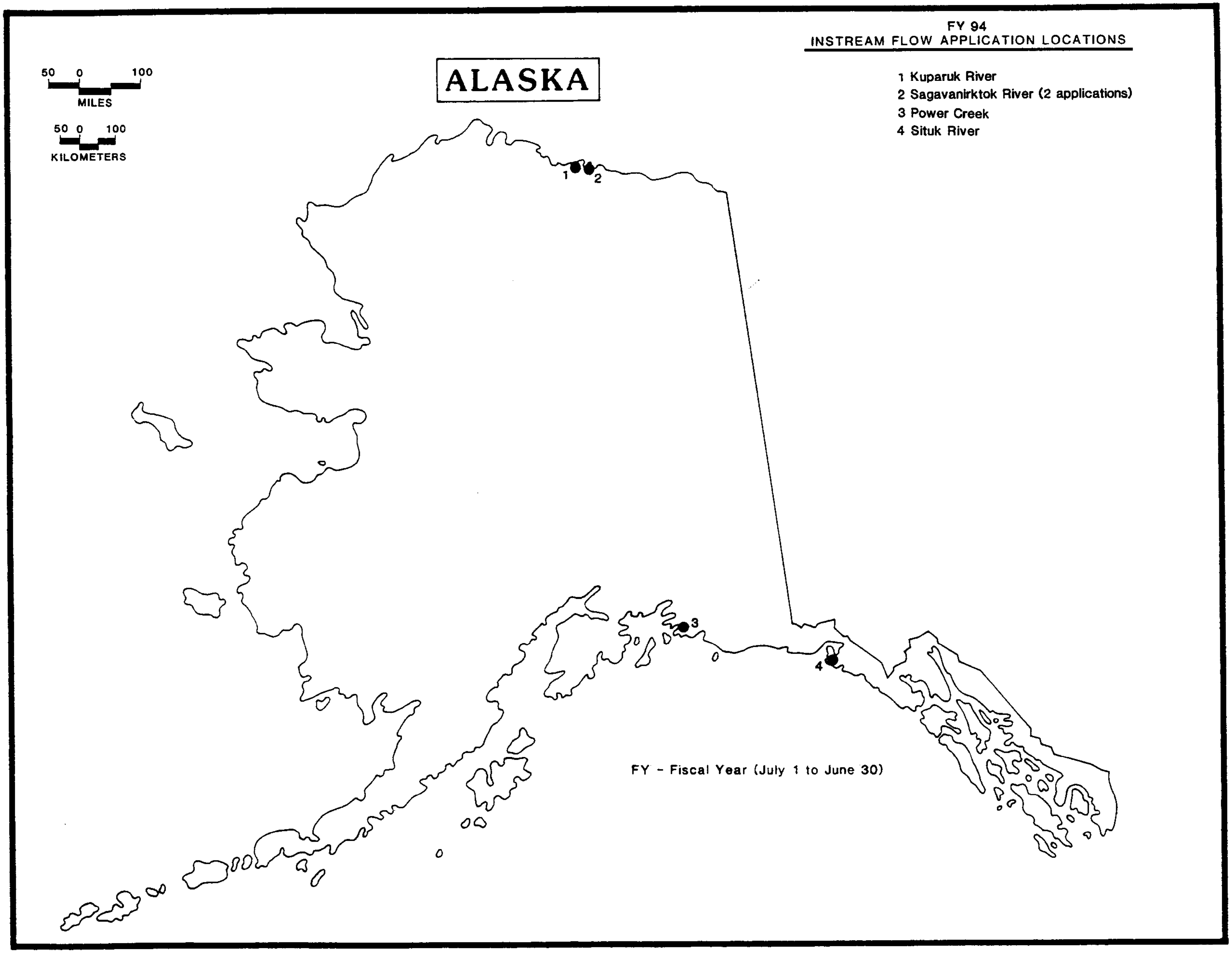


Figure 1. Locations of instream flow reservation application reaches, July 1, 1993 to June 30, 1994.

must be documented and include a description of the procedures. This information must accompany the resulting instream flow application.

The Tennant Method, also referred to as the Montana Method (Tennant 1972, 1976), was selected as the basis for quantifying instream flow requirements for the FY 94 study sites. The Tennant Method analysis was combined with an evaluation of mean daily flow, monthly flow, and other hydrologic characteristics (Orsborn and Watts 1980; Estes 1984; Estes and Orsborn 1986; Shaw 1988) to determine whether sufficient water could be expected to be within each study reach during the various periods of the year in which the reservation was requested, and to enable a refinement of the instream flow choices derived with these analyses.

Flow databases of the USGS, required for performing all of these analyses, were obtained via archived data on tape acquired from the USGS for historical data and downloaded from local USGS computers for current data.

Each data set was transferred into Statistical Analysis System (SAS) data files (SAS 1985). Summary analysis was used to check the data for simple errors. After initial error checking was complete, the data were analyzed by a series of SAS programs using the procedures outlined below to estimate the long-term average annual and average monthly mean daily flow values and the monthly (and/or semi-monthly) flow duration parameters.

Descriptive information pertaining to the fishery and hydrologic characteristics of the study sites were acquired through literature review and interviews with ADF&G biologists, USGS hydrologists, DNR Division of Water hydrologists, and other state, federal, and private resource specialists that were known to have data pertinent to the reservation analyses. ADF&G biologists and USGS hydrologists, most familiar with each study site, assisted with the refinement of this information whenever discrepancies occurred.

Tennant Method:

The choice of the Tennant Method was based on its acceptance by both the DNR and courts as a valid instream flow analytical procedure, and the limited availability of data, previous analyses, and financial resources required to prepare instream flow applications.

The first step of the Tennant Method was to calculate the average annual flow, QAA, (arithmetic mean of the annual mean of mean daily flows for all years of record) for each stream reach. Next, each QAA was multiplied by eight Tennant Method coefficients (percentages) to calculate instream flows for eight habitat categories. Seven of the Tennant Method habitat categories (ranging from 10% to 100% of the QAA) represent a range of poor to optimum habitat quality conditions for fish and wildlife. The eighth category (200% of the QAA) represents the short-term flushing flow that Tennant (1972) considers necessary to maintain channel substrate characteristics suitable for fish spawning and egg incubation, and benthic invertebrate production. Research by Estes (1984, Reiser et al. 1985) suggests supplemental analyses are required to modify or substitute for Tennant Method flushing flow calculations.

Next, hydrologic analyses were performed to estimate baseline flow conditions in each stream reach. This involved calculating mean monthly flows (QAM), the arithmetic mean of the monthly mean daily discharge for a given month for the entire period of record, and flow duration estimates (the expected frequency of occurrence of mean daily flows within a particular month).

Finally, seasonal instream flow requirements for individual life phases of fish for each stream reach were chosen by comparing the eight Tennant Method flows, fish periodicity data, QAM, and flow duration estimates. With the exception of flushing flows, instream flows were selected that corresponded to both fish periodicity and the highest of the other seven Tennant Method habitat categories that did not exceed flow duration estimates during that same period. During the months when spawning occurs, flows within the highest qualitative instream flow condition were selected from the Tennant analysis output that did not exceed those estimated by other hydrologic analyses (i.e. mean monthly flow or duration analysis values) during that same time period. During other life phase time periods, the highest of the flows were selected that were expected to occur within the system during that time period that fell within the Tennant ranges of "fair to excellent". When more than one life phase occurred for the same or different species during the same time period, the life phase for that time period requiring the highest instream flow value were requested for that time period.

Tennant's flushing flow recommendations were not used due to the inability to legally reserve this type of flow in free flowing systems. Resources were also unavailable to perform supplemental analyses suggested by Estes (1984) for modifying or substituting for Tennant's flushing flow calculations.

Average Annual Flow Procedures:

Calculation of QAA, from the existing USGS mean daily flow records for the stream reaches, involved first obtaining the mean of the mean daily flows within each water year (October 1-September 30):

$$qaa_h = \frac{\sum_{i=1}^{d_h} q_{hi}}{d_h} ; \qquad (1)$$

where: qaa_h equaled the mean annual daily flow for each year (*h*) of record; d_h equaled the number of days in each year of record (note that only complete years of record were used in this analysis; d_h varied only between leap and non-leap years); q_{hi} equaled the daily mean flow in cubic feet per second for each day in the record.

Next, QAA was estimated as a mean of the annual mean daily flow values over all complete years of record:

$$\hat{QAA} = \frac{\sum_{h=1}^{n} qaa_h}{n} ; \qquad (2)$$

where: n equaled the years of record (with complete daily flow records for each water year).

Mean Monthly Flow Procedures:

The QAM was estimated similarly by first estimating the mean daily discharge for each complete month in the record:

$$qam_{jh} = \frac{\sum_{k=1}^{d_{jh}} q_{jhk}}{d_{jh}} ; \qquad (3)$$

where: qam_{jh} equaled the monthly mean daily flow for each month (*j*) for each year of record (*h*); d_{jh} equaled the number of days in each month of record (note that only complete months of record were used in this analysis); q_{jhk} equaled the daily mean flow in cubic feet per second for each day in the record.

Next, QAM was estimated as a mean of the monthly mean daily flow values over all complete years of record:

$$\hat{QAM}_j = \frac{\sum_{h=1}^{n} qam_{jh}}{n_j} ; \qquad (4)$$

where: n_j equaled the years of record with complete daily flow records for each *j*.

Duration Analysis Procedures:

Flow duration estimates were calculated as percentiles of the distribution of observed values within the time periods involved over the years of record. For example, flow duration estimates for the month of April were calculated by combining all mean daily flow values for April (for all years having complete April records). Then the empirically defined distribution (observed-combined mean daily flow values) was calculated as follows. If the quantity to be calculated was defined as the "t^{th}" percentile, where $p = t / 100$, then setting:

$$np = j + g$$

where: n was equal to the number of observed mean daily flow values in the combined group (for example 300 days for a 10-year record of complete months of April); j was the integer part of n times p; and g was the fractional part of n times p.[2]

Then the t^{th} percentile (y) was defined as:

$$y = (x_{(j)} + x_{(j+1)}) / 2 \qquad \text{if } g = 0 ; \qquad (4a)$$

or

$$= x_{(j+1)} \qquad \text{if } g > 0 ; \qquad (4b)$$

where: $x_{(j)}$ and $x_{(j+1)}$ were the ordered (from smallest to largest) values in the combined group of mean daily flow values.

The above information was incorporated into instream flow application forms (Estes 1993) with other required information following procedures defined by the DNR (1985). Additional descriptions of procedures are presented in each instream flow application (ADF&G 1994a, b, c, d, e).

RESULTS

Analyses were completed and applications prepared to request instream flow protection for fish in five stream reaches in five river systems (Figure 1; Appendices A1-A5; ADF&G 1994a, b, c, d, e): Sagavanirktok River near Sagwon (Reach A), Sagavanirktok River near Pump Station Three (Reach B), Kuparuk River near Deadhorse, Power Creek near Cordova, and Situk River near Yakutat. Applications are undergoing review prior to submitting them to the DNR.

The lengths of the five stream reaches, ranged from approximately two-miles (Power Creek, Appendix A4) to 104 miles (Sagavanirktok River-Reach A, Appendix A1).

Fish periodicity for each stream is illustrated in Appendices A6-A10. Power Creek (Appendix A9) had the lowest variety of fish species (five) and the Sagavanirktok River-Reach A (Appendix A6) the most, with eleven species. Appendix A11 lists the common and scientific names of the fish species listed in the periodicity charts (Appendices A6-10).

Historical records of USGS mean daily flow data varied from 5 years for the Situk River to 46 years for Power Creek (Appendix A12).

---

2 For example, if n = 300 and we wanted to calculate the 97th percentile, then j = 291 and g = 0; or for the 2.5th percentile, then j = 7 and g = 5.

QAA, mean monthly flow, and Tennant Method results are summarized in Appendices A13-A17. QAA values ranged from 255 cubic feet per second (cfs) for Power Creek (Appendix A16) to 1,656 cfs for the Sagavanirktok River-Reach A (Appendix A13). Mean monthly flows ranged from 0 cfs in the Sagavanirktok River-Reach B during March (Appendix A14) to 11,364 cfs in the Kuparuk River during June (Appendix A15). Optimum habitat flows ranged from 153-255 cfs for Power Creek (Appendix A16) to 994-1,656 cfs (Appendix A13) for the Sagavanirktok River-Reach A. Poor habitat flows ranged from 26 cfs for Power Creek (Appendix A16) to 166 cfs for the Sagavanirktok River-Reach A (Appendix A13). Tennant flushing flow values ranged from 510 cfs for the Power Creek (Appendix A16) to 3,312 cfs (Appendix A13) for the Sagavanirktok River-Reach A.

Instream flow values requested usually ranged from 60% to 100% of the QAA for the spawning and passage seasons, and 10% to 40% of the QAA for incubation and rearing seasons (ADF&G 1994a, b, c, d, e).

There is presently no legal mechanism for reserving flushing flows in unregulated streams and rivers in Alaska. Research by Estes (1984) suggests flushing flow calculations, using the Tennant Method, require additional analyses that were not funded. Therefore, Tennant values were not modified and used for reserving flushing flows for the five river reaches. Nonetheless, to establish a basis for protecting flushing flows in these unregulated systems (until an acceptable method is developed) a statement was included in each application explaining that flushing flows were required to maintain fish habitat and (at a minimum) must be safeguarded whenever significant flow modifications or a structure capable of controlling flows is planned.

Instream flow regimes requested are not included in this report because they are subject to modification both while undergoing departmental review prior to submission to the DNR and during the various stages of the DNR adjudication process. These data will be presented in future reports following the completion of these processes.

DISCUSSION

Five instream flow applications were completed for FY 94. This is half of the 5-year average of ten applications prepared annually between 1986 and 1991 (Appendix A18; Estes 1987, 1988, 1989, 1990, 1991, 1992, 1993). The reduction in the number of applications completed can be attributed to the loss of seasonal support staff coinciding with a continual increase in the number of requests for instream flow related technical support by other staff, agencies, and the private sector.

In an attempt to compensate for these limitations, the ADF&G has developed and refined a cost-effective approach to acquire the majority of its instream flow protection for fish by using the Tennant Method as its primary technique for analyzing instream flow needs. When necessary, this method has been modified and new procedures (requiring minimal resource expenditures) developed to request specialized instream flow reservations (e.g., flushing flows, and water depth and area in lakes). Consequently, as a rule, uses of more sophisticated and expensive methods for reserving instream flows have been limited to situations where competition between out-of-stream uses and instream requirements was likely to be highly controversial and required an incremental quantitative flow analysis. Occasionally, projects under federal jurisdiction (e.g., projects requiring a Federal Energy Regulatory License) have also mandated a specific data collection and analytical procedure. In the past, supplemental funding was available for projects requiring application of the more sophisticated methods.

The Tennant Method requires minimal data and is one of the easiest and least expensive procedures for quantifying instream flows. It has been used for quantifying instream flows for all but five of the ADF&G applications since 1986. Supplemental resources were acquired on three occasions when the ADF&G selected to use the more sophisticated Instream Flow Incremental Methodology, IFIM (Bovee 1982), to evaluate fish habitat suitability for specific increments of water (Estes 1987). The IFIM is the most time consuming, data collection and analysis intensive, and expensive of the instream flow analytical procedures. A new method was developed and used to quantify and file for instream flows to protect fish spawning in an Alaskan lake by Estes and Hoffmann in 1989 (Estes 1989). The Estes and Orsborn Method was applied in Alaska for the first time in 1992 to quantify and request flushing flows in streams and rivers that have flow control structures (Estes 1992). The acceptance of the lake and flushing flow methods by the DNR remain unknown, because the applications based on these methods are pending in the adjudication process.

The DNR has received 66 applications for instream flows since passage of the 1980 enabling legislation (Appendix A18; Estes 1987, 1988, 1989, 1990, 1991, 1992, 1993; Harle 1988). Fifty-three of the applications were submitted by the ADF&G (Harle and Estes 1993), one by the U.S. Bureau of Land Management (BLM), four by the U.S. Fish and Wildlife Service (USFWS), four by the Anchorage Audubon Society, two by private individuals, one by the Arctic Unit of the Alaska Chapter of the American Fisheries Society (AFS), and one by the Juneau Chapter of Trout Unlimited (TU). Only the ADF&G, BLM, USFWS, TU, and AFS applications met DNR requirements and were accepted for adjudication. The other six applications were rejected by the DNR for a variety of reasons (Estes 1993; Harle and Estes 1993).

Alaska's instream flow laws and regulations were adopted, in part, to help sustain the valuable production of fishery resources. One may question why only a small number of sites have been afforded protection under these laws. There are several reasons: insufficient hydrologic data, costly and lengthy administrative processes, insufficient public education, and except for state agencies, application fees (Estes 1993; Harle and Estes 1993).

The dearth of hydrologic data in Alaska is perhaps the most limiting factor governing our ability to define instream flow and other water uses. Alaska has over approximately 40 percent of the nation's surface freshwater supply. Yet, only five-hundred-sixty-six USGS stream gaging sites have been established in Alaska since 1908 (Brabets 1994). This equates to flow measurements for less than 1 percent of Alaska's water bodies. Ten of these Alaskan gage sites have less than 1-year of continuous flow data, 94 have 1- to less than 5-years continuous flow data, 241 have 5- to less than 10-years of continuous flow data, 162 have 10- to less than 20-years continuous flow data, and 59 have 20- or more years of data (Appendix A19). Typically, no more than 25 percent of these Alaskan gages are active in any one year due to funding restrictions (Thompson 1992, Emery 1987, Emery 1989). Seventy-six USGS gaging stations are operating in Alaska during the present Water Year 1994 (October 1, 1993 to September 30, 1994). This represents an average of one stream gage per 7,600 square miles in Alaska. This contrasts significantly with the lower "48" average of one gage site per 400 square miles. A total of seven-hundred-ninety gage sites are operating in the three states of Washington, Oregon, and Idaho, or an average of one gage site per 310 square miles (Brabets 1994). This gaging trend in Alaska is especially alarming, because only 39 percent (221) of the Alaskan gage sites can meet the USGS 10-year minimum historical data standards for supporting a statistically reliable regional flow analysis.

Ironically, to quantify instream flow requirements and apply for instream flow water rights at ungaged stream reaches, one must use regional hydrologic models to estimate flow characteristics. It is obvious, the USGS databases, from which these models were developed, will limit one's ability to evaluate naturally occurring hydrologic patterns at these sites with confidence. It is also more time consuming to estimate flow characteristics for streams having a limited or non-existent database as opposed to summarizing data for a stream having an adequate historical record. Precipitation information also required for these ungaged flow models is also limited, further complicating the process for estimating flow availability.

Basic hydrologic data are required by all potential water users (out-of-stream and instream), and water management agencies to enable them to project the reliability and amount of water that might be available, even if there were no other competitors for their targeted water source. Continuous flow data are also necessary to manage and enforce existing water rights. Limited road systems, extremes in weather conditions, and difficulties such as loss of equipment to bears and other wildlife make data collection difficult and expensive in Alaska. Therefore, unless a commitment is made to close these data gaps in Alaska, we will continue to be limited to making decisions regarding water allocation using these models with little or no hope for improving the precision or accuracy of our flow estimates. Therefore, it should be obvious that additional gaging stations should be added for a minimum of 10- to 20-years to improve the accuracy of the information used to make decisions pertaining to water availability and allocation in Alaska.

Administrative processes are, in many instances, also a deterrent to potential instream flow applicants, including the ADF&G. Without additional staffing and financial resources, these processes could hamper the ability of the ADF&G to maintain its average production rate of eight applications per year. Regulations designed to relax some of the initial data requirements and related processes were adopted in 1990 (AAC 1993a), but have not been tested. And, a revised application form to accompany these new regulations has not been completed. The backlog of ADF&G applications including those to filed in 1994 ADF&G applications will each require from 1 to 3 weeks of time by ADF&G personnel to participate in the various phases of the DNR adjudication. Additionally, there are no fixed adjudication schedules because the DNR has a backlog of water rights applications. There have been no adjudications of ADF&G instream flow applications since 1991 (Estes 1993; Harle and Estes 1993). If too many adjudications were scheduled by the DNR (at any one time), the added resource and time requirements would overtax existing ADF&G

resources. Fortunately, a priority date and time is assigned to each application at the time it is accepted by the DNR. This protects applicants by establishing the order of priority for the allocation of water, regardless of when the adjudication process is completed. Thus, until a water right application is adjudicated, it can be assumed 100% of the original amount of water requested by an applicant must be managed on behalf of the applicant. To date, this has not resulted in any problems. However, as the backlog increases and time passes, it becomes more likely that those responsible for the original analyses and application preparation, and the DNR staff who completed the initial phases of an adjudication will have changed employment or responsibilities. It is also likely that competition for water from a pending instream flow water right location will increase over time. Experiences gained by other states indicate that instream flow protection is often not judged to be as important as other competing water uses when competition is keen. Accordingly these delays may result in less than desired instream flow protection than would otherwise be granted today while there is minimal competition.

Alaskan law requires the DNR to review instream flow water rights once every 10-years to evaluate whether flow modifications are warranted. Consequently, proprietors of instream flow water rights must maintain a permanent storage system for the original data and analyses. Documentation must be sufficient to enable original applicants (or representatives) to defend their instream flow water rights. This data storage requirement is costly in terms of space and serves as an impediment to private applicants with limited resources. It is also unclear whether owners of instream flow water rights must fund their own participation in 10-year reviews. There are no equivalent provisions for automatic reviews of out-of-stream or diversionary water rights.

Fees charged by the DNR for filing instream flow applications are another deterrent to applicants. With the exception of state agencies, all instream flow applicants are charged $500 per application (AAC 1993b). There is no charge to state agencies. This fee is expensive relative to application fees charged by the DNR for most other water rights and (unlike other water rights) is not based on the amount of water requested. An additional regulatory fee was adopted by the DNR in 1993 (AAC 1993c). It enables the DNR to charge for the cost of staff time expended on the adjudication of water rights that exceeds the application fee. This supplemental fee is discretionary and will probably serve as another obstacle for filing instream flow applications by the private sector, and perhaps federal agencies.

Formal programs to educate and assist the public to file for instream flow water rights are nonexistent. Procedural and background publications to aid instream flow applicants are inadequate. The DNR and other state agencies are however, in the process of developing a water education program to correct this deficiency. The ADF&G has also provided educational information, assistance, and lectures to the public upon request. The ADF&G provided technical instruction and assisted two private citizen organizations to perform instream flow analyses and prepare instream flow applications.

The above factors and the complexity of water law all contribute to the low number of applications filed. Some of these and related concerns have and are still being addressed by the Alaska Legislature, and an interagency federal, state, and local Water Management Council formed in 1992.

Alaska legislation enacted in 1992, relating to the export and marketing of water (House Bill 596), has the potential to affect instream flow protection on a large scale (Harle and Estes 1993; Estes 1992). Regulations to execute the provisions of the law have not been completed. Furthermore, there were unsuccessful legislative attempts to revise the water export and marketing law in 1994. Accordingly, the impact of this law cannot be fully assessed at this time.

Interest for exporting water from Alaska to other states and countries appears to be increasing. Two water use applications to export water from Alaska were filed by Sun Belt, a California based company, prior to the passage of HB 596. The applications are pending due to incomplete information. If these water rights are granted by the DNR, Sun Belt will withdraw water from Orchard Lake in Ketchikan and the tailrace of the Snettisham Hydroelectric Project in Juneau. It is unknown whether these two applications are grandfathered under earlier laws or subject to the provisions of HB 596. Water is presently being purchased from the Municipality of Anchorage water supply for export to Seattle, and eventually Saudi Arabia, by Alaska Glacier Fresh. The company hopes to eventually export 14 million gallons of water per tanker load using a Saudi Arabian ocean vessel (Prokosch 1993). The Municipality of Anchorage recently sold 1.7 million gallons of water to an unspecified industrial plant in Japan (Blumberg 1994). The water was sold for $3.14 per 1000 gallons, for a total sale of $5,338. The water is being transported to Japan by an industrial ocean tanker. The effects of water exports and sales will undoubtedly increase as time passes, placing a greater emphasis on the laws passed to regulate these activities.

The DNR portion of the 1993 Capital Improvement Project budget approved by the Alaska legislature included $200,000 funding to perform a stream gage network evaluation to evaluate the existing gage network and develop priorities for future gaging. Funding for this evaluation had been requested for several years (Estes 1991, 1992). The results of the evaluation expected by early 1995.

The Alaska Water Management Council (AWMC) was established in 1992 to improve water management through better interagency coordination and cooperation. The Governor of Alaska signed an Administrative Order formalizing the activities of the council in 1993 (Hickel 1993). During the past year, one meeting was held in the fall of 1993 to encourage participation by federal agencies. The Interagency Hydrology Committee for Alaska was requested to serve as the technical advisor to the AWMC.

Based upon the experiences of the ADF&G, the following recommendations are provided to improve instream flow protection:

1) Additional ADF&G instream flow staff (fishery biologists and hydrologists) and financial resources should be allocated to allow for a greater number of applications to be processed on an annual basis. Staff should also be provided to permit adjudication activities without impeding the completion of new applications.

2) Additional ADF&G instream flow staff (fishery biologists and hydrologists) and financial resources should be allocated to allow the ADF&G to provide better and more technical reviews of AS 46 water rights applications filed for water withdrawals, diversions, and impoundments. DNR submits these applications to the ADF&G to provide the Department an opportunity to express its instream flow and other fish and wildlife concerns pertaining to the proposed water uses.

3) Legislation should be enacted to fund additional stream gage data collection stations based upon the outcome of the ongoing network evaluation. The stations are required to improve flow projection models and estimates and to determine the availability of water for out-of-stream and instream uses.

4) Out-of-stream appropriations of water should be automatically reviewed by the DNR once every 10-years, as are instream flow reservations.

5) The DNR water rights data base should be fully automated.

6) All water rights acquired under grandfather provisions in 1966 should be evaluated to determine their accuracy based on hydrologic analyses of water availability. If analyses of flow data indicate water is overappropriated and public interest criteria were not addressed adequately, corrective adjustments should be made to the affected certificate of appropriation.

7) The Instream Flow Incremental Methodology should be used to reanalyze the adequacy of instream flow reservations obtained using the Tennant Method for the most important sport fisheries. If results indicate additional water should be reserved, a supplemental instream flow reservation application should be completed and filed.

8) All DNR water rights decisions and the rationale for granting, conditionally granting, or denying diversionary, withdrawal, and impoundment water rights (i.e. findings of fact and conclusion of law) should be in writing. This requirement is presently mandatory for instream flow water rights, but only optional for out-of-stream water rights.

9) Legislation should be enacted or regulations established that will guarantee a base level of instream flow protection for stream reaches that are classified as supporting fish.

10) A formal instream flow educational program should be funded to encourage public participation in the instream flow reservation process.

11) An instream flow methods and application handbook should be prepared to provide sufficient guidance for the public and other interested parties to file for instream flow reservations.

12) Private sector instream flow applicants should be exempt from optional administrative fees that can be assessed by DNR to pay for DNR staff adjudication time and resources.

13) The validity of statutory provisions, that can be interpreted to automatically grant instream flow water rights for water bodies within Alaska State Parks, should be established.

14) The DNR should acquire resources to implement a proposal agreed upon by the ADF&G and DNR for reducing the backlog of instream flow water rights applications.

15) Regulations for implementing all of the provisions of House Bill 596 should be completed.

16) DNR should reevaluate the validity of earlier policies preventing management of water that is diverted from a water body and not used.

In summary, the ability to complete instream flow applications by the ADF&G continually improves with experiences gained through analysis and preparation of each application. Unfortunately, data requirements and lengthy adjudication processes will continue to limit the number of reservations completed and submitted. To counter these limitations, additional resources will be required for data collection and analyses, and the preparation and defense of applications.

ACKNOWLEDGMENTS

The author expresses his appreciation to his supervisor, Mike Mills, for support of this program. Appreciation is also extended to regional and area biologists who contributed information and data for analysis: Alan Townsend, Fred DeCicco, Rob Bentz, Alvin Ott, Steven Elliott, and Kelly Hepler, Andy Hoffmann, Doug Vincent-Lang, Bob Johnson, Carl Hemming, and Bill Arvey. Contributions from: Carol Hepler for providing scientific illustration support; Allen Bingham, Gary Fidler, Allen Howe, Gail Heineman, Gwyn Alexander, Dora Sigurdsson, Ardys Armstrong and other Research and Technical Services Section staff who summarized and analyzed hydrologic data and/or provided editorial suggestions and assistance; Richard Kemnitz, Joe Dorava, Jimmy Buck, Bob Burrows, Bob Lamke, Gary Solin, Harold Seitz, Gordon Nelson, Phil Carpenter, Ken Thompson, Bruce Bigelow, Tim Brabets, Dick Snyder, and Ron Rickman (USGS) who provided hydrologic analysis support.

LITERATURE CITED

AAC (Alaska Administrative Code). 1993a. 11 AAC 93.142(b)(4), (6), and (7), and 11 AAC 93.147(c).

_____. 1993b. 11 AAC 05.010(a)(8)(viii)(B).

_____. 1993c. 11 AAC 05.010(a)(8)(O).

ADF&G (Alaska Department of Fish and Game). 1984. Instream flow work plan. Alaska Department of Fish and Game, Anchorage, Alaska.

_____. 1985. Alaska habitat management guides. Alaska Department of Fish and Game, Division of Habitat, Anchorage, Alaska.

_____. 1993. An atlas to the catalog of waters important for spawning, rearing or migration of anadromous fishes. Alaska Department of Fish and Game, Division of Habitat, Anchorage, Alaska.

_____. 1994a. *In Prep*. Application for reservation of water. Sagavanirktok River-Reach A. Sport Fish RTS No. I.700.300.7325. Located at the Alaska Department of Fish and Game. Anchorage, Alaska.

_____. 1994b. *In Prep*. Application for reservation of water, Sagavanirktok River-Reach B. Sport Fish RTS No. I.700.300.7325. Located at the Alaska Department of Fish and Game. Anchorage, Alaska.

_____. 1994c. *In Prep*. Application for reservation of water. Kuparuk River. Sport Fish RTS No. I.700.300.3875. Located at the Alaska Department of Fish and Game. Anchorage, Alaska.

_____. 1994d. *In Prep*. Application for reservation of water. Power Creek. Sport Fish RTS No. I.700.300.6760. Located at the Alaska Department of Fish and Game. Anchorage, Alaska.

_____. 1994e. *In Prep*. Application for reservation of water. Situk River. Sport Fish RTS No. I.700.300.8025. Located at the Alaska Department of Fish and Game. Anchorage, Alaska.

Blumberg, P. 1994. Japan buys water. Anchorge Daily News. August 23, 1994. Pages B1-2. Anchorage, Alaska.

Bovee, K. D. 1982. A guide to stream habitat analysis using the Instream Flow Incremental Flow methodology. Instream Flow Information Paper No. 122. FWS/OBS/82/26. U.S. Fish and Wildlife Service. Ft. Collins, Colorado.

Brabets, T. 1994. Unpublished data provided to Christopher Estes, Alaska Department of Fish and Game, in response to a data inquiry regarding U.S. Geological stream gaging historical database. U.S. Geological Survey. Water Resources Division. Anchorage, Alaska.

Curran, H. and L. Dwight. 1979. Analysis of Alaska Water Use Act and its interaction with Federal Reserved Water Rights. Institute of Water Resources. University of Alaska, Fairbanks. Fairbanks, Alaska.

DNR (Alaska Department of Natural Resources). 1985. State of Alaska instream flow handbook. Alaska Department of Natural Resources, Anchorage, Alaska.

Emery, P. A. 1987. Letter to Christopher Estes (Alaska Department of Fish and Game), November 9, 1987 regarding U.S. Geological Survey requirements to calculate stream flows. U.S. Geological Survey. Water Resources Division. Anchorage, Alaska.

_____. 1989. Letter to Christopher Estes (Alaska Department of Fish and Game), March 6, 1989, regarding U.S. Geological Survey stream flow gaging stations. U.S. Geological Survey. Water Resources Division. Anchorage, Alaska.

Estes, C. C. 1984. Evaluation of methods for recommending instream flows to support spawning by salmon. Master's thesis, Washington State University, Pullman, Washington.

_____. 1985. Organization of departmental instream flow program. Memorandum to Richard Logan, September 12, 1985. Alaska Department of Fish and Game, Anchorage, Alaska.

_____. 1987. Instream flow. Alaska Department of Fish and Game, Fishery Data Series No. 23, Juneau, Alaska.

_____. 1988. Annual summary of statewide instream flow reservation applications. Alaska Department of Fish and Game, Fishery Data Series No. 55, Juneau, Alaska.

_____. 1989. Annual summary of statewide instream flow reservation applications. Alaska Department of Fish and Game, Fishery Data Series No. 121, Juneau, Alaska.

_____. 1990. Annual summary of statewide instream flow reservation applications. Alaska Department of Fish and Game, Fishery Data Series No. 90-43, Anchorage, Alaska.

_____. 1991. Annual summary of Alaska Department of Fish and Game instream flow reservation applications. Alaska Department of Fish and Game, Fishery Data Series No. 91-65, Anchorage, Alaska.

_____. 1992. Annual summary of Alaska Department of Fish and Game instream flow reservation applications. Alaska Department of Fish and Game, Fishery Data Series No. 92-45, Anchorage, Alaska.

_____. 1993. Annual summary of Alaska Department of Fish and Game instream flow reservation applications. Alaska Department of Fish and Game, Fishery Data Series No. 93-43, Anchorage.

Estes, C. C. and M. L. Harle. 1987. Alaska's instream flow program. Instream Flow Chronicle. Colorado State University. Ft. Collins, Colorado. IV(1):1-2.

Estes, C. C. and J. F. Orsborn. 1986. Review and analysis of methods for quantifying instream flow requirements. Water Resources Bulletin. 22(3):389-398.

Harle, M. L. 1988. Private appropriations of instream flows in Alaska. In: Instream Flow Protection in the Western United States: A Practical Symposium. Natural Resources Law Center. March 31 - April 1, 1988. Edited by L. J. MacDonnell and T. A. Rice. First Edition. University of Colorado School of Law. Boulder, Colorado.

Harle, M.L. and C. C. Estes. 1993. An assessment of instream flow protection in Alaska. In: Instream Flow Protection in the Western United States. Edited by L. J. MacDonnell and T. A. Rice. Natural Resources Law Center. Revised Edition. University of Colorado School of Law. Boulder, Colorado.

Hickel, W. J. 1993. Administrative order number 133. State of Alaska. Office of the Governor. Juneau, Alaska.

Instream Flow Committee. 1986. Memorandum to directors, October 1, 1986. Alaska Department of Fish and Game, Anchorage, Alaska.

Mills, M. J. 1979. Statewide harvest study. 1977 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report 1978-1979, Project F-9-11, Volume 20 (SW-I-A), Juneau, Alaska.

_____. 1980. Statewide harvest study. 1978 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration, Annual Performance Report 1979-1980, Project F-9-12, Volume 21 (SW-I-A), Juneau, Alaska.

_____. 1981a. Statewide harvest study - 1979 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1980-1981, Project F-9-13, Volume 22 (SW-I-A), Juneau, Alaska.

_____. 1981b. Statewide harvest study - 1980 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1980-1981, Project F-9-13, Volume 22 (SW-I-A), Juneau, Alaska.

_____. 1982. Statewide harvest study - 1981 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1981-1982, Project F-9-14, Volume 23 (SW-I-A), Juneau, Alaska.

_____. 1983. Statewide harvest survey. 1982 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1982-1983, Project F-9-15, Volume 24 (SW-I-A), Juneau, Alaska.

_____. 1984. Statewide harvest survey. 1983 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1983-1984, Project F-9-16, Volume 25 (SW-I-A), Juneau, Alaska.

_____. 1985. Statewide harvest report. 1984 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1984-1985, Project F-9-17, Volume 26 (SW-I-A), Juneau, Alaska.

_____. 1986. Statewide harvest report. 1985 data. Alaska Department of Fish and Game, Federal Aid in Fish Restoration and Anadromous Fish Studies, Annual Performance Report 1985-1986, Project F-9-18, Volume 27 (RT-2), Juneau, Alaska.

_____. 1987. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau, Alaska.

_____. 1988. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau, Alaska.

_____. 1989. Alaska statewide sport fisheries harvest report, 1988. Alaska Department of Fish and Game, Fishery Data Series No. 122, Juneau, Alaska.

_____. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage, Alaska.

_____. 1991. Harvest, catch, and participation in Alaska sport fisheries in 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage, Alaska.

_____. 1992. Harvest, catch, and participation in Alaska sport fisheries in 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-40, Anchorage, Alaska.

_____. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage.

Orsborn, J. F. and F. J. Watts. 1980. Hydraulics and hydrology for fisheries biologists. U.S. Fish and Wildlife Service, Fisheries Academy, Kearneysville, Virginia.

Prokosch, G. 1993. Personal communication regarding water export and marketing legislation and activities. Alaska Department of Natural Resources. Division of Water. Anchorage, Alaska.

Reiser, D. W., M. P. Ramey, and T. R. Lambert. 1985. Review of flushing flow requirements in regulated streams. Pacific Gas and Electric Company. San Ramon, California.

SAS (SAS Institute Inc.). 1985. SAS guide for personal computers. Version 6 Edition. SAS Institute Inc. Cary, North Carolina.

Shaw, E. M., editor. 1988. Hydrology in practice. Van Nostrand Reinhold Co. Ltd., London, England.

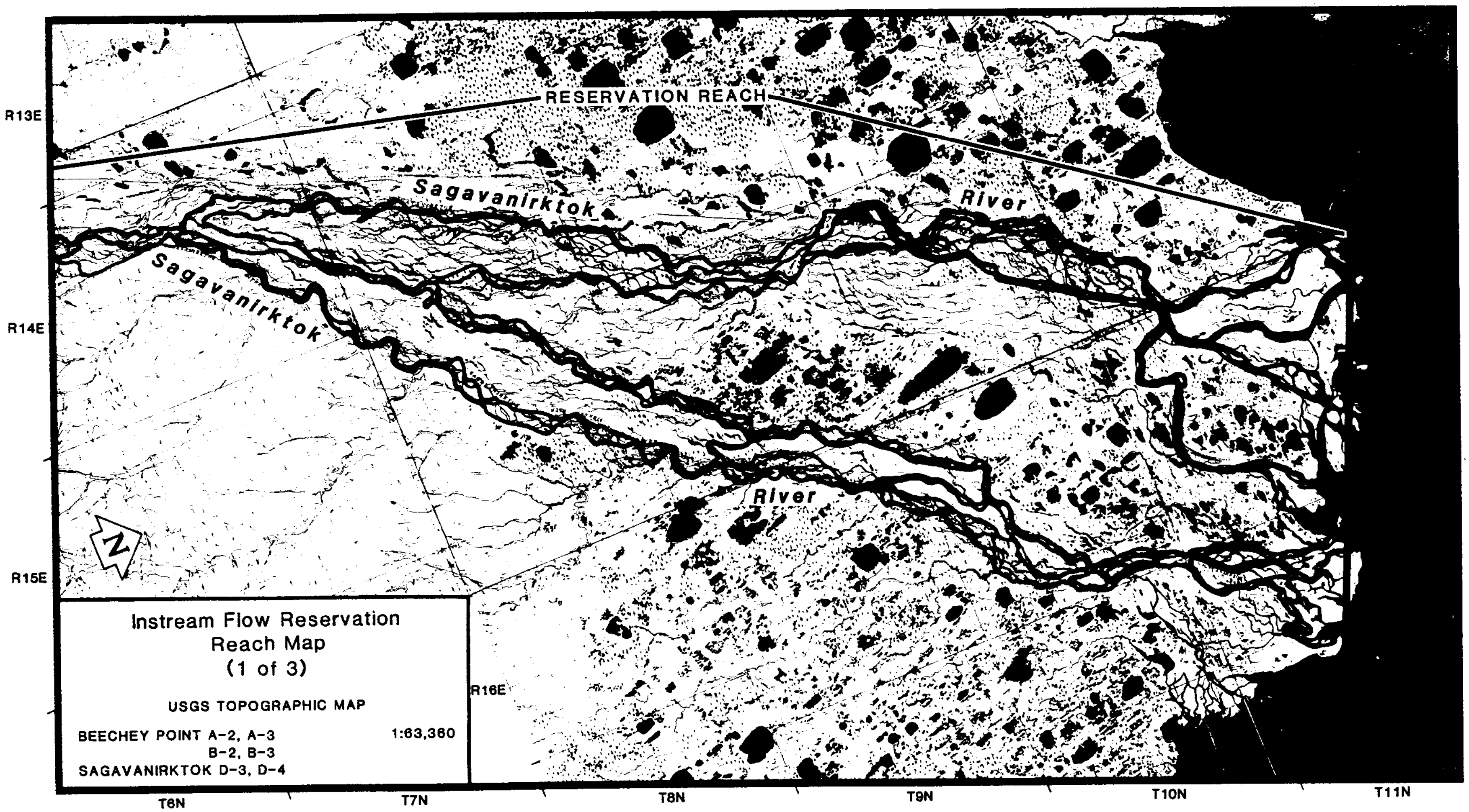
Tennant, D. L. 1972. A method for determining instream flow requirements for fish, wildlife and aquatic environment. Pages 3-11 *in* Pacific Northwest River Basin Commission Transcript of Proceedings of Instream Flow Requirements Workshop, March 15-16, 1972. Pacific Northwest River Basin Commission, Portland, Oregon.

_____. 1976. Instream flow regimes for fish, wildlife, recreation, and related environmental resources. Pages 359-373 *in* J. F. Orsborn and C. H. Allman, editors. Instream Flow Needs, Volume II, American Fisheries Society, Bethesda, Maryland.

Thompson, K. 1992. Alaska water-resources tidbits. U.S. Geological Survey. Water Resources Division. Anchorage, Alaska.

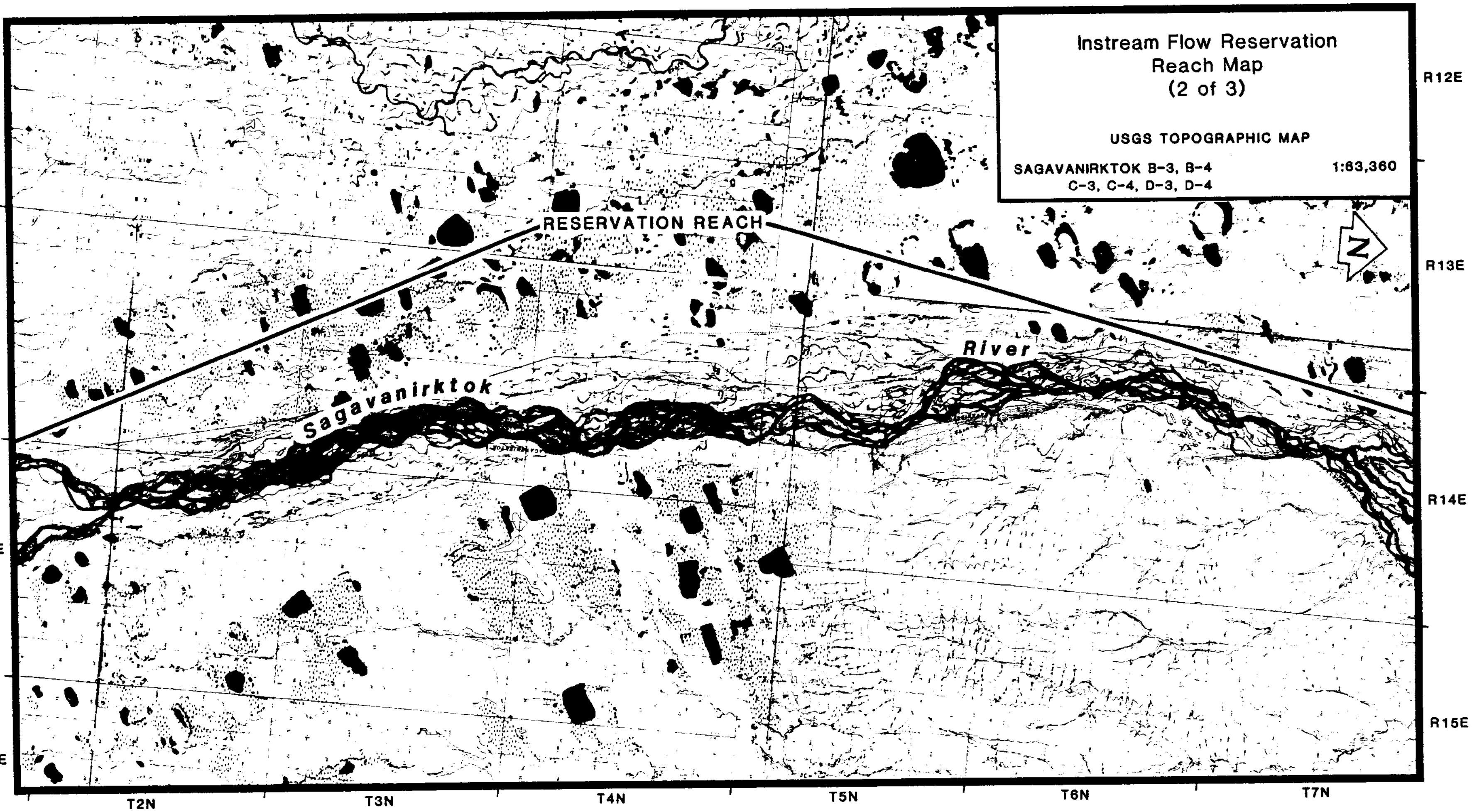
White, M. R. 1981. Opportunities to protect instream flows in Alaska. U.S. Fish and Wildlife Service. Office of Biological Surveys. Washington, D.C.

APPENDIX A



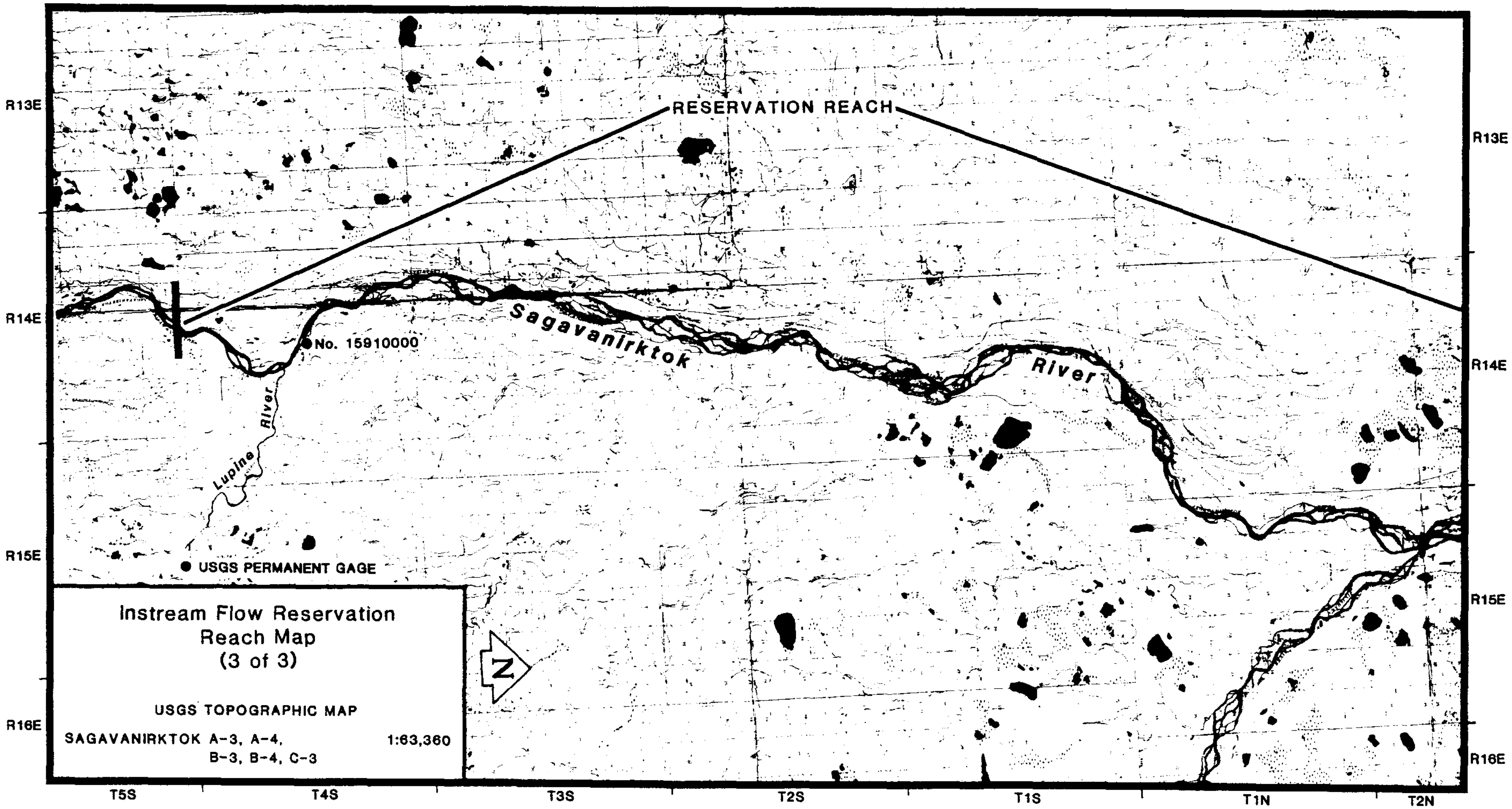
Appendix A1. Reservation reach boundaries, Sagavanirktok River-Reach A.

-continued-

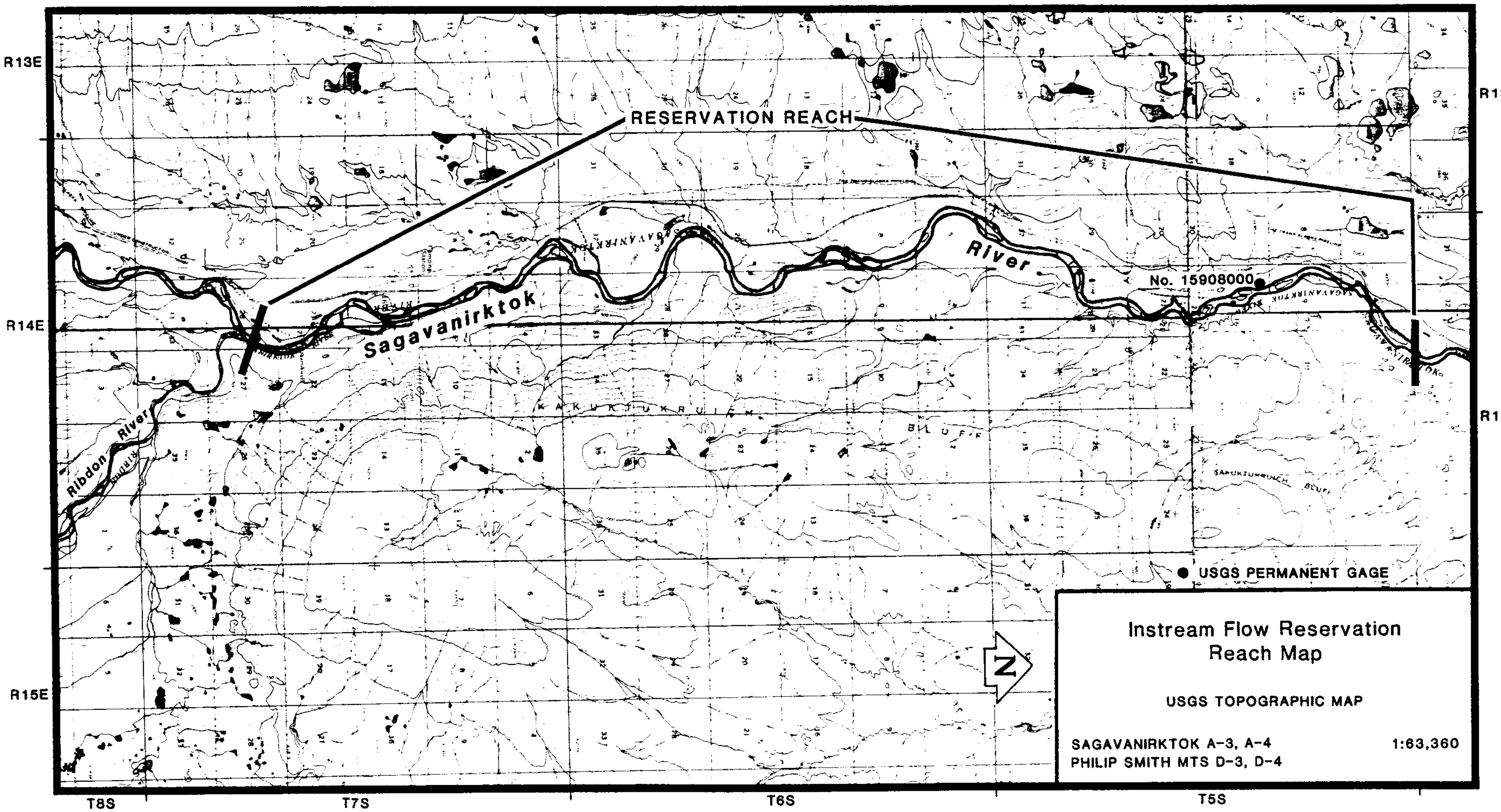


Appendix A1. (Page 2 of 3).

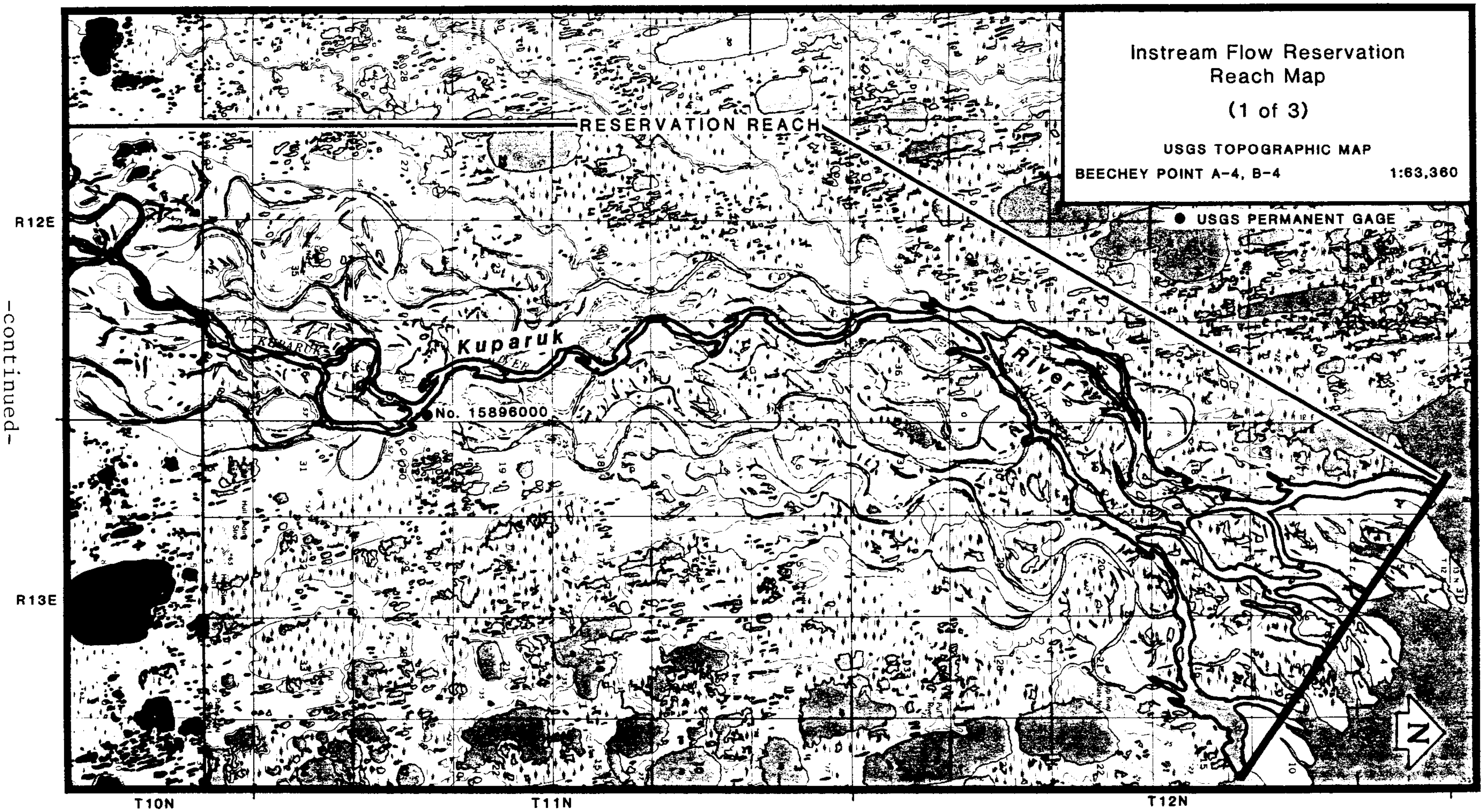
-continued-



Appendix A1. (Page 3 of 3).

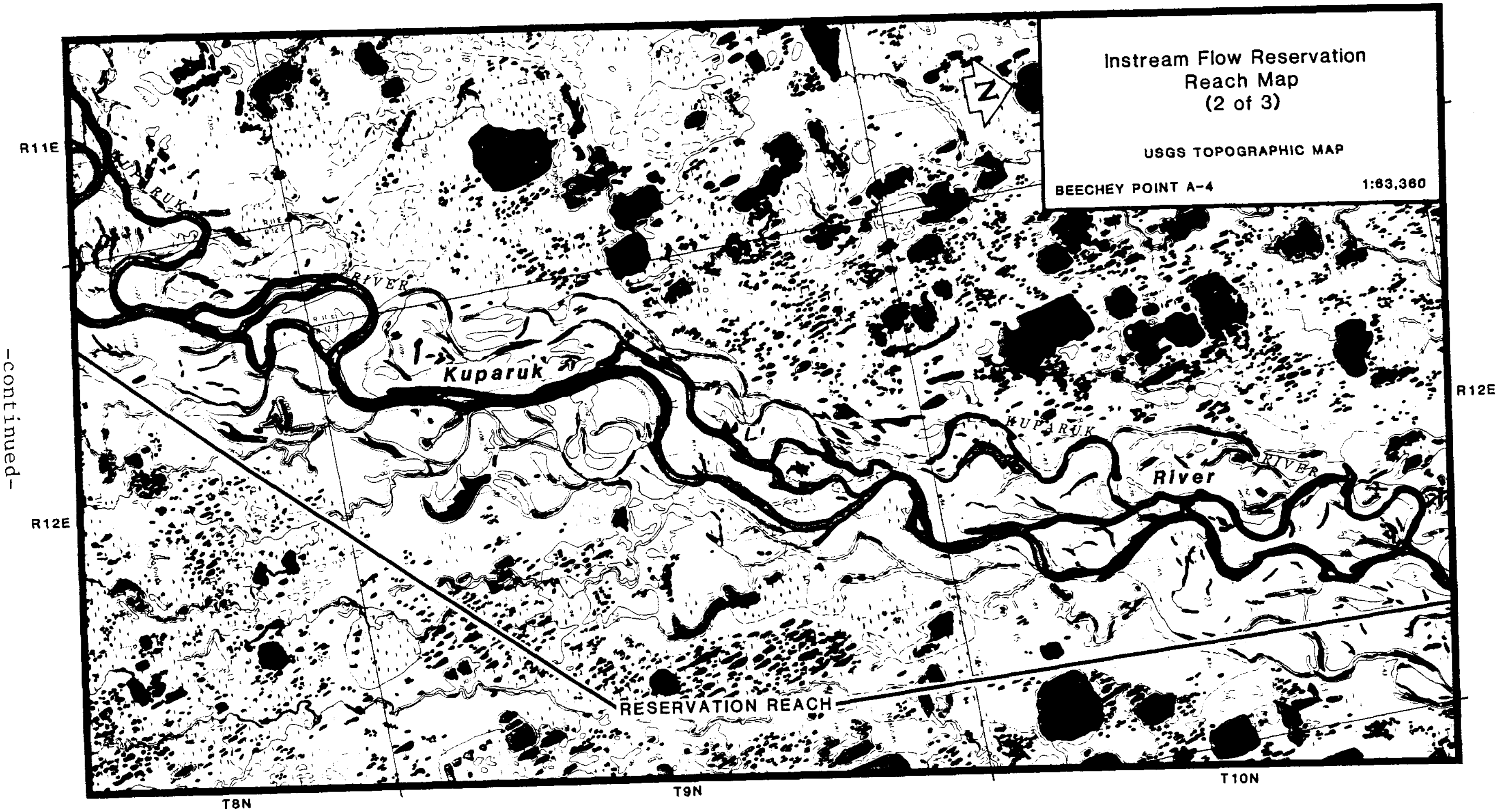


Appendix A2. Reservation reach boundaries, Sagavanirktok River-Reach B.

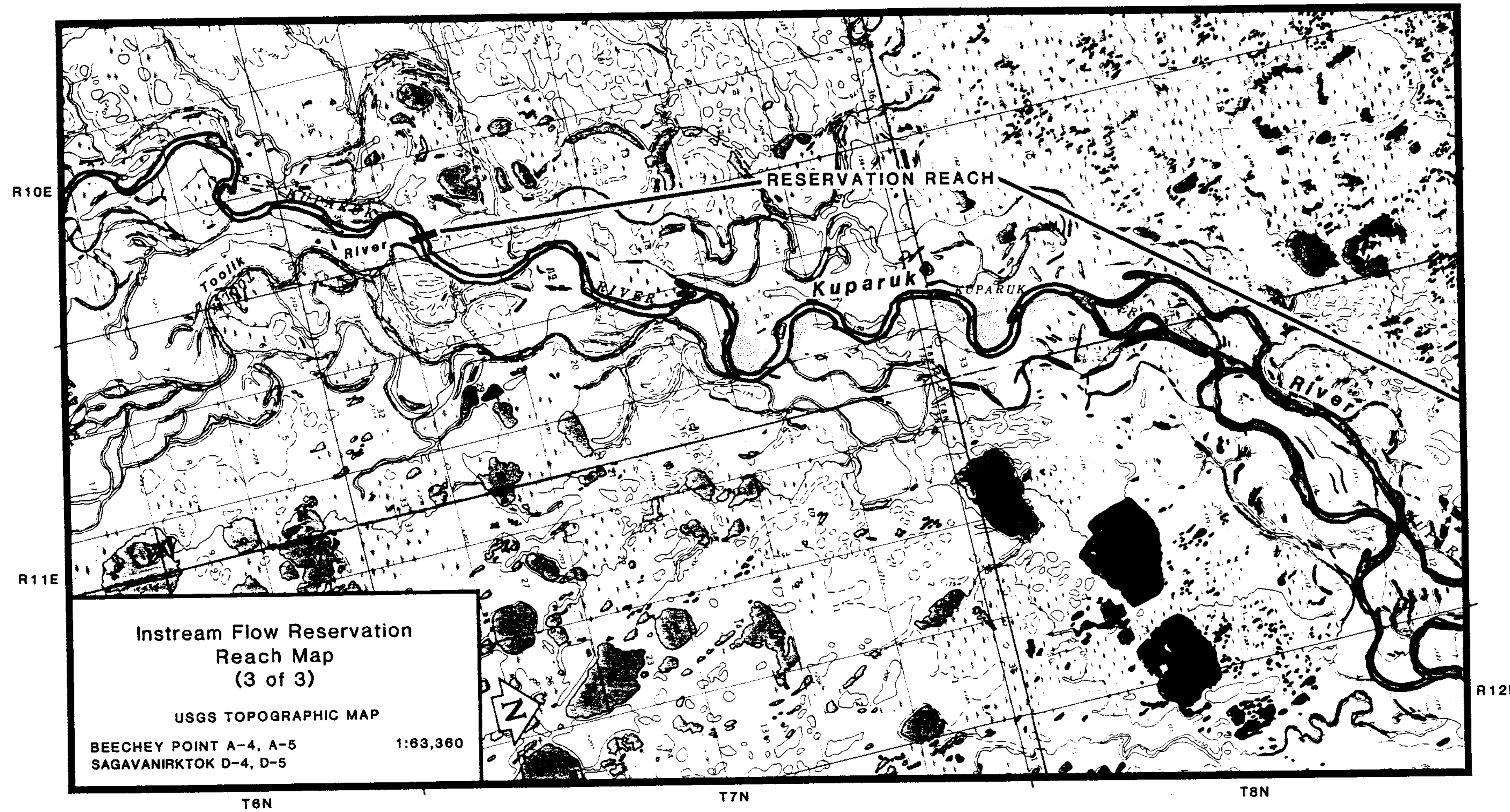


Appendix A3. Reservation reach boundaries, Kuparuk River.

-continued-

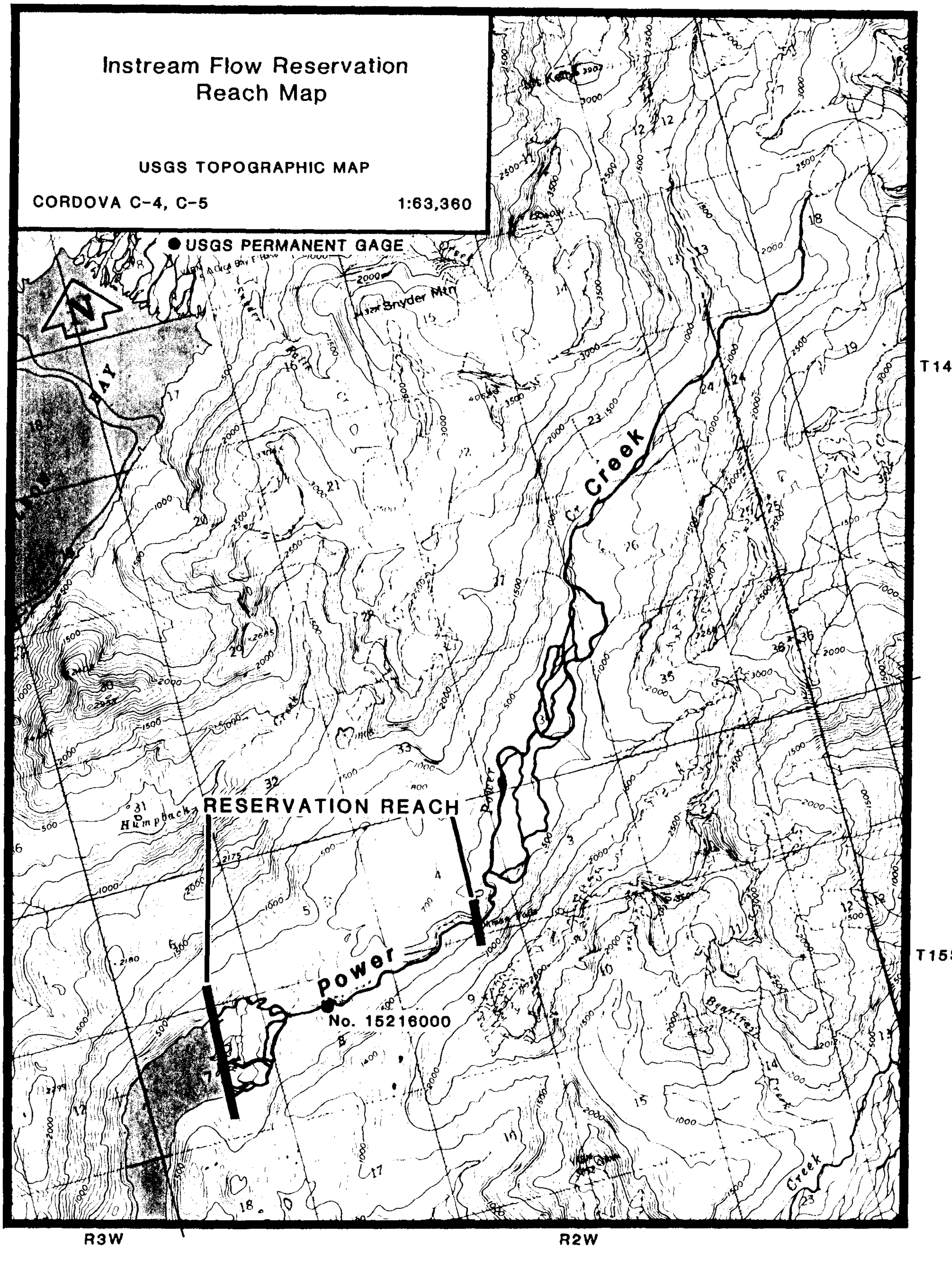


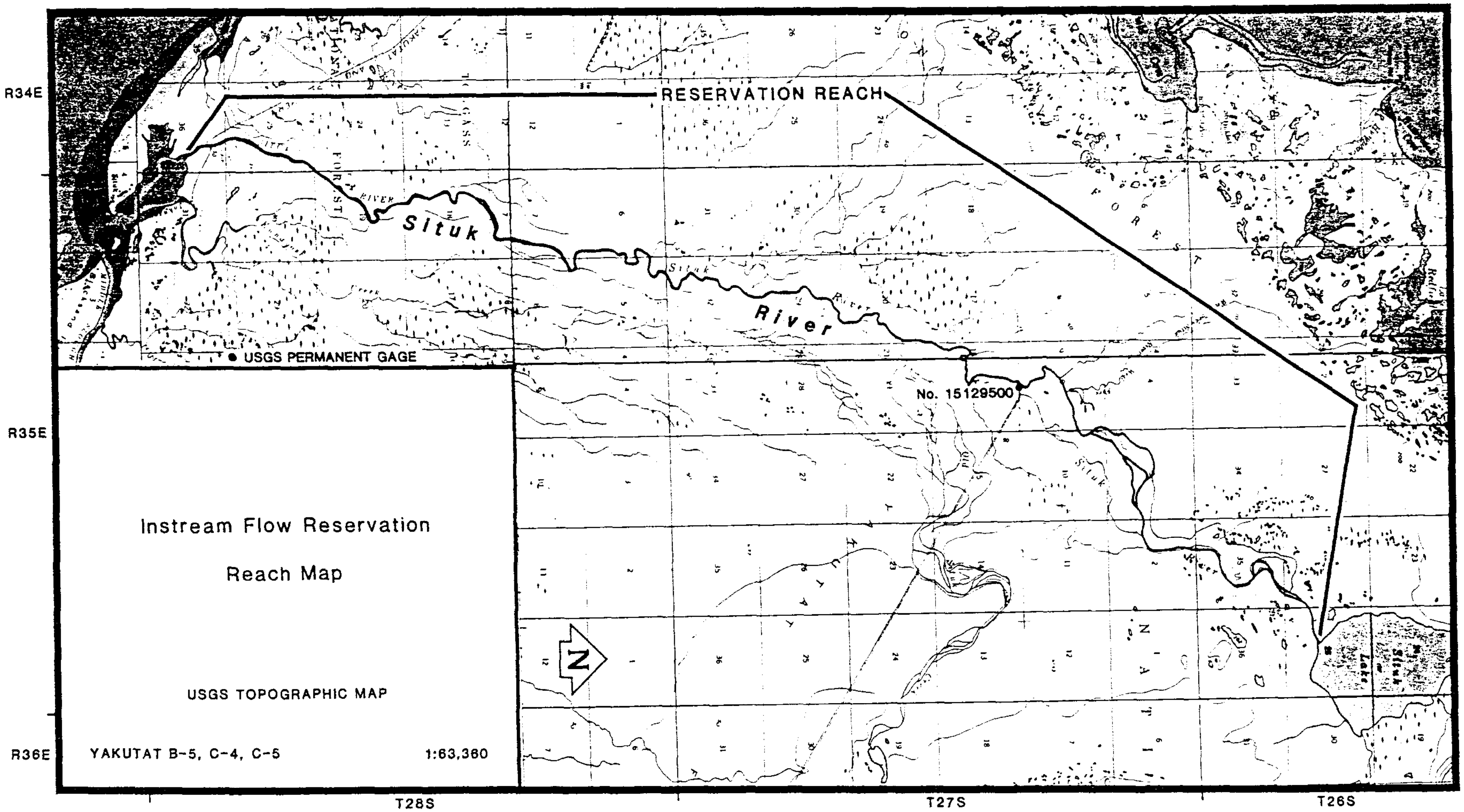
Appendix A3. (Page 2 of 3).



Appendix A3. (Page 3 of 3).

Appendix A4. Reservation reach boundaries, Power Creek.





Appendix A5. Reservation reach boundaries, Situk River.

Appendix A6. Species periodicity chart for Sagavanirktok River-Reach A.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PINK SALMON												
Passage						?XX	XXXX	XX?				
Spawning							XXXX	XXXX				
Incubation	XXXX	XXXX	XXXX	XXXX	XX		XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing					?XXX	XXXX	XX					
CHUM SALMON												
Passage						XXXX	XXXX	XXXX				
Spawning							XX	XXXX	?			
Incubation	XXXX	XXXX	XXXX	XXXX	X?		XX	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing				?	XXXX	XXXX	XX					
DOLLY VARDEN												
Passage					X	XXXX	XXXX	XXXX	XX			
Spawning									XXXX	XXXX		
Incubation									XXXX	XXXX	?	
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
ARCTIC GRAYLING												
Passage					X	XX		X	XX			
Spawning						XX						
Incubation						XXXX	?					
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
BURBOT												
Passage												
Spawning			XXXX	XXXX								
Incubation			XXXX	XXXX	XXXX	XXXX	?					
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
BROAD WHITEFISH												
Passage					X	XX		X	XX			
Spawning							X	XXXX	X			
Incubation							X	XXXX	XXXX	XXXX	?	
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
ROUND WHITEFISH												
Passage						XX	XXXX	XXXX	XX			
Spawning								XX	XX			
Incubation	XXXX	XXXX	XXXX	XXXX	XX			XX	XXXX	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX

Based on professional judgment of ADF&G biologists.
Passage life phase for anadromous fish is immigration.
Passage life phase for resident fish includes immigration and emigration.
Incubation life phase includes period from egg deposition to fry emergence.
? = Data not available or timing information is incomplete.

-continued-

Appendix A6. (Page 2 of 2).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ARCTIC CISCO												
Passage						XXXX	XXXX	XXXX	XX			
Spawning												
Incubation												
Rearing					?	XXXX	XXXX	XXXX	XX?			
LEAST CISCO												
Passage					XX	XXXX			XX	XX		
Spawning												
Incubation												
Rearing					?XX	XXXX	XXXX	XXXX	XXXX	XX?		
NINESPINE STICKLEBACK												
Passage						XX		X	XXX			
Spawning						XXXX	XX					
Incubation						XXXX	XXXX	?				
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
SLIMY SCULPIN												
Passage ?												
Spawning ?												
Incubation ?												
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX

Based on professional judgment of ADF&G biologists.
Passage life phase for anadromous fish is immigration.
Passage life phase for resident fish includes immigration and emigration.
Incubation life phase includes period from egg deposition to fry emergence.
? = Data not available or timing information is incomplete.

Appendix A7. Species periodicity chart for Sagavanirktok River-Reach B.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CHUM SALMON												
Passage						XXXX	XXXX	XXXX	XX			
Spawning							XX	XXXX	XX			
Incubation	XXXX	XXXX	XXXX	XXXX	XXX?		XX	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing				?	XXXX	XXXX	XX					
DOLLY VARDEN												
Passage				X	XX		XXXX	XXXX	XX			
Spawning								X	XXXX	XXXX		
Incubation								X	XXXX	XXXX	XXXX	
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
ARCTIC GRAYLING												
Passage					XX	XX		XX	XX			
Spawning						XX						
Incubation						XXXX						
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
BURBOT												
Passage												
Spawning			XXXX	XXXX								
Incubation			XXXX	XXXX	XXXX	XXXX	?					
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
ROUND WHITEFISH												
Passage					XX	XXXX	XXXX	XXXX	XX			
Spawning								XX	XX			
Incubation	XXXX	XXXX	XXXX	XXXX	XX			XX	XXXX	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
SLIMY SCULPIN												
Passage ?												
Spawning ?												
Incubation ?												
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX

Based on professional judgment of ADF&G biologists.
Passage life phase for anadromous fish is immigration.
Passage life phase for resident fish includes immigration and emigration.
Incubation life phase includes period from egg deposition to fry emergence.
? = Data not available or timing information is incomplete.

Appendix A8. Species periodicity chart for Kuparuk River.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ARCTIC GRAYLING												
Passage					XX	XXXX	XXXX	XXXX	XX			
Spawning						XX						
Incubation						XXXX						
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
BURBOT												
Passage												
Spawning			XXXX	XXXX								
Incubation			XXXX	XXXX	XXXX	XXXX	?					
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
BROAD WHITEFISH												
Passage					XX	XXXX	XXXX	XXXX	XX			
Spawning ?												
Incubation ?												
Rearing					XX	XXXX	XXXX	XXXX	XX			
ROUND WHITEFISH												
Passage						XX	XXXX	XXXX	XX			
Spawning							XX	XXXX				
Incubation	XXXX	XXXX	XXXX	XXXX	XX		XX	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
ARCTIC CISCO												
Passage					XX	XXXX	XXXX	XXXX	XX			
Spawning												
Incubation												
Rearing					?XX	XXXX	XXXX	XXXX	XX?			
NINESPINE STICKLEBACK												
Passage						XX		X	XXX			
Spawning						XXXX	XX					
Incubation						XXXX	XXXX	?				
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
SLIMY SCULPIN												
Passage ?												
Spawning ?												
Incubation ?												
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX

Based on professional judgment of ADF&G biologists.
Passage life phase for anadromous fish is immigration.
Passage life phase for resident fish includes immigration and emigration.
Incubation life phase includes period from egg deposition to fry emergence.
? = Data not available or timing information is incomplete.

Appendix A9. Species periodicity chart for Power Creek.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
COHO SALMON												
Passage	XX							XX	XXXX	XXXX	XXXX	XXXX
Spawning	XX								?XX	XXXX	XXXX	XXXX
Incubation	XXXX	XXXX	XXXX	XXXX	XX				?XX	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
SOCKEYE SALMON												
Passage							XXXX	XXXX	XXXX			
Spawning							XX	XXXX	XXXX	XX		
Incubation	XXXX	XXXX	XXXX	XXXX			XX	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
PINK SALMON												
Passage							XXXX	XXXX	XX			
Spawning							X	XXXX	XX			
Incubation	XXXX	XXXX	XXXX	XXXX			X	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing			?X	XXXX	XXX?							
DOLLY VARDEN												
Passage		XXXX	XXXX	XXXX			XX	XXXX	XXXX	XXXX	XXXX	
Spawning								XX	XXXX	XXXX	XX	
Incubation	XXXX	XXXX	XXXX	XX				XX	XXXX	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
CUTTHROAT TROUT												
Passage			XX	XXXX	XXXX	XXXX	XX		XXXX	XXXX	XXXX	
Spawning				XXXX	XXXX							
Incubation				XXXX	XXXX	XXXX	XXXX	?				
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX

Based upon professional judgment of ADF&G biologists.
Passage life phase for anadromous fish is immigration.
Passage life phase for resident fish includes immigration and emigration.
Incubation life phase includes period from egg deposition to fry emergence.
? = Data not available or timing is incomplete.

Appendix A10. Species periodicity chart for Situk River.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
COHO SALMON												
Passage	XXXX	XXXX	X					XXX	XXXX	XXXX	XXXX	XXXX
Spawning	XXXX								X	XXXX	XXXX	XXXX
Incubation	XXXX	XXXX	XXXX						X	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
PINK SALMON												
Passage							XXXX	XXXX	XXXX	XXXX		
Spawning							X	XXXX	XXXX	XXXX		
Incubation							X	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing			XXXX	XXXX								
CHUM SALMON												
Passage							XXXX	XXXX	XXXX	XXXX		
Spawning							X	XXXX	XXXX	XXXX		
Incubation							X	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing			XXXX	XXXX								
SOCKEYE SALMON												
Passage						XXXX	XXXX	XXXX	XXXX	XXXX		
Spawning							XXXX	XXXX	XXXX	XXXX		
Incubation	XXXX	XXXX	XXXX	XXXX			XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
CHINOOK SALMON												
Passage						XXXX	XXXX	XXXX	XXXX			
Spawning							XX	XXXX	XXXX			
Incubation	XXXX	XXXX	XXXX				XX	XXXX	XXXX	XXXX	XXXX	XXXX
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
STEELHEAD TROUT												
Passage	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Spawning			X	XXXX	XXXX	XXXX	X					
Incubation			X	XXXX	XXXX	XXXX	XXXX	XXXX				
Rearing	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX

Based upon professional judgment of ADF&G biologists.
Passage life phase for anadromous fish is immigration.
Passage life phase for resident fish includes immigration and emigration.
Incubation life phase includes period from egg deposition to fry emergence.
? = Data not available or timing is incomplete.

-continued-

Appendix A10. (Page 2 of 2).

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
DOLLY VARDEN													
Passage		XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Spawning		XXXX	XXXX										
Incubation		XXXX	XXXX	XXXX	XXXX	XXXX	XXXX						
Rearing		XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
EULACHON													
Passage				XXXX	XXXX	XXXX	XX						
Spawning				XXXX	XXXX	XXXX	XX						
Incubation				XXXX	XXXX	XXXX	XXX?						
Rearing	?												
RIVER LAMPREY													
Passage					XXXX	XXXX	XXXX	XXXX	XXXX				
Spawning	?												
Incubation	?												
Rearing				XXXX	XXXX								
SLIMY SCULPIN													
Passage		XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX
Spawning	?												
Incubation	?												
Rearing		XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX	XXXX

Based upon professional judgment of ADF&G biologists.
Passage life phase for anadromous fish is immigration.
Passage life phase for resident fish includes immigration and emigration.
Incubation life phase includes period from egg deposition to fry emergence.
? = Data not available or timing is incomplete.

Appendix A11. Common and scientific names of fishes identified in periodicity charts (Appendices A6-A10).

COMMON NAME	SCIENTIFIC NAME
Arctic cisco	*Coregonus autmnalis*
Arctic grayling	*Thymallus arcticus*
Broad Whitefish	*Coregonus nasus*
Burbot	*Lota lota*
Chinook salmon	*Oncorhynchus tshawytscha*
Chum salmon	*Oncorhynchus keta*
Coho salmon	*Oncorhynchus kisutch*
Cutthroat trout	*Oncorhynchus clarki*
Dolly Varden	*Salvelinus malma*
Eulachon	*Thaleichthys pacificus*
Humpback whitefish	*Coregonus pidshian*
Least Cisco	Coregonus sardinella
Ninespine stickleback	*Pungitius pungitius*
Northern pike	*Esox lucius*
Pink salmon	*Oncorhynchus gorbushca*
Rainbow trout	*Oncorhynchus mykiss*
River lamprey	*Lampetra ayresi*
Round whitefish	*Prosopium cylindraceum*
Slimy sculpin	*Cottus cognatus*
Sockeye salmon	*Oncorhynchus nerka*
Steelhead trout	*Oncorhynchus mykiss*
Threespine stickleback	*Gasterosteus aculeatus*

Appendix A12. Summary of hydrologic data for instream flow reservation application reaches (Appendices A1-A5).

Stream/Reach	USGS Site Number	Years of Daily Flow Record
Sagavanirktok River near Pump Station 3	15908000	1982-Present
Sagavanirktok River near Sagwon	15910000	1970-1978
Kuparuk River near Deadhorse	15896000	1971-Present
Situk River near Yakutat	15129500	1988-Present
Power Creek near Cordova	15216000	1947-Present

Appendix A13. Tennant Method analysis for Sagavanirktok River-Reach A.

Tennant Method Flow Classifications (adapted from Tennant 1975)

Narrative Description of Flows	Seasonal Base Flow (Q) Regimens as Percentages (%) of Average Annual Flow (QAA)	
Location	% of QAA	Sagavanirktok River-Reach A Flow (cfs)
Month	Nov.- Apr.	
QAA	100	1656
Flushing or Maximum	200	3312
Optimum Range	60-100	994-1656
Outstanding	40	662
Excellent	30	497
Good	20	331
Fair or Degrading	10	166
Poor or Minimum	10	166
Severe Degradation	<10	<166
Month	May - Oct.	
QAA	100	1656
Flushing or Maximum	200	3312
Optimum Range	60-100	994-1656
Outstanding	60	994
Excellent	50	828
Good	40	662
Fair or Degrading	30	497
Poor or Minimum	10	166
Severe Degradation	<10	<166

Monthly Flow Characteristics

Month	Long-term Mean Monthly Flow (cfs)
Jan	4
Feb	2
Mar	2
Apr	2
May	1083
Jun	7306
Jul	4852
Aug	4224
Sep	1702
Oct	429
Nov	124
Dec	24

Appendix A14. Tennant Method analysis for Sagavanirktok River-Reach B.

Tennant Method Flow Classifications (adapted from Tennant 1975)

Narrative Description of Flows	Seasonal Base Flow (Q) Regimens as Percentages (%) of Average Annual Flow (QAA)	
Location	% of QAA	Sagavanirktok River-Reach B Flow (cfs)
Month	Nov.- Apr.	
QAA	100	1404
Flushing or Maximum	200	376
Optimum Range	60-100	113-1404
Outstanding	40	562
Excellent	30	421
Good	20	281
Fair or Degrading	10	140
Poor or Minimum	10	140
Severe Degradation	<10	<140
Month	May - Oct.	
QAA	100	1404
Flushing or Maximum	200	2808
Optimum Range	60-100	842-1404
Outstanding	60	842
Excellent	50	702
Good	40	562
Fair or Degrading	30	421
Poor or Minimum	10	140
Severe Degradation	<10	<140

Monthly Flow Characteristics

Month	Long-term Mean Monthly Flow (cfs)
Jan	11
Feb	1
Mar	0
Apr	5
May	993
Jun	5574
Jul	3670
Aug	1646
Sep	449
Oct	145
Nov	40
Dec	39

Appendix A15. Tennant Method analysis for Kuparuk River.

Tennant Method Flow Classifications (adapted from Tennant 1975)

Narrative Description of Flows	Seasonal Base Flow (Q) Regimens as Percentages (%) of Average Annual Flow (QAA)	
Location	Kuparuk River	
	% of QAA	Flow (cfs)
Month	Nov.- Apr.	
QAA	100	1326
Flushing or Maximum	200	2652
Optimum Range	60-100	796-1326
Outstanding	40	530
Excellent	30	398
Good	20	265
Fair or Degrading	10	133
Poor or Minimum	10	133
Severe Degradation	<10	<133
Month	May - Oct.	
QAA	100	1326
Flushing or Maximum	200	2652
Optimum Range	60-100	796-1326
Outstanding	60	796
Excellent	50	663
Good	40	530
Fair or Degrading	30	398
Poor or Minimum	10	133
Severe Degradation	<10	<133

Monthly Flow Characteristics

Month	Long-term Mean Monthly Flow (cfs)
Jan	1
Feb	1
Mar	1
Apr	1
May	971
Jun	11364
Jul	901
Aug	1461
Sep	1283
Oct	190
Nov	18
Dec	3

Appendix A16. Tennant Method analysis for Power Creek.

Tennant Method Flow Classifications (adapted from Tennant 1975)

Narrative Description of Flows	Seasonal Base Flow (Q) Regimens as Percentages (%) of Average Annual Flow (QAA)	
Location	Power Creek	
	% of QAA	Flow (cfs)
Month	Dec.- Apr.	
QAA	100	255
Flushing or Maximum	200	510
Optimum Range	60-100	153-255
Outstanding	40	102
Excellent	30	77
Good	20	51
Fair or Degrading	10	26
Poor or Minimum	10	26
Severe Degradation	<10	<26
Month	May - Nov.	
QAA	100	255
Flushing or Maximum	200	510
Optimum Range	60-100	153-255
Outstanding	60	153
Excellent	50	128
Good	40	102
Fair or Degrading	30	77
Poor or Minimum	10	26
Severe Degradation	<10	<26

Monthly Flow Characteristics

Month	Long-term Mean Monthly Flow (cfs)
Jan	74
Feb	62
Mar	46
Apr	57
May	210
Jun	453
Jul	531
Aug	515
Sep	503
Oct	349
Nov	168
Dec	92

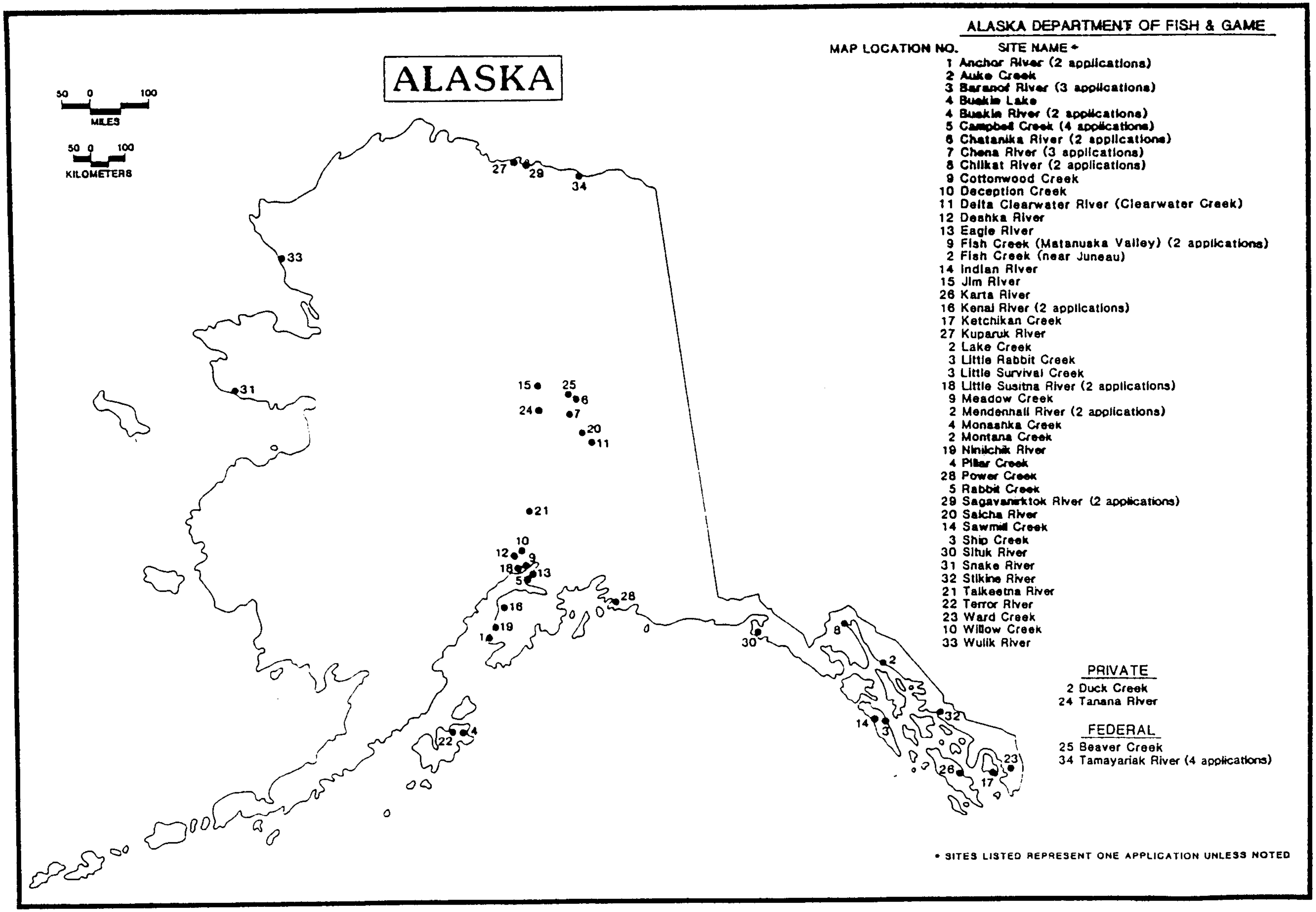
Appendix A17. Tennant Method analysis for Situk River.

Tennant Method Flow Classifications (adapted from Tennant 1975)

Narrative Description of Flows	Seasonal Base Flow (Q) Regimens as Percentages (%) of Average Annual Flow (QAA)	
Location	Situk River	
	% of QAA	Flow (cfs)
Month	Jan.- Dec.	
QAA	100	332
Flushing or Maximum	200	664
Optimum Range	60-100	199-332
Outstanding	60	199
Excellent	50	166
Good	40	133
Fair or Degrading	30	100
Poor or Minimum	10	33
Severe Degradation	<10	<33

Monthly Flow Characteristics

Month	Long-term Mean Monthly Flow (cfs)
Jan	275
Feb	213
Mar	266
Apr	228
May	292
Jun	244
Jul	193
Aug	322
Sep	534
Oct	562
Nov	354
Dec	453



Appendix A18. Locations of instream flow reservation application reaches, July 1, 1986 to June 30, 1994.

Appendix A19. Historical data summary for U.S. Geological Survey continuous streamflow gage sites in Alaska, 1908 to September 1994 (Brabets 1994).

NUMBER OF GAGE SITES	PERIOD OF RECORD (YEARS)
10	0 to < 1
94	1 to < 5
241	5 to < 10
162	10 to < 20
59	>20