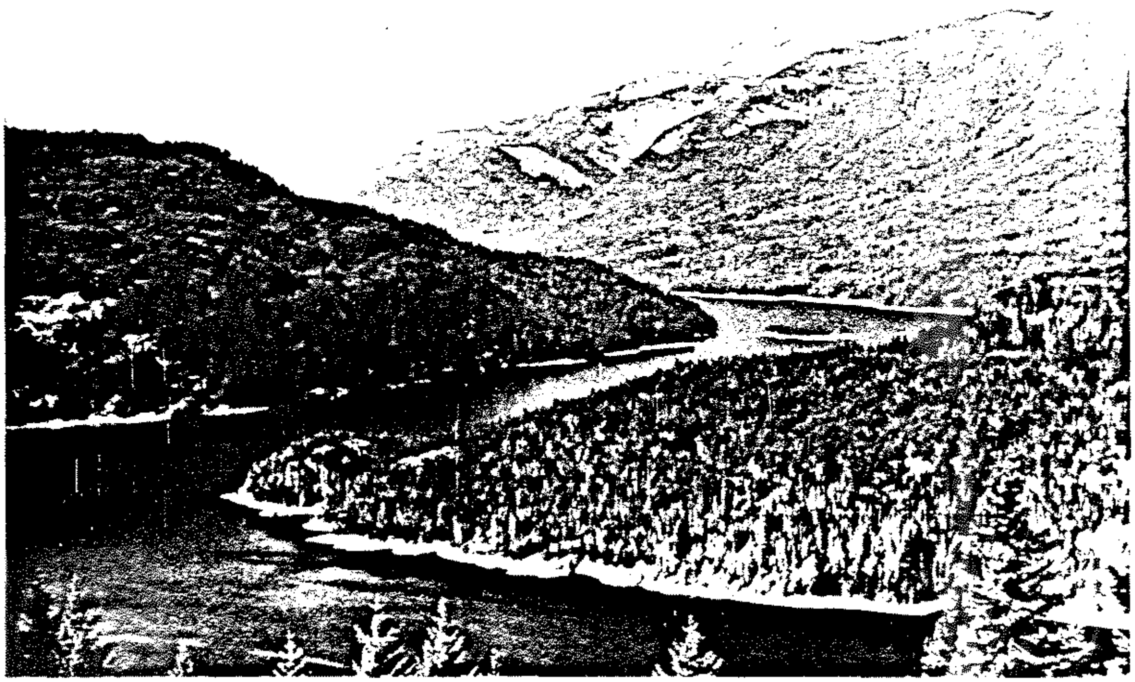
SKAGIT RIVER
HYDROELECTRIC PROJECT

FERC No. 553

ROSS LAKE LEVELS ANALYSIS

VOLUME I
Report



City of Seattle
City Light Department

JUNE 1991

SKAGIT RIVER
HYDROELECTRIC PROJECT

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Ross Lake Levels Analysis

Volume I
Report

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with assistance from
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Submitted to

Seattle City Light

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EXECUTIVE SUMMARY

I. Introduction

The City of Seattle, City Light Department (the City) is the owner and operator of the Skagit River Hydroelectric Project, Federal Energy Regulatory Commission (FERC) No. 553. The original license for the project, issued in 1927, expired in 1977. Since that time, the City has been conducting a number of studies, many of them related to downstream fisheries. More recently, and in response to inquiries by FERC and the intervenors (1), the City has hired consultants to evaluate project impacts in several areas. One area of intensive study has been an analysis of the impact of Ross Lake levels.

Operation of Ross Lake has been characterized by annual drawdowns of about 100 feet. (2) The lake is generally at or near full pool during the mid to late summer months, and reaches its lowest level in early spring. The annual cycle of Ross Lake levels has impacts on, and is affected by, a number of other resources. These include:

- downstream anadromous fisheries
- electric power generation
- erosion (includes archaeological resources)
- flood protection
- recreation
- resident fisheries
- visual quality

The relationships between Ross Lake levels and these resources are not only important, but most of them have not previously been quantified or otherwise studied in depth. The City has commissioned a series of studies to evaluate these relationships. These and other relevant studies are listed in the report bibliography, section 7.0. This report contains the results of those studies.

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(1) U.S. Department of the Interior (National Park Service, Fish and Wildlife Service, Bureau of Indian Affairs), U.S. Department of Commerce (National Marine Fisheries Service), U.S. Department of Agriculture (Forest Service), Skagit System Cooperative Tribes (Upper Skagit, Sauk-Suiattle, Swinomish), Washington State Departments of Ecology, Fisheries, and Wildlife, and North Cascades Conservation Council.

(2) Diablo and Gorge Lakes are operated as diurnal reservoirs for Ross Lake; although their levels go up and down, they do so on a much smaller scale than Ross Lake—about five feet—and on a daily and not annual basis.

II. Current Impacts of Ross Lake Drawdowns on Visual Quality, Recreation, and Resident Fisheries

The studies looked at the current impacts of the annual drawdown on visual quality, recreation, and resident fisheries. The major conclusions in these areas are as follows:

A. Visual Quality

The visual contrast (3) and single user impacts (3) of Ross Lake drawdowns vary from low to high and depend on the time of year and location of the view. The studies showed that viewers generally are not present during the maximum drawdown (February through April); the overall visual quality impact (3) of Ross Lake drawdowns is therefore low. The majority of viewers see Ross Lake when the lake level is at or near full pool—July through September—when the visual contrast and single user impacts are low.

B. Recreation

The primary non-aesthetic recreation impact of the annual Ross Lake drawdown is on boaters, due to diminished access to the lake via boat ramps and docks and to boat-in campground facilities. Boat ramp and campground access is most affected in May and June. However, the studies showed that the number of boaters in May and June is about one-fifth of the total number of annual users, so the impact is low. (Boaters are not generally present when the lake is very low in April and after October.)

The annual drawdown has a beneficial impact on downstream recreation by modulating the natural short-term extremes of Skagit River flows. The operating regime of the Skagit Project allows for a longer whitewater boating season on the upper Skagit by providing sufficient late-summer flows. This results in peak use during August and September, which is not typical for whitewater opportunities, and probably leads to higher total use than would occur with unregulated flows. Scenic floating and boat fishing are made easier by maintaining relatively more stable flows that provide ample water for boating. While not specifically a product of the annual drawdown, the flood control provided by Ross dam helps to reduce Skagit River flood peaks, making river-oriented recreation activities easier and safer and reducing damage to shoreline recreation facilities.

C. Resident Fisheries

The annual Ross Lake drawdown has mixed effects on resident fisheries in the following ways: 1) the drawdown increases potentially available spawning habitat in tributary streams as the lake recedes from approximately elevation 1595 feet, although the amount of habitat at these lower elevations is less than that available at full pool; 2) as the lake level rises in late spring, fish redds in tributary streams are inundated by rising lake levels, which in some cases kills the unhatched eggs; 3) the spawning habitat above full pool

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(3) These terms are defined and explained in detail in Ross Lake Early-Season Recreational Activity and Visual Quality Assessment (Parametrix, 1989). In that study the word index is often used in place of impact.

elevation in some tributaries is not accessible until the lake is almost at full pool, and this generally occurs too late in the spring for the fish to use the habitat for reproduction; and 4) the drawdown permits the avoidance of spill over Ross dam which is harmful to the fishery. The studies conclude that current Ross Lake drawdowns probably do not have significant overall impacts on the already enhanced resident fishery.

III. Potential Impacts of Early Refill Alternatives on Recreation, Downstream Anadromous Fisheries, Resident Fisheries, Power Production, Flood Protection, and Shoreline Erosion

As part of the lake level studies, the consultants investigated the potential impacts of a series of early refill alternatives on other resources. The identified impacts would be on reservoir and downstream recreation, downstream anadromous fisheries, power production, and flood protection.

A. Recreation

The studied early refill alternatives would improve the recreation experience on Ross Lake in two ways: 1) the aesthetic experience would improve; and 2) access to the lake and to boat-in campgrounds would be less affected by reservoir drawdown. Both of these benefits would occur primarily in May and June. The improved recreation opportunities might result in an increase in early season use of Ross Lake; the studies calculate that a realistic projection of increased on-lake use would be less than 3 percent over current levels, or about 1000 user days [(4)]. This projection is based on an aggressive refill target of full pool on May 31; other alternatives would have a correspondingly lower increase. The study estimated the dollar value of the realistic increase in recreational use due to May 31 refill as less than $20,000 per year; the maximum conceivable benefit would be $243,500 per year with this alternative.

Early refill would affect downstream recreation activities by reducing Skagit River flows from January through March or April, and increasing flows from May through July. The primary effect of this change would be on upper Skagit whitewater boating, where current May and June use might be displaced or reduced because flows would be too high at this time of year. Winter flows would still be sufficient for scenic floating and boat fishing, while opportunities for these activities would also probably not be diminished by the higher May-July flows.

B. Anadromous Fisheries

In the time since the original Skagit project license expired in 1977, the City in cooperation with appropriate intervenors, and based on numerous, detailed studies, has implemented changes in the operation of the project to further project downstream anadromous fisheries. The City and the intervenors have continued to work toward an overall agreement for an operating regime for that license.

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(4) A user day, or activity day, is one visitor present for any part of one day.

The present studies were designed to indicate the impacts of various Ross Lake early season refill alternatives on the downstream anadromous fisheries due to changes in flows. The studies included sensitivity analyses to compare the impacts of a range of flows on protection levels of the anadromous fisheries.

Early season refill ha the potential to affect downstream anadromous fisheries by 1) changing the timing of flow releases from the reservoirs, 2) affecting the project's abilities to meet minimum flow requirements at different times of the year, and 3) increasing spill.

The impacts are summarized as follows:

- Early season refill causes definite, negative impacts on pink and chum salmon.
- Early season refill does not significantly impact chinook salmon.
- Early season refill causes modest increases in protection in certain months of the steelhead run, and little or no impact in other months.
- The overall impact on numbers of fish is negative because the steelhead runs which are benefitted are very small in comparison with the salmon runs which are harmed. The magnitude of the adverse impact increases substantially with earlier refill.
- Increased minimum flows are a key element in protecting downstream anadromous fisheries. Early season refill impairs the project's ability to meet increased minimum flows.

C. Resident Fisheries

Early season refill could open up some currently unavailable spawning habitat to fisheries resident in Ross Lake. The positive effect of increased availability of spawning habitat is offset by a reduction of habitat due to flooding of other tributary streams which currently provide spawning below the full pool elevation. Providing new access to the spawning habitat in the tributary streams might also displace utilization by resident fisheries currently present in those streams.

The quantity of any changes in habitat due to early refill is small relative to the overall quantity of habitat in the watershed. The impacts of early season refill on resident fish spawning habitat are not likely to be significant. Furthermore, early refill would increase the incidence and volume of spill at Ross Dam, which would increase the risk that adult fish would be flushed from Ross Lake.

D. Power Production

Early season refill impacts power production by 1) moving a portion of the project's power production from winter to summer, and 2) spilling more water, which is then not available to produce power. The summary of the impacts of early season refill alternatives is as follows:

- Summer power does not meet the region's peak winter load demands and is therefore worth less than winter power, and is harder to market. The earlier and higher the refill target, the greater is the negative economic impact.

- The cost of the early season refill alternatives is large; the alternative with the smallest impact costs more than $10,000,000 over the term of the license (in present net worth with a 3 percent discount rate), while the higher impact alternatives (earlier and higher refill) cost up to $130,000,000.

E. Flood Protection

A major benefit of the Skagit project is flood protection. Flood protection is obtained by having Ross Lake below full pool during the winter flood and spring runoff seasons. High flows that would otherwise flood the valley downstream are stored in the reservoir and released gradually. Early season refill reduces flood protection by decreasing the storage capacity of Ross Lake, particularly during the spring runoff.

The studies did not quantify the downstream flooding impact of early refill alternatives. The studies do indicate that the periodic average peak flows below the project and the number of spill events will increase, and that the increases are greater with the earlier refill alternatives. The logical conclusion is that early refill alternative will reduce the project's ability to provide flood protection.

F. Shoreline Erosion

Other resources affected by Ross Lake levels include shoreline soils (erosion) and archaeological sites. Adverse impacts are caused by wave action; these impacts are exacerbated by lake levels pausing at the elevation of important sites and by continued operation of the lake at or above 1602.5 feet. The lake levels studies did not quantify the change in impact of early season refill on soils erosion. However, it can be deduced that erosion impacts will increase with early season refill alternatives; the earlier in the season that the reservoir is filled, the greater the period of time that the lake level will be at or above 1602.5. Early refill is not likely to significantly change the ramping rates of the reservoir, which is dependent on the weather.

IV. Tradeoffs Between Resources

Implementation of earlier refill would impact the studied resources in the following ways:

- Ross Lake recreation and visual quality would be improved.

- Downstream whitewater boating use and opportunities would probably be reduced somewhat, while other downstream recreation activities would not likely be affected.

- Resident fisheries would probably not be significantly impacted one way or the other.

- Shoreline erosion would probably not be significantly impacted, but those impacts which occur are likely to be negative.
- Flood protection would likely be negatively impacted.
- Downstream anadromous fisheries would be negatively impacted.
- Power generation would be negatively impacted.
- With a May 31 refill target, the cost:benefit ratio of the quantifiable impacts (power and reservoir recreation) ranges from 327:1 (using realistic reservoir recreation benefits) to 27:1 (using maximum possible reservoir recreation benefits).

V. Conclusion

The certain, quantifiable costs of early season refill are much greater than the potential benefits. The non-quantifiable benefits—primarily improved aesthetic experience of Ross Lake by early season recreational users— do not affect many people relative to the numbers of City ratepayers and downstream residents who will or may be adversely impacted by early season refill. The City concludes that the benefits of early season refill do not justify the costs. The City proposes to operate the project as follows:

1. The City shall fill Ross Lake as early and as full as possible after April 15 each year, subject to adequate runoff, anadromous fisheries protection flows (specified in the Skagit River Anadromous Fish Flow Plan, Section 6 of the fisheries settlement agreement), flood protection, minimized spill, and firm power generation needs. Subject to the above constraints and hydrologic conditions permitting, the City shall achieve full pool by July 31 each year.

2. The City shall hold the reservoir as close to full pool as possible through Labor Day weekend, subject to adequate runoff, anadromous fisheries protection flows (specified in the Skagit River Anadromous Fish Flow Plan, Section 6 of the fisheries settlement agreement), flood protection, minimized spill, and firm power generation needs.

3. In any overdraft year (i.e., in those years in which Ross Lake is drafted below the energy content curve), the City shall bring the Ross Lake level up to the variable energy content curve (VECC) no later than March 31, subject to adequate runoff, anadromous fisheries protection flows (specified in the Skagit River Anadromous Fish Flow Plan, Section 6 of the fisheries settlement agreement), flood protection, minimized spill, and firm power generation needs.

4. The flood protection curve will be set by the U.S. Army, Corps of Engineers. The current curve requires drafting beginning on October 1 and reaching elevation 1592 by November 15.

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1.0 INTRODUCTION

1.1 BACKGROUND

Ross Lake, the reservoir formed by Ross dam on the upper Skagit River in Washington (see Figure 1-1 for general location), is a major part of the Skagit River Hydroelectric Project (No. 553) owned and operated by the City of Seattle, City Light Department (City). The Skagit Project also includes Diablo and Gorge dams and reservoirs located downstream from Ross, and support facilities associated with all three plants. The City filed an application for relicensing the project with the Federal Energy Regulatory Commission (FERC) in 1977, when the original 50-year license for the project expired. Between 1977 and the present, the City has conducted numerous studies of project operations and area resources in support of its relicense application. These studies have been undertaken in consultation with various government agencies, Indian tribes, and public organizations that have been granted official standing as intervening parties in the relicensing proceeding.

Through the consultation process, the FERC and the intervenors have identified several resource issues to be resolved in the relicensing process. One of these issues concerns the operating pattern of Ross dam and reservoir and the associated effects on recreation and other lake-oriented resources, which is the subject of this report.

Ross Lake and its adjacent upland areas provide recreational opportunities of national significance. The lake is surrounded by the Ross Lake National Recreation Area administered by the National Park Service (NPS). Ross Lake and its shoreline areas provide a destination attraction for several types of recreational activities, including vehicle camping, backcountry camping, boating, fishing, backcountry hiking and horseback riding, and day hiking. Recreational resources and facilities at Ross Lake have several unique and unusual characteristics, including a number of boat-in campsites, a floating resort, and a naturally-reproducing trout fishery. In addition to these direct uses of the lake, hundreds of thousands of motorists annually view Ross Lake for brief periods as they pass by along Washington State Route (SR) 20, the major highway through the North Cascade mountains.

Reservoir operations are of concern because one of the primary uses of Ross Lake is to provide electric power for City customers. Annual streamflow and power demand characteristics result in large fluctuations in the reservoir level over the course of the year. Reservoir levels typically reach a minimum in late March or early April, and rise through the spring and summer as snowmelt runoff flows into the reservoir. Under current operations, the reservoir is filled by July 31, remains full through late August or early September, and then is drafted (lowered) during the fall and winter to meet power demands during the primary heating season. Unvegetated shoreline areas are exposed at lower lake elevations, and facilities that provide access to boating and other activities can be difficult or impossible to use. Lake level fluctuations can, therefore, adversely affect the visitor experience by reducing the utility of recreation facilities or diminishing the visual quality of the lake and its visual environment.

1.2 PURPOSE

This report documents the results of an analysis of Ross Lake levels and their effects on key local resources. The overall goal of the lake level analysis was to investigate the merits of changing the current operating pattern to accomplish refilling of the lake earlier in the recreation season. This was to be done by assessing the effects of early refill on the resources and resource uses that would be subject to change, and conducting a complete, balanced evaluation of the relative gains and losses. Specific objectives of the study were to perform detailed analysis of existing conditions and expected changes from early refill with respect to reservoir and downstream recreation, visual quality, downstream anadromous fisheries, the resident fishery, and power generation. Early refill effects in these areas were to be quantified where possible, and converted into economic measures where appropriate. Additional objectives were formulated during the course of the study through identification of concerns related to shoreline erosion, archaeological resources, and flood hazards. These issues were addressed primarily in a qualitative manner.

The lake levels analysis was conducted in direct response to requests from intervenors, principally the NPS and the North Cascades Conservation Council (NCCC). Both of these organizations participated in developing the scope for the study, and in regular consultation meetings where status reports were provided and preliminary results were presented. The current lake levels analysis is a more detailed and comprehensive version of a prior study conducted by the City in 1988 (SCL, 1988), also at the request of intervenors. A basic purpose of the current study was to test the outcome of early refill alternatives using a considerably different prioritization of power generation and refill objectives from the original study.

1.3 APPROACH

The lake levels analysis was conducted using available data on Ross Lake resources and existing City computer models used for power and streamflow planning purposes. Data were developed to sufficiently characterize existing conditions and assess the specific early refill issues pertaining to each resource area. Extensive reliance was placed on key prior studies conducted by or for the City in relation to the project. In particular, the lake levels analysis was intended to build upon the results of an early-season recreation and visual quality study done in 1989 (Parametrix, Inc., 1989).

The consequences of early refill were assessed by evaluating the simulated outcomes of a series of specific refill scenarios. A total of twelve refill scenarios, including the current operation or base case, were defined based on varying combinations of refill target dates, refill target elevations, and stipulated downstream flow constraints. Eight scenarios, including seven early refill alternatives to the current operation, reflected the existing negotiated constraints on downstream flows. Four other scenarios based on the minimum flow stipulated in the original FERC license for the project were also defined, for sensitivity testing purposes. Each refill scenario was identified by a specific refill target date and elevation.

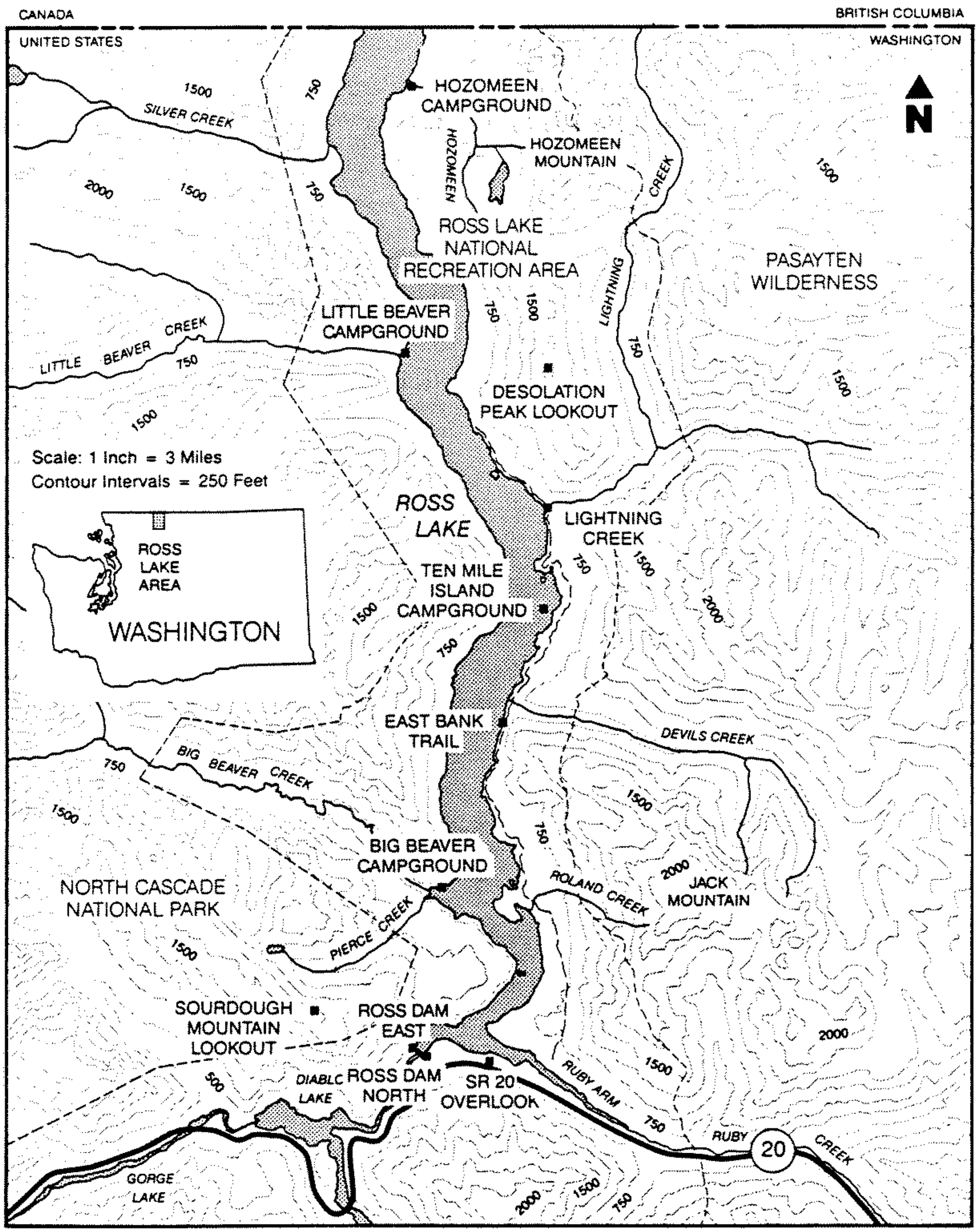
The outcomes of the 12 refill scenarios were simulated using the City's HYDRO model, a computerized planning model that simultaneously considers hydrologic data, physical plant characteristics, and all applicable operating rules and constraints. The HYDRO model produced simulated operating results with respect to Ross Lake elevations, downstream releases from the project, the volume of water spilled (not used for generation) at each of the three Skagit River dams, and total project generation. These results were developed for a simulation period based upon a 50-year record of hydrologic data.

The simulated results from the HYDRO model provided the basis for several other elements of the analysis, particularly the downstream fisheries component. The simulated 50-year streamflows from the HYDRO model runs were used directly as input data for another City model, the FISH-POWER model, which calculated the downstream spawning protection levels for anadromous fish associated with each refill scenario. An additional comparative analysis was done using the FISH-POWER model using higher minimum flow levels to simulate provision of higher spawning protection levels. Reservoir elevation data from the HYDRO results were also applied to various aspects of the recreation and shoreline erosion assessment, while the simulated streamflows were reviewed with respect to influences on flood hazards. Detailed information on study methods is provided in the respective technical sections of the report, including flow diagrams depicting the basic components of the key models used in the analysis.

1.4 REPORT ORGANIZATION

This report is presented in three volumes, with two appendix volumes accompanying the main text. The remainder of this volume includes separate chapters for each of the primary resource areas originally defined in the study scope, an integrating chapter that includes discussion of all resources of concern, and a glossary and references. The key technical chapters on recreation, fisheries and power generation (Chapters 2, 3 and 4, respectively) each have sections on study methods, existing conditions and early refill effects, along with a summary assessment. Chapter 4 includes additional discussion of the simulation process and results, due to the more complex nature of the power generation analysis. The first appendix volume includes supporting data on recreation, hydrology, simulation results, and economic valuation of power generation effects. The last of the three volumes is a catalog of photographs of Ross Lake recreation facilities at different reservoir elevations.

Figure 1-1. General location map of Ross Lake.



Source: Reproduced from Parametrix, Inc., 1989.

2.0 RECREATION AND VISUAL QUALITY

Recreational activity and visual quality at Ross Lake are the driving issues behind the lake levels study, as indicated in Chapter 1. Visual quality within the Ross Lake viewshed is adversely affected at certain times of the year when the level of Ross Lake is significantly below full pool; this opinion has been widely held within some circles for decades, and was documented to considerable technical detail in a recent study sponsored by the City (Parametrix, Inc. 1989). One of the key questions involved in the lake level analysis is whether this adverse visual quality effect translates into a significant adverse effect on recreation at Ross Lake. Acting on the hypothesis that there is such a relationship, the relicensing process intervenors requested the City to conduct a detailed technical study of the effects of reservoir operation on recreation and other resources.

Due to the management and human use patterns of Ross Lake, virtually all viewers who would experience any visual quality effects associated with the reservoir level are in the area for some type of recreational pursuit. Consequently, the visual quality issues and effects are essentially subsumed within the analysis of recreational issues and effects. Subsequent references in this document to the Ross Lake recreation studies, therefore, implicitly incorporate the pertinent visual quality elements.

The initial objective of the recreation component of the lake level analysis was to quantify the effect of existing reservoir operations on recreation at Ross Lake, and quantitatively assess the potential effects (presumed to be positive) of early refill on recreation. The approach to this effort involved a five-step process. The first step was to characterize key aspects of existing conditions. The second step was a qualitative assessment of the various Ross Lake recreational user groups to identify the specific ways in which the reservoir level could affect their use of Ross Lake, and determine the likely sensitivity of their use pattern to changes in the lake level. This was followed by a study of the physical effects of lake level variation on the existing recreation facilities. A comparative analysis of the seasonal patterns of use for Ross Lake and other similar resources constituted the fourth part of the recreation analysis. Finally, the results of the first four steps were combined to produce estimates of potential changes in the level of recreation use that could result from early refill of Ross Lake.

In commenting on the draft lake levels analysis report, several intervenors requested that an assessment of downstream recreation be added to the scope of the report. The City agreed to include a general and qualitative analysis of water-based recreation on the Skagit River downstream of the Skagit Project in the final report. Consequently, the City compiled information already available concerning existing downstream recreational activities and use patterns. Information on the seasonal nature of these downstream uses was reviewed against river flow data to assess in general terms the effects of both the existing Ross Lake operation and early refill on downstream recreation. While some quantitative information on existing uses is presented, no attempt was made to project potential shifts in use levels resulting from early refill.

2.1 STUDY METHODS

The recreation component of the study was primarily conducted through compilation and analysis of secondary data obtained through literature search or requests for agency file data. Primary data on lake level physical effects were collected through periodic field surveys of Ross Lake recreation facilities. Estimates of potential effects of early refill on recreational use were derived through simple arithmetic operations. Further information on the methods used for the various steps of the analysis is provided below.

Characterization of existing conditions addressed three subject areas. Data on existing recreational access and facilities at Ross Lake were obtained from the extensive inventory work conducted in 1989 for the recreation planning component of the relicensing studies (Envirosphere Company, 1989). Information on Ross Lake user groups and activity levels was extracted from prior City contract studies designed to support the lake level analysis (Parametrix, Inc. 1989). Historical reservoir elevation data were obtained from standard water resources publications from the U. S. Geological Survey (USGS, various years).

Physical relationships between lake levels and the utility of shoreline recreational facilities were investigated by means of a series of surveys of the recreation sites on Ross Lake from late summer 1989 through early 1990. Ebasco Environmental crews using City boats visited all recreation sites on Ross Lake on each of 12 surveys from August 19, 1989 through May 22, 1990. These surveys covered lake elevations from 1600.28 feet to 1551.61 feet. The field crews took a variety of measurements covering physical relationships of the boat ramps, docks, and campgrounds to the lake surface at the respective lake elevations. The field crews also photographed all sites on each survey, and recorded incidental observations of boats and users observed while conducting the surveys.

With respect to the final results, the key aspect of the reservoir recreation analysis was the assessment of seasonal distribution patterns of recreational use at Ross Lake and comparable areas elsewhere in Washington. This was accomplished by reviewing historical data on recreational use by month for Ross Lake, other resources within the North Cascades National Park Service Complex, and selected units of the Washington state park system. Absolute numbers for each use category analyzed were converted into percentage terms so the respective areas could be compared. Data sources for Ross Lake and other North Cascades areas were the 1989 Parametrix and Envirosphere reports, respectively, while data on state park use were obtained from the monthly and annual reports compiled by the Washington State Parks and Recreation Commission (WSPRC, 1984-1988).

The final element of the Ross Lake portion of the recreation analysis was the estimation of potential changes in use from early refill, which was done in two steps. Initially, observations from the comparative analysis of seasonal use distribution were used to set a realistic ceiling on early season (essentially May to June) recreational use at Ross Lake. This use pattern was interpreted to represent the maximum change in use from early refill, specified as a near full reservoir by the end of May.

This generic refill scenario and result was considered to be equivalent to the most aggressive early refill alternative considered in the fisheries and power generation simulation model analyses, specifically a refill target of elevation 1601.5 feet on May 31. Potential changes in recreational use associated with the remaining refill alternatives were subsequently scaled from this basic result, in rough proportion to their lake elevation changes relative to existing conditions and the most aggressive refill scenario.

As indicated above, the results of the reservoir reservoir recreation analysis are denominated in terms of the number of Ross Lake recreational users; the effects of early refill are stated as potential increases from the existing level of recreational use. The City recognizes that, at the conceptual level, lake levels operate directly on the value of the recreation experience and indirectly on the level of use. For some users, the value of the experience is diminished when the lake level is noticeably below full pool, but the users still choose to recreate at Ross Lake under these conditions. For other users, however, the value of the experience is reduced to the point that other recreation resources become more attractive and the users choose not to recreate at Ross Lake (at least not when the reservoir is low). The City does not believe it would be practical or cost-effective to obtain the type of user sensitivity data needed to estimate the diminished value effects. Virtually all Ross Lake recreational use occurs when the lake is full or nearly so (Parametrix, Inc., 1989); therefore, diminished value effects are likely to be quite small, and would not add significantly to any effect of lake levels on the level of use.

The assessment of downstream recreation was conducted in generally the same manner as the other elements of the recreation analysis, although with less quantification and analytical rigor. Data on existing downstream recreation activities and use levels were obtained from the 1989 recreation inventory for the entire Skagit Project evaluation area (Envirosphere Company, 1989). Selected personal contacts were made with river users or other authoritative sources to identify flow-related constraints on recreational use of the river. Effects of existing reservoir operations and early refill were assessed on the basis of comparing typical river flows by month with the existing distribution of use by month. Due to the level of information available, this assessment was limited to identifying whether specific operational patterns would likely have a positive or negative effect on downstream use, without addressing the magnitude of the expected change.

2.2 EXISTING RESERVOIR RECREATION CONDITIONS

Evaluation of the effects of lake levels on reservoir recreation involved relatively detailed characterization of existing recreational access and facilities, recreational user groups and activity levels, and reservoir levels. Relevant data for these three subject areas are provided below. Largely because prior documents prepared for the relicensing studies are the key information sources, these sections are of a summary nature.

2.2.1 Recreational Access and Facilities

Ross Lake is a long, narrow lake, extending about 22 miles to the north from Ross dam, situated in very mountainous terrain of the North Cascades. Due to its physical setting, access to Ross Lake from user origin points is rather limited. Direct access to the lake by road is only possible at Hozomeen at the northern end of Ross Lake (see Figure 2-1).

This route requires travel from Canada Highway 3 near Hope, B.C. southward over approximately 40 miles of the Silver-Skagit Road, a gravel road that reaches Hozomeen through the upper Skagit Valley. This road ends along the shore of Ross Lake about 1.5 miles south of Hozomeen.

Direct access to the south end of Ross Lake requires travel by boat, foot, or floatplane. Washington State Route 20 (SR 20) passes within 1 mile of Ross Lake, but there are no secondary roads connecting the reservoir to the highway. Recreationists approaching Ross Lake via SR 20 actually reach the lake by foot or horse travel along the Ross dam or East Bank trails. An alternate but more complicated means of access to the south end of Ross Lake is by way of water travel across Diablo Lake, which has direct or indirect road access from SR 20 at two locations. Users transit Diablo Lake by paddling their own canoes and kayaks or by riding the twice-daily City tug from the Diablo landing; trips by both modes terminate at Ross dam. The final leg to Ross Lake covers about 1 mile and 400 feet of vertical elevation along the Ross dam haul road, which can be accomplished by a paid truck transport service operated by the Ross Lake Resort.

A small number and proportion of Ross Lake users arrive by floatplane. Those who do are generally customers of the Ross Lake Resort, which is located near Ross dam. While permitted by law and regulation, this mode of travel is not regarded favorably by the NPS. Weather conditions also often create unsafe conditions for travel through the canyon reach and for landing on Ross Lake.

Once at Ross Lake, travel on or along the lake is by water or trail. The trail to Ross dam continues along the lower one-third of the western shoreline up to Big Beaver. Little Beaver is the only other point along the west bank with trail access, with trail connections to Big Beaver and west to Whatcom and Hannegan passes. The East Bank trail, which connects SR 20 with Hozomeen, is located close to the shoreline for approximately 8 to 10 miles between Roland Creek and Lightning Creek. The Ross Lake Resort also operates a water taxi service, which primarily serves campers without boats and hikers. People travelling on Ross Lake by boat must either have their own boat or rent a boat from the resort.

Developed recreational facilities at and near Ross Lake are summarized in Table 2-1. (While trails are not developed facilities in the traditional sense, they are constructed features that are significant to several user groups.) Most of these facilities are concentrated at the north and south ends of the lake. Facilities at the north end of the lake include the Hozomeen vehicle campground and all four boat ramps, including one situated just north of the border in Canada. While not listed in the table, the NPS also manages a visitor contact station and the northern terminus for the East Bank trail at Hozomeen, and BC Parks operates the 88-unit Ross Lake campground (Envirosphere Company, 1989).

The most significant facility at the south end of the lake is the Ross Lake Resort, with its cabins, boat rental, fuel, and water taxi services. The Ross dam haul road and a small boat dock at the end of this road are also used by most recreationists gaining access at the south end of the lake. Two small, paved highway overlooks along SR 20 south of the lake provide expansive views and are visited by large numbers of highway travellers.

Table 2-1. Ross Lake recreational facilities summary.

Type of Facility	Number of Sites	Number of Individual Units
Vehicle campgrounds	1	122
Backcountry boat-in camps	17	61
Backcountry hiker camps	9	23
Backcountry horse camps	6	9
Resorts	1	14
Boat ramps	4	4 (1)
Overlooks	2	16 (2)
Trails	6	60 (3)

(1) Represents number of individual launch lanes.
(2) Represents approximate number of parking spaces available.
(3) Represents approximate number of trail miles.

Sources: Envirosphere Company, 1989.
Parametrix, Inc., 1989.

The remaining facilities indicated in Table 2-1 are small backcountry campgrounds and trails distributed along the Ross Lake shoreline or in adjacent upland areas, and intended to serve specific user groups. The backcountry camps range in size from 1 to 7 individual camp units, and most of the boat-in camps have small docks. Ten of the 17 boat-in camps are located along the east side of the lake, 4 are on the west side, and 3 are on islands. The 9 separate hiker camps and 6 horse camps are mostly situated along the East Bank trail away from the Ross Lake shoreline, although several boat-in camps that are accessed by trail are also open to use by hikers and horse riders.

2.2.2 User Groups and Activity Levels

Data on recreational activity levels at Ross Lake are summarized in Table 2-2. (While these figures are cited from previous studies sponsored by the City, the actual use data were obtained from the NPS, the Washington Department of Transportation and the Washington Department of Wildlife.) Total annual use among all eight user groups averages approximately 932,600 activity days (defined as one person for any portion of a day). SR 20 motorists represent by far the dominant use in actual numbers, averaging over 890,000 activity days per year or 95 percent of the total. This number measures total travellers passing by Ross Lake on the highway and able to view it, and not the number stopping at either of the two Ross Lake overlooks.

Table 2-2. Ross Lake user groups and existing activity levels.

		--------Average Annual Use (1)-------	
	People	Visitor Nights	Activity Days
Hozomeen Car Campers	6,800	17,018	17,000
Hozomeen Day Users	7,763	---	7,800
Boat Campers	4,385	7,666	7,700
Backcountry Hikers	1,309	1,816	1,800
Horse Riders	84	126	100
Resort Guests	1,800	5,309	5,300
Day Hikers	2,575	---	2,600
SR 20 Motorists	890,297	---	890,300
TOTAL	915,013	31,935	932,600
Total, Minus SR 20	24,716	31,935	42,300

(1) Over 1984-1988 period, generally.

Sources: Envirosphere Company, 1989.
Parametrix, Inc., 1989.

Because SR 20 motorists are only indirect recreational users of Ross Lake, Table 2-2 also includes a row for total use exclusive of SR 20. This direct or on-lake use amounts to an annual average of about 42,300 activity days. Hozomeen car campers are the largest user group among the on-lake subtotal, with about 17,000 activity days per year. This is about 40 percent of all on-lake use, and more than two times the activity level of the next largest user group. Hozomeen day users, boat campers and resort guests each account for well over 12 percent of all on-lake use. Trail use of all types amounts to approximately 4,500 annual activity days, ranging from 100 activity days for horse riders to 2,600 for day hikers. Aggregate trail use represents slightly less than 11 percent of average annual on-lake use. Approximately 75 percent of all on-lake activity is overnight use.

2.2.3 Reservoir Levels

Ross Lake is formed by a concrete-arch dam completed to elevation 1615 feet in 1949. Based on the elevations of the spillway gates and the intake invert, the physical limits of reservoir elevation are as follows:

Maximum Elevation	1604.0 ft.
Full Pool Elevation	1602.5 ft.
Minimum Elevation	1475.0 ft.
Maximum Drawdown	127.5 ft.

Under normal operation, the target refill date for Ross Lake is July 31 with a target elevation of 1602.5 feet or full pool. Ross Lake is normally maintained at full pool through at least the end of August. If fisheries and energy requirements and streamflow conditions permit, full pool is maintained through Labor Day. The reservoir is then drawn down consistently (except for possible temporary increases during heavy rain events) over the winter period, September through March, for the production of power and the maintenance of anadromous fishers runs. Elevations below 1590 are not typically reached until the beginning of November. The reservoir typically reaches its lowest elevation by mid-April, somewhere around 1510 feet. The reservoir may be drafted lower or may end the winter period at a higher elevation, depending upon water conditions. Refill typically begins in mid-April and is completed by the end of July.

The annual pattern of reservoir drafting and refill is illustrated in Figure 2-2. The data presented in this graph are for water years 1961 through 1987. Key observations derived from these data are summarized in Table 2-3. As indicated in Table 2-3, Ross Lake has filled to elevation 1602.5 in every year but one since 1967. The reservoir only filled to elevation 1592 feet during the extremely low water conditions of 1977, which was the driest single water year on record. Ross Lake was drafted to the minimum elevation of 1475 feet one time during the period, in 1975, but in most years the drawdown was considerably less than the maximum possible. Annual minimum elevations over the period averaged about 1522 feet, corresponding to an average drawdown of 80.5 feet below full pool.

Within this historical period, reservoir conditions from 1981 through the present are of greatest interest because the Skagit Interim Flow Agreement was settled in that year. Actual reservoir elevations over the past eight years therefore best illustrate the operation of the reservoir under current objectives and constraints, although this period of record is brief. Summary Ross Lake elevation data for water years 1980 through 1987 (the most recent complete year available from USGS) are provided in Table 2-4, in the same format used for Table 2-3. The results are virtually identical to those of the previous table, particularly with respect to the frequency of filling and the annual drawdown.

Ross Lake elevation data for a similar, but slightly earlier, historical period have been used to construct the graph in Figure 2-3 (this graph has been directly adapted from a similar graph presented in the 1989 Parametrix report). This figure illustrates the typical reservoir elevation pattern over the primary recreation season, and the extent of annual variation above or below the average lake levels at a given time. On average during this period, Ross Lake began the recreation season at about elevation 1535 feet (67 feet below full pool) on May 1, increased to 1565 feet by the end of May and nearly 1590 feet by mid-June, and reached essentially full pool by early July. The reservoir did not typically fall much below 1600 feet until the latter part of September.

Minimum and maximum lake levels varied considerably around the average during the refill season. May 1 elevations ranged from about 1515 feet to over 1570 feet during this period, while the range for May 31 was from 1545 feet to about 1595 feet. The range of historical elevations narrows greatly by the end of the refill period. The lowest June 30 elevation from 1978 through 1986 was slightly above 1590 feet, while the minimum and maximum readings for the last half of July are all between about 1600 feet and 1603 feet.

Table 2-3. Summary of reservoir level historical conditions, water years 1961-1987.

Reservoir Characteristic	Elevation (ft.)	Time or Frequency
Full Pool	1602.5	20 of 26 years, all 1967 and later; 1977 filled only to 1592 ft.
Minimum Elevation	1475	once in 26 years, in spring 1975
Highest Annual Minimum	1570	in 1963, 1981
Average Annual Minimum	1522	—
Average Annual Drawdown	80.5	—

Source: USGS, various years.

Table 2-4. Summary of reservoir level historical conditions, water years 1980-1987.

Reservoir Characteristic	Elevation (ft.)	Time or Frequency
Full Pool	1602.5	7 of 8 years; filled to 1601.5 in 1987
Minimum Elevation	1490	in spring 1980
Highest Annual Minimum	1568	in 1981
Average Annual Minimum	1521	—
Average Annual Drawdown	81.5	—

Source: USGS, various years.

2.3 SENSITIVITY OF RESERVOIR RECREATION USE TO LAKE LEVEL

In order to determine whether recreational use of Ross Lake is likely to change in response to early refilling of the reservoir, it is necessary to assess the sensitivity of Ross Lake users to lake level variation. In this application, the term sensitivity does not refer to users' aesthetic sensibilities or their degree of preference for a full lake, but rather to the likelihood that users would change their activity consumption level in response to a change in lake level. Stated differently, the objective is to identify potential users who might likely be avoiding Ross Lake during the early part of the recreation season specifically because the lake is still drawn below full pool.

There are two possible effect mechanisms that could be responsible for altering recreational use patterns if potential Ross Lake users are actually avoiding the lake during the early season. Some users could be highly sensitive to visual quality and would refuse to visit Ross Lake until the reservoir were sufficiently high that shoreline visual quality effects were minimal. Alternatively, activity patterns for users who are dependent upon specific recreational facilities would likely be changed if the lake level rendered those facilities unusable at certain times.

These two components of use sensitivity to lake level are discussed below in Sections 2.3.1 and 2.3.2. The visual quality section includes a brief summary of a specific assessment of early season visual quality at Ross Lake. The discussion of the facility component of user sensitivity is presented primarily in conceptual terms, due to the lack of user-derived response data. However, site-specific information on actual conditions at Ross Lake recreation facilities at various lake levels is presented in Section 2.4, which allows informed judgment as to the likely significance of facility-based use effects.

2.3.1 Visual Quality Component

The visual quality of Ross Lake at various reservoir elevations was analyzed and documented in detail in a predecessor report (Parametrix, Inc., 1989) prepared for the current relicensing effort, and need not be addressed extensively here. Briefly, photographic and video documentation of four different lake levels was obtained at ten representative viewpoints along the Ross Lake shoreline, SR 20, and high elevation trails near the lake. Visual quality ratings of the lake and surroundings were developed for each viewpoint and lake level, and were analyzed to assess the overall visual effect of lower lake elevations during the early part of the recreation season.

The early-season visual quality study documented a variety of specific visual changes when the lake is significantly below full pool. These include color contrast and prominent horizontal lines in some exposed shoreline areas, numerous stumps remaining from when the lake bottom was originally cleared, prominent exposed deltas at some creek mouths, and a large expanse of stump-covered mudflat at the shallower north end of the lake (Parametrix, Inc., 1989). These types of changes from baseline visual quality were measured on a quantitative scale, as were duration of view, viewer sensitivity, and number of viewers at each viewpoint.

Viewer sensitivity levels were assigned to the respective user groups through professional judgment of factors such as the users dependence on mechanized equipment and participation in activities that did not directly involve aesthetic appreciation. Among five user groups evaluated, the study team considered hikers to have the highest expectations and sensitivity to change in visual quality, and SR 20 motorists to have the lowest sensitivity. Horse riders were also considered to be relatively sensitive to visual change, while boaters and car campers (both largely mechanized users) were placed below the midpoint of the sensitivity scale.

The primary conclusion of the early-season visual quality study was that the greatest visual impacts do not occur when reservoir elevations are lowest, but rather in late June and early July when the reservoir elevation is likely to be near or slightly above 1590 feet (Parametrix, Inc., 1989). This is largely because few visitors are present to be affected by views at the lower lake levels in May and early June, but the higher level of recreational use after about mid-June brings many more viewers in contact with significant areas of exposed shoreline. This conclusion admittedly describes the relative magnitude of the existing visual quality impacts from reservoir drawdown, but it does not explain why this impact pattern occurs. It still leaves open the question of whether there is a cause-and-effect relationship between very low lake levels and low recreational use, or whether low early-season use is attributable to other factors.

The early-season visual quality study also included a number of other observations or conclusions that are germane to the present analysis. The baseline (full pool) visual quality was rated highest at the Desolation Peak, Lightning Creek and SR 20 viewpoints, and was rated lowest at Hozomeen, Ross dam and the East Bank trail. Among other factors, these ratings reflect the more expansive and varied views from higher-elevation viewpoints away from the shoreline and lowered visual quality from landscape modifications at the north and south ends of the lake. At lake levels below full pool, the visual impacts for individual users were determined to be greatest at the Lightning Creek, Big Beaver and Little Beaver viewpoints, where high shoreline contrast and long viewer duration combined for the strongest visual effect. Conversely, the impact to the individual user was least at the SR 20, Ross dam, Desolation Peak and Sourdough Peak viewpoints. While users at these viewpoints were considered to generally have high expectations and visual sensitivity, view duration at those sites tends to be short. Further, the contrast of the exposed shoreline is greatly reduced by distance at the three elevated viewpoints away from the shoreline.

2.3.2 Facility Component

Some recreational activities at Ross Lake require or are facilitated by certain types of developed recreational facilities. If these facilities are inoperable or difficult to use at lower lake elevations, recreational use of these facilities would likely be displaced or diminished. However, in order for such a facility-based effect on the level of use to occur, there would have to be some demand for use of the facilities at the times of the year when they are affected by low lake levels.

As discussed in Section 2.2.1, recreational facilities in the Ross Lake area include a vehicle campground, backcountry camps, a resort, boat ramps, overlooks, and trails. In addition, small boat docks are provided at 12 of the backcountry camps, the Hozomeen campground, and the boat launches. Among these facilities, utility of the boat ramps, docks, and the resort (which floats) can logically be directly affected by lake elevation. The vehicle campground and the backcountry camps located along the lakeshore can be indirectly affected by low lake levels; these facilities have a very strong water orientation, and their attractiveness to users is no doubt reduced if the distance to the water is increased.

The physical ability to use the remaining facilities in the area is not affected at all by lake elevation. Utility of the SR 20 overlooks is determined by road conditions, specifically the seasonal closure of SR 20 due to snow. While significant portions of the trails in the area follow along the lakeshore, these trail segments are located above elevation 1602.5 feet and are not affected physically by lake levels.

The dependence upon recreational facilities that are influenced by lake levels varies considerably between and even within user groups. For example, resort guests obviously are totally dependent on the ability of Ross Lake Resort to function normally; if the lake level prevented normal floating operation at certain times of year, no resort use would be possible at these times. Conversely, day hikers and SR 20 motorists have no dependence on facilities that are influenced by lake levels. Hikers and horse riders have little dependence on these facilities, but some of them do stay at lakeshore camps that can be indirectly affected by lake levels.

Based on their facility needs, any facility-based effects of lake levels on recreation use levels are likely to be concentrated among boat campers and Hozomeen car campers and day users. Members of each user group rely to varying degrees on boat ramps and docks (see more detailed discussion in Section 2.4), the utility of which is highly and directly affected by lake levels. Use of both types of facilities becomes impossible when they are dewatered, and is difficult over a small range of lake elevation above that point.

Usable boat ramps are an absolute requirement for most people who operate power boats on Ross Lake. Exceptions to this statement include users who rent small outboard boats from Ross Lake Resort, and those using cartop boats with small engines. All power boaters using trailered boats, however, can be assumed to require on operable boat ramp to be able to use Ross Lake. This class of power boaters accounts for an unknown portion of total users among boat campers, Hozomeen car campers, and Hozomeen day users. NPS (1980-1989) data indicate that power boaters accounted for about 80 percent of all boat use on Ross Lake in recent years. Therefore, it can be assumed that most boat campers use power boats and require an operable boat ramp (although some use rental boats from the resort). Dependence on boat ramps is probably slightly less among the two Hozomeen user groups, because not all of these users are also boaters.

Conceptually, usable boat docks are a much less binding or important requirement for water-dependent activities. Boats can still be beached when a nearby dock is dewatered, and NPS use data clearly document that boater use occurs at times and locations when usable docks are not available. Lack of a usable dock is no doubt a more significant determinant of behavior for certain types of boaters, such as those with deeper-draft power boats, or in certain locations where exposure to wind and waves would be a concern. In general, though, there is no evidence indicating that boaters are likely to avoid Ross Lake early in the recreation season because boat docks are unusable.

User-derived response data on the importance of usable docks are not available to demonstrate this conclusion. However, the conclusion is supported by analysis of actual boater use intensity at boat camps with docks versus those without docks. Because these data are reported observations of actual user behavior, they represent revealed preferences of the users. Summary data on use intensity by site are provided in Table 2-5. The figures in this table were derived by dividing the average annual boater use at each camp by the number of camp units at each site, yielding the average number of visitor nights per unit per year at each boat camp. This is a simple measure of campsite popularity that controls for the variation in number of camp units among the various boat camps. While some of these camps are accessible to hikers and horse riders, visitor nights by these users are excluded from the calculations.

If the presence of a dock were a significant factor in the selection of campsites by boat campers, this should be reflected in noticeably higher use intensity at the boat camps with docks. It is apparent from the table, however, that this is not the case. The 12 camps with docks account for 79 percent of total boat camp capacity and 78 percent of all boat camper visitor nights. The 5 camps without docks represent 21 percent of the capacity and nearly 22 percent of boat camper use. Use intensity at the camps without docks averaged 127.7 visitor nights per camp unit per year, slightly higher than the figure of 122.2 visitor nights for units at camps with docks. The intensity figures for the 17 individual camps indicates there are both high and low intensity levels in each group.

Based on these results, it seems clear that factors other than dock availability are responsible for campsite selection among boat campers in general. By extension, the fact that a dock is dewatered at certain times should also not be a determining factor in deciding where to camp or whether to visit Ross Lake.

The indirect effect of low lake levels on campground utility is difficult to address with any degree of quantification or precision. As long as a given campground is open and accessible and weather conditions permit, some campers will be inclined to use the site. Once these basic conditions are met, proximity to water becomes one of many site attractiveness factors that could influence camper behavior. It is likely that there is some distance threshold associated with water-oriented campsites beyond which campers would not use the site, and this threshold would vary considerably among campers. The existence and nature of such thresholds are of lesser significance than campers' choices among alternative sites. All other things being equal between two water-oriented campsites, a user could be expected to select the campground or site that was closest to the water at the time of use.

This observation probably has varying implications for the different types of camps at Ross Lake. Potential users of the Hozomeen campground would likely be selecting among Hozomeen and alternative lakeshore vehicle campgrounds at other lakes, and might be more inclined to go elsewhere at times when Ross Lake is a significant distance from the campground. Boat campers face a much narrower universe of boat-in campsites from which to choose, and few alternatives to Ross Lake. Therefore, they would be less likely to choose to use another resource as long as there were acceptable campsite alternatives at Ross Lake that were tolerably close to the water.

Table 2-5. Visitor use intensity at Ross Lake boat camps.

Boat Camp	Number of Camp Units	Average Annual Boater Use (Visitor Nights)	Average Annual Use Per Unit (Visitor Nights)
WITH DOCKS:			
Green Point	7	328	46.9
Cougar Island	3	419	139.7
McMillan	3	384	128.0
Spencer	2	433	216.5
Big Beaver	7	742	106.0
May Creek	1	252	252.0
Rainbow Point	3	394	131.3
Devils Junction	1	200	200.0
Lightning Creek	6	755	125.8
Cat Island	6	918	153.0
Little Beaver	6	816	136.0
Silver Creek	4	346	86.5
Subtotal	49	5987	122.2
Percent of Total	79.0	78.3	–
WITHOUT DOCKS:			
Roland Point	1	188	188.0
Tenmile Island	3	434	144.7
Dry Creek	4	392	98.0
Ponderosa	2	295	147.5
Boundary Bay	3	351	117.0
Subtotal	13	1660	127.7
Percent of Total	21.0	21.7	-
TOTAL	62	7647	123.3

Source: Parametrix, Inc., 1989.

To summarize, it appears that any facility-based influence of lake levels on recreational use at Ross Lake is most likely related to the utility of boat ramps. Certain segments of some of the user groups are highly dependent upon boat ramps, and the Ross Lake ramps are known to be inoperable at certain lake elevations. Resort guests also have a high degree of facility dependence, but the effect of lake level fluctuations on the resort remains to be investigated. The importance of operable boat docks to user behavior appears to be minimal, and the significance of lake level effects on both docks and campgrounds is heavily subject to the availability of alternative sites.

2.3.3 Qualitative Assessment of User Group Sensitivity

The preceding discussions provide some generic, conceptual observations concerning the possible extent of the visual quality and facility components of lake level effects on recreational use. To quantitatively estimate the range of potential effects, however, it was necessary to make a more specific identification of users who are most likely to alter their use patterns. This was accomplished through a qualitative assessment of the attractions, use requirements, and preferences that can reasonably be postulated for the respective Ross Lake user groups. The process involved was largely intuitive, as no survey data addressing user motivations and preferences were available. However, a number of the observations made for this effort were dictated by obvious access or equipment needs and by known aspects of the management setting, such as fishing seasons and facility operating seasons. Observations concerning the attraction factors for various user groups are also supported by published information on activities and opportunities in the Ross Lake area.

The result of this assessment is a qualitative rating of the sensitivity of the recreation activity level of each user group to low lake levels. For example, a high sensitivity level for a given user group is an indication that some users from that group are considered highly likely to consciously avoid Ross Lake early in the recreation season. These ratings are based on joint consideration of the physical requirements of the various uses and the presumed visual sensitivity of the users, with no attempt made to specifically measure or weight the contribution of either component.

These user group sensitivity ratings are not used in any of the subsequent analyses to directly determine potential changes in recreational use as a result of early refill. However, the conclusions of the user group assessment are used indirectly to help guide the application of potential seasonal distribution patterns to Ross Lake use. The primary purposes for conducting the user group assessment are to add descriptive detail to the recreation activity data and to provide a basis to judge the reasonableness of any projected use changes associated with early refill.

2.3.3.1 <u>Hozomeen Car Campers</u>

The Hozomeen campground consists of 122 individual units distributed among two larger camping areas and several small clusters of units. One portion of the campground is a large, relatively open area with about 45 units that is built on fill placed along the edge of Ross Lake. This area is popularly known as "Winnebago Flats," because use is dominated by large motor homes and trailers. Vegetation is sparse and the separation distance between camp units is small, presenting the appearance of a commercial recreational vehicle (RV) park or urban trailer park during heavy use periods. The upper Hozomeen boat ramp is immediately adjacent to the camping area, and users of the first tier of sites can dock or beach their boats right in front of their camps.

Another sizable concentration of camp units at Hozomeen is situated on a small knoll about 1 mile south of Winnebago Flats. The lower Hozomeen boat ramp is located within a few hundred yards, but the knoll camping area has little direct access or linkage to the water. The remaining camp units at Hozomeen are scattered along the campground access road at various locations, and do not have direct frontage on the lake.

Hozomeen car campers are probably attracted to the area for a variety of reasons. The presence of quality fishing and boating opportunities on Ross Lake is no doubt a primary factor, and maybe the most important attraction for the majority of users. Hozomeen is also relatively remote, representing a 4- to 6-hour drive for most users, and has a comparatively low development standard. No fee is charged for camping because garbage service is not provided, and the restroom facilities have vault toilets rather than flush toilets and running water as at other NPS vehicle campgrounds. The service level at Hozomeen therefore tends to attract both self-contained campers and campers who wish to avoid the higher development standards that are typical in NPS areas. RV campers in particular also appear to be attracted by the social setting at Winnebago Flats, which is conducive to multi-party groups camping together.

The only physical requirements for use of the Hozomeen campground are that the road be open and plowed and the campsites free of snow. The managed season for Hozomeen is generally from May 15 through October, so management conforms to these requirements. Most Hozomeen campers, at least those using Winnebago Flats, probably have boats and need access to water. Usable boat ramps can therefore be considered a strong preference for Hozomeen campers in general, and a requirement for a large segment of the boating population. Similarly, campers at Winnebago Flats no doubt prefer to be reasonably close to the water.

One of the major determinants of use patterns at Hozomeen is institutional rather than physical, that being the timing of the trout fishing season. The vast majority of the boating activity on Ross Lake also involves participation in fishing. For many users fishing is the primary purpose of the visit, and a boat provides the means to this end. For many years the Ross Lake fishing season has not opened until around June 15, well after the general late-April opener for lakes and reservoirs, to protect the naturally-reproducing rainbow trout stock during the spawning period. Consequently, Hozomeen users who come largely to fish have little or no inclination to visit before mid-June, but generate large crowds on opening day. Due to new regulations adopted in 1989, beginning in 1990 the Ross Lake fishing season will open around July 1.

The study team for the Ross Lake early-season visual quality study considered Hozomeen car campers to have low visual sensitivity compared to to other Ross Lake user groups (Parametrix, Inc., 1989). This rating reflects strong tendencies to use mechanized equipment (RV camping and power boating) and apparent acceptance or tolerance of modified visual quality. While most or all Hozomeen campers would no doubt prefer to have the water high enough to cover the stumps and mudflats at the north end of the lake, past behavior indicates that many potential users will tolerate exposed stumps and mudflats if they can satisfy their primary recreation purposes. Large numbers of people come to Hozomeen every year for the fishing opener in mid-June, when Ross Lake is typically 12 to 15 feet below full pool and impaired visual quality is very evident.

Overall, the activity patterns of Hozomeen car campers are considered to be moderately sensitive to lake level fluctuations, i.e., they are moderately likely to avoid Ross Lake under certain drawdown conditions. This conclusion is based on the subjective balancing of a relatively strong dependence on operable boat ramps and a relatively weak reaction to visual quality. The typical user will still come to Ross Lake if the fishing season is open and water conditions permit boat launching. The value of the experience for these users may be reduced slightly by diminished visual quality, but the visual effect is not sufficient to deter most users from coming to Ross Lake early in the season. Because fishing is such a prominent attraction and activity at Hozomeen, the sensitivity of use patterns to lake levels among this group will be significantly less after the 1990 change in the opening day of the season.

2.3.3.2 Hozomeen Day Users

Little documented evidence on Hozomeen day users is available. Estimates of day user numbers are made on a regular basis, but records of their activities or characteristics are not kept. In view of the limited day-use recreation opportunities present at Hozomeen, the quality fishing and boating opportunities on Ross Lake probably represent the dominant attraction for this user group. There are no developed facilities specifically designed to accommodate picnicking, swimming, or other common day-use activities.

Hiking opportunities are limited to dead-end outings on the upper part of the East Bank trail, which heads southeast (away from the lake) from the knoll camping area toward Hozomeen Lake. Hozomeen is also beyond the typical day-use driving range from population centers.

Collectively, these factors suggest that boat fishing on Ross Lake accounts for the vast majority of day-use activity at Hozomeen. Aside from the limited opportunities for other activities, NPS staff have observed that visitors camped on the Canadian side of the border often use the NPS ramps at Hozomeen to launch their boats; this would be recorded as day-use activity at the U.S. facilities. Therefore, the available evidence indicates that Hozomeen day users are heavily dependent upon usable boat ramps.

Hozomeen day users are probably similar to typical Hozomeen campers in terms of their site-related preferences and visual sensitivity. They are not likely inclined to visit Ross Lake until the fishing season opens, and are likely to tolerate impaired visual quality as long as they can fish. Compared to the car campers, Hozomeen day users are probably more likely to alter their use patterns in response to low lake levels, because they are more dependent upon boat ramps and access to water. Consequently, the overall sensitivity of use level relative to lake elevation for Hozomeen day users was judged to be high.

2.3.3.3 Boat Campers

Ross Lake boat campers enjoy quality opportunities for a camping experience that is rare within the surrounding region. There are few other lakes where boaters can camp at improved facilities that are not accessible by road. Moreover, the setting at Ross Lake is generally more scenic, more remote, and less modified by human presence than at comparable opportunities. In addition to the unusual camping setting, Ross Lake boat campers enjoy and are attracted by the quality fishing and boating opportunities described earlier. Another probable attraction factor for this user group is the campsite reservation system used for backcountry campsites in Ross Lake NRA. A boat-camping trip on Ross Lake requires considerable travel effort and logistical planning, and many potential users would probably be deterred without the relative certainty of a reserved campsite.

The distinctive physical requirements for this user group include camps that are free of snow and reasonably dry, and some means to get a boat onto Ross Lake. The three alternative means are to launch a power or nonpower boat at Hozomeen, rent a canoe or power boat at Ross Lake Resort, and bring in a nonpower boat via Ross dam. The latter two access methods are not affected by low lake elevations, so only one segment of the boat camper population has a strong facility dependence. Boat campers are also likely to attach the greatest significance to the distance from the fluctuating shoreline to the stationary boat camps, as they must transport gear from boat to camp.

Boat campers as a group were assigned an intermediate visual sensitivity rating by the Parametrix (1989) study team. Members of this group using nonpower boats probably have somewhat higher visual sensitivity than the group as a whole. Consequently, boat campers would be somewhat likely to avoid Ross Lake in the early season because they did not like the appearance of the lake and shoreline.

The use intensity data for boat camps that were presented previously in Table 2-5 are also relevant to this discussion, as they provide an important indicator of site preference. As measured by average annual visitor nights per camp unit, the most popular boat camps are May Creek, Spencer, Devils Junction and Roland Point. Three of these camps have only one unit each, while Spencer has two units that are well separated physically and oriented in different directions. These data strongly suggest that the opportunity for solitude is the most important factor in campsite selection among Ross Lake boat campers. If that is indeed the case, it is reasonable to expect that some boat campers would be willing to accept lower visual quality in exchange for more solitude during the early part of the season.

The tendency of boat campers to change their activity patterns appears to be affected by several competing influences. Facility dependence is high for boat campers entering at Hozomeen, but nonexistent for the other elements of this user group. Visual sensitivity to low lake elevations appears to be moderate to high, but could be partially offset by desires for solitude. Therefore, boat campers are considered to have a moderate overall sensitivity of use to lake levels.

2.3.3.4 Backcountry Hikers

In addition to the standard range of backcountry purposes and motivations, backcountry hikers in the Ross Lake area are attracted by a number of factors specific to this setting. One of the most important factors is probably that most of the Ross Lake trails are open for use comparatively early in the hiking season. The trails along the east bank, west from Little Beaver, and north from Ross dam to Big Beaver and beyond are all at relatively low elevations (1600 to 2600 feet, except near Beaver Pass) and are generally accessible in May. In contrast, many high-country areas are often closed by snow until late July or even early August. Hikers who are anxious to be on the trails in May and June have relatively few alternatives available, and Ross Lake is well known as an accessible early-season opportunity.

The configuration of the trail system serving the Ross Lake area is also probably a significant attraction factor, because it provides several opportunities for one-way or loop trips. The Crater Mountain-Devils Dome Loop is a well publicized hiking route east of Ross Lake that includes part of the East Bank trail as one segment of the loop. Some backcountry hikers at Ross Lake are attracted by the provision of improved, lake-oriented camping facilities. Other attractions include specific natural features of interest, such as the old-growth cedar trees in the Big Beaver valley and the high viewpoints of Sourdough Mountain and Desolation Peak. Few hikers are motivated by fishing opportunities, as Ross Lake is best fished by boat and the lower reaches of the tributary streams are closed to fishing.

Ross Lake backcountry hikers have minimal facility requirements, which are that trails and camps are open and usable. As indicated previously, hikers do not use facilities that are directly affected by low lake elevations. Hikers staying at shoreline camps would be indirectly affected by drawdown through increased distance to water, but this effect would be less significant than for boat campers who have to carry gear from the lakeshore to camp.

Conversely, hikers have a high sensitivity to the visual effects of lake drawdown. The Parametrix (1989) study assigned hikers the highest visual sensitivity rating among Ross Lake users, because they have long view durations, the least dependence on mechanized equipment, and the highest tendency to prefer wilderness settings. Even hikers who are first-time visitors to the area are also likely to have prior knowledge of the early-season visual quality, as hiking guidebooks publicize both the early accessibility and the exposed shoreline prior to full pool (Spring and Manning, 1979).

Balancing the various considerations, backcountry hikers probably have a moderate to high likelihood of changing their use patterns in response to early-season lake levels. This is entirely due to their high visual sensitivity. Hikers who are inclined to be active early in the season clearly face a tradeoff between visual quality and limited accessible opportunities. However, a sizable segment of the hiker population is active only during the peak months of the season, and lake levels would have little or no effect on the activity patterns of these users.

2.3.3.5 Horse Riders

The sensitivity assessment for horse riders closely parallels that for backcountry hikers. The attraction factors are virtually identical, although the early opening of trails is less significant for horse riders. This is partly because trails usually are passable to hikers well before they are sufficiently dry for horses, and partly because much of the Ross Lake horse use appears to occur as part of high-country trips east of the lake.

In addition to dry trails, horse users require specialized facilities at camps and trailheads, and trails with grades and tread conditions suitable for horses. None of these facility requirements are related to lake levels. Horse riders have strong preferences for a visually appealing environmental and relatively high visual sensitivity.

The use patterns of Ross Lake horse riders are considered to have a low overall sensitivity to change with lake levels. While their visual sensitivity would indicate the potential to avoid Ross Lake when visual quality is reduced, their need for dry trails already reduces the likelihood that many horse riders would be present during May and early June. Moreover, the geographic pattern of horse use seems to indicate a relatively low orientation to Ross Lake and a greater orientation to nearby mountain areas.

2.3.3.6 Resort Guests

As with boat campers, Ross Lake offers a very unusual setting for people staying at Ross Lake Resort. The lack of direct auto access makes the resort comparatively remote, and the floating character of the resort is highly distinctive. The Ross Lake fishery is the primary attraction for virtually all resort guests. Opportunities for activities other than fishing and boating are limited to hiking via the trail connecting the resort with Ross dam and Big Beaver. Ross Lake Resort has a high rate of repeat business, indicating strong customer loyalty.

The resort must remain afloat to be usable, but the use of multiple anchoring systems at different elevations allows the resort structures to move up and down with the lake level. Resort users do have two other absolute requirements related to facilities, however. One requirement is for open road access to either the landing at Diablo or the Ross dam trailhead, as few guests fly in to the resort. The other requirement is that the fishing season be open, because the operating season for the resort is essentially coincident with the fishing season. Ross Lake Resort is very definitely a fishing resort, and the resort owners evidently see little or no demand for lodging prior to the fishing season.

The visual sensitivity of resort guests was not assessed in the early-season visual quality study, but would presumably be somewhere between that of boaters and SR 20 motorists. The resort has the highest development standard of all recreation facilities on the lake, and is at the south end of the lake where several landscape modifications are evident.

Overall, the quantity of use at Ross Lake Resort is not likely to be very sensitive to low lake levels. This is largely because the resort is not open for business during most of the time when lake drawdown reduces visual quality. Moreover, the opening of the fishing season is the busiest time of year at the resort, even though Ross Lake has generally been noticeably below full pool by the traditional mid-June opener. Any sensitivity in use levels that might currently exist is likely to be diminished in the future, with the opening of fishing season shifted back to around July 1.

2.3.3.7 Day Hikers

Day hikers at Ross Lake, as defined for this study, consist of people using the trail from SR 20 to Ross dam, and possibly beyond. Actual records of this use are not maintained by the NPS; Parametrix (1989) estimated the activity level for this user group at an assumed proportion to overnight hikers going to Big Beaver. There are no specific points of interest beyond Ross dam that are within typical day-hiking distance of the trailhead, so the dam and lake must be the objective of most day hikers using this trail. Many users are likely attracted to the Ross dam trail because it is a short trail (posted as 0.8 km at the trailhead) with the trailhead located immediately adjacent to the highway.

In order for this use to occur, SR 20 and the trailhead must be open and plowed and the trail must be passable. These requirements have no relation to the lake level, and no other facility requirements are evident. Day hikers at Ross Lake probably have relatively high visual sensitivity. However, the influence of this sensitivity with respect to lake level is probably reduced because views of the lake are limited to the lower section of the trip to the dam. Further, the visual experience in this area includes significant modifications created by the dam, haul road, and other facilities, which minimizes the incremental visual effect when the lake is low.

The nature of the day hiking opportunity near Ross dam is critical to determining whether the level of this use is likely to be reduced by early season lake levels. Due to the short length of the trail, lack of major natural attractions, and distance from population centers, it is highly unlikely that the Ross dam trail is the primary destination for day hikers using the trail. Consequently, for most users this activity is a by-product or joint product use with other activities undertaken on the same trip. Typical users of this trail might be people camped at Colonial Creek and exploring the local area, or SR 20 motorists who happen to pull into the trailhead and decide to hike the trail out of curiosity. Use of this nature suggests that Ross Lake day hikers typically have little prior knowledge of lake level or other conditions at the end of the trail, or that they wish to see a major hydroelectric development. In either case, it is unlikely that the lake elevation would have much influence on the decision to hike the trail. Consequently, the sensitivity of use level for this user group is judged to be low.

2.3.3.8 <u>SR 20 Motorists</u>

People who view Ross Lake while passing by on SR 20 are in that location for a variety of travel purposes. Four distinct types of recreational purposes can be identified, including people travelling the Cascade Loop route, vacation travellers, recreationists heading to or from activity destinations east of Ross Lake, and Ross Lake NRA overnight visitors travelling to or from day-use destinations in the area. Much of the traffic on SR 20 is nonrecreational, however, including travel for various commercial, administrative and private purposes. SR 20 motorists can only drive past Ross Lake if the highway is open and plowed, but there are no other unique or distinctive requirements or preferences among this user group.

SR 20 motorists were assigned the lowest visual sensitivity rating in the early-season visual quality study, due to the short duration of their view of the lake and heavy reliance on mechanized equipment (Parametrix, Inc., 1989). The visual quality study also concluded that the contrast of exposed shoreline as seen from SR 20 was significantly diminished by the intervening distance.

Most travellers on SR 20 in this location are in view of Ross Lake for approximately 1 minute under normal travel conditions. The small percentage of all motorists who stop at one of the overlooks probably view the lake for 5 to 10 minutes, on average. Given the brief extent of this activity in relation to the common travel purposes, viewing Ross Lake from SR 20 must be incidental to the trip for virtually all users and not a destination activity. Some campers from Colonial Creek or elsewhere nearby might drive a few miles to one of the overlooks just to view the lake, but sightseers from Seattle would not drive 3 hours for this destination purpose. Considering the incidental nature of this viewing activity and the very short duration, the lake elevation is extremely unlikely to influence any individual's decision whether to travel SR 20. Therefore, the sensitivity of aggregate SR 20 use to change resulting from low lake elevations is considered to be minimal or nonexistent.

2.4 LAKE LEVEL EFFECTS ON RESERVOIR RECREATION FACILITIES

The material in Sections 2.3.2 and 2.3.3 provided a conceptual discussion of the facility component of lake level effects on the level of reservoir recreation use. It attempted to relate the general way in which different types of recreational users would be expected to respond to lake level effects on the utility of recreational facilities. To complete an assessment of potential facility-based effects at Ross Lake, it is necessary to evaluate actual data relating the utility of shoreline recreational facilities to specific lake elevations.

Field surveys of the Ross Lake recreational facilities were conducted at varying intervals during the 1989-1990 drawdown period to develop these site-specific data, as described in Section 2.1. The primary objectives of the field studies was to determine the lake elevations at which the boat ramps and docks become unusable due to insufficient water. Observations of the lake level in relation to campgrounds and the resort were also recorded. Once the minimum usable elevations for all facilties were established, these figures were compared to historical data on the timing of various lake levels to evaluate the current potential for facility-based displacement of recreational use. The results of this process are described below for each type of facility.

2.4.1 Boat Ramps

The four boat ramps near Hozomeen are critical access facilities for certain segments of the user population, specifically day and overnight users with trailered boats. The utility of these ramps during periods of relatively low lake elevations, particularly at the traditional mid-June fishing opener, has been a significant concern to recreationists for some time. Johnston (1989) noted that the lake level of 1589 feet on opening day in 1985 had a significant effect on fishing activity because it was difficult to launch and retrieve boats and most of the Canadian portion of the reservoir was dewatered. The City has in the past issued press releases advising boaters of the operating limits of the ramps and actual lake levels at specific times.

Data on the minimum usable elevations and operating seasons for the four Ross Lake boat ramps are presented in Table 2-6. The variation in minimum usable elevations illustrates the different construction and locational situations of the four ramps. The International Point facility is a new ramp constructed by BC Parks immediately north of the international border, as part of a major day-use development. This location is at the extreme north end of Ross Lake, near the mouth of the Skagit River, in a shallow area that is dewatered with relatively little reservoir drawdown. Consequently, the International Point ramp is comparatively short and extends only to an operating limit of 1592 feet. The approach to the ramp by a shallow channel through stumps effectively limits the operating range to about 1595 feet for many boats.

The upper and lower Hozomeen ramps are located about 0.5 mile and 1.5 miles south of International Point, respectively. These two ramps were originally built to the same configuration, but the lower Hozomeen ramp was modified and extended within the past few years (personal communication, Gary Mason, National Park Service, North Cascades National Park Service Complex, January 16, 1990). The approach to the lower ramps is also through a channel that is relatively deep and free of obstructions. Consequently, the lower Hozomeen ramp can be used down to at least elevation 1583 feet. The upper Hozomeen ramp has a much more difficult approach, and a minimum usable elevation of 1589 feet. Due to the shallowness of this area, the waterline also recedes rapidly as the lake starts to drop. By elevation 1583, navigable water for power boats is up to 0.5 mile from the upper Hozomeen ramp.

The fourth boat ramp is a little-used facility about 1 mile further south of the lower Hozomeen ramp, which is termed East Landing by the NPS (and is also known as the SCL Launch or Government Launch). This facility is not specifically designed and constructed as a boat ramp, but is simply the point where the end of the Hozomeen road becomes submerged by the lake. At full pool, the road in this area travels parallel and immediately adjacent to the shoreline, then dips diagonally across a steep slope into the water. The geometry of the road is such that this launch can be used over a wide range of elevations, although limited space would appear to make maneuvering a boat difficult. The field studies were not able to determine the actual range of operation, but the minimum usable elevation for East Landing appears to be 1565 feet.

The minimum usable elevations were reviewed against actual water conditions during the 1980s to determine approximate minimum, average, and maximum operable seasons for the four ramps (see Table 2-6). On the average, East Landing is operable from the end of May through late October. In contrast, the typical season for the International Point ramp (had it been in place throughout the 1980s) would have been only about three months, from June 25 to September 23. With average recent water conditions, the two Hozomeen ramps are operable from about mid-June through mid-October.

The two Hozomeen ramps are clearly the most important facilities due to the limited operating range at International Point and difficult maneuvering conditions at East Landing. Consequently, the key elevations with respect to launching boats are 1583 and 1589 feet. A lake level of 1583 feet provides reasonable access to one conventional ramp plus East Landing. When the reservoir elevation reaches 1589 feet, typically about 5 to 6 days later in the refill season, two conventional ramps are accessible and total launching capacity exceeds 100 boats per day.

The ramp and reservoir data were further reviewed to assess historical ramp utility at key times of the recreation season. The single most significant date to evaluate is the opening of fishing season, which traditionally has been near June 15 but will be shifted to around July 1 beginning in 1990. Other key dates include Memorial Day, when the first spurt of recreational activity on Ross Lake usually occurs, and the closing of the fishing season on October 31.

Table 2-6. Minimum usable elevations and operable seasons for Ross Lake boat ramps.

Ramp	Minimum Usable Elevation	Minimum Operable Season (1)	Average Operable Season (1)	Maximum Operable Season (1)
International Point	1595(2)	Jul 5-Sep 13	Jun 25-Sep 23	Jun 10-Oct 5 (est)
Upper Hozomeen/ Winnebago Flats	1589(3)	Jun 28-Sep 30	Jun 18-Oct 10	May 25-Oct 20
Lower Hozomeen	1583(4,5)	Jun 23-Oct 10	Jun 12-Oct 18	May 20-Oct 31
East Landing/ SCL Launch	1565(6)	Jun 12-Oct 31	May 31-Oct 25	All year

(1) Based on 1980-1989 lake level records.

(2) Due to shallow approach and stumps; water depth at ramp sufficient to about 1592.

(3) Conservative estimate; could be usable for some boats as low at 1585.

(4) Past City press releases have used figure of 1592 for both Hozomeen ramps.

(5) Slightly conservative estimate, could be usable down to 1581. Current ramp recently constructed, old ramp had more limited range.

(6) Estimated from past City press releases.

Sources: SCL field studies, 1989-1990.
USGS, various years.

Actual reservoir elevations on these four key dates (using May 27 to approximate Memorial Day) from 1980 through 1989 are indicated in Table 2-7. Observations on ramp utility based on these data are summarized as follows:

Memorial Day

- No ramps would be usable in up to 6 of 10 years; boating use in these years would be limited to hand-carried boats
- East Landing would be only ramp usable in 3 of 10 years
- A conventional ramp would rarely be usable (1 of 10 years)

Table 2-7. Ross Lake elevations (feet) on key dates, 1980-1989.

Year	May 27	June 15	July 1	October 31
1980	1571	1593	1602	1590
1981	1591	1602	1603	1595
1982	1539	1572	1595	1595
1983	1547	1584	1596	1586
1984	1547	1574	1597	1591
1985	1556	1589	1601	1592
1986	1565	1600	1602	1592
1987	1578	1594	1599	1583
1988	1564	1584	1597	1583
1989	1560	1594	1601	1585
Average	1562	1589	1599	1589
Maximum	1591	1602	1603	1595
Minimum	1539	1572	1595	1583

Sources: USGS, various dates.
Personal communication, Jonah Tsui, Seattle City Light, Power Supply and Planning, January 15, 1990.

June 15

- Power boat access would be possible in all years, although limited to East Landing in 2 years.
- One conventional ramp would be available in 8 out of 10 years, and two ramps in 6 of 10 years.
- International point would probably have been usable only 2 of 10 years (possibly 4 of 10).

July 1

- All boat ramps would have been usable in all 10 years.

October 31

- Both U.S. conventional ramps would be usable in 6 of 10 years.
- At least 1 conventional ramp would be usable every year.

Several conclusions on ramp utility are possible from these observations. Memorial Day accessibility for power boating is quite limited, although potential use at this time of year is limited to a fairly small minority of users due to typical seasonal use patterns and habits. Launching conditions are generally good by June 15, and the significance of this date will diminish markedly with the new fishing regulations. The recent July 1 lake elevation has consistently been 1595 feet or higher, so there will be full ramp utility by July 1. Finally, typical ramp accessibility through October is adequate for the low level of existing and potential use at this time of year. Overall, continuation of the current Ross lake operating pattern in the future should not present a major use constraint attributable to the operating range of the boat ramps. It should also be noted that the recent modification of the lower Hozomeen ramp appear to have made a significant improvement in launching accessibility during key parts of June.

The City has agreed to further improve boat access at Hozomeen; in the Settlement Agreement on Recreation and Aesthetics, the City has agreed to extend the ramp at Lower Hozomeen to approximately 1575 feet (SCL, 1991a).

2.4.2 Boat Docks

During the 1989 recreation season there were a total of 19 small boat docks located around Ross lake. These included 14 docks at 12 of the boat camps (there were two docks each at Little Beaver and Lightning Creek); two docks at Winnebago Flats, serving the campground and the upper Hozomeen boat ramp; one dock near the Hozomeen ranger station; one dock at the lower Hozomeen ramp; and a small dock at the end of the Ross dam haul road that is used primarily by Ross Lake Resort. Six of these docks were of wood construction, while the remaining 13 were newer metal docks of standard NPS design.

Data on the operating ranges of these docks are provided in Table 2-8. To summarize this information, all of the docks are usable at elevation 1598 feet, and none (except the movable dock at the haul road) are usable below 1582 feet. The minimum usable elevation for most docks is between elevations 1592 and 1596, which corresponds to 6 to 10 feet of drawdown. The docks at Cat Island and Little Beaver have the greatest operating ranges. Based on the recent historical reservoir elevation data, these two docks would typically be usable before June 15. The typical operable season for other docks around the lake does not begin until about June 21, but all docks would be usable by about June 27 under average recent water conditions.

Evaluation of use intensity data for the boat camps resulted in the conclusion that the existence of a usable dock did not seem to be a significant factor in the use patterns of boat campers, as discussed in Section 2.3.2. The actual operating range data presented above indicate that most or all of the docks are typically usable when the vast majority of users are present, which is from late June through early September. Further, at least two docks will likely be operable from mid-June through early October, and should be capable of serving the demand for docking facilities in the lower-use "shoulder" periods on either side of the peak season. Considering these factors, the operating range of the boat docks on Ross Lake does not appear to be a significant or measurable constraint on the level of recreation use.

Table 2-8. Minimum usable elevations and average operable seasons for Ross Lake boat docks.

Dock Location	Minimum Usable Elevation (ft.)	Average Operable Season (1980s)
Ross Dam (Resort)	movable	unlimited(1)
Green Point	1597	Jun 27 - Sep 18
Cougar Island	1593	Jun 22 - Oct 1
McMillan	1596	Jun 26 - Sep 22
Spencer	1593	Jun 22 - Oct 1
Big Beaver	1593	Jun 22 - Oct 1
May Creek	1592	Jun 21 - Oct 3
Rainbow Point	1593	Jun 22 - Oct 1
Devil's Junction	1594	Jun 24 - Sep 28
Lightning Creek	1596	Jun 26 - Sep 22
Cat Island	1586	Jun 14 - Oct 10
Little Beaver (Steel)	1582	Jun 12 - Oct 15
Silver Creek	1598	Jun 30 - Sep 13
Lower Hozomeen (2)	1593	Jun 22 - Oct 1
Upper Hozomeen Ramp (2)	1596	Jun 26 - Sep 22
Upper Hozomeen CG (2)	1597	Jun 27 - Sep 18

(1) While this dock could theoretically operate at any elevation, the end of the haul road on the south side of the lake only extends to about elevation 1560.

(2) These facilites are courtesy docks provided at the indicated locations.

Sources: SCL field studies, 1989-1990.
USGS, various years.

2.4.3 Campgrounds

The 1989-1990 field surveys of Ross Lake recreation facilities included measurement of the physical distance from camping areas to the water's edge at each elevation. Selected results from this effort are included as Table 2-9. These data indicate that the separation distance can increase fairly rapidly as the lake is lowered, particularly at sites such as Silver Creek and Hozomeen at the shallower north end of Ross Lake.

The threshold distance at which users will likely refuse to use a water-oriented site is probably less significant than the distance relationships among alternative sites. The data in Table 2-9 suggest that sites such as Silver Creek will likely be bypassed readily by users at elevations below 1590 to 1595 feet, because there are numerous alternative sites that are closer to the water. With the reservoir at 1592 feet, which typically occurs around June 21 and again in early October, 10 of the boat camps are still within 50 feet of the water, and all but 3 camps are within 100 feet. Intuitively, distances of this magnitude do not seem likely to be significant deterrents to users. Even down to elevation 1583, generally corresponding to the mid-June to mid-October period, more than half of the camps are within 100 feet of the water. Therefore, most early season users still have a wide selection of sites that are reasonably close to the water, and would not seem likely to avoid Ross Lake due to this distance factor.

2.4.4 Resort

The cabins and main buildings at Ross Lake Resort are floating structures, and are not moored to one fixed anchor point on shore. The facilities are tended throughout the year so that the moorings can be reset to follow the lake level. From a purely physical standpoint, the resort could operate over any period and lake level range desired by the owners.

Ross Lake Resort has historically followed an operating period that is generally coincident with the fishing season, opening in mid-June and closing at the end of October or in early November. Lake levels, therefore, do not impede access to the resort or the ability to use resort facilities and equipment during this season. With the utility of the resort at any given time determined by management and not the lake level, there is no facility-based lake level effect on use at Ross Lake Resort.

Table 2-9. Campground-to-water distances at selected Ross Lake elevations.

Location	Elevation 1598	Elevation 1592	Elevation 1583
Green Point *	25	62	128
Cougar Island*	19	49	88
Roland Point	35	71	113
McMillan*	12	40	77
Spencer*	13	43	109
Big Beaver*	28	54	97
May Creek*	11	24	48
Rainbow Point*	8	32	114
Devil's Junction*	23	40	79
Tenmile Island	32	46	58
Dry Creek	29	110 (est)	250 (est)
Ponderosa	25	47	71
Lightning Horse*	40 (est)	100 (est)	132
Lightning Creek*	33	92	199
Cat Island*	8	34	82
Little Beaver*	7	28	47
Boundary Bay	25	51	83
Silver Creek*	34	147	320 (est)
Hozomeen*	17	82	1000-1500 (est)

* Indicates camps with docks, including a floating dock used during the season at the Lightning Horse Camp.

Source: SCL field studies, 1989-1990

2.4.5 Overall Facility Assessment

The recreation facility measurements relative to reservoir elevations are summarized in Table 2-10 for the boat ramps, boat docks, and campgrounds on Ross Lake. This table indicates the number of ramps and docks that are usable, and the number of campgrounds within 100 feet of the water's edge at given elevations, based on the data presented in earlier tables. As indicated in the preceding discussions, half of the boat ramps are still usable through the first 20 feet of drawdown, while more than half of the campgrounds are still within 100 feet of the lakeshore over this same range. Fewer than half of the docks are usable below 10 feet of drawdown, although it was demonstrated earlier that lack of a usable dock does not appear to be a deterrent to use of a given site.

Evaluation of the actual utility of the various Ross Lake recreation facilities at different lake elevations supports and generally parallels the conceptual assessment presented in Sections 2.3.2 and 2.3.3. Based on the determinations of operating ranges and seasons and the distance measures, the nature of specific effects on the level of use can be summarized as follows:

Boat ramps -	possible negative effect on level of use, but not major, under average water conditions. Effect will diminish with later fishing opener, starting in 1990.
Docks -	possible negative influence for individual camps, but not significant for aggregate use.
Campgrounds -	negative effect an aggregate use unlikely and not measurable.
Ross Lake Resort -	no effect.

The facility component of lake level effects on the amount of use at Ross Lake are limited to certain types of facilities, relatively small portions of potential use season, and selected user groups. Specifically, an effect can be postulated for car campers, Hozomeen day users, and boat campers who have trailered boats and wish to use Ross Lake before about mid-June. There are no apparent techniques for predicting the magnitude of these facility-based effects directly, but subsequent analysis should allow for these effects in conjunction with aesthetic-based effects.

2.5 ANALYSIS OF SEASONAL USE DISTRIBUTION

The prior assessments of the potential reactions of the respective Ross Lake user groups to low early-season lake levels have identified the user groups most likely to change their activity levels in response to lake levels, and the expected direction of change. However, none of the information reviewed to date has indiciated the likely magnitude of any such changes or how they could be quantified. The critical step in implementing the recreation

Table 2-10. Summary of usable Ross Lake recreation facilities, by reservoir elevation.

	NUMBER OF FACILITIES BY TYPE		
Reservoir Elevation	Usable Boat Ramps (4 total)	Usable Boat Docks (16 total)	Campgrounds Within 100 Feet of Water (19 total)
1602.5	4	16	19
1600	4	16	19
1598	4	16	19
1597	4	15	19
1595	4	10	18
1593	3	9	17
1592	3	4	16
1590	3	3	14
1588	2	3	13
1585	2	2	11
1583	2	2	10
1580	1	1	8
1575	1	1	5
1570	1	1	3
1565	1	1	1
1560	0	1	0
1555	0	0	0

(1) The 100-foot distance to water is used here simply as a benchmark, and not to connote that campgrounds are unusable beyond that distance.

Source: Compiled or estimated from Tables 2-6, 2-8, and 2-9.

component of the lake level study was to conduct a comparative analysis of the seasonal use distribution pattern for Ross Lake and for similar recreation resources elsewhere in Washington. The results of this analysis are presented below, including a review of the existing seasonal distribution pattern for use at Ross Lake, comparable information for other resources in the North Cascades, and seasonal patterns for a number of state parks in Washington. The objective of this comparism is to determine the "normal" pattern of seasonal distribution that should be expected, and whether Ross Lake use is conforming to the norm.

2.5.1 Existing Ross Lake Seasonal Distribution

The existing seasonal distribution of Ross Lake recreation use, measured in activity days, is indicated on Table 2-11. The figures for each user group and period represent the average use for that period from 1984 through 1988. (Note that the total figure for each user group is the actual annual averge reported in the Parametrix (1989) report, whereas the corresponding figures in Table 2-2 were rounded to the nearest hundred.)

It is evident from the table that the dominant use in all periods is on SR 20, which accounts for a minimum of 94 percent of the total for any period. Most of the on-lake use originates at Hozomeen in the November -April and June-October periods, or all periods but May. Boat campers outnumber all other non-Hozomeen, on-lake users combined during the June-August period, but still amount to about one-third of aggregate Hozomeen-based use. Aside from Hozomeen users, the dominant on-lake group in September and October is resort guests.

The numerical data from Table 2-11 have been converted into percentage terms in Table 2-12. Comparison of the percentage distribution patterns among user groups suggests several observations about some of the factors that influence Ross Lake use on a seasonal basis. Most significantly, the percentage data demonstrate that virtually all user groups follow a consistent pattern of little use through May, increasing to a moderate level in June and a peak through July and August. The summer peak gradually declines to moderate use again in September, light use in October, and minimal use through fall and winter.

Boat campers have the highest concentration of use in the July-August peak season, at 71.5 percent of the annual total, followed by Hozomeen day users and hikers. SR 20 motorists have the lowest July-August concentration, with only 42.3 percent of total annual use occuring in those two months. SR 20 travel has a much more even seasonal distribution than any other user group, indicating less reliance on outdoor activity as a part of the trip and a significant proportion of users who are not travelling primarily for recreation.

Backcountry hikers have a relatively high proportion of use in May, reflecting early-opening nature of the lakeside trails. Horse riders do not use Ross Lake area trails until June, shift elsewhere in July as more trails open up, and then are most active in August when high trails east of Ross Lake open to use. Resort use starts later in the year because Ross Lake Resort does not open until fishing season, but this use is spread much more evenly through October; this is probably because resort guests can stay warm and dry in adverse weather conditions.

Table 2-11. Existing distribution of average annual Ross Lake recreation use, by period and user group (in activity days).

User Group	Nov - April	May	June	July	Aug	Sept	Oct	Total
Hozomeen Car Campers	206	43	3,870	5,392	4,258	2,183	1,066	17,018
Hozomeen Day Users	275	52	1,038	2,811	2,727	361	498	7,763
Boat Campers(1)	0	85	1,422	2,501	2,981	649	28	7,666
Backcountry Hikers(1)	0	148	285	523	649	194	18	1,816
Horse Riders(1)	0	2	36	22	45	20	0	126
Resort Guests	99	0	442	1,328	1,393	1,257	791	5,309
Day Hikers	31	96	460	778	880	314	16	2,575
SR 20 Motorists	55,644	73,347	132,320	206,411	159,478	93,326	55,644	890,297
TOTAL	56,255	73,773	139,873	219,766	172,411	98,304	58,061	932,570
TOTAL, Minus SR 20 Motorists	611	426	7,553	13,355	12,933	4,978	2,417	42,273

(1) Backcountry permit data in Parametrix (1989) report cover only May to October period, capturing estimated 98.8 percent of annual use; figures in above table may omit minor activity in Nov to April period.

Source: Parametrix, Inc. (1989; Tables 2-2 and 3-14 a through f).

Table 2-12. Existing percentage distribution of Ross Lake recreation use, by period and user group.

User Group	Nov - April	May	June	July	Aug	Sept	Oct	Total
Hozomeen Car Campers	1.2	0.3	22.9	31.2	25.2	12.9	6.3	100
Hozomeen Day Users	3.5	0.7	13.4	36.2	35.1	4.7	6.4	100
Boat Campers	0	1.1	18.6	32.6	38.9	8.5	0.4	100
Backcountry Hikers(1)	0	8.1	15.7	28.8	35.7	10.7	1.0	100
Horse Riders(1)	0	1.8	28.9	17.6	35.6	15.9	0.2	100
Resort Guests(1)	1.9	9	8.3	25.0	26.2	23.7	14.9	100
Day Hikers	1.2	3.7	17.9	30.2	34.2	12.2	0.6	100
SR 20 Motorists	6.3	8.2	14.9	19.1	23.2	17.9	10.5	100
TOTAL	6.0	7.9	15.0	23.6	18.5	10.5	6.2	100
TOTAL, Minus SR 20 Motorists	1.5	1.0	17.9	31.6	30.6	11.8	5.7	100

(1) Calculated from Table 2-10.

2.5.2 Comparison to Similar Local Resources

Seasonal use patterns at other resources within the North Cascades National Park Service Complex probably provide the best comparison to the Ross Lake use pattern. Other areas in the North Cascades receive generally the same weather as Ross Lake, are served by the same primary access route (except for the Hozomeen area), and are probably viewed by most recreationists as part of the same complex of attractions. Unless other significant causal factors exist, such as significant differences in average elevation levels, the seasonal pattern of use for a given activity at Ross Lake should closely parallel the distribution for the same use at a different resource in the North Cascades.

The NPS maintains records of use for all developed facilities within the North Cascades complex, and for certain key types of recreational activity, on a monthly basis. These monthly reports for 1984 through 1988 were reviewed to identify appropriate sets of data for comparison with the various Ross Lake user group data. Percentage distribution data were developed for other local NPS resources considered to be comparable to Hozomeen car campers and day users, boat campers, backcountry hikers, and resort guests. These data are presented in Tables 2-13 through 2-16. No comparisons were undertaken for horse riders, day hikers, or SR 20 motorists, based on the conclusions of the user group sensitivity assessment discussed in Section 2.3.3. Both day hikers and horse riders were judged to have a low sensitivity to lake level effects (meaning a low tendency to adjust their use level in response to lake elevations at a given time of year), and horse riders are so few in number that any change in use would be inconsequential to the overall analysis. The use sensitivity level for SR 20 motorists was considered to be minimal or nonexistent.

The comparison of seasonal use distribution for Hozomeen car campers is indicated in Table 2-13. In this case, the seasonal pattern for Hozomeen was compared to the correspondning data for the NPS campgrounds at Colonial Creek and Gorge Lake, and in the Skagit District as a whole (including use at these three campgrounds, plus Goodell Creek and Newhalem Creek). The percentage figures indicate that the Hozomeen share is roughly equivalent to the other areas in the November-April period, and for the June-September season overall. However, Hozomeen has a relatively much lower proportion of use in May than Colonial Creek or Gorge Lake (although the latter two areas still have small percentages for May) and a much higher share in June. The cause of the May-June use differences is not certain, but the most likely explanation is variation in fishing seasons. Diablo Lake is open for fishing all year and Gorge Lake opens in late April, so campers at Colonial and Gorge have this significant activity attraction available to them in May. The delayed fishing opener at Ross Lake, which in the past has produced strong mid-June opening day peaks, probaby causes Hozomeen users to shift into June some use that might otherwise occur in May. It is unknown whether this shifting of use would account for all of the May-June variation.

Table 2-13. Comparison of North Cascades seasonal use distribution for car camping.

Period	Hozomeen (1)	Colonial (2) Creek	Gorge (2) Lake	Total, NPS (2) Skagit District
	PERCENTAGE OF ANNUAL USE BY PERIOD			
Nov - Apr	1.2	1.3	2.8	1.3
May	0.3	3.9	4.3	1.3
June	22.9	13.1	14.7	11.6
July	31.2	27.0	27.4	30.7
August	25.2	36.0	32.3	36.4
September	12.9	16.0	13.9	14.9
October	6.3	2.6	3.2	4.0
TOTAL	100	100	100	100
Jul-Aug	56.4	63.0	59.7	67.1
Jun-Sep	92.2	92.1	88.3	93.6

(1) Calculated from Table 2-10.

(2) Calculated from NPS (1980-1989) monthly use reports.

A similar comparison for Hozomeen day use is provided in Table 2-14. Day-use figures for individual facilities can not be broken out very easily from the NPS reports, so the entire NPS Skagit District was used. Again, Hozomeen and the Skagit District have equivalent shares of annual day use in the November-April and June-September periods, and Hozomeen has a lower percentage for May. However, in this case day use at Hozomeen is much more concentrated in July and August and is proportionally much lower in September compared to Skagit District day use. These differences probably reflect day use activities that differ considerably in character. Hozomeen day use appears to consist primarily of fishing and boating, which are strongly influenced by weather patterns and the timing of the Ross Lake fishing season. The Skagit District day use figures are dominated by a heavy component for SR 20 travel that does not have such prominent mid-summer peaks (see Table 2-12).

Table 2-14. Comparison of North Cascades seasonal use distribution for day use.

Period	PERCENTAGE OF ANNUAL USE BY PERIOD Hozomeen (1)	NPS Skagit District (2)
Nov - Apr	3.5	4.4
May	0.7	4.1
June	13.4	12.1
July	36.2	27.1
August	35.1	31.6
September	4.7	15.4
October	6.4	6.9
TOTAL	100	100
Jul-Aug	71.3	58.7
Jun-Sep	89.4	86.2

(1) Calculated from Table 2-10.
(2) Calculated from NPS (1980-1989) monthly use reports.

The seasonal patterns for both boat camping and backcountry hiking are covered in Table 2-15. There is no particularly good comparision group available for Ross Lake boat campers, because data for the boat camps on Diablo Lake and on Lake Chelan in the NPS Stehekin District were not processed in the predecessor analysis of backcountry permit data (for the early-season studies). Consequently, the best available use components for comparison to the Ross Lake boat campers are probably the car camping data for the Skagit District and Colonial Creek. However, data for other backcountry use categories are also included here, because boat camp use is considered backcountry use. The share of boat camp use in May is much less than for Colonial Creek, although it is similar to that for all Skagit District vehicle campgrounds, while the June boat camp figure is considerably higher than the other two categories. As with Hozomeen car campers, this could be indicative of Ross Lake boat campers shifting use from May into June.
The distribution pattern for Ross Lake hikers can reasonably be compared to those for other backcountry areas in the Skagit District and in the Stehekin District, if elevation differences are taken into account. The figures for Ross Lake hikers show much larger shares of total use in May and June than for the other Skagit or Stehekin backcountry

Table 2-15. Comparison of North Cascades seasonal use distribution for backcountry boat camping and hiking.

	PERCENTAGE OF ANNUAL USE BY PERIOD					
Period	Ross[1] Boat Campers	NPS Skagit Campers [2]	Colonial Creek CG [2]	Ross Hikers [1]	Other Skagit Backcountry [2,3].	Stehekin [2] Backcountry
Nov - Apr	0	1.3		1.3	0	2.8
May	1.1	1.3		3.9	8.1	2.0
June	18.6	11.6		13.1	15.7	3.1
July	32.6	30.7		27.0	28.8	15.6
August	38.9	36.4		36.0	35.7	38.5
September	8.5	14.9		16.0	10.7	34.8
October	0.4	4.0		2.6	1.0	3.1
TOTAL	100	100		100	100	100
Jul-Aug	71.5	67.1		63.0	64.5	54.1
Jun-Sept	98.6	93.6		92.1	90.0	92.0

(1) Calculated from Table 2-10.

(2) Calculated from NPS (1980-1989) monthly use reports.

(3) Represents Skagit District total exclusive of Ross Lake boat campers and hikers.

categories. This indicates the early-season accessibility of several main trails near Ross Lake, while other Skagit backcountry areas and the Stehekin District have proportionally more high-elevation use areas. Conversely, the September share for Ross Lake hiking use is much lower than for the other two components.

The final seasonal use comparison in this set involves the Ross Lake Resort, and is summarized in Table 2-16. The percentage distribution pattern in this case was compared to figures for Diablo Lake Resort over two different periods, and for all concessioner lodging in the North Cascades complex (Ross and Diablo Lake Resorts plus the North Cascades Lodge in Stehekin). The distribution patterns for Ross Lake Resort and Diablo Lake Resort from 1984 through 1988 are generally similar, although use at Diablo is more concentrated in June, July and August and is noticeably lower in October. The Ross percentages are even closer to those for aggregate concessioner lodging.

The 1980-1983 data for Diablo Lake Resort are included to illustrate historical experience with springtime resort use. This resort was open for all or most of the year through 1983, then was operated on a shorter season beginning in June from 1984 through 1988. The current reports for Ross and Diablo resorts show no use in May or earlier in the spring, indicating that the operators of both resorts felt there was insufficient demand for business in the spring to open before June.

2.5.3 Comparison to Selected State Parks

To provide a broad base of comparison, seasonal use distribution patterns were also reviewed for a number of Washington state parks. The monthly distribution of total visitation, day use, and overnight use at 22 state parks was calculated from WSPRC monthly attendance reports for 1984 through 1988. The 22 selected parks are all located on lakes, and include parks from both the eastern and western parts of the state and lakes with and without seasonal drawdowns. Comparisons of seasonal use distribution were made for several groups of state parks, generally using the overnight visitor distribution for the state parks and total Ross on-lake use (75 percent of which is overnight use) as the variables for comparison.

To provide a more concise focus, the results of this analysis are only highlighted here in the text. The results of five separate comparisions are summarized in Table 2-17, while detailed tables for these comparisons are included in Appendix A.

The comparisons of use patterns involving Ross Lake and the various groups of state parks demonstrated that user behavior in May and June is critical to the outcome of the lake level analysis. Therefore, the scope of Table 2-17 is limited to the use percentage figures for these two months. These figures indicated that the May share of annual use at Ross Lake is much lower than the average for any of the state park groups, at 1 percent compared to a simple average of up to 13 percent.

Conversely, the share of annual use occurring in June was higher for Ross Lake than the average for any of the state park categories, particularly for parks located in western Washington or the Cascade mountains.

Table 2-16. Comparison of North Cascades seasonal use distribution for resort lodging.

	PERCENTAGE OF ANNUAL USE BY PERIOD			
Period	Ross Lake [1] Resort	Diablo Lake [2] Resort, 1980-83	Diablo Lake [2] Resort, 1984-1988	NCNP Complex [2] Concessioner Lodging
Nov - Apr	1.9	8.1	2.6	5.2
May	0	5.0	0	2.7
June	8.3	8.4	11.4	10.7
July	25.0	22.6	19.6	23.3
August	26.2	34.0	37.0	29.1
September	23.7	15.9	24.3	20.4
October	14.9	6.1	8.8	9.3
TOTAL	100	100	100	100
Jul-Aug	51.2	56.6	56.6	52.4
Jun-Sep	83.2	80.9	92.3	83.5

(1) Calculated from Table 2-10.

(2) Calculated from NPS (1980-1989) monthly use reports.

Table 2-17. Summary of comparisons of seasonal use distribution for Ross Lake and five categories of Washington state parks.

Comparison Subject	PERCENTAGE OF ANNUAL USE BY PERIOD May Range	 May Average (3)	 June Range	 June Average (3)
A. Ross Lake (1)	1	1	18	18
B. State Park Category (2)				
1. Western Washington Lake, Winter Drawdown	9	9	14	14
2. Western Washington Lakes, No Winter Drawdown	6 to 8	7	11 to 16	4
3. Cascade Mountains, Eastern Slope Lakes	6 to 9	7	12 to 18	15
4. Eastern Washington Parks on Popular April Fishing Lakes	9 to 17	12	14 to 20	17
5. Columbia/Okanogan Basin State Parks	8 to 28	13	12 to 22	16

(1) Represents percentage figures for toal on-lake use (excludes SR 20 motorists).

(2) Represents percentage figures for overnight use, calculated from WSPRC (1984-1988) monthly attendance reports.

(3) Averages are not weighted for attendance variation.

The highest proportions of use in May are associated with eastern Washington state parks that receive heavy fishing activity in April or are regarded as having reliable warm, dry, sunny weather, particularly in the spring. Without these types of special early-season attractions, state parks with similar resources to Ross Lake tend to receive about 7 to 9 percent of their total annual use in May. The parks noted for good spring weather or April fishing also have higher shares of use in June than the other three categories of state parks, but their peak-season figures for July and August are considerably lower.

2.5.4 Conclusions from Comparative Analysis

The results of both sets of area comparisons support a number of observations and inferences concerning how and why the seasonal distribution of use at Ross Lake does not fit the normally expected pattern. The Ross Lake share of total use that occurs in May is much lower than the corresponding figure for any other resource evaluated, while the June share is comparable to or higher than that for other resources. For the types of activities occurring at Ross Lake, it appears that a significant proportion of annual use (10 percent or more) will occur in May only if there is a special attraction, such as good fishing or reliable warm, dry, sunny weather. The "normal" May use share for resources without these types of special spring attractions appears to be at most 6 to 9 percent of annual total, or 20 to 33 percent of July use. However, based on data for user groups elsewhere in the NPS Skagit District, use in Ross Lake NRA in general is below this "normal" level, presumably due to user expectations of comparatively cool, cloudy, wet weather in May. Further, Ross Lake does not have one significant May attraction that is common to all other comparable resources, which is the ability to fish (legally) in May.

Therefore, the May use proportions and ratios for comparable activities elsewhere in Ross Lake NRA represent realistic ceilings for use at Ross Lake if action were taken to increase the attractiveness of early-season use, specifically earlier refill of the reservoir. The May use share at Ross Lake would still probably not reach this ceiling without a concurrent open fishing season, but it is important to know the upper bounds of a potential change.

The monthly use shares for Ross Lake user groups also suggest that some users are already shifting use that would otherwise occur in May into June or later in the summer. Many would not even consider going to Ross until at least mid-June, common to normal behavior among recreationsts elsewhere. Such time-shifting of use at Ross Lake could be due to weather, the opening of the fishing season, early season lake levels, or some combination of these factors. Regardless of the cause, the key implication is that some amount of the use affected by low lake levels may only be displaced in time, rather than in location. Consequently, any shortfall in early-season use below the "normal" level would not necessarily represent a net increase in use if early refill were implemented.

2.6 POTENTIAL CHANGES IN RESERVOIR RECREATION USE WITH EARLY REFILL

The conclusions from Sections 2.3 through 2.5 can be combined and applied to the existing Ross Lake recreation use patterns to estimate how much the use level might change in response to early refill of Ross Lake. The information presented in Sections 2.3 and 2.4 indicated that the early-season activity levels for some Ross Lake user groups probably are reduced below their normal or natural level due to low lake elevations, and likely would increase somewhat with early refill. The comparative analysis of seasonal use distribution patterns illustrated what the normal seasonal pattern of use might be, based on early-season similarities and differences among various recreation resources. The increase in recreation use expected to result from early refill can, therefore, be approximated by assuming early-season Ross Lake use would rise to reflect a different early-season proportion.

This procedure was implemented in two different ways to illustrate the range of potential changes in use associated with early refill. Initially, a maximum hypothetical increase in use was calculated using a very liberal assumption as to the effect on the seasonal distribution pattern. A revised calculation was subsequently undertaken using assumptions on early season use proportions thought to be much more realistic. The resulting estimates of aggregate use were interpreted to represent the maximum potential use level with the most aggressive early refill alternative. Use levels resulting from other refill alternatives were scaled from this benchmark alternative on the basis of relative lake elevations on key dates.

2.6.1 Maximum Hypothetical Use Increase

Ross Lake essentially fills, at least to a point where all boat ramps are usable and drawdown is less than 10 feet, by July 1 under current conditions. If an adverse effect on the level of early-season use exists, it would primarily affect the use quantity in June. The use level for May would be affected to a lesser extent in absolute terms given the large relative differences in existing use between May and June.

Refilling Ross Lake to a mid-1590s level by May 31 would be equivalent to stretching the use season by one month. Therefore, the maximum possible increase in use from early refill would be approximated by assuming that monthly use totals for affected user groups would shift ahead one month, i.e., future May use would be equivalent to current June use, and future June use equivalent to current July use. It is highly questionable whether such a shift would occur, because people would still not be able to fish at Ross Lake until July 1, but it represents the outer bounds of potential change.

This simulated shift in use for May and June was implemented for six user groups considered likely to produce higher use with early refill. (Despite the earlier conclusion that day hikers would probably not respond in this way, a simulated use increase for day hikers was included to assure that no potential use effects would be excluded. Each calculation is included in Appendix A, and the results are summarized in Table 2-18.

Simulating an added month of activity at high levels of use in this way would increase the total annual use for the six affected user groups by from 21 to 37 percent. The overall effect would be to increase total on-lake use by 13,180 activity days per year, or 31 percent above the existing average annual use level. Because no increase in use was simulated for SR 20 motorists, the potential increase of 13,180 activity days represents only about 1 percent of current total Ross Lake use.

Table 2-18. Maximum hypothetical use level with early refill [1].

User Group	Current Average Annual Use Level (Activity Days)	Maximum Future Annual Use with Early Refill (ADs)	Maximum Annual Use Increase (Activity Days)	Percent Change
Hozomeen Car Campers	17,018	22,367	5,349	31.4
Hozomeen Day Users	7,763	10,521	2,758	35.5
Boat Campers	7,666	10,082	2,416	31.5
Backcountry Hikers	1,816	2,192	376	20.7
Horse Riders	126	126	0	0
Resort Guests	5,309	6,638	1,329	25.0
Day Hikers	2,575	3,527	952	37.0
SR 20 Motorists	890,297	890,297	0	0
TOTAL	932,570	945,750	13,180	1.4
TOTAL, Minus SR 20 Motorists	42,273	55,453	13,180	31.2

(1) Simulated by assuming future May use would be equivalent to current June use, and future June use would be equivalent to current July use, for user groups considered likely to respond to early refill with increased use levels. Early refill defined as reservoir essentially full by May 31.

2.6.2 Realistic Hypothetical Use Increase

The prior simulation is not a very plausible outcome of early refill because it ignores the weather- and habit-related factors that largely cause seasonal patterns of recreational use. Recreation patterns are heavily influenced by weather, and use records and survey data both indicate that large segments of the recreating public do not engage in active outdoor recreation activities until sufficiently warm and dry weather conditions can be expected. Similarly, annual school and work schedules have created deep-seated tendencies among many recreationists to confine all or most of their outdoor activities to the summer season. In western Washington, these factors act as a natural constraint on the level of recreation use in May and June that affects virtually all active outdoor pursuits and recreation resources.

Consequently, a more realistic simulation would be to assume that Ross Lake use would take on the early-season use distribution pattern of comparable resources if early-season lake levels were considerably higher. This process can be implemented directly from the seasonal use comparisons presented in Section 2.5. In cases where Ross Lake use appears lower than normal in May and June, based on the pattern for comparable resources, it can be assumed that the Ross Lake May and June proportions might rise to "normal" levels with early refill. However, the definition of normal levels must take into account significant differences that would continue with early refill, such as differences in fishing seasons.

For computational ease, this was implemented by applying the ratios of May/July use and June/July use for comparable resources to escalate Ross Lake use for May and June. For example, if the May/July use ratios were 0.05 for a Ross Lake user group and 0.1 for a comparable use, May use for the Ross Lake group might be escalated to equal 10 percent of existing July use for that group. This process was also applied to Hozomeen car camping and day use, boat camping, backcountry hiking, and day hikers, without explicitly following the conclusion of the qualitative assessment of use sensitivity to lake level with respect to day hikers. However, in this case no increase in early-season use was simulated for Ross Lake Resort because it was not considered to be realistic that the resort would open earlier in the year and successfully attract customers at that time.

Comparable local resources were used as guidelines for these calculations, as use of other resources in the North Cascades provides the best indication of what normal seasonal use distribution patterns for Ross Lake might be (absent low early-season lake levels). Analysis of state park use distribution patterns indicated that Ross Lake does not have the early-season attraction factors that would lead to the comparatively high proportions of early season use experienced at a number of state parks.

The results of this exercise are summarized in Table 2-19, while estimation details are again provided in Appendix A. If the normal seasonal use distribution patterns for comparable resources are taken as a guide, the most that Ross Lake use would increase in response to early refill would be about 1,000 activity days per year, or 2.4 percent of the existing annual total for all on-lake use. The simulated percentage increases for individual user groups range from 0.8 percent for day hikers to 12.2 percent for backcountry hikers.

For reasons stated at the beginning of this section, the estimate of 1,000 additional activity days per year is considered the best possible estimate of the effect of early refill on the level of Ross Lake recreational use. This estimate is subject to both potential overstatement and understatement of the actual change if early refill were implemented. The 1,000 activity-day figure reflects a static change from existing conditions and would understate future increased use effects if overall Ross Lake use increased over time. Sources of overstatement include the fact that this estimate does not account for shifting the opening of the Ross Lake fishing season to about July 1, which will modify the existing seasonal distribution pattern and would dampen the increased use effect of early refill. An increase of 1,000 activity days would also only occur in years when Ross Lake was essentially full by May 31. As reported in Section 4.5.1, May 31 refill targets could only be met about 60 percent of the time.

Table 2-19. Realistic hypothetical use level with early refill [1].

User Group	Existing Average Annual Use	Realistic Hypothetical Annual Increase	Projected Realistic Use Level	Percent Change
Hozomeen Car Campers	17,018	334	17,352	2.0
Hozomeen Day Users	7,763	260	8,023	3.4
Boat Campers	7,666	165	7,831	2.2
Backcountry Hikers	1,816	221	2,037	12.2
Horse Riders	126	0	126	0
Resort Guests	5,309	0	5,309	0
Day Hikers	2,575	21	2,596	0.8
SR 20 Motorists	890,297	0	890,297	0
TOTAL	932,570	1,001	933,571	0.1
TOTAL, Minus SR 20 Motorists	42,273	1,001	43,274	2.4

(1) Simulated by assuming future May and June use at Ross Lake would more closely approach May and June use proportions for comparable resources, for user groups considered likely to respond to early refill with increased use levels. Early refill defined as reservoir essentially full by May 31.

Perhaps the most significant source of overstatement of potential use effects concerns the nature of current shifts in use induced by early-season lake levels. The preceding analysis effectively assumes that any early-season use displaced by low lake elevations either does not occur or is shifted to another resource, thereby representing a net loss to aggregate annual Ross Lake use. In reality, Ross Lake users can and probably do shift their use in time only, and not location, in response to lake levels. Knowing that the lake will be low in May and early June, many users no doubt consciously schedule their trips to Ross Lake for later in the season when both water and weather conditions will be more favorable. This type of behavior would help to explain the abnormally low proportion of Ross Lake use in May and the high concentration in July and August.

2.6.3 Potential Effects of Specific Alternatives

Both of the potential use estimates described above were based on early refill of Ross lake in a conceptual sense, specifically refilling the lake to an elevation at least in the mid 1590s by May 31. A lake level in this range would make all three U.S. boat ramps fully operable, and would noticeably soften the visual effects of drawdown in most areas. This represents a practical specification of the lake condition judged to be necessary to gain the full recreation use effect estimated, but does not correspond directly to any early refill alternative specified for computer analysis of fisheries and power generation effects.

As described in Sections 3.3.3 and 4.1.2, twelve specific refill scenarios were subjected to detailed numerical analysis using existing City simulation models. These include eight scenarios based on the minimum streamflow requirements of the Skagit Interim Flow Agreement, the current set of negotiated project flow constraints. These eight scenarios consist of the current refill target of elevation 1602.5 feet on July 31, which is termed the base case, and seven early refill alternatives to the base case (Alternatives 1 through 7) that involve varying combinations of refill target dates and elevations. The remaining four scenarios (Alternatives 8 through 11) reflect reservoir operations based on the minimum flow requirements of the original FERC license, which were used for sensitivity testing. The latter four scenarios also include a modified base case and a smaller set of early refill target dates and elevations.

Among the various refill scenarios, Alternative 6 corresponds reasonably well with the conceptual early refill definition used to estimate early refill effects on recreation use. Alternative 6 has a refill target of elevation 1601.5 on May 31. However, the simulation analysis results indicate that this target would only be met in 29 years out of 50, and that the actual lake level on May 31 would average about 1591 feet over 50 years (see Sections 4.4 and 4.5 for explanation).

Alternative 6, therefore, most closely approximates the refill situation that would produce the estimated increase of 1,000 annual activity days, the maximum increase that could realistically be expected to occur with early refill. In order to quantify the potential use effects of the other refill scenarios, their associated use levels must be scaled between the existing condition and the maximum potential increase on the basis of some objective relationship. For convenience and consistency, the average simulated May 31 lake level was used to develop these ratios of the degree of change, which were then multiplied against the maximum increase of 1,000 activity days. This measure is admittedly crude, but the small magnitude and variation of the increased use effects do not warrant a more sophisticated analysis.

Simulated lake elevations averaged over 50 years for all 12 scenarios are graphed in Figures 4-5 and 4-6. Average lake elevations on May 31 interpreted from these graphs are listed in Table 2-20, along with the corresponding ratios used to scale the recreation use effects of the alternatives and the resulting use levels. The scaled potential changes in the annual recreation use level range from 0.1 percent for Alternative 8 (the base case with lower minimum flows) to 2.4 percent for Alternatives 6 and 11. (An additional simulation run based on the minimum flow requirments of the 1991 settlement agreement was performed subsequent to preparation of the draft lake levels analysis report. This scenario employed the refill target of elevation 1602.5 feet by July 31 and resulted in minimal differences in reservoir elevations compared to the base case, as described in Section 4.4.5. Consequently, it was not considered necessary to incorporate this additional scenario into this exercise of scaling recreation use changes relative to Alternative 6.)

2.6.4 Valuation of Potential Use Effects

For comparability with the power generation analysis, which identified the power costs associated with the early refill alternatives, the hypothetical recreation use increases were also converted into dollar terms. This was done by multiplying the estimated maximum and realistic hypothetical annual use increases by user-day dollar values appropriate to each user group. The user-day values were generally derived from a comprehensive review of existing research on the subject of empirical estimates of amenity values (Sorg and Loomis, 1984), as described in more detail in Appendix A. The user-day values developed for this application ranged from $6.75 for day hikers to $40.00 for resort guests.

The user-day values and the aggregate annual values calculated for the two hypothetical use increase scenarios are indicated in Table 2-21. Summing the aggregate value products for the maximum hypothetical use increase yields a figure of nearly $243,500 per year. This represents the maximum conceivable annual benefit of refilling Ross Lake by May 31 of every year. The more realistic estimate of potential annual recreation benefits is about $18,200. Given the results presented in Table 2-19, the values of the annual recreation benefits for the remaining refill alternatives would range between approximately $900 and the $18,200 figure.

Over a 30-year license term, the total future value of recreation benefits with the maximum hypothetical use increase would amount to about $7.3 million. Discounting this stream of future values to the present, to reflect humans' time preference for money, produces a present net worth of nearly $4.8 million at a 3 percent discount rate or just over $3.0 million at a discount rate of 7 percent. The total future value of the realistic hypothetical use increase is approximately $546,000, and the corresponding present values are $357,000 at 3 percent and $226,000 at 7 percent.

Table 2-20. Potential annual use levels for twelve refill scenarios.

Refill Scenario	Average May 31[1] Lake Level (ft.)	Lake Level [2] Ratio	Proportional [3] Recreation Use Increase (ADs)	Potential Future Annual Use (ADs)	Percent Change In Use
A. INTERIM AGREEMENT SCENARIOS					
Base Case					
1602.5 July 31	1,550	0.00	0	42,300	0
Early Refill Alternatives					
Alt. 1, 1601.5 June 30	1559	0.21	210	42,510	0.5
Alt. 2, 1592.0 June 30	1554	0.10	100	42,400	0.2
Alt. 3, 1601.5 June 15	1576	0.62	620	42,920	1.5
Alt. 4, 1592.0 June 15	1569	0.45	450	42,750	1.1
Alt. 5, 1580.0 June 15	1561	0.26	260	42,560	0.6
Alt. 6, 1601.5 May 31	1591	1.00	1000	43,300	2.4
Alt. 7, 1592.0 May 31	1585	0.83	830	43,130	2.0
B. ORIGINAL LICENSE MINIMUM FLOW SCENARIOS					
Alt. 8, 1602.5 July 31 (equivalent to base case)	1552	0.05	50	42,350	0.1
Alt. 9, 1601.5 June 30	1560	0.24	240	42,540	0.6
Alt. 10, 1592.0 June 30	1555	0.12	120	42,420	0.3
Alt. 11, 1601.5 May 31	1592	1.00	1000	43,300	2.4

(1) Based on 50-year simulation results.

(2) Reflects ratio of change from May 31 base case lake level.

(3) Product of lake level ratio and realistic hypothetical use increase with early refill, from Table 2-17.

Table 2-21. Economic value of maximum and realistic hypothetical use increases with early refill.

User Group	Typical User-Day Value ($) (1)	Maximum Annual Use Increase (2) (Activity Days)	Aggregate Annual Value ($) (1)	Realistic Annual Use Increase (ADs)	Aggregate Annual Value ($) (3)
Hozomeen Car Campers	$16.50	5,349	$88,259	334	$5,511
Hozomeen Day Users	12.00	2,758	33,096	260	3,120
Boat Campers	21.75	2,416	52,548	165	3,589
Backcountry Hikers	26.50	376	9,964	221	5857
Horse Riders	26.50	0	0	0	0
Resort Guests	40.00	1,329	53,160	0	0
Day Hikers	6.75	952	6,426	21	142
SR 20 Motorists	8.50(5)	0	0	0	0
TOTAL	---	13,180	$243,453	1,001	$18,219
TOTAL, Minus SR 20 Motorists	---	13,180	$243,453	1,001	$18,219

(1) Using approximate values selected from Sorg and Loomis (1984), except for SR 20 motorists, escalated to the present.
(2) From Table 2-16.
(3) Product of activity days and user-day values.
(4) From Table 2-17.
(5) User-day value based on Forest Service RPA program (FS, 1986); 8.50/x notation indicates that view of Ross comprises unknown fraction of total sightseeing day for these users.

2.7 DOWNSTREAM RECREATION

As indicated at the beginning of this chapter, the City agreed to an intervenor request to add an assessment of downstream recreation to the final report on the lake level analysis. Downstream recreation was not included in the original scope of the analysis because it was considered to be an insignificant issue in terms of the effects of early refill. Nevertheless, for completeness the City has prepared the following summary of downstream recreation relative to the operation of Ross dam and the overall Skagit Project. Existing recreation activities and use patterns in the downstream portion of the evaluation area are described in Section 2.7.1. An overview of the flow-related influence of the existing Skagit Project operations on these activities is provided in Section 2.7.2. Potential effects on downstream recreation as a result of early refill, based on expected changes in the monthly distribution of Skagit River flows, are discussed in Section 2.7.3.

2.7.1 Existing Activities and Use Patterns

The Skagit River provides a wide variety of water-based and water-oriented recreation opportunities. Water-based activities include primarily nonmotorized boating and fishing from the bank or boats. Prominent water-oriented activities include camping or picnicking at developed facilities along the shoreline, viewing wildlife and related interpretive displays, and viewing scenery in selected locations where SR 20 provides views of the river. These activities are generally concentrated in certain locations along the river, rather than occurring continuously. They also are influenced to varying degrees by the volume of flow in the river. The water-oriented activities in particular have a weak connection with the river flow level, one that is primarily based on aesthetics. The Skagit is a large river that carries a considerable volume of water even during the low-flow times of the year. Therefore, the flow-related aesthetic characteristics of the river should not be affected by fluctuations in flow, to the extent that water-oriented recreational activities along the shoreline would be adversely affected.

Similarly, the desirability or accessibility of fishing from the river bank should not be significantly affected by river flow fluctuations associated with Skagit Project operations. Aside from flood flows, which the project helps to control, the ability to fish the river from the bank depends primarily on the provision of legal access to the shoreline and the presence of fish in the river. If access and fish are present, anglers will be able to use the river regardless of Skagit Project effects on downstream flows.

Due to the limited influence of project operations on the above activities, the focus of the downstream recreation assessment will be on three key water-based activities: whitewater boating, scenic floating and boat fishing. These three activities are the most prominent of the downstream water-based uses and, because they employ watercraft, they are the most susceptible to flow fluctuations related to project operations. Existing conditions for each of these activities are summarized below.

2.7.1.1 Whitewater Boating

Whitewater boating occurs on the upper section of the Skagit River above Marblemount. The upper Skagit whitewater run is generally considered to be from the Goodell Creek campground near Newhalem to a semi-developed takeout point at Copper Creek, although some users also float the river downstream from Copper Creek. The upper Skagit run is 10 miles long, has an average gradient of 2.3 percent, and is rated as Class III on the six-point international scale of river difficulty (Furrer,1979). The river is comparatively unchallenging except in the "S Bend" section, where it flows through a series of narrow rock chutes. Boating use is managed by the NPS, which requires users to obtain permits and limits on-river stops to a designated site at Damnation Creek.

The upper Skagit run is floated in rafts, canoes and kayaks. NPS records indicate that several commercial outfitters operate raft trips on the upper Skagit, but private boaters account for most of the total river use. Total use over the 1980-1988 period averaged 1,666 people per year, of which about 59 percent were private boaters and 41 percent were on commercial trips (see Table 2-22). The highest annual use total during this period was in 1980, when use was reported at just under 3,300 people. Both commercial and private user numbers have fluctuated considerably from year to year, with the lowest use levels reported during the mid-1980s.

The monthly distribution of the whitewater boating use is indicated in Table 2-23. Some river use occurs in every month of the year, but use is concentrated in the summer months, particularly the late summer. Over the entire 1980-1988 period, 52 percent of all use has occurred in the months of August and September combined. July and October also receive considerable shares of total use, at about 15 and 12 percent, respectively. Relatively little use occurs during the spring, while the months of November through March account for only 6 percent of total annual use.

2.7.1.2 Scenic Floating

Scenic floating on the Skagit River consists of nonmotorized boating on the river below Copper Creek. Watercraft used for this activity include rafts, canoes and kayaks. Over 58 miles of the river are available for this type of use, and river difficulty in this section is generally considered Class I (Interagency Whitewater Committee, 1985). Numerous access sites are available for boaters, including facilities at Marblemount, Rockport, Concrete, and several locations farther downstream (Envirospere Company, 1989). Most of the access facilities are maintained by state or local government agencies, while management of most of the river corridor (from Bacon Creek to near Hamilton) itself is by the U.S. Forest Service, as part of the Skagit Wild and Scenic River.

The nonwhitewater portion of the Skagit River is used to some degree at all times of the year, but the most popular form of scenic floating activity consists of raft trips to view bald eagles that feed and roost along the river during the winter. Virtually all of this use occurs between Marblemount and Rockport. Several commercial outfitters offer eagle-viewing float trips and account for a large proportion of the total use for this activity. Organizations such as the Nature Conservancy, which manages a bald eagle preserve near Rockport, and local environmental groups also arrange raft trips that can attract large numbers of users. Private boaters in rafts, canoes and kayaks also frequent the river during the prime eagle-viewing months of December through February.

User counts for scenic floating are not available, as there currently is no permit system or ongoing monitoring program that would yield these data. However, based on limited field observations from Nature Conservancy staff and a field research program sponsored by the

Table 2-22. Upper Skagit River whitewater boating use, 1980–1988.

Year	-----COMMERCIAL-----		---------PRIVATE--------		-----------TOTAL---------	
	People	Boats	People	Boats	People	Boats
1980	2350	333	943	314	3293	647
1981	1512	225	1188	396	2700	621
1982	1314	175	1538	356	2852	531
1983	678	149	900	197	1598	346
1984	411	71	774	187	1185	258
1985	519	85	964	196	1483	281
1986	930	162	1118	271	2048	433
1987	1075	176	1209	361	2284	537
1988	449	79	882	273	1331	352
TOTAL	9258	1455	9516	2551	18,774	4006
Average	1029	162	1057	283	2086	445
Percent of Total	49.3	36.4	50.7	63.6	100	100

Source: NPS, 1980–1989.

Table 2-23 Monthly distribution of upper Skagit River whitewater boating use, 1980–1988.

	VISITS BY MONTH												
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
1980	0	15	25	145	135	159	672	989	843	178	116	16	3293
1981	62	40	49	95	84	72	318	597	952	360	64	7	2700
1982	15	55	52	17	224	67	510	986	620	274	24	8	2852
1983	8	31	19	80	57	126	197	545	321	199	13	2	1598
1984	19	14	14	72	41	40	273	209	411	69	19	4	1185
1985	10	38	7	30	25	125	138	668	206	122	62	52	1483
1986	19	59	19	92	59	394	223	553	252	361	8	9	2048
1987	34	56	50	30	105	320	231	237	540	533	132	14	2284
1988	13	19	27	46	64	81	172	398	427	63	4	17	1331
TOTAL	180	327	262	607	794	1384	2734	5184	4572	2159	442	129	18,774
Annual Avg.	20	36	29	67	88	154	304	576	508	240	49	14	2086
Percent of Annual Total	1.0	1.7	1.4	3.2	4.2	7.4	14.6	27.6	24.4	11.5	2.3	0.7	—

Source: NPS, 1980–1989.

Forest Service, City consultants previously estimated the current annual level of eagle-viewing float trips at 3,200 visits. Nonmotorized boating activity on the Skagit River below Copper Creek is considered to be very light during other seasons of the year, so the eagle viewing activity appears to account for a large majority of all scenic floating use.

2.7.1.3 Boat Fishing

The Skagit River is popular among anglers, particularly those fishing for anadromous species. As described in more detail in Chapter 3, the river supports chinook, coho, pink and chum salmon and both winter and summer steelhead. Many anglers fish the river from the banks in various locations where public access is possible, but most fishing activity occurs from boats. Based on personal contacts with sources familiar with local fishing conditions and patterns, boat fishing accounts for at least 60 percent of all Skagit River sport fishing activity (Envirosphere Company, 1989; personal communication, S. Fransen, Skagit System Cooperative, Fisheries Division, LaConner, Washington, February 25, 1991). Boat fishing patterns are varied, but typically involve drifting through a specific pool or section of the river; some anglers use nonmotorized drift boats and only float downstream, while others with power boats drift a target section of the river and motor back upstream for repeated drifts. This type of activity is concentrated around certain access sites with boat launches, particularly Howard Miller/Steelhead County Park at Rockport and Faber's Landing near Concrete. Boat fishing is also supported to varying degrees by facilities at numerous other access sites maintained by the Washington Department of Wildlife (WDW).

In a previous study commissioned by the City, total annual boat fishing use in the Skagit Project evaluation area was estimated at approximately 17,800 visits (Envirosphere Company, 1989). This figure includes fishing activity on the tributary Sauk, Suiattle and Cascade rivers as well as the mainstem Skagit; the estimated Skagit River share was 15,700 visits per year. This estimate covers fishing for salmon and winter and summer steelhead, but does not include effort associated with sea-run cutthroat trout, Dolly Varden or resident fish.

Boat fishing on the Skagit River occurs at virtually all times of the year, and varies within the year according to the migration patterns of the respective fish species. The river generally opens for salmon sport fishing on July 1 (personal communication, S.Fransen, Skagit System Cooperative, Fisheries Division, LaConner, Washington, February 25, 1991). Anglers target chinook salmon primarily during July and August, followed by coho salmon in September and October. Fishing for chum salmon generally occurs from early October through the end of November. Winter steelhead fishing begins in earnest around December 1 and continues through April, although the last month of the winter steelhead season is a "quality fishery" requiring release of all caught fish and use of fly-fishing gear only. The river is closed to steelhead fishing in May, then opens again for the summer steelhead season from June into the fall.

Precise estimates of the distribution of boat fishing activity within the year have not been developed. However, fisheries sources commonly assume that winter steelhead fishing accounts for up to 75 percent of total use. Boat fishing activity from December through April therefore probably amounts to from 2,500 to 3,000 visits per month. If the remaining portion of total use is distributed evenly from June through November, the level of activity in these months is probably on the order of 600 to 900 visits per month.

2.7.2 Effects of Current Reservoir Operations

The City has not conducted an in-depth analysis of the ways or degree to which existing Skagit Project operations might influence the above downstream recreational uses. This subject was not identified as an issue area in the original scope development for the lake levels analysis, and has been added in the interest of completeness. In requesting this addition to the final lake levels report, the intervenors agreed that a purely descriptive and qualitative assessment would be sufficient. Consequently, the discussion of the effects of existing operations and the potential effects of early refill (in Section 2.7.3) focus in general terms on the types of potential changes and the direction of change for the key downstream activities.

2.7.2.1 Whitewater Boating

The most evident influence of project operations on the upper Skagit whitewater run is in shaping the distribution of use within the year. The operating regime of the project results in sustained downstream flows throughout the summer season, as a result of continuous power production and the large storage capacity of the project. Natural (unregulated) Skagit River flows would be significantly lower in late summer, after runoff peaks from the late- spring/early-summer snowmelt have receded and basinwide precipitation has diminished. The higher late-season flows allow the upper Skagit rafting season to be extended into late summer and early fall, as indicated by the use data presented in Table 2-22. This is unusual in that most recreational rivers (at least those without flow regulation by dams), including nearby rivers such as the Sauk and Suiattle, do not have boatable flows in late summer, generally after July (Envirosphere Company, 1989). Commercial outfitters, recognizing the seasonal flow patterns of the respective rivers, tend to concentrate scheduling of upper Skagit trips in August, September and even October when they know that other whitewater alternatives will be limited or unavailable.

Skagit Project operations therefore allow a longer season of operation for the upper Skagit whitewater run. This section of the river is technically usable all year, as indicated in Table 2-22, although the effective use season is from April through October. In contrast, other popular Washington whitewater rivers such as the Cispus, Sauk, Skykomish, Suiattle, and Wenatchee provide only spring and summer boating activity that generally ends in late June or early July (Interagency Whitewater Committee, 1985; North, 1987).

In conjunction with the longer season, the Skagit River seasonal flow pattern produces a late-summer peak in the distribution of whitewater use. Peak use on whitewater streams with spring-summer seasons generally occurs in May and June, and these two months combined will probably account for 70 to 80 percent of total annual use. August is the peak use month for the upper Skagit run, and September has the second-highest monthly use share. Use in August and September combined is generally about 50 percent of the annual total, while about 75 to 80 percent of annual use typically occurs from July through October. These percentage data also illustrate that the longer season tends to diminish the concentration of use in any month or two-month period.

In addition to influencing the seasonal distribution of use, it is possible that total whitewater boating activity on the upper Skagit is higher than would occur with unregulated flows. Whether this is in fact the case depends upon subjective judgment as to the inherent attractiveness of the Skagit as a whitewater opportunity. Based on the limited number and extent of rapids and the moderate degree of difficulty, the upper Skagit is not as attractive to the typical user as many other Washington streams. This is borne out in the higher level of use and publicity for popular unregulated streams, such as the Wenatchee, Methow and Skykomish. When boating is available on these and other opportunities (in spring and early summer), relatively few users select the Skagit; use on the upper Skagit run appears to increase only when competing alternatives are greatly diminished in late summer. Consequently, it is possible that whitewater use on the Skagit would be less than half of the current level if boatable flows were not available through the late summer and early fall.

A comparison with the use pattern on the Tieton River appears to support this possibility. The Tieton, located in the Yakima River basin in eastern Washington, is well-known among whitewater users for a short but intense September use season based on scheduled releases from Rimrock Dam. In 1990, over 4,900 commercial and private boaters floated the Tieton in four days of a two-weekend season (Washington Recreational River Runners, 1990). This four-day total is about three times the average annual use figure for the upper Skagit, and indicates the relative attraction strength of two competing late-season opportunities.

While the availablity of boatable late-season flows appears to increase the overall level of use on the upper Skagit, it is also possible that the project flow regime reduces the amount of use during the spring and early summer. This could occur through the project's modulation of peak runoff flows, primarily from snowmelt, that typically happen during May and June under natural conditions. Skagit River flows at Newhalem average between 6,000 and 6,500 cfs during June and July, which are the highest-flow months of the year (USGS,various years; see also Table 4-3). Flows in August and September, the periods of highest use, average about 3,900 cfs and 3,000 cfs, respectively. Boaters tend to avoid the upper Skagit when flows reach about 7,000 cfs, and seem to prefer the rapids more when flows are in the 3,000-3,500 cfs range (personal communications, S.Fransen, Skagit System Cooperative, Fisheries Division, LaConner, Washington, February 25,1991; R. Amundson, Wild Waters, Inc., Federal Way, Washington, February 25, 1991). Therefore, it appears more likely that boaters who prefer the upper Skagit at high flows still have that opportunity during early summer, and that few or no boaters would be interested in using the peak flows that would occur if the river were unregulated (which would be well over 7,000 cfs)

2.7.2.2 Scenic Floating and Boat Fishing

Scenic floating and boat fishing on the Skagit River below Copper Creek have similar flow-related requirements, and can be considered together in assessing the effects of existing project operations. Both activities require suitable flow volumes and water velocities, such that the river is deep enough to be navigable but not too fast or full of debris to be unsafe. Project operations clearly influence both of these variables, and can theoretically contribute to river flows that are either too low or too high for these water- based activities. However, the degree of project influence diminishes significantly as major tributaries enter the river downstream. Major contributions of unregulated water include the Cascade River at Marblemount and the Sauk River near Rockport, while the Baker River near Concrete is a major regulated tributary.

The Skagit Project, as is typical with major storage projects, modulates flow extremes on the Skagit River over the course of the year. Peak spring-summer runoff flows are largely retained in Ross Lake to provide water for power generation during the colder months and fall-winter flood flows are partially controlled by the project, so extreme high flows on the Skagit are less than would occur in an unregulated condtion. Annual low flows are higher than would otherwise occur, due to the release of stored water and the maintenance of specified minimum flows through agreements with fisheries interests. These required minimum flows are never less than the natural inflow to the project.

By modulating natural flow extremes in this way, the Skagit Project can only have neutral or positive effects on downstream boating activities. Peak runoff and flood flows would be somewhat higher without the project, so opportunities for scenic floating and boat fishing could conceivably be curtailed at certain times of the year compared to the current operation. The degree of flood control provided by the project also helps to reduce flood damage to shoreline recreation facilties that support these activities.

Navigability during low-flow conditions similarly is maintained or enhanced by the Skagit Project, although the lack of sufficient water for boating appears to be of minimal concern. The Skagit is a large river with a considerable volume of flow at all times of the year. Further, low-flow conditions occur primarily in late summer and early fall, when there is relatively little floating or boat fishing use on the river. It is likely that the flow in the Skagit River never gets too low for use by floaters (personal communication, S. Fransen, Skagit System Cooperative, Fisheries Division, LaConner, Washington, February 25, 1991), particularly during the winter eagle-viewing season. Experienced anglers in jet boats likewise can probably navigate the river at all times of the year. The river probably gets too low at certain times of year for power boats with conventional outboard motors, particularly in selected shallow areas above Rockport that are known to frequent users. Low flows that hamper anglers with power boats probably do not happen during the bulk of the winter steelhead season, but this category of users generally stays off the river above Rockport during the late-summer low-flow period.

2.7.3 Potential Effects of Early Refill

Early refill of Ross Lake would create significant shifts in the pattern of Skagit River flows from January through July. Average monthly flows at Gorge during the winter months would be reduced by up to 2,500 cfs, while flows in May and June could be increased by over 4,000 cfs. Winter flows would generally remain at or slightly above 3,000 cfs, while late-spring average monthly flows would exceed 7,000 cfs for several of the early refill alternatives examined. (See Sections 4.4 and 4.5 for a more complete discussion of changes in streamflow patterns as a result of early refill.)

These changes in river flows have either neutral or somewhat negative consequences for whitewater boating on the upper Skagit run. As indicated above in Section 2.7.2.1, 7,000 cfs appears to be approximately the upper limit of boatable flows on this run. By increasing average monthly flows at Gorge above this level during May and June in several cases, early refill would likely reduce or preclude whitewater use during this portion of the season. Late spring is well before the current peak-use portion of the boating season, but still receives a considerable amount of use. Such an effect could be tempered somewhat by a shifting of use from May and June into July. However, the early refill cases would also result in July flows of from 4,000 to 6,000 cfs, which are still above the flow levels that boaters appear to prefer. Therefore, it is possible that early refill would result in a small decrease in overall boating use on the upper Skagit whitewater run. This possibility would be greatest with the more aggressive early refill scenarios, such as those based on May 31 refill target dates.

The flow changes associated with early refill would not likely have noticeable effects, either positive or negative, on scenic floating or boat fishing. Average flows during the winter months, when most of the use for these activities occurs, would be reduced somewhat but would still be well above the low-flow levels where navigability might be a concern for some users. The increases in average flows during May and June would not likely be of any consequence below the whitewater run. This is because the river is considerably larger and wider below Marblemount, and the character of rapids is not a determining use factor in this reach. Given these considerations, there should not be any direct effects from early refill on the ability to use the river for scenic floating or boat fishing. These activities could be indirectly affected through flow-related changes to the downstream fishery resources, which are discussed in Section 3.3 of this report.

2.8 SUMMARY ASSESSMENT

The reservoir recreation use analysis indicates that low lake levels in late spring probably do reduce the aggregate level of recreational use that would otherwise occur at Ross Lake if the reservoir were full or nearly so. The quantity of annual use for some Ross Lake user groups is probably not constrained at all by lake levels, while use by other groups is reduced to varying degrees in proportion to the combined sensitivity to adverse facility and aesthetic effects. A qualitative assessment of these specific components of potential lake level effects determined that seven of eight Ross Lake user groups might tend to alter their seasonal use patterns in response to early-season lake levels. However, this type of reaction was considered to be moderately or highly likely for only four groups, including Hozomeen car campers and day users, boat campers and backcountry hikers. Sensitivity of use level to low early-season lake levels was judged to be low for horse riders, resort guests and day hikers, and minimal or nonexistant for SR 20 motorists. Diminished utility of the Ross Lake boat ramps was identified as the primary source of facility-based effects, and is likely the most significant early-season use deterrent for Hozomeen users. Diminished early-season visual quality would be the primary effect mechanism for hikers, and possibly boat campers as well.

The physical operating ranges for recreational facilities on Ross Lake were determined through field measurements taken at various lake elevations. Comparison of these data with recent historical water conditions indicated that boat ramps present the primary facility concern, but that any negative effects on the level of use should not be major under average water conditions. Lack of usable boat docks may have a negative influence at times on the use of individual camps, but should not have an effect on the aggregate level of use. Likewise, aggregate recreational use is not likely to be adversely affected by physical effects on the utility of campgrounds or the Ross Lake Resort.

Analysis of seasonal use distribution patterns established that early-season use proportions at Ross Lake are different from those of other comparable resources,.

particularly with respect to lower Ross Lake use in May. This is likely influenced to some degree by low early-season lake levels. However, the effect of lake levels on the seasonal distribution of use at Ross is probably less than the effect of weather or the timing of the fishing season. Late-spring (primarily in May) use at Ross Lake NRA is proportionally less than at comparable resources elsewhere, probably due largely to weather patterns. Late-spring use at Ross Lake itself is proportionally less than in the NRA as a whole, probably due largely to the late opening of fishing season. The opportunity to fish at a quality lake is no doubt a major part of the recreation attraction for most members of most Ross Lake user groups. Most Ross users therefore naturally have little incentive to be present in May and early June.

The maximum possible use increase that could be gained from refilling Ross Lake by May 31 is estimated at approximately 13,200 annual activity days, equivalent to 31 percent of annual on-lake use and 1 percent of total use. The value of this hypothetical activity to the users is estimated at somewhat less than $250,000 per year. The present value of this annual benefit over a 30-year license term, using a 3 percent discount rate, is estimated at approximately $4.8 million. This level of change in use is considered extremely unlikely, in view of a variety of evidence of likely user behavior responses and comparable seasonal distribution patterns.

A realistic estimate of the effect of lake levels on recreation use indicates that Ross Lake use might increase by about 1,000 activity days per year, or about 2 percent of current annual on-lake use, if the lake were refilled by May 31 (corresponding to refill Alternative 6). This potential change in use would have an annual value of less than $20,000, and a net present value over 30 years of $357,000. Refill alternatives involving combinations of lower target elevations or later dates would yield lower estimated use changes and values.

Either of the above estimates overstate the actual change in aggregate use by not accounting for the time-shifting of use to later periods of the year, the effect of the adopted change in the fishing opener from approximately June 15 to July 1, or the relatively low frequency with which Ross Lake could be refilled by May 31. The estimates of hypothetical use increases with early refill assume that May-June use below the expected normal is a net loss for the year. In reality, many Ross Lake users who would otherwise be inclined to use the area in May or June are simply scheduling their activity for later in the year, but are not decreasing their annual level of use. Ross Lake users will continue to concentrate their activity in the July-August period as long as there is sufficient user capacity at that time.

This reservoir recreation analysis has only addressed the potential effects of lake levels on the aggregate level of recreational use, by measuring the number of users who might avoid Ross Lake because the lake is low in late spring. People who do use Ross when the lake is low would presumably enjoy and value their experience more if the lake were full. Theoretically, the value of such a change could be measurable or it could be approaching zero. In application, there is insufficient information to attempt such an evaluation, so reduced experience values attributable to lake levels have not been incorporated into this analysis. It is not expected that they would significantly affect the indications of the results, because the calculations would involve small user numbers and small fractions of both total user numbers and respective user-day values.

A qualitative assessment of relationships between project operations and downstream recreation uses indicates that whitewater boating would likely be negatively affected by early refill, while scenic floating and boat fishing would not be affected. Early refill would increase flows on the Skagit River below Gorge during May and June to the point that whitewater boating would often be undesirable during this period. This could cause a shifting, or more likely an outright decrease, in the relatively small proportion of total annual use that presently occurs in late spring.

Figure 2-1. Ross Lake area and recreational facilities.

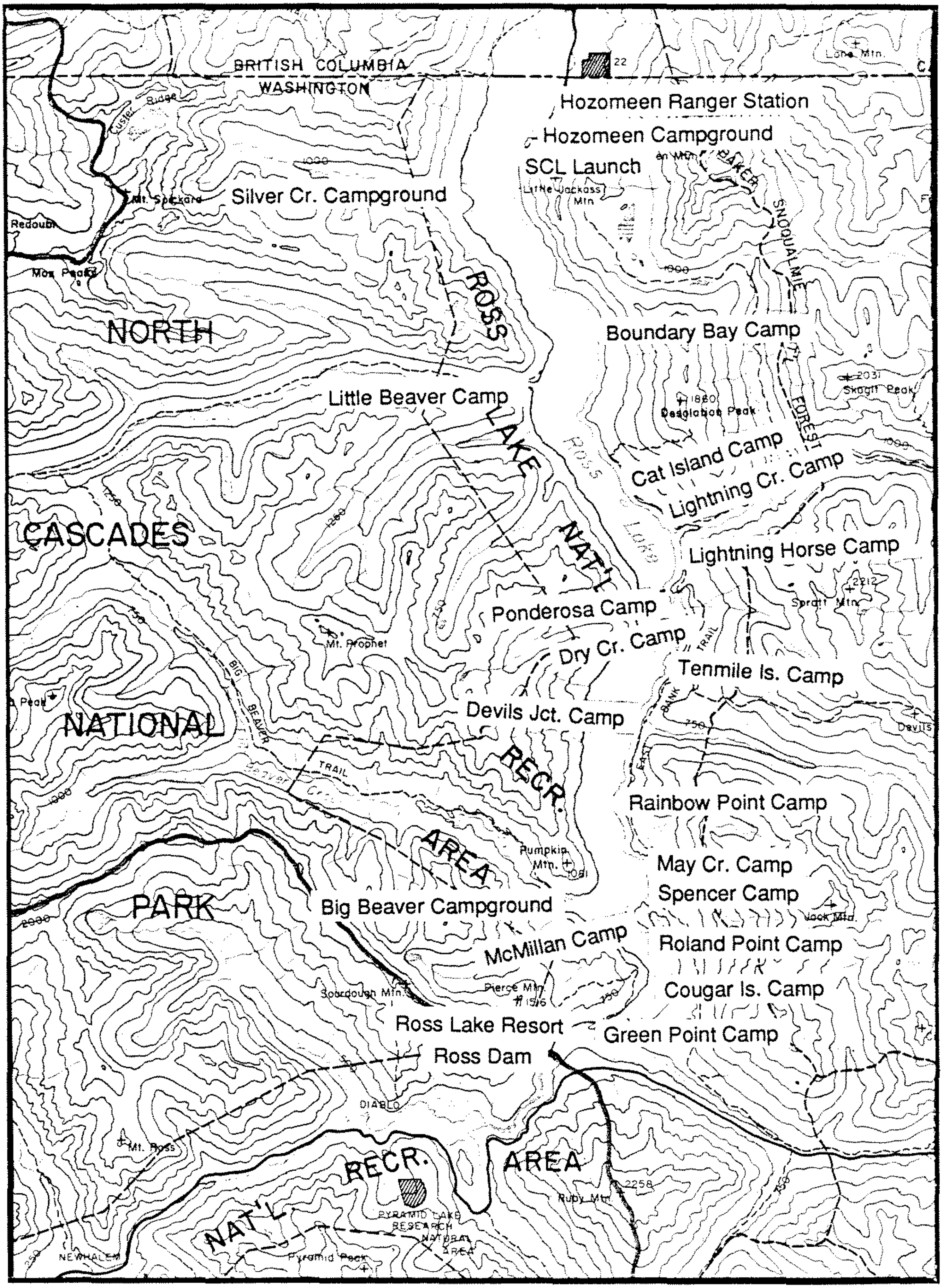
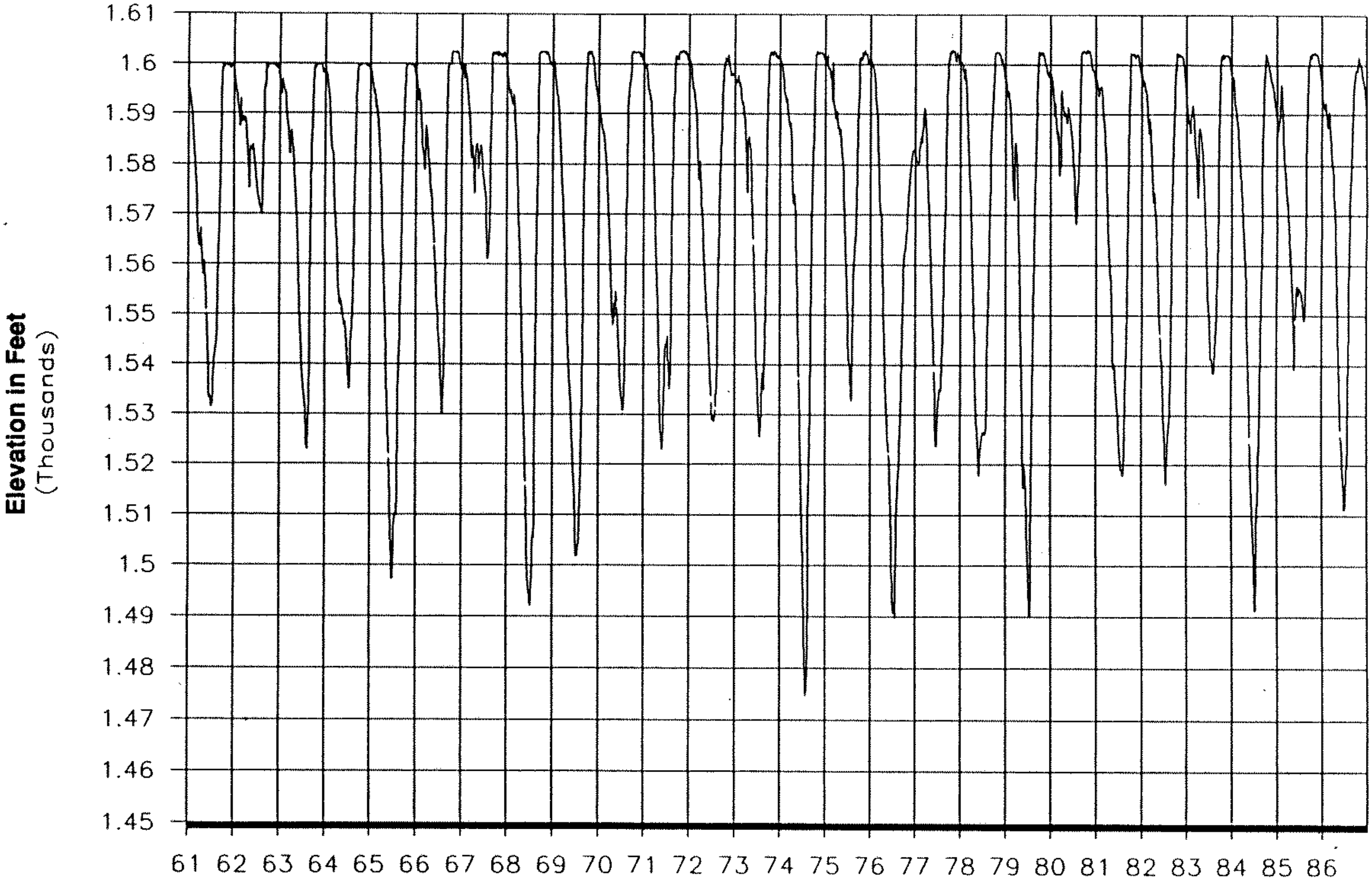
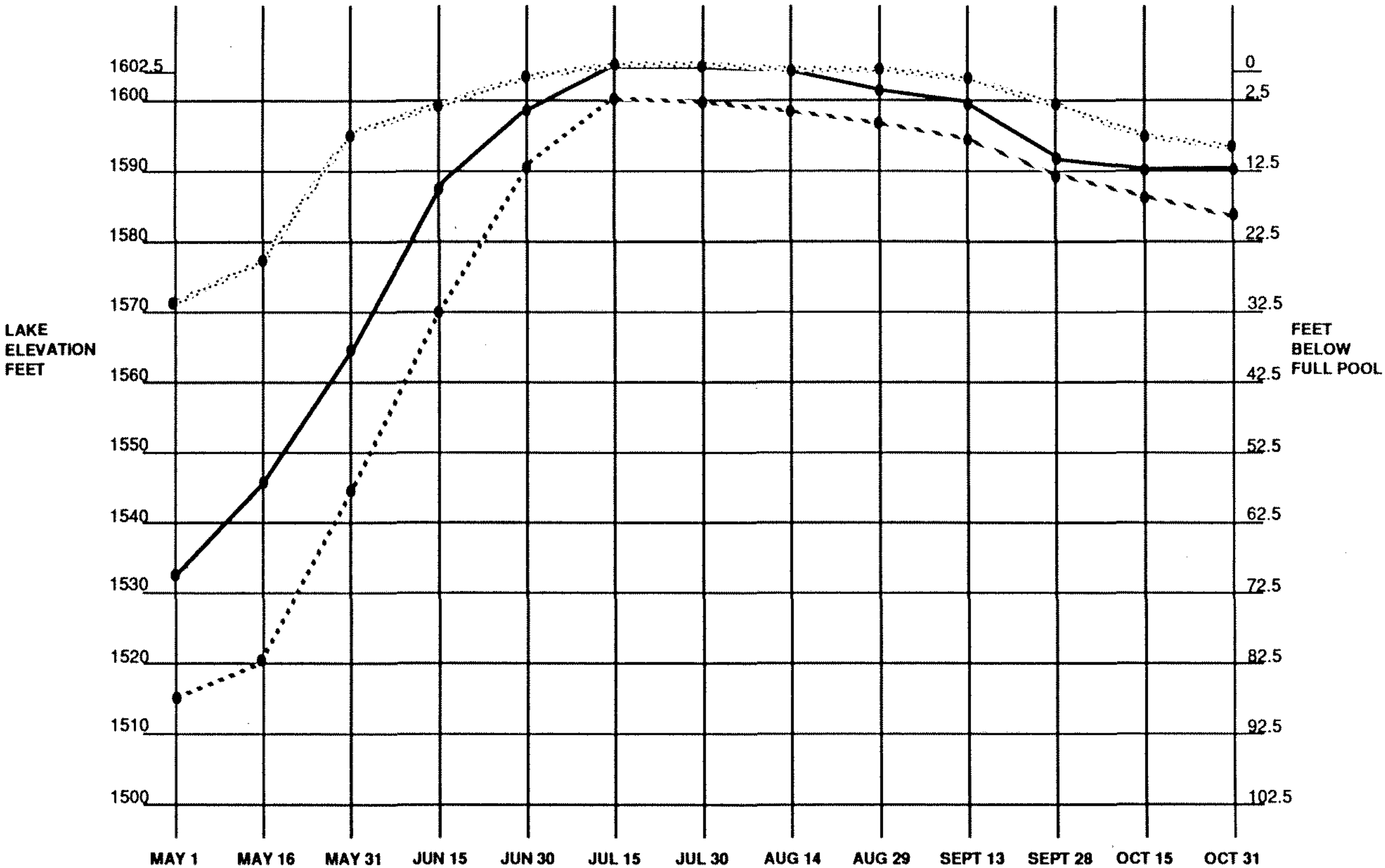


Figure 2-2. Ross Lake Elevations, October 1, 1961 - September 30, 1987.



Source: USGS, various years.

Figure 2-3. Ross Lake May-October elevations, 1978 - 1986



Sources: Parametrix, Inc., 1989
USGS, Various years.

3.0 FISHERY RESOURCES

The fisheries component of the lake level analysis included two primary elements that separately addressed the relationship of Ross Lake levels to downstream anadromous fisheries and the reservoir resident fishery. Both types of fish resources could be affected by early refill of Ross Lake, although the effect mechanisms would be distinctly different. Study methods, existing conditions, and the effects of early refill on these fishery resources are discussed below in Sections 3.1 through 3.4. An overall assessment addressing the net balance of these effects is provided in Section 3.5.

3.1 STUDY METHODS

3.1.1 Downstream Fisheries

Fishery resources of the Skagit River downstream of the Skagit Project have received extensive study over the past three decades or more. The river supports several species of anadromous fish and is influenced by two major hydroelectric projects (the Skagit Project and Puget Power's Baker Project), so interest in these fishery resources has historically been very high. The City has sponsored or participated in many studies of Skagit River fisheries, and has worked cooperatively to develop databases and analytical models that address these resources. As one outcome of this long-term research effort, the City has developed a specific model that analyzes the effect of various streamflow regimes on Skagit River anadromous fisheries. This model, which is termed the FISH-POWER model by the City, provided the primary analytical tool for the downstream fisheries component of the lake levels study.

The FISH-POWER model is essentially an automated set of procedures to operate analysis of a database on spawning habitat in the river, the Effective Spawning Habitat (ESH) database and model. The ESH model is a series of look-up tables that quantifies the spawning habitat available at a given streamflow volume. It distinguishes habitat according to the different fish species and geographic reaches of the river. The ESH model was originally developed during the early 1980s, but was recently updated by a fisheries consultant under contract to the City. Documentation of the development and contents of the ESH model is contained in a recent report (SCL, 1990) available from the City. The updated ESH model has been reviewed and accepted for appropriate application in studies by the fisheries agencies and tribes participating in the Skagit Project relicensing process.

A flow diagram representing the use of the FISH-POWER model in the downstream fisheries analysis, and its relationship to other study elements, is included as Figure 3-1. In application, use of the FISH-POWER model is rather simple and straightforward. The required data inputs consist of a set of daily streamflows. The FISH-POWER model analyzes the flows against the ESH model to determine the spawning protection level associated with the specified flow regime. The spawning protection results are stated in terms of the percentage of total potential spawning redds, by species and run, that would receive adequate spawning and incubation flows.

Two sets of flow data inputs were required for the downstream fisheries analysis of this study. One set consisted of the outflow results from the HYDRO model simulations of various Ross Lake refill scenarios (see Section 4.1 for complete discussion of the HYDRO model and its results). However, the FISH-POWER model also requires data on Skagit River flows at Marblemount, whereas the HYDRO model only addresses Skagit Project outflow at Newhalem. Consequently, operation of the FISH-POWER model also required construction of a database on Skagit River accretions (tributary inflows) between Newhalem and Marblemount.

Available historical data for Newhalem-Marblemount accretions were limited to daily flow records for October 1943 through June 1944, October 1946 through September 1951, and May 1976 to the present. Therefore, it was necessary to develop a synthetic flow record for the remainder of the historical period of record (1928 through 1978). These synthetic flows were developed from a correlation analysis designed to predict Newhalem-Marblemount accretions based on Cascade River flows at Marblemount, using a continuous Cascade River record extending from October 1928 through 1979.

In developing these synthetic flows, it was determined that an adjustment to the initial results was needed to adequately represent monthly low-flow conditions. Monthly adjustment factors were developed from ratios relating the synthetic monthly low flows to actual observed monthly low flows. Key statistical measures and the flow database resulting from this procedure are documented in Appendix B.

Once the complete flow record had been assembled for both flows at Newhalem and Newhalem-Marblemount accretions, the FISH-POWER model was operated to determine the redd protection levels associated with each refill scenario. The results of this operation are summarized in Section 3.3.3; the actual computer output is too voluminous for reproduction with this report, but is available for review at the City's offices.

The output of the FISH-POWER model expresses redd protection as a percentage level. However, the redd protection levels do not provide a suitable indication of the downstream fisheries effect of refill alternatives unless they are translated into less abstract terms. To better illustrate potential effects, in this case the redd protection levels were converted into numerical measures of potential run sizes using a two-step process.

The first step involved stating the redd protection levels of the various refill alternatives as an index or ratio to the base case, to put all refill scenarios on a common scale for later multiplication. These index numbers were then multiplied by estimates of the current sizes of the respective fish runs, to provide relative indicators of the potential changes in run sizes that could be associated with the refill scenarios. (Appropriate qualifiers for this procedure and its results are discussed in Section 3.3.3.) Data on numbers of fish in the respective runs were taken from recent historical averages reported by Washington (1984), which were escalated to reflect increases in typical run sizes during recent years.

3.1.2 Reservoir Fishery

Unlike the situation for downstream fisheries, specific models are not available to analyze the effects of early Ross Lake refill on the reservoir fishery. Data that would allow a highly quantitative analysis are also limited, as are any research findings that demonstrate relationships between the reservoir fish population and lake levels. Consequently, the reservoir fishery element of the lake level study was a relatively limited and qualitative assessment based on the available literature.

Numerous studies of fish in Ross Lake and tributary streams have been conducted, dating back to at least the early 1970s. However, due to their specific content and the nature of the issues, it was possible to base the reservoir fishery analysis on two key literature sources. One is a comprehensive review of the Ross Lake fishery by the Washington Department of Wildlife's (WDW) resident fishery biologist for the area (Johnston, 1989). This information source documents the results of field studies on Ross Lake by WDW from 1985 through 1988, and presents a thorough history of the fishery and a review of prior research. The second key information source is a report on the early-season Ross Lake fisheries studies conducted under contract to the City during 1989. This report (SCL, 1989) includes a stream catalog for Ross Lake tributary streams and documents results of spawner surveys.

The methodological approach for this resident fishery assessment was simply to formulate specific issues relating to potential early refill effects and review the two key sources for material addressing the specific issues. No attempt was made to quantify any predicted effects in terms of numbers of fish, length of tributary streams, amount of spawning habitat available, or other measures.

3.2 EXISTING CONDITIONS

3.2.1 Downstream Fisheries

The Skagit River supports runs of four species of salmon and both winter and summer steelhead. The salmon species include chinook, coho, pink, and chum. Among these species, coho salmon spawn in tributary streams and side channels, and their spawning success is not affected by the volume and timing of flows in the mainstem river. Most hatchery-raised steelhead also do not spawn in the river. The downstream fisheries analysis therefore focused on wild steelhead and chinook, pink and chum salmon.

The numbers of fish in these respective runs vary considerably. Pink salmon are by far the most numerous, with the pink run size typically at least seven times the size of the next largest run (chum). There can also be large annual variations in run size for a given species. This is particularly true of pink salmon, which return to the Skagit only during odd-numbered years. Chum salmon also have a very strong alternating pattern of large runs in even-numbered years and comparatively small runs in odd-numbered years.

The only significant baseline data requirement for this downstream fisheries analysis was to obtain or develop estimates of total run sizes for each of the salmonid species that are of concern in this case. The primary information source for this task was a 1984 study by Washington comparing salmonid run sizes on the Skagit, Fraser, Nooksack and Stillaguamish rivers. This study provided estimated moving averages of run sizes on these steams over varying periods of analysis; the data for the Skagit were used to develop estimates of current average Skagit River run sizes.

Because Washington's estimates applied to periods extending only through 1982, it was necessary to adjust these figures to approximate current levels. Based on suggestions from City fisheries staff, Washington's estimates for salmon were increased by about 20 percent to account for an apparent trend of larger salmon runs on the Skagit over the last few years. The nature of the analysis does not require state-of-the-art, precise estimates of run sizes. The objective is to illustrate relative magnitudes of both baseline run sizes and potential changes resulting from early refill, so it is sufficient to use a consistent source that allows reasonable approximations of run sizes.)

The results of this procedure are summarized in Table 3-1. This table indicates for each species the total run size estimate provided by Washington (1984), the specific source in Washington's report and the applicable period for his average, and the projected current run size. The current annual estimates for the three salmon runs range from over 1 million for pinks to 34,000 for chinook. The size of the wild steelhead run, which was not escalated due to the apparent run size pattern since 1983, is the smallest of the four at 8,500 fish per year.

Table 3-1. Development of estimates of current run sizes for Skagit River salmonid species.

Species	Washington (1984) Estimate of Total Run Size	Washington (1984) Specific Source and Period of Average	Projected Current Run Size
Chinook	28,110	Table 3, 1965-82	34,000
Pink	866,630	Table 4, 1959-81	1,040,000
Chum	114,380	Table 4, 1968-82, even	137,000
Steelhead	8,500	Appendix B17, 1977-83 (wild fish only)	8,500

Source: Washington, 1984.

In commenting on the draft report for the lake levels analysis, the WDW noted that the wild steelhead run on the Skagit River has been considerably higher than the 8,500 indicated above. The WDW reports that the total run has averaged 12,900 fish from 1985 through 1989 (personal communication, R.G. Engman, Washington Department of Wildlife, Region 4 Habitat Management, Mill Creek, Washington, May 15, 1990; see Chapter 6). The City has therefore used the higher figure of 12,900 fish in the final report.

A further subdivision of the steelhead numbers was necessary to provide the level of detail needed relative to FISH-POWER model results. Steelhead spawn in the river from March through July or later, and FISH-POWER model output determines the level of redd protection separately for steelhead spawning in March, April and May (June and July are high-flow months when there is minimal risk of insufficient spawning or incubation flows).

Prior City and WDW field studies and spawning surveys have determined that the percentage distribution of steelhead spawning is presently 7 percent in March, 38 percent in April, 44 percent in May and 11 percent in June and subsequent months (personal communication, K. Kurko, Seattle City Light, Environmental Affairs Division, February 9, 1990). Applying these percentages to the total average run of 12,900 fish yields the following monthly figures (rounded to the nearest hundred):

March	900
April	4,900
May	5,700

3.2.2 Reservoir Fishery

Ross Lake presents an unusual resident fishery situation, as the present lake fishery is totally dependent upon natural reproduction. No hatchery fish are planted directly into the lake or the Canadian Skagit River, and there are no official or adopted plans to artificially supplement the existing natural stocks (Johnston, 1989). The fishery is dominated by rainbow trout, but also includes cutthroat trout, Dolly Varden char (also known as bull trout), and eastern brook trout (also a char, despite the popular name). While all trout and char reproduction in the system is natural, not all fish in the drainage are native to the system. Plants of rainbow, cutthroat, and eastern brook have been made in various tributary streams to Ross Lake, but these plants are believed to have had little effect on the wild stocks of Ross Lake (Johnston, 1989).

The population of harvestable fish in Ross Lake was estimated to range between 146,000 and 206,000 during the early 1970s (Johnston, 1989). Rainbow trout accounted for 95 percent of the total fish population. Updated population estimates for more recent years have not been made by the Washington Department of Wildlife or other researchers. However, based on an analysis of catch-per-unit-effort trend data, WDW staff concluded that the fish population declined markedly from the early 1970s to the mid-1980s (Johnston, 1989).

Ross Lake is a popular fishery resource and receives heavy fishing pressure. WDW estimated total annual fishing effort at 14,550 angler days in 1985 and 18,125 angler trips (which would exceed angler days by an unknown margin) in 1986 (Johnston, 1989). The corresponding estimates of rainbow trout harvest produced by this effort were 18,504 fish in 1985 and 22,524 fish in 1986 (the total for all species would be higher by a few percent). These figures are considerably lower than rainbow trout harvest estimates for the 1971 to 1974 period, which ranged from 35,137 to 37,947 fish.

The rainbow trout of the Ross Lake Skagit River system follow a variety of significant migratory movements during the course of the year and over the normal fish life cycle (Johnston, 1989). Spawning occurs in the tributary streams, including the upper Skagit River in Canada. Spawning adults generally migrate to their natal streams between late April and late June. Adults may return to the lake after spawning or remain in the stream to feed into September, but all return to the lake by fall for overwintering. Juvenile fish tend to migrate from the spawning streams to the lake shoreline by age 1, then move offshore to midlake feeding areas in midsummer at age 1 or 2. Larger fish of about 12 inches in length and up also engage in an annual feeding migration to the mouths of tributary streams, and farther upstream in the larger tributaries. This typically begins in late spring or early summer, and ends when the fish return to the lake in mid-fall.

Ross Lake has many tributary streams of varying sizes, but not all provide potential or available spawning habitat. Based on spawning habitat surveys conducted as part of the City's early-season fisheries studies for Ross Lake, 12 tributaries have spawning habitat available under certain conditions (SCL, 1989). (A 13th stream, Devils Creek, was also surveyed but provides no available habitat due to multiple barriers to upstream passage.) Because the lower portions of these streams are inundated at higher reservoir elevations, the amount of available spawning habitat in some streams varies considerably with the lake level. Barriers to upstream passage can also either be exposed or submerged, depending upon the reservoir elevation decreasing or increasing.

The total amount of trout spawning habitat available in Ross Lake tributary streams does not change consistently with the lake level. The total habitat available is greatest at full pool, where it is estimated at 271,000 square feet (see Figure 3-1; this figure actually indicates that available habitat could be maximized if the reservoir elevation could somehow be reduced to 1300 feet, but this is irrelevant to the current study). The habitat area is least when the lake level is at about 1595 feet, providing an estimated 233,000 square feet of spawning area. Available habitat varies with elevation between these extremes; at the minimum reservoir elevation of 1475 feet, it is 260,000 square feet. The amount of spawning habitat available decreases gradually as reservoir elevation increases to about 1595 feet, then jumps to the maximum amount when the reservoir fills to slightly above that elevation. The major difference between the maximum and minimum habitat quantities is explained by whether barriers to passage in Lightning and Big Beaver creeks are submerged, which occurs at about elevation 1596 to 1597 feet. Ross Lake typically reaches this elevation between about June 20 and July 1, which is after the bulk of the late-April to late-June spawning period.

Figure 3-1 also illustrates well the relative contributions of the various tributaries to total spawning habitat available. The Skagit River upstream of Ross Lake provides an estimated 170,000 square feet of spawning area, which represents from 63 to 73 percent of the total habitat available at any given reservoir elevation. Moreover, this habitat quantity is available under all conditions, and is not affected by the reservoir elevation. Ruby Creek provides the second largest contribution to total habitat available, ranging from about 62,000 square feet to 80,000 square feet depending on lake level. Devils, Little Beaver, Roland, and Silver creeks collectively provide a small amount of habitat (2,000 square feet) that is essentially constant regardless of lake level. Arctic, Dry, Hozomeen, No Name, and Pierce creeks also provide a small contribution that can range from 0 to approximately 10,000 square feet. Big Beaver and Lightning creeks can provide 36,000 and 2,000 square feet of spawning area, respectively, but only when the reservoir is above approximately 1597 feet. These two potential contributions represent 14 percent of the maximum available area under existing reservoir conditions.

3.3 EARLY REFILL EFFECTS ON DOWNSTREAM FISHERIES

3.3.1 Fishery Flow Requirements

Streamflow levels in the Skagit River during spawning and incubation periods are critical to spawning success and production levels for the various fish runs. A key objective in managing the anadromous fishery resources is to keep flows sufficiently high during spawning periods that fish may access enough spawning habitat, and to maintain flows that will keep the redds submerged during the ensuing incubation periods. This objective is supported by establishing minimum flow requirements for Skagit Project releases during critical periods. However, it is also important that flows be moderated at these times, as excessive flows can also be damaging to spawning and incubation as well. Extremely high flows can scour out redds and destroy eggs, while short-term high flows during spawning will lead to dewatered redds if adequate incubation flows cannot be maintained.

Two different flow requirements for the Skagit Project have been established due to these concerns over fishery needs. The original FERC operating license for the project specified a minimum release of 1000 cfs or natural inflow, whichever is less. This requirement represents an absolute lower bound on project releases. In response to studies of fishery flow requirements, the City subsequently negotiated a new contractual agreement with the National Marine Fisheries Service, the Washington Departments of Fisheries and Game (now Wildlife), and the Skagit System Indian Tribes (the Sauk-Suiattle and Upper Skagit Tribes and the Swinomish Tribal Community). This Skagit Interim Flow Agreement (FERC, 1981) provides for various conditions of flow regulation from the Skagit Project, including minimum flow levels and constraints on maximum flows and flow fluctuations. The agreement also provided for a two-year program of flow-related fisheries studies, and was intended to lead to a future long-term resolution of flow regulation issues. The Interim Agreement was initially implemented in 1981, and was modified slightly in 1984.

The Interim Agreement specifies instantaneous minimum flows that the City shall maintain at Newhalem during various periods of the year, subject to exception during times of insufficient water conditions. These minimum flow provisions are listed in Table 3-2. The flow requirements vary slightly for October in even- and odd-numbered years, due to the alternating pattern of pink salmon runs. The stipulated minimum flows range from 1000 cfs during June to 2300 cfs from February 1 through April 15.

The City also agreed to undertake all reasonable means to limit maximum flows at Newhalem, so as not to contribute to excessive Skagit River flows that would be damaging to fish (FERC, 1981). The Interim Agreement identifies both target maximum flows at Newhalem and preferred fisheries flows, which are indicated in Table 3-3. Target maximums generally apply from late August through the end of October (4200 cfs) and again from late November through the end of December (7000 cfs). No limits are placed on maximum flows from January through most of August, or the first three weeks of November. The agreement recognizes that targets will often not be met from October through December due to load and flow conditions.

Table 3-2. Skagit interim flow agreement, minimum streamflow levels.

Time Period	Flow (cfs)
July 1-15	1325
July 16-31	1325
August 1-15	1325
August 16-31	1400
September 1-30	1400
October 1-31	1200(1)
November 1-30	1800
December 1-31	1800
January 1-31	1900
February 1-28	2300
March 1-15	2300
March 16-31	2300
April 1-15	2300
April 16-30	2000
May 1-15	1700
May 16-31	1700
June 1-15	1000
June 16-30	1000

Source: FERC, 1981 (as modified in 1984)

(1) October minimum flows are 1400 cfs in odd-numbered years.

Table 3-3. Skagit interim flow agreement, maximum streamflow levels.

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

Source: FERC, 1981 (as modified in 1984)

3.3.2 Lake Level—Streamflow Interactions

Skagit River flows at the Newhalem gage are essentially determined by Skagit Project releases at Gorge, as inflow between Gorge and the Newhalem gage is limited to the contribution of Ladder Creek. Project releases at Gorge reflect both releases from Ross and natural inflow between Ross and Gorge. While inflow in this area can be substantial (primarily from Thunder and Stetattle creeks), Ross releases are usually the primary factor (see discussion in Section 4.2.4.2). In turn, releases at Ross are influenced by the existing level of the reservoir and the drafting and inflow rates for Ross Lake. In general, a higher refill rate during a given time period will translate into reduced releases at Ross, and vice versa.

Early refill of Ross Lake would generally redistribute the pattern of higher and lower flows during the year, reducing total flow volumes at Gorge from fall through winter but increasing flows from approximately March through June. One of the primary effects of early refill would be to shift the peak flow period from June and July into May and June. This results from the operational changes required to implement early refill. The reservoir must be held to a higher level (lesser draft rate) by March 1 to achieve the refill target with an unchanged volume of total inflow. Due to the uncertainties of flow forecasting, particularly with respect to the timing of the annual runoff, the higher reservoir elevation at any given time during the refill period reduces the amount of storage available to accept inflows. The need to avoid excessive spill later in the runoff season therefore results in higher releases in May and early June, in order to maintain storage space for later inflow.

3.3.3 Downstream Fishery Protection Levels of Refill Alternatives

As indicated in the methods discussion, the assessment of early refill effects on downstream fisheries involves a three-step process based on results obtained through the operation of the FISH-POWER model. The results of this model are stated in terms of spawning protection levels, specifically the percentage of potential redds protected under a given project outflow pattern. These percentage protection levels for the twelve refill scenarios evaluated are presented in Table 3-4.

The twelve refill scenarios evaluated through the HYDRO model include eight scenarios based on the minimum streamflow requirements of the Skagit Interim Flow Agreement, which were previously indicated in Table 3-2. These eight scenarios consist of the current refill target of elevation 1602.5 feet on July 31, which is termed the base case, and seven early refill alternatives to the base case that involve varying combinations of refill target dates and elevations. The remaining four scenarios reflect reservoir operations based on the minimum flow requirements of the original FERC license, which has been specified for this application as 1000 cfs in each month. The latter four scenarios also include a base case and a smaller set of early refill target dates and elevations.

Averaged over the entire simulation period, the base case (current operations) results in spawning protection levels ranging from 50.3 percent for May steelhead to 99.5 percent for chinook salmon. Protection levels exceed 90 percent for all three salmon runs and March steelhead.

The remainder of the table indicates a variety of changes in protection levels with the different refill scenarios. In general, these changes are confined within a relatively narrow band around the base protection levels, particularly with the refill scenarios based on the Interim Agreement minimum flows. The figures for the salmon runs reflect a pattern in which the protection levels for any early refill alternative are equal to or less than the corresponding protection levels of the base case. The simulated average protection level remains at 99.5 percent for chinook salmon with all seven of these refill alternatives. Pink salmon protection levels are the same or somewhat lower among this group, ranging as low as 92 percent for Alternative 7. Average protection levels for chum salmon decline in all early refill cases, with a maximum decrease of 3.8 percentage points. These changes are generally attributable to flows during the fall salmon spawning periods that meet or exceed the Interim Agreement minimum flows, but are less than corresponding flows under the base case.

The steelhead results shown in Table 3-4 exhibit a different pattern, both from month to month and compared to the salmon results. Among the Interim Agreement scenarios, protection levels for March steelhead are lower than base case levels for all alternatives, with a maximum decrease from the current 94.2 percent to 86.9 percent for Alternative 1. April steelhead protection levels decrease by up to 5.6 percentage points for Alternatives

Table 3-4. Averaged spawning protection levels (percent of redds protected) for 12 refill scenarios, using Interim Agreement and original FERC license minimum flow constraints.

Refill Scenario	Fish Run					
	Chinook	Pink	Chum	March Steelhead	April Steelhead	May Steelhead
A. INTERIM AGREEMENT SCENARIOS (1)						
Base Case						
1602.5 July 31	99.5	93.1	92.1	94.2	86.6	50.3
Early Refill Alternatives (2)						
Alt2, 1592 June 30	99.5	93.1	91.4	89.3	82.2	51.8
Alt1, 1601.5 June 30	99.5	93.1	90.4	86.9	81.0	55.9
Alt5, 1580 June 15	99.5	93.0	90.4	90.0	83.4	57.2
Alt4, 1592 June 15	99.5	92.9	88.9	90.3	86.3	59.3
Alt3, 1601.5 June 15	99.5	92.7	88.8	92.4	86.7	60.8
Alt7, 1592 May 31	99.5	92.7	88.8	93.3	87.8	59.0
Alt6, 1601.5 May 31	99.5	92.0	88.3	93.5	88.5	59.1
B. ORIGINAL LICENSE MINIMUM FLOW SCENARIOS (3)						
Alt8, 1602.5 July 31 (Equivalent to base case)	99.3	91.8	89.9	93.4	85.6	50.7
Alt10, 1592 June 30	99.2	91.0	88.5	88.0	80.5	52.3
Alt9, 1601.5 June 30	99.1	91.0	85.5	83.3	77.8	56.8
Alt11, 1601.5 May 31	96.8	79.6	74.6	90.1	82.1	58.0

(1) Reflect minimum flow constraints specified in Skagit Interim Flow Agreement, ranging from 1000 cfs to 2300 cfs per period.

(2) Alternatives are arranged out of numerical sequence, based on descending order of salmon protection levels.

(3) Reflect minimum flow constraint of 1000 cfs,per original FERC license.

Source: SCL, 1990.

1, 2, 4 and 5, but increase by up to 1.9 points for Alternatives 3, 6 and 7. Protection levels for May steelhead increase for all of these cases, ranging as high as 60.8 percent for Alternative 3. This figure represents an improvement of 21 percent over the base case protection level.

Spawning protection levels for the refill scenarios based on original FERC license minimum flows are lower than the corresponding results for the Interim Agreement flows in virtually all cases. Further, the negative changes from base protection levels tend to have larger magnitudes. Chinook, pink and chum salmon protection levels are noticeably lower in these four cases, dropping below 80 percent for both pink and chum with the most aggressive early refill scenario. Compared to the base case, steelhead protection levels in this group decline by up to 10.9 points for March and 8.8 points in April. Protection levels for May steelhead are again higher than the base case, ranging as high as 58 percent, although the increases are somewhat less than among the Interim Agreement scenarios.

Two additional calculations were performed to convert the percentage protection levels into more tangible measures, specifically numbers of fish. Initially, the redd protection levels for Alternatives 1 through 11 were indexed to those of the base case, as any new refill scenario would present a change from current conditions. With the base case protection levels set at 1.0, the figures for the other scenarios range from .810 to 1.209, given their ratio to the base case protection percentage. (Because this step is a simple division process, the results are not reproduced here.)

The second step involved multiplying the average run size for the respective runs by the protection level indices, using the baseline data presented in Section 3.2.1. The results of this procedure are indicated in Table 3-5. These figures should be interpreted with careful recognition of what this analysis is attempting to demonstrate. Due to the accuracy of the total run size estimates and the fact that the spawning protection levels address potential (rather than actual) spawning habitat, these results are not represented as specific projections of future run sizes resulting from a given refill scenario. However, they do provide a useful and illustrative approximation of the relative magnitude of potential changes in run sizes, averaged over the simulation period, that could result from the degree of changes in spawning protection levels.

With this qualifier, the data in Table 3-5 support a number of key observations. Probably the most significant is that all of the early refill alternatives would likely result in net reductions of total numbers of fish returning to the Skagit River. This reflects the extreme numerical dominance of the salmon runs, which collectively would experience at least some decrease in redd protection levels with all of the early refill alternatives. Because salmon are collectively much greater in number relative to steelhead, the decreases in salmon protection would more than offset the instances of increases in protection levels for steelhead. This is not to suggest that all fish have equal value and should be weighted equally without respect to species. Nevertheless, any early refill proposal is certain to be evaluated by fisheries agencies and the tribes in terms of whether there is any loss for any particular species. The fact that one species may gain is not likely to be accepted as justification for losses to other species.

Table 3-5. Potential average run size for Interim Agreement and original FERC license refill scenarios (number of fish, to nearest 100). (1)

Refill Scenario	Fish Run						Total Fish	Net Change From Base Case
	Chinook	Pink	Chum	March Steelhead	April Steelhead	May Steelhead		
A. INTERIM AGREEMENT SCENARIOS (2)								
Base Case								
1602.5 July 31	34,000	1,040,000	137,000	900	4900	5700	1,222,500	—
Early Refill Alternatives (3)								
Alt2, 1592 June 30	34,000	1,040,000	135,900	900	4700	5900	1,221,400	-1,100
Alt1, 1601.5 June 30	34,000	1,040,000	134,500	800	4600	6300	1,220,200	-2,300
Alt5, 1580 June 15	34,000	1,039,000	134,500	900	4700	6500	1,219,600	-2,900
Alt4, 1592 June 15	34,000	1,037,900	132,200	900	4900	6700	1,216,600	-5,900
Alt3, 1601.5 June 15	34,000	1,035,800	132,100	900	4900	6900	1,214,600	-7,900
Alt7, 1592 May 31	34,000	1,035,800	132,100	900	5000	6700	1,214,500	-8,000
Alt6, 1601.5 May 31	34,000	1,027,500	131,400	900	5000	6700	1,205,500	-17,000
B. ORIGINAL LICENSE MINIMUM FLOW SCENARIOS (4)								
Alt8, 1602.5 July 31 (Equivalent to base case)	33,900	1,025,400	133,700	900	4800	5700	1,204,400	-18,100
Alt10, 1592 June 30	33,900	1,016,100	131,700	800	4600	5900	1,193,000	-29,500
Alt9, 1601.5 June 30	33,900	1,016,100	127,100	800	4400	6400	1,188,700	-33,800
Alt11, 1601.5 May 31	33,100	889,200	111,000	900	4600	6600	1,045,400	-177,100

(1) Potential run size based on indexed percentage redd protection levels from Table 3-4.

(2) Reflect minimum flow constraints specified in Skagit Interim Flow Agreement, ranging from 1000 cfs to 2300 cfs per period.

(3) Alternatives are arranged out of numerical sequence, based on descending order of salmon protection levels.

(4) Reflect minimum flow constraint of 1000 cfs, per original FERC license.

Table 3-5 also indicates that the potential decreases in total fish numbers are greater for the more aggressive early refill scenarios, and are further enlarged by refill scenarios based on original license minimum flows. This observation is illustrated graphically in Figure 3-2. Among the Interim Agreement cases, net changes range from a potential average loss of 1100 fish per year with Alternative 2 (refill to 1592 on June 30) to a loss of 17,000 fish with Alternative 6. Reducing the minimum flow constraint would have much greater effect. Continued current operations with lower permissible minimum flows could translate into 18,100 fewer fish per year, while the most aggressive early refill case could cause a decrease of more than 177,100 fish.

The potential changes in fish numbers calculated for the Interim Agreement scenarios are not extremely large relative to the existing run sizes. Indeed, the City recognizes that the indicated changes are sufficiently small that they might escape detection if an early refill alternative were implemented and monitored. However, the City also is well aware of the reality of fisheries issues, which is that any potential reductions in absolute numbers of specific runs will be resisted by the agencies and Tribes regardless of their small relative change.

3.4 EARLY REFILL EFFECTS ON RESERVOIR FISHERY

Fluctuating water levels in Ross Lake have also been of concern with respect to affecting the recreational trout fishery of Ross Lake. Early refill alternatives for Ross Lake could have several possible effects on lake fish populations. The key issues relating to reservoir levels and their potential effects are:

1. Lake level influence on blockage of rainbow trout migrating into tributary streams for spawning during May and June.

2. Inundation of spawning redds in lower tributaries by rising lake water and resulting egg mortality during June and July.

3. Migration and passage mortality of fish from the lake during intermittent spills at Ross dam.

4. Reduced production of trout in Ross Lake resulting from the combined effects of the previous three impacts.

The likelihood and significance of each of these four effects on the Ross Lake fishery are summarized below.

3.4.1 Spawning Access to Tributary Streams

Ross Lake trout require access to tributary streams for spawning, but access has at times been blocked. Two types of tributary blockage have been observed in Ross Lake, woody debris jams and natural geologic barriers (steep cascades and waterfalls). Fluctuations in lake levels encourage formation of woody debris jams by stranding, wind-driven floating logs along shoreline areas, sometimes in the proximity of tributaries. High lake levels may prevent movement of woody debris into lower and more passable sections of the channel. Woody debris has been identified as a problem to passage of fish in streams located in logged watersheds, including those in the Ross Lake system. As with other streams in which log jams are a problem, mechanical removal of jams has proven to be the most feasible solution to increasing fish migration.

In Johnston's (1989) review of the Ross Lake fisheries, maintenance of high lake levels was suggested as a possible way of increasing fish passage through naturally occurring waterfalls and boulder barriers near tributary mouths. Johnston's recommendation was based on several tributaries where existing barriers would be partially inundated at full pool lake levels. Though passage of fish may be facilitated by maintenance of full pool during spawning periods, actual increases in numbers of spawning fish using tributaries would likely be insignificant when compared to the total number of spawning fish in the Ross Lake system. Several of the tributaries would gain only limited amounts of spawning area upon allowing access at mouth barriers by increasing early season lake levels, because existing barriers upstream would prevent further access to spawning gravels. The recent resident fisheries study sponsored by the City (SCL, 1989) indicated that increases in spawning area obtained by inundating tributary mouth barriers would represent only a small fraction of the total spawning habitat available in the Ross Lake system (including tributaries and the upper Skagit River). The maximum increase in available habitat through inundation of barriers would be a combined 38,000 square feet in Big Beaver and Lightning creeks. This habitat quantity would represent a gross increase of up to 16 percent over the minimum total habitat available, which would occur at about elevation 1595 feet (see Section 3.2.2). However, realizing this gain would require filling the reservoir to near full pool for a significant portion of the spawning season, probably by about May 31.

This study further indicated that some spawning habitat would be lost by increased lake elevations during the early spring, due to inundation of spawning gravels existing in tributary stream channels below full pool elevation. Consequently, net gains in spawning habitat by increasing lake levels would probably be minimal. Blasting or other mechanical methods to modify fish passage barriers would provide a better alternative than maintaining the lake at full pull in order to increase spawning in the Ross Lake system. It is also recommended that the carrying capacity of blocked tributaries be estimated prior to barrier removal efforts, since fish resident to tributary streams may fully utilize existing gravels. Migration of spawners into tributaries fully seeded with resident trout would not necessarily increase the Ross Lake system's trout production.

3.4.2 Inundation of Spawning Redds

Studies of egg and embryo survival in rainbow trout redds in lower sections of Ross Lake tributaries suggested that low survival occurred when redds were inundated by rising lake waters. These studies were summarized in Johnston's 1989 report on the Ross Lake fisheries. The studies indicated that water velocities through redds declined substantially after inundation, resulting in high mortality rates of eggs. Recent studies conducted for the City suggest that sedimentation, rather than decreased velocity due to inundation, is more responsible for high mortality rates in tributary sections below full pool elevation (SCL, 1989). These latter studies found egg mortality to be low within inundated gravels as long as sediment concentrations were not high. Higher mortality was observed in tributary sections having a high sediment load. Thus, egg and embryo mortality may be more a function of tributary sediment load, and not lake level. This observation is substantiated by numerous studies in logged streams which indicate that sedimentation is a leading factor of egg and embryo mortality. Egg mortality would be expected to be higher regardless of sediment load if velocities through gravels were minimal. However, studies indicate that velocities are maintained to a certain extent by stream currents in gravels inundated by the lake.

3.4.3 Outmigration During Spill Events

Johnston's (1989) report suggested that spills at Ross dam could have significant impacts on Ross Lake trout populations because of outmigration and passage mortality. This conclusion was based on the recovery of 14 tagged fish from Ross Lake which were recovered below Ross dam after a continuous spill which occurred between May 22 and July 20, 1972. Calculations employing the number of tagged fish found below the dam, tag recovery success, and number fish tagged in the lake indicated that 16,000 fish were lost from the lake during this spill. This number is suspect due to the small sample size of fish used for extrapolation. Even so, it should be emphasized that the 1972 event was one of two extreme spill events which occurred over a fifty year period. The other spill event occurred during the 1833-34 water year. These two spill events account for 40 percent of the total volume of water spilled during a fifty year period. Consequently, it should be recognized that loss of fish from Ross Lake during spill events is currently very infrequent, and is not likely to have a detrimental effect on long-term trout populations, if current operations are maintained.

Hydrological simulations for Ross Lake early refill alternatives indicate that the number of major spills would significantly increase with earlier filling of the reservoir, particularly when higher lake elevation levels were maintained (see Section 4.4). For example, refilling to 1601.5 ft on June 15 (Alternative 3) would result in 7 major spills over a fifty year period of simulation. Moreover, refilling to 1601.5 ft on May 31 (Alternative 6) would increase the the number of major spills to 34 over the fifty year period. This frequency of major spill events could have significantly detrimental impacts on lake fish populations.

3.4.4 Reduced Trout Production in Ross Lake

Declining trout production in Ross Lake has been a major concern of fish managers and recreationists. The reason for declining production has not been determined, though declining primary production, overfishing, and operation of Ross Lake (e.g., spill mortality) have been indicated by resource agencies as possible contributing factors. Johnston's (1989) report provides documentation for this decline in production mainly from catch-per-unit-effort (i.e., fishing success) records, which Johnston contends is a good indicator of total trout production in the lake.

Fishing success records from Johnston's report are presented in Figure 3-3, and provide much insight to the fish production "problem" in Ross Lake. Angling success has progressively declined from 1941 to 1983, and has been approaching a stable (asymptotic) level of about 2 fish per day since the late 1960s and early 1970s. In reference to these data, speculation that Ross Lake is on the verge of a population "collapse" is unfounded.

Since the relationship between angling success and time is curvilinear, the log-log plot in Figure 3-4 best describes this for regression purposes. Angling success has predictably declined with time, with very little deviation from the regression line (R-squared of 0.83). Consequently, factors such as catch regulations and lake operation, which vary discretely from one year to the next, are not likely to be responsible for a progressive decline in fish production. It cannot be said that the angling success data support the conclusion that angling pressure directly affects angling success, due to the lack of such a relationship in Figure 3-5.

Factors which more likely explain this decline are those which incrementally change over time, such as primary production. Progressive stabilization of the watershed after logging of the reservoir area would result in lower inputs of nutrients, dissolved organic carbon, and particulate organic carbon from year to year. Resulting declines in lake primary and secondary production could provide an explanation for the temporal pattern in trout populations observed in Ross Lake.

3.5 SUMMARY ASSESSMENT

3.5.1 Downstream Fishery Resources

On balance, any of the early refill alternatives evaluated in this analysis would have adverse effects on downstream fishery resources. Estimated effects on salmon runs are consistently negative across all alternatives, while steelhead could be positively or negatively affected (compared to current operations), depending upon the month of spawning. The degree of change would vary, with the largest negative effects associated with the most aggressive early refill scenarios.

The analysis indicated that pink and chum salmon runs would be negatively affected, to a minor degree, by all early refill alternatives. Chinook salmon and March steelhead would be essentially unaffected by early refill. April steelhead would be affected negatively by three of the June refill cases (slightly), positively affected (slightly) by one May 31 refill case, and not affected by the other alternatives. May steelhead would be affected positively, by up to 21 percent in total average run size, by all early refill alternatives.

The small negative effects on pink and chum salmon involve large numbers of fish, while the small positive effects on steelhead involve small numbers of fish. Because salmon are collectively so much greater in number relative to steelhead, the net balance of salmon decreases against steelhead increases is an overall decrease in total fish for every early refill alternative. Refill cases based on original license minimum flows of 1000 cfs have significantly greater negative effects on spawning protection and potential run sizes.

The results cited above are all based on potential changes from current Ross Lake operations, which reflect the current negotiated minimum and maximum flow provisions. However, the Interim Agreement is a temporary settlement that will be replaced by a new long-term agreement negotiated through the Skagit Project relicensing process. The City has been involved in studies and negotiations with the fisheries agencies and tribes for several years since the development of the Interim Agreement. These activities will probably result in changes to the negotiated flow requirements that would likely have significance to the lake level analysis.

Among other issues, the negotiations have focused on requests by the fisheries interests to increase the levels of spawning protection provided by Skagit Project releases. To illustrate the potential effects of a long-term flow agreement on the lake level analysis, the City repeated the prior FISH-POWER model operations using flow constraints incorporated within a flow agreement proposal currently under consideration. The calculated protection levels resulting from this sensitivity test are reported in Table 3-6.

Comparing the base case figures to those in Table 3-4 indicates that the new flow regulation proposal would result in increased protection levels for all runs, particularly for April and May steelhead, relative to the Interim Agreement flow regulation. With no other changes in current operations, base case protection levels for the three salmon species would increase by up to 4 percentage points. Steelhead protection levels would rise from 86.6 percent to 94.8 percent for April, and from 50.3 percent to 75.2 percent for May.

Table 3-6. Averaged spawning protection levels (percent of redds protected), for 8 refill scenarios, using proposed long-term minimum flow constraints. (1)

	Fish Run					
Refill Scenario	Chinook	Pink	Chum	March Steelhead	April Steelhead	May Steelhead
Proposed Base Case(1)						
1602.5 July 31	99.9	97.1	94.9	97.7	94.8	75.2
Early Refill Scenarios (1)						
Alt2, 1592 June 30	99.9	97.1	94.5	95.2	92.1	75.4
Alt1, 1601.5 June 30	99.9	96.8	92.5	92.5	89.3	78.6
Alt5, 1580 June 15	99.9	96.9	92.5	93.7	90.4	80.0
Alt4, 1592 June 15	99.8	96.1	90.7	93.5	90.9	80.7
Alt3, 1601.5 June 15	99.8	95.2	90.2	94.4	91.7	81.8
Alt7, 1592 May 31	99.8	94.4	89.5	94.7	92.2	78.6
Alt6, 1601.5 May 31	99.7	93.3	88.9	95.0	92.5	78.2

(1) Protection levels based on current proposed set of long-term flow regulation conditions, one of which provides for minimum flows as high as 2600 cfs when water is available to support downstream fishery needs.

Source: SCL, 1990.

The percentage values in Table 3-6 are incrementally higher than the corresponding percentages from the original analysis in all cases. However, there are some differences in performance among the refill scenarios with the new flow proposal substituted for Interim Agreement flows. With the new flow proposal, chinook salmon protection levels for Alternatives 3, 4, 6 and 7 are slightly lower than in the base case, whereas no difference was calculated in the original analysis. Similarly, pink salmon protection levels in Table 3-6 range from 97.1 percent down to 93.3 percent, which is more than double the respective range in Table 3-4. The chum salmon percentages in Table 3-6 also cover a wider range below the base case than in the original analysis. The base case would provide a higher protection level for April steelhead than any of the early refill alternatives, unlike the situation with the original analysis The early refill alternatives would still improve protection levels for May steelhead compared to the base case, but the magnitude of change would be no more than 9 percent, compared to a maximum increase of 21 percent shown in Table 3-4.

The fish run size calculations that are companion to Table 3-6 are presented in Table 3-7. These figures reflect what the run sizes could be with the proposed set of flow regulation conditions, given existing run sizes and the ratio of existing (base case) protection levels to the protection levels indicated in Table 3-6. The run size calculations for this set of refill scenarios are also illustrated graphically in Figure 3-6.

The proposed long-term flow agreement was calculated to allow potential total fish runs averaging up to 1,274,700 fish per year (with the current refill target), or 52,200 more fish per year than the current operation under the Interim Agreement. With this higher base and a wider range in protection levels across the refill scenarios, the net changes in total fish shown in Table 3-7 are larger in most cases than the corresponding data from Table 3-5. The calculated net changes from the base case refill scenario under the proposed flow agreement include one case, Alternative 2, which shows a net increase in fish runs; the potential increase in this case is 4,100 fish. For the other six alternatives included in this analysis, the results range from losses of 1,900 fish to 48,600 fish. The corresponding figures from Table 3-5, reflecting early refill changes under the Interim Agreement flows, ranged from losses of 1,100 to 17,000 fish. Consequently, under the proposed flow agreement the negative effects of early refill on potential anadromous fish runs could be up to three times as large in absolute terms compared to the effects under the current Interim Flow Agreement, except for the possible beneficial effects of Alternative 2.

The proposed flow levels contemplated in the foregoing analysis are not final. Negotiations between the City and the fisheries agencies and tribes have resulted in a downstream anadromous fisheries flow plan that increases fisheries protection levels beyond those provided for in the Interim Agreement. This flow plan is very similar to, and a minor refinement of, the proposed flow agreement assessed above.

Taken as a whole, these data suggest that the magnitude of the negative effects of early refill on spawning protection levels will be greater in the future under the long-term flow agreement that is likely to be implemented. Given that such an agreement will be more protective of fishery resources than the current Interim Agreement, adoption of a new flow regulation program will establish a higher baseline condition against which early refill scenarios would be evaluated. The operative comparison would still be the refill

Table 3-7. Potential average run size for 8 refill scenarios, using proposed long-tem minimum flow constraints. (1), (2)

Refill Scenario	Fish Run: Chinook	Pink	Chum	March Steelhead	April Steelhead	May Steelhead	Total Fish	Net Change From Base Case
Proposed Base Case								
1602.5 July 31	34,100	1,084,700	141,100	900	5400	8,500	1,274,700	—
Early Refill Alternatives								
Alt2, 1592 June 30	34,100	1,084,700	140,600	1000	6000	12,400	1,278,800	4,100
Alt1, 1601.5 June 30	34,100	1,081,600	137,500	1000	6000	12,000	1,272,200	-2,500
Alt5, 1580 June 15	34,100	1,082,600	137,500	900	5800	11,900	1,272,800	-1,900
Alt4, 1592 June 15	34,100	1,073,300	134,900	900	5700	11,600	1,260,500	-14,000
Alt3, 1601.5 June 15	34,100	1,063,900	134,100	900	5700	11,400	1,250,100	-24,600
Alt7, 1592 May 31	34,100	1,054,600	133,200	900	5700	11,300	1,239,800	-34,900
Alt6, 1601.5 May 31	34,100	1,042,100	132,200	900	5600	11,200	1,226,100	-48,600

(1) Potential run size based on index of redd protection levels from Table 3-6 to base case protection levels in Table 3-4, multiplied by existing average run size.

(2) Refill scenarios based on current proposed set of long-term flow regulation conditions, one of which provides for minimum flows as high as 2600 cfs when water is available to support downstream fishery needs.

alternatives relative to the base case, and the relative differences would be greater with the proposed flow agreement. Consequently, the negative fishery effects identified in Section 3.3.3 are actually understated (in all but one case) compared to changes from the future baseline condition.

3.5.2 Reservoir Fishery Resources

Due to more limited available information, the reservoir fishery assessment does not offer the level of detail or support provided for downstream fisheries. The extent of the analysis is essentially to identify likely or potential directions of change for four specific issues associated with early refill.

The most significant reservoir fishery issue, at least in terms of past attention, is probably access to tributary streams for spawning. The study concluded that early refill of Ross Lake could facilitate passage of spawning fish past barriers near tributary mouths, but the potential gain would be only a small fraction of the total spawning habitat now available. Furthermore, this positive change would be at least partially offset by inundation of spawning redds in the lower reaches of tributary streams. The likely balance of these gains and losses is unknown, but the affected area involved and existence of competing forces suggest that the magnitude of any net change would likely be small.

The third identified mechanism by which early refill could affect the reservoir fishery is flushing of adult fish from the lake during spill events. A large number of fish are projected to have been lost from Ross Lake during a major spill in 1972. The exact circumstances of this spill have not been defined, nor has it been determined whether a spill of similar dimensions under current operating practices would have similar flushing effects on fish. However, it is clear that early refill would significantly increase the frequency and volume of spill at Ross, and that any resulting effect on the reservoir fishery would be negative.

The final issue addressed in the reservoir fishery assessment did not involve a specific early refill effect, but rather the possible cause(s) of the documented decline in Ross Lake trout production. As indicated in Section 3.4.4, this decline is probably attributable to some long-term environmental change, and not to fluctuating water conditions that vary considerably from year to year.

Considering all four resident fishery issues, the primary conclusions are that the existing refill pattern is probably not the cause of the fishery decline, and that early refill would involve two potential negative changes and one potential positive change, none of which would have significant effects in the Ross Lake trout population. The net balance of these effects may be either positive or negative, but the degree of gain or benefit to the resident fishery from early refill is almost certain to be very small.

4.0 POWER GENERATION

The third major component of the Ross Lake level study was the analysis of the effects of early refill on the generation of electric power from the Skagit Project plants. This analysis was the most complex part of the lake level study, as it involved extensive computer analysis of hydrologic data and a mathematical model simulating the operation of the Skagit Project. This model was iteratively operated for each of 13 potential refill scenarios, producing specific results for lake levels, streamflows, power generation outputs, and spill volumes over a 50-year period of record. This process allowed the identification of any changes in power generation levels, relative to current operations, associated with each specific early refill alternative.

As in previous chapters, study methods for this analysis are summarized in Section 4.1 and baseline conditions relative to power generation are described in Section 4.2. A detailed discussion of the construction and operation of the simulation model used in the analysis is provided in Section 4.3. The basic results of the 13 refill cases analyzed are presented in Section 4.4 and are compared with respect to key output parameters in Section 4.5. The economic aspects of the power generation results are described in Section 4.6, and a summary of the complete analysis is provided in Section 4.7.

4.1 STUDY METHODS

The analysis reported here examines the interactions between changes in refill scheduling for recreational enhancement and the use of the water resource for electric energy production. Under current operations, the City attempts to refill Ross Lake to full pool, 1602.5 feet of elevation, by July 31 of each year. The full pool level is then, under normal conditions, maintained through the end of August. This is normal operation of the reservoir and defines the *base case* referred to in the analysis of early refill alternatives.

The City is obligated to follow this operating pattern under the terms of the Pacific Northwest Coordination Agreement (BPA et al., 1964). The coordination agreement is a contractual arrangement among the sixteen organizations that operate major generating resources in the Pacific Northwest. The agreement went into effect in 1965 and extends through June 30, 2003. This contract is designed to coordinate planning and operations in order to maximize the firm load carrying capability of the region's generating resources. The foundation of this arrangement is mutual support through the interchange of energy between the various parties. These interchanges (wheeling) allow the displacement of thermal energy by hydroelectric power and provide emergency stand-by capacity.

In addition, provisions of the coordination agreement are designed to compensate for the effects of water conditions that can vary widely between the different hydrologic areas within the region. This coordination is achieved through contractual provisions for the planning and operation of individual hydroelectric projects. Under the agreement, each party is entitled to a firm load capability equal to its hydroelectric generation capability in the critical streamflow period (defined in the agreement) with full upstream storage release. (There are certain exceptions for reimbursement of Canadian Treaty benefits and restoration of generation losses to any party which result from the Treaty. The Canadian Treaty is a separate, mutually beneficial agreement governing water storage on the hydrologic system. It is beyond the scope of this report.)

In order to satisfy these entitlements, formal elevation schedules have been developed for the operation of each hydro project under adverse water conditions. These schedules are known as "Proportional Draft Rules." When adverse water conditions threaten the ability of the system to maintain firm load, these rules are put into effect in that period. The imposition of a Proportional Draft Rule in a given period for a particular reservoir is known as a "Proportional Draft Point," or PDP. PDP is an end-of-period target elevation for the reservoir. When PDP is imposed, the party owning the resource is obligated to draft the reservoir to PDP or, alternately, to supply the equivalent amount of energy to the coordinated system from other sources.

The coordination agreement provides a major portion of the guidance or constraints under which the City operates Ross Lake and the remainder of the Skagit Project. However, a number of other significant factors also govern project operations and the level of Ross Lake at any given time. These include flood control requirements imposed by the U.S. Army Corps of Engineers, minimum streamflow levels negotiated with fisheries agencies and Indian tribes, the level and timing of customer power demands, other City contractual obligations, and the need for periodic maintenance of project facilities. Finally, there are also absolute physical limits on lake levels and downstream releases represented by the size and configuration of the three project dams and reservoirs.

Realistic evaluation of the power generation effects of early refill requires simultaneous consideration of all of these operating constraints and objectives. This can only be accomplished through use of a complex mathematical model that accurately represents the physical dimensions of the system, specifies in numerical terms all of the various constraints or objectives applied to project operation, and stipulates the priority or order of precedence for all of these factors. The model used to implement this analysis is a power planning model developed several years ago by the City, termed the HYDRO model. Details concerning inputs to and operation of the HYDRO model are provided subsequently in this section and Section 4.3. Documentation of the model itself is available through the City (SCL, undated).

The philosophy of the current study differs from previous studies of early refill. By agreement among the City and the relicensing process intervenors, one major premise of this analysis is that early refill alternatives that have no impact on firm energy production will be evaluated. A previous study conducted by the City (SCL, 1988) modeled early refill as an absolute constraint, resulting in significant impact on firm energy production. The previous studies found the costs associated with reduced firm energy production to be extremely large. This study models early refill as a *self imposed* constraint, allowing early refill to be sacrificed for firm energy production during periods of low water conditions. Under the design of this study, PDP requirements take precedence over satisfying early refill targets.

Two major criteria for structuring any analysis are validity and usefulness. In order to satisfy these criteria the analysis is designed around three basic considerations. These are:

(1) The analysis must address the impacts of early refill under a variety of water conditions, represented by actual hydrologic data for the Skagit River system over an appropriate period of historical record.

(2) The analysis must examine several possible refill strategies.

(3) The lake levels analysis must reasonably represent hydroelectric plant operations.

These considerations form the basis for the technical approach used in this study. Each is addressed in detail below.

4.1.1 Hydrologic Data for the Analysis

In order to address a representative range of possible water conditions, the HYDRO program analyses of refill alternatives were conducted with a hydrologic database covering 50 years of historical record. The period of record for these water conditions extends from July 1, 1928, through June 30, 1978. The 1928 beginning of this database is necessary to incorporate the "critical period" used as a standard in Northwest power planning, which extends from September 1928 through February 1932. This 42-month period of low-water conditions represents the minimum long-term water availability for power generation, and therefore the basis for determining the firm power capacity for each generating resource. The 1928-1978 period covers the full range of streamflow conditions for the Skagit River, including periods of drought, below normal, normal, above normal, and flood conditions. Activities involved in developing and applying this 50-year hydrologic database are summarized below.

4.1.1.1 Data and Information Sources

Watershed and flow data for the Skagit River are available from several sources, including the U.S. Geological Survey (Williams, 1984, USGS, various years), the Washington State Department of Ecology (Drost, 1978) and Seattle City Light's internal flow records and power production records. Drost's work provides an excellent description of the hydrologic and climatologic setting of the Skagit River. Data on specific watershed characteristics including forest cover, pondage, average elevation and other parameters are available from a USGS open file report (Cummans, 1975).

Climatic data on precipitation, temperature, and snowpack exist for various years, and are generally published by the National Oceanic Atmospheric Administration through the National Climatic Data Center (NCDC, various years). Older records were published by the U. S. Weather Bureau (USWB, various years). The Soil Conservation Service maintains an online data service that includes snowpack data, flow data and climatologic data (SCS, 1988)

4.1.1.2 Database Preparation

To model early refill scenarios, it was determined that inflow data would be required on a monthly basis for the period September through February and on a semimonthly basis for the period March through August. The semimonthly breakdown permitted the evaluation of a greater number of early refill scenarios and was also useful for developing a regression analysis of the relationship between forecast flow and previous flow and climatic conditions.

Natural inflow data were required for four locations for the HYDRO model and one additional location for the FISH-POWER model. Locations included natural inflow to Ross Lake from the 999-square mile tributary area around the lake, and the downstream areas between Ross dam and Diablo dam (126 square miles), Diablo dam and Gorge dam (34 square miles) and Gorge dam and Newhalem (16 square miles). Inflow between Gorge dam and Newhalem was used as a data check. Natural inflows between Newhalem and Marblemount were required on a daily basis and were synthesized from Cascade River flow data (USGS gage 12182500) for years when the accretion data from Newhalem to Marblemount were unavailable from the historic record (See Table 4-1 for available data for Skagit River at Marblemount).

The computation of natural inflow into Ross Lake is fairly complex. The City had developed daily flow values for the period 1945 through 1978 and monthly flow data for the entire period of interest (July 1928 through June 1978). These values were reviewed, and, in some cases, corrected. Inflow had been estimated based on power production records and recorded Ross Lake elevations. Evaporation was implicitly included as a loss to natural inflow, such that natural inflow is herein defined as net natural inflow after evaporation losses. An adjustment for evaporation was made for flow records prior to the operation of Ross dam and also during the initial filling period.

Semimonthly flow data prior to 1945 was developed from USGS records. Table 4-1 summarizes USGS gages and corresponding period of record available. Almost all the flow data indicated in Table 4-1 were used to develop or verify the flows used in the HYDRO model. Key gages used in the development of accretions between Ross dam and Newhalem included Thunder Creek, Stetattle Creek, Newhalem Creek and Skagit River at Newhalem. Though Newhalem Creek is below the Newhalem gage, its data proved useful for estimating flows for the ungaged tributaries south of the Skagit between Diablo dam and Newhalem.

4.1.1.3 Regression Analysis for Flow Forecasting

Current practice at the City is to use several snow courses to develop data on water equivalency throughout the watershed. These data are used to develop forecast equations from past records and regression analysis to forecast the seasonal and monthly distribution of runoff. The oldest continuous snow courses were established after World War II and several others have much shorter records. Currently 15 snow courses are in use, but earlier years in the period of interest had fewer snow courses or none at all.

It is important in running the HYDRO model to capture the effect of runoff forecasting and timing, particularly when evaluating early refill scenarios. With refill targeted for August, there is a high probability that most snowmelt will have occurred by then. Refill forecasting in May or June is subject to greater error. It was necessary to develop an alternative forecasting approach with comparable estimating errors that included the complete period of interest, herein referred to as the hydrometeorological approach.

Table 4-1. U.S. Geological Survey historical stream gage data.

USGS GAGE NUMBER	DESCRIPTION	DRAINAGE AREA (SQ. MI.)	LATITUDE (1)	LONGITUDE (2)	AVERAGE ANNUAL FLOW (CFS) (3)	START PERIOD OF RECORD	END PERIOD OF RECORD	YEARS OF RECORD (4)	MISSING YEARS
12171000	LIGHTNING CREEK NEAR NEWHALEM, WASH.	129.0	485330	1205850	299	OCT 1943	MAY 1948	5	
12171500	SKAGIT RIVER AB DEVILS CR NR NEWHALEM, WASH.	655.0	485030	1210220	1,514	APR 1940	SEP 1945	6	
12172000	BIG BEAVER CREEK NEAR NEWHALEM, WASH.	63.2	484640	1210420	417	MAR 1940	SEP 1969	16	OCT '48-OCT '63
12172500	SKAGIT RIVER NEAR NEWHALEM, WASH.	780.0	484450	1210150	2,660	MAR 1930	MAR 1940	11	
12173000	GRANITE CR NR NEWHALEM WASH	71.0	484140	1205330	177	OCT 1946	APR 1948	2	
12173500	RUBY C BELOW PANTHER C, NR NEWHALEM, WASH.	206.0	484230	1205810	714	SEP 1948	SEP 1969	15	OCT '56-SEP '62
12174000	RUBY CREEK NEAR NEWHALEM, WASH.	210.0	484320	1210030	610	JUN 1919	MAY 1949	24	APR '20-AUG '28
12174500	SKAGIT R BELOW RUBY C, NEAR NEWHALEM, WASH.	999.0	484420	1210340	3,178	JUN 1919	SEP 1930	12	
12175000	ROSS RESERVOIR NEAR NEWHALEM, WASH.	999.0	484358	1210402	NA	MAR 1940	PRESENT	28	
12175400	THUNDER CR BLW MCALLISTER CR NR NEWHALEM, WASH.	91.7	483800	1210300	608	OCT 1957	SEP 1962	5	
12175500	THUNDER CREEK NR. NEWHALEM, WASH.	105.0	484022	1210418	609	OCT 1930	PRESENT	59	
12176000	THUNDER CREEK NEAR MARBLEMOUNT, WASH.	114.0	484230	1210600	663	MAR 1919	SEP 1930	12	
12176500	DIABLO RESERVOIR NEAR NEWHALEM, WASH.	1,125.0	484256	1210752	NA	OCT 1929	PRESENT	9	
12177000	SKAGIT R AT REFLECTOR BAR, NR NEWHALEM, WASH.	1,125.0	484250	1210830	4,260	DEC 1913	SEP 1922	9	
12177500	STETATTLE CREEK NEAR NEWHALEM, WASH.	22.0	484320	1210858	184	JAN 1914	SEP 1984	53	APR '14-NOV '14 MAY '15-SEP '33
12177700	GORGE RESERVOIR NEAR NEWHALEM, WASH.	1,159.0	484153	1211225	NA	JUN 1960	PRESENT	9	
12178000	SKAGIT RIVER AT NEWHALEM, WASH.	1,175.0	484019	1211442	4,411	OCT 1908	PRESENT	75	JUN '14-SEP '20 IN WA STATE WSB 6
12178100	NEWHALEM CREEK NR. NEWHALEM, WASH.	27.9	483922	1211414	176	JAN 1961	PRESENT	29	
12179000	SKAGIT RIVER ABV ALMA CR, NR MARBLEMOUNT, WASH.	1,274.0	483627	1212137	5,391	OCT 1950	PRESENT	39	
12179800	SKAGIT R. ABOVE BACON CREEK NEAR MARBLEMOUNT WA.	1,289.0	483510	1212311	4,928	APR 1977	SEP 1983	7	
12180000	BACON CREEK NEAR MARBLEMOUNT, WASH.	50.9	483520	1212340	424	AUG 1943	SEP 1950	8	
12181000	SKAGIT RIVER AT MARBLEMOUNT, WASH.	1,381.0	483135	1212540	5,957	SEP 1943	PRESENT	20	AUG '44-SEP '46 OCT '51-APR '76
12182500	CASCADE RIVER AT MARBLEMOUNT, WASH.	172.0	483137	1212450	1,031	OCT 1928	SEP 1980	52	

(1) FIRST TWO DIGITS ARE DEGREES, NEXT TWO ARE MINUTES, FINAL TWO ARE SECONDS
(2) FIRST THREE DIGITS ARE DEGREES, NEXT TWO ARE MINUTES, FINAL TWO ARE SECONDS
(3) AVERAGE ANNUAL FLOW FROM EARTHINFO USGS DAILY VALUES COMPACT DISK
REFLECTS HISTORICAL REGULATED SKAGIT RIVER FLOWS AFTER 1929 ON THE SKAGIT BELOW DIABLO
(4) PARTIAL WATER YEARS ARE COUNTED AS A YEAR OF RECORD

To accomplish this objective, the flow database was expanded to include average period maximum and minimum temperature at 4,000 feet elevation, total precipitation (based on Concrete, Diablo and Ross dams) and a representative May 1 water equivalent snowpack (developed from various locations in the Skagit watershed as well as from Mount Baker). The regression equations were developed using all available data from July, 1928 through June, 1987 and in some cases estimates of missing data based on other locations. Standard errors slightly lower than the current multi-station snow course approach were computed and the flow forecasts and standard error from the hydrometeorological approach were implemented on the model. The hydrometeorological approach uses information that would be available to a future forecaster at the time the forecast is to be made, and no prior knowledge or forecast of future meteorological conditions is required. The only requirement is a long period of climatological and streamflow data. Earlier work by Tangborn (1976) confirmed the validity of this approach.

4.1.2 Refill Strategies Examined in the Analysis

A number of alternative operating scenarios are examined in this analysis. All alternative scenarios involve achieving and maintaining some specific lake level prior to the current target refill date. A base case is included in the analysis as a control and basis for comparison. This base case involves refilling to elevation 1602.5 feet (full pool) by July 31, operating under the current minimum flow requirements of the project license.

Under each of the alternative scenarios, refill to full pool by July 31 is still required once the early refill target has been achieved. The schedule of refill target dates and target elevations for the alternative scenarios and the base case is shown in Table 4-2.

Table 4-2. Schedule of target dates and elevations defining scenarios.

Target	----------------Target Refill Elevation (feet)---------------			
Refill Date	1580.0	1592.0	1601.5	1602.5
May 31		●	●	
June 15	●	●	●	
June 30		●	●	
July 31				●

Current operations of the Skagit Project are subject to restrictions on minimum streamflows downstream of the project that have been negotiated between the City and the fisheries agencies and affected Indian tribes. These minimum flows are stipulated in the Skagit Interim Flow Agreement (FERC, 1981), which was initially implemented in 1981 and modified slightly in 1984. The initial set of refill scenarios (the base case and seven refill alternatives) were analyzed using Interim Agreement flows as constraints in the HYDRO model. A second set of four alternatives using the minimum flows originally specified in the FERC license for the Skagit Project was also evaluated, to test the sensitivity of model results to changes in flow constraints. Consideration of refill alternatives employing relaxed flow constraints was specifically requested by the intervenors. In review of the draft lake levels report during early 1990, the intervenors also requested that the HYDRO model be operated on the basis of the flow requirements of the settlement agreement being negotiated at the time. Results of this additional alternative are included in the final report.

4.1.3 Representing Actual Operations in the Analysis

In order to reasonably represent projected Ross Lake levels, operation of the Skagit Project must be simulated as close as possible to the manner in which the project would actually be operated. In the real world, these plants are operated as an integrated system. Operation of Ross is, in part, governed by the effects any given action will have upon downstream plants. The combined software and datasets used for this project simulate operations at Ross and both downstream plants. The simulation focuses on Ross as the *primary* plant (furthest upstream) because release from its reservoir is a major determinant of flow at Diablo and Gorge.

Further, the simulated operation of Ross follows the methods actually used to make operating decisions as closely as possible. The primary rules governing operation at Ross are schedules of elevation levels by operating period. These schedules are generally referred to as "rule curves." The primary rule curves impacting this analysis are:

- The Variable Energy Content Curve (VECC) which defines the *lower bounds* for acceptable operating elevations; and,

- The Flood Control Curve (FCC) and Spill Control Curve (SPCC) which, together, define the *upper bounds* for acceptable operating elevations.

These rule curves are defined and fully explained in Section 4.3. The VECC, FCC, and SPCC are tabulated and utilized much as they would be in real world operations. In addition, other constraints (license requirements, contractual agreements, etc.) and practical considerations are encompassed in the simulation methodology. The overall relationship among these various parts of the simulation process are represented schematically in Figure 4-1. Each early refill strategy is modeled separately as an additional constraint on the simulated operation of Ross Dam.

In keeping with the goal of realistic modeling, none of the simulations use information that would not have been available to the City. That is, in each historical period being simulated, data for subsequent periods are treated as unknown. Where necessary, reasonable forecasts (that could have been made at that point in time) are used for simulated operations planning.

There are some unavoidable differences between real world operation and the simulations. Real world operation may be characterized by the following:

- Nearly instantaneous control over streamflow at Ross
- Nearly instantaneous feedback from downstream plants
- Frequent update of rule curves derived from snowpack and run-off data (VECC and SPCC) as new data become available

Conversely, simulated operation of the Skagit plants may be characterized by the corresponding points:

- Average daily streamflows are used for each period in the analysis
- Feedback from downstream plants is modeled by iterative application of the simulation software over the streamflow data
- Rule curves (VECC and SPCC) are derived from the best possible forecasts
  - Forecasts are made using regression models from cleaned and balanced streamflow data
  - Disaggregate time periods (18 periods per year) are used for finer control during the refill season

The simulation software consists of the City HYDRO model for simulating power plant operations and both preprocessor and postprocessor software. This ancillary software was developed by SRC specifically for the simulations required by this project. In addition, the SRC staff made two modifications to the HYDRO model.

The HYDRO model estimates released flow, reservoir elevation, energy production, and spill for each operating period. These estimates are produced by relatively simple algorithms which embody the physical and engineering characteristics of each plant. The primary inputs required by the HYDRO model are streamflow, minimum allowable flow, minimum and maximum allowable elevation, and desired operating level (for each period of operation). The desired operating level for the primary plant (Ross) is either input as a fixed elevation (used for PDP) or as a desired level of outflow (used for normal operation). The desired operating level may be modified by the model according to the interaction of the constraints and other inputs.

SRC's modifications to the HYDRO model were required because of the structure of the model and the requirements of the study. The City model was developed for a UNIVAC mainframe and was later converted by City staff to run on IBM-PC compatible microcomputers. The PC version of the HYDRO model, as delivered to SRC, routed all simulation results directly to the PC's parallel port in line printer format. The first major modification made was to reroute all output to disk files. This was necessary for postprocessing as well as for compiling the tables and figures appearing in this report.

The second modification was the enhancement of the source code governing restrictions to operation of hydro projects with reservoirs (as opposed to "run of river" plants). This was required both because of the way the project team chose to apply the simulation model and because of data problems encountered in the simulations. The project team elected to use minimum elevations compiled from the rule curves listed above as a model input. The model was modified to allow the *minimum operating elevation* to be violated when necessary to maintain required fisheries flow. Previously, the minimum elevation specified was taken as absolute by the model. This modification made the *physical limits* of the reservoir absolute and gave fisheries flow inputs precedence over the minimum operating elevation inputs. This allowed the model to better represent actual operations than was previously possible.

As noted above, conflicts arising between rules are solved by imposing *precedence* of the individual rules. The modifications to the HYDRO model solved another frequent problem, excessive spill. Often this problem arises because simulated operation under PDP requires drafting the reservoir so far below the ending elevation of the previous period that part of the released water cannot be used for generation. The root of this problem is that the PDP levels used are not derived directly from the streamflow data used for the simulations. PDP levels are derived from the flow data used by the Northwest Power Pool, which represent Columbia River basin conditions. These data do not precisely match the streamflow data used in the simulations.

The postprocessor and preprocessor software is designed to minimize this problem. Spills are detected in the output file by the postprocessor and recorded as an input matrix for the preprocessor. The preprocessor sets up the input files for the HYDRO model. Wherever spill occurred in a previous simulation run, the preprocessor overrides PDP control of Ross and changes the input file to run the simulation with a spill avoidance outflow level. The spill avoidance outflow level in any period is dependent upon the maximum capacity of downstream plants, as corrected for maintenance outages and downstream accretions in flow. Iteration continues until no *new* spill is found in the HYDRO model output.

4.2 EXISTING CONDITIONS

4.2.1 Skagit Project Plant Descriptions

4.2.1.1 Ross Plant (SCL, 1985)

The Ross plant is located on the Skagit River in Whatcom County, Washington (N 48° 43' 49", W 121° 04' 12"). Construction of this plant was begun in September 1937, and continued in three stages. The third step of the dam was completed June 30, 1949, and accepted by the City on August 18 of the same year.

The Ross plant is an arch-type dam made of concrete, 540 feet high from bedrock to surface of the roadway, and 208 feet thick at its base. The first, second, and third steps used 909,214 yards of concrete, creating a spillway crest elevation of 1582 feet. The top of the dam has an elevation of 1615 feet and is traversed by a roadway 1300 feet long.

Twelve radial-type spillway gates, each 20 by 19.5 feet with risers 2.5 feet high, are situated above the spillway crest. The present configuration of the plant results in the following physical operating parameters:

Top of Spillway Gates.. elev 1604.0 ft.
Normal Maximum Pool Level of Ross Lake...................... elev 1602.5 ft.
Minimum Pool Level of Ross Lake .... elev 1475.0 ft.
Maximum Gross Head .... 397.5 ft.
Minimum Gross Head.. 270.0 ft.
Tailwater .... elev 1205.0 ft.

Usable water storage is 1,052,000 acre-feet, with a maximum drawdown of 127.5 feet based on the elevation of the intake invert. The total present capacity of the reservoir with maximum water elevation is 1,435,000 acre-feet. Provisions of the federal license limit the maximum allowable reservoir elevation during the period from October 1 through March 15, in order to provide storage for flood control.

The powerhouse is located on the left bank of the Skagit River, about 1100 feet downstream from the dam. The powerhouse contains four turbines, each rated at 140,000 horsepower (hp) at 150 revolutions per minute (r/min). Ultimate head for this capacity is 440 feet, but actual head will vary with drawdown of the reservoir. Also located in the powerhouse are four generators built by Westinghouse Electric Corporation. Nameplate ratings for each are 100,000 kVA at 0.9 power factor (PF), 13,800 volts, three phase, 60 hertz. No house units are provided at the Ross plant.

Peak capability (in January, with median water) is 90,000 kW for each of the four units , creating a total plant capacity at annual winter system peak of 360,000 kW (360 megawatts [MW]). The maximum plant capability for the Ross Plant at maximum reservoir elevation is 450,000 kW (450 MW). Maximum plant output equals approximate water flow of 16,000 cubic feet per second at full reservoir.

4.2.1.2 Diablo Plant (SCL, 1985)

The Diablo plant is located on the Skagit River in Whatcom County, Washington (N 48° 42' 57", W 121° 08' 24"). Construction of this plant began in 1927 and was completed in late 1929. Its first unit commenced regular service October 20, 1936.

Diablo is a concrete arch dam, 146 feet thick at the base, 1180 feet long at the crest, and 389 feet high. The dam provides 50,000 acre-feet of usable storage (with drawdown to elevation 1125 feet) in Diablo Lake. Since completion of the Ross facility, this storage is no longer drafted. Diablo's reservoir is currently utilized for regulation of discharged water from the Ross plant, for the use of the Diablo and Gorge plants. This results in a typical operating pattern of daily cycling within the range of normal reservoir elevations, with the reservoir drafted to meet daily load peaks and refilled during off-peak hours. Operational constraints involving hydraulic head are as follows:

Normal Maximum Pool Level of Diablo Lake...................... elev 1205 ft.
Normal Minimum Pool Level of Diablo Lake....................... elev 1200 ft.
Normal Tailwater .... elev 875 ft.
Normal Gross Head .... 330 ft.

The Diablo powerhouse is located approximately 0.5 mile downstream of the dam on the right bank and receives water through a tunnel 1900 feet long and 290-foot penstocks.

The powerhouse contains two main turbines and two house units. The main units are rated for 97,000 hp at 171.5 r/min. In 1958, modernization measures increased the output to 108,500 hp from each unit. The two smaller house units are each rated at 2200 hp and 720 r/min. There are two main generators and two house generators as well, manufactured by Westinghouse Electric Corporation. The main units are nameplate rated at 67,000 kVA, 13,800 volts, 2790 amperes, and 0.8 PF, three-phase. The smaller house units are nameplate rated at 1500 kVA, 2400 volts, 361 amperes, and 0.8 PF, three-phase.

Peak capability for the Diablo Plant at maximum reservoir elevation is 78,000 kW each for the two main units and 1,500 kW each for the smaller units, for a total of 159,000 kW (159 MW). Maximum plant output equals approximate water flow of 7,130 cubic feet per second at full reservoir.

4.2.1.3 Gorge Plant (SCL, 1985)

The Gorge plant is located on the Skagit River in Whatcom County, Washington (N 48° 40' 33", W 121° 14' 21"). The federal permit was issued in 1918, and construction begun in 1919. Gorge's first unit began regular service in 1924, but the fourth and final unit did not commence operation until 1951.

The oldest of the three facilities, Gorge has had the most extensive structural revisions. The original crib structure built in 1918 was replaced by a concrete structure in 1950. This concrete diversion dam was in place until 1960, when the present Gorge High Dam was put into operation. The High Dam is a combination concrete thin arch and gravity dam, 300 feet high and 670 feet long.

The Gorge reservoir is 4.5 miles long with a maximum elevation of 875 feet. Usable storage is 6,600 acre-feet of a total capacity of 8,500 acre-feet. Gorge is typically operated in a daily cycling pattern similar to that of Diablo. Operational constraints involving hydraulic head are as follows:

Top of Spillway Gates	elev 875 ft.
Normal Maximum Pool Level of Gorge Lake	elev 874 ft.
Normal Minimum Pool Level of Gorge Lake	elev 865 ft.
Normal Tailwater	elev 495 ft.
Normal Gross Head	380 ft.

The powerhouse, which is located more than 2 miles downstream of the dam, contains four turbines modified to utilize the gross head of 380 feet. Units #21 and #22, originally installed in 1924, were modified in 1959 and re-rated at 45,000 hp. Unit #23 (installed 1929) was modified in 1961 and re-rated at 45,000 hp. In 1960, Unit #24 (installed 1951) was re-rated to 95,000 hp after modification. The new ratings are based on "model test results" and a net head of 325 feet which occurs at full plant output, and take tunnel losses into account as well. In addition, three of the four generators at this plant were modernized (rebuilt with new iron and rewound) in 1982 to upgrade their rating to 38,000 kVA with 0.97 PF. Unit #24, installed in 1951, maintains its nameplate rating of 66,700 kVA, 0.9 PF, and 11,000 volts.

Peak capability is 32,000 kW each for Units #21-#23, and 79,000 kW for Unit #24, creating a total plant capacity of 175,000 kW (175 MW). Maximum plant output equals approximate water flow of 7,440 cubic feet per second at full reservoir.

4.2.2 Typical Operating Pattern

Under normal operation, the (contractual) target refill date for Ross Lake is July 31 with a target elevation of 1602.5 feet, or full pool. Ross Lake is normally maintained at full pool through at least the end of August. Full pool is maintained through Labor Day, if fisheries and energy requirements and streamflow conditions make this possible.

The reservoir is then drawn down consistently over the winter period, September through March, for the production of power and the maintenance of anadromous fisheries runs. Elevations below 1590 are not typically reached until the beginning of November. September and October are usually the months having the lowest natural streamflow, and operation during these months is often driven by fisheries considerations. The highest generation levels are normally November through February, when energy demand is greatest (winter peak). January energy production is typically highest, at around 440 average MW for the entire project. October energy production is typically lowest, slightly below 180 average MW.

Typically, the reservoir reaches its lowest elevation by mid April, somewhere around 1510 feet. The reservoir may be drafted as low as 1475 feet or may end the winter period at a higher elevation, depending upon water conditions. Refill typically begins in mid April and is completed by the end of July. Typical operating elevations for Ross Lake, based on average conditions over the 50-year period of analysis, are shown in Figure 4-2.

Flows on the Skagit River are of most interest at Gorge, where they are directly related to fisheries protection at and below that point on the Skagit. Monthly average outflow levels at Gorge vary throughout the year, typically ranging from 2000 to 5500 cfs (cubic feet per second). Outflow follows the draft and refill pattern at Ross, which is the primary plant on the Skagit. Outflow is typically lowest when high reservoir levels are being maintained (August through October). Conversely, outflow is typically highest during drafting for energy production in November through February. Thereafter, average outflow levels are gradually decreased in order to achieve refill.

On a daily basis, Ross, Diablo, and Gorge are typically cycled to produce maximum energy output during daily peak load hours. Outflow from Ross is usually slowed significantly during the night, in order to facilitate the cycling of Diablo and Gorge, which have very small reservoirs relative to Ross. This daily cycle is not relevant to the modeling and simulations performed in this study.

4.2.3 System Interaction Factors

Electric power systems are operated in a highly integrated manner. Consequently, several levels of system interaction factors influence the operation of any given resource to varying degrees. At one level, the three plants of the Skagit Project are operated as an integrated system, with varying specific objectives applicable to each plant. Skagit Project operations are in turn affected by system interaction factors relative to the remainder of the City system. Additional City generating resources include the Newhalem, Cedar Falls, and Boundary projects, while the City also supplies a sizable minority of its power demand through purchases from the Bonneville Power Administration (BPA). Conditions at Ross Lake are therefore linked to distant circumstances on the Cedar and Pend Oreille rivers and within the BPA system. Through the Coordinated Agreement, Skagit Project operations are also related to the operation of all major generating resources in the Pacific Northwest.

To the extent possible, these system interaction factors are accounted for in the power generation analysis, through the provisions of the HYDRO model. For example, regionwide relationships and commitments are largely represented through the proportioned draft rules. However, it is not feasible in a computer model to explicitly to account for all possible interaction factions that could affect the management of the Ross reservoir.

4.2.4 Water Management

Current and past reservoir levels and streamflows in the Skagit Project area reflect the water management program of the City, as constrained by various operating requirements imposed by or negotiated with other parties. The following sections provide a brief summary of key reservoir level and streamflow characteristics during the period since the various project components were completed. This discussion is based upon actual conditions as measured by the City and the U.S. Geological Survey; subsequent discussions in Section 4.4 and later in this report are based on simulated water conditions over a 50-year period of record.

4.2.4.1 Reservoir Levels

As indicated in Section 4.2.1, Ross Lake is formed by a concrete-arch dam completed to elevation 1,615 ft in 1949. Storage began March 11, 1940 with a normal maximum pool of 1,600 feet. In July, 1967 the taintor gates were raised. Treaty limits the elevation of Ross Lake to 1,602.50 feet, which represents the current maximum normal pool, although the top of the taintor gates is actually at elevation 1,604 feet.

As of water year 1987 (all reservoirs are analyzed through 1987, the latest published USGS Water Resources Data for Washington), the maximum observed Ross Lake elevation was 1,603.23 feet on July 20, 1981. The minimum pool occurred on April 5, 1952 at elevation 1,348.50 feet, prior to filling of the reservoir at the present dam height. The normal minimum pool is 1,475 feet (USGS, 1987). Historical average water conditions for Ross Lake were previously reported in Section 2.2.3. To briefly recap this information, Ross Lake has reached full pool (or at least within 1 or 2 feet) every year since 1967, except for the extremely low-water conditions of 1977. The annual minimum elevation over the last 26 years of record has averaged about 1522 feet, which corresponds to an annual average drawdown reaching 80.5 feet below full pool.

Diablo reservoir is also formed by a concrete-arch dam, completed in 1930. Storage began in October of 1929. The top of the taintor gates is at elevation 1,205 feet, the normal maximum pool. The normal minimum pool is at elevation 1,195 feet. The maximum elevation of 1,206.5 feet occurred on July 14, 1933. The USGS has not determined the minimum pool, however the contents of Diablo reservoir fell to 28,420 acre-feet on the last day of March in 1951, which is close to elevation 1,100 feet based on the City's volume equation for Diablo. Under normal conditions, the level of Diablo Lake currently fluctuates between elevations 1200 and 1205 feet on a daily basis. The normal operating range extended somewhat below 1200 feet prior to 1986, when end-of-day (midnight) elevations between 1197 and 1200 feet were frequently recorded.

Gorge reservoir is formed by a concrete-arch and gravity dam. Storage began on June 27, 1960, though actual completion was December 27, 1960. The maximum water surface elevation in Gorge reservoir was reached on June 1, 1982, when the water level was at 880.01 feet. The minimum pool since 1960 was 819.40 feet on July 20, 1965. The normal pool ranges between elevation 865 feet and the top of gates at elevation 875 feet, although current operation usually keeps the reservoir above elevation 870 feet. Daily records for 1981 through 1987 indicate that ending elevations below 870 feet occurred about 14 days per year, on average.

4.2.4.2 Streamflows

The Skagit River at Newhalem (USGS Gage 12178000) has a continuous period of record dating back to October, 1920 (USGS records from October 1908 through May 1914 also exist, as well as Washington State Water Supply Bulletin 6 monthly records from June, 1914 through September, 1920). The USGS record is characterized as excellent and includes a total of 79 years, and best represents the historical flows which resulted from the operation of the City's three Skagit River hydroelectric projects.

The maximum discharge at Newhalem for the period of record was 63,500 cfs on November 29, 1909. A flood of 115,000 cfs is estimated to have occurred in 1815. A minimum instantaneous flow of 54 cfs was recorded on November 1, 1943. The 79 year long USGS record through 1987 had an average discharge of approximately 4,400 cfs for the 1,175 square mile drainage area. Estimates of flow adjusted for change in the contents of the three Skagit reservoirs are also made by USGS.

Table 4-3 summarizes average monthly flow for USGS Gage 1217800, Skagit River at Newhalem, for water years 1954 through 1987. Water year 1954 was the first normal water year in which Ross Lake filled to elevation 1,600 feet. As indicated in the table, average monthly flows are highest in June and July, when snowmelt runoff usually peaks. December and January also have relatively high average monthly flows, due to the influence of winter rainstorms. Overall, monthly average flows range from about 2,970 cfs in September to over 6,460 cfs in July, and the annual average is over 4,200 cfs.

Table 4-3. Average Skagit River flows at Newhalem, Washington, 1954 to 1987.

Flows in Cubic Feet per Second (cfs) (USGS Gage 12178000)	
Month	Average
Oct	3285.2
Nov	4447.6
Dec	5025.2
Jan	5223.5
Feb	4937.3
Mar	4543.8
Apr	4003.6
May	4047.7
Jun	6334.8
Jul	6464.4
Aug	3890.6
Sep	2971.3
Annual	4204.3

4.3 SIMULATED PROJECT OPERATIONS

4.3.1 Operating Rule Definition

The simulated operation of a hydroelectric plant such as Ross Dam is controlled by a series of constraints, or operating rules. The normal refill target, 1602.5 feet of elevation on July 31, is subsumed into the operating constraints in the form of "rule curves." The various rule curves governing operation essentially describe the upper and lower limits of acceptable operating elevation for different periods of the year. The early refill scenarios are modeled by incorporating their specific refill requirements into the relevant rule curves for each simulation.

Before providing further detail on the simulation process and the various rules of operation, definition of some terms and their abbreviations is necessary. The definitions presented below are intended to be introductory rather than comprehensive. More complete information appears elsewhere in the text and in the attached Glossary.

- Assured Refill Curve (**ARC**): The ARC is a schedule of operating elevations for January 1 through August 31 which, when followed, assures that the reservoir will reach full pool by July 31.

- Critical Rule Curve (**CRC**): The CRC is a schedule of elevations used as a guide for determining operating elevations during critical water periods.

- Energy Content Curve (**ECC**): The ECC is a schedule of *target* operating elevations which normally follows the Critical Rule Curve (CRC) for September through December, and follows the Assured Refill Curve (ARC) for January through August.

- Flood Control Curve (**FCC**): The FCC is an inflexible operating constraint. It delineates the maximum allowable operating elevation for each period. The FCC is imposed by the Army Corps of Engineers through the FERC license for the Skagit Project.

- Proportional Draft Point (**PDP**): Under the Pacific Northwest Coordination Agreement, specific operating elevation requirements may be imposed for each reservoir during any period to assure the firm load capability of the entire Pacific Northwest power system (Bonneville Power Administration, et al., 1964). These periodic operating constraints are Proportional Draft Points.

- Spill Control Curve (**SPCC**): The SPCC is a schedule of operating elevations based on expected inflow and designed to prevent the (wasteful) release of water in excess of that which can be used for electric generation. The SPCC schedule is treated as the *upper bounds* of operating elevations for January through August.

- Variable Energy Content Curve (**VECC**): The VECC is also a schedule of operating elevations based on expected inflow. The VECC defines the expected *lower bounds* of acceptable operating elevations for January through August.

Several of the operating rule curves described above are interrelated. Although the FCC and CRC are predefined, the remaining curves are derived from the streamflow data or forecasts for a particular operating year and from other curves. The interrelationships of the rule curves and data are shown in Figure 4-3. Derivation of the curves as shown in Figure 4-3 proceeds from left to right.

As noted earlier, the VECC, SPCC, and FCC are the primary rules governing normal operation of the reservoir. A typical operating profile for Ross Lake within the bounds of these rule curves is shown in Figure 4-4. The reservoir's highest elevations for the year are maintained during late July and through August. The reservoir is drawn down consistently over the winter period, September through March, for the production of power and the maintenance of fisheries runs. Refill typically begins in April and is completed by the end of July.

4.3.2 Construction of Operating Rules

Some of the operating rules defined above are specified to the City by outside parties, such as the flood control curve and proportional draft points. Other curves are defined in concept by the Coordinated Agreement or other sources, but must be translated into specific elevation schedules through analysis involving water conditions and physical plant characteristics. In order to operationalize all rules for simulation with the HYDRO model, specific elevations had to be computed for the assured refill curve, energy content curve, variable energy content curve, and spill control curve.

4.3.2.1 Computing the Assured Refill Curve (ARC)

The first curve to be derived for the simulations is the assured refill curve (ARC). Normally, the ARC insures that the reservoir refills by July 31 if the third worst annual water conditions on historical record were to be experienced. For the early refill analysis, the ARC is redefined to insure that the reservoir would refill to the target elevation by the refill date *and refill to full by July 31 if the third worst water conditions were to occur.* Thus, the ARC varies by refill date and elevation and there is only one ARC for each alternative scenario. The base case ARC currently in use was available in the 14-period operating year format normally used for regulation. (April and August were subdivided in the 14-period operating year.) For the purposes of this study, an ARC for the 18-period operating year was generated and provides a benchmark for the software developed to compute assured refill curves for each of the alternative scenarios.

The ARCs for the alternative scenarios were derived from the third worst operating year of the 50 years of data *for each early refill period.* For example, the ARC for the May 31 refill case is based on the third worst operating year of the 50 year data set, considering only those streamflows from January 1 through May 31. An additional constraint is placed on the computation, in that the early refill ARC for each scenario is never allowed to fall below the base case ARC in any period.

Computation of the ARC is performed from the target refill date backward, e. g., from May to January for the May 31 scenario. This is done by first computing the volume of water in the reservoir on the refill date (the reservoir volume corresponding to the target refill elevation). The volume of water flowing into the reservoir is then computed for the (preceding) period. This volume inflow is then reduced by fisheries protection (outflow) requirements for the relevant period. Next, the resulting reservoir volume (produced by subtraction from the subsequent period's volume) is converted back to its corresponding reservoir elevation (at end of period). This elevation is then checked against the physical limits of the reservoir. Computation is then made for the next earlier period, until the schedule is complete. Finally, the ARC for each period between the early refill target date and July 31 is set to the greater of the early refill elevation or the base case ARC elevation.

4.3.2.2 Computing the Energy Content Curve (ECC)

The next curve computed is the energy content curve (ECC). The ECC is defined simply as the higher of the CRC and ARC for each period. Normally, the ECC follows the critical rule curve (CRC) schedule September through December, and follows the assured refill curve (ARC) for January through August. Neither the ARC nor the CRC varies by year. Therefore, there is only one ECC for each alternative scenario.

4.3.2.3 Computing the Variable Energy Content Curve (VECC)

The variable energy content curve (VECC) is dependent upon expected streamflows as forecast at each period between January and July 31. In real world operations, the VECC for the current operating year is estimated before the beginning of winter, and continually re-estimated and updated as snow pack and snow melt data become available. Thus, a separate VECC is required for each operating year of each scenario being simulated.

The VECC is computed in a "backward" fashion, from ending period to beginning period. The computations begin at the specific refill target date and elevation. The computation is performed similarly to the ARC calculations, period by period, allowing for inflow volume and fisheries requirements.

However, there are major differences between the VECC and ARC calculations. First, the VECC calculation uses forecast streamflow volumes at Ross and at Diablo as forecast in each (current) period. Second, the total expected inflows at Ross are adjusted downward to the 95% confidence limit of the forecast. (The 95% confidence limit for VECC calculations is specified in the Pacific Northwest Coordination Agreement; it is designed to ensure that there is only a 5% chance of failure in reaching refill. The adjustment factor used is 1.687 times the standard error -- 95% confidence on one tail of the t-distribution for 50 degrees of freedom.) This confidence adjustment is then proportionally distributed to the component flow forecasts for each period. Finally, the forecast accretion between Ross and Diablo dams (expected inflow beyond Ross dam) is deducted from the fisheries flow requirement for each period. This accretion is not considered in the ARC calculations because these flows are not available for refilling Ross.

We wish to avoid introducing bias by using "perfect knowledge" of the historical dataset. Thus, a forecast is made *at each period* using only the knowledge available in that period. A "current" VECC is then computed *for each forecast*. This models the real world operation of updating VECC during the snowpack accumulation and run-off seasons. A complete (preliminary) VECC forecast is made for each period from the target refill date backward to the "current" period. To illustrate this somewhat confusing process, Figure 4-5 shows the order in which these forecasts are made and the periods they would cover for the base case, refill to 1602.5 on July 31.

In order to determine what the elevation of the reservoir should be on January 1, a forecast of runoff in every period between January and the coordination refill date of July 31 must be available. Realizing that the reservoir must refill by the refill date, one can work backwards to solve for the minimum reservoir elevation in each period based on expected streamflow, as represented in Figure 4-5. Only elevation for January matters, since by the time February 1 arrives, the quantity of water runoff for January is known, as is the revised snowpack forecast. This process is updated each period, and so only the diagonal elements of the figure define VECC, since all interior elevations could be better estimated with updated snowpack data and actual runoff from previous periods.

Once the final VECC is compiled, each point is compared to the ECC for the respective scenario. The VECC may not be above the corresponding ECC in any period (by definition). These computations span January through the refill date. The VECC for each period between the early refill target date and July 31 is set to the greater of the early refill elevation or the base case VECC elevation for the corresponding period and operating year.

4.3.2.4 Computing the Spill Control Curve (SPCC)

The spill control curve (SPCC), like the VECC, is dependent upon expected streamflows as forecast at each period for which the curve is computed, and the SPCC must be calculated for each of the 50 operating years modeled. Unlike the VECC, it is inappropriate to modify the spill control curves for each early refill scenario. Conceptually, spill control defines how a hydro project is operated, rather than operational considerations defining spill control. (This is in distinct contrast to the VECC; energy content *is* affected by operational considerations.) Therefore, separate SPCC calculations need not be made for each scenario. The base case set of spill control curves is used for all of the simulations, although the SPCC may be *overridden* by the target refill elevation *on and after the target refill date.*

The SPCC is computed in a "backward" fashion for each set of forecast flows in a manner similar to the VECC computations. Each set of computations begins at the base case refill target date and elevation (July 31 at 1602.5 feet) with the corresponding reservoir volume. The streamflow forecasts and standard errors used for the VECC calculations are the same data used to compute SPCC. The computation is performed as before, period by period, allowing for inflow volume and fisheries requirements and downstream accretions.

The major difference between the SPCC and VECC calculations is that the expected inflows at Ross are adjusted *upward* to the 60% confidence limit of the forecast for each period to compute SPCC. (The adjustment factor used is .225 times the standard error -- 60% confidence on one tail of the t-distribution for 50 degrees of freedom.) This confidence adjustment is then proportionally distributed to the component flow forecasts for each period.

The 60% confidence factor used in these calculations is taken from City operating procedures. The selection of this confidence level by the City is based on informed judgement and previous experience in hydro operations. Higher confidence limits (such as the 95% used for VECC calculations) have been tested and found to be too restrictive, impacting both refill and fisheries flow requirements. The lower confidence limit used for computing the SPCC reflects the precedence of achieving refill over avoiding spill.

The final SPCC curve is compiled from the preliminary forecasts in the same manner used to construct the final VECC. Each value is taken "at point of forecast." For example, the entry for May 31 is taken from the preliminary curve based on the May 31 forecast.

Once the final SPCC for a given operating year is computed it is compared point by point to the flood control curve (FCC). The SPCC may not be above the FCC in any period. The SPCC is computed for January 31 through July 31. In the individual early refill simulations, the SPCC for each period between the early refill target date and July 31 may be overridden by the early refill elevation.

4.3.3 Order of Precedence

Simulated operation of the hydroelectric projects on the Skagit is performed by systematically implementing satisfaction of the refill targets, subject to the operating rules and other constraints. Physical constraints, license requirements, and contractual constraints are imposed in addition to the rule curves described above. The practical considerations relevant to prudent operation of the resource also enter into the simulation structure. These constraints and rules imposed on operation of the resource have a distinct order of precedence.

The order of precedence specified for the rules directly affects the simulation results. Some rules, such as physical limits and license requirements, are never violated. In general, however, rules with lower precedence may be intentionally violated in order to conform to a rule of higher precedence. This situation occurs frequently in the simulations. The operating rules are presented here in descending order of importance, i. e., the rule having highest precedence appears first. Refill objectives are not included on this list because they are not constraints; the simulation model attempts to meet the refill objectives within the limits imposed by the constraints.

(1) Operation cannot violate the physical limits of the reservoir. The minimum elevation (empty pool) is 1475.0 feet. The maximum elevation (full pool) is 1602.5 feet.

(2) Operation cannot violate the Skagit Project's operating license. The original license specified a minimum outflow of 1000 cfs or natural inflow, whichever is less. A constant of 1000 cfs was used to operationalize this rule.

(3) Reservoir elevation may not exceed the flood control curve (FCC) imposed by the Army Corps of Engineers under the FERC license agreement.

(4) Outflow at Gorge (downstream of Ross) must be maintained at or above the minimum fisheries flow levels specified by the Skagit Interim Flow Agreement (FERC,1981), as modified in 1984 (except for simulation runs based on the minimum flow requirements of the FERC license).

(5) Operation of the primary reservoir, Ross Lake, should *minimize* spill (the release of water in excess of that which can be utilized for electric generation) at Ross and at both downstream plants, Diablo and Gorge.

(6) Operation should follow the elevations specified as proportional draft points (PDP) whenever PDP is imposed under the Pacific Northwest Coordination Agreement (Bonneville Power Administration, et al., 1964).

(7) The reservoir elevation may not fall below the variable energy content curve (VECC) during the relevant portion of the year.

(8) The reservoir elevation may not exceed the spill control curve (SPCC) during the relevant portion of the year.

(9) Within the operating frontier specified by these constraints, Ross and the downstream plants (Diablo and Gorge) will be operated to meet the City's energy generation requirements.

By way of example, rule 6 (PDP) takes precedence over rule 7 (VECC). When PDP is imposed under the Coordination Agreement, this can cause the reservoir to be *intentionally* drafted *below* the elevation specified as VECC.

The list above contains two different general types of rules. Five of these rules and constraints are defined in terms of *elevation*, the lake level height in feet above sea level. The others (license constraint, fish flow rule, spill rule, and desired generation level) are specified in terms of *streamflow*. Translation between elevation and streamflow is done within the simulation software by using two definitional relationships. One is the relationship between reservoir elevation and reservoir volume. The other is the relationship between volume displaced and average daily flow.

The practical considerations in the list above (numbers 5 and 9) are the determining factors in scheduling maintenance outages of all three Skagit River plants. The maintenance schedules used for Ross, Diablo, and Gorge are consistently imposed on the base case and on all refill alternatives modeled. The analysis accounts for realistic facility maintenance requirements without allowing it to influence the study results.

4.4 SIMULATION RESULTS

4.4.1 General Effects of Early Refill

The imposition of any early refill requirement can be expected to have a number of effects on the Skagit power resource. The severity of these effects will, logically, be directly proportional to how high the target elevation is set and how early it is to be achieved.

The refill date and target elevation directly affect how deeply the reservoir may be drafted during the winter months, which comprise the system peak demand. Maintaining higher lake levels can only be accomplished by reducing winter outflow from Ross. This has the effect of directly reducing winter electric energy production at Ross as well as the downstream plants, Diablo and Gorge.

Maintaining higher elevations also translates directly to reducing the *available* storage capacity of the reservoir. Reduction in available storage may require increases in the amount of water released during the later part of the refill period as the reservoir approaches its capacity. This effect could be exacerbated by weather patterns which result in late snowmelt (abnormally high summer run-off and streamflows) during the refill period. These factors can be expected to result in increased electric energy production during the summer months.

Should the refill date be set too early and the target elevation too high, then the available storage capacity may be insufficient to completely control the streamflow during the latter part of the refill (summer) season. This would result in *spilling* once the reservoir has reached its capacity. Spill is defined simply as the release of water *in excess* of that which can be used for generation. It follows that water spilled, by definition, is lost electric energy production. Excessive spilling, which translates directly to high streamflows below Ross, may have consequences beyond energy production. This is certainly true should the outflow from Ross reach flood levels. Excessive streamflow has the potential to damage fisheries (see sections 3.3 and 3.4) and also impair recreational use of the resource.

Operating decisions for the Ross plant are based on the interactions between streamflow regulation, power production, spill and flood control, fisheries protection, and recreational and aesthetic use of the resource. In the simulation process each alternative scenario specifies a refill date and elevation determined to enhance certain uses of the resource. The inputs to the simulation software are then based on the interactions between flow regulation, power production, elevation, spill and flood control, and fisheries mitigation.

4.4.2 Base Case

The base case scenario reflects normal operation of the Skagit plants. Under normal operation, the target refill date for Ross Lake is July 31. The base case target elevation is 1602.5 feet, or full pool. Ross Lake is normally maintained at full pool through at least the end of August. Full pool is maintained through Labor Day, if fisheries and energy requirements and streamflow conditions make this possible. The reservoir is drawn down consistently over the winter period, September through March, for the production of power and the maintenance of flood control and fisheries runs. Refill typically begins in mid April and is completed by the end of July. The base case simulation conforms to the minimum fisheries flow requirements as set forth in the Interim Agreement (FERC, 1981, as modified in 1984).

Over the 50 year simulation period of historical water conditions, Ross Lake achieves the base case refill target 72 percent of the time (36 years out of 50; see detailed tables of simulated results in Appendix C). Of the 14 instances when refill was not achieved, 13 are caused by PDP conditions. The remaining instance is caused by insufficient streamflow and preceding PDP conditions. The average lake level over the 50 simulation years is about elevation 1550 on May 31 and elevation 1586 on June 30 (see Figure 4-6).

Average outflow (under average water conditions) at Gorge is highest during January and February, at 5950 and 5568 average cfs, respectively. Average outflow at Gorge is lowest during September and October, at 2844 and 2684 average cfs, respectively. The lowest level of outflow occurring in the simulations is during October of the 1941-1942 water year (1200 cfs), which is its fisheries flow requirement under the Interim Agreement. The only fisheries flow requirements below 1200 cfs are for June, and the minimum June requirements are always exceeded. The highest levels of outflow, in excess of 9800 cfs, occur in May, June, and July during extreme high water years. The highest single level of outflow occurs in July of the 1972-1973 water year at a monthly average of 12,468 cfs. The second highest outflow occurs in June of the 1933-1934 water year at 9894 cfs.

The higher rates of flow in January and February result from the release of stored water for energy production corresponding to winter peak loads. The next highest rates of flow generally occur in June and July, which are typically the highest natural streamflow periods. The lowest outflows are typically in September and October, which correspond to the lowest natural streamflow periods at Ross.

Under the base case scenario there are only two incidences of spill at Ross. These occur during May and June of the 1933-1934 water year. These spills at Ross are caused by a combination of extreme high flow conditions, near full pool (from flood control in previous periods), and a 50 percent regularly scheduled maintenance outage. Spill occurred at all three plants during those months.

Counting occurrences of spill at any of the three plants, there are 32 months of a possible 600 (50 years x 12 months) in which spill occurs under the base case scenario (see Appendix C). Spill occurs most frequently in July (9 times), August (6 times), October (6 times) and November (4 times). The July spills were by far the largest, spilling a combined total of 1,845,000 acre-feet of water at Ross, Diablo and Gorge over the 50 years simulated. The August spills reached a combined total of 209,000 acre-feet. The October spills reached a combined total of 770,000 acre-feet. A total of 205,000 acre-feet were spilled in November.

Spilling in June, July, and August is caused by persistent high streamflow. Once the maximum storage capacity at Ross is reached, any inflow in excess of the flow-through capacity of the generators must be spilled. In contrast, spills occurring in October, November, and (less frequently) December are, typically, not caused by the lack of storage capacity. Spills do occur during these months, but are caused by the imposition of the FCC (flood control curve) at Ross. This causes high outflow from Ross, resulting in spill at the downstream plants.

The largest single incidence of spill occurred during July of the 1972-1973 water year, spilling a total of 716,000 acre-feet at Diablo and Gorge. The two extreme water years 1933-1934 and 1972-1973 account for over 40 percent of the total spill over the 50-year simulation period under the base case scenario.

Under average water conditions, the highest levels of energy production from the combined Skagit resources (Ross, Diablo, and Gorge) occur during January and February. Average January production is 327 GWh, or 440 average MW. Average February production is 271 GWh or 403 MW. These energy production levels correspond to average plant factors (over all three plants) of 63.4 percent and 58.0 percent, respectively. These plant factors are computed relative to the peaking capability of the combined Skagit plants, 694 MW, at system peak under normal water conditions. (The published energy production data have been rounded to the nearest whole number; all computations reported were made prior to rounding.)

The lowest energy production levels, under average water conditions, occur in September and October. Average September energy production is 141 GWh or 195 MW, at a plant factor of 28.1 percent. Average October production is 132 GWH or 177 MW, at a plant factor of 25.6 percent.

For purposes of comparison, combined average *annual* plant factors for these three Skagit plants would be in the range of 35 to 40 percent, depending upon the definition of average water conditions (40, 50, or 72 year period) and whether maximum production capacity is defined at system peak (694 MW) or at maximum reservoir elevations (784 MW).

The most volatile months are May, June, and July. Energy production during these months varies greatly, according to streamflow conditions and reservoir elevation. Average energy production in each of these months is in the range of 270 to 320 MW, but may fall as low as 20 percent of average during low water conditions, or rise to as much as 200 percent of average during high water conditions. The highest energy production in any single month observed in the simulation results is 598 MW during July for the 1972-1973 water year. This occurs due to high water (late runoff) after the reservoir is already at full pool from high streamflows during the previous June. The lowest two monthly energy production values from the base case simulation were 56.6 MW in October and 70.1 MW in June of the 1941-1942 water year. The October value occurred under PDP conditions. June's low production was the result of low streamflows following PDP conditions, and the minimal release of water in an attempt to achieve refill.

The following seasonal generation patterns occur under the base case simulation runs.

Generation (GWh)	Summer	Winter	Total
Simulation 50-Year Total	54,074	77,572	131,645
Average Simulation Year	1,081	1,551	2,633

The monthly, seasonal, and annual values for electric energy production are shown in Table 4-4 for each year of the base case simulation. The months appear in their simulation order; the operating year labeled 1929 reports generation for July 1928 through June 1929, inclusive. Electric energy production is reported in gigawatthours (GWh), which is equivalent to *millions of kilowatthours*. The column labeled "Summer" is shows the sub-total for April through August, inclusive. The column labeled "Winter" shows the sub-total for September through March, inclusive. The column labeled "Annual Energy" displays the total of all twelve months of each operating year.

4.4.3 Alternatives Based on Interim Agreement Flows

The intent of the power generation component of the lake level study was to model the consequences of a change in refill targets, with all other factors remaining the same as in current operations. Consequently, the initial set of refill alternatives incorporated the streamflow constraints of the 1981 Interim Agreement in all cases. A total of seven alternatives in this set were evaluated, the results of which are summarized below; additional documentation of detailed results is provided in Appendix C.

The seven refill alternatives based on Interim Agreement flows were specified according to varying target dates and elevations, as follows:

- Alternative 1 - Refill to 1601.5 on June 30
- Alternative 2 - Refill to 1592.0 on June 30
- Alternative 3 - Refill to 1601.5 on June 15
- Alternative 4 - Refill to 1592.0 on June 15
- Alternative 5 - Refill to 1580.0 on June 15
- Alternative 6 - Refill to 1601.5 on May 31
- Alternative 7 - Refill to 1592.0 on May 31

Table 4-4. Power production under base case (refill by July 31).

	Electric Generation (GWh) Base Case Refill: 1602.5 feet on July 31												Electric Generation (GWh)		
	Month												Season		Annual Energy (GWh)
	7	8	9	10	11	12	1	2	3	4	5	6	Summer	Winter	
1929	263	123	173	148	243	217	301	111	117	101	78	247	812	1,311	2,123
1930	168	151	67	65	129	198	207	240	161	188	147	113	766	1,067	1,834
1931	299	167	86	67	166	252	270	226	246	172	112	247	997	1,313	2,311
1932	296	182	94	63	137	234	288	284	197	173	138	225	1,013	1,297	2,310
1933	132	163	157	148	322	229	369	331	342	196	302	221	1,015	1,898	2,914
1934	217	270	163	249	358	295	360	326	345	320	397	373	1,577	2,095	3,672
1935	305	314	92	78	238	227	345	324	287	300	136	242	1,296	1,589	2,886
1936	304	184	146	145	137	166	294	226	227	172	185	228	1,073	1,341	2,413
1937	113	186	144	87	136	215	306	111	161	169	83	312	862	1,160	2,021
1938	301	323	91	101	193	222	328	271	170	187	313	272	1,396	1,377	2,773
1939	138	224	114	68	121	148	326	275	236	189	131	288	969	1,288	2,257
1940	146	193	149	83	163	217	338	302	235	195	131	140	804	1,488	2,292
1941	110	165	59	124	141	117	334	272	237	219	70	58	622	1,283	1,905
1942	56	101	54	42	236	223	342	274	225	132	66	50	406	1,398	1,804
1943	87	126	157	93	88	225	326	268	229	245	178	263	899	1,386	2,285
1944	339	190	154	81	118	230	322	242	128	98	66	96	788	1,275	2,064
1945	254	152	87	63	111	238	304	181	173	114	95	113	728	1,157	1,885
1946	88	321	157	122	183	94	332	269	232	202	308	312	1,231	1,388	2,619
1947	209	166	173	162	138	228	329	261	229	185	142	283	984	1,520	2,504
1948	211	146	171	158	242	228	334	270	234	185	251	289	1,082	1,637	2,719
1949	266	196	166	158	246	236	334	264	222	176	247	266	1,151	1,627	2,779
1950	205	306	134	109	324	242	373	327	345	268	306	285	1,371	1,855	3,225
1951	353	232	166	168	348	372	338	315	365	330	325	317	1,557	2,072	3,628
1952	232	158	167	169	217	232	270	261	116	182	110	135	816	1,432	2,248
1953	136	173	148	73	118	140	313	266	243	263	226	265	1,063	1,300	2,363
1954	177	191	162	168	262	227	372	322	353	314	305	307	1,295	1,866	3,161
1955	328	319	182	175	367	232	340	274	242	244	131	246	1,268	1,812	3,080
1956	279	208	168	216	375	233	372	273	293	217	282	309	1,295	1,929	3,224
1957	364	201	159	228	241	233	343	273	240	208	237	277	1,287	1,716	3,004
1958	308	215	82	55	104	232	326	263	176	99	174	225	1,021	1,239	2,260
1959	303	151	93	107	231	317	367	334	297	317	325	303	1,398	1,746	3,144
1960	293	180	209	246	356	230	369	270	238	193	165	313	1,144	1,918	3,062
1961	241	180	170	153	233	227	316	257	353	276	225	288	1,210	1,709	2,919
1962	314	232	141	80	156	230	322	266	245	191	123	136	997	1,440	2,437
1963	113	167	168	159	225	254	335	262	247	207	243	213	942	1,651	2,593
1964	112	167	163	183	294	226	334	333	265	329	285	301	1,194	1,796	2,990
1965	259	220	166	176	242	230	332	264	238	190	133	253	1,056	1,647	2,703
1966	223	190	174	172	233	229	330	267	149	187	93	188	880	1,555	2,436
1967	150	172	149	144	178	260	335	331	355	266	280	265	1,133	1,752	2,884
1968	276	181	161	210	308	228	356	322	359	347	332	305	1,442	1,945	3,386
1969	230	168	160	160	233	233	330	273	232	184	137	277	997	1,622	2,619
1970	218	151	146	179	226	233	226	266	169	158	119	149	795	1,446	2,241
1971	59	232	111	71	89	234	322	312	297	308	305	311	1,215	1,436	2,650
1972	270	237	170	178	206	226	328	256	294	322	301	377	1,506	1,657	3,164
1973	445	278	164	165	216	223	312	251	140	101	63	127	1,014	1,472	2,485
1974	207	198	89	56	112	224	351	328	345	316	309	281	1,312	1,506	2,817
1975	343	280	165	98	142	229	333	272	236	193	161	265	1,241	1,476	2,717
1976	206	168	170	166	312	383	366	331	357	325	314	302	1,315	2,085	3,400
1977	229	309	173	165	116	114	334	270	241	190	74	100	903	1,413	2,316
1978	301	188	62	59	118	229	329	174	212	190	117	139	936	1,184	2,120

Note: Summer is April through August, inclusive. Winter is September through March, inclusive.

4.4.3.1 Alternative 1 - Refill to 1601.5 on June 30

This scenario has the effect of increasing average outflow in late summer. It also exhibits significant impacts on energy production. The number of periods in the simulation which exhibit flow rates in excess of 7000 cfs from Gorge approximately double relative to the base case.

Under this alternative, Ross Lake achieves the early refill target 72 percent of the time (36 years out of 50). Of the 14 instances when refill is not achieved, 10 are caused by PDP conditions. Four instances are caused by the combination of insufficient streamflow and preceding PDP conditions.

Average outflow patterns change with this alternative scenario. Mean outflow at Gorge is highest during July at 6776 average cfs (up from 4946 cfs under the base case). January and February mean outflows are reduced to 5572 and 5074 average cfs, respectively. Average outflow at Gorge is still lowest during September and October, being nearly unchanged from the base case. The highest levels of outflow, in excess of 9800 cfs, occur in May, June, and July during extreme high water years. The highest single level of outflow still occurs in July of the 1972-1973 water year, but is increased to 13,452 cfs.

Under this alternative there is no change in the frequency or amount of spill from Ross itself. However, counting occurrences of spill at any of the three plants, there are 56 months of a possible 600 in which spill occurs under this alternative (up from 32 under the base case). Spill occurs most frequently in June (8 times) and July (27 times). The July spills were by far the largest, spilling a combined total of 7,764,000 acre-feet of water at Ross, Diablo, and Gorge over the 50 years simulated. This is an increase in volume of 320 percent over the base case July spills. The June spills reached a combined total of 1,134,000 acre-feet, while June spills totaled 581,000 acre-feet in the base case. Spill patterns in other months were virtually unchanged.

The largest single incidence of spill occurred during July of the 1954-1955 water year, spilling a total of 837,000 acre-feet at Diablo and Gorge. The two extreme water years 1933-1934 and 1972-1973 (representing the worst spill years in the base case results) showed a total increase of 34 percent in the amount of water spilled. The total amount of water spilled over the 50 year simulation period increased from 4,191,000 acre-feet under the base case to 10,663,000 acre-feet under the alternative, an increase of 154 percent. The two worst water years account for only 21 percent of the total spill over the 50 year simulation period under this alternative, compared to 40 percent for the base case.

Under this early refill alternative, the highest level of energy production from the combined Skagit resources (Ross, Diablo, and Gorge) occurs during January and July. Average January production drops 6.4 percent (compared to the base case) to 306 GWh, or 411 average MW. Average July production increases 32 percent to 303 GWh, or 407 MW. These energy production levels correspond to an average plant factor (over all three plants) of approximately 59 percent. Energy production in June is reduced by 17 percent, on average. The lowest energy production levels, under average water conditions, occur in September and October and remain unchanged by this alternative. In general, summer energy production increases, while winter energy production is reduced, under this alternative.

The following generation patterns occur under this scenario.

Generation (GWh)	Summer	Winter	Total
Simulation 50-Year Total	54,813	75,416	130,229
Average Simulation Year	1,096	1,508	2,605

4.4.3.2 Alternative 2 - Refill to 1592.0 on June 30

This scenario exhibits the least impacts on average elevation and streamflow compared to the base case. It has the second lowest impact on energy generation of any of the Interim Agreement alternatives. The number of periods in the simulation which exhibit flow rates in excess of 7000 cfs from Gorge are approximately 1.5 times the base case.

Under this alternative, Ross Lake achieves the early refill target 78 percent of the time (39 years out of 50). Of the 11 instances when refill is not achieved, 8 of these are caused by PDP conditions. Three instances are caused by the combination of insufficient streamflow and preceding PDP conditions.

Average outflow patterns change slightly with this alternative scenario. Mean outflows are increased in July to 5847 average cfs (up from 4946 cfs under the base case). June outflow drops from 5279 average cfs (base case) to 4807 average cfs. Average outflow at Gorge is still lowest during September and October, being nearly unchanged from the base case. The highest levels of outflow, in excess of 9800 cfs, occur in May, June, and July during extreme high water years. These extremes are unchanged by the alternative.

Under this alternative there is no change in the frequency or amount of spill from Ross itself. However, counting occurrences of spill at any of the three plants, there are 41 months of a possible 600 in which spill occurs under this alternative (up from 32 under the base case). Spill occurs most frequently in July (17 times). Total July spills were by far the largest, spilling a combined total of 4,778,000 acre-feet of water at Ross, Diablo and Gorge over the 50 years simulated. This is an increase in volume of 159 percent over the base case July spills. Spill patterns in other months were virtually unchanged.

The two extreme water years 1933-1934 and 1972-1973 (representing the worst spill years in the base case results) showed a total increase of 22 percent in the amount of water spilled. The total amount of water spilled over the 50 year simulation period increased from 4,191,000 acre-feet under the base case to 7,128,000 acre-feet under Alternative 2, an increase of 70 percent. The two worst water years account for only 29 percent of the total spill over the 50 year simulation period under this alternative.

Under this early refill alternative, the highest level of energy production from the combined Skagit resources (Ross, Diablo, and Gorge) occurs during January and July. Average January production drops marginally to 322 GWh, or 432 MW. Average July production increases 16 percent to 266 GWh, or 357 MW. These energy production levels correspond to average plant factors (over all three plants) of 62.3 and 51.4 percent, respectively. Energy production in June is reduced by 11 percent, on average. The lowest energy production levels, under average water conditions, occur in September and October and remain almost unchanged by this alternative. In general, summer energy production increases, winter energy production is reduced.

The following generation patterns occur under this scenario.

Generation (GWh)	Summer	Winter	Total
Simulation 50-Year Total	54,396	76,603	130,999
Average Simulation Year	1,088	1,532	2,620

4.4.3.3 Alternative 3 - Refill to 1601.5 on June 15

This scenario indicates significant impacts on average elevation, streamflow, and energy generation. The number of periods in the simulation which exhibit flow rates in excess of 7000 cfs from Gorge are more than four times the base case. Most of these occur between June 1 and July 31. The average impacts on lake elevation are substantial as early in the operating year as February.

Under this alternative, Ross Lake achieves the early refill target 62 percent of the time. Of the 19 instances when refill is not achieved, 10 are caused by PDP conditions. Nine instances are caused by the combination of insufficient streamflow and preceding PDP conditions.

Average outflow patterns change with this alternative scenario. Mean outflow at Gorge is highest during July at 7219 average cfs (up from 4946 cfs under the base case). January and February mean outflows are reduced by approximately 1000 cfs each to 4993 and 4,538 average cfs, respectively. Average outflow at Gorge is still lowest during September and October, being nearly unchanged from the base case. The highest levels of outflow, in excess of 13,000 cfs, occur in June and July during extreme high water years. The highest single level of outflow still occurs in July of the 1972-1973 water year, but is increased to 13,644 cfs.

Under this alternative there are seven incidences of spill from Ross itself (as opposed to two in the base case). Counting occurrences of spill at any of the three plants, there are 84 months of a possible 600 in which spill occurs under this alternative (up from 32 under the base case). Spill occurs most frequently in June (36 times) and July (27 times). The June spills were by far the largest, spilling a combined total of 10,866,000 acre-feet of water at Ross, Diablo and Gorge over the 50 years simulated. July spills totaled 8,332,000 acre-feet. (June spills totaled 581,000 acre-feet and July 1,845,000 acre-feet in the base case.) Spill patterns in other months were virtually unchanged.

The two extreme water years 1933-1934 and 1972-1973 (representing the worst spill years in the base case results) showed a total increase of 36 percent in the amount of water spilled. The total amount of water spilled over the 50 year simulation period increased from 4,191,000 acre-feet under the base case to 20,963,000 acre-feet under the alternative, an increase of 400 percent. The two worst water years account for only 11 percent of the total spill over the 50 year simulation period under this alternative.

Under this early refill alternative, the highest levels of energy production from the combined Skagit resources (Ross, Diablo, and Gorge) occurs during June and July. Average January production drops to 368 MW (from 440 MW in the base case), a 16 percent decrease. Average July production increases 35 percent to 416 MW (from 308 MW in the base case). The lowest energy production levels, under average water conditions, occur in September and October and remain unchanged by this alternative. In general, summer energy production increases, while winter energy production is reduced.

The following generation patterns occur under this scenario.

Generation (GWh)	Summer	Winter	Total
Simulation 50-Year Total	57,843	70,456	128,299
Average Simulation Year	1,157	1,409	2,566

4.4.3.4 Alternative 4 - Refill to 1592.0 on June 15

This scenario has significant impacts on average elevation, streamflow, and energy generation. The number of periods in the simulation which exhibit flow rates in excess of 7000 cfs from Gorge are more than three times the base case. Most of these occur between June 1 and July 31. The average impacts on lake elevation are substantial as early in the operating year as February.

Under this alternative, Ross Lake achieves the early refill target 68 percent of the time (34 years out of 50). Of the 16 instances when refill is not achieved, 10 are caused by PDP conditions. Six instances are caused by the combination of insufficient streamflow and preceding PDP conditions.

Average outflow patterns change with this alternative scenario. Mean outflow at Gorge is highest during July at 6696 average cfs (up from 4946 cfs under the base case). January and February mean outflows are reduced to 5425 and 4739 average cfs, respectively. Average outflow at Gorge is still lowest during September and October, being nearly unchanged from the base case. The highest levels of outflow, in excess of 11,000 cfs, occur in June and July during extreme high water years. The highest single level of outflow still occurs in July of the 1972-1973 water year, but is increased to 13,644 cfs.

Under this alternative the incidence of spill from Ross itself is unchanged. Counting occurrences of spill at any of the three plants, there are 64 months of a possible 600 in which spill occurs under this alternative (up from 32 under the base case). Spill occurs most frequently in June (21 times) and July (22 times). The July spills were the largest, spilling a combined total of 7,938,000 acre-feet of water at Ross, Diablo and Gorge over the 50 years simulated. June spills totaled 5,322,000 acre-feet. (June spills totaled 581,000 acre-feet and July 1,845,000 acre-feet in the base case.) Spill patterns in other months were virtually unchanged.

The two extreme water years 1933-1934 and 1972-1973 (representing the worst spill years in the base case results) showed a total increase of 36 percent in the amount of water spilled. The total amount of water spilled over the 50 year simulation period increased from 4,191,000 acre-feet under the base case to 15,024,000 acre-feet under the alternative, an increase of 259 percent. The two worst water years account for only 15 percent of the total spill over the 50 year simulation period under this alternative.

Under this early refill alternative, the highest levels of energy production from the combined Skagit resources (Ross, Diablo, and Gorge) occurs during January and July. Average January production drops to 400 MW (from 440 MW in the base case), a 9 percent decrease. Average July production increases 30 percent to 400 MW (from 308 MW in the base case). The lowest energy production levels, under average water conditions, occur in September and October and remain unchanged by this alternative. In general, summer energy production increases, while winter energy production is reduced.

The following generation patterns occur under this scenario.

Generation (GWh)	Summer	Winter	Total
Simulation 50-Year Total	56,477	73,192	129,669
Average Simulation Year	1,130	1,464	2,593

4.4.3.5 Alternative 5 - Refill to 1580.0 on June 15

This scenario exhibits measurable impacts on average elevation and streamflow. It has the least impact on energy generation of any of the Interim Agreement alternatives. The number of periods in the simulation which exhibit flow rates in excess of 7000 cfs from Gorge are approximately two times the base case.

Under this alternative, Ross Lake achieves the early refill target 76 percent of the time (38 years out of 50). Of the 12 instances when refill is not achieved, 9 are caused by PDP conditions. Three instances are caused by the combination of insufficient streamflow and preceding PDP conditions.

Average outflow patterns change with this alternative scenario. Mean outflow at Gorge is highest during July at 6137 average cfs (up from 4946 cfs under the base case). January and February mean outflows are reduced to 5843 and 4966 average cfs, respectively (compared to 5951 and 5568 cfs in the base case). Average outflow at Gorge is still lowest during September and October, being nearly unchanged from the base case. The highest levels of outflow, in excess of 9000 cfs, occur in May, June, and July during extreme high water years. The highest single level of outflow still occurs in July of the 1972-1973 water year, but is increased to 13,514 cfs.

Under this alternative the incidence of spill from Ross itself is unchanged. Counting occurrences of spill at any of the three plants, there are 46 months of a possible 600 in which spill occurs under this alternative (up from 32 under the base case). Spill occurs most frequently in June (8 times) and July (16 times). The July spills were by far the largest, spilling a combined total of 6,415,000 acre-feet of water at Ross, Diablo and Gorge over the 50 years simulated. June spills totaled 2,256,000 acre-feet. (June spills totaled

581,000 acre-feet and July 1,845,000 acre-feet in the base case.) Spill patterns in other months were virtually unchanged.

The two extreme water years 1933-1934 and 1972-1973 (representing the worst spill years in the base case results) showed a total increase of 36 percent in the amount of water spilled. The total amount of water spilled over the 50 year simulation period increased from 4,191,000 acre-feet under the base case to 10,437,000 acre-feet under the alternative, an increase of 249 percent. The two worst water years account for only 21 percent of the total spill over the 50 year simulation period under this alternative.

Under this early refill alternative, the highest levels of energy production from the combined Skagit resources (Ross, Diablo, and Gorge) occurs during January and July. Average January production drops to 432 MW (from 440 MW in the base case), a 2 percent decrease. Average February production drops to 359 MW (from 403 MW in the base case), an 11 percent decrease. Average July production increases 19 percent to 367 MW (from 308 MW in the base case). The lowest energy production levels, under average water conditions, occur in September and October and remain unchanged by this alternative. In general, summer energy production increases, while winter energy production is reduced.

The following generation patterns occur under this scenario.

Generation (GWh)	Summer	Winter	Total
Simulation 50-Year Total	55,059	75,457	130,516
Average Simulation Year	1,101	1,509	2,610

4.4.3.6 Alternative 6 - Refill to 1601.5 on May 31

This scenario exhibits the most extreme impacts on average elevation, streamflow, and energy generation of any of the Interim Agreement alternatives tested. The number of periods in the simulation which exhibit flow rates in excess of 7000 cfs from Gorge is more than six times the base case. Most of these occur between June 1 and July 31. The average impacts on lake elevation are very substantial as early in the operating year as February.

Under this alternative, Ross Lake achieves the early refill target 58 percent of the time (29 years out of 50). Of the 21 instances when refill is not achieved, 3 are caused by PDP conditions. The other 18 instances are caused by the combination of insufficient streamflow and preceding PDP conditions.

Average outflow patterns change dramatically with this alternative scenario. Mean outflow at Gorge is highest during June at 9828 average cfs (up from 5279 cfs under the base case). Average outflow at Gorge during July increases to 7001 average cfs (up from 4946 under the base case). January and February mean outflows are reduced to 3568 and 3710 average cfs, respectively (compared to 5951 and 5568 cfs in the base case). Average outflow at Gorge is still lowest during September and October, being nearly unchanged from the base case. The highest levels of outflow, in excess of 10,000 cfs, occur in May, June, and July during extreme high water years. The highest single level of outflow occurs in June of the 1972-1973 water year at 18,941 cfs.

Under this alternative the incidence of spill at Ross itself is significantly increased. There are 34 incidences of spill from Ross under this early refill alternative, compared to 2 spills in the base case. Counting occurrences of spill at any of the three plants, there are 97 months of a possible 600 in which spill occurs under this alternative (up from 32 under the base case). Spill occurs most frequently in May (12 times), June (38 times) and July (28 times). The June spills were by far the largest, spilling a combined total of 24,296,000 acre-feet of water at Ross, Diablo, and Gorge over the 50 years simulated. July spills totaled 8,341,000 acre-feet. May spills totaled 2,206,000 acre-feet. (June spills totaled 581,000 acre-feet, July 1845,000 acre-feet and May spills 441,000 acre-feet in the base case.) Spill patterns in other months were virtually unchanged, with the exception of one new spill occurring in April.

The two extreme water years 1933-1934 and 1972-1973 (representing the worst spill years in the base case results) showed a total increase of 51 percent in the amount of water spilled. The total amount of water spilled over the 50 year simulation period increased from 4,191,000 acre-feet under the base case to 36,201,000 acre-feet under the alternative, an increase of 764 percent. The two worst water years account for only 7 percent of the total spill over the 50 year simulation period under this alternative.

Under this early refill alternative, the highest levels of energy production from the combined Skagit resources (Ross, Diablo, and Gorge) occur during June and July. Average January production drops to 258 MW (from 440 MW in the base case), a 41 percent decrease. Average February production drops to 268 MW (from 403 MW in the base case), a 34 percent decrease. Average June production increases 50 percent to 497 MW (from 330 MW in the base case). Average July production increases 37 percent to 421 MW (from 308 MW in the base case). The lowest energy production levels, under average water conditions, occur in September and October and remain unchanged by this alternative. In general, summer energy production is significantly increased, while winter energy production is severely reduced.

The following generation patterns occur under this scenario.

Generation (GWh)	Summer	Winter	Total
Simulation 50-Year Total	61,612	62,910	124,521
Average Simulation Year	1,232	1,258	2,490

4.4.3.7 Alternative 7 - Refill to 1592.0 on May 31

This scenario produces the second most severe impacts on average elevation, streamflow, and energy generation. The number of periods in the simulation which exhibit flow rates in excess of 7000 cfs from Gorge are approximately five times the base case. Most of these occur between June 1 and July 31. The average impacts on lake elevation are very substantial as early in the operating year as February.

Under this alternative, Ross Lake achieves the early refill target 60 percent of the time (30 years out of 50). Of the 20 instances when refill is not achieved, 3 are caused by PDP conditions. The other 17 instances are caused by the combination of insufficient streamflow and preceding PDP conditions.

Average outflow patterns change significantly with this alternative scenario. Mean outflow at Gorge is highest during June at 8928 average cfs (up from 5279 cfs under the base case). Average outflow at Gorge during July increases to 6897 average cfs (up from 4946 under the base case). January and February mean outflows are reduced to 4123 and 3978 average cfs, respectively (compared to 5951 and 5568 cfs in the base case). Average outflow at Gorge is still lowest during September and October, being nearly unchanged from the base case. The highest levels of outflow, in excess of 10,000 cfs, occur in May, June, and July during extreme high water years. The highest single level of outflow occurs in June of the 1972-1973 water year at 18,165 cfs.

Under this alternative the incidence of spill at Ross itself is significantly increased. There are 18 incidences of spill from Ross under this early refill alternative, compared to 2 spills in the base case. Counting occurrences of spill at any of the three plants, there are 82 months of a possible 600 in which spill occurs under this alternative (up from 32 under the base case). Spill occurs most frequently in June (34 times) and July (26 times). The June spills were by far the largest, spilling a combined total of 17,259,000 acre-feet of water at Ross, Diablo and Gorge over the 50 years simulated. July spills totaled 8,313,000 acre-feet. May spills totaled 2,206,000 acre-feet. May spills totaled 637,000 acre-feet. (June spills totaled 581,000 acre-feet, July 1,845,000 acre-feet and May spills 441,000 acre-feet in the base case.) Spill patterns in other months were virtually unchanged.

The two extreme water years 1933-1934 and 1972-1973 (representing the worst spill years in the base case results) showed a total increase of 32 percent in the amount of water spilled. The total amount of water spilled over the 50 year simulation period increased from 4,191,000 acre-feet under the base case to 27,531,000 acre-feet under the alternative, an increase of 557 percent. The two worst water years account for only 8 percent of the total spill over the 50 year simulation period under this alternative.

Under this early refill alternative, the highest levels of energy production from the combined Skagit resources (Ross, Diablo, and Gorge) occur during June and July. Average January production drops to 301 MW (from 440 MW in the base case), a 32 percent decrease. Average February production drops to 288 MW (from 403 MW in the base case), an 29 percent decrease. Average June production increases 47 percent to 485 MW (from 330 MW in the base case). Average July production increases 34 percent to 413 MW (from 308 MW in the base case). The lowest energy production levels, under average water conditions, occur in September and October and remain unchanged by this alternative. In general, summer energy production is significantly increased, while winter energy production is severely reduced.

The following generation patterns occur under this scenario.

Generation (GWh)	Summer	Winter	Total
Simulation 50-Year Total	61,334	65,542	126,876
Average Simulation Year	1,227	1,311	2,538

4.4.4 Alternatives Based on Original FERC License Minimum Flows

As requested by the intervenors, a portion of the power generation analysis was conducted using different minimum streamflow constraints. The intent of this effort was to test the sensitivity of the modeling results to changes in flow requirements, and to indicate the influence of flow constraints on the feasibility of early refill. This was accomplished by setting a minimum bound on project outflow at Gorge based on the minimum instream flow originally stipulated in the FERC license for the Skagit Project, and re-running several of the refill scenarios through the HYDRO model. The project license originally (prior to the 1981 Interim Agreement) required a minimum flow of 1000 cfs or natural inflow, whichever is lower, so a constant figure of 1000 cfs was used for this application. Full duplication of the initial analyses was considered to be unnecessary, so this variation was applied to the base case and three other refill scenarios, as follows:

Alternative 8 - Refill to 1602.5 on July 31
Alternative 9 - Refill to 1601.5 on June 30
Alternative 10 - Refill to 1592.0 on June 30
Alternative 11 - Refill to 1601.5 on May 31

The effects of the original FERC license minimum flow scenarios are very similar to those described above for the Interim Agreement alternatives. Average ending reservoir elevations for these alternatives are shown in Figure 4-7. Slight differences are caused by the reduction in minimum flow requirements, and primarily affect the results only in low water years.

The general trend is to exacerbate the pattern of reduced winter energy production and higher summer energy production. This is due to the generally lower natural flows in winter months, when the fisheries flow requirements are generally imposed.

Because of the similarity of these results to the alternatives already described, the following results are summarized without the level of detail accompanying the previous section.

4.4.4.1 Alternative 8 - Refill to 1602.5 on July 31

This scenario exhibits only minor differences in the key parameters from the base case. The only difference between the structure of this alternative and the base case is the reduction of fisheries flow requirements to the original license minimum. The results are decreased fisheries protection and minor adverse impacts on energy production.

Generation (GWh)	Summer	Winter	Total
Simulation 50-Year Total	54,283	77,389	131,672
Average Simulation Year	1,086	1,548	2,633

4.4.4.2 Alternative 9 - Refill to 1601.5 on June 30

This scenario has the effect of increasing streamflow in late summer. It also exhibits significant impacts on energy production. The number of periods in the simulation which exhibit flow rates in excess of 7000 cfs from Gorge approximately double relative to the base case. Fisheries protection is reduced under this alternative.

The following generation patterns occur under this scenario.

Generation (GWh)	Summer	Winter	Total
Simulation 50-Year Total	55,089	75,182	130,271
Average Simulation Year	1,102	1,504	2,605

4.4.4.3 Alternative 10 - Refill to 1592.0 on June 30

This scenario exhibits the least impacts on average elevation, streamflow, and flooding. It has the lowest impact on energy generation of any of the original license requirement early refill alternatives. The number of periods in the simulation which exhibit flow rates in excess of 7000 cfs from Gorge are approximately 1.5 times the base case. Fisheries protection is reduced under this alternative.

The following generation patterns occur under this scenario.

Generation (GWh)	Summer	Winter	Total
Simulation 50-Year Total	54,629	76,403	131,032
Average Simulation Year	1,093	1,528	2,621

4.4.4.4 Alternative 11 - Refill to 1601.5 on May 31

This scenario produces the most severe impacts on average elevation, streamflow, and energy generation of *any alternative* tested. The number of periods in the simulation which exhibit flow rates in excess of 7000 cfs from Gorge are more than six and one half times the base case. Most of these occur between June 1 and July 31. The average impacts on lake elevation are very substantial as early in the operating year as February. Fisheries protection is reduced under this alternative.

The following generation patterns occur under this scenario.

Generation (GWh)	Summer	Winter	Total
Simulation 50-Year Total	63,767	60,369	124,135
Average Simulation Year	1,275	1,207	2,483

4.4.5 Results Based on 1991 Settlement Agreement

The City has been involved in studies and negotiations with the fisheries agencies and tribes concerning downstream flows for several years since the development of the Interim Agreement. These negotiations have resulted in a downstream anadromous fisheries flow plan that increases fisheries protection levels beyond those provided for in the Interim Agreement. The new flow plan is incorporated as Section 6 of the fisheries settlement agreement, a part of the overall 1991 Settlement Agreement for the Skagit Project to be signed by all parties involved.

In reviewing the draft report on the lake levels analysis in early 1990, several intervenors requested that another refill scenario based on the proposed flow agreement be evaluated by the City. In response, the City developed one additional refill scenario incorporating the flow provisions of the 1991 Settlement Agreement as constraints in the HYDRO model. The flow provisions of the new agreement, the modeling changes required to simulate these provisions, and the corresponding HYDRO model results are summarized below. Comparison of these results with the other refill scenarios is discussed in Sections 4.5 and 4.6.

The purpose of the effort described here is to examine the effects of the 1991 Settlement Agreement through simulation modeling of operations on the Skagit at Ross, Diablo, and Gorge dams. The simulation scenario followed here is one of normal refill. The targets are identical to the base case targets used for the lake levels analysis, as described in Section 4.4.2; the refill target is to achieve an elevation of 1602.5 feet at the Ross Lake reservoir on July 31 of each year. The simulation period, stream flow data, and any elements of the analysis not mentioned here are all consistent with the base case. For the sake of brevity, this section concerns itself primarily with changes to software, input datasets, and the new results, using the previous analysis and results as a starting point.

4.4.5.1 The New Fisheries Agreement

Modeling the 1991 Settlement Agreement has required substantial modification and expansion of all computer programs and most datasets involved in the simulation. These modifications arise directly from the complexity of the new agreement. In order to present these revisions in an understandable fashion it is necessary to briefly describe the major relevant points of the new agreement. These points are:

- Restrictions on downramping amplitudes (flow reduction)

- Significant revisions have been made to both the mechanics and the levels of minimum flow requirements

  - Minimum flow requirements are now specified for two points on the Skagit, rather than at a single point

  - New absolute minimum fisheries protection flows for some time periods are specified

  - Minimum flow requirements during incubation periods are now subject to dynamic revision depending upon actual flow levels during the several spawning seasons

- Target flow levels for reservoir operation are now dynamically revised through the computation of Planned Spawning Flows during the steelhead spawning seasons

- Operational guidelines during steelhead spawning are further clarified through the computation of the Steelhead Spawning Control Curve (SHSCC)

A number of revisions to the original modeling effort have been made to be consistent with the City's planned implementation of the 1991 Settlement Agreement . (It is assumed here that if any aspect of the planned implementation is inconsistent with any current agreements these inconsistencies would be corrected by future filings, revisions to agreements, or revisions to the current implementation plan.) The City's current implementation strategy is modeled through the revisions to data or the coding of algorithms for the following:

- New target flow levels for Skagit operations

- Exceptions to operation under the Proportional Draft Point (PDP) rules of the Coordination Agreement during certain salmon spawning periods

- Restrictions on the dynamic revision of minimum flows for steelhead incubation

4.4.5.2 Simulation Model Adjustments

The 1991 Settlement Agreement describes targets and restrictions on Skagit plant operations in terms of *instantaneous* rates of streamflow. The data frequency utilized in the simulation software is 18 periods per year (six months are divided into two periods each).

The simulation is performed in terms of *average* rates of flow over the simulation periods. As a consequence, this simulation (as with all simulations) is an imperfect representation of reality. We have attempted to implement the limitations and targets of the agreement in terms of average flow, wherever appropriate. Those restrictions of the proposed settlement agreement that significantly affect average streamflows have been modeled as closely as possible.

The following description of changes to the simulation software and data follows the points of the 1991 Settlement Agreement as described above. Notes on the revisions required to model the City's implementation strategy are included in the sections concerning the relevant portion of the new agreement.

RESTRICTIONS ON DOWNRAMPING

The 1991 Settlement Agreement sets forth various restrictions on the maximum hourly changes to instantaneous flow. These restrictions cannot be modeled reasonably within the current framework due to the extremely detailed time step involved. (In fact, simulating the specified downramping conditions would require a model with a data frequency of 8,760 hourly periods per year.) It is assumed for the purposes of this simulation that these hourly flow change (ramping rate) restrictions will be met. Any changes in periodic stream flow arising in the simulations can be met in reality without any implicit or inherent violation of the downramping restrictions. Other factors and rules of operation would be violated long before excessive downramping would occur over an entire simulation period.

RESTRICTIONS ON INSTANTANEOUS MAXIMUM FLOWS

Restrictions on maximum instantaneous flows have much the same character as downramping restrictions. We have endeavored to include restrictions on maximum average flows in the simulation under "normal" operating conditions. The planned operating target flows specified by the City for this simulation are consistently below the maximum flow restrictions of the new agreement. These flow targets should result in operation within the bounds specified under the new agreement, between the minimum and maximum flow schedules in a given period, and allow sufficient storage to avoid violation of the flow amplitude restrictions.

Given the flow targets specified by the City, the maximum daily flow restrictions will be violated if only and only if adhering to those conditions would directly cause spill or result in violation of the spill control curve (SPCC) or the flood control curve (FCC). These conditions pertain only to periods of excessive inflow, and appear in the language of the new agreement as exceptions to the maximum daily flow restrictions in any case. The operating flow targets for the current and the original simulations appear in Table 4-5.

The implementation strategy also includes some new exceptions to operation under PDP during salmon spawning seasons. In keeping with the limitations on maximum daily flow, the simulation model will not allow operation under PDP to directly cause flow at Gorge (Newhalem) to exceed 3000 cfs during September or October, or 4000 cfs during December. These limitations are actually more strict than the maximum flows specified in the agreement, which range from 4000 to 4600 cfs. The difference arises from our simulation on the basis of period average (rather than daily average) flow. These levels

Table 4-5. Target outflow levels (cfs) at Gorge [1], by flow agreement.

Time Period	Downstream Fisheries Settlement Agreement (1991)		Interim Fisheries Flow Agreement (1981, 1984)	
	Even Years	Odd Years	Even Years	Odd Years
July 1–15	5000	5000	5000	5000
July 16–31	5000	5000	5000	5000
August 1–15	5000	5000	5000	5000
August 16–31	3800	3000	5000	5000
September 1–31	3800	3000	3300	3300
October 1–31	3800	3000	3300	3000
November 1–30	4000	4000	4500	4500
December 1–31	4000	4000	4200	4200
January 1–31	6000	6000	6000	6000
February 1–28	5500	5500	5500	5500
March 1–15	4500[2]	4500[2]	4500	4500
March 16–31	4500[2]	4500[2]	4500	4500
April 1–15	4000[2]	4000[2]	4000	4000
April 16–30	4000[2]	4000[2]	4000	4000
May 1–15	3000[2]	3000[2]	3000	3000
May 16–31	3000[2]	3000[2]	3000	3000
June 1–15	5000[2]	5000[2]	5000	5000
June 16–30	6000[2]	6000[2]	5000	5000

(1) The 1991 Settlement Agreement actually specifies flows to be maintained at the Newhalem gage, which is just downstream from Gorge dam; see text for explanation.

(2) These targets are dynamically revised by the Planned Spawning Flow.

also make allowance for some leeway on the part of the simulation model to correct for revised minimum flows (discussed below), or to make other corrections based on the relevant rule curves.

MINIMUM FLOW REQUIREMENTS

As mentioned above, the new agreement specifies minimum flows to be maintained at two points on the Skagit. There are now schedules of minimum flow as measured at the Newhalem gage and as calculated at Marblemount. The interim (old) fisheries agreement and the original simulations have no requirements pertaining to stream flows at Marblemount. In order to implement these new minimums, two assumptions are made for simplifying the simulation process.

The first assumption is that minimum flows for Newhalem may be imposed at Gorge dam without damage to the integrity of the analysis. This assumption simplifies the data requirements. The project team already has data on streamflows at Ross and accretion data from Ross to Diablo, from Diablo to Gorge, and from Gorge to Marblemount. This first assumption drastically simplifies the data requirements for implementing the new minimums. As the Gorge to Newhalem watershed is relatively small (limited to Ladder Creek), and accretions between Gorge and Newhalem are small, this assumption does no significant damage to the integrity of the analysis. In fact, the small accretion between Gorge and Newhalem may be viewed as an additional guarantee that minimum flows at Newhalem will be met in the simulations.

In order to implement minimum flow requirements at Marblemount, the second assumption is the stipulation of a (simulated) "run of the river" hydro plant at Marblemount. A "run of the river" plant is assumed to have essentially no reservoir and, therefore, no capability for independently affecting any change in streamflow. This fictitious Marblemount plant is modeled with no energy capability, resulting in a zero contribution to peak and average energy production. The only purpose for the inclusion of a Marblemount plant (sic) is to enable the hydro model to check minimum streamflows at that point on the Skagit. This assumption produces no change in the simulated peak or average energy generation levels. The assumption does, however, result in changes in streamflow by requiring greater releases from Ross dam when minimum flow conditions at Marblemount are not being met. The introduction of a simulated Marblemount plant has no impact on any other aspect of the simulation model's performance.

The new fisheries agreement specifies absolute minimum flows to be maintained both at Newhalem (modeled at Gorge) and at Marblemount. These absolute minimum flows are presented in Table 4-6. The new absolute minimum flows are higher than those from the Interim Agreement during some periods and lower during others. During most periods in which the minimum flows are lower they will be subject to revision, as discussed below.

In addition to the absolute minimums, the 1991 Settlement Agreement includes language specifying the mechanics for dynamic revision of minimum flow levels at both Gorge and Marblemount. The agreement defines the spawning and incubation periods for six fish species. These six species are comprised of three species of salmon and three sub-species of steelhead. The species included in the agreement are:

Table 4-6. Absolute minimum fisheries flows (cfs), by flow agreement.

	Downstream Fisheries Settlement Agreement (1991)			Interim Fisheries Flow Agreement (1981, 1984)	
	GORGE[1]		MARBLEMOUNT	GORGE	
Time Period	Even Years	Odd Years	All Years	Even Years	Odd Years
July 1–15	1500	1500	3823	1325	1325
July 16–31	1500	1500	3823	1325	1325
August 1–15	2000[2]	2000[2]	2000	1325	1325
August 16–31	2000[2]	2000[2]	2000	1400	1400
September 1–31	1500	1500	---	1400	1400
October 1–31	1500	1500	---	1200	1400
November 1–30	1000	1100	---	1800	1800
December 1–31	1000	1400	---	1800	1800
January 1–31	1400	1400	---	1900	1900
February 1–28	1800	1800	3000	2300	2300
March 1–15	1800	1800	3000	2300	2300
March 16–31	1800	1800	3000	2300	2300
April 1–15	1800	1800	3000	2300	2300
April 16–30	1800	1800	3000	2000	2000
May 1–15	1500	1500	3000	1700	1700
May 16–31	1500	1500	3000	1700	1700
June 1–15	1500	1500	3584	1000	1000
June 16–30	1500	1500	3584	1000	1000

(1) The 1991 Settlement Agreement actually specifies flows to be maintained at the Newhalem gage, which is just downstream from Gorge dam; see text for explanation.

(2) Set to 1500 when flow at Gorge less than 2300 cfs.

- Chum salmon
- Pink salmon
- Chinook salmon
- Steelhead spawning in March
- Steelhead spawning in April
- Steelhead spawning in May/June

The terms of the agreement specify that minimum fisheries protection flows during spawning and incubation must be periodically revised, depending upon the season spawning flow for each species. Included in the agreement are the definition of season spawning flow and a table for each of the six species describing revised minimum flows indexed to various levels of spawning flow.

The new agreement defines season spawning flow at any given time as the average of the 10 highest daily flows over the spawning period to date. The season spawning flow is measured at the Newhalem gage. Again, some compromise is necessary to implement the language of the agreement in a simulation model of monthly and twice-monthly periodicity. The season spawning flow has been simulated as the highest average flow during any simulation period in which a species is spawning. A set of 6 season spawning flow records are kept, one for each species. The season spawning flow in the simulation model is measured at Gorge. These records are continually updated over each period as the simulation model is run.

During each period of the simulation the operational characteristics for Ross dam are computed from the inputs. These inputs are either (1) the planned outflow from Ross dam, or (2) the planned ending elevation of Ross Lake. Once the operation is initially simulated for the given period, Ross outflow plus the appropriate accretion is checked against the downstream minimum fisheries flow requirements.

A new routine has been added to the simulation model to check the minimum flow requirement for each downstream site against the minimum flow tables taken from the new agreement. At each period of the simulation the fish flow minimum from the main input file is checked against values retrieved from these tables for each species. (These tables are indexed to the season spawning flow, as recorded from previous simulation periods.) The maximum of the 7 possible values (input minimum and 6 values from the tables) becomes the new fisheries flow minimum for a particular period and site (Gorge or Marblemount). If the outflow from Ross plus the relevant accretion does not meet or exceed this (revised) minimum, a flag is set and the simulation for that period is recomputed with a new target outflow level for Ross dam.

Once the model has completed processing of the spawning and incubation periods for a particular species, the season spawning flow record for that species is cleared in order to process the next simulation year without corrupting the algorithm.

There are certain exceptions to this general methodology which are written into the agreement. In particular, SCL will not be required to increase flows at Newhalem (modeled at Gorge) above 2600 cfs in order to meet minimum flow at Marblemount of 3000 cfs. This exception has been modeled by simply modifying the input data for Marblemount accretions. The accretions between Gorge and Marblemount have been set to a minimum of 400 cfs. Thus, this exception is now implicit without requiring further programming revisions to the simulation software.

Additionally, the new agreement provides that the City is not to be held liable for excessive spawning period flows that are caused by required releases from Ross which are beyond their control. When extreme (high) downstream flows occur during a spawning period due to high inflows at Ross and the requirements of the spill control curve (SPCC) or the flood control curve (FCC), these conditions will constitute an exception.

Such exceptional conditions will not affect the season spawning flow or, therefore, increase the future incubation period (dynamically adjusted) minimum fisheries flows for the relevant species. Such an exception is necessary for extreme water conditions if operations during subsequent periods are to be conducted in a reasonable fashion. Stated differently, the purpose of this exception is to produce minimum incubation flow requirements which are consistent with the Critical Rule Curve (CRC), the variable energy content curve (VECC), and the absolute minimum elevation of the Ross Lake reservoir.

The new higher target flow levels for operation under the City's implementation strategy for the 1991 Settlement Agreement are designed to satisfy most of the minimum incubation requirements without further adjustment. In light of this approach and the exceptions mentioned above, some limits on the season spawning flow as recorded for the three salmon species have been programmed into the dynamic revision routine for incubation flows. These limits to the recorded season spawning flow, as specified by the City, are 4500 cfs for chinook, 4000 cfs for pinks, and 4600 cfs for chum. Again, these limits will not be exceeded by the simulation model under any condition that does not already constitute an exception under the language of the agreement.

PLANNED SPAWNING FLOWS

The 1991 Settlement Agreement also provides a mechanism for dynamically revising planned flows on the Skagit at Newhalem during steelhead spawning periods. The planned outflows from Ross were static in the initial simulations for the lake levels analysis. This means they were computed externally to the simulation model, and revised only to meet minimum flow requirements. The new agreement specifies a set of dynamic equations which are implemented in the simulation model to compute and revise planned flows at Newhalem (and, hence, outflows from Ross) on an ongoing basis during simulation of steelhead spawning and incubation periods (March 1 through June 30). Once again, we implement the agreement in the simulation model under the assumption that these conditions may be imposed at Gorge, rather than at Newhalem.

In essence, these equations define the planned spawning flow (at Gorge) for any given period as a function of the following:

- The reservoir elevation at the beginning of the period
- The SPCC (spill control curve) elevation on June 30 as forecasted at the beginning of the period

- The forecasted volume inflow expected at Gorge between the beginning of the period and June 30

- A set of implicit assumptions concerning the distribution of total (March 1 – June 30) inflow among and between the individual time periods involved

In order to implement the terms of the agreement we computed forecasted volumes over each of the relevant periods (March 1 – June 30, March 16 – June 30, April 1 – June 30, etc.) from the input data for the SPCC and VECC computational sub-models. No adjustments for confidence intervals were made to the forecasted volume inflows for this exercise. These data became a new input file for the simulation model. Additionally, the periodic forecasted values for the June 30 SPCC elevation were retrieved and tabulated. These data became another new input file for the simulation model.

The equations for Planned Spawning Flow appearing in the agreement were specified on a monthly basis for the period March 1 through June 30. The simulation periods over this range of dates are all twice monthly (15 or 16 day) periods. Therefore, the four equations appearing in the agreement were disaggregated to a set of eight equations corresponding to the simulation periods. These equations were then encoded as a new routine in the simulation model.

This new Planned Spawning Flow routine is called at the beginning of each simulation period as the operational values for Ross dam are being set. The Planned Spawning Flow is returned if the period falls in the relevant range (March–June) and the current operation is not being conducted under PDP (proportional draft point). A new operational outflow level is computed for Ross dam by subtracting the current period's Ross to Gorge accretion from the Planned Spawning Flow. This newly revised outflow target is checked against the minimum fisheries flow (from the input card deck) and is ignored if it is too low. (While a low value would be revised in any case, this value may actually be negative if the forecasted volume inflow is low enough. This check circumvents several computational problems associated with passing negative values to the simulation routines.)

Further, if the new outflow target for Ross produces a flow at Gorge which is consistent with the Planned Spawning Flow, but below the minimum fisheries flow *as revised for a particular species* (see previous section), release from Ross will be increased accordingly. The Planned Spawning Flow routine is called at the "beginning" of the simulation period. The routine which dynamically revises fisheries flow minimums is called at the "end" of the simulation period. If a violation is found at that time, the period is simulated again with a new outflow target computed for Ross, regardless of the Planned Spawning Flow value.

If the new Ross outflow target computed from the Planned Spawning Flow is too high, the simulation model will automatically correct for this occurrence. Several problems could cause the new outflow target to be revised. Should the new target cause spill at Ross, Diablo, or Gorge, it will be revised downward. Similarly, if the new outflow target would draft Ross Lake below the minimum elevation specified by the VECC (variable energy content curve) it will be revised. These simulated actions are consistent with the language of the new agreement. Such occurrences will arise primarily from forecast error.

STEELHEAD SPAWNING CONTROL CURVE

The 1991 Settlement Agreement also includes equations and language defining the Steelhead Spawning Control Curve (SHSCC). This new control curve is a schedule of elevations computed over the same period as the Planned Spawning Flow, March through June. Under the agreement on which this simulation modeling effort was based, the SHSCC is computed *daily* and used to define a new minimum end of period operating elevation at Ross for each day during steelhead spawning.

While the agreement contemplates *daily* computation, the most frequent recalculation possible within the simulation framework is twice monthly. Because of the importance of these new dynamic mechanisms in the fisheries agreement, we endeavored to implement the SHSCC computations in the simulation model. The SHSCC calculations, as adapted to the simulation model's data frequency, are based on the following:

- The reservoir elevation at the beginning of the period
- The forecasted volume inflow expected at Gorge over the course of the current period
- The Planned Spawning Flow for the current period

The volume corresponding to the (twice monthly) SHSCC elevation is calculated by the following formula:

$$VF(t+1) = VF(t) + FVI(t) - [PSF(t) * NDAYS(t)]$$

where:			
	VF(t+1)	=	SHSCC end of period reservoir volume
	VF(t)	=	Beginning of period reservoir volume
	FVI(t)	=	Forecasted volume inflow over the period
	PSF(t)	=	Planned Spawning Flow for the period
	NDAYS(t)	=	Number of days in the period
	t	=	The current period

The simulated SHSCC point is the reservoir elevation corresponding to the initial reservoir volume plus the forecasted inflow for the period minus the volume outflow corresponding to the Planned Spawning Flow.

Initial simulations of the new agreement included this computation of the *SHSCC* points. Again, these simulated SHSCC points are computed on a *twice-monthly* basis. These simulated SHSCC points were used as a new minimum end of (two-week) period elevation whenever the SHSCC was valid. That is, whenever the SHSCC point fell between the SPCC (spill control curve, or maximum elevation) and the VECC (variable energy content curve, or minimum elevation).

In these initial simulations, the SHSCC points that were installed as new operating minimums often degraded the simulation model's behavior. In many cases, the simulation model could not achieve the Planned Spawning Flow levels. Ross outflow was, in these cases, reduced because achieving the Planned Spawning Flow level caused a violation of the new (twice-monthly SHSCC) minimum. This would not be the expected result were the computations carried out on a daily basis.

This behavior is attributed primarily to two factors. The first is the difference in data frequency between the simulation and the requirements of the agreement. The second factor is forecast error for the individual periodic (two-week) forecasts of volume inflow. When these forecasts are higher than the actual stream flows that develop, the simulated SHSCC points are correspondingly higher than the ending elevation which results from strictly following the Planned Spawning Flow.

In a daily computation of SHSCC, the reservoir operators would be constantly correcting for forecast error, as each day's data on actual stream flows were measured and recorded. Ideally, the SHSCC point would rapidly approach the VECC point over the course of an operating period. In the simulation model this constant correction and refinement cannot be made.

Further, in the simulation framework, we do a much better job of forecasting the total volume inflow over the entire runoff season than we do of forecasting the volume inflow over any two-week period. In other words, our computation of Planned Spawning Flow is much more reliable than our computation of the SHSCC point in any given period.

Further review and discussion with City personnel led to the following resolution of the problem. The Steelhead Spawning Control Curve (SHSCC) is not implemented as a minimum elevation in the simulation model. The divergence between the two-week data frequency of the model and the intended daily computation of the SHSCC is simply too great. The limitations of the simulation model simply preclude the proper application of the SHSCC as intended under the agreement. While the routine which computes the SHSCC points has not been removed from the model, these data are essentially ignored in the simulation run reported here. The primary effect of this adjustment is that simulated Ross Lake elevations may be slightly lower than actual levels.

4.4.5.3 Effects of the 1991 Settlement Agreement

The simulation results of the 1991 Settlement Agreement do not represent a severe departure from the Interim Agreement base case simulation. Both simulations attempt to achieve elevation 1602.5 feet by July 31 in each simulation year. The new simulation results relative to lake levels, outflow patterns, spill, and power generation are summarized below. Detailed results are included in Appendix C.

The results indicate that Ross Lake would reach the refill target of 1602.5 feet by July 31 in 36 years out of 50, or 72 percent of the time. Of the 14 instances when refill is not achieved, 13 are caused by PDP conditions and one instance is caused by insufficient streamflow and preceding PDP conditions. The average lake level over the 50 simulation years is about elevation 1550 on May 31 and elevation 1586 on June 30.

Average simulated outflow at Gorge is highest in January and February, at about 6100 and 5650 cfs, respectively. Average outflow is lowest during September and October, at approximately 2650 and 2720 cfs, respectively. The lowest level of outflow occurring in the simulations is 1500 cfs, which is the minimum flow requirement for several periods in the 1991 Settlement Agreement. Simulated outflows of 1500 cfs occur during portions of 11 water years, all during the months of May, September, and October. The highest simulated outflow is an average of over 15,000 cfs during the first two weeks of July in the 1972–1973 water year. Outflows exceed 10,000 cfs during two other periods.

Simulated operation of the 1991 Settlement Agreement resulted in two incidences of spill at Ross, during May and June of the 1933–1934 water year and April of the 1963–1964 year. Spills at Diablo and Gorge also occur at these times. Overall, spills occur during a total of 3 months at Ross, 42 months at Diablo, and 35 months at Gorge. The two extreme water years of 1933–1934 and 1972–1973 account for over 45 percent of the total spill over the 50-year simulation period.

Total energy generation with the simulation based on the 1991 Settlement Agreement range from 1,696 GWh to 3,648 GWh. Over the entire simulation period, the highest generation levels occur in January and February, and the lowest in September and October. Average January production is approximately 339 GWh, or about 454 average MW. Average September production is 129 GWh, or approximately 173 MW. The highest monthly production observed in any year is 445 GWh during July of the 1972–1973 water year, while the lowest is 53 GWh in October of the 1940–1941 water year. Over the 50 simulation years, seasonal and total generation patterns resulting under this scenario are summarized as follows:

Generation (GWh)	Summer	Winter	Total
Simulation 50-Year Total	54,118	77,312	131,429
Average Simulation Year	1,082	1,546	2,629

4.5 COMPARISON OF ALTERNATIVES

The HYDRO model produced quantified results for four key parameters, which are lake levels, streamflows, spill, and energy production. This section of the report provides a comparison of the results for these four parameters across the 13 refill scenarios evaluated. Due to the supplemental nature of the simulation based on the 1991 Settlement Agreement, results of this scenario are discussed in terms of incremental differences compared to the Interim Agreement base case.

4.5.1 Lake Levels

Under current operation (base case) Ross Lake is refilled by the end of July, and maintained at or near full through the end of August. Drafting for fisheries flow requirements and winter energy production normally begins during September. Significant drafting for winter energy production begins in November and continues through the end of March. The early refill alternatives do not significantly affect operations between the end of August and the end of December, but they begin to show significant effects on reservoir elevation during January. Elevation impacts continue to be felt until normal refill is achieved at the end of July. Under the base case, Ross Lake is drafted by approximately 95 feet of elevation, on average over 50 years, by mid April. The most aggressive early refill alternative (May 31 target dates) reduce average annual drafting to approximately 50 or 55 feet. The June 15 target date alternatives reduce total winter drafting to 70 to 79 feet. The effects of the other early refill alternatives on lake levels are proportionally less significant.

As noted in the summary, early refill decreases the amount of water drafted from Ross during the winter season. The *average* elevations at Ross under each Interim Agreement fisheries flow scenario are shown in Figure 4-6. The *average* elevations at Ross under each license requirement fisheries flow scenario are shown in Figure 4-7. These are arithmetic means taken over the 50 years of results for each simulation.

As the figures show, early refill does not alter operations from August through the end of December. (The reduction of flow requirements under the license requirements alternatives has a relatively small effect on *average* elevations. These small effects are not apparent due to the scale of the figures.) This is consistent with maintaining normal full pool refill by July 31 under all scenarios. Thereafter, operation is consistent under each scenario until the VECC, as modified for early refill, comes into effect in January.

Early refill effects appear between January and mid-July. These effects are in direct proportion to both the date of refill and the specific target elevation. As expected, more aggressive refill dates cause greater impacts. The same is true of refill target elevations. Under the most extreme alternative (earliest refill to highest target), achieving 1601.5 feet on May 31, the average elevation at the beginning of the refill season is more than *40 feet* higher than under the base case. The greatest impacts result from the earlier refill dates at the end of May and in mid-June with target elevations at 1592.0 and 1601.5 feet.

The implementation of those scenarios following license requirement fisheries flows have, inherently, even lower outflow levels during historically low operating years. The minimum flows come into play only during low water periods. (The normal outflow targets for generation from Ross are always above both license and Interim Agreement flow requirements. Only when these desired levels cannot be met does the simulation model invoke minimum fisheries flows at whatever level is specified.) This contributes to the increase average lake levels.

Aside from the average lake level, the refill alternatives vary with respect to the frequency of meeting the refill targets. Success in achieving refill targets ranges from 58 percent with Alternative 6 (1601.5 feet on May 31) to 78 percent for Alternative 2 (1592.0 feet on June 30). The primary cause of inability to meet refill targets is imposition of PDP conditions. The study was designed to sacrifice early refill targets for the production of firm energy when necessary (PDP). PDP can obstruct early refill in two ways. If PDP is imposed during the period which contains the target early refill date, early refill is automatically overruled. PDP may also cause early refill to be missed when it is imposed in a period prior to the target date and subsequent streamflows are insufficient to meet the target elevation. In many cases, PDP conditions are directly responsible for 60 to 75 percent of the instances of failure to meet directly the refill target. However, in the May 31 refill cases insufficient streamflow contributes to virtually all such instances.

Figure 4-8 shows the number of times that simulated operation failed to achieve refill as defined under each particular Interim Agreement scenario. The areas marked as being in PDP on the graph show the number of times the refill failure was caused by PDP on the refill date. The other failures are caused by combinations of insufficient streamflow and PDP conditions in other periods. Figure 4-9 reports similar results for the original license requirement fisheries flow scenarios.

Implementing the flow requirements of the 1991 Settlement Agreement would have little effect on actual lake levels with operations under the base case refill targets. As shown in Figure 4-10, the simulated elevation curve for the 1991 Settlement Agreement tracks very closely with the ending elevations for the Interim Agreement base case. The simulation results underlying the respective curves (see Appendix C) indicate that lake levels would be up to approximately 2 feet higher with the 1991 agreement from late April through late June, and up to 1 foot higher in September and October. Simulated average end-of-period lake elevations for these two scenarios are indicated in Table 4-7. The 1991 Settlement Agreement yielded the same results as the Interim Agreement base case with respect to failure in meeting the refill targets. Both scenarios result in failure to refill to elevation 1602.5 by July 31 in 14 of 50 simulation years, as indicated in Figure 4-11, with 13 of these 14 occurrences caused by PDP.

Table 4-7. Average April–October ending elevation at Ross, Interim Agreement base case vs. 1991 Settlement Agreement.

	------------------AVERAGE ELEVATION (FT) OVER 50 YEARS------------------	
Time Period	1981/84 Interim Agreement	1991 Settlement Agreement
April 1–15	1500.3	1509.2
April 16–30	1509.8	1511.1
May 1–15	1524.8	1523.6
May 16–31	1549.8	1550.6
June 1–15	1571.8	1573.5
June 16–30	1586.4	1587.0
July 1–15	1594.4	1594.7
July 16–31	1597.5	1597.5
August 1–15	1596.3	1596.0
August 16–31	1594.4	1594.3
September	1591.4	1592.4
October	1590.4	1591.1

4.5.2 Streamflows

As with reservoir elevation, streamflows during the period from the end of July through the end of December are not significantly affected by early refill. Streamflows under the base case are generally highest during the winter peak months, when Ross Lake is drafted for energy production. Aggressive early refill (mid June and May targets) totally alter this pattern. Streamflows become highest at and after the early refill target dates. Winter streamflows are significantly depressed by the operating rule requirements that more water must be stored to meet the early refill targets.

Figure 4-12 shows the *average* regulated outflows from Ross Lake under each Interim Agreement scenario. Figure 4-13 presents the corresponding results for the original license requirement regulated outflows; the base case (under the Interim Agreement) is also plotted on Figure 4-13 for reference. These data are also arithmetic means taken over the 50 years of simulation results for each case. The most striking aspects of the average outflow rates plotted in Figures 4-12 and 4-13 are the extreme increases under early refill between late May and early August. In fact, these plots reflect only *regulated outflow* and do not account for *spill*, which also rises significantly under the more extreme early refill scenarios. These rises in outflow rates underscore an important consideration in the operation of Ross Lake. This consideration is flood control, particularly as it relates to early refill.

Achieving the early refill targets in three of the simulation cases causes extremely high rates of outflow during May and June in some years. The three early refill scenarios which result in simulated flooding *in an average year* are: 1601.5 feet on May 31, 1592.0 feet on May 31, and 1601.5 feet on June 15. In point of fact, the Army Corps of Engineers has expressed concern that it may be necessary for them to impose extended flood control levels, were the City to adopt early refill. The current flood control curve (FCC) imposed by the Corps sets maximum allowable elevations for October 31 through March 15. The Corps has not, historically, imposed flood control levels beyond March 15 because Ross has always been operated as a predominantly winter producing resource. Because of winter drafting for energy production, elevation at Ross has typically been well below the stipulated March flood control level even as late as mid-June under current operation (base case).

Figure 4-14 charts the number of periods in which average outflows from Gorge exceeded 7000 cfs under each of the Interim Agreement scenarios simulated. The 7000 cfs flow level is the *maximum* acceptable flow level on the Skagit for fisheries protection. The flow levels used in compiling this chart are total streamflows from Gorge, which include both regulated flow and spill. Figure 4-15 reports the corresponding set of results for the original license requirement alternatives.

Compared to the Interim Agreement base case, streamflows would not be significantly affected by the 1991 Settlement Agreement. The average outflow results for these two cases are shown graphically in Figure 4-16. The 1991 Settlement Agreement results in slightly higher flows in May, late June through early August, and January through March. Conversely, flows would be somewhat lower in September, December, and April, and late May through early June. The magnitudes of these differences are less than 400 cfs. The outflow differences from March through June would have the overall effect of smoothing the average flow levels during this period, which is one of the major expressed objectives of the Settlement Agreement.

4.5.3 Spill

Spilling is the release of water which is not used for electric generation at the time of release. Thus, spill translates into lost energy production. There are essentially two different causes of major spilling at any of the Skagit plants studied here. Spill occurs most frequently in summer, concentrated in June, July, and August. Summer spill is caused by (persistent) high streamflow after refill. (Refill may occur early with high streamflow conditions.) Once the maximum storage capacity at Ross is reached, any inflow in excess of the flow-through capacity of the generators must be spilled. In contrast, winter spills occurring in October, November, and (less frequently) December are, typically, not caused by the lack of storage capacity. Spills do occur during these months, but are caused by the imposition of the FCC (flood control curve) at Ross. This causes high outflow from Ross, resulting in spill at the downstream plants.

Energy loss through spill may be exacerbated by partial maintenance outage of the generating facilities at any of the three plants. The modeling effort undertaken here uses a realistic maintenance schedule and applies it consistently across the base case and early refill scenarios. Therefore, maintenance scheduling is not a significant factor in judging the differences in spill between the base case and the alternatives.

The effect of early refill is to increase the amount of water spilled. The effect of increased spill is in direct proportion to the aggressiveness of the refill target dates and elevations chosen for analysis. For any given target refill elevation, an earlier refill date causes increased spill. Similarly, for any given refill date, a higher target elevation increases spill.

Under the base case scenario there are only two incidences of spill at Ross. These occur during May and June of the 1933-1934 water year, an historic flood year. These spills at Ross are caused by a combination of extreme high natural streamflow conditions, near full pool (from storage for flood control in previous periods), and a 50 percent regularly scheduled maintenance outage. Spill occurred at all three plants during those months.

Counting occurrences of spill at any of the three plants, there are 32 months of a possible 600 (50 years x 12 months) in which spill occurs under the base case scenario. Spill occurs most frequently in July, August, October and November. The combined 50 year total spilled from all three plants was 4191 thousand acre-feet of water.

The spill impacts are summarized in Table 4-8 for the Interim Agreement fisheries flow scenarios. The original license minimum flow scenarios are not significantly different in their effects on spill. The summaries shown are total number of months with spill occurrences and total quantities spilled over the entire 50-year simulation period.

Even the least aggressive early refill alternatives examined have significant impact on spill. In general, June and July show the most frequent incidence of spill for later refill target dates. The early refill alternatives with refill target dates in mid-June or in May change the

Table 4-8. Spill under Interim Agreement refill scenarios.

Refill Scenario	Number of Months With Spill	50 Year Total Amount Spilled (1000 Acre-Feet)	Percent Increase in Amount Spilled (percent)
1602.5 - July 31 (base case)	32	4190.79	---
1592.0 - June 30	41	7127.83	70
1601.5 - June 30	56	10663.34	154
1580.0 - June 15	46	10437.44	149
1592.0 - June 15	64	15024.16	259
1601.5 - June 15	84	20962.73	400
1592.0 - May 31	82	27530.86	557
1601.5 - May 31	97	36200.58	764

pattern of spilling. Under these alternatives, the months of June and July have the most frequent incidence of spill. Setting the refill target date to May 31 also increases the incidence of spill in that month.

The incidence of simulated spill is somewhat higher with the 1991 Settlement Agreement relative to the Interim Agreement base case. Spill occurs in a total of 42 months over 50 years for the 1991 Settlement Agreement simulation, compared to 32 months for the Interim Agreement base case (see Appendix C). In terms of the total volume of water spilled, the new agreement would result in an increase of approximately 23 percent over 50 years.

4.5.4 Energy Production

Under the base case scenario (current operation) the three Skagit plants are all operated as a winter peaking energy resource. Energy production reaches its highest levels in January and February, the months of peak energy demand. Aggressive early refill actually alters the entire energy production pattern of these resources. Under the early refill alternatives with elevations at 1592 feet and above for June 15 and May 31 target dates, the Skagit plants are converted to a summer peaking energy resource. Under these alternatives, energy production in June and July is greater than energy production in January and February, given average water conditions. The less aggressive early refill alternatives have a similar, if less pronounced effect, of merely depressing winter energy production and increasing summer energy production. Early refill also has the effect of decreasing average annual total energy production. Again, the severity of this effect corresponds to the height of the target elevation and how early it is to be achieved. Energy production over the 50 year simulation period is summarized in Table 4-9 for the 12

Table 4-9. Simulated total 50-year Skagit Project energy production, original refill scenarios.

Energy Production in GWh Analysis Period: July 1, 1928 through June 30, 1979						
	Interim Agreement Fisheries Flows			License Requirement Fisheries Flows		
Refill Date and Target Elevation at Ross Lake	Summer Season Sub-Total	Winter Season Sub-Total	50 Year Grand Total	Summer Season Sub-Total	Winter Season Sub-Total	50 Year Grand Total
July 31 - 1602.5 Base Case Scenario	54,074	77,572	131,645	54,283	77,389	131,672
June 30 - 1592.0	54,396	76,603	130,999	54,629	76,403	131,032
June 30 - 1601.5	54,813	75,416	130,229	55,089	75,182	130,271
June 15 - 1580.0	55,059	75,457	130,516			
June 15 - 1592.0	56,477	73,192	129,669			
June 15 - 1601.5	57,843	70,456	128,299			
May 31 - 1592.0	61,334	65,542	126,876			
May 31 - 1601.5	61,612	62,910	124,521	63,767	60,369	124,135

NOTE: Summer Season is defined as April through August, inclusive.
Winter Season is defined as September through March, inclusive.

original refill scenarios. These total and seasonal energy production summaries for the 50 year simulation period are illustrated in Figures 4-17 through 4-22.

The amount of energy produced from a given amount of outflow increases with elevation (head), and the simulation model takes account of this relationship. However, the mitigating effect of higher head is insignificant relative to the outflow reductions (Figures 4-12 and 4-13) during the winter season under any of the early refill scenarios. Winter energy production is always decreased by early refill or the reduction of fisheries flow requirements. Increased outflow and the contributing effect of higher head combine to increase average summer energy production under early refill. The combined effect is an average decrease in annual energy production.

The importance of the *timing* of energy production must also be stressed. This is due to the pattern of energy demand in the City service territory, and the region in general. Energy demand is significantly higher during the winter season. If the City experiences an energy deficit, it occurs during the winter season. When the City experiences an energy surplus it generally occurs during the summer season. By shifting total generation from the Skagit plants toward the summer, the early refill alternatives work counter to the utility's power planning needs and objectives.

A portion of the lost energy production associated with early refill is also attributable to spill. By definition, spilled water is not available for generation purposes, and therefore represents a direct loss of the resource. The simulation model does not include a procedure to separate the energy costs of spills from those of generation shaping (shifting generation from winter to summer). However, given the large increases in the incidence and volume of spill compared to the base case (see Table 4-8) it can be assumed that energy generation losses from spills account for an increasing proportion of total generation losses as the refill targets are advanced.

The direction and magnitude of energy effects for the Interim Agreement refill scenarios is shown in the distribution curves appearing in Figures 4-23 through 4-25. These graphs illustrate the effects on energy production, relative to the base case, on an annual and seasonal basis over the 50 year simulation period for each Interim Agreement early refill scenario. As indicated in Figure 4-23, total energy generation with any of the early refill alternatives actually exceeds base case generation in some simulation years. However, this is limited to less than 20 of the 50 years, and the increases never exceed about 250 GWh. Conversely, early refill results in decreased total generation in most years, and by larger margins that range up to about 550 GWh per year. Figure 4-24 clearly shows that early refill winter generation never exceeds the base case level, and usually is much lower in half or more of the simulation years. The summer pattern shown in Figure 4-25 is nearly the reverse, with early refill generally resulting in higher summer generation in from about 25 to 40 of the simulation years. However, the magnitudes of the decreases in winter generation shown in Figure 4-24 are clearly larger than the magnitudes of summer increases in Figure 4-25. Once again, the effects are directly proportional to both how early the refill date is set and the height of the target elevation.

Figures 4-26 through 4-28 display the results for the license requirement alternative scenarios. Note that these results are relative to the *Interim Agreement base case*. The *base case*, by definition, refers to the manner in which the Skagit plants are currently operated. The counterproductive, yet relatively modest, effects on energy production of following the original license minimum fish flows, as opposed to the Interim Agreement, can be seen on these figures by examining the original license requirement scenario for refill to 1602.5 on July 31. The only change from the base case for this scenario is the general reduction of minimum fisheries flow levels. Figures 4-26 and 4-27 illustrate very sharply the much larger decreases in total and winter generation associated with refilling to elevation 1601.5 feet in May 31, compared to the other refill alternatives in this set.

The 1991 Settlement Agreement would not have a significant incremental impact on energy production relative to the Interim Agreement base case. Simulated total annual, winter and summer generation for these two cases are compared graphically in Figures 4-29, 4-30, and 4-31. In all three graphs, the generation patterns and levels are nearly identical. Aggregate generation levels over 50 years for these two cases are indicated in Table 4-10. The 1991 Settlement Agreement would reduce winter generation by only 0.33 percent (260 GWh) compared to the Interim Agreement, and total generation by only 0.16 percent.

4.6 VALUATION OF ENERGY PRODUCTION EFFECTS

A critical step in the power generation analysis is to conduct an economic assessment of the generation effects of the early refill alternatives. The power produced by the Skagit Project has a large economic value, and a reduction in generation from the project would translate into real economic costs to the City and its ratepayers. Consequently, the power generation analysis included a task to identify the economic effects of the early refill alternatives. This task generally involved establishing an appropriate price for power generated in each season, calculating the value of power produced in each year, and discounting the annual generation values to determine a present value for each alternative.

4.6.1 Approach

The unit energy prices used to evaluate changes in energy production should accurately reflect the market for secondary (surplus firm energy and nonfirm, or economy, energy) power in the Pacific Northwest. (The analysis documented in this chapter employed a basic premise of avoiding any sacrifice of firm power generation, so the generation effects of the alternatives involve only non-firm power.) Unfortunately, it is much easier to envisage how the valuation of net energy effects of early refill should be conducted than it is to determine what the worth is of increased summer generation and the price of winter replacement power would be.

In this analysis, we have used results from the Bonneville Power Administration's (BPA) Systems Analysis Model (SAM) to simulate the power transactions that would occur in the future. SAM is a large computer model that simulates, among other things, power sales transactions both in the region and to the Pacific Southwest. For the purposes of this study, we value future changes in energy production from the Skagit plants according to

Table 4-10. Simulated total 50-year Skagit Project energy production, Interim Agreement base case vs. 1991 Settlement Agreement.

Fisheries Agreement	--------------ELECTRIC GENERATION (GWh)----------- Summer	Winter	Total
1981/84 Interim Agreement	54,073.60	77,571.85	131,645.45
1991 Settlement Agreement	54,117.69	77,312.15	131,429.84
Percentage Change	0.08 (%)	–0.33 (%)	–0.16 (%)

the forecast power transactions for secondary energy, since the City would not be entitled to purchase firm energy at the priority firm rate, used for BPA sales of firm power to its preference customers.

The most recent SAM run reports secondary power prices for the period 1989 through 2008. These prices are differentiated by energy season. The SAM definition of the energy seasons differ slightly from those used by the City and in other sections of this report. The SAM summer energy season is defined as April through August. The SAM winter season is September through March, inclusive. The energy valuation analysis uses SAM seasons and seasonal prices for the period 1990 through 2008. These prices are reported in real 1990 dollars (i.e. net of inflation) and appear in Table 4-11.

In some of the forecast years, such as 1990 through 1992 and 1995-1996, the summer prices for secondary energy indicated in Table 4-11 are very near the winter prices. However, in 10 of the forecast years the winter price exceeds the summer price by a substantial margin, ranging from $4.52 to $34.19 per MWh. Overall, including years of relatively little price difference, the winter price exceeds the summer price in 15 of the 19 forecast years. The average of the winter prices over the forecast period is $39.68 per MWh, which is $6.74 more than the $32.94 per MWh average of the summer prices (a difference equivalent to 0.67 cents per kilowatthour, the common unit for retail power rates).

The Northwest power system is interconnected with a number of other generators and purchasers of power. The interaction of the buyers and sellers of energy establishes the value of power in any given period. In general, the primary determinants of the value of power are the water conditions in the Northwest system, the availability of thermal and hydro resources, and the level of power demand.

Table 4-11. Forecasted real prices for secondary energy in real 1990 dollars per megawatthour.

	Summer	Winter
1990	22.24	22.52
1991	24.91	25.32 (1)
1992	26.24	26.76
1993	23.87	28.39
1994	21.41	31.06
1995	34.22	33.35
1996	35.09	34.56
1997	28.78	36.40
1998	36.79	37.90
1999	39.00	39.32
2000	40.45	39.04
2001	33.02	40.79
2002	41.76	50.27 (1)
2003	35.79	41.93
2004	45.87	44.54
2005	24.97	44.85
2006	46.73	80.92 (1)
2007	28.68	47.82
2008	36.07	48.10

(1) Note: SAM did not predict any secondary sales in these periods. We constructed these prices for the valuation by using the average ratio of winter to summer price for the surrounding years and the summer price for the year in question to construct a price for the missing period.

Source: Personal communication, Eric Westman, Bonneville Power Administration, Resource Planning, Portland, Oregon, November 30, 1989.

The SAM model uses a forecast of resources and demand in its simulation of power transactions. SAM also probabilistically selects water conditions in the future years, so that the simulated price for power reflects the resources currently available to produce energy, energy demand, and water conditions. However, water conditions considered in SAM are dominated by the water conditions in the Columbia River watershed. The Skagit River watershed is hydrologically isolated from the Columbia, and water conditions often differ between the two basins.

For the purposes of this project, we have made *no* assumptions concerning future water conditions on the Skagit. The reasons for this are several. First, obtaining and analyzing the Columbia River water conditions as forecasted by SAM would be an undertaking well beyond the scope of this study. Further, no data on the correlation of water conditions between the Columbia and Skagit watersheds are readily available. Second, developing such a correlation analysis and, subsequently, a simulation for the Skagit corresponding to the SAM run would involve a level of effort well beyond available resources.

It would be reasonable to expect that *low water* conditions on the Columbia would result from region-wide weather patterns which would result in *low water* conditions on the Skagit. Low water conditions on the Skagit cause lower summer surpluses under early refill and exacerbate the winter energy losses. Larger winter energy deficits from early refill would have the effect of increasing the price paid for replacement energy purchases. High water conditions on the Skagit have the opposite effect under early refill, increasing summer surpluses. However, larger surpluses would reduce the price obtained for sale of the energy. The effects of early refill on energy production would have corresponding effects on the secondary energy market prices. These price effects on the secondary market are, obviously, not incorporated in the SAM simulation.

Thus, in order to present a conservative estimate, the analysis makes no assumption about water conditions on the Skagit in individual forecast years (1990-2008). Hence, each year is treated as an average of the results over the 50-year early refill simulation period. The seasonal data corresponding to the SAM definitions are constructed by adding the appropriate months from the average simulation year for each early refill alternative. The seasonal differences from the base case are then computed and evaluated. The value of energy in each forecast period is determined using the real seasonal secondary energy prices reported above.

The present worths of these differences are computed using a 3 percent discount rate. This 3 percent discount rate was chosen to correspond with the discount rate used by the City for internal economic analyses. As an alternative, the present worths of these differences are also presented as computed using a 7 percent discount rate, to indicate the sensitivity of the results to varying time preferences for money.

Several other assumptions enter into the analysis. These assumptions also tend to cause the results to represent a lower bound for the energy related costs of early refill.

- First, the analysis assumes that winter losses in energy production can be replaced at the prices specified. This presupposes that secondary energy supplies will be sufficient. Again, it also disregards the potential price effects of increased demand on the secondary power market, which could become significant under the more aggressive early refill alternatives.

- Second, it is assumed that the summer surplus energy production could be sold at the prices specified. This presupposes two additional conditions. One is the underlying assumption that the market can absorb this additional supply without inducing price effects. The other underlying assumption is that it would be physically and politically possible to schedule transmission (wheeling) of the entire surplus on the North-South Intertie. (The historical market for Pacific Northwest surplus energy production during summer months is Southern California. Local demand would probably be insufficient to absorb the surpluses under aggressive early refill.) Access to the Intertie has been a contentious subject in recent years, so this is probably an optimistic assumption.

4.6.2 Results

The results of the energy valuation analysis for the initial 11 early refill alternatives are summarized in Table 4-12. The complete results of the energy valuation analysis are presented in Appendix D. The time horizon of the analysis is nineteen years.

As shown in the summary provided in Table 4-12, the energy costs of the early refill alternatives are significant. Compared to current operations (the base case), the value of the decreased power generation associated with the seven refill alternatives based on Interim Agreement flows ranges from a total present worth of about $7.9 million (in 1990 dollars) to over $93 million over the 1990-2008 period of analysis. Forecasted prices beyond 2008 were not available, so the estimation of energy costs was truncated at this point rather than use arbitrary forecast values. Therefore, the estimated energy costs understate the actual cost of each alternative over a 30-year license period.

The least-cost early refill alternative under the Interim Agreement would be Alternative 2, involving refilling to elevation 1592.0 by June 30. On an annual basis, the future values of the energy costs range from about $0.3 million to nearly $1.3 million per year, and total over $10.6 million for the 1990-2008 period. (See Appendix D for annual details of the energy cost analysis.) When discounted at a rate of 3 percent, the future energy costs associated with Alternative 2 have a present value estimated at nearly $7.9 million.

Alternative 5, refilling to elevation 1580 on June 15, has the second-lowest energy costs. This alternative would involve long-term energy costs valued at over $14.4 million, in present value terms, based on future values that sum to over $19.6 million.

The refill alternatives with May 31 target dates have by far the highest associated energy costs. Refilling to elevation 1592.0 by May 31 (Alternative 7) would cost an estimated $66.2 million over the period of analysis. The cost of achieving an essentially full pool

Table 4-12. Present worth of power generation benefits of early refill alternatives at a 3 percent discount rate (1990-2008).

Alternative	Target Elevation in Feet	Target Refill Date	Summer (1990 $)	Winter (1990 $)	Total (1990 $)
INTERIM AGREEMENT FLOW SCENARIOS					
6	1601.5	May 31	71,835,761	-164,922,955	-93,087,194
7	1592.0	May 31	69,195,335	-135,358,982	-66,163,647
3	1601.5	June 15	36,037,428	-80,182,753	-44,145,325
4	1592.0	June 15	23,068,539	-49,468,516	-26,399,978
5	1580.0	June 15	9,600,372	-24,028,330	-14,427,958
1	1601.5	June 30	7,266,834	-24,492,121	-17,225,287
2	1592.0	June 30	3,302,823	-11,166,202	-7,863,379
ORIGINAL LICENSE MINIMUM FLOW SCENARIOS					
11	1601.5	May 31	92,490,546	-193,674,740	-101,184,194
10	1601.5	June 30	10,072,341	-27,344,024	-17,271,684
9	1592.0	June 30	5,699,525	-13,629,904	-7,930,379
8	1602.5	July 31	1,949,945	-2,009,262	-59,317

Note: Negative numbers indicate the costs of purchasing replacement power in the winter, using forecasted prices from BPA's Systems Analysis Model. Annual figures are expressed in real 1990 dollar terms. Present values are calculated using a 3 percent discount rate.

(elevation 1601.5) by May 31 is estimated at nearly $93.1 million in present worth terms. The future values of the annual costs of this alternative (Alternative 6) range from over $3.2 million to $16.7 million, and total nearly $126.8 million over the 1990-2008 period.

The early refill alternatives based on the original FERC license minimum flows exhibit a similar cost pattern to the initial set of alternatives. (Continuing current operations subject to the different flow constraint would result in a long-term energy cost of about $59,000.) The least-cost alternative to the base case under this flow constraint would also involved filling to elevation 1592.0 on June 30 (Alternative 10). The energy cost of this alternative is slightly more than $7.9 million, and exceeds the cost of the corresponding Interim Agreement scenario (Alternative 2) by about $67,000. At the other extreme, refilling to 1601.5 by May 31 would have a long-term cost estimated at nearly $101.2 million. This is about $8.1 million more than the cost of the parallel Alternative 6.

It should be noted that the costs expressed for the original license minimum fisheries flow scenarios are energy costs only. The actual costs for these alternatives would be higher if they included quantification of the damage to fish runs resulting from reduced minimum flows at key times of the year. This quantification has not been attempted, but the economic evaluation of power generation effects demonstrated that the refill alternatives based on original license minimum flows would exacerbate the energy costs of the corresponding Interim Agreement cases.

To test the sensitivity of the energy cost results, the economic evaluation of the early refill alternatives was also conducted using a higher 7 percent discount rate. The higher discount rate has the effect of more rapidly diminishing the present worth of future costs, which shortens the period of time over which these costs would be greater than zero and reduces the total present worth of the cost for any given alternative.

The results of this sensitivity analysis are summarized in Table 4-13. The energy cost present worth is somewhat lower for each alternative, but the costs remain substantial for every early refill case. Compared to the primary analysis using a 3 percent discount rate, the estimated energy cost for the least cost alternative (Alternative 2) decreases from about $7.9 million to $5.5 million. Alternative 6, refilling to 1601.5 on May 31, would still have an energy cost of nearly $65 million using a 7 percent discount rate, versus $93.1 million in the prior analysis.

The energy costs presented in Tables 4-12 and 4-13 represent the long-term present value of lost energy only over the 1990 to 2008 period. Future annual costs over the remainder of the 30-year license term cannot be estimated to the same level because forecasted energy prices are not available. However, the potential magnitude of the 30-year costs can be illustrated using the prior figures for the 1990-2008 period. With Alternative 2, the undiscounted annual costs from 1990 to 2008 totaled $10,640,000, for an annual average of $560,000. If real energy prices over the remaining 11 years of the license term remained at the average of the 1990-2008 period, the future costs of energy in the remaining 11 years would be $6,160,000. Adding the future costs for the two periods yields a total 30-year future value of $16,800,000. The present value of this figure would be about $10,976,000 at a discount rate of 3 percent, and $6,949,000 with a discount rate of 7 percent. These present worth figures are 40 percent and 26 percent higher than the respective Alternative 2 costs from Tables 4-12 and 4-13.

Similar changes result if the present value of the highest-cost alternative are approximated over 30 years. The future value of energy costs for Alternative 6 averages approximately $6,672,000 over the 1990-2008 period. If this average cost is extended over a 30-year term, the total future value amounts to $200,160,000. Discounting this figure at 3 percent yields a 30-year present value for Alternative 6 of approximately $130,800,000, while the present value with a 7 percent discount rate would be about $82,800,000.

Table 4-13. Present worth of power generation benefits of early refill alternatives at a 7 percent discount rate (1990-2008).

Alternative	Target Elevation in Feet	Target Refill Date	Summer (1990 $)	Winter (1990 $)	Total (1990 $)
INTERIM AGREEMENT FLOW SCENARIOS					
6	1601.5	May 31	52,134,725	-117,088,727	-64,954,002
7	1592.0	May 31	50,218,439	-96,099,484	-45,881,045
3	1601.5	June 15	26,154,124	-56,926,560	-30,772,436
4	1592.0	June 15	16,741,967	-35,120,676	-18,378,709
5	1580.0	June 15	6,967,460	-17,059,157	-10,091,697
1	1601.5	June 30	5,273,897	-17,388,430	-12,114,533
2	1592.0	June 30	2,397,020	-7,927,558	-5,530,538
ORIGINAL LICENSE MINIMUM FLOW SCENARIOS					
11	1601.5	May 31	67,124,913	-137,501,349	-70,376,436
10	1601.5	June 30	7,309,990	-19,413,168	-12,103,177
9	1592.0	June 30	4,136,424	-9,676,689	-5,540,265
8	1602.5	July 31	1,415,170	-1,426,496	-11,326

Note: Negative numbers indicate the costs of purchasing replacement power in the winter, using forecasted prices from BPA's Systems Analysis Model. Annual figures are expressed in real 1990 dollar terms. Present values are calculated using a 7 percent discount rate.

Implementation of the 1991 Settlement Agreement would result in an incremental cost in lost energy production compared to the Interim Agreement base case. Using ratios indicating relative generation levels and energy costs among the Interim Agreement, Alternative 2, and the Settlement Agreement, the energy costs of the latter can be simply approximated. This exercise results in incremental present-value costs for the 1991 Settlement Agreement of approximately $2.6 million through 2008 and $4.2 million over a full 30 years, using a 3 percent discount rate. With a 7 percent discount rate, these costs amount to approximately $1.8 million and $2.3 million, respectively.

4.7 SUMMARY ASSESSMENT

The preceding material in this chapter described the technical approach for and results of an in-depth analysis of the power generation effects of shifting to an operating pattern for early refill of Ross Lake. In summary, the analysis demonstrated that all of the early refill alternatives considered resulted in measurable decreases in power generated by the Skagit Project, at a substantial cost to the City. The estimated energy costs of the early refill alternatives reflect both lower quantities of energy produced as well as a shift in the timing of generation to periods when the power produced has a lower unit value. The analysis also indicated that the alternatives based on original FERC license minimum flow constraints are more adverse than the corresponding alternatives incorporating Interim Agreement flows. Consequently, only the latter alternatives are emphasized in the subsequent material.

The key results of the analysis were presented in Tables 4-9 and 4-12, which respectively summarized the changes in energy production and the economic valuation of those changes. In terms of total energy generation over the 50-year simulation period, the early refill alternatives result in decreases of from 0.5 percent to 5.4 percent compared to generation under the base case. While these generation changes are not large in percentage terms, the unit power values are such that even a very small decrease in power generation represents a highly significant annual and long-term cost. As reported in Section 4.6, the 0.5 percent generation decrease attributable to Alternative 2 (refilling to elevation 15920 on June 30) translates into a long-term energy cost over the 1990-2008 cost forecast period estimated at $7.9 million and an average annual cost of over $0.5 million. Extended over the full term of a 30-year license, the present value of the energy costs for this alternative would likely be about $11 million or higher. The 5.4 percent decrease associated with Alternative 6 (refilling to elevation 1601.5 on May 31) represents an average annual cost of nearly $6.7 million and a long-term cost of $93.1 million through the year 2008. With no increase in real energy prices beyond 2008, the 30-year cost of this alternative would have a present value of over $130 million.

These energy production and cost figures indicate that early refill of Ross Lake would be expensive to implement, but they cannot be fully evaluated without considering the effectiveness of the alternatives in terms of increasing early-season lake levels. (Complete evaluation of power generation effects also requires that they be considered in balance with recreation, fishery and other changes, as discussed in Chapter 5.) A numerical summary of key measures for the base case and each of the Interim Agreement refill alternatives is provided in Table 4-14; in addition to the energy quantities and costs discussed above, these measures include the success rates in meeting the refill targets and average lake levels on specified key dates.

Under current operations simulated over 50 years of hydrologic record, the refill target of elevation 1602.5 on July 31 is achieved 72 percent of the time (36 years out of 50). The highest success rates in meeting the early refill targets are 78 percent for Alternative 2 and 76 percent for Alternative 5, both of which represent relatively minor changes from current operating practices (as measured by average lake levels on given dates). The refill alternatives with May 31 target dates have the lowest success rates, with the refill target achieved 58 percent of the years for Alternative 6 and 60 percent for Alternative 7.

Table 4-14. Summary of performance measures for refill scenarios. (1)

Refill Scenario	Percent Change, 50-Year Total Generation(2)	Change in Energy Value ($ million)	Percent of Years Refill Target Met(3)	Average Elevation, June 30(3)	Average Elevation, June 15(3)	Average Elevation, May 31(3)
Base Case (1602.5 on July 31)	--	--	72	1586	1572	1550
Alternative 1 (1601.5 on June 30)	-1.1	-17.2	72	1596	1582	1559
Alternative 2 (1592.0 on June 30)	-0.5	-7.9	78	1592	1577	1554
Alternative 3 (1601.5 on June 15)	-2.5	-44.1	62	1598	1595	1576
Alternative 4 (1597.0 on June 15)	-1.5	-26.4	68	1597	1589	1569
Alternative 5 (1580.0 on June 15)	-0.9	-14.4	76	1594	1582	1561
Alternative 6 (1601.5 on May 31)	-5.4	-93.1	58	1599	1596	1591
Alternative 7 (1592.0 on May 31)	-3.6	-66.2	60	1598	1595	1585

(1) All scenarios based on Interim Agreement minimum flows.
(2) Derived from Table 4-5.
(3) Over 50 years of simulation period.

The refill target success rates are not directly comparable, because they do not indicate the relative lake levels or the magnitude of the shortfall in years when the refill target is not achieved. The last three columns in Table 4-14 provide more specific data on the changes in early-season lake levels, on average over the 50-year simulation period, that would be achieved with the early refill alternatives. These table entries were developed from visual inspection of the lake level graphs shown in Figure 4-6.

These elevation data indicate that average lake levels would generally fall several feet short of the target levels, largely because the shortfalls in years when the targets are not met reduce the overall average elevations. For example, while the refill target for Alternative 1 is elevation 1601.5 on June 30, the actual elevation on June 30 would average about 5 feet lower. Average actual elevations would equal or exceed the stated refill targets for the lowest-cost alternatives (Alternatives 2 and 5). In other cases, the difference between refill targets and actual elevations ranges from about 3 feet to about 10 feet. The largest shortfall applies to the most aggressive refill scenario of Alternative 6, where the average May 31 elevation of about 1591 would be well below the target of 1601.5.

More significantly, the elevation data in Table 4-14 illustrate the degree of improvement in early-season lake levels that could be gained for the energy costs associated with the various alternatives. Comparing the base case to the least-cost Alternative 2, Ross Lake would be from 4 to 6 feet higher on average on these key dates if this refill strategy were implemented. With either the base case or Alternative 2, lake levels on May 31 and June 15 would still be below elevations at which most recreation facilities become usable, so the higher lake level on these dates would not translate into tangible recreation benefit. Alternative 2 would yield an average increase in the June 30 lake level from elevation 1586 to 1592 feet, which would have some positive effect on recreational facilities and visual quality. This 6-foot increase in the average lake level on June 30 would be gained at an energy cost totalling $7.9 million from 1990 to 2008, and probably at least $11 million over the 30-year license term. The elevation differences from the base case across the three dates are also fairly constant for Alternative 1 (about 10 feet) and Alternative 5 (8 to 11 feet). In these cases, improvement of average lake levels by about 10 feet would carry energy costs of $17.2 million and $14.4 million, respectively, over the 1990-2008 forecast period.

With the other refill cases, the differences are much larger for May 31 elevations and narrow to a smaller range for June 30. May 31 average elevations range from 1550 feet (base case) to 1591 feet (Alternative 6), a difference of 41 feet, while the June 30 figures vary by only 13 feet, from elevation 1586 to 1599.

The performance measures for the 1991 Settlement Agreement would cause little rearrangement to the figures in Table 4-14 if they were substituted for the Interim Agreement base case. Total simulated 50-year energy production with the Settlement Agreement is 0.33 percent less than with the Interim Agreement base case, so changing the base case benchmark would cause slight reductions in the percentage losses of generation and the incremental costs of those losses. The only other change between the two cases would be in the average elevation on June 15, which would be 1574 feet for the 1991 Settlement Agreement (an increase of 2 feet over the Interim Agreement average).

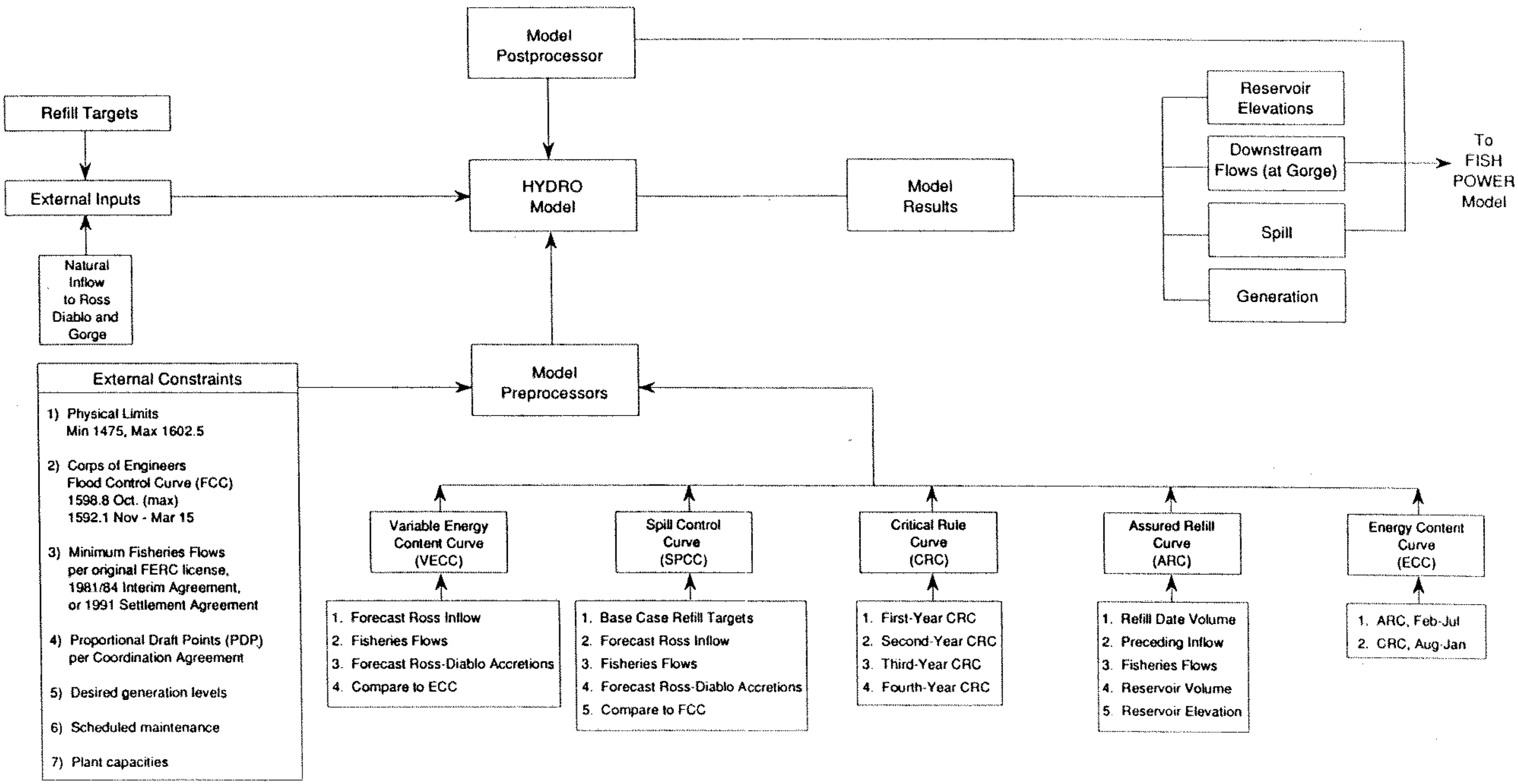


Figure 4-1. Schematic representation of simulation process

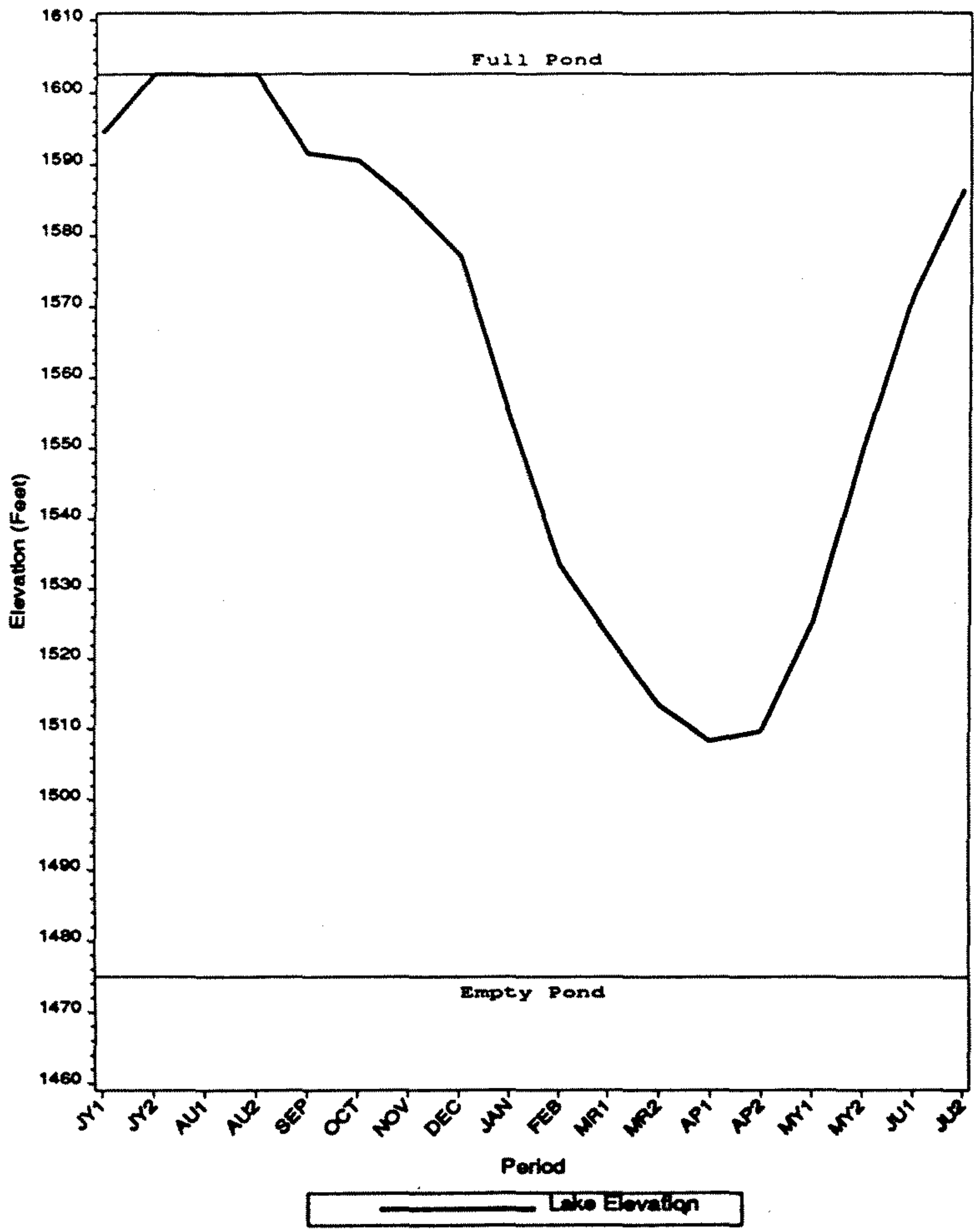


Figure 4-2. Typical operating elevations at Ross Lake.

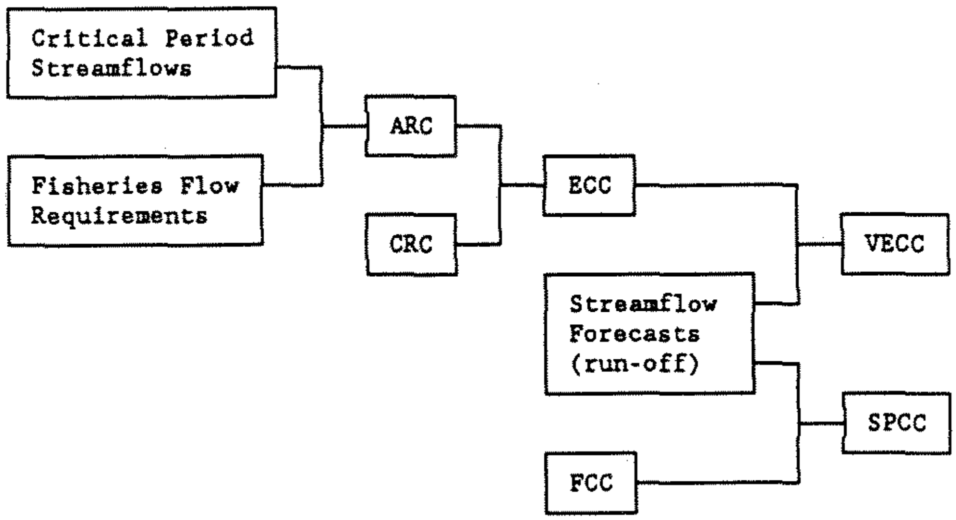


Figure 4-3. **Interrelationships of operating rules curves and data.**

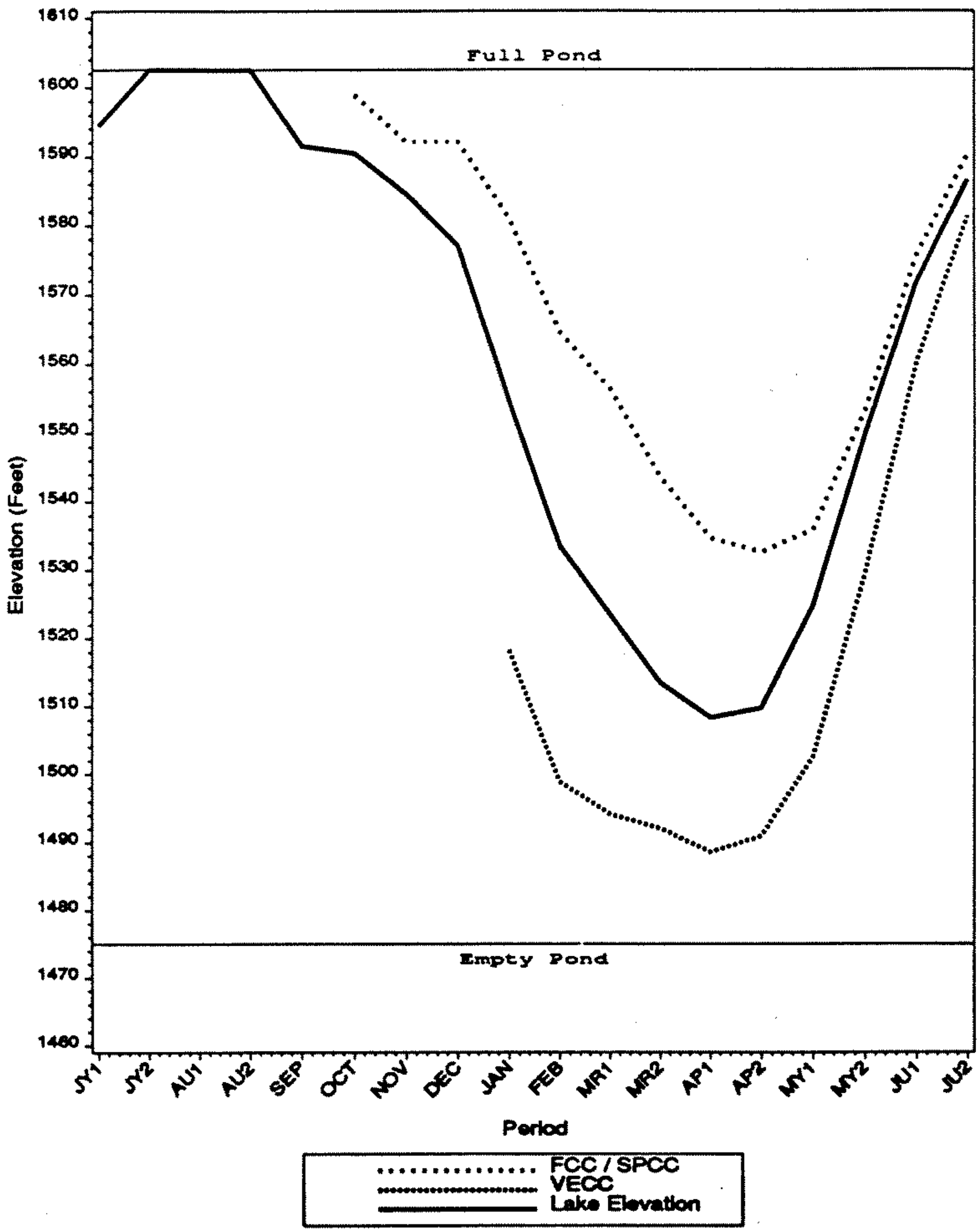


Figure 4-4. Typical operations at Ross Lake.

PERIODS FORECAST

FORECAST NUMBER

Forecast Date	No.	Jan.	Feb.	March 1-15	March 16-31	April 1-15	April 16-30	May 1-15	May 16-31	June 1-15	June 16-30	July 1-15	July 16-30
Jan. 1	1	1	1	1	1	1	1	1	1	1	1	1	1
Feb. 1	2		2	2	2	2	2	2	2	2	2	2	2
Mar. 1	3			3	3	3	3	3	3	3	3	3	3
Mar. 16	4				4	4	4	4	4	4	4	4	4
Apr. 1	5					5	5	5	5	5	5	5	5
Apr. 16	6						6	6	6	6	6	6	6
May 1	7							7	7	7	7	7	7
May 16	8								8	8	8	8	8
June 1	9									9	9	9	9
June 16	10										10	10	10
July 1	11											11	11
July 16	12												12

Figure 4-5. Periodic VECC forecasts in order of occurrence.

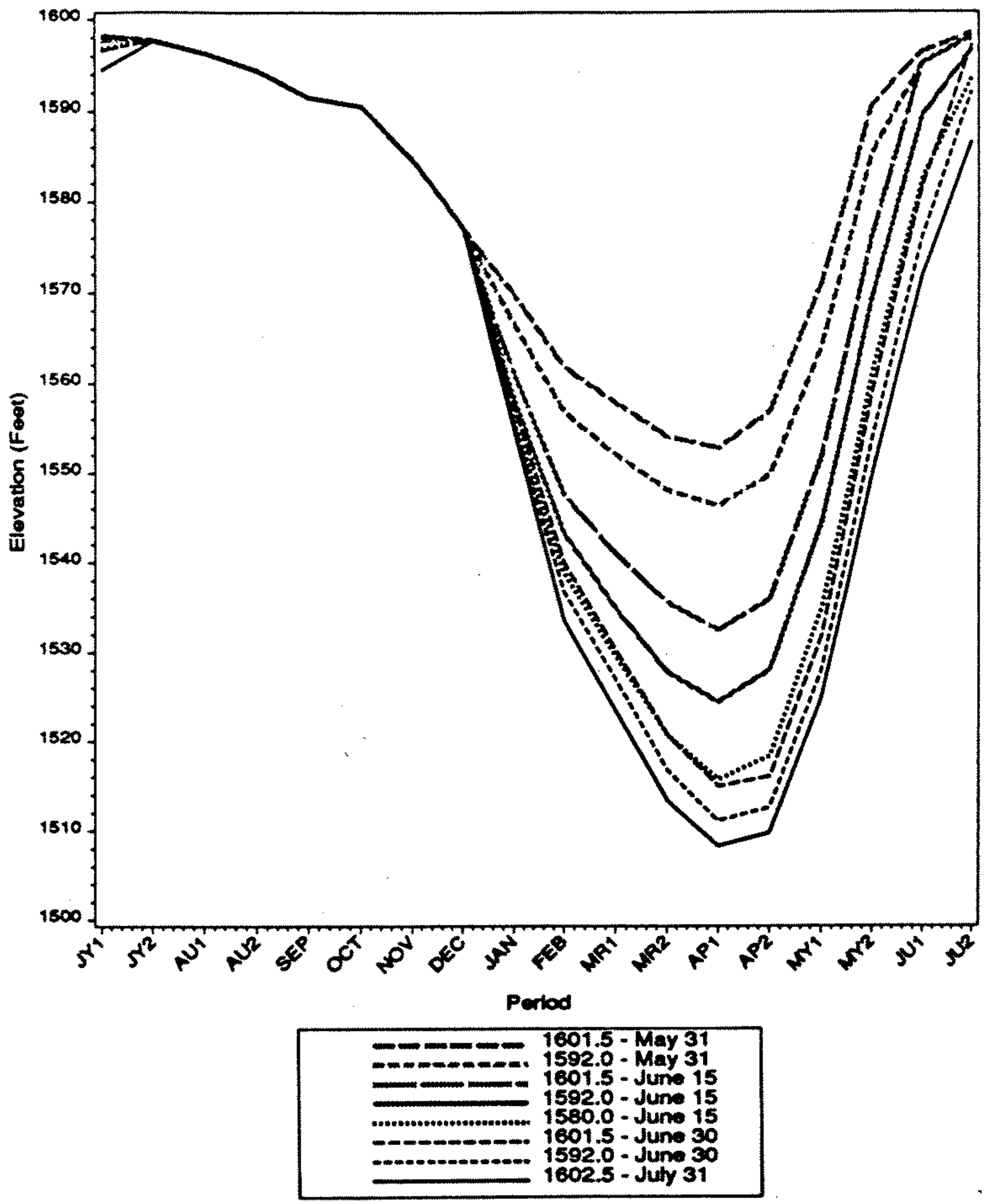


Figure 4-6. Average ending elevation for Interim Agreement refill scenarios.

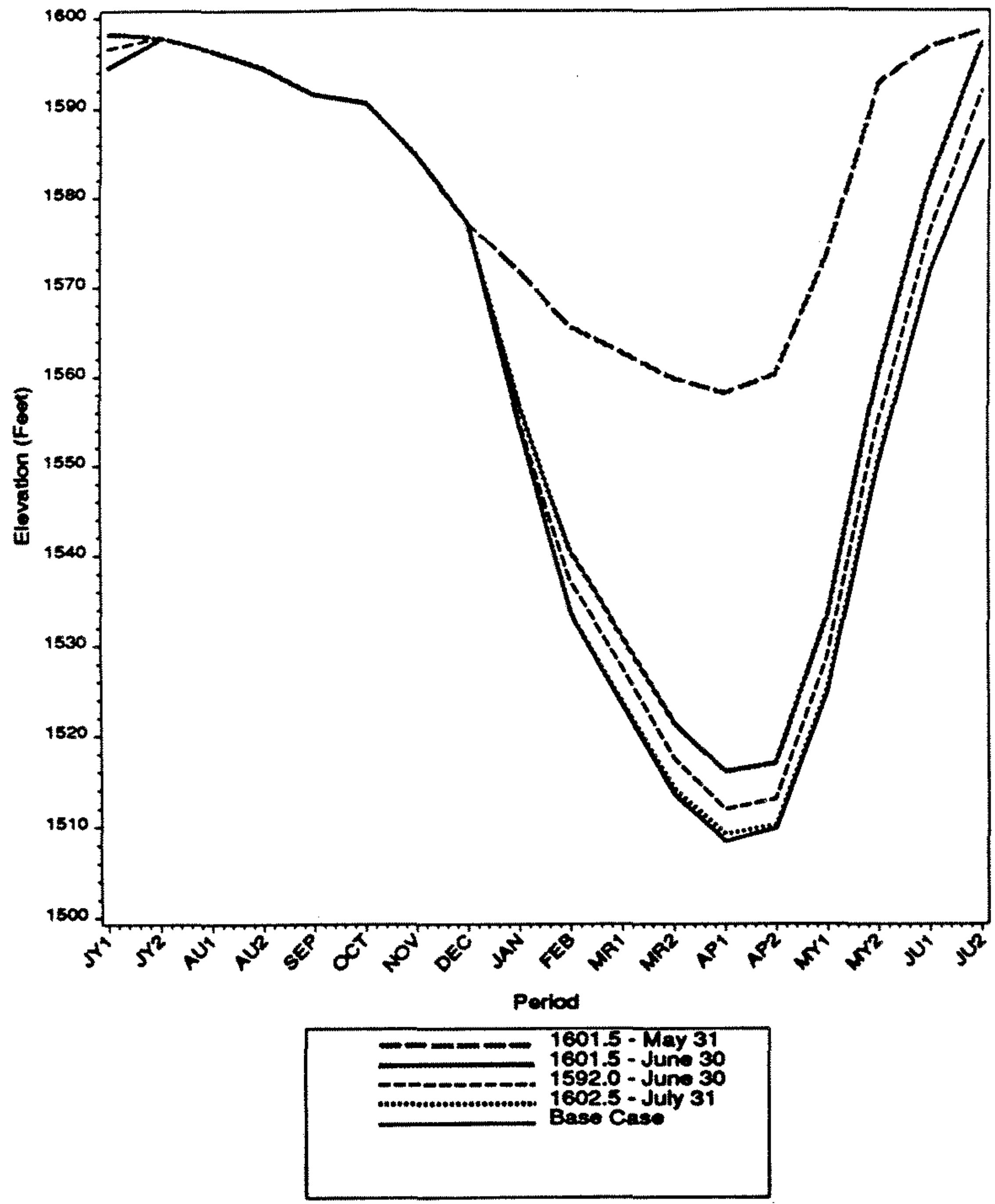


Figure 4-7. **Average ending elevation for original license minimum flow scenarios.**

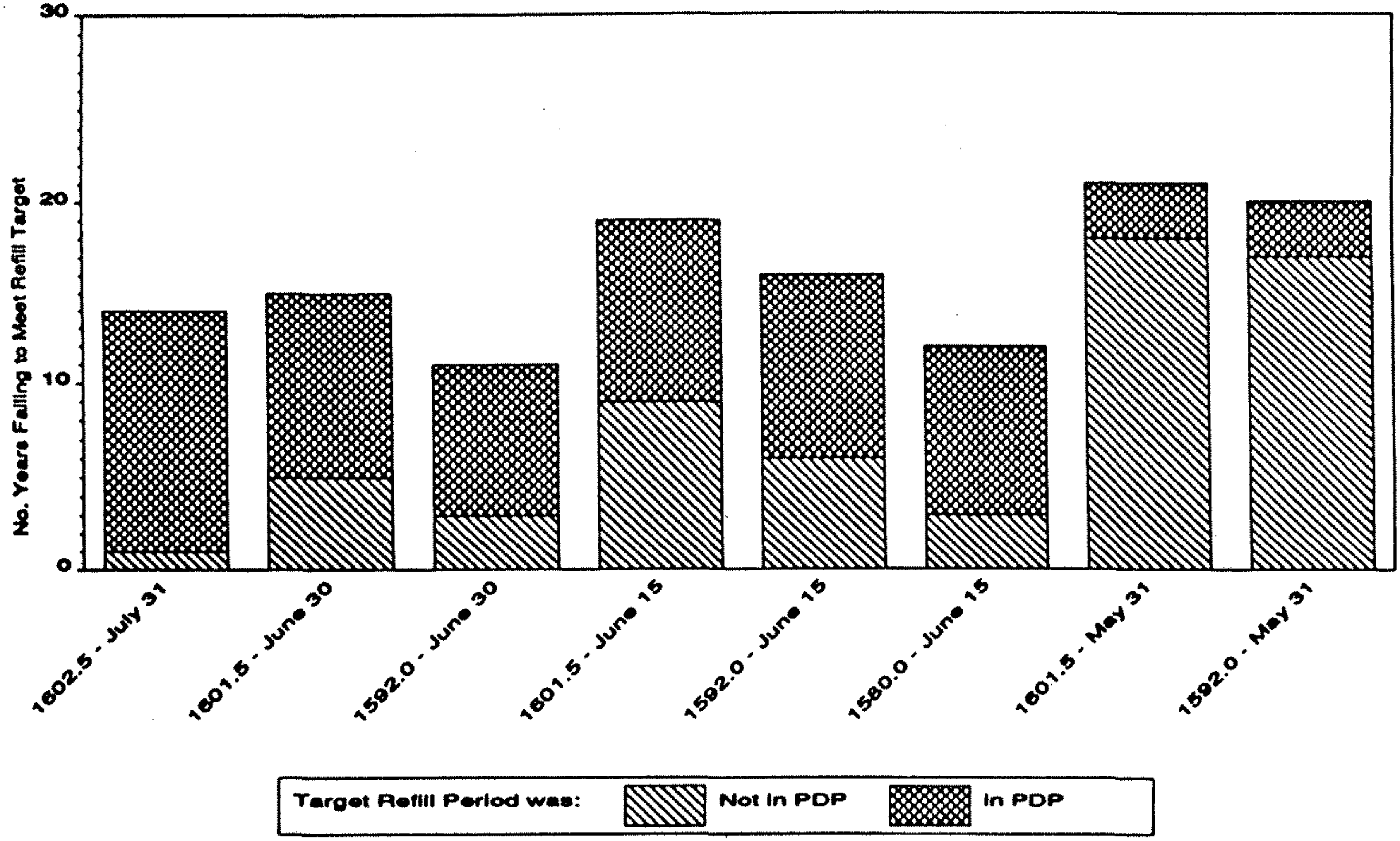


Figure 4-8. Failure to achieve target refill elevation for Interim Agreement refill scenarios (number of years out of 50).

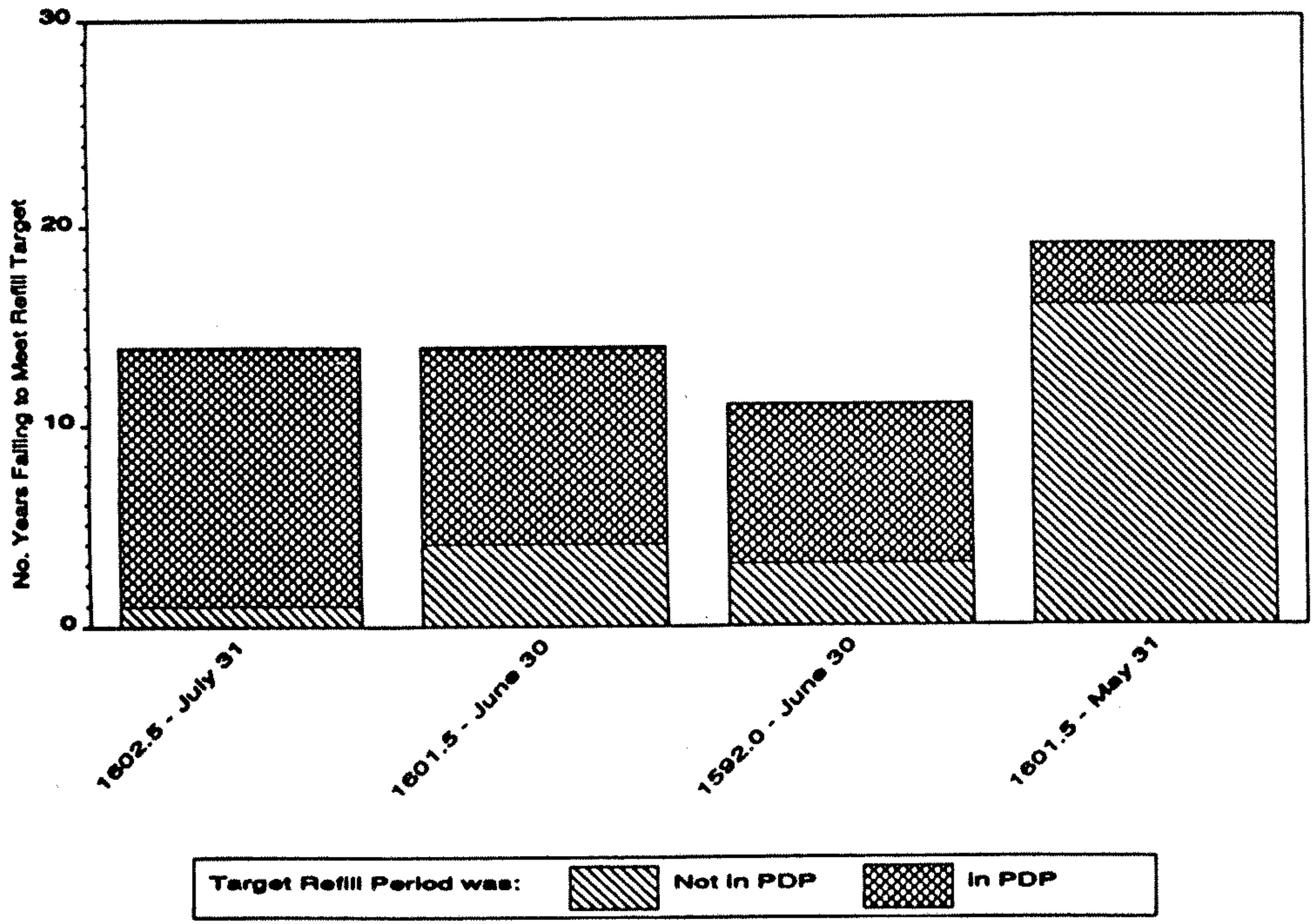
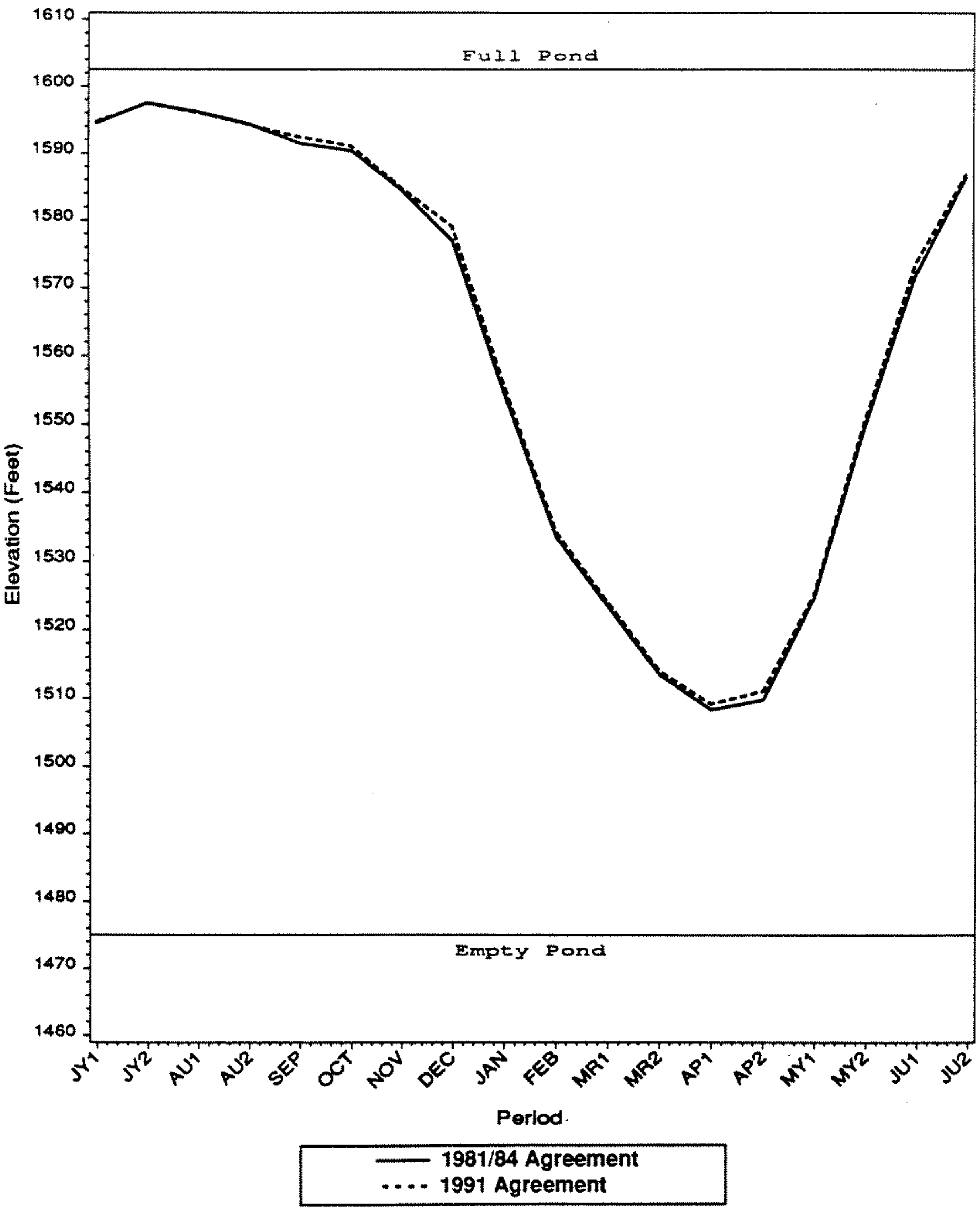


Figure 4-9. Failure to achieve target refill elevation for original license minimum flow scenarios (number of years out of 50).

Figure 4-10. Average ending elevation, Interim Agreement base case vs. 1991 Settlement Agreement.



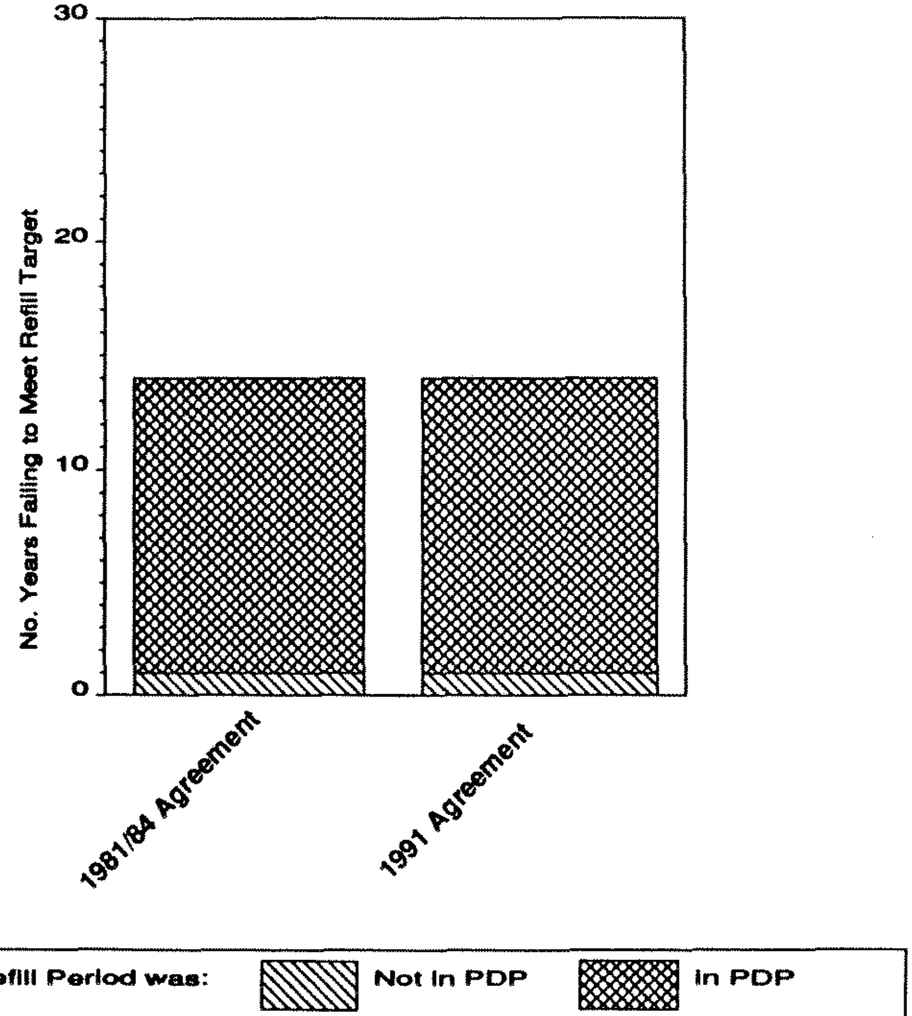


Figure 4-11. Failure to achieve target refill elevation, Interim Agreement base case vs. 1991 Settlement Agreement

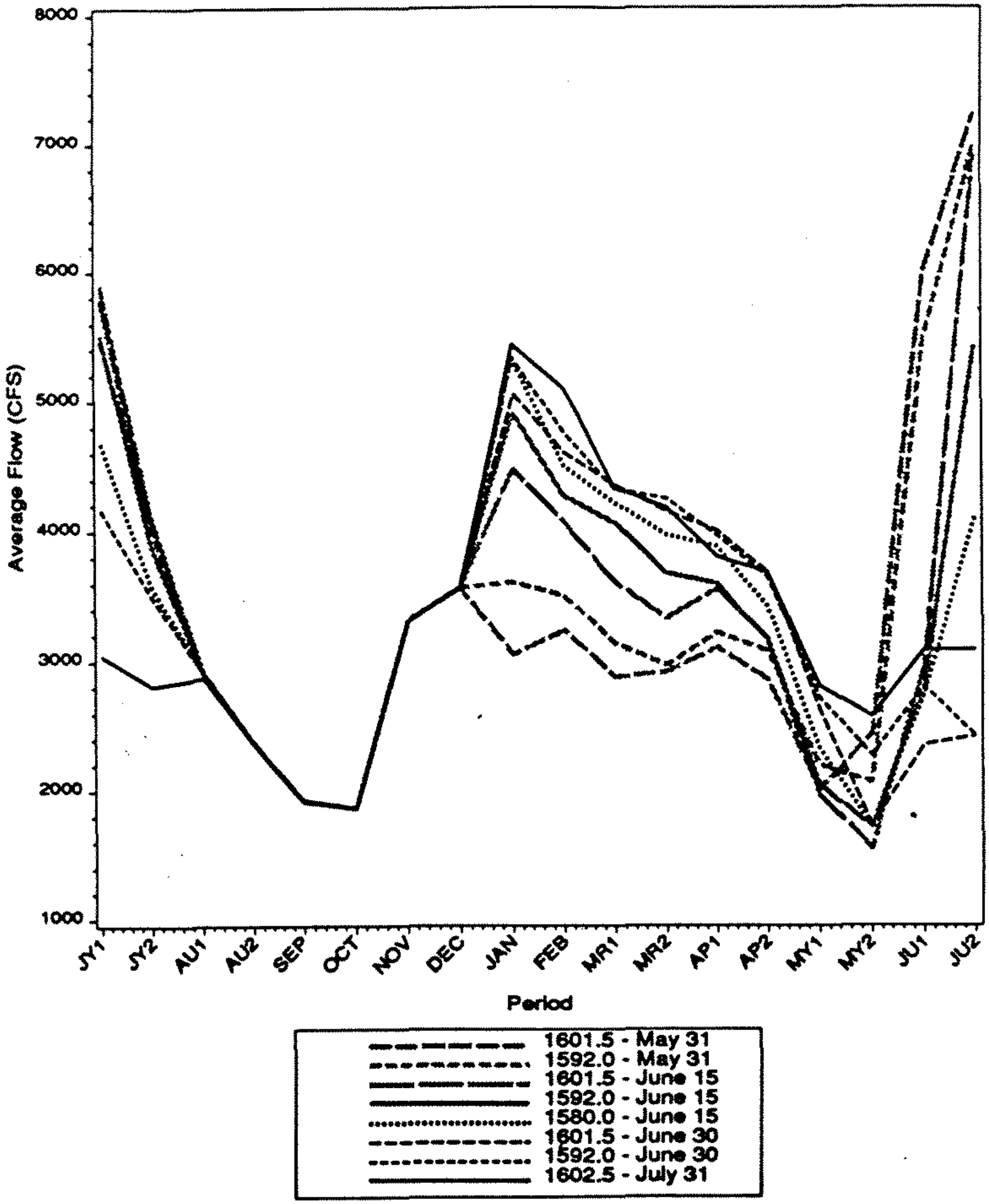


Figure 4-12. Average regulated flow for Interim Agreement refill scenarios.

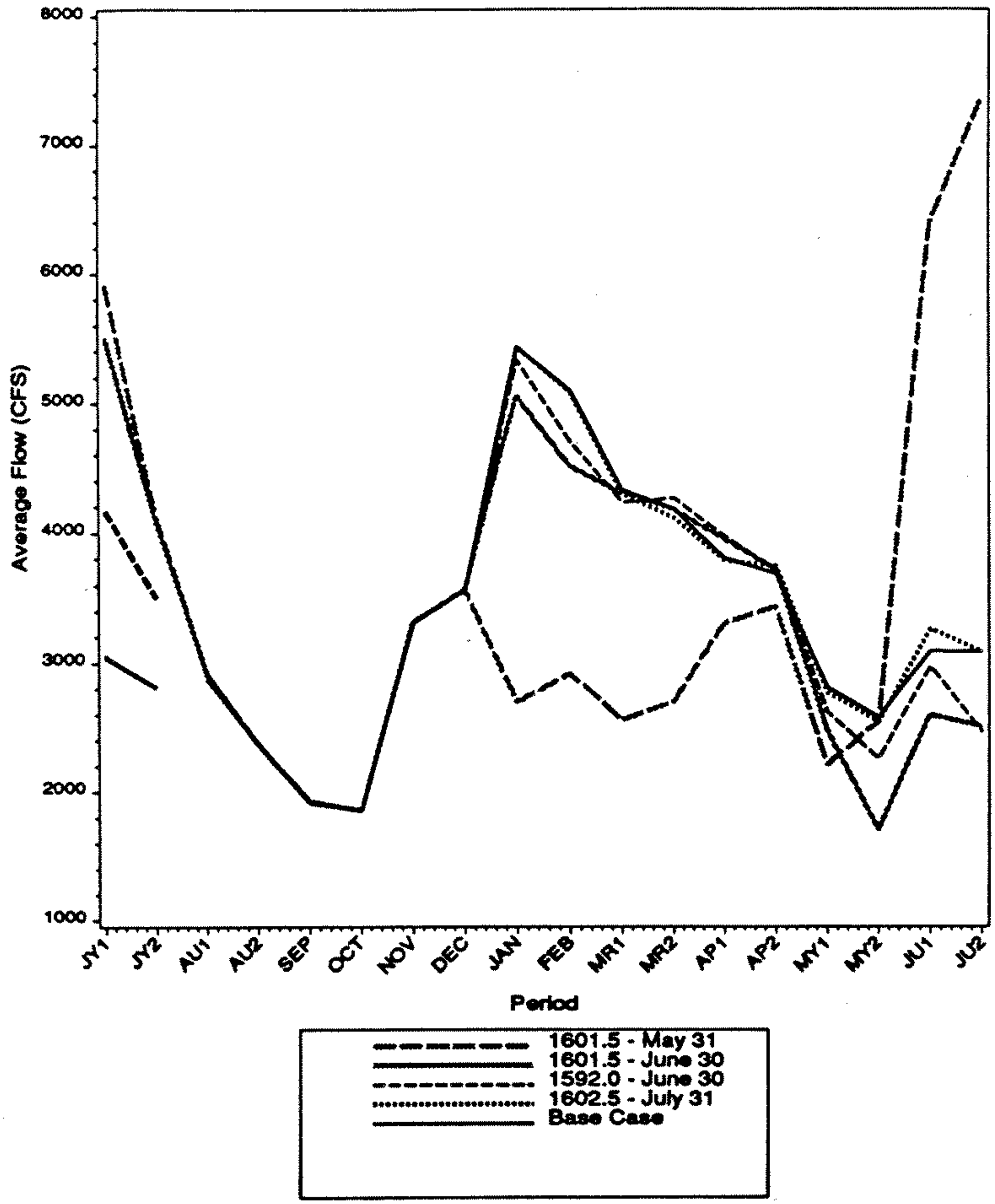
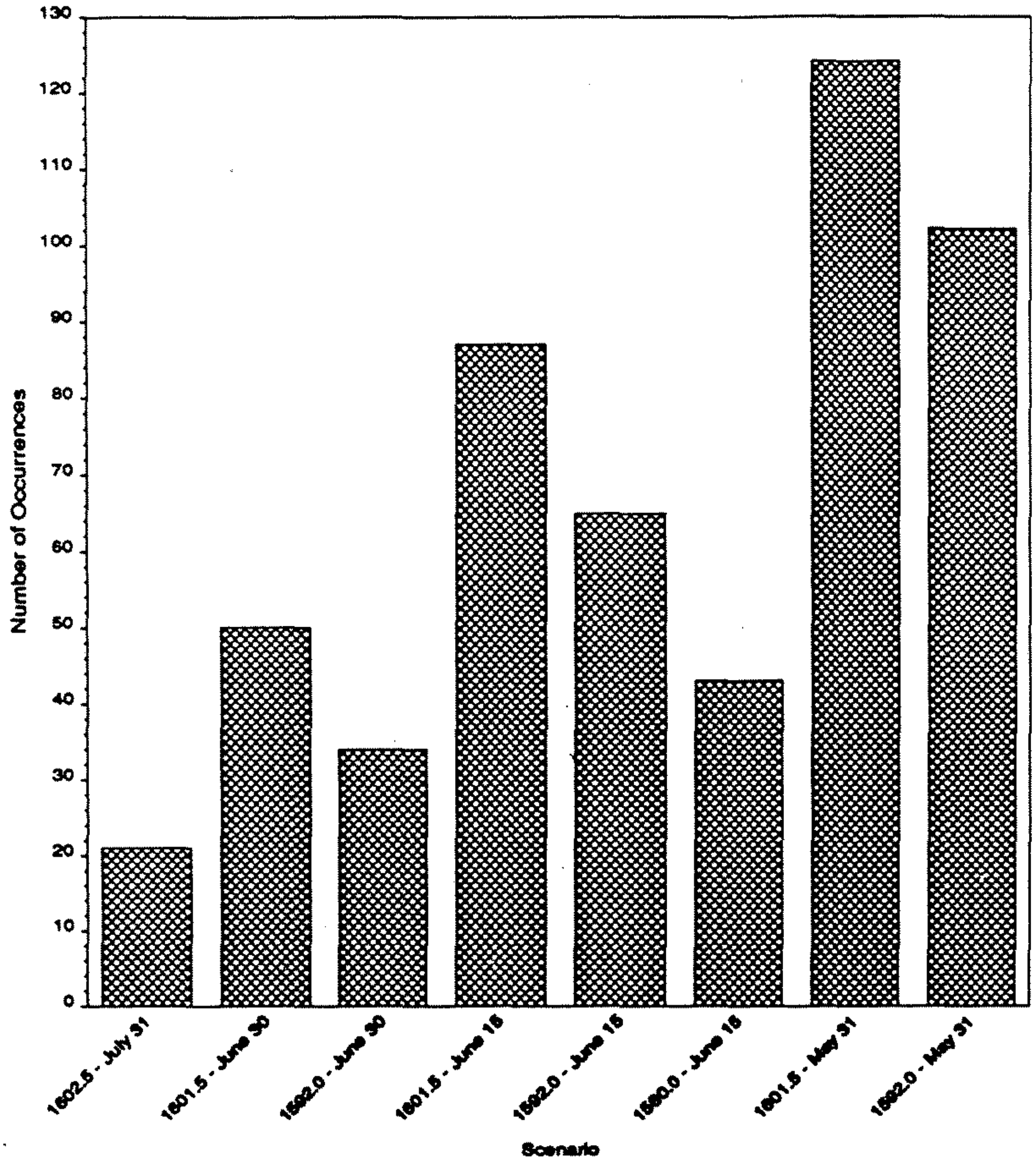
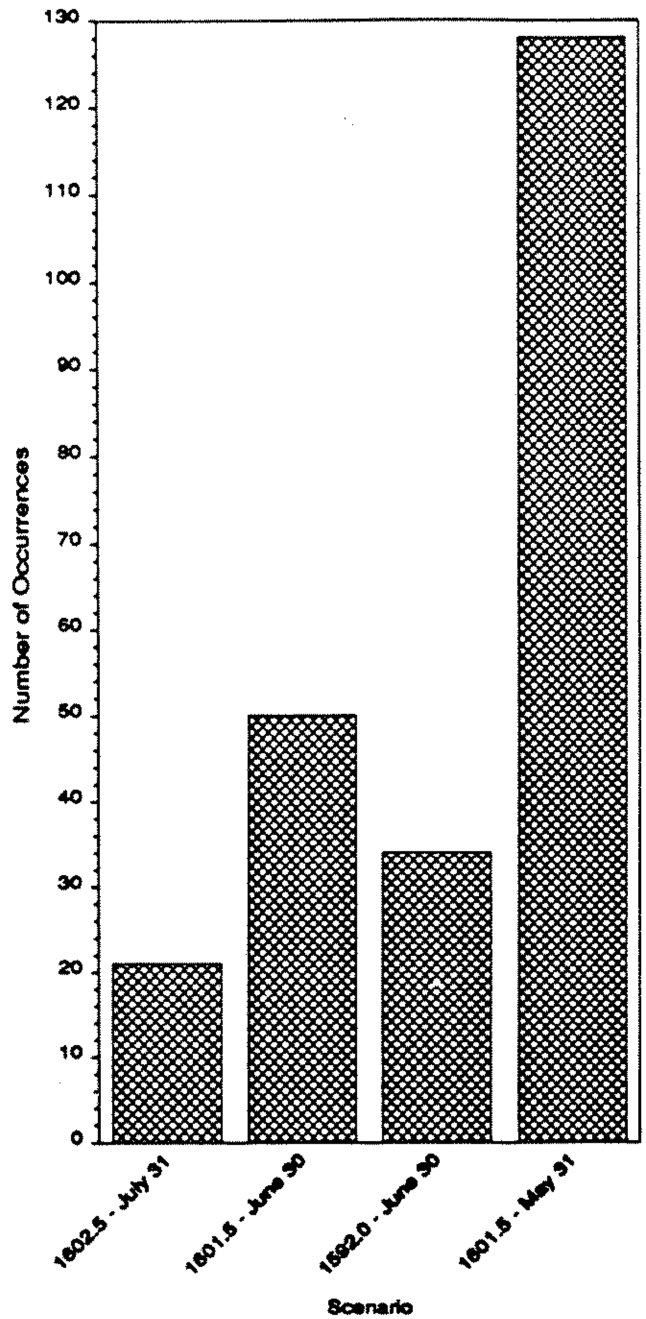


Figure 4-13. **Average regulated flow for original license minimum flow scenarios.**



NOTE: Outflow measured at Gorge. 900 periods are analyzed for each scenario.

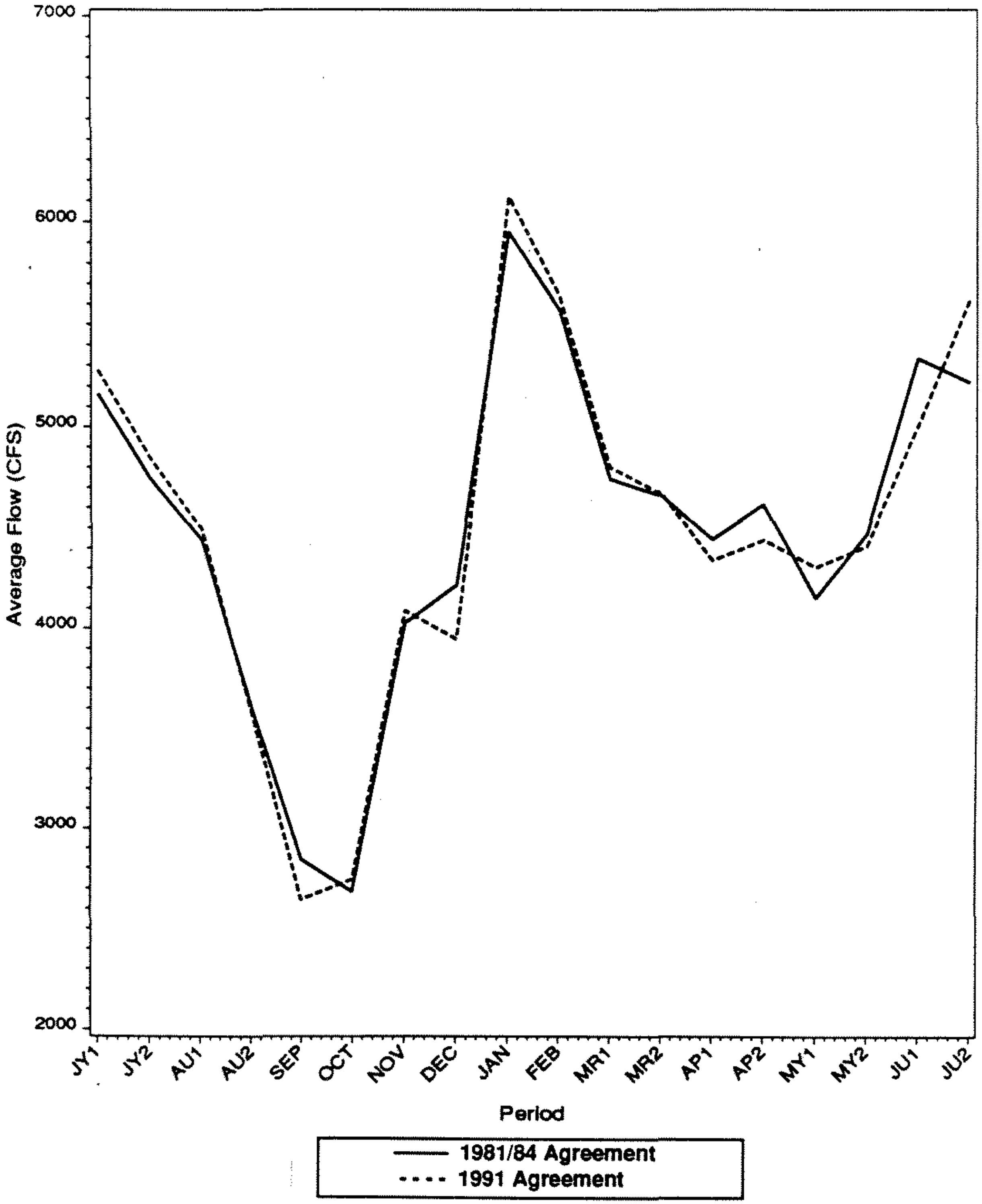
Figure 4-14. Number of periods with average stream flow above 7000 cfs for Interim Agreement refill scenarios.



NOTE: Outflow measured at Gorge. 900 periods are analyzed for each scenario.

Figure 4-15. Number of periods with average stream flow above 7000 cfs for original license minimum flow scenarios.

Figure 4-16. Average outflow at Gorge, Interim Agreement base case vs. 1991 Settlement Agreement.



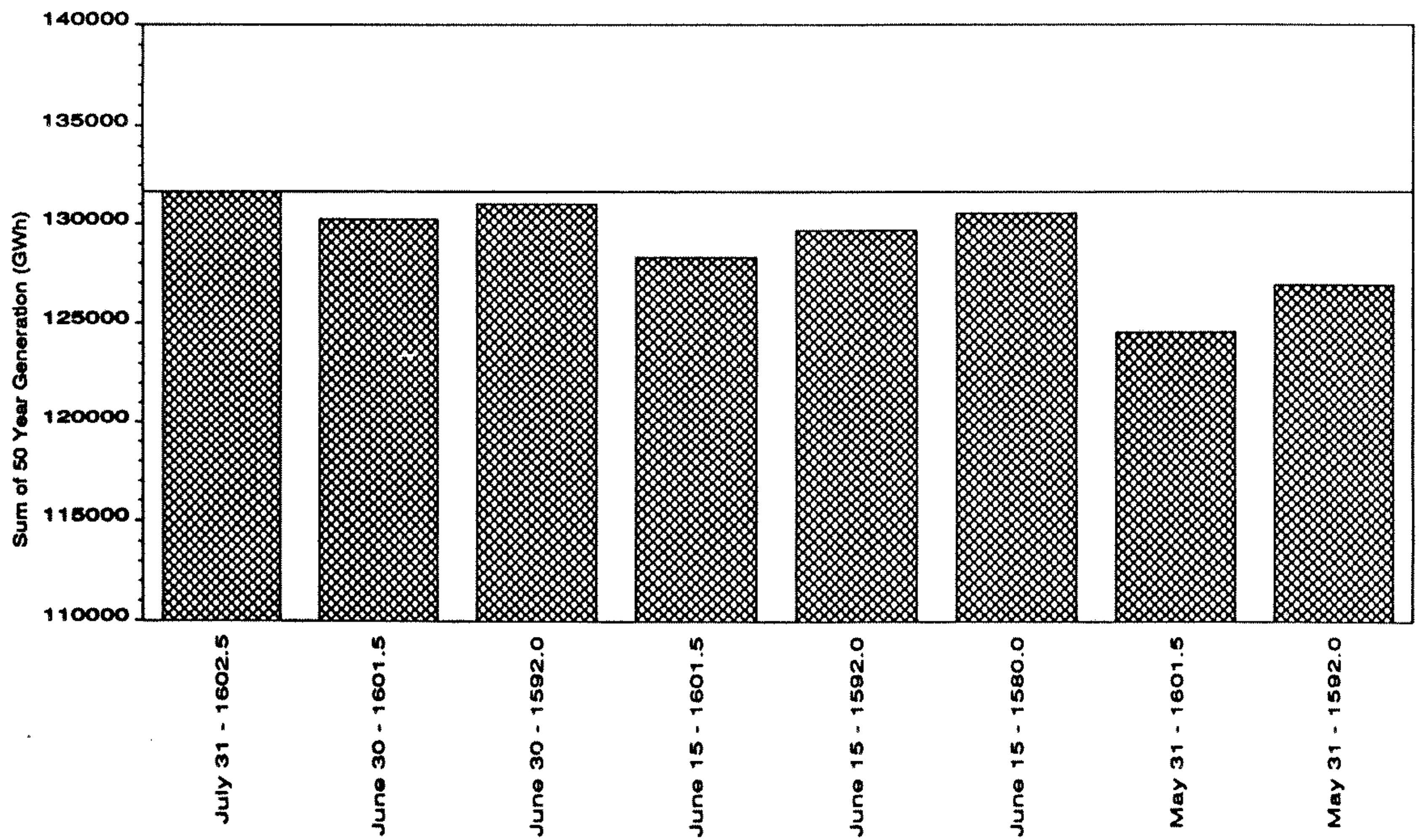


Figure 4-17. Sum of 50-year energy production for Interim Agreement refill scenarios.

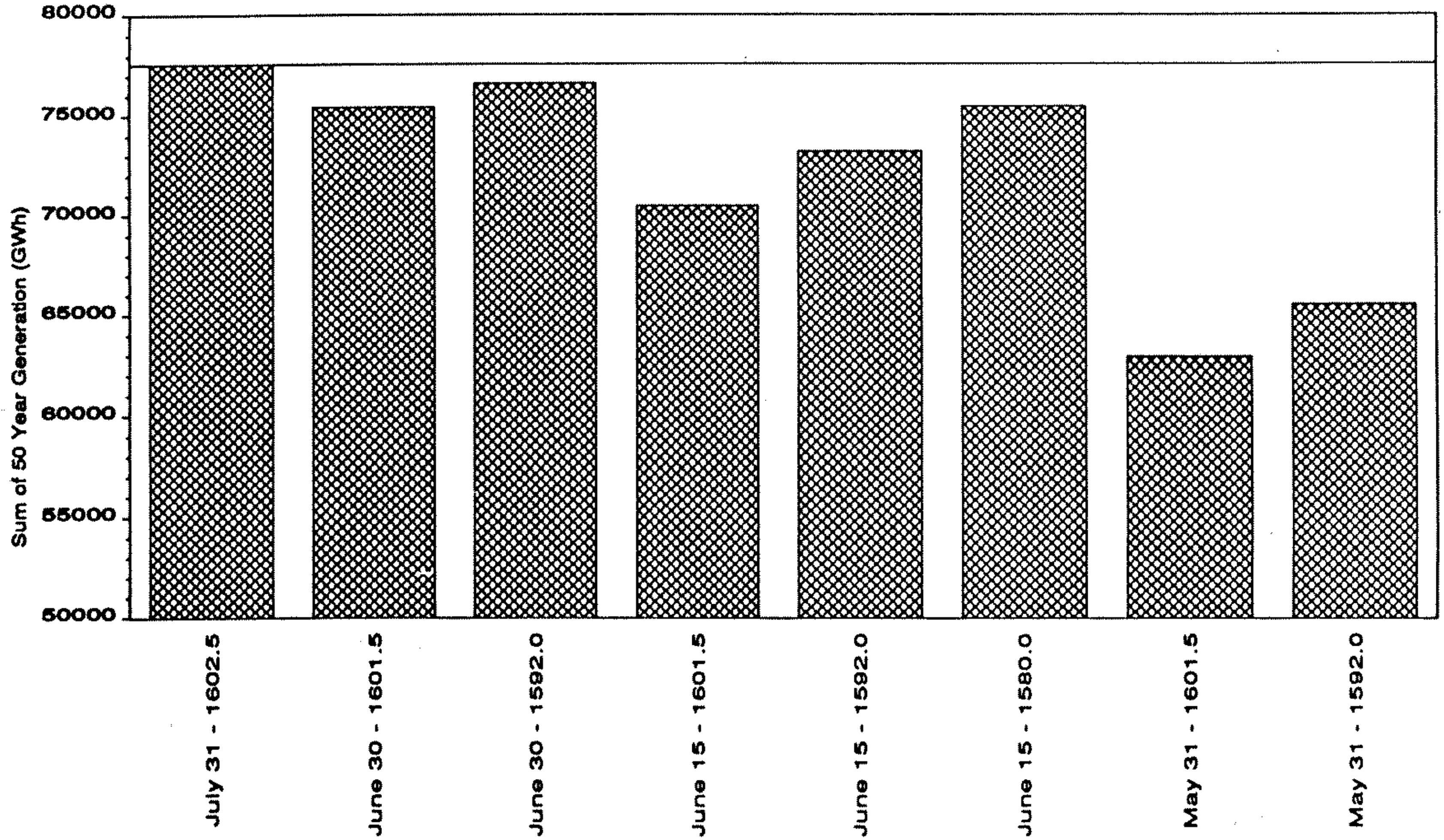


Figure 4-18. Sum of 50-year energy production winter season subtotal for Interim Agreement refill scenarios.

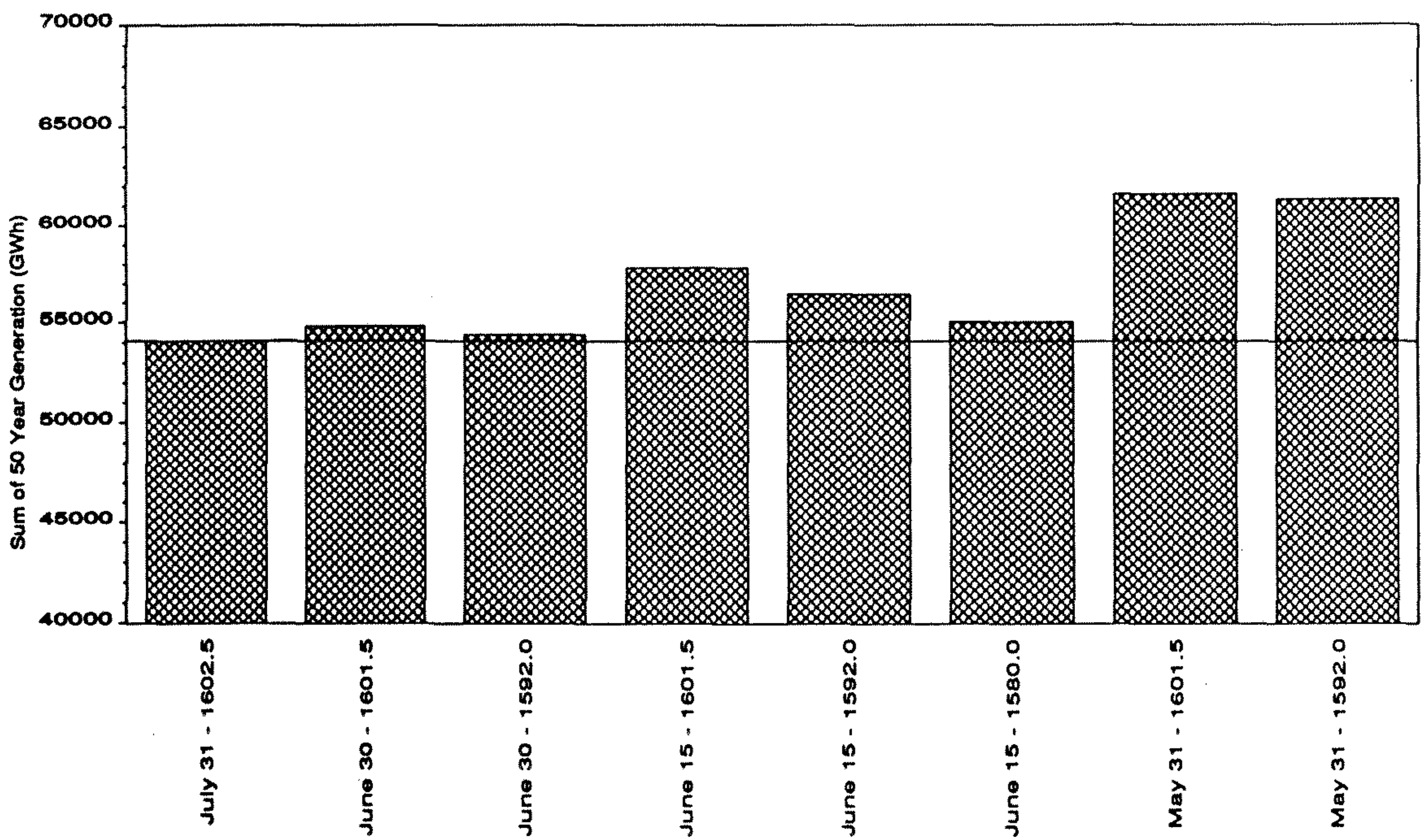


Figure 4-19. Sum of 50-year energy production summer season subtotal for Interim Agreement refill scenarios.

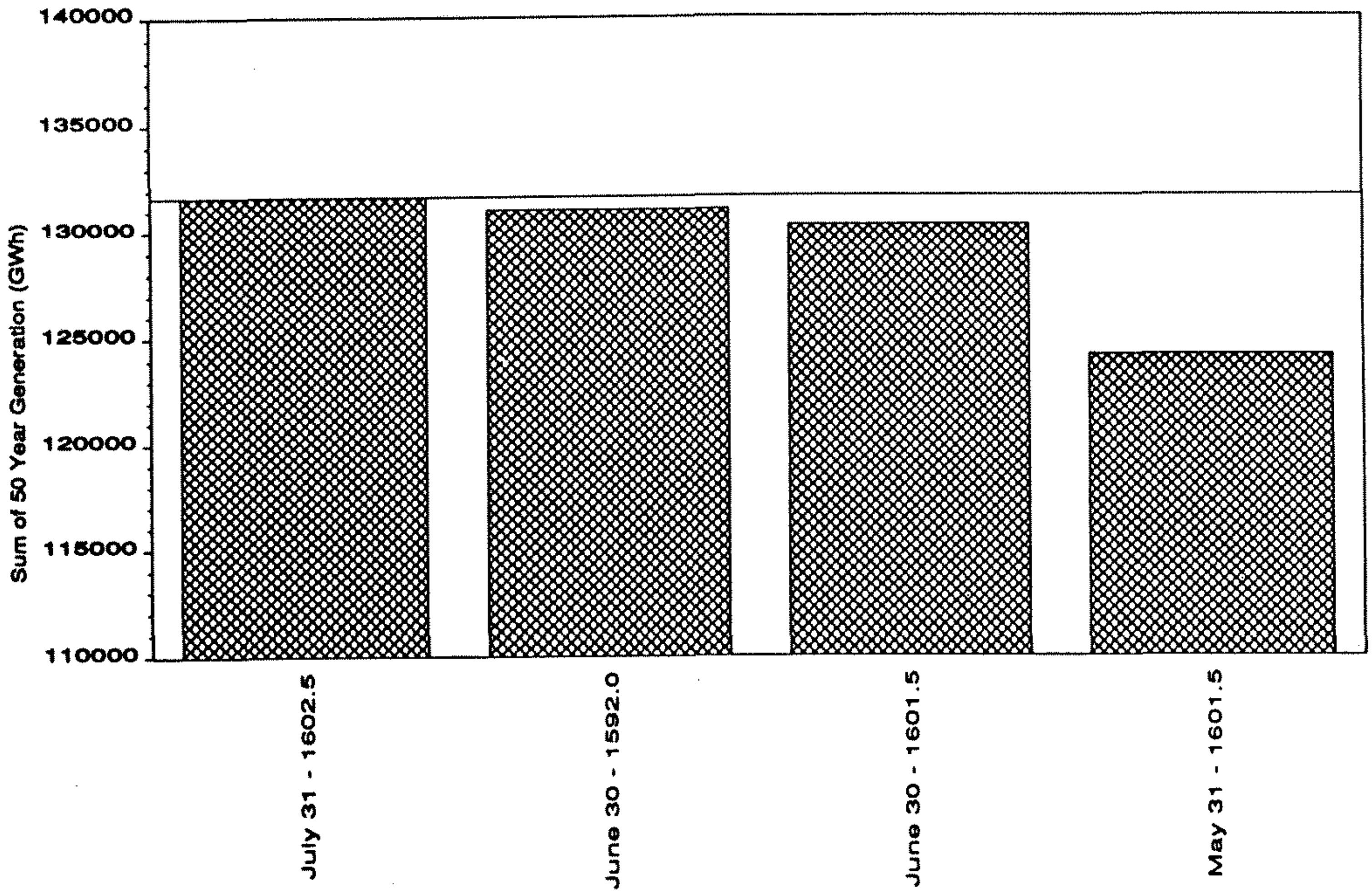


Figure 4-20. Sum of 50-year energy production for original license minimum flow scenarios.

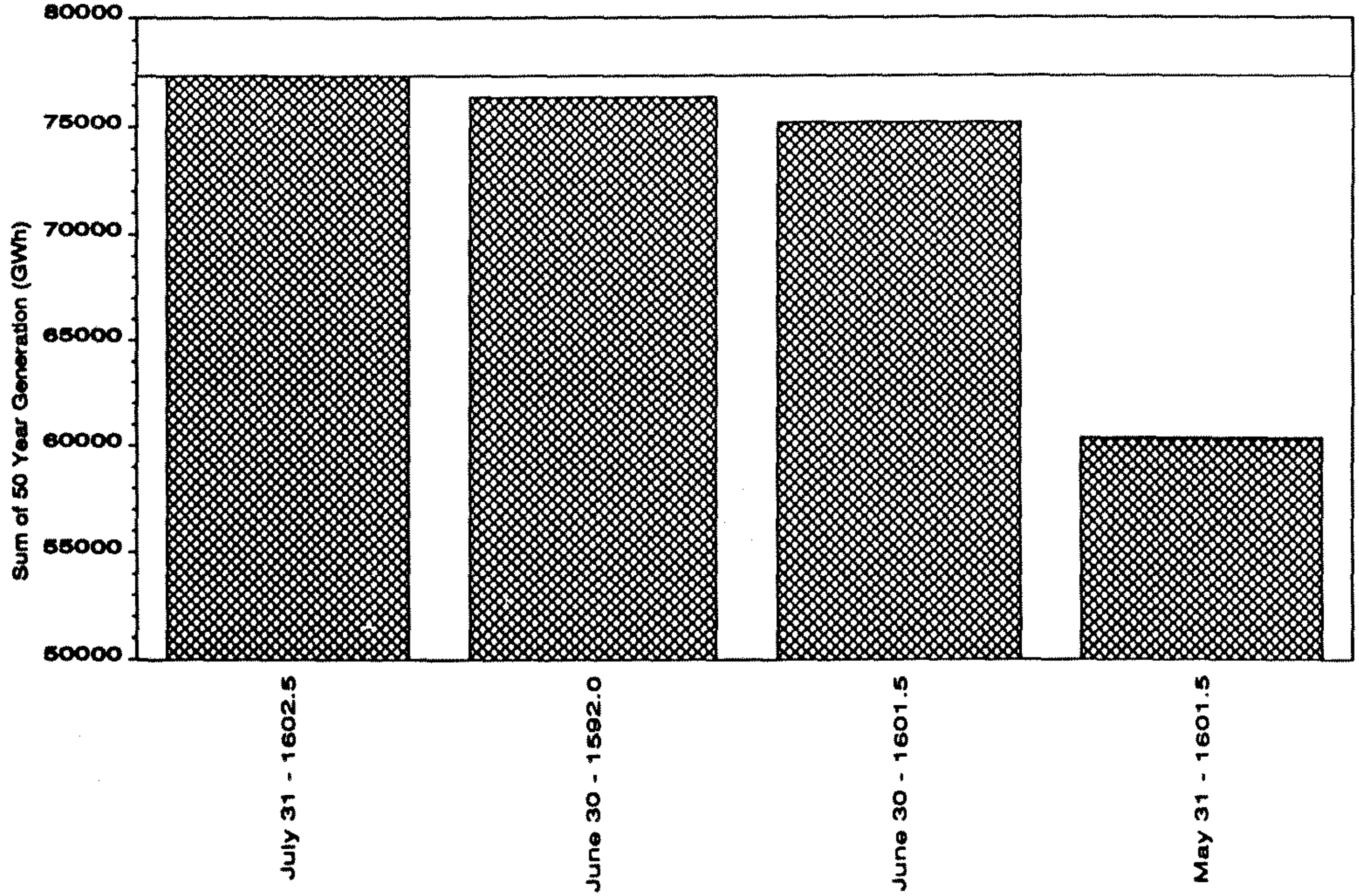


Figure 4-21. Sum of 50-year energy production; winter season subtotal for original license minimum flow scenarios.

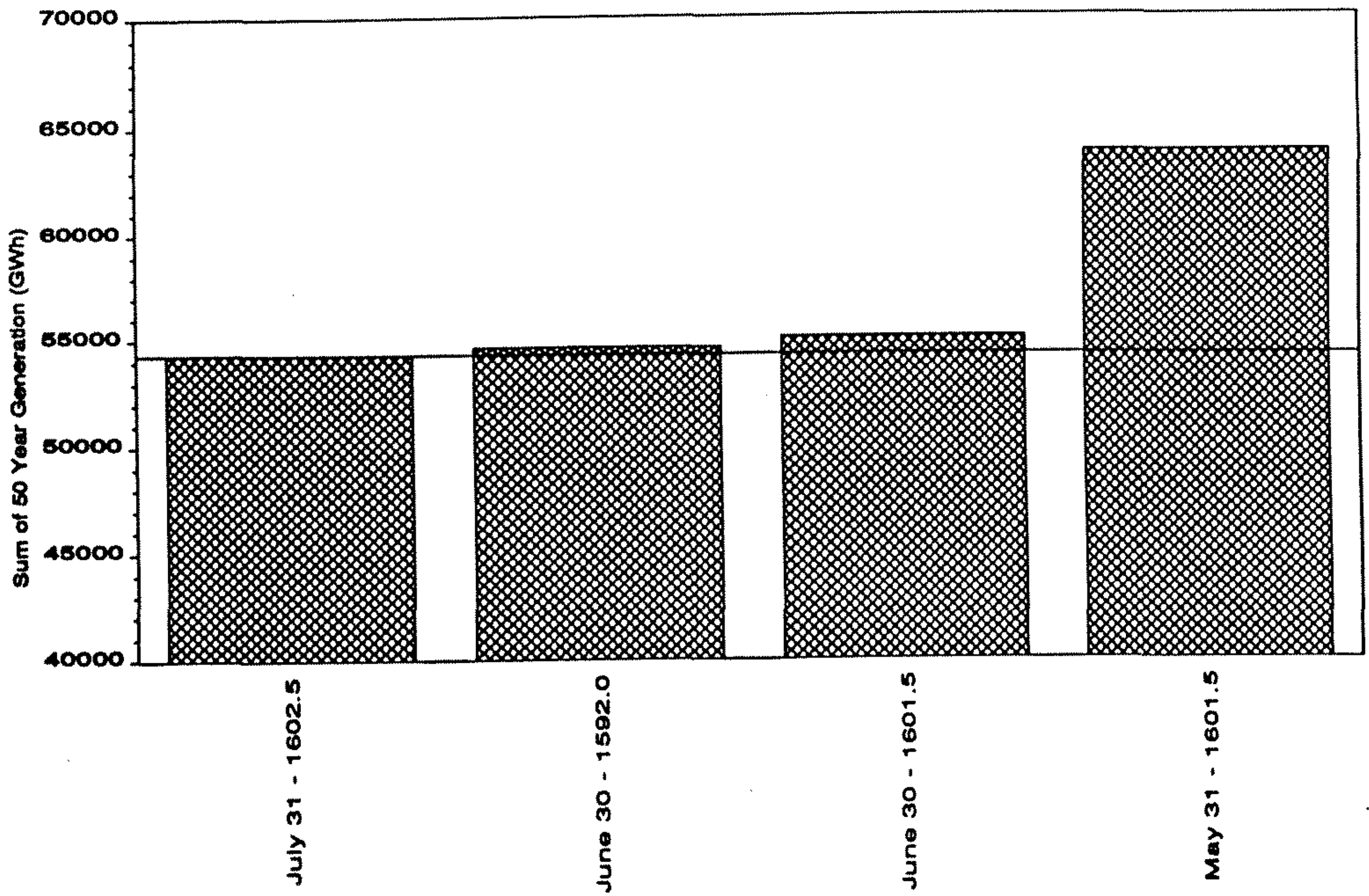


Figure 4-22. Sum of 50-year energy production; summer season subtotal for original license minimum flow scenarios.

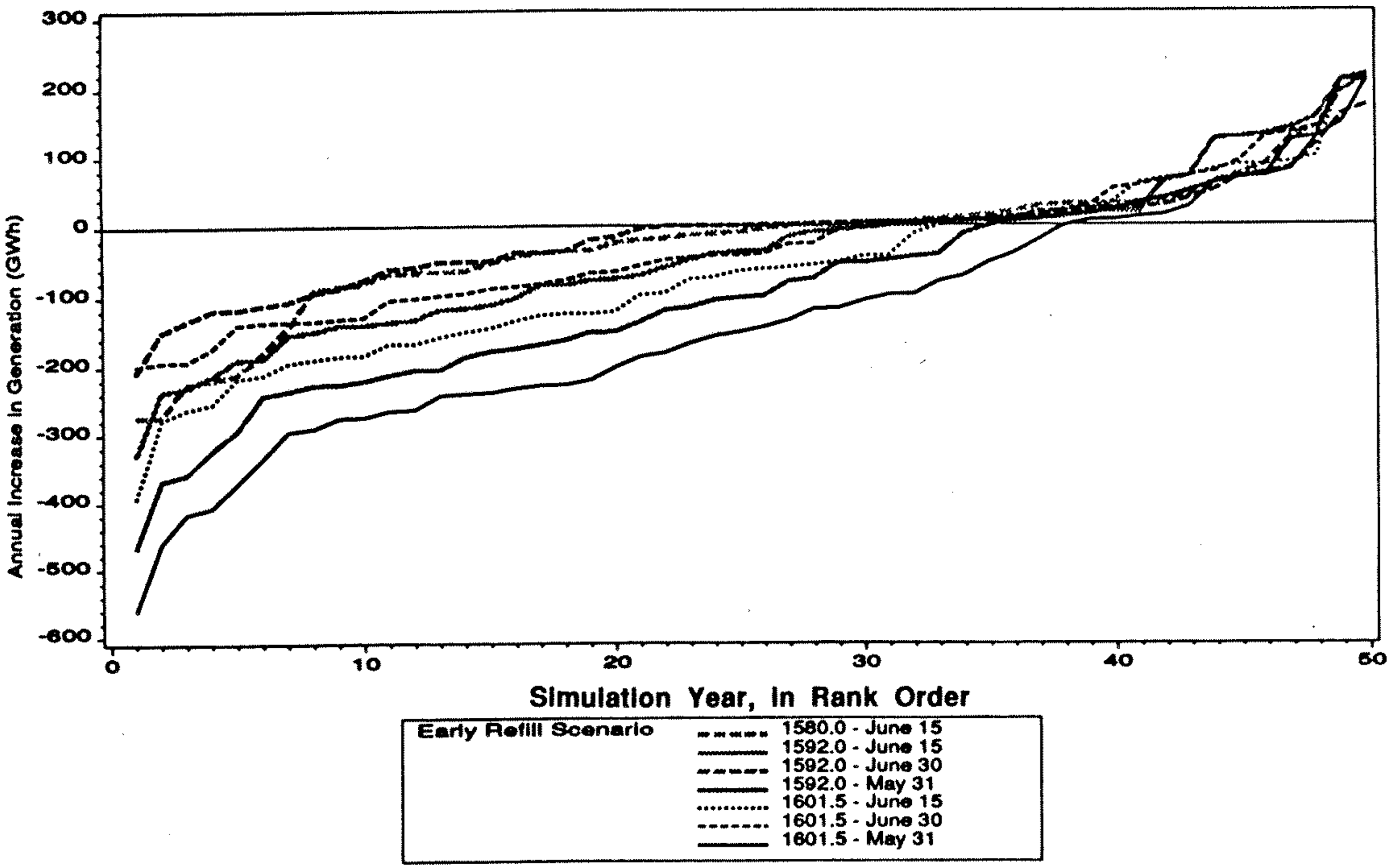


Figure 4-23. Distribution of increase in annual energy production under Interim Agreement refill scenarios.

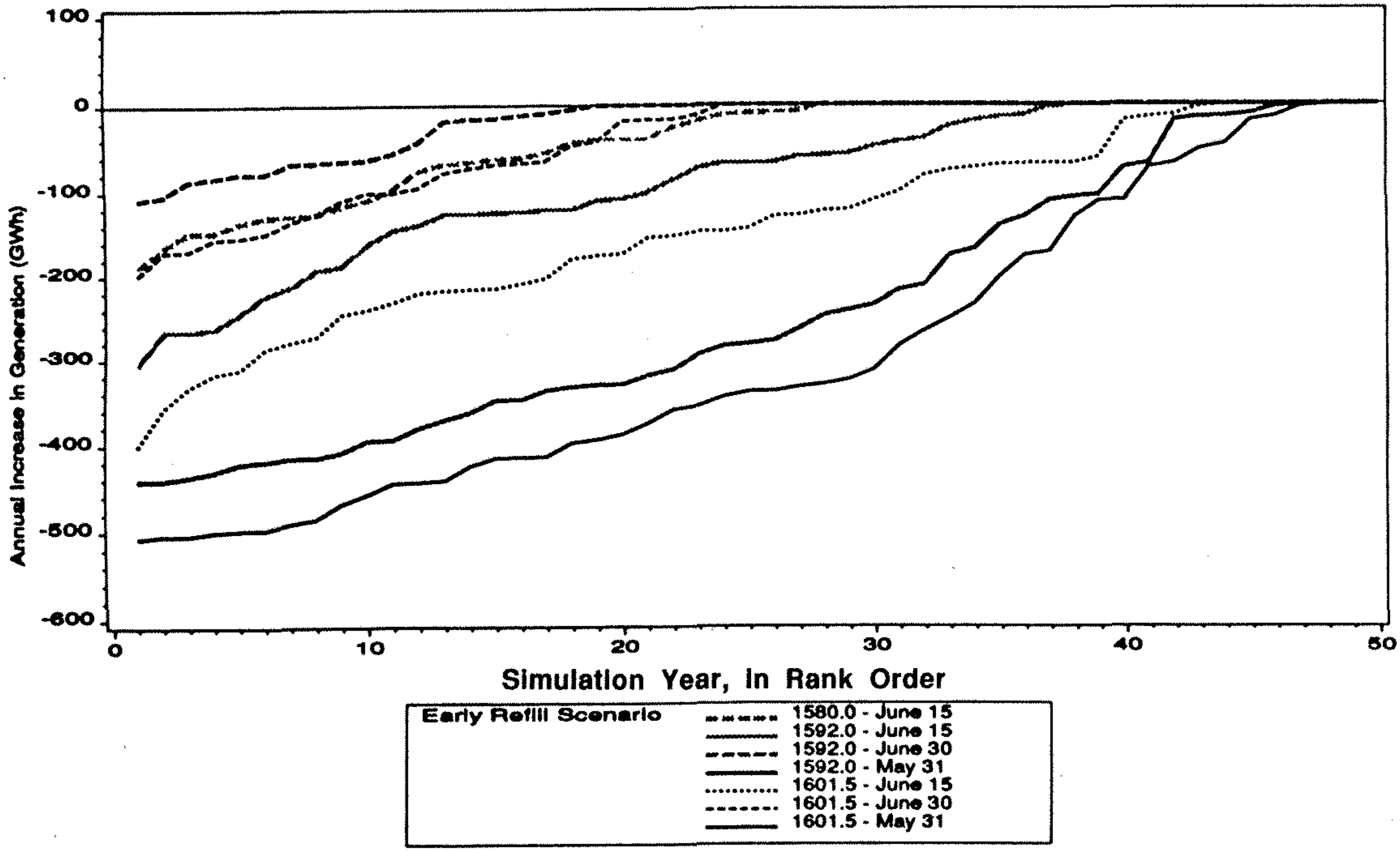


Figure 4-24. Distribution of increase in winter seasonal energy production under Interim Agreement refill scenarios.

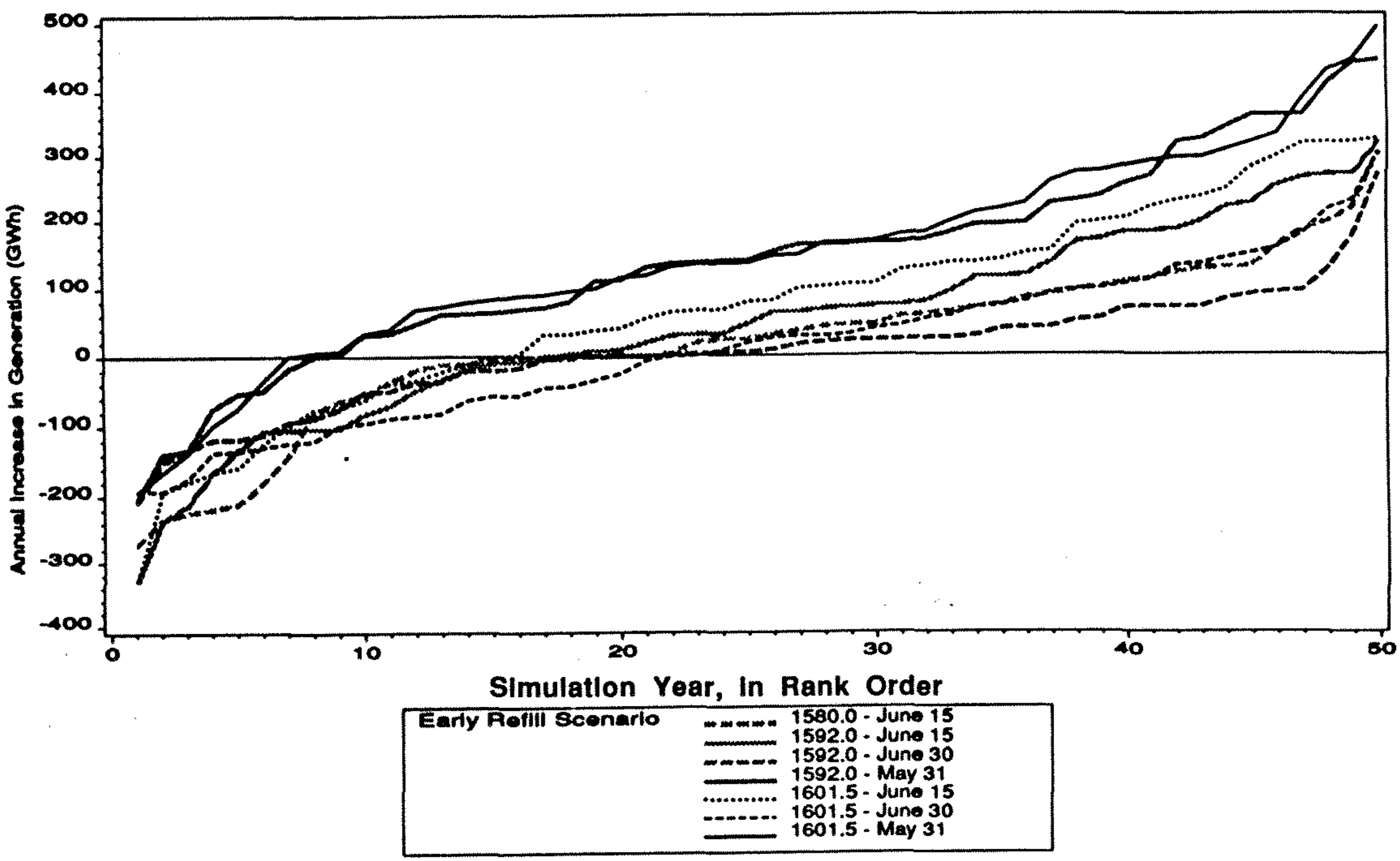


Figure 4-25. Distribution of increase in summer seasonal energy production under Interim Agreement refill scenarios.

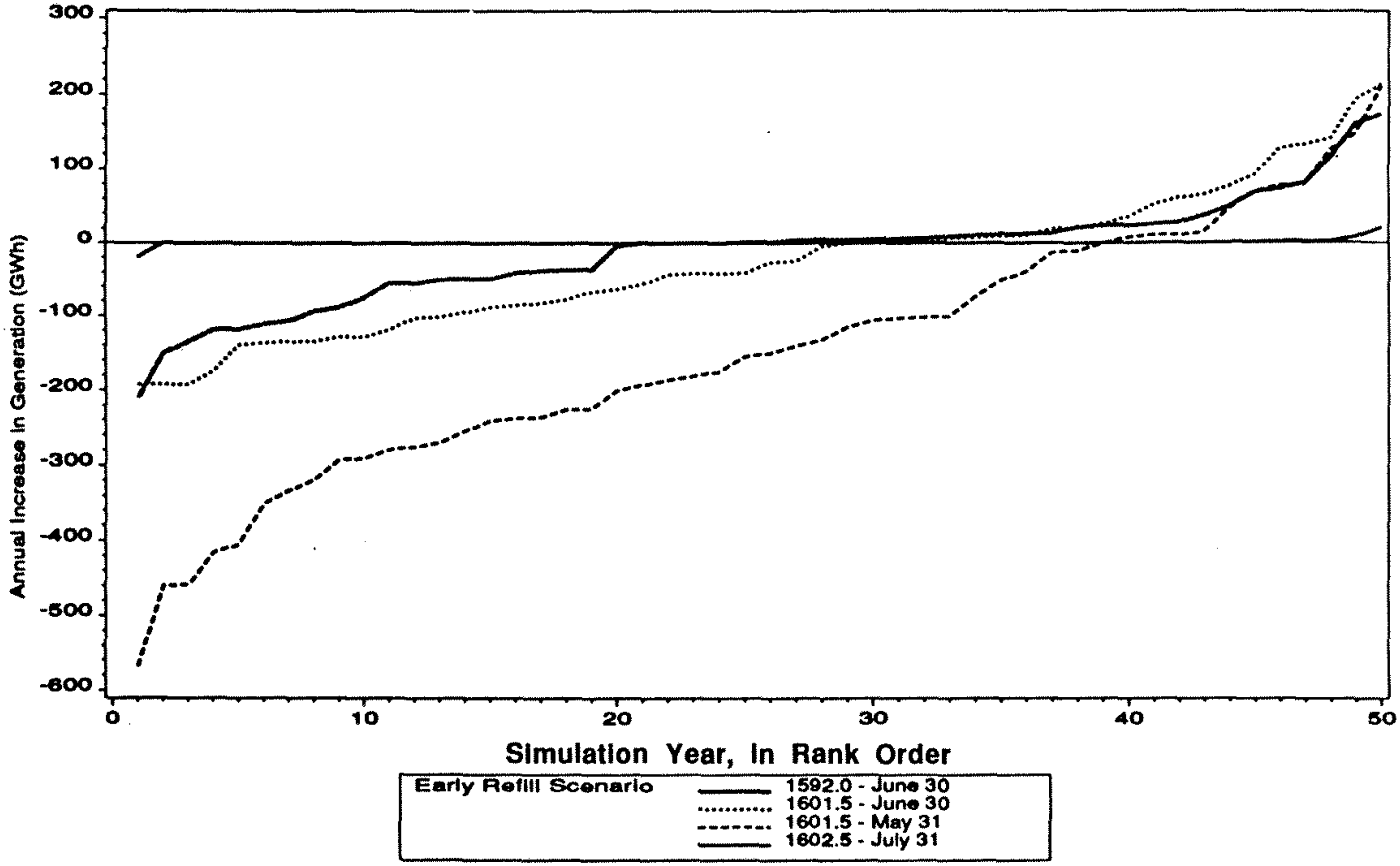


Figure 4-26. Distribution of increase in annual energy production under original license minimum flow scenarios.

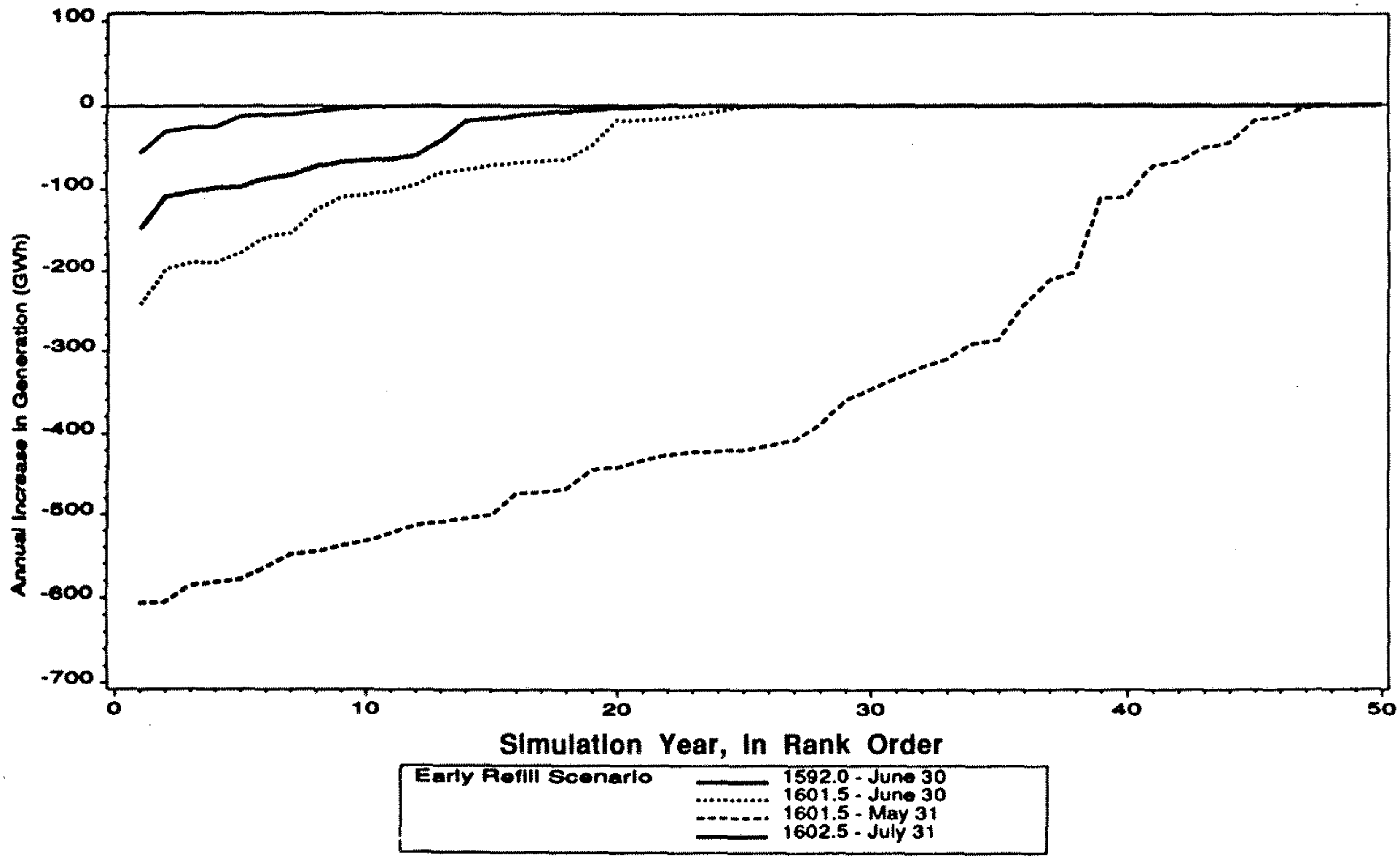


Figure 4-27. **Distribution of increase in winter seasonal energy production under original license minimum flow scenarios.**

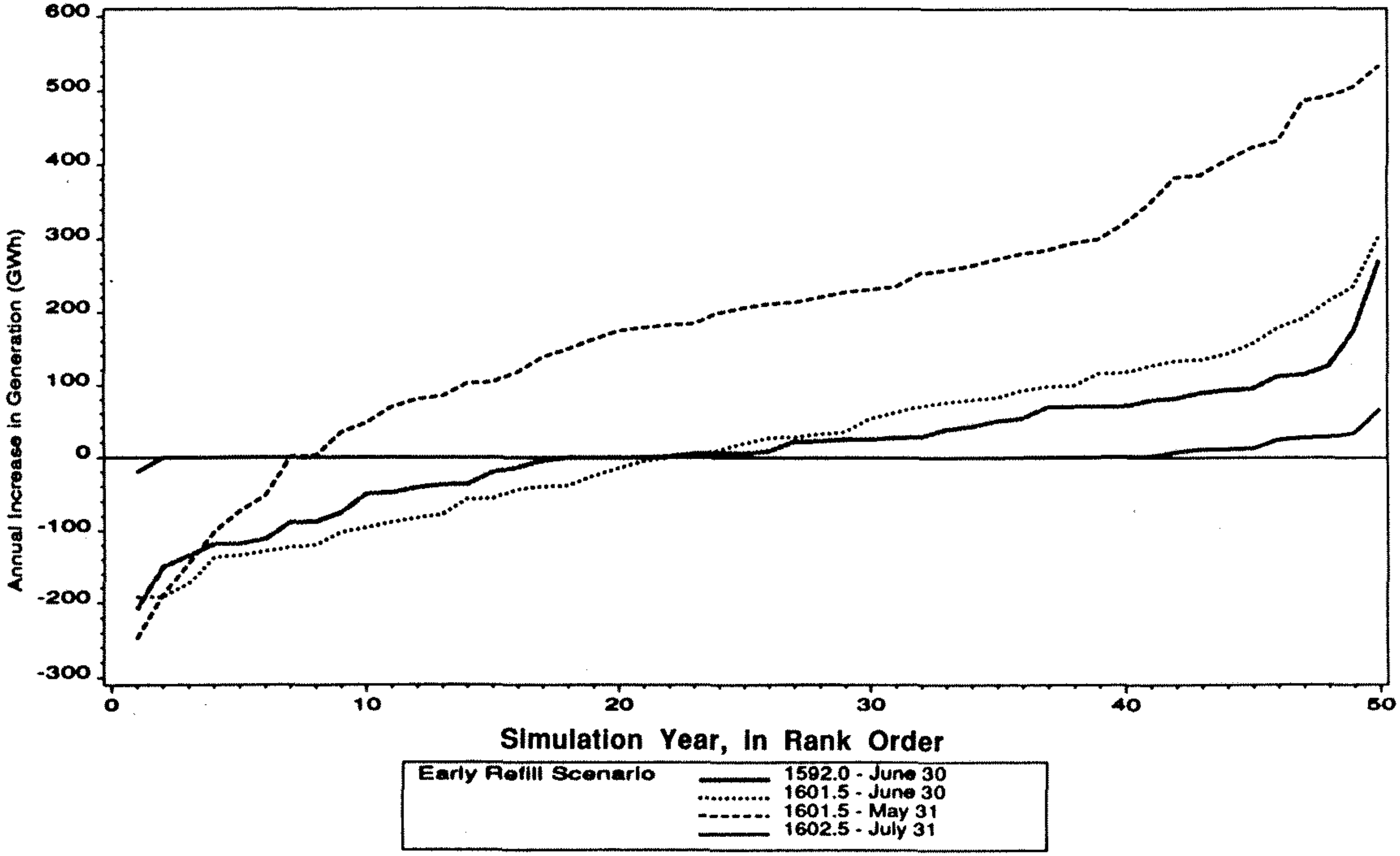


Figure 4-28. Distribution of increase in summer seasonal energy production under original license minimum flow scenarios.

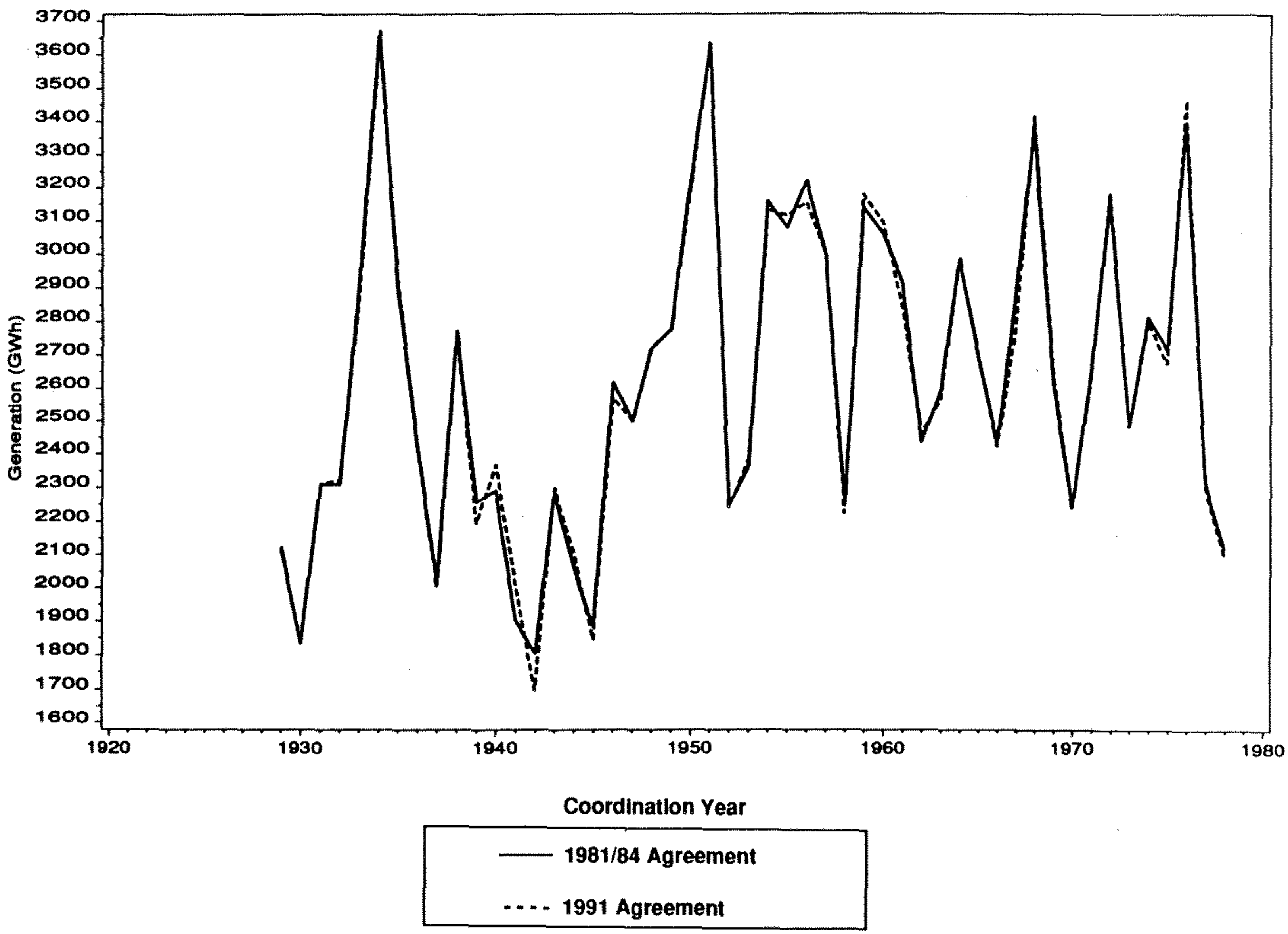


Figure 4-29. Annual energy production, Interim Agreement base case vs. 1991 Settlement Agreement.

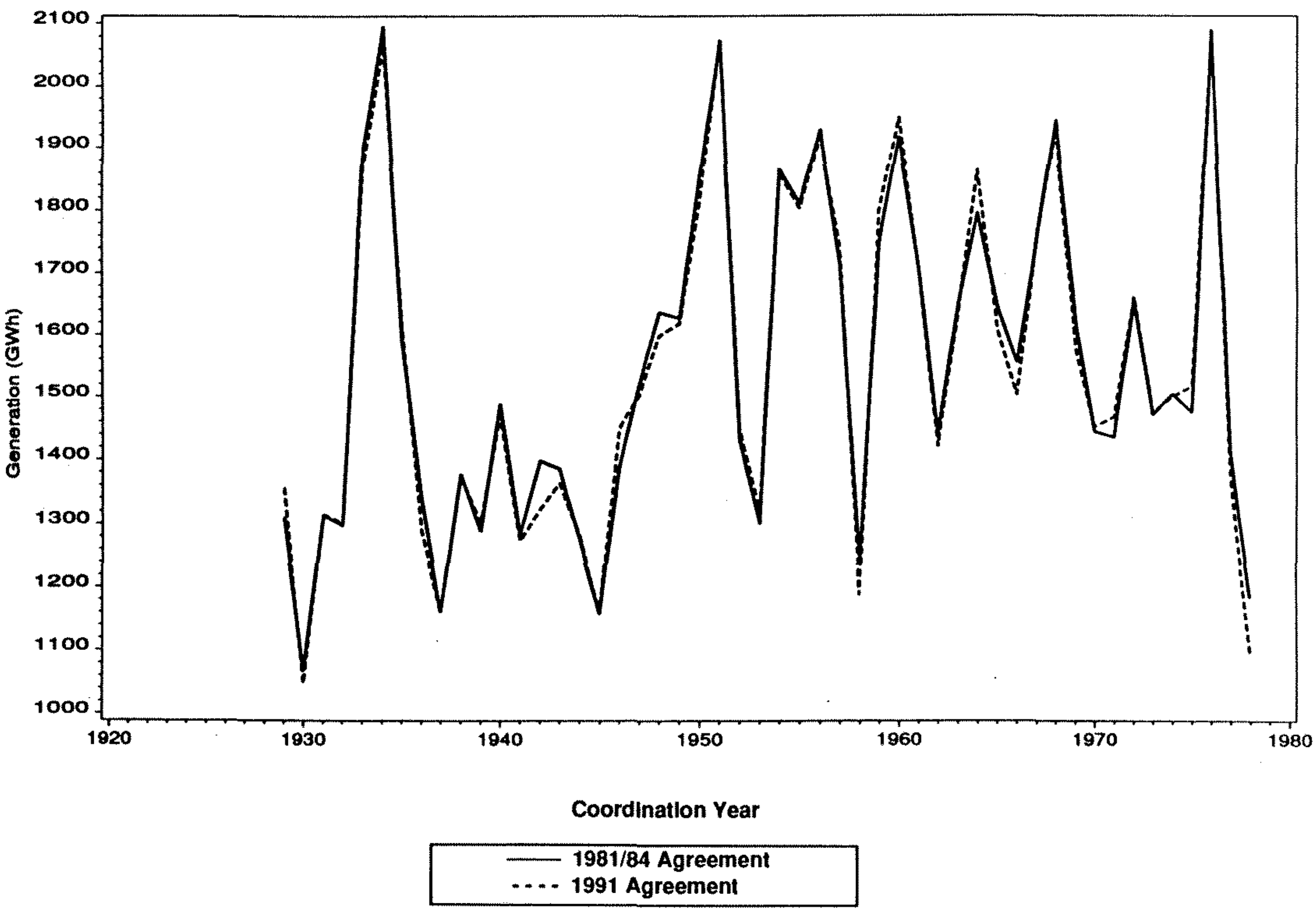


Figure 4-30. Winter energy production, Interim Agreement base case vs. 1991 Settlement Agreement.

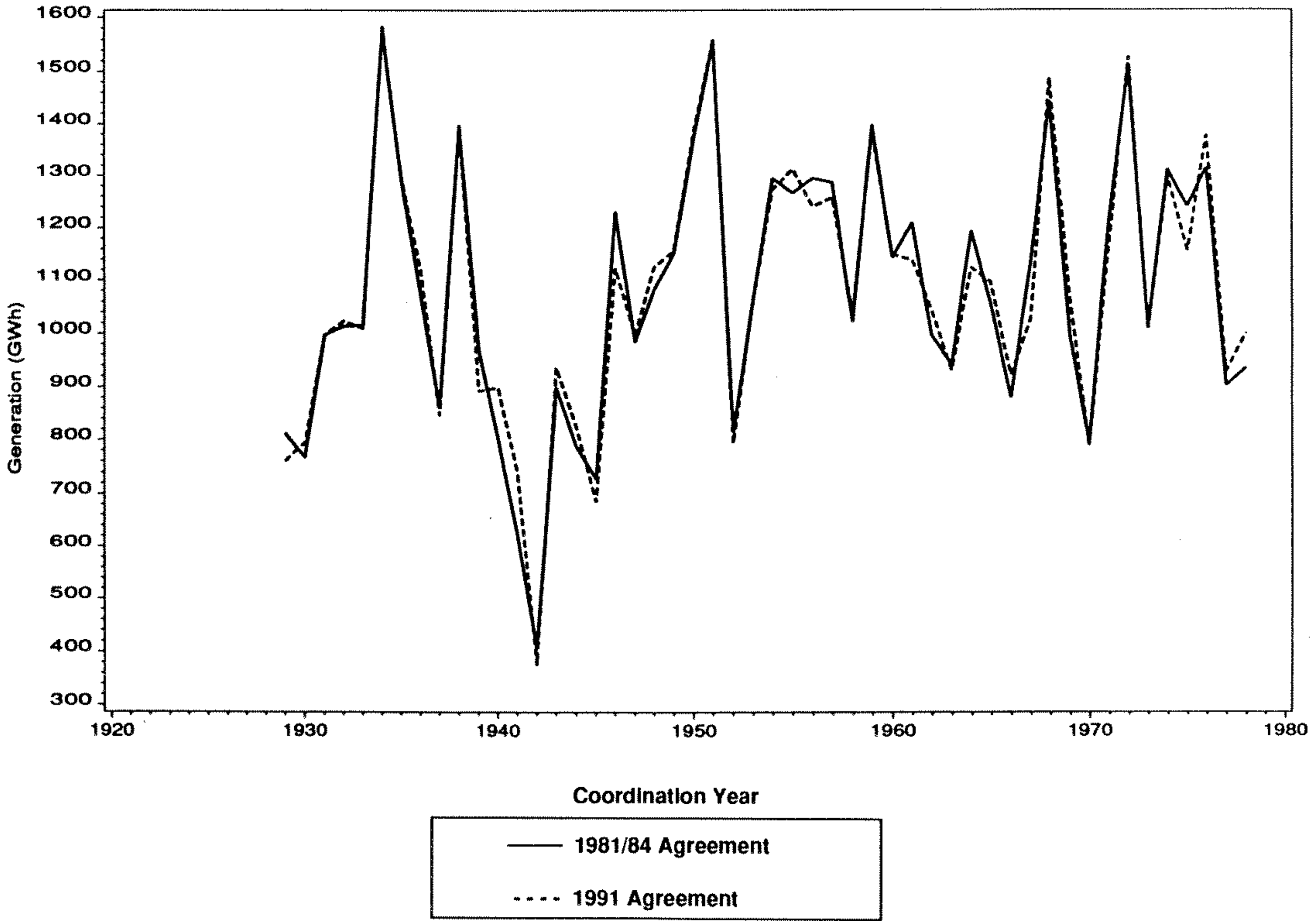


Figure 4-31. Summer energy production, Interim Agreement base case vs. 1991 Settlement Agreement.

5.0 INTEGRATED ASSESSMENT OF EARLY REFILL

Complete evaluation of the merits of early refill at Ross Lake requires simultaneous balancing of the effects on the three major resource areas, and consideration of tradeoffs among recreation and visual quality, fisheries, and power generation that would be associated with early refill. In addition, there are several additional issues for which little specific information is available, but which should nevertheless be included in the overall evaluation. Once all appropriate factors have been considered, final judgment of the merits of early refill should be based on whether the benefits of early refill justify the costs, and the effectiveness of the refill scenarios in meeting early refill objectives. These aspects of the integrated evaluation of early refill are discussed below in Sections 5.1, 5.2 and 5.3.

5.1 TRADEOFF RELATIONSHIPS

The material presented in Chapters 2, 3 and 4 identified a number of tradeoffs associated with early refill. These included tradeoffs involving the water resource itself and use of the water to support recreation and visual quality, downstream and reservoir fisheries, and electric power production.

The most obvious and fundamental tradeoff relationship highlighted by the lake levels analysis is that at any given time Skagit River water can either be stored in Ross Lake or released downstream. A higher refill rate at Ross during a specific period will generally translate into reduced downstream releases from the project during the same period and vice versa. Therefore, a given volume of water can be used to meet storage-related objectives in the reservoir or flow maintenance objectives at Ross dam and downstream, but cannot support both types of objectives at the same time.

While increasing storage to meet early refill results in concurrent reductions in downstream flows, this relationship is not uniform over a water year; inflow to the reservoir is not dependent upon the rate or volume of storage, so the stored water must be released at some point to accommodate inflow. Therefore, early refill of Ross Lake would generally redistribute the pattern of higher and lower flows during the year, reducing total flow volumes at Gorge from fall through winter but increasing flows from approximately March through June. One of the primary effects of early refill would be to shift the peak flow period from June and July into May and June. This results from the operational changes required to implement early refill. The reservoir must be held to a higher level (lesser draft rate) through March 31 to achieve the refill target with an unchanged volume of total inflow. Due to the uncertainties of flow forecasting, particularly with respect to the timing of the annual runoff, the higher reservoir elevation at any given time during the refill period reduces the amount of storage available to accept inflows. The need to avoid excessive spill later in the runoff season therefore results in higher releases in May and early June, in order to maintain storage space for later inflow. These changes in flow rates and timing have varying effects on downstream fisheries and power generation, as described subsequently.

The primary resources investigated in the analysis are not affected uniformly by early refill, because some are benefitted by increased storage while others benefit from changes in streamflow volumes or timing. Consequently, an improvement in one of the resource areas through early refill will be gained at the expense of worsened conditions in another resource area. The direction of change for the effects of early refill on the respective resources are summarized as follows:

Reservoir Recreational/Visual Quality	- positive
Downstream Recreation	- negative
Downstream Fisheries	- negative
Reservoir Fishery	- uncertain, may be neutral
Power Generation	- negative

The only positive effect of early refill that is relatively certain would involve reservoir recreation, where higher lake levels in the late spring would improve the utility of shoreline recreation facilities and the visual quality of the lake environment. These improvements would be expected to translate into somewhat higher levels of aggregate annual recreation use on Ross Lake itself, on the order of 2 percent above the existing level. Improvements in visual quality would also marginally increase the value of the recreation experience for all users of the Ross Lake area.

These benefits would be offset slightly by adverse overall effects on downstream recreation. Whitewater boating opportunities on the upper Skagit River would be reduced or precluded during May and June of many years, due to the early refill effect of substantially increasing outflows at Gorge during that period. This would probably result in a decrease in total annual whitewater use, although the magnitude would be less in absolute terms (numbers of users) than the changes on Ross Lake. Scenic floating and boat fishing on the Skagit River would not be affected by early refill.

The recreation and visual quality benefits from early refill would involve a tradeoff with downstream fishery resources, which would experience negative effects overall. Early refill also involves a tradeoff within the downstream fishery resource category. Reduced streamflows during the fall and winter would result in lower protection levels for downstream salmon spawning and incubation. Decreases in salmon spawning protection levels range up to 4 percent for the Interim Agreement refill alternatives, and up to 19 percent for the original FERC license minimum flow scenarios. Higher April and May flows caused by project operation for early refill could generally improve conditions for steelhead in the Skagit River, increasing average protection levels by up to 21 percent. Due to the overwhelming numerical dominance of the salmon runs compared to steelhead, the net impact on downstream fisheries would be negative for all but one of the refill scenarios. Based on the projected spawning protection levels of the proposed flow agreement, it appears that Alternative 2 (refill to elevation 1592 by June 30) could increase total fish runs by less than 0.5 percent.

The reservoir fishery also has a mixture of positive and negative relationships with early refill, which obscure the overall balance of effects on resident fish. Early refill is commonly expected to have a positive association with the reservoir fishery, because higher early-season lake levels would inundate barriers in some Ross Lake tributary streams that currently block access to potential spawning habitat during much of the spawning season. However, early refill would also have a negative effect on resident trout spawning, as higher lake levels would inundate the lower reaches of tributary streams that are currently used for spawning. Early refill would also significantly increase the frequency and volume of spill at Ross, which could have the negative effect of flushing resident fish from Ross Lake. The net balance of these effects on the reservoir fishery may be either positive or negative, although the degree of change is likely to be small in either case.

The recreation and visual quality benefits of early refill involve a significant tradeoff with power generation. By increasing lake levels over existing conditions, early refill increases the hydraulic head at Ross dam and actually contributes to improved power generation efficiency at certain times of the year. However, this positive influence is swamped by two major negative effects. The uncertain balancing act required to accommodate early refill and late spring-early summer inflows at Ross Lake would cause increases in the frequency and volume of spilled water at all three Skagit dams. Consequently, all of the early refill alternatives would result in a decrease in total Skagit Project generation over the long term, ranging from 0.5 to 5.4 percent of total project generation among the Interim Agreement refill alternatives.

The redistribution of the high and low flows during the year would also have a significant negative impact on the aggregate value of power generated at the Skagit Project, as a result of seasonal differences in energy prices. Reduced flows through the Skagit Project during the fall and winter would be accompanied by reduced generation during the period of highest general power demand and highest unit energy prices. Conversely, the higher flows during the refill season would increase power generation at a time of relatively lower demand and lower prices. Early refill therefore represents a shift in time of power generation from the winter, when the electricity is needed to meet City customer demands, to the spring-summer period when the power is likely to be surplus to City needs and of lower value on the open market. The values of the winter losses are much greater than the values of summer gains, contributing to a strong negative overall effect of early refill on power generation.

The power generation component of the lake levels analysis also illuminated two key tradeoffs involving the operating rules used to simulate project operation. A fundamental rule used in the simulation process was that firm power production would not be sacrificed in order to meet refill targets. The consequences of this rule are that power generation costs are lower than they would be if highest priority were placed on meeting refill targets, but that refill targets are not met in approximately 20 to 40 percent of the refill years. The operating rules also gave higher priority to minimizing spill than to refilling the reservoir. Average early-season lake levels and the success rates for meeting refill targets would both be higher if the spill control constraint were relaxed or eliminated, but doing so would increase the power generation costs of the early refill alternatives.

5.2 ADDITIONAL CONSIDERATIONS

Several issues outside of the three primary resource areas arose during the course of the lake levels analysis. The FERC relicensing process intervenors, primarily the National Park Service, requested that the study address the potential effects of early refill on shoreline erosion and archaeological resources at Ross Lake. Once the HYDRO model simulation process had been completed, review of the results with respect to streamflows indicated potential concern over contribution to increased flood hazards in downstream reaches of the Skagit River. These additional issues were identified sufficiently late in the process that they could not be investigated to the same extent as recreation, fisheries, and power generation. Nevertheless, current knowledge of these issues is summarized below in the interest of providing the most comprehensive review possible of all currently suspected effects of early refill.

5.2.1. Shoreline Erosion and Archaeological Resources

Shoreline erosion at the three Skagit Project reservoirs has been a significant concern during the relicensing proceeding, and has been the subject of a separate cooperative study by the City and the National Park Service. Ross Lake has the most extensive and severe shoreline erosion, as 25 percent of the total shoreline is in some stage of retreat (NPS, 1990). NPS field studies of erosion problems at Ross Lake identified numerous locations of slope instability, mass failure via debris slides in areas of loose sediments, slumping of large blocks of cohesive bank sediments, and small-scale slides and general bank retreat in various locations.

The NPS (1990) concluded that wave impacts were the dominant cause of shoreline erosion, and that lake level fluctuations contributed to erosion by focusing wave energy on different parts of the bank as the reservoir level rises and falls. Fluctuating water levels also transport eroded material downslope, preventing the formation of beaches and causing wave energy to be concentrated directly on lakeshore bluffs when the lake is at full pool. At an assumed average bank recession rate of 1 foot per year along eroding shoreline reaches, the NPS estimated that shoreline erosion caused a loss of approximately 1.7 acres of upland area per year at Ross Lake.

In response to these identified erosion problems, the City sponsored development of a site-specific erosion control plan (Ebasco Environmental and National Park Service, 1990). The draft plan proposes to implement a variety of erosion control measures, including anchored lugs, rock shore protection (riprap), cribbing, gabions and establishment of vegetation Because undercutting of toe-slopes along the shoreline is the primary cause of bank recession and slope instability, the erosion control measures emphasize stabilizing the bottoms of eroding slopes. The draft erosion control plan proposes such measures at 46 specific sites on Ross Lake.

Soil erosion issues with respect to early refill generally reflect concerns over static lake levels and the rate of change of reservoir elevation (NPS, 1990). Erosion is concentrated at a specific point along the bank when the normal refill or drafting pattern is interrupted and the lake elevation remains relatively constant for several days. Similarly, erosion of bluffs and disturbed areas at recreational facilities is concentrated when the reservoir is at full pool. A final concern regarding static lake levels is that prolonged durations of lake levels between full pool and approximately 10 feet below full pool would undercut the foundations of proposed erosion control measures. The primary documented concern over the rate of change in lake levels is that rapid drawdown might increase erosion through groundwater influence on mass movement processes. Conversely, it would appear that rapid refill during late spring and early summer would work to restrict erosion by minimizing the time duration at any specific elevation. As a result of these concerns, it is important to consider whether early refill of Ross Lake would improve, worsen or have no effect on these specific erosion factors.

Based on preliminary review of the lake elevation data from the HYDRO model simulation results, early refill would have no effect on some of these shoreline erosion factors and a negative effect on others. There should be no effect on the frequency or extent of interruptions to refill or drafting patterns, because these events are caused primarily by natural forces and are independent of the operating rule curves. Maintenance of a static elevation for several days during the refill period would require an extended period of sufficiently cold, dry conditions to significantly retard snow melt and reduce inflow to Ross.

Early refill would negatively influence shoreline erosion by extending the duration of lake levels at full pool or within 10 feet. In years when the reservoir did completely fill, the early refill alternatives would advance the date of reaching full pool by up to one month. With the lake typically held at full pool through at least the end of August, this could translate into an increase of up to 100 percent in the number of days annually at full pool. Similarly, the early refill alternatives would cause the Ross Lake level to reach 1590 feet by up to 35 days earlier in the refill period. Further, the refill trajectories for the most aggressive refill alternatives tend to visibly flatten after reaching elevation 1590 or 1595 (see Figures 4-5 and 4-6), causing the reservoir to spend more time perched in the most sensitive elevation zone, which is within 5 to 10 feet of full pool. These aspects of the respective refill patterns indicate that early refill would accelerate erosion of lake bluffs and recreation sites, as well as increasing the risk of undercutting the foundations of erosion control measures.

The early refill alternatives would only alter reservoir operations during the refill period, roughly April through June or July, and would not change the reservoir drawdown pattern from existing conditions. Therefore, early refill would be neutral with respect to increased erosion resulting from an accelerated drawdown rate.

However, changing the reservoir operation to implement early refill would alter the rate of lake level increase during spring and early summer. With the existing refill target of elevation 1602.5 on July 31, the average refill rate from April 15 to July 15 over the entire simulation period would be about 1.4 feet per day. Alternatives 6 and 11, involving refill targets of elevation 1601.5 by May 31, would reduce the average refill rate over the same period to about 0.7 and 0.6 feet per day, respectively. This would not have the same significance as an extended static lake level, but would appear to increase shoreline erosion somewhat from the existing condition. The average refill rate for the other early refill alternatives ranges from about 0.9 to 1.4 feet per day, and in most cases is near 1.3 feet per day.

Concerns over archaeological resources relative to lake levels are very closely linked to those of shoreline erosion. Archaeological sites located along the banks of the reservoir are exposed at various lake elevations, and are subject to physical damage through sedimentation or bank recession. Early refill would therefore increase the potential for damage to those sites in the upper ranges of the lake elevation, by increasing the number of days when the lake is at these levels. This effect may be offset somewhat by a reduced probability that sites at very low lake elevations, generally between 1510 and 1550 feet, would be exposed in any given year and subject to erosion. This effect would result because the early refill alternatives would reduce the maximum annual drawdown.

5.2.2 Flood Protection

The Federal Emergency Management Agency (FEMA) completed flood insurance studies on the Skagit River in 1982 and 1984 (FEMA, 1982, 1984). The following flood control measures were summarized by FEMA in the 1984 report:

> The City of Seattle (Seattle City Light) owns and operates Ross Reservoir on the upper Skagit River, the only project on the main stem of the Skagit River with available flood storage. Ross Reservoir has 1,052,300 acre-feet of usable storage between elevations 1,602 and 1,475 feet, of which 120,000 acre-feet are reserved for flood control in compliance with the Federal Energy Regulatory Commission license.
>
> Puget Power operates two hydroelectric power projects on the Baker River: Lower and Upper Baker Dams and Reservoirs located at RM 1.12 and 9.29, respectively. The Baker River streamflows have been subject to varying degrees of flood-control regulation since completion of the Lower Baker Dam project in 1927 and the Upper Baker Dam project in 1959. Flood-control storage was increased in 1977 from 16,000 to 74,000 acre-feet at the Upper Baker project to more effectively regulate the Skagit River flows west of Concrete.
>
> During the November through March flood season, flood control regulation commences when the flow in the Skagit River near Concrete is forecast to reach or exceed 90,000 cfs within the next 8 hours. The COE then directs operation of the Ross and Baker projects flood-control operations. Project releases are selected with reference to formal operating plans which consider flow at Concrete, reservoir pool elevations, and observed and forecast reservoir inflows. Releases from both projects are regulated to minimum levels until the flood peak has passed and the Skagit River has begun to recede at Concrete. Subsequently, project discharge is increased to draft storage from the reservoirs so that flood-control storage space is regained.
>
> Sixteen diking districts maintain approximately 56 miles of levees and 39 miles of sea dikes in the Skagit River delta. Additional levees protect farmland and residences elsewhere in the county, but none of the levees or dikes are adequate to protect against a 100-year tidal or riverine flood.

The flood-control provisions of the FERC license for the Skagit Project specify maximum reservoir elevations necessary to maintain flood control storage at various times of the year. Monthly flood control elevations for Ross Lake are summarized as follows:

March 31 through September 30	1,602.5 feet
October 1 through October 31	1,598.8 feet
November 30 through March 15	1,592.1 feet

The flood frequency at several locations in the Skagit River basin are summarized in Table 5-1. The 100-year flood near Sedro Woolley is calculated at a discharge of 229,000 cfs. The five most severe floods since gaging began resulted in the following peak discharges near Sedro Woolley:

November 1909	220,000 cfs
December 1917	195,000 cfs
December 1921	210,000 cfs
November 1949	140,000 cfs (estimated)
February 1951	150,000 cfs (estimated)

The 1982 FEMA study determined the following correspondence between flood recurrence interval and flood stage at river mile 55.6 at Concrete, which encompasses a 2,737 square mile drainage area:

Recurrence (years)	Peak Discharge (cfs)	Water Surface Elevation (feet NGVD)
10	124,000	174.5
50	193,000	183.9
100	226,000	187.8
500	329,000	197.0

River mile 55.6 is at the western limit of flooding affecting the town of Concrete, and is located 1.5 miles upstream of the USGS gage (Skagit River at Concrete, 12194000) upon which the discharges are based. The areal extent and corresponding elevations for flooding in other locations along the Skagit are provided in detail in the aforementioned FEMA studies.

The specific influence of early refill on downstream peak discharges and flood hazards is not known at this time, because the HYDRO model is not formulated to allow identification of daily or instantaneous peak discharges from the Skagit Project. The simulation results quantify discharge rates averaged over two-week or one-month periods, while significant flood events typically have a duration of only a few days. Project discharges could therefore be quite high for a few days without drastically elevating the average outflow for the entire period. There is no common scale or rule of thumb relating average two-week outflows to likely short-term peak discharges within that period. However, some tentative inferences as to the degree of potential effects can be derived from review of historical daily Skagit River flow records and the simulation results with respect to the key May-June period.

From October 1953 through July 1989, there were seven instances in which the peak daily flow on the Skagit River near Concrete during May or June exceeded 50,000 cfs. The highest average daily flow among these cases was 69,200 cfs in June 1972. These actual flow peaks for the spring runoff season are less than 60 percent of the 10-year peak discharge of 124,000, and are also well below the 90,000 cfs level at which flood control regulation activities are initiated.

Table 5-1. Summary of peak flood discharges for Skagit River and major tributaries.

Flooding Source and Location	Drainage Area (Square Miles)	Peak Discharge (cfs) 10-Year	50-Year	100-Year
Skagit River				
Near Concrete	2,737	124,000	193,000	226,000
Near Sedro Woolley	3,015	132,000	200,000	229,000
Cascade River				
At Marblemount	172	14,300	23,800	28,500
Sauk River				
Near Sauk	714	52,500	81,000	94,000
Suiattle River				
At Mouth	346	25,800	46,600	58,000
Samish River				
Near Burlington	87.8	4,670	7,100	11,500
Baker River				
At Concrete	297	31,500	44,500	51,000

Source: FEMA, 1984

The maximum influence of early refill on peak May-June flows can be addressed to some degree by comparing simulated project outflows under the base case and Alternative 6 (refilling to elevation 1601.5 on May 31) for these high-flow years of the historical record. For example, the average simulated outflow from the Skagit Project for June 1967 is 6315 cfs, while the corresponding outflow for Alternative 6 is 17,639 cfs, an increase in average flows over the period of over 11,300 cfs. Therefore, the peak daily flow near Concrete during June 1967 water conditions would have been at least 80,800 cfs if Alternative 6 were governing project operations.

The actual June 1967 peak flow at Newhalem was about 2.4 times the mean flow for that month. Applying this ratio to the Alternative 6 average flow for June 1967 indicates that the peak daily flow during that month could conceivably exceed 42,000 cfs, or about 27,000 cfs above the potential base case peak daily flow. If implementation of Alternative 6 would actually equate to an increase of 27,000 cfs in the peak daily flow, the peak flow near Concrete for the June 1967 period would be about 96,500 cfs. This is still below the 10-year discharge level, but above the threshold level for flood control operations. Compared to the base case, Alternative 6 would increase monthly average flows in the other months of the highest May-June historical peaks by about 4700 to 11,600 cfs. Actual peak/mean flow ratios suggest that daily peak flows during these months with Alternative 6 could be from 8600 cfs to 23,500 cfs above the base case figures.

The simulated increases in May-June average flows, and the apparent level of increases in peak May-June flows, demonstrate that the most aggressive early refill scenarios would add appreciably to peak Skagit River flows near Concrete during the springtime of high-runoff years. Because the recorded spring peaks are considerably below the overall peaks associated with winter floods, however, the simulated results suggest that early refill should not elevate peak May-June discharges to levels that would be associated with significant flood damage in the lower reaches of the Skagit River. Nevertheless, the Corps of Engineers has informally expressed concern to the City about the influence of early refill on flood control levels. In the absence of more specific information, this may reflect concern over potential damage to downstream levees from elevated water levels during the peak runoff season.

5.3 NET BENEFITS AND EFFECTIVENESS OF EARLY REFILL

A summary of the gains and losses from early refill, covering all effects that are presently identifiable, is provided in Table 5-2. These gains and losses have been quantified for reservoir recreation, downstream fisheries, and power generation, for which more detailed analysis was possible. Due to limited available information and inconclusive evidence, only expected or potential directions of change have been identified for downstream recreation, the reservoir fishery, shoreline erosion and archaeological resources, and flood hazard.

The directions of change indicated in the table clearly demonstrate that the effects of early refill across all resource concerns are predominantly negative. The shoreline erosion and flood hazard effects considered outside the scope of the basic analysis add to the list of negative effects discussed in Section 5.1.

Because reservoir recreation is the only resource for which there is a demonstrated positive effect from early refill, implementation of early refill can only be justified if the net recreation benefits exceed the costs to other resources. The maximum recreation benefits of 1,000 additional activity days would apply to Alternative 6, refilling by May 31, and would have a present value over the 30-year license term of less than $0.4 million. The power costs of this alternative would be about $93.1 million in present value over the 1990-2008 period for which forecast prices are available, and at least $131 million over 30 years. Actual costs would be higher if the potential downstream recreation and anadromous fish losses were added to the economic calculation. Other early refill alternatives have lower power costs but also have lesser recreation benefits. In all cases the reservoir recreation benefits amount to only a small fraction of the corresponding power costs, and net benefits are overwhelmingly negative.

This relationship of comparatively very small reservoir recreation benefits and very large power generation costs holds true under even the most optimistic assumptions of changes in recreation use due to early refill. Even if it were assumed that refilling Ross Lake by May 31 would effectively add another month to the peak recreation season (ignoring the

Table 5-2. Summary of gains and losses from early refill, by refill scenario (compared to existing conditions).

	INTERIM AGREEMENT SCENARIOS						
Refill Scenario	Recreation (Activity Days)[1]	Downstream Recreation	Downstream Fisheries (no. of fish)	Reservoir Fishery[2]	Power Generation (Value in $000s)[3]	Shoreline Erosion/ Archaeology	Flood Hazard
INTERIM AGREEMENT SCENARIOS							
Alt. 1, 1601.5 June 30	+ 210	–	-2,300	+ or -	-$17,225	–	–
Alt. 2, 1592.0 June 30	+ 100	–	-1,100	+ or -	-7,863	–	–
Alt. 3, 1601.5 June 15	+ 620	–	-7,900	+ or -	-44,145	–	–
Alt. 4, 1592.0 June 15	+ 450	–	-5,900	+ or -	-26,400	–	–
Alt. 5, 1580.0 June 15	+ 260	–	-2,900	+ or -	-14,428	–	–
Alt. 6, 1601.5 May 31	+ 1,000	–	-17,000	+ or -	-93,087	–	–
Alt. 7, 1592.0 May 31	+ 830	–	-8,000	+ or -	-66,164	–	–
ORIGINAL LICENSE MINIMUM FLOW SCENARIOS							
Alt. 8, 1602.5 July 31 (equivalent to base case)	+ 50	–	-18,100	0	-59	0	0
Alt. 9, 1601.5 June 30	+ 240	–	-33,800	+ or -	-7,930	–	–
Alt. 10, 1592.0 June 30	+ 120	–	-29,500	+ or -	-17,272	–	–
Alt. 11, 1601.5 May 31	+ 1,000	–	-177,100	+ or -	-101,184	–	–

(1) Based on typical user day values, increases in activity days would range up to $18,200 per year, and $357,000 in present value over 30 years at a 3 percent discount rate.

(2) Reservoir fishery changes involve competing positive and negative effects. It is uncertain whether the balance of these effects is positive or negative, but the magnitude is small in either caae.

(3) Figures reflect present value of changes in power generation over 1990-2008 forecast period, using a 3 percent discount rate. Over entire 30-year license term, present value of power losses would range from about $11 million for Alternative 2 to $131 million for Alternative 6.

underlying natural and social causes of existing seasonal use patterns), the maximum increase in reservoir recreation use would be about 13,200 annual activity days. The annual value of a change of this magnitude would be somewhat less than $0.25 million, and the present value over 30 years (discounted at 3 percent) would be approximately $4.8 million. The corresponding power generation costs would still outweigh recreation benefits of this level by a ratio of 27:1.

The effectiveness of the early refill alternatives must also be considered in the final evaluation. Due to the structure of the lake level simulation analysis, with refill targets used as soft constraints that were inferior to firm power generation and spill control, the simulated operation results fell considerably short of the refill targets. Success in meeting the refill targets ranged from 58 percent of the simulation years for Alternative 6 (elevation 1601.5 on May 31) to 78 percent for Alternative 2 (elevation 1592 on June 30).

Conversely, Alternative 6 produced the greatest increase in average lake levels on given dates, compared to the base case, while Alternative 2 resulted in the smallest elevation gains. These figures illustrate that relatively minor increases in early season lake levels can be achieved with considerably more regularity than can more significant elevation increases.

Achieving greater effectiveness in meeting early refill objectives would require treating refill as a hard constraint, allowing firm energy production to be sacrificed to meet refill targets. The City's prior analysis of early refill at Ross (SCL, 1988) adopted such an operating rule structure, resulting in June 1 and June 16 refill targets being met 85 percent of the time. The only years in the 1988 analysis in which refill targets were not met were when cold weather in April and May delayed snowmelt runoff. In contrast, imposition of POP conditions was the primary cause of failure to meet refill targets in the current analysis. This situation would be avoided if early refill requirements were declared to the coordination agreement parties, but at the cost of sacrificed firm power. The City's 1988 analysis estimated the present value over 30 years of firm power losses only (effects on secondary power were not incorporated in the analysis) at $50 million for refilling by June 16 and $100 million for refilling by June 1 (SCL, 1988). Total costs with secondary energy effects included would presumably have been considerably higher.

6.0 INTERVENOR REVIEW COMMENTS AND CITY RESPONSES

The draft Ross Lake levels report was released for review in March 1990. The City received comment letters on the draft report from WDW and NPS. These comment letters are reproduced on the following pages. Individual comments from these letters are identified by number in the letter margins. City responses to these comments follow the letters.

CURT SMITCH
Director

STATE OF WASHINGTON
DEPARTMENT OF WILDLIFE
16018 Mill Creek Blvd., Mill Creek, WA 98012 Tel. (206) 775-1311

May 15, 1990

RECEIVED
MAY 18 1990
Environmental Affairs Division

Toby Thaler
Associate Environmental Analyst
Environmental Affairs Division
Seattle City Light
1015 Third Avenue
Seattle, WA 98104-1198

Re: Skagit River Project, Ross Lake Levels Analysis,
Draft Report, FERC 553

Dear Mr. Thaler:

We have reviewed this report and have the following comments.

Out of necessity, because of time constraints, our review focused on those analyses dealing with resident and anadromous fishery issues. Our lack of comments on other issues or analyses, therefore, should not be construed as acceptance of those results or conclusions even though some may have a direct or indirect effect on matters of concern to this agency.

Executive Summary, II. Current Impacts of Ross Lake Drawdowns...., Resident Fisheries, p 2. Conclusions stated are misleading in that they do not consider all relevant factors or seem to contradict conclusions given in the main body of the report. Reservoir drawdown does not increase available spawning habitat. According to statements at p 3-6, the greatest amount of habitat is available at full pool. To the extent that some tributaries have spawning habitat within the drawdown zone, only a portion exists between reservoir elevations typical during the spawning period and full pool. And, as you point out, survival in that zone is highly variable from stream to stream and possibly from year to year. (1)

Not considered at all are drawdown effects on food resources available to Ross Reservoir trout. The extent and duration of annual reservoir drawdown, reduction in surface area and consequential bottom exposure, has a significant negative effect on food resources that would otherwise be available. This fact is well documented in studies that were conducted to define the effects of the High Ross project. Lost benthic invertebrate production in particular, results in a paucity of large food items of special importance to larger trout. (2)

These larger fish are prized in the fishery. Because they are also mature, spawning age fish, they are essential to the reproductive viability of the population. But loss of benthic food resources negatively affects their growth, post spawning recovery and survival. We therefore do not agree that Ross Reservoir drawdowns have no significant impacts.

Additionally, whether this is an "already enhanced fishery" is irrelevant to the issue of identifying and implementing what is necessary to assure its continued existence and viability. (3)

Ibid, III. Potential Impacts of Early Refill Alternatives..., p 3. Resident trout are not discussed at all. This is a serious omission and fails to convey important information concerning drawdown effects on spawning habitat availability, benthic food resources and spill. (4)

Ibid, IV. Trade-offs Between Resources, p 5. Based on the facts, it is clear that resident trout will be significantly impacted. Means to mitigate these impacts should be proposed. (5)

3.0 Fishery Resources, 3-1 Study Methods, Downstream Fisheries, p 3-1. It is stated the "...ESH model has been reviewed and accepted by the fisheries agencies and tribes..." This model is a very preliminary version of a comprehensive model still under development. We are using it because there is, at present, no alternative. We regard it as a tool to be used with caution and subject to confirmation as to its accuracy and reliability. (6)

Ibid, Reservoir Fishery, p 3-2. Apparently, only two references were consulted and, judging from the resulting discussion, only partially used. It is unfortunate that this important subject received such cursory treatment. (7)

3.2 Existing Conditions, Downstream Fisheries, p 3-3. It is not entirely accurate to say that hatchery steelhead do not spawn in the river. While formal egg taking occurs at cultural facilities, hatchery steelhead that are not harvested, or taken for culture, do spawn naturally. (8)

Ibid, p 3-4. The size of the wild steelhead run is stated to be 8,500 fish. It is not clear what period of time this figure refers to. Several years ago, the wild steelhead spawning escapement goal was 8,500. Subsequently, that escapement goal has been increased and total returns are considerably larger. Total wild steelhead run size 1985 through 1989 has averaged 12,900 and has been as large as 15,790. (9)

The last paragraph indicates wild steelhead spawn through

July. While some spawning does occur this late, it is substantially complete by mid-June. Regarding redd protection during June or July, we would not say that risk of insufficient incubation flows is nonexistent. In low or early runoff years, such as this year, there may be significant risk. (10)

Ibid, Reservoir Fisheries, p 3-6. While it is true the Skagit provides a large portion of available spawning habitat, Ross Reservoir trout do not appear to use available spawning tributaries in proportion to their size. Several tributaries in Washington are used far more intensely, for their size, than the Canadian Skagit. By their distribution, the fish make it clear it may be much better to have available spawning habitats well distributed among many streams than to rely on one large, but underutilized, source such as the Skagit. The relative importance of such sources as Big Beaver, and Lightning Creek, if made more available, may be far greater than their fractional area. If each tributary is home to discrete populations, enhanced access to south end tributaries may be essential to maintain south end populations. (11)

3.3 Early Refill Effects on Downstream Fisheries, Lake Level-Streamflow Interactions, p 3-9. The very last sentence of this section seems to be contradictory. If the discussion is addressing early refill, how can storage space be maintained later to control spill when the reservoir is already full to provide early refill? (12)

Ibid, Downstream Fishery Protection Levels of Refill Alternatives, p 3-9. As we have stated in many discussions, we have strong reservations, with regard to the procedure of taking estimated protection level, and converting these to fishery damages. Basic data necessary for accurate estimation are not available and resulting estimates do not include all impacts. Such exercises serve more to mislead than to enlighten. (13)

The last paragraph on p 3-13 is counterproductive and should be stricken. (14)

3.4 Early Refill Effects on Reservoir Fishery, p 3-1. Stated potential effects seem contradictory to previously stated facts and conclusions. How could early refill result in blockage of rainbow trout from tributary streams when most spawning habitat becomes available at or near full pool? With early refill, how is egg mortality in June or July increased? (15)

Ibid, Spawning Access to Tributary Streams, p 3-14 & 15. We strongly feel the importance of habitats in Big Beaver and Lightning Creeks may far outweigh their simple fraction of (16) the estimated total. As previously discussed, these habitats would be a large contribution to habitats available in the south portion of Ross Reservoir. And, alternative means of providing trout access to these areas would be an important opportunity to mitigate impacts and enhance the present fishery.

Ibid, Reduced Trout Production in Ross Lake, p 3-16. On reading this section, we can only conclude the authors failed to consider all relevant facts: In the face of increasing fishing pressure, declining total catch and catch per unit effort it is concluded angling pressure is not a factor. Rather, it is postulated to be an unidentified factor associated with declining primary productivity, perhaps a consequence of logging, in spite of the fact that this watershed may be one of least logged in the state. (17)

3.5 Summary Assessment, Reservoir Fishery Resources, p 3-19 to 3-21. As discussed previously, the stated impacts are contradictory. Additionally, a further discussion alludes to relationships between drawdown and decline of the Ross fishery resource. We have never contended that reservoir drawdown is the sole reason for the decline. It is one of several factors, that acting together, are reflected in the current state of this fishery. More accurately and importantly, we do believe that reservoir drawdown and consequential blockage to spawning habitats, subsequent inundation of redds and related mortality and drawdown effects on food resources act to limit the natural resiliency of this resource to withstand outside forces such as fishing pressure, that has and will continue to increase. Unless compensating steps are taken, this fishery will continue to decline in productivity and may be at risk of collapse. (18)

Thank you for the opportunity to comment.

Very truly yours,

R. Gary Engman
Mitigation Coordinator
Region 4 Habitat Management

c: NCNP
NCCC
Region
Division

Transmitted by FAX 5/16/90

r-11

United States Department of the Interior

TAKE PRIDE IN AMERICA

NATIONAL PARK SERVICE

Lake Chelan National Recreation Area
Ross Lake National Recreation Area
North Cascades National Park
2105 Highway 20
Sedro Woolley, Washington 98284 - 1799

SEATTLE CITY LIGHT RECEIVED 90 MAY 18 AIO 25 REFERRED

RECEIVED MAY 18 1990 Environmental Affairs Division

7+ Supt/EAD ✓

IN REPLY REFER TO:
A3815

May 16, 1990

Randall W. Hardy, Superintendent
City of Seattle - City Light Department
1015 Third Avenue
Seattle, Washington 98104-1198

Dear Mr. Hardy:

At the request of your staff operating the Recreation, Land Use and Visual Quality forum related to the relicensing of the Skagit River Project #553, we are providing specific comments on the "Draft Report: Skagit River Project Ross Lake Levels Analysis, March 1990."

As we have stated in the past, it our intent to manage the North Cascades National Park Service Complex as a part of the larger natural, cultural, and socio-economic ecosystem which surrounds the Skagit River Project. As noted in our comments specific interrelationships between lake level management considerations have been integrated and presented in the form of a comprehensive NOCA position.

It is our position that management of the level of Ross Lake must include: adequate provision for key pool elevations necessary for lake based outdoor recreation, provide an appropriate level of protection for downstream anadromous fishery resources, minimize adverse effects on the native resident trout fishery and tributary aquatic systems, limit adverse effects on visual quality, and work in concert with archaeological and erosion control mitigation programs. It is proposed that Seattle City Light commit to the conditions specified in our detailed comments in its new FERC License.

We are in general agreement with application of the base case lake level management regime - as would be modified by the fisheries flow agreement (in preparation) - for the operation of Ross Lake under the new FERC License. Further agreement on the acceptability of this management regime is contingent on satisfactory provision of the requirements set forth in the attachment and completion of internal National Park Service and Department of the Interior review.

enc. ✓
cc: Proj. Mgmt. (5) ✓

13

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These comments are provided for the purposes of technical assistance and should not be considered all inclusive nor the final position of the National Park Service or the Department of the Interior.

We appreciate the opportunity to comment.

Sincerely,

John R. Earnst
Superintendent

Enclosure

COMMENTS BY NORTH CASCADES NATIONAL PARK SERVICE COMPLEX
(NOCA)
ON
"DRAFT REPORT: SKAGIT RIVER PROJECT
ROSS LAKE LEVELS ANALYSIS
MARCH 1990"

May 14, 1990

DRAFT REPORT: SKAGIT RIVER PROJECT
ROSS LAKE LEVELS ANALYSIS

COMMENT: NOCA seeks to insure that management of the level of Ross Lake includes adequate provision for key pool elevations necessary for lake based outdoor recreation, provides an appropriate level of protection for downstream anadromous fishery resources, minimizes adverse effects on the native resident trout fishery and tributary aquatic systems, limits adverse effects on visual quality, and works in concert with archaeological and erosion control mitigation programs. 1

The comprehensive management of the level of Ross Lake for these concerns has been developed into a series of key lake level requirements. Although several are expressed in terms of recreational facilities, these requirements effectively integrate the range of concerns associated with lake level management. It is recognized that basinwide drought events in the Skagit River drainage may adversely affect achievement of these requirements. 2

NOCA proposes the following key requirements relating to lake level management: 3

(1) Boater access is provided to Ross Lake by boat ramp facility at Hozomeen no later than June 15 of each year.

(2) Boater facilities (docks) at Hozomeen and most boat-in access campgrounds along Ross Lake are accessible as early as possible after June 14 and not later than July 1 of each year.

(3) Full pool is achieved as early as possible after April 15 and not later than July 31 of each year.

(4) Full pool is maintained from July 31 through Labor Day of each year.

(5) Boater access to Ross Lake by boat ramp facility at Hozomeen is maintained through October 31 of each year.

NOCA boat ramps currently provide trailered boat access to a minimum effective lake elevation of 1581.5' (allows 3' of water above toe of boat ramp). Based on discussions during recent intervenor forum meetings it is understood that SCL is currently reviewing boat access requirements to Ross Lake at Hozomeen. NOCA recognizes that this review will result in the modification or reconstruction of an existing launch ramp facility by SCL. Such a facility is intended to increase the reliability of access to the lake by June 15 and not to increase the length of the primary recreation season on Ross Lake. This facility improvement would be in addition to the projects currently included in the SCL Draft Recreation Plan. 4

The NOCA recognizes that a few docks can not be modified or relocated to advance the date of their accessibility, e.g. NPS finger dock north of 'Winnebago Flat' and Silver Creek Boat-In Campground dock. Based on discussions during recent intervenor forum meetings it is understood that SCL is investigating facility modifications or relocations that would improve dock accessibility where feasible. These facility improvements would be in addition to the projects currently included in the SCL Draft Recreation Plan. 5

NOCA POSITION: NOCA is in general agreement with the application of the base case scenario to the operation of the Ross Lake pool levels under the new FERC License. NOCA understands that this scenario would follow current operations as modified by the fisheries flow agreement (in preparation) in lieu of the Interim Fisheries Agreement minimum flows. Although not included in the Draft Report, SCL has also reported that base case modelling using the proposed fisheries flow agreement minimums generates a slightly higher lake level by June 15, on average, than that reported on page 4-50 of the Draft Report. 6

Further agreement on the acceptability of the base case - fisheries flow agreement modified - lake level management regime is contingent on satisfactory provision of the following:

(1) Inclusion of a condition in the new FERC License stipulating the key pool level requirements detailed above (under Comments). Recognition of these requirements is crucial to the perpetuation of reservoir based outdoor recreation and the conservation of natural and cultural resources through the term of the License. Such consistency with the purposes for which the Ross Lake NRA was established is required under the new FERC License. NOCA requests that this condition conclude with a requirement for NPS approval of any alteration or modification to lake level management, prior to its implementation, during the term of the License. 7

(2) Demonstrate the reported improved refill performance of the lake level model using the base case, under the proposed fisheries flow agreement, over that of the base case under the Interim Fisheries Agreement conditions. NOCA requests an opportunity to review the results of this improved refill lake level simulation using results developed in the same format as used in Appendix C of the Draft Report. 8

(3) Commitment by SCL to increase the reliability of boater access to the lake at Hozomeen by June 15 through the modification or reconstruction of an existing launch ramp facility. NOCA recommends that provision for this access improvement be added to the SCL Draft Recreation Plan. A similar commitment is sought for dock modifications or relocations that would improve dock accessibility by July 1 where feasible. 9

(4) Commitment by SCL to declare under the Pacific Northwest Coordination Agreement (PNCA) an annual operational constraint that precludes implementation of PNCA proportional draft points (PDPs) that would result in a failure to meet the key lake levels detailed above (under Comments) through refill. 10

(5) Commitment by SCL to normalize lake level with the Variable Energy Content Curve (VECC) no later than March 31 of each year following "overdraft" from the reservoir. 11

(6) Seek through the U.S. Army Corps of Engineers utilization of a Variable Flood Control Curve (VFCC) under the new FERC License in lieu of the current fixed Flood Control Curve (FCC) in governing this reservoir refill/drawdown constraint. 12

Responses to comment letters on Ross Lake Level Analysis, March 1990, are provided below. Responses to comments are by numbers indicated on letters.

Letter from Washington Department of Wildlife, May 15, 1990

1. The discussion of this issue in the executive summary has been clarified.

2. The executive summary has been modified to acknowledge the issue of drawdown effects on food resources. However, the specific consequences of annual drawdown on food resources mentioned in the comment would not be measurably changed by early refill, so this issue is not addressed in Chapter 3.

3. The fact that the Ross Lake resident fishery is substantially enhanced over the pre-project conditions is relevant to a determination of what is an appropriate management plan. Actions to improve the lake fishery are strictly for enhancement, and therefore of lower priority than actions to mitigate for adverse impacts downstream, such as on anadromous fisheries. Nevertheless, the City views the lake fishery as extremely important, and proposes to operate the project so as to minimize impacts on the enhanced resource.

4. The impacts of early-season refill on resident fisheries are discussed in section 3.4. A summary of this discussion has been added to the executive summary.

5. The City's proposed operation of the project will not significantly impact the resident fisheries. Early-season refill would not significantly add to the existing level of resource enhancement. Mitigation of non-provable, minimal impacts to an already enhanced resource, at great expense to other resources, is not appropriate.

6. The ESH is the state-of-art method for determining impacts of a hydroelectric project on anadromous fisheries. The agencies have accepted its use on that basis. The City accepts that as a model the ESH can be improved in the process of implementation.

7. Johnston, 1989, references and summarizes all work on Ross Lake resident fisheries to date. The City relied on the data displayed in that report to reach the conclusions in the current study. It was not necessary to reexamine the ground already covered by the WDW's researcher.

8. The sentence has been reworded.

9. The sizes of the various runs are used here as an index for comparison of relative impacts, with no attempt to display the most precise and current actual run sizes. Nevertheless, since the WDW has provided substitute numbers that are significantly different, the City has applied the WDW figure in the final report.

10. The text has been modified to delete reference to no risk. The City still feels the risk is minimal.

11. The Upper Skagit resident fishery thrived on the habitat available before and after the construction of the project. There is no evidence to support the proposition that south end tributaries are essential to maintain a fishery which has been at an enhanced level for forty years.

12. The early-season refill process would begin earlier than May and June; the City would have to begin filling earlier before it has knowledge of the amount and timing of the runoff to come. There is no way to accurately predict the timing of the runoff even after the amount is known by mid-spring. The outflow at Ross Dam is reduced in early spring in order to fill earlier because we can't count on the runoff coming early enough for early refill. When the main runoff starts in May and June, more water needs to be released in order to avoid spilling toward the end of the runoff when the reservoir is in fact already full due to earlier holding back of releases in order to meet the early refill target. Basically, the early-season refill curve reshapes the Ross dam release curve lower in the early spring in ignorance of the ultimate timing of the runoff, forcing a greater chance of spill late in the spring.

13. The purpose of this section (and the FISH-POWER model generally) is to assess relative impacts, not to quantify damages. The report has carefully qualified the accuracy of the data and estimation techniques. Discussion of potential changes to run sizes is important to developing any understanding of the magnitude of early refill effects.

14. Comment noted. The text has been modified to clarify the City's position.

15. Text has been edited for clarity.

16. Comment noted. See response to Comment 11.

17. The text enumerates all potential factors. The reference to logging of the reservoir area has been clarified.

18. The City proposes an operating regime, agreed to by all the fisheries agency and tribal intervenors, which will minimize impacts on the enhanced Ross Lake resident fishery and the downstream anadromous fisheries. The City agrees that limiting fishing pressure and bag limits, such as have been adopted commening in the 1990 season, are also necessary to maintain a healthy resident fishery. The City agrees that the stated impacts are offsetting, rather than contradictory; early refill would increase habitat in two tributaries (Lightning and Big Beaver creeks), while at the same time inundating available habitat in other tributaries and increasing the potential for loss of fish through spill.

Letter from National Park Service dated May 16, 1990

1. The City agrees with the stated resource protection objectives of a Ross Lake level management scheme. The City proposes to manage the lake levels to protect the listed resources to the greatest extent possible. However, the use of the words "key pool elevations" implies an ability to manage to meet target elevations which does not exist. The City cannot guarantee that the lake will be at a specific elevation on target dates each year. The City has used fifty hydrologic years to determine the lake level elevation on the

average as a result of alternative operational schemes, as well as the number of years that the average will not be met, and the deviation which can be expected by projecting the past hydrologic record through the new license period. These statistical analyses of the impacts on lake levels of the proposed operating scheme, including the negotiated downstream anadromous fisheries flow plan, are included in the final report.

2. Basinwide drought events are one of the reasons target elevations cannot be met except on the average (not "each year"), and why even averages may not be met through the new license period (if the hydrology in the basin for the next thirty years does not follow as expected from the past fifty).

3. See responses to comments 1 and 2. The City agrees with the goals, but not with setting them as firm targets to be met "each year." The City also notes that the performance standards indicated in items 1, 2, and 5 are already met in most years with existing operations.

4. As a result of negotiations between the City and the National Park Service and other intervenors, a settlement agreement has been executed which addresses this issue (SCL, 1991a, Section 3.4.1).

5. As a result of negotiations between the City and the National Park Service and other intervenors, a settlement agreement has been executed which addresses this issue (SCL, 1991a, Section 3.4.2).

6. As a result of negotiations between the City and the National Park Service and other intervenors, a settlement agreement has been executed which addresses this issue (SCL, 1991a, Section 2.1.1; SCL, 1991b, Section 4.0). Similar provisions are included in each settlement agreement for the Skagit Project relicensing proceeding. A table has been added to this report (Table 4-7) that indicates the higher early season lake levels, in an average hydrologic year, attained because of implementation of the 1991 Anadromous Fish Flow Plan (SCL, 1991b).

7. See responses to comments 1 and 2. The City and the National Park Service have agreed on mitigation plans for the Project, including a Ross Lake level operating scheme. See response to comment 6. The agreements between the City and the National Park Service do not preclude either party from requesting a reconsideration of the provisions of these plans, either informally or before the FERC, if justified by changes in circumstances.

8. The requested analysis has been completed and is included in the final report at section 4.4.5 and in Appendix C.

9. See responses to comments 4 and 5.

10. See reponses 1 and 2 regarding "key dates." The City's commitment to operate Ross Lake as agreed with the intervenors will become part of the new FERC license and take precedence over the PNCA.

11. The City is committed to this action; see response to comment 6.

12. The City will coordinate with the NPS in making recommended changes to the flood control curve at the appropriate time. The Corps of Engineers will not entertain such proposals until it has received a formal request for comment from the FERC.

7.0 GLOSSARY

Acre-feet. A meaure of volume of water. One acre-foot is the volume of water required to cover an area of one acre (43,560 square feet) to a depth of one foot. An acre-foot is equivalent to 326,000 gallons, 43,560 cubic feet, or 0.5042 second foot day (sfd).

ARC - Assured Refill Curve. A schedule of operating elevations which assures that the reservoir elevation will reach a specified level at a selected target date. Calculation of an ARC is based on the third lowest natural volume inflow for the historical period of record beginning July 1928, less minimum discharge, non-power, and fisheries requirements.

cfs. A measure of rate of flow. cfs is an abbreviation for cubic feet per second. While cfs units are normally used to quantify *instantaneous* rates of flow, the Seattle City Light (SCL) Hydro Model software used for this study reads and reports data on the basis of *average daily cfs*. For the sake of brevity, this study uses the SCL convention of reporting *average daily flows* as cfs, rather than as average cfs.

CRC - Critical Rule Curve. A schedule of elevations used as a guide for determining operating elevations during critical water periods. The Pacific Northwest Coordination Agreement defines the CRC as: "A guide to the use of storage water from each reservoir when reservoirs of the Coordinated System are required to operate below their Energy Content Curves (ECC). The Critical Rule Curve for each reservoir shall consist of one or more reservoir elevations at the end of each Period ... to supply the Firm Energy Load Carrying Capability of the Coordinated System in the event that there should be a recurrence of Critical Period streamflows."

In general, these rule curves are schedules of reservoir levels covering four years of an historical critical water period, with a different rule curve specified for each of the four years. PDP (see below) levels are estimated from this matrix as needed by interpolation based on relative (current to historical) water conditions for the coordinated system.

ECC - Energy Content Curve. A schedule of *target* operating elevations which normally follows the critical rule curve (CRC) schedule through the end of January, thereafter following the assured refill curve (ARC) until the end of period (historically, the end of August). The imposition of a proportional draft point (PDP) supercedes operation under ECC.

FCC - Flood Control Curve. A schedule of maximum allowable operating elevations imposed by the Army Corps of Engineers under the FERC operating license for Ross Dam. This schedule is designed to prevent the uncontrollable release of water (flooding) based on historically high operating years. This curve defines the *absolute upper bounds* of operating elevations for the reservoir.

PDP - Proportional Draft Point. An end of period (target) operating elevation which is imposed when the reservoir has not refilled. The PDP condition may also be imposed exogenously by coordination agreements when water conditions are critical on the coordinated system as a whole. (See Critical Rule Curve.) An imposed PDP condition supercedes normal operating elevation targets. PDP elevations are always met *unless* compliance with PDP would:

- violate minimum flows under license agreement,
- violate minimum fisheries flow requirements under contractual agreement,
- cause spill from the specified reservoir or from downstream plants.

In such cases the utility is still obligated to arrange for the provision of equivalent *energy* to that which would have been generated by following the PDP operating constraint.

SHSCC - Steelhead Spawning Control Curve. A schedule defining minimum end-of-period operating elevations for Ross Lake during the steelhead spawning period (March 1 through June 30). The SHSCC is based on the reservoir elevation at the beginning of the period, the forecast volume inflow expected at Gorge over the course of the period, and the planned spawning flow for the period. The SHSCC is a new computation procedure developed specifically to model provisions of the 1991 Settlement Agreement in the lake levels analysis.

SPCC - Spill Control Curve. A schedule of operating elevations, based on expected inflow for a reservoir, designed to prevent the release of water in excess of that which can be utilized for electricity generation. In general, this is a schedule defining the *upper bounds* of operating elevations for the reservoir. The SPCC is computed for the period January through August, inclusive.

sfd - Second Foot Day. A measure of volume. Specifically, the volume of water displaced in one day by a constant flow of one cubic foot per second.
1 (sfd) = 1 (Day) x 1 (cfs). One sfd is equivalent to 86,400 cubic feet, 1.9835 acre-feet, or 646,000 gallons.

Spill - Spill is any portion of the outflow of water from a reservoir which is *in excess* of the amount which can be utilized for electricity generation.

VECC - Variable Energy Content Curve. A schedule defining the *expected* lower bounds of operating elevations. The initial VECC is estimated from the water supply forecast (forecast streamflows at 95 percent confidence level) and the desired reservoir elevation as of a specific refill date. VECC is computed by starting with the expected refill elevation and its corresponding volume and working backward through each period of the streamflow forecasts. Each entry in the final VECC is taken as the lesser of the initial VECC estimate or the corresponding ECC. The VECC computed for an early refill may not fall below the base VECC levels for normal refill. This schedule of elevations includes consideration of minimum flows required for fisheries resources. The VECC is computed for the period January through August, inclusive.

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