Columbia River System Operation Review

Final Environmental Impact Statement

Appendix A

River Operation Simulation (ROSE)

BONNEVILLE POWER ADMINISTRATION

US Army Corps of Engineers
North Pacific Division

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

DOE/EIS-0170

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PUBLIC INVOLVEMENT IN THE SOR PROCESS

The Bureau of Reclamation, Corps of Engineers, and Bonneville Power Administration wish to thank those who reviewed the Columbia River System Operation Review (SOR) Draft EIS and appendices for their comments. Your comments have provided valuable public, agency, and tribal input to the SOR NEPA process. Throughout the SOR, we have made a continuing effort to keep the public informed and involved.

Fourteen public scoping meetings were held in 1990. A series of public roundtables was conducted in November 1991 to provide an update on the status of SOR studies. The lead agencies went back to most of the 14 communities in 1992 with 10 initial system operating strategies developed from the screening process. From those meetings and other consultations, seven SOS alternatives (with options) were developed and subjected to full–scale analysis. The analysis results were presented in the Draft EIS released in July 1994. The lead agencies also developed alternatives for the other proposed SOR actions, including a Columbia River Regional Forum for assisting in the determination of future SOSs, Pacific Northwest Coordination Agreement alternatives for power coordination, and Canadian Entitlement Allocation Agreements alternatives. A series of nine public meetings was held in September and October 1994 to present the Draft EIS and appendices and solicit public input on the SOR. The lead agencies received 282 formal written comments. Your comments have been used to revise and shape the alternatives presented in the Final EIS.

Regular newsletters on the progress of the SOR have been issued. Since 1990, 20 issues of *Streamline* have been sent to individuals, agencies, organizations, and tribes in the region on a mailing list of over 5,000. Several special publications explaining various aspects of the study have also been prepared and mailed to those on the mailing list. Those include:

- The Columbia River: A System Under Stress
- The Columbia River System: The Inside Story
- Screening Analysis: A Summary
- Screening Analysis: Volumes 1 and 2
- Power System Coordination: A Guide to the Pacific Northwest Coordination Agreement
- Modeling the System: How Computers are Used in Columbia River Planning
- Daily/Hourly Hydrosystem Operation: How the Columbia River System Responds to Short–Term Needs

Copies of these documents, the Final EIS, and other appendices can be obtained from any of the lead agencies, or from libraries in your area.

Your questions and comments on these documents should be addressed to:

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PREFACE: SETTING THE STAGE FOR THE SYSTEM OPERATION REVIEW

WHAT IS THE SOR AND WHY IS IT BEING CONDUCTED?

The Columbia River System is a vast and complex combination of Federal and non–Federal facilities used for many purposes including power production, irrigation, navigation, flood control, recreation, fish and wildlife habitat and municipal and industrial water supply. Each river use competes for the limited water resources in the Columbia River Basin.

To date, responsibility for managing these river uses has been shared by a number of Federal, state, and local agencies. Operation of the Federal Columbia River system is the responsibility of the Bureau of Reclamation (Reclamation), Corps of Engineers (Corps) and Bonneville Power Administration (BPA).

The System Operation Review (SOR) is a study and environmental compliance process being used by the three Federal agencies to analyze future operations of the system and river use issues. The goal of the SOR is to achieve a coordinated system operation strategy for the river that better meets the needs of all river users. The SOR began in early 1990, prior to the filing of petitions for endangered status for several salmon species under the Endangered Species Act.

The comprehensive review of Columbia River operations encompassed by the SOR was prompted by the need for Federal decisions to (1) develop a coordinated system operating strategy (SOS) for managing the multiple uses of the system into the 21st century; (2) provide interested parties with a continuing and increased long–term role in system planning (Columbia River Regional Forum); (3) renegotiate and renew the Pacific Northwest Coordination Agreement (PNCA), a contractual arrangement among the region's major hydroelectric–generating utilities and affected Federal agencies to provide for coordinated power generation on the Columbia River system; and (4) renew or develop new Canadian Entitlement Allocation Agreements (contracts that divide Canada's share of Columbia River Treaty downstream power benefits and obligations among three participating public utility districts and BPA). The review provides the environmental analysis required by the National Environmental Policy Act (NEPA).

This technical appendix addresses only the effects of alternative system operating strategies for managing the Columbia River system. The environmental impact statement (EIS) itself and some of the other appendices present analyses of the alternative approaches to the other three decisions considered as part of the SOR.

WHO IS CONDUCTING THE SOR?

The SOR is a joint project of Reclamation, the Corps, and BPA—the three agencies that share responsibility and legal authority for managing the Federal Columbia River System. The National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), and National Park Service (NPS), as agencies with both jurisdiction and expertise with regard to some aspects of the SOR, are cooperating agencies. They contribute information, analysis, and recommendations where appropriate. The U.S. Forest Service (USFS) was also a cooperating agency, but asked to be removed from that role in 1994 after assessing its role and the press of other activities.

HOW IS THE SOR BEING CONDUCTED?

The system operating strategies analyzed in the SOR could have significant environmental impacts. The study team developed a three–stage process—scoping, screening, and full–scale analysis of the strategies—to address the many issues relevant to the SOR.

At the core of the analysis are 10 work groups. The work groups include members of the lead and cooperating agencies, state and local government agencies, representatives of Indian tribes, and members of the public. Each of these work groups has a single river use (resource) to consider.

Early in the process during the screening phase, the 10 work groups were asked to develop an alternative for project and system operations that would provide the greatest benefit to their river use, and one or more alternatives that, while not ideal, would provide an acceptable environment for their river use. Some groups responded with alternatives that were evaluated in this early phase and, to some extent, influenced the alternatives evaluated in the Draft and Final EIS. Additional alternatives came from scoping for the SOR and from other institutional sources within the region. The screening analysis studied 90 system operation alternatives.

Other work groups were subsequently formed to provide projectwide analysis, such as economics, river operation simulation, and public involvement.

The three–phase analysis process is described briefly below.

- **Scoping/Pilot Study**—After holding public meetings in 14 cities around the region, and coordinating with local, state, and Federal agencies and Indian tribes, the lead agencies established the geographic and jurisdictional scope of the study and defined the issues that would drive the EIS. The geographic area for the study is the Columbia River Basin (Figure P–1). The jurisdictional scope of the SOR encompasses the 14 Federal projects on the Columbia and lower Snake Rivers that are operated by the Corps and Reclamation and coordinated for hydropower under the PNCA. BPA markets the power produced at these facilities. A pilot study examining three alternatives in four river resource areas was completed to test the decision analysis method proposed for use in the SOR.
- **Screening**—Work groups, involving regional experts and Federal agency staff, were created for 10 resource areas and several support functions. The work groups developed computer screening models and applied them to the 90 alternatives identified during screening. They compared the impacts to a baseline operating year—1992—and ranked each alternative according to its impact on their resource or river use. The lead agencies reviewed the results with the public in a series of regional meetings in September 1992.
- **Full–Scale Analysis**—Based on public comment received on the screening results, the study team sorted, categorized, and blended the alternatives into seven basic types of operating strategies. These alternative strategies, which have multiple options, were then subjected to detailed impact analysis. Twenty–one possible options were evaluated. Results and tradeoffs for each resource or river use were discussed in separate technical appendices and summarized in the Draft EIS. Public review and comment on the Draft EIS was conducted during the summer and fall of 1994. The lead agencies adjusted the alternatives based on the comments, eliminating a few options and substituting new options, and reevaluated them during the past 8 months. Results are summarized in the Final EIS.

Alternatives for the Pacific Northwest Coordination Agreement (PNCA), the Columbia River Regional Forum (Forum), and the Canadian Entitlement Allocation Agreements (CEAA) did not use the three–stage process described above. The environmental impacts from the PNCA and CEAA were not significant and there were no anticipated impacts from the Regional Forum. The procedures used to analyze alternatives for these actions are described in their respective technical appendices.

For detailed information on alternatives presented in the Draft EIS, refer to that document and its appendices.

WHAT SOS ALTERNATIVES ARE CONSIDERED IN THE FINAL EIS?

Seven alternative System Operating Strategies (SOS) were considered in the Draft EIS. Each of the seven SOSs contained several options bringing the total number of alternatives considered to 21. Based on review of the Draft EIS and corresponding adjustments, the agencies have identified 7 operating strategies that are evaluated in this Final EIS. Accounting for options, a total of 13 alternatives is now under consideration. Six of the alternatives remain unchanged from the specific options considered in the Draft EIS. One is a revision to a previously considered alternative, and the rest represent replacement or new alternatives. The basic categories of SOSs and the numbering convention remains the same as was used in the Draft EIS. However, because some of the alternatives have been dropped, the numbering of the final SOSs are not consecutive. There is one new SOS category, Settlement Discussion Alternatives, which is labeled SOS 9 and replaces the SOS 7 category. This category of alternatives arose as a consequence of litigation on the 1993 Biological Opinion and ESA Consultation for 1995.

The 13 system operating strategies for the Federal Columbia River system that are analyzed for the Final EIS are:

SOS 1a Pre Salmon Summit Operation represents operations as they existed from around 1983 through the 1990–91 operating year, prior to the ESA listing of three species of salmon as endangered or threatened.

SOS 1b Optimum Load–Following Operation represents operations as they existed prior to changes resulting from the Regional Act. It attempts to optimize the load–following capability of the system within certain constraints of reservoir operation.

SOS 2c Current Operation/No–Action Alternative represents an operation consistent with that specified in the Corps of Engineers' 1993 Supplemental EIS. It is similar to system operation that occurred in 1992 after three species of salmon were listed under ESA.

SOS 2d [New] 1994–98 Biological Opinion represents the 1994–98 Biological Opinion operation that includes up to 4 MAF flow augmentation on the Columbia, flow targets at McNary and Lower Granite, specific volume releases from Dworshak, Brownlee, and the Upper Snake, meeting sturgeon flows 3 out of 10 years, and operating lower Snake projects at MOP and John Day at MIP.

SOS 4c [Rev.] Stable Storage Operation with Modified Grand Coulee Flood Control attempts to achieve specific monthly elevation targets year round that improve the environmental conditions at storage projects for recreation, resident fish, and wildlife. Integrated Rules Curves (IRCs) at Libby and Hungry Horse are applied.

SOS 5b Natural River Operation draws down the four lower Snake River projects to near river bed levels for four and one–half months during the spring and summer salmon migration period, by assuming new low level outlets are constructed at each project.

SOS 5c [New] Permanent Natural River Operation operates the four lower Snake River projects to near river bed levels year round.

SOS 6b Fixed Drawdown Operation draws down the four lower Snake River projects to near spillway crest levels for four and one–half months during the spring and summer salmon migration period.

SOS 6d Lower Granite Drawdown Operation draws down Lower Granite project only to near spillway crest level for four and one–half months.

SOS 9a [New] Detailed Fishery Operating Plan includes flow targets at The Dalles based on the previous year's end–of–year storage content, specific volumes of releases for the Snake River, the drawdown of Lower Snake River projects to near spillway crest level for four and one–half months, specified spill percentages, and no fish transportation.

SOS 9b [New] Adaptive Management establishes flow targets at McNary and Lower Granite based on runoff forecasts, with specific volumes of releases to meet Lower Granite flow targets and specific spill percentages at run–of–river projects.

SOS 9c [New] Balanced Impacts Operation draws down the four lower Snake River projects near spillway crest levels for two and one–half months during the spring salmon migration period. Refill begins after July 15. This alternative also provides 1994–98 Biological Opinion flow augmentation, integrated rule curve operation at Libby and Hungry Horse, a reduced flow target at Lower Granite due to drawdown, winter drawup at Albeni Falls, and spill to achieve no higher than 120 percent daily average for total dissolved gas.

SOS PA Preferred Alternative represents the operation proposed by NMFS and USFWS in their Biological Opinions for 1995 and future years; this SOS operates the storage projects to meet flood control rule curves in the fall and winter in order to meet spring and summer flow targets for Lower Granite and McNary, and includes summer draft limits for the storage projects.

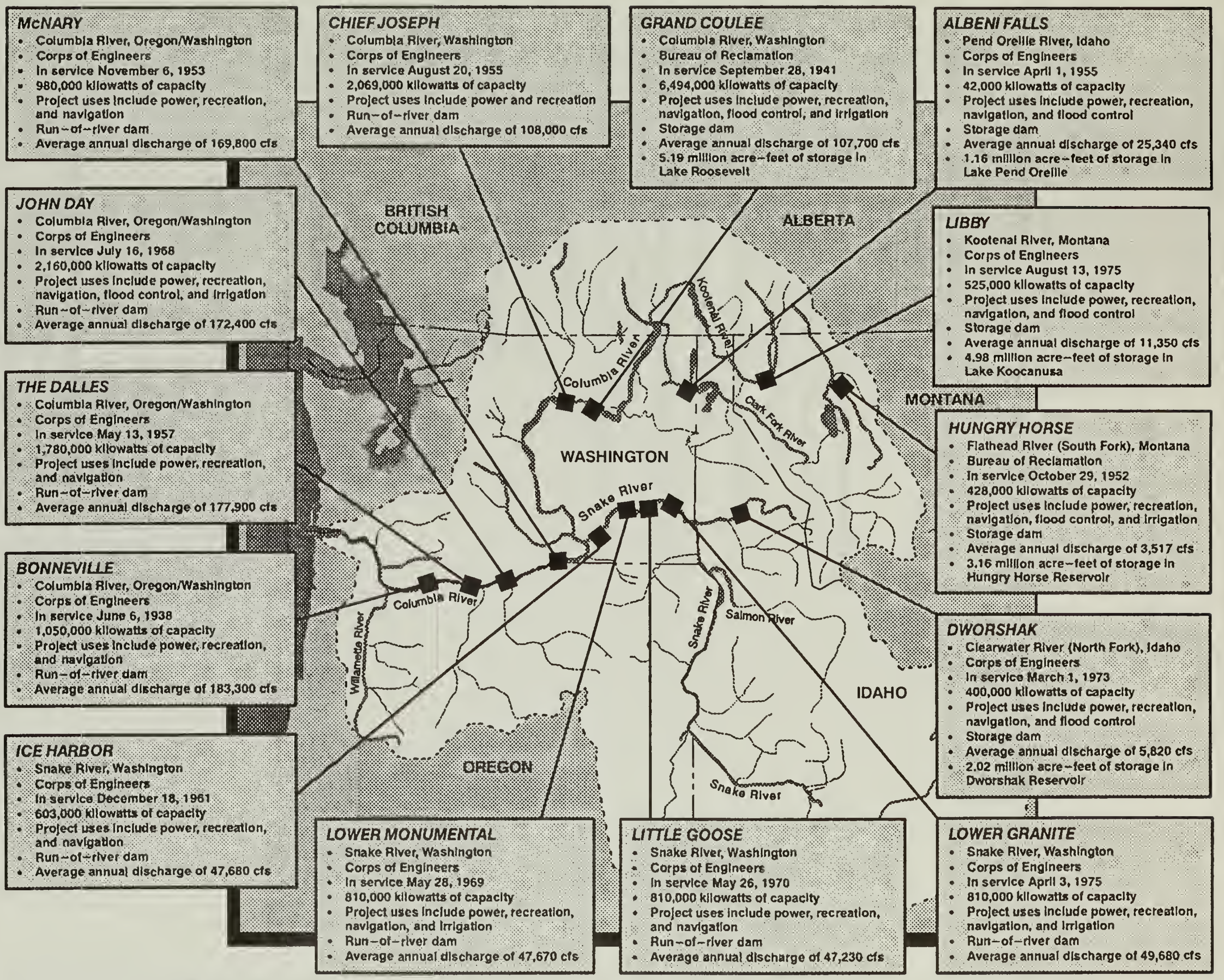
WHAT DO THE TECHNICAL APPENDICES COVER?

This technical appendix is 1 of 20 prepared for the SOR. They are:

A. River Operation Simulation
B. Air Quality
C. Anadromous Fish & Juvenile Fish Transportation
D. Cultural Resources
E. Flood Control
F. Irrigation/Municipal and Industrial Water Supply
G. Land Use and Development
H. Navigation
I. Power
J. Recreation
K. Resident Fish
L. Soils, Geology, and Groundwater
M. Water Quality
N. Wildlife
O. Economic and Social Impacts
P. Canadian Entitlement Allocation Agreements
Q. Columbia River Regional Forum
R. Pacific Northwest Coordination Agreement
S. U. S. Fish and Wildlife Service Coordination Act Report
T. Comments and Responses

Each appendix presents a detailed description of the work group's analysis of alternatives, from the scoping process through full–scale analysis. Several appendices address specific SOR functions (e.g., River Operation Simulation), rather than individual resources, or the institutional alternatives (e.g., PNCA) being considered within the SOR. The technical appendices provide the basis for developing and analyzing alternative system operating strategies in the EIS. The EIS presents an integrated review of the vast wealth of information contained in the appendices, with a focus on key issues and impacts. In addition, the three agencies have prepared a brief summary of the EIS to highlight issues critical to decision makers and the public.

There are many interrelationships among the different resources and river uses, and some of the appendices provide supporting data for analyses presented in other appendices. This River Operation Simulation appendix relies on supporting data contained in Appendix A. For complete coverage of all aspects of River Operation Stimulation , readers may wish to review all appendices in concert.



1 million acre feet = 1.234 billion cubic meters
1 cubic foot per second = 0.028 cubic meters per second

Figure P–1. Projects in the System Operation Review.

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CHAPTER 1

INTRODUCTION

1.1 SCOPE

The River Operation Simulation Experts (ROSE) work group is comprised of representatives of the Corps, BPA, Reclamation, NMFS, Pacific Northwest Utilities Conference Committee (PNUCC), and Northwest Power Planning Council (NPPC). ROSE was responsible for using computer hydroregulation models to simulate the operation of the river system for all of the alternatives evaluated in screening and full scale analysis in SOR. These models are complex computer programs which sequentially route streamflows through each dam in the system, calculating the streamflows, reservoir elevations, spill, power generation and other information at each project and pertinent locations on the river system.

ROSE first reviewed specifications of proposed alternatives to determine whether such alternatives were formulated adequately to be run on hydroregulation models. If not, ROSE worked with the SOR work groups or project management to develop more definitive specifications that prescribed the system operating scenario adequately to allow processing through the hydroregulation models. ROSE was also responsible for working with the work groups responding to their inquiries regarding the hydroregulation results and to reconfigure studies as appropriate to better simulate the desired System Operation Strategies (SOS).

1.2 STUDY PROCESS

The study process followed by ROSE was similar throughout both the screening and full–scale stage of analysis in SOR. ROSE began by coordinating with work groups and others to ensure that alternatives were described in sufficient detail to allow simulation using hydroregulation models. Following this, ROSE completed the hydroregulation studies and provided the results to work groups. Although the hydroregulation studies were run by BPA and the Corps, all members of ROSE actively participated in reviewing the results prior to providing them to work groups. The hydroregulation results provided to work groups consisted of project data such as average monthly flows, end–of–month elevations, and other similar information, as well as system–wide data such as monthly energy generation. In both screening and full scale analysis, ROSE worked with the work groups and others to ensure that hydroregulation studies met the stated objectives as closely as possible. Once the final hydroregulation was completed for an alternative, ROSE developed descriptions of the results using graphs, tables, and text.

1.2.1 Screening

In the screening stage of SOR, ROSE ran hydroregulation studies for 90 alternatives using the HYDROSIM and HYSSR hydroregulation models from BPA and the Corps, respectively. Results were provided for five different water years ranging from very dry to very wet conditions to express the range of conditions which might be encountered.

1.2.2 Full–Scale

During full–scale analysis, hydroregulation studies were run for 7 alternatives with options using BPA's HYDROSIM model only. In full–scale, results were provided for a total of 21 hydroregulation studies, for 50 years of data, using the water records from 1928 to 1978. In the Final SOR Environmental Impact Statement, the number of hydroregulation studies was reduced to 13. Work groups determined whether to evaluate data for the entire 50 year period of record or use only selected years.

CHAPTER 2

A REVIEW OF HYDROREGULATION MODELING

Water surges past the giant turbines and into the tailrace at Grand Coulee Dam. Tailwater below the dam rises, and the current swells as the Columbia River moves along its 1,200 mile journey to the Pacific Ocean. Fifty miles downstream at Chief Joseph, operators will either hold back some of the flow or release it all on to Wells, Rocky Reach, and Rock Island Dams.

From one project to the next, runoff from Canadian and Northwest snowfields makes its way down the river. Streamflows build and diminish, and reservoir elevations rise and fall as the water enters manmade lakes and is released through powerhouses and over spillways.

Hydroregulation−−regulating water−−is the process planners and operators use to make decisions about routing water through the series of hydro projects in the Columbia River Basin. Those decisions are geared to make the most efficient use of the water in the river and its tributaries, and to meet multiple objectives−−from controlling floods to irrigating crops to generating electricity.

Regulating a system as complex as the Columbia requires continuous planning and powerful tools.

Today, planning and regulation are processes assisted by automation. The tools of the trade are sophisticated computer programs that in a matter of minutes can calculate the river system's response to a variety of streamflow and operating conditions. The programs are also referred to as "models" because they model or simulate operations of the river system. From the data the models provide, analysts can estimate the systemwide impacts of projected operations.

This chapter describes the concept of hydroregulation modeling and how these computer models are used to determine flows, elevations and other information for projects in the system from which environmental effects are estimated.

2.1 THE ROLE OF MODELS IN PLANNING

2.1.1 Why We Need Computer Models

The Columbia River Basin covers 258,000 square miles. The Columbia River and dozens of large tributaries drain this area, which extends from Canada to Nevada and from western Wyoming to the Pacific Ocean.

There are more than 150 dams and reservoirs on the coordinated river system, 31 of them operated by Federal agencies, that work together to satisfy many needs. Hydroregulation models simulate how major projects in this system will react to changes in operations and to a wide range of runoff conditions. They also help plan how to use the water most efficiently.

In the SOR, ten major river uses are considered: navigation, flood control, irrigation and water supply, electric power generation, anadromous fish migration, resident fish habitat, wildlife habitat, recreation, water quality, and protection of cultural and historical sites.

What happens at each project to meet one or more of these objectives has an effect on other projects, both up and downstream. Hydroregulation models enlarge the planners' ability to analyze how the variables interact when there is more or less water in the system and when operating changes are considered for any or all projects.

Calculations that would take weeks and months by hand take minutes with a computer. The speed with which the computer processes data makes it possible to consider far more information and to make timely and precise adjustments to operations.

2.1.2 When Were the Models Developed?

Computer models have become so pervasive in the planning environment, it's hard to remember life without them. But in the 1930s, 40s, and 50s, when the hydro system was smaller and less complex, hydroregulation was done using mechanical desk calculators and hand–drawn spreadsheets. This limited the amount of operating information that could be analyzed. Operations at each project were updated individually.

Hydroregulation models began to replace hand calculations in the late 1950s and early 1960s. The comprehensive planning models used today by BPA and the Corps have their roots in mainframe computer programs that were developed in the mid–1950s. The models continue to evolve as computer capabilities expand, precision in modeling increases, and river operations become more complicated.

2.1.3 The Columbia River Models

There are three primary hydroregulation models used today for medium– and long–term planning on the Columbia River: the Hydro System Seasonal Regulation Program (HYSSR), the Hydro Simulator Program (HYDROSIM), and the Pacific Northwest Coordination Agreement Seasonal Regulation Program (HYDREG).

On a conceptual level, the models are almost identical. But since the agencies that designed and use them have distinct missions, each does have a unique point–of–view. The models were developed independently and are used to perform studies based on specific agency and constituent needs. Information and expertise is often shared among the agencies and the analysts, and in some instances, one model produces data that is used for studies run on another model.

HYSSR is the oldest of the three models. It has its genesis in a model developed by the Corps for its 1958 comprehensive system planning study. HYSSR simulates the characteristics of the Northwest hydro system under varying electric energy requirements (load) and streamflow conditions, over an extended period of time.

HYDROSIM was developed by BPA in 1990 and 1991. It evolved from earlier programs called HYDRO2 and HYDRO6, which were written in the 1960s. Like HYSSR, HYDROSIM simulates the operating characteristics of the Northwest hydro system under varying load and flow conditions, over an extended period of time.

HYDREG was originally developed in the 1960s at BPA, but it is now maintained and operated by the Northwest Power Pool. HYDREG is used to establish seasonal guidelines for coordinated operation of hydro projects included in the Pacific Northwest Coordination Agreement (PNCA). The guidelines maximize power benefits while satisfying multiple nonpower uses of the river.

2.2 THE BASICS OF STREAMFLOW ROUTING

2.2.1 The Continuity Equation

Hydroregulation models are sequential streamflow routing models. At the heart of each model is the same calculation. It is called the continuity equation, and it goes like this:

The reservoir outflow (O) in any time period is equal to reservoir inflow (I) during the same period minus the change in reservoir storage (ΔS) minus losses (L).

Put another way, $O = I - \Delta S - L$.

For each dam in the system, the program calculates what the outflow would be:

- given the inflow (from natural runoff and releases from any upstream projects), and
- the change in storage at that dam (ΔS is positive if water is added to storage; ΔS is negative if water is released from storage), minus

- losses (from diversions, withdrawals, or evaporation).

In many cases, the object of operation is to provide a particular flow on a river reach for navigation, fish passage, or power generation. The problem then is to determine how storage must change in the reservoir to ensure that this flow requirement is met. In such cases, the continuity equation would be set up and solved as follows:

$$\Delta S = I - O - L.$$

The calculation in this instance determines the change in storage given inflow, outflow, and losses.

The model repeats the continuity equation for each project considered and for each period in an analysis.

The model calculates this information sequentially. In a full system analysis, the computation starts with the uppermost storage reservoir on the system. The outflow at the first project, plus or minus any major changes along the way, such as an irrigation diversion or the confluence with a tributary, becomes the inflow at the next project. And so the model continues, calculating the streamflows and reservoir elevations for the period at every project on the system.

2.2.2 Using the Models to Meet Objectives

Hydroregulation models can be used to help determine how to meet a variety of operating objectives. For example, one of the objectives on the Columbia River system is power generation. The models compute the outflow at each dam. Using another set of equations, the outflow can be converted to electrical power production; that is, megawatts (MW).

Energy generation relies on project flows. The amount of power produced depends on three factors:

(1) How much water is flowing through the turbines, usually measured in cubic feet per second (cubic meters per second).

(2) The vertical distance the water falls, called "head." This is the difference between the height of the water behind the dam (forebay elevation) and the height of the water below the dam (tailwater elevation).

(3) The efficiency of the generating equipment. Hydro project efficiencies generally range from 85 to 95 percent.

The equation for calculating how much power can be generated at a project is:

$$\text{Power (kw)} = \text{Flow (cfs)} \times \text{Head (feet)} \times \text{Efficiency} \times \frac{1}{11.8}$$

or

$$P = \frac{Q \times H \times E}{11.8}$$

As an example: Power from 100,000 cfs (2,832 m^3/s) of water flowing

through Grand Coulee at full pool would be calculated as follows:

- Head = 1290 − 962 = 328 ft (100 m.)
- Efficiency is about 0.88

$$\text{so, } P = \frac{100{,}000 \times 328 \times 0.88}{11.8} = 2{,}450{,}000 \text{ KW} = 2{,}450 \text{ MW}$$

Once the conversion to power is made, the model adds up the power generation (megawatts) determined for all of the projects. The result is a figure that represents the systemwide power output in megawatts.

Flood control is another key objective in Columbia River operations. Maximum flows, above which flooding will occur, have been established at key points on the river. Streamflow routing models can help determine how much water must be stored in the reservoirs during flood periods so that rivers will be kept below flood levels.

At Vancouver, Washington, for instance, flows that exceed 600,000 cfs (16,992 m^3/s) will cause floods. A model can demonstrate whether planned operations upriver will contain the flood or whether the maximum flow target at Vancouver will be exceeded.

Hydroregulation models can be used to assess whether planned operations will provide flows adequate to protect fish and wildlife habitat at various places on the river and to move young salmon to sea. For example, the Water Budget, established by the Northwest Power Planning Council in 1984, aims to achieve a minimum flow target during the spring and early summer at Priest Rapids Dam on the Columbia and at Lower Granite Dam on the Snake River. This helps fish move more quickly between projects. The models are used to determine how much water must be released from storage projects to ensure that these flow targets are met.

On a complex river system such as the Columbia, where there are numerous competing river uses, streamflow routing models help in planning operations that attempt to satisfy a combination of objectives at the same time. The three models discussed in this chapter consider all system uses simultaneously.

2.2.3 Control Points

The previous discussion touched on an essential part of the streamflow routing models – control points. Control points are identified and characterized in the models. They are points on the river where streamflow or elevation targets or both have been established and where they are measured or gaged. In the Columbia River models, all of the run–of–river dams and storage reservoirs are control points.

There are other control points on the system where flow or elevation targets have been established to meet a particular need. At Vernita Bar on the mid–Columbia River, for example, a seasonal flow target protects chinook salmon spawning grounds. Releases from Hells Canyon Dam are made to keep an adequate navigation depth on the Snake River downstream at Lime Point, another example of a control point. And, as noted earlier, Vancouver, Washington, is the control point used to gage flood control operations to protect the highly developed areas along the lower Columbia River.

Given an operating proposal, the models attempt to operate the reservoir system to meet the specified objectives, and they report elevations and/or streamflows at each control point. If the computer output shows that a certain operation will not meet the targets at one or more points, adjustments to the operating criteria may be made to bring outcomes closer. More water may be held upriver if the elevation at a downriver control point is too high. Additional water may be released from a reservoir if the flow at a downriver control point is too low.

It should be noted, however, that at times not all of the targets can be met simultaneously. The models have built–in priority lists (which can be changed if necessary) for which some targets take precedence over others at a given control point. For example, flood control objectives always take precedence over hydropower requirements. This topic appears again in Section 2.5 when specific types of model runs are described. Table 2–1 provides a list of projects and control points for which data was outputted from the hydroregulation models in full–scale analysis.

2.3 THE MODEL INPUTS

A product is only as good as the parts that go into it. And the output of the hydroregulation models is only as up–to–date and accurate as the data that is input. The models themselves can run in a matter of minutes. Preparing the data in anticipation of a run can take weeks.

Hydroregulation models are general purpose models, designed to be driven by the data. Each model is basically a suite of programs. The "hydroregulator" is the centerpiece of the models and there are 20 to 30 subroutines. As many as 20 ancillary programs prepare data files that will be used by the hydroregulation models. The key pieces of input data are described below. Much of the data for each model are stored as tables and graphs in master project files.

Table 2–1. Hydroregulation Output Data Locations

Name	Location
Mica	Columbia River, British Columbia, Canada
Arrow	Columbia River, Castlegar, British Columbia
Libby	Kootenai River, Libby, Montana
Bonners Ferry	Kootenai River, Bonners Ferry, Montana
Duncan	Columbia River, British Columbia, Canada
Corra Linn	Columbia River, Nelson, British Columbia
Brilliant	Columbia River, Castlegar, British Columbia
Hungry Horse	Flathead River, Hungry Horse, Montana
Columbia Falls	Flathead River, Columbia Falls, Montana
Kerr	Flathead River, Polson, Montana
Albeni Falls	Pend Oreille River, Newport, Washington
Grand Coulee	Columbia River, Grand Coulee, Washington
Chief Joseph	Columbia River, Bridgeport, Washington
Wells	Columbia River, Azwell, Washington
Rocky Reach	Columbia River, Wenatchee, Washington
Rock Island	Columbia River, Wenatchee, Washington
Wanapum	Columbia River, Ephrata, Washington
Priest Rapids	Columbia River, Ephrata, Washington
Brownlee	Snake River, Cambridge, Idaho
Dworshak	Snake River, Ahsahka, Idaho
Spalding	Snake River, Spalding, Idaho
Lower Granite	Snake River, Almota, Washington
Little Goose	Snake River, Starbuck, Washington
Lower Monumental	Snake River, Matthaw, Washington
Ice Harbor	Snake River, Pasco, Washington
McNary	Columbia River, Umatilla, Oregon
John Day	Columbia River, Rufus, Oregon
The Dalles	Columbia River, The Dalles, Oregon
Bonneville	Columbia River, Bonneville, Oregon

2.3.1 Streamflow Records

Streamflow records are the backbone of the hydroregulation studies. These records are essentially the inflow of water at various points in the system. The Columbia River hydroregulation models currently have at their disposal a 50–year historical streamflow record, 1928 to 1978. (The record is periodically extended, and ten more years will soon be added.) The streamflow measurements recorded for these years are adjusted to account for irrigation diversions and depletions and other changes in conditions since they were gathered. The adjustments are made to simulate natural streamflows as closely as possible and to put the entire set of streamflows on a common base.

For example, the irrigation system in the region was developed gradually. Measurements taken in 1928 at any control point on the river would not reflect the level of irrigation diversions that now take place. The records are adjusted on a 10–year cycle to recognize present–day conditions. They also reflect current operation of tributary reservoirs that are not modeled in the hydroregulator, such as those in the upper Snake, Yakima, and Deschutes Basins. In essence, the model simulates what would happen on today's river system given the precipitation and weather conditions that actually occurred in 1928. The source for the current streamflow data is the Columbia River Water Management Group's publication, "1980 Level Modified Streamflow."

2.3.2 Project Characteristics

The models also incorporate the physical characteristics of the projects in the Columbia River system. These include minimum and maximum reservoir elevations, storage–elevation relationships, tailwater elevations, and powerplant characteristics.

The number of projects for which this information is included varies among the models. And it can change with the particular study or operation being simulated. HYSSR generally runs with 65 projects. HYDROSIM uses 80, but it also performs studies that use only 36. The Northwest Power Pool model, HYDREG, includes the largest number of projects, 150.

2.3.3 Project Operating Requirements

Operating requirements are the power production and nonpower requirements that define a project's operation. These include the maximum and minimum amount of water that can be released from a project at one time (discharge), and the maximum and minimum reservoir content. These constraints may serve to protect areas downstream from a project. For example, a large instantaneous release could endanger fish spawning grounds below a dam. Constraints may also aim to preserve resources at a reservoir: when water is drawn down too low, resident fish and shoreline vegetation suffer.

Many operating requirements are seasonal. For example, to keep reservoirs from overflowing their banks during the high runoff period, they must be drawn down before the middle of April in anticipation of the spring snowmelt. Reservoir elevations are allowed to go higher in July, when the danger of flooding is gone, and vacationers want a full lake for boating. Tables in the model incorporate these seasonal variations.

Normally, operating requirements are specified by the project owners and submitted to the Northwest Power Pool for PNCA planning. In the SOR, the operating requirements are specified in the form of System Operating Strategies.

2.3.4 System Power Loads

Hydroregulation models are used to compute the system's ability to meet electricity loads in the Northwest and to generate electricity to sell outside the region. Loads (the amount of power that customers of the power system need at any given time) are input to the models. Different computer studies answer different questions: Is the system capable of meeting the projected load? How much power can be generated under a given set of operating conditions? Will thermal generation be needed in addition to hydro generation to meet the load? If so, how much?

2.3.5 Thermal Resources

The models may incorporate other power generating resources, such as coal and nuclear (thermal) plants, as part of the computation in certain studies. The ability of these resources to contribute to the region's power supply is a consideration in determining how and whether the region's generating resources can meet current and future loads. Thermal plant data affects the regulations for reservoirs in the coordinated system.

2.3.6 Rule Curves

Rule curves represent reservoir water levels and provide guidance in meeting project purposes. In some cases, the curves set elevations that must be met in each time period. At other times, they specify upper or lower elevations that are not to be violated. There are also occasions when rule curves define a range over which operations are permitted. Rule curves can be a product of the hydroregulation models, and they can be data input used to compute operations.

The operating year on the Columbia River system is August 1 through July 31. Before each new operating year, studies are made using the hydroregulation models and historical streamflow records to derive the rule curves for multipurpose operation of the dams on the river. The models use the rule curves to predict how much energy could be produced during the coming year under differing water conditions.

2.3.7 Ranges of Requirements

One valuable use of the hydroregulation models is to test ranges of operating requirements to evaluate the impact on project outputs and river uses. For example, possible operating scenarios may be established to compare current operations with a hypothetical or future situation. The models will compute and report the flows and elevations that would result from a number of operations. This use of the models is essential in the SOR. They provide the basis for determining how operating changes affect the multiple uses.

2.3.8 Where Does the Data Come From?

Input data are developed in several different ways. Long–established means for collecting and preparing the data needed for the models exist. The data falls roughly into three categories:

- Data that is permanent
- Data that is revised annually
- Data that is revised only as needed.

Many program files operate year after year with no changes. In general, these are the physical characteristics of hydro projects. Load and power rule curves, on the other hand, are updated frequently. Appropriate revisions are made to reflect such things as current lists of resources and operating requirements. Data that are revised only as needed include such things as nonpower operating requirements. If a new requirement is established, the information goes into the program files. For example, in 1984, when fish–related flow targets were established in the Water Budget, these were entered into the data files.

Some data come from other government agencies. The U.S. Geological Survey collects streamflow measurements; the U.S. Natural Resources Conservation Service calculates snowpack; and the Northwest River Forecast Center uses much of this information to develop streamflow (volume) forecasts.

And as described above with rule curves, the output of one hydroregulation model becomes the input for another, or for a new computation with the same model. HYDROSIM calculates rule curves that are used in many studies elsewhere, and both HYSSR and HYDROSIM are used to develop new operating requirements that are input to HYDREG in developing rule curves under the PNCA.

2.4 A CLOSEUP OF THE COLUMBIA RIVER MODELS

The hydroregulation models are similar in many ways. They are all sequential streamflow routing models that simulate the same basic physics. Each operates over a year that is divided into 14 periods.

(Each month is a period; April and August are divided into two periods because streamflows vary greatly from the first half to the second half of these months.) All three models are written in a computer language called FORTRAN.

The models all assume that water released at the uppermost project on the river during a specific period will reach the ocean during the same period.

2.4.1 Hydro Simulator Program (HYDROSIM)

HYDROSIM is the newest of the three models. It was written to replace two of BPA's earlier hydroregulation programs that could not share data with some of the agency's new power marketing and economic models, in particular the System Analysis Model (SAM). HYDROSIM incorporated the hydroregulation code used in SAM so data files can be easily interchanged between the models.

HYDROSIM models operations of the Pacific Northwest hydro system. HYDROSIM can be used to determine critical rule curves and the availability of firm energy, or to examine operations under other historical streamflow conditions.

In its "Proportional Draft" mode, HYDROSIM simulates operations of the reservoirs under the PNCA. The program begins the simulation by drawing system reservoirs down to energy content curves. (This curve defines the lower limit under the PNCA to which a reservoir can be drawn down to produce secondary (nonfirm) energy.) If the simulated system is unable to meet the system's firm load, all reservoirs are drafted to first–year critical rule curves; if the system is still short of energy, reservoirs are drafted to second–year critical rule curves. The simulation continues, until the firm load is met.

Critical period planning is required by the Pacific Northwest Coordination Agreement. The critical period is the portion of the historical 50–year streamflow record that would produce the least amount of energy, with all reservoirs drafted from full to empty. This energy value is called the hydro system's Firm Energy Load Carrying Capability (FELCC). The hydroregulation computer studies produce rule curves that define reservoir elevations that must be maintained to ensure firm energy requirements can be met under the most adverse historical streamflow conditions.

In recent years, the critical period has been based on the 42–month interval from September 1, 1928, through February 29, 1932. This is often referred to as the four–year critical period. A critical rule curve is derived for each year of the four years; they are called Critical Rule Curves 1, 2, 3, and 4.

In HYDROSIM'S "Fixed" mode, each period's operation for all or some of the reservoirs is specified in advance by the modeler. Storage at each reservoir will be drafted or filled as specified (unless constrained by physical or operational limits). The program begins at the most upstream project and proceeds downstream, setting operation at each plant based on the user–specified operating mode. After operation is set, the program calculates flows and megawatt values.

Most studies use a combination of fixed mode and proportional draft. Some projects are fixed, and others are free to draft among rule curves.

The program checks project operating requirements against the flows and elevations it is calculating. There are 10 "flags" in the program to alert the user that a target operation was not reached due to a physical or operational limit. When a requirement is flagged, the operator may make adjustments appropriate to the situation.

The flags are in the program in priority order, as shown below:

SH –– Permanent Storage Maximum

SL –– Permanent Storage Minimum

QR –– Restriction Flow

UR –– Flood Control

KR –– Kerr split period operation (Specific to Kerr Dam)

QH –– Maximum discharge or flow in the river

QL –– Minimum discharge or flow in the river

DR –– Draft rate limit (bank erosion) or recreation season limits

SM -- Minimum reservoir content for nonpower uses, e.g. irrigation

FG -- Full Gate (Water above full gate is spill)

2.4.2 Hydro System Seasonal Regulation Program (HYSSR)

HYSSR was written to analyze the Columbia River system, and is capable of simulating the region's hydro and flood control operations as they are to be carried out under terms of the Columbia River Treaty between the United States and Canada, and the PNCA. It also accounts for all other nonpower operating requirements.

The Corps uses a separate model called Streamflow Synthesis and Reservoir Regulation (SSARR) for its flood control operations and daily river forecasting. (SSARR also develops the flood control rule curves used in the three hydroregulation models.)

HYSSR can be used in one of several single-objective modes or in a combination of modes. For example, in the "Fixed Rule-Curve Level" mode, the user specifies the rule curve to which each storage project will be operated. There are seven rule curves from which to choose: the flood control (upper) rule curve; the energy content curve; the first, second, third, or fourth year critical rule curves; and empty. Flows and power generation are computed based on the rule curve specified.

HYSSR is often used to model target flows. In the "Meet Target Stream Flows" mode, the user specifies the target streamflows at control points on the river. The model will attempt to meet these targets, starting at the uppermost control point in the basin and proceeding downstream. Selected storage projects upstream of a control point will be drafted proportionately to meet the desired target.

In all modes, the model checks the operating constraints at each project. That means the model is programmed to look at all operating limits and alert the user if a simulation shows operations would be outside those bounds.

HYSSR is used to support several regular annual studies, including the region's refill studies. The PNCA planning goal is to generate secondary energy only to the extent that there is a 95% confidence that reservoirs will refill. Analysts use HYSSR to determine whether planned operations will meet that goal in any given year by running simulations that span the 50 years of streamflow records.

Other studies for which HYSSR is used include: modification of flood control operations; analysis of new storage projects; and evaluation of the potential impacts of revised irrigation depletion levels, water budget alternatives, and various provisional draft strategies.

2.4.3 PNCA Seasonal Regulation Program (HYDREG)

The Northwest Power Pool model sets the regulations for coordinated operation of the region's hydroelectric system. HYDREG takes the individual operating rights and requirements from the region's project owners and blends them into an operating regimen known as the Actual Energy Regulation (AER).

HYDREG was written to guide the coordinated operation of the Northwest hydro system as directed by the PNCA. It aims to maximize power production while fulfilling all project constraints and the nonpower uses of the system. It is run as often as weekly during the course of the operating year to produce the AER.

The AER determines the energy capability of each project, each party to the PNCA, and of the coordinated system as a whole. The AER also provides the draft point at each reservoir that serves as the basis for rights and obligations among upstream and downstream parties during actual operations.

There are three components or processes in the model. The driving function is to regulate the reservoirs; that is, to determine the desired reservoir contents at the end of each of the 14 periods, based on reservoir rule curves and utility loads. (HYDREG reports reservoir contents, which are derived from elevations.) The second process simulates the operation of individual projects. This process successively operates each hydro plant and calculates discharge, tailwater and forebay elevations, and flow reductions for fish spill and bypass. A third process computes the energy generation and peak capability at each hydro project.

HYDREG supports many studies in the region. It is used to develop the Northwest Power Pool Operating Program for the PNCA members and for the Pool as a whole. (Not all utilities in the Pool are parties to the PNCA.) It calculates the Firm Energy Load Carrying Capability (FELCC) for the coordinated system and for each utility within the system, and it determines what are known as "headwater benefits," the payments downstream beneficiaries make to storage project owners. HYDREG also calculates each party's interchange rights and obligations under the PNCA. These are sales and exchanges among utilities that keep the coordinated system operating most efficiently.

2.5 FROM DATA TO DECISIONS

The output of a hydroregulation model is numbers. There are streamflows, expressed in cubic feet per second (cfs); reservoir elevations, given as feet above mean sea level; reservoir contents, represented in either thousand acre feet (KAF) or thousand second–foot days (ksfd); power generation in megawatts; and spill, expressed in cfs. Data are presented by project and for the total system.

In general, there are three types of studies: continuous; refill; and critical period. Each of these studies answers a different kind of question or set of questions about system operations.

2.5.1 The Continuous Study

The continuous study gives planners an opportunity to look at what would happen on today's system of hydro projects under a typical long–term sequence of streamflow conditions, such as the 50–year historical period from August 1928 to July 1978. The model begins its simulation on August 1, 1928, with all reservoirs full and with a prescribed set of rule curves or operating criteria for the upcoming year. It then sequentially calculates the flows and reservoir elevations that would result for each project on the river for each period in that year.

At the end of the 12–month (14–period) calculation, the study continues, modeling system operations using the July 31, 1929, reservoir elevations to begin the subsequent contract year. And so the analysis goes over 50 years, with the final elevations at the end of each water year becoming the starting elevations for the upcoming year. This is the type of study which is used to determine the critical period, which is the sequence of months in the historical streamflow records that would produce the least water for power generation.

2.5.1.1 Adjusting Operations. A primary use of the continuous study is to determine the impacts of a specific operating change. For example, a proposal may be made to keep a certain reservoir full for an extra month during each year to lengthen the recreation season. Instead of drawdown beginning in September, it would begin in October. A continuous study can be run to simulate how that change in operation would affect streamflows and elevations at other projects on the river over a 50–year period. The study will yield data that can be used to demonstrate the types and magnitude of impacts that delaying drawdown at this project would have on other aspects of the hydro system.

With this long–term view, planners are able to determine whether an operating change that looks feasible in the first two or three years has a fatal flaw at some point in the future. A set of operations geared to meet a particular flow target might not strain the system in the first year or two. But analysis of a 50–year continuous study could show that in five, six, or ten years, storage reservoirs are depleted, leaving boat ramps and recreation areas stranded, crops withering in dry fields, and electrical energy production greatly reduced.

2.5.1.2 Evaluating Resources. A continuous study can also help judge if and where to install a new hydro generating plant. A computer run is made for a "base case," that is, the way the system operates without the prospective generator. Then a run is made that includes the new plant. With 50 years of operation simulated by computer, planners can determine how much energy the new generator could be expected to produce and whether historical water conditions suggest the installation would be viable.

The analysis will also show whether the addition of the new project will increase the FELCC output of other projects in the system, which could be the case if the new project has seasonal storage. Additional studies can be made with varying dam heights, more or fewer generating units, or different project locations to see where it would be of the most benefit.

The continuous study can help to point out the tradeoffs that exist with any new operating scenario on a multi–use system. And it is a mechanism to test a potential operating decision. If boaters on one lake have a longer season, what would this mean next spring for fish downriver? Would a boost in flow help this year's migrating fish at the expense of the smolts five years from now? If BPA sells a large quantity of secondary energy next year, will there be enough power to meet firm loads in the following year?

The continuous study also provides information to answer economic questions. If a new generator is installed at an existing powerhouse on the lower Columbia, how much water can be anticipated to fuel its operation? How much power would be available for sale? What percentage of the time could it be expected to operate efficiently given historical water conditions? These are real–life questions the region's power planners and water managers grapple with continually, and the computer simulations help provide the flows and elevations to assess these questions.

2.5.2 The Refill (Non–Continuous) Study

Using historical streamflow records, hydroregulation models simulate the likelihood reservoirs will refill over a year of operations. Refill is important for a number of reasons, but in particular, it is the region's hedge against dry years in the future. The amount of snow and rainfall is anybody's guess before winter begins, so it's prudent to have as much water on hand in the reservoirs as possible.

The 50–year refill study is actually 50 separate one–year studies. The reservoirs are set at the beginning of the study, August 1, 1928, to the elevations shown in the AER for July 31 of the preceding operating year. Operations are then simulated using the 1928–29 streamflow record. The reservoirs are reset to the same elevation again at the beginning of the next year in the historical sequence (the 1929–30 streamflow record). The simulation is repeated, using the historical streamflow records for each of the remaining 48 years. This gives planners the opportunity to look at how 50 different water conditions would play out on today's Columbia River hydro system.

A non–continuous refill study can also be conducted with the elevations set at some level other than full. For example, a study may be run at mid–year to test the refill probability through the rest of the operating year. The beginning elevation is set to match the way a project has actually been operated during the first part of the year. The simulation tests 50 different historical streamflow sequences for the remainder of the year.

Under the PNCA, system operations are planned so there is an acceptable probability reservoirs will refill. The Corps uses its HYSSR model to run the annual 50–year Coordination Agreement Refill Test to assure that the operating rule curves developed under the PNCA have a 75 percent probability of refilling reservoirs by July 31. Operations must be adjusted and new rule curves developed if that standard is not met.

The Refill Test is used to verify that PNCA operations have an acceptable probability of resulting in refill, and it is used to devise future operating rule curves. From the test, the Corps calculates the Assured Refill Curve for the following year. This curve will guide operations during the fixed drawdown period (late summer and fall) when the volume of the next spring runoff is unknown.

While refill is the primary use of this study, there are other uses for the non–continuous analysis. Since the reservoirs start each contract year at the same level, it is a way to examine 50 individual water years for many purposes, such as projecting the amount of energy that could be produced given the current level of system reservoirs.

2.5.3 The Critical Period Study

Critical period planning defines how much hydro system energy should be considered firm. Hydroregulation models are used to generate the rule curves, which govern critical period operations, and to define FELCC of the system.

The Northwest Power Pool uses HYDREG to determine the critical period rule curves and FELCC which are used to operate the system under the PNCA. BPA uses HYDROSIM for critical period studies to plan resource acquisitions and to determine the United States' benefits from Canadian reservoirs. Some of this data also goes into calculating rates and projecting revenues.

The critical rule curves are developed by simulating system operations using the streamflows that were available in the 42–month period from September 1928 to February 1932. This calculation also yields the system's FELCC, that is, how much energy the system can be expected to generate under these adverse streamflow conditions. The Northwest Power Pool's hydroregulation allocates FELCC to the members of the PNCA, according to the projects they own and operate, and based on other contract provisions.

In a critical period study, the model takes the initial storage content (full) for each reservoir and simulates the operation for each period through the first year, using 1928/29 water. The reservoir content at the end of the first period is the beginning content for the next period, and so forth. A critical rule curve is plotted using the end–of–period reservoir content numbers. This first critical rule curve is known as Critical Rule Curve 1 (CRC1).

The reservoir content at the end of the first year of the critical period becomes the beginning content for the second year. The model simulates another year of operations, and the reservoir contents at the end of the 14 periods are plotted as CRC2. The study continues through the 42–month critical period. The final result is four critical rule curves. CRC4 will indicate that all reservoirs are empty at the end of the critical period.

Planners determine how much power can be generated if all of the reservoirs are drafted to CRC1, CRC2, CRC3, and CRC4, by converting the outflow to megawatts. This type of study is particularly important for BPA in determining how much firm and secondary energy can be produced and sold from the Federal hydro system.

Critical period planning is premised on unusually low water conditions. During most years, there is more water in the system than the critical rule curves reflect. Consequently, BPA runs analyses that look at many ways to take advantage of water conditions that are more likely to occur.

2.5.4 Modeling SOSs

All of the hydroregulation models can be modified, using variables in almost infinite combinations, to create different operating scenarios. For example, load growth can be held constant in a long–term analysis or a study can be run using a low, medium, or high–growth forecast. In some studies, a project or group of projects might be input as having a fixed operation in order to determine how the rest of the hydro system would compensate. These variations in operating strategy do not mean changing the program. The models are designed to accommodate them effectively.

CHAPTER 3

STUDY METHODS AND SCREENING RESULTS

In describing SOR study methods and hydroregulation models, it should be noted that the primary use of the models was to provide study results which could be compared to other alternatives such as the no action alternative (SOS 2) to determine changes resulting from different project operation strategies. The study results can also be used to get a better understanding of how the projects would operate under different water conditions such as during low or high runoff conditions. However, due to the complexity of the Columbia River system and the differences in runoff conditions which can occur throughout the basin from year to year, it can be difficult to accurately predict from the model results what exact reservoir elevations or streamflows might be expected under a given type operation for a specific runoff condition. This is because runoff patterns throughout the basin may be different, project operations may be different, and the projects may have started the year at different storage levels.

The results from the hydroregulation models used in screening and full–scale analysis were available only in monthly or semi–monthly (April and August are split into two periods each) format. Since these data are of monthly or semi–monthly time interval, short–term (hourly, daily, and weekly) changes in the operations are not discernible. However, many of the work groups required information on short–term operations to fully evaluate the impacts of changes. Therefore, other models or analytical techniques were often used by work groups to estimate typical short–term operations based on hydroregulation results.

3.1 STUDY METHODS: SCREENING ANALYSIS

ROSE began the screening analysis phase by defining modeling procedures and evaluating available resources. It was initially determined that all hydroregulations should be performed with BPA's HYDROSIM model using only five selected years of data. These five years were selected to span the range of water conditions from very dry to very wet. The other significant ROSE activity in the early stages of screening was the review of system operating strategies submitted by work groups and others to determine whether the strategies were defined in enough detail to allow hydroregulations to proceed. Through an iterative process, ROSE and the work groups developed strategies from basic concepts to detailed screening operating strategies.

Once operating strategies were defined in adequate detail, ROSE proceeded to perform the studies using the HYDROSIM model and review the results to determine whether the strategy had been modeled correctly (for details on HYDROSIM and other hydroregulation models, refer to the SOR publication "Modeling the System, How Computers are used in Columbia River Planning"). Hydroregulation modeling was an iterative process in which several hydroregulation runs and reviews were often necessary before delivering the final product to work groups.

As the number of alternatives increased, it became apparent that resources were not available to meet deadlines using only BPA's HYDROSIM model. Since the Corps had already completed a number of hydroregulation studies required for SOR on its HYSSR model as part of the "Columbia River Salmon Flow Measures Options Analysis/Environmental Impact Statement", it was decided that the Corps HYSSR model would also be used for hydroregulation studies. "Base Case" studies depicting overall system operations in 1990–91 were run on both models.

There were differences in modeling assumptions used in HYSSR and HYDROSIM which led to some differences when comparing model runs for the same alternative. Among the more significant of these was the fact that the HYSSR studies were run as *continuous studies* in which reservoir elevations were started each water year at the elevation they ended in the preceding water year. In contrast, HYDROSIM studies were run as *refill studies* in which reservoirs were started at the same elevation each water year (the elevation for a median year). In order to resolve this difference between the models, work groups always compared results from a particular model only with results from a base case or other alternative produced by the same model.

3.2 STUDY METHODS: FULL–SCALE ANALYSIS

With some exceptions, the study method used by ROSE in full–scale analysis was similar to that used in screening. The three major differences were: 1) only the HYDROSIM model was used in full–scale analysis; 2) all of the hydroregulation studies run in full–scale analysis were continuous studies with reservoir elevations started at the same level they ended after the previous year; and 3) work groups were provided with a complete set of data for all 50 years in full–scale, compared with only 5 selected years in screening.

Use of a single model was made possible by the reduction and consolidation of alternatives from the screening analysis. This often increased the complexity of the strategy and required more iterations of model runs before the final elements of the strategy were agreed upon.

3.3 SCREENING RESULTS

Screening results are described in the publication "SOR Screening Analysis, Volumes 1 and 2".

CHAPTER 4

ALTERNATIVES AND THEIR IMPACTS

4.1 GENERAL DESCRIPTION OF ALTERNATIVES

Seven alternative System Operating Strategies (SOS) were considered in the Draft EIS. Each of the 7 SOSs contained several options, bringing the total number of alternatives considered to 21. This Final EIS also evaluates 7 operating strategies, with a total of 13 alternatives now under consideration when accounting for options. Section 4.1 of this chapter describes the 13 alternatives and provides the rationale for including these alternatives in the Final EIS. Operating elements for each alternative are summarized in Table 4–1. Later sections of this chapter describe the effects of these alternatives on River Operation Simulation.

The 13 final alternatives represent the results of the third analysis and review phase completed since SOR began. In 1992, the agencies completed an initial effort, known as "Screening" which identified 90 possible alternatives. Simulated operation for each alternative was completed for five water year conditions ranging from dry to wet years, impacts to each river use area were estimated using simplified analysis techniques, and the results were compared to develop 10 "candidate SOSs." The candidate SOSs were the subject of a series of public meetings held throughout the Pacific Northwest in September 1992. After reviewing public comment on the candidate strategies, the SOR agencies further reduced the number of SOSs to seven. These seven SOSs were evaluated in more detail by performing 50–year hydroregulation model simulations and by determining river use impacts. The impact analysis was completed by the SOR workgroups. Each SOS had several options so, in total, 21 alternatives were evaluated and compared. The results were presented in the Draft EIS, published in July, 1994. As was done after Screening, broad public review and comment was sought on the Draft EIS. A series of nine public meetings was held in September and October 1994, and a formal comment period on the Draft EIS was held open for over 4 1/2 months. Following this last process, the SOR agencies have again reviewed the list of alternatives and have selected 13 alternatives for consideration and presentation in the Final EIS.

Six options for the alternatives remain unchanged from the specific options considered in the Draft EIS. One option (SOS 4c) is a revision to a previously considered alternative, and the rest represent replacement or new alternatives. The basic categories of SOSs and the numbering convention remains the same as was used in the Draft EIS. However, because some of the alternatives have been dropped, the final SOSs are not numbered consecutively. There is one new SOS category, Settlement Discussion Alternatives, which is labeled SOS 9 (see Section 4.1.6 for discussion).

The 13 alternatives have been evaluated through the use of a computerized model known as HYDROSIM. Developed by BPA, HYDROSIM is a hydroregulation model that simulates the coordinated operation of all projects in the Columbia River system. It is a monthly model with 14 total time periods. April and August are split into two periods each, because major changes can occur in streamflows in the first and second half of each of these months. The model is based on hydrologic data for a 50–year period of record from 1928 through 1978. For a given set of operating rule inputs and other project operating requirements, HYDROSIM will simulate elevations, flows, spill, storage content and power generation for each project or river control point for the 50–year period. For more detailed information, please refer to Appendix A, River Operation Simulation.

The following section describes the final alternatives and reviews the rationale for their inclusion in the Final EIS.

Table 4–1. SOS Alternative–1

Summary of SOS

SOS 1 Pre-ESA Operation	SOS 2 Current Operations	SOS 4 Stable Storage Project Operation
SOS 1 represents system operations before changes were made as a result of the ESA listing of three Snake River salmon stocks. SOS 1a represents operations from 1983 through the 1990–91 operating year, influenced by Northwest Power Act; SOS 1b represents how the system would operate without the Water Budget and related operations to benefit anadromous fish. Short-term operations would be conducted to meet power demands while satisfying nonpower requirements.	SOS 2 reflects operation of the system with interim flow improvement measures in response to the ESA salmon listings. It is consistent with the 1992–93 operations described in the Corps' 1993 Interim Columbia and Snake River Flow Improvement Measures Supplemental EIS. SOS 2c represents the operating decision made as a result of the 1993 Supplemental EIS and is the no action alternative for the SOS. Relative to SOS 1a, primary changes are additional flow augmentation in the Columbia and Snake Rivers and modified pool levels at lower Snake and John Day reservoirs during juvenile salmon migration. SOS 2d represents operations of the 1994-98 Biological Opinion issued by NMFS, with additional flow aumentation measures compared to SOS 2c.	SOS 4 would coordinate operation of storage reservoirs to benefit recreation, resident fish, wildlife, and anadromous fish, while minimizing impacts to power and flood control. Reservoirs would be managed to specific elevations on a monthly basis; they would be kept full longer, while still providing spring flows for fish and space for flood control. The goal is to minimize reservoir fluctuations while moving closer to natural flow conditions. SOS 4c attempts to accommodate anadromous fish needs by shaping mainstem flows to benefit migrations and would modify the flood control operations at Grand Coulee.

Actions by Project

	SOS 1	SOS 2	SOS 4
LIBBY	**SOS 1a** Normal 1983–1991 storage project operations **SOS 1b** • Minimum project flow 3 kcfs • No refill targets • Summer draft limit of 5–10 feet	**SOS 2c** Operate on system proportional draft as in SOS 1a **SOS 2d** • Provide flow augmentation for salmon and sturgeon when Jan. to July forecast is greater than 6.5 MAF • Meet sturgeon flows of 15, 20, and 12.5 kcfs in May, June, and July, respectively, in at least 3 out of 10 years	**SOS 4c** • Meet specific elevation targets as indicated by integrated Rule Curves (IRCs); IRCs are based on storage content at the end of the previous year, determination of the appropriate year within the critical period, and runoff forecasts beginning in January • IRCs seek to keep reservoir full (2,459 feet) June-Sept; minimum annual elevation ranges from 2,399 to 2,327 feet, depending on critical year determination • Meet variable sturgeon flow targets at Bonners Ferry during May 25-August 16 period; flow targets peak as high as 35 kcfs in the wettest years

KAF = 1.234 million cubic meters   MAF = 1.234 billion cubic meters

Table 4–1. SOS Alternative–1

SOS 5 Natural River Operation	SOS 6 Fixed Drawdown	SOS 9 Settlement Discussion Alternatives	SOS PA
SOS 5 would aid juvenile salmon by increasing river velocity. The four lower Snake River projects would have new outlets installed, allowing the reservoirs to be drawn down to near the original river elevation. The "natural river" operation would be done for 4 1/2 months in SOS 5b and year-round in SOS 5c. John Day would also be operated at MOP for 4 months, and flow augmentation measures on the Columbia River portion of the basin would continue as in SOS 2c.	SOS 6 involves drawing down lower Snake River projects to fixed elevations below MOP to aid anadromous fish. SOS 6b provides for fixed drawdowns for all four lower Snake projects for 4 1/2 months; SOS 6d draws down Lower Granite only for 4 1/2 months. John Day would also be operated at MOP for 4 months, and flow augmentation measures on the Columbia River portion of the basin would continue as in SOS 2c.	SOS 9 represents operations suggested by the USFWS, NMFS, the state fisheries agencies, Native American tribes, and the Federal operating agencies during the settlement discussions in response to the *IDFG v. NMFS* court proceedings. This alternative has three options, SOSs 9a, 9b, and 9c, that represent different scenarios to provide increased river velocities for anadromous fish by establishing flow targets during migration and to carry out other actions to benefit ESA-listed species. The three options are termed the Detailed Fishery Operating Plan (9a), Adoptive Management (9b), and the Balanced Impacts Operation (9c).	SOS PA represents the operation recommended by NMFS and the USFWS Biological Opinions issued March 1, 1995. This SOS supports recovery of ESA-listed species by storing water during the fall and winter to meet spring and summer flow targets, and protects other resources by setting summer draft limits to manage negative effects, by providing flood protection, and by providing for reasonable power generation.

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b Operate on system proportional draft as in SOS 1a **SOS 5c** Operate on system proportional draft as in SOS 1a	**SOS 6b** Operate on system proportional draft as in SOS 1a **SOS 6d** Operate on system proportional draft as in SOS 1a	**SOS 9a** • Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation period • Provide sturgeon flow releases April-Aug. to achieve up to 35 kcfs at Bonner's Ferry with appropriate ramp up and ramp down rates **SOS 9b** • Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation • Provide sturgeon flow releases similar to SOS 2d • Can draft to elevation 2,435 by end of July to meet flow targets **SOS 9c** • Operate to the Integrated Rule Curves and provide sturgeon flow releases as in SOS 4c	**SOS PA** • Operate on minimum flow up to flood control rule curves beginning in Jan., except during flow augmentation period • Strive to achieve flood control elevations in Dec. in all years and by April 15 in 75 percent of years • Provide sturgeon flows of 25 kcfs 42 days in June and July • Provide sufficient flows to achieve 11 kcfs flow at Bonner's Ferry for 21 days after maximum flow period • Draft to meet flow targets, to a minimum end of Aug. elevation of 2,439 feet, unless deeper drafts needed to meet sturgeon flows

1 kcfs = 28 cms   1 ft = 0.3048 meter

Table 4–1. SOS Alternative–2
Actions by Project

	SOS 1	SOS 2	SOS 4
HUNGRY HORSE	**SOS 1a** Normal 1983–1991 storage project operations **SOS 1b** • No maximum flow restriction from mid-Oct. to mid-Nov. • No draft limit; no refill target	**SOS 2c** Operate on system proportional draft as In SOS 1a **SOS 2d** Operate on system proportional draft as in SOS 1a	**SOS 4c** • Meet specific elevation targets as indicated by Integrated Rule Curves (IRCs), similar to operation for Libby • IRCs seek to keep reservoir full (3,560 feet) June-Sept.; minimum annual elevation ranges from 3,520 to 3,450 feet, depending on critical year

	SOS 1	SOS 2	SOS 4
ALBENI FALLS	**SOS 1a** Normal 1983–1991 storage project operations **SOS 1b** No refill target	**SOS 2c** Operate on system proportional draft as In SOS 1a **SOS 2d** Operate on system proportional draft as in SOS 1a	**SOS 4c** Elevation targets established for each month, generally 2,056 feet Oct.–March, 2,058 to 2,062.5 feet April–May, 2,062.5 feet (full) June, 2,060 feet July–Sept. (but higher if runoff high); Oct.–March draw-down to 2,051 feet every 6th year

KAF = 1.234 million cubic meters   MAF = 1.234 billion cubic meters

Table 4–1. SOS Alternative–2

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b Operate on system proportional draft as in SOS 1a **SOS 5c** Operate on system proportional draft as in SOS 1a	**SOS 6b** Operate on system proportional draft as in SOS 1a **SOS 6d** Operate on system proportional draft as in SOS 1a	**SOS 9a** • Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation period **SOS 9b** • Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation • Can draft to meet flow targets, to a minimum end-of-July elevation of 3,535 feet **SOS 9c** • Operate to the Integrated Rule Curves as in SOS 4c	**SOS PA** • Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation period • Strive to achieve flood control elevations by April 15 in 75 percent of the years • Draft to meet flow targets, to a minimum end-of-August elevation of 3,540 feet

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b Operate on system proportional draft as in SOS 1a **SOS 5c** Operate on system proportional draft as in SOS 1a	**SOS 6b** Operate on system proportional draft as in SOS 1a **SOS 6d** Operate on system proportional draft as in SOS 1a	**SOS 9a** Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation period **SOS 9b** • Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation period • Can draft to meet target flows, to a minimum end-of-July elevation of 2,060 feet **SOS 9c** • Elevation targets established for each month, generally no lower than 2,056 feet Dec.—April, no lower than 2,057 feet end of May, full (2,062.5 feet) June—Aug., 2,056 feet Sept.—Nov.	**SOS PA** • Operate to flood control elevations by April 15 in 90 percent of the years • Operate to help meet flow targets, but do not draft below full pool through Aug.

1 kcfs = 28 cms

1 ft = 0.3048 meter

Table 4–1. SOS Alternative–3
Actions by Project

	SOS 1	SOS 2	SOS 4
GRAND COULEE	**SOS 1a** • Operate to meet Water Budget target flows of 134 kcfs at Priest Rapids in May 1/ • Meet minimum elevation of 1,240 feet in May **SOS 1b** • No refill target of 1,240 feet in May • Maintain 1,285 feet June–Sept.; minimum 1,220 feet rest of year • No May–June flow target	**SOS 2c** • Storage of water for flow augmentation from January through April • Supplemental releases (in conjunction with upstream projects) to provide up to 3 MAF additional (above Water Budget) flow augmentation in May and June, based on sliding scale for runoff forecasts • System flood control space shifted from Brownlee, Dworshak **SOS 2d** • Contribute, in conjunction with upstream storage projects, up to 4 MAF for additional flow augmentation • Operate in summer to provide flow augmentation water and meet downstream flow targets, but draft no lower than 1,280 feet	**SOS 4c** • Operate to end-of-month elevation targets, as follows: 1,288 Sept.-Nov 1,287 Dec. 1,270 Jan. 1,260 Feb. 1,270 Mar. 1,272 Apr. 15 1,275 Apr. 30 1,280 May 1,288 Jun.-Aug. • Meet flood control rule curves only when Jan.-June runoff forecast exceeds 68 MAF

	SOS 1	SOS 2	SOS 4
PRIEST RAPIDS	**SOS 1a** • Meet May-June flow targets 1/ • Maintain minimum flows to meet Vernita Bar Agreement 2/ **SOS 1b** • No May flow target • Meet Vernita Bar Agreement	**SOS 2c** Operate as in SOS 1a **SOS 2d** Operate as in SOS 1a	**SOS 4c** Operate as in SOS 1a

1/ Flow targets are weekly averages with weekend and holiday flows no less than 80 percent of flows over previous 5 days.
2/ 55 kcfs during heavy load hours October 15 to November 30; minimum instantaneous flow 70 kcfs December to April
KAF = 1.234 million cubic meters MAF = 1.234 billion cubic meters

Table 4–1. SOS Alternative–3

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b	**SOS 6b**	**SOS 9a**	**SOS PA**
Operate on system proportional draft and provide flow augmentation as in SOS 2c	Operate on system proportional draft and provide flow augmentation as in SOS 2c	• Operate to meet flood control requirements and Vernita Bar agreement • Provide flow augmentation releases to help meet targets at The Dalles of 220-300 kcfs April 16-June 15, 200 kcfs June 16-July 31, and 160 kcfs Aug. 1-Aug.31, based on appropriate critical year determination • In above average runoff years, provide 40% of the additional runoff volume as flow augmentation	• Operate to achieve flood control elevations by April 15 in 85% of years • Draft to meet flow targets, down to minimum end-of-Aug. elevation of 1,280 feet • Provide flow augmentation releases to meet Columbia River flow targets at McNary of 220-260 kcfs April 20-June 30, based on runoff forecast, and 200 kcfs July-Aug.
SOS 5c	**SOS 6d**	**SOS 9b**	
Operate on system proportional draft and provide flow augmentation as in SOS 2c	Operate on system proportional draft and provide flow augmentation as in SOS 2c	• Operate on minimum flow up to flood control rule curves year-round, except during flow augmentation period • Can draft to meet flow targets, bounded by SOS 9a and 9c targets, to a minimum end-of-July elevation of 1,265 feet	
		SOS 9c	
		• Operate to meet McNary flow targets of 200 kcfs April 16-June 30 and 160 kcfs in July • Can draft to meet flow targets, to a minimum end-of-July elevation of 1,280 feet • Contribute up to 4 MAF for additional flow augmentation, based on sliding scale for runoff forecasts, in conjunction with other upstream projects • System flood control shifted to this project	

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b	**SOS 6b**	**SOS 9a**	**SOS PA**
Operate as in SOS 1a	Operate as in SOS 1a	Operate as in SOS 1a	Operate as in SOS 1a
SOS 5c	**SOS 6d**	**SOS 9b**	
Operate as in SOS 1a	Operate as in SOS 1a	Operate as in SOS 1a	
		SOS 9c	
		Operate as in SOS 1a	

1 kcfs = 28 cms   1 ft = 0.3048 meter

Table 4–1. SOS Alternative–4

Actions by Project

	SOS 1	SOS 2	SOS 4
SNAKE RIVER ABOVE BROWNLEE	**SOS 1a** Normal 1990—91 operations; no Water Budget flows	**SOS 2c** Release up to 427 KAF (190 KAF April 16—June 15; 137 KAF Aug.; 100 KAF Sept.) for flow augmentation	**SOS 4c** Same as SOS 1a
	SOS 1b Same as SOS 1a	**SOS 2d** • Release up to 427 KAF, as in SOS 2c • Release additional water obtained by purchase or other means and shaped per Reclamation releases and Brownlee draft requirements; simulation assumed 927 KAF available	

	SOS 1	SOS 2	SOS 4
BROWNLEE	**SOS 1a** • Draft as needed (up to 110 KAF in May) for Water Budget, based on target flows of 85 kcfs at Lower Granite • Operate per FERC license • Provide system flood control storage space	**SOS 2c** Same as SOS 1a except for additional flow augmentation as follows: • Draft up to 137 KAF in July, but not drafting below 2,067 feet; refill from the Snake River above Brownlee in August • Draft up to 100 KAF in Sept. • Shift system flood control to Grand Coulee • Provide 9 kcfs or less in November; fill project by end of month • Maintain November monthly average flow December through April	**SOS 4c** Same as SOS 1a except slightly different flood control rule curves
	SOS 1b • No maximum flow restriction from mid-Oct. to mid-Nov. • No draft limit; no refill target	**SOS 2d** Same as SOS 2c, plus pass additional flow augmentation releases from upstream projects	

KAF = 1.234 million cubic meters

MAF = 1.234 billion cubic meters

Table 4–1. SOS Alternative–4

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b Same as SOS 1a **SOS 5c** Same as SOS 1a	**SOS 6b** Same as SOS 1a **SOS 6d** Same as SOS 1a	**SOS 9a** Provide up to 1.927 MAF through Brownlee for flow augmentation, as determined by Reclamation **SOS 9b** Provide up to 927 KAF through Brownlee as determined by Reclamation **SOS 9c** Provide up to 927 KAF through Brownlee as determined by Reclamation	**SOS PA** Provide 427 KAF through Brownlee for flow augmentation, as determined by Reclamation

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b Same as SOS 4c **SOS 5c** Same as SOS 4c	**SOS 6b** Same as SOS 4c **SOS 6d** Same as SOS 4c	**SOS 9a** • Draft up to 110 KAF in May, 137 KAF in July, 140 KAF in Aug., 100 KAF in Sept. for flow augmentation • Shift system flood control to Grand Coulee **SOS 9b** • Draft up to 190 KAF April-May, 137 KAF in July, 100 KAF in Sept. for flow augmentation • Shift system flood control to Grand Coulee • Provide an additional 110 KAF in May if elevation is above 2,068 feet and 110 KAF in Sept. if elevation is above 2,043.3 feet **SOS 9c** Same as SOS 9b	**SOS PA** Draft to elevation 2,069 feet in May, 2,067 feet in July, and 2,059 feet in Sept., passing inflow after May and July drafts

1 kcfs = 28 cms 1 ft = 0.3048 meter

Table 4–1. SOS Alternative–5

Actions by Project

	SOS 1	SOS 2	SOS 4
DWORSHAK	**SOS 1a** • Draft up to 600 KAF in May to meet Water Budget target flows of 85 kcfs at Lower Granite • Provide system flood control storage space **SOS 1b** • Meet minimum project flows (2 kcfs, except for 1 kcfs in August); summer draft limits; maximum discharge requirement Oct. to Nov. (1.3 kcfs plus inflow) • No Water Budget releases	**SOS 2c** Same as SOS 1a, plus the following supplemental releases: • 900 KAF or more from April 16 to June 15, depending on runoff forecast at Lower Granite • Up to 470 KAF above 1.2 kcfs minimum release from June 16 to Aug. 31 • Maintain 1.2 kcfs discharge from Oct. through April, unless higher required • Shift system flood control to Grand Coulee April–July if runoff forecasts at Dworshak are 3.0 MAF or less **SOS 2d** • Operate on 1.2 kcfs minimum discharge up to flood control rule curve, except when providing flow augmentation (April 10 to July 31) • Provide flow augmentation of 1.0 MAF plus 1.2 kcfs minimum discharge, or 927 KAF and 1.2 kcfs, from April 10-June 20, based on runoff forecasts, to meet Lower Granite flow target of 85 kcfs • Provide 470 KAF from June 21 to July 31 to meet Lower Granite flow target of 50 kcfs • Draft to 1,520 feet after volume is expended, if Lower Granite flow target is not met; if volume is not expended, draft below 1,520 feet until volume is expended	**SOS 4c** Elevation targets established for each month: 1,599 feet Sept.-Oct.; flood control rule curves Nov.-April; 1,595 feet May; 1,599 feet June-Aug.;

KAF = 1.234 million cubic meters

MAF = 1.234 billion cubic meters

Table 4–1. SOS Alternative–5

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b • Operate to local flood control rule curve • No proportional draft for power • Shift system flood control to lower Snake projects • Provide Water Budget flow augmentation as in SOS 1a • Draft to refill lower Snake projects if natural inflow is inadequate **SOS 5c** • Operate to flood control during spring • Refill in June or July and maintain through August • Draft for power production during fall	**SOS 6b** Same as SOS 5b **SOS 6d** Same as SOS 5b	**SOS 9a** • Remove from proportional draft for power • Operate to local flood control rule curves, with system flood control shifted to Grand Coulee • Maintain flow at 1.2 kcfs minimum discharge, except for flood control or flow augmentation discharges • Operate to meet Lower Granite flow targets (at spillway crest) of 74 kcfs April 16-June 30, 45 kcfs July, 32 kcfs August **SOS 9b** • Similar to SOS 9a, except operate to meet flow targets at Lower Granite ranging from 85 to 140 kcfs April 16-June 30 and 50-55 kcfs in July • Can draft to meet flow targets to a min. end-of-July elevation of 1,490 feet **SOS 9c** • Similar to SOS 9a, except operate to meet Lower Granite flow target (at spillway crest) of 63 kcfs April-June • Can draft to meet flow targets to a min. end-of-July elevation of 1,520 feet	**SOS PA** • Operate on minimum flow-up to flood control rule curve year-round, except during flow augmentation period • Draft to meet flow targets, down to min. end-of-Aug. elevation of 1,520 feet • Sliding-scale Snake River flow targets at Lower Granite of 85 to 100 kcfs April 10-June 20 and 50 to 55 kcfs June 21-Aug. 31, based on runoff forecasts

1 kcfs = 28 cms   1 ft = 0.3048 meter

Table 4–1. SOS Alternative–6

Actions by Project

LOWER SNAKE

SOS 1	SOS 2	SOS 4
SOS 1a • Normal operations at 4 lower Snake River projects (within 3 to 5 feet of full pool, daily and weekly fluctuations) • Provide maximum peaking capacity of 20 kcfs over daily average flow in May	**SOS 2c** • Operate reservoirs within 1 foot above MOP from April 16 to July 31 • Same as SOS 1a for rest of year	**SOS 4c** Same as SOS 2c
SOS 1b Same as 1a, except: • No minimum flow limit (11,500 cfs) during fall and winter • No fish-related rate of change in flows in May	**SOS 2d** Same as SOS 2c	

LOWER COLUMBIA

SOS 1	SOS 2	SOS 4
SOS 1a • Normal operations at 4 lower Columbia projects (generally within 3 to 5 feet of full pool, daily and weekly fluctuations) • Restricted operation of Bonneville second powerhouse	**SOS 2c** Same as SOS 1a except: lower John Day to minimum irrigation pool (approx. 262.5 feet) from April 15 to Aug. 31; operate within 1.5 feet of forebay range, unless need to raise to avoid irrigation impacts	**SOS 4c** Same as SOS 2c, except operate John Day within 2 feet of elevation 263.5 feet Nov. 1 through June 30
SOS 1b Same as 1a, except no restrictions on Bonneville second powerhouse	**SOS 2d** Same as SOS 2c	

KAF = 1.234 million cubic meters MAF = 1.234 billion cubic meters

Table 4–1. SOS Alternative–6

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b • Draft 2 feet per day starting Feb. 18 • Operate at natural river level, approx. 95 to 115 ft below full pool, April 16-Aug. 31; drawdown levels by project as follows, in feet: Lower Granite 623 Little Goose 524 L. Monumental 432 Ice Harbor 343 • Operate within 3 to 5 ft of full pool rest of year • Refill from natural flows and storage releases **SOS 5c** Same as SOS 5b, except drawdowns are permanent once natural river levels reached; no refill	**SOS 6b** • Draft 2 feet per day starting April 1 • Operate 33 feet below full pool April 16-Aug. 31; drawdown levels by project as follows, in feet: Lower Granite 705 Little Goose 605 L. Monumental 507 Ice Harbor 407 • Operate over 5-foot forebay range once drawdown elevation reached • Refill from natural flows and storage releases • Same as SOS 1a rest of year **SOS 6d** • Draft Lower Granite 2 feet per day starting April 1 • Operate Lower Granite near 705 ft for 4 1/2 months, April 16-Aug. 31	**SOS 9a** • Operate 33 feet below full pool (see SOS 6b) April 1-Aug. 31 to meet L. Granite flow targets (see Dworshak); same as SOS 1a rest of year • Spill to achieve 80/80 FPE up to total dissolved gas cap of 120% daily average; spill cap 60 kcfs at all projects **SOS 9b** • Operate at MOP, with 1 foot flexibility April 1-Aug. 31; same as SOS 1a rest of year • Spill to achieve 80/80 FPE up to total dissolved gas cap of 120% daily average; spill caps range from 18 kcfs at L. Monumental to 30 kcfs at L. Granite **SOS 9c** • Operate 35 to 45 feet below full pool April 1-June 15 to meet L. Granite flow targets (see Dworshak), refill by June 30; same as SOS 1a rest of year • Spill to achieve 80/80 FPE, as in SOS 9b	**SOS PA** • Operate at MOP with 1 foot flexibility between April 10 - Aug. 31 • Refill three lower Snake River pools after Aug. 31, Lower Granite after Nov. 15 • Spill to achieve 80% FPE up to total dissolved gas cap of 115% 12-hour average; spill caps range from 7.5 kcfs at L. Monumental to 25 kcfs at Ice Harbor

SOS 5	SOS 6	SOS 9	SOS PA
SOS 5b Same as SOS 2, except operate John Day within 1.5 feet above elevation 257 feet (MOP) from May 1 through Aug. 31; same as SOS 2c rest of year **SOS 5c** Same as SOS 5b	**SOS 6b** Same as SOS 5 **SOS 6d** Same as SOS 5	**SOS 9a** • Same as SOS 5, except operate John Day within 1 foot above elevation 257 feet April 15-Aug. 31 • McNary flow targets as described for Grand Coulee • Spill to achieve 80/80 FPE, up to total dissolved gas cap of 120% daily average, as derived by agencies **SOS 9b** • Same as SOS 2, except operate John Day at minimum irrigation pool or 262.5 feet with 1 foot of flexibility from April 16-Aug. 31 • McNary flow targets as described for Grand Coulee • Spill to achieve 80/80 FPE, up to total dissolved gas cap of 120% daily average, as derived by Corps **SOS 9c** Same as SOS 9b, except operate John Day at minimum operating pool	**SOS PA** • Pool operations same as SOS 2c, except operate John Day at 257 feet (MOP) year-round, with 3 feet of flexibility March-Oct. and 5 feet of flexibility Nov.-Feb. • Spill to achieve 80% FPE up to total dissolved gas cap of 115% 12-hour average; spill caps range from 9 kcfs at John Day to 90 kcfs at The Dalles

1 kcfs = 28 cms   1 ft = 0.3048 meter

4.1.1 SOS 1-Pre–ESA Operation

This alternative represents one end of the range of the SOR strategies in terms of their similarity to historical system operations. This strategy reflects Columbia River system operations before changes were made as a result of the ESA listing of three Snake River salmon stocks. This SOS has two options:

- **SOS 1a (Pre–Salmon Summit Operation)** represents operations as they existed from 1983 through the 1990–91 operating year, including Northwest Power Act provisions to restore and protect fish populations in the basin. Specific volumes for the Water Budget would be provided from Dworshak and Brownlee reservoirs to attempt to meet a target flow of 85 kcfs (2,380 cms) at Lower Granite Dam in May. Sufficient flows would be provided on the Columbia River to meet a target flow of 134 kcfs (3,752 cms) at Priest Rapids Dam in May. Lower Snake River projects would operate within 3 to 5 feet (0.9 to 1.5 m) of full pool. Other projects would operate as they did in 1990–91, with no additional water provided from the Snake River above Brownlee Dam.

- **SOS 1b (Optimum Load–Following Operation)** represents operations as they existed prior to changes resulting from the Northwest Power Act. It is designed to demonstrate how much power could be produced if most flow–related operations to benefit anadromous fish were eliminated including: the Water Budget; fish spill requirements; restrictions on operation of Bonneville's second powerhouse; and refill targets for Libby, Hungry Horse, Grand Coulee, Dworshak, and Albeni Falls. It assumes that transportation would be used to the maximum to aid juvenile fish migration.

4.1.2 SOS 2-Current Operations

This alternative reflects operation of the Columbia River system with interim flow improvement measures made in response to ESA listings of Snake River salmon. It is very similar to the way the system operated in 1992 and reflects the results of ESA Section 7 consultation with NMFS then. The strategy is consistent with the 1992–93 operations described in the Corps' *1993 Interim Columbia and Snake Rivers Flow Improvement Measures Supplemental EIS* (SEIS). SOS 2 also most closely represents the recommendations issued by the NMFS Snake River Salmon Recovery Team in May 1994. Compared to SOS 1, the primary changes are additional flow augmentation in the Columbia and Snake Rivers and modified pool levels at lower Snake and John Day reservoirs during juvenile salmon migration. This strategy has two options:

- **SOS 2c (Final SEIS Operation- No Action Alternative)** matches exactly the decision made as a result of the 1993 SEIS. Flow augmentation water of up to 3.0 MAF (3.7 billion m^3) on the Columbia River (in addition to the existing Water Budget) would be stored during the winter and released in the spring in low–runoff years. Dworshak would provide at least an additional 300 KAF (370 million m^3) in the spring and 470 KAF (580 million m^3) in the summer for flow augmentation. System flood control shifts from Dworshak and Brownlee to Grand Coulee would occur through April as needed. It also provides up to 427 KAF (527 million m^3) of additional water from the Snake River above Brownlee Dam.

- **SOS 2d (1994–98 Biological Opinion)** matches the hydro operations contained in the 1994–98 Biological Opinion issued by NMFS in mid–1994. This alternative provides water for the existing Water Budget as well as additional water, up to 4 MAF, for flow augmentation to benefit the anadromous fish migration. The additional water of up to 4 MAF would be stored in Grand Coulee, Libby and Arrow, and provided on a sliding scale tied to runoff forecasts. Flow targets are established at Lower Granite and McNary.

In cases such as the SOR, where the proposed action is a new management plan, the No Action Alternative means continuing with the present course of action until that action is changed (46 FR 13027). Among all of the strategies and options, SOS 2c best meets this definition for the No Action Alternative.

4.1.3 SOS 4-Stable Storage Project Operation

This alternative is intended to operate the storage reservoirs to benefit recreation, resident fish, wildlife, and anadromous fish while minimizing impacts of such operation to power and flood control. Reservoirs would be kept full longer, but still provide spring flows for fish and space for flood control. The goal is to minimize reservoir fluctuations while moving closer to natural flow conditions. For the Final EIS, this alternative has one option:

- **SOS 4c (Stable Storage Operation with Modified Grand Coulee Flood Control)** applies year–round Integrated Rule Curves (IRCs) developed by the State of Montana for Libby and Hungry Horse. Other reservoirs would be managed to specific elevations on a monthly basis; they would be kept full longer, while still providing spring flows for fish and space for flood control. The goal is to minimize reservoir fluctuations while moving closer to natural flow conditions. Grand Coulee would meet elevation targets year–round to provide acceptable water retention times; however, upper rule curves would apply at Grand Coulee if the January to July runoff forecast at the project is greater than 68 MAF (84 billion m^3).

4.1.4 SOS 5-Natural River Operation

This alternative is designed to aid juvenile salmon migration by drawing down reservoirs (to increase the velocity of water) at four lower Snake River projects. SOS 5 reflects operations after the installation of new outlets in the lower Snake River dams, permitting the lowering of reservoirs approximately 100 feet (30 m) to near original riverbed levels. This operation could not be implemented for a number of years, because it requires major structural modifications to the dams. Elevations would be: Lower Granite – 623 feet (190 m); Little Goose – 524 feet (160 m); Lower Monumental – 432 feet (132 m); and Ice Harbor – 343 feet (105 m). Drafting would be at the rate of 2 feet (0.6 m) per day beginning February 18. The reservoirs would refill again with natural inflows and storage releases from upriver projects, if needed. John Day would be lowered as much as 11 feet (3.3 m) to minimum pool, elevation 257 feet (78.3 m), from May through August. All other projects would operate essentially the same as in SOS 1a, except that up to 3 MAF (3.7 billion m^3) of water (in addition to the Water Budget) would be provided to augment flows on the Columbia River in May and June. System flood control would shift from Brownlee and Dworshak to the lower Snake River projects. Also, Dworshak would operate for local flood control. This alternative has two options:

- **SOS 5b (Four and One–half Month Natural River Operation)** provides for a lower Snake River drawdown lasting 4.5 months, beginning April 16 and ending August 31. Dworshak would be drafted to refill the lower Snake River projects if natural inflow were inadequate for timely refill.

- **SOS 5c (Permanent Natural River Operation)** provides for a year–round drawdown, and projects would not be refilled after each migration season.

4.1.5 SOS 6-Fixed Drawdown

This alternative is designed to aid juvenile anadromous fish by drawing down one or all four lower Snake River projects to fixed elevations approximately 30 to 35 feet (9 to 10 m) below minimum operating pool. As with SOS 5, fixed drawdowns depend on prior structural modifications and could not be instituted for a number of years. Draft would be at the rate of 2 feet (0.6 m) per day beginning April 1. John Day would be lowered to elevation 257 feet (78.3 m) from May through August. All other projects would operate essentially the same as under SOS 1a, except that up to 3 MAF (3.7 billion m^3) of water would be provided to augment flows on the Columbia River in May and June. System flood control would shift from Brownlee and Dworshak to the lower Snake projects. Also, Dworshak would operate for local flood control. This alternative has two options:

- **SOS 6b (Four and One–half Month Fixed Drawdown)** provides for a 4.5–month drawdown at all four lower Snake River projects beginning April 16 and ending August 31. Elevations would be: Lower Granite – 705 feet (215 m); Little Goose – 605 feet (184 m); Lower Monumental – 507 feet (155 m); and Ice Harbor – 407 feet (124 m).
- **SOS 6d (Four and One–half Month Lower Granite Fixed Drawdown)** provides for a 4.5–month drawdown to elevation 705 feet at Lower Granite beginning April 16 and ending August 31.

4.1.6 SOS 9-Settlement Discussion Alternatives

This SOS represents operations suggested by USFWS and NMFS (as SOR cooperating agencies), the State fisheries agencies, Native American tribes, and the Federal operating agencies during the settlement discussions in response to a court ruling in the *IDFG v. NMFS* lawsuit. The objective of SOS 9 is to provide increased velocities for anadromous fish by establishing flow targets during the migration period and by carrying out other actions that benefit ESA–listed species. The specific options were developed by a group of technical staff representing the parties in the lawsuit. The group was known as the Reasonable and Prudent Alternatives Workgroup. They developed three possible operations in addition to the 1994–98 Biological Opinion. This strategy has three options:

- **SOS 9a (Detailed Fishery Operating Plan [DFOP])** establishes flow targets at The Dalles based on the previous year's end–of–year storage content, similar to how PNCA selects operating rule curves. Grand Coulee and other storage projects are used to meet The Dalles flow targets. Specific volumes of releases are made from Dworshak, Brownlee, and upper Snake River to try to meet Lower Granite flow targets. Lower Snake River projects are drawn down to near spillway crest level for 4 1/2 months. Specific spill percentages are established at run–of–river projects to achieve no higher than 120 percent daily average total dissolved gas. Fish transportation is assumed to be eliminated.
- **SOS 9b (Adaptive Management)** establishes flow targets at McNary and Lower Granite based on runoff forecasts. Grand Coulee and other storage projects are used to meet the McNary flow targets. Specific volumes of releases are made from Dworshak, Brownlee, and the upper Snake River to try to meet Lower Granite flow targets. Lower Snake River projects are drawn down to minimum operating pool levels and John Day is at minimum irrigation pool level. Specific spill percentages are established at run–of–river projects to achieve no higher than 120 percent daily average for total dissolved gas.
- **SOS 9c (Balanced Impacts Operation)** draws down the four lower Snake River projects to near spillway crest levels for 2 1/2 months during the spring salmon migration period. Full drawdown level is achieved on April 1. Refill begins after June 15. This alternative also provides 1994–98 Biological Opinion flow augmentation (as in SOS 2d), IRC operation at Libby and Hungry Horse, a reduced flow target at Lower Granite due to drawdown, limits on winter drafting at Albeni Falls, and spill to achieve no higher than 120 percent daily average for total dissolved gas.

4.1.7 SOS PA-Preferred Alternative

This SOS represents the operation recommended by NMFS and USFWS in their respective Biological Opinions issued on March 1, 1995. SOS PA is intended to support recovery of ESA–listed species by storing water during the fall and winter to meet spring and summer flow targets, and to protect other resources by managing detrimental effects through maximum summer draft limits, by providing public safety through flood protection, and by providing for reasonable power generation. This SOS would operate the system during the fall and winter to achieve a high confidence of the fall and winter to achieve a high confidence of refill to flood control elevations by April 15 of each year, and use this stored water for fish flow augmentation. It establishes spring flow targets at McNary and Lower Granite based on runoff forecasts, and a similar sliding scale flow target at Lower Granite and a fixed flow target at McNary for the summer. It establishes summer draft limits at Hungry Horse, Libby, Grand Coulee, and Dworshak. Libby is also operated to provide flows for Kootenai River white sturgeon. Lower Snake River projects are drawn down to minimum operating pool levels during the spring and summer. John Day is operated at minimum operating pool level year–round. Specific spill percentages are established at run–of–river projects to achieve 80–percent FPE, with no higher than 115–percent 12–hour daily average for total dissolved gas measured at the forebay of the next downstream project.

4.1.8 Rationale for Selection of the Final SOSs

Table 4–2 summarizes the changes to the set alternatives from the Draft EIS to the Final EIS.

SOS 1a and 1b are unchanged from the Draft EIS. SOS 1a represents a base case condition and reflects system operation during the period from passage of the Northwest Power Planning and Conservation Act until ESA listings. It provides a baseline alternative that allows for comparison of the more recent alternatives and shows the recent historical operation. SOS 1b represents a limit for system operation directed at maximizing benefits from development–oriented uses, such as power generation, flood control, irrigation and navigation and away from natural resources protection. It serves as one end of the range of alternatives and provides a basis for comparison of the impacts to power generation from all other alternatives. Public comment did not recommend elimination of this alternative because it serves as a useful milepost. However, the SOR agencies recognize it is unlikely that decisions would be made to move operations toward this alternative.

In the Draft EIS, SOS 2 represented current operation. Three options were considered. Two of these options have been eliminated for the Final EIS and one new option has been added. SOS 2c continues as the No Action Alternative. Maintaining this option as the No Action Alternative allows for consistent comparisons in the Final EIS to those made in the Draft EIS. However, within the current practice category, new operations have been developed since the original identification of SOS 2c. In 1994, the SOR agencies, in consultation with the NMFS and USFWS, agreed to an operation, which was reflected in the 1994–98 Biological Opinion. This operation (SOS 2d) has been modeled for the Final EIS and represents the most "current" practice. SOS 2d also provides a good baseline comparison for the other, more unique alternatives. SOS 2a and 2b from the Draft EIS were eliminated because they are so similar to SOS 2c. SOS 2a is identical to SOS 2c except for the lack of an assumed additional 427 KAF of water from the upper Snake River Basin. This additional water did not cause significant changes to the effects between SOS 2a and 2c. There is no reason to continue to consider an alternative that has impacts essentially equal to another alternative. SOS 2b is also similar to SOS 2c, except it modified operation at Libby for Kootenai River white sturgeon. Such modifications are included in several other alternatives, namely SOS 2d, 9a, 9c, and the Preferred Alternative.

SOS 3a and 3b, included in the Draft EIS, have been dropped from consideration in the Final EIS. Both of these alternatives involved anadromous fish flow augmentation by establishing flow targets based on runoff forecast on the Columbia and Snake Rivers. SOS 3b included additional water from the upper Snake River Basin over what was assumed for SOS 3a. This operation is now incorporated in several new alternatives, including SOS 9a and 9b. Public comment also did not support continued consideration of the SOS 3 alternatives.

Table 4–2. Summary of Alternatives in the Draft and Final EIS

Draft EIS Alternatives		Final EIS Alternatives	
SOS 1	Pre–ESA Operation	SOS 1	Pre–ESA Operation
SOS 1a	Pre–Salmon Summit Operation	SOS 1a	Pre–Salmon Summit Operation
SOS 1b	Optimum Load Following Operation	SOS 1b	Optimum Load Following Operation
SOS 2	Current Practice	SOS 2	Current Practice
SOS 2a	Final Supplemental EIS Operation	SOS2c	Final Supplemental EIS Operation – No–Action Alternative
SOS 2b	Final Supplemental EIS with Sturgeon Operations at Libby	**SOS 2d**	**1994–98 Biological Opinion Operation**
SOS2c	Final Supplemental EIS Operation – No–Action Alternative		
SOS 3	Flow Augmentation		
SOS 3a	Monthly Flow Targets		
SOS 3b	Monthly Flow Targets with additional Snake River Water		
SOS 4	Stable Storage Project Operation	SOS 4	Stable Storage Project Operation
SOS 4a1	Enhanced Storage Level Operation	**SOS 4c**	**Enhanced Operation with modified Grand Coulee Flood Control**
SOS 4a3	Enhanced Storage Level Operation		
SOS 4b1	Compromise Storage Level Operation		
SOS 4b3	Compromise Storage Level Operation		
SOS 4c	Enhanced Operation with modified Grand Coulee Flood Control		
SOS 5	Natural River Operation	SOS 5	Natural River Operation
SOS 5a	Two Month Natural River Operation	SOS 5b	Four and One Half Month Natural River Operation
SOS 5b	Four and One Half Month Natural River Operation	**SOS 5c**	**Permanent Natural River Operation**
SOS 6	Fixed Drawdown	SOS 6	Fixed Drawdown
SOS 6a	Two Month Fixed Drawdown Operation	SOS 6b	Four and One Half Month Fixed Drawdown Operation
SOS 6b	Four and One Half Month Fixed Drawdown Operation	SOS 6d	Four and One Half Month Lower Granite Drawdown Operation
SOS 6c	Two Month Lower Granite Drawdown Operation		
SOS 6d	Four and One Half Month Lower Granite Drawdown Operation		
SOS 7	Federal Resource Agency Operations	**SOS 9**	**Settlement Discussion Alternatives**
SOS 7a	Coordination Act Report Operation	**SOS 9a**	**Detailed Fishery Operating Plan**
SOS 7b	Incidental Take Statement Flow Targets	**SOS 9b**	**Adaptive Management**
SOS 7c	NMFS Conservation Recommendations	**SOS 9c**	**Balance Impacts Operation**
		SOS Preferred Alternative	

Bold indicates a new or revised SOS alternative

SOS 4 originally included 5 options in the Draft EIS. They were similar in operation and impact. In SOS 4a and 4b, the primary feature was the use of Biological Rule Curves for Libby and Hungry Horse reservoirs. SOS 4c also included these rule curves but went further by optimizing the operation of the other storage projects, particularly Grand Coulee and Dworshak. For the Final EIS, the SOR agencies have decided to update the alternative by substituting the IRC for the Biological Rule Curves and by eliminating SOS 4a and 4b. The IRCs are a more recent, acceptable version of minimum elevations for Libby and Hungry Horse. Significant public comment in support of this alternative with IRCs was received. Similar to SOS 2 above, SOS 4a and 4b were not different enough in operation or impacts to warrant continued consideration.

The Natural River (SOS 5) and the Spillway Crest Drawdown (SOS 6) alternatives in the Draft EIS originally included options for 2 months of drawdown to the appropriate pool level and 4 1/2 months of drawdown. The practicality of 2–month drawdowns was questioned during public review, particularly for the natural river. It did not appear that the time involved in drawing down the reservoirs and later refilling them provided the needed consideration for other uses. Flows are restricted to refill the reservoirs at a time when juvenile fall chinook are migrating downstream and various adult species are returning upstream. The 2 1/2 month drawdown strategies (SOS 5a, 6a, and 6c) have been dropped from the Final EIS. However, 2 1/2 month spillway crest drawdown at all four lower Snake projects is still an element in SOS 9c, so the impacts associated with this type of operation are assessed in the Final EIS.

A new option was added to SOS 5, namely SOS 5c. This option includes natural river drawdown of the lower Snake River projects on a permanent, year–round basis. The Corps received comment on this type of alternative during the review of Phase I of the SCS, a reconnaissance assessment of potential physical modifications for the system to enhance fish passage. Many believe the cost for such modification would be less than that required for periodic, temporary drawdowns, which would require specialized facilities to enable the projects to refill and operate at two different pool elevations.

SOS 7 Federal Resource Agencies Operations, which included 3 options in the Draft EIS, has been dropped from the Final EIS and replaced with an alternative now labeled as SOS 9 that also has 3 options. SOS 7a was suggested by the USFWS and represented the State fishery agencies and tribes' recommended operation. Since the issuance of the Draft EIS, this particular operation has been revised and replaced by the DFOP (SOS 9a). The SOR agencies received comment that the DFOP was not evaluated, but should be. Therefore, we have included this alternative exactly as proposed by these agencies; it is SOS 9a. SOS 7b and 7c were suggested by NMFS through the 1993 Biological Opinion. This opinion suggested two sets of flow targets as a way of increasing flow augmentation levels for anadromous fish. The flow targets came from the Incidental Take Statement and the Conservation Recommendation sections of that Biological Opinion. The opinion was judged as arbitrary and capricious as a result of legal action, and these operational alternatives have been replaced with other alternatives that were developed through settlement discussions among the parties to this lawsuit. SOS 7b and 7c have been dropped, but SOS 9b and 9c have been added to represent operations stemming from NMFS or other fishery agencies. In particular, SOS 9b is like DFOP but has reduced flow levels and forgoes drawdowns. It is a modification to DFOP. SOS 9c incorporates elements of operation supported by the State of Idaho in its "Idaho Plan." It includes a 2 1/2–month spillway crest drawdown on the lower Snake River projects and several other elements that attempt to strike a balance among the needs of anadromous fish, resident fish, wildlife and recreation.

Shortly after the alternatives for the Draft EIS were identified, the Nez Perce Tribe suggested an operation that involved drawdown of Lower Granite, significant additional amounts of upper Snake River water, and full pool operation at Dworshak (i.e., Dworswak remains full year round). It was labeled as SOS 8a. Hydroregulation of that operation was completed and provided to the Nez Perce Tribe. No technical response has been received from the Nez

Perce Tribe regarding the features or results of this alternative. However, the elements of this operation are generally incorporated in one or more of the other alternatives, or impose requirements on the system or specific projects that are outside the range considered reasonable. Therefore, this alternative has not been carried forward into the Final EIS.

The Preferred Alternative represents operating requirements contained in the 1995 Biological Opinions issued by NMFS and USFWS on operation of the FCRPS. These opinions resulted from ESA consultation conducted during late 1994 and early 1995, which were a direct consequence of the lawsuit and subsequent judgement in *Idaho v. NMFS*. The SOR agencies are now implementing this operating strategy and have concluded that it represents an appropriate balance among the multiple uses of the river. This strategy recognizes the importance of anadromous fish and the need to adjust river flows to benefit the migration of all salmon stocks, as well as the needs of resident fish and wildlife species at storage projects.

4.2 ALTERNATIVES AND IMPACTS

Impacts associated with the various strategies are described below. In addition to the text description of impacts, tables and graphs are used to provide numerical and graphic information. Table 4–3 describes results for all alternatives and options. Another set of tables of results for each individual alternative and option is found in Technical Exhibit B and graphs can be found in Technical Exhibit C. Impacts are discussed in terms of six major factors. These are reservoir elevations, refill probability, flows, power generation, water travel time, and water retention time at Grand Coulee. The results of each alternative are compared to SOS 2c, the "no–action" alternative. The discussion of impacts and comparisons with SOS 2c primarily refer to data for the project and river locations shown in tables in Technical Exhibit B. Reservoir elevation results refer to end–of–month elevations. Refill probability refers to the percentage of years out of 50 in which reservoirs refill to within 5 feet of full by July. Flows refer to average monthly discharge. Power generation refers to average total hydro power generation, including both firm and non–firm energy. Water travel time refers to the average velocity of the water and is used as a measure of the travel time required for juvenile salmon migrating downstream. Water retention time refers to the amount of time water is retained in a reservoir and is used in relating the amount of time nutrients have to develop in the stable water. Hydroregulation study results are available upon request from the SOR project managers or ROSE Coordinator.

In addition to describing impacts associated with each alternative and option, various anomalies which were found in some of the hydroregulation results are also described. These anomalies represent a wide range of conditions in which objectives of the alternative were not always met in the hydroregulation results. These conditions were due to errors in the modeling process, limitations in the models, and other reasons. The impact of most of the anomalies described was fairly minor and therefore it was decided not to correct them at this stage of the analysis. They have been documented and will be corrected in future hydroregulation studies.

4.2.1 SOS 1a – Pre–Salmon Summit Operation

Impacts

Reservoir Elevations – Average reservoir elevations were lower under SOS 1a than they were under the no–action alternative, SOS 2c. The only major exception is at Brownlee, where the average reservoir elevation was two feet (0.6 m.) higher. This difference at Brownlee was probably attributable to incorporation of the operation identified in the Idaho Power "Fall Chinook Interim Recovery Plan and Study" into SOS 2c. This operation drafts Brownlee to augment downstream flows on the Snake River by as much as 400,000 acre–feet (493.6 million m^3), compared to flow augmentation volumes of 150,000 acre–feet (185.1 million m^3) under SOS 1a. Drafting of the reservoir results in lower average elevations in SOS 2c than in SOS 1a.

Refill Probability – Refill probability in July was higher for all storage reservoirs in SOS 1a than in SOS 2c. This result was expected since SOS 2c involves drafting more water from reservoirs in the spring and summer for flow augmentation than does SOS 1a.

Flows – January to April flows were generally higher in SOS 1a than in SOS 2c, but May to June flows were generally lower in SOS 1a than in SOS 2c due to a lesser amount of flow augmentation in SOS 1a than in SOS 2c. For example, Priest Rapids May–June flows were about 8,000 cfs (226.6 m^3/s) lower in SOS 1a than in SOS 2c.

Power Generation – Average system energy in SOS 1a was 138 MW higher than SOS 2c. This is due to the fact that there is more operational flexibility in the system in SOS 1a than in SOS 2c.

Water Travel Time – The water travel times for SOS 1a were somewhat higher than those computed for SOS 2c. This result was expected since SOS 1a incorporates very few of the actions designed to reduce water travel time such as reservoir drawdown and flow augmentation.

Water Retention Time – The water retention time at Grand Coulee for SOS 1a was approximately the same as for SOS 2c. This is due to the fact that the reservoir is operated in a similar manner in both studies during the time period when water retention time was calculated.

Anomalies

The only major anomaly which has been identified in SOS 1a involves Lower Granite reservoir elevations in May. The objective of the hydroregulation was to maintain the reservoir elevations at 735.3 feet (224.1 m.) throughout the year. However, in 13 of the 50 years modeled, the reservoir elevations drop below 735.3 feet (224.1 m.), down to as low as 682.5 feet (208.0 m.). It is thought that this problem is due to the fact that the reservoir is being inadvertently drafted in May to contribute to the spring water budget volume. This problem can be easily corrected in future hydroregulations, and therefore, for purposes of analysis, it is suggested that the reservoir is assumed to be at elevation 735.3 feet (224.1 m.) throughout the year.

4.2.2 SOS 1b – Optimum Load-Following Operation

Impacts

Reservoir Elevations – Reservoir elevations were lower on average under SOS 1B than under SOS 2c. The only exception to this trend was at Brownlee, where the average reservoir elevation was about two feet higher. As in SOS 1a, the reason for this was thought to be due to the additional reservoir drafts associated with the Idaho Power Company "Fall Chinook Interim Recovery Plan and Study." Lower overall reservoir elevations in SOS 1B were expected, since it allows maximum flexibility for power generation.

Refill Probability – Refill probability in July was higher for all storage reservoirs in SOS 1B than in SOS 2c. Similar to SOS 1a, this result was expected since SOS 2c involves more drafting for flow augmentation and because refill reliability is of higher priority when the system is operated strictly for power as in SOS 1B.

Flows – Spring flows were lower in SOS 1B than in SOS 2c due to lesser amounts of flow augmentation in SOS 1B.

Power Generation – Average system energy in SOS 1B is 309 MW higher than SOS 2c. These results are expected since the primary objective of SOS 1B was to optimize the load carrying capability of the system.

Water Travel Time – Similar to SOS 1a, the water travel times were generally higher for SOS 1b when compared to SOS 2c. No actions to improve water travel time were included in this alternative either.

Water Retention Time – The water retention time for SOS 1b was not significantly different than for SOS 2c.

Anomalies

None reported.

4.2.3 SOS 2c – Final Supplemental EIS Operation, With 427 KAF (526.9 million m^3) Upper Snake Water

Impacts

Impacts of this strategy are described in comparisons with all other strategies.

Anomalies

The only anomaly which has been found with SOS 2c is that John Day reservoir was modeled at the summer drawdown elevation of 262.5 feet (80.0 m.) beginning April 15, rather than May 1.

4.2.4 SOS 2d – 1994–98 Biological Opinion

Impacts

Reservoir Elevations – Reservoir elevations for SOS 2d were similar to SOS 2c for all projects except Dworshak, which was about 18 feet lower on average and 44 feet lower at the end of July. This was due to the fact that larger volumes of water for flow augmentation were released from Dworshak under this strategy.

Refill Probability – Refill probability at Dworshak, Grand Coulee, and Libby decreased due to increased amounts of draft from the reservoirs for flow augmentation. At other projects, it remained about the same.

Flows – Average flows in May through June were slightly lower than SOS 2c at both Lower Granite and The Dalles. During the summer period from July through August, the average flows at Lower Granite and The Dalles were higher than SOS 2c due to the increased amounts of draft from the reservoirs for flow augmentation.

Power Generation – The average system energy was about 35 MW lower than for SOS 2c.

Water Travel Time – The water travel time was the same as for SOS 2c during the spring period and slightly lower during the summer due to the higher flows during this period. The overall decrease in travel time from the upper Snake River down through Bonneville Dam was 3 days.

Water Retention Time – Water retention time at Grand Coulee was increased by 3 days in the spring and decreased by 12 days in the summer. The spring value of 31 days was the highest of any alternative.

Anomalies

None reported.

4.2.5 SOS 4c – Revised Stable Pool Operation

Impacts

Reservoir Elevations – Average reservoir elevations were higher under SOS 4c than under SOS 2c for all projects shown in Table 4–3, Technical Exhibit B. Similar to all other options under SOS 4, this result was expected, since the objective of the strategy was to maintain higher reservoir elevations to improve conditions for recreation, resident fish, and wildlife.

Refill Probability – Refill probability in July for SOS 4c was higher than under SOS 2c, again due to the objective of maintaining higher reservoirs.

Flows – Spring and summer flows on the Columbia River at Priest Rapids and The Dalles were higher under SOS 4c. Spring and summer flows on the lower Snake River were lower due to removal of water budget draft requirements at Dworshak.

Power Generation – Average system energy under SOS 4c was 54 MW lower than under SOS 2c.

Water Travel Time – The water travel time during both the spring and summer was essentially the same as for SOS 2c.

Water Retention Time – Water retention time was slightly higher in the spring and 4 days less in the summer compared to SOS 2c.

Anomalies

None reported.

Table 4–3. Pertinent Data (SOS 2c through SOS PA)

	SOS 2c	SOS 1a	SOS 1b	SOS 2d	SOS 4c	SOS 5b	SOS 5c	SOS 6b	SOS 6d	SOS 9a	SOS 9b	SOS 9c	SOS PA
LIB Jul EOM Elev, ft	2453.5	2451.4	2450.6	2451.6	2454.6	2450.8	2450.8	2450.8	2450.8	2392.7	2441.6	2454.5	2439.2
Julys LIB did not fill*	13	12	13	18	11	15	15	15	15	47	45	10	40
LIB Avg Pool Elev, ft	2402.2	2400.1	2396.2	2397.5	2424.2	2397.9	2397.9	2397.9	2397.9	2382.8	2402.9	2424.2	2404.4
HHR Jul EOM Elev, ft	3541.7	3540.3	3537.1	3541.7	3559.5	3539.7	3539.7	3539.7	3539.7	3501.1	3550.1	3559.5	3550
Julys HHR did not fill*	23	19	20	22	0	22	20	22	22	41	23	0	26
HHR Avg Pool Elev, ft	3503	3500.2	3496.5	3503	3535.5	3499.7	3499.7	3499.7	3499.7	3477.5	3531.7	3535.4	3531.6
GCL Jul EOM Elev, ft	1289.7	1289.9	1289.7	1287	1288	1289.7	1289.7	1289.7	1289.7	1265.3	1281.3	1286.2	1285.9
Julys GCL did not fill*	2	0	0	14	0	0	0	0	0	33	21	19	20
GCL Avg Pool Elev, ft	1274.4	1270.7	1270.5	1277.1	1278	1274.4	1274.4	1274.4	1274.4	1264.8	1275.2	1274.9	1277.6
PRD MAY–JUN Discharge, cfs	165,956	157,255	156,266	166,530	174,141	165,540	165,540	165,540	165,540	185,814	178,229	166,150	173,730
BRN Jul EOM Elev,ft	2068.6	2067.8	2067.8	2068.6	2068.6	2068.6	2068.6	2068.6	2068.6	2068.5	2057.9	2057.9	2067.1
Julys BRN did not fill*	42	32	32	42	42	42	42	42	42	31	50	50	50
BRN Avg Pool Elev, ft	2059.2	2061.4	2061.4	2059.1	2060.7	2059.2	2059.2	2059.2	2059.2	2055.9	2053.3	2053.3	2063.8
DWR JUL EOM Elev, ft	1580.6	1590.7	1593.8	1536.8	1598.7	1600	1600	1600	1600	1571.7	1524	1573.6	1551.9
Julys DWR did not fill*	39	17	11	50	1	0	0	0	0	25	50	41	41
DWR Avg Pool Elev, ft	1553.9	1549	1548.7	1535.7	1563.6	1554.2	1554.2	1559.9	1559.9	1545.4	1520.5	1549.6	1533.9
LGR APR2–JUN Discharge, cfs	100,277	97,309	96,600	99,727	98,229	97,645	97,645	97,666	97,666	104,070	101,802	97,737	99,920
LGR JUL–AUG Discharge, cfs	32,016	31,311	30,874	33,867	30,088	29,433	29,433	29,433	29,433	41,073	33,857	34,262	39,895
TDA APR2–JUN Discharge, cfs	268,039	259,741	257,103	267,265	274,892	267,903	267,902	267,923	267,923	300,032	292,817	264,514	280,854
TDA JUL–AUG Discharge, cfs	151,631	150,229	152,758	162,383	159,455	148,479	148,448	148,454	148,099	192,719	177,173	172,470	177,095
Average System Energy, MW	15,416	15,554	15,725	15,381	14,581	14,588	14,449	15,139	15,327	14,320	14,774	14,686	15,108
Snake R. Travel Time, APR2–JUN, (days)	8	9	9	8	8	1	1	3	3	3	3	3	7
Snake R. Travel Time, JUL–AUG, (days)	25	28	29	23	26	2	2	8	8	6	7	7	20
Columbia R. Travel Time From Snake R. Confluence to BON, APR2–JUN, (days)	9	9	10	9	9	8	8	8	8	8	8	8	8
Columbia R. Travel Time From Snake R. Confluence to BON, JUL–AUG, (days)	16	17	16	15	16	16	16	16	15	12	13	13	13
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, APR2–JUN (days)	17	18	19	17	17	9	9	11	11	11	11	11	15
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, JUL–AUG (days)	41	45	45	38	42	18	18	24	23	18	20	20	33
Grand Coulee Water Retention Time, APR2–JUN (days)	28	27	28	31	30	27	24	28	28	21	23	25	24
Grand Coulee Water Retention Time, JUL–AUG (days)	51	51	49	39	47	52	52	52	52	29	37	42	42

4.2.6 SOS 5b – Natural River Operation, 4.5–Month Drawdown

Impacts

Reservoir Elevations – Average reservoir elevations were lower under SOS 5b than under SOS 2c for Libby and Hungry Horse. They were the same for Grand Coulee and Brownlee, and higher for Dworshak. They were expected to be higher at Dworshak because no drafts were made from the project for water budget and the reservoir was held near the flood control rule curve elevation unless it was necessary to draft water to help refill the lower Snake projects following drawdown.

Refill Probability – Refill probability in July for SOS 5b was generally the same as under SOS 2c, however, refill probability was improved at Dworshak due to the reservoir being held at higher levels through most of the year. Compared to SOS 5a, Dworshak refill probability in July was higher because the project was not drafted to refill the lower Snake projects until September due to the longer drawdown period.

Flows – Spring flows for SOS 5b were about the same as for SOS 2c. Summer flows on the lower Snake and lower Columbia were lower as a result of decreased flows from the lower Snake projects during the refill period following drawdown as well as the removal of drafts for water budget from Dworshak.

Power Generation – Average system energy in SOS 5b was 828 MW lower than in SOS 2c. As in SOS 5a, this difference was primarily due to the fact that the lower Snake projects were unable to generate power when drawn down to the levels specified in this alternative.

Water Travel Time – For the Snake River, travel times for SOS 5b and SOS 5c were the lowest of any alternative in both the spring and summer. This result is expected since these alternatives incorporated a drawdown of lower Snake projects to natural river condition, which is designed to decrease water travel time. The travel time for the Columbia River in the spring was 8 days. Although this is the lowest travel time attained, it was also achieved under seven other alternatives. In the summer, the travel time in the Columbia was 16 days, which is the same as for SOS 2c. The overall decrease in travel time from the upper Snake River down through Bonneville Dam compared to SOS 2c was 8 days in the spring and 23 days in the summer.

Water Retention Time – Water retention time at Grand Coulee was the same as SOS 2c in the spring and 1 day higher in the summer. The 52–day retention time attained in the summer was the highest achieved and was only attained in 3 other alternatives.

Anomalies

Two anomalies were identified in this option. The first is that in September, Ice Harbor reservoir is not always refilling completely to elevation 438.7 feet. The other anomaly identified in this option is that at certain times Dworshak operates to a minimum flow of 2,000 cfs (56.6 m^3/s), rather than 1,200 cfs (34.4 m^3/s).

4.2.7 SOS 5c – Permanent Natural River Operation

Impacts

Reservoir Elevations – Reservoir elevations were slightly lower at Libby and Hungry Horse and higher at Dworshak, particularly in July. The higher elevations at Dworshak were due to the fact that the reservoir was not drafted for flow augmentation during the spring and summer. Reservoir elevations at Grand Coulee and Brownlee were the same as SOS 2c.

Refill Probability – The refill probability decreased slightly at Libby and Grand Coulee and increased slightly at Hungry Horse. Eliminating the storage draft from Dworshak for flow augmentation resulted in the reservoir refilling at the end of July in every year. This only occurred in three other alternatives. Reservoir refill probability at Brownlee was unchanged.

Flows – Flows were lower in the spring and summer periods for both the Columbia and Snake River systems. This was the result of reductions in reservoir draft for flow augmentation.

Power Generation – Average system energy was 967 MW lower than SOS 2c. This is among the lowest of any alternatives due to the reduced generation associated with reservoir drawdown at the lower Snake and John Day projects.

Water Travel Time – As described above, water travel times in the Snake River for SOS 5c and SOS 5b were the lowest of any alternative. The results in the Columbia River were also similar to SOS 5b, which had the lowest travel time in the spring and the same travel time as SOS 2c in the summer. The overall decrease in travel time from the upper Snake River down through Bonneville Dam compared to SOS 2c was 8 days in the spring and 23 days in the summer, which matched SOS 5b as the lowest overall travel time of any alternative.

Water Retention Time – Water retention time was 4 days less than SOS 2c in the spring and the same in the summer.

Anomalies

None reported.

4.2.8 SOS 6b – Drawdown Operation, 4 projects, 4.5–Month Drawdown

Impacts

Reservoir Elevations – Average reservoir elevations were lower under SOS 6b than under SOS 2c for Libby and Hungry Horse. They were the same for Grand Coulee and Brownlee, and higher for Dworshak. They were expected to be higher at Dworshak because no drafts were made from the project for water budget and the reservoir was held near the flood control rule curve elevation unless it was necessary to draft water to help refill the lower Snake projects following drawdown.

Refill Probability – Refill probability in July for SOS 6b was generally the same as under SOS 2c, however, refill probability was improved at Dworshak due to the reservoir being held at higher levels through most of the year.

Flows – Spring flows for SOS 6b were about the same as for SOS 2c. Summer flows on the lower Snake and lower Columbia were lower as a result of decreased flows from the lower Snake projects during the refill period following drawdown as well as the removal of drafts for water budget from Dworshak.

Power Generation – Average system energy in SOS 6b was 277 MW lower than in SOS 2c. This difference was primarily due to the fact that the lower Snake projects generation capability was limited when drawn down to the levels specified in this option.

Water Travel Time – The water travel times resulting from this alternative for both the Snake and Columbia River systems were lower than those for SOS 2c. This result was expected because it incorporated drawdown of lower Snake and John Day projects.

Water Retention Time – The water retention time was about the same as for SOS 2c.

Anomalies

The only anomaly identified in this option is that at certain times Dworshak operates to a minimum flow of 2,000 cfs (56.6 m^3/s), rather than 1,200 cfs (34.4 m^3/s).

4.2.9 SOS6d – Drawdown Operation, Lower Granite only, 4.5–Month Drawdown

Impacts

Reservoir Elevations – Average reservoir elevations were slightly lower under SOS 6d than under SOS 2c for Libby and Hungry Horse. They were the same for Grand Coulee and Brownlee, and higher for Dworshak. They were expected to be higher at Dworshak because no drafts were made from the project for water budget and the reservoir was held near the flood control rule curve elevation unless it was necessary to draft water to help refill Lower Granite following drawdown.

Refill Probability – Refill probability in July for SOS 6d was generally the same as under SOS 2c, however, refill probability was improved at Dworshak due to the reservoir being held at higher levels through most of the year.

Flows – Spring and summer flows for SOS 6d were about the same as for SOS 2c. Summer flows on the lower Snake and lower Columbia were lower as a result of decreased flows from Lower Granite during the refill period following drawdown as well as the removal of drafts for water budget from Dworshak.

Power Generation – Average system energy in SOS 6d was 89 MW lower than in SOS 2c. This difference was primarily due to the fact that Lower Granite's generation capability was limited when drawn down to the levels specified in this option.

Water Travel Time – The water travel times resulting from this alternative for both the Snake and Columbia River systems were lower than those for SOS 2c, primarily due to the fact that it incorporated drawdown of lower Snake and John Day projects.

Water Retention Time – The water retention time was about the same as for SOS 2c.

Anomalies

The only anomaly identified in this option is that at certain times Dworshak operates to a minimum flow of 2,000 cfs (56.6 m^3/s), rather than 1,200 cfs (34.4 m^3/s).

4.2.10 SOS 9a – Detailed Fishery Operating Plan

Impacts

Reservoir Elevations – Because of the higher volumes of water drafted from many storage reservoirs for flow augmentation in this alternative compared to SOS 2c, reservoir elevations at these projects are significantly lower than in SOS 2c. At Libby, Hungry Horse, and Grand Coulee, the reservoir elevations experienced are the lowest of any alternative. At Dworshak and Brownlee they are also lower than SOS 2c.

Refill Probability – Reservoir refill probability is also very low for many projects compared to SOS 2c due to the large drafts of storage for flow augmentation. At Libby and Grand Coulee, reservoir refill probability is the lowest of any alternative, and it is also lower for Hungry Horse. Refill probability at Dworshak and Brownlee is higher than SOS 2c because in SOS 9a, less water is drafted from these projects during the summer. This is partially due to the fact that in this alternative higher volumes of water from the Upper Snake system are assumed to be available to help meet lower Snake flow targets. In addition, flow targets on the lower Snake River are lower than in SOS 2c. This is because in SOS 9a the lower Snake projects are drawn down to spillway crest elevation. Operation at spillway crest elevation decreases the water travel time for the same amount of flow, thereby allowing the flow targets to be reduced from what they are in the SOS 2c when the projects are operated at a higher elevation.

Flows – Flows in the Columbia and Snake River systems are the highest of any alternative evaluated, both for the spring and summer periods.

Power Generation – Average system energy was 1,096 MW lower than in SOS 2c. This is the lowest of any alternative evaluated. It is a result of reduced generation associated with both reservoir drawdowns in the lower Snake and John Day projects as well as large amounts of flow augmentation and spill.

Water Travel Time – Water travel time was lower than SOS 2c for both the Snake and Columbia River systems. On the Columbia River system, the water travel time was the lowest of any alternative. This result is expected since one of the primary objectives of this alternative was to minimize water travel time.

Water Retention Time – The water retention time at Grand Coulee was the lowest of any alternative. This was due to the low reservoir levels in Grand Coulee associated with large drafts for flow augmentation. Water passes through the reservoir more quickly when the reservoir is drawn down and this results in decreased water retention time.

Anomalies

None reported.

4.2.11 SOS 9b – Adaptive Management

Impacts

Reservoir Elevations – Reservoir elevations at the end of July are lower for Libby, Grand Coulee, Brownlee, and Dworshak than they are in SOS 2c. Average reservoir elevations are the same as SOS 2c for Libby, they are higher at Grand Coulee and Hungry Horse, and they are lower for Brownlee and Dworshak.

Refill Probability – Refill probability is lower than SOS 2c for Libby, Grand Coulee, Brownlee, and Dworshak. At Brownlee and Dworshak, the projects never refill at the end of July in any year due to the large amount of storage that is drafted for flow augmentation during this period.

Flows – Spring and summer flows on the Columbia and Snake River systems are higher than SOS 2c due to the higher volumes of flow augmentation incorporated in SOS 9b.

Power Generation – Average system energy was 642 MW lower than in SOS 2c.

Water Travel Time – Water travel time was lower than SOS 2c during all periods and for both river systems. This was expected since this alternative incorporates larger volumes of flow augmentation and more reservoir drawdown than SOS 2c.

Water Retention Time – Water retention time was lower than SOS 2c due to lower reservoir elevations during the spring and summer periods.

Anomalies

None reported.

4.2.12 SOS 9c – Balanced Impacts Operation (Idaho Plan)

Impacts

Reservoir Elevations – Under this alternative, reservoir elevations were higher than SOS 2c for Libby and Hungry Horse and they were lower for Grand Coulee, Dworshak, and Brownlee. Higher elevations at Libby and Hungry Horse were the result of incorporating Integrated Rule Curves (IRCs) at these projects. These IRCs attempt to keep the reservoirs higher for resident fish and other uses. Lower elevations at the other projects are due to higher amounts of flow augmentation used to meet flow targets for anadromous fish.

Refill Probability – Refill probability at the storage projects generally corresponded to the reservoir elevation results. At Libby and Hungry Horse, the refill probability improved because the reservoirs were held higher in accordance with the IRCs. At the other storage projects, the refill probability was lower than for SOS 2c because of the increased drawdown caused by higher levels of flow augmentation.

Flows – Spring flows were lower and summer flows were higher in both the lower Columbia and Snake River systems. The lower spring flows were the result of operating to lower flow targets in the Snake River during the spring. This was done because during this period the projects were drawn down to near spillway crest. Under this operation, the flow targets did not need to be as high to achieve the same flow velocity as was achieved under SOS 2c when the projects were operated at higher levels. The higher summer flows were due to higher flow targets during this period in SOS 9c than in SOS 2c.

Power Generation – Average system energy was 730 MW lower than in SOS 2c. Some of the factors that contributed to this reduced generation were drawdown of lower Snake projects, implementation of IRCs at Libby and Hungry Horse, and increased flow augmentation.

Water Travel Time – Water travel time was lower than SOS 2c during all periods and for both river systems. This result was expected since this alternative incorporates larger volumes of flow augmentation and more reservoir drawdown than SOS 2c

Water Retention Time – Water retention time was again lower than SOS 2c due to lower reservoir elevations at Grand Coulee during the spring and summer periods.

Anomalies

None reported.

4.2.13 SOS PA – Preferred Alternative

Impacts

Reservoir Elevations – Average reservoir elevations were higher than SOS 2c for Libby, Hungry Horse, Grand Coulee, and Brownlee. July reservoir elevations were higher for Hungry Horse and lower for the remaining projects. The higher average elevations were the result of operating the projects closer to elevations required for flood control during the flood control period. Lower elevations in July were due to increased use of reservoir storage to provide water for flow augmentation.

Refill Probability – The refill probability at the storage projects was lower than SOS 2c because of the increased draft of reservoirs during the summer for higher levels of flow augmentation. Brownlee Reservoir never fully refilled in July in this alternative.

Flows – For the lower Snake River projects, spring flows were about the same as SOS 2c and summer flows were higher. Columbia River flows were higher than SOS 2c in both the spring and summer. These changes in flow were expected since the volume of water released for flow augmentation increased for SOS PA compared to SOS 2c.

Power Generation – Average system energy was 308 MW lower than in SOS 2c. This change was primarily due to the increased flow augmentation included in this alternative.

Water Travel Time – Water travel time was lower than SOS 2c during all periods and for both river systems. This result was expected since this alternative incorporates larger volumes of flow augmentation than SOS 2c. The overall decrease in travel time from the upper Snake River down through Bonneville Dam compared to SOS 2c was 2 days in the spring and 8 days in the summer.

Water Retention Time – Water retention time was lower than SOS 2c due to lower reservoir elevations at Grand Coulee during the spring and summer periods.

Anomalies

None reported.

CHAPTER 5

ROSE COMPARISON OF ALTERNATIVES

In Chapter 4, the results of each alternative were compared to SOS 2c, the "No–Action" alternative. In Chapter 5, the results of all alternatives and options are compared to each other using the same general categories from Chapter 4 of reservoir elevation, refill probability, flows, and average energy generated. The comparison of alternatives provided below refers to results shown in Table 4–3.

5.1 RESERVOIR ELEVATIONS

In comparing all alternatives and options in terms of reservoir elevation at Libby, it was found that average yearly elevations and elevations at the end of July were lowest under SOS 9a. Yearly average reservoir elevations at Libby were highest under SOS 4c and SOS9c. The end of July reservoir elevations were highest under SOS 4c. At Hungry Horse, average yearly and end of July reservoir elevations were lowest under SOS 9a. At Grand Coulee, yearly average elevations and end of July elevations were lowest under SOS 9a. These results are due to the fact that the largest drafts of water from reservoirs for flow augmentation were made under this operating strategy. Reservoir elevations at Hungry Horse were highest under SOS 4c. At Grand Coulee, average yearly reservoir elevations were also highest under SOS 4c.

At Dworshak, average yearly reservoir elevations and end of July elevations were lowest under SOS 9b. These results also seem reasonable, because SOS 9b drafts large volumes of water from Dworshak for flow augmentation, causing an even larger decrease of the average reservoir elevation than occurs under other alternatives with flow augmentation. Average yearly reservoir elevations at Brownlee were fairly consistent among all alternatives, ranging from a minimum of 2,053.3 feet (625.8 m.) under SOS 9b and SOS 9c to 2,063.8 feet (629.0 m.) under SOS PA.

5.2 REFILL PROBABILITY

At Libby, refill probability in July was highest under SOS 9a. Refill probability at Hungry Horse was highest under SOS 4c. Conversely, refill probability at Libby and Hungry Horse was lowest under alternative SOS 9a. The low refill probability at these projects under SOS 9a reflects the fact that the projects were used to provide relatively large volumes of water for flow augmentation.

At Grand Coulee, refill probability in July ranged from 100 percent under many alternatives, to refilling only about 34 percent of the time under SOS 9a. The low refill probability at Grand Coulee under SOS 9a is the result of large drafts from Grand Coulee to provide water for flow augmentation under this option.

Refill probability at Dworshak in July is 100 percent under SOS's 5b, 5c, 6b, and 6d. Under SOS 4c, the reservoir is also maintained at fairly high and stable levels for resident fish, wildlife, and recreation, thereby improving refill probability. Under SOS's 5b, 5c, 6b, and 6d, this high refill probability is because the reservoir is maintained at high elevations to enable it to provide water from storage to help refill the lower Snake projects if needed following drawdown. Refill probability at Dworshak is lowest under SOS's 2d, and 9b, in which the reservoir never completely refills in July in any year. This is due to large drafts which occur for flow augmentation. Finally, at Brownlee, operations do not vary significantly under any of the options, so refill probabilities do not change much from one option to another.

5.3 FLOW

Spring flows on the Columbia River from April 16 through June are lowest under SOS 1b. The same is true for flows at Lower Granite from April 16 though June. These results are expected because this option optimizes the system for power generation and does not provide higher flows during these spring periods specifically for fish. The maximum flow at Priest Rapids from May through June occurred under SOS 9a. This alternative attempts to meet specified target flows in spring, thereby causing the release of large volumes of water to provide high flows. At Lower Granite, spring flows during the period April 16 through June were highest under SOS 3b and highest during the period July through August under SOS 9a. At The Dalles, flows in the spring and summer were highest under SOS 9a. These results also seemed reasonable, since the objective of this option was to provide flow augmentation.

5.4 POWER GENERATION

Average energy was maximized under SOS 1b, and was at a minimum under SOS 9a. These results were reasonable because SOS 1b was designed to optimize power production and SOS 9a involved drawdown on the lower Snake River and flow augmentation from other projects. This type of drawdown operation restricted the ability to generate on the lower Snake projects during the drawdown period and other projects were not able to completely compensate for this loss due to large releases and spill for flow augmentation.

5.5 WATER TRAVEL TIME

Water travel time was lowest for the spring and summer periods under SOS 5b and SOS 5c. This occurred because under both of these operating strategies, the projects on the lower Snake River were drawn down to natural river conditions. As expected, this had a dramatic impact by increasing the velocity of the water and thereby decreasing the travel time for a given level of flow. Under these strategies, the travel time was reduced by 7 days in the spring and 23 days in the summer compared to SOS 2c. The highest travel time in the Snake River system occurred under SOS 1b, which might be expected since it incorporated no actions designed to decrease travel time such as reservoir drawdown or flow augmentation. The lowest water travel time in the spring for the Columbia River system was 8 days, and this was achieved under 8 different strategies, from SOS 5b to SOS PA. In the summer, the lowest travel time achieved for the Columbia River system was 12 days under SOS 9a. This result was expected since this alternative combined some of the highest amounts of flow augmentation in the lower Columbia River during the summer with reservoir drawdown to spillway crest at the John Day project. The overall travel time from the upper Snake River down through the Columbia River at Bonneville Dam was lowest under SOS 5b and SOS 5c. This was again due to the significant decrease in travel time through the Snake River system associated with drawdown of lower Snake projects to natural river conditions.

5.6 WATER RETENTION TIME

The water retention time at Grand Coulee was highest under SOS 2d in the spring and SOSs 5b, 5c, 6b, and 6d in the summer. The high water retention times under these strategies were primarily due to high reservoir levels during the spring and summer period at Grand Coulee. The alternative with the lowest water retention time was SOS 9a. This was the result of very low reservoir levels experienced under this strategy during the spring and summer periods due to large releases of water from storage for flow augmentation.

CHAPTER 6

LIST OF PREPARERS

Table 6–1. List of Preparers, Bonneville Power Administration

Name	Education/Years of Experience	Experience and Expertise	Role In Preparation
Steve Davis	B.S. Civil Engineering 7 years	Hydroregulation Studies	Hydroregulaton
Ken Dragoon	M.S. Physics 11 years	Hydroregulation System Operations	Hydroregulation
Jed Folts	B.S. Engineering, Math 10 years	Hydroregulation Programming	Hydroregulation
Bob Neal	B.S. Physics 15 years	Hydroregulation System Operations	Hydroregulation
Audrey Perino	M.A. Economics 15 years	Hydroregulation System Economics	Hydroregulation
Jenny Wilson	B.S. Elec. Engineering 8 years	Hydroregulation System Operations	Hydroregulation
Philip Thor	B.S. Mechanical Engineering 17 years	System Operations	Strategy Development and Review

Table 6–2. List of Preparers, Corps of Engineers

Name	Education/Years of Experience	Experience and Expertise	Role In Preparation
James Barton	M.B.A. Management B.S. Civil Engineering 15 years	Hydraulic Engineering	ROSE Coordinator Hydroregulation Review
Dick Mittelstadt	M.S. Civil Engineering B.S. Mech. Engineering 32 years	Hydropower Engineering	Hydroregulation Review
Chris Lynch	M.S. Civil Engineering B.S. Math 8 years	Hydrologic	Technical Support

Table 6–3. List of Preparers, Bureau of Reclamation

Name	Education/ Years of Experience	Experience/ Expertise	Expertise	Role In Preparation
Jim Fodrea	B.S. Civil Engineering 19 years	Power System Planning	Power System Planning	Former Rose Chair, Hydroregulation Review
Romeo Wisco	B.S. Elec. Engineering 15 years	Power System Analysis	Power System Analysis	Hydroregulation Review

Table 6–4. List of Preparers, Northwest Power Planning Council

Name	Education/Years of Experience	Experience/Expertise	Role In Preparation
John Fazio	M.S. Physics B.S. Physics 16 years	Power System Analysis	Hydroregulation Review

Table 6–5. List of Preparers, Pacific Northwest Utilities Conference

Name	Education/Years of Experience	Experience/Expertise	Role In Preparation
Rick Paschall	M.S. Economics B.S. Mathematics 9 years	Power System Analysis	Hydroregulations & Review

CHAPTER 7

GLOSSARY OF TERMS AND ACRONYMS

Acre–foot: The volume of water that will cover an area of one acre to a depth of one foot (326,000 gallons or 0.5 second foot days). It equals 1,233.5 m^3.

Actual Energy Capability (AEC): Each PNCA party's generating capability based on operating the coordinated system's reservoirs to the energy content curve or to proportional draft points.

Actual Energy Regulation (AER): Hydro regulation study used to determine each party's Actual Energy Capability.

Anadromous fish: Fish, such as salmon or steelhead trout, that hatch in fresh water, migrate to and mature in the ocean, and return to fresh water as adults to spawn.

Annual operating plan: A yearly plan for operating reservoirs on the Columbia River. Such a plan is specifically required by the Columbia River Treaty and by the Pacific Northwest Coordination Agreement.

Assured Operating Plan: A study mandated by the Columbia River Treaty that determines U.S. and Canadian benefits of Treaty projects.

Assured refill curve (ARC): A representation of the lowest drawdown level from which a reservoir could refill given a repetition of the third–lowest runoff year of record.

Average megawatt (aMW): The average amount of energy (in megawatts) supplied or demanded over a specified period of time; equivalent to the energy produced by the continuous operation of one megawatt of capacity over the specified period.

Baseload: In a demand sense, a load that varies only slightly in level over a specified time period. In a supply sense, a plant that operates most efficiently at a relatively constant level of generation.

Bypass system: Structure in a dam that provides a route for fish to move through or around the dam without going through the turbines.

Canadian Entitlement: Canada's share of hydro–power generated at downstream projects by the use of the Columbia River Treaty projects.

Canadian Entitlement Allocation Agreements: Contracts that specify how much power is to be provided by the five mid–Columbia projects as a result of increased flows made possible by the Columbia River Treaty projects.

Capacity: The maximum sustainable amount of power that can be produced by a generating resource at specified times under specified conditions or carried by a transmission facility; also, the maximum rate at which power can be saved by a nongenerating resource.

Capacity/energy exchange: A transaction in which one utility provides another with capacity service in exchange for additional amounts of firm energy (exchange energy) or money, under specified conditions, usually during off–peak hours.

Columbia River Treaty: U.S.–Canadian agreement for bilateral development and management of the Columbia River to achieve flood control and increased power production.

Columbia Storage Power Exchange (CSPE): A non–profit corporation of 11 Northwest utilities that issued revenue bonds to purchase the Canadian Entitlement and sell it to 41 Northwest utilities through a Bonneville Power Administration exchange agreement.

Composite Reservoir: A PNCA operational procedure that simplifies in–lieu energy transactions by treating federal upstream reservoirs as one reservoir located at Grand Coulee and assuming the same flow time between these upstream reservoirs and the mid–Columbia projects.

Coordinated operation: The operation of interconnected electrical systems to achieve greater reliability and economy; as applied to hydro resources, the operation of a group of hydro plants to obtain optimal regional power benefits.

Content: An amount of water stored in a reservoir, usually expressed in terms of KSFD or MAF.

Critical period: That portion of the historical 50–year streamflow record which, when combined with the drafting of all storage reservoirs from full to empty, would produce the least amount of energy shaped to seasonal load patterns.

Critical rule curves (CRC): A set of curves that define reservoir elevations that must be maintained to ensure that firm energy requirements can be met under the most adverse historical streamflow conditions. Critical rule curves are derived for all years in the critical period. They are used for proportional draft of reservoirs.

Critical water: Streamflows which occurred during the critical period.

Cubic feet per second (cfs): A unit of measurement pertaining to flow or discharge of water. One cfs is equal to 449 gallons per minute. A thousand cubic feet per second is abbreviated as kcfs.

Demand: The rate at which electric energy is used, whether at a given instant, or averaged over any designated period of time.

Discharge: Volume of water released from a dam or powerhouse at a given time, usually expressed in cubic feet per second.

Displacement: The substitution of less expensive energy generation for more expensive energy generation (usually hydroelectric energy transmitted from the Pacific Northwest or Canada is substituted for more expensive coal and oil–fired generation in California). Such displacement usually means that a thermal plant can reduce or shut down its production, saving money and often reducing air pollution.

Draft: Release of stored water from a storage reservoir.

Drawdown: The distance that the water surface of a reservoir is lowered from a given elevation as water is released from the reservoir. Also refers to the act of lowering reservoir levels. (Similar to draft.)

Elevation: Height in feet above sea level. Usually refers to reservoir forebay; used interchangeably with content because a forebay elevation implies a specific reservoir content. Tailwater level is also expressed as an elevation.

Energy: The ability to do work (i.e., exert a force over distance). Energy is measured in calories, joules, KWH, BTUs, MW–hours, and average MWs.

Energy content curves (ECC): A set of curves that establishes limits on the amount of reservoir drawdown permitted to produce energy in excess of FELCC.

FELCC: Firm energy load carrying capability (FELCC) is the amount of energy the region's generating system, or an individual utility or project, can be called on to produce on a firm basis during actual operations. FELCC is made up of both hydro and non–hydro resources, including power purchases.

Firm energy: The amount of energy that can be generated given the region's worst historical water conditions. It is energy produced on a guaranteed basis.

Fish ladders: A series of ascending pools constructed to enable salmon or other fish to swim upstream around or over a dam.

Fish passage facilities: Features of a dam that enable fish to move around, through, or over without harm. Generally an upstream fish ladder or a downstream bypass system.

Fixed drawdown period: The late summer and fall when the volume of the next spring runoff is not yet known, and reservoir operations are guided by fixed rule curves based on historical streamflow patterns.

Flood control rule curve: A curve, or family of curves, indicating the minimum reservoir drawdown required to control floods. (Also called Mandatory Rule Curve or Upper Rule Curve).

Flow: The volume of water passing a given point per unit of time. Same as streamflow.

Forced outage: An unforeseen outage that results from emergency conditions.

Forced outage reserves: Peak generating capability planned to be available to serve peak loads during forced outages of generating units.

Forebay: The portion of a reservoir at a hydroelectric plant that is immediately upstream of a dam or powerhouse.

Forebay elevation: Height of the forebay above sea level.

Freshet: A rapid rise in streamflow caused by heavy rains or snowmelt.

Generation: Act or process of producing electric energy from other forms of energy. Also refers to the amount of electric energy so produced.

Headwater benefits: Gains in usable downstream energy as a result of upstream storage.

Historical streamflow record: The unregulated streamflow data base of the 50 years beginning in July 1928; data are modified to adjust for factors such as irrigation depletions and evaporation for the particular operating year being studied.

Hydraulic Head: The vertical distance between the surface of the reservoir and the surface of the river immediately downstream from the powerhouse. Head is the difference between forebay and tailwater elevations.

Hydroelectricity: The production of electric power through use of the gravitational force of falling water.

Hydrology: The science dealing with the continuous cycle of evapotranspiration, precipitation, and runoff.

Hydrometeorological observations: Data that combine snowpack measurements and climatic forecasts to predict runoff.

Inflow: Water that flows into a reservoir or forebay during a specified period.

In—lieu energy: Energy provided by a reservoir owner instead of water to which a downstream party is entitled.

Intake: The entrance to a conduit through a dam or water facility.

Interchange energy: Electric energy received by one utility system usually in exchange for energy to be delivered to another system at another time or place. Interchange energy is different from a direct purchase or sale, although accumulated energy balances are sometimes settled in cash.

Interruptible: A supply of power which, by agreement, can be shut off on relatively short notice (from minutes to a few days).

KAF: A thousand acre feet; same as .504 thousand second foot days.

KCFS: A measurement of water flow equivalent to 1,000 cubic feet of water passing a given point for an entire second.

KSFD: A volume of water equal to 1,000 cubic feet of water flowing past a point for an entire day. Same as 1.98 KAF.

Levee: An embankment constructed to prevent a river from overflowing.

Load: The amount of electric power or energy delivered or required at any specified point or points on a system. Load originates primarily at the energy—consuming equipment of customers.

Lock: A chambered structure on a waterway closed off with gates for the purpose of raising or lowering the water level within the lock chamber so ships can move from one elevation to another along the waterway.

MAF: Million acre feet. The equivalent volume of water that will cover an area of one million acres to a depth of one foot. One MAF equals 1,000 KAF.

Mainstem: The principal river in a basin, as opposed to the tributary streams and smaller rivers that feed into it.

Megawatt–hour (MWh): A unit of electrical energy equal to one megawatt of power applied for one hour.

Megawatts (MW): A megawatt is one million watts, a measure of electrical power or generating capacity. A megawatt will typically serve about 1,000 people. The Dalles Dam produces an average of about 1,000 megawatts.

Mid–Columbia: The section of the Columbia River from Grand Coulee Dam to its junction with the Snake River.

Nitrogen supersaturation: A condition in which the concentration of dissolved nitrogen exceeds the saturation level of water. Excess nitrogen can harm the circulatory systems of fish.

Nonfirm energy: Energy in excess of firm energy, which is available when water conditions are better than those in the critical period; generally such energy is sold on an interruptible (nonguaranteed) basis. Also called secondary energy.

Nonpower operating requirements: Operating requirements at hydroelectric projects that pertain to navigation, flood control, fish and wildlife, recreation, irrigation, and other nonpower uses of the river.

Northwest Power Pool Coordinating Group: An operating group made up of BPA, the Corps, Reclamation, and public and private generating utilities in the Northwest. One of the group's functions is administering the Pacific Northwest Coordination Agreement.

Offpeak hours: Period of relatively low demand for electrical energy, as specified by the supplier (such as the middle of the night).

Operating limits: Also called operating requirements or constraints. Limits or requirements that must be factored into the planning process for operating reservoirs and generating projects. (Also see nonpower operating requirements, above, and operating requirements, below.)

Operating procedure: Alternative method substituted for a provision in the PNCA contract by agreement of parties, clarification of the contract, or method for carrying out a procedure.

Operating requirements: Guidelines and limits that must be followed in the operation of a reservoir or generating project. These requirements may originate from authorizing legislation, physical plant limitations, environmental impact analysis, or input from government agencies and other entities representing specific river uses. Operating requirements are submitted annually to the Northwest Power Pool by project owners for planning purposes.

Operating rule curve: A composite curve, derived from a family of curves, indicating how a reservoir is to be operated under specific conditions. The operating rule curve accounts for multiple operating objectives, including flood control, hydropower generation, releases for fish migration, and refill.

Operating year: The 12–month period from August 1 through July 31.

Outage: In a power system, the state of a component (such as a generating unit, transmission line, etc.) when it is not available to perform its function due to some event directly associated with the component.

Outflow: The water that is released from a project during a specified period.

Pacific Northwest Coordination Agreement: A binding agreement among BPA, the Corps, Reclamation, and the major hydro generating utilities in the Pacific Northwest that stemmed from the Columbia River Treaty. The Agreement specifies a multitude of operating rules, criteria, and procedures for coordinating operation of the Pacific Northwest hydropower system for power production. It directs operation of major generating facilities as though they belonged to a single owner.

Peak load: The maximum electrical demand in a stated period of time. It may be the maximum instantaneous load or the maximum average load within a designated period of time.

Project: Run–of–river or storage dam and related facilities; also a diversion facility.

Project outflow: The volume of water per unit of time released from a project. Same as discharge and outflow.

Proportional draft: A condition in which all reservoirs are drafted among rule curves in the same proportion to meet firm loads.

Proportional draft point (PDP): Reservoir elevation that guides operations whenever drafting to the ECC will not produce FELCC; all reservoirs' PDPs are the same proportional distance between the critical rule curves unless restricted by Non Power Requirements.

Provisional energy: Energy produced by drafting below the ECC or PDP and delivered under contracts which provide for the return of the energy to the delivering utility under certain conditions. Provisional energy is called Advance Energy in contracts between BPA and its direct service industrial customers.

Refill: The point at which the hydro system is considered "full" from the seasonal snowmelt runoff. Also, refers to the annual process of filling a reservoir.

Reliability: For a power system, a measure of the degree of certainty that the system will continue to meet load for a specified period of time.

Reregulation: Storing erratic discharges of water from an upstream hydroelectric plant and releasing them relatively uniformly from a downstream storage plant.

Reregulating reservoir: A reservoir located downstream from a hydroelectric peaking plant having sufficient pondage to store the widely fluctuating discharges from the peaking plant and release them in a relatively uniform manner downstream.

Reservoir content: See content and reservoir storage.

Reservoir draft rate: The rate at which water, released from storage behind a dam, reduces the elevation of the reservoir.

Reservoir elevation: The height above sea level of the water stored behind a dam. Same as forebay elevation.

Reservoir storage: The volume of water in a reservoir at a given time. Same as reservoir content. Reservoir storage implies a reservoir elevation. Tables are used to convert content to elevation at each reservoir.

Resident fish: Fish species that reside in fresh water throughout their lives.

Restoration: Adjustments that permit all PNCA projects to carry the same firm energy load with as without Canadian Treaty storage; projects losing load–carrying capability are restored by projects gaining capability.

Rule curves: Water levels, represented graphically as curves, that guide reservoir operations. See critical rule curves, energy content curves, and flood control rule curves.

Run–of–river dams: Hydroelectric generating plants that operate based only on available inflow and a limited amount of short–term storage (daily/weekly pondage).

Secondary energy: Hydroelectric energy in excess of firm energy, often used to displace thermal resources. Sometimes called nonfirm energy.

Secretary's Principles: The framework of rights and obligations that forms the basis of PNCA.

Shaping: The scheduling and operation of generating resources to meet seasonal and hourly load variations. Load shaping on a hydro system usually involves the adjustment of reservoir releases so that generation and load are continuously in balance.

Shifting: In planning, moving surplus or deficit FELCC from one year of the critical period to another to increase the FELCC's value.

Smolt: A juvenile salmon or steelhead migrating to the ocean and undergoing physiological changes to adapt its body from a freshwater to a saltwater environment.

Spawning: The releasing and fertilizing of eggs by fish.

Spill: Water passed over a spillway without going through turbines to produce electricity. Spill can be forced, when there is no storage capability and flows exceed turbine capacity, or planned, for example, when water is spilled to enhance juvenile fish survival.

Spillway: Overflow structure of a dam.

Storage energy: The energy equivalent of water stored in a reservoir above normal bottom elevation.

Storage reservoirs: Reservoirs that have space for retaining water from springtime snowmelts. Careful scheduling of reservoir refill serves to prevent floods in high runoff years. Retained water is released as necessary for multiple uses—power production, fish passage, irrigation, and navigation.

Streamflow: The rate at which water passes a given point in a stream, usually expressed in cubic feet per second (cfs).

Surplus: Energy generated that is beyond the immediate needs of the producing system. This energy may be sold on an interruptible basis or as nonfirm power.

Tailwater: Water immediately below the power plant. Tailwater elevation refers to the level of that water.

Thermal power plant: Generating plant that converts heat energy into electrical energy. Coal, oil, and gas—fired power plants and nuclear power plants are common thermal resources.

Thermal Resource: Electrical generating means that rely on conventional fuels such as coal, oil, and gas.

Transmission: Transporting electric energy in bulk from one point to another in the power system rather than to individual customers.

Transmission grid: An interconnected system of electric transmission lines and associated equipment for transferring electric energy in bulk.

Turbine: Machinery that converts kinetic energy of a moving fluid, such as falling water or steam, to mechanical power. Turbines are used to turn generators that convert mechanical energy to electricity.

Usable storage: Water occupying active storage capacity of a reservoir.

Usable storage capacity: The portion of the reservoir storage capacity in which water normally is stored, or from which water is withdrawn for beneficial uses, in compliance with operating agreements.

Variable energy content curve (VECC): The January through July portion of the energy content curve. The VECC is based on the expected amount of spring runoff.

Water Budget: A volume of water to be reserved and released in the spring if needed to assist in the downstream migration of juvenile salmon and steelhead.

Water Rights: Priority claims to water. In western States, water rights are based on the principle "first in time, first in right," meaning older claims take precedence over newer ones.

Watt: A measure of the rate at which energy is produced, exchanged, or consumed.

Wheeling: Using transmission facilities of one system to transmit power of and for another system.

TECHNICAL EXHIBIT A

SYSTEM OPERATING STRATEGY (SOS) ALTERNATIVES

A.1 SOS 1 – PRE–ESA OPERATION

Objective: Base case operations without the various measures directed at anadromous fish or resulting from ESA consultation.

Discussion/Background: This SOS has two options. One option establishes a reference case upon which all other alternatives are built. It incorporates the basic operating requirements of the physical system and the traditional river uses. The other option represents one end of the range of possibilities for power generation, namely maximum possible generation, matching load to resources in a manner that will minimize power costs.

SOS 1a Pre–Salmon Summit Operation represents operations as they existed from around 1983 through the 1990–91 operating year, prior to the recent listing of three species of salmon as endangered or threatened. Most analytical simulations use this operation as a base case.

SOS 1b Optimum Load–Following Operation represents operations as they existed prior to changes resulting from the Regional Power Act. It attempts to optimize the load following capability of the system within certain constraints of reservoir operation. This operation is designed to demonstrate how much power could be produced if most flow–related operations to benefit anadromous fish were eliminated. It assumes that maximum fish transportation would be used to aid juvenile fish migration.

Requirements for SOS 1a: Water Budget – provide sufficient flow on the Columbia to meet a target of 134,000 cfs at Priest Rapids in May. Draft water budget volume, up to maximum allowed from specific reservoirs (see below), as needed to attempt to meet an 85,000 cfs target at Lower Granite in May.

- Libby – assume no additional changes to Libby operations for the benefit of Kootenai white sturgeon.
- Vernita Bar – maintain a minimum flow at Priest Rapids to meet Vernita Bar Agreement.
- Upper Snake River operations – maintain operations as they existed in 1990–91; assumes no additional water volume from the Upper Snake river.
- Dworshak – draft up to 600 KAF from Dworshak in May for Water Budget; assume no system flood control transfer from Dworshak to Grand Coulee.
- Brownlee – draft up to 110 KAF draft in May for Water Budget; assume no system flood control transfer from Brownlee to Grand Coulee.
- Lower Snake Projects – operate the 4 lower Snake Projects within 3–5 feet of full pool.

Requirements for SOS 1b: Eliminate the following requirements – Water Budget, fish spill requirements, restrictions on operation of Bonneville's Second Powerhouse, refill targets at Libby, Hungry Horse, Grand Coulee, Dworshak and Albeni Falls, and fish–related rate of change on Snake River flows in May.

- Keep the following operations the same as in the base case (**SOS 1a**) or as noted – Canadian project operations remain the same, Vernita Bar Agreement is met, the same Energy Content Curves (ECCs) and Variable Energy Content Curves (VECCs) are used as in the base case, and current provisional drafting allowed.

- Libby – change minimum project flow to 3000 cfs, and meet summer draft limits (i.e., 5 to 10 feet).

- Hungry Horse – eliminate maximum flow restriction from mid–October through mid–November, and eliminate draft limit.

- Grand Coulee – eliminate requirement for 1240 feet elevation in May, meet 1285 feet elevation in July through September, and meet 1220 feet elevation limit.

- Upper Snake River operations – maintain operations as they existed in 1990–91; assumes no additional water volume from the Upper Snake river.

- Dworshak – meet minimum project flows (i.e., 2000 cfs, except in August, 1000 cfs), meet summer draft limits, and meet maximum discharge requirement October through November (i.e., 1300 cfs plus inflow).

- Lower Snake Projects – remove minimum flow limit (i.e., 11,500 cfs) during fall and winter.

Short–term Operation Requirements: Operate in the short–term to meet power demands while satisfying non–power requirements.

- Flood Control – interpolate linearly between end of month flood control elevations on a daily basis. Load factoring is allowed within a specified forebay range.

- Vernita Bar Agreement – provide 55 kcfs during heavy load hours from October 15 through November. Provide instantaneous minimum flow of 70 kcfs from December through April.

- Priest Rapids – meet flow targets which are weekly averages with weekend and holiday flows no less than 80% of previous five days during May and June.

- Lower Snake River – provide maximum peaking capacity of 20 kcfs above average daily flow during May.

A.2 SOS 2 – CURRENT OPERATIONS

Objective: Operations consistent with the final operations specified in the Corps of Engineers' 1993 Supplemental EIS, or operations that have resulted from previous ESA consultations (that have occurred annually during the SOR).

Discussion/Background: This SOS has two options. They represent operations that resulted after three species of salmon were listed as threatened or endangered and they reflect the 1993 and the 1994 ESA consultations. These options model actual operating strategies of those years. The first option is also consistent with that specified in the Corps' 1993 Supplemental EIS. It was the no–action alternative in the SOR Draft EIS and will continue to be such in the Final EIS. The second option updates current operations to the last official Biological Opinion issued for 1994–98.

SOS 2c Final Supplemental EIS Operation – No–Action Alternative matches exactly the decision made as a result of the Supplemental EIS in 1993, which includes up to 427 KAF of additional Upper Snake water. It also reflects the operation in the 1993 Biological Opinion.

SOS 2d 1994–98 Biological Opinion matches the hydro operations contained in the 1994–98 Biological Opinion issued by the National Marine Fisheries Service in mid–1994.

Requirements for SOS 2c: Libby – assume no additional changes to Libby operations for the benefit of Kootenai white sturgeon.

- Flow Augmentation – provide both the existing water budget (Columbia and Snake Rivers) and an additional amount of water, up to 3 MAF, based on a sliding scale tied to runoff forecasts on the Columbia to aid anadromous fish migration. The additional water of up to 3 MAF is stored in Grand Coulee and Arrow.

- Upper Snake – provide an additional 427 KAF of upper Snake River water for flow augmentation shaped accordingly: 190 KAF from April 16 through June 15, 137 KAF in August, and 100 KAF in September.

- Dworshak – provide supplemental releases as follows: (1) draft 900 KAF or more from April 16 to June 15, the exact volume depending on runoff forecast and flows at Lower Granite, and (2) draft up to 470 KAF above 1.2 kcfs minimum release from June 16 to August 31; shift system flood control to Grand Coulee for April – July runoff forecasts at Dworshak up to 3.0 MAF.

- Brownlee – draft up to 137 KAF in July (storage to be refilled with 137 KAF release from Upper Snake in August) and 100 KAF in September; shift system flood control to Grand Coulee.

- Lower Snake – operate to within one foot of MOP from April 16 through July 31.

- John Day – lower reservoir to minimum irrigation pool (MIP, approximate elevation 262.5 feet) from April 15 to August 31; the pool would be held to this level unless it is necessary to raise it to avoid impacts to irrigation impacts.

Short–term Operation Requirements: Operate in the short–term to meet power demands while satisfying non–power requirements.

- Flood Control – interpolate linearly between end of month flood control elevations on a daily basis. Load factoring is allowed within a specified forebay range.

- Grand Coulee – provide flow augmentation while not limiting peaking ability of the project or other downstream Mid–Columbia projects. Month average flow changes may result in changes in 50–hour peaking at some projects.

- Vernita Bar Agreement – provide 55 kcfs during heavy load hours from October 15 through November. Provide instantaneous minimum flow of 70 kcfs from December through April.

- Priest Rapids – meet flow targets which are weekly averages with weekend and holiday flows no less than 80 percent of previous five days during May and June.

- Dworshak – provide instantaneous flows of not less than 1.2 kcfs or greater than 25 kcfs. Summer draft of 470 KAF, water budget and flood control shift are assumed to be released flat and not shapeable for power.

- Lower Snake River – operate within 1 foot of minimum operating pool.

- John Day – operate with 1.5 feet forebay range near 262.5 feet.

A.3 SOS 4 – STABLE STORAGE PROJECT OPERATION

Objective: Elevation targets at storage projects to address recreation, resident fish and wildlife needs.

Discussion/Background: This SOS attempts to coordinate operations at the various storage projects so that recreation, resident fish, wildlife and anadromous fish uses are improved while minimizing the impact to power generation and flood control. Reservoirs are managed to specific elevation levels on a monthly basis. The goal is to minimize reservoir fluctuations, while moving closer toward natural flow conditions. This SOS has one option.

SOS 4c Stable Storage Operation with Modified Grand Coulee Flood Control applies Integrated Rules Curves (IRC) developed by Montana at Libby and Hungry Horse year round. Dworshak and Albeni Falls are operated to specific elevations. Grand Coulee is also operated to specific elevations to provide acceptable water retention times and applies flood control rule curves only when the January–July forecast at the project is greater than 68 MAF.

Requirements for SOS 4c: Flood Control – use new modified flood control rule curves based on runoff forecast where they apply.

- Libby – meet specific elevation targets by the end of the month based on a critical year determination (which is based on end of year content for the previous year) and runoff forecasts beginning in January, known as IRCs. The range of forecasts are divided into five percentiles to determine the particular rule curve of the family of curves to operate on. The elevations and table used to determine the appropriate curve are as follows:

Date	A	B	C	D	E	F
Sept	2459	2459	2459	2459	2459	2459
Oct	2452	2452	2452	2452	2452	2447
Nov	2434	2434	2434	2434	2434	2429
Dec	2411	2411	2411	2411	2411	2403
Jan	2410	2403	2399	2392	2387	2379
Feb	2405	2397	2390	2373	2363	2353
Mar	2399	2390	2379	2366	2339	2327
Apr 15	2413	2402	2374	2363	2339	2327
Apr 30	2427	2416	2374	2363	2339	2327
May	2445	2445	2456	2459	2459	2459
Jun	2459	2459	2459	2459	2459	2459
Jul	2459	2459	2459	2459	2459	2459
Aug 15	2459	2459	2459	2459	2459	2459
Aug 31	2459	2459	2459	2459	2459	2459

Curve	Crit 1	Crit 2	Crit 3	Crit 4
A	0			
B	20	0		
C	40	20	0	
D	60	40	20	
E	80	60	40	0, 20
F		80	60, 80	40, 60, 80

Crit = critical year; 0 = 0% (lowest 1/5 of years); 80 = 80% quintile (highest 1/5 of years)

- Libby also releases water to meet sturgeon flow targets (kcfs) at Bonner's Ferry as indicated in the following table:

Date	Wettest 40% of years	Next 20% of years	Next 20% of years	Dryest 20% of years
May 25	16.4	12.5	8	4 kcfs
June 1	35	25	15	4 kcfs
July 5	35	25	15	4 kcfs
July 15	24.7	18	10	4 kcfs
Aug 16	16.1	11	7	4 kcfs

- Hungry Horse – meet specific elevation targets by the end of the month based on a critical year determination (which is based on end of year content for the previous year) and runoff forecasts beginning in January, known as IRCs. The range of forecasts are divided into five percentiles to determine the particular rule curve of the family of curves to operate on. The elevations and table used to determine the appropriate curve are as follows:

Date	A	B	C	D	E	F	G	H	I
Sept	3560	3560	3560	3560	3560	3560	3560	3560	3560
Oct	3553	3553	3553	3553	3553	3548	3548	3545	3545
Nov	3544	3544	3544	3544	3544	3536	3536	3530	3530
Dec	3533	3533	3533	3533	3533	3524	3524	3515	3515
Jan	3520	3520	3520	3520	3520	3511	3511	3500	3500
Feb	3520	3511	3507	3502	3492	3500	3496	3486	3480
Mar	3520	3505	3497	3488	3468	3482	3473	3463	3450
Apr 15	3520	3505	3497	3488	3468	3479	3470	3461	3450
Apr 30	3528	3516	3497	3488	3468	3491	3483	3476	3464
May	3544	3538	3529	3524	3514	3527	3523	3519	3514
Jun	3560	3560	3560	3560	3560	3560	3560	3560	3560
Jul	3560	3560	3560	3560	3560	3560	3560	3560	3560
Aug 15	3560	3560	3560	3560	3560	3560	3560	3560	3560
Aug 31	3560	3560	3560	3560	3560	3560	3560	3560	3560

Curve	Crit 1	Crit 2	Crit 3	Crit 4
A	0			
B	20			
C	40	0		
D	60	20, 40		
E	80	60	0	
F		80	20, 40	
G			60	0
H			80	20
I				40, 60, 80

Crit = critical year; 0 = 0% (lowest 1/5 of years); 80 = 80% quintile (highest 1/5 of years)

- Grand Coulee – meet the following elevation targets by the end of the indicated month: September through November – 1288 feet (2 feet below full pool), December – 1287, January – 1270, February – 1260, March – 1270, April 15 – 1272, April 30 – 1275, May – 1280, June through August – 1288. Flood control rule curves apply only when January through July runoff forecast is greater than 68 MAF.
- Dworshak – meet the following elevation targets by the end of the indicated month: September through October – 1599 feet (1 foot below full pool), November through April – flood control rule curves, May – 1595, June through August – 1599.
- Albeni Falls – meet the following elevation targets by the end of the indicated month: September – 2060 feet (2.5 feet below full pool), October – 2056, November through March – 2056, April through May – between 2058 and 2062.5, June – 2062.5, July through August – 2060 but allow higher levels for flooding for one month, every 6th year have as the October through March drawdown level 2051 feet.

Short–term Operation Requirements: Flood Control – linearly interpolated flood control elevation changes on a daily basis between end of month elevations. Flood control curves are maximum elevations and Integrated Rule Curves are minimum elevations. When these two elevation requirements reduce forebay range to less than 2 feet, then operation will be within a 2 foot range (1 foot at Albeni Falls) with load factoring not to exceed 1 foot in any 24–hour period.

- Libby – operate at 16 kcfs in November as an instantaneous maximum release rather than a daily average.

- Sturgeon Flows – provide flow for sturgeon during the six–week high flow period as instantaneous requirements. No load factoring is allowed when 15, 25 or 35 kcfs flows are being provided. Under critical water conditions, normal operation and load factoring is possible. During ramp up and ramp down periods, hourly ramp rates are not exceeded. Load factoring is allowed above a minimum flow of 11 kcfs at Bonners Ferry during July and August. During ramp up, load factoring is limited to 5 kcfs in any 24–hour period. During ramp down, no load factoring allowed.

- Vernita Bar Agreement – no restrictions are imposed by the agreement.

- Priest Rapids – meet flow targets which are weekly averages with weekend and holiday flows no less than 80% of previous five days average during May and June.

- Dworshak – provide instantaneous flows of not less than 1.2 kcfs or greater than 25 kcfs. Summer generation is shaped with no net drafts over 1–week periods.

- Lower Snake River – operate within 1 foot of minimum operating pool from April 16 through July.

- John Day – operate within 2 foot forebay range near 263.5 feet November 1 through June 30.

A.4 SOS 5 – NATURAL RIVER OPERATION

Objective: Reduce four lower Snake Projects' operating elevations to near river bed with new outlets.

Discussion/Background: This SOS represents an operation that attempts to aid anadromous fish by speeding water travel time. This would be done by installing new outlets in the lower Snake River dams, permitting the lowering of reservoirs to near the original riverbed levels. This SOS has two options.

SOS 5b Four and One–Half Month Natural River Operation assumes the drawdown lasts for four and one–half months. Drawdown begins on April 16.

SOS 5c Permanent Natural River Operation assumes the drawdown occurs year round with no refill of the projects to normal operating ranges.

Requirements for SOS 5b and 5c: Flow Augmentation – provide 3.45 MAF water budget and up to 3.0 MAF additional water under low runoff conditions on Columbia River.

- Upper Snake River – maintain operations as they existed in 1990–91; assume no additional water volume from the Upper Snake river.

- Dworshak – remove from proportional draft for power and operate to local flood control rule curves with system flood control shifted to lower Snake projects; draft to refill lower Snake projects if natural inflow is inadequate for refill.

- Lower Snake projects – drawdown from normal operating pool levels to the following elevations April 16 through August 31 in **SOS 5b** and permanently in **SOS 5c:**

	Full Pool Levels	Drawdown Levels
Lower Granite	738 feet	623 feet
Little Goose	638 feet	524 feet
Lower Monumental	540 feet	432 feet
Ice Harbor	440 feet	343 feet

- Refill – use a combination of natural flows and storage releases while meeting minimum flows at lower Snake projects to refill in **SOS 5b**.
- John Day – lower reservoir elevation to 257 feet from May through August

Short–term Operation Requirements: Flood Control – linearly interpolate flood control elevation changes on a daily basis between end of month elevations. Load factoring is allowed within a specified forebay range.

- Grand Coulee – provide flow augmentation while not limiting peaking ability of the project or other downstream Mid–Columbia projects. Month average flow changes may result in changes in 50–hour peaking at some projects.
- Vernita Bar Agreement – provide 55 kcfs during heavy load hours from October 15 through November. Provide instantaneous minimum flow of 70 kcfs from December through April.
- Priest Rapids – provide flow targets which are weekly averages with weekend and holiday flows no less than 80% of previous five days during May and June.
- Dworshak – provide instantaneous flows of not less than 1.2 kcfs or greater than 25 kcfs. Operate on flood control rule curve from January through July but do not violate minimum flow. Project can be used for short periods to meet firm peak loads.
- Lower Snake River – for **SOS 5b**, draft to natural river levels at a rate of 2 feet per day starting on February 18 with little daily fluctuations for daytime power production. Generation is not possible once projects are more than 50 feet below normal operating levels. Projects are refilled by reducing outflow to minimum at most downstream project and passing inflow at upper projects, working upstream as each project fills.
- John Day – operate within 1.5 feet forebay range near 257 feet from May through August.

A.5 SOS 6 – FIXED DRAWDOWN

Objective: Reduce four lower Snake Projects' operating elevations to below minimum operating pool.

Discussion/Background: This SOS represents an operation that attempts to aid anadromous fish by speeding water travel time. This SOS has two options.

SOS 6b Four and One–Half Month Fixed Drawdown Operation draws down all four reservoirs for four and one–half months.

SOS 6d Four and One–Half Month Lower Granite Drawdown Operation draws down Lower Granite project only for four and one–half months.

Requirements for SOS 6b: Flow Augmentation – provide 3.45 MAF water budget and up to 3.0 MAF additional water under low runoff conditions on Columbia River.

- Upper Snake River operations – maintain operations as they existed in 1990–91; assume no additional water volume from the Upper Snake river.
- Dworshak – remove from proportional draft for power and operate to local flood control rule curves with system flood control shifted to lower Snake projects; draft to refill lower Snake projects if natural inflow is inadequate for refill.

- Lower Snake River Projects – drawdown from normal operating pool levels to the following elevations from April 16 through August 31:

	Full Pool Levels	Drawdown Levels
Lower Granite	738 feet	705 feet
Little Goose	638 feet	605 feet
Lower Monumental	540 feet	507 feet
Ice Harbor	440 feet	407 feet

- Refill – use a combination of natural flows and storage releases while meeting minimum flows at lower Snake projects.

- John Day – lower reservoir elevation to 257 feet from May through August

Requirements for SOS 6d: Flow Augmentation – provide 3.45 MAF water budget and up to 3.0 MAF additional water under low runoff conditions on Columbia River.

- Upper Snake River operations – maintain operations as they existed in 1990–91; assume no additional water volume from the Upper Snake river.

- Dworshak – remove from proportional draft for power and operate to local flood control rule curves with system flood control shifted to lower Granite project; draft to refill lower Granite project if natural inflow is inadequate for refill.

- Lower Granite Project – drawdown from normal operating pool level of 738 feet to 705 feet from April 16 through August 31.

- Refill – use a combination of natural flows and storage releases while meeting minimum flows at lower Snake projects.

- John Day – lower reservoir elevation to 257 feet from May through August.

Short–term Operation Requirements: Flood Control – linearly interpolate flood control elevation changes on a daily basis between end of month elevations. Load factoring is allowed within a specified forebay range.

- Grand Coulee – provide flow augmentation while not limiting peaking ability of the project or other downstream Mid–Columbia projects. Month average flow changes may result in changes in 50–hour peaking at some projects.

- Vernita Bar Agreement – provide 55 kcfs during heavy load hours from October 15 through November. Provide instantaneous minimum flow of 70 kcfs from December through April.

- Priest Rapids – provide flow targets which are weekly averages with weekend and holiday flows no less than 80% of previous five days during May and June.

- Dworshak – provide instantaneous flows of not less than 1.2 kcfs or greater than 25 kcfs. Operate on flood control rule curve from January through July but does not violate minimum flow. Project can be used for short periods to meet firm peak loads.

- Lower Snake River – draft to drawdown level at a rate of 2 feet per day starting on April 1 with little daily fluctuations for daytime power production. Once drawdown level is reached, projects operate over 5 foot forebay range. Projects are refilled by reducing outflow to minimum at most downstream project and passing inflow at upper projects, working upstream as each project fills.

- John Day – operate within 1.5 feet of forebay range near 257 feet from May through August.

A.6 SOS 9 – SETTLEMENT DISCUSSION ALTERNATIVES

Objective: Provide increased flows for anadromous fish by establishing flow targets during the migration period and by carrying out other actions that benefit ESA listed species.

Discussion/Background: This SOS represents operations suggested by the U.S. Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS) (as SOR cooperating agencies), the State fisheries agencies, Native American Tribes, and the Federal operating agencies during the settlement discussions in response to a court ruling in the lawsuit *IDFG v. NMFS*. The specific options were developed by a group of technical staff representing the parties in the lawsuit. The group was known as the Reasonable and Prudent Alternatives Workgroup. They developed three possible operations in addition to the 1994–98 Biological Opinion. Thus, this SOS has three options:

SOS 9a Detailed Fishery Operating Plan (DFOP) establishes flow targets at The Dalles based the previous years end–of–year storage content similar to how PNCA selects operating rule curves. Specific volumes of releases are made from Dworshak, Brownlee and Upper Snake River to try to meet Lower Granite flow targets. Lower Snake River projects are drawn down to near spillway crest level for four and one–half months. Specific spill percentages are established at run–of–river projects and spill caps are used to prevent excessive total dissolved gas. Fish transportation is assumed to be eliminated.

SOS 9b Adaptive Management — establishes flow targets at McNary and Lower Granite based on runoff forecasts. Specific volumes of releases are made from Dworshak, Brownlee and Upper Snake River to try to meet Lower Granite flow targets. Lower Snake River projects are drawn down to minimum operating pool levels and John Day is at minimum irrigation pool level. Specific spill percentages are established at run–of–river projects to achieve no higher than 120% daily average for total dissolved gas.

SOS 9c Balanced Impacts Operation (Idaho Plan) – draws down the four lower Snake River projects to near spillway crest levels for two and one–half months during the spring salmon migration period. Full drawdown level is achieved on April 1. Refill begins after June 15. This alternative also provides 1994–98 Biological Opinion flow augmentation, Integrated Rule Curve operation at Libby and Hungry Horse, a reduced flow target at Lower Granite due to drawdown, winter drawup at Albeni Falls, and spill caps are used to prevent excessive total dissolved gas.

Requirements for SOS 9a: Flood Control – use new modified flood control rule curves based on runoff forecast where appropriate.

- Libby – operate on minimum flow up to flood control rule curves year round except during the flow augmentation period. Provide sturgeon flow releases to achieve up to 35 kcfs at Bonner's Ferry with appropriate ramp up and ramp down rates according to the following interpretation of these flows for modeling:

Date	Flow Target
April 1–15	4 kcfs
April 16–30	11.5 kcfs
May	26 kcfs
June	35 kcfs
July	23 kcfs
August 1–15	12.9 kcfs
August 15–31	8.2 kcfs

- Hungry Horse – operate on minimum flow up to flood control rule curves year round except during the flow augmentation period.
- Grand Coulee – do not violate flood control, Vernita Bar or local requirements. April through August – operate to meet flow targets at The Dalles according to following table. The targets are selected using the previous August end–of–month storage content for Grand Coulee and Arrow com-

bined – first year (above 94%), second year (between 83 and 94%), and third/fourth year (below 83%).

Period	1st Year	2nd Year	3rd & 4th Year
4/16 – 6/15	300 kcfs	260 kcfs	220 kcfs
6/16 – 7/31	200 kcfs	200 kcfs	200 kcfs
8/1 – 8/31	160 kcfs	160 kcfs	160 kcfs

In better than average runoff years, 40% of the above average volume is also provided as flow augmentation with 50% of this additional water released between April 16 and June 15, 30% between June 16 and July 31, and the remaining 20% during August.

- Brownlee – draft up to 110 KAF in May, 137 KAF in July, 140 KAF in August, and 100 KAF in September; shift system flood control to Grand Coulee.
- Upper Snake River – provide 1.927 MAF of water through Brownlee as determined by the Bureau of Reclamation
- Dworshak – remove from proportional draft for power and operate to Flood Control Rule Curves with system flood control shifted to Grand Coulee. Maintain flow at minimum (1.2 kcfs) in all months except when additional release is needed to provide flow augmentation to meet Lower Granite flow targets or flood control releases. Flow targets at Lower Granite (assuming full pool and spillway crest elevations) are as follows:

Period	Flow Target at full pool	Flow Target at spillway
4/16 – 6/30	140 kcfs	74 kcfs
7/1 – 7/31	85 kcfs	45 kcfs
8/1 – 8/31	60 kcfs	32 kcfs

- Lower Snake River Projects – drawdown from normal operating pool levels to the following elevations from April 1 through August 31:

	Full Pool Levels	Drawdown Levels
Lower Granite	738 feet	705 feet
Little Goose	638 feet	605 feet
Lower Monumental	540 feet	507 feet
Ice Harbor	440 feet	407 feet

- Spill – provide spill to achieve 80/80 FPE up to total dissolved gas cap of 120% daily average as derived by the State agencies. The maximum spill amounts are Lower Granite – 60 kcfs, Little Goose – 60 kcfs, Lower Monumental – 60 kcfs, Ice Harbor – 60 kcfs, McNary – 150 kcfs, John Day – 70 kcfs, The Dalles – 175 kcfs, Bonneville – 105 kcfs.
- John Day – lower reservoir elevation to 257 feet with 1 foot of flexibility from April 15 through August 31.

Requirements for SOS 9b: Flood Control – use new modified flood control rule curves based on runoff forecast where appropriate.

- Libby – operate on minimum flow up to flood control rule curves year round except during the flow augmentation period. Provide sturgeon flow releases similar to that modeled in **SOS 2d**. The project can be drafted to meet flow targets down to a minimum end of July elevation of 2435 feet.
- Hungry Horse – operate on minimum flow up to flood control rule curves year round except during the flow augmentation period. The project can be drafted to meet flow targets down to a minimum end of July elevation of 3535 feet.
- Grand Coulee – operate on minimum flow up to flood control rule curves year round except during the flow augmentation period. The project can be drafted to meet flow

targets down to a minimum end of July elevation of 1265 feet.

- Albeni Falls – operate on minimum flow up to flood control rule curves year round except during the flow augmentation period. The project can be drafted to meet flow targets down to a minimum end of July elevation of 2060 feet.

- Columbia River Flow Targets – use sliding scale flow targets based on January–July forecast for the Columbia River at The Dalles. At McNary, upper bound is DFOP targets (300 and 200 kcfs for spring and July, respectively) and lower bound is 1994–98 Biological Opinion targets (200 and 160 kcfs).

- Brownlee – draft up to 190 KAF April through May, 137 KAF in July, and 100 KAF in September; shift system flood control to Grand Coulee. An additional 110 KAF and 100 KAF will be provided in May and September if the project is above 2068 feet and 2043.3 feet, respectively.

- Upper Snake River – provide 927 KAF of water through Brownlee as determined by the Bureau of Reclamation

- Dworshak – remove from proportional draft for power and operate to Flood Control Rule Curves with system flood control shifted to Grand Coulee. Maintain flow at minimum (1.2 kcfs) in all months except when additional release is needed to provide flow augmentation to meet Snake River flow targets or flood control releases. The project can be drafted to meet flow targets down to a minimum end of July elevation of 1490 feet.

- Snake River Flow Targets – use sliding scale flow targets based on April–August forecast for the Snake River at Lower Granite. The upper bound is DFOP targets (140 and 85 kcfs for spring and July, respectively) and lower bound is 94–98 Biological Opinion targets (85 and 50 kcfs).

- Lower Snake projects – operate at MOP with 1 foot of flexibility between April 1 and August 31.

- Spill – provide spill to achieve 80/80 FPE up to total dissolved gas cap of 120% daily average as measured at the forebay of the next downstream project and derived by the Corps of Engineers. The maximum spill amounts are Lower Granite – 30 kcfs, Little Goose – 30 kcfs, Lower Monumental – 18 kcfs, Ice Harbor – 25 kcfs, McNary – 50 kcfs, John Day – 30 kcfs, The Dalles – 90 kcfs, Bonneville – 105 kcfs.

- John Day – operate at MIP or 262.5 feet with 1 foot of flexibility from April 16 through August.

Requirements for SOS 9c: Flood Control – use new modified flood control rule curves based on runoff forecast where appropriate.

- Libby – operate to the Integrated Rule Curves and provide sturgeon flow releases as modeled in **SOS 4c**.

- Hungry Horse – operate to the Integrated Rule Curves as modeled in **SOS 4c**.

- Grand Coulee – operate to meet the Columbia River flow targets. The project can be drafted to meet flow targets down to a minimum end of July elevation of 1280 feet.

- Albeni Falls – operate to the following elevations – no lower than 2056 feet from December through April, no lower than 2057 feet by the end of May, full (i.e., 2062.5 feet) from June through August, and down to 2056 feet by December from September through November.

- Flow Augmentation – provide both the existing water budget (Columbia and Snake Rivers) and an additional amount of water, up to 4 MAF, based on a sliding scale tied to runoff forecasts on the Columbia to aid anadromous fish migration. The additional water is stored in Libby, Grand Coulee and Arrow.

- Columbia River Flow Targets – flow augmentation water is released to attempt to meet 200 kcfs and 160 kcfs flow targets at McNary from April 16 to June 30 and in July, respectively.

- Brownlee – draft up to 190 KAF April through May, 137 KAF in July, and 100 KAF in September; shift system flood control to Grand Coulee. An additional 110 KAF and 100 KAF will be provided in May and September if the project is above 2068 feet and 2043.3 feet, respectively.

- Upper Snake River – provide 927 KAF of water through Brownlee as determined by the Bureau of Reclamation

- Dworshak – remove from proportional draft for power and operate to Flood Control Rule Curves with system flood control shifted to Grand Coulee. Maintain flow at minimum (1.2 kcfs) in all months except when additional release are needed to provide flow augmentation to meet Snake River flow targets or flood control releases. The project can be drafted to meet flow targets down to a minimum end of July elevation of 1520 feet.

- Snake River Flow Targets – flow augmentation water is released to attempt to meet an equivalent flow of 140 kcfs (at spillway elevation, this flow target is 63 kcfs at Lower Granite from April 1 to June 15. The same flow target would apply through the end of June as the projects refill. No flow target thereafter.

- Lower Snake River Projects – drawdown from normal operating pool levels to the following elevations from April 1 through June 15. Refill by June 30.

	Full Pool Levels	Drawdown Levels
Lower Granite	738 feet	695 feet
Little Goose	638 feet	595 feet
Lower Monumental	540 feet	495 feet
Ice Harbor	440 feet	405 feet

- Spill – provide spill to achieve 80/80 FPE up to total dissolved gas cap of 120% daily average as measured at the forebay of the next downstream project and derived by the Corps of Engineers. The maximum spill amounts are Lower Granite – 30 kcfs, Little Goose – 30 kcfs, Lower Monumental – 18 kcfs, Ice Harbor – 25 kcfs, McNary – 50 kcfs, John Day – 30 kcfs, The Dalles – 90 kcfs, Bonneville – 105 kcfs.

- John Day – operate at MIP or 262.5 feet with 1 foot of flexibility from April 16 through August.

Short–term Operation Requirements: Flood Control – interpolate linearly flood control elevation changes on a daily basis between end of month elevations. Load factoring is allowed within a specified forebay range.

- Grand Coulee – provide flows while not limiting peaking ability of the project or other downstream Mid–Columbia projects. Month average flow changes may result in changes in 50–hour peaking at some projects.

- Vernita Bar Agreement – provide 55 kcfs during heavy load hours from October 15 through November. Provide instantaneous minimum flow of 70 kcfs from December through April.

- Flow Targets – provide flow targets which are biweekly averages with weekend and holiday flows no less than 80% of previous five days.

- Dworshak – provide instantaneous flows of not less than 1.2 kcfs or greater than 25 kcfs.

Drafts for flow augmentation are assumed to be released at a constant rate and are not shapeable for power.

- Spill – provide the spill during the nighttime hours. Nighttime flows are assumed to be no lower than 80% of the daytime flows. This assumption results in spill over a 12–hour period of just over twice the amount shown for monthly spill.

A.7 SOS PA – PREFERRED ALTERNATIVE

- Dworshak – operate on minimum flow up to flood control rule curves year round except during the flow augmentation period. The project is drafted to meet flow targets down to a minimum end of August elevation of 1520 feet.
- Snake River Flow Targets – use sliding scale flow targets based on April–July runoff forecast for the Snake River at Lower Granite. For the spring (April 10 – June 20), the upper bound is 100 kcfs and lower bound is 85 kcfs assuming forecast runoff of between 20 and 16 MAF. For the summer (June 21 – August 31), the upper bound is 55 kcfs and lower bound is 50 kcfs assuming forecast runoff of between 28 and 16 MAF.
- Lower Snake projects – operate at MOP with 1 foot of flexibility between April 10 and August 31. The lower three Snake River pools fill thereafter. Lower Granite pool fills after November 15th.
- Spill – provide spill to achieve 80% FPE up to total dissolved gas cap of 115% 12 hour average as measured at the forebay of the next downstream project and derived by the Corps of Engineers. Spill occurs at all projects during the spring. However, when average flow at Lower Granite is less than 100 kcfs, then no spill occurs at Lower Granite. When average flow at lower Granite is less than 85 kcfs, then no spill occurs at Lower Granite, Little Goose and Lower Monumental. Spill occurs at all non–collector projects during the summer. Spill occurs for 12 hours a day except for Ice Harbor, The Dalles and Bonneville which spills for 24 hours. The percentage of total flow that is spilled is:

	Spring	Summer
Lower Granite	80%	*
Little Goose	80%	*
Lower Monumental	81%	*
Ice Harbor	27%	70%
McNary	50%	*
John Day	33%	86%
The Dalles	64%	64%
Bonneville	**	**

* - spill is not recommended

** - 80% FPE is not obtainable with spill cap; Bonneville spills up to the cap

Objective: Support recovery of ESA–listed species by storing water during the fall and winter to meet spring and summer flow targets, by managing detrimental effects to other natural resources through maximum summer draft limits, and by providing public safety through flood protection and by providing for reasonable power generation.

Discussion/Background: This SOS represents the operation recommended by the National Marine Fisheries Service (NMFS), and the U.S. Fish and Wildlife Service (USFWS) Biological Opinions issued on March 1, 1995. Thus, this SOS has one option:

SOS PA – Preferred Alternative – operates system during the fall and winter to achieve a high confidence of refill to flood control elevations by April 15th of each year, and uses this stored water for flow augmentation. It establishes spring flow targets at McNary and Lower Granite based on runoff forecasts, a similar sliding scale flow target at Lower Granite for the summer and fixed flow target at McNary for the summer. It sets summer draft limits at

Hungry Horse, Libby, Grand Coulee and Dworshak. Libby operates for Kootenai River white strugeon. Lower Snake River projects are drawn down to minimum operating pool levels during the spring and summer. John Day is at minimum operating pool level year round. Specific spill percentages are established at run–of–river projects to achieve 80% FPE with spill caps to prevent excessive total dissolved gas measured at the forebay of the next downstream project.

Requirements for SOS PA: Flood Control – use new modified flood control rule curves based on runoff forecast where appropriate.

- Libby – operate on minimum flow up to flood control rule curves beginning in January of each year except during the flow augmentation period. Strive to achieve flood control elevations in December in all years and by April 15th 75% of the years. Provide sturgeon flow releases of 25 kcfs for 42 days during May, June and July in years when the runoff forecast for Libby is above 6.1 MAF, and at least once in every three years. Although the hydroregulation study was run with a constant sturgeon flow release of 25 kcfs for 42 days, in actual operation, the objective is to maintain a flow of 35 kcfs at Bonners Ferry. Specific ramps up and down are used before and after maximum flow is achieved. Flow of 11 kcfs is maintained at Bonner's Ferry for 21 days after the maximum flow period. The project is drafted to meet flow targets down to a minimum end of August elevation of 2439 feet. However, deeper drafts are possible to meet sturgeon flow requirements.

- Hungry Horse – operate on minimum flow up to flood control rule curves year round except during the flow augmentation period. Strive to achieve flood control elevations by April 15th 75% of the years. The project is drafted to meet flow targets down to a minimum end of August elevation of 3540 feet.

- Grand Coulee – operate to achieve flood control elevations by April 15th 85% of the years. The project is drafted to meet flow targets down to a minimum end of August elevation of 1280 feet.

- Albeni Falls – operate to achieve flood control elevations by April 15th 90% of the years. The project is used to meet flow targets but is not drafted below elevation 1280 through August. Reservoir elevation reaches the lowest point during December and refills during the remainder of the operating year.

- Columbia River Flow Targets – use sliding scale flow targets based on January–July forecast for the Columbia River at The Dalles. The flow target is established at McNary. For the spring (April 20 – June 30), the upper bound is 260 kcfs and lower bound is 220 kcfs assuming forecast runoff of between 105 and 85 MAF. For the summer (July 1 – August 31), a fixed flow target of 200 kcfs is established.

- Brownlee – draft to elevation 2069 feet during May, no refill and pass inflow; draft to elevation 2067 feet in July, no refill and pass inflow; and draft to 2059 feet in September.

- Upper Snake River – provide 427 KAF of water through Brownlee as determined by the Bureau of Reclamation

- The spill caps are Lower Granite –13.5 kcfs, Little Goose – 12.5 kcfs, Lower Monumental – 7.5 kcfs, Ice Harbor – 25 kcfs, McNary – 22.5 kcfs, John Day – 9 kcfs, The Dalles – 90 kcfs, Bonneville – 75 kcfs.

- John Day – operate at MOP or 257 feet with 3 feet of flexibility from March through October and with 5 feet of flexibility from November through February.

Short–term Operation Requirements: Flood Control – linearly interpolate flood control elevation changes on a daily basis between end of month elevations. Load factoring is allowed within a specified forebay range.

- Grand Coulee – provide flows while not limiting peaking ability of the project or other downstream Mid–Columbia projects. Month average flow changes may result in changes in 50–hour peaking at some projects.
- Emergency conditions – draft storage projects to ensure system reliability to avoid 1) threatened inability to meet firm loads due to emergency circumstances (such as major temperature drops, loss of a major resource or loss of an intertie); or 2) voltage and transmission instability.
- Vernita Bar Agreement – provide 55 kcfs during heavy load hours from October 15 through November. Provide instantaneous minimum flow of 70 kcfs from December through April.
- Flow Targets – flow targets are seasonal averages.
- Dworshak – provide instantaneous flows of not less than 1.2 kcfs or greater than 25 kcfs. Drafts for flow augmentation are assumed to be released flat and not shapeable for power.
- Spill – see above on amount and timing of spill. Nighttime flows are assumed to be no lower than 80% of the daytime flows. For those projects with 12–hour spill, this assumption results in spill over a 12–hour period of just over twice of the amount shown for monthly spill.
- Peaking – turbine generator units at lower Snake and Columbia Rivers operate within 1% of peak efficiency March 15 to October 31 (for Columbia projects) and March 15 to November 30 (for Snake projects).

TECHNICAL EXHIBIT B

HYDROREGULATION COMPARISON TABLES

The tables in Exhibit B depict key data for each alternative at various locations in the system compared to the no action alternative, SOS 2c. The data in the tables is based on hydroregulation results for the 50–year period of record, from 1928 to 1978. Reservoir elevation and refill data is presented for 5 key storage projects (Libby, Hungry Horse, Grand Coulee, Brownlee, and Dworshak). River flow information is provided for Priest Rapids and The Dalles on the Columbia River and Lower Granite on the lower Snake River. Average system energy refers to average total hydropower generation, including both firm and non firm energy. Water travel time refers to the average velocity of the water and is used as a measure of the travel time required for juvenile salmon migrating downstream. Water retention time refers to the amount of time water is retained in a reservoir. It is used in relating the amount of time nutrients have to develop in the stable water. Details of the information presented is described below.

Reservoir elevation data is presented in terms of average yearly reservoir elevation and end–of–July reservoir elevation. Reservoir elevation in July was selected because under most alternatives, a key objective is to have reservoirs full by July to provide for recreation, water supply, and other uses. Another important basis for comparison is refill probability in July. For the purposes of these tables, compilations were made to show the number of years out of 50 in which the reservoir did not refill to within 5 feet of full.

Flow data is presented for spring and summer periods and represents the average flow for the period under consideration. For example, at Priest Rapids, the flow data for the May–June period is the average of monthly flows for May and June. At Lower Granite and The Dalles, average flows were provided for the spring (April 16 – June 30) and summer (July 1 – August 31).

Water travel time is provided for the spring and summer periods. It is presented for the lower Snake and Columbia River systems individually as well as for the combined system from the confluence of the Snake and Clearwater Rivers down to the Columbia River at Bonneville Dam. Water retention time is provided for the spring and summer periods for Grand Coulee Reservoir only.

The acronyms used in the tables are described as follows:

EOM –	End–of–month
MW –	Megawatt
LIB –	Libby Reservoir
HHR –	Hungry Horse Reservoir
GCL –	Grand Coulee Reservoir
PRD –	Priest Rapids Dam
BRN –	Brownlee Reservoir
DWR –	Dworshak Reservoir
LGR –	Lower Granite Reservoir
TDA –	The Dalles

Table B–1. Comparison of key data for SOS 2c and SOS 1a

	SOS 2c	SOS 1a	Change
LIB Jul EOM Elev, ft	2453.5	2451.4	−2.1
Julys LIB did not fill*	13	12	−1
LIB Avg Pool Elev, ft	2402.2	2400.1	−2.1
HHR Jul EOM Elev, ft	3541.7	3540.3	−1.4
Julys HHR did not fill*	23	19	−4
HHR Avg Pool Elev, ft	3503	3500.2	−2.8
GCL Jul EOM Elev, ft	1289.7	1289.9	0.2
Julys GCL did not fill*	2	0	−2
GCL Avg Pool Elev, ft	1274.4	1270.7	−3.7
PRD MAY−JUN Discharge, cfs	165,956	157,255	−8701
BRN Jul EOM Elev, ft	2068.6	2067.8	−0.8
Julys BRN did not fill*	42	32	−10
BRN Avg Pool Elev, ft	2059.2	2061.4	2.2
DWR JUL EOM Elev, ft	1580.6	1590.7	10.1
Julys DWR did not fill*	39	17	−22
DWR Avg Pool Elev, ft	1553.9	1549	−4.9
LGR APR2−JUN Discharge, cfs	100,277	97,309	−2968
LGR JUL−AUG Discharge, cfs	32,016	31,311	−705
TDA APR2−JUN Discharge, cfs	268,039	259,741	−8298
TDA JUL−AUG Discharge, cfs	151,631	150,229	−1402
Average System Energy, MW	15,416	15,554	138
Snake R. Travel Time, APR2−JUN, (days)	8	9	1
Snake R. Travel Time, JUL−AUG, (days)	25	28	3
Columbia R. Travel Time From Snake R. Confluence to BON, APR2−JUN, (days)	9	9	0
Columbia R. Travel Time From Snake R. Confluence to BON, JUL−AUG, (days)	16	17	1
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, APR2−JUN (days)	17	18	1
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, JUL−AUG (days)	41	45	4
Grand Coulee Water Retention Time, APR2−JUN (days)	28	27	−1
Grand Coulee Water Retention Time, JUL−AUG (days)	51	51	0

* within five feet of full

Table B–2. Comparison of key data for SOS 2c and SOS 1b

	SOS 2c	SOS 1b	Change
LIB Jul EOM Elev, ft	2453.5	2450.6	−2.9
Julys LIB did not fill*	13	13	0
LIB Avg Pool Elev, ft	2402.2	2396.2	−6
HHR Jul EOM Elev, ft	3541.7	3537.1	−4.6
Julys HHR did not fill*	23	20	−3
HHR Avg Pool Elev, ft	3503	3496.5	−6.5
GCL Jul EOM Elev, ft	1289.7	1289.7	0
Julys GCL did not fill*	2	0	−2
GCL Avg Pool Elev, ft	1274.4	1270.5	−3.9
PRD MAY−JUN Discharge, cfs	165,956	156,266	−9690
BRN Jul EOM Elev, ft	2068.6	2067.8	−0.8
Julys BRN did not fill*	42	32	−10
BRN Avg Pool Elev, ft	2059.2	2061.4	2.2
DWR JUL EOM Elev, ft	1580.6	1593.8	13.2
Julys DWR did not fill*	39	11	−28
DWR Avg Pool Elev, ft	1553.9	1548.7	−5.2
LGR APR2−JUN Discharge, cfs	100,277	96,600	−3677
LGR JUL−AUG Discharge, cfs	32,016	30,874	−1142
TDA APR2−JUN Discharge, cfs	268,039	257,103	−10936
TDA JUL−AUG Discharge, cfs	151,631	152,758	1127
Average System Energy, MW	15,416	15,725	309
Snake R. Travel Time, APR2−JUN, (days)	8	9	1
Snake R. Travel Time, JUL−AUG, (days)	25	29	4
Columbia R. Travel Time From Snake R. Confluence to BON, APR2−JUN, (days)	9	10	1
Columbia R. Travel Time From Snake R. Confluence to BON, JUL−AUG, (days)	16	16	0
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, APR2−JUN (days)	17	19	2
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, JUL−AUG (days)	41	45	4
Grand Coulee Water Retention Time, APR2−JUN (days)	28	28	0
Grand Coulee Water Retention Time, JUL−AUG (days)	51	49	−2

* within five feet of full

Table B–3. Comparison of key data for SOS 2c and SOS 2d

	SOS 2c	SOS 2d	Change
LIB Jul EOM Elev, ft	2453.5	2451.6	−1.9
Julys LIB did not fill*	13	18	5
LIB Avg Pool Elev, ft	2402.2	2397.5	−4.7
HHR Jul EOM Elev, ft	3541.7	3541.7	0
Julys HHR did not fill*	23	22	−1
HHR Avg Pool Elev, ft	3503	3503	0
GCL Jul EOM Elev, ft	1289.7	1287	−2.7
Julys GCL did not fill*	2	14	12
GCL Avg Pool Elev, ft	1274.4	1277.1	2.7
PRD MAY−JUN Discharge, cfs	165,956	166,530	574
BRN Jul EOM Elev, ft	2068.6	2068.6	0
Julys BRN did not fill*	42	42	0
BRN Avg Pool Elev, ft	2059.2	2059.1	−0.1
DWR JUL EOM Elev, ft	1580.6	1536.8	−43.8
Julys DWR did not fill*	39	50	11
DWR Avg Pool Elev, ft	1553.9	1535.7	−18.2
LGR APR2−JUN Discharge, cfs	100,277	99,727	−550
LGR JUL−AUG Discharge, cfs	32,016	33,867	1851
TDA APR2−JUN Discharge, cfs	268,039	267,265	−774
TDA JUL−AUG Discharge, cfs	151,631	162,383	10752
Average System Energy, MW	15,416	15,381	−35
Snake R. Travel Time, APR2−JUN, (days)	8	8	0
Snake R. Travel Time, JUL−AUG, (days)	25	23	−2
Columbia R. Travel Time From Snake R. Confluence to BON, APR2−JUN, (days)	9	9	0
Columbia R. Travel Time From Snake R. Confluence to BON, JUL−AUG, (days)	16	15	−1
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, APR2−JUN (days)	17	17	0
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, JUL−AUG (days)	41	38	−3
Grand Coulee Water Retention Time, APR2−JUN (days)	28	31	3
Grand Coulee Water Retention Time, JUL−AUG (days)	51	39	−12

* within five feet of full

Table B–4. Comparison of key data for SOS 2c and SOS 4c

	SOS 2c	SOS 4c	Change
LIB Jul EOM Elev, ft	2453.5	2454.6	1.1
Julys LIB did not fill*	13	11	−2
LIB Avg Pool Elev, ft	2402.2	2424.2	22
HHR Jul EOM Elev, ft	3541.7	3559.5	17.8
Julys HHR did not fill*	23	0	−23
HHR Avg Pool Elev, ft	3503	3535.5	32.5
GCL Jul EOM Elev, ft	1289.7	1288	−1.7
Julys GCL did not fill*	2	0	−2
GCL Avg Pool Elev, ft	1274.4	1278	3.6
PRD MAY–JUN Discharge, cfs	165,956	174,141	8185
BRN Jul EOM Elev, ft	2068.6	2068.6	0
Julys BRN did not fill*	42	42	0
BRN Avg Pool Elev, ft	2059.2	2060.7	1.5
DWR JUL EOM Elev, ft	1580.6	1598.7	18.1
Julys DWR did not fill*	39	1	−38
DWR Avg Pool Elev, ft	1553.9	1563.6	9.7
LGR APR2–JUN Discharge, cfs	100,277	98,229	−2048
LGR JUL–AUG Discharge, cfs	32,016	30,088	−1928
TDA APR2–JUN Discharge, cfs	268,039	274,892	6853
TDA JUL–AUG Discharge, cfs	151,631	159,455	7824
Average System Energy, MW	15,416	14,581	−835
Snake R. Travel Time, APR2–JUN, (days)	8	8	0
Snake R. Travel Time, JUL–AUG, (days)	25	26	1
Columbia R. Travel Time From Snake R. Confluence to BON, APR2–JUN, (days)	9	9	0
Columbia R. Travel Time From Snake R. Confluence to BON, JUL–AUG, (days)	16	16	0
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, APR2–JUN (days)	17	17	0
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, JUL–AUG (days)	41	42	1
Grand Coulee Water Retention Time, APR2–JUN (days)	28	30	2
Grand Coulee Water Retention Time, JUL–AUG (days)	51	47	−4

* within five feet of full

Table B–5. Comparison of key data for SOS 2c and SOS 5b

	SOS 2c	SOS 5b	Change
LIB Jul EOM Elev, ft	2453.5	2450.8	−2.7
Julys LIB did not fill*	13	15	2
LIB Avg Pool Elev, ft	2402.2	2397.9	−4.3
HHR Jul EOM Elev, ft	3541.7	3539.7	−2
Julys HHR did not fill*	23	22	−1
HHR Avg Pool Elev, ft	3503	3499.7	−3.3
GCL Jul EOM Elev, ft	1289.7	1289.7	0
Julys GCL did not fill*	2	0	−2
GCL Avg Pool Elev, ft	1274.4	1274.4	0
PRD MAY−JUN Discharge, cfs	165,956	165,540	−416
BRN Jul EOM Elev, ft	2068.6	2068.6	0
Julys BRN did not fill*	42	42	0
BRN Avg Pool Elev, ft	2059.2	2059.2	0
DWR JUL EOM Elev, ft	1580.6	1600	19.4
Julys DWR did not fill*	39	0	−39
DWR Avg Pool Elev, ft	1553.9	1554.2	0.3
LGR APR2−JUN Discharge, cfs	100,277	97,645	−2632
LGR JUL−AUG Discharge, cfs	32,016	29,433	−2583
TDA APR2−JUN Discharge, cfs	268,039	267,903	−136
TDA JUL−AUG Discharge, cfs	151,631	148,479	−3152
Average System Energy, MW	15,416	14,588	−828
Snake R. Travel Time, APR2−JUN, (days)	8	1	−7
Snake R. Travel Time, JUL−AUG, (days)	25	2	−23
Columbia R. Travel Time From Snake R. Confluence to BON, APR2−JUN, (days)	9	8	−1
Columbia R. Travel Time From Snake R. Confluence to BON, JUL−AUG, (days)	16	16	0
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, APR2−JUN (days)	17	9	−8
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, JUL−AUG (days)	41	18	−23
Grand Coulee Water Retention Time, APR2−JUN (days)	28	27	−1
Grand Coulee Water Retention Time, JUL−AUG (days)	51	52	1

* within five feet of full

Table B–6. Comparison of key data for SOS 2c and SOS 5c

	SOS 2c	SOS 5c	Change
LIB Jul EOM Elev, ft	2453.5	2450.8	−2.7
Julys LIB did not fill*	13	15	2
LIB Avg Pool Elev, ft	2402.2	2397.9	−4.3
HHR Jul EOM Elev, ft	3541.7	3539.7	−2
Julys HHR did not fill*	23	20	−3
HHR Avg Pool Elev, ft	3503	3499.7	−3.3
GCL Jul EOM Elev, ft	1289.7	1289.7	0
Julys GCL did not fill*	2	0	−2
GCL Avg Pool Elev, ft	1274.4	1274.4	0
PRD MAY−JUN Discharge, cfs	165,956	165,540	−416
BRN Jul EOM Elev, ft	2068.6	2068.6	0
Julys BRN did not fill*	42	42	0
BRN Avg Pool Elev, ft	2059.2	2059.2	0
DWR JUL EOM Elev, ft	1580.6	1600	19.4
Julys DWR did not fill*	39	0	−39
DWR Avg Pool Elev, ft	1553.9	1554.2	0.3
LGR APR2−JUN Discharge, cfs	100,277	97,645	−2632
LGR JUL−AUG Discharge, cfs	32,016	29,433	−2583
TDA APR2−JUN Discharge, cfs	268,039	267,902	−137
TDA JUL−AUG Discharge, cfs	151,631	148,448	−3183
Average System Energy, MW	15,416	14,449	−967
Snake R. Travel Time, APR2−JUN, (days)	8	1	−7
Snake R. Travel Time, JUL−AUG, (days)	25	2	−23
Columbia R. Travel Time From Snake R. Confluence to BON, APR2−JUN, (days)	9	8	−1
Columbia R. Travel Time From Snake R. Confluence to BON, JUL−AUG, (days)	16	16	0
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, APR2−JUN (days)	17	9	−8
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, JUL−AUG (days)	41	18	−23
Grand Coulee Water Retention Time, APR2−JUN (days)	28	24	−4
Grand Coulee Water Retention Time, JUL−AUG (days)	51	52	1

* within five feet of full

Table B–7. Comparison of key data for SOS 2c and SOS 6b

	SOS 2c	SOS 6b	Change
LIB Jul EOM Elev, ft	2453.5	2450.8	−2.7
Julys LIB did not fill*	13	15	2
LIB Avg Pool Elev, ft	2402.2	2397.9	−4.3
HHR Jul EOM Elev, ft	3541.7	3539.7	−2
Julys HHR did not fill*	23	22	−1
HHR Avg Pool Elev, ft	3503	3499.7	−3.3
GCL Jul EOM Elev, ft	1289.7	1289.7	0
Julys GCL did not fill*	2	0	−2
GCL Avg Pool Elev, ft	1274.4	1274.4	0
PRD MAY−JUN Discharge, cfs	165,956	165,540	−416
BRN Jul EOM Elev, ft	2068.6	2068.6	0
Julys BRN did not fill*	42	42	0
BRN Avg Pool Elev, ft	2059.2	2059.2	0
DWR JUL EOM Elev, ft	1580.6	1600	19.4
Julys DWR did not fill*	39	0	−39
DWR Avg Pool Elev, ft	1553.9	1559.9	6
LGR APR2−JUN Discharge, cfs	100,277	97,666	−2611
LGR JUL−AUG Discharge, cfs	32,016	29,433	−2583
TDA APR2−JUN Discharge, cfs	268,039	267,923	−116
TDA JUL−AUG Discharge, cfs	151,631	148,454	−3177
Average System Energy, MW	15,416	15,139	−277
Snake R. Travel Time, APR2−JUN, (days)	8	3	−5
Snake R. Travel Time, JUL−AUG, (days)	25	8	−17
Columbia R. Travel Time From Snake R. Confluence to BON, APR2−JUN, (days)	9	8	−1
Columbia R. Travel Time From Snake R. Confluence to BON, JUL−AUG, (days)	16	16	0
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, APR2−JUN (days)	17	11	−6
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, JUL−AUG (days)	41	24	−17
Grand Coulee Water Retention Time, APR2−JUN (days)	28	28	0
Grand Coulee Water Retention Time, JUL−AUG (days)	51	52	1

* within five feet of full

Table B–8. Comparison of key data for SOS 2c and SOS 6d

	SOS 2c	SOS 6d	Change
LIB Jul EOM Elev, ft	2453.5	2450.8	−2.7
Julys LIB did not fill*	13	15	2
LIB Avg Pool Elev, ft	2402.2	2397.9	−4.3
HHR Jul EOM Elev, ft	3541.7	3539.7	−2
Julys HHR did not fill*	23	22	−1
HHR Avg Pool Elev, ft	3503	3499.7	−3.3
GCL Jul EOM Elev, ft	1289.7	1289.7	0
Julys GCL did not fill*	2	0	−2
GCL Avg Pool Elev, ft	1274.4	1274.4	0
PRD MAY−JUN Discharge, cfs	165,956	165,540	−416
BRN Jul EOM Elev, ft	2068.6	2068.6	0
Julys BRN did not fill*	42	42	0
BRN Avg Pool Elev, ft	2059.2	2059.2	0
DWR JUL EOM Elev, ft	1580.6	1600	19.4
Julys DWR did not fill*	39	0	−39
DWR Avg Pool Elev, ft	1553.9	1559.9	6
LGR APR2−JUN Discharge, cfs	100,277	97,666	−2611
LGR JUL−AUG Discharge, cfs	32,016	29,433	−2583
TDA APR2−JUN Discharge, cfs	268,039	267,923	−116
TDA JUL−AUG Discharge, cfs	151,631	148,099	−3532
Average System Energy, MW	15,416	15,327	−89
Snake R. Travel Time, APR2−JUN, (days)	8	3	−5
Snake R. Travel Time, JUL−AUG, (days)	25	8	−17
Columbia R. Travel Time From Snake R. Confluence to BON, APR2−JUN, (days)	9	8	−1
Columbia R. Travel Time From Snake R. Confluence to BON, JUL−AUG, (days)	16	15	−1
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, APR2−JUN (days)	17	11	−6
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, JUL−AUG (days)	41	23	−18
Grand Coulee Water Retention Time, APR2−JUN (days)	28	28	0
Grand Coulee Water Retention Time, JUL−AUG (days)	51	52	1

* within five feet of full

Table B–9. Comparison of key data for SOS 2c and SOS 9a

	SOS 2c	SOS 9a	Change
LIB Jul EOM Elev, ft	2453.5	2392.7	−60.8
Julys LIB did not fill*	13	47	34
LIB Avg Pool Elev, ft	2402.2	2382.8	−19.4
HHR Jul EOM Elev, ft	3541.7	3501.1	−40.6
Julys HHR did not fill*	23	41	18
HHR Avg Pool Elev, ft	3503	3477.5	−25.5
GCL Jul EOM Elev, ft	1289.7	1265.3	−24.4
Julys GCL did not fill*	2	33	31
GCL Avg Pool Elev, ft	1274.4	1264.8	−9.6
PRD MAY−JUN Discharge, cfs	165,956	185,814	19858
BRN Jul EOM Elev, ft	2068.6	2068.5	−0.1
Julys BRN did not fill*	42	31	−11
BRN Avg Pool Elev, ft	2059.2	2055.9	−3.3
DWR JUL EOM Elev, ft	1580.6	1571.7	−8.9
Julys DWR did not fill*	39	25	−14
DWR Avg Pool Elev, ft	1553.9	1545.4	−8.5
LGR APR2−JUN Discharge, cfs	100,277	104,070	3793
LGR JUL−AUG Discharge, cfs	32,016	41,073	9057
TDA APR2−JUN Discharge, cfs	268,039	300,032	31993
TDA JUL−AUG Discharge, cfs	151,631	192,719	41088
Average System Energy, MW	15,416	14,320	−1096
Snake R. Travel Time, APR2−JUN, (days)	8	3	−5
Snake R. Travel Time, JUL−AUG, (days)	25	6	−19
Columbia R. Travel Time From Snake R. Confluence to BON, APR2−JUN, (days)	9	8	−1
Columbia R. Travel Time From Snake R. Confluence to BON, JUL−AUG, (days)	16	12	−4
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, APR2−JUN (days)	17	11	−6
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, JUL−AUG (days)	41	18	−23
Grand Coulee Water Retention Time, APR2−JUN (days)	28	21	−7
Grand Coulee Water Retention Time, JUL−AUG (days)	51	29	−22

* within five feet of full

Table B–10. Comparison of key data for SOS 2c and SOS 9b

	SOS 2c	SOS 9b	Change
LIB Jul EOM Elev, ft	2453.5	2441.6	−11.9
Julys LIB did not fill*	13	45	32
LIB Avg Pool Elev, ft	2402.2	2402.9	0.7
HHR Jul EOM Elev, ft	3541.7	3550.1	8.4
Julys HHR did not fill*	23	23	0
HHR Avg Pool Elev, ft	3503	3531.7	28.7
GCL Jul EOM Elev, ft	1289.7	1281.3	−8.4
Julys GCL did not fill*	2	21	19
GCL Avg Pool Elev, ft	1274.4	1275.2	0.8
PRD MAY−JUN Discharge, cfs	165,956	178,229	12273
BRN Jul EOM Elev, ft	2068.6	2057.9	−10.7
Julys BRN did not fill*	42	50	8
BRN Avg Pool Elev, ft	2059.2	2053.3	−5.9
DWR JUL EOM Elev, ft	1580.6	1524	−56.6
Julys DWR did not fill*	39	50	11
DWR Avg Pool Elev, ft	1553.9	1520.5	−33.4
LGR APR2−JUN Discharge, cfs	100,277	101,802	1525
LGR JUL−AUG Discharge, cfs	32,016	33,857	1841
TDA APR2−JUN Discharge, cfs	268,039	292,817	24778
TDA JUL−AUG Discharge, cfs	151,631	177,173	25542
Average System Energy, MW	15,416	14,774	−642
Snake R. Travel Time, APR2−JUN, (days)	8	3	−5
Snake R. Travel Time, JUL−AUG, (days)	25	7	−18
Columbia R. Travel Time From Snake R. Confluence to BON, APR2−JUN, (days)	9	8	−1
Columbia R. Travel Time From Snake R. Confluence to BON, JUL−AUG, (days)	16	13	−3
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, APR2−JUN (days)	17	11	−6
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, JUL−AUG (days)	41	20	−21
Grand Coulee Water Retention Time, APR2−JUN (days)	28	23	−5
Grand Coulee Water Retention Time, JUL−AUG (days)	51	37	−14

* within five feet of full

Table B–11. Comparison of key data for SOS 2c and SOS 9c

	SOS 2c	SOS 9c	Change
LIB Jul EOM Elev, ft	2453.5	2454.5	1
Julys LIB did not fill*	13	10	−3
LIB Avg Pool Elev, ft	2402.2	2424.2	22
HHR Jul EOM Elev, ft	3541.7	3559.5	17.8
Julys HHR did not fill*	23	0	−23
HHR Avg Pool Elev, ft	3503	3535.4	32.4
GCL Jul EOM Elev, ft	1289.7	1286.2	−3.5
Julys GCL did not fill*	2	19	17
GCL Avg Pool Elev, ft	1274.4	1274.9	0.5
PRD MAY−JUN Discharge, cfs	165,956	166,150	194
BRN Jul EOM Elev, ft	2068.6	2057.9	−10.7
Julys BRN did not fill*	42	50	8
BRN Avg Pool Elev, ft	2059.2	2053.3	−5.9
DWR JUL EOM Elev, ft	1580.6	1573.6	−7
Julys DWR did not fill*	39	41	2
DWR Avg Pool Elev, ft	1553.9	1549.6	−4.3
LGR APR2−JUN Discharge, cfs	100,277	97,737	−2540
LGR JUL−AUG Discharge, cfs	32,016	34,262	2246
TDA APR2−JUN Discharge, cfs	268,039	264,514	−3525
TDA JUL−AUG Discharge, cfs	151,631	172,470	20839
Average System Energy, MW	15,416	14,686	−730
Snake R. Travel Time, APR2−JUN, (days)	8	3	−5
Snake R. Travel Time, JUL−AUG, (days)	25	7	−18
Columbia R. Travel Time From Snake R. Confluence to BON, APR2−JUN, (days)	9	8	−1
Columbia R. Travel Time From Snake R. Confluence to BON, JUL−AUG, (days)	16	13	−3
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, APR2−JUN (days)	17	11	−6
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, JUL−AUG (days)	41	20	−21
Grand Coulee Water Retention Time, APR2−JUN (days)	28	25	−3
Grand Coulee Water Retention Time, JUL−AUG (days)	51	42	−9

* within five feet of full

Table B–12. Comparison of key data for SOS 2c and SOS PA

	SOS 2c	SOS PA	Change
LIB Jul EOM Elev, ft	2453.5	2439.2	−14.3
Julys LIB did not fill*	13	40	27
LIB Avg Pool Elev, ft	2402.2	2404.4	2.2
HHR Jul EOM Elev, ft	3541.7	3550	8.3
Julys HHR did not fill*	23	26	3
HHR Avg Pool Elev, ft	3503	3531.6	28.6
GCL Jul EOM Elev, ft	1289.7	1285.9	−3.8
Julys GCL did not fill*	2	20	18
GCL Avg Pool Elev, ft	1274.4	1277.6	3.2
PRD MAY−JUN Discharge, cfs	165,956	173,730	7774
BRN Jul EOM Elev, ft	2068.6	2067.1	−1.5
Julys BRN did not fill*	42	50	8
BRN Avg Pool Elev, ft	2059.2	2063.8	4.6
DWR JUL EOM Elev, ft	1580.6	1551.9	−28.7
Julys DWR did not fill*	39	41	2
DWR Avg Pool Elev, ft	1553.9	1533.9	−20
LGR APR2−JUN Discharge, cfs	100,277	99,920	−357
LGR JUL−AUG Discharge, cfs	32,016	39,895	7879
TDA APR2−JUN Discharge, cfs	268,039	280,854	12815
TDA JUL−AUG Discharge, cfs	151,631	177,095	25464
Average System Energy, MW	15,416	15,108	−308
Snake R. Travel Time, APR2−JUN, (days)	8	7	−1
Snake R. Travel Time, JUL−AUG, (days)	25	20	−5
Columbia R. Travel Time From Snake R. Confluence to BON, APR2−JUN, (days)	9	8	−1
Columbia R. Travel Time From Snake R. Confluence to BON, JUL−AUG, (days)	16	13	−3
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, APR2−JUN (days)	17	15	−2
Travel Time From Snake R at Clearwater R. Confluence to Columbia R at BON, JUL−AUG (days)	41	33	−8
Grand Coulee Water Retention Time, APR2−JUN (days)	28	24	−4
Grand Coulee Water Retention Time, JUL−AUG (days)	51	42	−9

* within five feet of full

TECHNICAL EXHIBIT C

HYDROREGULATION COMPARISON GRAPHS

The graphs in Exhibit C depict key data for each alternative at various locations in the system. The data is presented under four main headings:

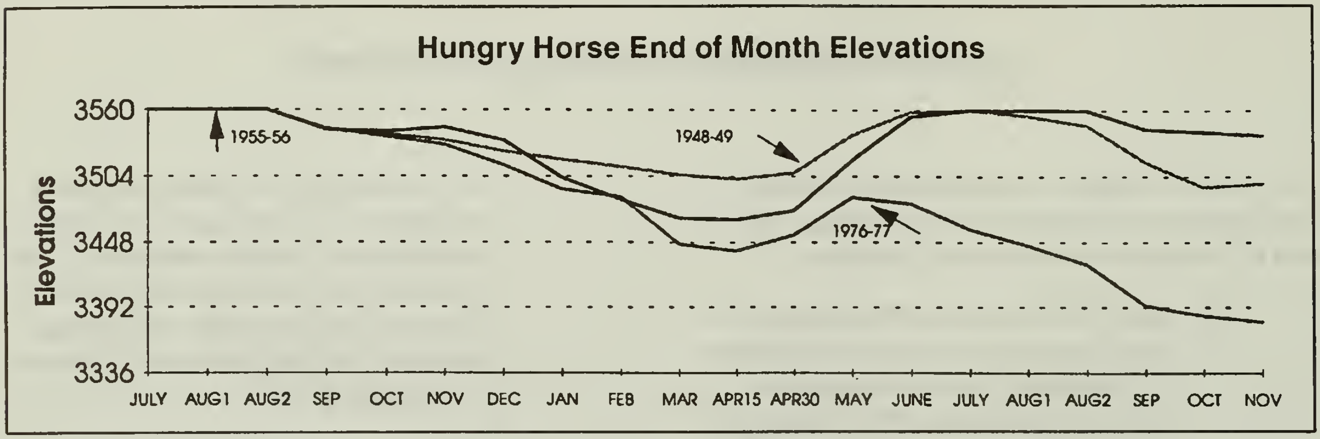
(1) End–of–month reservoir elevations and average monthly reservoir outflows are presented for representative wet (1955–56), average (1948–49) and dry (1976–77) water years. This data is presented for Hungry Horse, Libby, Grand Coulee, and Dworshak. For Priest Rapids (Priest), Lower Granite, and The Dalles, only outflow is presented. This is because these are run–of–river projects with limited storage and therefore reservoir elevations do not fluctuate throughout the year as widely as for the other storage projects presented.

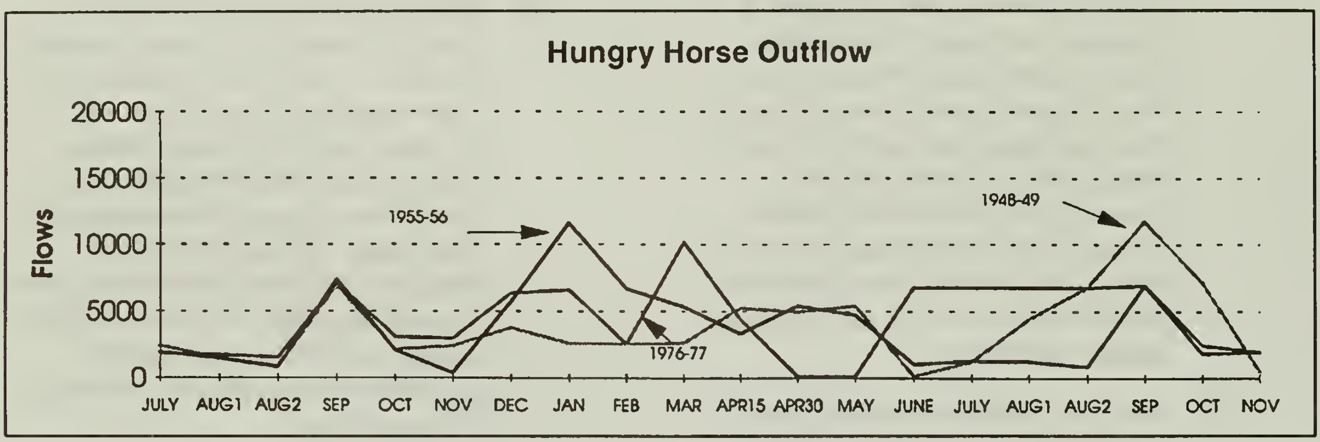
(2) Reservoir elevation–duration curves are presented for the end–of–July reservoir elevation for Libby, Hungry Horse, Grand Coulee, and Dworshak. These curves are based on end–of–July reservoir elevation data for the entire 50 year period of record from 1928–78 and show the percent of time a given elevation is equalled or exceeded. For example, at Libby under SOS 1a (Table C–1), the percent of time the reservoir is at or above elevation 2, 416 is about 95%. This would be expected since the objective under this alternative is to refill the reservoir to elevation 2,459 (full) by July.

(3) Spring flows from April 16 through June 30 (labeled in the graph headings as "Apr2 – June") are depicted with flow–duration curves. These are provided for Libby, Hungry Horse, Grand Coulee, Priest Rapids, Dworshak, Lower Granite, Brownlee, and The Dalles. The period April 16 through June 30 was selected since this is a critical period for anadromous fish migration. These curves show the probability of equalling or exceeding different flows.

(4) Summer flows from July 1 through August 31 (labeled in the graph headings as "July – Aug2") are shown for the same locations as described above for spring flows. This period was also selected based on anadromous fish migration.

Table C–1. SOS1a





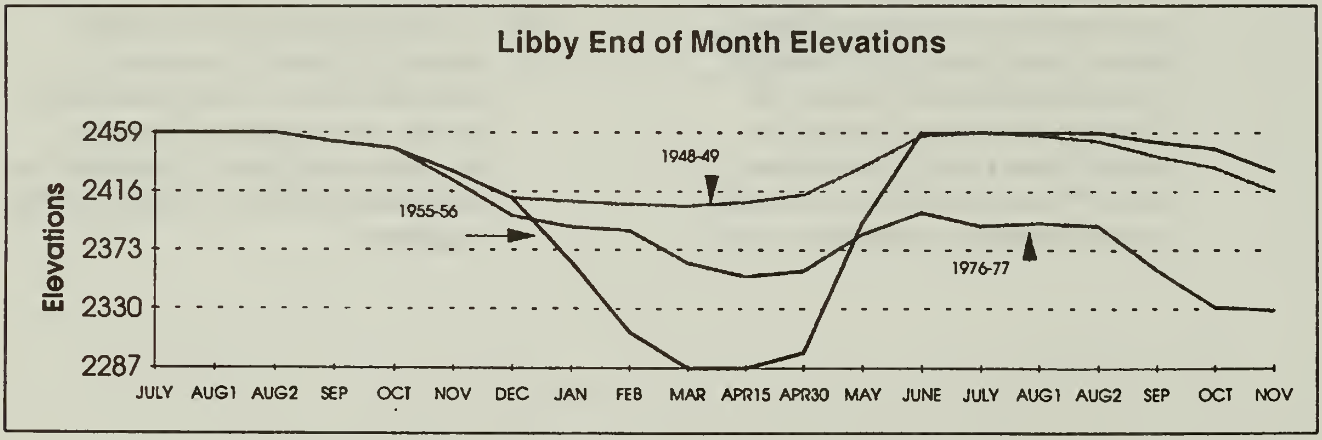
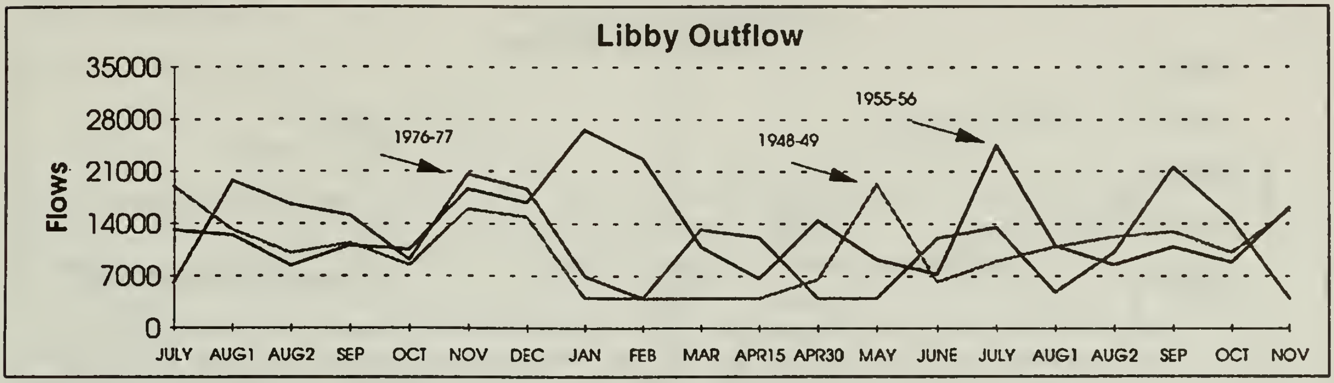
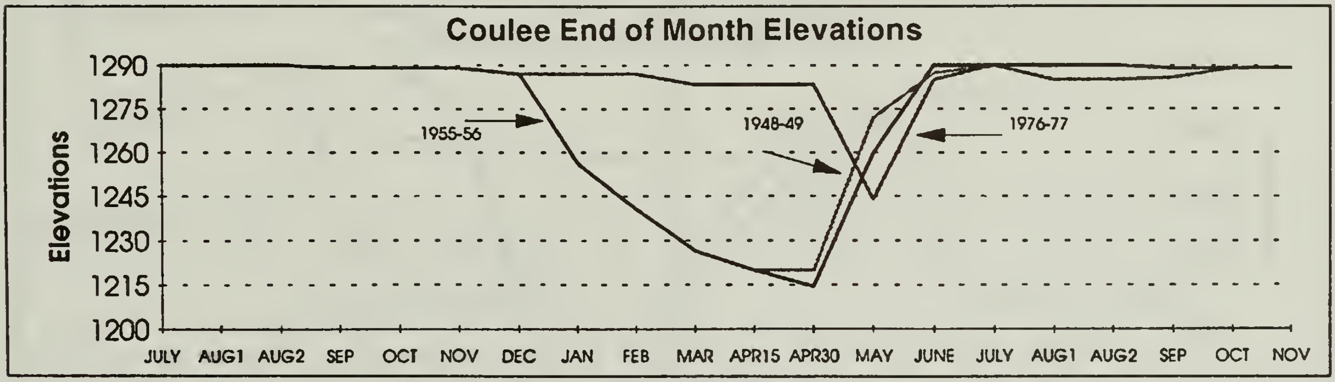
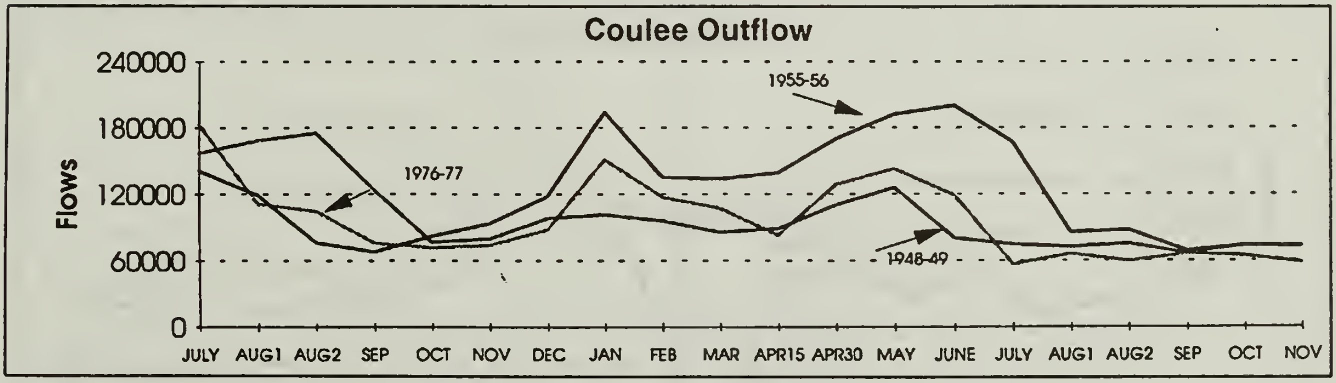


Table C–1. SOS1a – CONT







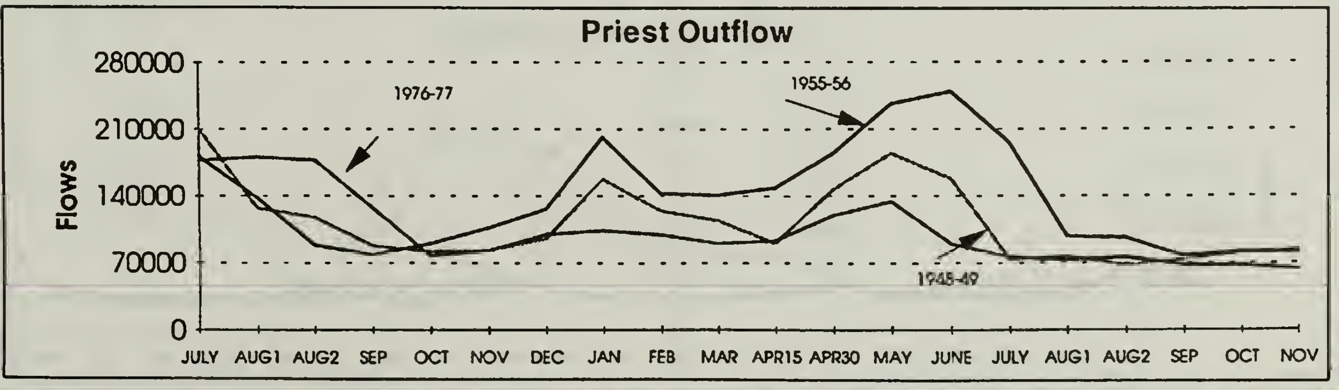
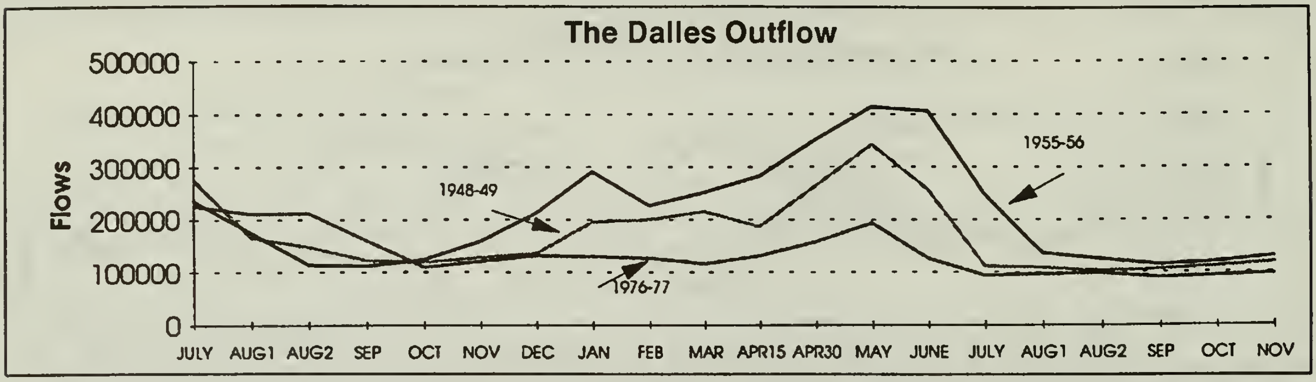
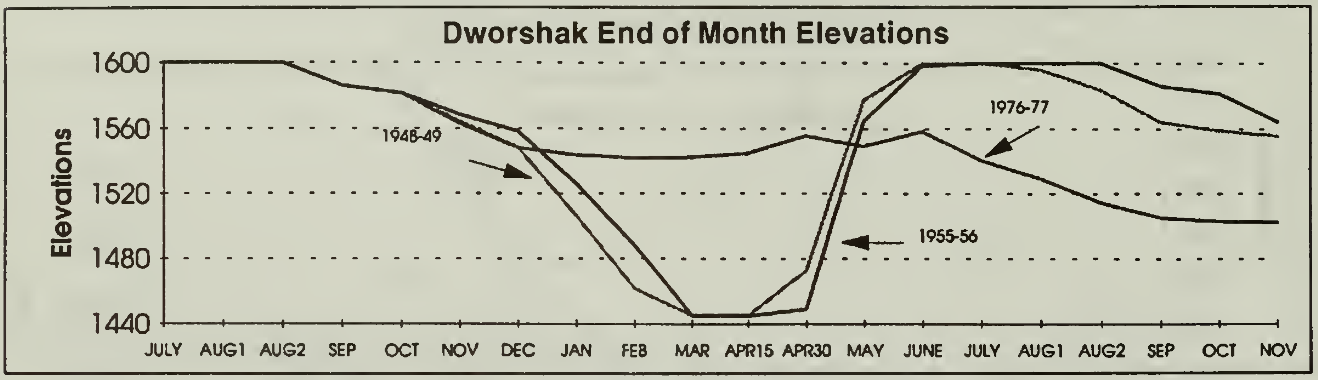
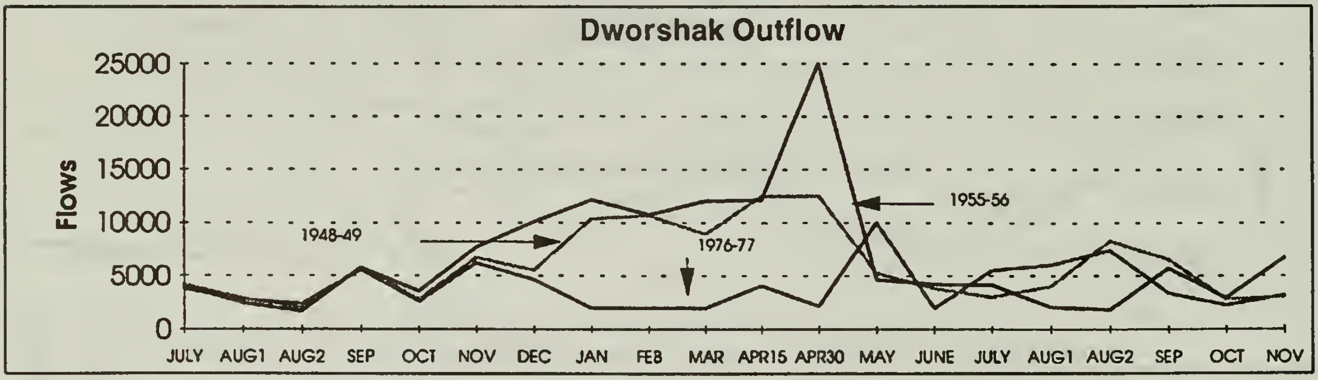


Table C–1. SOS1a – CONT







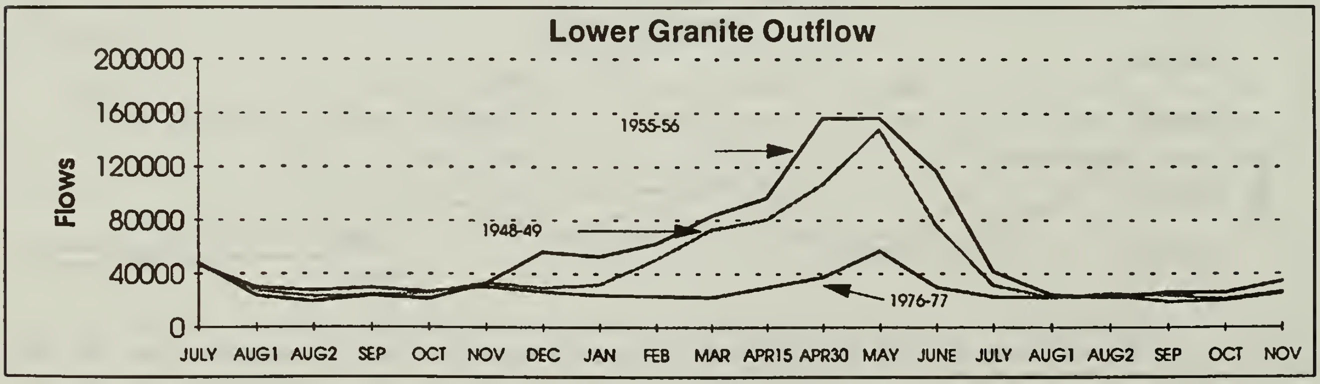
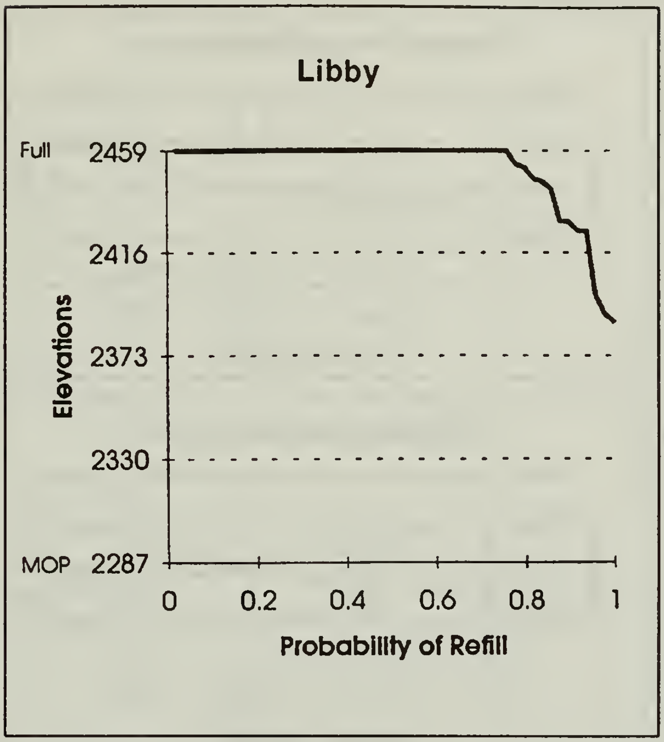
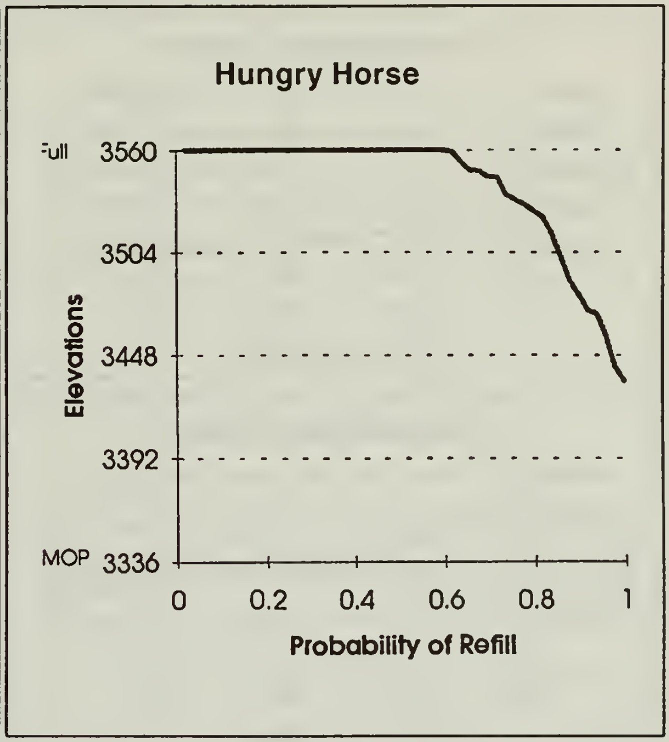
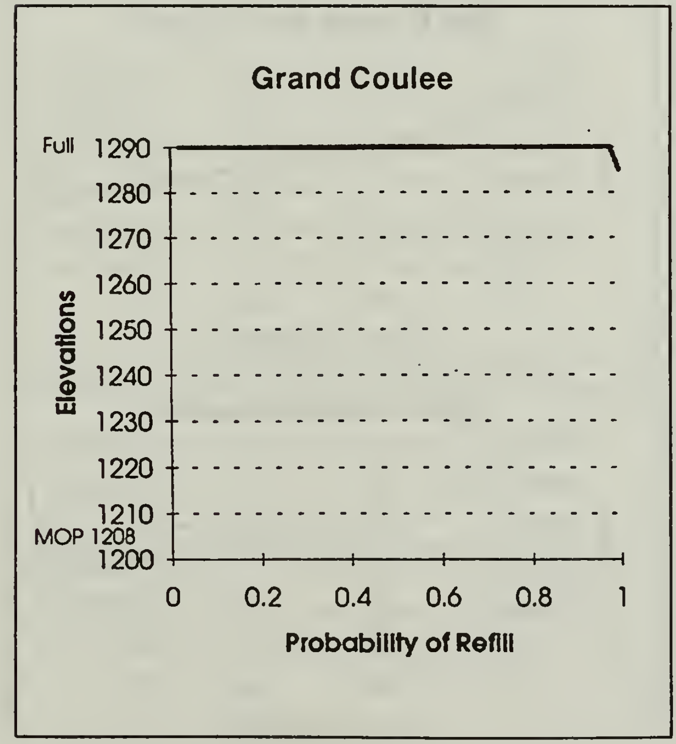


Table C-1. SOS1a – CONT

JULY ELEVATIONS







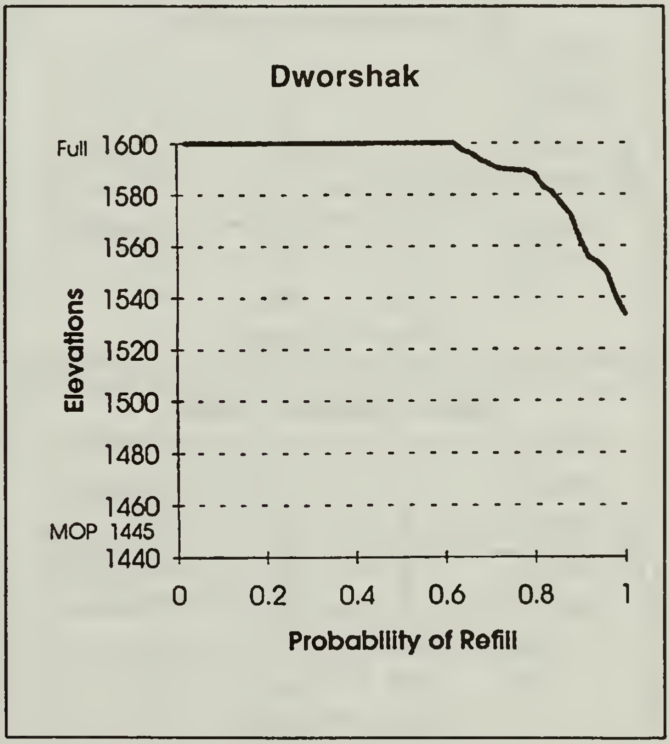
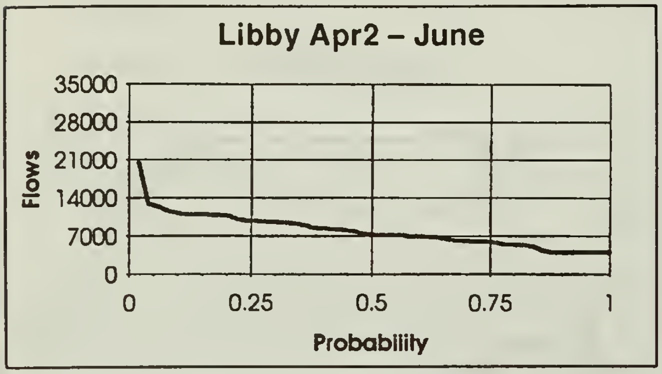
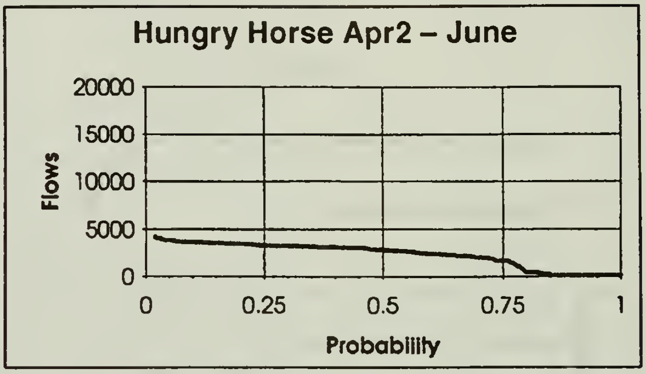
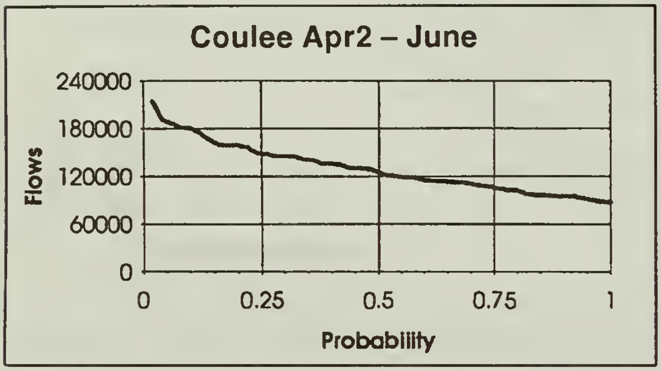


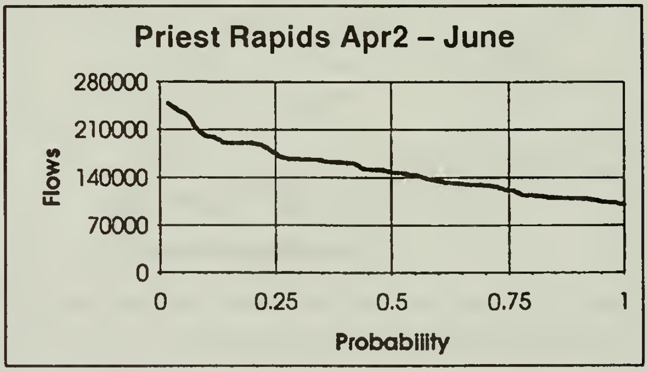
Table C–1. SOS1a – CONT

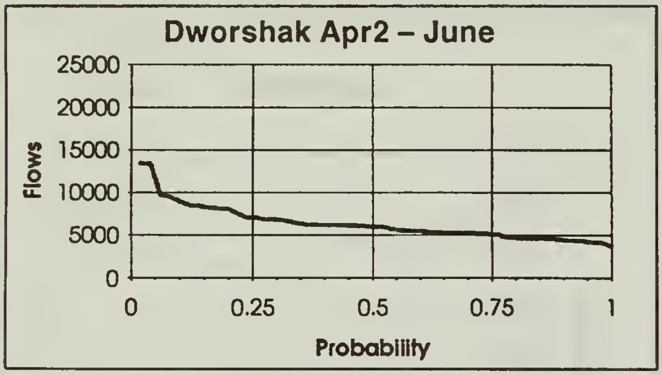
SPRING FLOWS

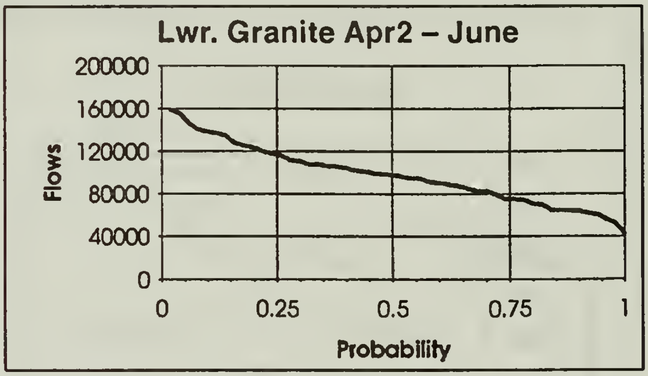


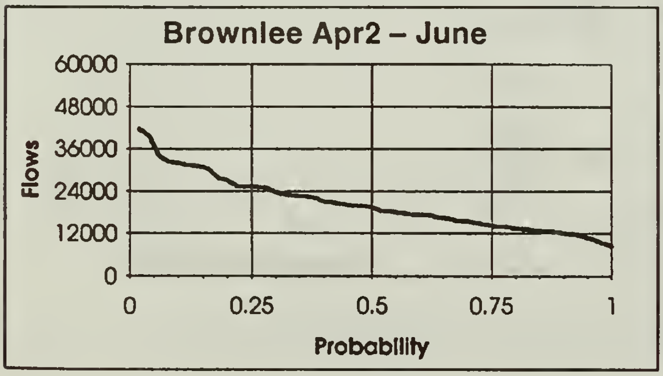












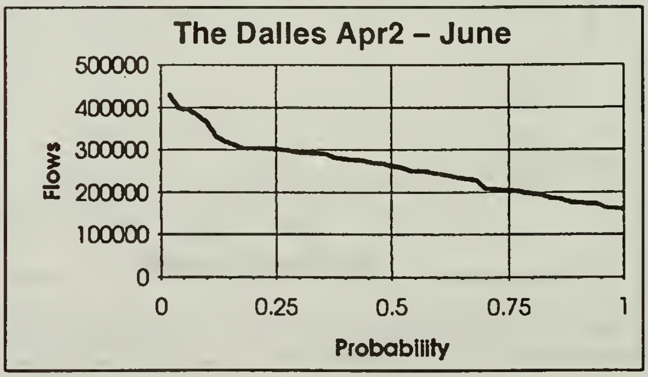
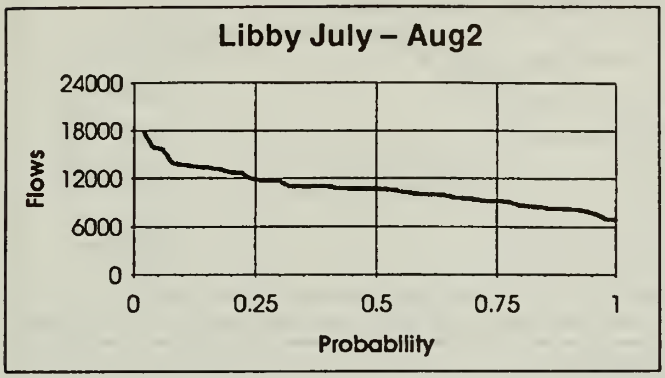
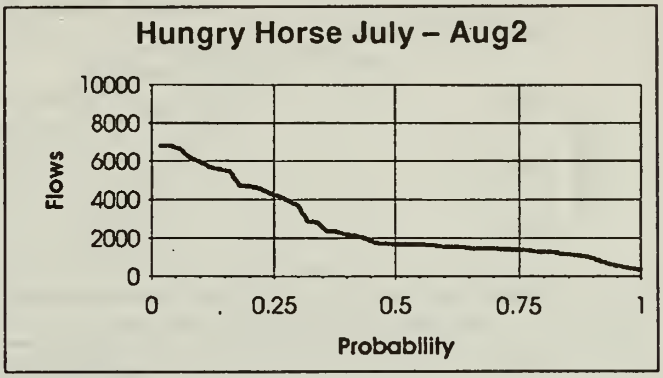
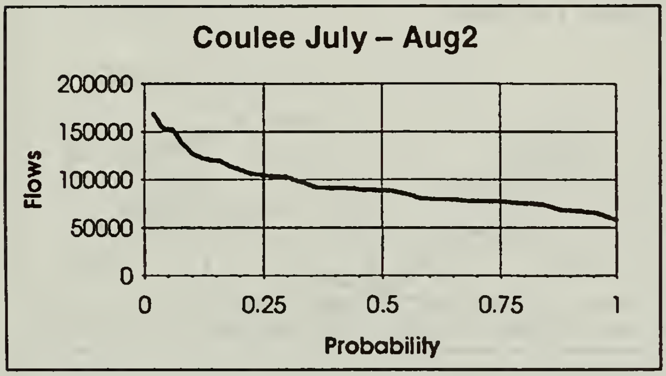


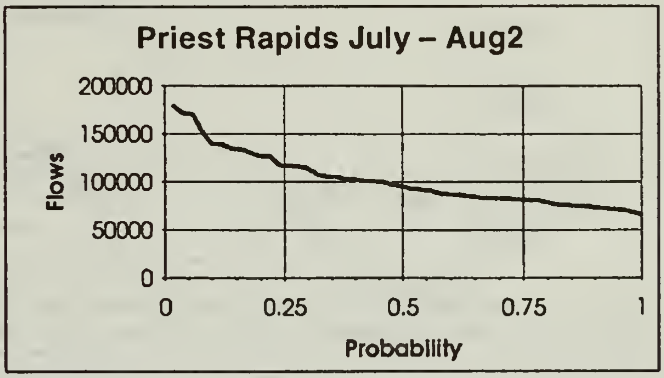
Table C–1. SOS1a – CONT

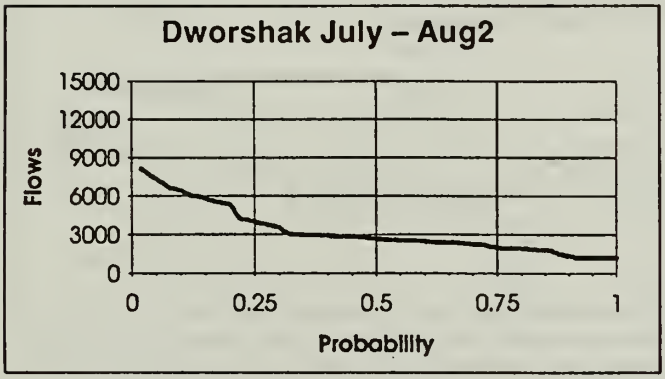
SUMMER FLOWS

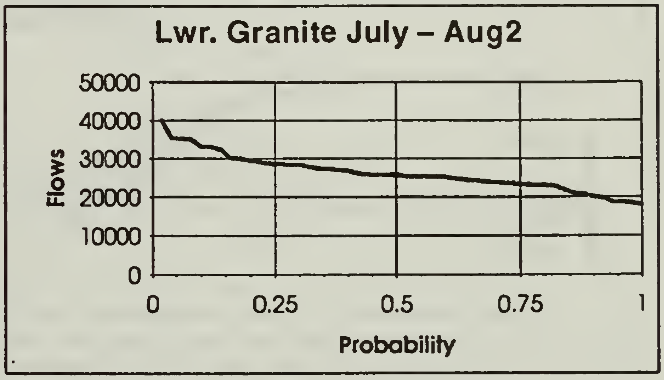


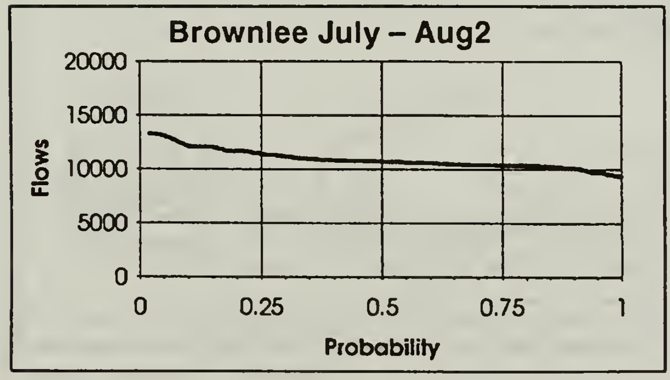












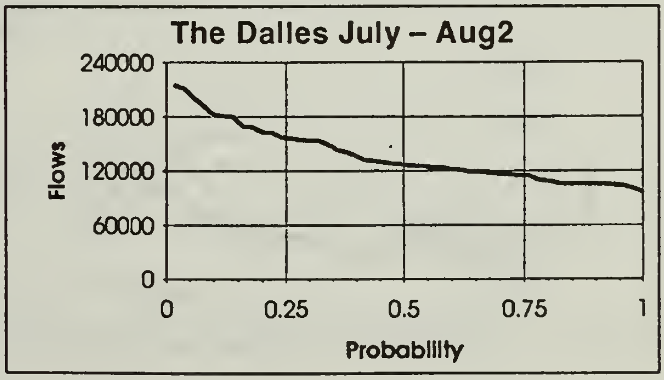
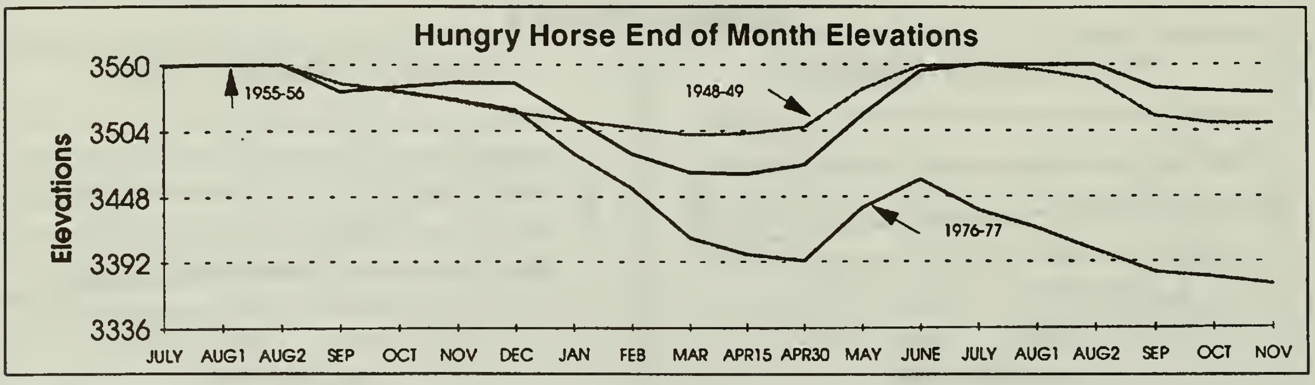
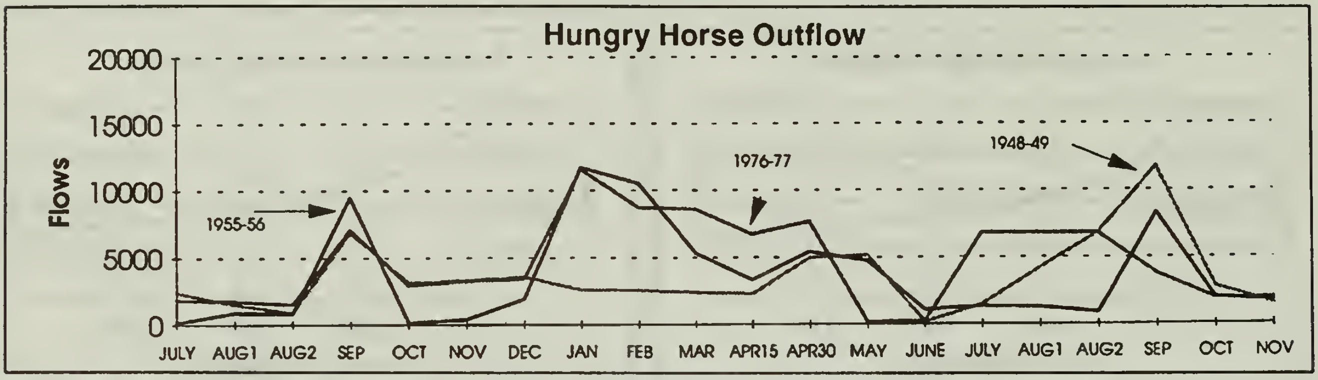
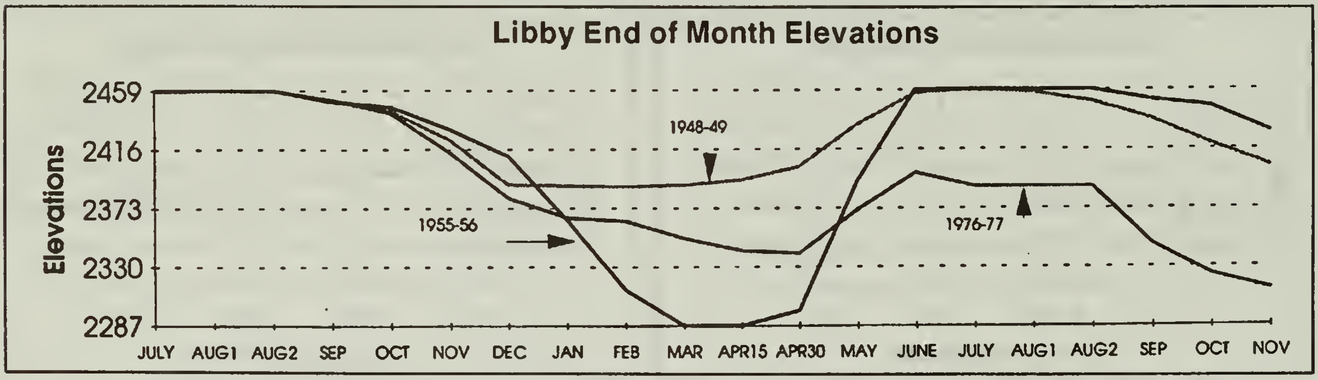


Table C–2. SOS1b







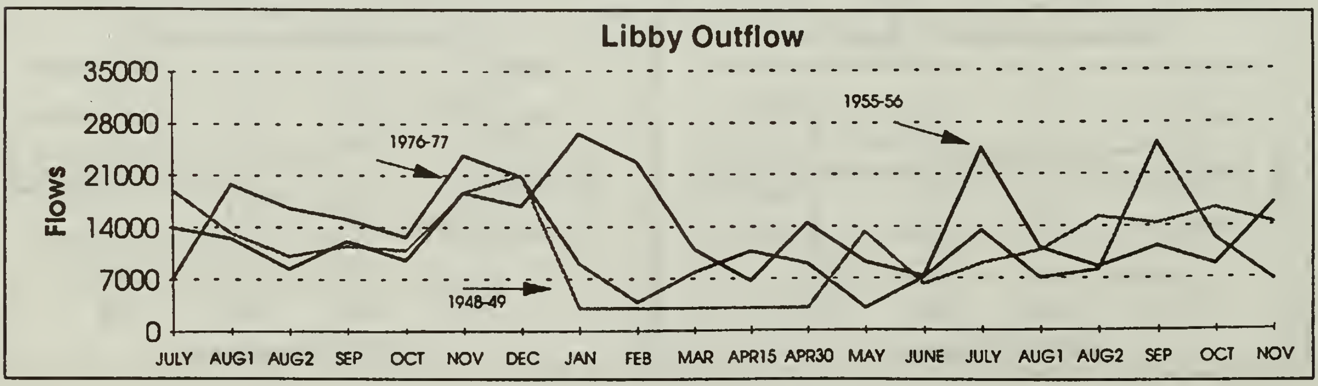
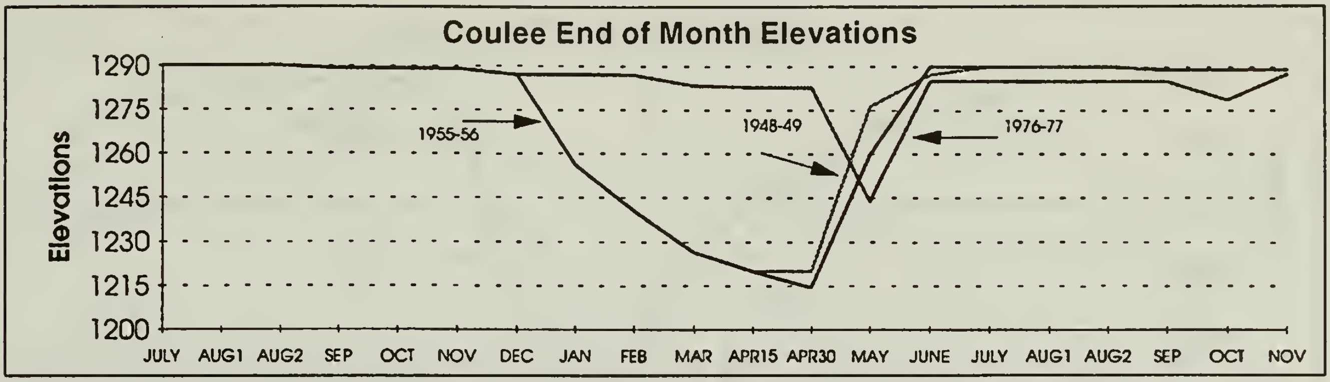
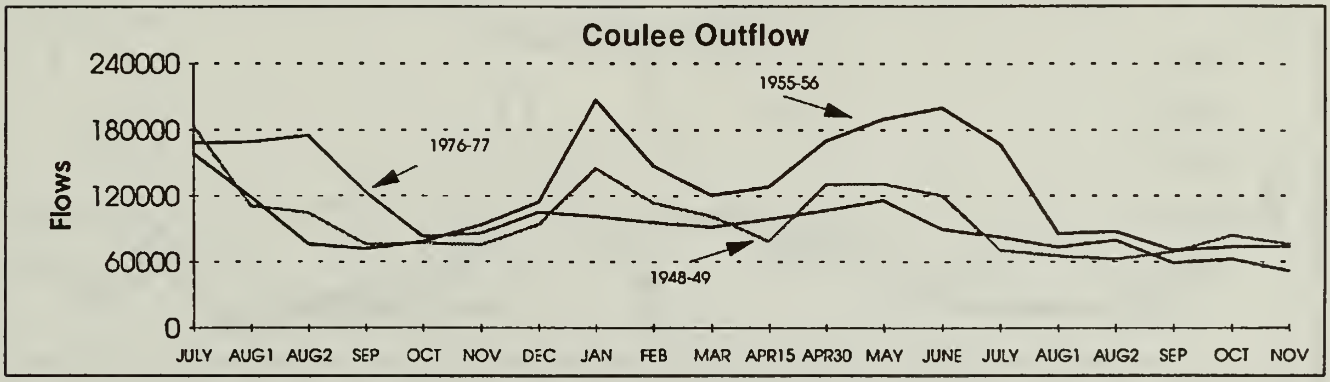
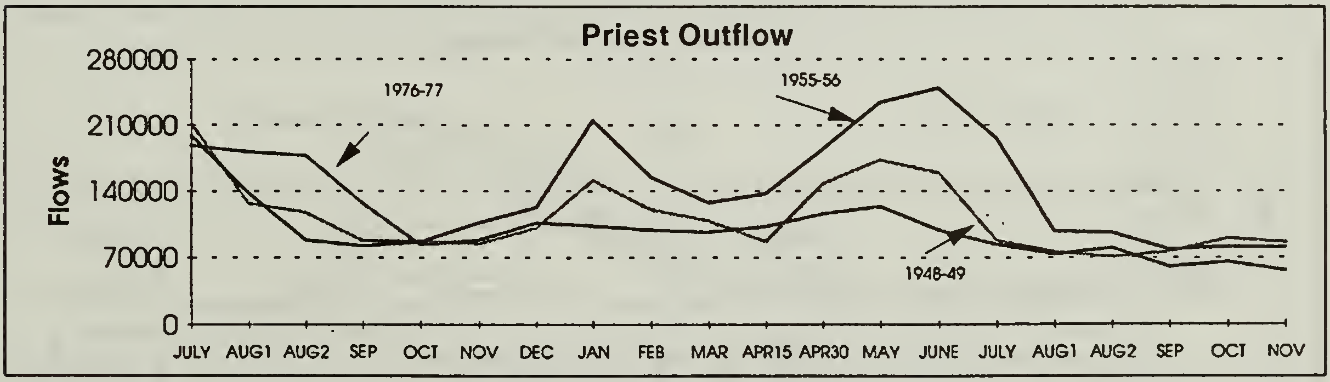


Table C–2. SOS1b – CONT







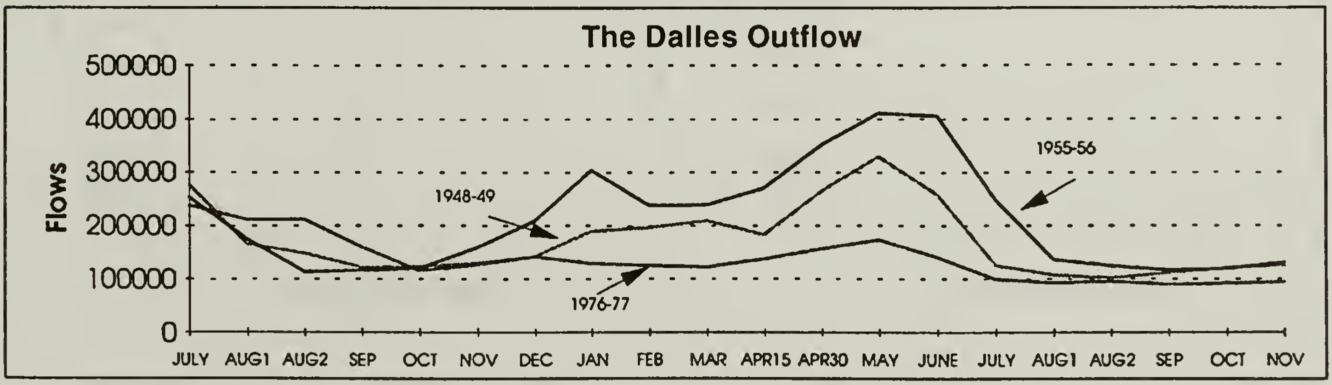
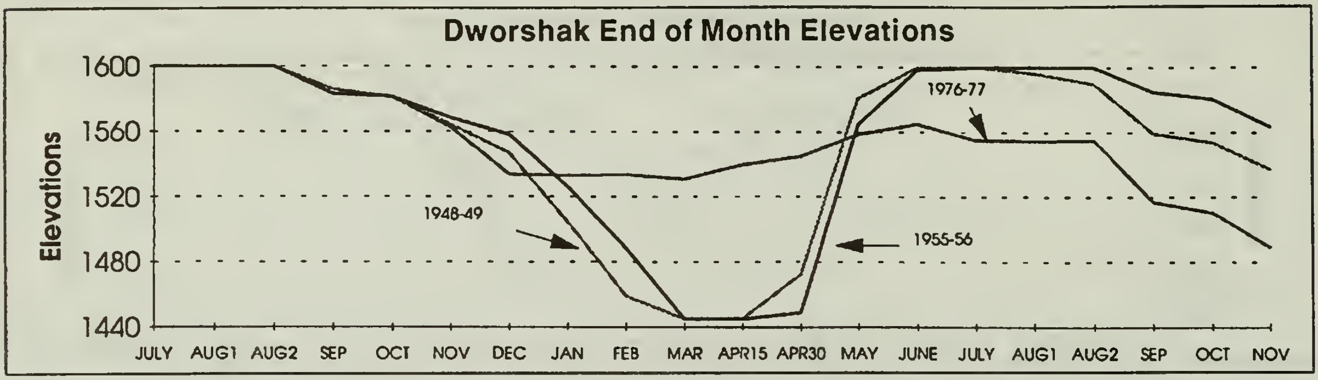
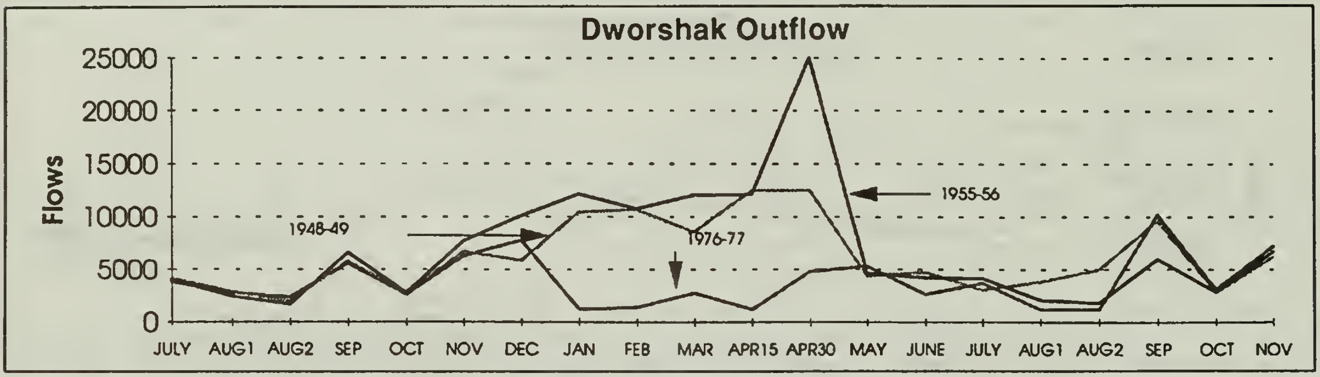


Table C–2. SOS1b – CONT





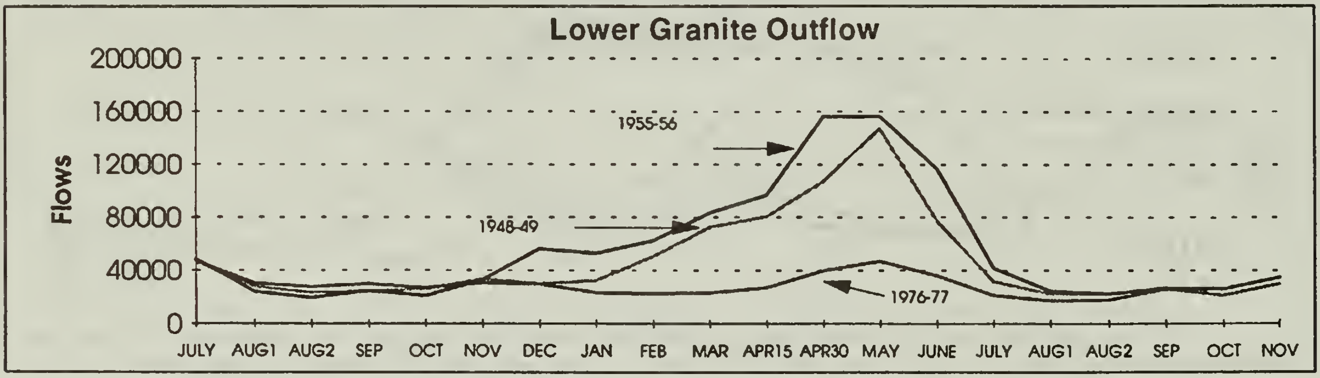


Table C–2. SOS1b – CONT

JULY ELEVATIONS

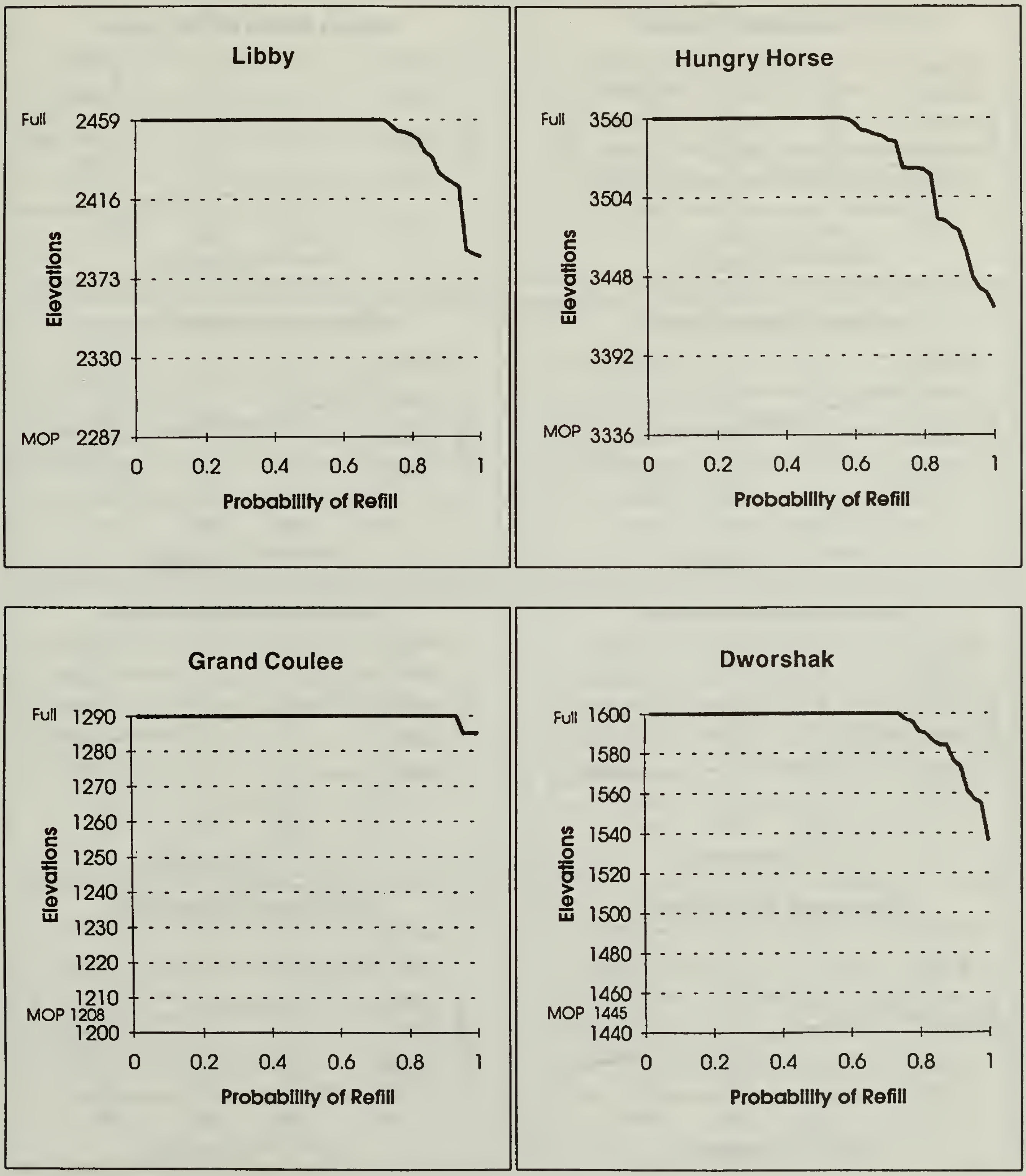


Table C–2. SOS1b – CONT

SPRING FLOWS

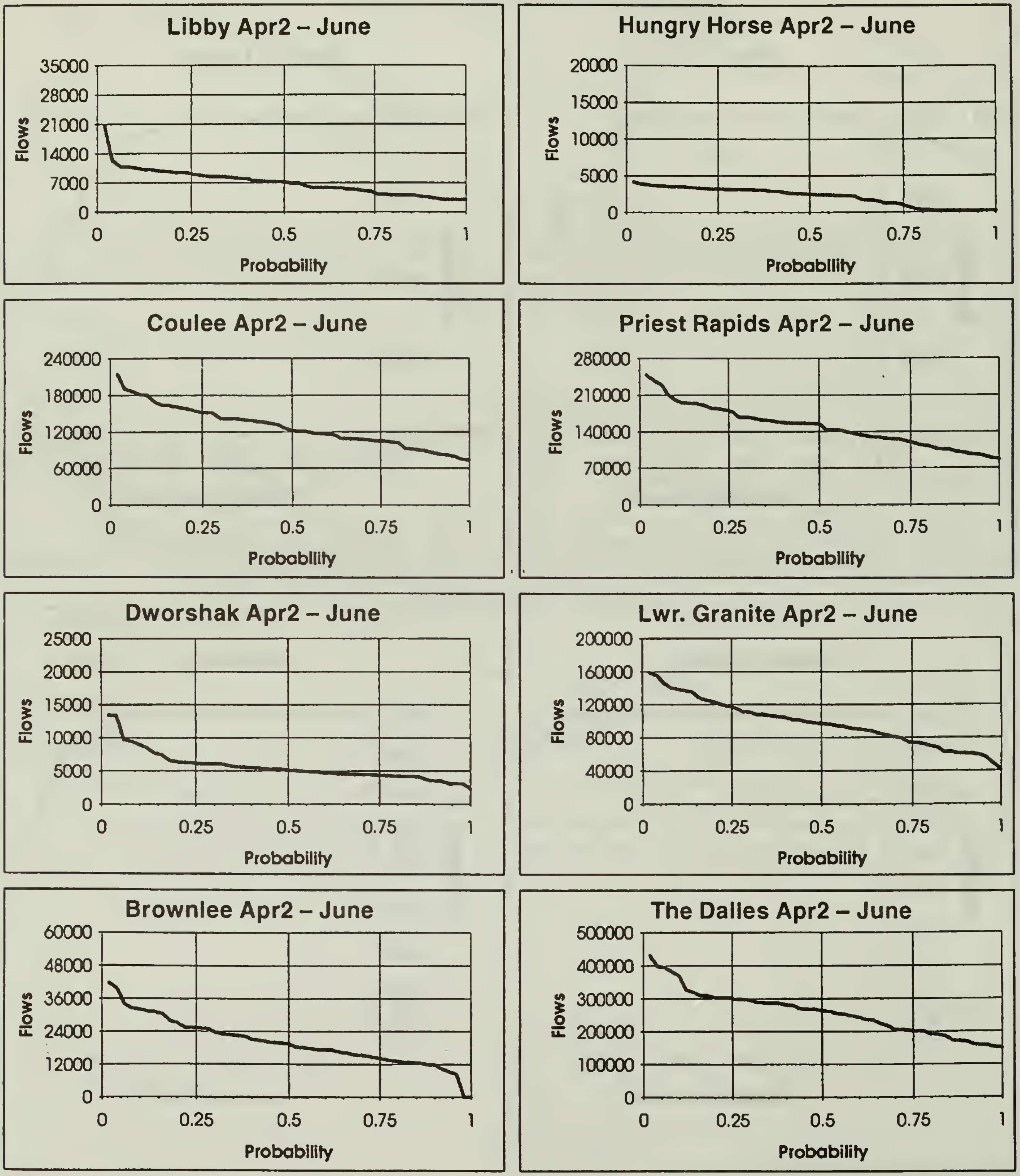


Table C–2. SOS1b – CONT

SUMMER FLOWS

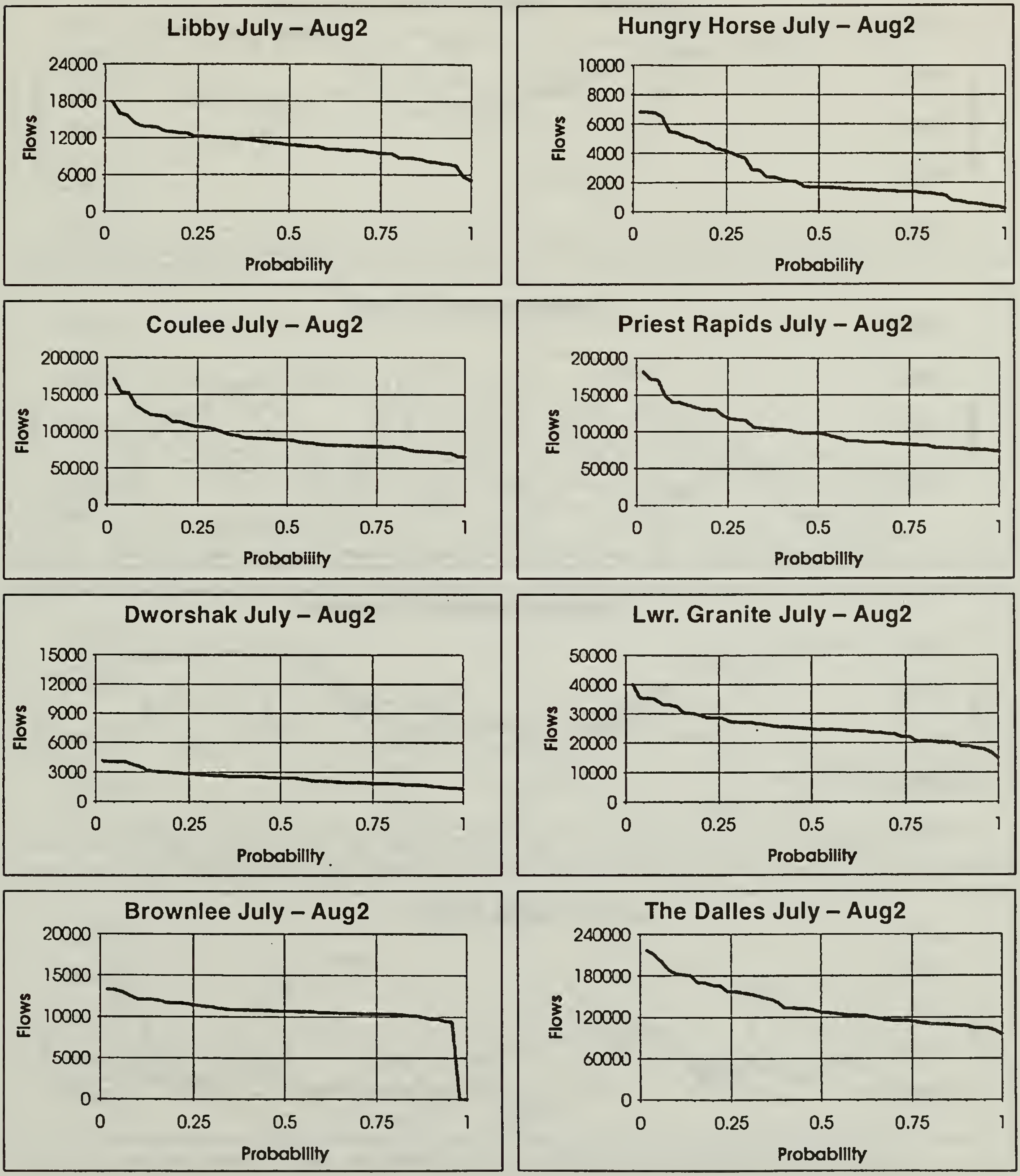
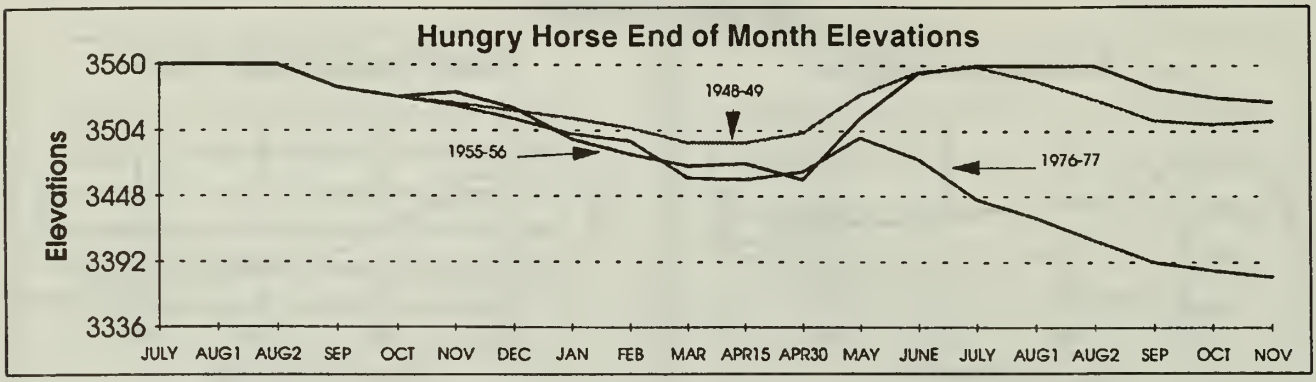
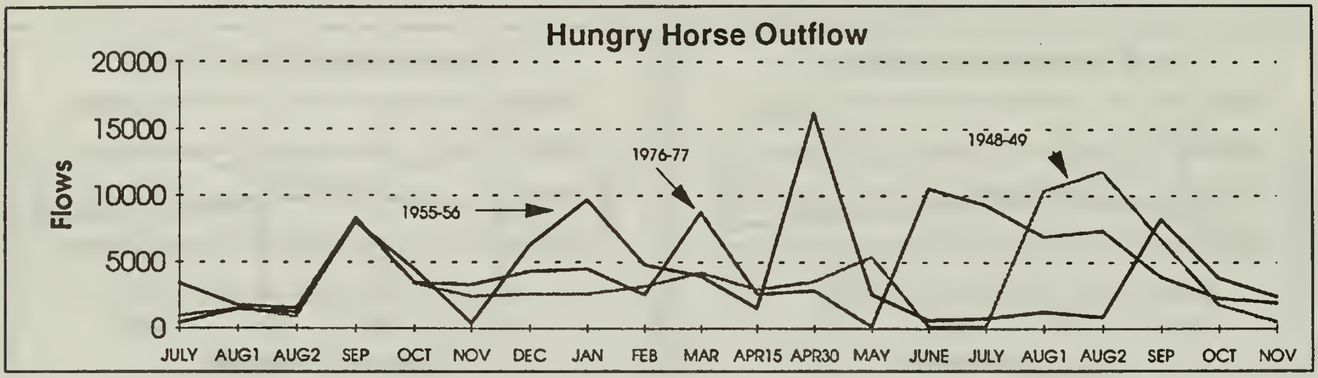
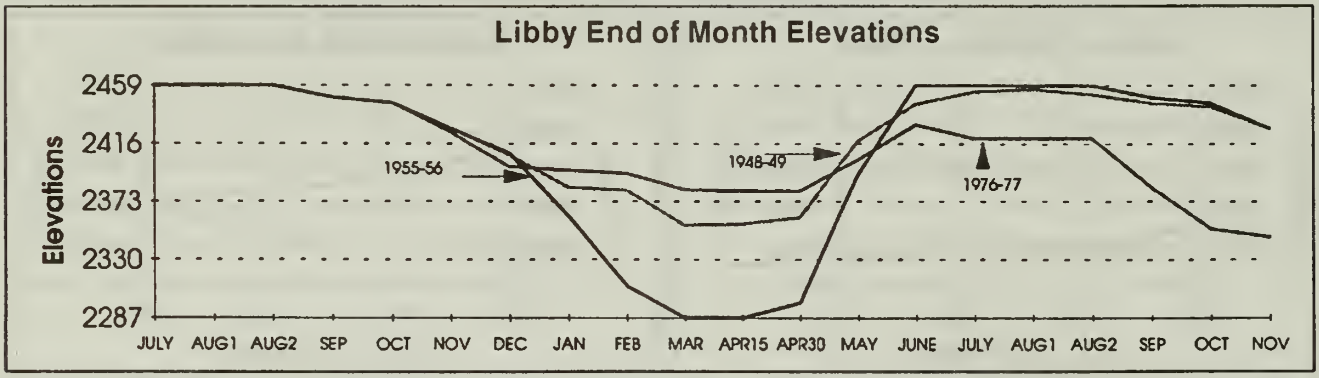


Table C–3. SOS2c







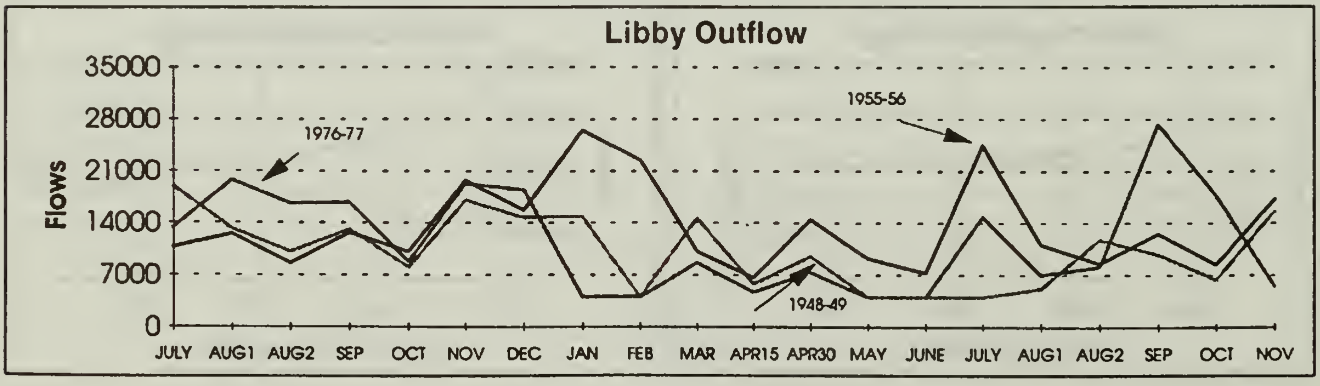
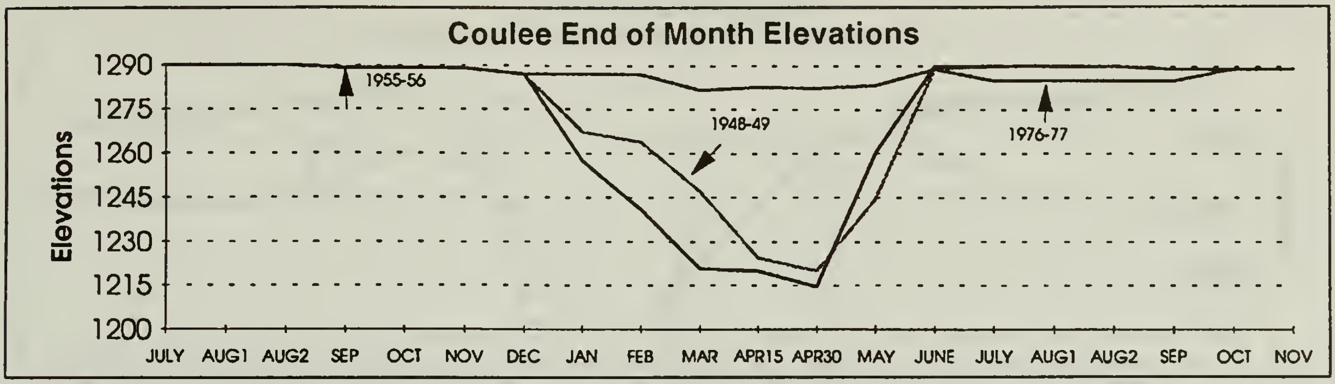
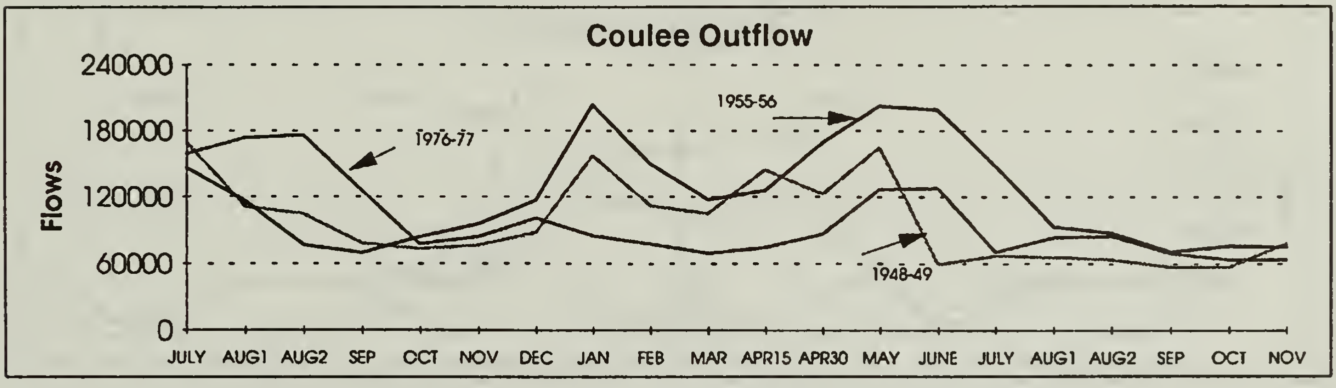
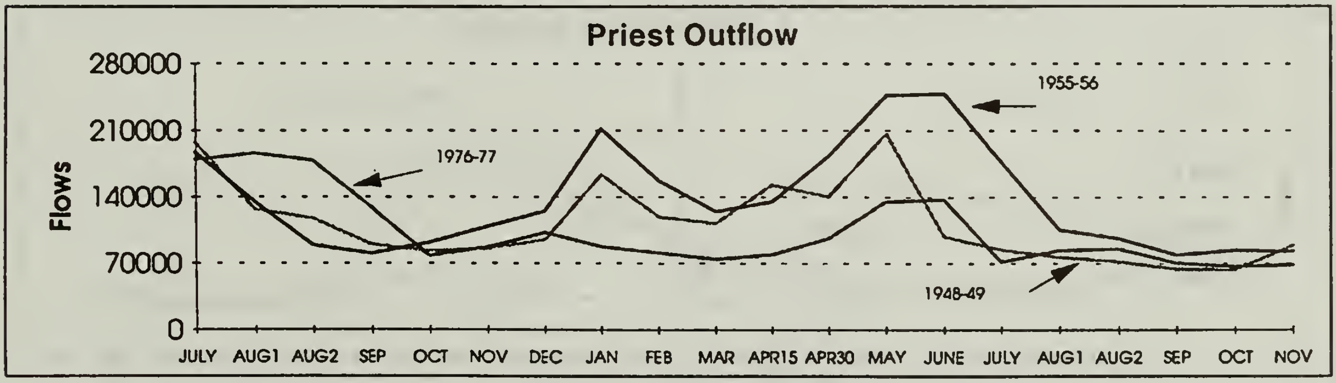


Table C–3. SOS2c – CONT







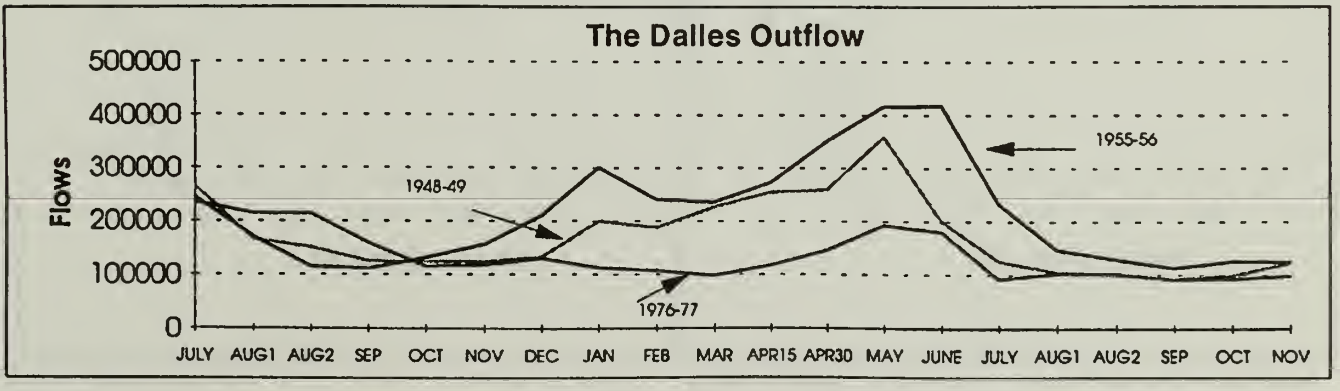
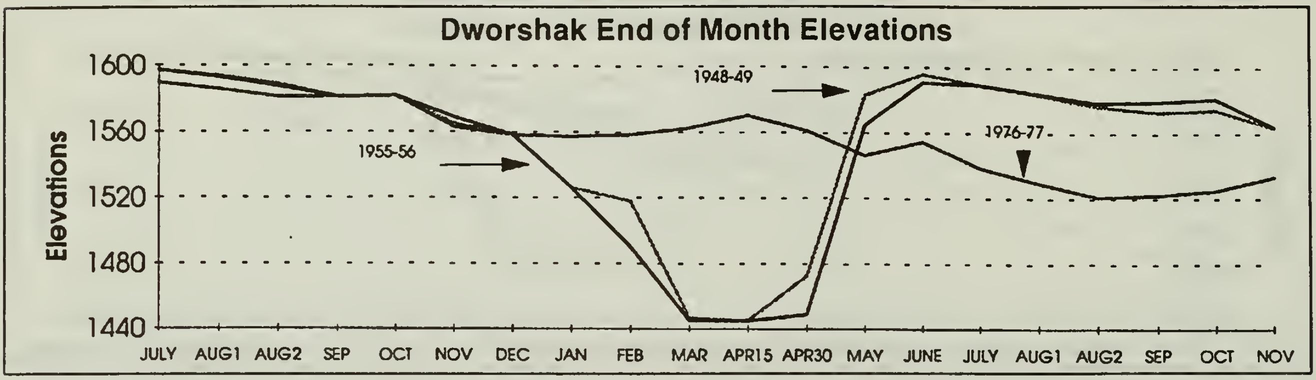
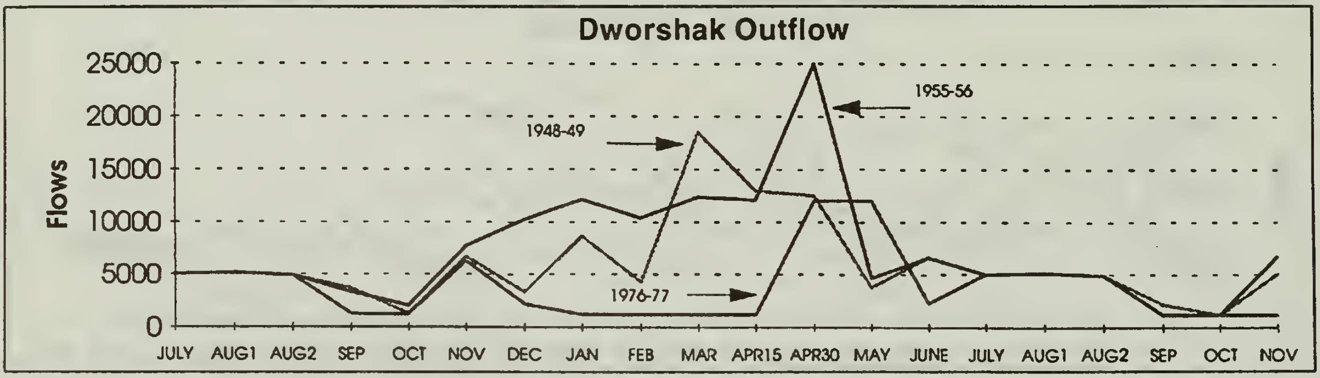


Table C–3. SOS2c – CONT





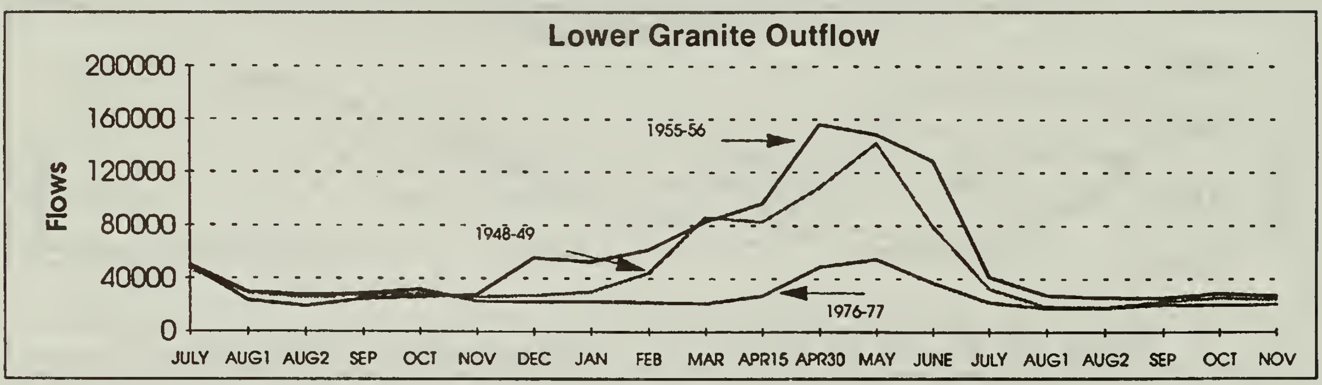
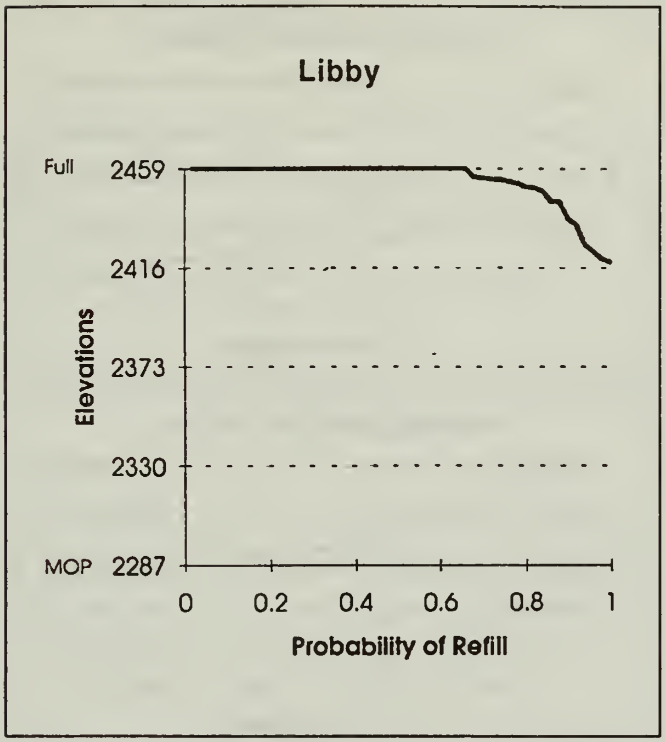
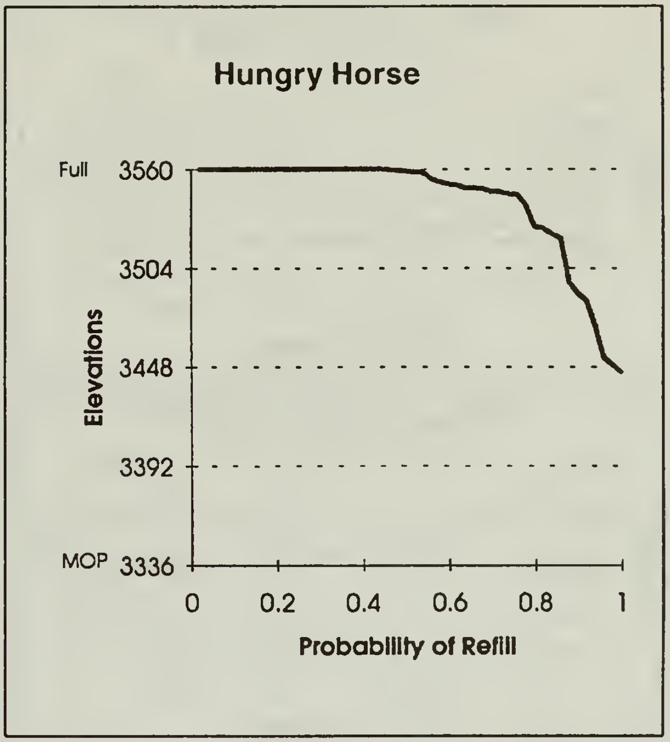
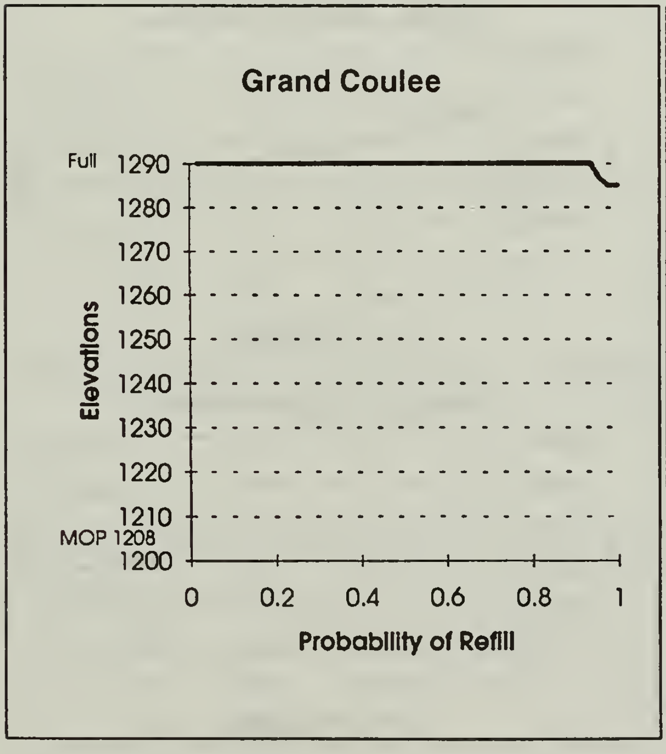


Table C–3. SOS2c – CONT

JULY ELEVATIONS







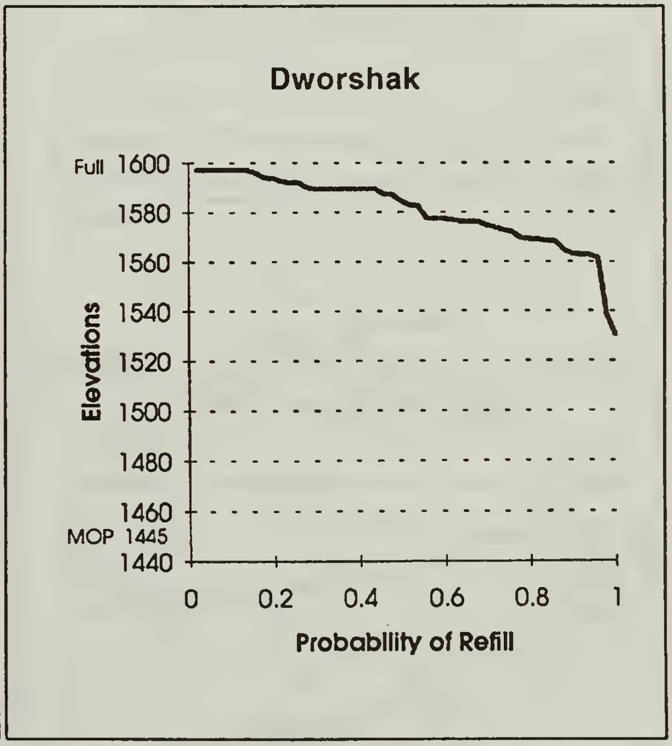


Table C-3. SOS2c – CONT

SPRING FLOWS

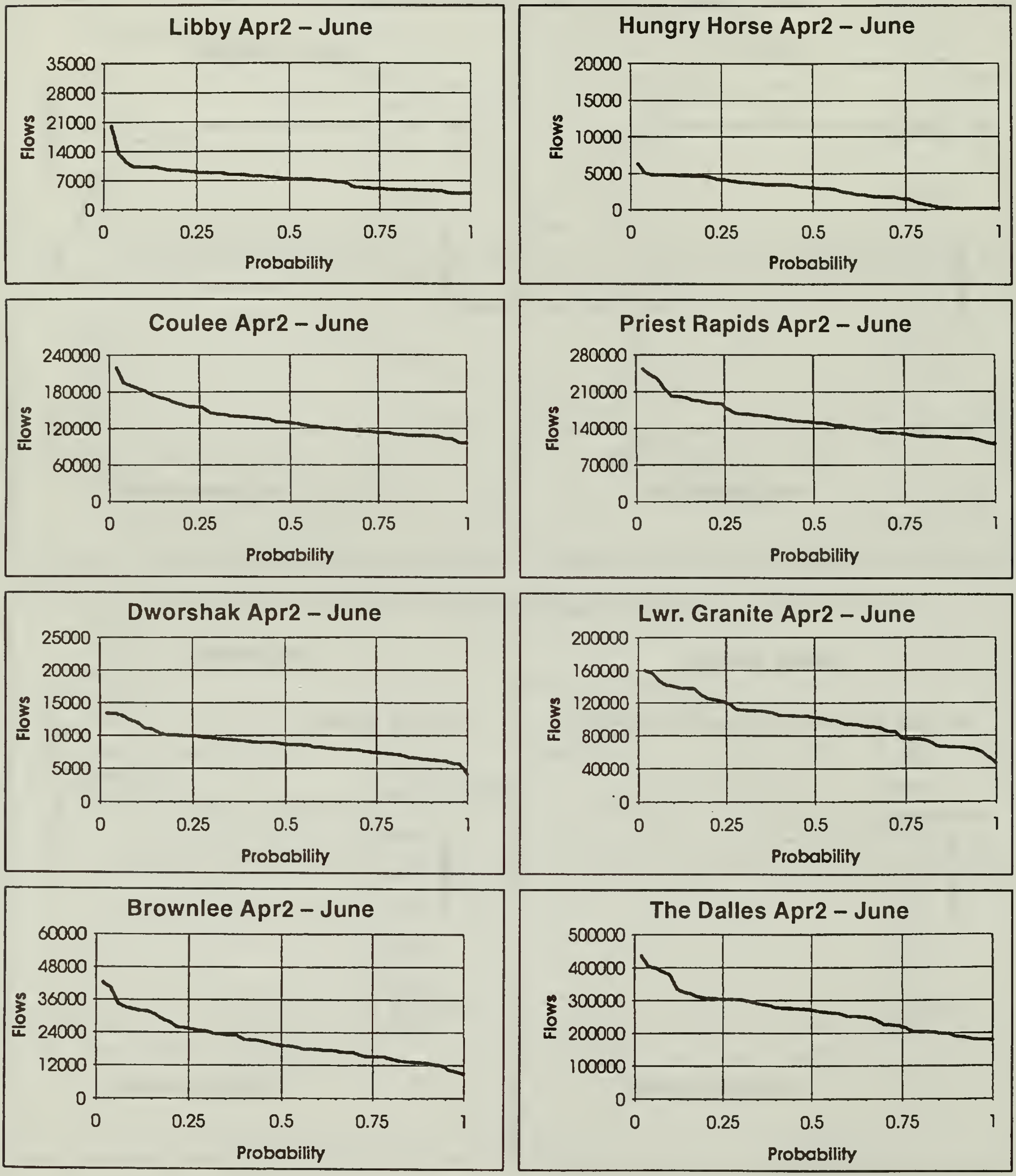


Table C–3. SOS2c – CONT

SUMMER FLOWS

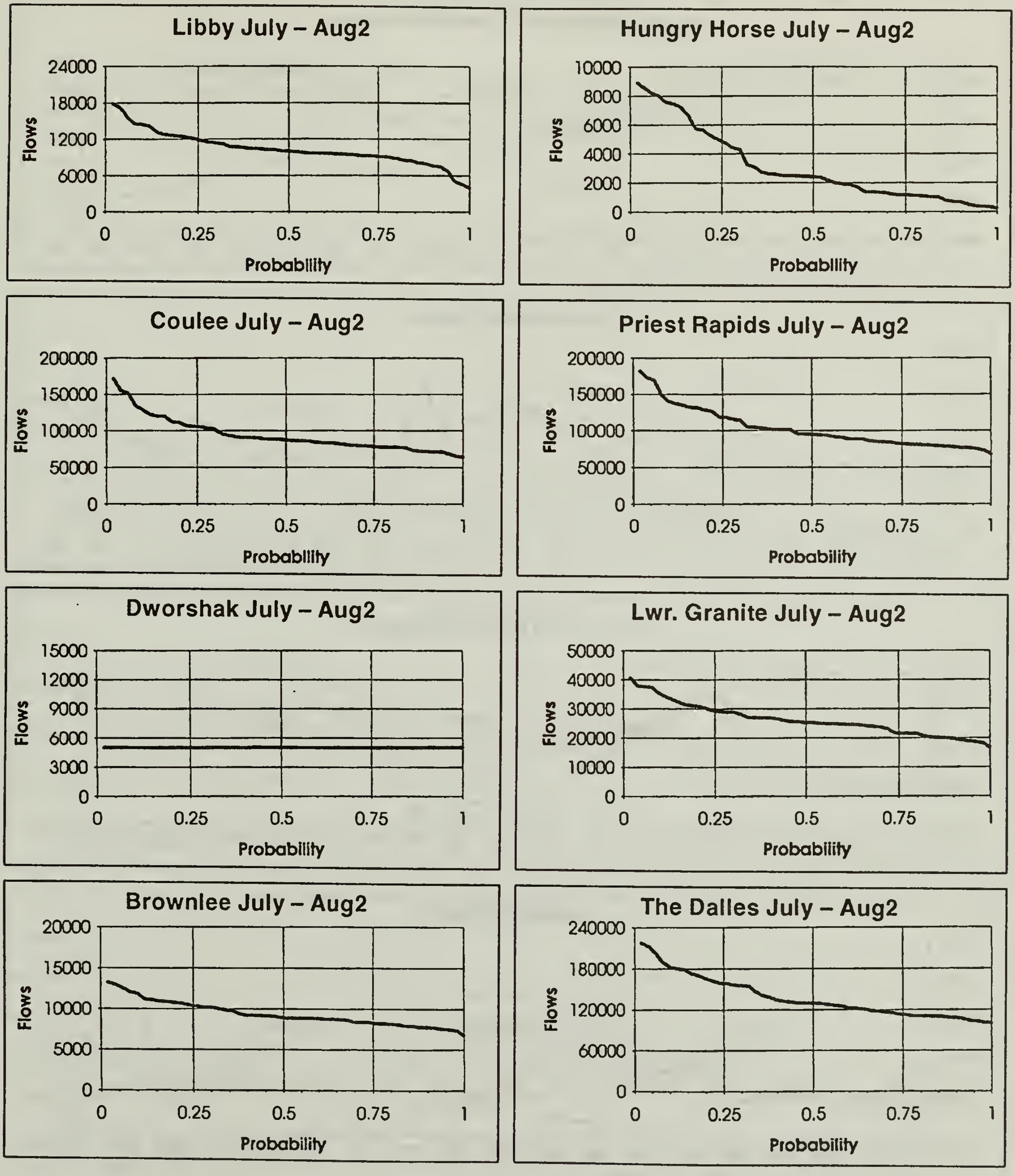
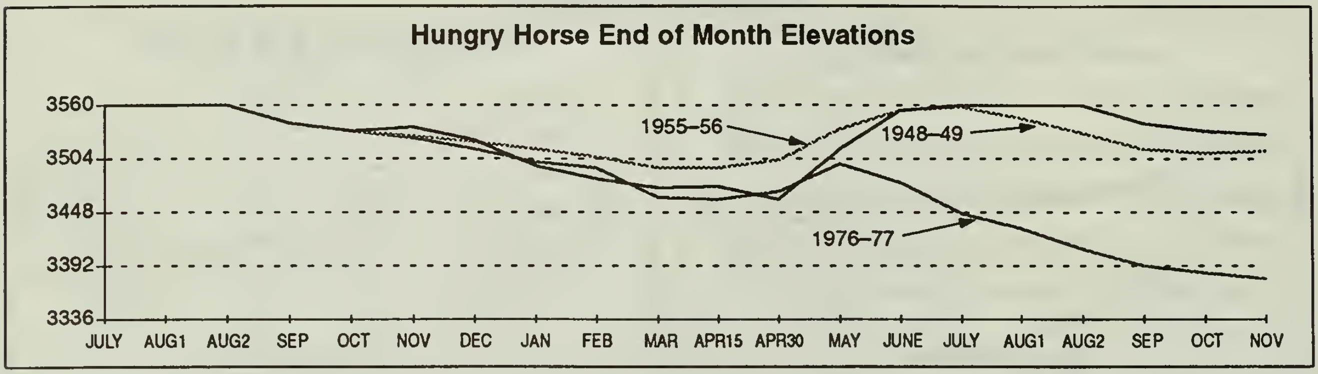
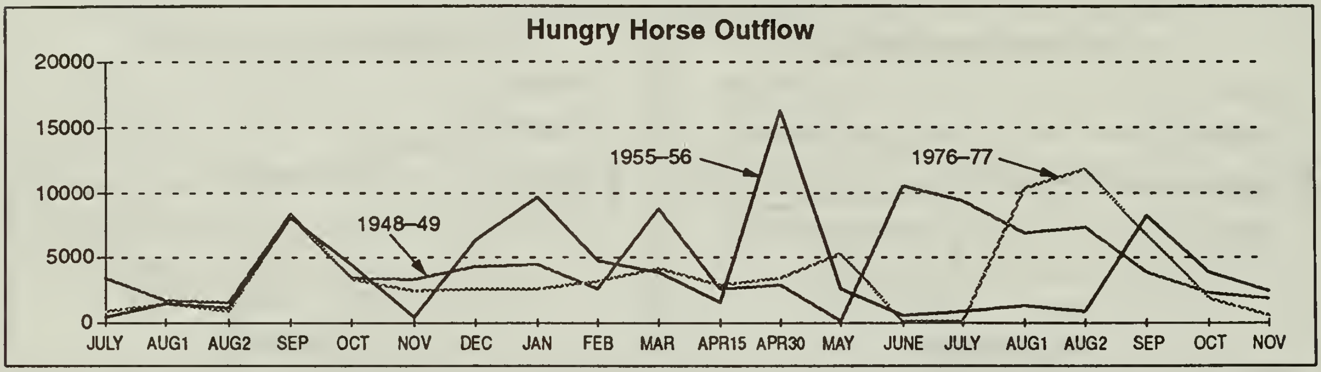
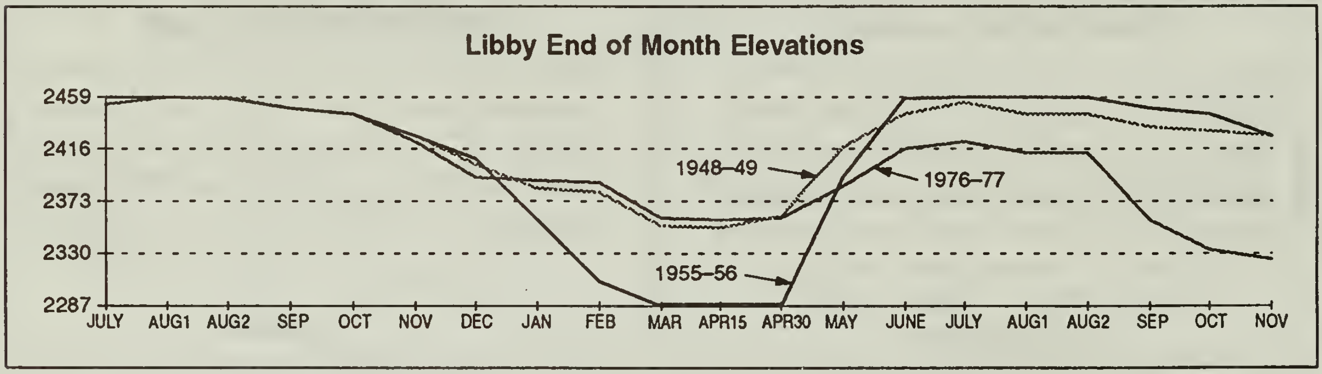


Table C–4. SOS2d







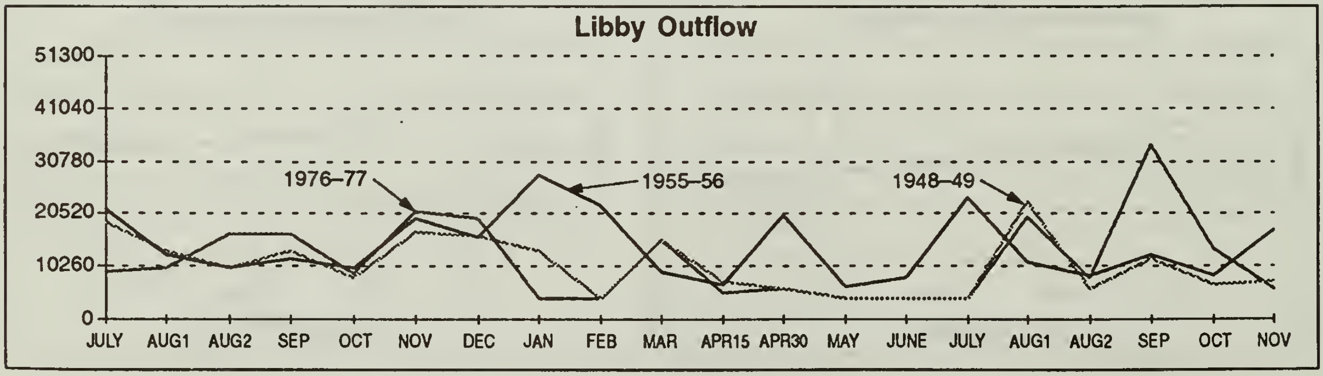
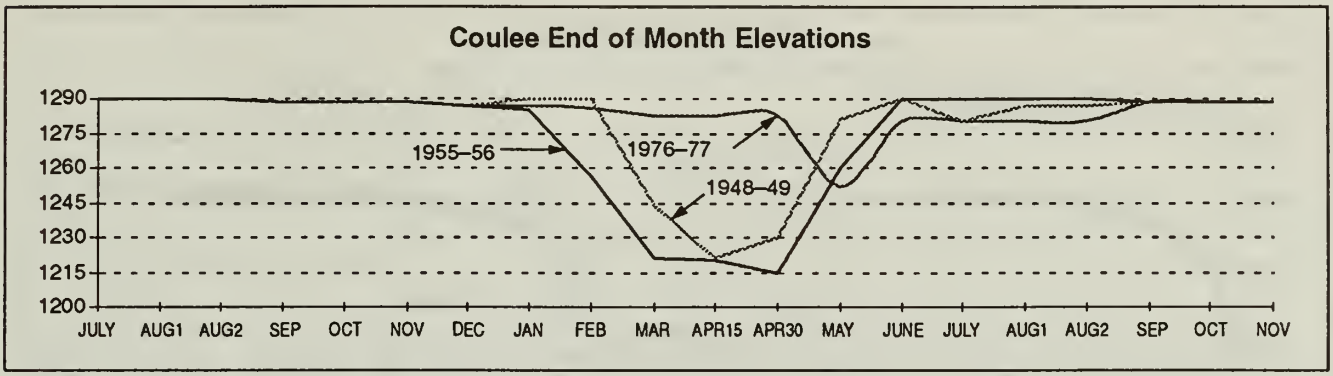
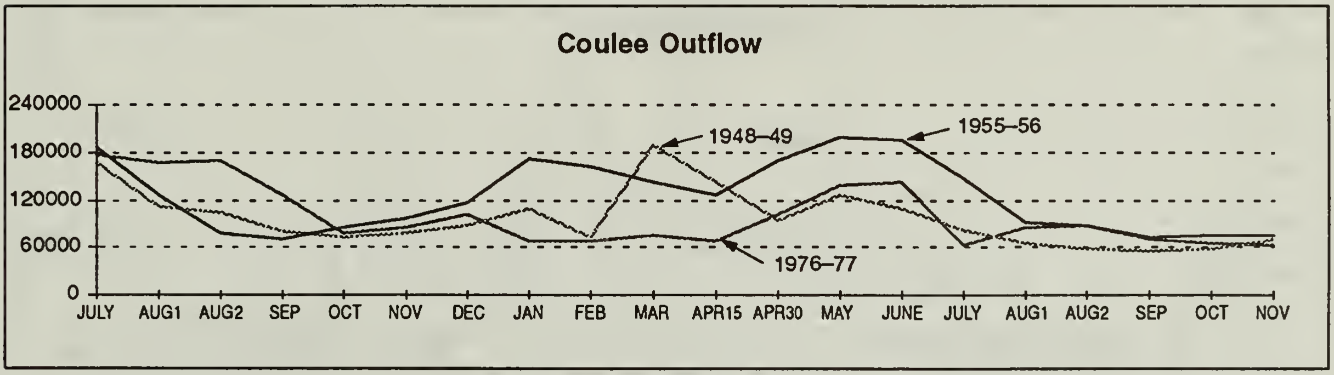
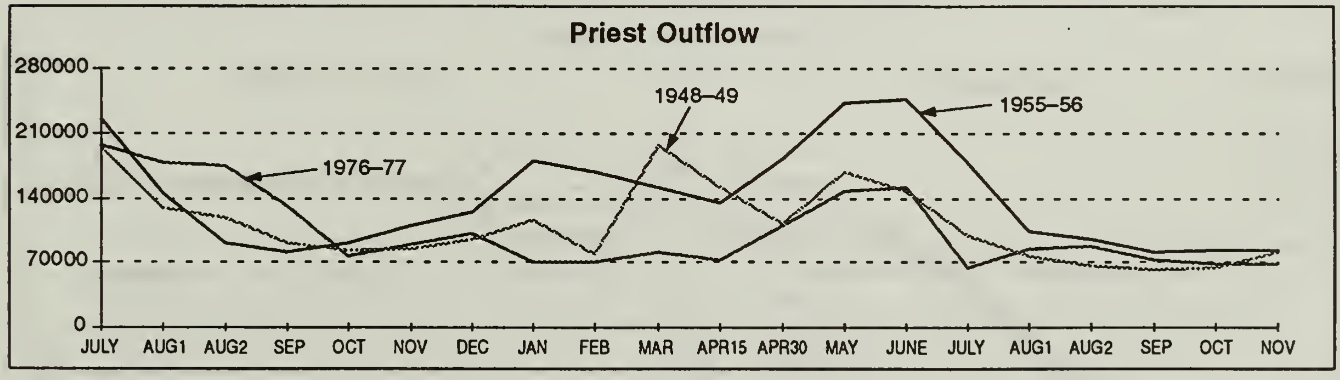


Table C–4. SOS2d – CONT







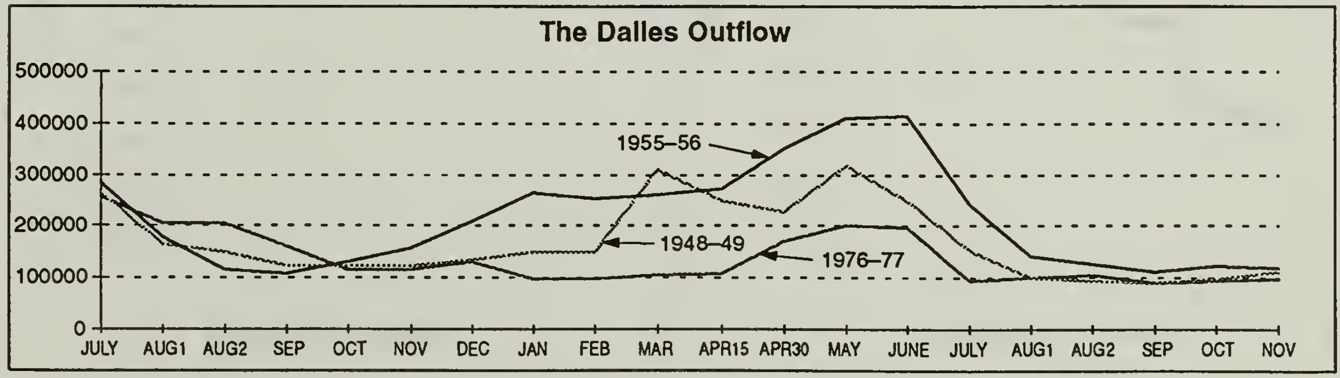
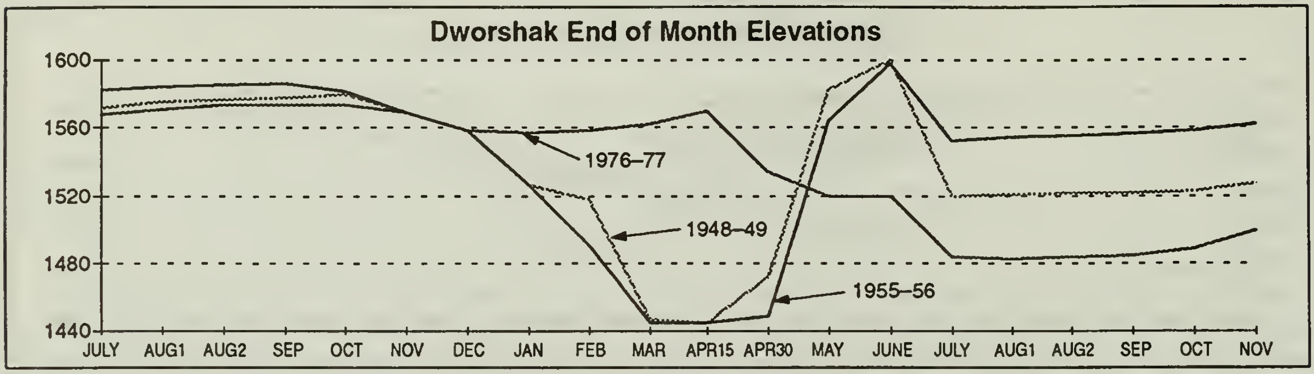
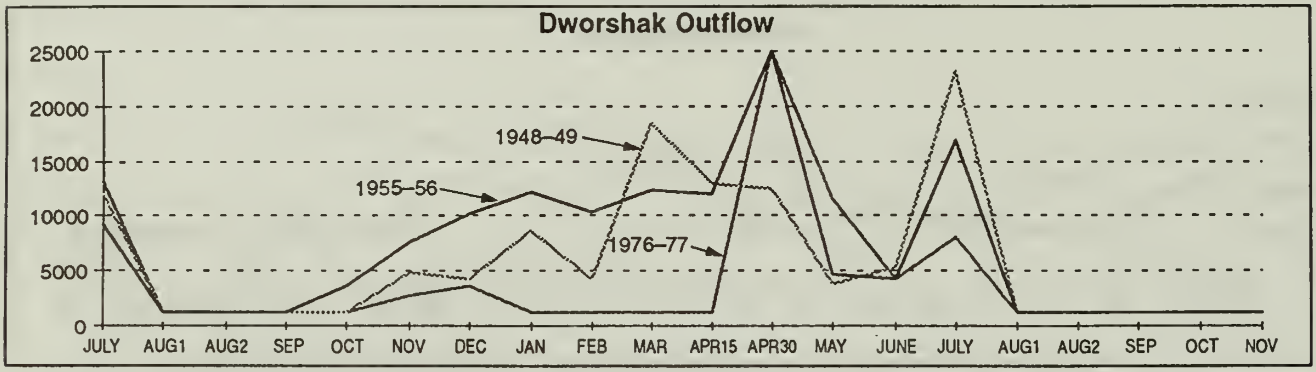


Table C–4. SOS2d – CONT





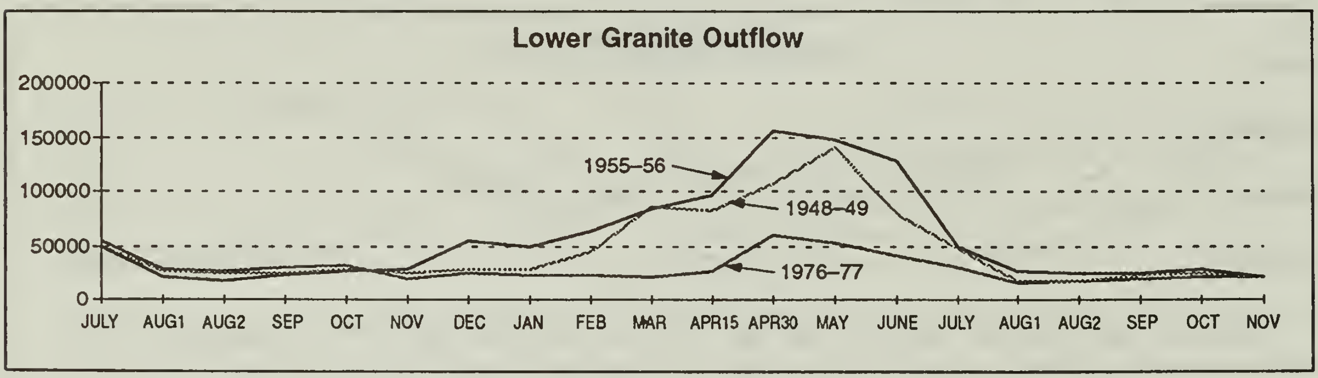


Table C–4. SOS2d – CONT

JULY ELEVATIONS

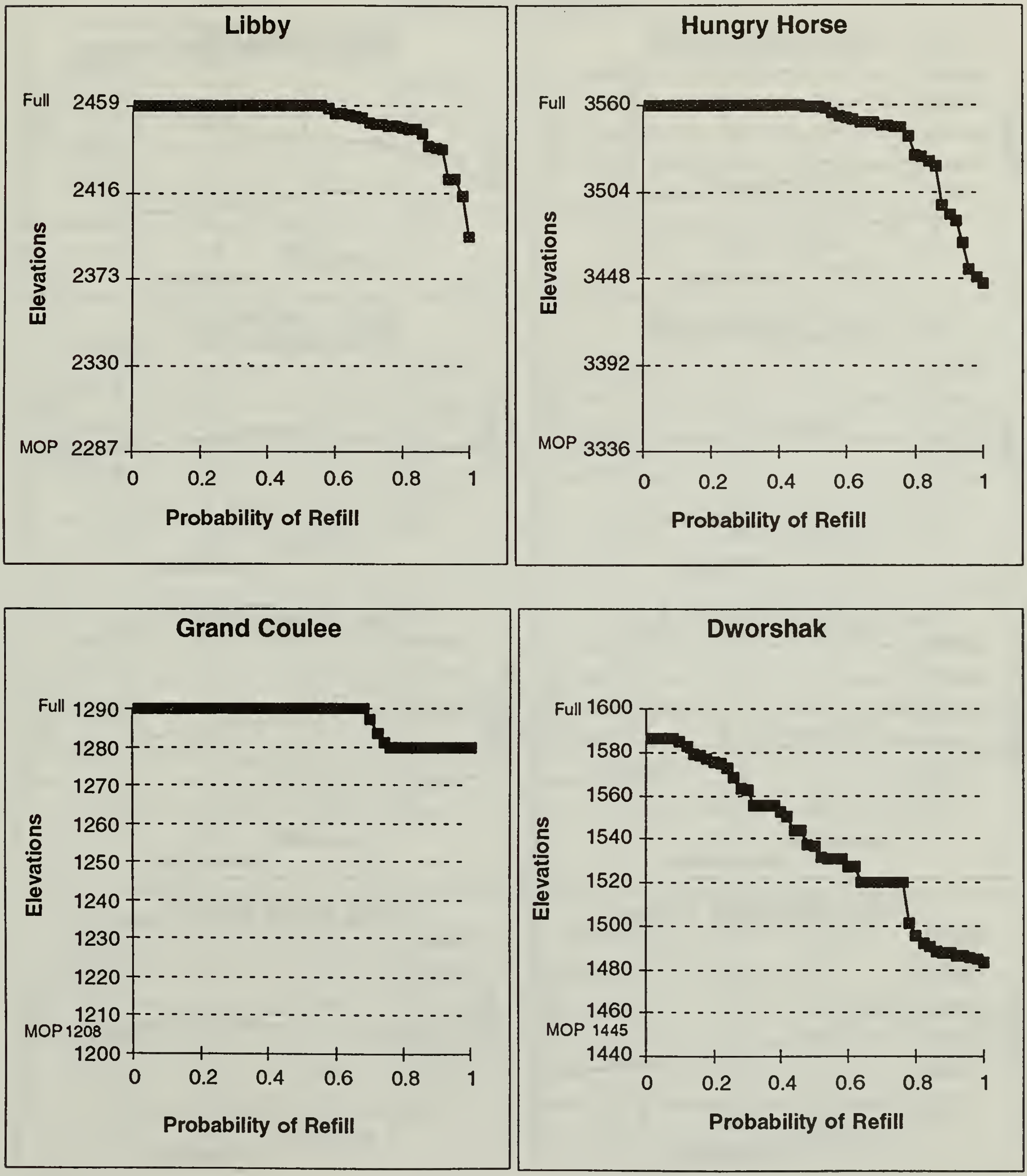


Table C–4. SOS2d – CONT

SPRING FLOWS

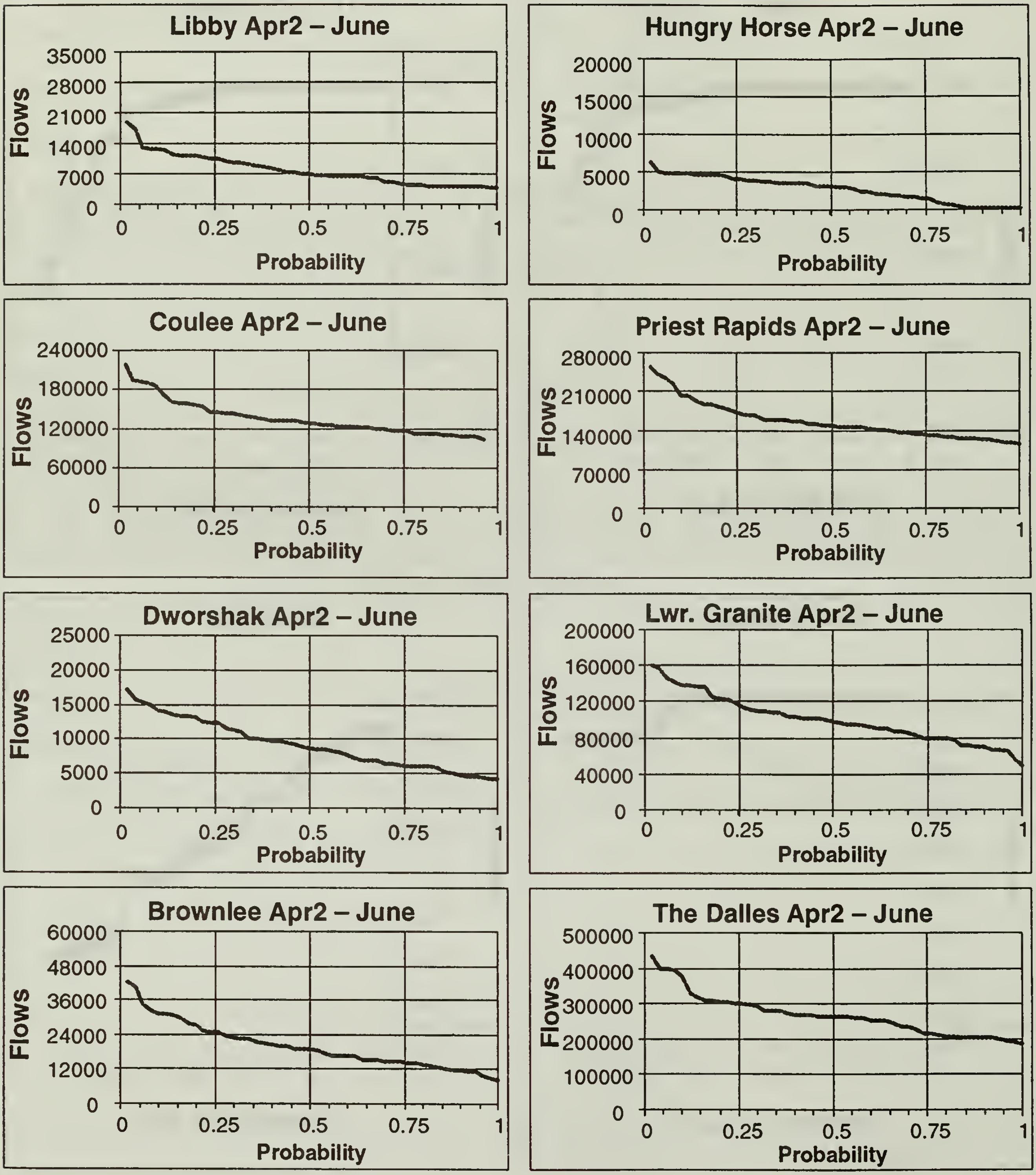
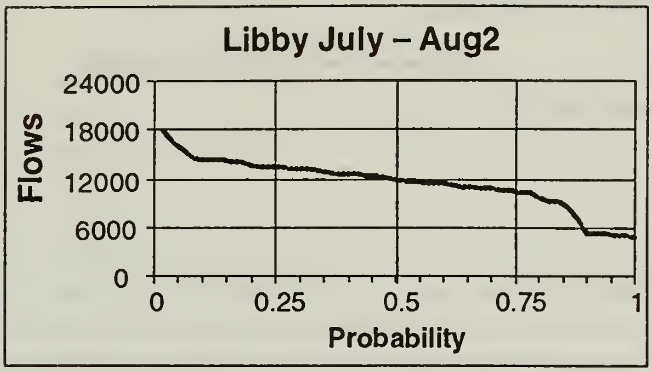
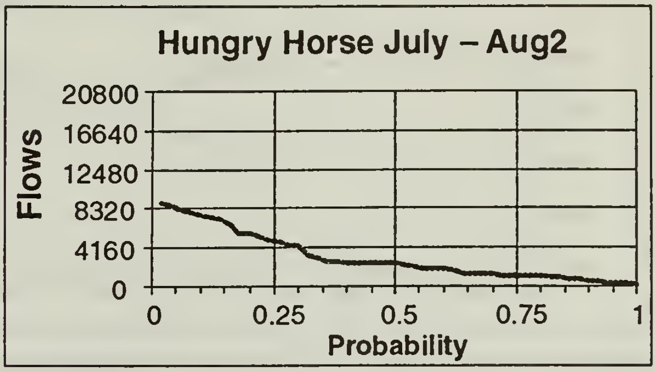
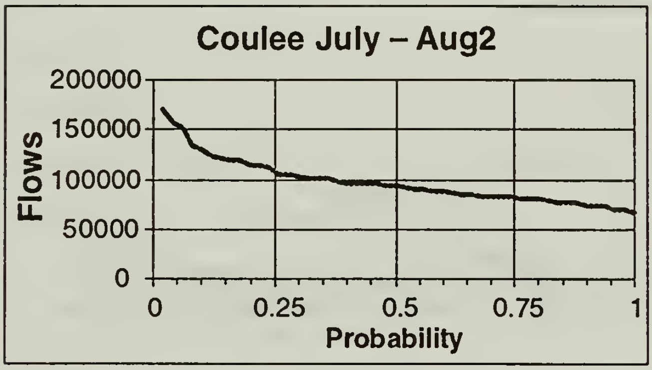


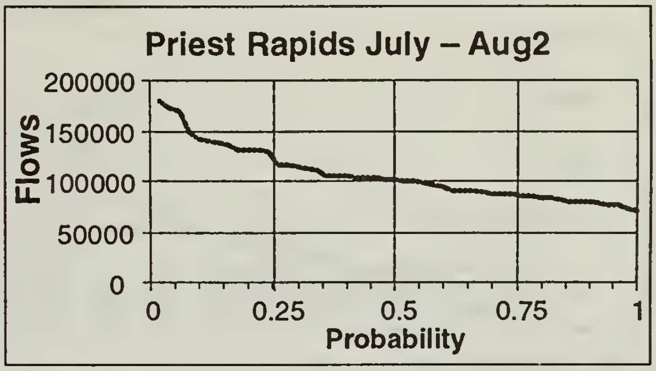
Table C–4. SOS2d – CONT

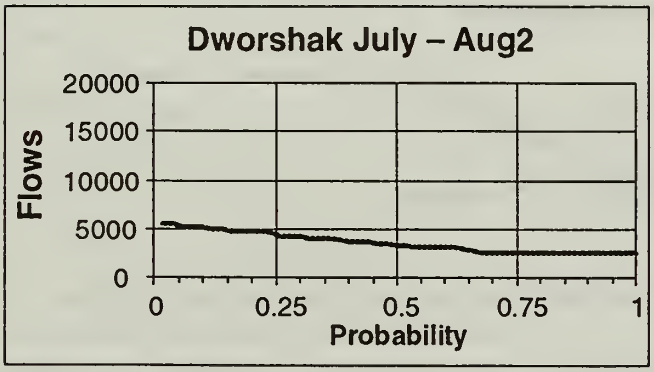
SUMMER FLOWS

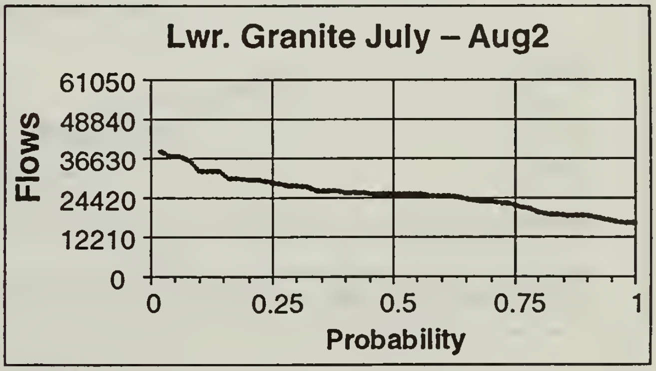


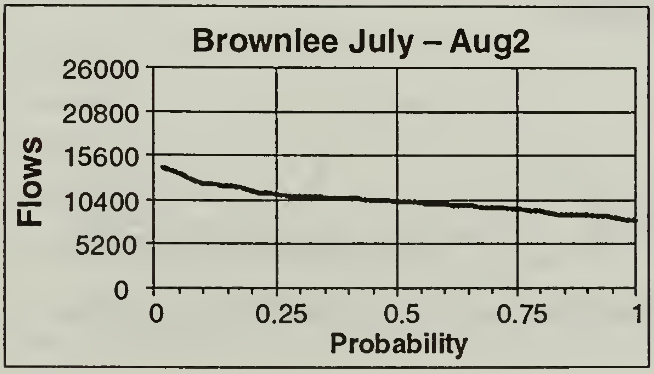












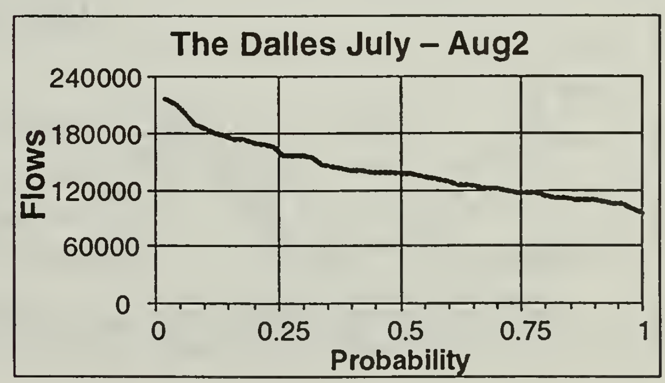
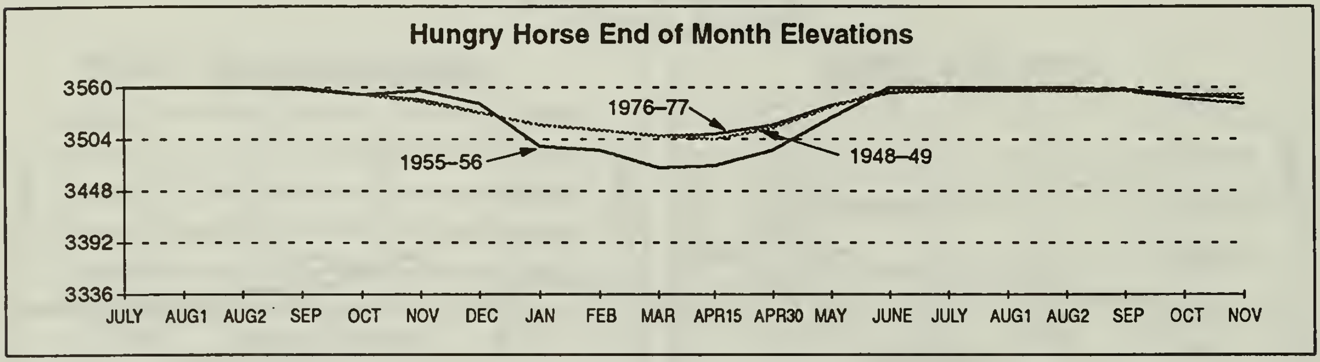
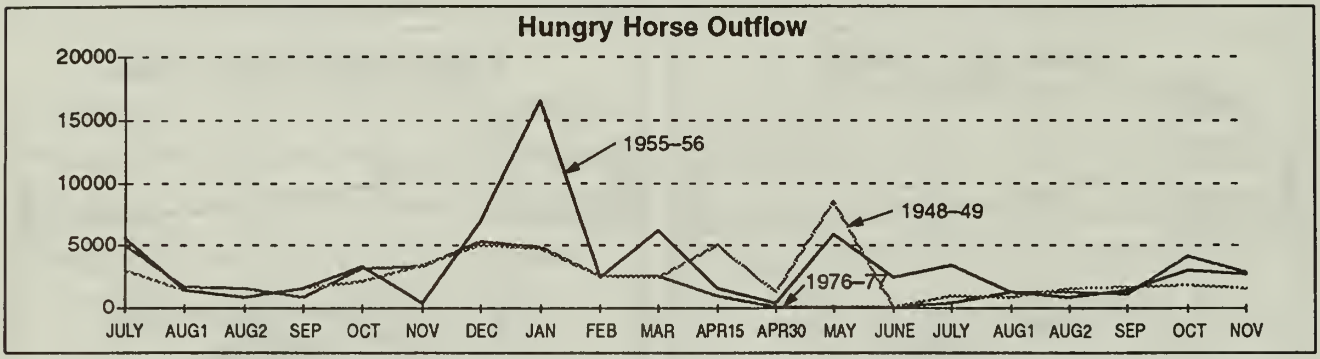
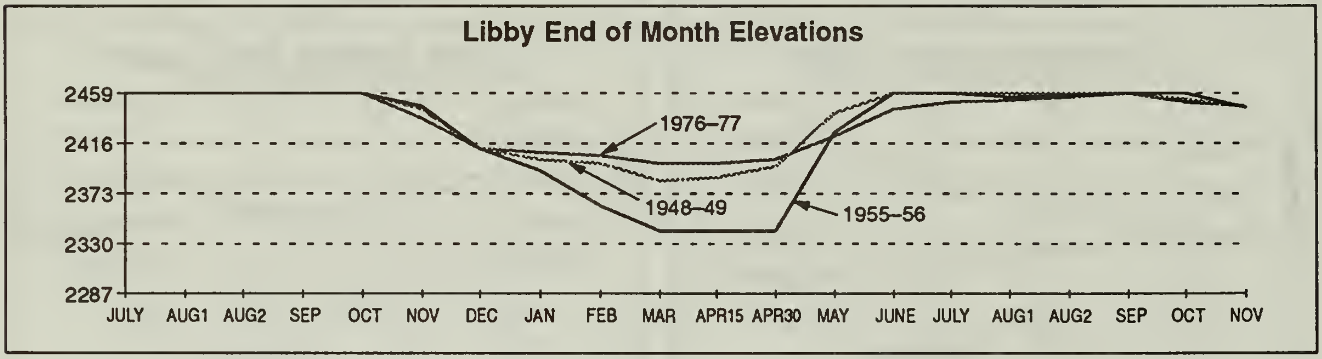


Table C–5. SOS4c







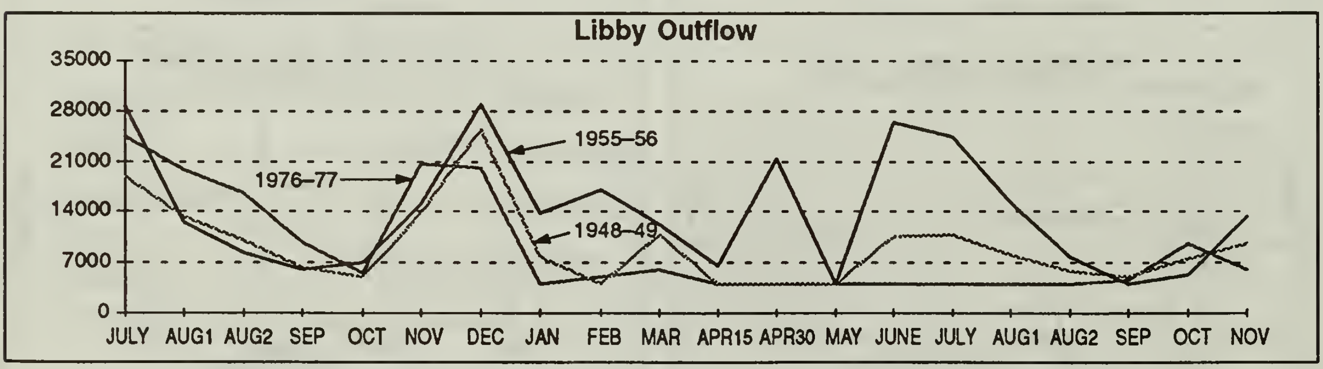
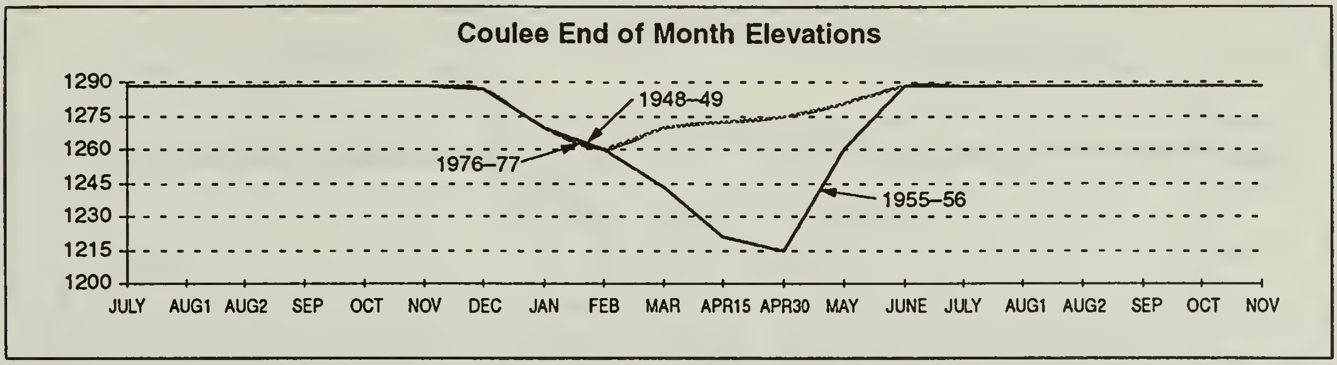
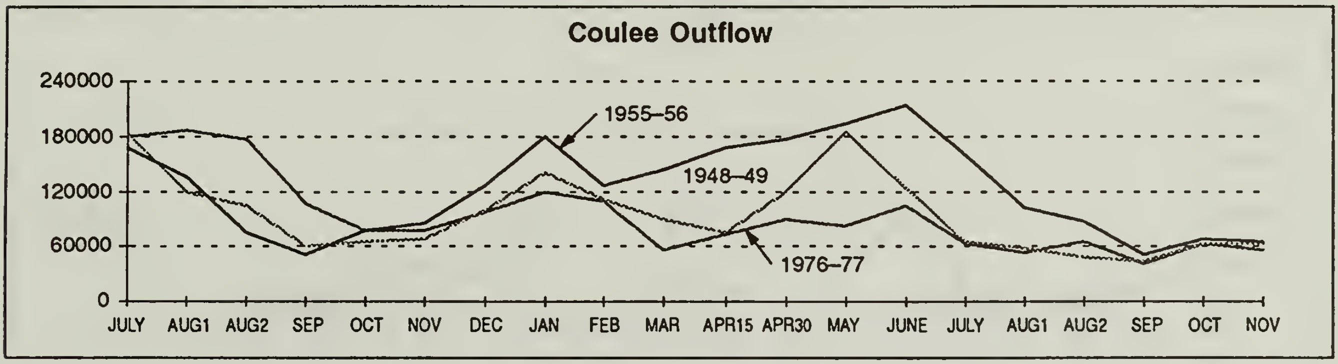
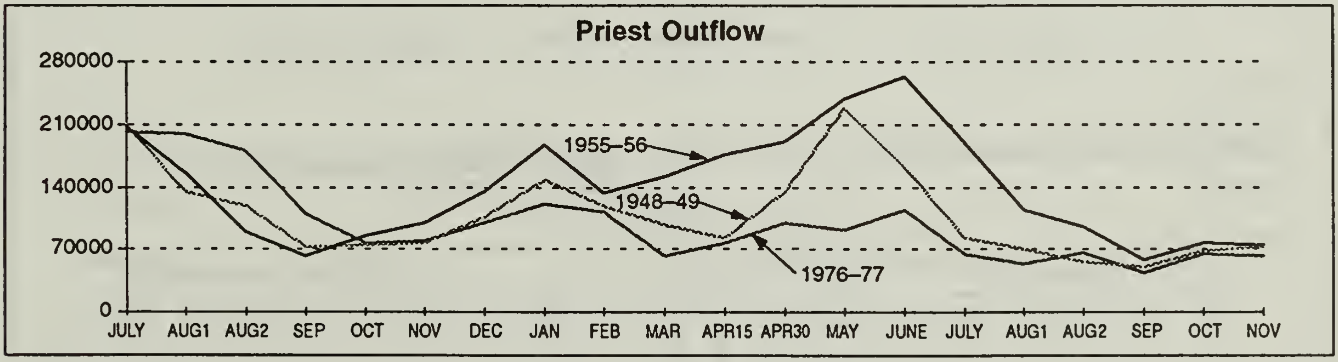


Table C–5. SOS4c – CONT







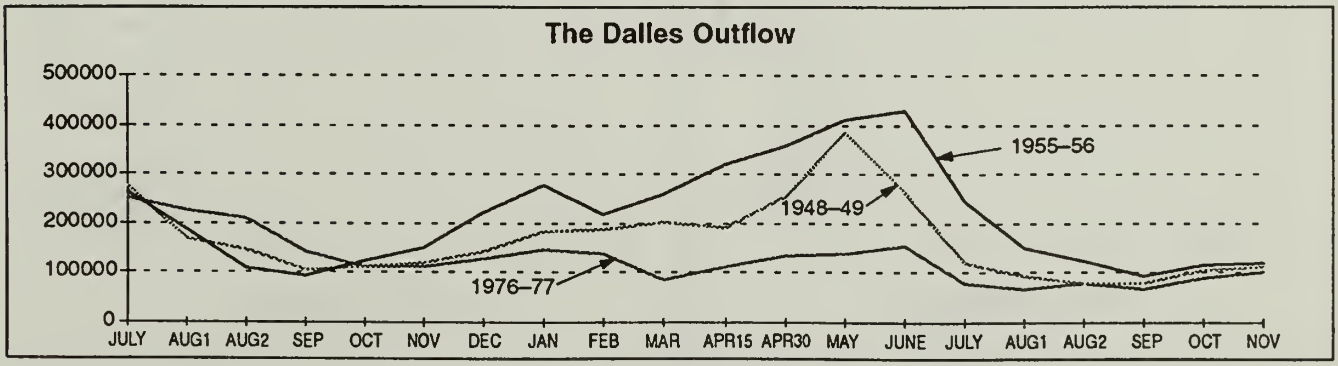
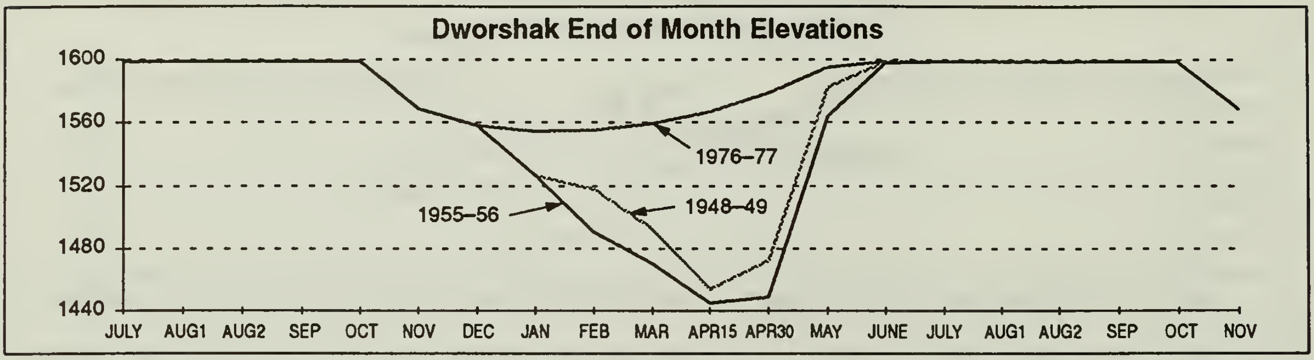
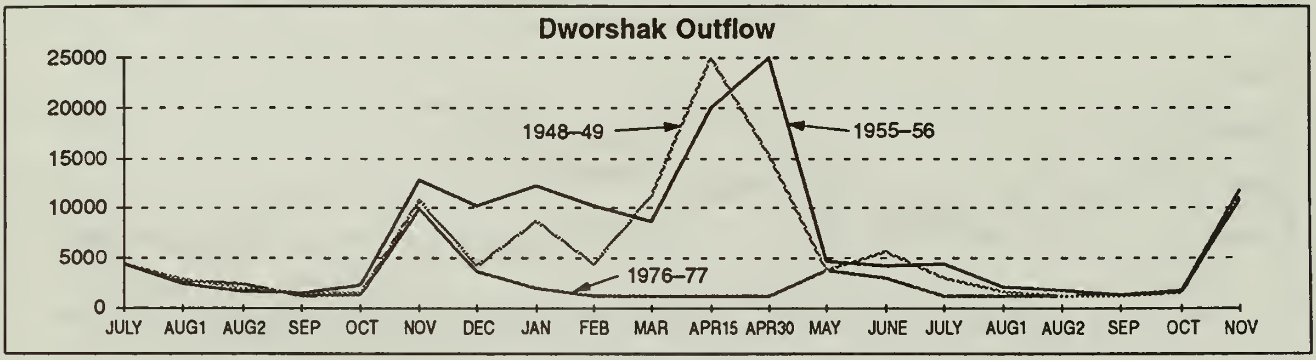


Table C–5. SOS4c – CONT





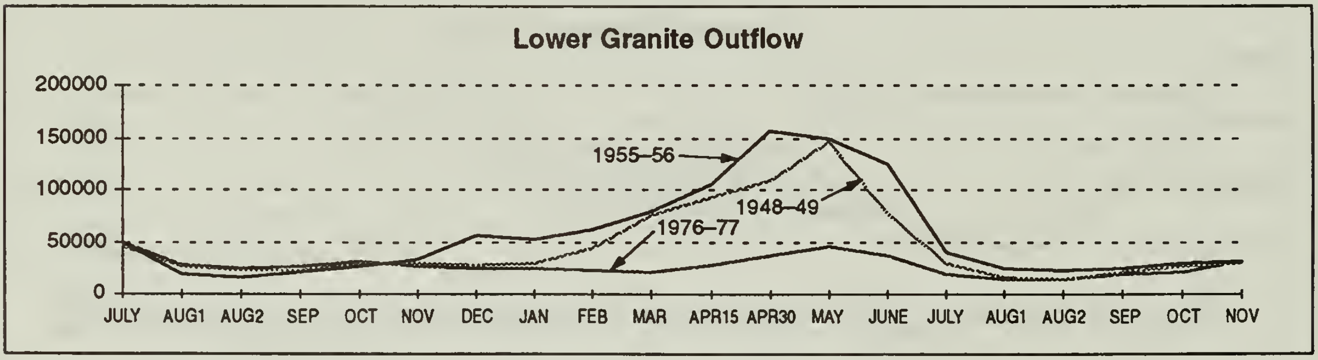


Table C–5. SOS4c – CONT

JULY ELEVATIONS

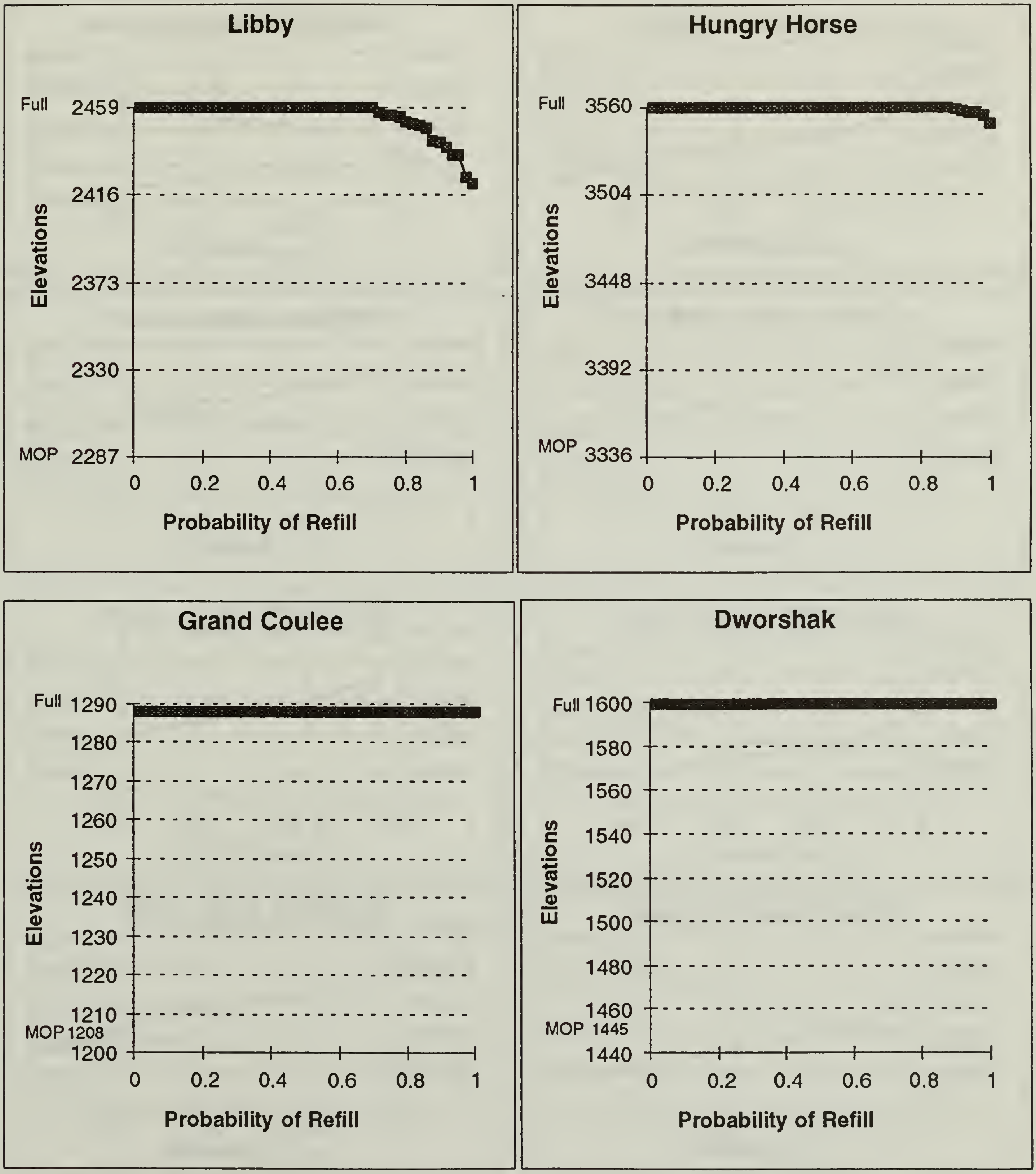


Table C–5. SOS4c – CONT

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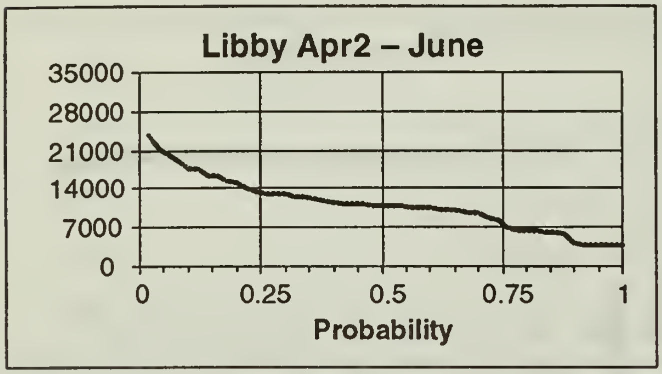
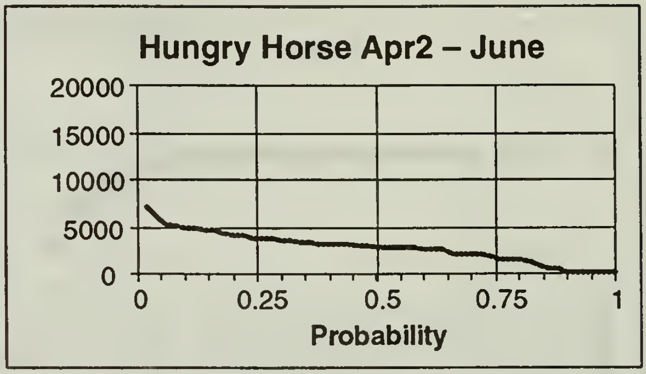
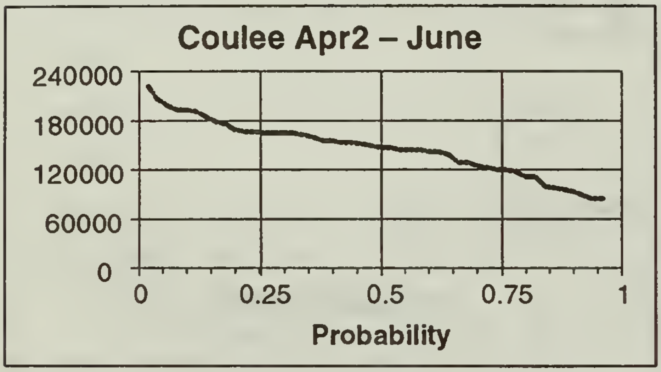
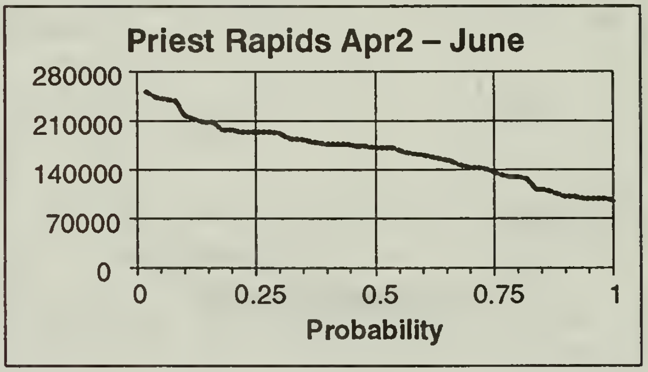
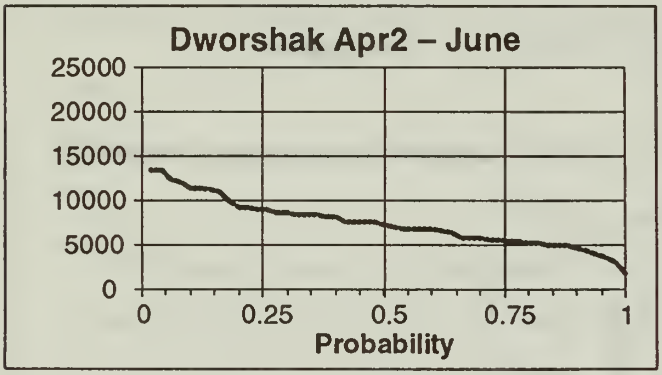
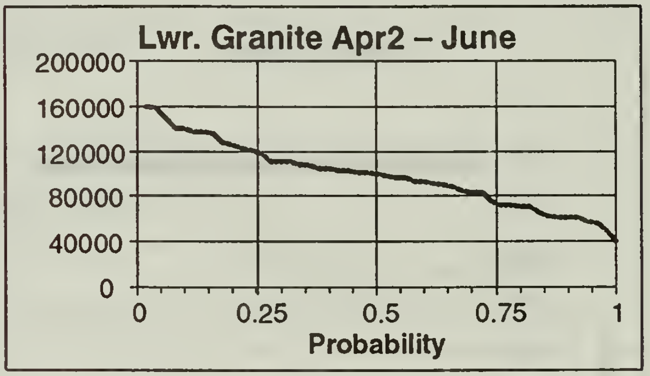


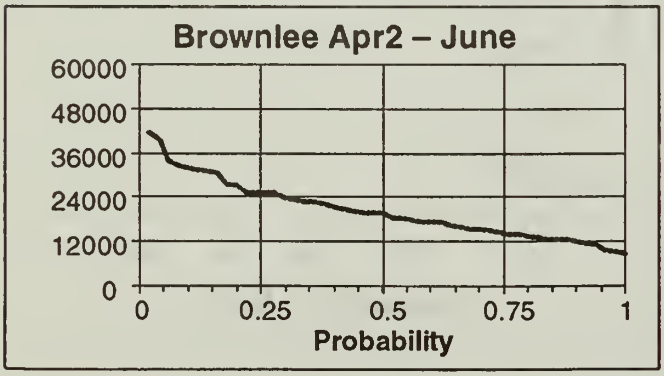












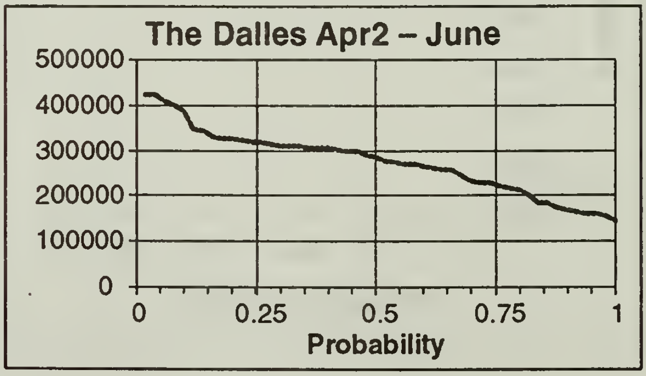
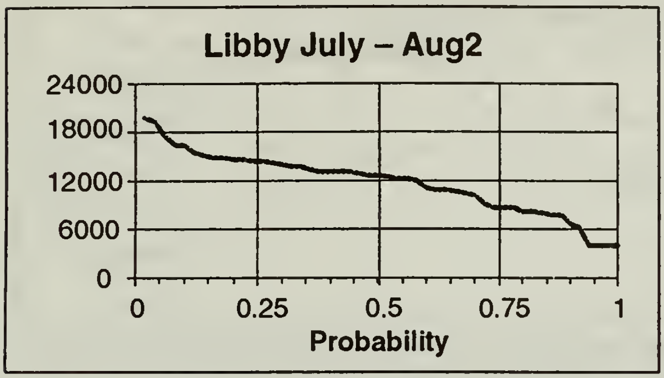
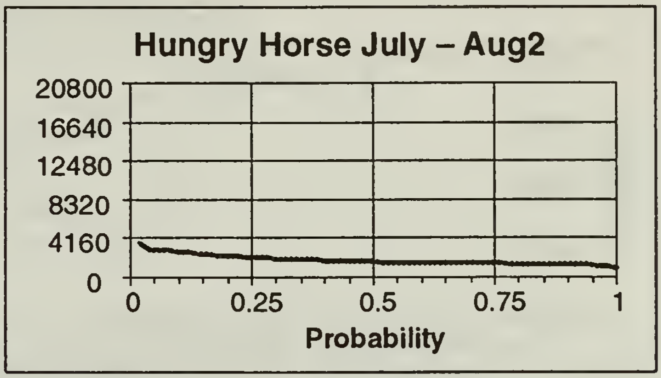
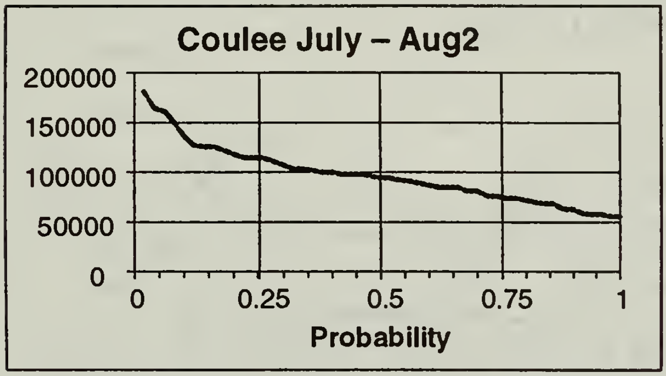


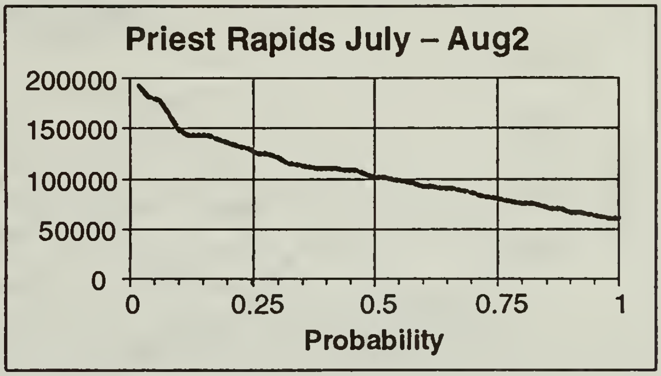
Table C–5. SOS4c – CONT

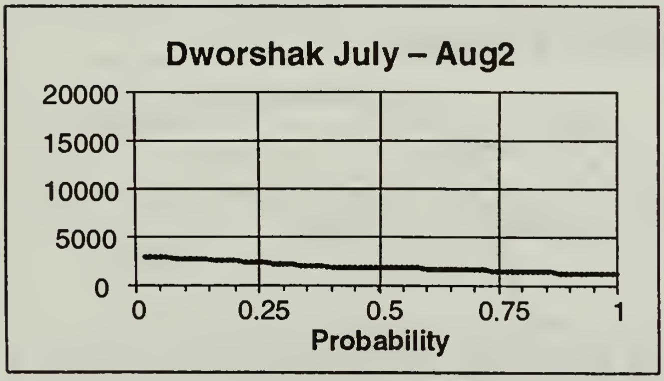
SUMMER FLOWS

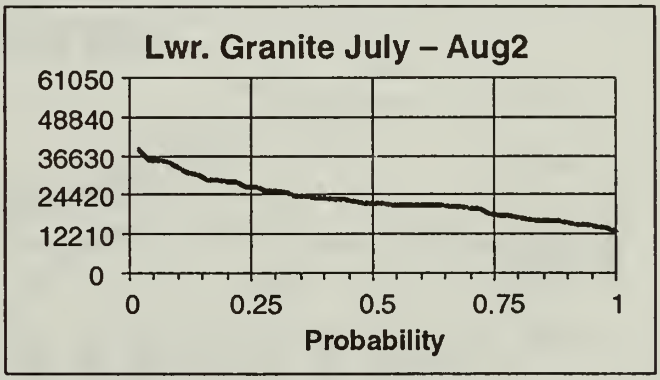


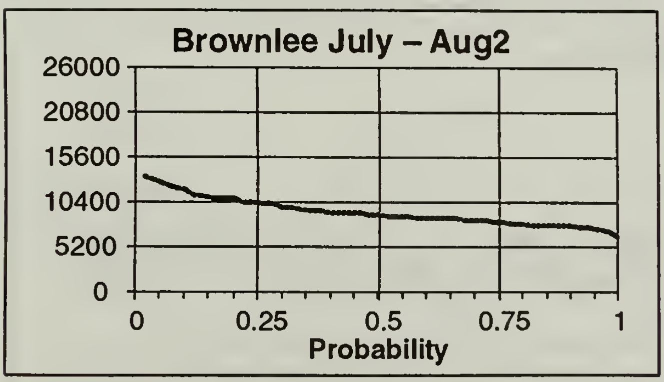












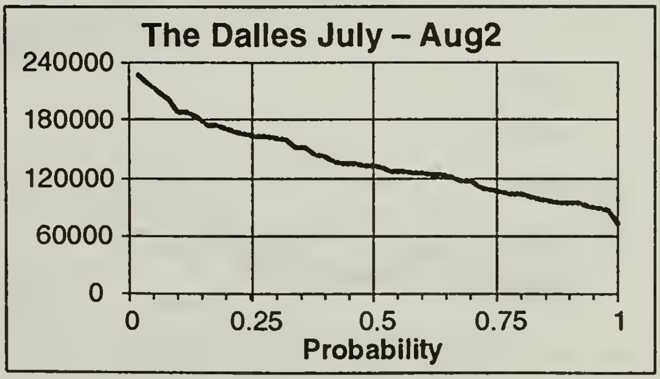


Table C–6. SOS5b

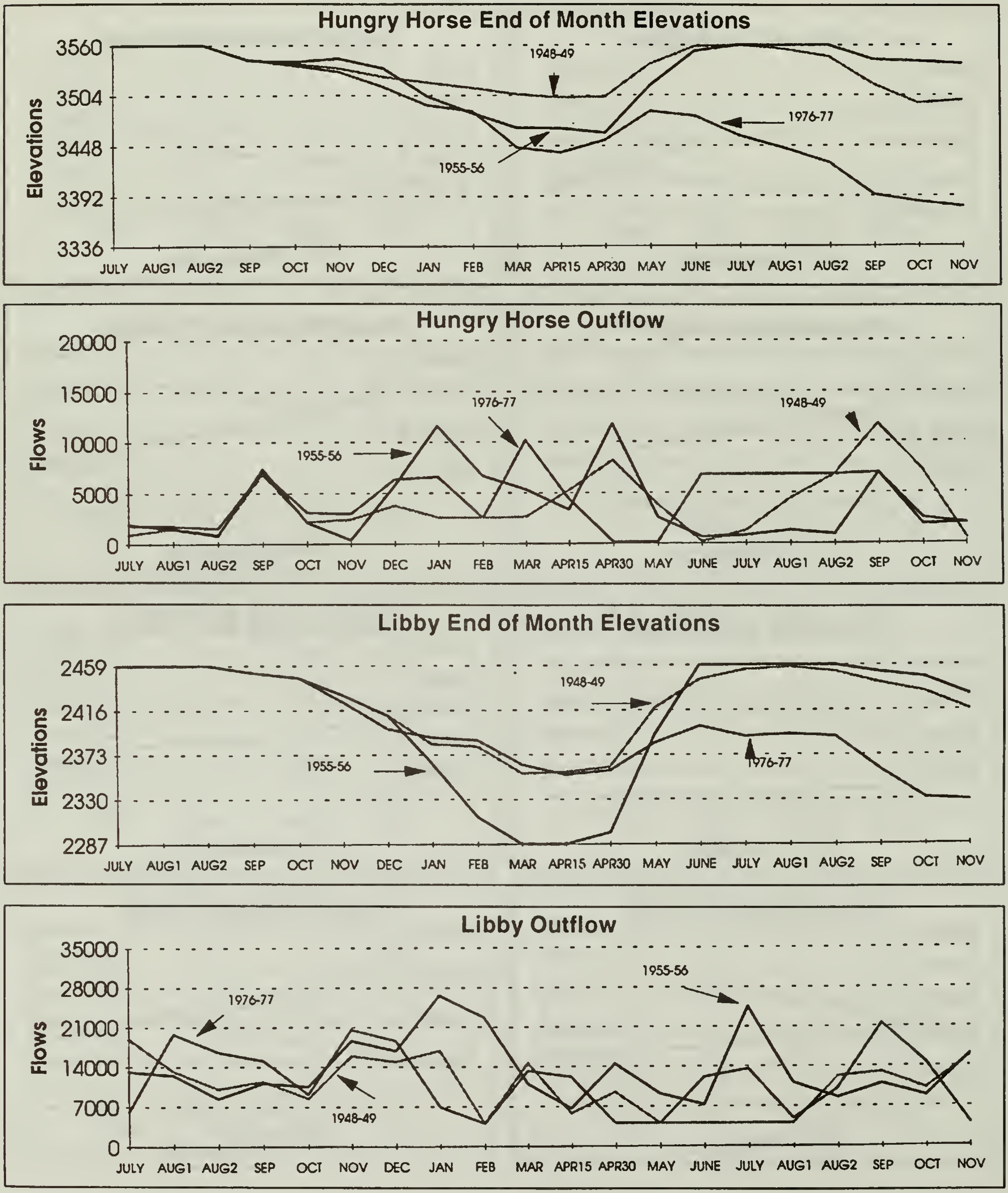
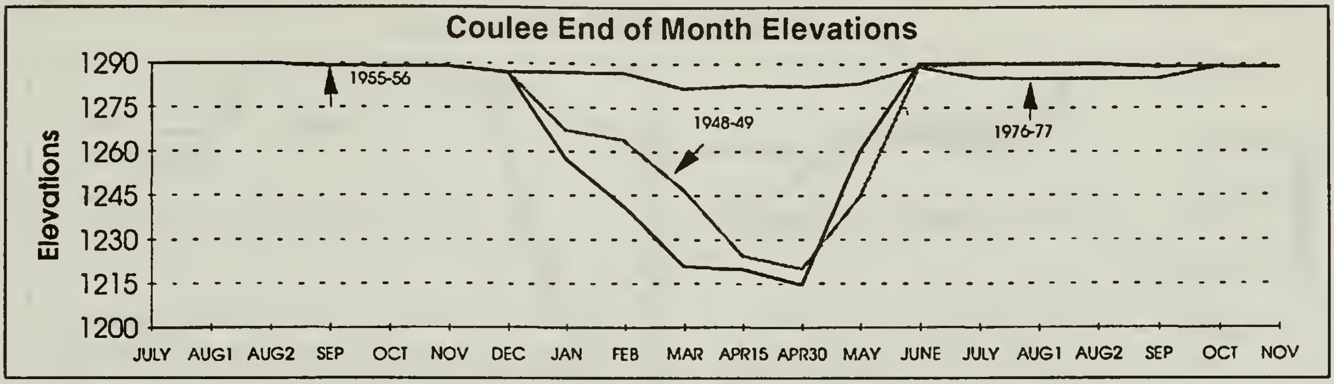
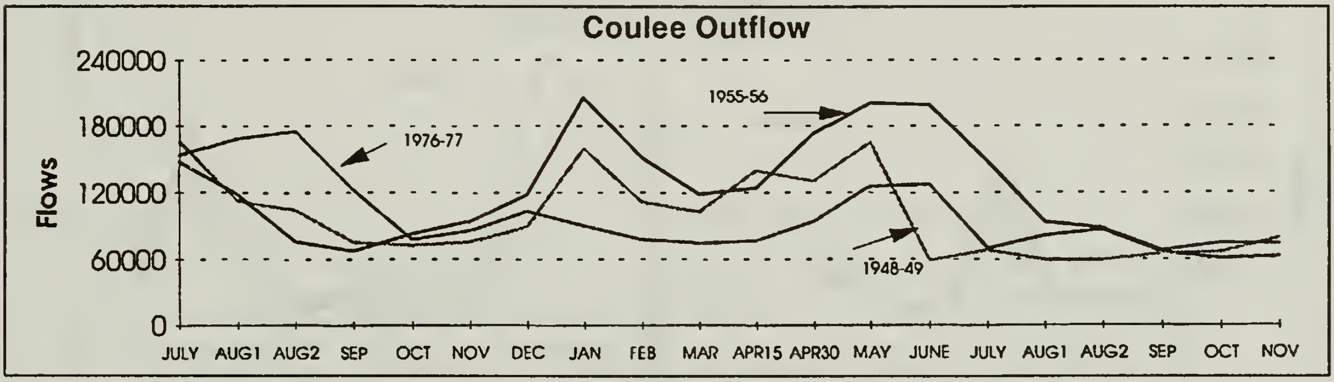
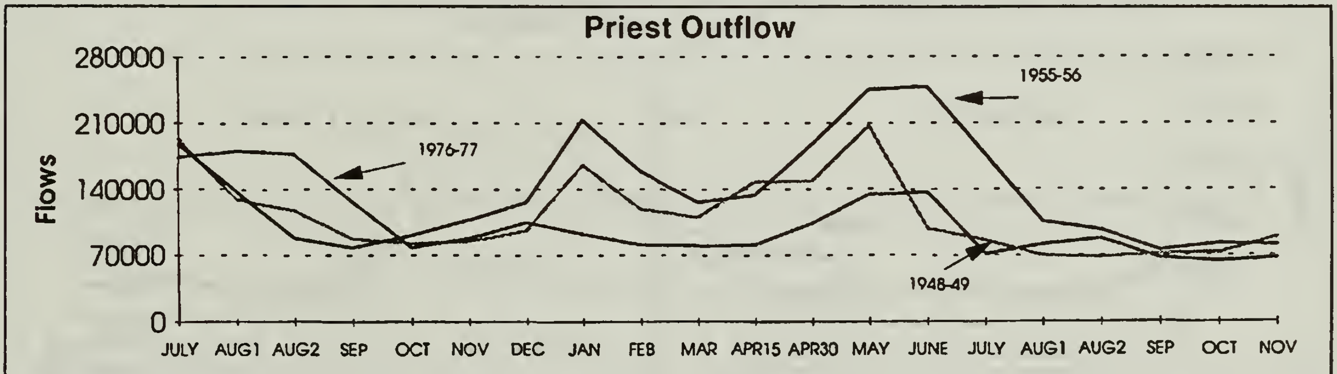


Table C–6. SOS5b – CONT







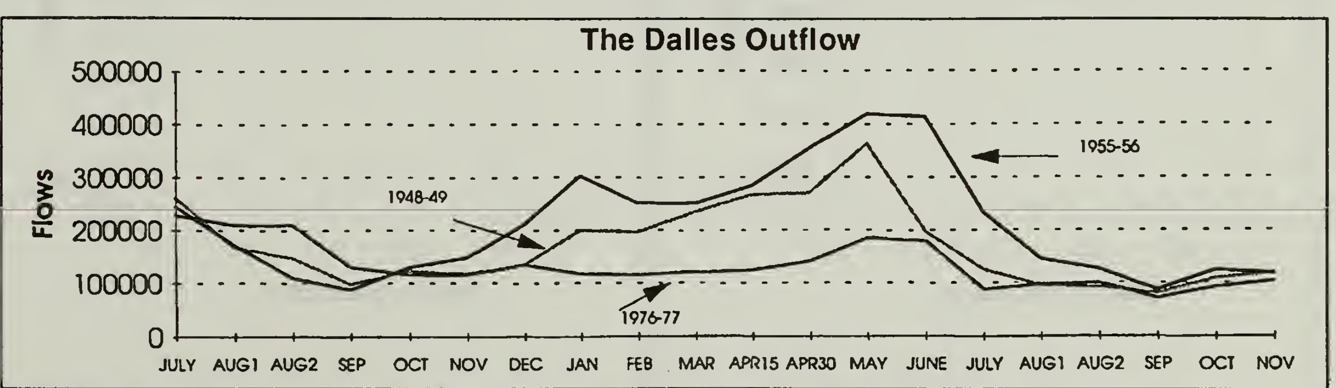
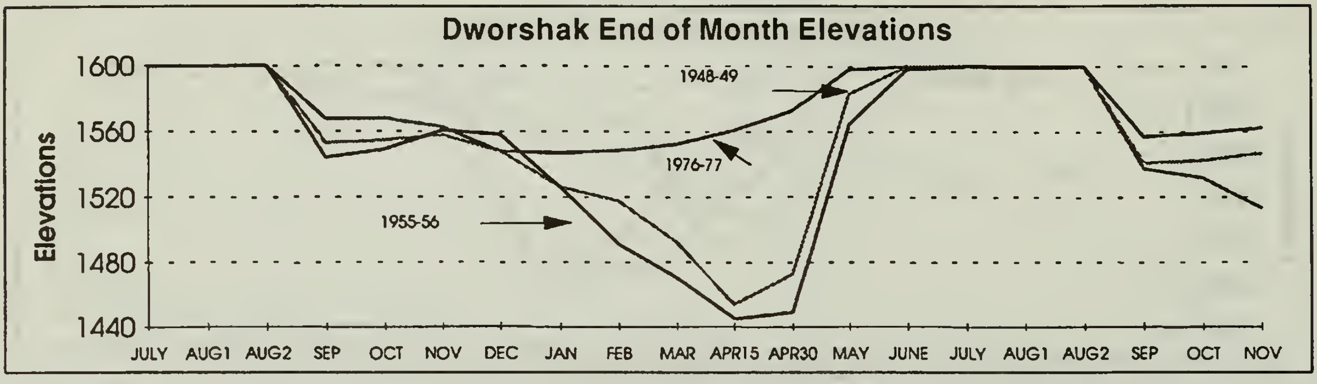
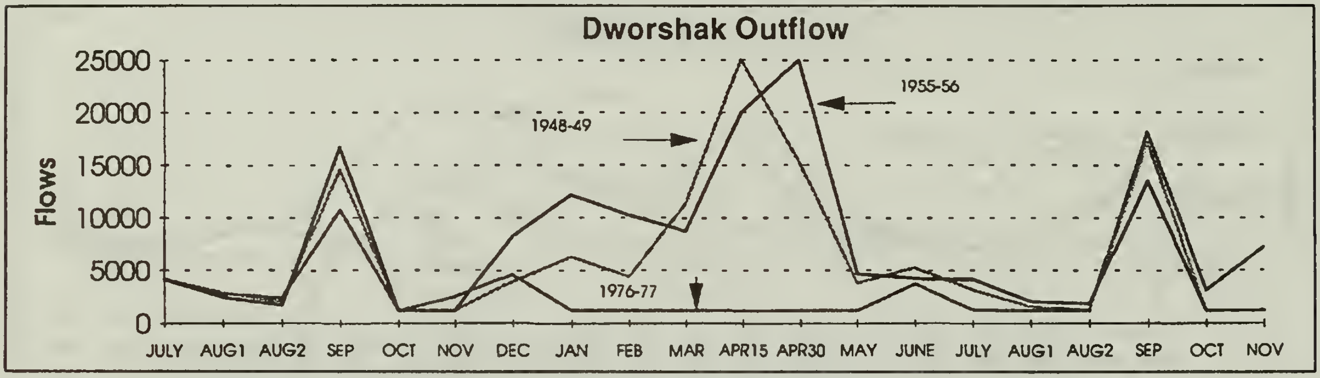


Table C–6. SOS5b – CONT





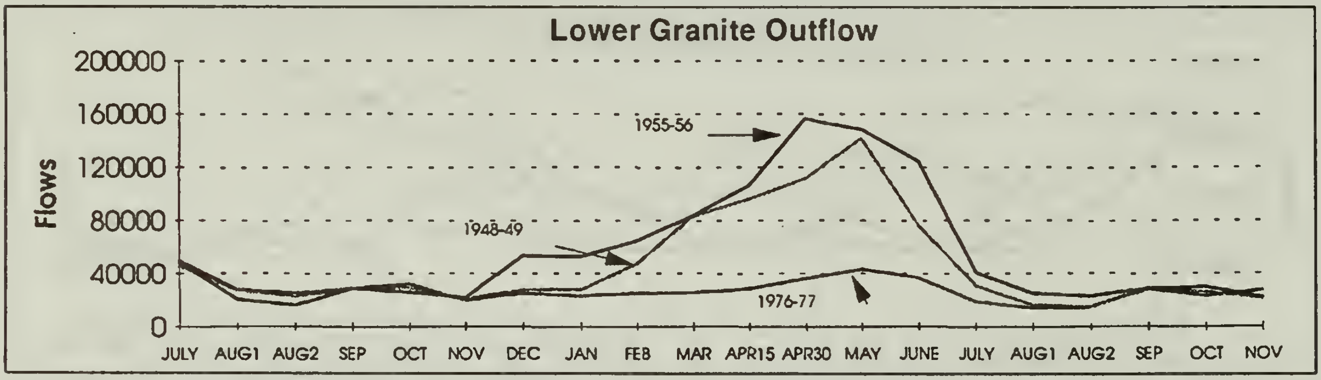
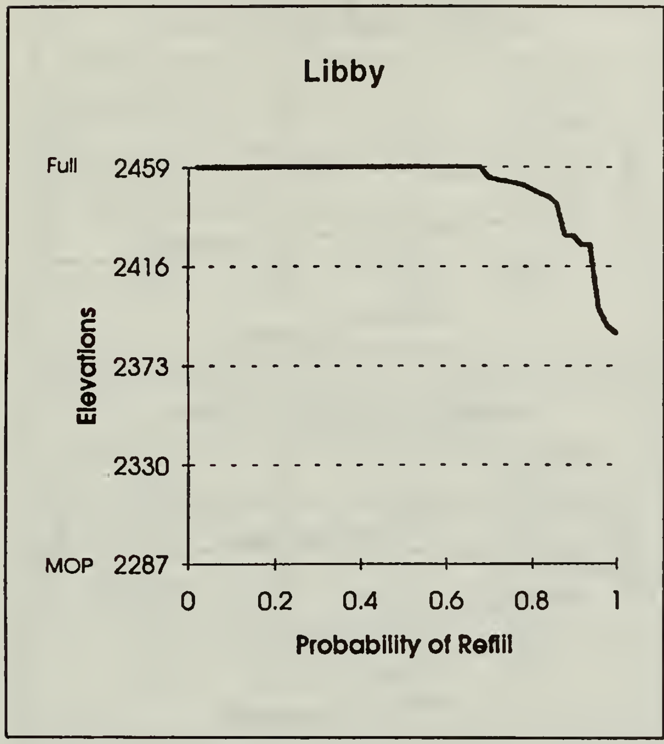
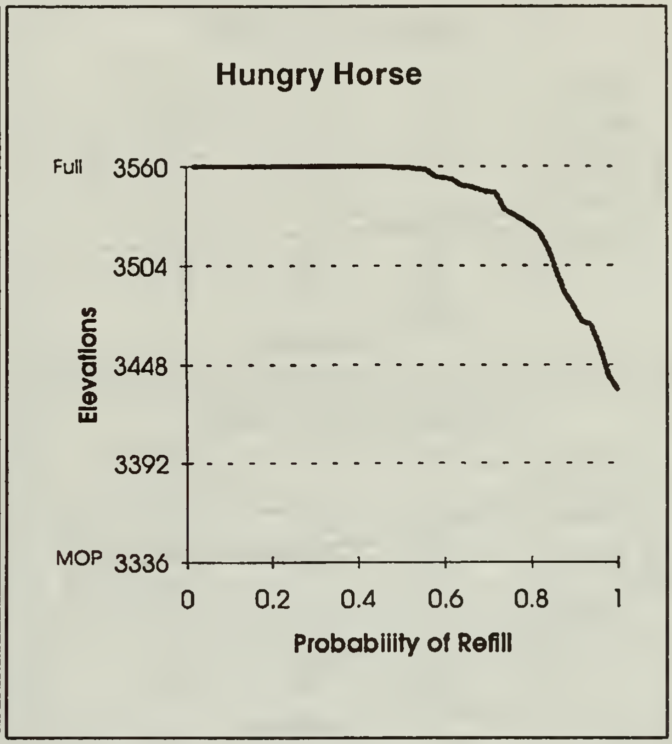
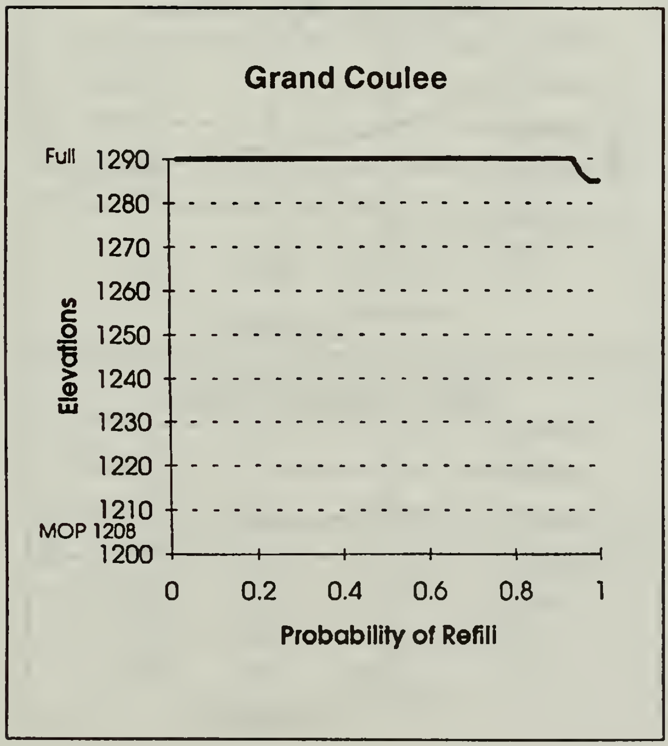


Table C–6. SOS5b – CONT

JULY ELEVATIONS







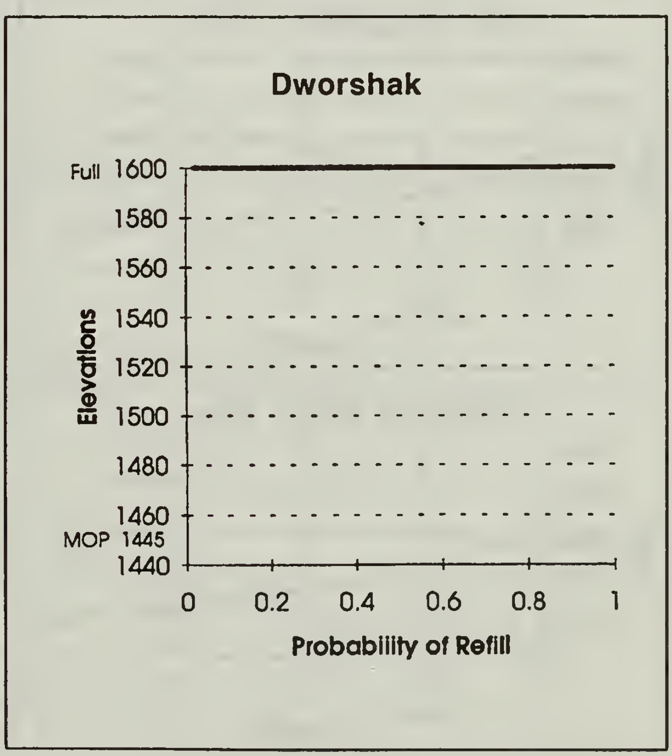
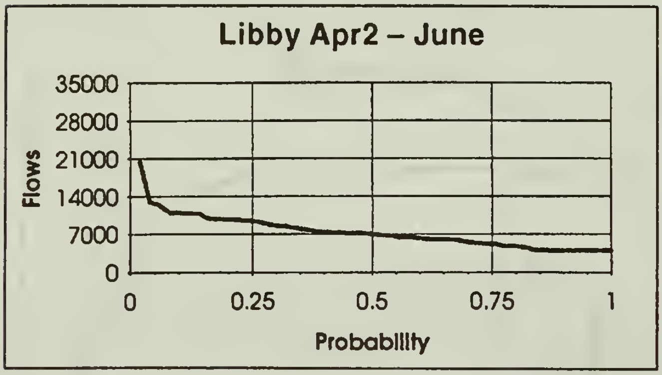
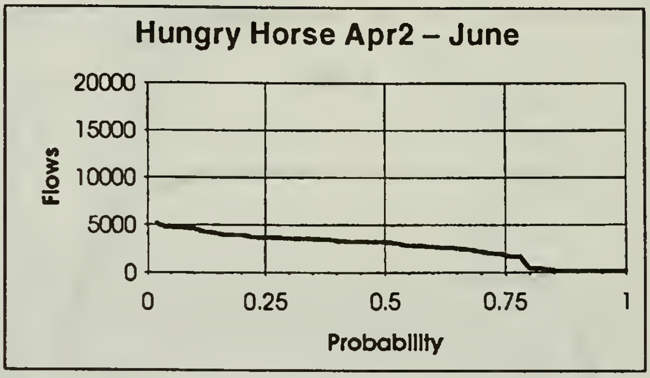
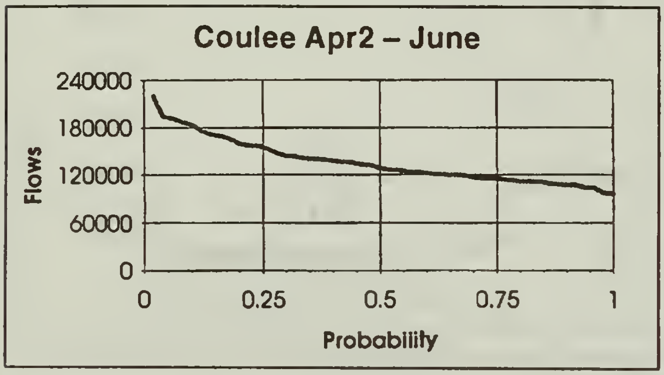


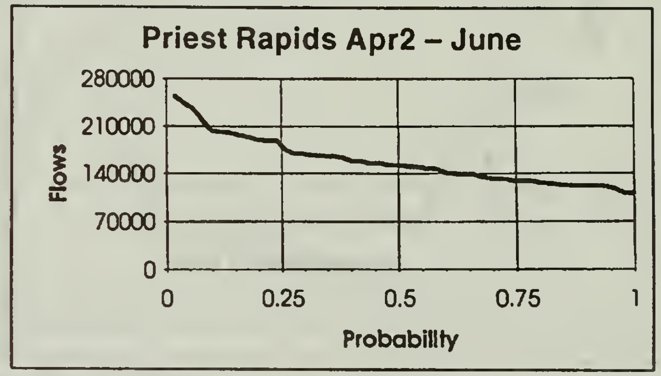
Table C–6. SOS5b – CONT

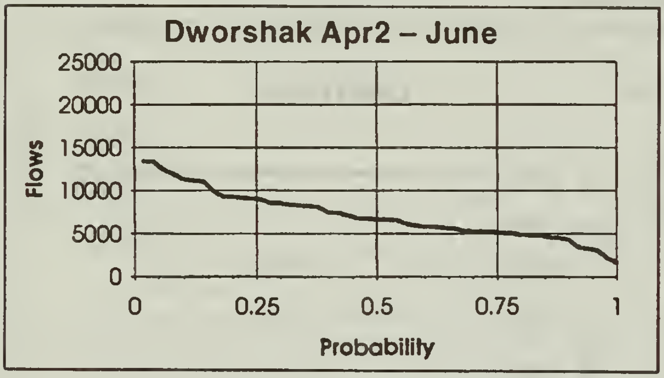
SPRING FLOWS

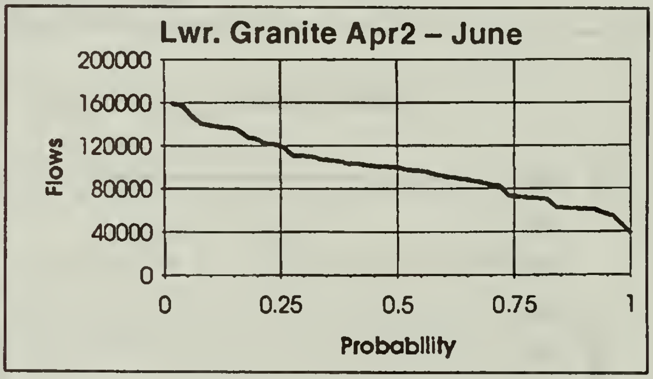


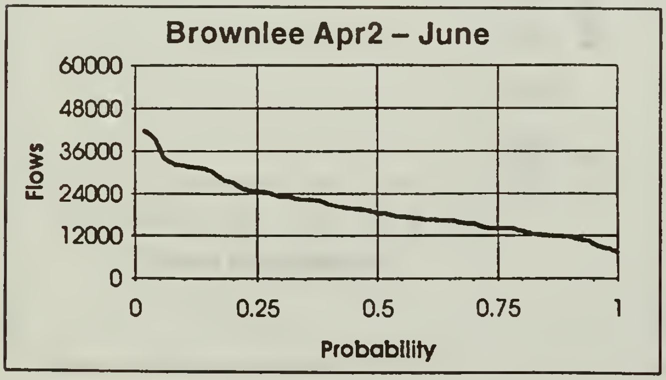












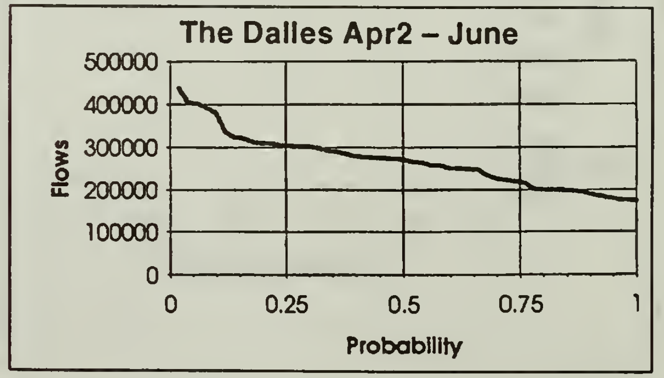


Table C–6. SOS5b – CONT

SUMMER FLOWS

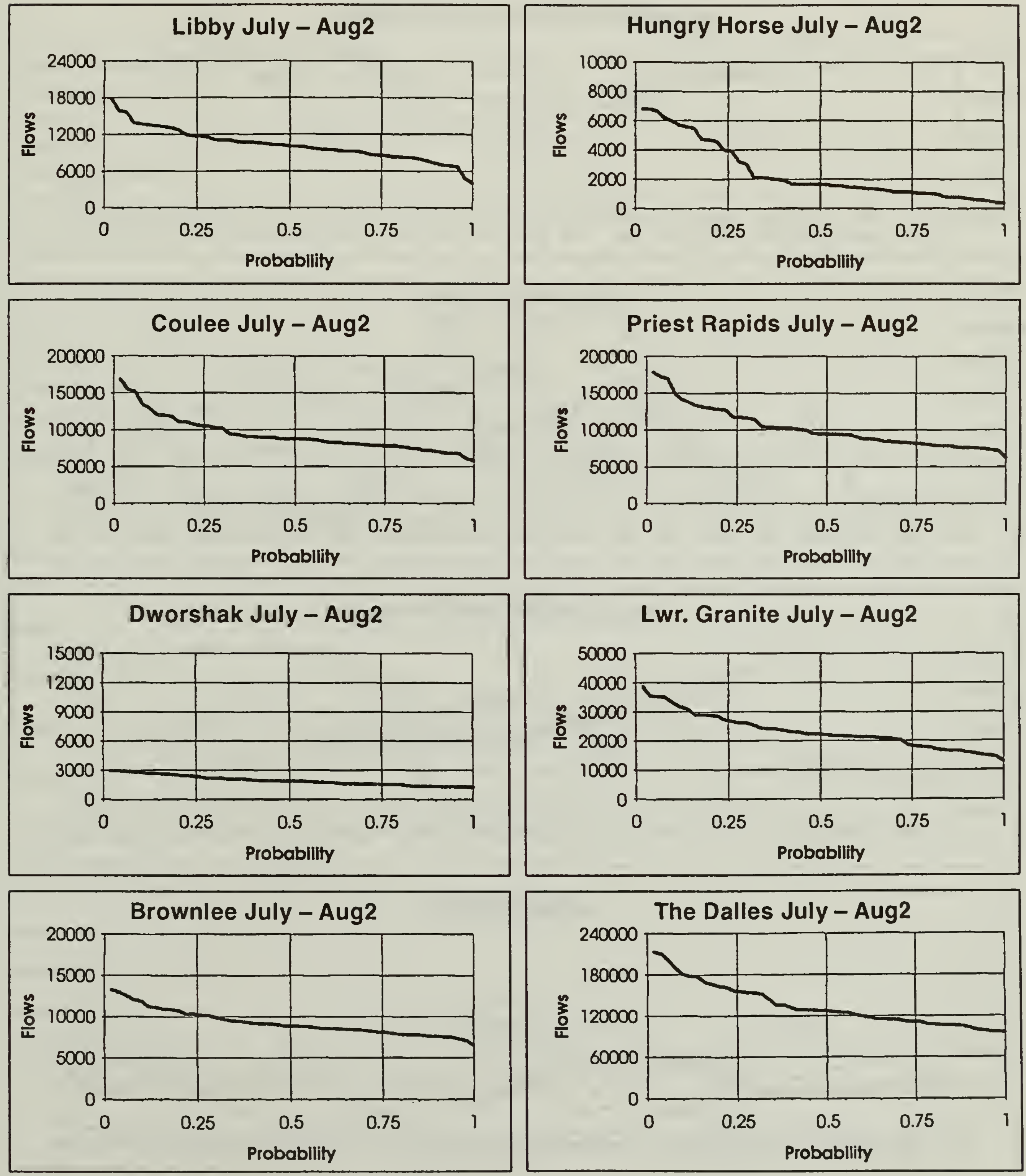
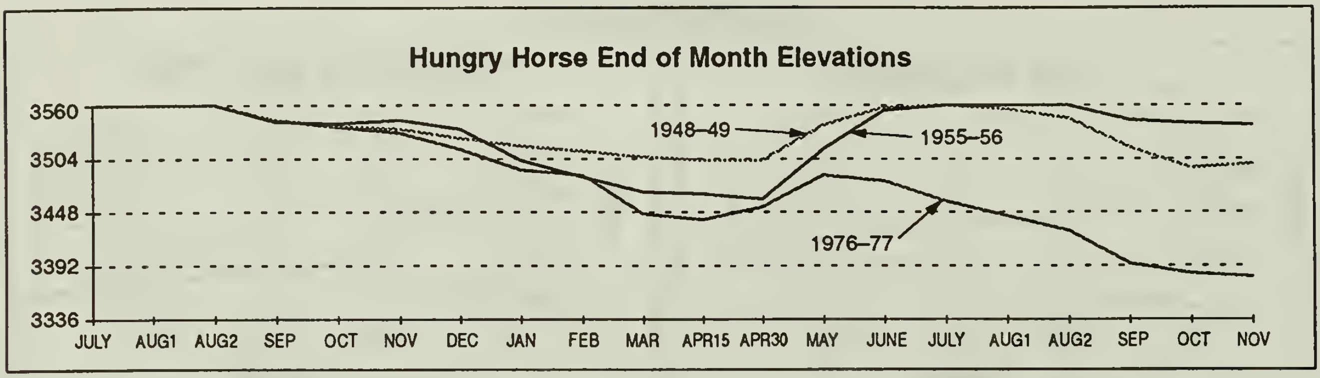
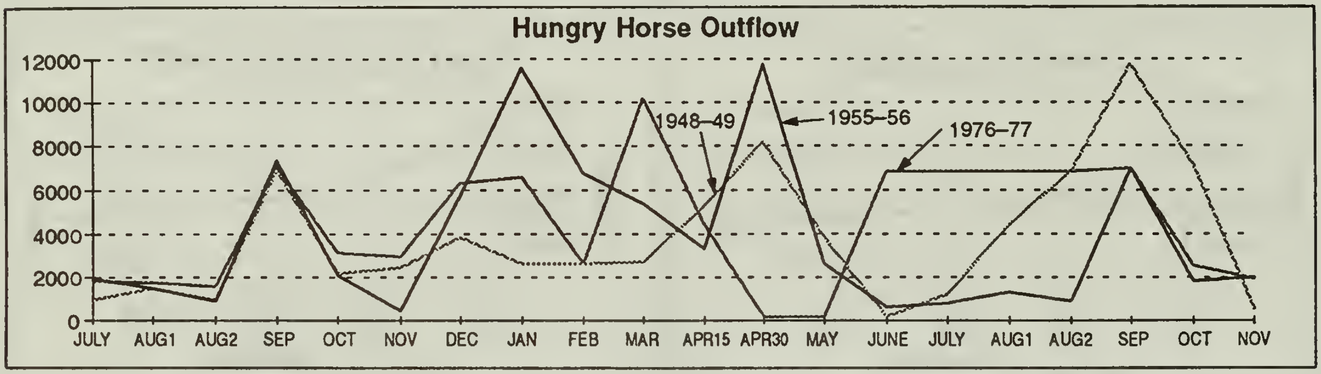
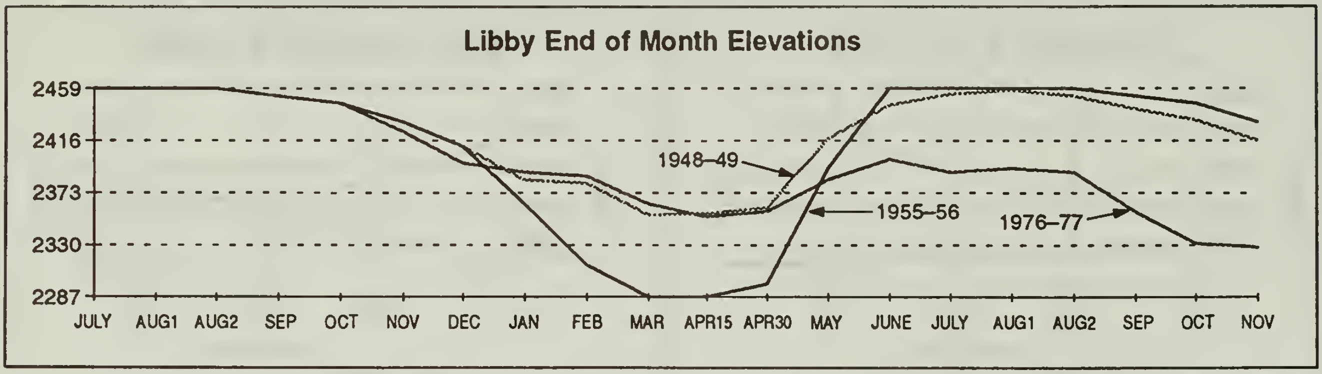


Table C–7. SOS5c







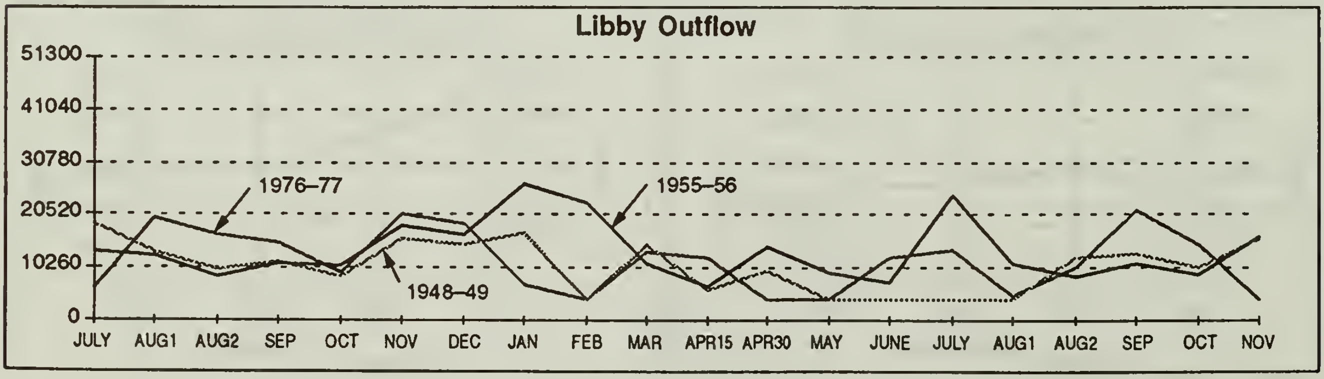
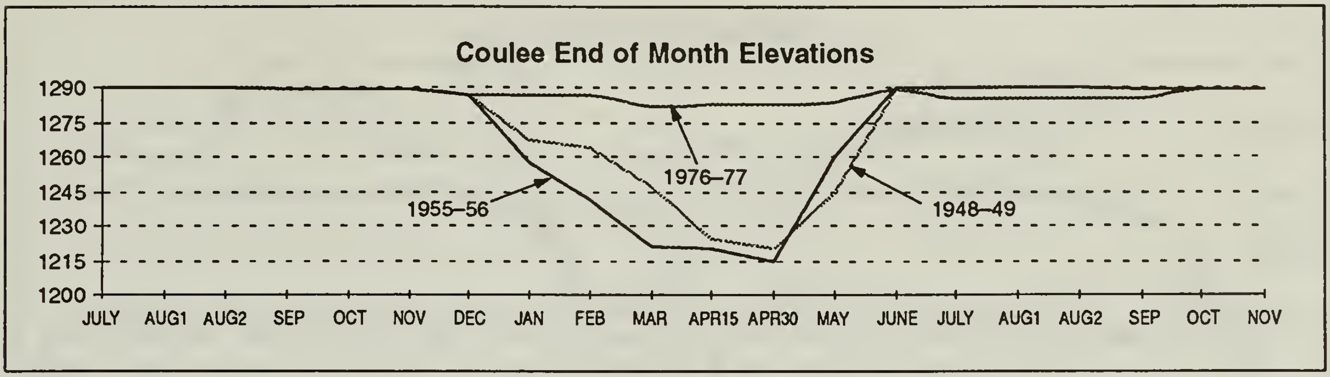
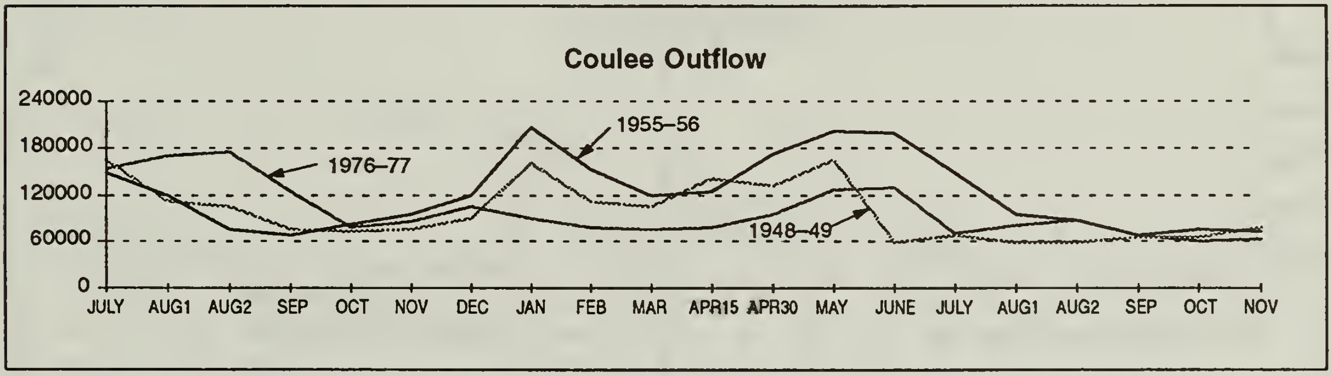
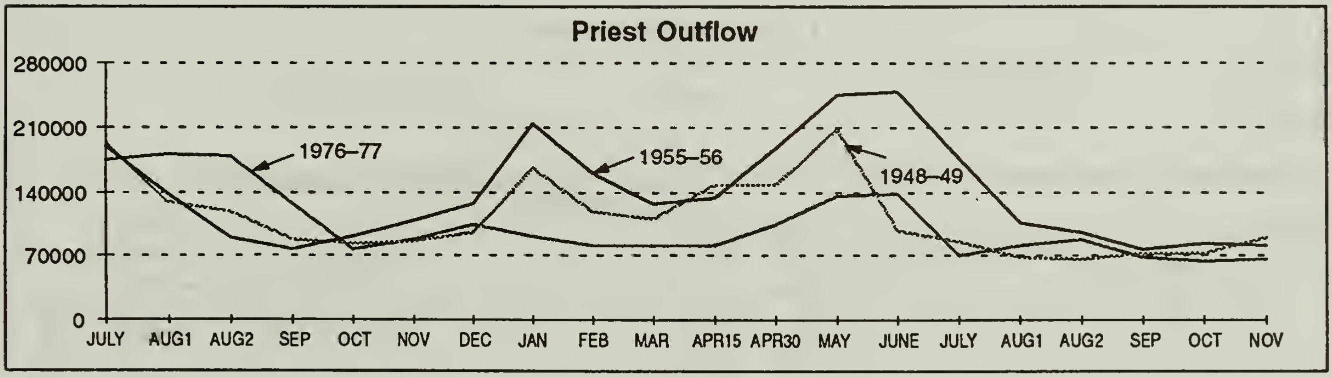


Table C–7. SOS5c – CONT







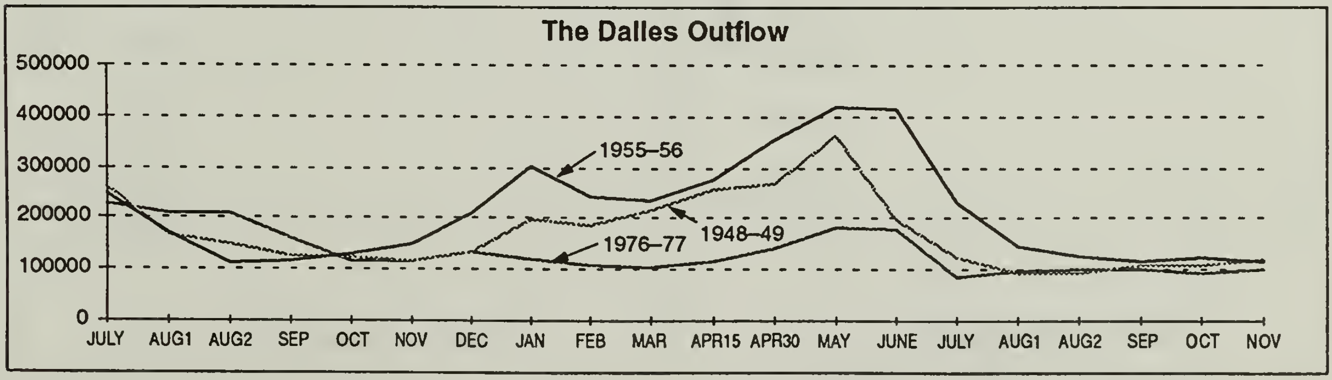
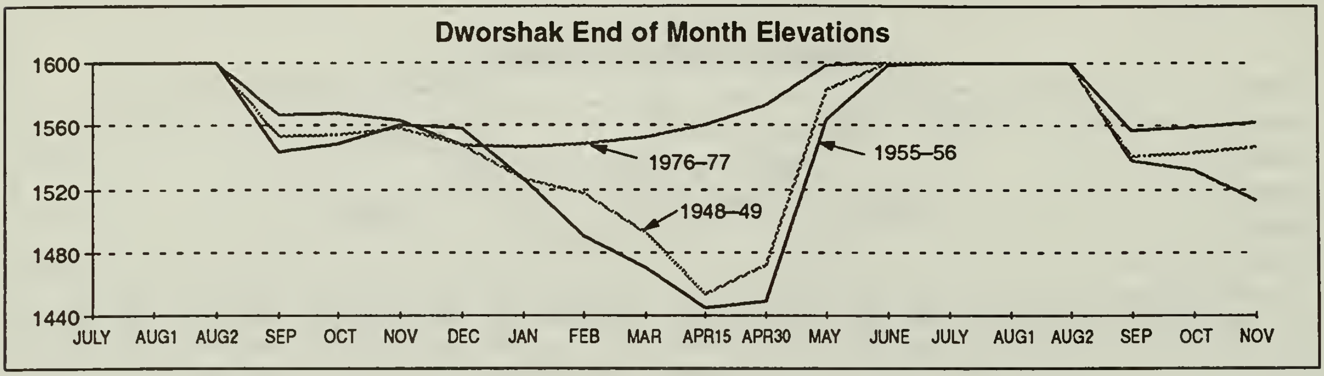
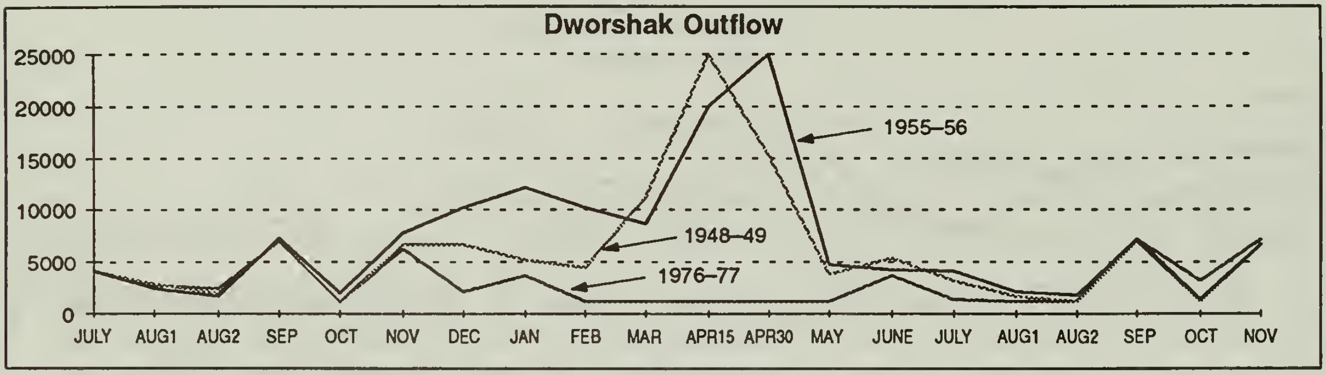


Table C–7. SOS5c – CONT





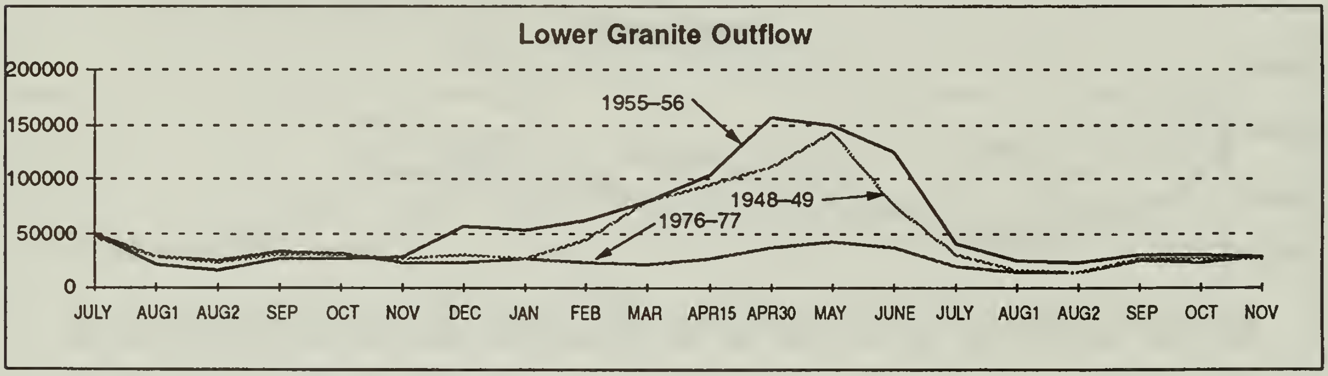


Table C–7. SOS5c – CONT

JULY ELEVATIONS

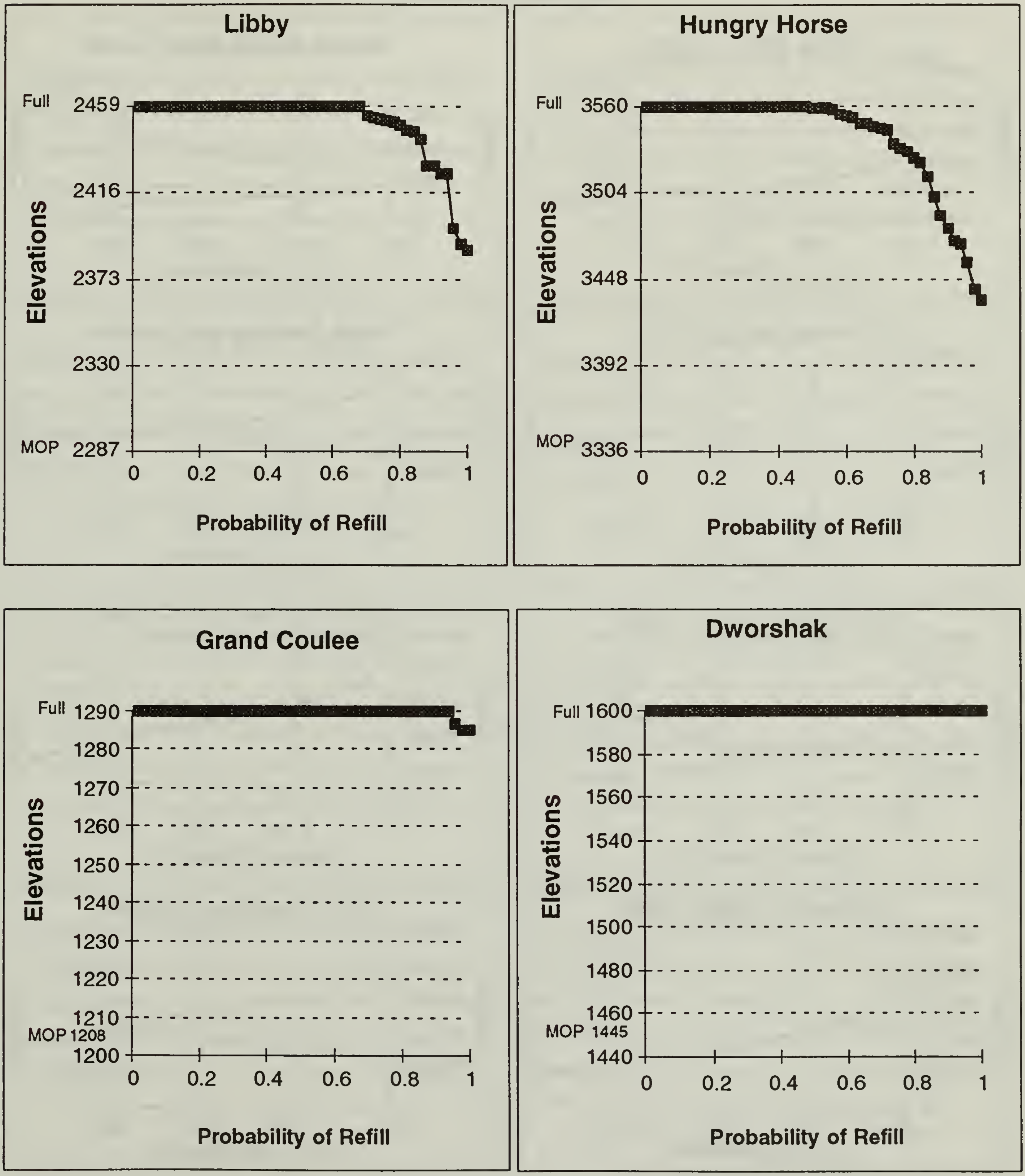
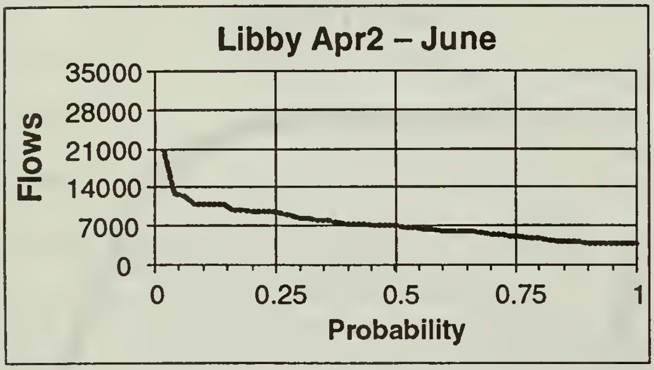
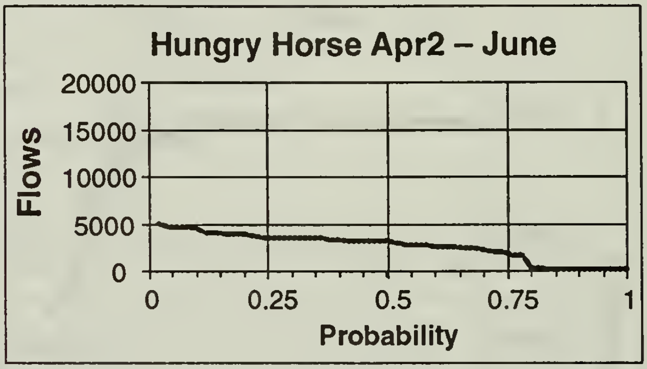
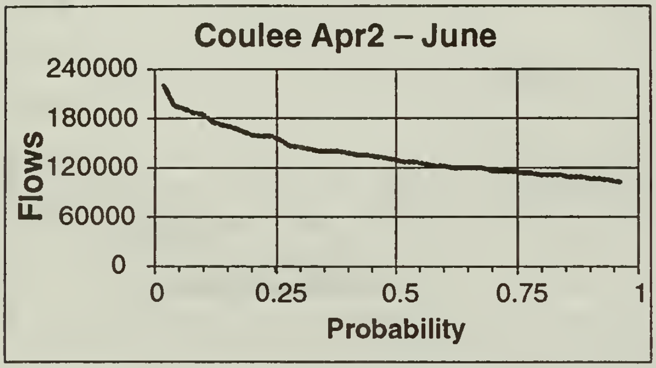


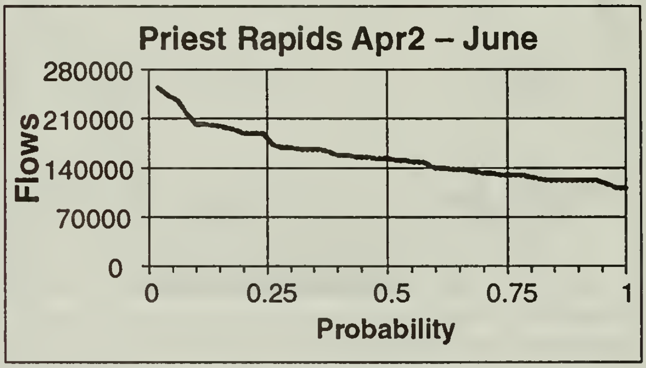
Table C–7. SOS5c – CONT

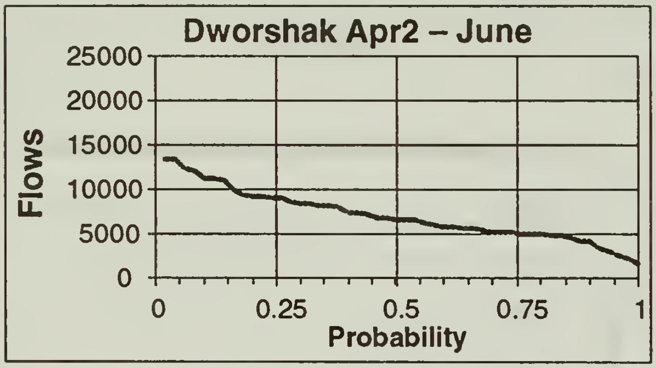
SPRING FLOWS

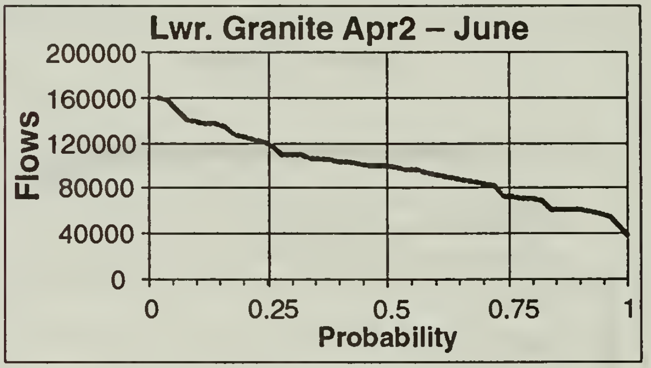


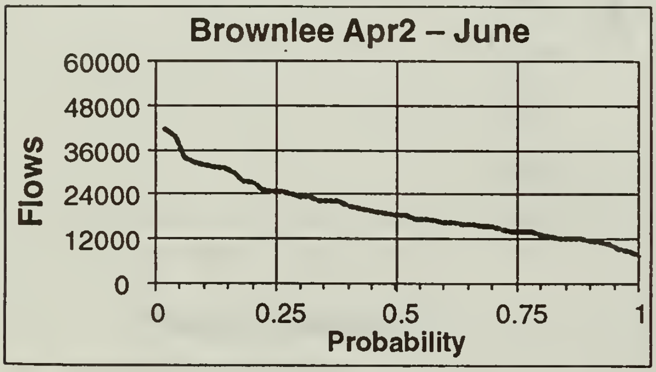












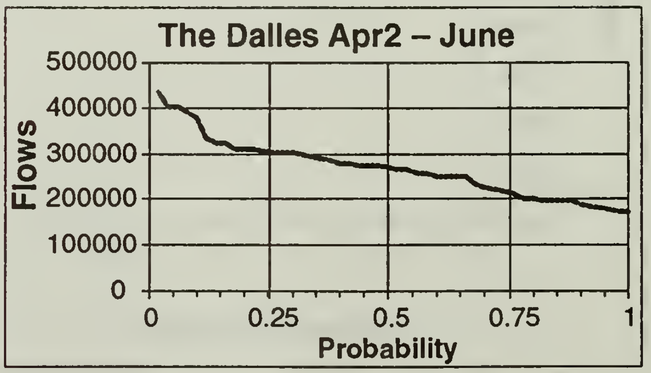
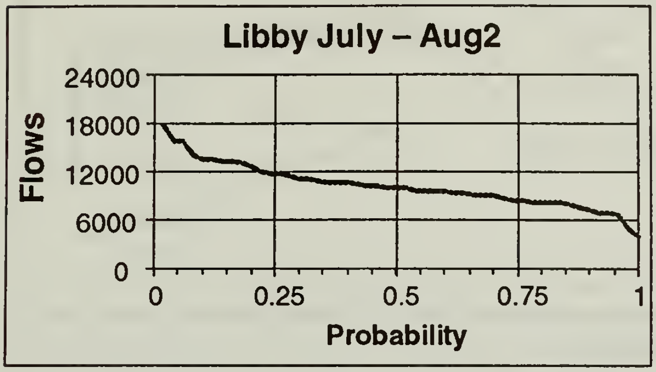
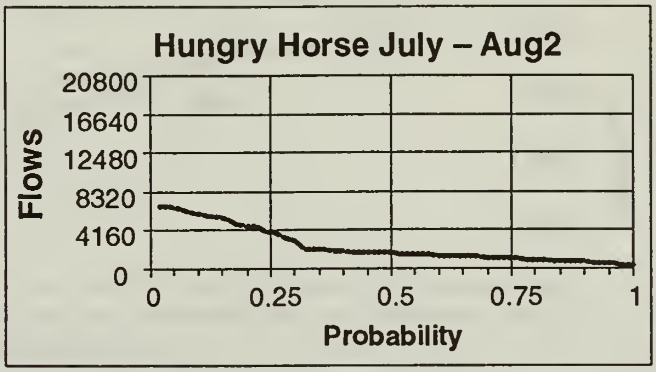
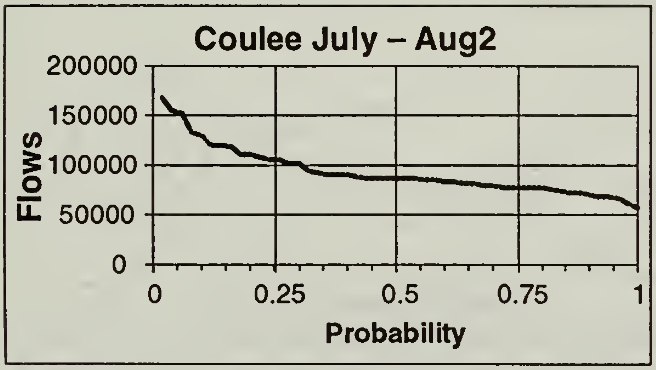


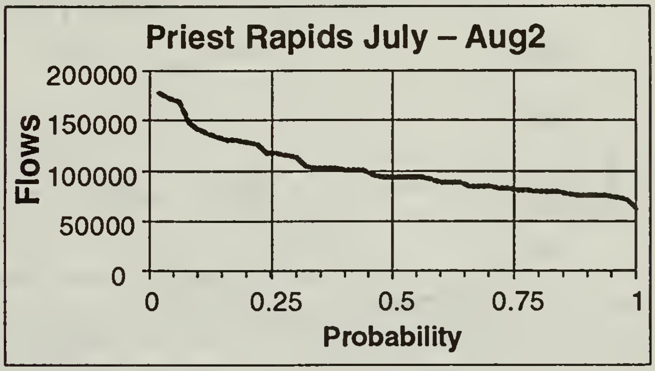
Table C–7. SOS5c – CONT

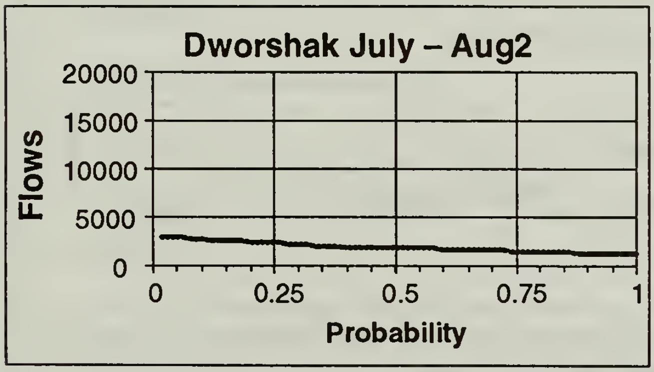
SUMMER FLOWS

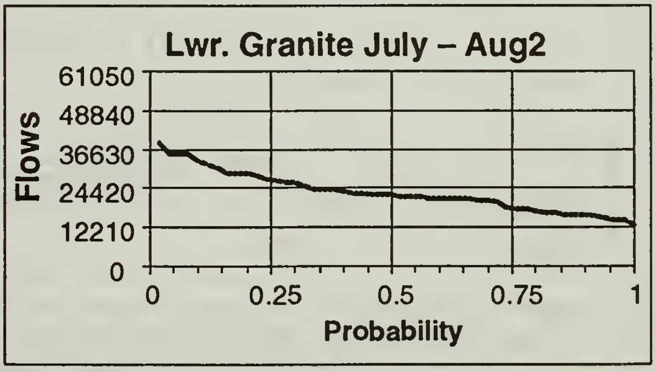


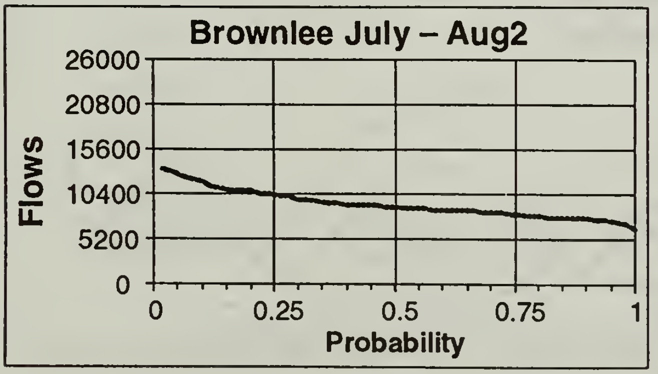


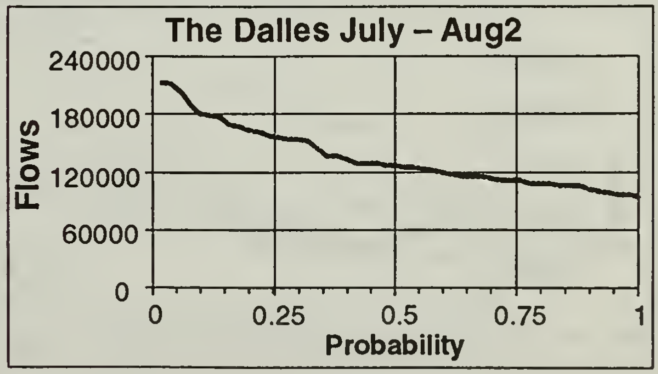












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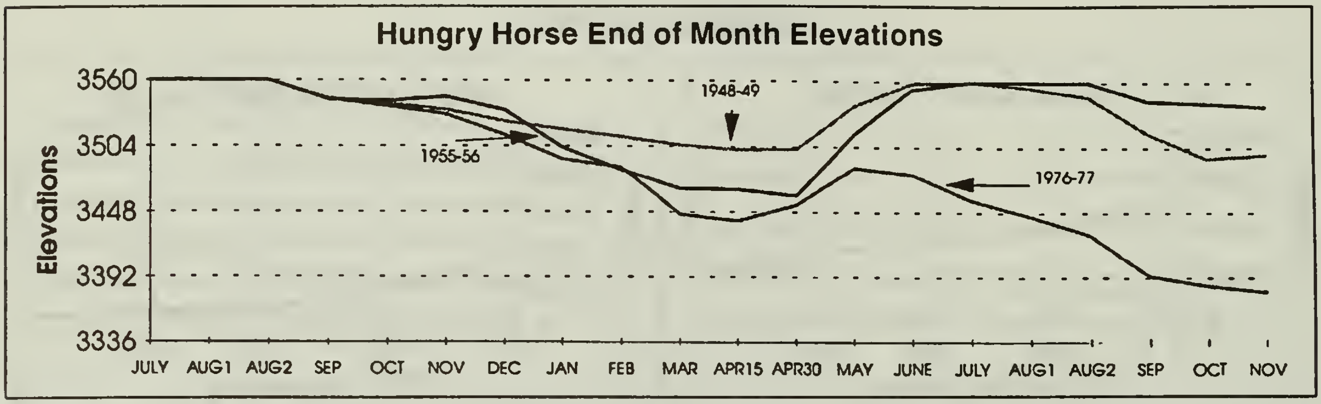
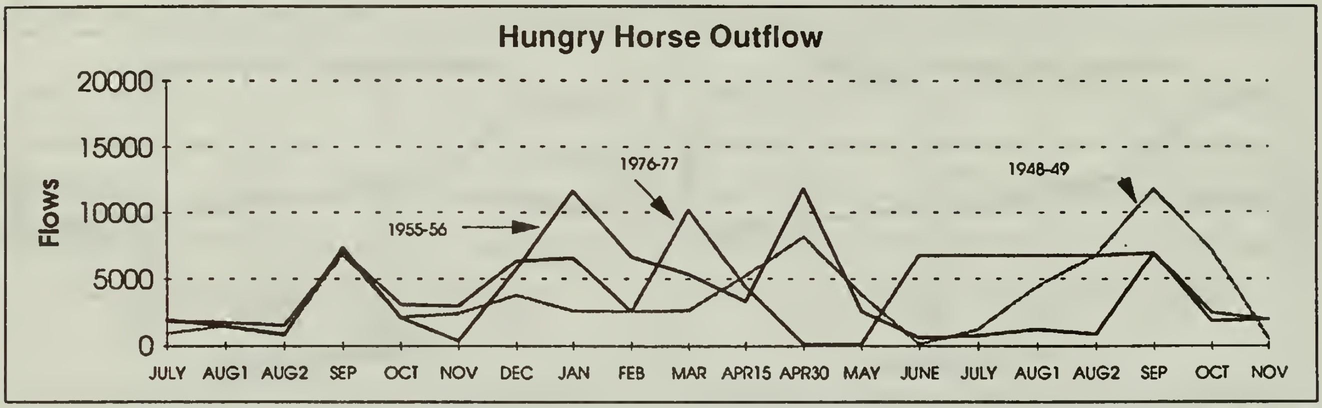
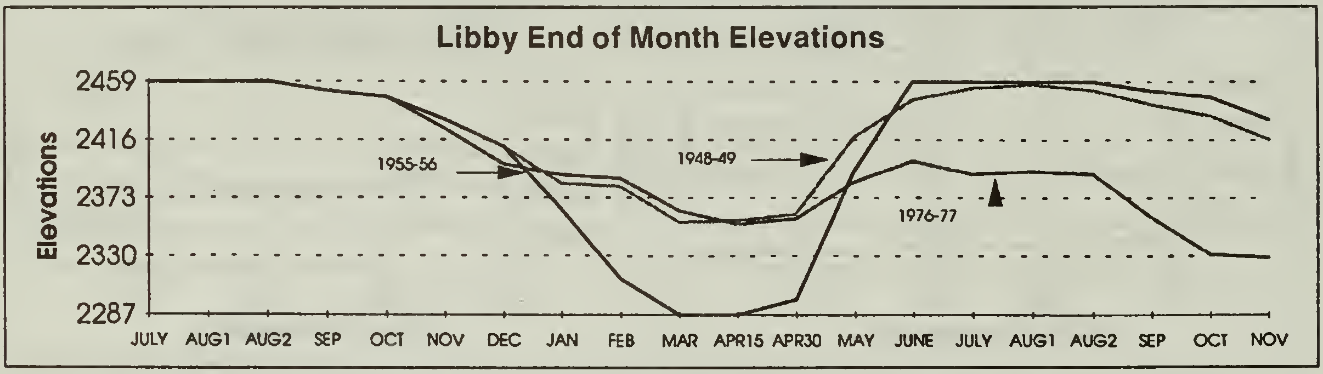






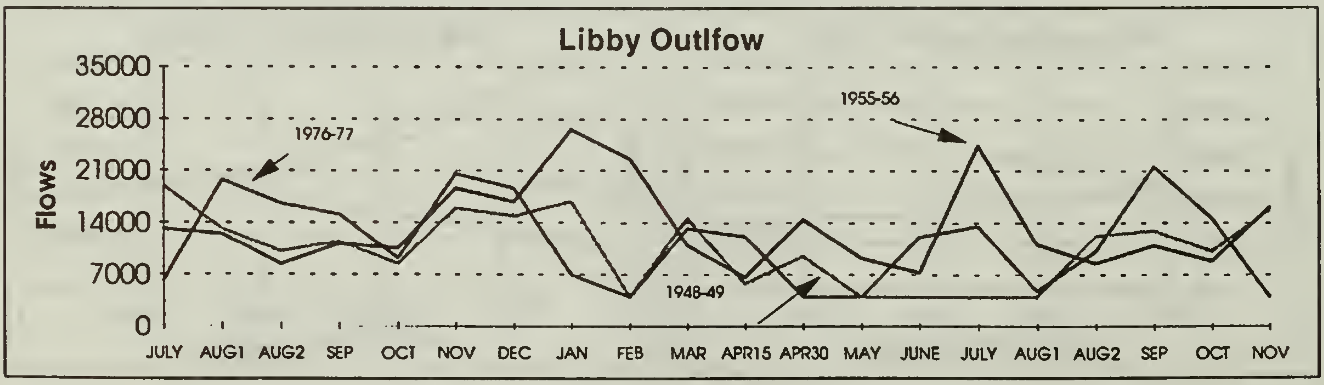
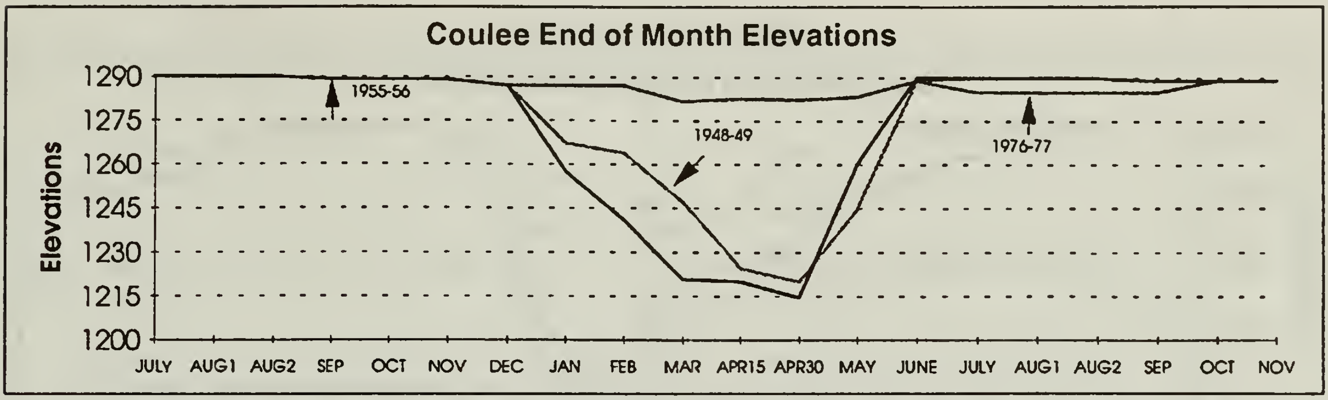
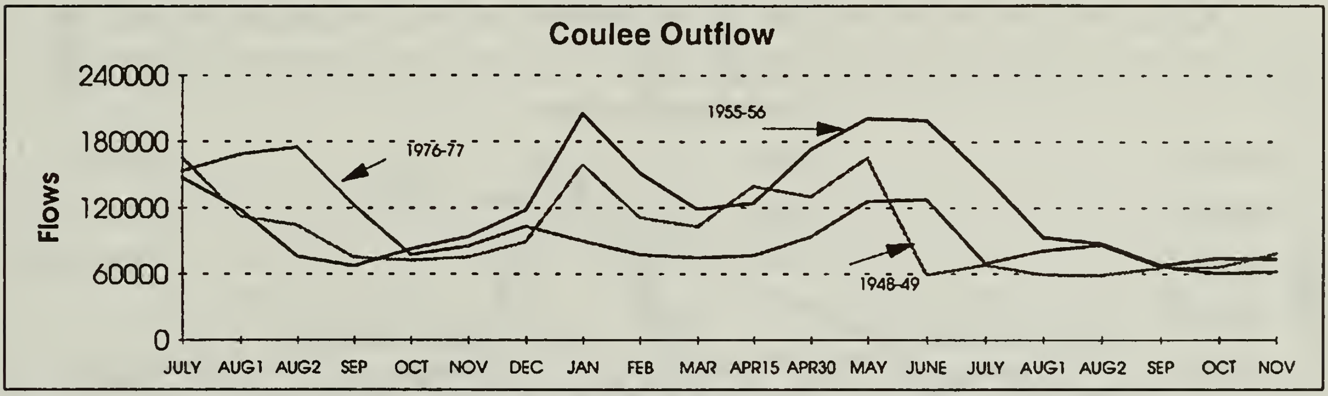
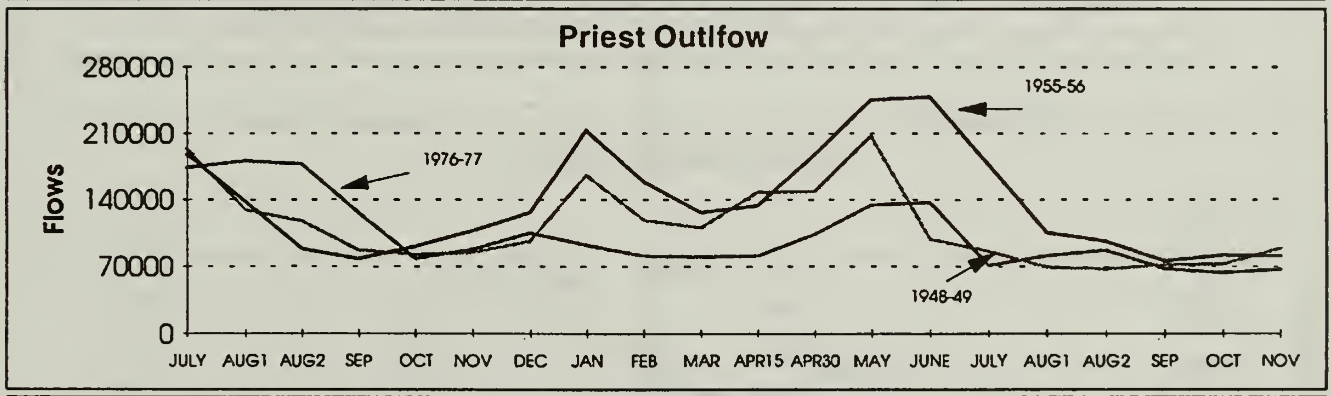


Table C–8. SOS6b – CONT







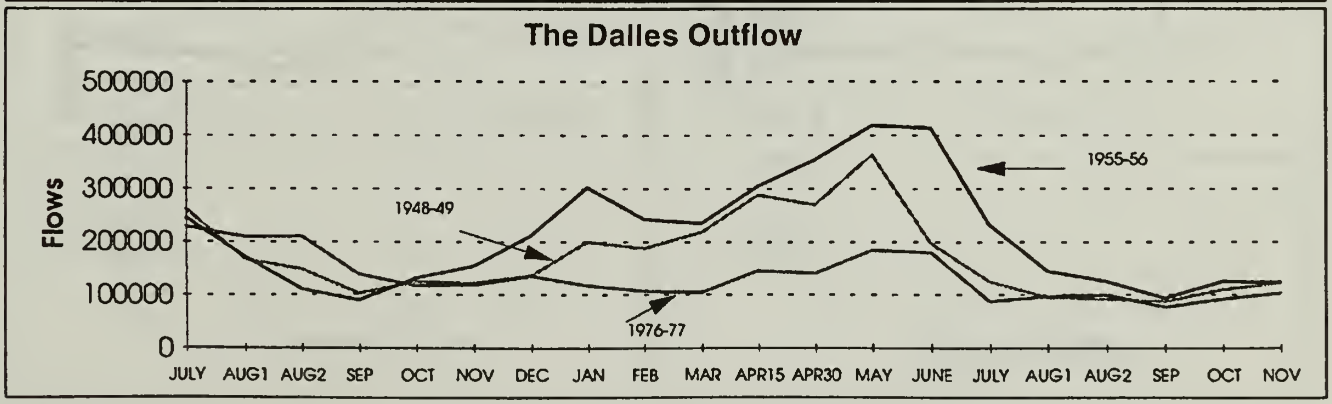
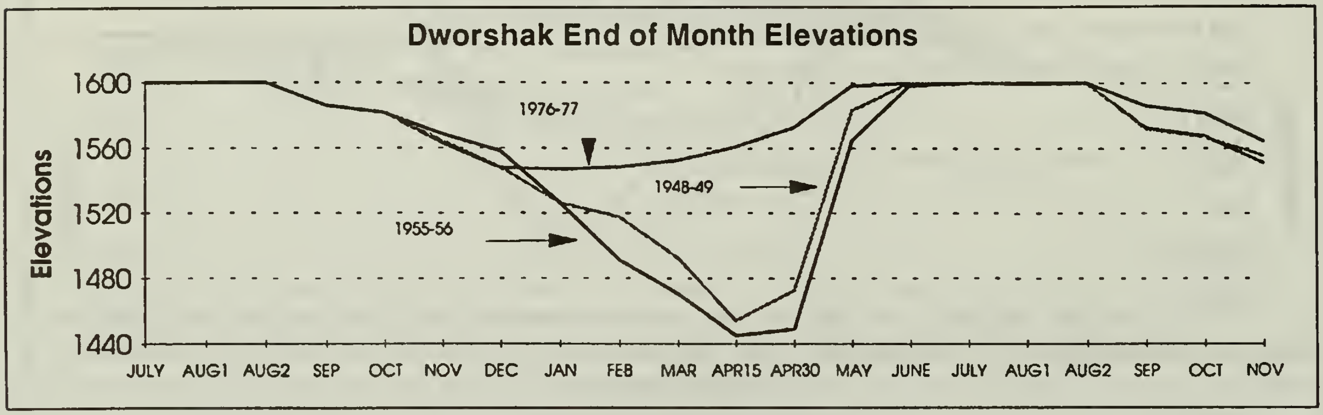
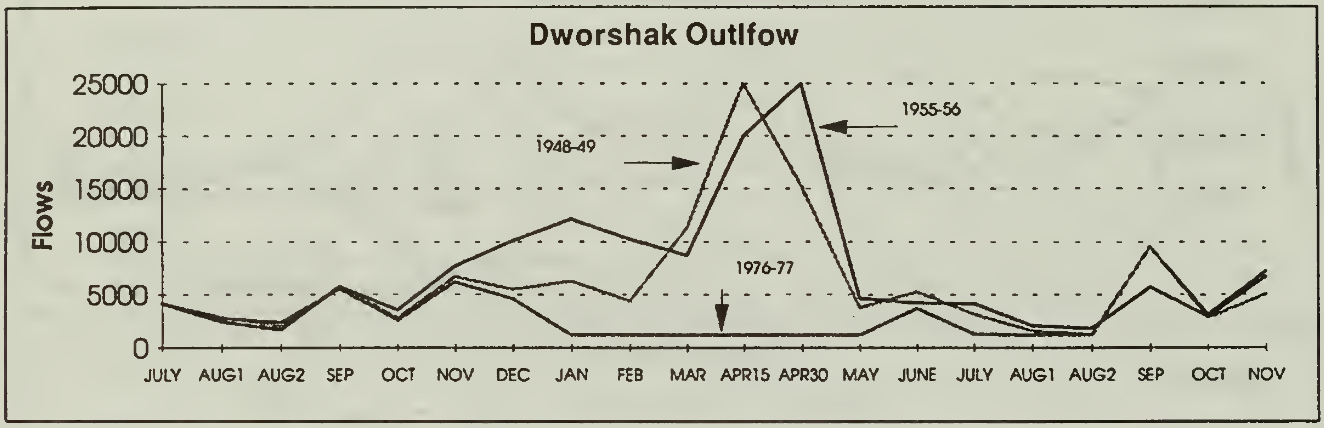


Table C–8. SOS6b – CONT





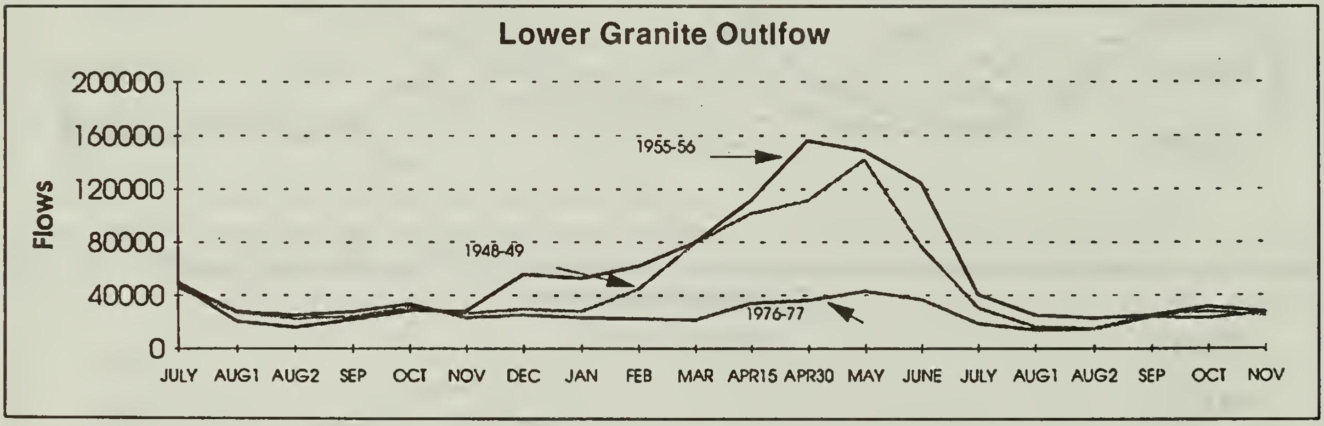
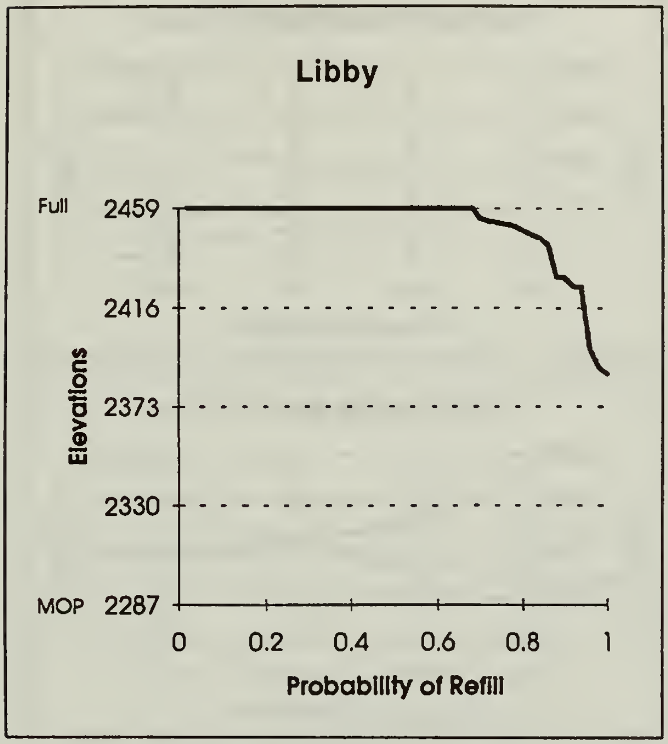
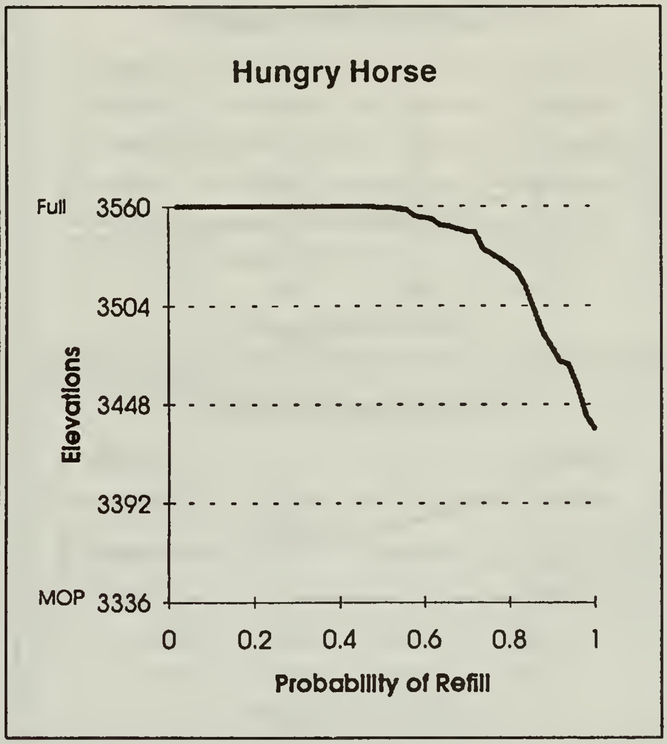
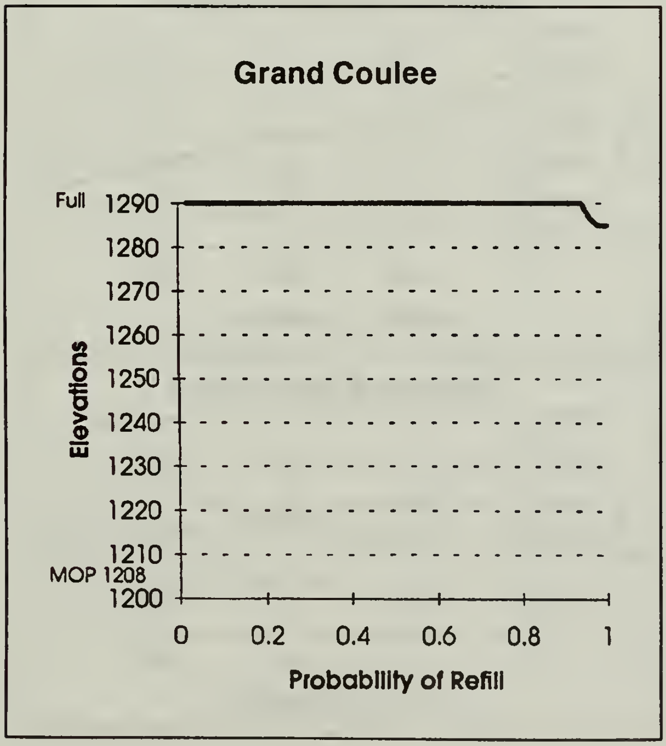


Table C–8. SOS6b – CONT

JULY ELEVATIONS







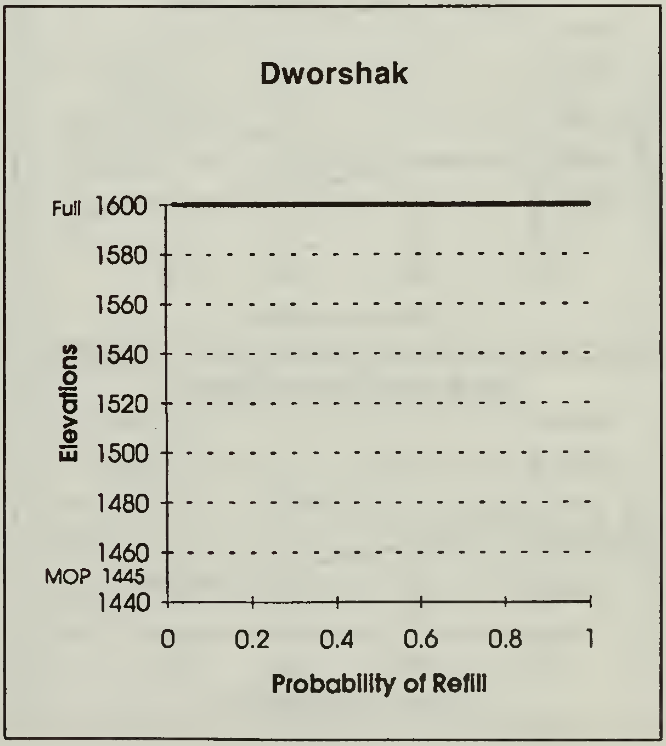


Table C–8. SOS6b – CONT

SPRING FLOWS

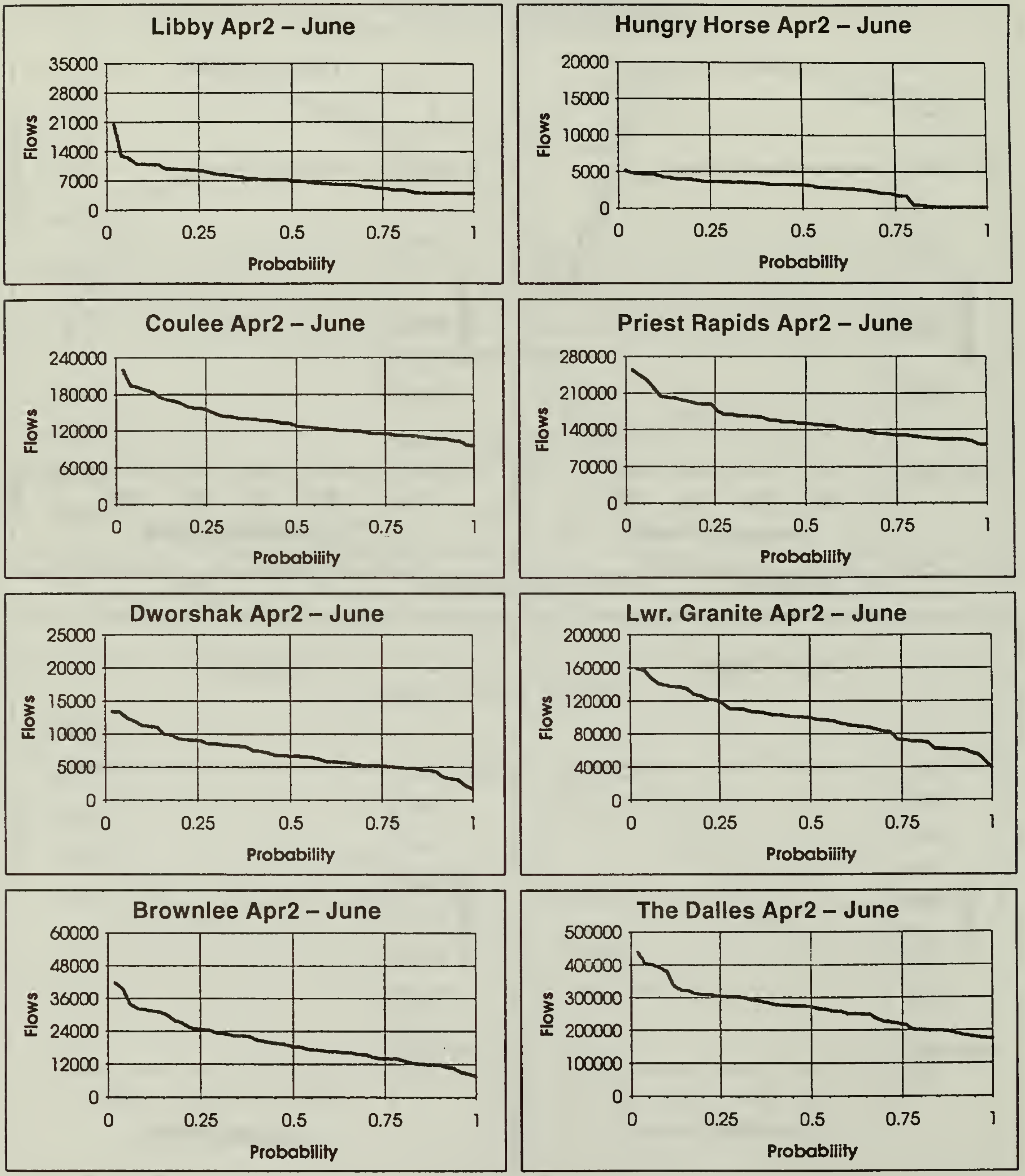


Table C–8. SOS6b – CONT

SUMMER FLOWS

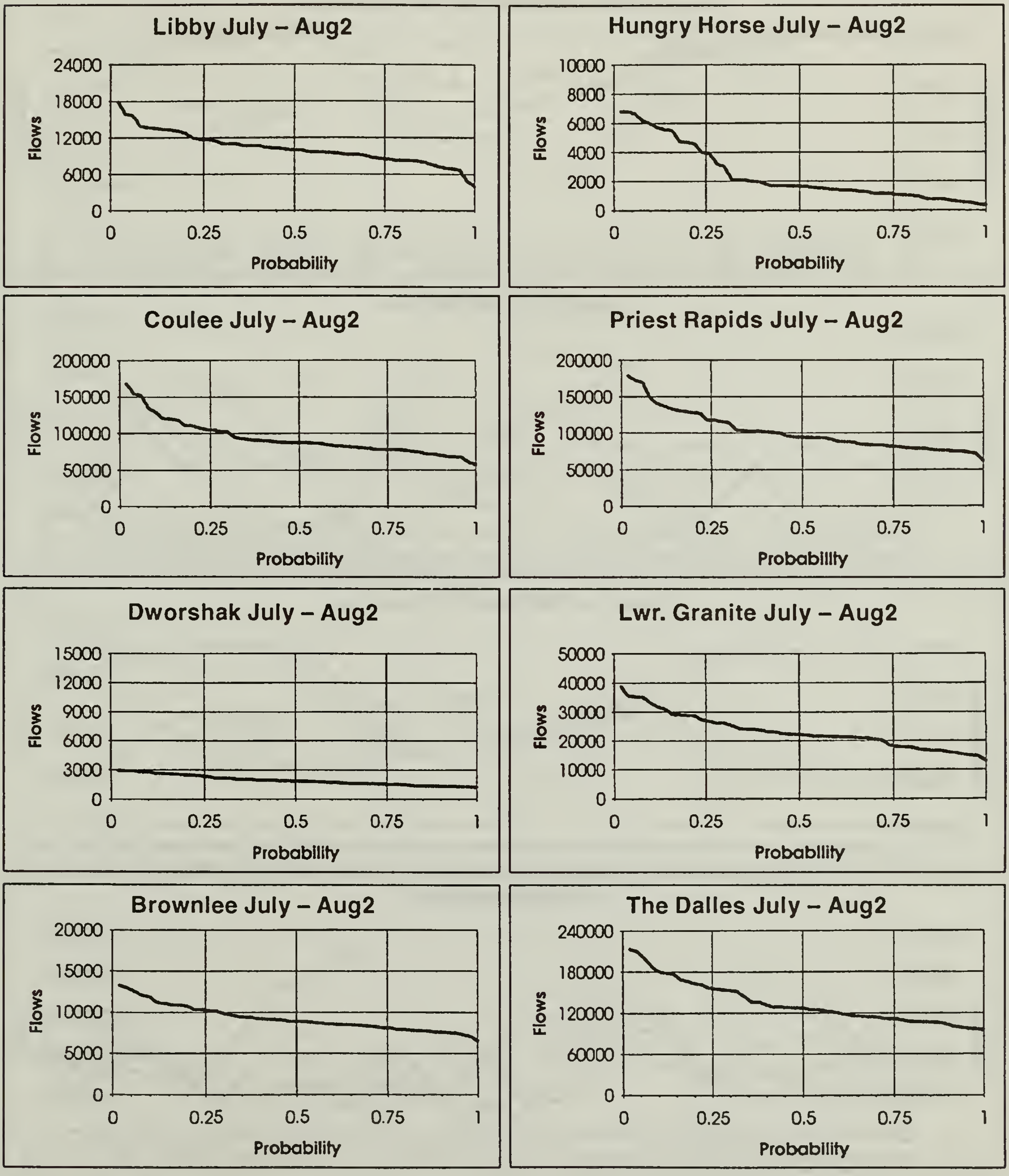
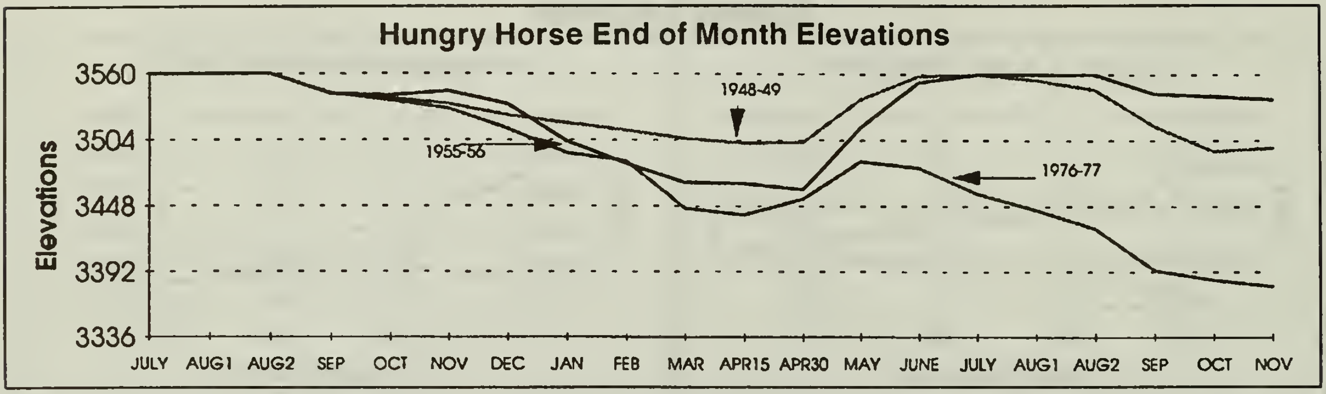
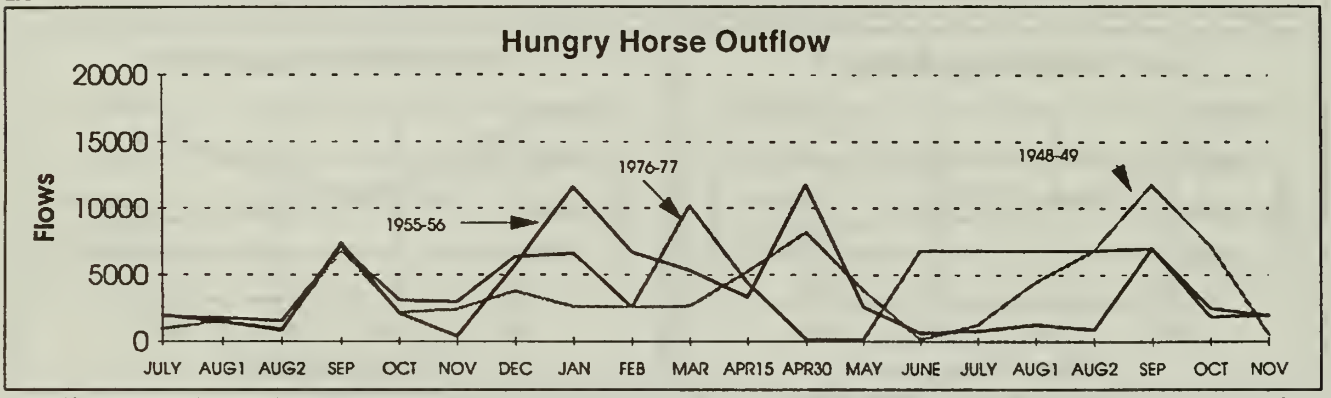
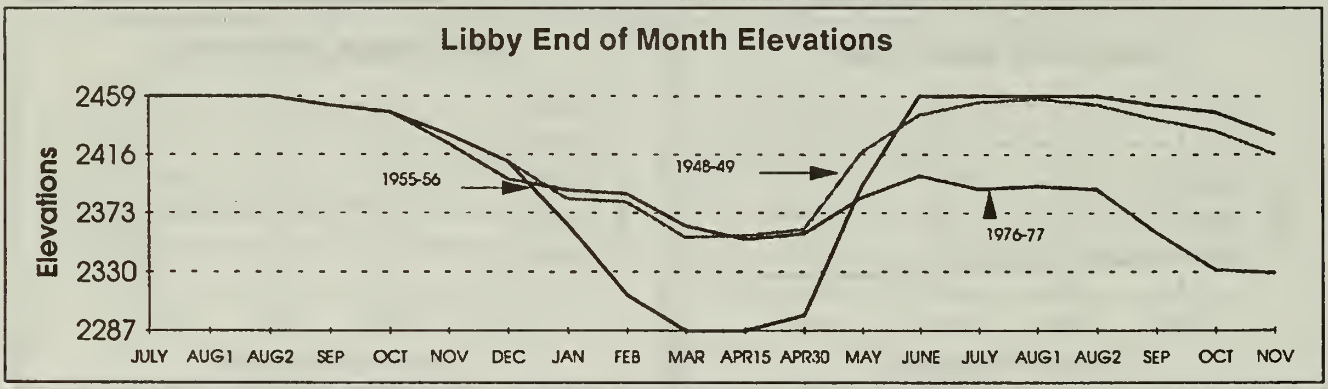


Table C–9. SOS6d







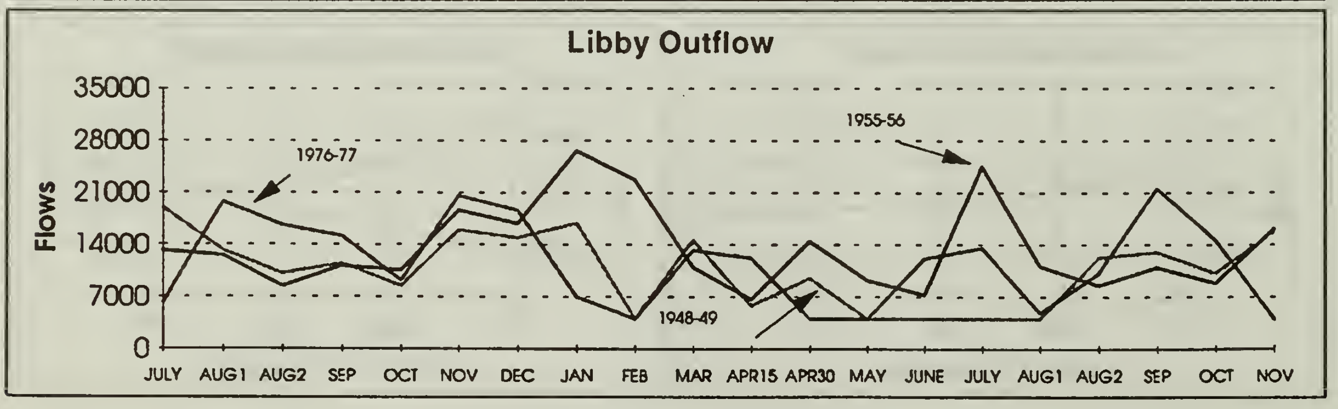


Table C–9. SOS6d – CONT

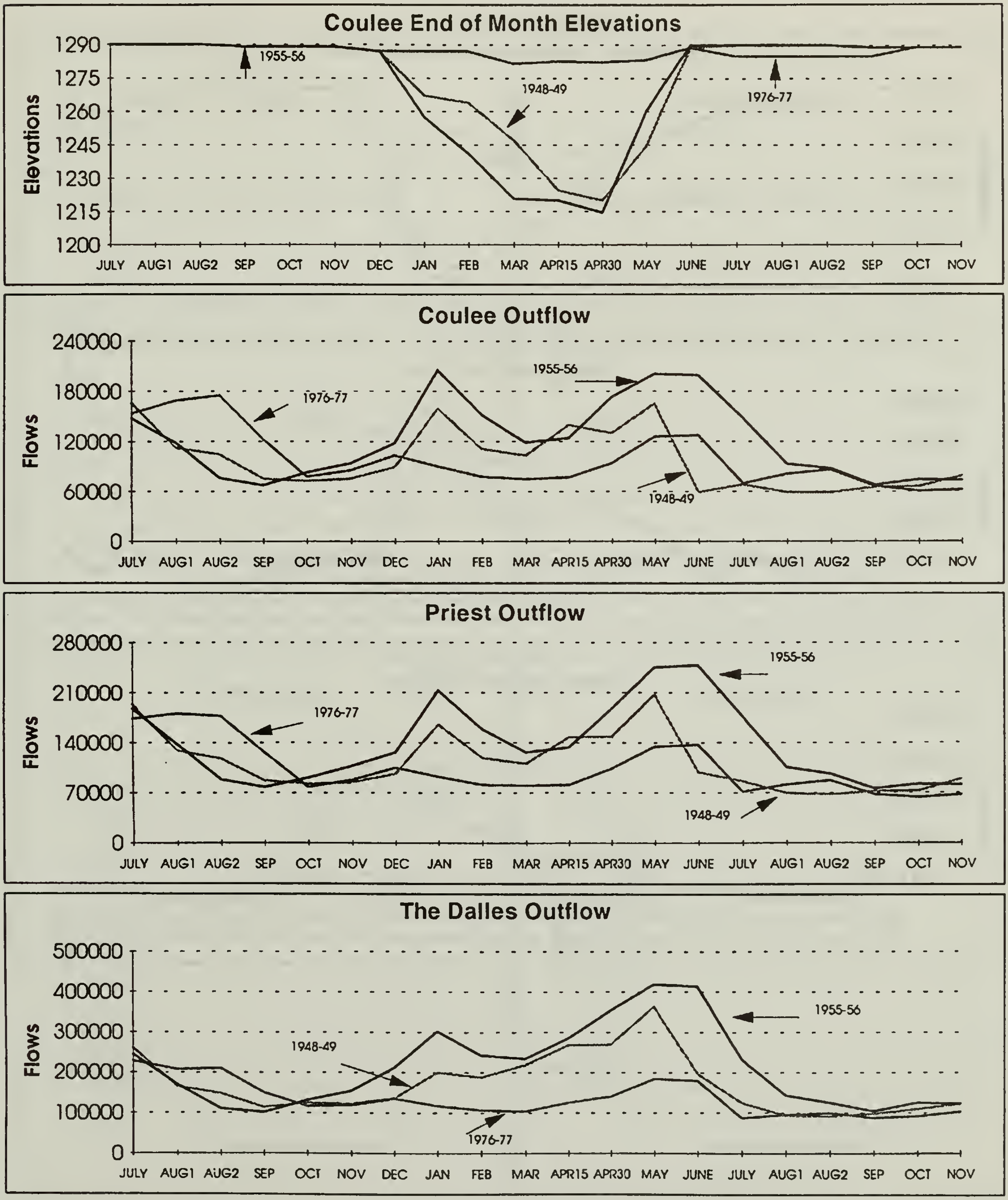
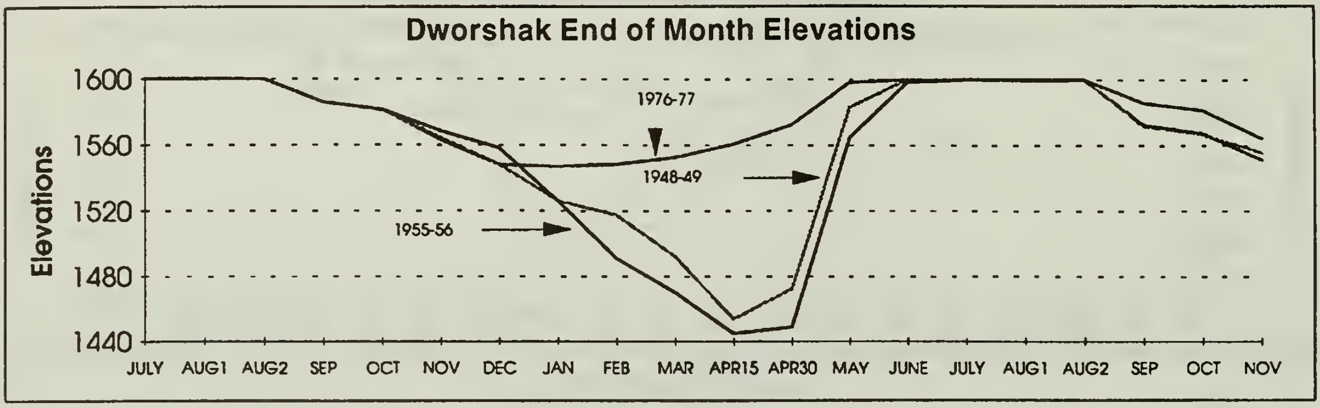
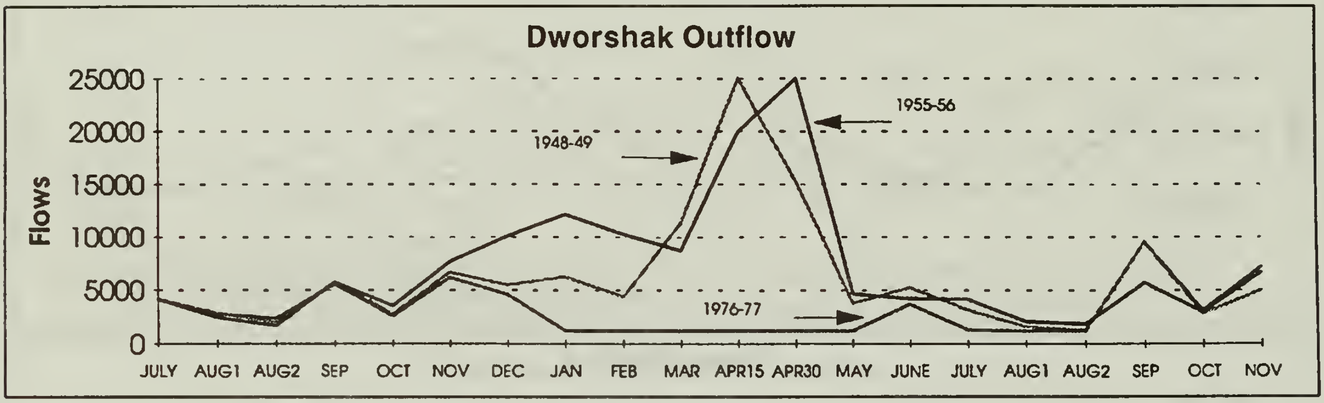


Table C–9. SOS6d – CONT





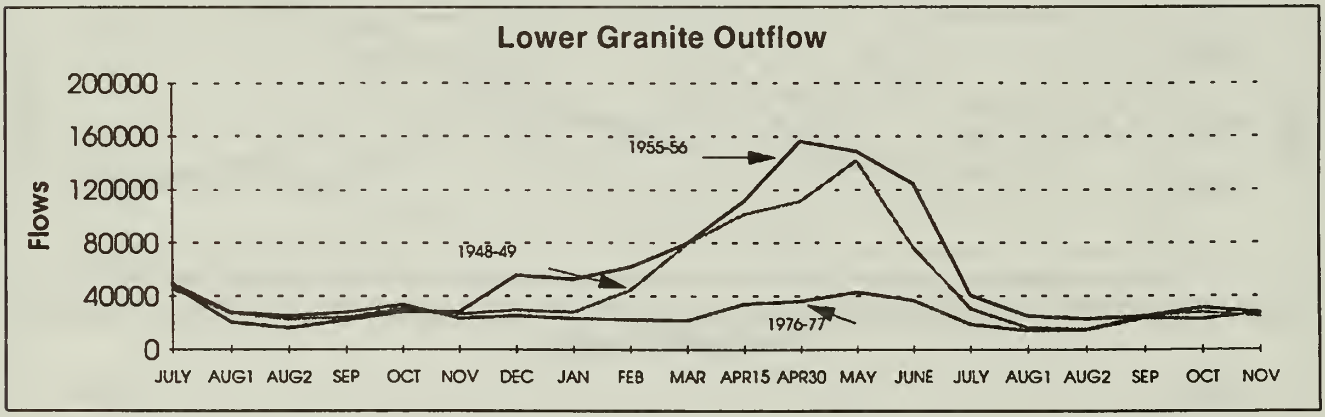


Table C–9. SOS6d – CONT

JULY ELEVATIONS

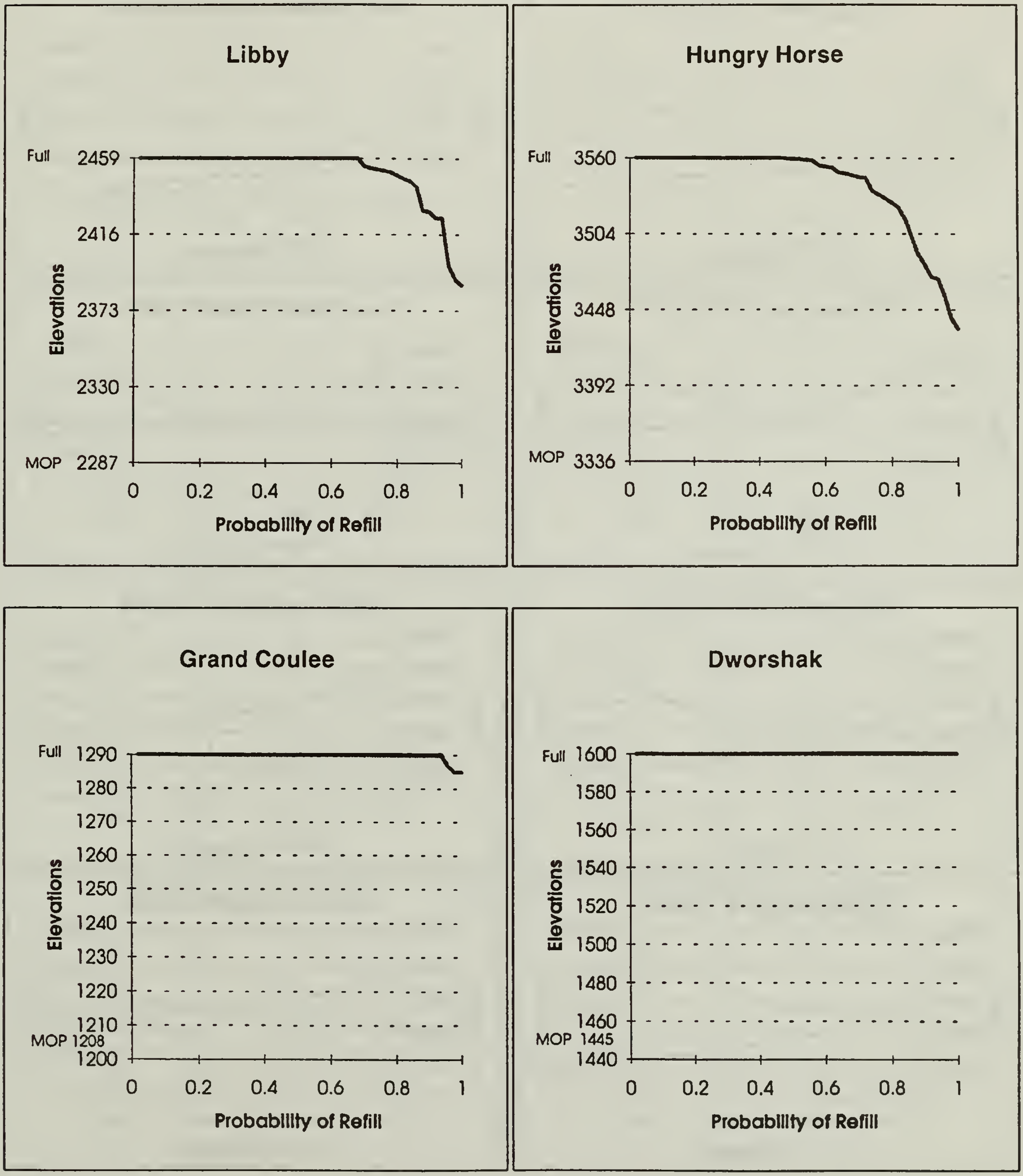
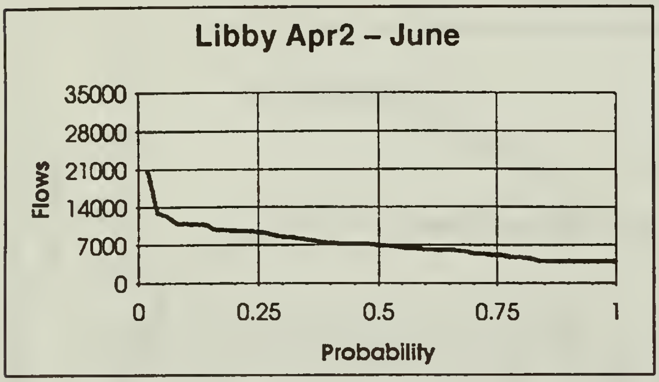
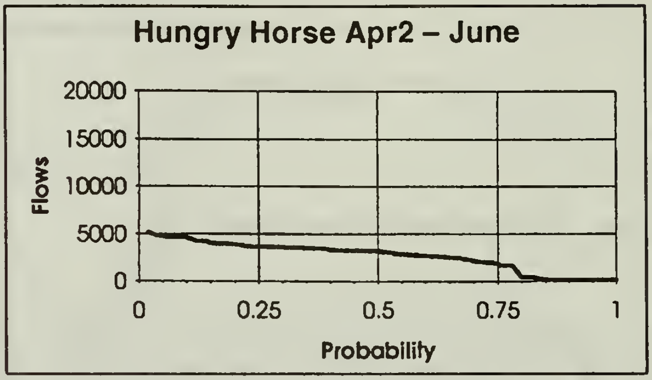
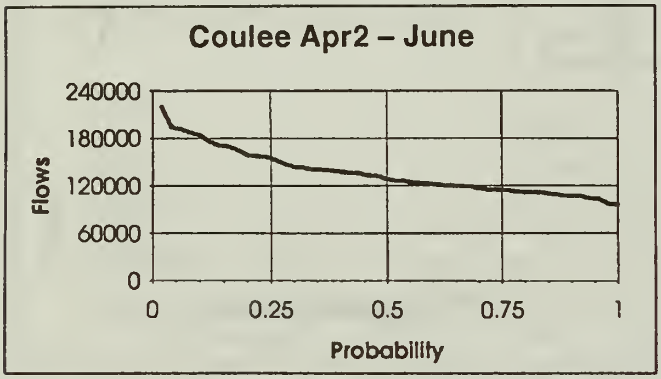


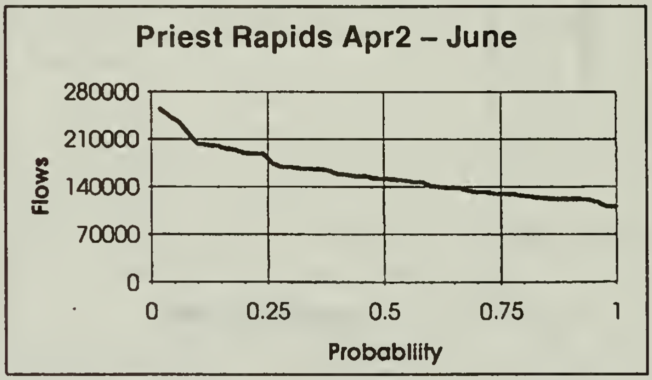
Table C–9. SOS6d – CONT

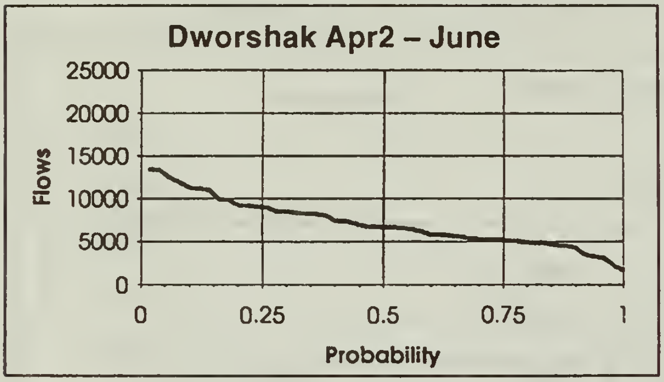
SPRING FLOWS

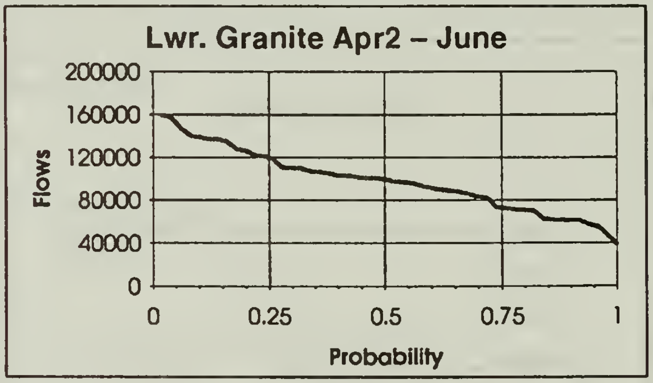


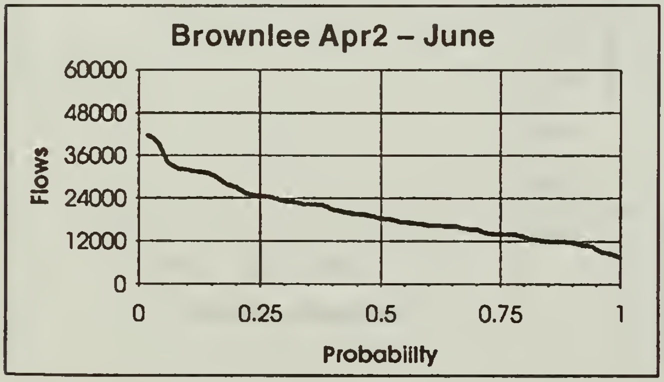












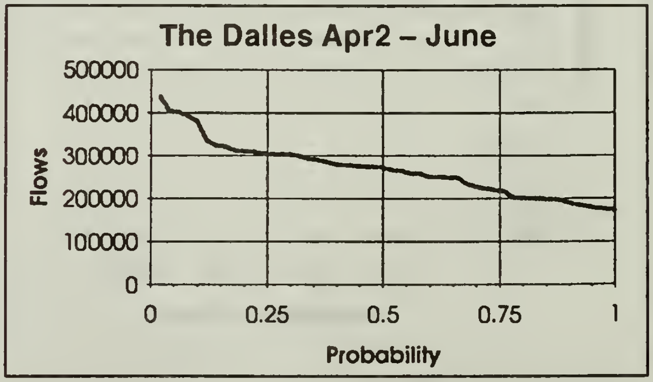


Table C–9. SOS6d – CONT

SUMMER FLOWS

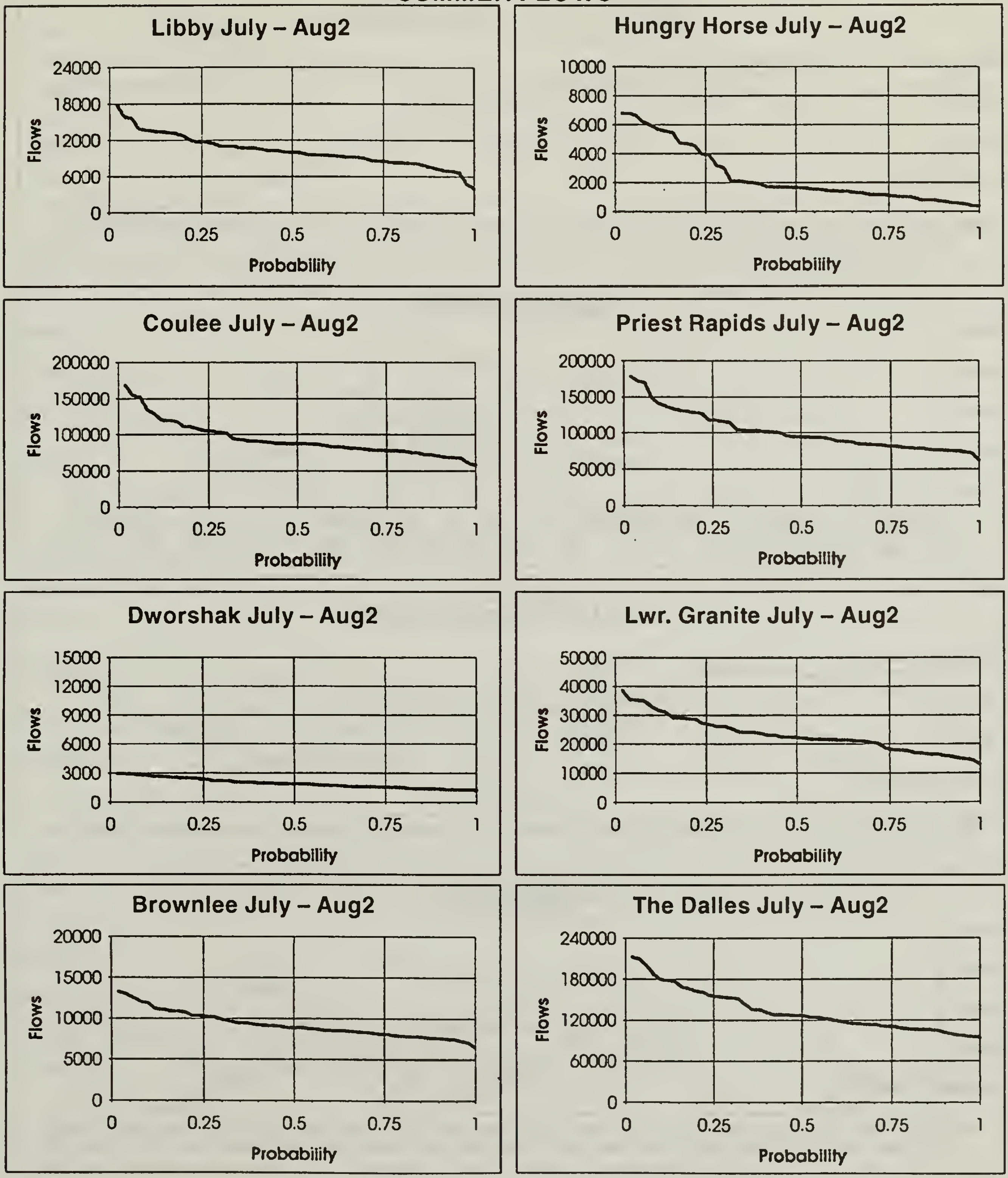
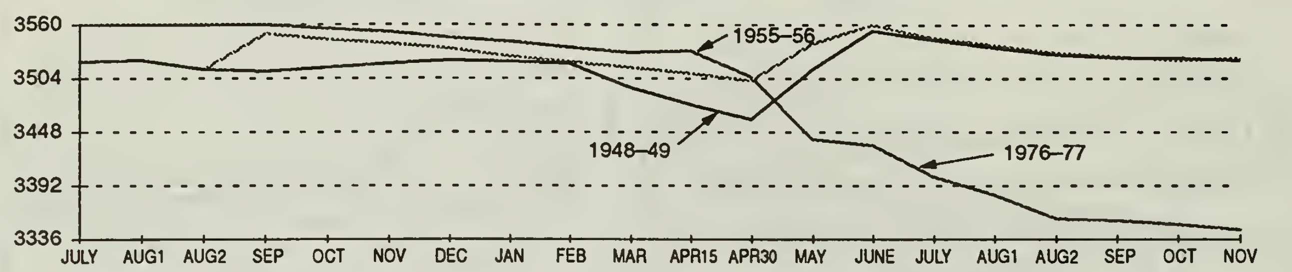
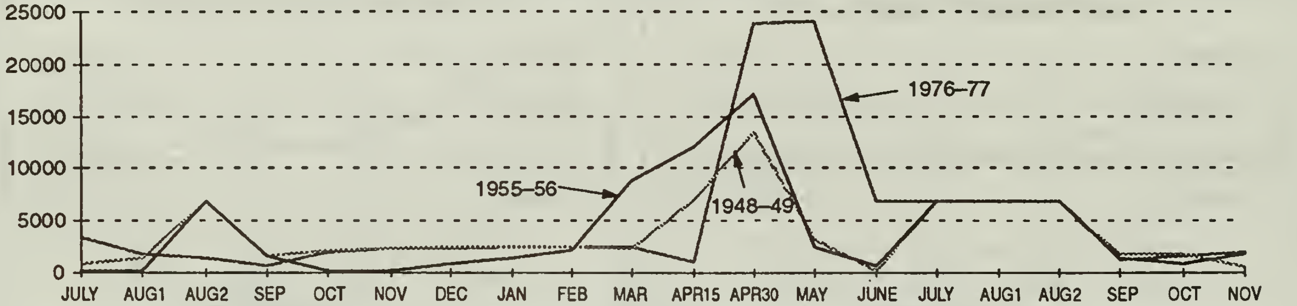


Table C–10. SOS9a

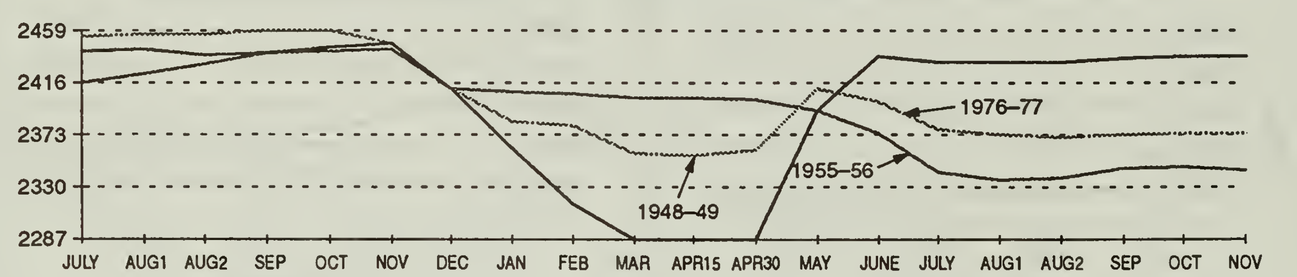
Hungry Horse End of Month Elevations



Hungry Horse Outflow



Libby End of Month Elevations



Libby Outflow

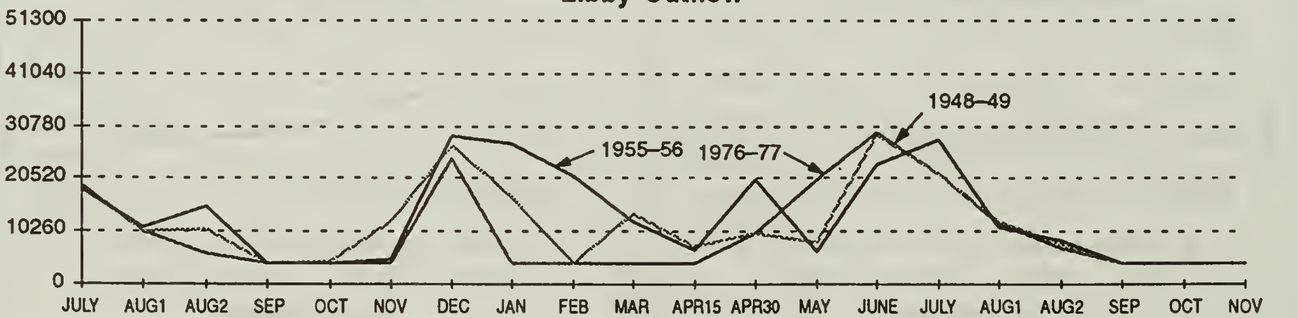
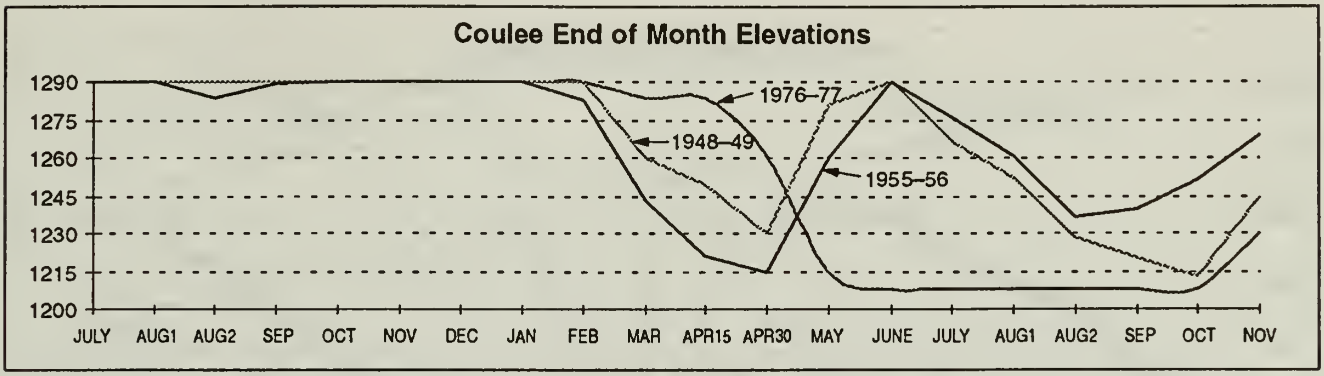
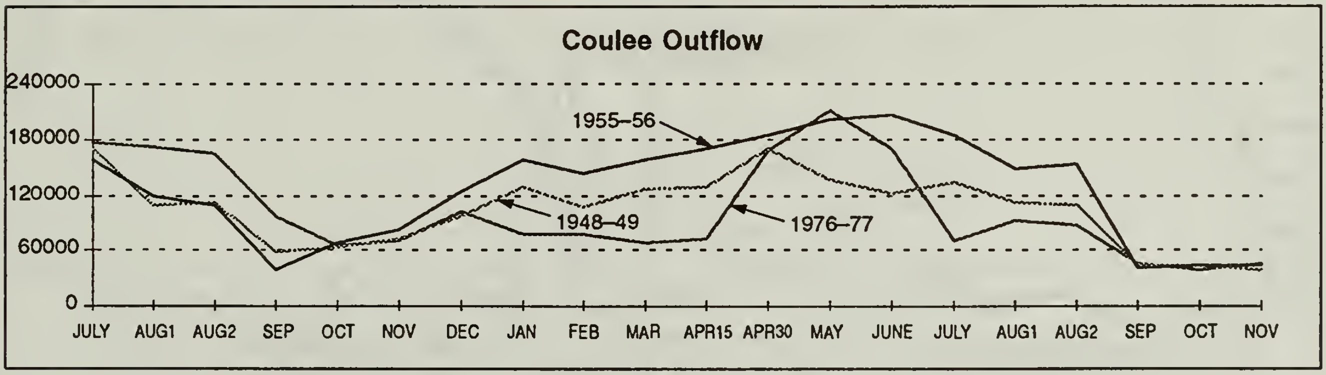
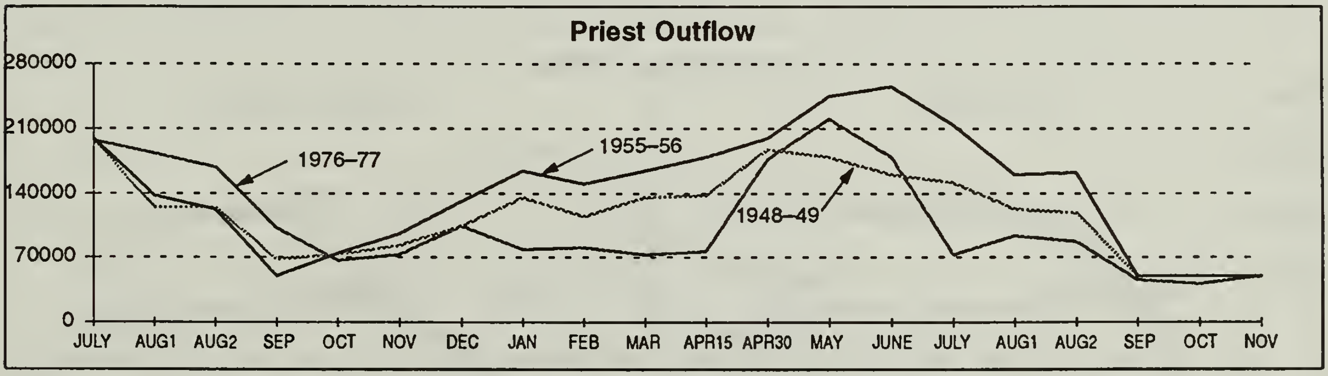


Table C–10. SOS9a – CONT







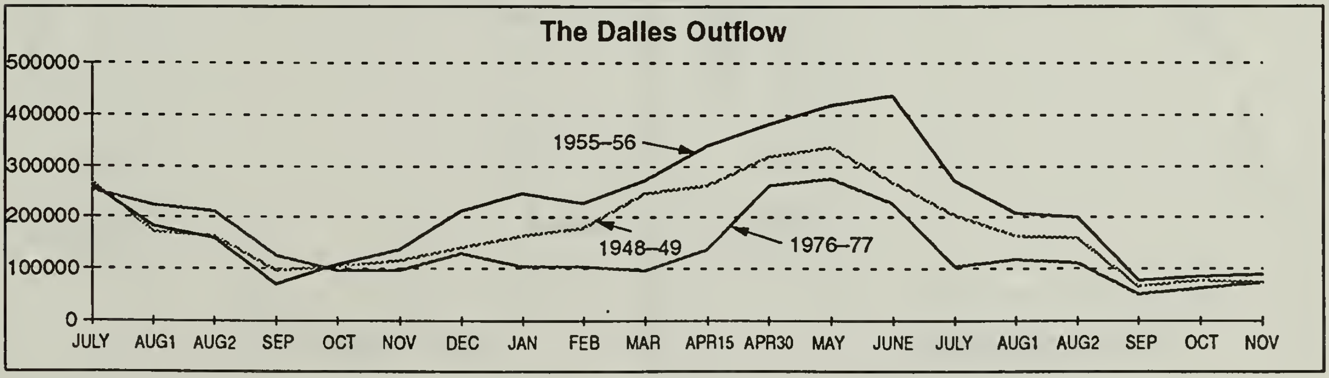
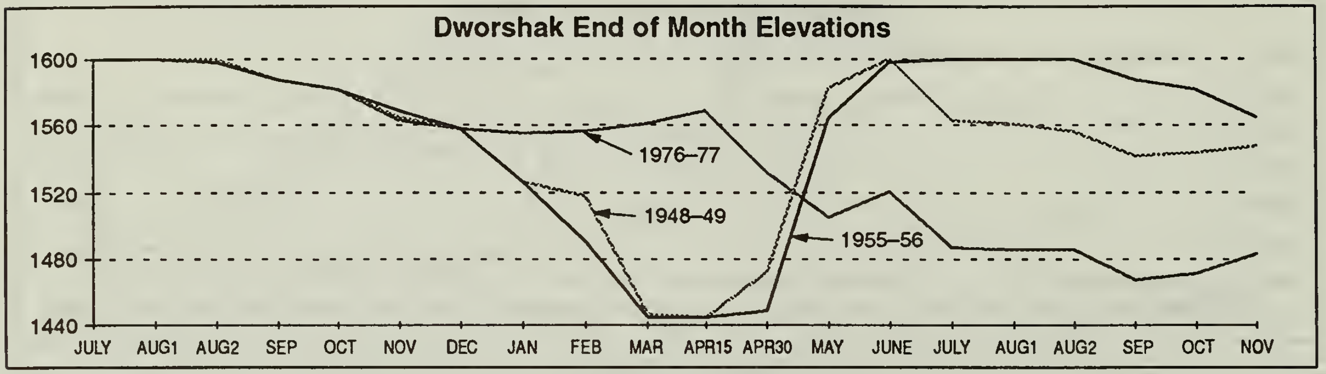
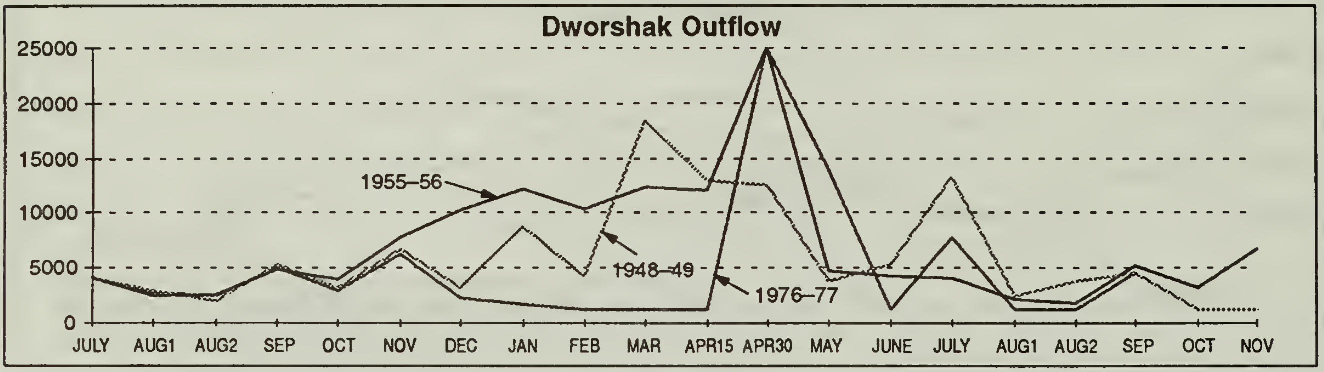


Table C–10. SOS9a – CONT





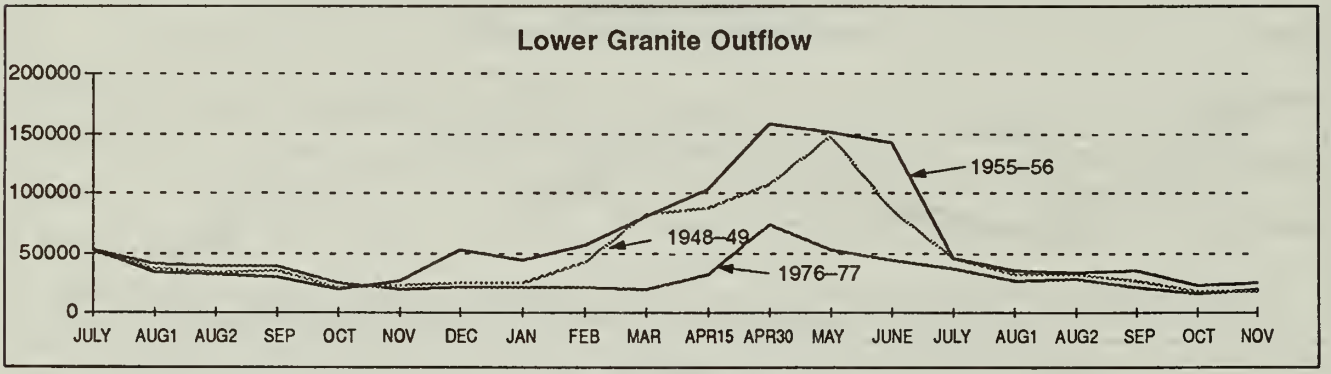


Table C–10. SOS9a – CONT

JULY ELEVATIONS

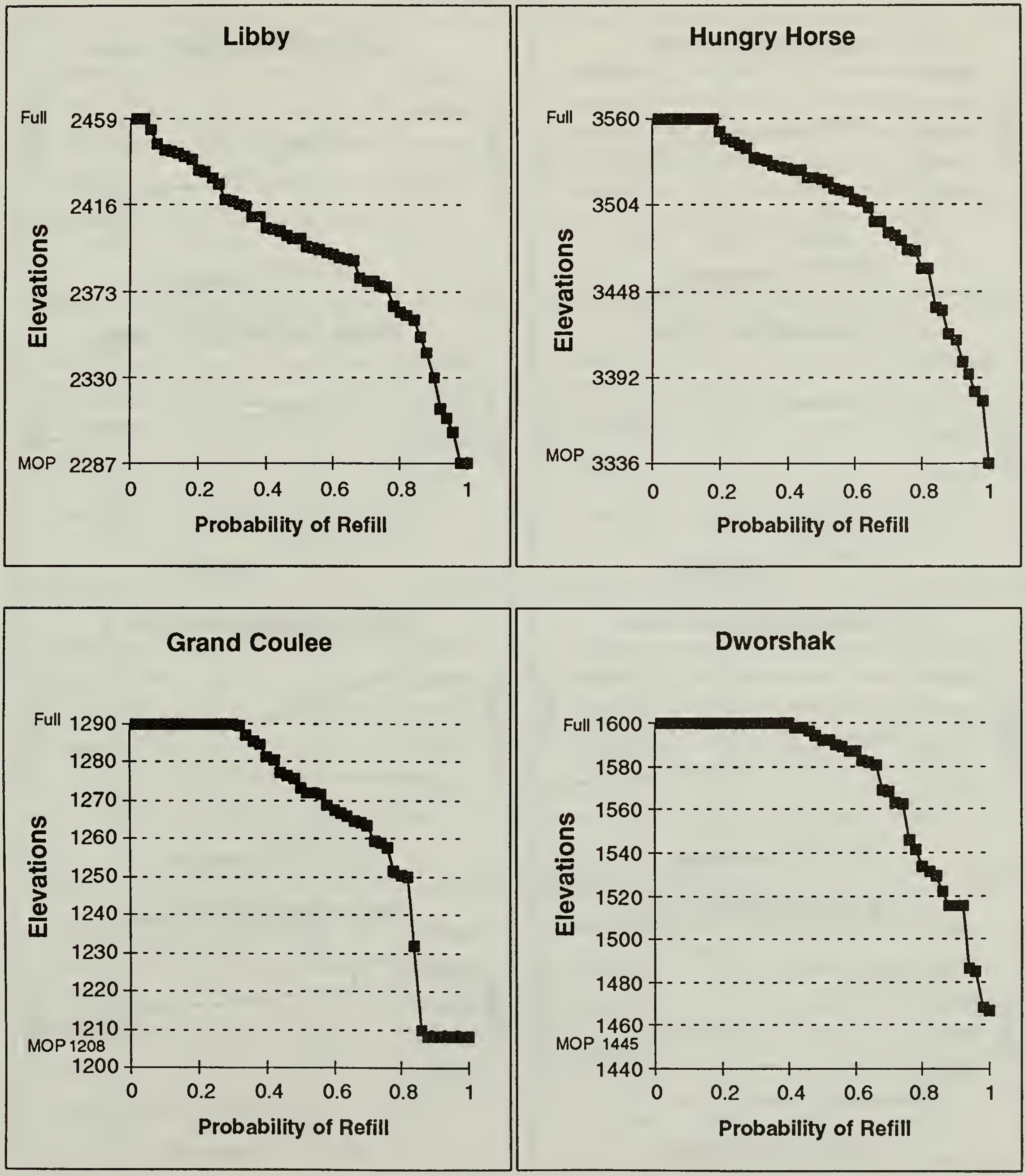


Table C–10. SOS9a – CONT

SPRING FLOWS

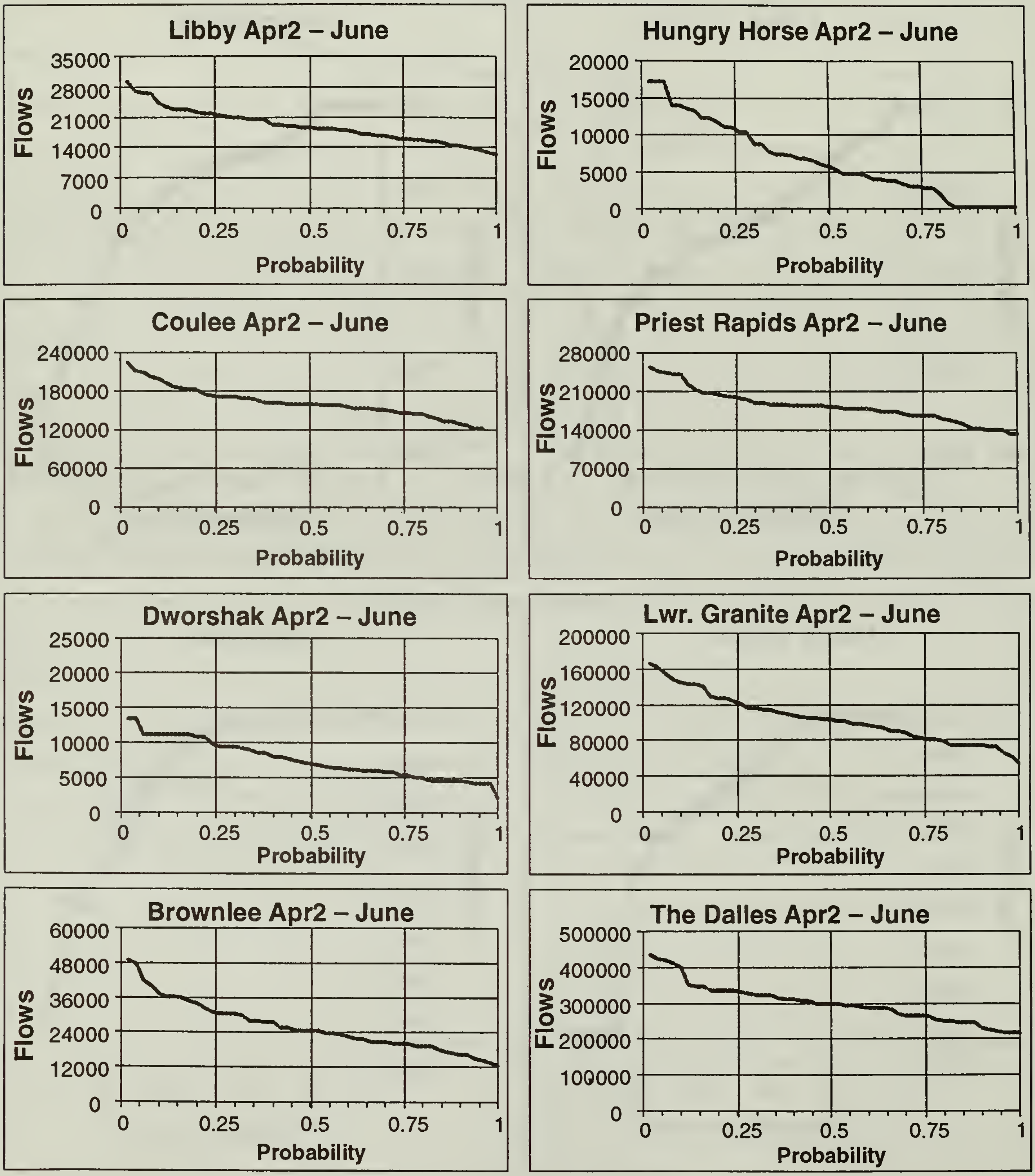
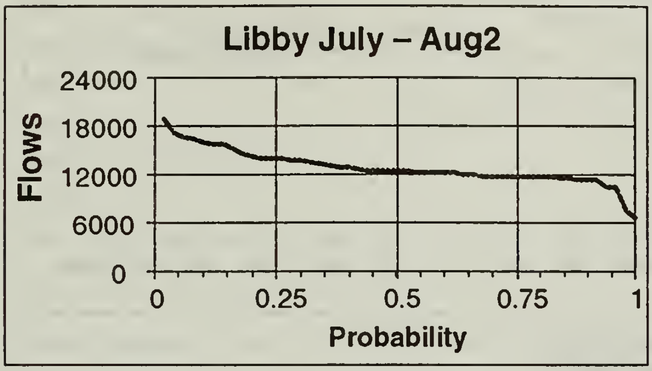
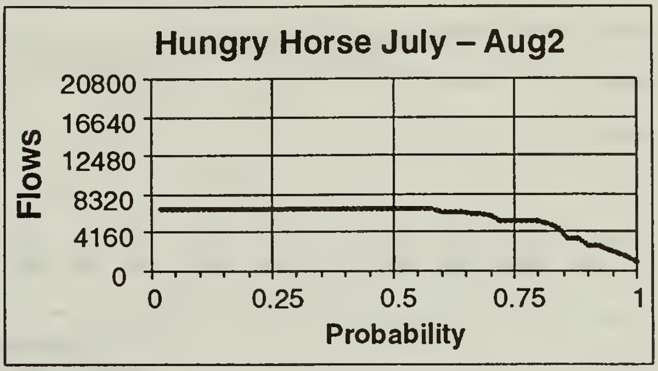
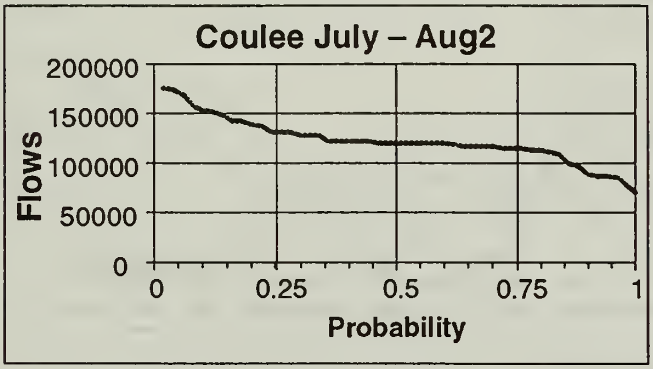


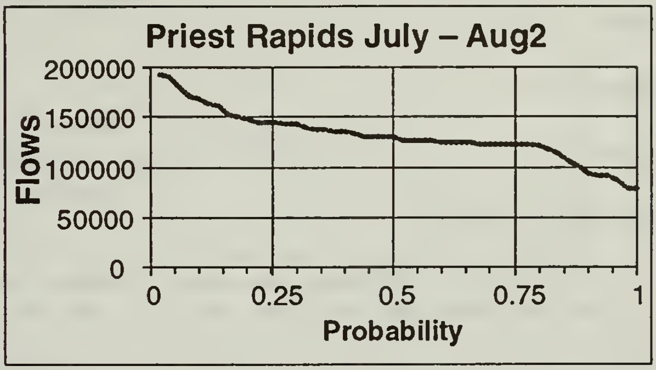
Table C–10. SOS9a – CONT

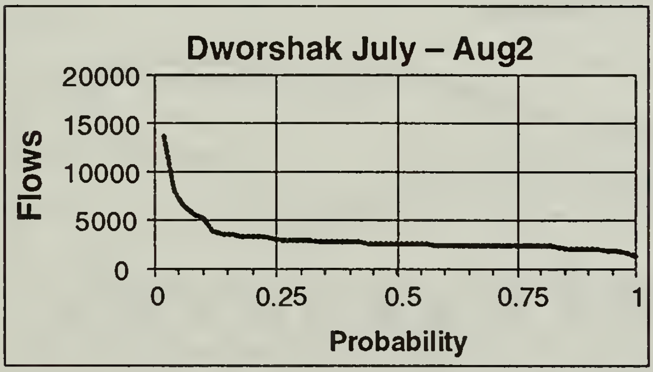
SUMMER FLOWS

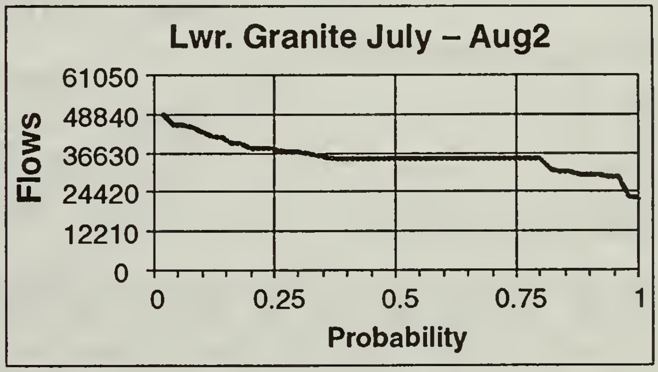


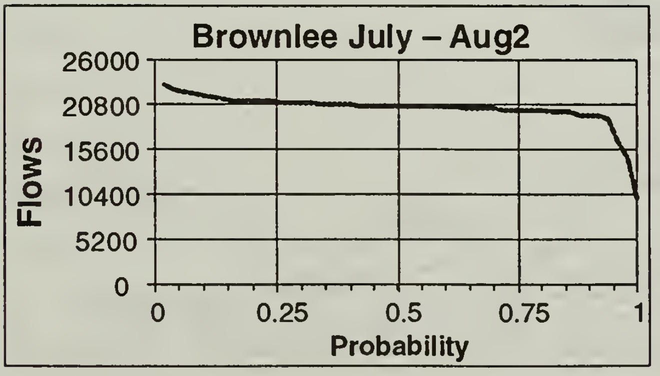












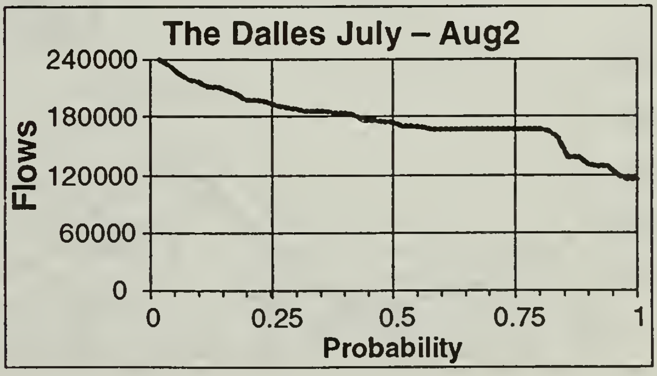
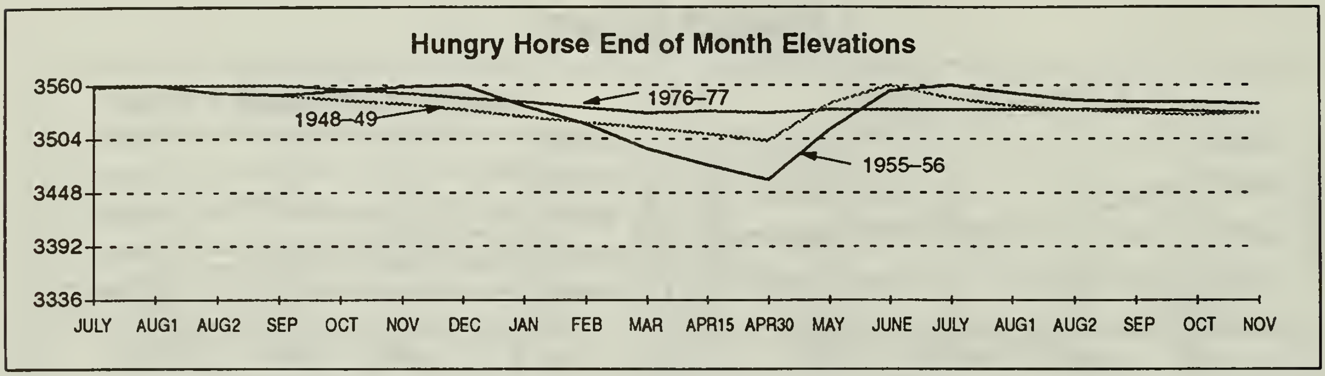
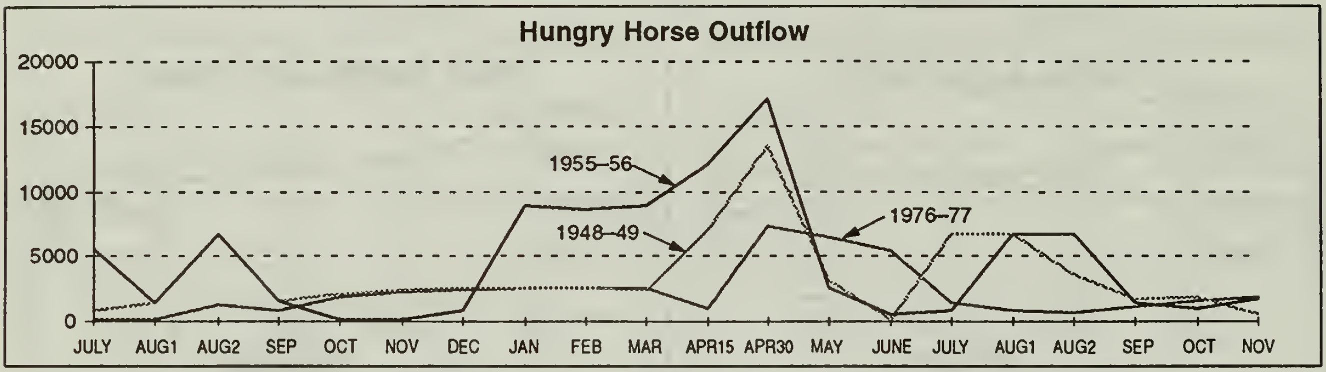
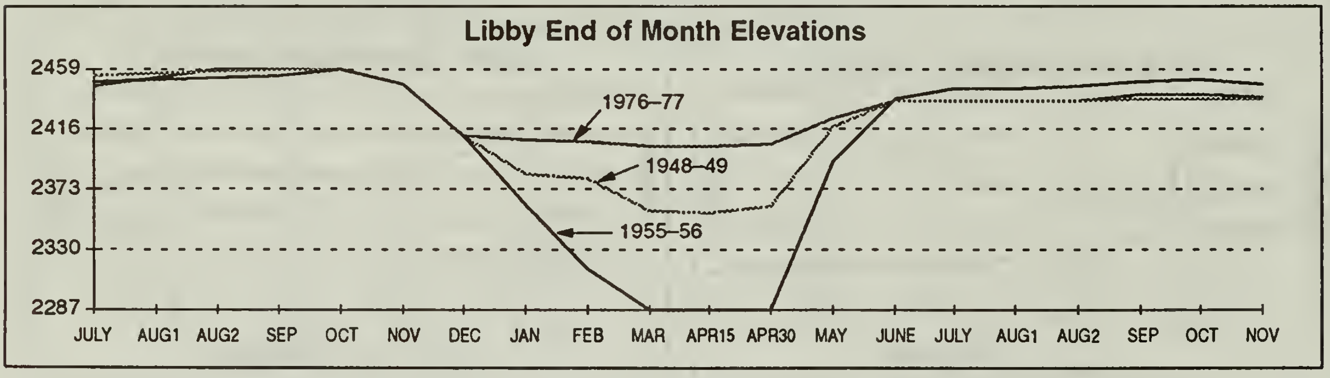


Table C–11. SOS9b







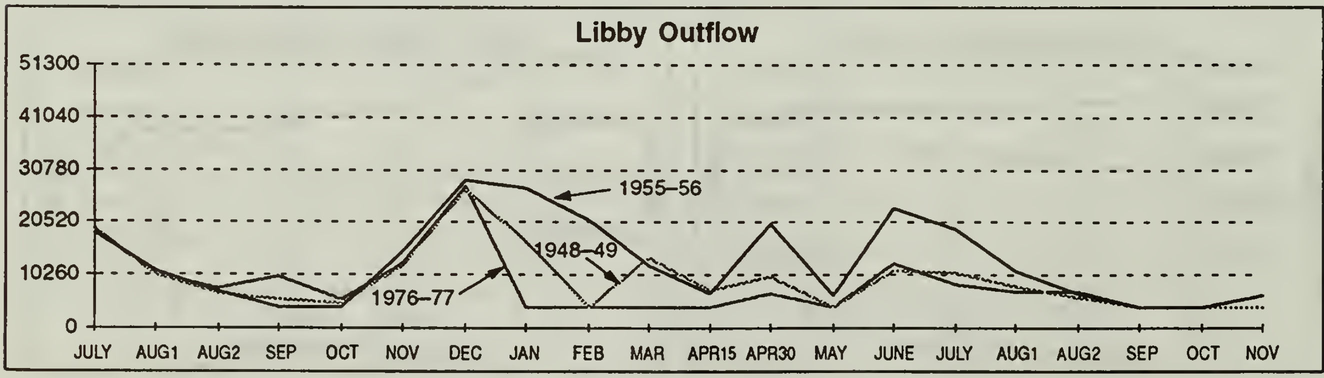
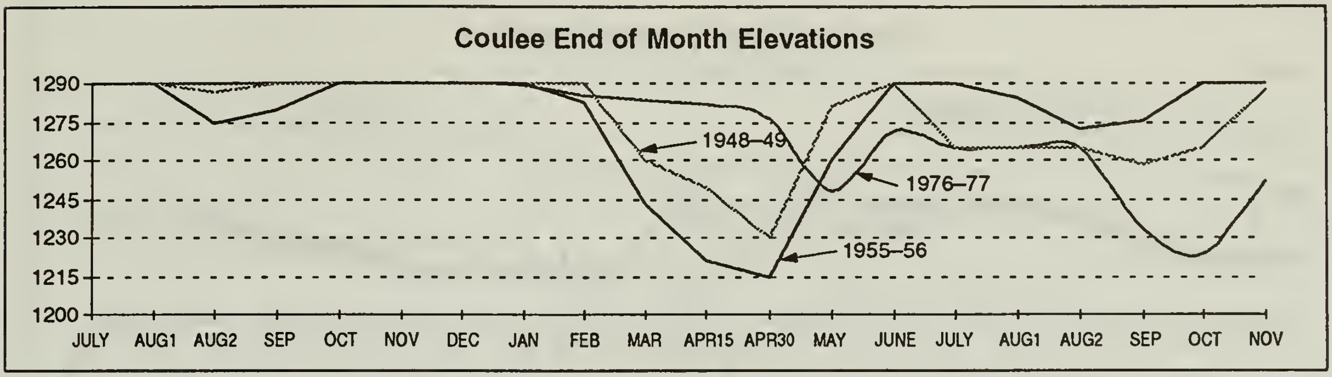
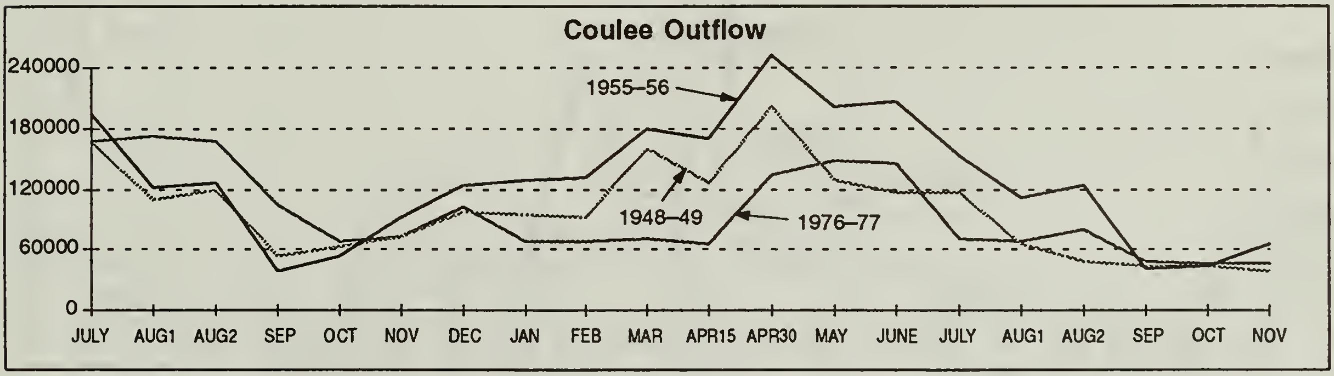
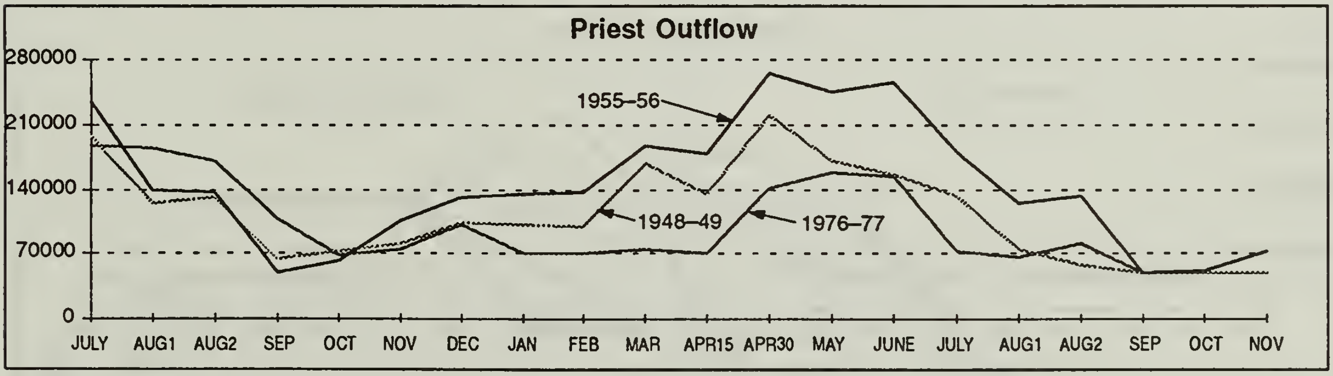


Table C–11. SOS9b – CONT







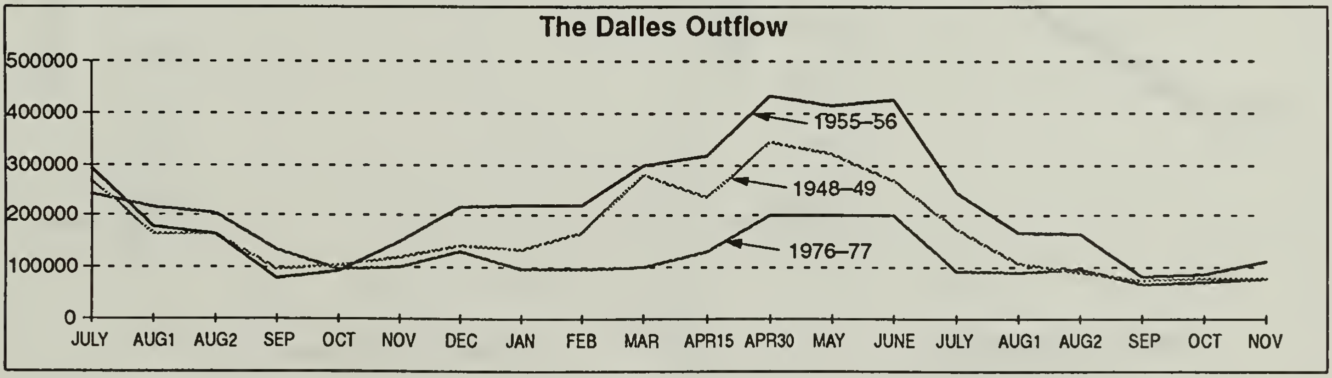
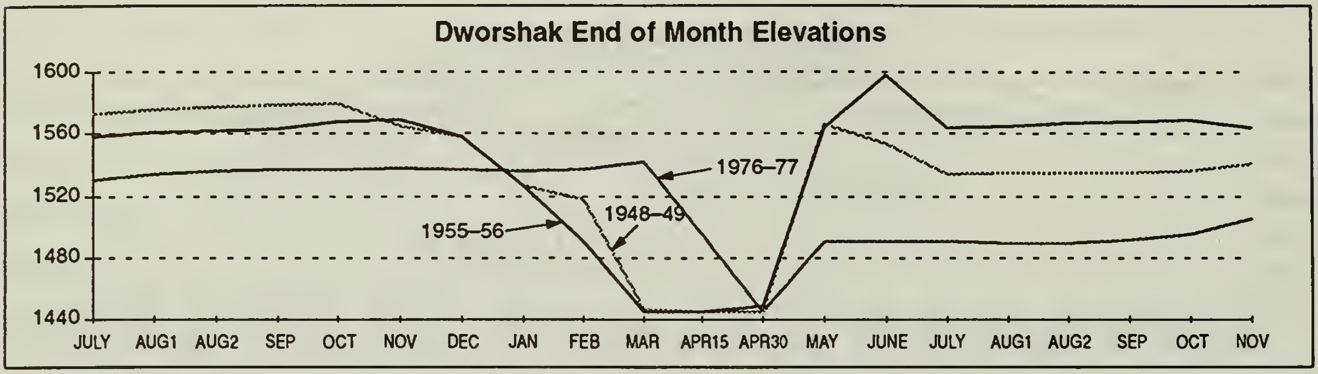
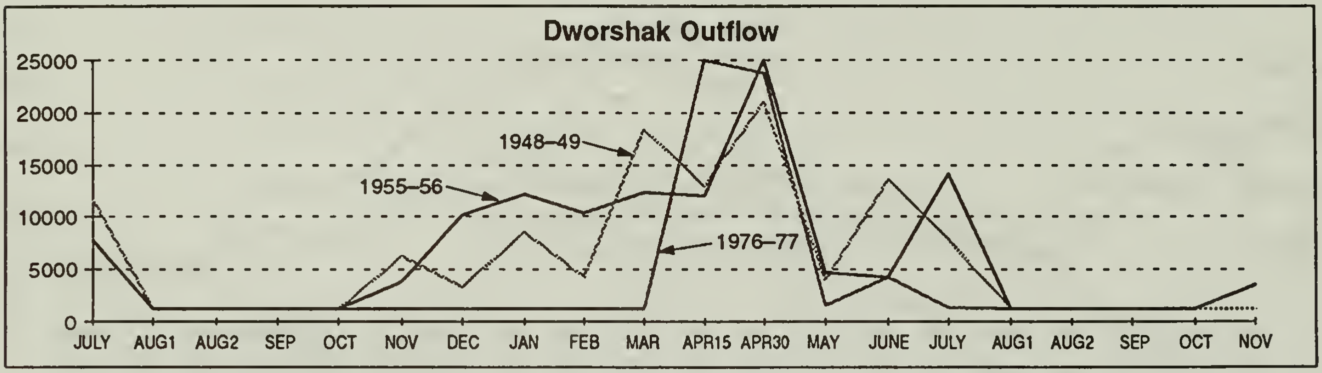


Table C–11. SOS9b – CONT





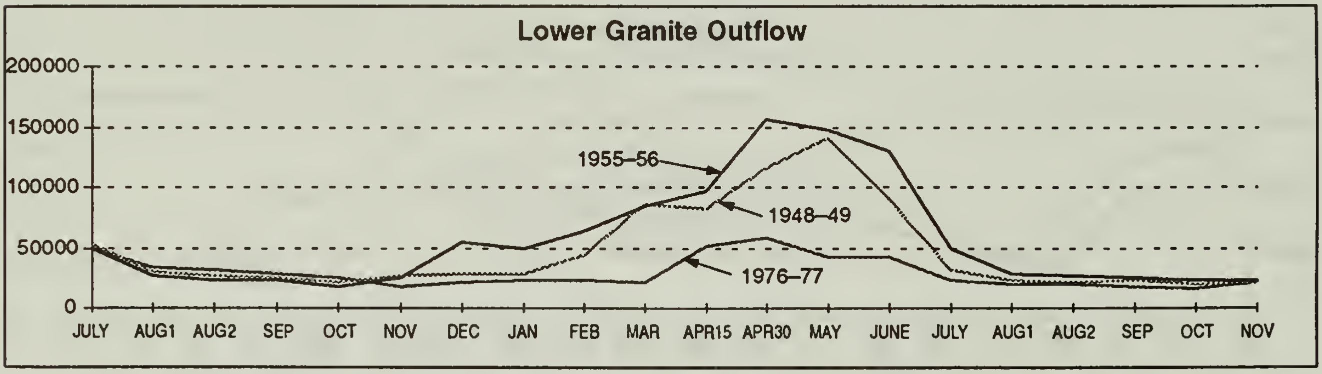
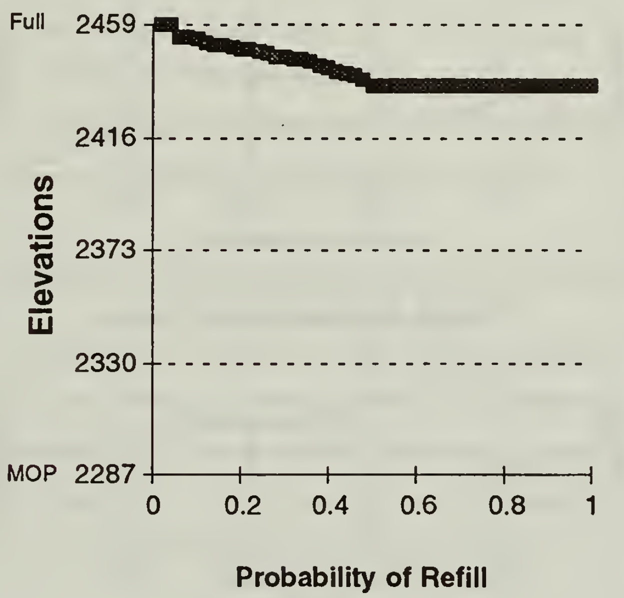


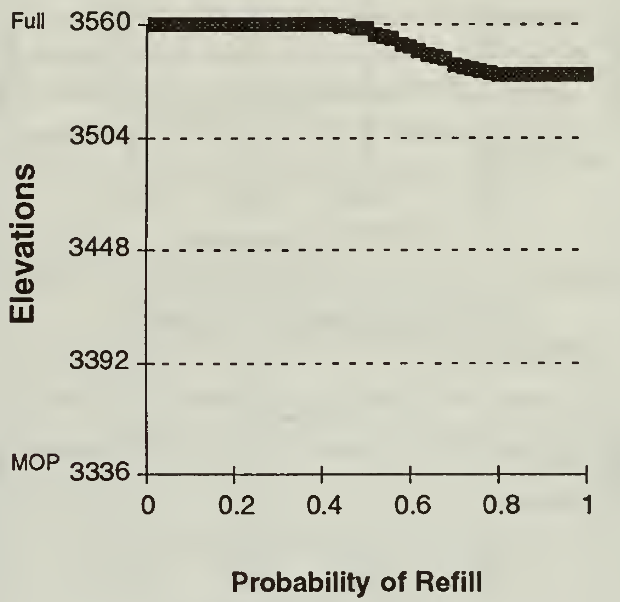
Table C–11. SOS9b – CONT

JULY ELEVATIONS

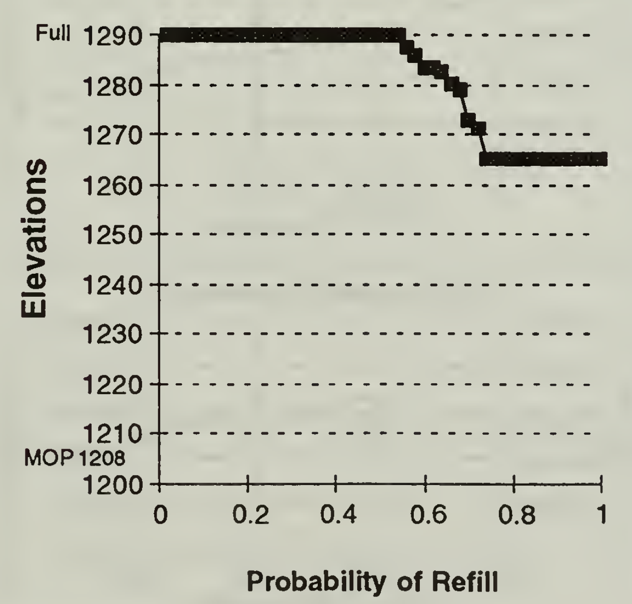
Libby



Hungry Horse



Grand Coulee



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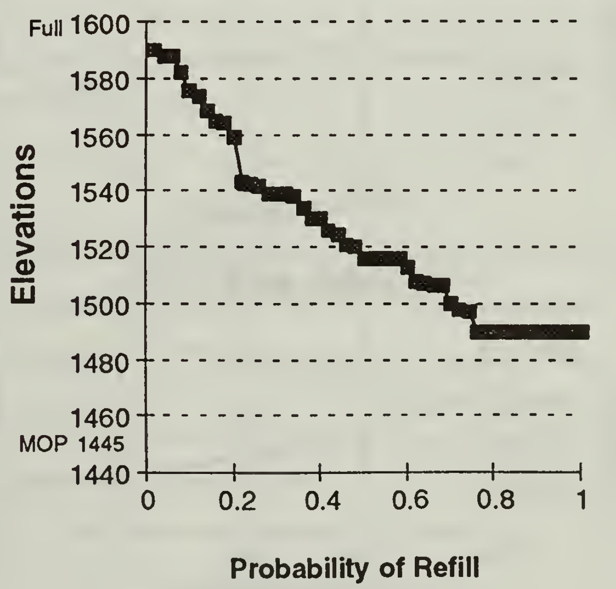
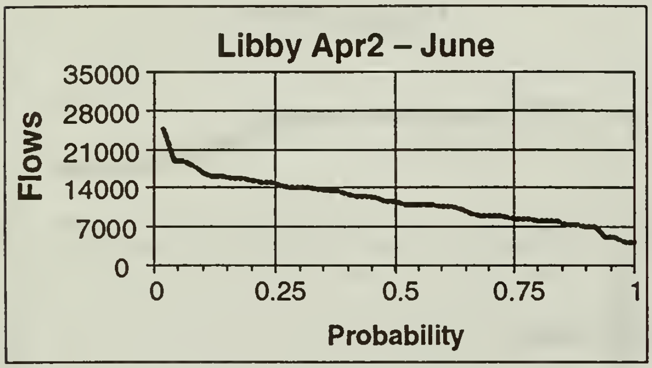
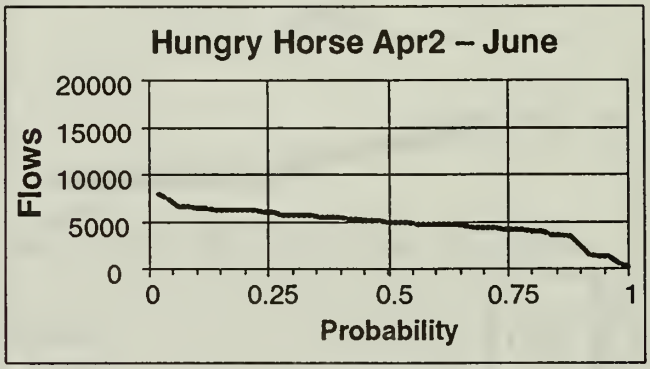
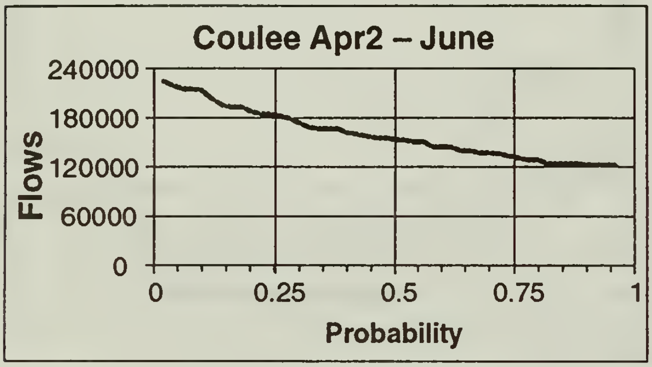


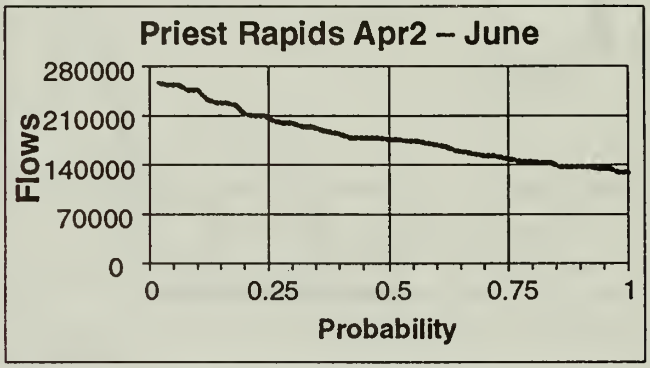
Table C–11. SOS9b – CONT

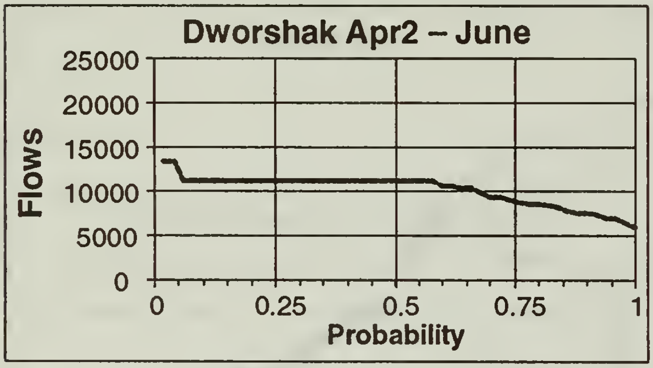
SPRING FLOWS

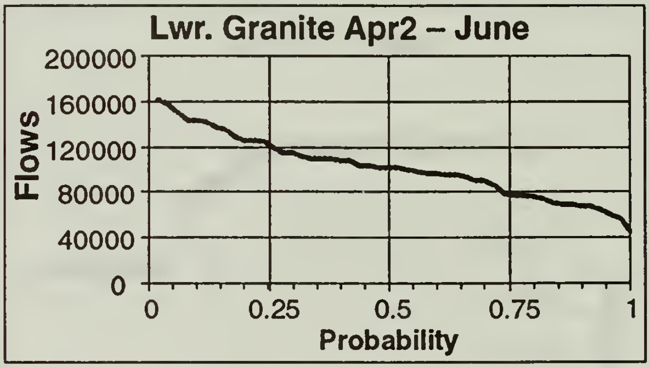


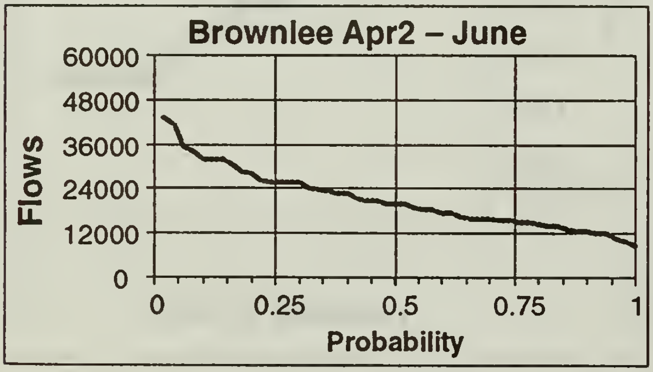












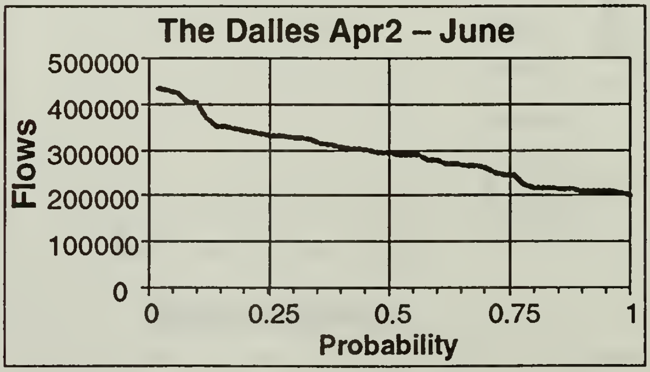


Table C–11. SOS9b – CONT

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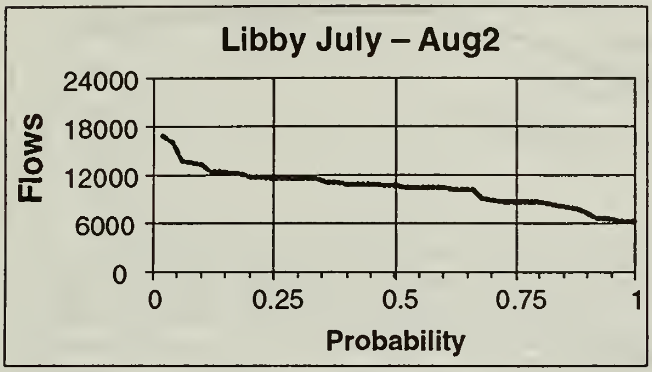

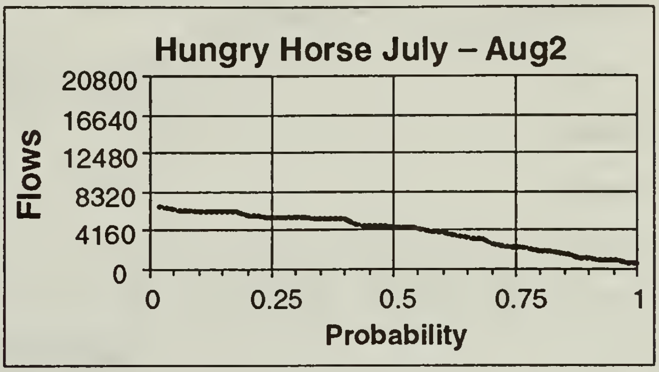

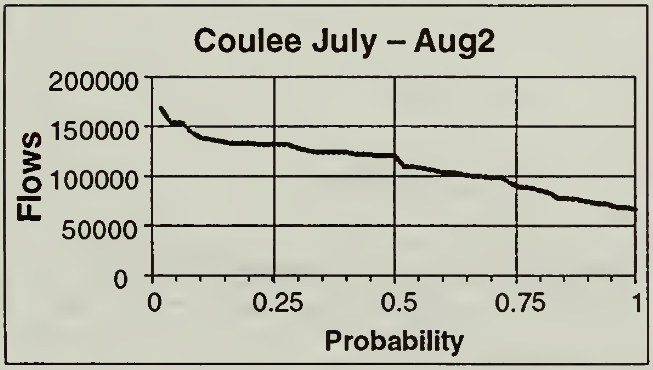

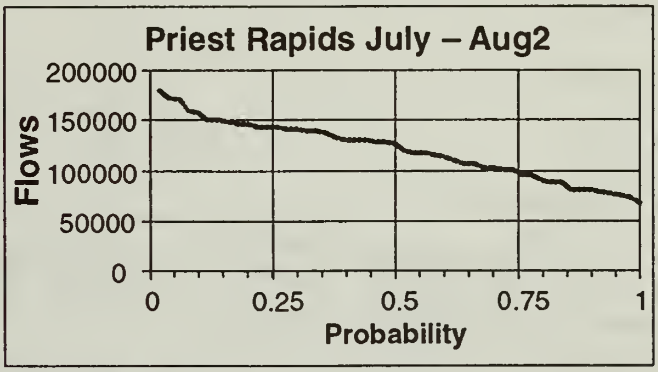

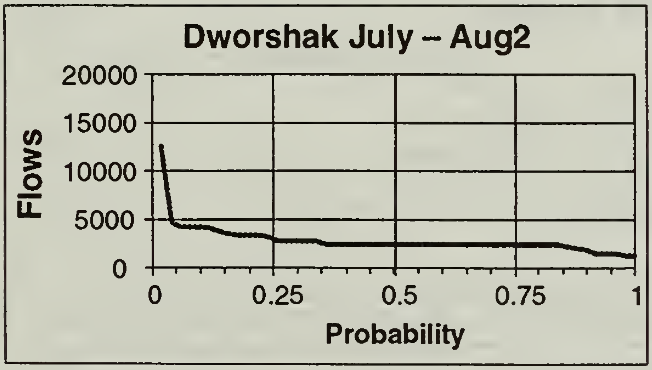

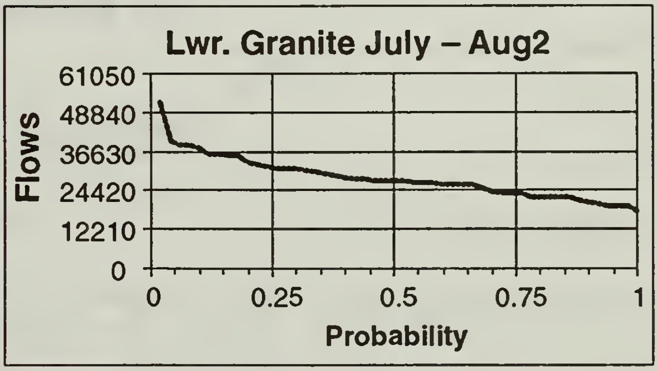

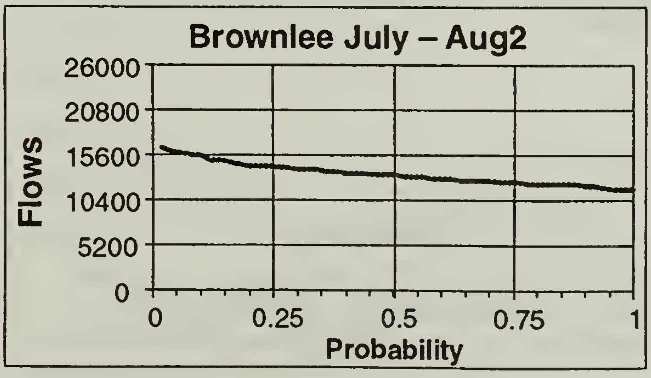

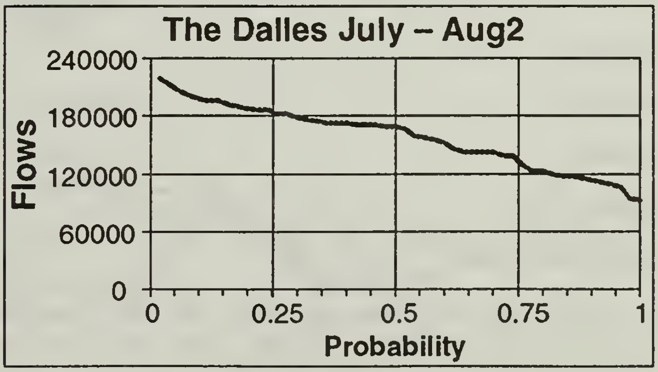

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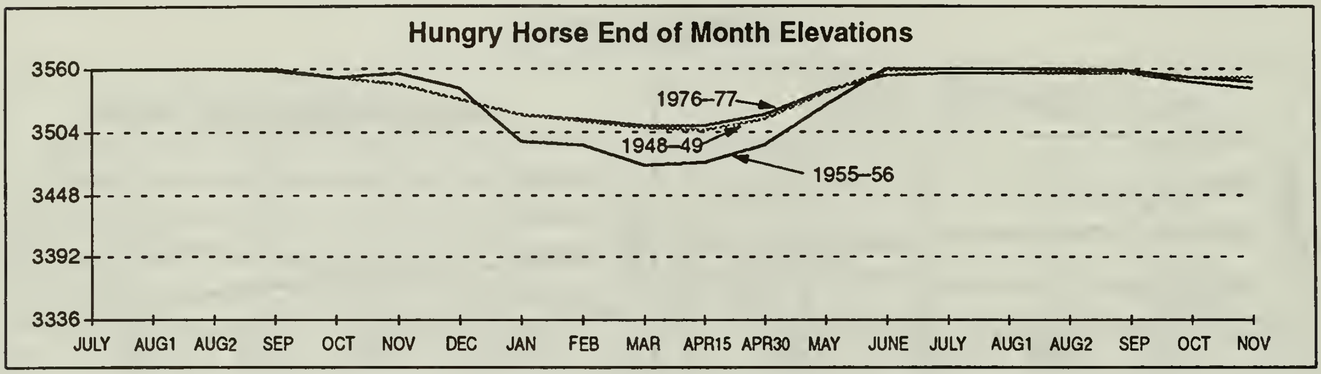
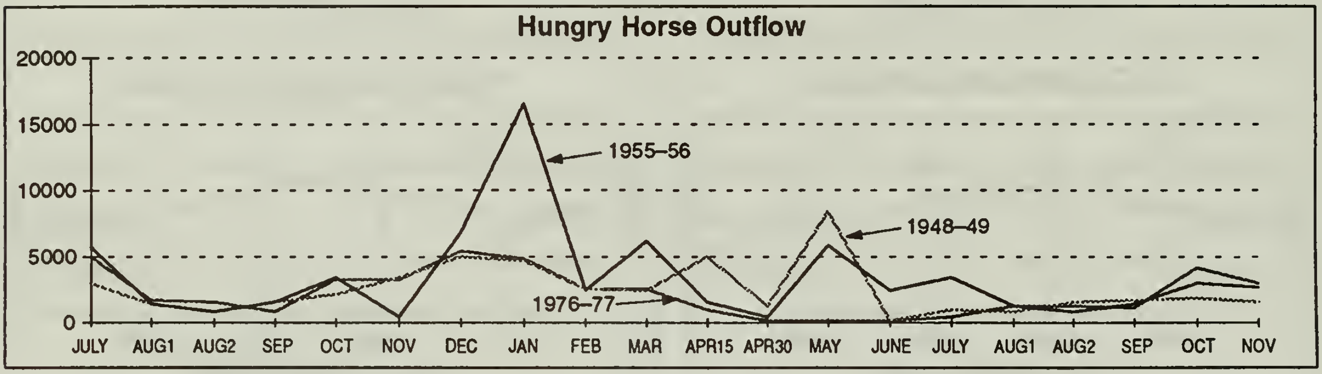
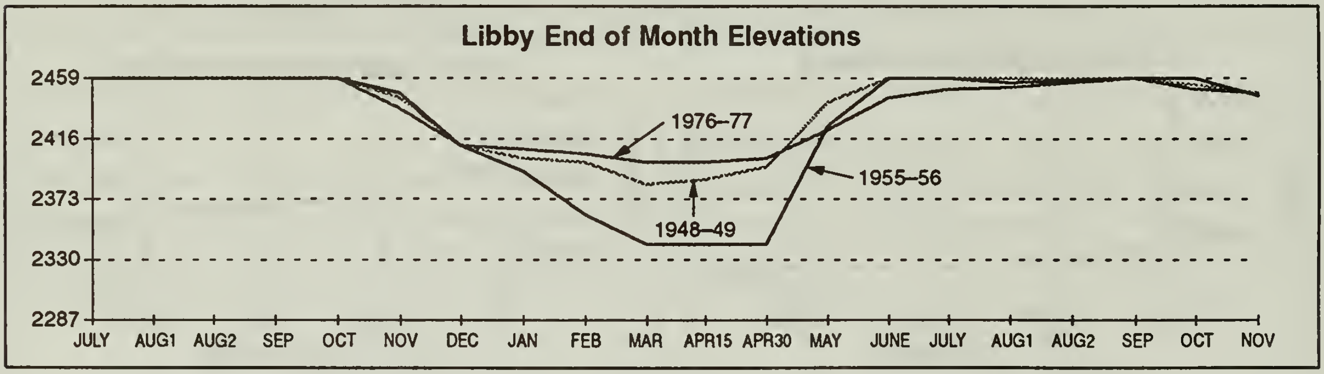






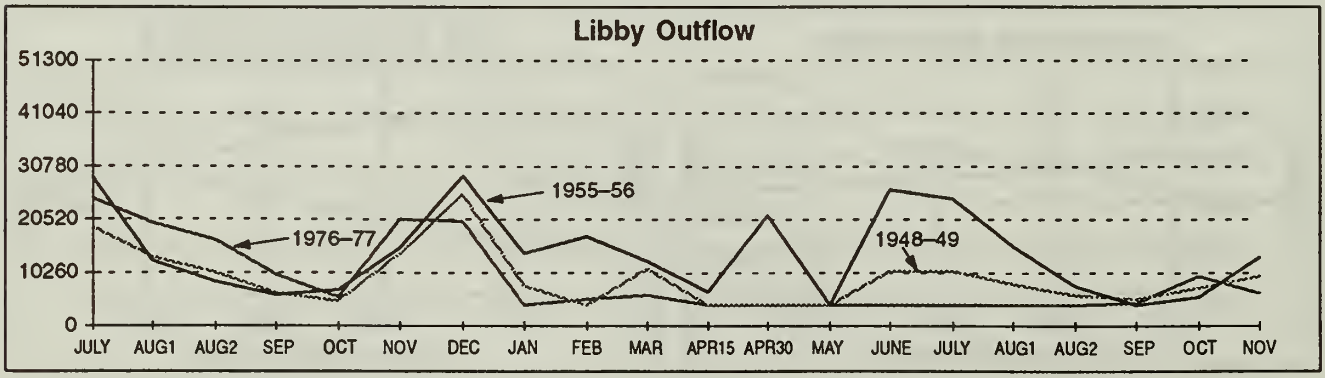
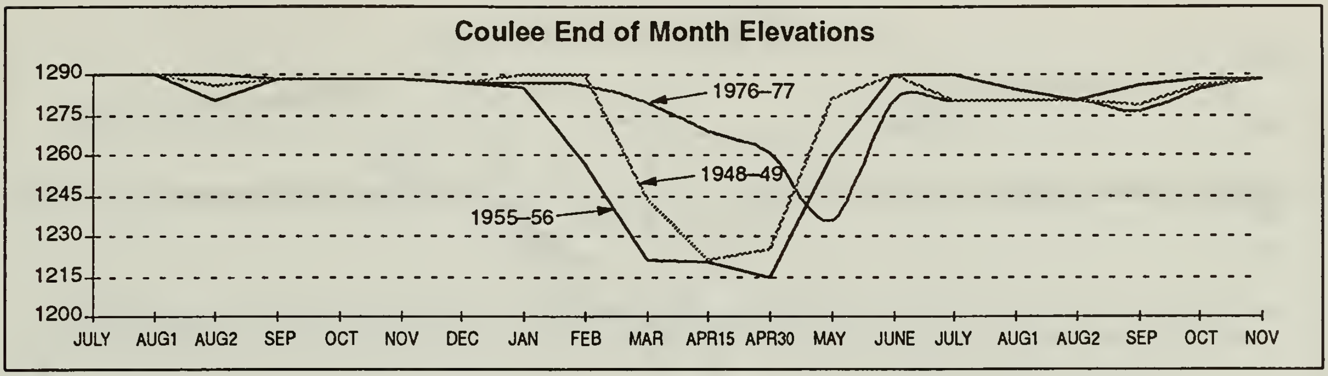
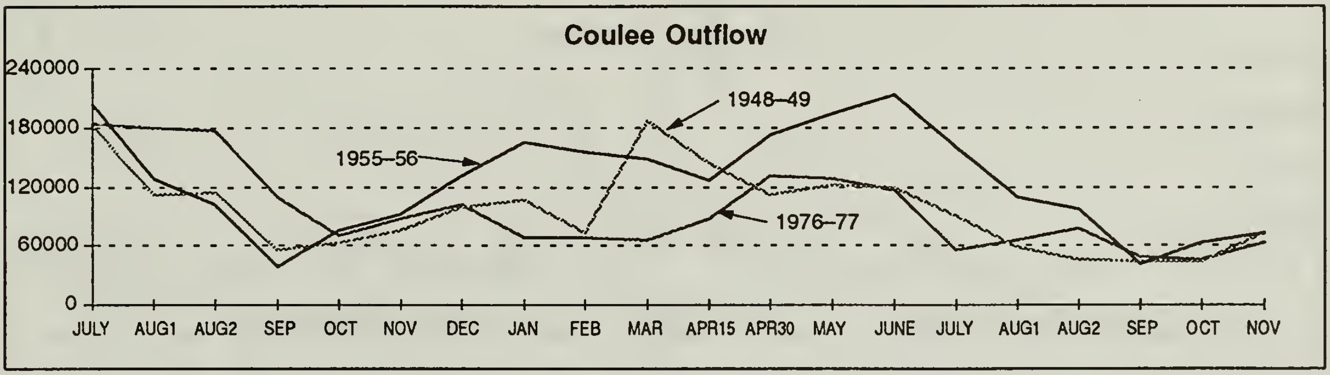
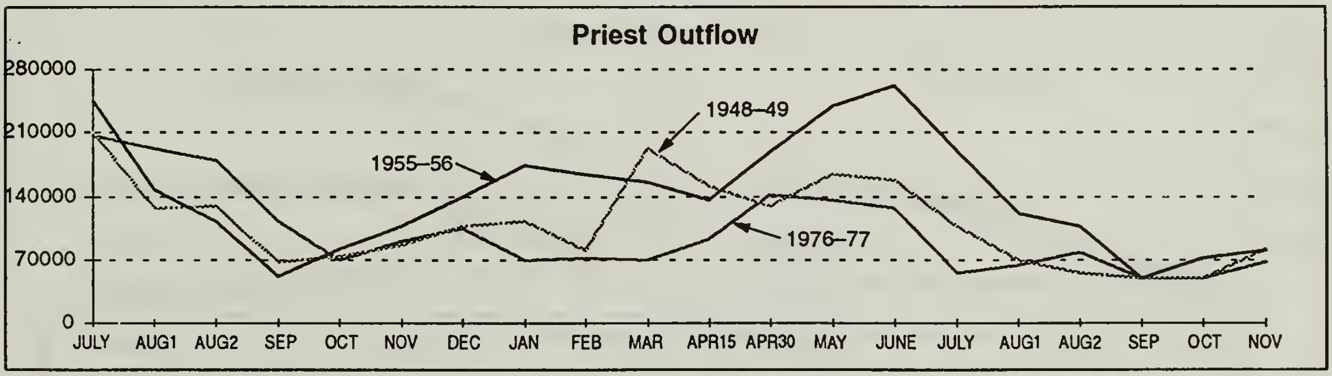


Table C-12. SOS9c – CONT







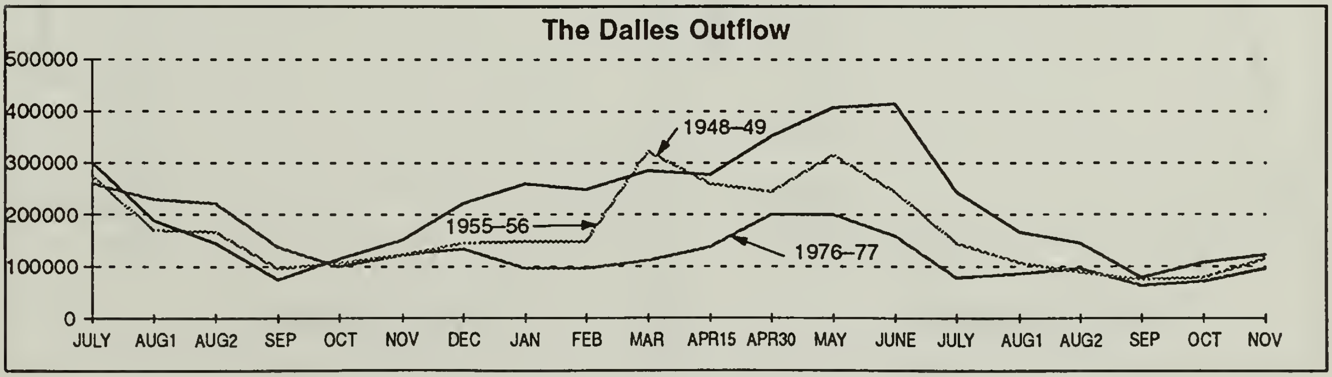
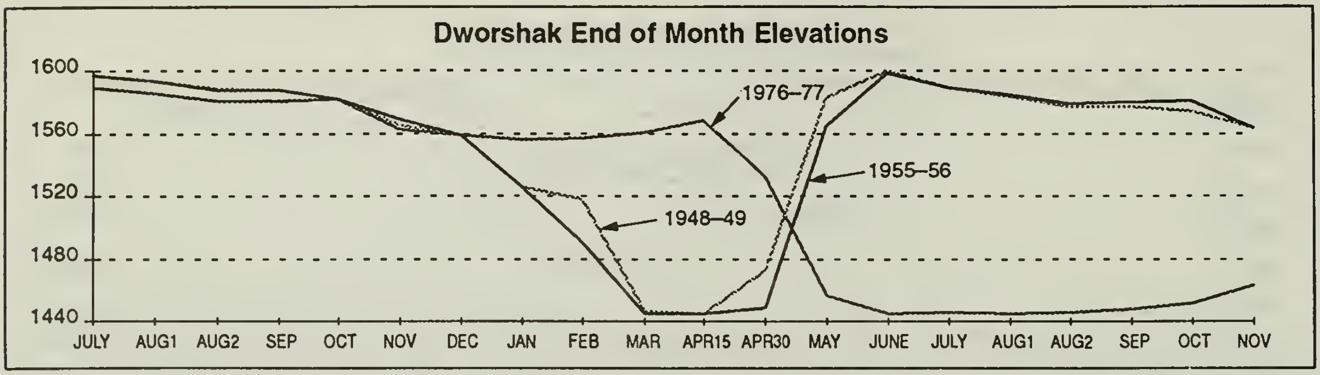
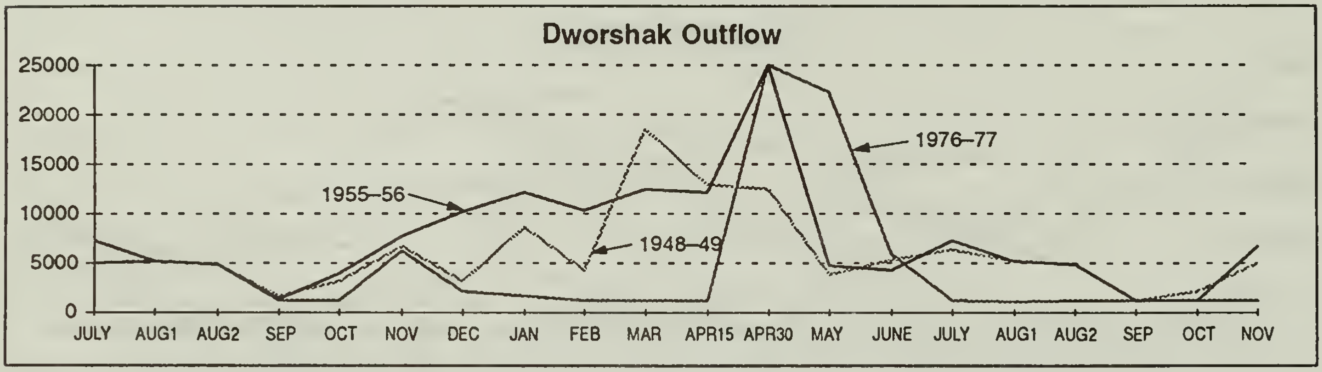


Table C–12. SOS9c – CONT





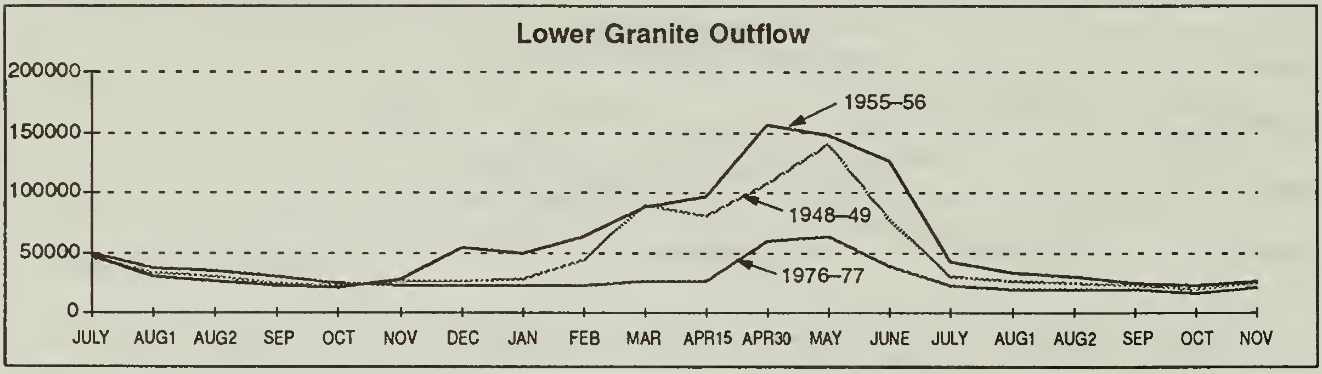


Table C–12. SOS9c – CONT

JULY ELEVATIONS

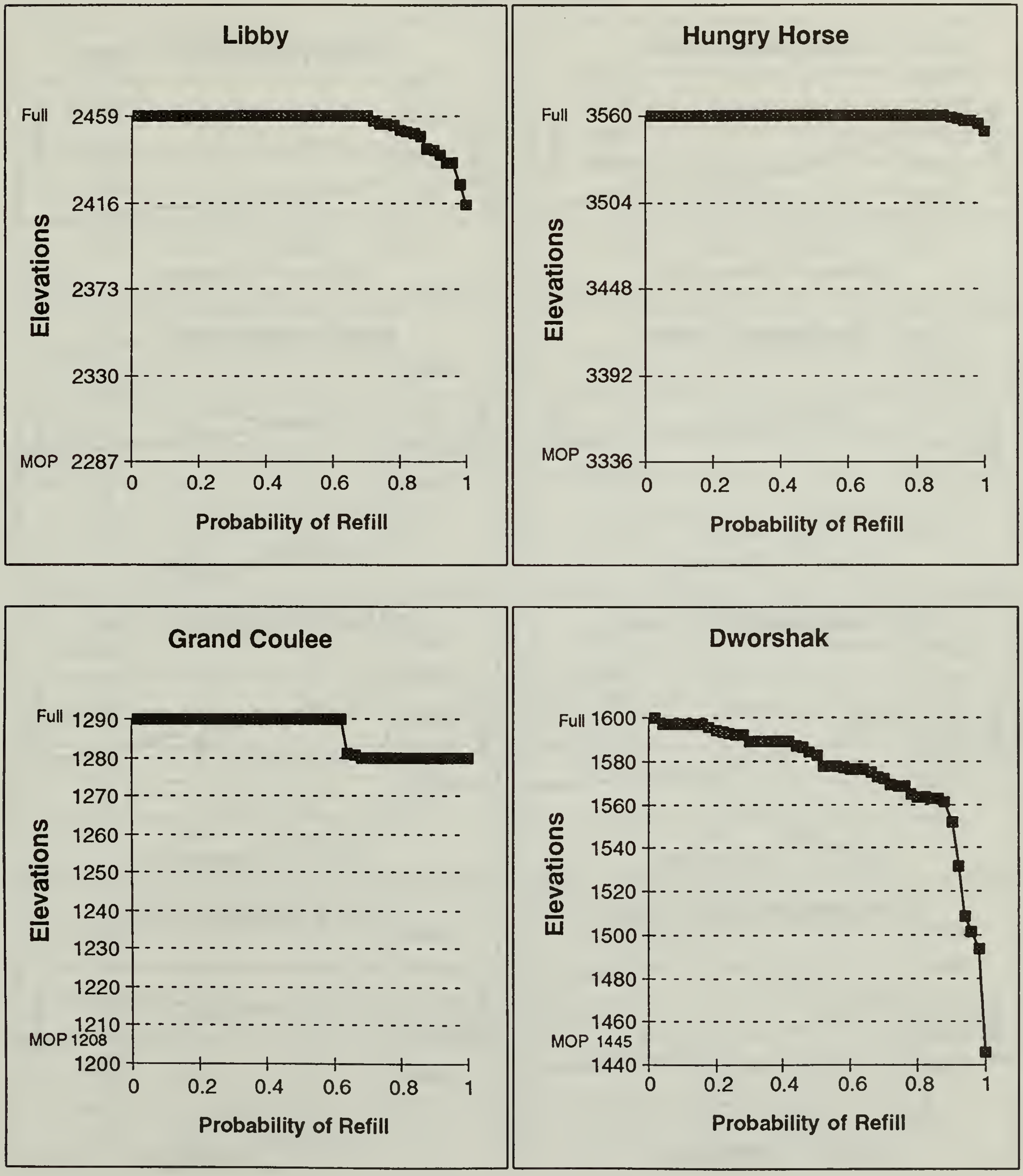
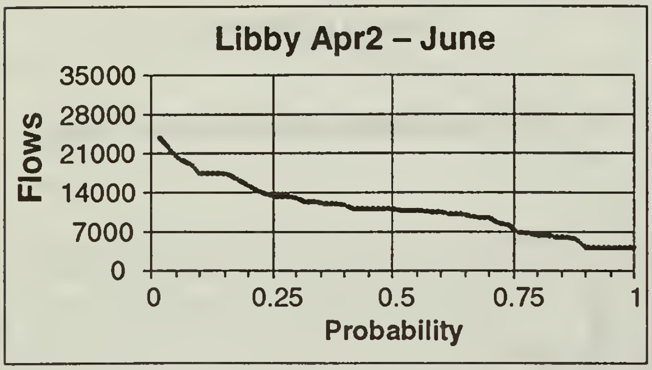
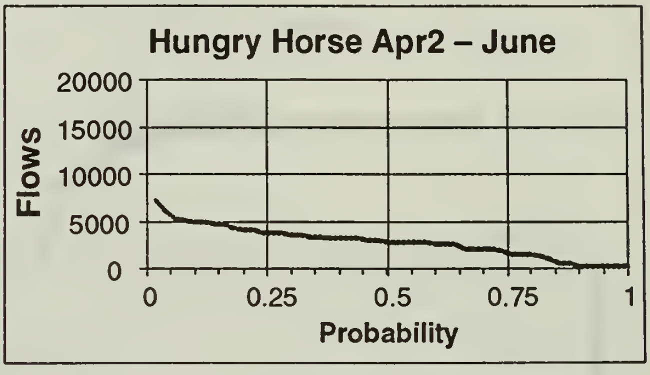
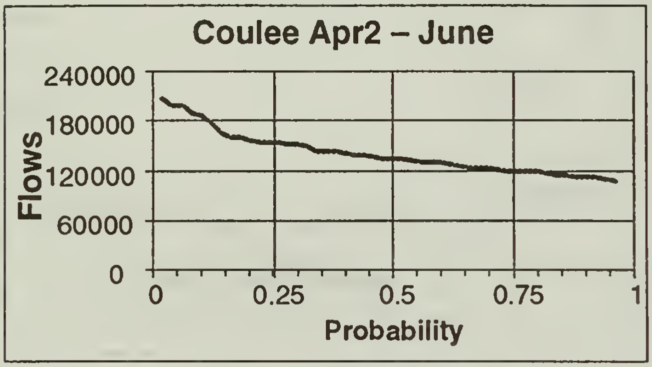


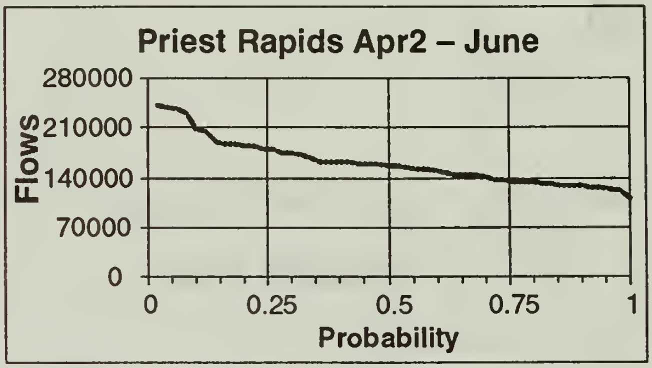
Table C–12. SOS9c – CONT

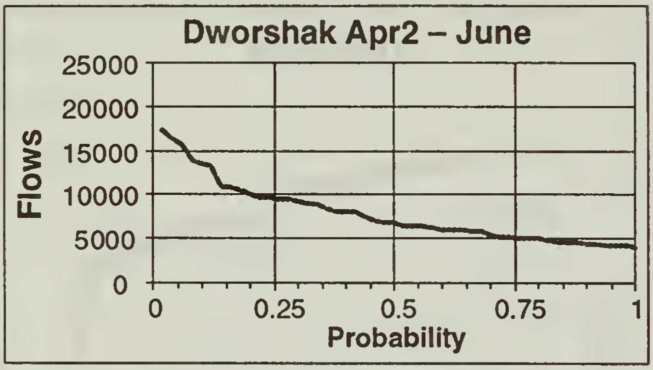
SPRING FLOWS

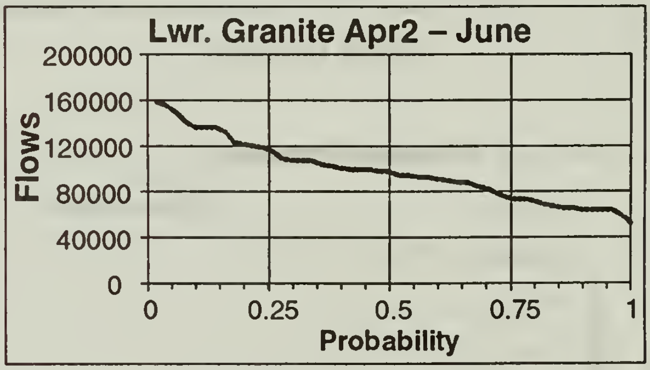


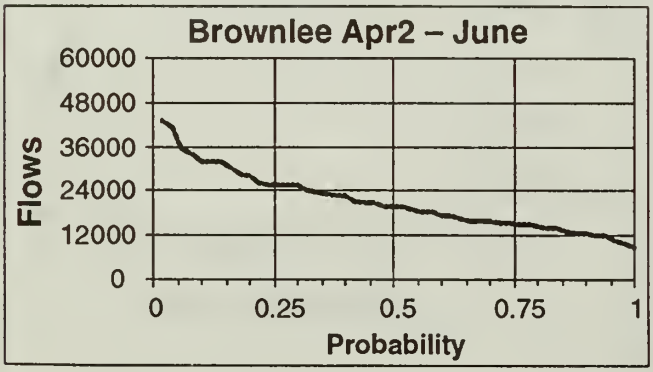












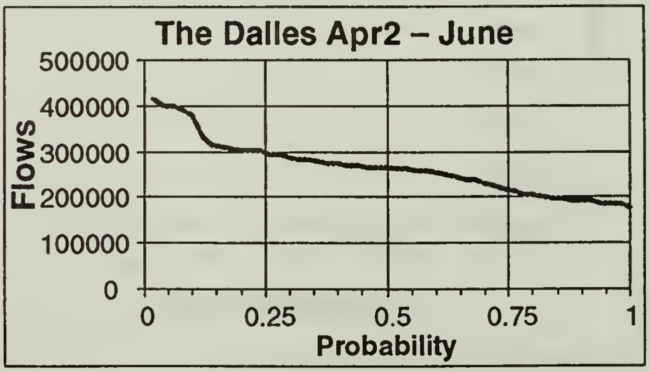
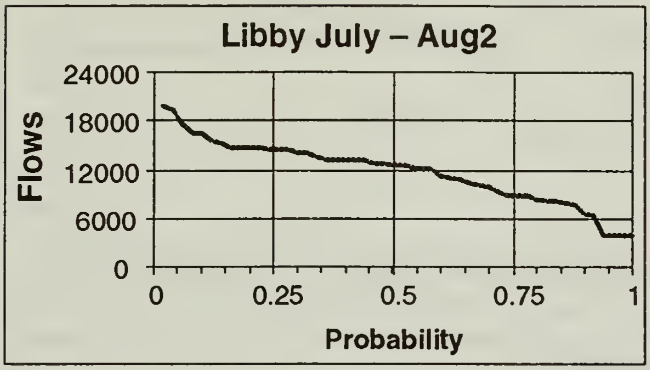
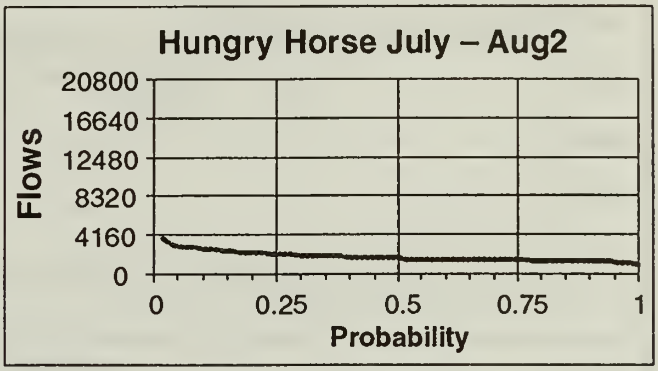
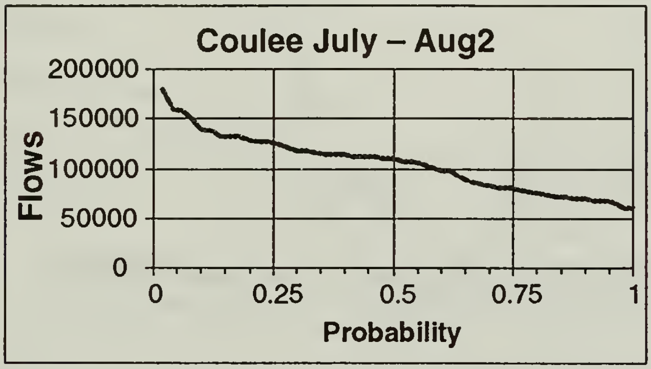


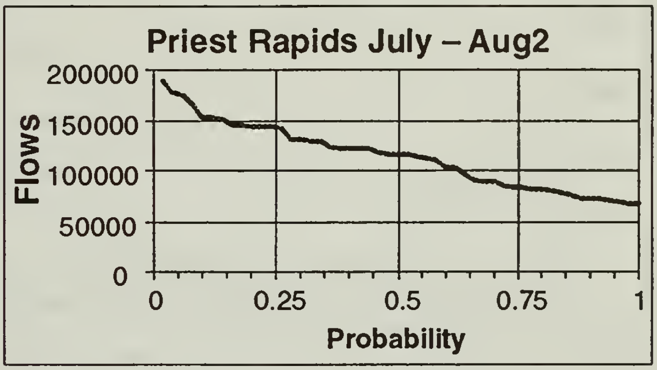
Table C–12. SOS9c – CONT

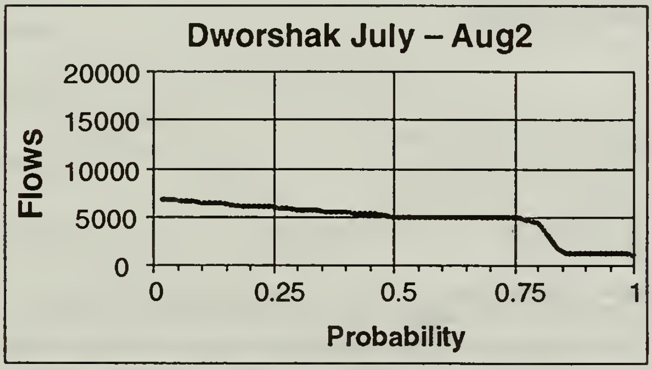
SUMMER FLOWS

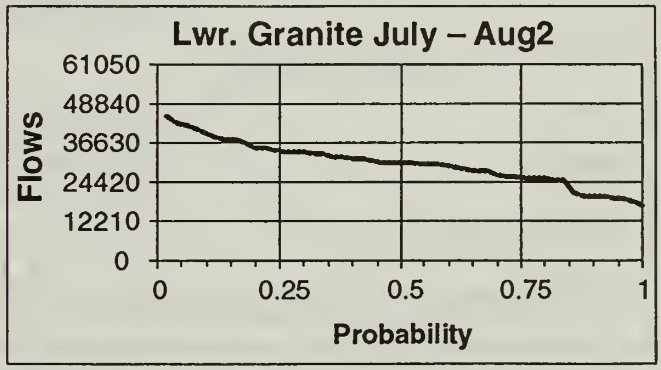


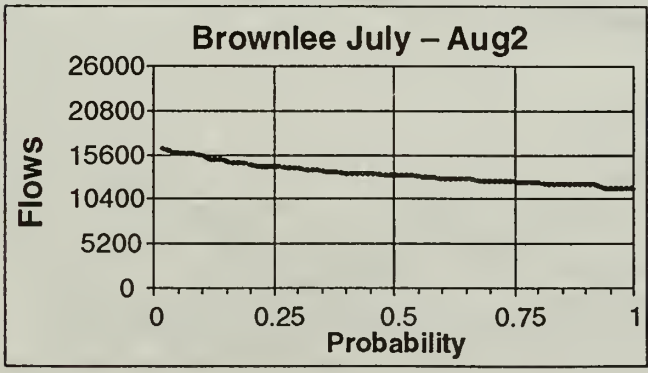


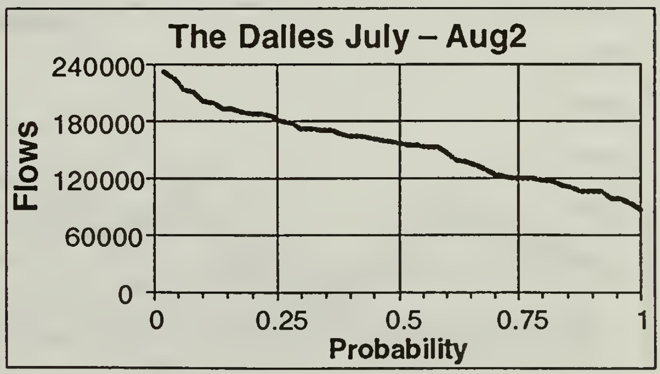












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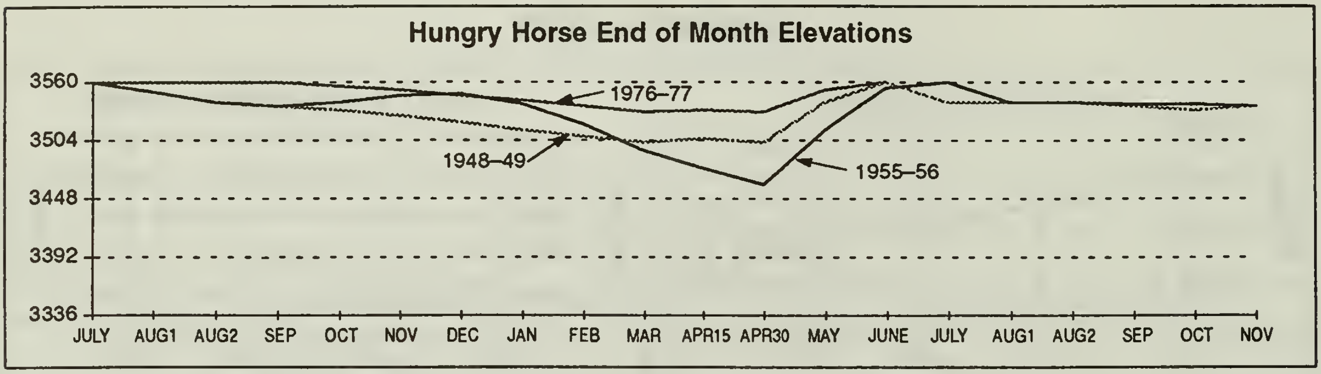
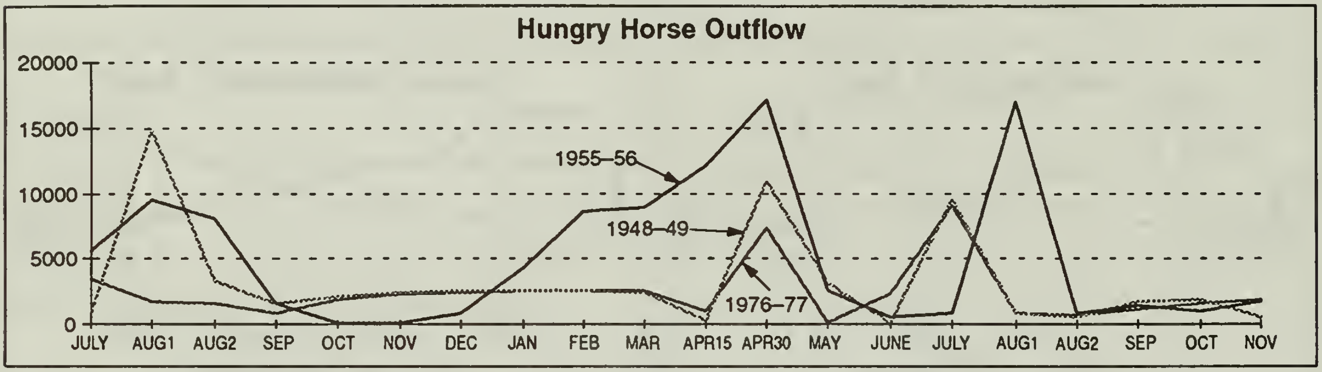
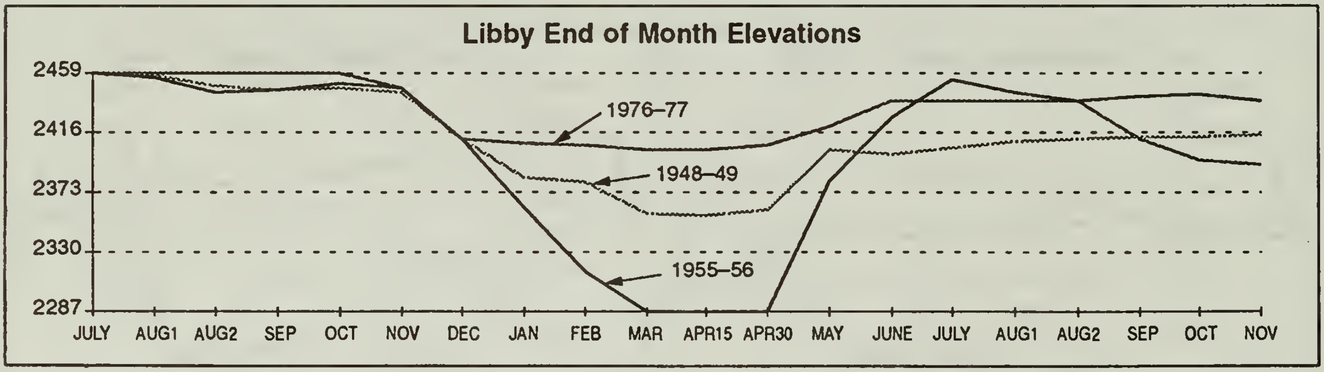






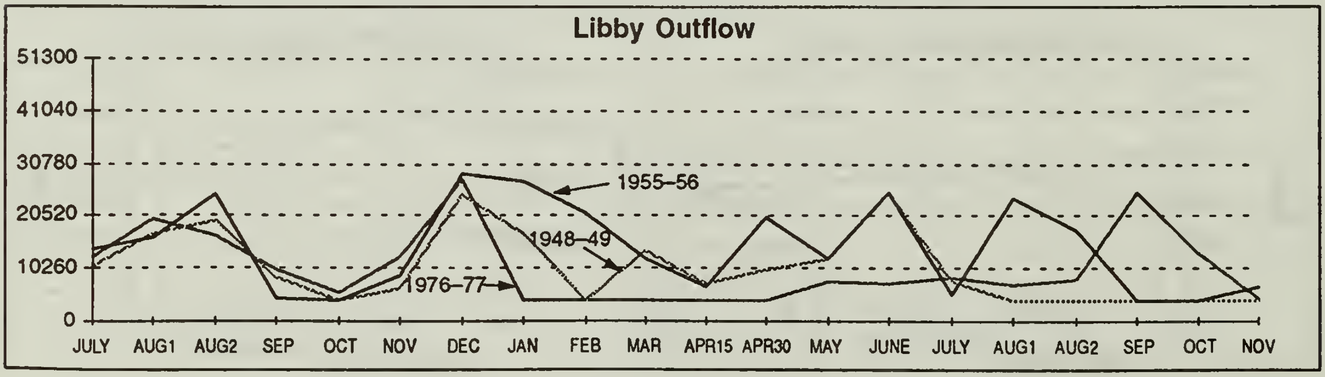
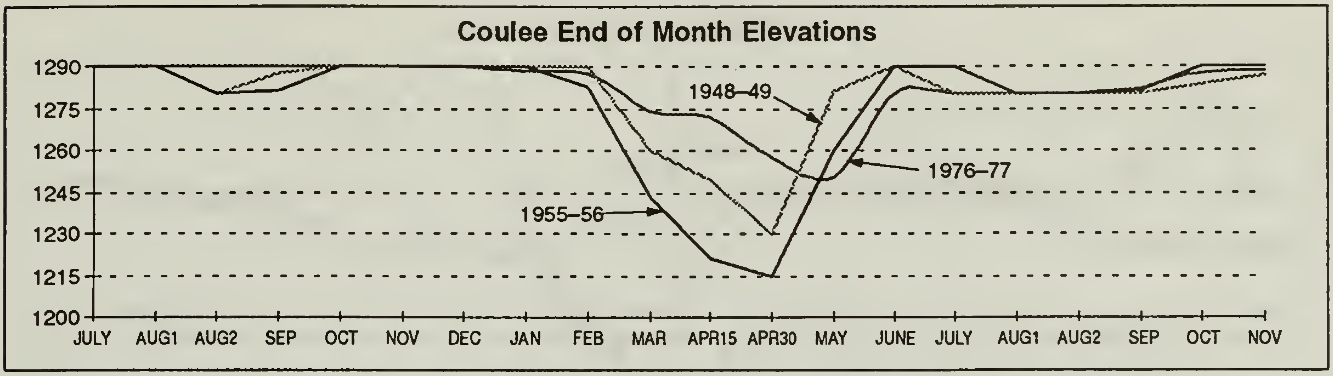
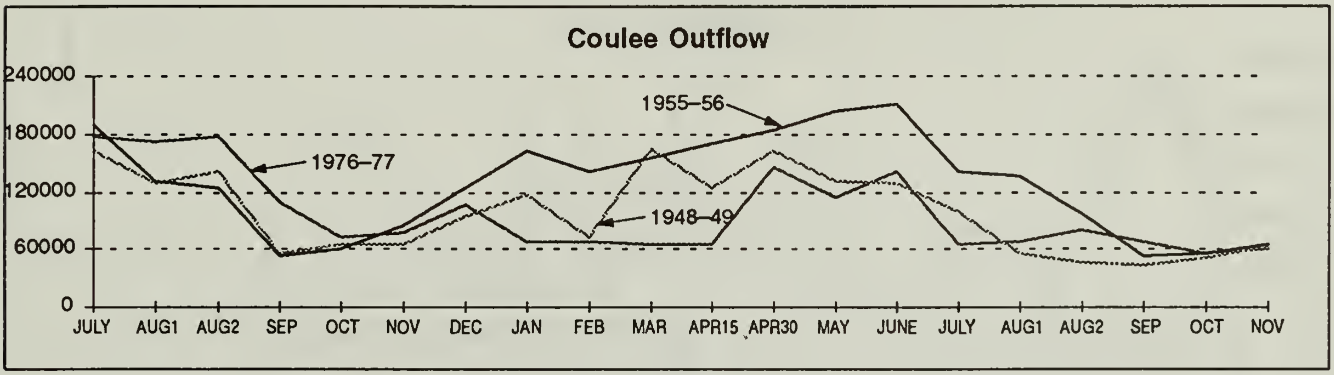
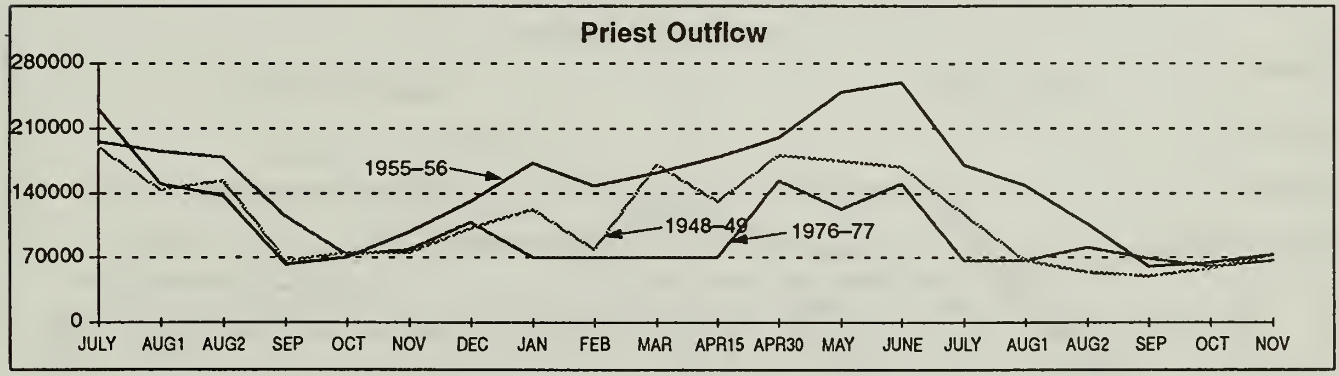


Table C–13. SOS PA – CONT







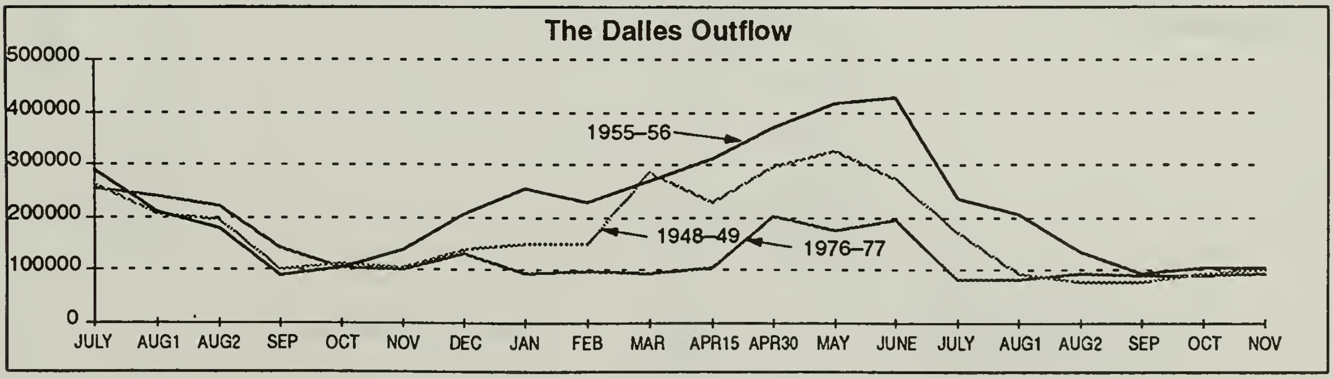
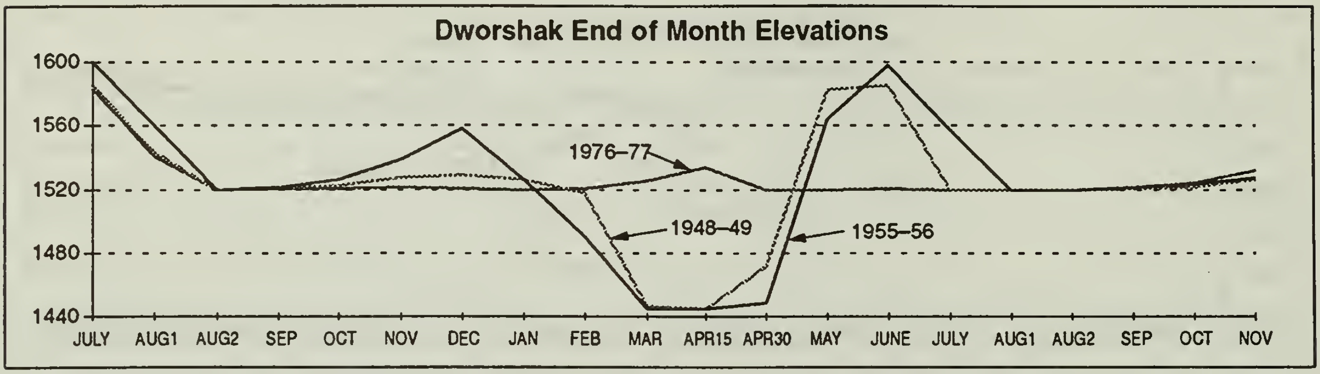
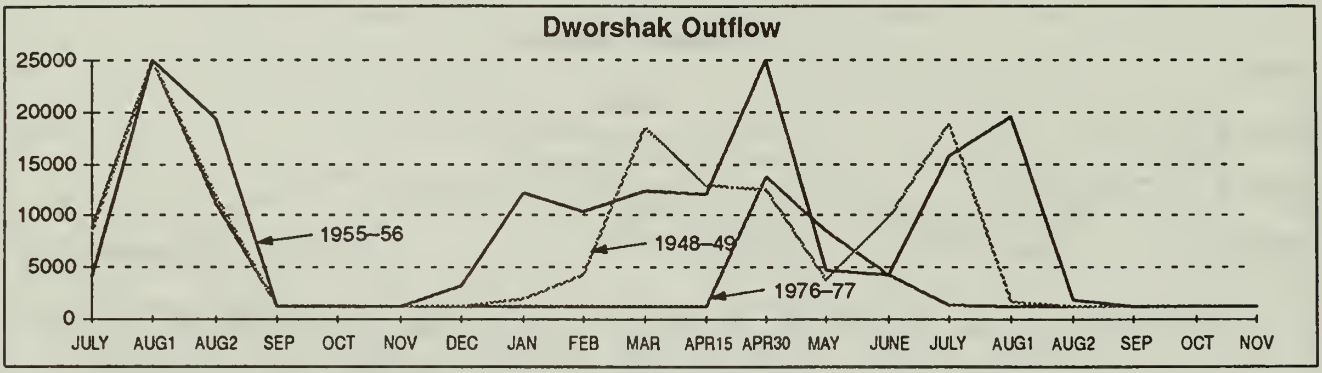
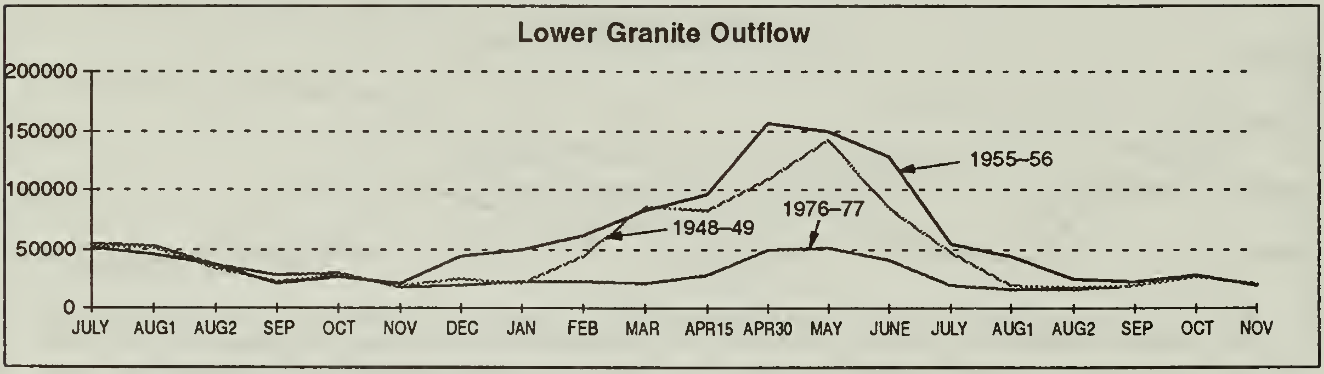


Table C–13. SOS PA – CONT







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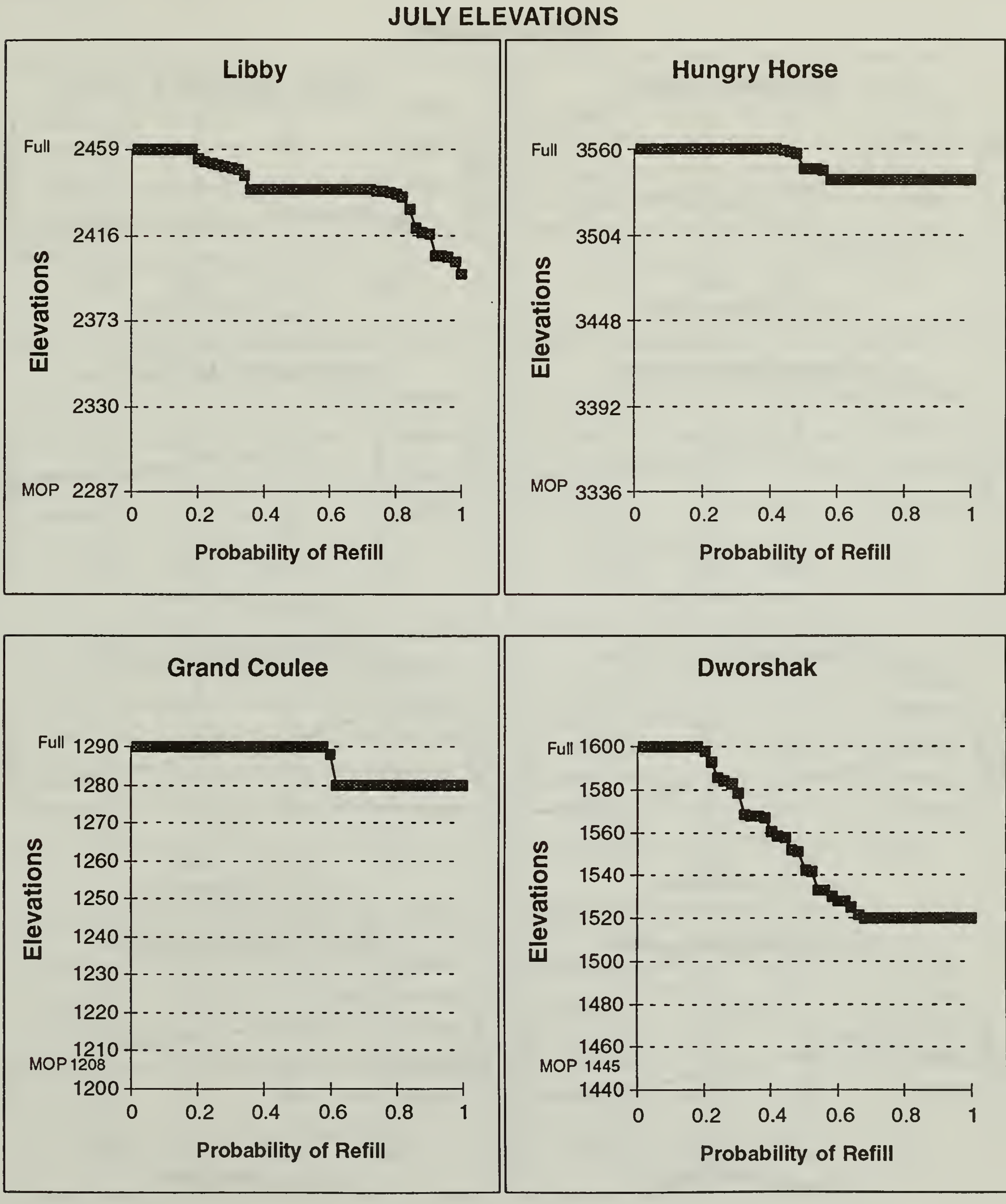


Table C–13. SOS PA – CONT

SPRING FLOWS

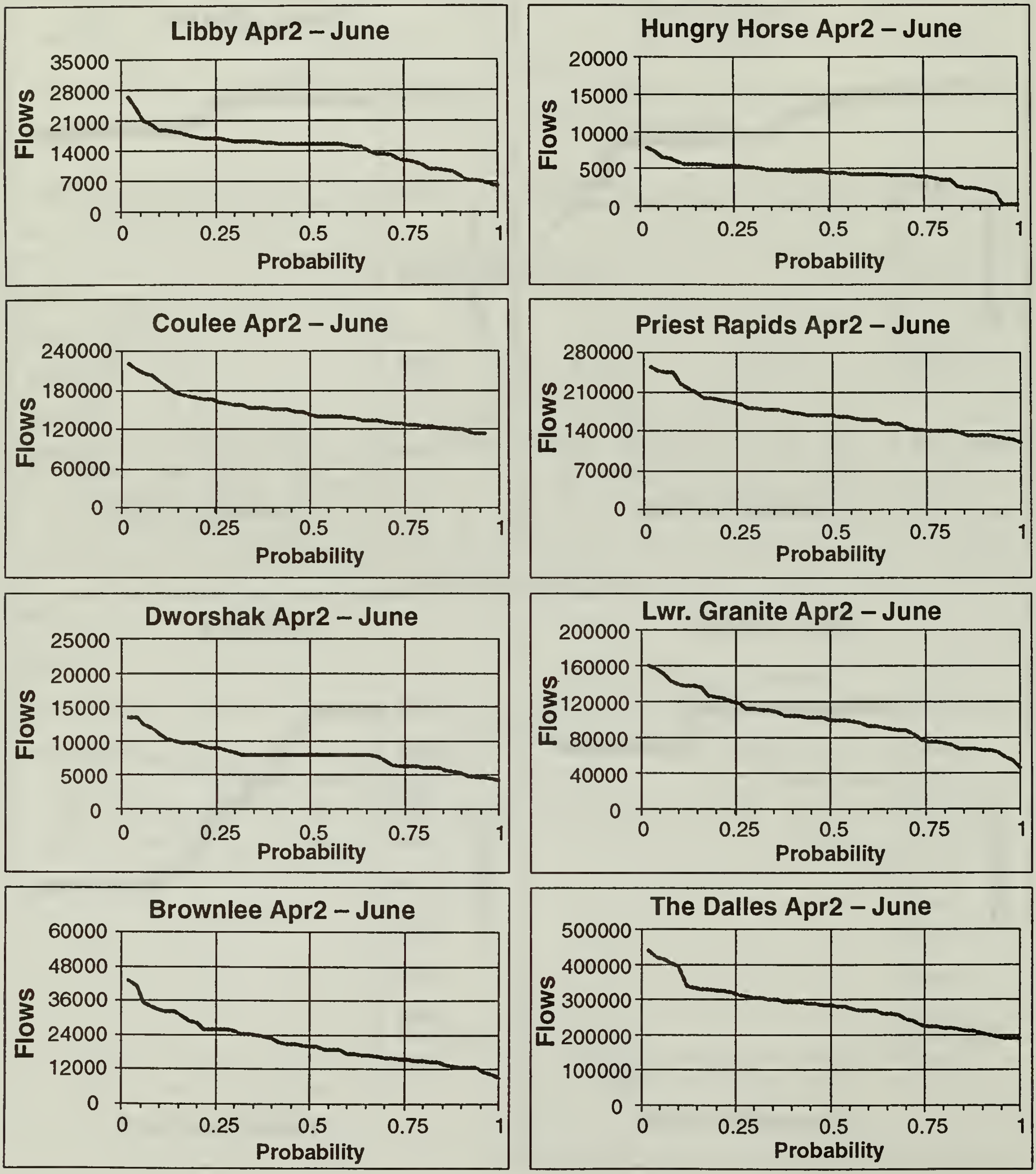
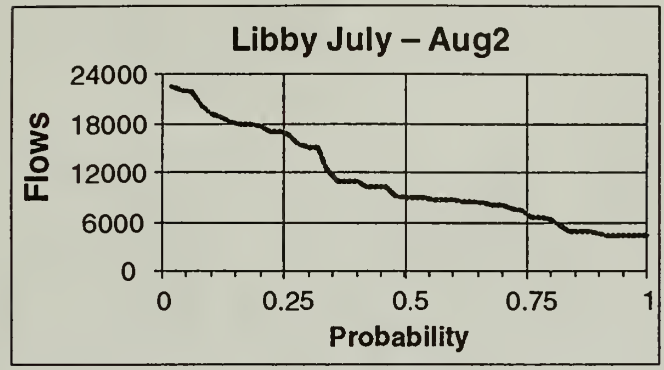
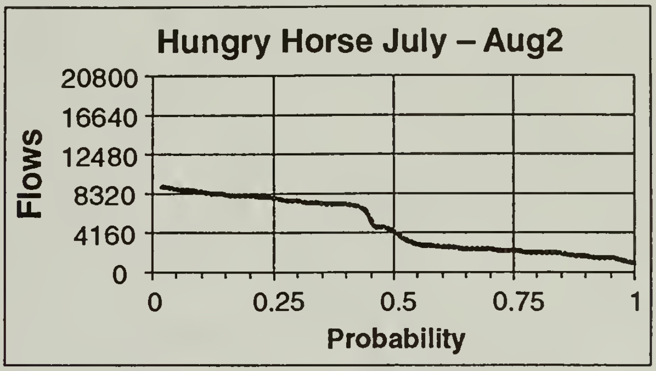
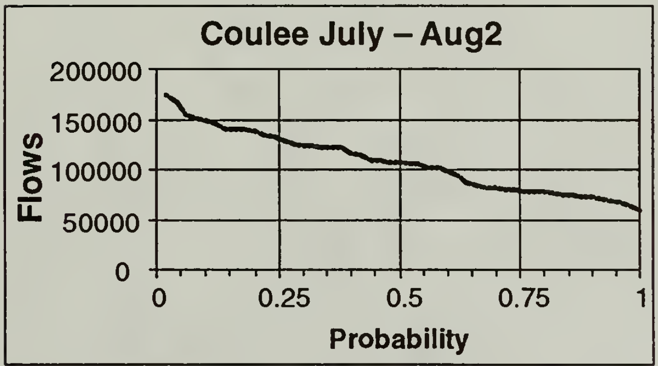


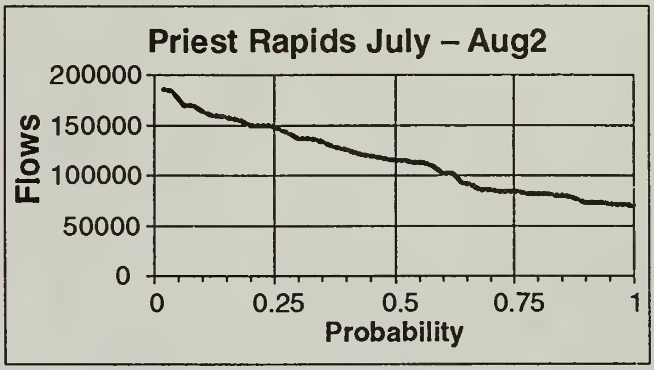
Table C–13. SOS PA – CONT

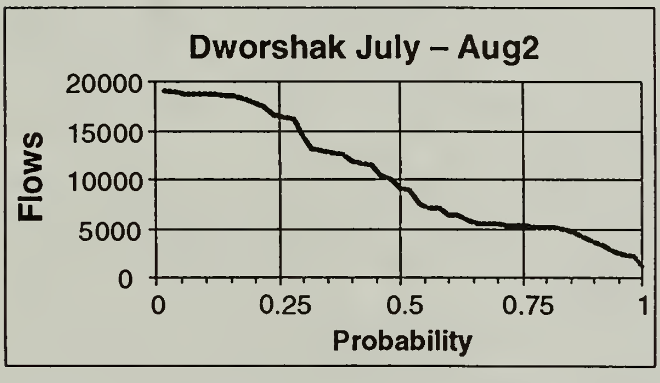
SUMMER FLOWS

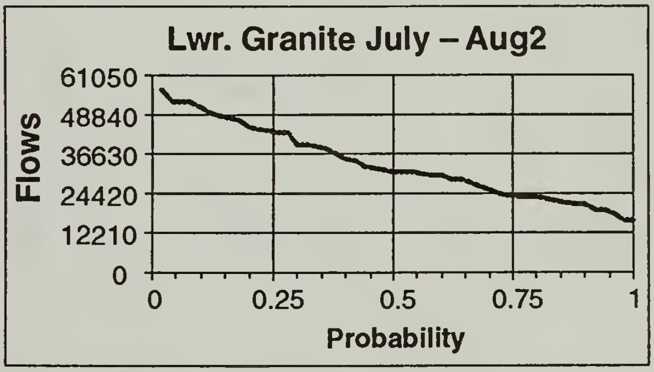


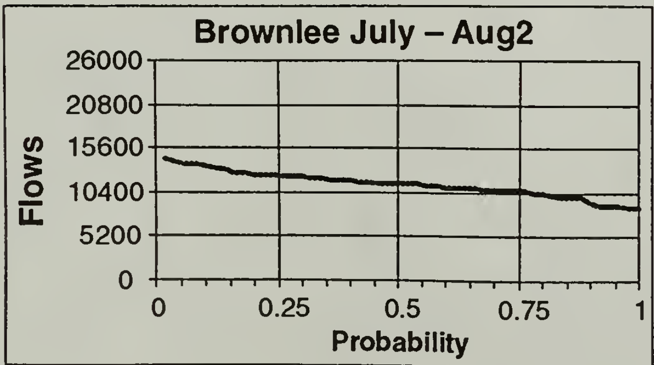


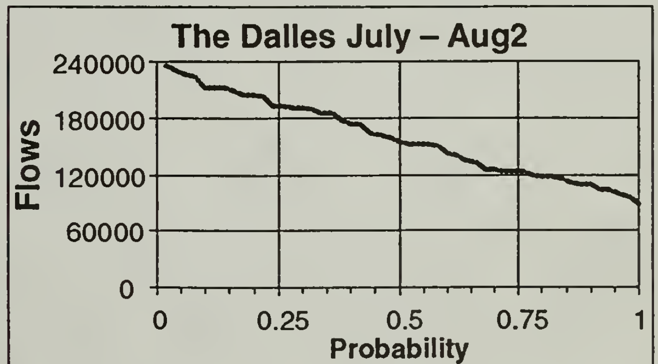












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