Columbia River System Operation Review

Final Environmental Impact Statement

Appendix E

Flood Control

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.

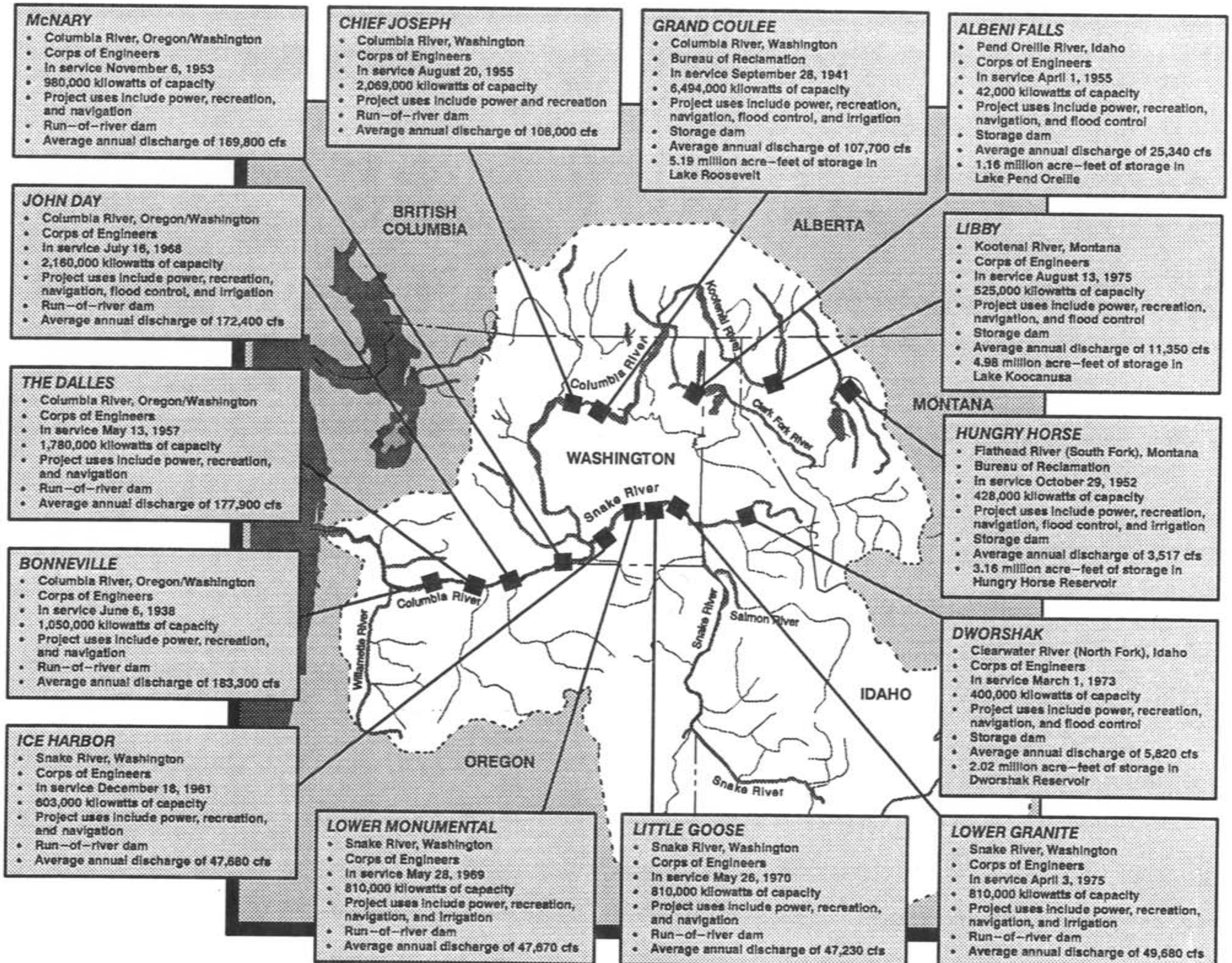
WHAT DO THE TECHNICAL APPENDICES COVER?

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 Flood Control appendix relies on supporting data contained in Appendices A and O. For complete coverage of all aspects of Flood Control, readers may wish to review River Operation Simulation (ROSE) and Economic and Social Impacts 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 ISSUES AND CONCERNS RAISED DURING THE SCOPING PROCESS

The Corps of Engineers, Bonneville Power Administration, and Bureau of Reclamation (the three operating agencies) conducted a scoping process consisting of a series of regionwide public meetings and solicitation of written comments in the summer of 1990. Comments on flood control issues were received from all parts of the Columbia River basin. The following includes issues raised in the public scoping process, as well as those brought for consideration by members of the Flood Control Work Group (FCWG). The work group members' issues tended to be specific rather than general; whereas, those from the public were both.

1.1.1 General Discussion

Most commenters felt that flood control was an important SOR priority, though a few advocated its reevaluation in light of its impact of fish and wildlife. One individual recommended eliminating flood control (including the dams). Others addressed the need to fine–tune planning and forecasting tools in order to make flood control drawdowns/water releases more efficient and predictable.

1.1.2 Specific Comments

There were many individual issues identified by the public as well as by members of the work group. They are listed below. Some of the items brought in by the public were outside the scope of the FCWG's task (these are identified with the notation "n/a"). Disposition of each of the remaining items is noted in parentheses at the end of each item.

1.1.2.1 Priority concerns

- Evaluate the role of flood control and consider flood control tradeoffs in the system operations (addressed through SOS formulation)
- Flood control capability should be addressed and optimized (reflected in study).
- Consider weather forecasting abilities in relation to flood control storage (being addressed by northwest agencies in response to Northwest Power Planning Council's fish and wildlife program).

1.1.2.2 Fisheries and flood control

- An SOR pamphlet implied that flood control reservoirs helped fish when they actually impeded them (addressed through SOS formulation).
- Change flood control for fish passage flow improvements (addressed through SOS formulation).
- Recommend investigating alternative levels of flood control storage and analyzing how excess storage could be used to meet other system objectives, especially instream flows (addressed through SOS formulation).
- Recommend a continental design for flood control and various water uses (n/a)
- Recommend stopping all development in flood–prone areas and moving people and their works out of such areas to begin a return to a native ecosystem (n/a)

1.1.2.3 Local concerns

- The Snake River and its storage facilities are already operated at their maximum efficiency and provide benefits including flood control, and therefore time should be spent to combat problems generated downstream (addressed through SOR scoping).

- Request timely rehabilitation of the Tri–Cities region's levees and Federal shore lands and consideration of a long–term solution of the flooding potential of the Yakima River (n/a).
- Does potential removal of levees along the river in Tri–Cities jeopardize flood control (n/a)?
- Lake Koocanusa should be at full pool by 1 June and drawdown not started until 1 October (addressed through SOS formulation).
- Flood control is more important downstream than at Libby (addressed through SOS formulation).

1.1.2.4 Planning/forecasting

- Recommend EIS address problems of inaccurate runoff forecasting and conservative flood control rule curves (underway outside of SOR).
- More risk should be assumed in flood control planning to gain higher probabilities of reservoir refill (SOS premise is that level of flood protection is not compromised).
- Improve reliability of runoff forecasting (underway outside of SOR).
- Early season releases for flood control are in opposition to all other uses; need to consider innovative ways to reduce flood hazards (Economics Work Group addressing flood mitigation).
- Releases for flood control operations should be considered within the availability of storage capacity in downstream reservoirs; decisions should be made to maximize the availability of water against the results of a slight error in control of all flood waters (addressed through SOS formulation).
- Flood control rule curves for Dworshak and Brownlee should be altered to provide water for downstream fish (addressed through SOS formulation).
- Spring drawdown to mitigate floods should be closely related to winter snowpack to avoid excess drawdown (addressed through FCWG analysis).
- Want Snake River federal projects released from the flood control rule curves to allow flows for fish, especially in low water years (n/a).
- Evaluate lower Snake flood control rule curves to shift flood control responsibility to Columbia River projects (addressed through System Configuration Studies).

1.1.2.5 Payment for flood benefit

- Benefits from flood control accrue principally to downstream users; EIS should develop mechanisms so that governments behind the storage reservoirs are provided with an equitable share of the benefits (n/a).

1.2 WORK GROUP FORMATION AND SCOPE OF ITS EFFORTS

The Flood Control Work Group (FCWG) was formed of representatives of the COE, BPA, and USBR, who as a group developed the initial logic for screening SOR alternatives. Other interest groups with a knowledge of and interest in flood control operations (BC Hydro, PNUCC, NWPPC, Idaho Power, Idaho Department of Water Resources, U.S. Fish and Wildlife Service, Washington Department of Ecology, and the Association of Lower Columbia Flood Control Districts) were added to the FCWG to incorporate a broader perspective in the analysis and reporting on the screening of SOR alternatives and ensuing descriptions and analysis of the System Operating Strategies (SOS) and the corresponding impacts to existing flood control objectives. The work group is also called upon to: 1) ensure that modeling is performed in accordance with prescribed operating rule curves; 2) identify potential sources of errors; 3) assess results for flood control violations; and 4) coordinate with other workgroups on common issues. The FCWG is charged with reviewing the Columbia River SOSs as determined under the SOR process and determining the effect each has on current flood control capability at various locations in the Columbia River Basin. These SOSs were compared, relatively, to the no–action SOS. The no–action SOS will ultimately be compared to the existing level of flood control protection. An assumption for SOR is that the current level of flood protection will not be compromised, and mitigation will be used, if necessary, to maintain that level of protection. Evaluation of mitigation costs will be performed by the Economics Work Group.

1.3 STUDY PROCESS

The study process is made up of two components: screening and full scale analysis. The objective of each is the same – to identify the flood control impact of a wide variety of system operating objectives. The screening process used a methodology to approximate the flood control impacts, because a large number of alternatives had to be evaluated in a short time. This methodology used mean monthly flow as a computational time step and relied on only five years to establish a statistical sample. Details of the screening process can be found in "Screening Analysis, Volume 1, Description and Conclusions." In contrast, the full scale analysis utilized a daily computational time step to better define the flood hydrograph, and it used a 50–year study database. Frequency curves were derived according to the standards set forth in the Water Resources Council's Bulletin #17B. This methodology provided a much more clear and accurate picture of flood impacts.

1.3.1 Screening Analysis

In the workgroup evaluation, comments acquired during SOR scoping meetings were gathered and incorporated. All 90 screening alternatives were evaluated using a spreadsheet which took monthly flows from the hydroregulating model (HYDROSIM or HYSSR) and estimated annual peaks and associated damages at key damage centers. A combined meeting of all the workgroups was held and the 90 alternatives were distilled down to six major system operating strategies (later expanded to seven) which were then formulated in detail for full scale analysis.

1.3.2 Full Scale

The study process began with the monthly modeling of the SOR alternatives and strategies with the 50 year HYDROSIM regulator model which computes reservoir outflows and elevations. These data were then input into a detailed model of the Columbia River operated on a daily time step. The monthly streamflows and pool elevations served as a guide to simulate 50 years of daily flood control regulation through the use of SSARR/AUTOREG, a model that simulates reservoir operations and floodwave movement in a river system. The final product is a set of flow–frequency curves for each of the seven control points and two reservoir elevations defined in paragraph 2.2.3. These curves were used by the Economics Work Group to determine expected annual damages for the corresponding damage centers. A more complete description of the damage centers can be found in the Economics Work Group appendix.

CHAPTER 2

FLOOD CONTROL IN THE COLUMBIA BASIN TODAY

2.1 HISTORIC PERSPECTIVE ON FLOOD CONTROL

2.1.1 Historic Floods

The Columbia River historical runoff record at The Dalles, dating from 1879 through the present, reveals 6 years in which daily peak unregulated flows exceeded 900,000 cubic feet per second (cfs) (25,000 cubic meters per second, m^3/s) at The Dalles: 1880, 1894, 1948, 1956, 1972, and 1974. The current major damage flow is 600,000 cfs (21,200 m^3/s). The largest daily peak in recent history, (999,000 cfs, 28,000 m^3/s, based on 1980–level inflows) occurred on May 30, 1948 and was largely unregulated because virtually no upstream storage was available. The 1948 flood, throughout the region, resulted in 38 deaths, destroyed 5,000 homes, left 35,000 homeless, forced evacuation of 100,000, flooded 251,000 acres, breached 13 levees, and caused $103 million in damage (1948 dollars). Oregon's second largest city at the time, Vanport, on the Columbia River opposite Vancouver, Washington, was destroyed. (DOE–BP–7, U.S. Government Printing Office: 1981–796–874, "Columbia River Power for the People", p.159). In 1972 and again in 1974, floods of roughly the same magnitude as 1948 occurred if unregulated peaks are compared. However, these two events were regulated by upstream storage (most of which was added after 1948 as part of the Columbia River Treaty; see paragraph 2.1.3) to below major damage level. The largest flood of record at The Dalles was the 1894 flood, which inundated the city for approximately 60 days. Notable floods have occurred at tributary sites in the basin, sometimes independent of the total basin flood. For example, the largest flood of record on the Flathead River in Montana was in 1964, and in 1933 at Spalding on the Clearwater River, ID.

2.1.2 Early Flood Control Planning

Section 1 of the River and Harbor Act of January 21, 1927 directed that surveys be made in accordance with the recommendations of House Document No. 308, Sixty–ninth Congress, first session. Under "308" authority, a comprehensive report on the Columbia River and minor tributaries was prepared and submitted to Congress in 1932 and was published as House Document No. 103, Seventy–third Congress, first session. Although a flood control plan was not contemplated at this time, the report recommended a 10–dam plan of development on the Mainstem Columbia River. In 1948, a review of the "308" report was published. This report was much more comprehensive in that it summarized the studies of present and anticipated future needs of all parts of the basin for flood control and other uses. A comprehensive plan developed by the USBR was reviewed and corroborated the 1948 Review Report. The Corps and the Bureau reached agreement on jurisdiction for construction and on plans for coordinated system operation of the projects for multiple purposes. The Corps would build the mainstem reservoirs whose primary functions were power, flood control, and navigation. The Bureau would build the upstream reservoirs and facilities whose functions were primarily for irrigation and power. BPA would market the electrical energy. This review report of 1948 was published as House Document No. 531, Thirty–first Congress, second session. This study was underway when the 1948 flood occurred, which served to reinforce the importance of the document.

Changing social and economic conditions in the basin led to yet another review report, published in 1958. The report developed a plan identified as the Major Water Plan, which was considered to encompass most of the remaining project and practicable opportunities within the United States portion of the

Columbia River basin. The potential for development within the Canadian portion of the basin was recognized, but no consideration was given to its development because this was a matter requiring international study.

2.1.3 Columbia River Treaty

On September 16, 1964, the U.S. and Canada ratified the Columbia River Treaty (Treaty) which formed the basis for major hydropower–related developments on the Columbia River system. Under terms of the Treaty, four water storage projects were built: Mica, Arrow (Hugh Keenlyside), and Duncan in Canada; and Libby in the U.S. The combined active storage of these projects is approximately 25 million acre–feet, which more than doubled the previously existing storage capability of the system. This action led to the development of the Columbia River Treaty Flood Control Plan completed in draft form in 1968, and finalized in 1972. This plan provides the basis for current flood control operations.

2.1.4 Standard Project Flood (SPF)

In general terms, the standard project flood (SPF) may be defined as a hydrograph representing runoff from the standard project storm (SPS) and snowmelt. The standard project storm for a snowmelt–based SPF is based on estimates of the most critical combinations of snow, temperature, and water losses considered reasonably characteristic of the region. The system SPF was most recently developed in 1969, and reflects all of the current Treaty projects. The unregulated peak flow for the SPF at The Dalles is 1,550,000 cfs (43,896 m^3/s) and the regulated peak flow is 900,000 cfs (23,789 m^3/s). Further information on the SPF and Probable Maximum Flood is available in: Memorandum Report, Columbia River Basin, Lower Columbia River Standard Project Flood and Probable Maximum Flood, September 1969, U.S. Army Engineer Division, North Pacific, Portland Oregon.

2.2 FLOOD CONTROL GUIDANCE

A task force established by the U.S. and Canadian entities in 1965 developed the 1968 draft Columbia River Treaty Flood Control Plan. This task force was made up of the Corps of Engineers and Bonneville Power Administration from the U.S. Entity and British Columbia Hydro and Power Authority for the Canadian Entity. Modifications made in 1971 by the Corps were accepted by the Entities in 1972. This Treaty Plan is but a part of the overall Flood Control Plan for the Columbia River Basin which provides flood control protection in both the U.S. and Canada. The Flood Control Plan was developed from studies of runoff data from 1928–1958, the 1894 flood, and from the Columbia River Basin SPF (see paragraph 2.1.4). The Flood Control Act of 1944 gave the Corps the authority to operate any project for flood control which was built with Federal funds, e.g., Grand Coulee and Hungry Horse. In addition, flood control projects authorized by the Federal Energy Regulatory Commission (FERC) are also subject to Corps regulation during a flood, e.g. Brownlee. Project operating rules were developed to provide protection for floods allowing for error in forecasts and to maintain a high level of confidence of refill. The Flood Control Plan is comprised of the following elements: 1) A storage reservation diagram for each reservoir which determines the evacuation requirement as a function of the seasonal volume runoff forecast, 2) Outflow diagrams which determine the discharge requirement as a function of the volume runoff forecast, and 3) Charts and diagrams that define local and system flood control operating criteria.

2.3 RUNOFF FORECASTS

The seasonal volume runoff forecasts used to determine reservoir evacuation requirements are statistical procedures that correlate precipitation and snowpack against runoff. Project owners are responsible for the development of reservoir–specific forecasts while the Soil Conservation Service and National Weather Service are responsible for the development of downstream forecasts. Forecasts are made beginning in January and are updated regularly through June. It is these forecasts that are used to determine reservoir evacuation requirements needed prior to the start of the spring and summer runoff. The forecast period for: Dworshak is April–July inflow, Libby and Duncan is April–August inflow, Hungry Horse is May–September inflow, Mica and Arrow are April–August unregulated flow at The Dalles, Grand Coulee is April–August unregulated flow at The Dalles corrected for available upstream storage other than Grand Coulee.

2.4 FLOOD CONTROL RULE CURVE DEVELOPMENT

Every flood control project uses a storage reservation diagram (SRD), which, based on runoff volume forecasts, specifies the amount of flood storage space to be made available by the beginning of the refill period. Figure 2–1 is an example of an SRD for Libby project. The SRD is the key element when examining flood control effectiveness or considering an alternative operating policy. The SRDs are derived through systematic analysis of historic floods reflecting the project's authorized operating objectives and considering the possibility of encountering forecast error. Most SRDs are developed in the design phases of the project development. In the mid–1980s, the Corps of Engineers conducted a systematic review of SRDs for all flood control projects in the United States portion of the Columbia River basin. The purpose of this study was to ascertain whether SRDs could be modified to benefit downstream fish–flow operations while not decreasing flood control capability. The analysis led to the modification of the SRDs at Libby, Grand Coulee, Dworshak, and Brownlee. These rule curves are presently being used in operations and are reflected in base case (SOS 2c) SOR studies. The SRD is modified to reflect the change in storage draft requirements based on the desired strategy of the system or project operation.

2.5 CONCEPTS OF RESERVOIR OPERATION FOR FLOOD CONTROL

The Pacific Northwest has two principal flood seasons. November through March is the rain–produced flood period. These floods occur most frequently on streams west of the Cascade Mountains, the result of intense rainstorms of several days duration. Snowmelt often augments these floods. May through July is the snowmelt flood period. East of the Cascades, snowmelt floods dominate the runoff pattern for the Columbia Basin. Several factors determine the magnitude of the flood, including: the amount of snow in the basin; whether or not a critical sequence of hot weather occurs during the spring; and whether spring rainfall adds to the runoff.

From the season–long perspective, flood control operations include: drawing down the reservoirs to provide an adequate amount of space to store the runoff; and filling the reservoir space in a strategic fashion to minimize downstream damages. In the Columbia, where large floods involve more runoff than can be stored, reservoir releases must be adjusted to prevent one or more projects from storing too rapidly. The strategy for refill is aided by computer simulations of the river on a daily basis.

Forecasts of the water supply runoff volume determine how much space should be evacuated from reservoirs for downstream flood protection. The forecasts are based primarily on snowpack and precipitation measurements. Flood control operation has two objectives: operating the system to minimize damaging flows on the Lower Columbia River, and operating individual reservoirs to minimize damage to local areas. Storage reservoirs often have provisions for both local flood control and system flood control, and in such cases, the criterion calling for greater drawdown is followed.

The Columbia River Treaty Flood Control Operating Plan (1972) contains the following basic principles of operation, which are applicable not only to Treaty storage but all flood control projects in the basin as well:

1. Two distinct periods of operations are recognized: (1) the winter drawdown period in which flood control storage space is attained in accordance with storage reservation diagrams; (2) the spring refill period during which flood regulation is implemented.

2. For purposes of regulation during the refill period, two main categories of reservoir

projects are: (1) Category I, headwater reservoirs operated with fixed (usually minimum) releases; and (2) Category IV, reservoirs operated with variable releases for downstream flood control. These two categories are the most important for system regulation, and the variable release reservoirs (Arrow, Grand Coulee, and John Day) represent those that require continual adjustment during the spring runoff to achieve the flood control regulation in the lower river.

3. A variable controlled flow objective at The Dalles is utilized, in which years with higher runoff are regulated to a higher controlled flow to account for the inability to completely regulate all flood events and to make the most effective use of storage. Further, the controlled flow objectives can change during the course of a flood, as storage space is depleted in Category IV reservoirs.

2.5.1 System control

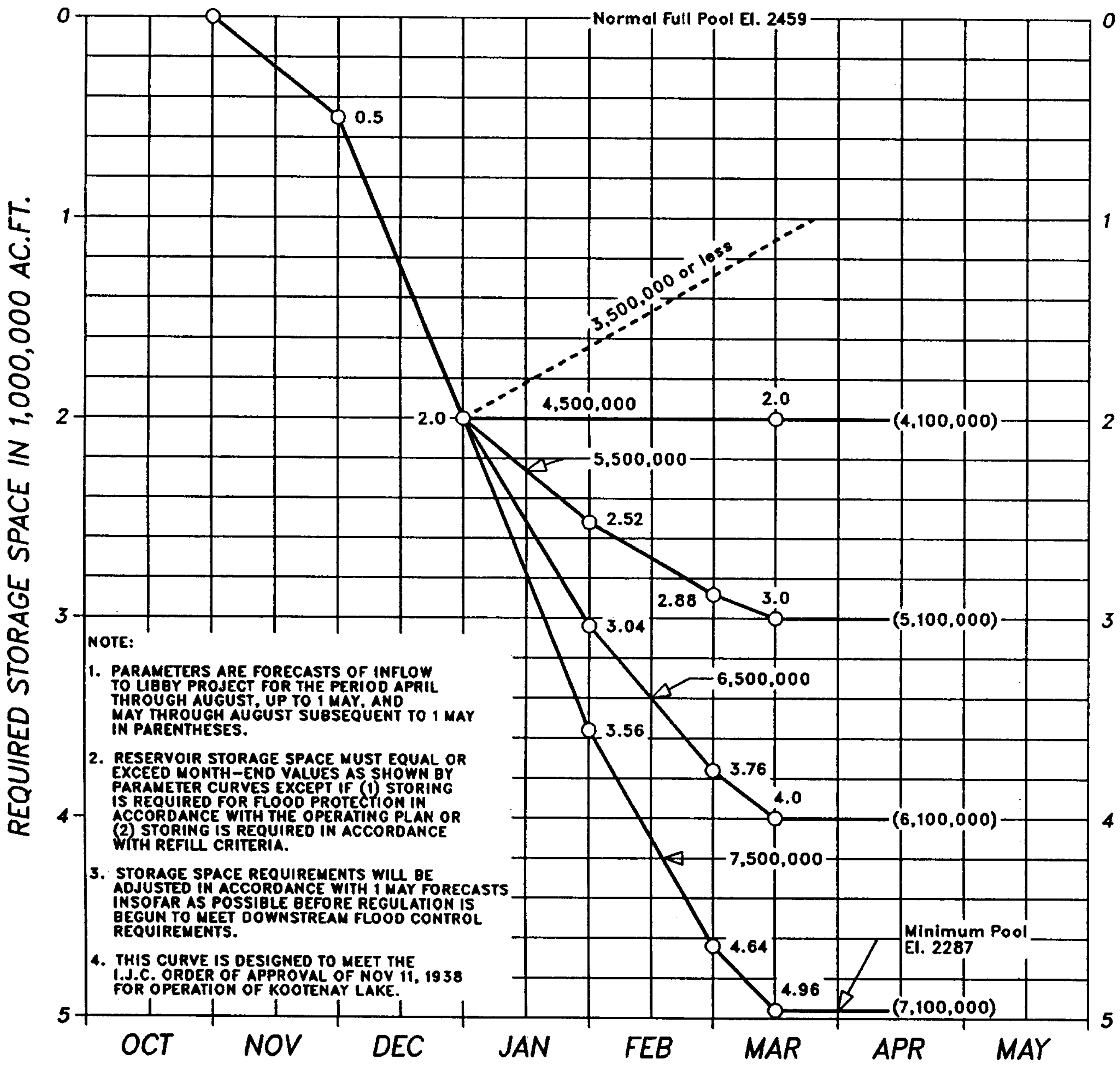
The objective of system flood control operations is to reduce peak flows on the Lower Columbia. This is the largest single damage area in the basin, which includes portions of the city of Portland, Oregon and extensive rural areas protected by 42 diking districts along 120 river miles. The projects that are regulated for system flood control are: Hungry Horse, Libby, Grand Coulee, Brownlee, Dworshak, and John Day in the U.S., and Mica, Arrow, and Duncan in Canada. The Corps has developed a multiple–use reservoir storage plan involving coordinated operation of these projects whose primary authorization and justification is based upon their contribution to reducing floods in the lower Columbia.

2.5.1.1 Shifting system flood control to Grand Coulee

A shift in system flood control from Dworshak to Grand Coulee is designed primarily to minimize the 30 April flood control draft at Dworshak by using system flood control space in Grand Coulee that would otherwise be required from Dworshak. This preserves Dworshak water which can be used to provide flow augmentation below Dworshak. Following is a description of the process for determining if and how much space can be transferred. On the first of each of the months of January–April, if the April–July volume runoff forecast at Dworshak is 3.0 maf (3.702 x $10^9 m^3$) or less and flood control space is anticipated to be available (prior to a shift) at Grand Coulee (based on its SRD), then the 15 April flood control draft at Dworshak (as specified by its SRD) is reduced by the amount of storage which can be transferred to Grand Coulee, which is then drafted appropriately. Local flood control below Dworshak must be preserved. The April–July forecast is reviewed at the beginning of each month and the 15 April draft requirement at Dworshak and potential shift to Grand Coulee is re–evaluated. On 1 April, two possibilities emerge: 1) if the April–July forecast shows that the 30 April flood control draft requirement at Dworshak is more than had been indicated by earlier forecasts, then that space must be made available by 30 April (Dworshak must draft, providing potential flow augmentation), or 2) if the April–July forecast shows that the 30 April flood control draft requirement at Dworshak is less than had been indicated by earlier forecasts, then Dworshak must only fulfill the 30 April flood control draft requirement as specified by its SRD. In either case, Grand Coulee must then meet its 30 April flood requirement.

2.5.2 Local Control

Local flood control operation is required in the winter as well as the spring for some projects. The winter period, subject to rain–produced flooding, generally uses fixed flood control rule curves. This period is much more unpredictable in nature due to the inability to forecast rain. These rule curves are developed for the storage projects based on studies of historical runoff. The spring period, when the more predictable snowmelt runoff occurs, requires rule curves that reflect a variable storage space availability as discussed in paragraph 2.4. Generally during the spring period, storage evacuation for system flood control provides protection for most projects for local areas as well.



FLOOD CONTROL OPERATING PLAN
COLUMBIA RIVER TREATY
SEPTEMBER 1972

Figure 2–1. Libby Project Flood Control Storage Reservation Diagram

CHAPTER 3

FULL SCALE STUDY METHODS

3.1 EVALUATION CRITERIA

3.1.1 Control Point Flow Requirements

Nine key stream gages (referred to as "control points" downstream of storage projects or along their shoreline) on the Columbia and tributary rivers were selected by the FCWG to appraise flood damage impacts. See Table 3–1 for descriptions of the control points and their corresponding river reaches. Flood potential at all other Columbia River Basin locations that are not specifically included can be readily addressed by observing the flows at one or more upstream control points, however. During any flood control operation, all control point flows and elevations are attempted to be met. The exception is The Dalles whose control flow varies from year to year depending on the amount of upstream storage space available and forecasted unregulated flow at The Dalles. Damages at The Dalles accumulate rapidly when flows exceed 450,000 cfs (12745 m^3/s).

3.1.2 Stage–Frequency

The keystone of any evaluation of the effects of project operation change(s) on flood control effectiveness is the stage–frequency or flow–frequency curve (commonly referred to as a flood frequency curve). It provides a simple and thorough summary of the probability of a peak flow (river stage) occurring. By definition, the abscissa is exceedance frequency, and the ordinate is the stage or flow. The coordinates of any point on the frequency curve indicate, on the average, how rare that particular peak is, or the probability that it will be exceeded in any year. The FCWG used the standard procedure set forth in Bulletin #17B of the Water Resources Council Guidelines for Developing Flood Flow Frequency to develop all frequency curves except those for Lake Pend Oreille and Flathead Lake. Both of these locations' frequency curves were "hand–drawn" because the log–Pearson Type III probability distribution (used by Bulletin # 17B) is not recommended for reservoir elevations.

3.1.3 Reservoir Operation Impacts

The first set of frequency curves was developed for System Operating Strategy (SOS) 2C, which is the no–action alternative. Subsequent changes to system operation will yield a different set of frequency curves which are compared (primarily graphically) on a location by location basis to the corresponding curve from SOS 2C. Impacts of a proposed regulation are readily visible. The set of frequency curves for an SOS are then given to the Economics Work Group to determine the flood damage associated with that SOS.

3.2 PROCEDURE

The FCWG provided flood control upper rule curves (URC) to the HYDROSIM modelers, based upon a modified SRD or other guidance defined by an SOS. A URC for a project is developed for each year based on the volume forecast for the runoff season (see paragraph 2.3), which is then used with the SRD to prescribe the amount of project flood control space required. The last official forecast is 1 April and is used to prescribe the amount of space to be made available by 30 April (the date of maximum flood control storage requirement). For each SOS, the HYDROSIM model provided end of month reservoir elevations and monthly average reservoir outflows which the FCWG used to estimate the flows at each of the control points described in Table 3–1. This was accomplished with a daily simulation model, SSARR (see paragraph 3.2.1). A necessary assumption to evaluate operations on a daily basis is that the monthly reservoir outflows produced by HYDROSIM occur for each day of the month. This, of course, is not the way a reservoir is normally operated; however, to maintain consistency with other work group studies involved in the SOR process, a common set of operating data must be used by all. The constant daily flows were then combined with 50 years of historic daily uncontrolled flows throughout the Columbia, and the system was operated using the SSARR model driven by AUTOREG (see below for a brief discussion of SSARR and AUTOREG). Any constraints or operating requirements set forth in the SOS being analyzed were adhered to by the FCWG. The one–day peak annual flow for each of the control points for each of the 50 years was recorded, and the frequency curves were developed. After careful consideration, the FCWG determined that a "hands–on" (detailed) regulation need not be performed. A detailed regulation consists of fine–tuning project outflows to optimize project outflows for maximum possible system and local flood control. The decision not to conduct a detailed regulation on any of the SOSs was based primarily on the fact that the considerable time and effort involved would not provide any significant additional information.

3.2.1 SSARR Model Overview/Data Requirements

The Streamflow Synthesis and Reservoir Regulation (SSARR) computer was designed for both real–time streamflow forecasting and river system studies, using a daily (or more frequent) computational time step. The model of the Columbia River basin provides mathematical simulations of reservoir operations, water movement through the river system, and the effects of lakes, diversions, etc. that are used to evaluate various operations including flood control. Of primary interest to flood control studies are peak flows and stages at control points throughout the basin. Input data needed for SSARR for the study include:

1. Characteristic data which describe physical features such as drainage area, reservoir storage capacity, and watershed characteristics that affect runoff.
2. Initial Condition data for specifying current conditions of all watershed–runoff indexes, incremental flows over the entire basin, and initial reservoir elevations and outflows.
3. Discharge and elevation time–series, from historic records or simulated by HYDROSIM.
4. Miscellaneous Job Control and Time Control data which specify items such as total computation period, routing intervals, and other computer instructions to control input–output alternatives.

3.2.2 AUTOREG Model

AUTOREG was developed to interface with SSARR for the purpose of simulating Columbia River daily operations in a substantially reduced amount of time. The SOR process requires a multifaceted analysis of alternative operating strategies described by monthly modeling for an historic 50–year period. Flood control operations involving peak flows must be analyzed in shorter time increments of daily or hourly simulations. AUTOREG was developed to substantially reduce the time element involved in simulating the highly complex Columbia River Basin for the purpose of the SOR and future studies. Currently, upon receipt of a HYDROSIM output, AUTOREG/SSARR can process 50 years of the complete Columbia system (including development of frequency curves) in approximately 4 hours. Prior to the development of AUTOREG, the same analysis would have taken a minimum of 5 weeks.

AUTOREG's three major functions include:

1. Automation of input into the SSARR model.
2. Automatic regulation of the entire river system in accordance with specified rule curves and HYDROSIM outflows and elevations.
3. Checks of SSARR output that include violations of rule curve operations, minimum and maximum flow violations, and river stage violations. This assists the regulator in evaluating the simulations quickly.
4. Integration of SSARR with a new data base system.
5. Creation of output displays and graphics.

Table 3–1. Control Points and River Reaches Evaluated for Flooding

CONTROL POINT	RIVER REACH	ZERO DAMAGE	MAJOR DAMAGE
Flow at Columbia River at Birchbank, BC	Columbia River from below the confluence of Arrow Lakes and Brilliant Dam to the U.S. border	225,000 cfs, 6,372 m^3/s	280,000 cfs, 7,930 m^3/s
Stage at Kootenai River at Bonners Ferry, ID	Kootenai River from Libby Dam to and including Bonners Ferry	1,766.5 feet, 538.4 meters	1,774.0 feet 540.7 meters
Flow at Flathead River at Columbia Falls, MT	Flathead River from Columbia Falls, MT to Flathead Lake	52,000 cfs, 1,470 m^3/s	82,800 cfs 2,345 m^3/s
Stage at Flathead Lake at Somers, MT	Flathead Lake shoreline	2893.1 feet, 881.8 meters	2894.5 feet 882.2 meters
Flow at Flathead River nr Polson, MT	Flathead River from Kerr Dam to Thompson Falls Dam	28,000 cfs, 790 m^3/s	80,000 cfs 2,266 m^3/s
Stage at Pend Oreille Lake nr Hope, ID	Lake Pend Oreille shoreline	2,062.5 feet, 628.7 meters	2,065.0 feet 629.4 meters
Flow at Pend Oreille River at Newport, WA	Pend Oreille River from Albeni Falls Dam to the Columbia River	85,000 cfs, 2,410 m^3/s	120,000 cfs 3,398 m^3/s
Flow at Clearwater River at Spalding, ID	Clearwater River from Dworshak Dam to the Snake River and then to the Columbia River	112,000 cfs, 3,172 m^3/s	129,300 cfs 3,662 m^3/s
Flow at Columbia River at The Dalles, OR	Columbia River between Bonneville Dam (river mile 145) and river mile 40	450,000 cfs, 12,744 m^3/s	750,000 cfs 21,240 m^3/s

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 flood control.

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**	**SOS 2c**	**SOS 4c**
	Normal 1983–1991 storage project operations	Operate on system proportional draft as in SOS 1a	• 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
	SOS 1b	**SOS 2d**	
	• Minimum project flow 3 kcfs • No refill targets • Summer draft limit of 5–10 feet	• 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	

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	**SOS 6b**	**SOS 9a**	**SOS PA**
Operate on system proportional draft as in SOS 1a	Operate on system proportional draft as in SOS 1a	• 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	• 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
SOS 5c	**SOS 6d**	**SOS 9b**	
Operate on system proportional draft as in SOS 1a	Operate on system proportional draft as in SOS 1a	• 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	

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 2c** 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 1b • No maximum flow restriction from mid-Oct. to mid-Nov. • No draft limit; no refill target	**SOS 2d** Operate on system proportional draft as in SOS 1a	

	SOS 1	SOS 2	SOS 4
ALBENI FALLS	**SOS 1a** Normal 1983–1991 storage project operations	**SOS 2c** 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 drawdown to 2,051 feet every 6th year
	SOS 1b No refill target	**SOS 2d** Operate on system proportional draft as in SOS 1a	

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 6b** 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 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 5c Operate on system proportional draft as in SOS 1a	**SOS 6d** Operate on system proportional draft as in SOS 1a	**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 5	SOS 6	SOS 9	SOS PA
SOS 5b Operate on system proportional draft as in SOS 1a	**SOS 6b** 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 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.
SOS 5c Operate on system proportional draft as in SOS 1a	**SOS 6d** Operate on system proportional draft as in SOS 1a	**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.	

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	**SOS 6b**	**SOS 9a**	**SOS PA**
Same as SOS 1a	Same as SOS 1a	Provide up to 1.927 MAF through Brownlee for flow augmentation, as determined by Reclamation	Provide 427 KAF through Brownlee for flow augmentation, as determined by Reclamation
SOS 5c	**SOS 6d**	**SOS 9b**	
Same as SOS 1a	Same as SOS 1a	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 5	SOS 6	SOS 9	SOS PA
SOS 5b	**SOS 6b**	**SOS 9a**	**SOS PA**
Same as SOS 4c	Same as SOS 4c	• 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	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
SOS 5c	**SOS 6d**	**SOS 9b**	
Same as SOS 4c	Same as SOS 4c	• 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	

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 6b** 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 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
SOS 5c • Operate to flood control during spring • Refill in June or July and maintain through August • Draft for power production during fall	**SOS 6d** Same as SOS 5b	**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	

1 kcfs = 28 cms   1 ft = 0.3048 meter

Table 4–1. SOS Alternative–6

Actions by Project

	SOS 1	SOS 2	SOS 4
LOWER SNAKE	**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 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 2c** • Operate reservoirs within 1 foot above MOP from April 16 to July 31 • Same as SOS 1a for rest of year **SOS 2d** Same as SOS 2c	**SOS 4c** Same as SOS 2c
LOWER COLUMBIA	**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 1b** Same as 1a, except no restrictions on 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 2d** Same as SOS 2c	**SOS 4c** Same as SOS 2c, except operate John Day within 2 feet of elevation 263.5 feet Nov. 1 through June 30

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

Table 4–1. SOS Alternative–6

SOS 5

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 6

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 9

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

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

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SOS 5

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 6

SOS 6b

Same as SOS 5

SOS 6d

Same as SOS 5

SOS 9

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

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 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., Dworshak 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 GENERAL DISCUSSION

The Flood Control Work Group (FCWG) used the flood–frequency curves for SOS 2c only for comparison to other SOSs. Even though most of the frequency curves for SOS 2c reasonably represent the official curves, the dollar amounts of flood damages presented by the Economics Work Group for all SOSs cannot be construed as "real" dollar amounts because the level of detail used in this analysis did not allow precise determination of damages. On a relative scale, however, the adopted frequency curves do accurately reflect which alternatives are better or worse than SOS 2c and each other.

4.2.1 VARQ (Variable Outflow based on Forecast)

During screening, the FCWG introduced a method of modifying SRDs, in which the outflow assumed during refill was allowed to vary based on forecast. This procedure was designed to reduce the 30 April system flood control draft at Libby, Hungry Horse, and Dworshak without compromising flood control substantially. Basically, the releases from these projects during refill (post–30 April) would be increased as the inflow volume runoff forecast to each project decreased. If water that is normally stored during the refill period is instead passed through the project, then the amount of space in the project required to store that water is reduced. Therefore, the 30 April draft requirement, as specified by the SRD, is reduced in lower runoff years. In years where the inflow volume runoff forecast is high, then flood control outflows during refill are set to minimum and full reservoir draft is effected.

The VARQ flood control rule curves are primarily associated with system flood control. So, in a given year, if the 30 April VARQ elevation at a project is higher than the elevation required for local flood control, then the VARQ elevation is lowered to that of local flood control. This was the case at Dworshak in all years. So when VARQ is said to be used at Dworshak, it is in reality the local flood control rule curve.

Preliminary assessments of VARQ both in the screening and full scale phases of SOR indicate that the impact to system flood control of implementing VARQ is relatively minor; although there is an increased risk of flooding at the local level. However, the FCWG believes that further refinements of the rules governing use of VARQ can improve its performance which may lead to its adoption on an official basis.

4.2.2 Birchbank

Birchbank flow is the sum of outflows from Arrow and the Kootenay River plus any minor local inflow between the confluence of the Kootenay and Columbia Rivers and the Birchbank gage (river mile 762.8, river kilometer 1235.7). The FCWG performed the flood control analysis of Birchbank using outflows produced by HYDROSIM for Mica, Duncan, Corra Linn and Revelstoke, and end–of–month elevations for Arrow.

4.2.3 Bonners Ferry

Bonners Ferry stage is influenced by results from three factors: 1) Libby outflow, 2) uncontrolled local inflow between Libby Dam and Bonners Ferry, and 3) Kootenay Lake forebay which can have backwater effects on Bonners Ferry. Therefore, the operations of Libby, Duncan, and Corra Linn influence the stage at Bonners Ferry. The constraints placed on Kootenay Lake elevations by the International Joint Commission (IJC) were adhered to by forcing Corra Linn Dam to follow an Upper Rule Curve which mimics the IJC guidelines. Libby Dam's outflows were determined by HYDROSIM.

4.2.4 Columbia Falls

Flow at Columbia Falls results from Hungry Horse outflows and uncontrolled local inflows from the middle and south forks of the Flathead River. The local inflows are by far the most damaging component of flooding at Columbia Falls. In 1964 a flood occurred in the Flathead basin that eclipsed all others in the basin to the point that the peak for 1964 tends to skew all frequency curves at Columbia Falls and Flathead Lake. This flood was primarily rain induced and is unlike most other floods which are caused primarily by snowmelt. The official frequency curve for Columbia Falls is actually a combined, or mixed population, curve of rainfall and snowmelt. Therefore, there are two upper portions of the curve, one defined by snowmelt and one defined by rainfall. The recorded 1964 and 1975 events define the upper portion of the frequency curve attributable to rainfall. The flood of 1964, if included with all other events, is a high outlier, which is an event that departs significantly from the trend of the remaining data. Normal treatment of a high outlier by Bulletin 17B is to: 1) drop the event, 2) recompute the statistics, 3) compute period of record weighting based on the new and initial statistics, and 4) recompute the frequency curve. The effect of this treatment is to lower the upper end of the frequency curve which was initially computed with the outlier as part of the data. This is the procedure adopted by the FCWG for the frequency analysis of Columbia Falls taking into account 1964. The flood of that year is by far the largest in all of the SOSs and therefore does not unfairly bias one SOS over another. The Columbia Falls frequency curves were developed by the FCWG taking into consideration the dominant and skewing effect of the 1964 flood. The FCWG modeled Columbia Falls using the outflows produced for Hungry Horse by HYDROSIM.

4.2.5 Kerr Dam/Flathead Lake

In day–to–day regulation, the forecast of a large flood would trigger a delay of the refill of Kerr Dam, which would make storage available in Flathead Lake, allow some of the flood water to be stored, and reduce the peak lake stage. In the HYDROSIM model runs, Flathead Lake's end–of–May "target elevation" is really a maximum pool limit established by a set of PNCA non–power requirements. This maximum pool limit did not force Flathead Lake's pool to be at a specific elevation by the end of May. In effect, this allowed the pool to "float" during May with limited regard to flood potential. In a few of the years, this tended to limit Flathead Lake's ability store flood water in June because the month started off ill–prepared to store runoff. Most of the time this did not force the lake above normal full pool; however, in a few of the medium–high runoff years, the maximum pool surcharged 0.1 or 0.2 of a foot. This is not considered realistic because routine real–time daily regulation would bring these peaks down to a normal level. See paragraph 3.2 for a detailed discussion of the reasons for the decision not to spend the time to perform a detailed regulation. The Flathead Lake frequency curves were developed taking this simulation problem into account using historic events as guidance. In all the SOSs, the FCWG regulated Flathead Lake as prescribed by the Kerr Dam outflows produced by HYDROSIM. The FCWG calculated Flathead Lake reservoir elevations by computing a change in lake contents (inflow minus outflow) and converting the resulting end–of–period storage to an elevation.

4.2.6 Albeni Falls Dam/Lake Pend Oreille

Pend Oreille Lake is operated almost identically to Flathead Lake with respect to end–of–May elevations. The FCWG modeled Lake Pend Oreille by releasing flows from Albeni Falls Dam as prescribed by the HYDROSIM model. The FCWG computed Lake Pend Oreille reservoir elevations by computing a change in lake contents (inflow minus outflow) and converting the resulting end–of period storage to an elevation.

4.2.7 Spalding

Dworshak Dam outflows, uncontrolled mainstem Clearwater River flows at Orofino, and uncontrolled local inflows between Dworshak Dam and Spalding contribute to flow at Spalding. Flows at the Spalding gage represent flows that will occur at the Lewiston Levee damage center, twelve miles below Spalding. Dworshak was regulated according to the outflows produced by HYDROSIM.

4.2.8 The Dalles

Although some very minor "flood" damages are incurred for flows as low as 200,000 cfs (5665 m^3/s), for this report, the reference level of 450,000 cfs (12,744 m^3/s) is used to represent a zero damage level. Water budget flows sustain flows for long periods of time when flow recession would otherwise occur. This can cause flooding problems behind leveed areas of the Lower Columbia River below Vancouver. Such problems occur when flows in the Columbia don't recede naturally when high tides are present; thus interior runoff (runoff behind levees) can't drain into the Columbia thereby causing "man–made" flooding behind the levees.

4.3 IMPACTS OF THE ALTERNATIVES

Some general summary information is available in several tables. Table 4–3 shows for each SOS which flood control upper rule curve(s) was used for Dworshak, Libby, Hungry Horse, and Grand Coulee in the corresponding HYDROSIM run. Tables 4–4 through 4–12 summarize the impacts of the alternative scenarios in terms of their flood–frequency values. Technical Exhibit A presents the adopted flood–frequency curves of the maximum one–day peak flows or stages for the 50 years studied for each control point for each SOS. The only results presented in this paragraph (4.3) are limited to Tables 4–3 through 4–12 and a discussion of how the no–action alternative, SOS 2c, compares with the official frequency curve for each control point location.

In order to make a connection with existing flood control criteria, the no–action alternative has to reflect current flood control guidelines as stated in the CRT–63 (June, 1991). This document updated flood control rule curves for major reservoirs and assessed system flood control capability (a frequency curve at The Dalles). Comparison of The Dalles' frequency curve from SOS 2c and that from CRT–63 shows that indeed the curves are similar.

SOS 2c shifted system flood control to Grand Coulee for April–July volume runoff forecasts up to 3.0 maf at Dworshak if space is available in Grand Coulee. See paragraph 2.5.1.1 for details of shifting flood control to Grand Coulee.

4.3.1 SOS 2c

The following paragraphs describe simulation results for SOS 2c in comparison with previously developed flood frequency curves. A frequency curve for SOS 2c reflects certain modeling assumptions already described, and it is limited to a 50–year period of record. A thorough frequency derivation would employ a longer period of record, if available, and make other adjustments that are a standard practice. These curves are denoted as "official" in the following discussions.

4.3.1.1 Birchbank flow

According to B.C. Hydro, there is no official frequency curve for the Birchbank location. However, B.C. Hydro did release a report (Report No. H 1598, 1983) which presented a regulated flood–frequency curve for Murphy Creek (just upriver of Trail, B.C.), which is very close to the Birchbank gage. No significant local inflow occurs between the Murphy Creek location and Birchbank. The published frequency curve is valid for exceedance frequencies of 20 percent and less (the upper end of the frequency curve). Only two points on this curve are comparable to that of SOS 2c: the 1 percent event of SOS 2c is 232,000 cfs (6570 m^3/s) compared to 252,000 cfs (7130 m^3/s) in the draft report; and the 10 percent event of SOS 2c is 185,000 cfs (5239 m^3/s) compared to 194,200 cfs (5500 m^3/s) in the draft report. This gives an indication that SOS 2c's frequency curve at Birchbank is reasonable and acceptable. Differences between the two curves can be attributed to different operating strategies for projects upstream of Birchbank.

4.3.1.2 Bonners Ferry stage

The official Bonners Ferry flood–frequency curve appears in CRT–63. The frequency curve for SOS 2c is very similar to the official curve and appears to adequately reflect existing conditions. Major damage protection afforded by the Libby project is now approximately equal to the 0.5 percent exceedance frequency (200–year event). On the other hand, there is strong evidence that the levees have not been maintained to their original standard, thus potentially lowering their degree of protection.

4.3.1.3 Columbia Falls flow

A detailed discussion of the development of the official Columbia Falls flood–frequency curve is in paragraph 4.2.4. The official curve is presented in CRT–63 which indicates that the zero damage level is 48,000 cfs (1360 m^3/s). Since the publication of CRT–63, some levee improvements have been made which have raised the zero damage level up to 52,000 cfs (1470 m^3/s). Because Hungry Horse controls only 37 percent of the drainage area above Columbia Falls, the exceedance of the zero damage level is a relatively frequent event (about once every three years on the SOS 2c frequency curve), even when Hungry Horse releases minimum outflows. The flood–frequency curve for Columbia Falls for SOS 2c is similar to the official curve, but a little steeper, which increases the mean and higher events slightly. The differences between the two curves are not dramatic, and SOS 2c appears to reasonably reflect existing conditions at Columbia Falls.

4.3.1.4 Flathead Lake stage

The most current flood–frequency curve for Flathead Lake stage was developed in 1965 by the Seattle District, Corps of Engineers. Unfortunately, the frequency curve does not include the 1964 or 1894 floods, which help to define the upper end of the frequency curve for Flathead Lake stage. Therefore the "official" flood–frequency curve tends to underestimate Flathead Lake's maximum annual stage for the larger floods. This is evident by looking at the SOS 2c frequency curve, which more accurately describes the current distribution of annual peak stage, where approximately once in every 10 years a flood will force Flathead Lake to above normal full pool. The SOS 2c simulation results in a number of years in which stages which are slightly above (within 0.2 to 0.3 foot, 0.06 to 0.09 meters) normal full pool. The FCWG believes that there is some regulation flexibility available to reduce those peaks down to normal full pool, and the frequency curve has been drawn to reflect this.

4.3.1.5 Flathead Lake (Kerr Dam) outflow

The flood peak attenuation effect of Flathead Lake is dramatically manifested by the frequency curve of Kerr outflow. For SOS 2c at Columbia Falls, the 1964 flood produced a peak of over twice the size of the next largest peak, yet the Kerr Dam outflow for 1964 is only 10 percent higher than the second largest event. An "official" flood–frequency curve for Flathead Lake outflow was prepared by the Seattle District, Corps of Engineers in 1967. The one percent event (100–year) for the official curve is 66,000 cfs (1869 m^3/s) compared with 80,000 cfs (2266 m^3/s) for SOS 2c. Both curves have the same flow for the 50 percent event. The SOS 2c curve is above the official curve for larger events because no detailed regulation was performed on Flathead Lake. The FCWG believes that a modest amount of regulation would bring the SOS 2c frequency more in line with the official curve. Therefore, the FCWG believes that the distribution of HYDROSIM regulated outflows for SOS 2c appears reasonable and depicts current operation.

4.3.1.6 Lake Pend Oreille stage

The relative magnitude of the 1964 flood in the Flathead does not carry through to the Clark Fork River for two reasons: 1) the 1964 flood was local to the Flathead basin only, and 2) the peak was attenuated by Flathead Lake. The highest elevation at Lake Pend Oreille in SOS 2c was in 1948, a flood which impacted the entire Columbia River basin. A preliminary "official" flood–frequency curve for Lake Pend Oreille stage was prepared in 1990 by the Seattle District, Corps of Engineers and includes events from 1914–1989. The 1894 flood provided guidance for the extreme upper end of the official frequency curve. The 1 percent event is exactly the same (2070 feet, 631.9 meters) for the SOS 2c and official frequency curves. However, in SOS 2c, the intersection of the upper end of the frequency curve with normal full pool (horizontal portion of the curve) is shifted left of the same intersection on the official curve. The official curve expects Lake Pend Oreille to be above normal full pool on the average once every 10 years, while SOS 2c indicates once every 4 years. As in the case of Flathead, The FCWG believes that there is some regulation flexibility available to reduce some of the events down to normal full pool and bring the SOS 2c frequency more in line with the official curve.

4.3.1.7 Lake Pend Oreille (Albeni Falls Dam) outflow

Over half of the years of regulated outflows from Albeni Falls dam for SOS 2c were above the zero damage level of 85,000 cfs (2410 m^3/s). However, according to the Economics Work Group, only "nuisance flooding" occurs between 85,000 cfs and 120,000 cfs (3398 m^3/s) at which point substantial damages begin to accrue. In SOS 2c, only six regulated flows at Newport were above 120,000 cfs. A preliminary "official" flood–frequency curve for Lake Pend Oreille outflow was prepared in 1990 by the Seattle District, Corps of Engineers and includes events from 1903–1989. The official frequency curve and that of SOS 2c are nearly identical. SOS 2c does a good job reflecting current conditions.

4.3.1.8 Spalding flow

The only "official" flood–frequency curve for Spalding (with the effects of Dworshak regulation) was published in 1963 by the Walla Walla District, Corps of Engineers. Dworshak had not yet been constructed, so the regulation of Dworshak was applied to all years which comprised the frequency curve. Unfortunately, the manner in which Dworshak was regulated for the development of the frequency curve is unknown. However, the frequency curve of the unregulated flows at Spalding provide an indication of the expected shape of the SOS 2c curve. From this information, the FCWG concluded that the flood–frequency curve for SOS 2c for Spalding flow was reasonable.

4.3.1.9 The Dalles flow

The frequency curve for The Dalles for SOS 2c is similar enough to the current official frequency curve published in CRT–63 (1987) to realistically represent current system flood control capability.

Table 4–3. Summary of Upper Rule Curves Used

SOS	DWORSHAK	LIBBY	HUNGRY HORSE	GRAND COULEE
1a	CRT–63	CRT–63	CRT–63	CRT–63
1b	CRT–63	CRT–63	CRT–63	CRT–63
2c	Shift to Grand Coulee	CRT–63	CRT–63	Shift from Dworshak
2d	Shift to Grand Coulee	IRC/CRT–63	CRT–63	Shift from Dworshak
4c	VARQ/Elev. Targets	IRC	IRC	IRC
5b	Shift to Lower Snake	CRT–63	CRT–63	CRT–63
5c	Shift to Lower Snake	CRT–63	CRT–63	CRT–63
6b	Shift to Lower Snake	CRT–63	CRT–63	CRT–63
6d	Shift to Lower Snake	CRT–63	CRT–63	CRT–63
9a	Shift to Grand Coulee	CRT–63	CRT–63	Shift from Dworshak
9b	Shift to Grand Coulee	CRT–63	CRT–63	Shift from Dworshak
9c	Shift to Grand Coulee	CRT–63	CRT–63	Shift from Dworshak
PA	Shift to Grand Coulee	CRT–63	CRT–63	Shift from Dworshak

CRT–63 →Official Curve as contained in Columbia River and Tributaries Study, CRT–63 (June, 1991)
IRC → Integrated Rule Curve
VARQ →Variable Outflow, 30 April flood control draft reduced to reflect increased outflows in May–July.

Table 4–4. Summary of SOSs for Birchbank Flow

SOS	No. of Years Above Flood Stage	Max. 1–Day Peak*	Year of Max. Peak	ADOPTED FREQUENCY CURVE Exceedance Frequency				
				1%	10%	50%	90%	99%
1a	1	229,416	1961	232,000	183,000	139,000	106,000	85,900
1b	1	227,456	1961	231,000	188,000	143,000	106,000	81,700
2c	1	231,385	1961	232,000	185,000	143,000	113,000	94,400
2d	0	217,271	1967	245,261	199,858	153,899	117,166	93,009
4c	1	237,201	1961	240,512	189,897	142,117	106,359	83,976
5b	1	230,617	1961	232,946	184,007	141,935	112,968	95,879
5c	1	230,873	1961	232,939	183,993	141,918	112,949	95,861
6b	1	230,617	1961	232,946	184,007	141,935	112,968	95,879
6d	1	230,617	1961	232,946	184,007	141,935	112,968	95,879
9a	1	233,896	1961	232,635	190,387	153,793	128,494	113,603
9b	0	214,238	1967	240,219	196,615	153,784	120,284	98,450
9c	0	219,295	1967	247,190	199,467	153,321	117,851	95,098
PA	0	219,985	1967	244,689	199,508	155,316	120,913	98,586

* Multiply flows in cfs by 0.0283 to convert to m^3/s.

Table 4–5. Summary of SOSs for Bonners Ferry Stage

SOS	No. of Years Above Flood Stage	Max. 1–Day Peak*	Year of Max. Peak	ADOPTED FREQUENCY CURVE Exceedance Frequency				
				1%	10%	50%	90%	99%
1a	1	1767.4	1974	1768.4	1763.4	1757.5	1751.9	1747.6
1b	1	1767.4	1974	1768.9	1763.5	1757.2	1751.3	1746.8
2c	2	1767.2	1974	1768.3	1763.3	1757.6	1752.0	1747.7
2d	1	1767.0	1948	1769.4	1763.7	1757.5	1752.1	1748.2
4c	6	1778.3	1961	1775.8	1769.0	1760.6	1752.3	1745.7
5b	2	1767.4	1974	1768.5	1762.9	1757.0	1751.8	1748.0
5c	2	1767.4	1974	1768.4	1762.9	1757.0	1751.8	1748.1
6b	2	1767.4	1974	1768.5	1762.9	1757.0	1751.8	1748.0
6d	2	1767.4	1974	1768.5	1762.9	1757.0	1751.8	1748.0
9a	4	1770.3	1934	1769.2	1765.8	1762.0	1758.6	1756.0
9b	4	1770.3	1934	1769.5	1765.0	1759.3	1753.4	1748.5
9c	6	1774.5	1948	1774.8	1767.5	1759.3	1751.7	1746.1
PA	9	1770.3	1934	1770.1	1766.1	1760.7	1754.9	1749.9

* Multiply elevations in feet by 0.3048 to convert to meters

Table 4–6. Summary of SOSs for Columbia Falls Flow

SOS	No. of Years Above Flood Stage	Max. 1–Day Peak*	Year of Max. Peak	ADOPTED FREQUENCY CURVE Exceedance Frequency				
				1%	10%	50%	90%	99%
1a	13	159,465	1964	90,000	65,000	42,000	27,000	19,500
1b	12	159,465	1964	90,000	65,000	42,000	27,000	19,500
2c	14	156,320	1964	90,000	65,000	42,000	27,000	19,500
2d	14	156,320	1964	109,816	70,019	42,665	27,599	20,182
4c	16	158,795	1964	105,823	72,662	44,966	27,251	17,833
5b	14	159,465	1964	90,000	65,000	42,000	27,000	19,500
5c	14	159,465	1964	111,116	69,401	42,038	27,564	20,640
6b	14	159,465	1964	90,000	65,000	42,000	27,000	19,500
6d	14	159,465	1964	90,000	65,000	42,000	27,000	19,500
9a	19	156,320	1964	103,111	71,767	46,779	31,042	22,512
9b	14	161,118	1964	107,291	72,066	45,041	28,709	20,173
9c	16	158,795	1964	106,012	72,583	44,754	27,019	17,624
PA	19	161,118	1964	113,169	71,484	44,497	30,367	23,674

* Multiply flows in cfs by 0.0283 to convert to m^3/s.

Table 4–7. Summary of SOSs for Flathead Lake Elevation

SOS	No. of Years Above Flood Stage	Max. 1-Day Peak*	Year of Max. Peak	ADOPTED FREQUENCY CURVE Exceedance Frequency				
				1%	10%	50%	90%	99%
1a	7	2894.2	1964	2894.7	2893.1	2893.1	2893.1	2893.1
1b	6	2894.2	1964	2894.7	2893.1	2893.1	2893.1	2893.1
2c	10	2894.6	1964	2894.7	2893.1	2893.1	2893.1	2893.1
2d	10	2896.6	1964	2894.7	2893.1	2893.1	2893.1	2893.1
4c	11	2895.3	1964	2894.7	2893.1	2893.1	2893.1	2893.1
5b	9	2894.2	1964	2894.7	2893.1	2893.1	2893.1	2893.1
5c	9	2894.2	1964	2894.7	2893.1	2893.1	2893.1	2893.1
6b	9	2894.2	1964	2894.7	2893.1	2893.1	2893.1	2893.1
6d	9	2894.2	1964	2894.7	2893.1	2893.1	2893.1	2893.1
9a	6	2894.8	1964	2894.7	2893.1	2893.1	2893.1	2893.1
9b	10	2894.7	1964	2894.7	2893.1	2893.1	2893.1	2893.1
9c	11	2894.8	1964	2894.7	2893.1	2893.1	2893.1	2893.1
PA	14	2895.1	1964	2895.5	2894.0	2893.1	2893.1	2893.1

* Multiply elevations in feet by 0.3048 to convert to meters

Table 4–8. Summary of SOSs for Flathead Lake Outflow

SOS	No. of Years Above Flood Stage	Max. 1–Day Peak*	Year of Max. Peak	ADOPTED FREQUENCY CURVE Exceedance Frequency				
				1%	10%	50%	90%	99%
1a	36	65,274	1964	80,000	52,000	37,100	19,300	10,000
1b	34	65,212	1964	80,000	52,000	37,100	19,300	10,000
2c	36	68,213	1964	80,000	52,000	37,100	19,300	10,000
2d	42	83,007	1974	80,000	52,000	37,100	19,300	10,000
4c	41	69,869	1964	80,000	52,000	37,100	19,300	10,000
5b	38	65,265	1964	80,000	52,000	37,100	19,300	10,000
5c	38	65,356	1964	80,000	52,000	37,100	19,300	10,000
6b	38	65,265	1964	80,000	52,000	37,100	19,300	10,000
6d	38	65,265	1964	80,000	52,000	37,100	19,300	10,000
9a	43	69,478	1964	80,000	52,000	37,100	19,300	10,000
9b	39	68,380	1964	80,000	52,000	37,100	19,300	10,000
9c	39	69,470	1964	80,000	52,000	37,100	19,300	10,000
PA	41	68,250	1964	87,000	61,000	42,700	26,300	10,000

* Multiply flows in cfs by 0.0283 to convert to m^3/s.

Table 4–9. Summary of SOSs for Lake Pend Oreille Elevation

SOS	No. of Years Above Flood Stage	Max. 1–Day Peak*	Year of Max. Peak	ADOPTED FREQUENCY CURVE Exceedance Frequency				
				1%	10%	50%	90%	99%
1a	16	2068.4	1948	2070.3	2065.2	2062.5	2062.5	2062.5
1b	16	2068.3	1948	2070.3	2065.2	2062.5	2062.5	2062.5
2c	17	2069.1	1948	2070.3	2065.2	2062.5	2062.5	2062.5
2d	24	2069.1	1948	2070.3	2065.2	2062.5	2062.5	2062.5
4c	19	2069.1	1948	2070.3	2065.2	2062.5	2062.5	2062.5
5b	17	2068.5	1948	2070.3	2065.2	2062.5	2062.5	2062.5
5c	17	2068.5	1948	2070.3	2065.2	2062.5	2062.5	2062.5
6b	17	2068.5	1948	2070.3	2065.2	2062.5	2062.5	2062.5
6d	17	2068.5	1948	2070.3	2065.2	2062.5	2062.5	2062.5
9a	19	2069.1	1948	2070.3	2065.2	2062.5	2062.5	2062.5
9b	20	2069.1	1948	2070.3	2065.2	2062.5	2062.5	2062.5
9c	20	2069.1	1948	2070.3	2065.2	2062.5	2062.5	2062.5
PA	19	2069.1	1948	2070.3	2065.2	2062.5	2062.5	2062.5

* Multiply elevations in feet by 0.3048 to convert to meters

Table 4–10. Summary of SOSs for Lake Pend Oreille Outflow

SOS	No. of Years Above Flood Stage	Max. 1–Day Peak*	Year of Max. Peak	ADOPTED FREQUENCY CURVE Exceedance Frequency				
				1%	10%	50%	90%	99%
1a	25	148,935	1948	170,000	125,000	82,200	36,500	14,000
1b	25	148,753	1948	170,000	125,000	82,200	36,500	14,000
2c	26	154,744	1948	170,000	125,000	82,200	36,500	14,000
2d	32	154,738	1948	170,000	125,000	82,200	36,500	14,000
4c	27	155,253	1948	170,000	125,000	82,200	36,500	14,000
5b	26	149,887	1948	170,000	125,000	82,200	36,500	14,000
5c	26	149,889	1948	170,000	125,000	82,200	36,500	14,000
6b	26	149,887	1948	170,000	125,000	82,200	36,500	14,000
6d	26	149,887	1948	170,000	125,000	82,200	36,500	14,000
9a	28	154,956	1948	170,000	125,000	82,200	36,500	14,000
9b	28	155,256	1948	170,000	125,000	82,200	36,500	14,000
9c	26	155,226	1948	170,000	125,000	82,200	36,500	14,000
PA	28	155,257	1948	170,000	125,000	82,200	36,500	14,000

* Multiply flows in cfs by 0.0283 to convert to m^3/s.

Table 4–11. Summary of SOSs for Spalding Flow

SOS	No. of Years Above Flood Stage	Max. 1–Day Peak*	Year of Max. Peak	ADOPTED FREQUENCY CURVE Exceedance Frequency				
				1%	10%	50%	90%	99%
1a	1	124,470	1948	120,000	87,400	60,700	43,400	33,700
1b	1	124,470	1948	120,000	88,200	59,600	39,600	28,000
2c	1	124,470	1948	118,000	90,600	63,600	43,300	30,900
2d	1	124,470	1948	118,600	88,765	63,039	45,413	35,124
4c	1	130,335	1948	122,045	92,346	62,643	40,289	26,980
5b	1	130,335	1948	124,556	92,872	61,725	38,786	25,431
5c	1	130,335	1948	122,890	92,544	62,362	39,808	26,476
6b	1	130,335	1948	122,890	92,543	62,362	39,807	26,476
6d	1	130,335	1948	122,890	92,543	62,362	39,807	26,476
9a	1	124,470	1948	124,124	88,206	59,770	41,813	31,971
9b	1	124,470	1948	116,174	91,181	66,046	46,483	34,149
9c	1	124,470	1948	122,218	88,405	60,305	41,780	31,366
PA	1	124,470	1948	119,881	89,308	62,238	43,374	32,312

* Multiply flows in cfs by 0.0283 to convert to m^3/s.

Table 4–12. Summary of SOSs for The Dalles Flow

SOS	No. of Years Above Flood Stage	Max. 1–Day Peak*	Year of Max. Peak	ADOPTED FREQUENCY CURVE Exceedance Frequency				
				1%	10%	50%	90%	99%
1a	20	780,135	1948	792,000	587,000	412,000	294,000	225,000
1b	20	775,978	1948	775,000	588,000	408,000	274,000	193,000
2c	22	782,598	1948	779,000	592,000	416,000	288,000	211,000
2d	18	754,046	1948	800,580	591,000	407,289	280,683	207,205
4c	18	758,432	1948	774,703	597,322	408,731	260,459	170,610
5b	23	784,719	1948	772,762	592,828	416,558	283,626	202,405
5c	23	784,719	1948	772,762	592,828	416,558	283,626	202,405
6b	19	711,283	1948	766,694	576,822	401,139	274,583	199,199
6d	23	789,858	1948	770,740	592,394	417,299	284,909	203,810
9a	20	758,369	1948	732,465	562,763	412,231	305,916	242,170
9b	23	761,401	1948	775,008	587,338	412,267	284,950	208,425
9c	13	741,831	1948	772,542	557,691	384,731	273,609	211,806
PA	22	760,683	1948	793,207	587,990	407,277	282,105	209,119

* Multiply flows in cfs by 0.0283 to convert to m^3/s.

CHAPTER 5

COMPARISON OF ALTERNATIVES

5.1 GENERAL DISCUSSION

This chapter will compare and contrast the SOSs. In many cases, the frequency curve for every location for one SOS is the same as for another SOS. Where differences exist, they will be noted with an explanation of what caused them and why. See Table 5–1 for a station–by–station summary of which SOSs were unique and/or similar. Exhibit A presents comparison graphs of each location's frequency curve for each SOS to the corresponding curve for SOS 2c (the no–action alternative). In Exhibit B, each graph presents a probability plot of the 50 year study period of maximum annual peak flow or stage with its adopted frequency curve drawn through the plotted points.

The 1990–91 Detailed Operating Plan (DOP) for Columbia River Treaty Storage was used as to specify the operation of Mica, Arrow, and Duncan. In almost all cases, the amount of 30 April draft at Mica was far more than required for flood control, which overstates flood control capability. Therefore, any recommendations from the SOR process which call for modification of flood control criteria will be subject to detailed study by the Corps of Engineers to evaluate the true effect to flood control of any change in project operation.

5.2 BIRCHBANK FLOW

For Birchbank flow, only SOS 9a was significantly different from SOS 2c. All other SOSs produced frequency curves similar to SOS 2c. See Tables 4–4 and 5–1 and Exhibit A for a comparison of alternatives for Birchbank flow. In general, the DOP should have produced nearly identical frequency curves at Birchbank for all of the SOSs. However for SOS9a, additional water was released from Libby for sturgeon which raised the pool of Kootenay Lake, which produced more outflow and raised the flows at Birchbank.

5.3 BONNERS FERRY STAGE

For Bonners Ferry stage, SOSs 4c, 9a, 9b, 9c, and PA were significantly different from SOS 2c and from one another. All other SOSs produced frequency curves similar to SOS 2c, 4c, 9a, 9b, 9c, or PA. The effect for all when compared to SOS 2c is increased flooding at Bonners Ferry. SOS 4c caused the most damages, followed by SOS 9c, SOS 9b, SOS 9a, and SOS PA. See Tables 4–5 and 5–1 and Exhibit A for a comparison of alternatives for Bonners Ferry stage.

The "Integrated Rule Curves (IRC)" alternative (SOS 4c) has attempted to accommodate flood control. A combination of DOP at Duncan, releases from Libby, winter runoff patterns, and Kootenay Lake maximum elevation limits imposed by the International Joint Commission (IJC) are controlling flood levels at Bonners Ferry. The higher winter elevation targets imposed by the IRCs, coupled with above average winter runoff make it impossible to evacuate the prescribed amount of water from Libby by 30 April without violating the IJC limits at Kootenay Lake. As a result, Libby cannot be drafted as prescribed, Bonners Ferry loses flood protection, and the resultant frequency curves at Bonners Ferry in these SOSs are significantly higher than the SOS 2c frequency curve. In general, scenarios that feature additional releases from Libby Dam for sturgeon produce more outflow which ultimately raises the flows at Bonners Ferry. This situation can be exacerbated when Lake Kookanusa is held high from regulation to Integrated Rule Curves. This can happen even if the IRCs are not in effect, but the IRCs exacerbate this condition.

5.4 COLUMBIA FALLS FLOW

For Columbia Falls, only SOS 9a was significantly different from SOS 2c. All other SOSs produced frequency curves similar to SOS 2c, or 9a. SOS 9a increased flood damages over SOS 2c. Significantly increased flows from Hungry Horse in April and May in all study years resulted in raising the SOS 9a frequency curve across all probabilities. See Tables 4–6 and 5–1 and Exhibit A for a comparison of alternatives for Columbia Falls flow.

5.5 FLATHEAD LAKE ELEVATION

For Flathead Lake elevation, only SOS PA was significantly different from SOS 2c. All other SOSs produced frequency curves similar to SOS 2c or PA. SOS PA increased flood damages over SOS 2c. In SOS5 and SOS6, Dworshak was removed from proportional draft requiring Hungry Horse and Libby to be drafted heavier than in SOS 2c to try and meet power demand. This caused an increase in flows from Hungry Horse, which caused inflows to Flathead Lake to increase, thereby raising the maximum annual forebay elevation. This accounts for the minor differences in the plotted points in the frequency curves of SOS 2c, SOS5, and SOS6. In real–time operation, foreknowledge of the interaction of the operations of Dworshak, Hungry Horse and Libby would reduce the number of times that Flathead Lake rises to above normal full pool. See Tables 4–7 and 5–1 and Exhibit A for a comparison of alternatives for Flathead Lake elevation.

When the frequency curves for SOS 2c, and PA are plotted together, the SOS PA curve shifts to the left of SOS 2c (see Figure 5–1), which ultimately forces Flathead to above normal maximum pool more frequently. Flathead's normal maximum pool is exceeded about about once every 10 years in SOS 2c and once every 4 years in SOS PA.

5.6 FLATHEAD LAKE/KERR DAM OUTFLOW

For Flathead Lake outflow, SOS PA was significantly different from SOS 2c. All other SOSs produced frequency curves similar to SOS 2c or SOS PA. SOS PA produced a higher frequency curve (more damages) than SOS 2c, but only for low to moderately high flows. The increase in outflows from SOS 2c to SOS PA is due to the increased elevations of Flathead Lake which increased the outflows of Kerr Dam. See Tables 4–8 and 5–1 and Exhibit A for a comparison of alternatives for Flathead Lake outflow.

5.7 LAKE PEND OREILLE ELEVATION

For Lake Pend Oreille elevation, all SOSs produced frequency curves similar to SOS 2c. See Tables 4–9 and 5–1 and Exhibit A for a comparison of alternatives for Lake Pend Oreille elevation. See paragraph 4.2.6 for details of the operation of Lake Pend Oreille.

5.8 LAKE PEND OREILLE/ALBENI FALLS OUTFLOW

For Lake Pend Oreille outflow, all SOSs produced frequency curves similar to SOS 2c. See Tables 4–10 and 5–1 and Exhibit A for a comparison of alternatives for Lake Pend Oreille outflow. See paragraph 4.2.6 for details of the operation of Lake Pend Oreille.

5.9 SPALDING FLOW

For Spalding flow, all SOSs produced frequency curves similar to SOS 2c. See Tables 4–11 and 5–1 and Exhibit A for a comparison of alternatives for Spalding flow.

5.10 THE DALLES FLOW

The true barometer of system flood control impacts is The Dalles frequency curve. SOSs 9a, and 9c were significantly different from one other and from SOS 2c. All other SOSs produced frequency curves similar to SOS 2c, 9a, or 9c. See Tables 4–12 and 5–1 and Exhibit A for a comparison of alternatives for The Dalles flow. Table 4–12 assumes that flooding starts at 450,000 cfs (12,735 m^3/s), but it is recognized that minor "nuisance flooding" starts at 200,000 cfs (5665 m^3/s), and serious flooding does not really start until flows reach 450,000 cfs (12,735 m^3/s). The combined short–term storage of the four lower Snake projects produced a flood control benefit at the Dalles for the full range of exceedance frequencies for SOS 6b. Drawing down Lower Granite only (as in SOS 6d) has no flood control effect on The Dalles.

The operation of each upstream storage project affects flow at The Dalles. In some cases, operations at two or more projects can be self–compensating, i.e., for an SOS, one project's operation can increase flows while flows can be reduced at another resulting in no net effect on flow at The Dalles. Thus there can be increased local flooding at one upstream location but no increased flooding at The Dalles.

5.11 SUMMARY OF RESULTS

- There were no SOSs specifically designed to view the effects of altering system or local flood control, yet each of the SOSs had flood control woven into its fabric.
- All SOSs which incorporate the Integrated Rule Curves decrease flood control capability both locally and at The Dalles. The development and supporting technical material of the IRCs are still under development.
- The effects on flood control due exclusively to VARQ rule curves (see paragraph 4.2.1) are not demonstrated in any of the SOSs because the use of VARQ is combined with other operational considerations. The FCWG believes, however, that VARQ has the potential to be an effective operational tool, which could result in increased spring flows with minimal impact to flood control capability. Future studies will determine the feasibility and rules of implementation of VARQ.
- All of the alternatives in SOS 1, SOS 2, SOS 4, SOS 5, and SOS PA produced the same results for flood control at all locations, i.e., no change from the no–action alternative.
- Flow augmentation raises and flattens out the lower end of a flood control frequency curve. This results in higher minimum flows sustained for longer periods of time which could conflict with the design criteria of levees and may increase dissolved gases. Therefore, even though the magnitude of the damaging flood peaks does not change, structural stress on levees may still occur. The FCWG recommends consideration be given to mitigation for levee degradation.
- Reservoir elevation targets raise the upper end of a flood control frequency curve. This results in higher peak flows and greater flood damages.
- All four Lower Snake projects must be drawn down (SOS 6b) for a flood control benefit to be realized at The Dalles. Drawing down Lower Granite only (SOS 6d), has little or no effect on flood control.
- The only location which receives a flood control benefit when compared to SOS 2c is The Dalles.

Table 5–1. SOS Comparison Matrix for Flood Control Work Group

SOS	BIRB	BFEI	CFMM	KERR ELEV	KERR FLOW	ALF ELEV	ALF FLOW	SPDI	TDA
1a	2c*	2c	2c	2c	2c	2c	2c	2c	2c
1b	2c	2c	2c	2c	2c	2c	2c	2c	2c
2c	NAA	NAA	NAA	NAA	NAA	NAA	NAA	NAA	NAA
2d	2c	2c	2c	2c	2c	2c	2c	2c	2c
4c	2c	X	2c	2c	2c	2c	2c	2c	2c
5b	2c	2c	2c	2c	2c	2c	2c	2c	2c
5c	2c	2c	2c	2c	2c	2c	2c	2c	2c
6b	2c	2c	2c	2c	2c	2c	2c	2c	X
6d	2c	2c	2c	2c	2c	2c	2c	2c	2c
9a	X	X	X	2c	2c	2c	2c	2c	X
9b	2c	X	2c	2c	2c	2c	2c	2c	2c
9c	2c	X	2c	2c	2c	2c	2c	2c	X
PA	2c	X	2c	X	X	2c	2c	2c	2c

* Each entry indicates to which other SOS the SOS in question is the same, e.g., for Birchbank, the frequency curve for SOS1a is the same as SOS2c. SOS 2c is the No-Action Alternative (NAA).

BIRB = Birchbank BFEI = Bonners Ferry CFMM = Columbia Falls ALF = Albeni Falls
SPDI = Spalding TDA = The Dalles X = Frequency curve significantly different from any other SOS

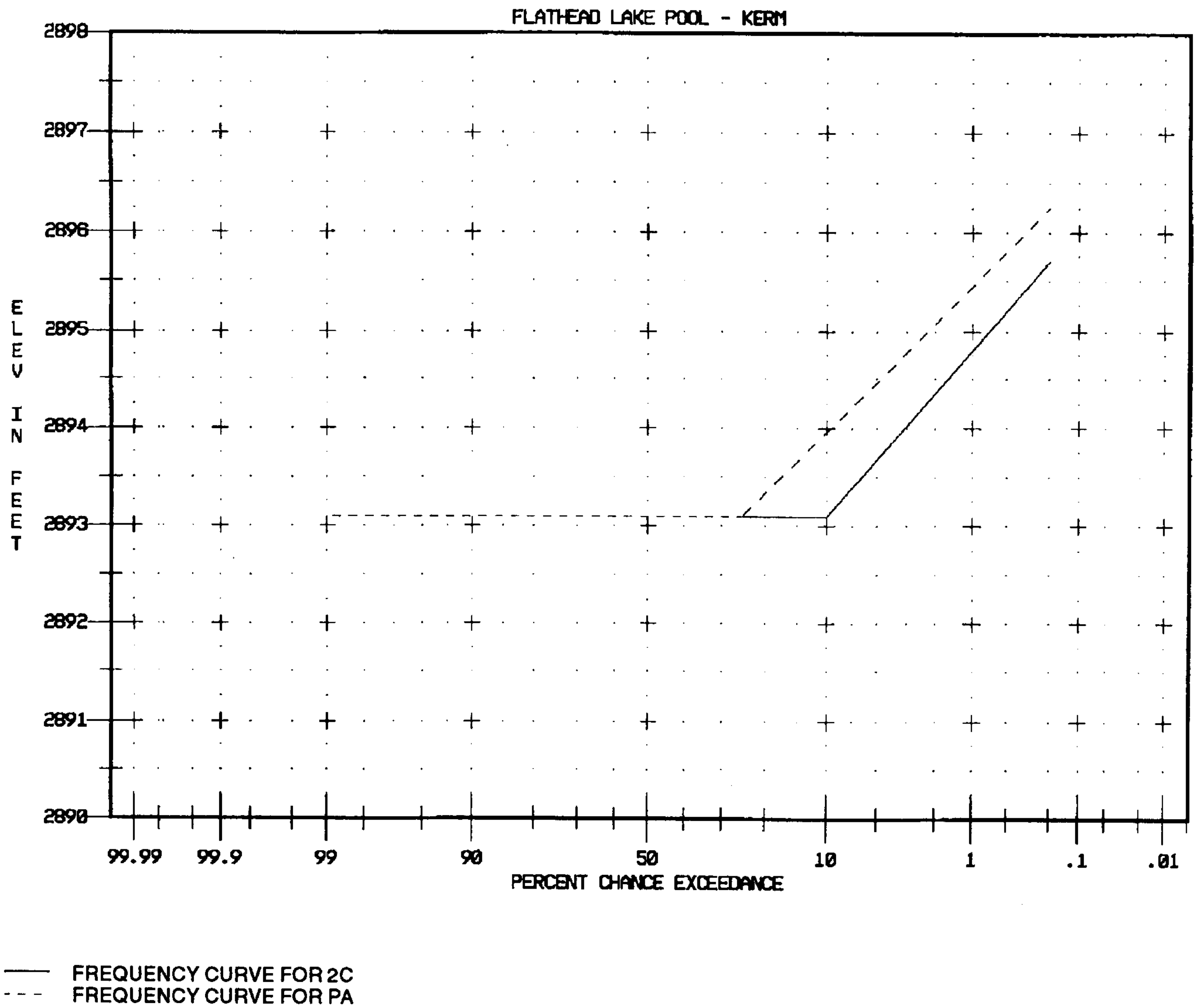

Figure 5–1. Frequency Curve for Flathead Lake Pool

CHAPTER 6

LIST OF PREPARERS

6.1 LIST OF PREPARERS

Table 6–1 gives a list of the preparers of this manual.

Table 6–1. List of Preparers

Name	Education/ (Years of Experience)	Experience & Expertise	Role in Preparation
Peter F. Brooks	M.S. Engineering B.S. Engineering Technology 20 years	Hydrology (flood control) and Water Resource Management	Technical and Impacts Analysis and Principal Author
Douglas D. Speers	M.S. Engineering B.S. Engineering 35 years	Hydrology (flood control) and Water Resource Management	Technical Analysis, Author, and Detailed Review
Patrick McGrane	M.S. Engineering B.S. Watershed Sciences 5 years	Hydrology and Reservoir Regulation	Technical Analysis, Author, and Detailed Review
Brian Kuepper	B.S. Engineering 5 years	Reservoir Operations	Author and Review
Dan Yribar	M.B.A. B.S. Engineering 25 years	Hydrology and Reservoir Operations	Technical Analysis and Review
James D. Ruff	M.S. Water Resources Management B.S. Engineering 20 years	Hydrology and Reservoir Operations	Technical Analysis and Review
Kelvin Ketchum	M.S. Engineering B.S. Engineering 15 years	Hydrology and Reservoir Operations	Review
Dave Reese	M.S. Engineering B.S. Engineering 20 years	Hydrology and Water Control	Review
William Gordon	B.S. Engineering 35 years	Hydrology and Reservoir Operations	Author and Review

CHAPTER 7

GLOSSARY

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

AUTOREG: A computer model specifically designed as a pre/post processor for the SSARR Model.

Biological Rule Curves: Curves developed in an attempt at optimizing reservoir elevations and discharges to meet fishery needs. Target levels are a function of the volume runoff forecast. The curves consider power and flood control requirements.

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

Control Points: Specific locations on river systems that serve as indicators in appraising the size and magnitude of flood events. For example, the gage at Bonners Ferry, Idaho is the control point below Libby Dam.

Critical Rule Curves (CRC): Graphic or tabular representations of reservoir storage water levels under critical streamflow conditions at various times of the year during all years of a critical period.

Cubic feet per second (cfs): A measurement of water flow representing one cubic foot of water moving past a given point in one second. One cfs is equal to 7.48 gallons per second and 0.028 m^3 per second.

Detailed Operating Plan (DOP): A strategy for regulation of the Canadian Columbia River Treaty projects negotiated on an annual basis by the Columbia River Treaty Operating Committee, a group consisting of representatives of the Corps, BPA, Reclamation, and BC Hydro. In and attempt to reflect the most current water availability and system demands, the DOP is an updated version of the Assured Operating Plan agreed upon by the Committee for long range planning six years earlier. If the Committee is unable to agree upon a satisfactory Detailed Operating Plan, then the Assured Operating Plan will govern Canadian Treaty project regulation in any given year.

Draft: Reduction of amount of water stored in a reservoir, usually measured in acre–feet or feet.

Drawdown: The distance the water surface of a reservoir is lowered from a given elevation as a result of withdrawing water.

Firm Energy Load Carrying Capability (FELCC): The amount of firm energy that the region's hydroelectric system, and individual system or project can be called on to produce during actual operations from all firm resources.

Flood Control Rule Curve (FCRC): A curve, or group of curves, indicating reservoir elevation or drawdown required to control floods.

Flood–Frequency Curve: A graphic presentation which indicates the probability that a particular flood event will be equalled or exceeded in any given year.

Flow Augmentation: Strategy which provides more water in the rivers than was historically provided to move juvenile fish rapidly downstream.

Headwater Project: The highest upstream dam in a given river basin. Libby, Hungry Horse and Dworshak are considered headwater projects.

Operating Rule Curve: A curve, or group of curves, indicating how a reservoir is to be operated under specific conditions and for specific purposes.

Outflow Diagram: Chart that is used to determine discharge from dams required as a function of the volume runoff forecast.

Pacific Northwest Coordination Agreement: A binding agreement among BPA, the Corps, Reclamation, and the major 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 system for power production. It directs operation of major generating facilities as though they belonged to a single owner.

Rule curves: Graphic representations of water levels, used to guide reservoir operations.

Run–of–river dams: Dams that provide little or no flood control storage. They often feature hydroelectric generating plants that operate based only on available streamflow and minimal short–term storage (hourly, daily, or weekly).

Spill: Water that passes over a spillway without going through turbines.

SSARR Model: (Streamflow Synthesis And Reservoir Regulation model) A computer model created to simulate the Columbia River System on a daily basis.

Storage Reservation Diagram: Chart used for flood control operations to determine reservoir evacuation requirements as a function of the volume runoff forecast.

Storage reservoirs: Reservoirs that have space for retaining water from springtime snowmelt. Retained water is released as necessary for multiple uses – power production, fish passage, irrigation, and navigation.

Upper Rule Curve: Representation of monthly flood requirements from SRD for system regulation studies.

VARQ: (Variable Discharge based on forecast) A strategy that allows greater releases from headwater projects during the refill period and correspondingly less draft when volume runoff forecasts are low.

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

Zero Damage Level: The stage or discharge associated with a control point which is the lower limit where damages occur, sometimes referred to as bankfull.

ACRONYMS AND ABBREVIATIONS

BPA	Bonneville Power Administration
BRC	Biological Rule Curves
CEAA	Canadian Entitlement Allocation Agreements
cfs	cubic feet per second
CORPS	U.S. Army Corps of Engineers
DOP	Detailed Operating Plan
EIS	Environmental Impact Study
ESA	Endangered Species Act
FCRC	Flood Control Rule Curve
FCWG	Flood Control Work Group
USFS	U.S. Forest Service
USF&WS	U.S. Fish and Wildlife Service
IJC	International Joint Commission
IRG	Integrated Rule Curve
maf	million acre feet
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NPS	National Park Service
NWPCC	Northwest Power Planning Council
PNCA	Pacific Northwest Coordination Agreement
PNUCC	Pacific Northwest Utilities Conference Committee
SEIS	Supplemental Environmental Impact Study
SOR	System Operation Review
SOS	System Operation Strategy
SRD	Storage Reservation Diagram
SSARR	Streamflow Synthesis and Reservoir Regulation Model
URC	Upper Rule Curve
USBR	U.S. Bureau of Reclamation
VARQ	Variable Discharge based on forecast

TECHNICAL

EXHIBIT A

FREQUENCY CURVE COMPARISONS, SOS 2C VS. ALL OTHERS

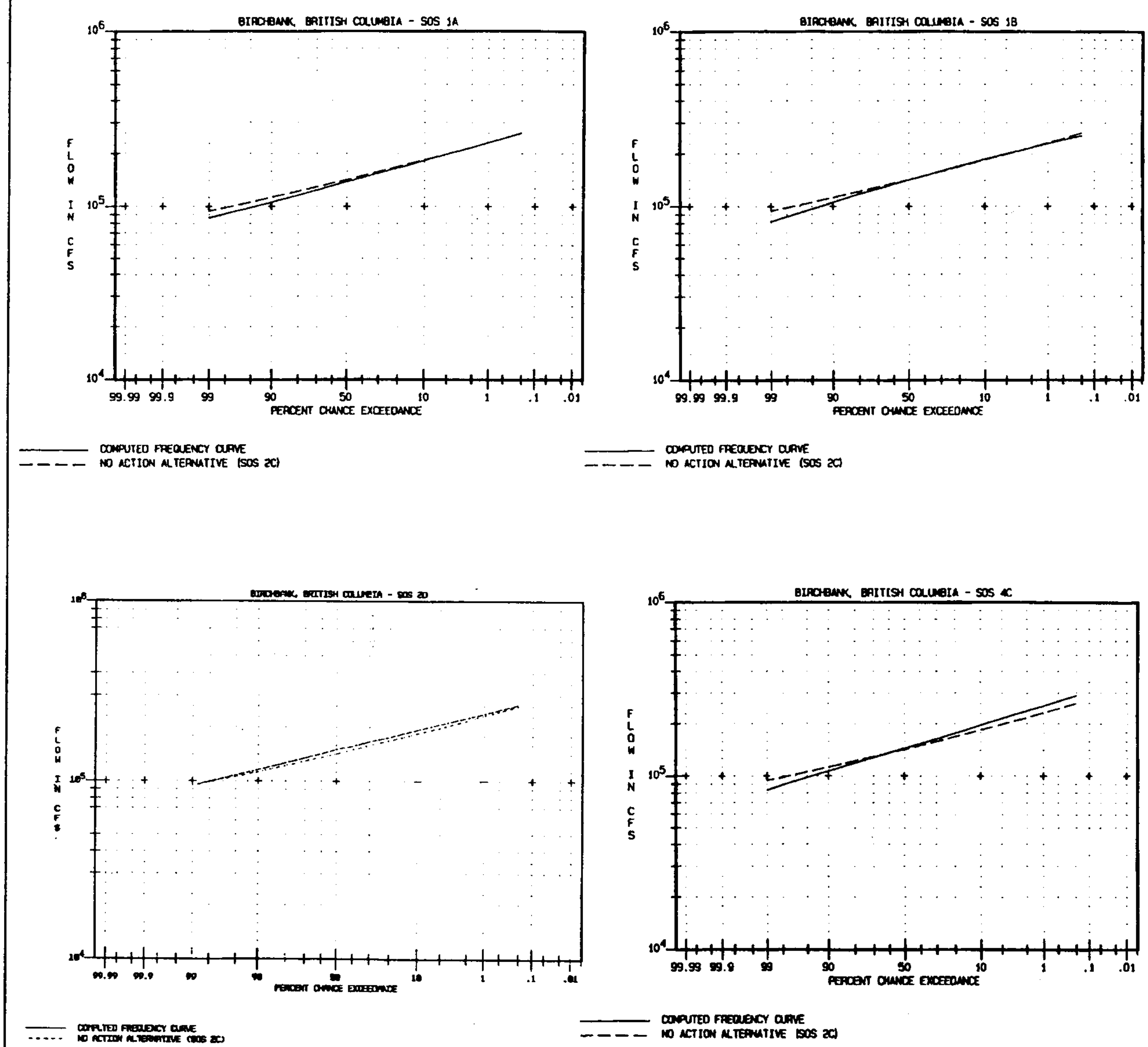

Figure A–1. Frequency Curve Comparison, SOS 2C vs. Birchbank, British Columbia

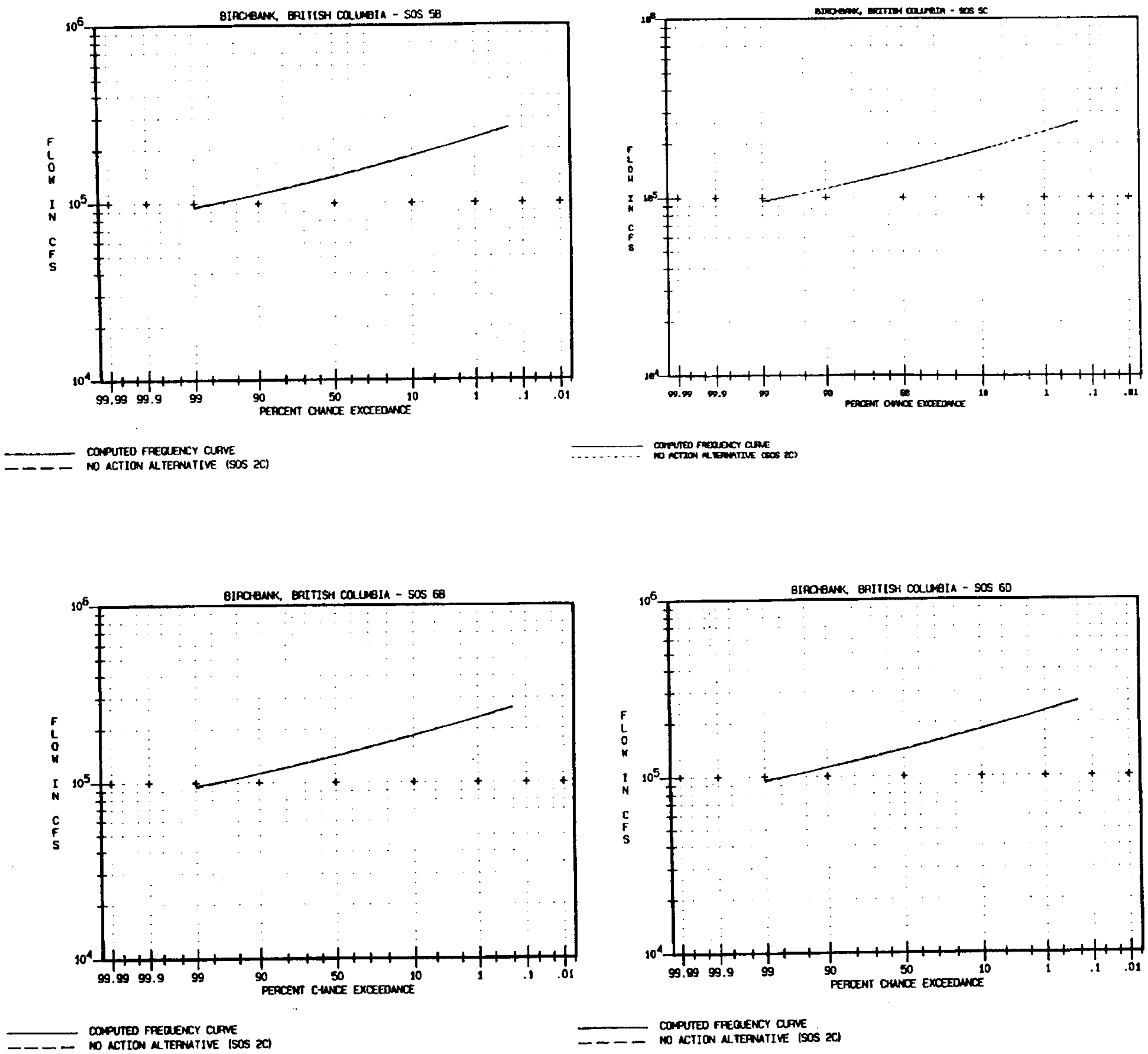

Figure A–1. Frequency Curve Comparison, SOS 2C vs. Birchbank, British Columbia – CONT

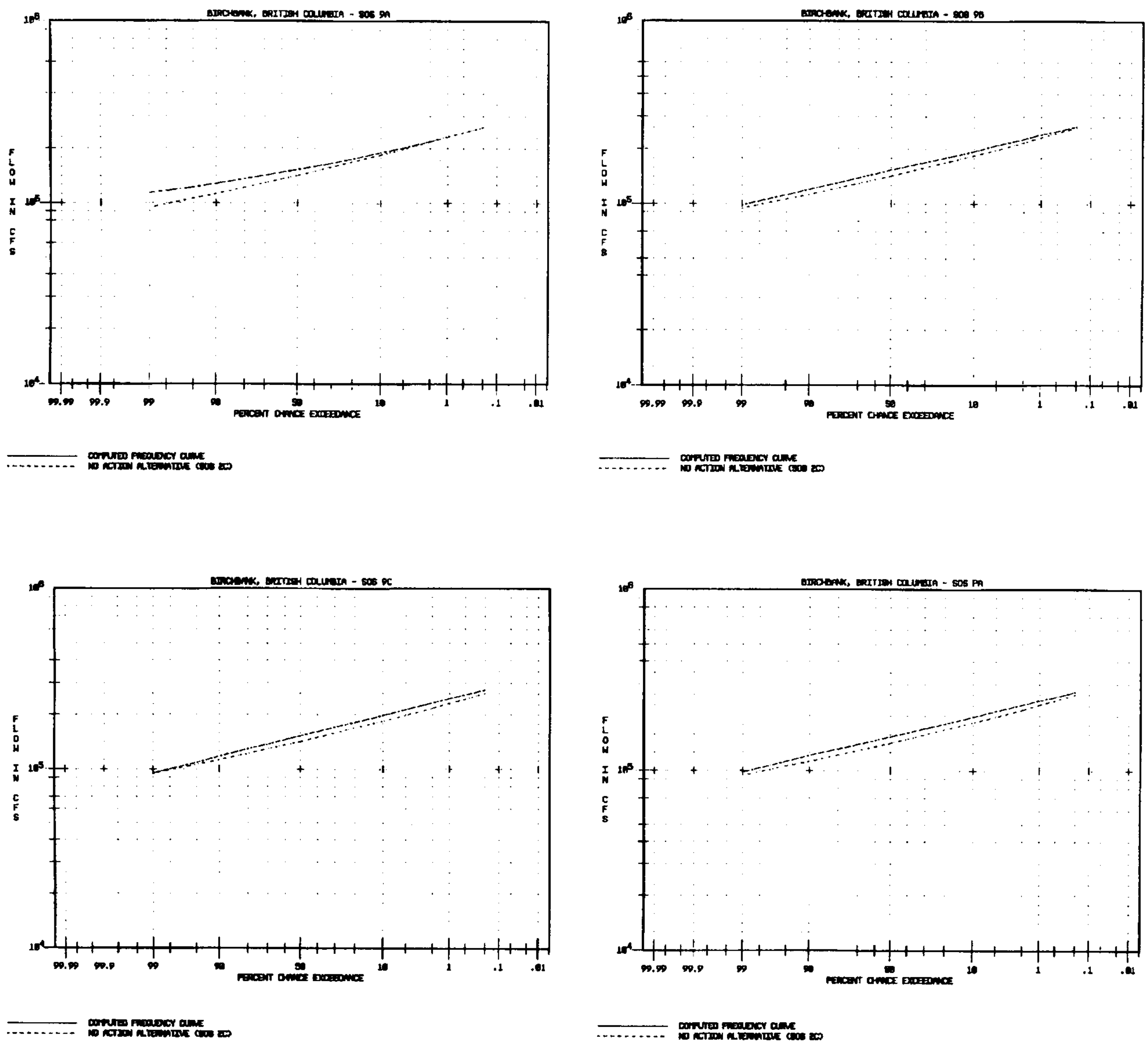

Figure A–1. Frequency Curve Comparison, SOS 2C vs. Birchbank, British Columbia – CONT

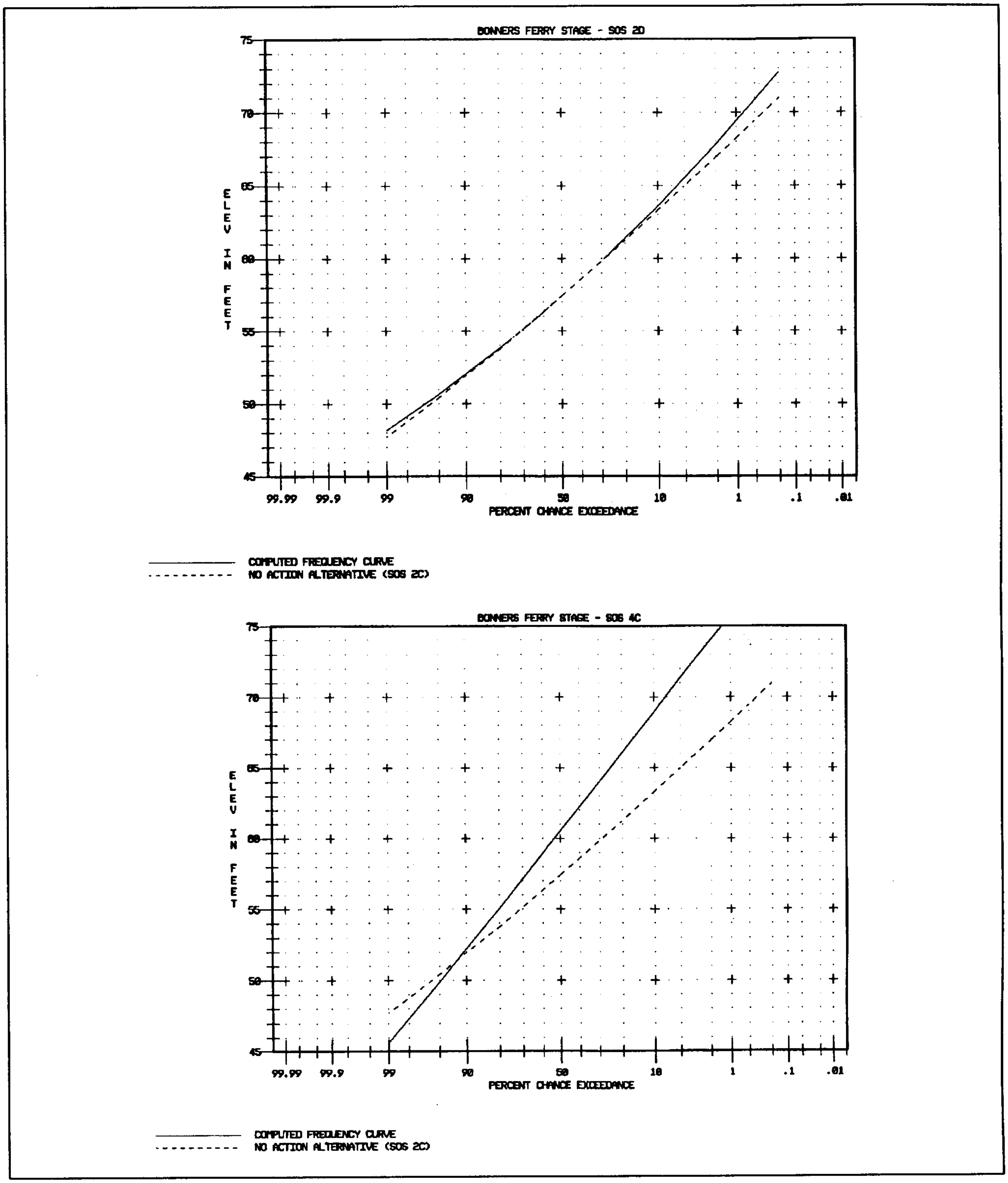

Figure A–2. Frequency Curve Comparison, SOS 2C vs. Bonners Ferry Stage

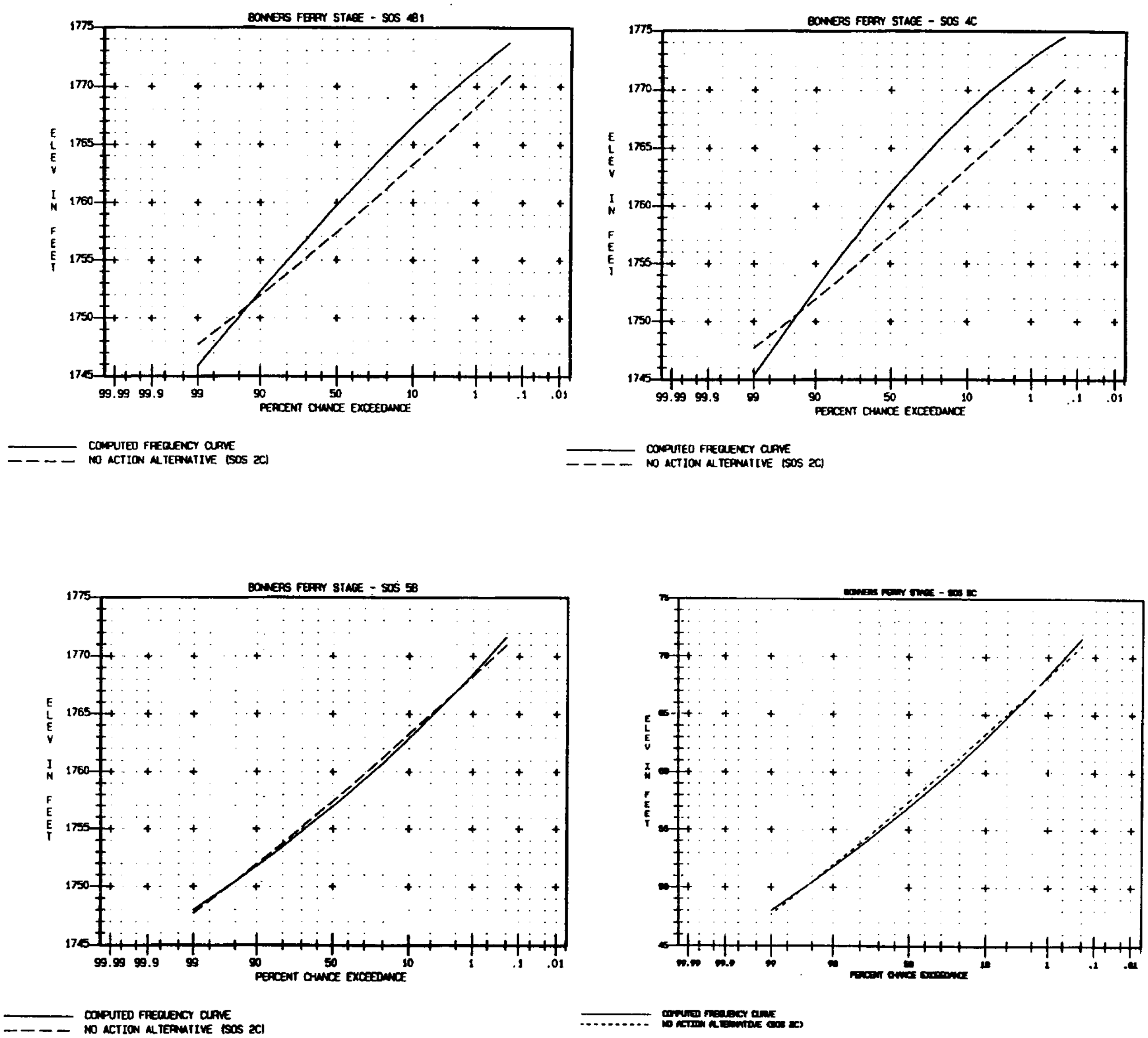

Figure A–2. Frequency Curve Comparison, SOS 2C vs. Bonners Ferry Stage – CONT

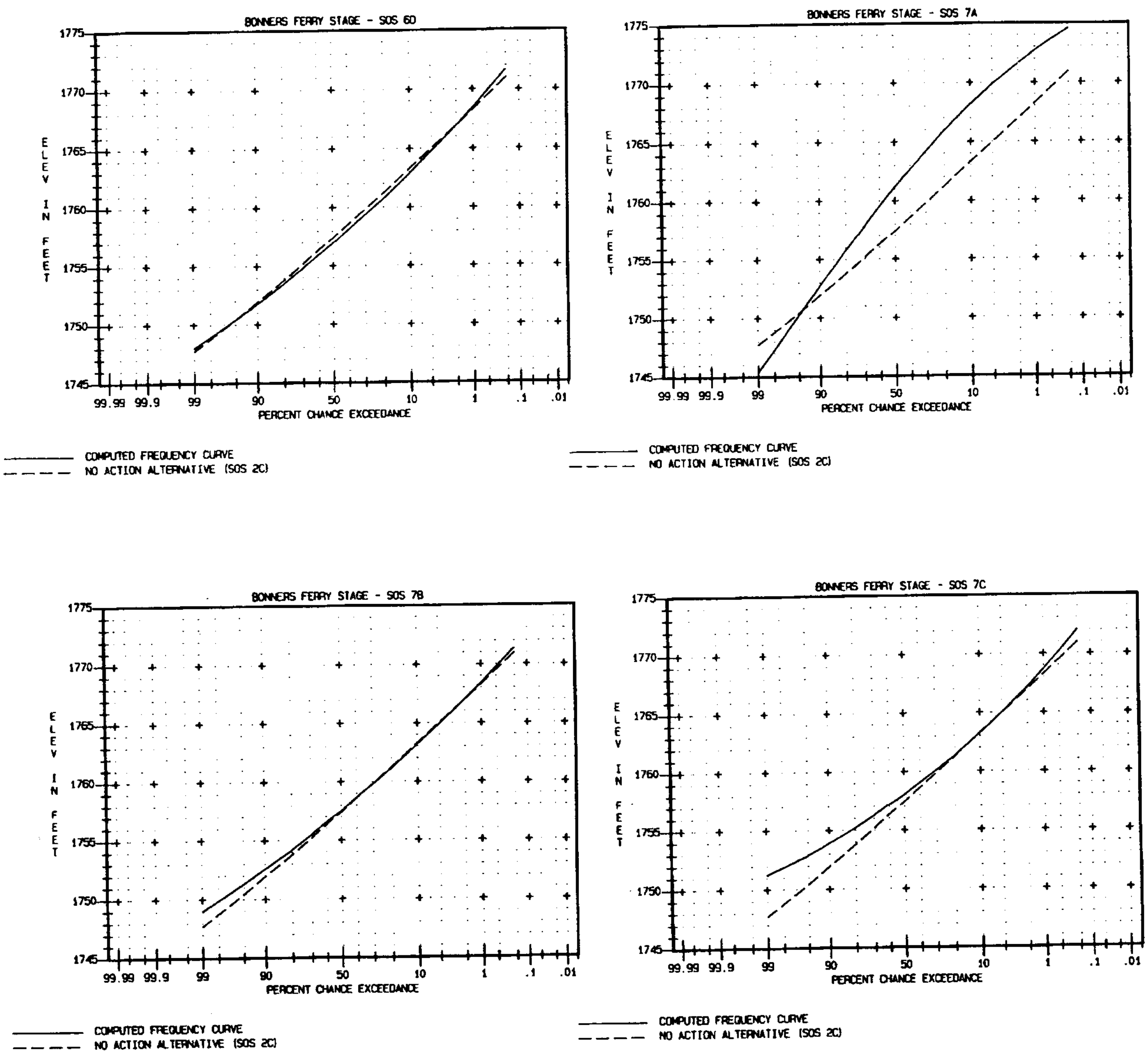

Figure A–2. Frequency Curve Comparison, SOS 2C vs. Bonners Ferry Stage – CONT

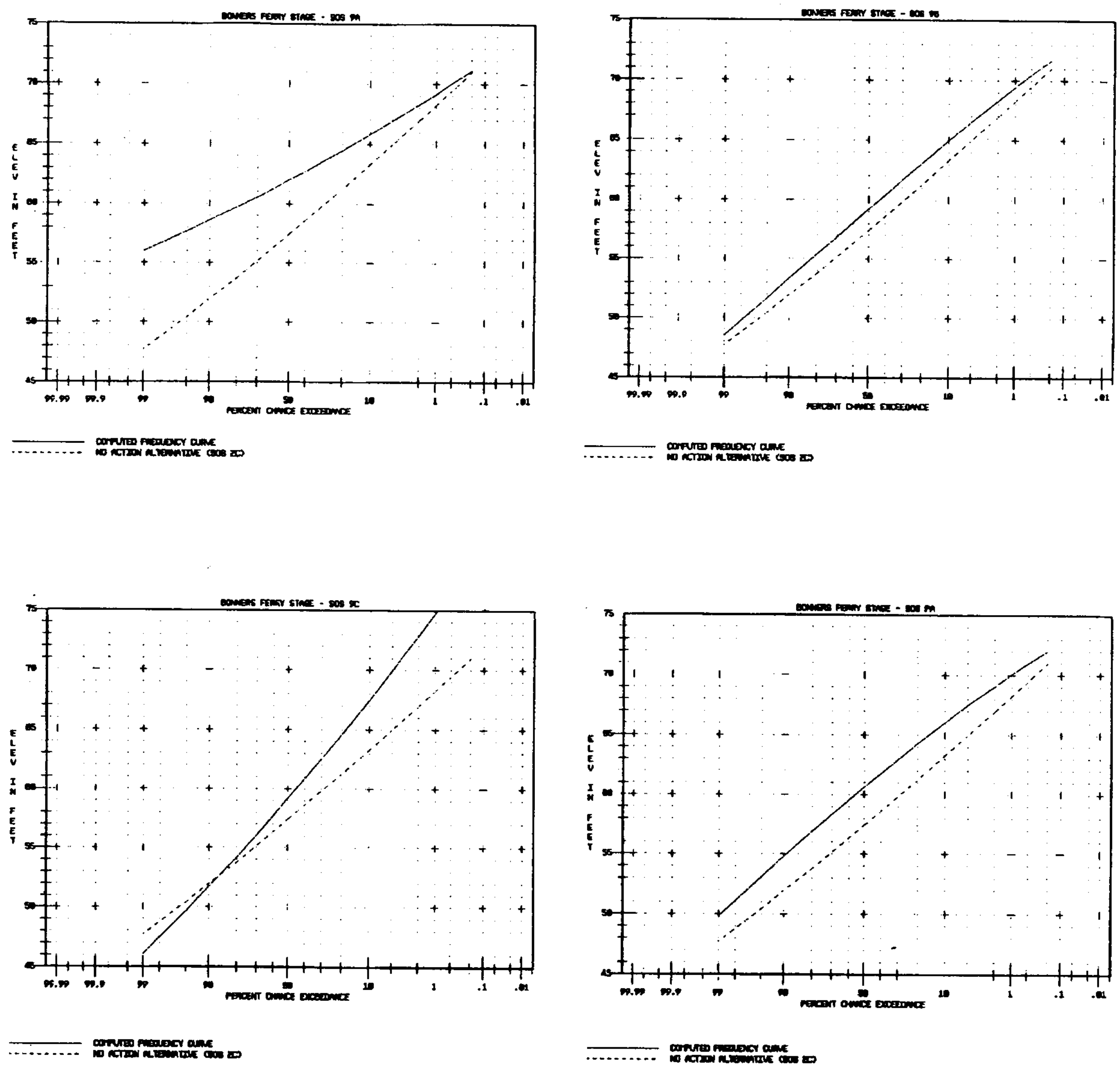

Figure A–2. Frequency Curve Comparison, SOS 2C vs. Bonners Ferry Stage – CONT

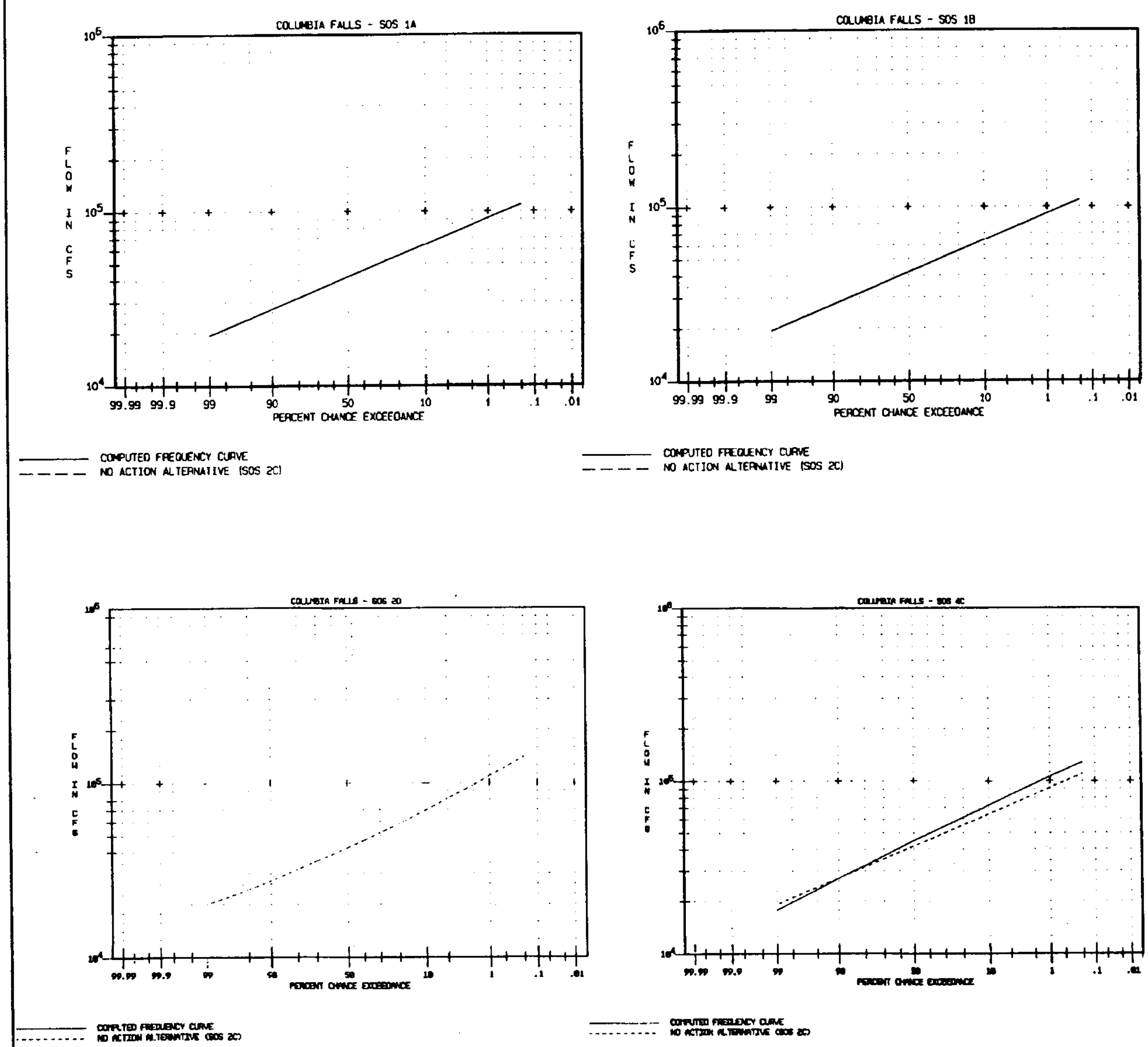

Figure A–3. Frequency Curve Comparison, SOS 2C vs. Columbia Falls

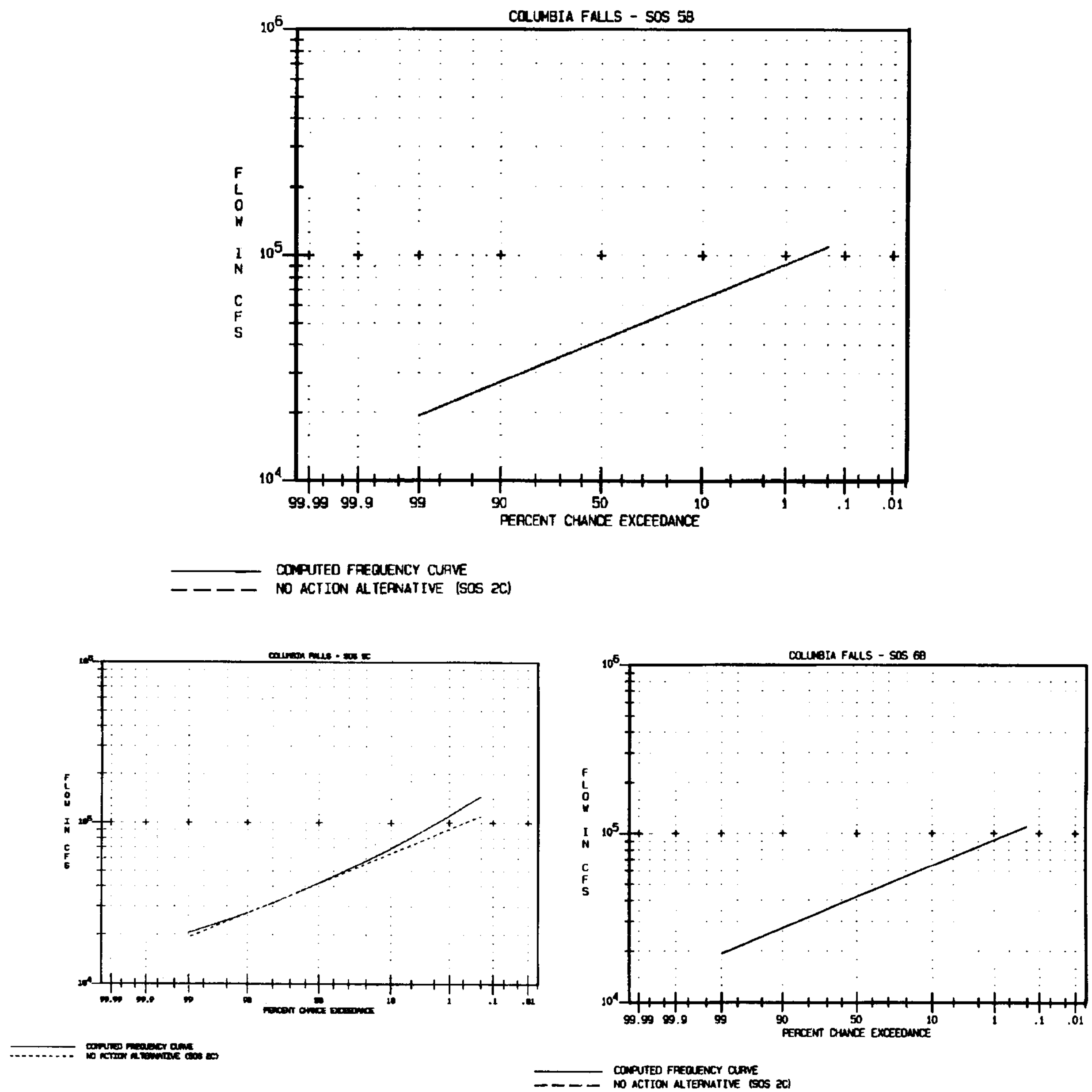

Figure A–3. Frequency Curve Comparison, SOS 2C vs. Columbia Falls – CONT

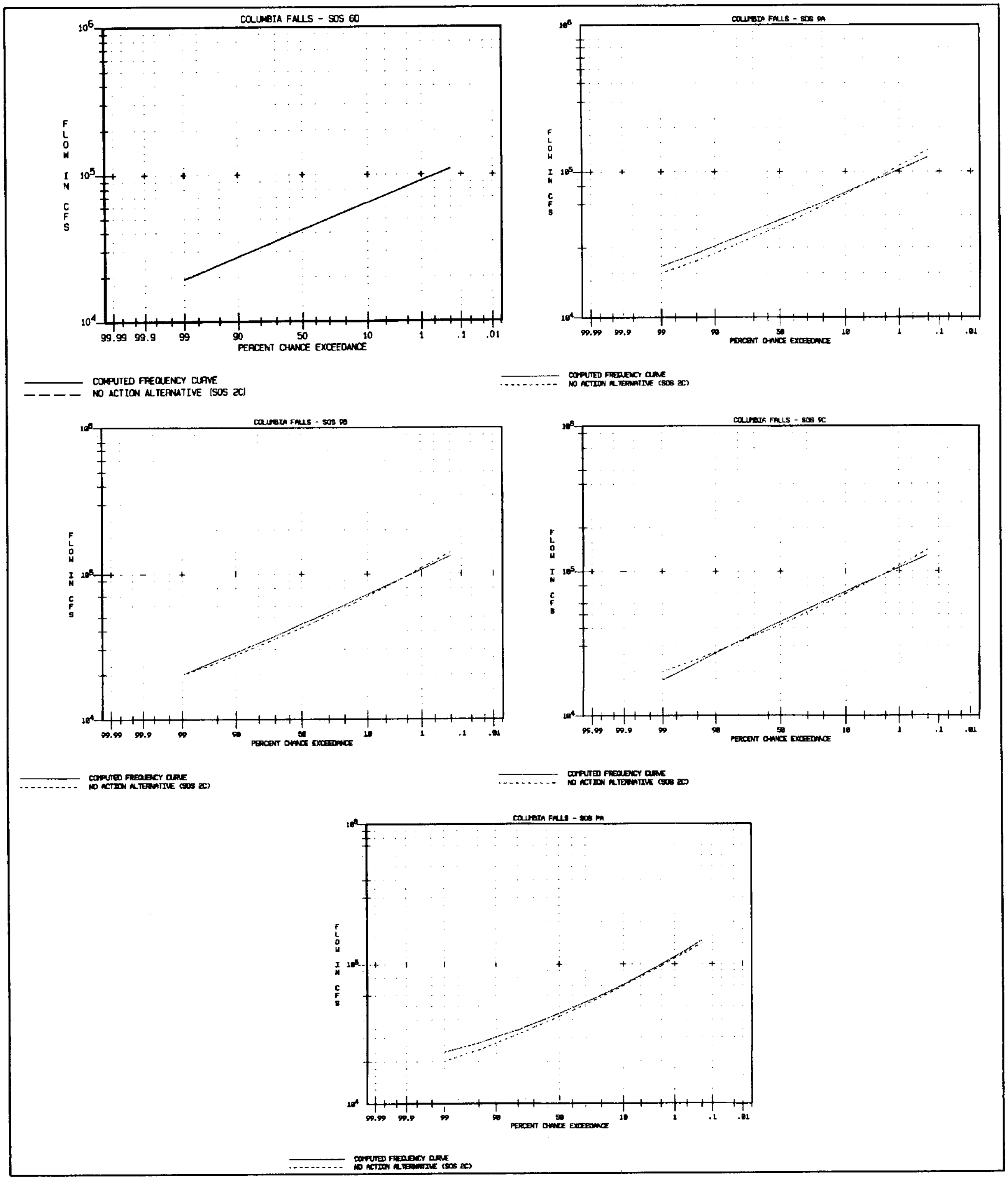

Figure A–3. Frequency Curve Comparison, SOS 2C vs. Columbia Falls – CONT

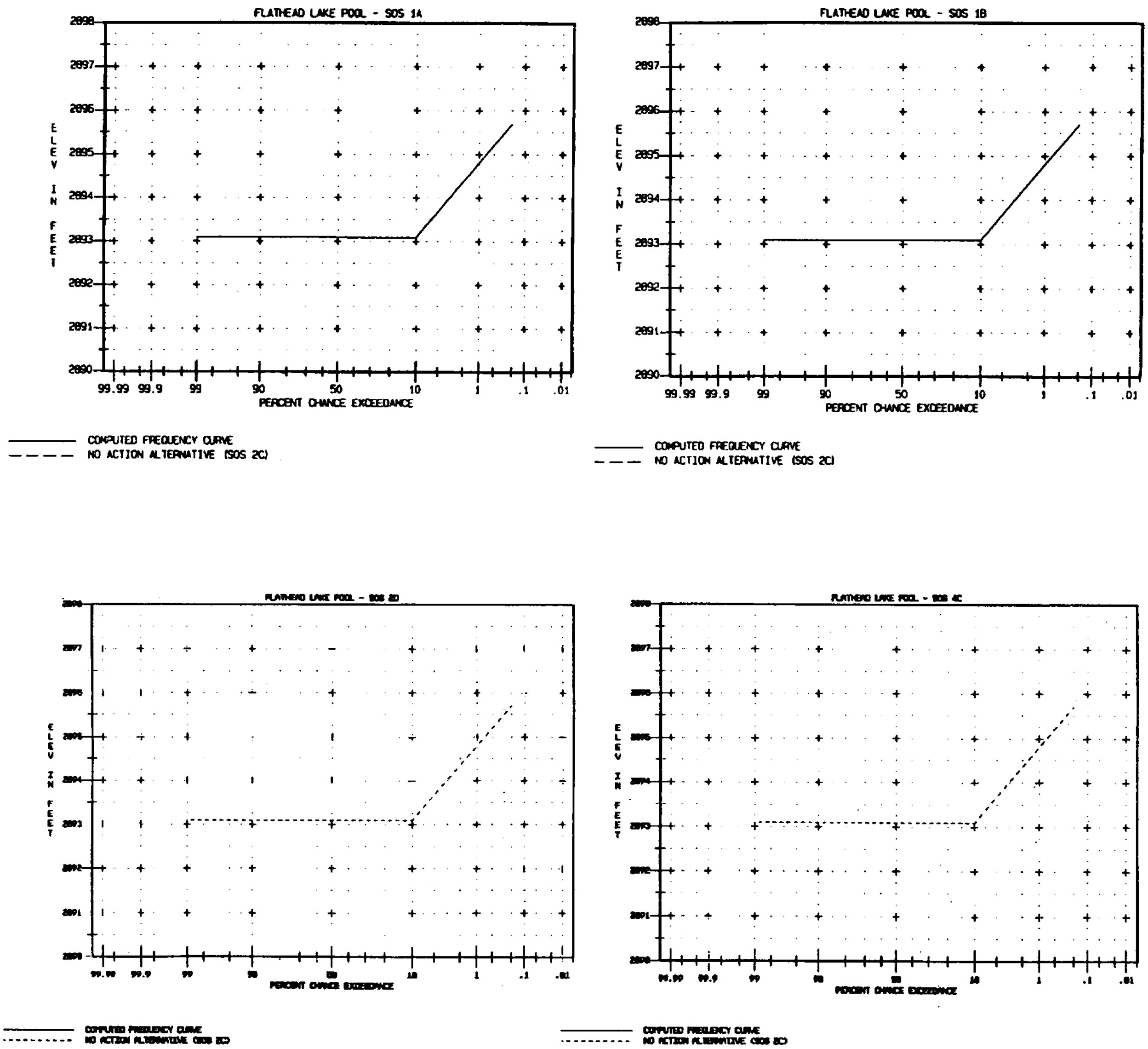

Figure A–4. Frequency Curve Comparison, SOS 2C vs. Flathead Lake Pool

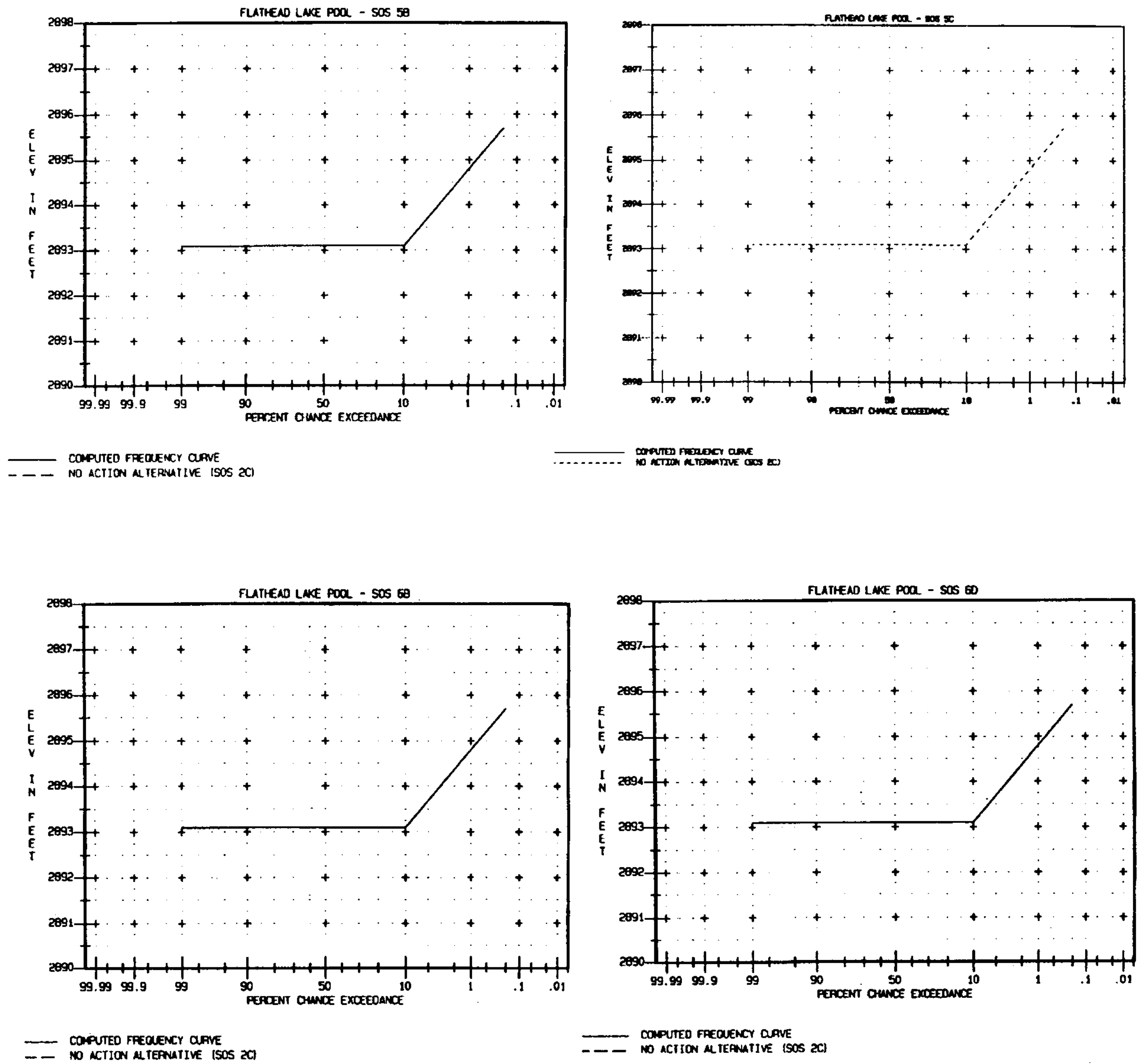

Figure A–4. Frequency Curve Comparison, SOS 2C vs. Flathead Lake Pool – CONT

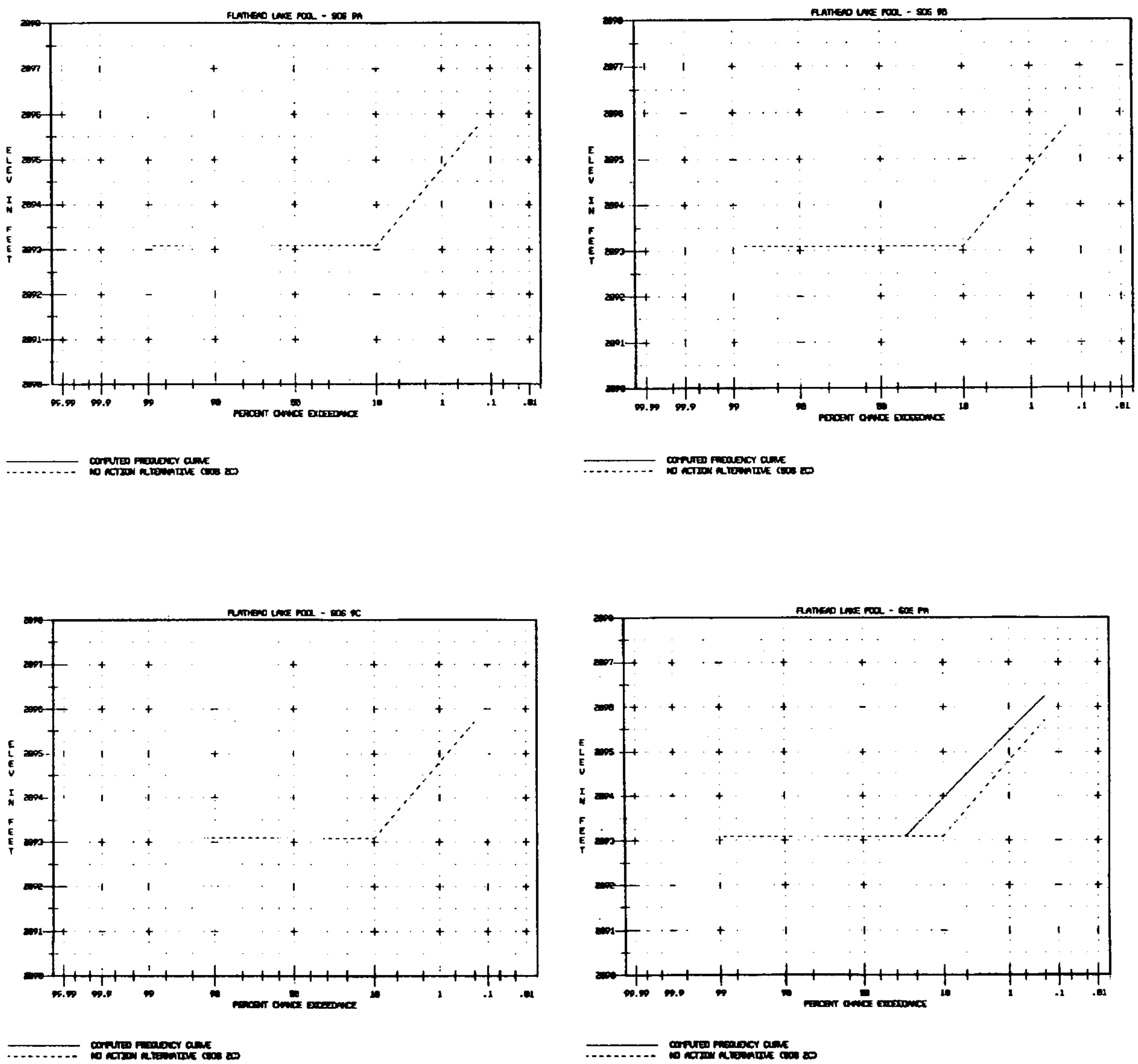

Figure A–4. Frequency Curve Comparison, SOS 2C vs. Flathead Lake Pool – CONT

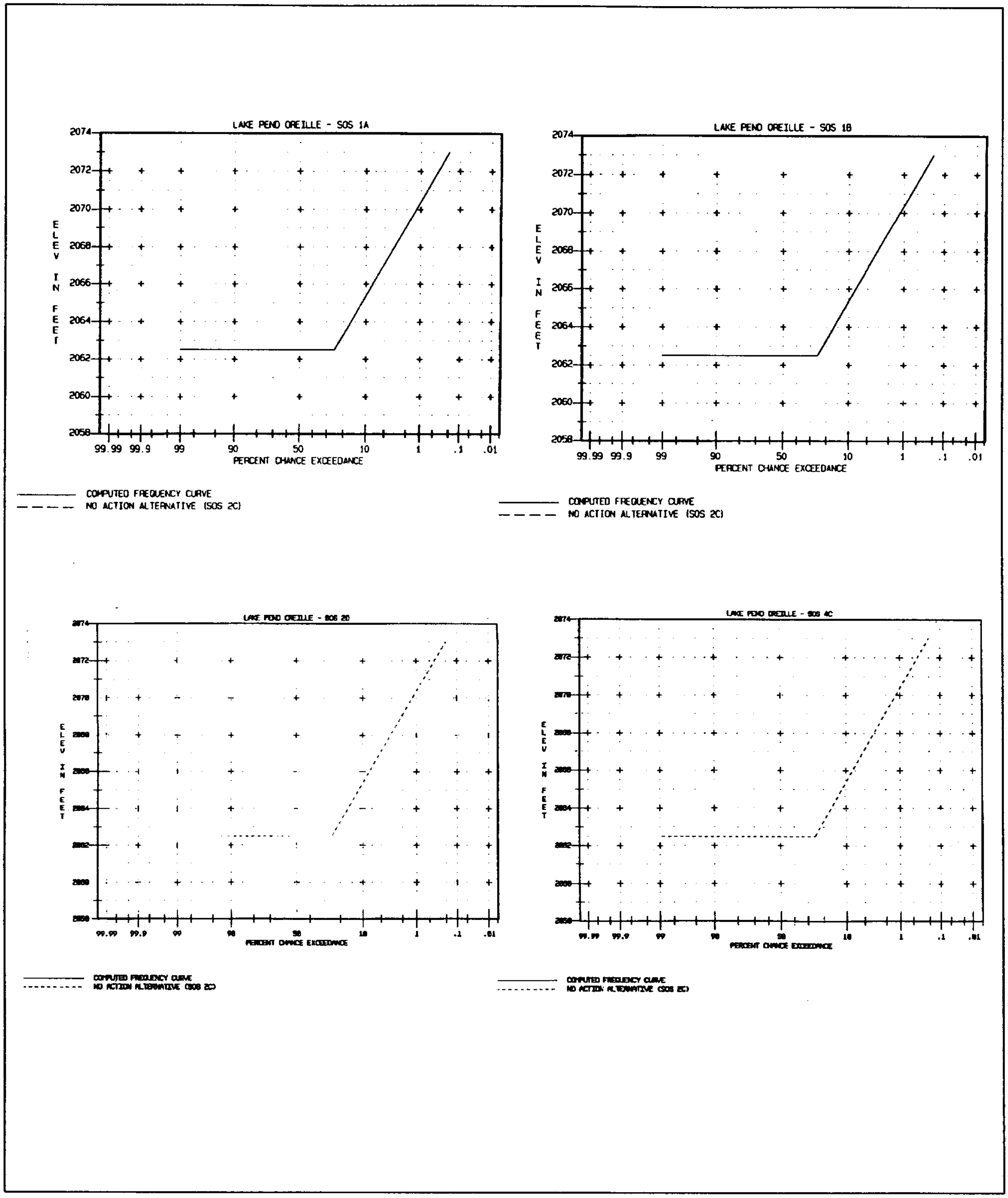

Figure A–5. Frequency Curve Comparison, SOS 2C vs. Lake Pend Oreille Outflow

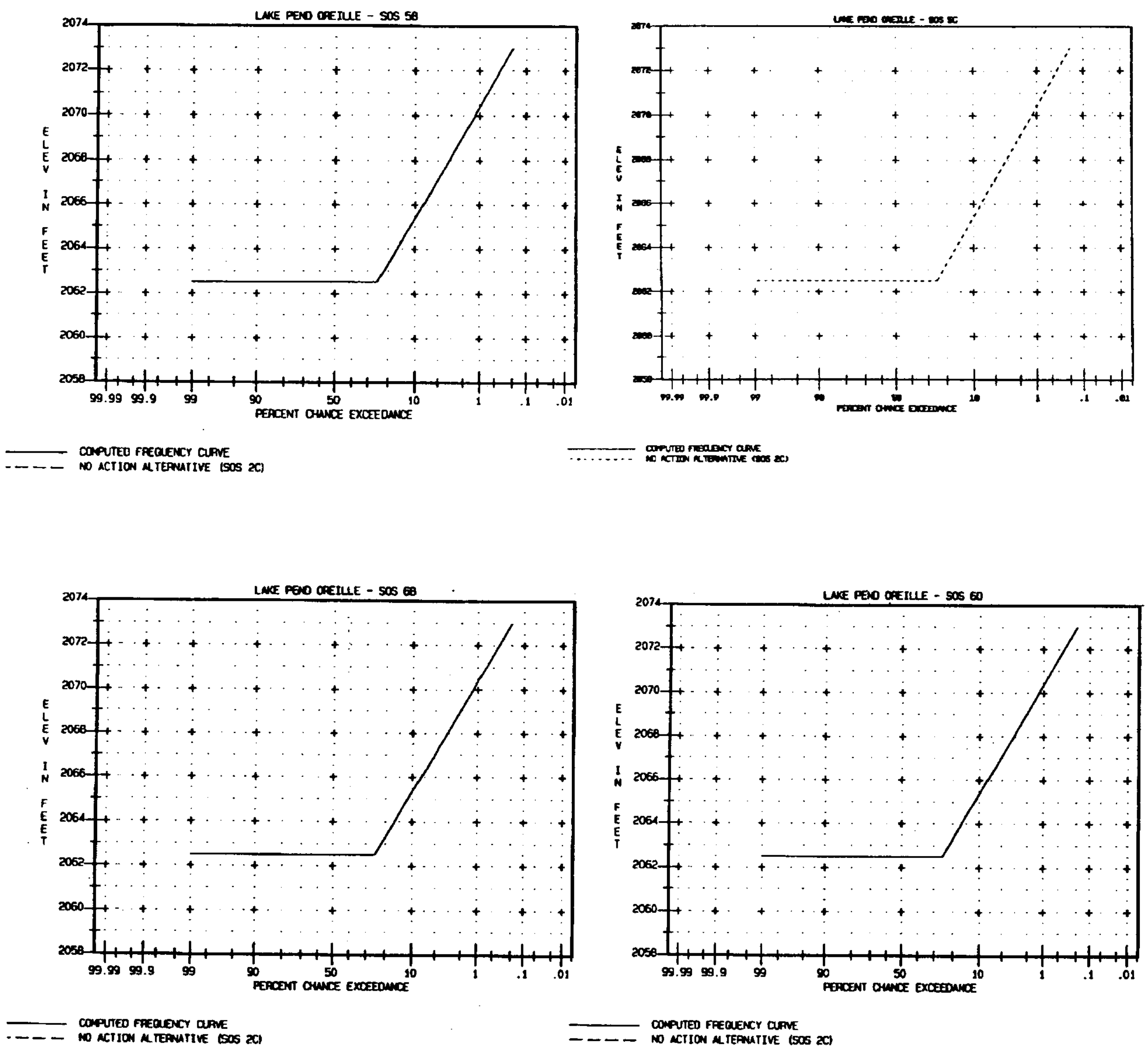

Figure A–5. Frequency Curve Comparison, SOS 2C vs. Lake Pend Oreille Outflow – CONT

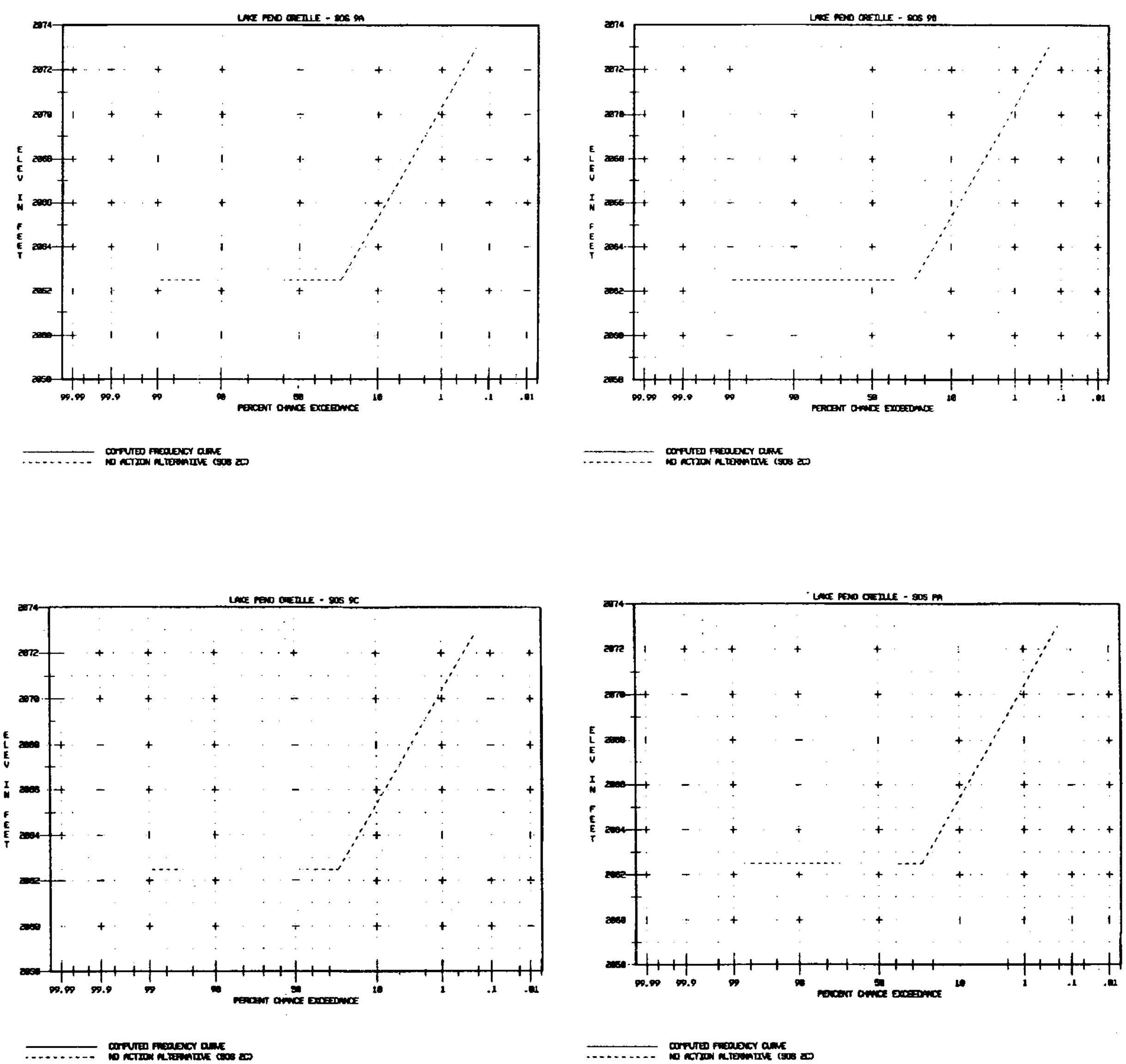

Figure A–5. Frequency Curve Comparison, SOS 2C vs. Lake Pend Oreille Outflow – CONT

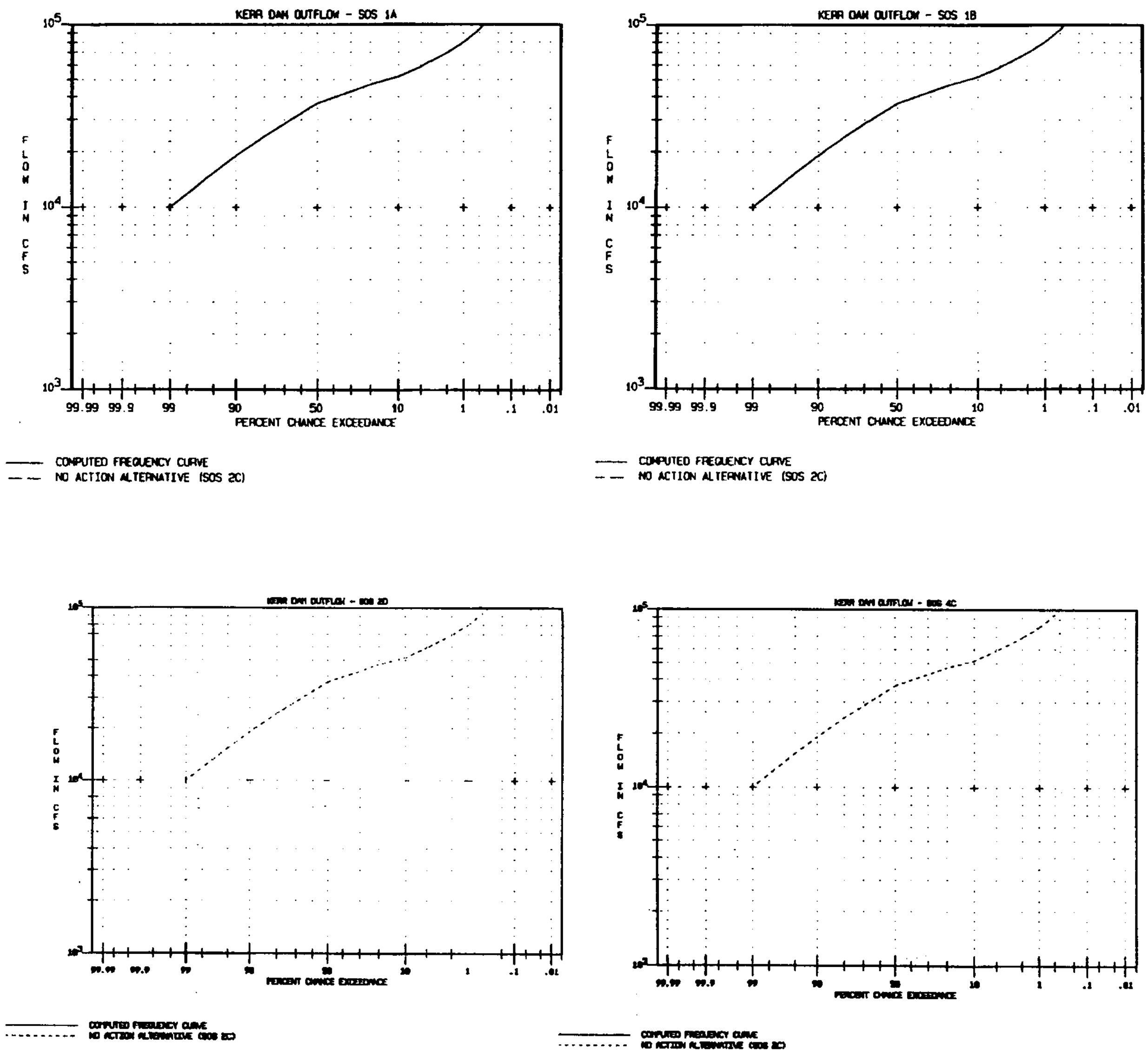

Figure A-6. Frequency Curve Comparison, SOS 2C vs. Kerr Dam Overflow

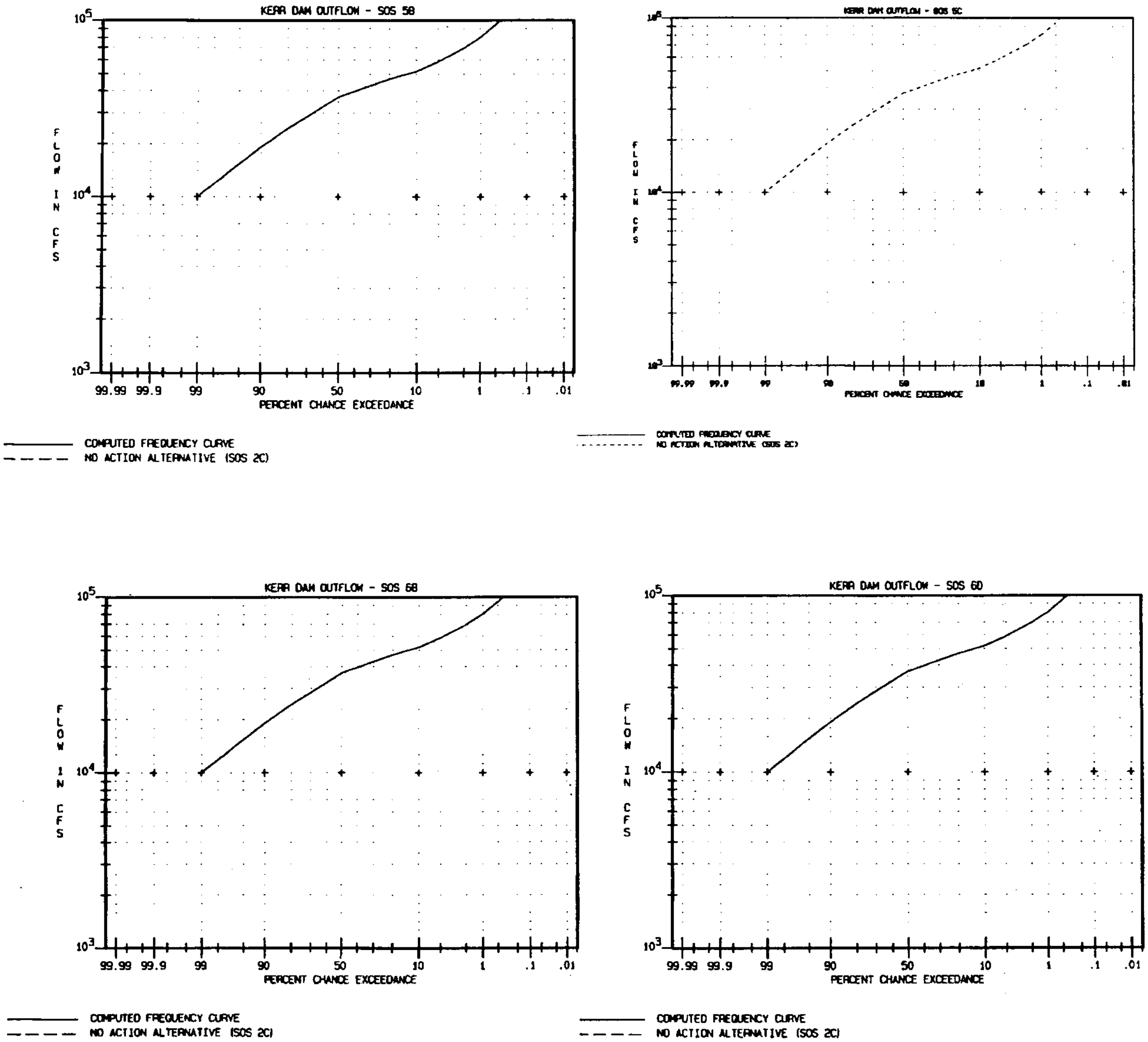

Figure A–6. Frequency Curve Comparison, SOS 2C vs. Kerr Dam Overflow – CONT

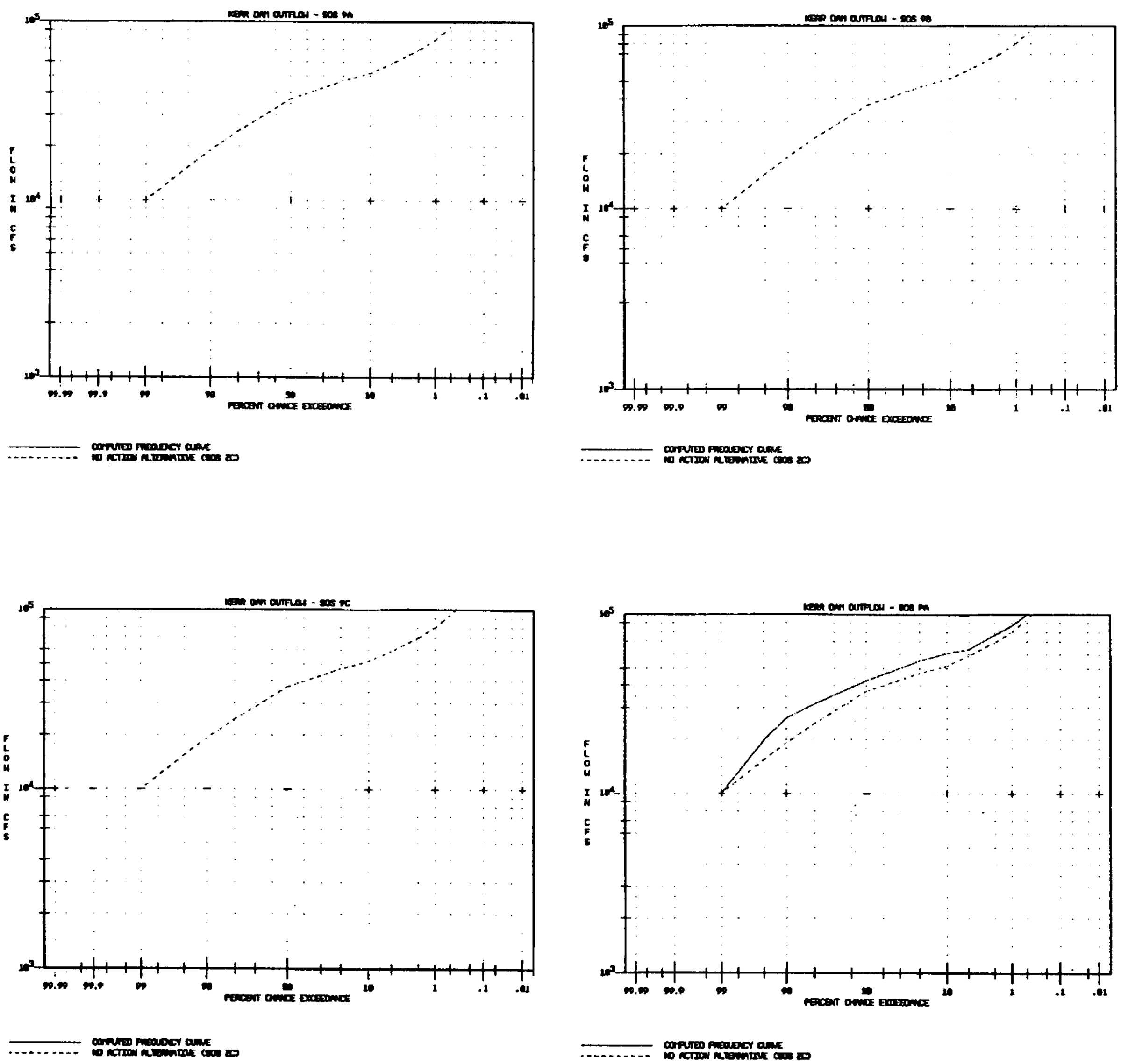

Figure A–6. Frequency Curve Comparison, SOS 2C vs. Kerr Dam Overflow – CONT

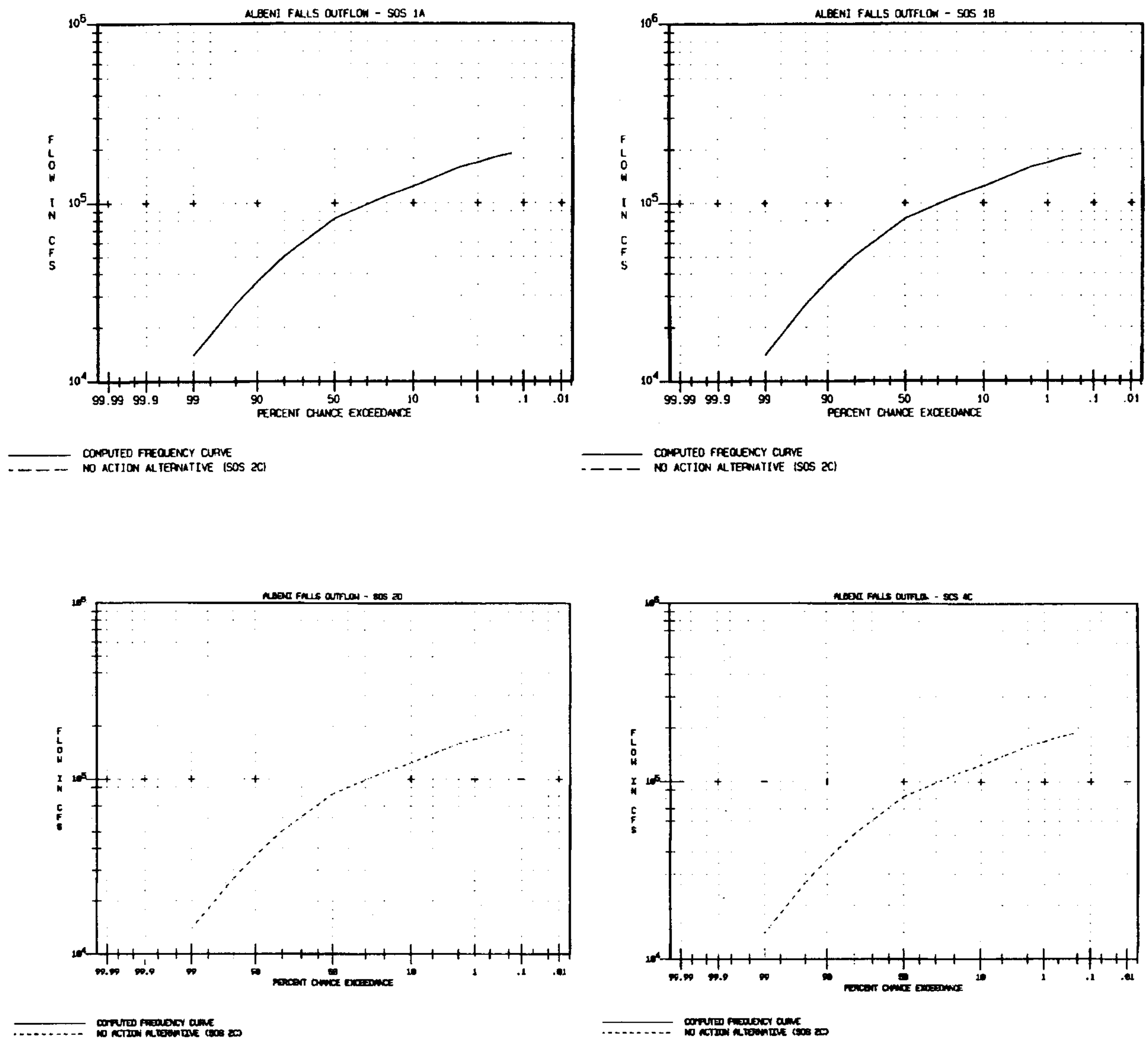

Figure A–7. Frequency Curve Comparison, SOS 2C vs. Albeni Falls Outflow

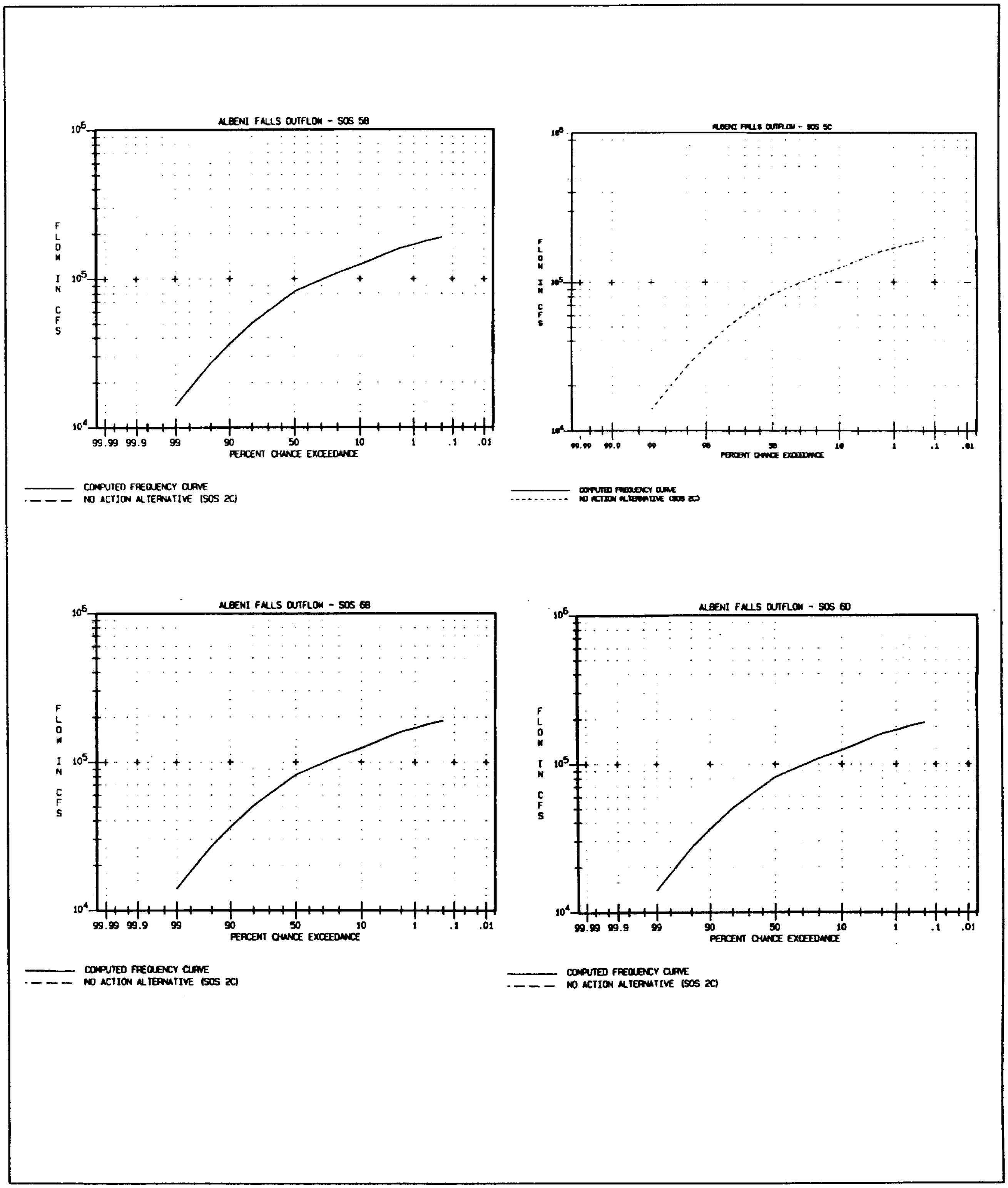

Figure A–7. Frequency Curve Comparison, SOS 2C vs. Albeni Falls Outflow – CONT

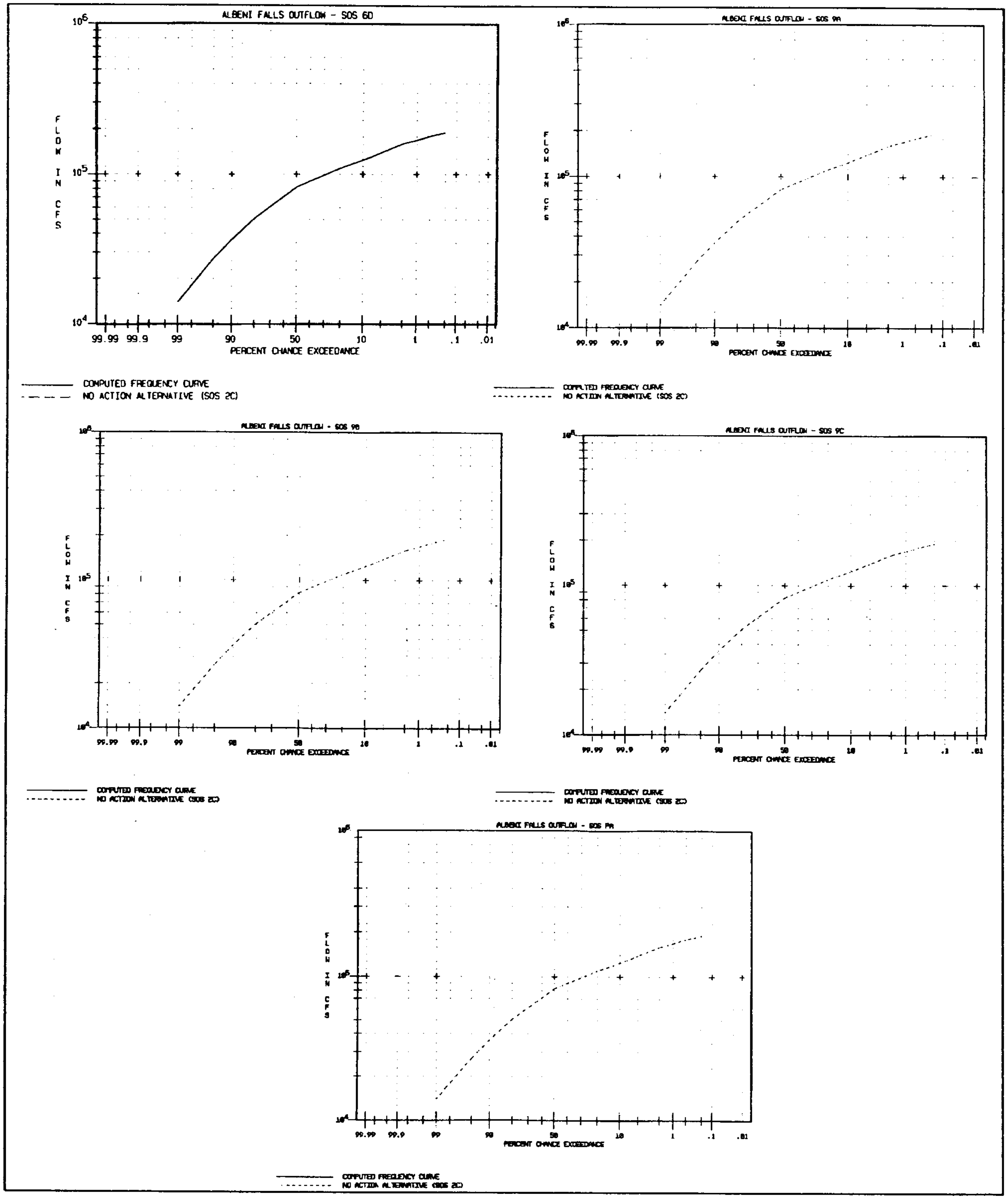

Figure A–7. Frequency Curve Comparison, SOS 2C vs. Albeni Falls Outflow – CONT

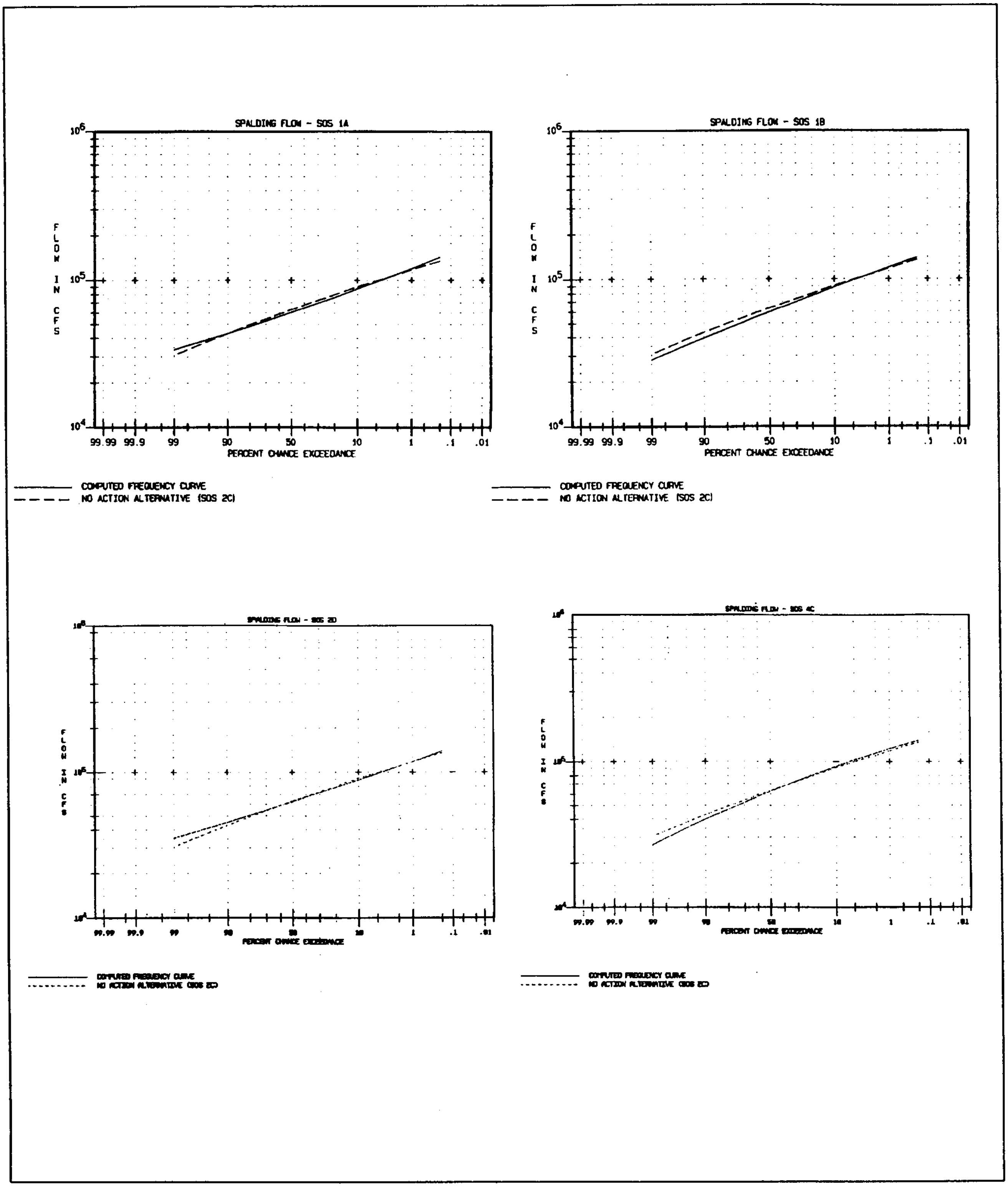

Figure A–8. Frequency Curve Comparison, SOS 2C vs. Spalding Flow

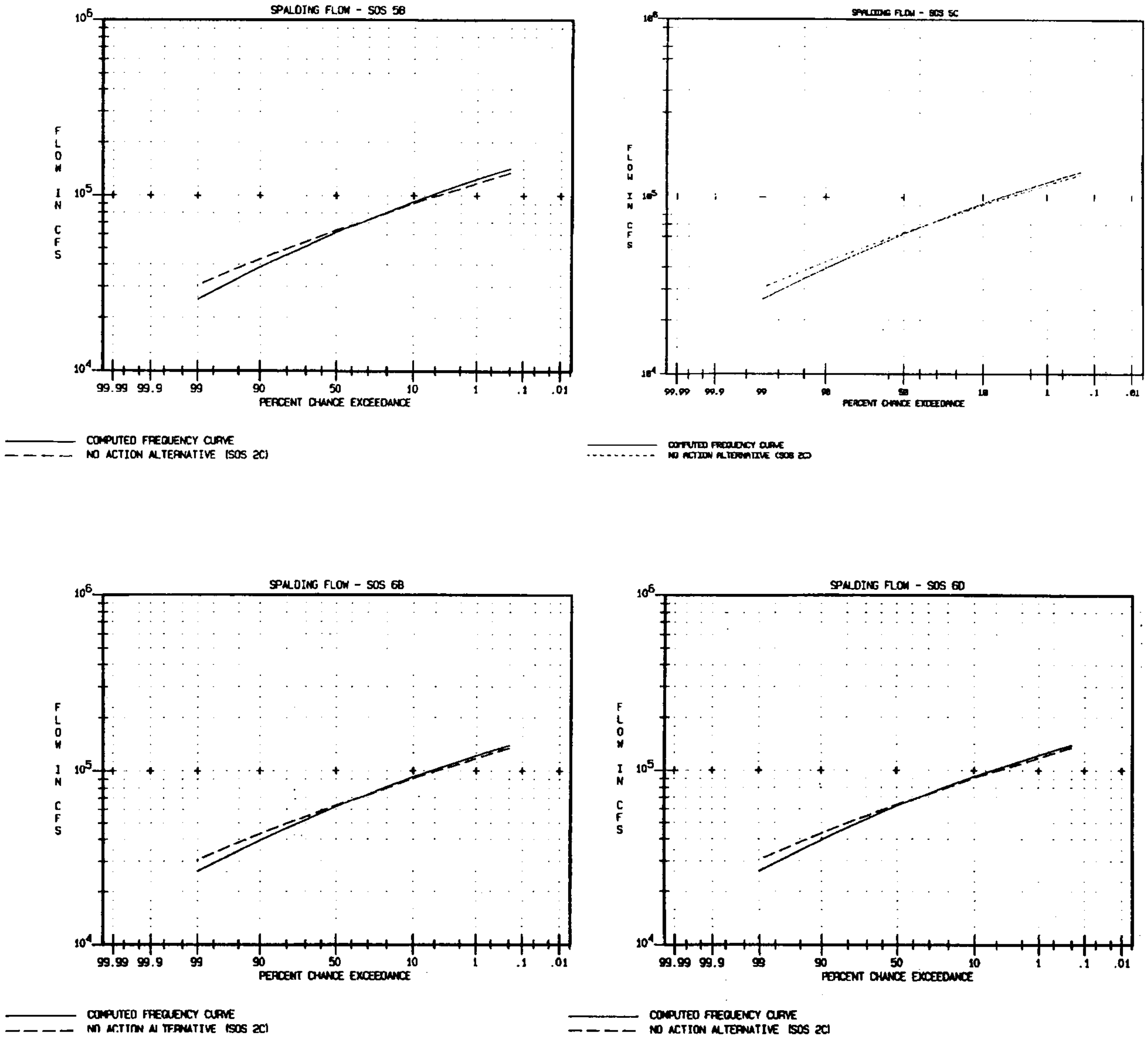

Figure A–8. Frequency Curve Comparison, SOS 2C vs. Spalding Flow – CONT

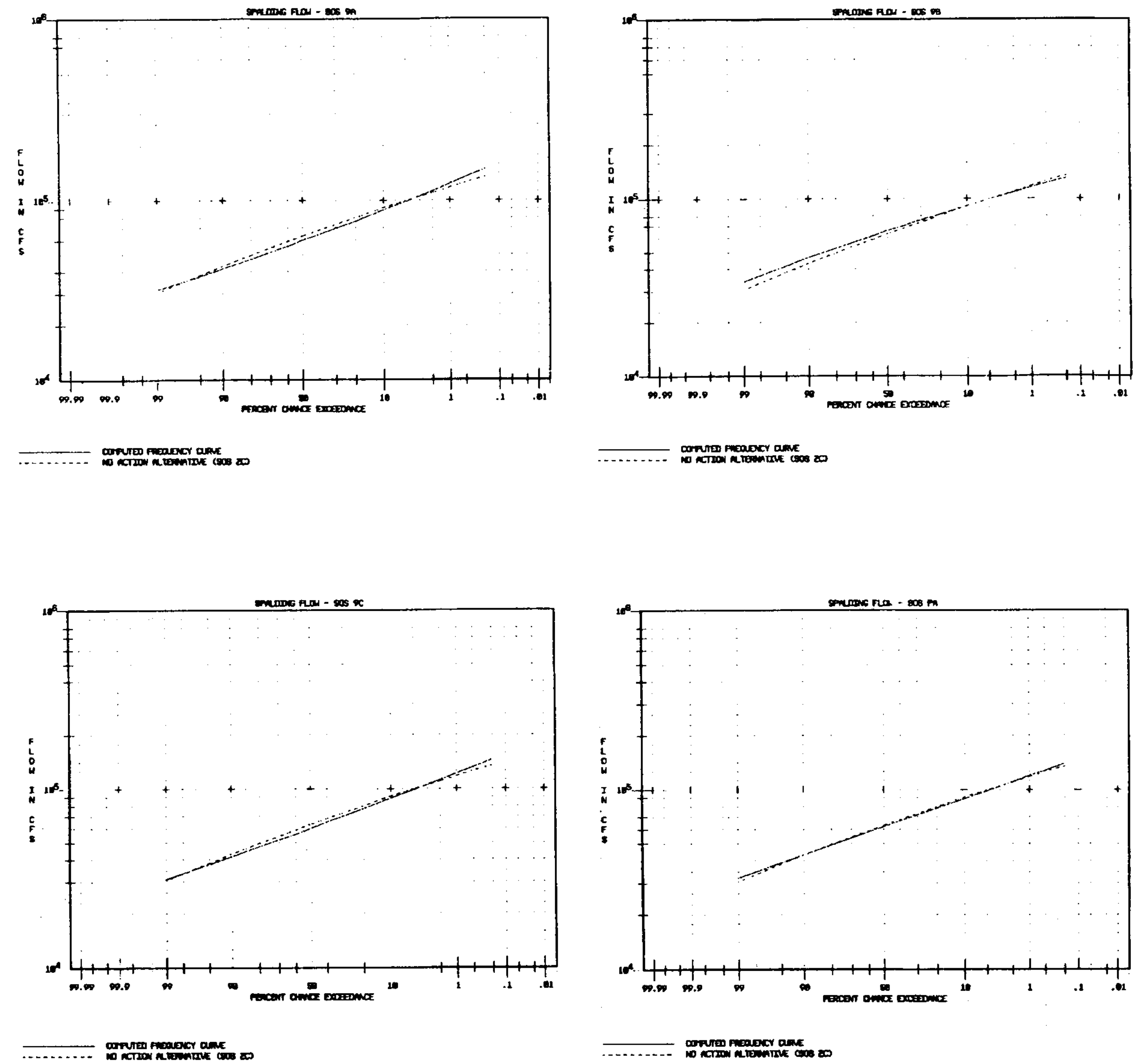

Figure A–8. Frequency Curve Comparison, SOS 2C vs. Spalding Flow – CONT

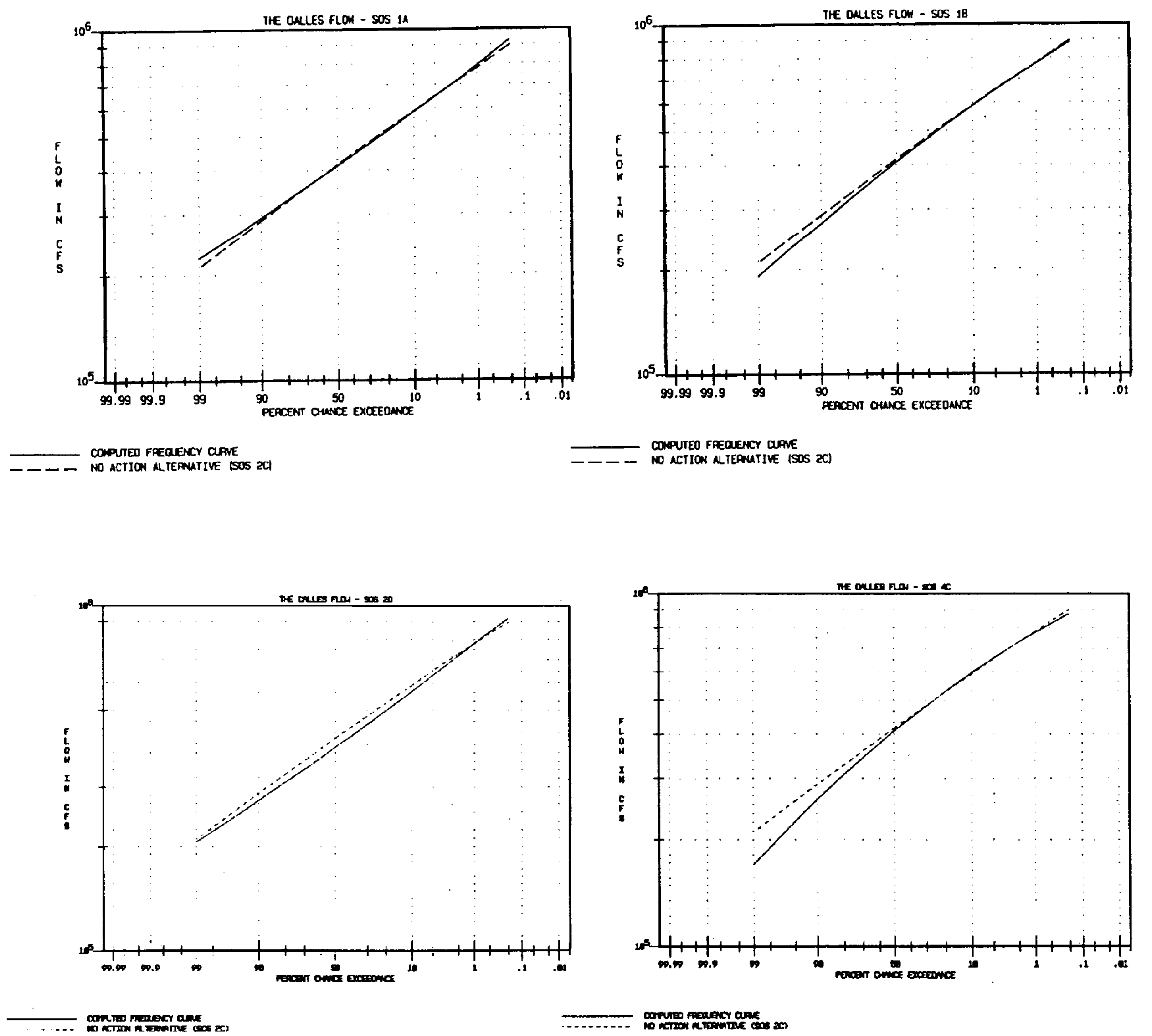

Figure A–9. Frequency Curve Comparison, SOS 2C vs. The Dalles Flow

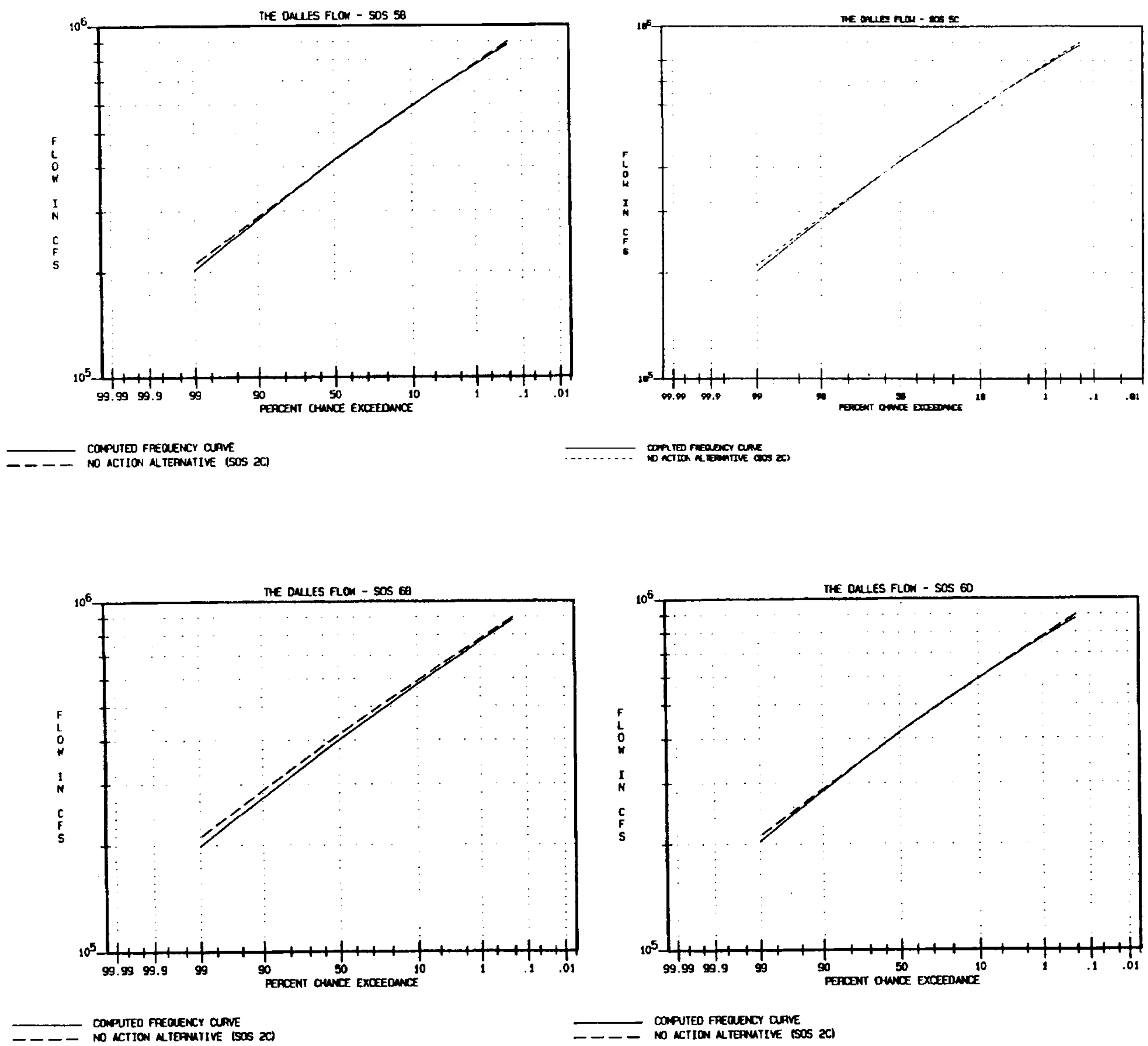

Figure A–9. Frequency Curve Comparison, SOS 2C vs. The Dalles Flow – CONT

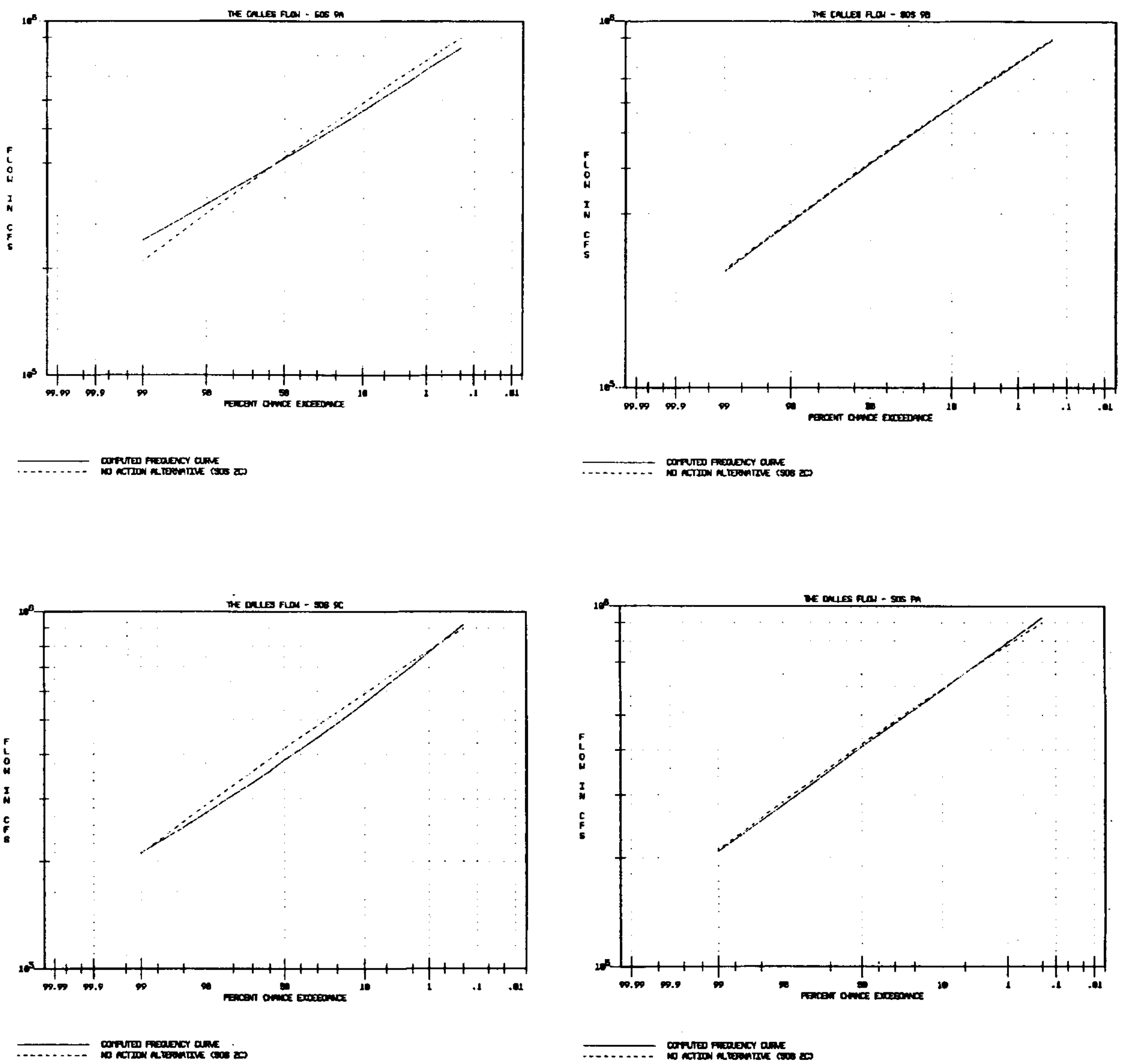

Figure A–9. Frequency Curve Comparison, SOS 2C vs. The Dalles Flow – CONT

TECHNICAL

EXHIBIT B

FREQUENCY CURVES

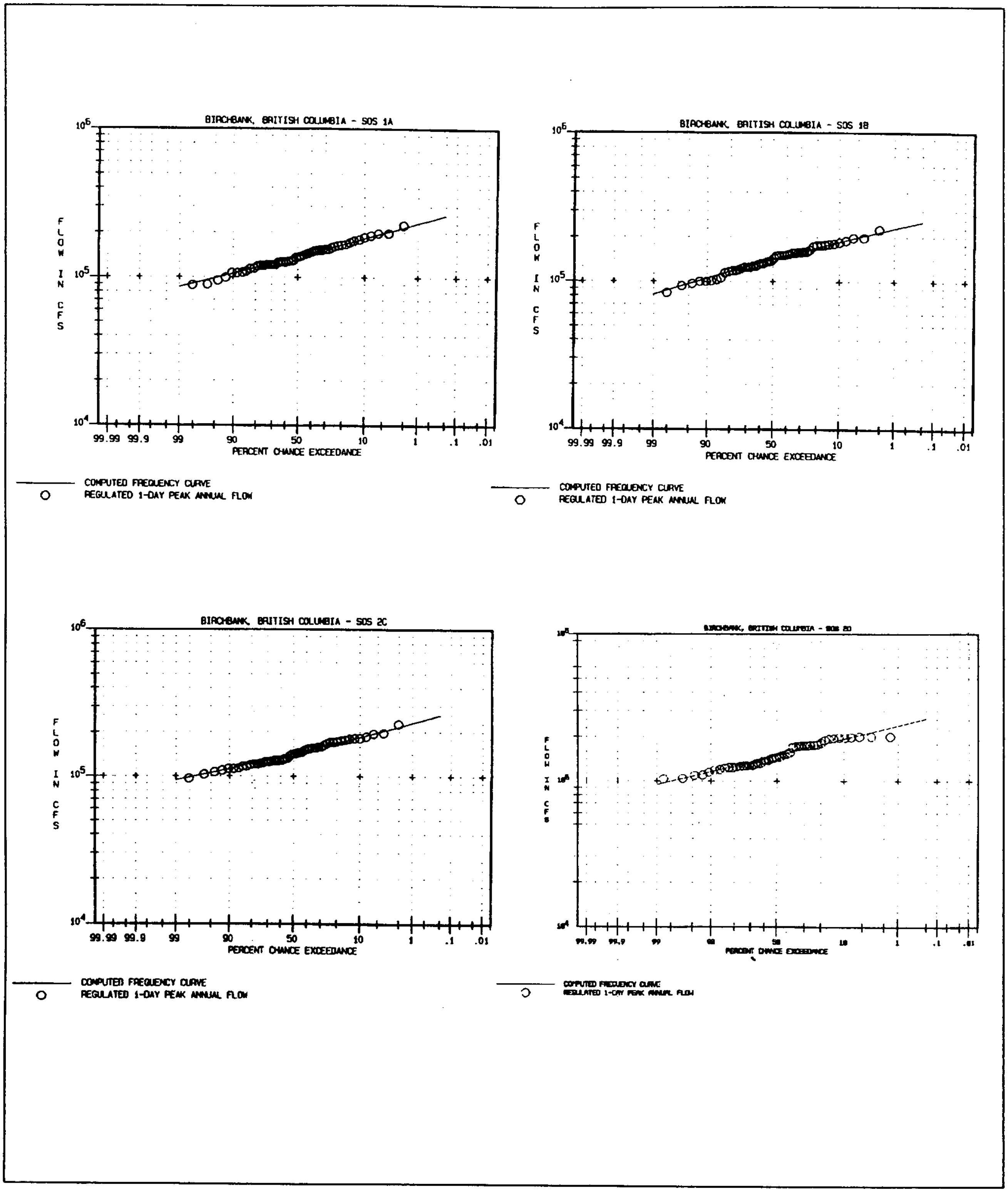

Figure B–1. Frequency Curves for Birchbank, British Columbia

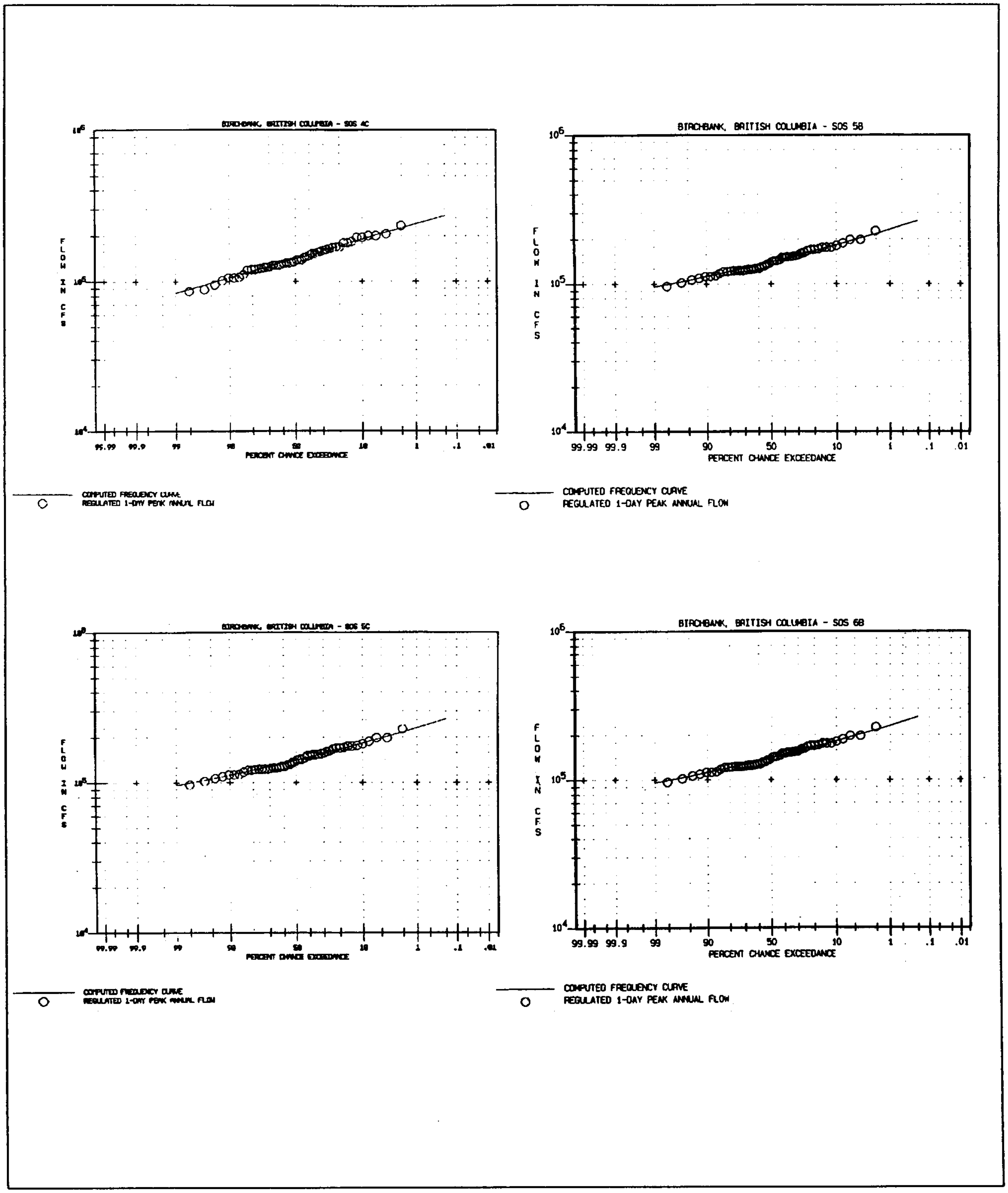

Figure B–1. Frequency Curves for Birchbank, British Columbia – CONT

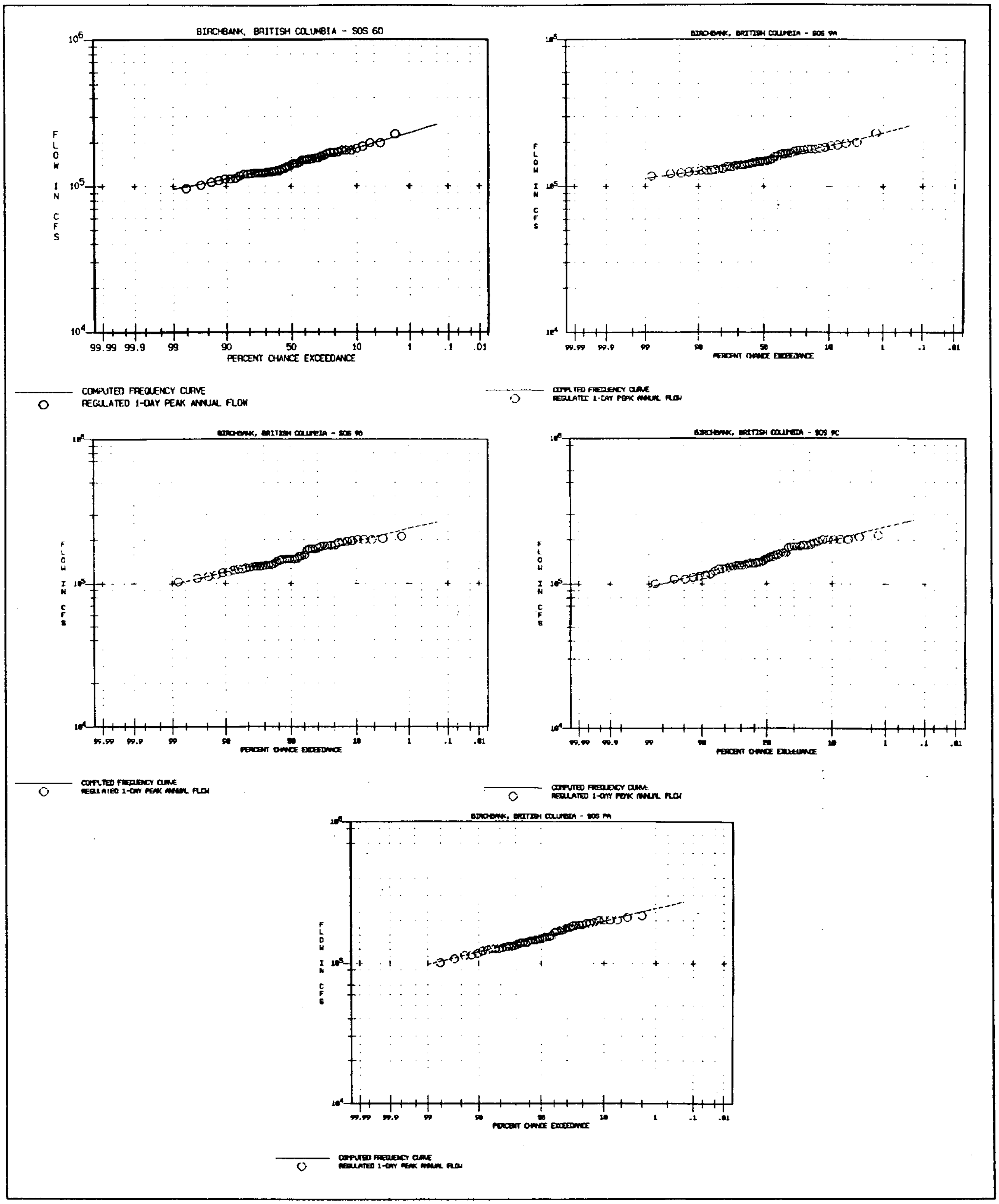

Figure B–1. Frequency Curves for Birchbank, British Columbia – CONT

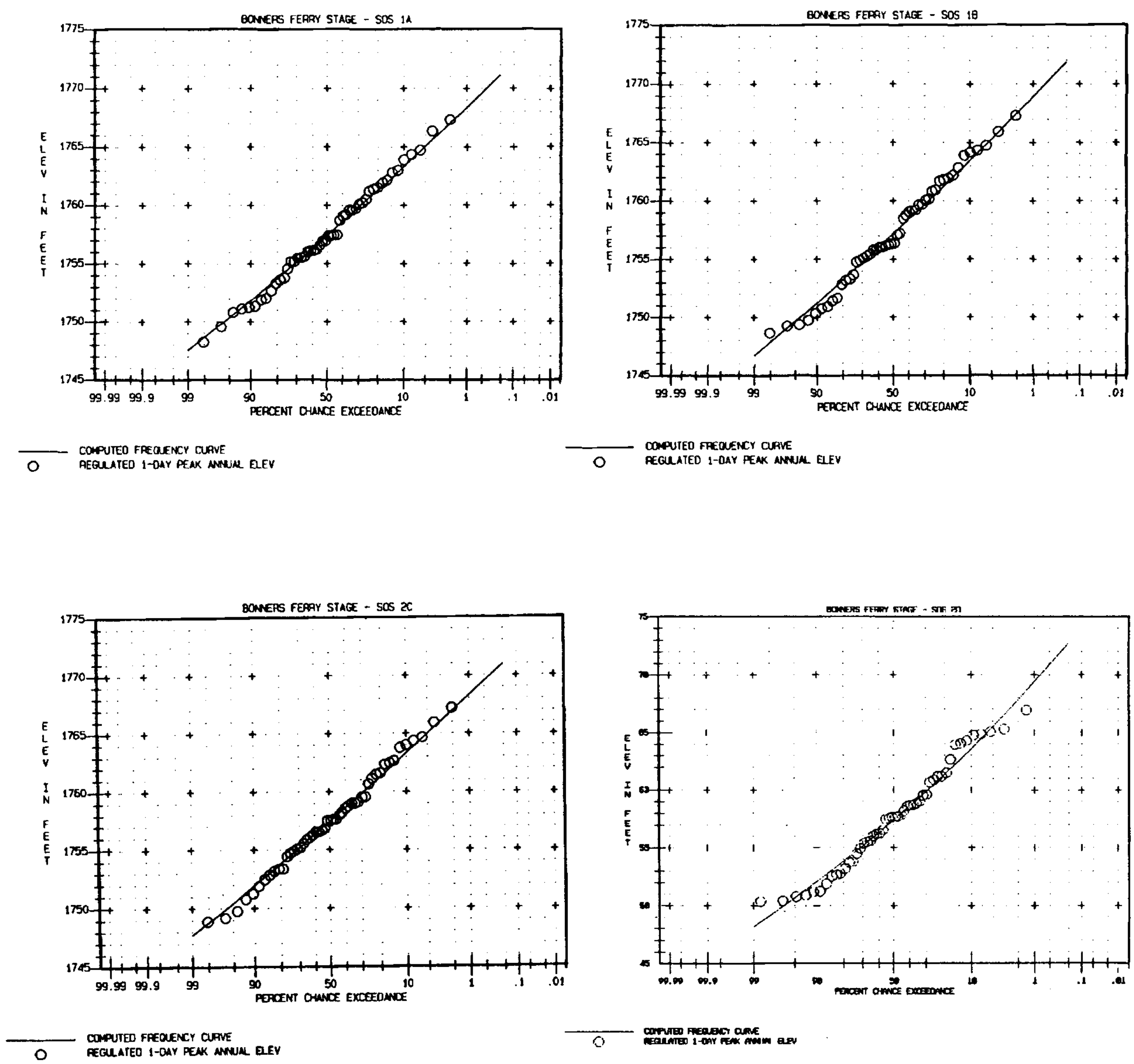

Figure B–2. Frequency Curves for Bonners Ferry Stage

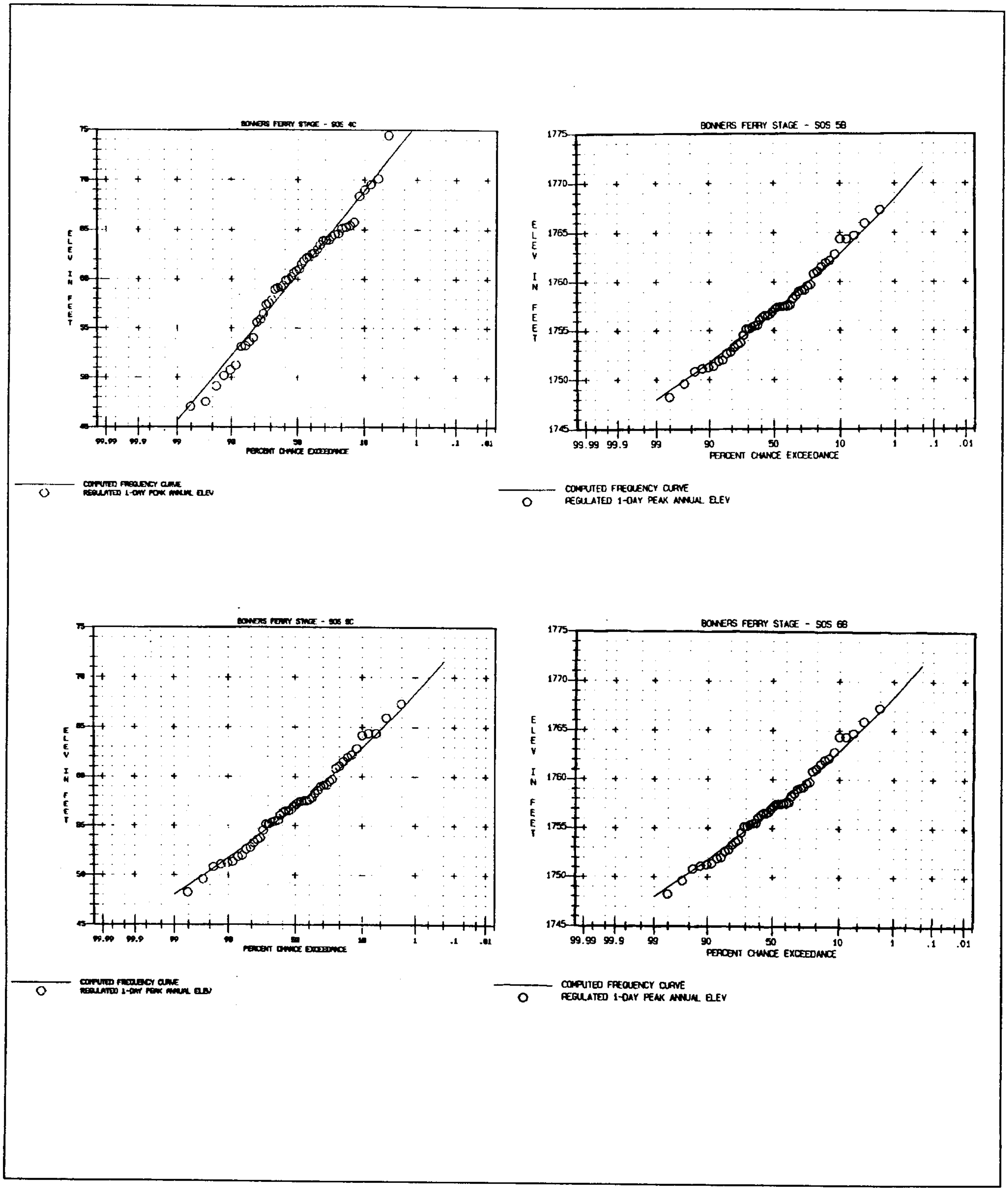

Figure B–2. Frequency Curves for Bonners Ferry Stage – CONT

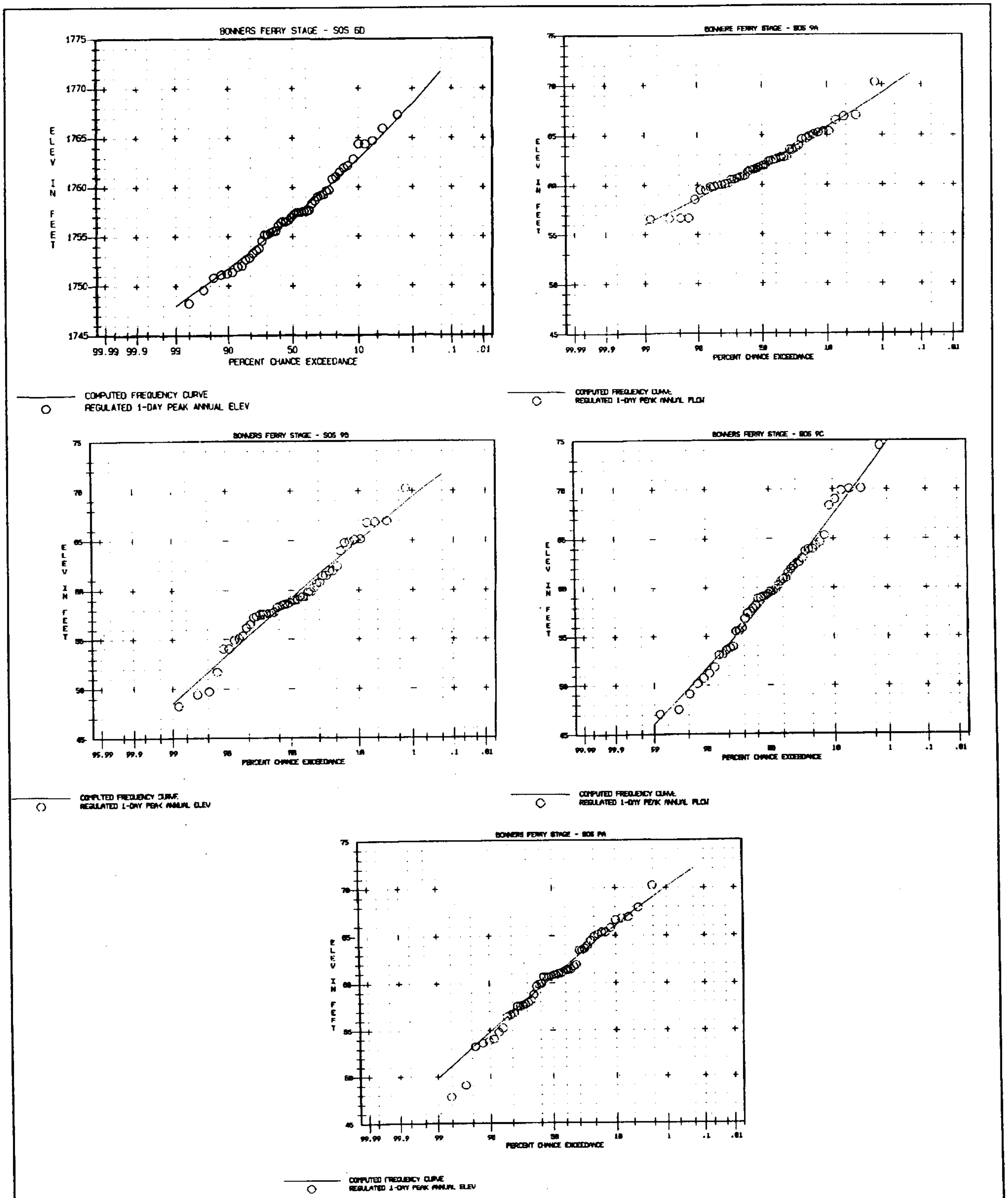

Figure B–2. Frequency Curves for Bonners Ferry Stage – CONT

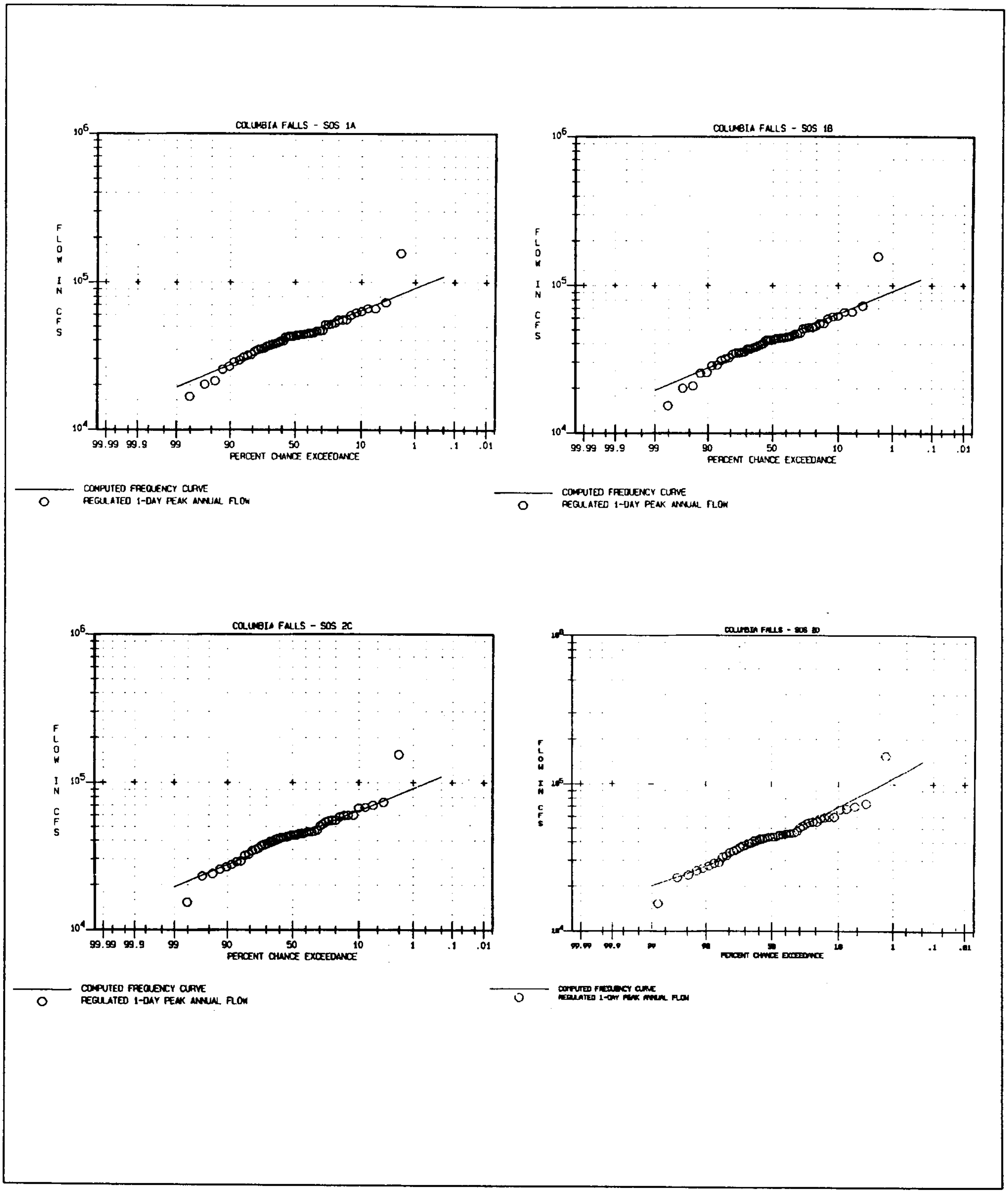

Figure B–3. Frequency Curves for Columbia Falls

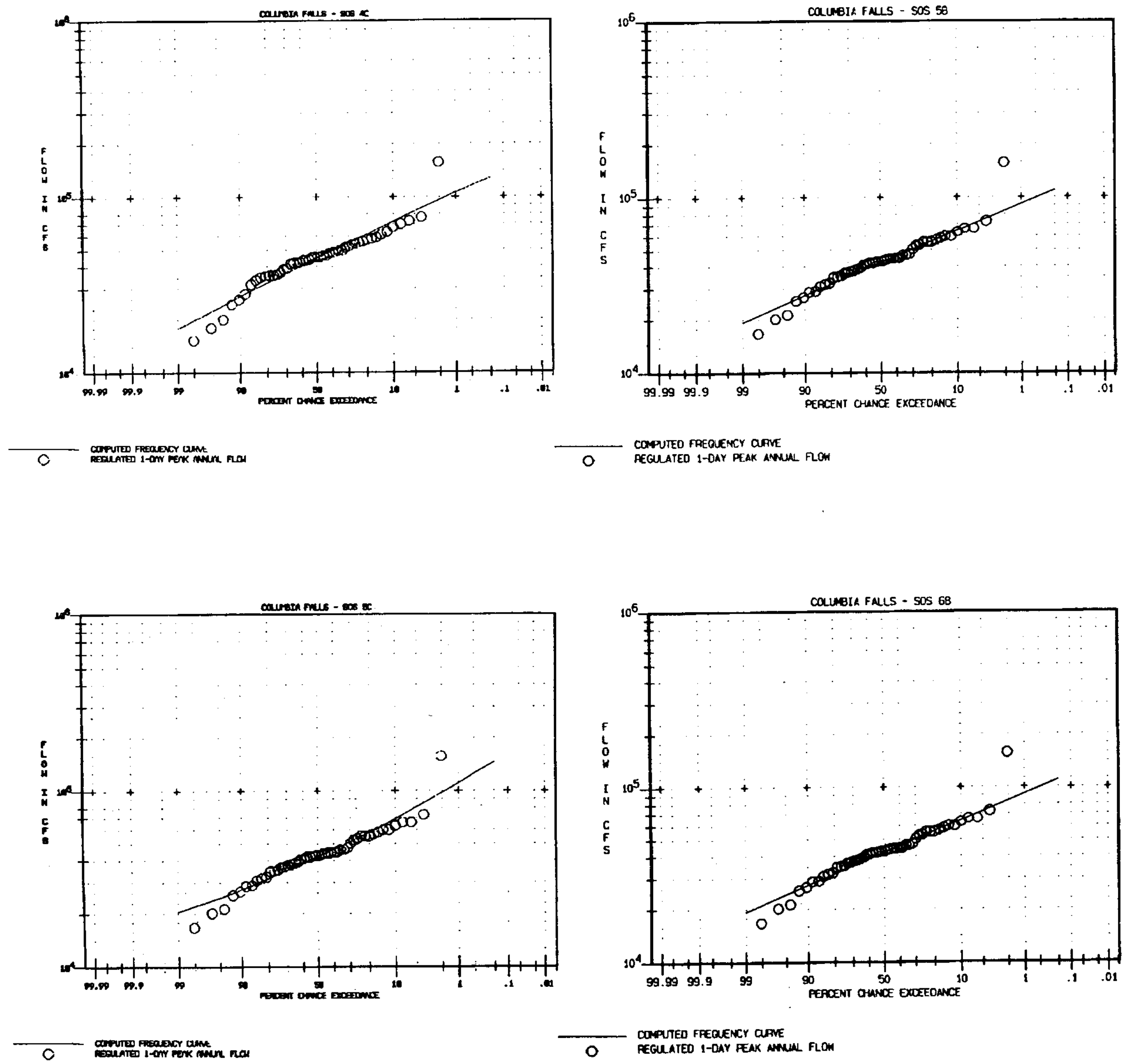

Figure B–3. Frequency Curves for Columbia Falls – CONT

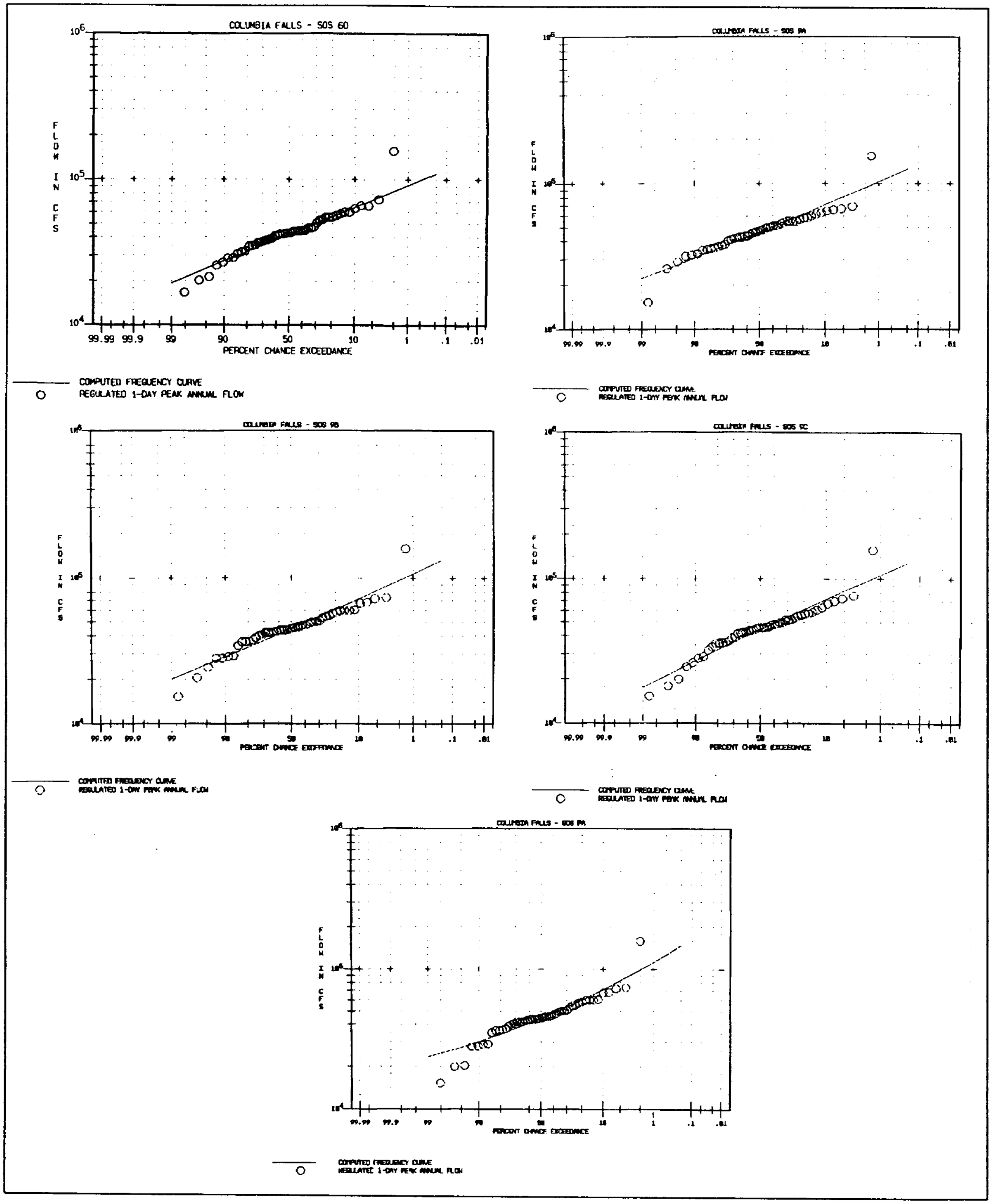

Figure B–3. Frequency Curves for Columbia Falls – CONT

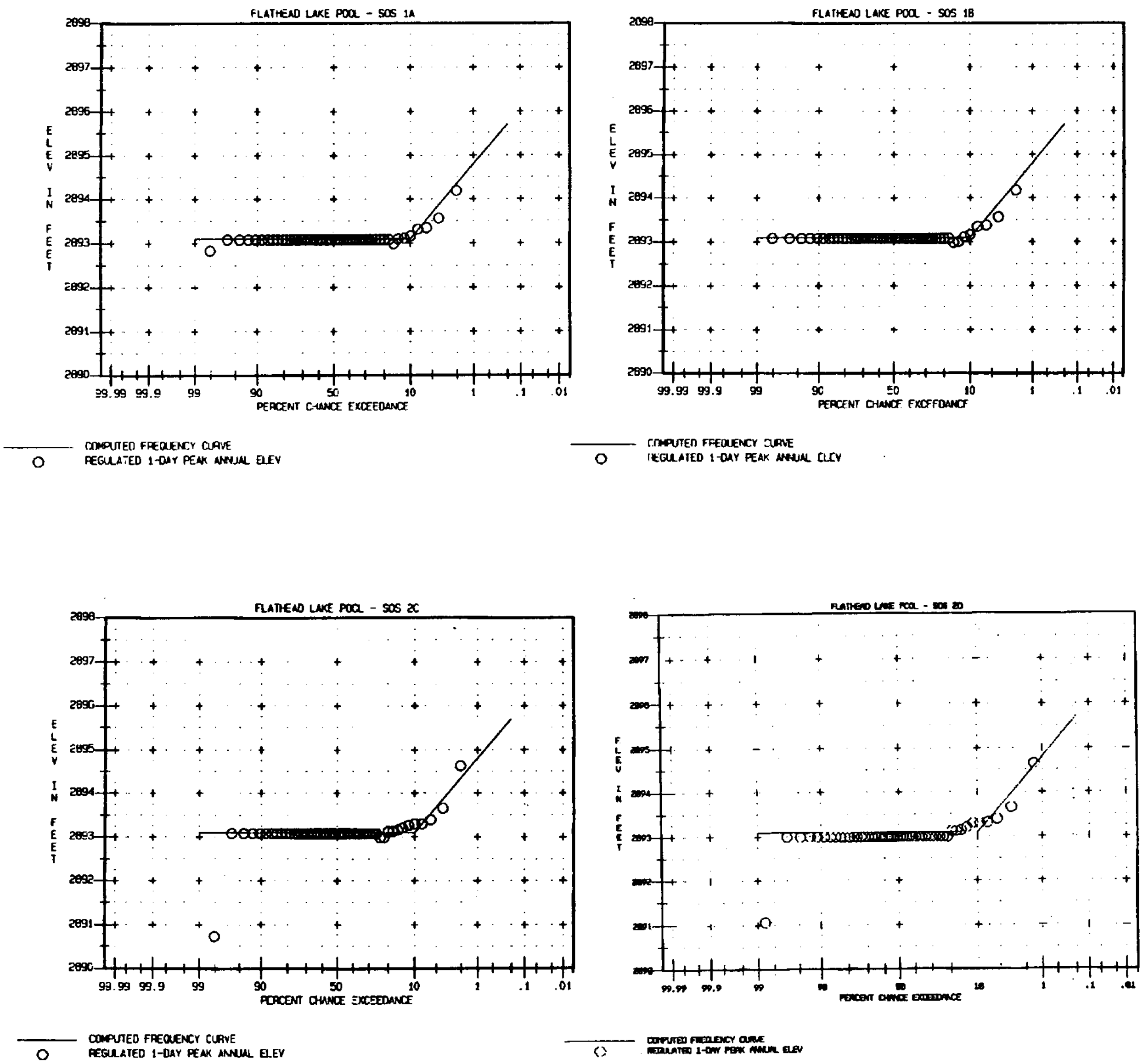

Figure B–4. Frequency Curves for Flathead Lake Pool

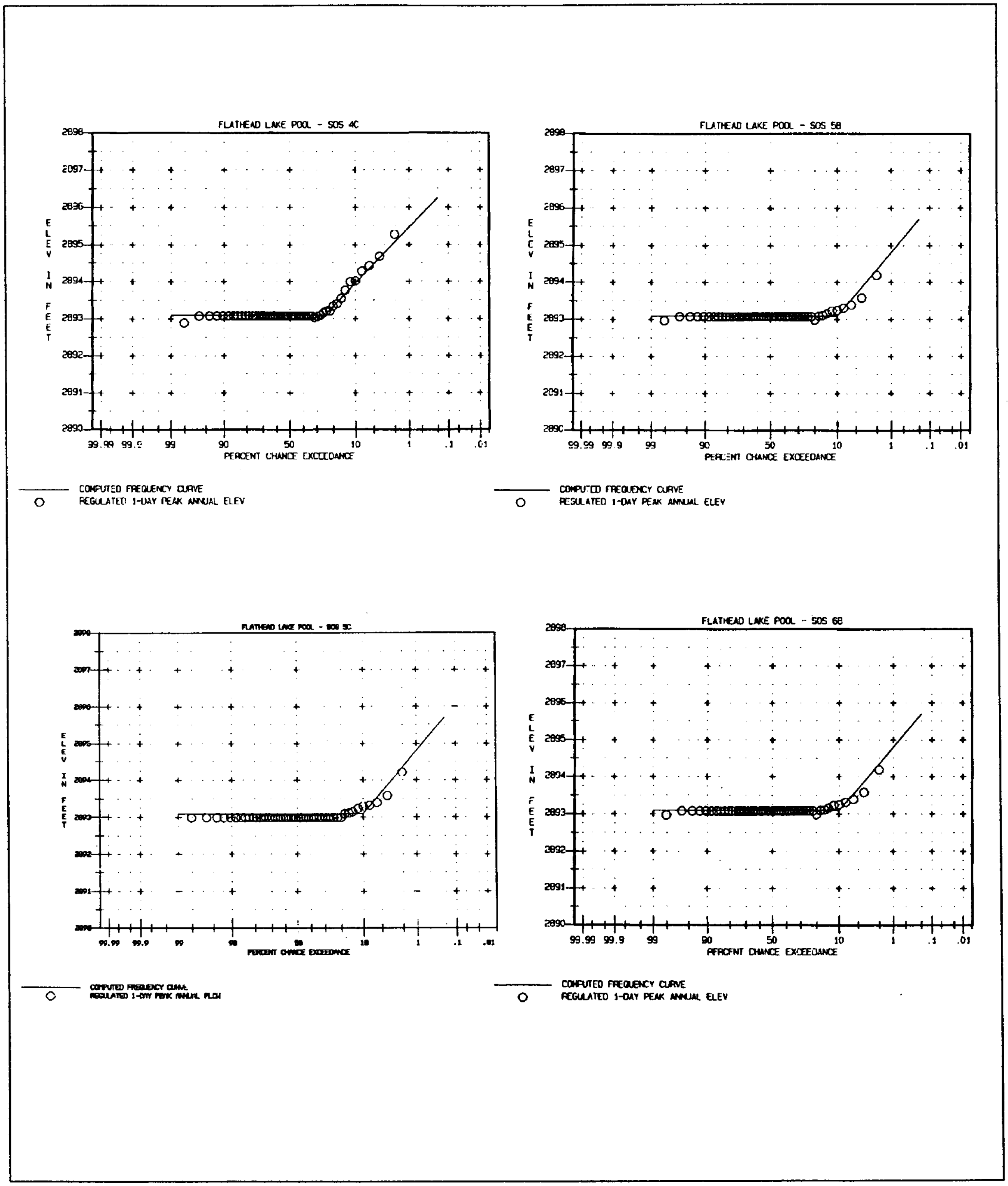

Figure B–4. Frequency Curves for Flathead Lake Pool – CONT

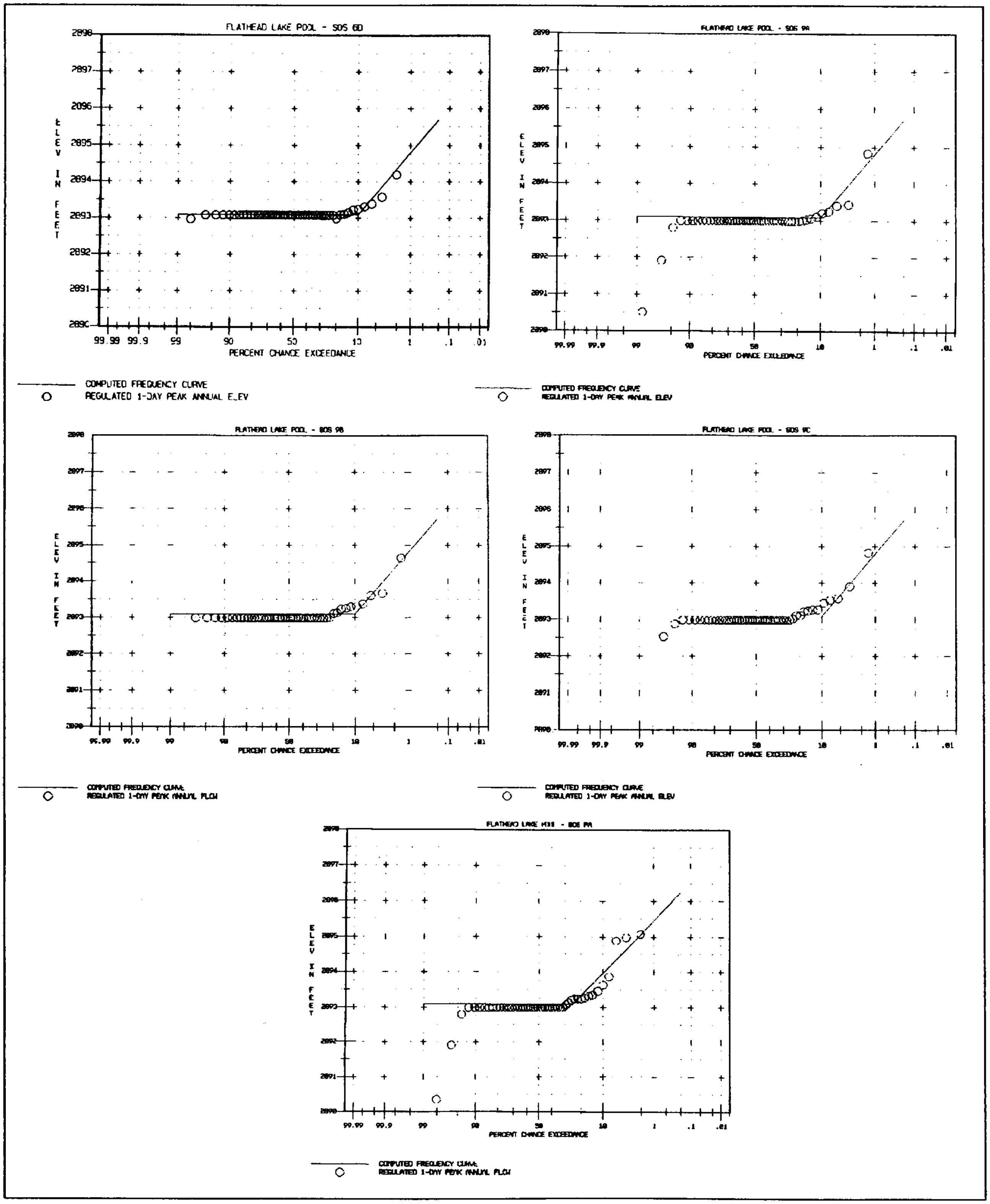

Figure B–4. Frequency Curves for Flathead Lake Pool – CONT

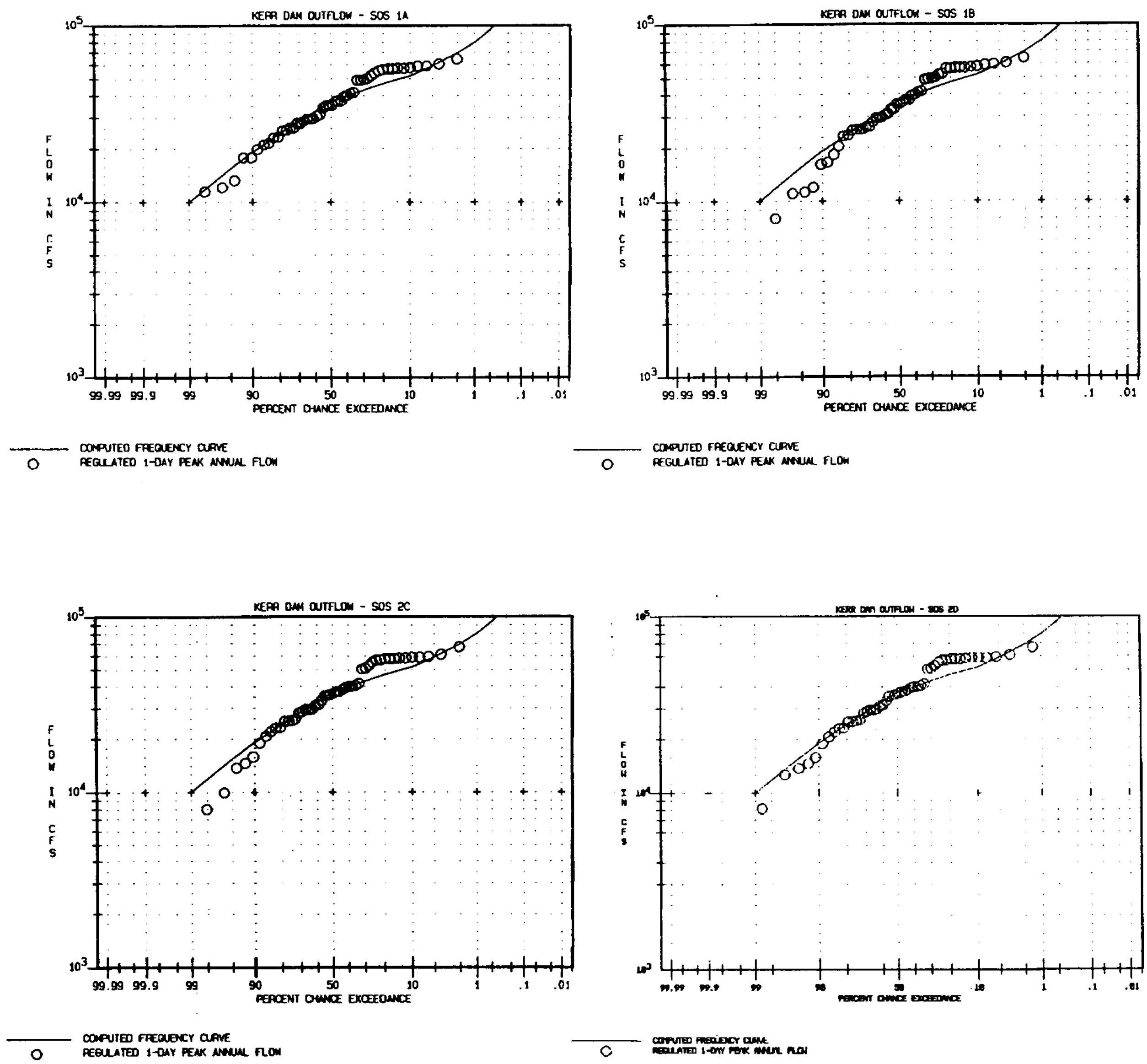

Figure B–5. Frequency Curves for Kerr Dam Outflow

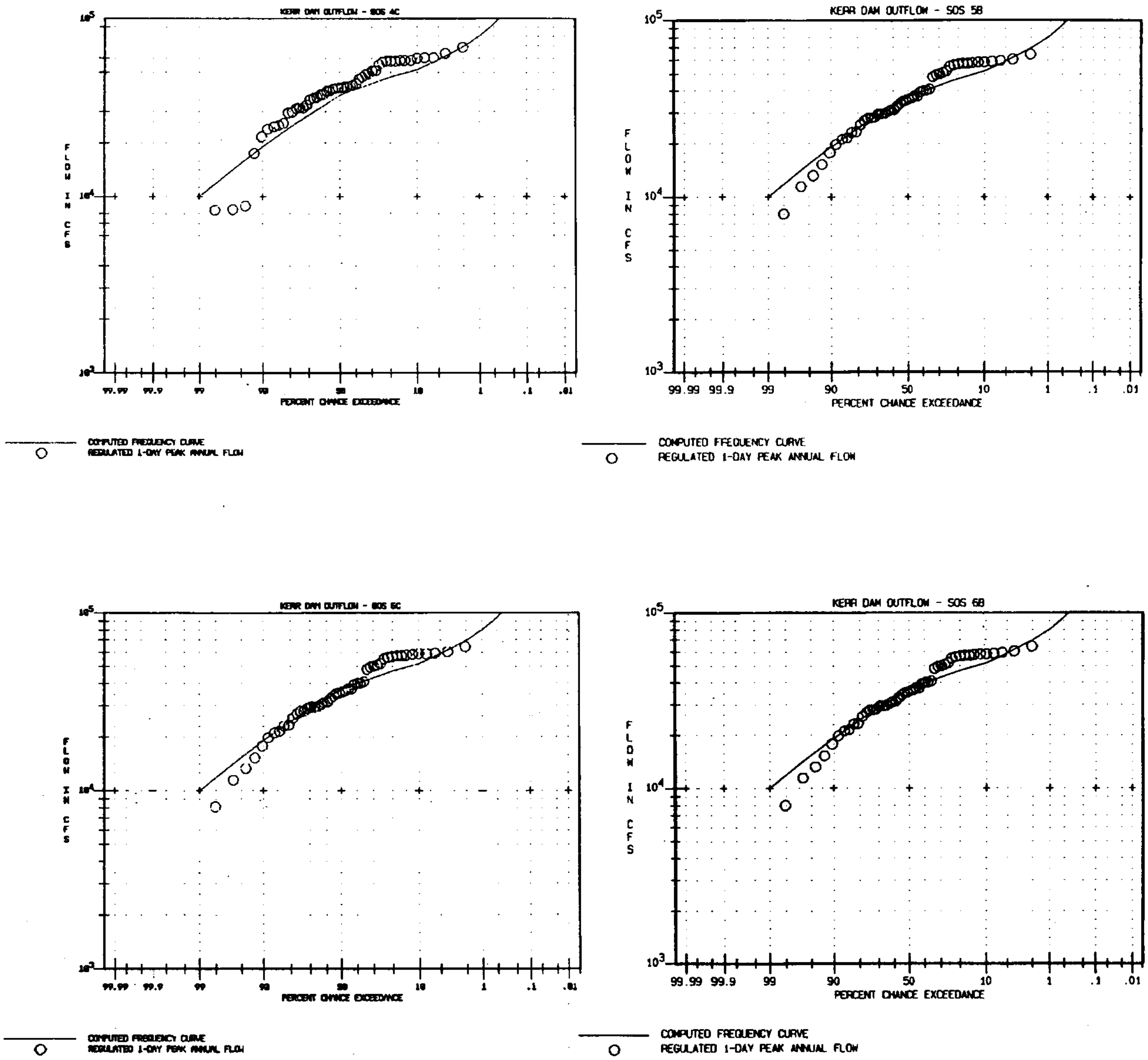

Figure B–5. Frequency Curves for Kerr Dam Outflow – CONT

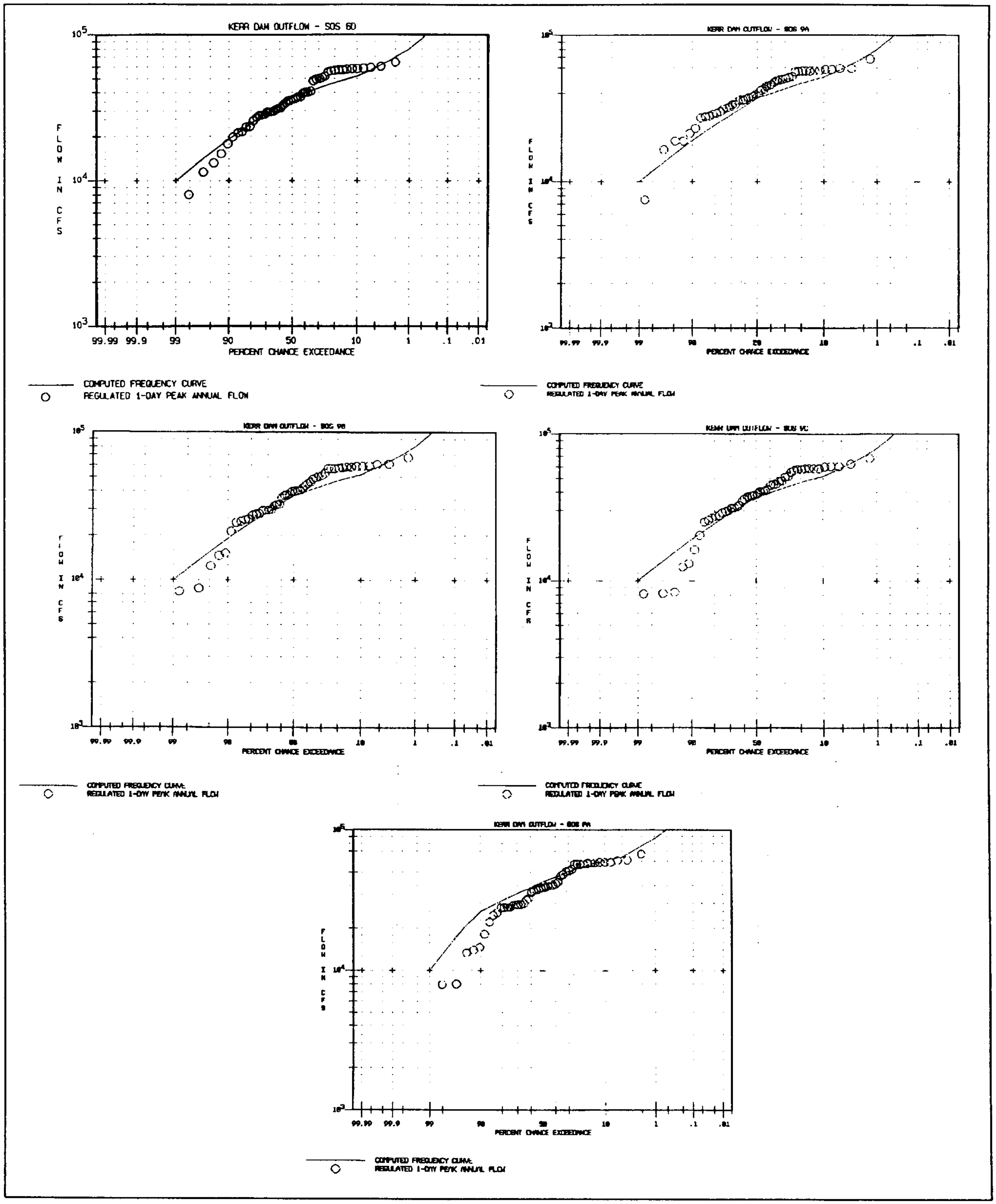

Figure B–5. Frequency Curves for Kerr Dam Outflow – CONT

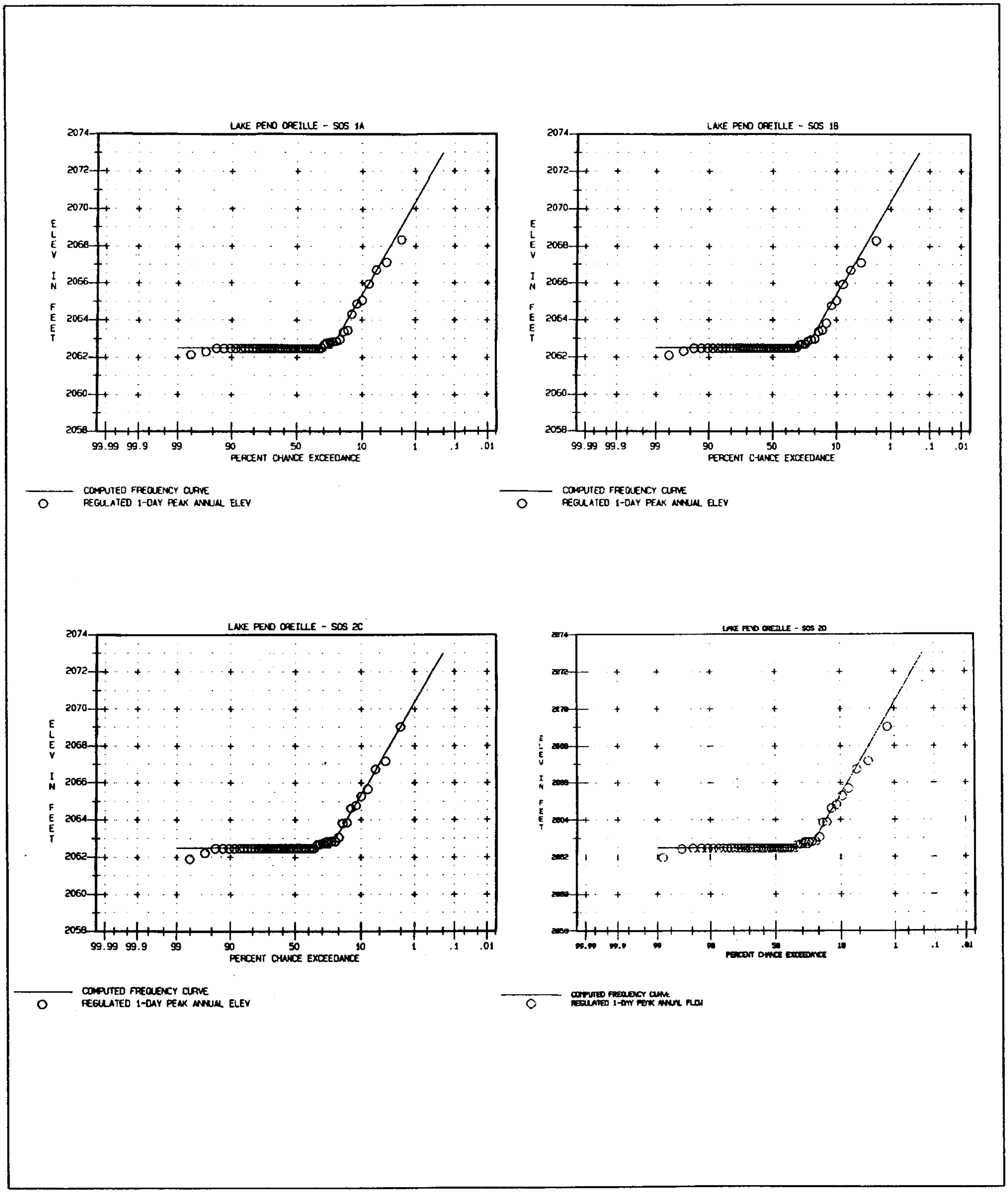

Figure B–6. Frequency Curves for Lake Pend Oreille

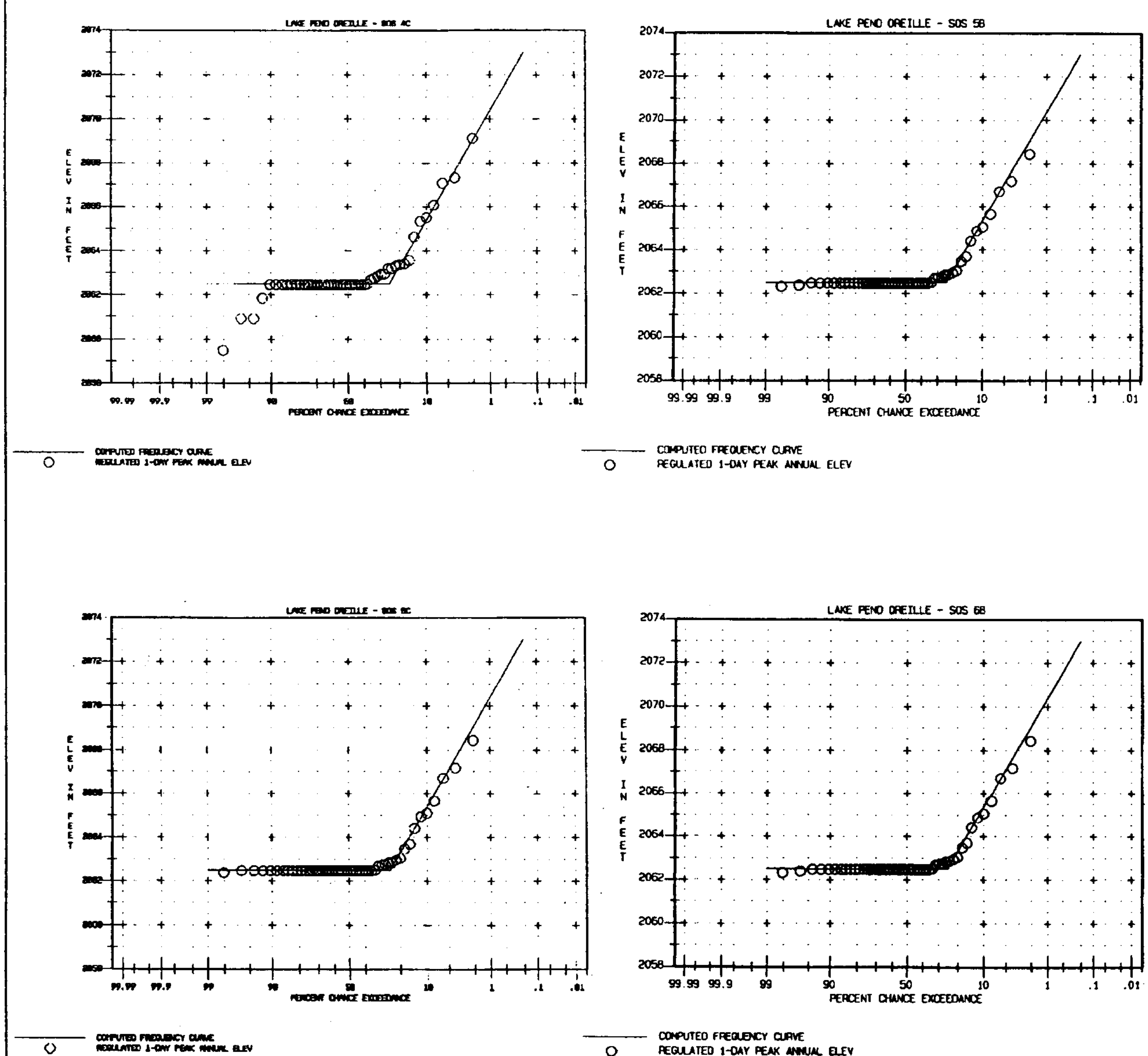

Figure B–6. Frequency Curves for Lake Pend Oreille – CONT

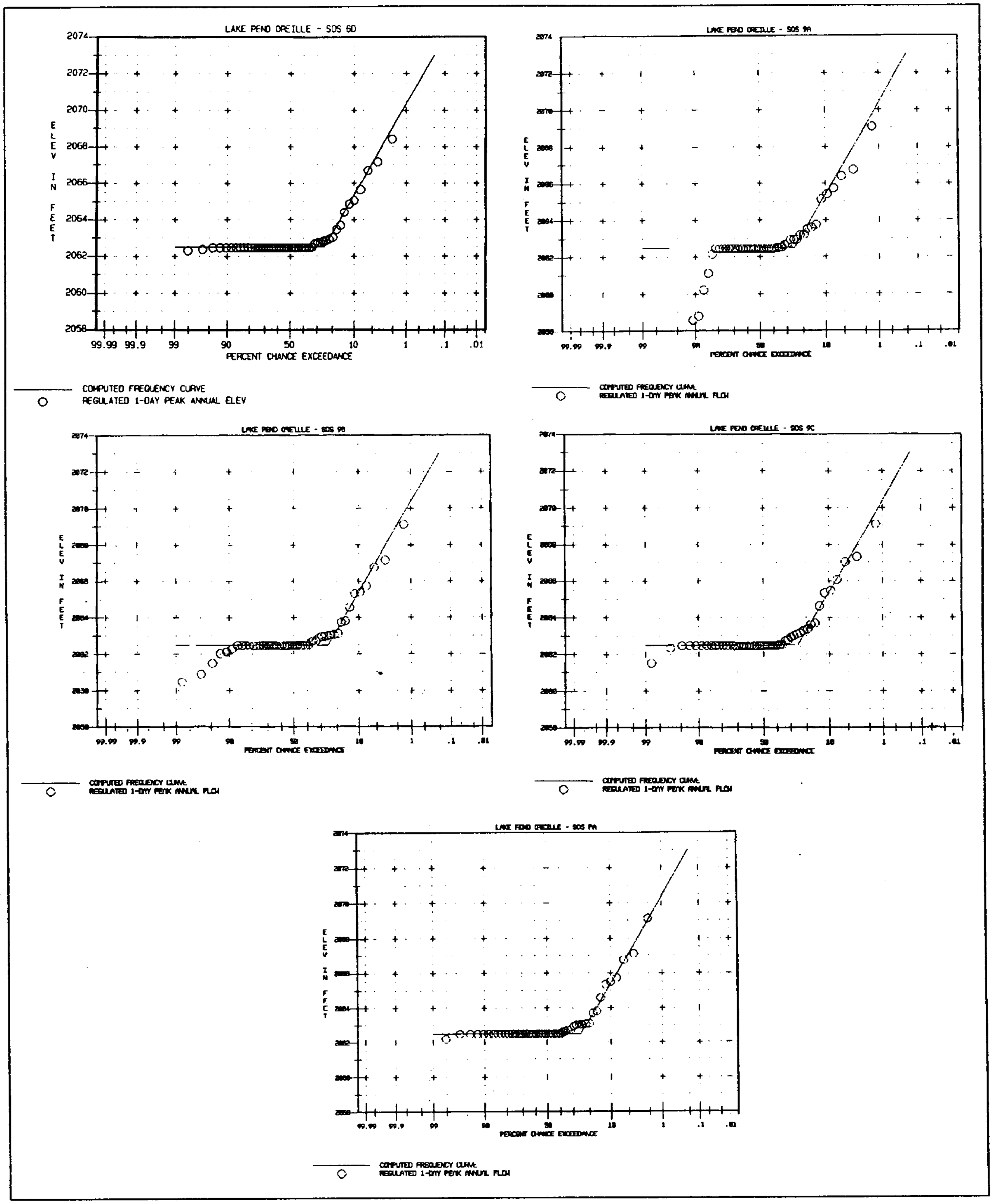

Figure B–6. Frequency Curves for Lake Pend Oreille – CONT

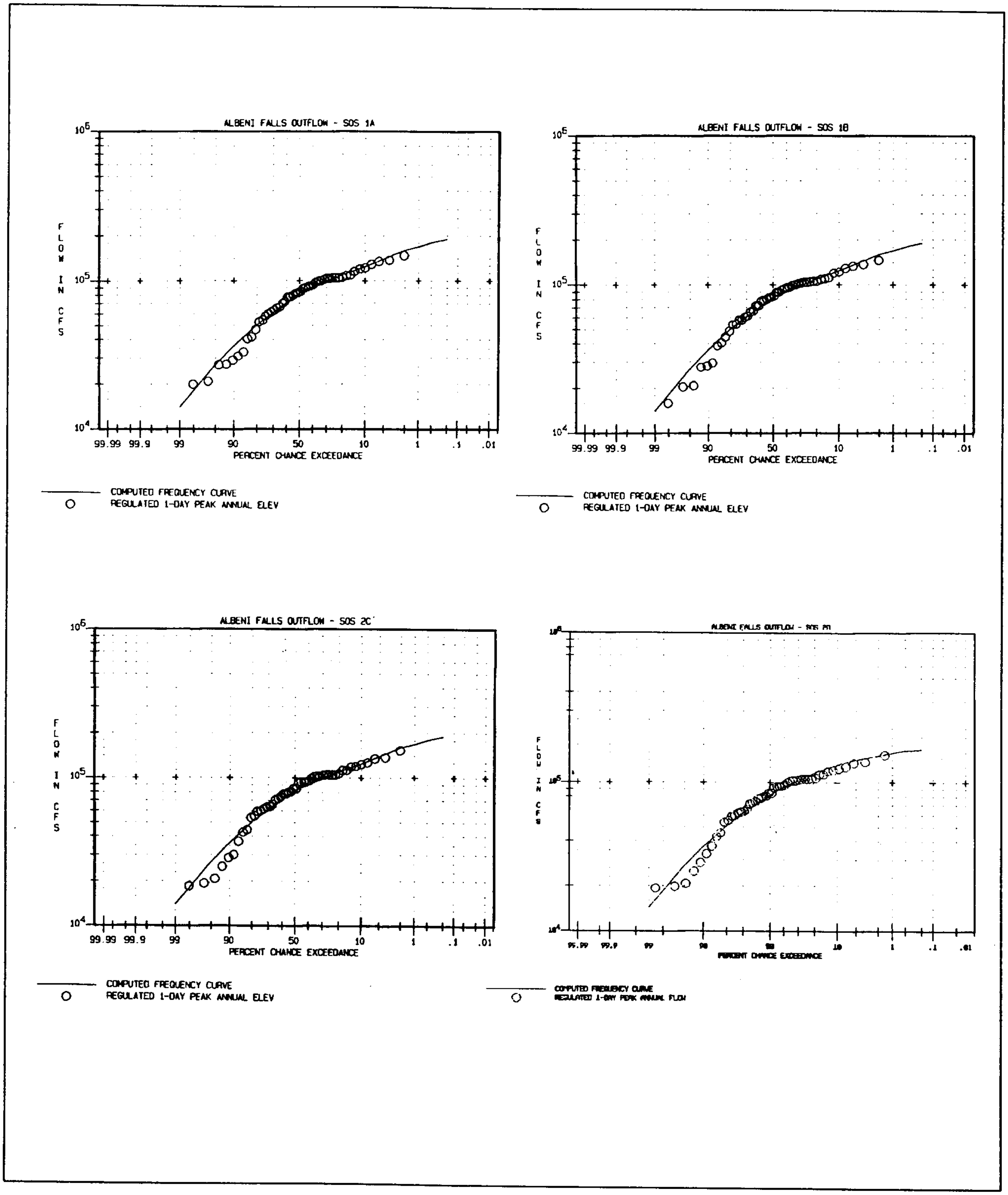

Figure B–7. Frequency Curves for Albeni Falls Outflow

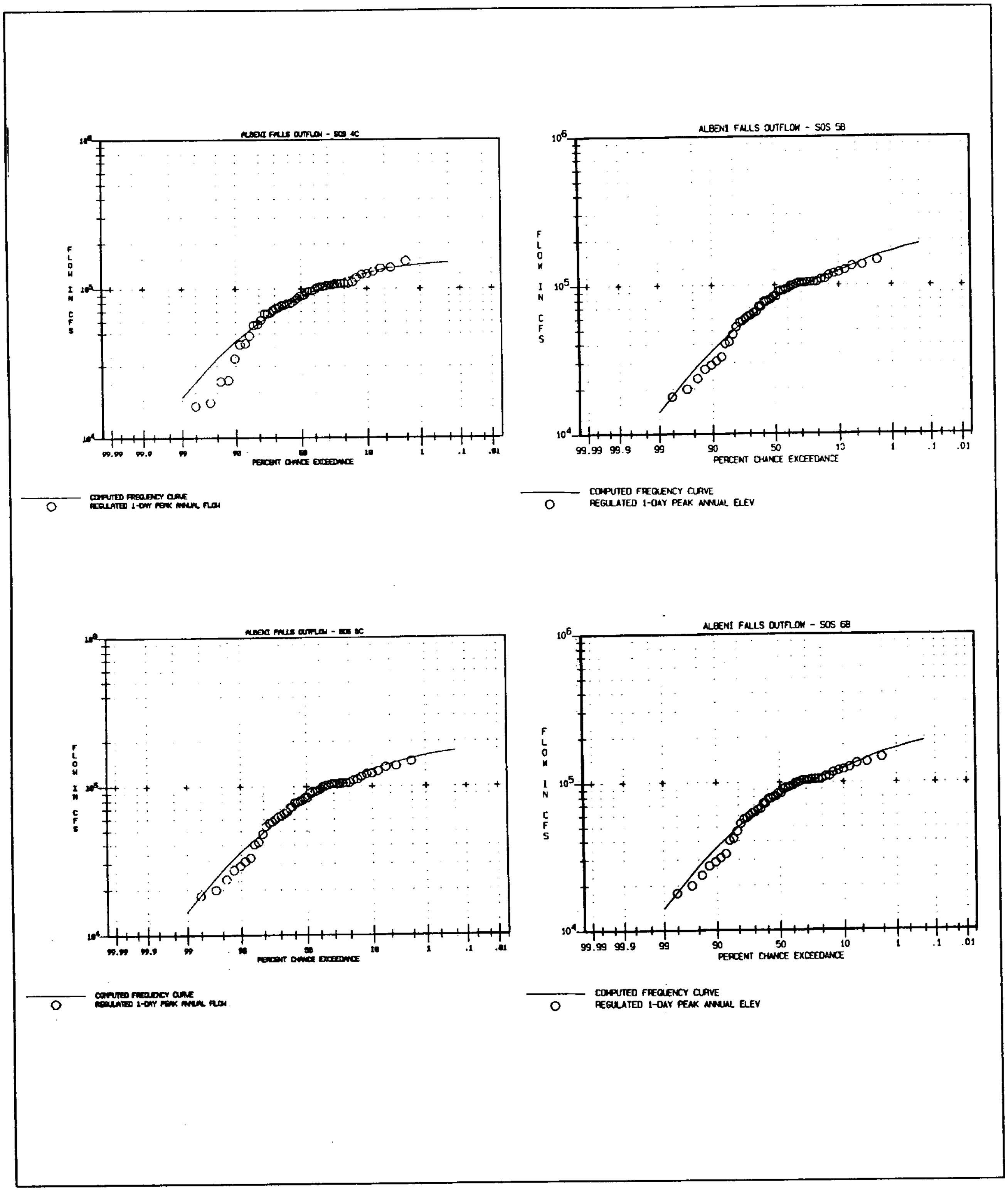

Figure B–7. Frequency Curves for Albeni Falls Outflow – CONT

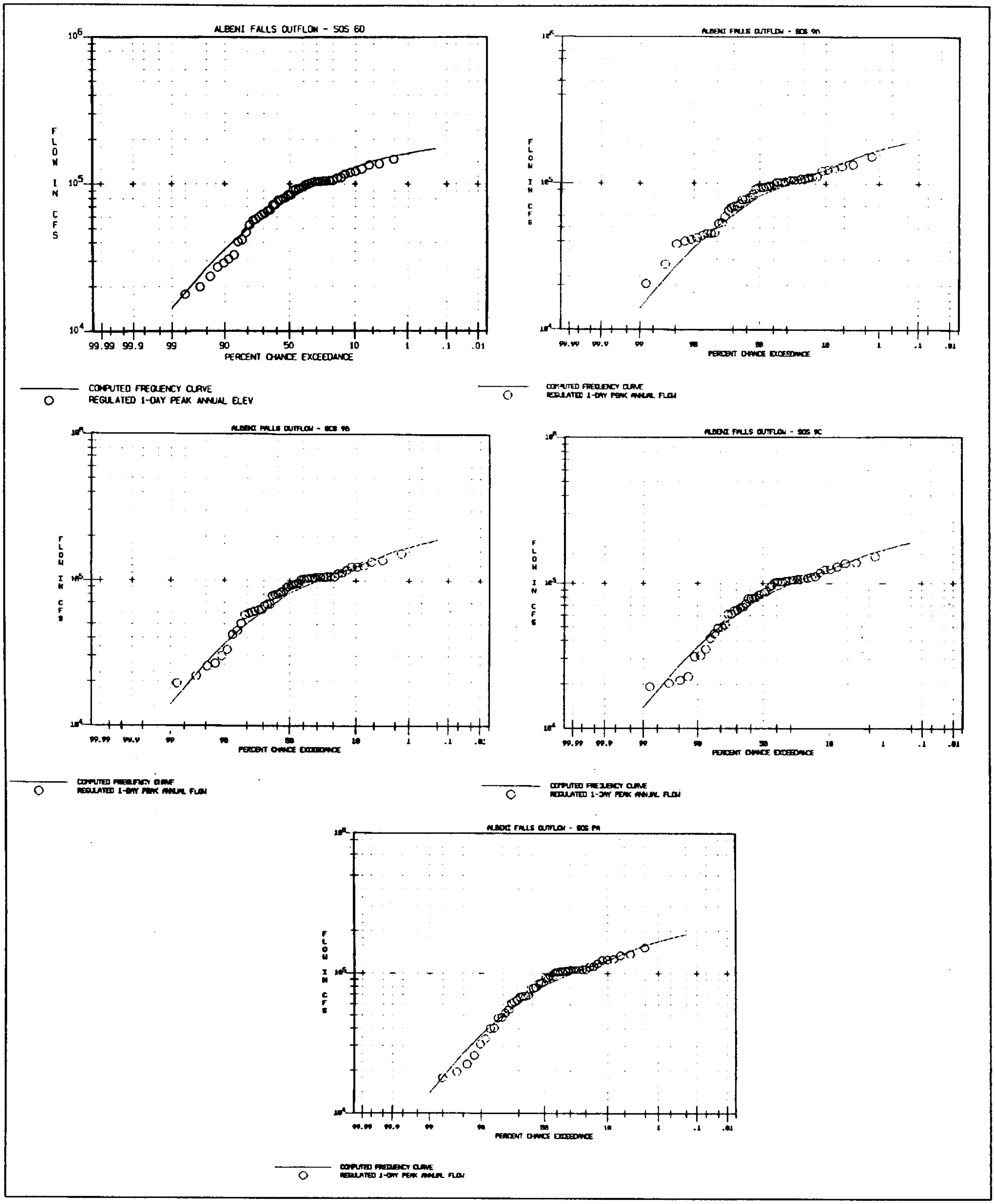

Figure B–7. Frequency Curves for Albeni Falls Outflow – CONT

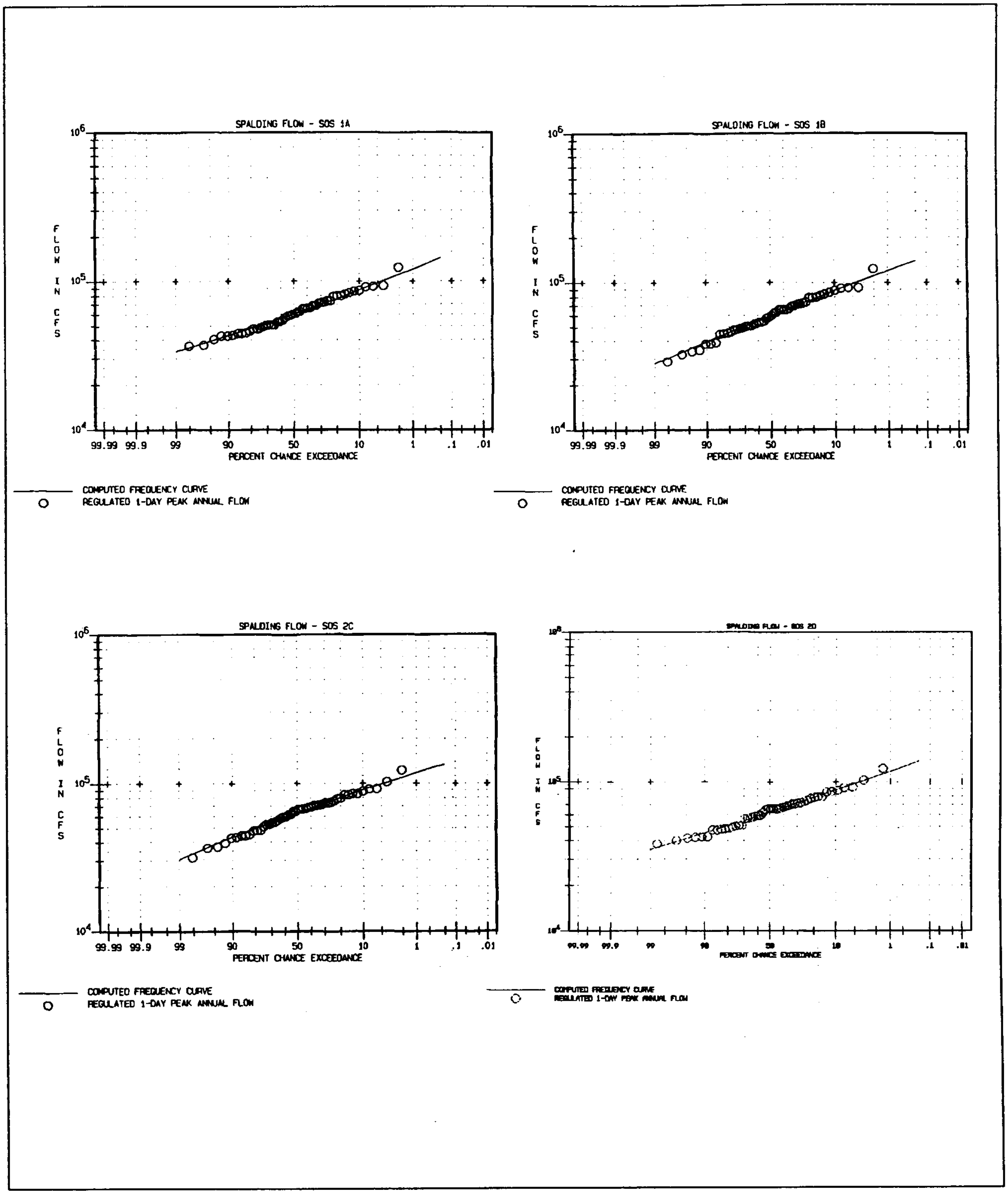

Figure B–8. Frequency Curves for Spalding Flow

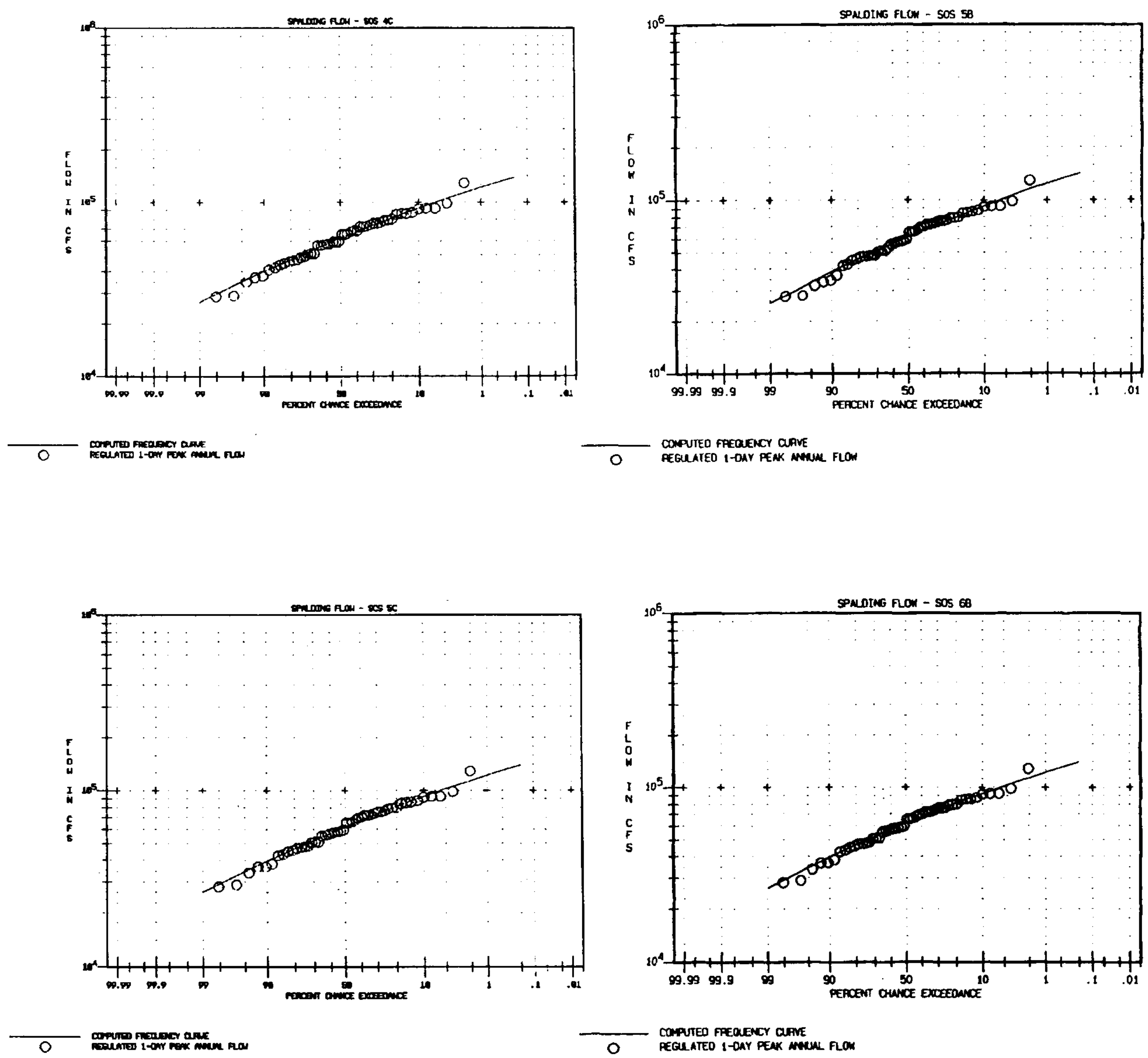

Figure B–8. Frequency Curves for Spalding Flow – CONT

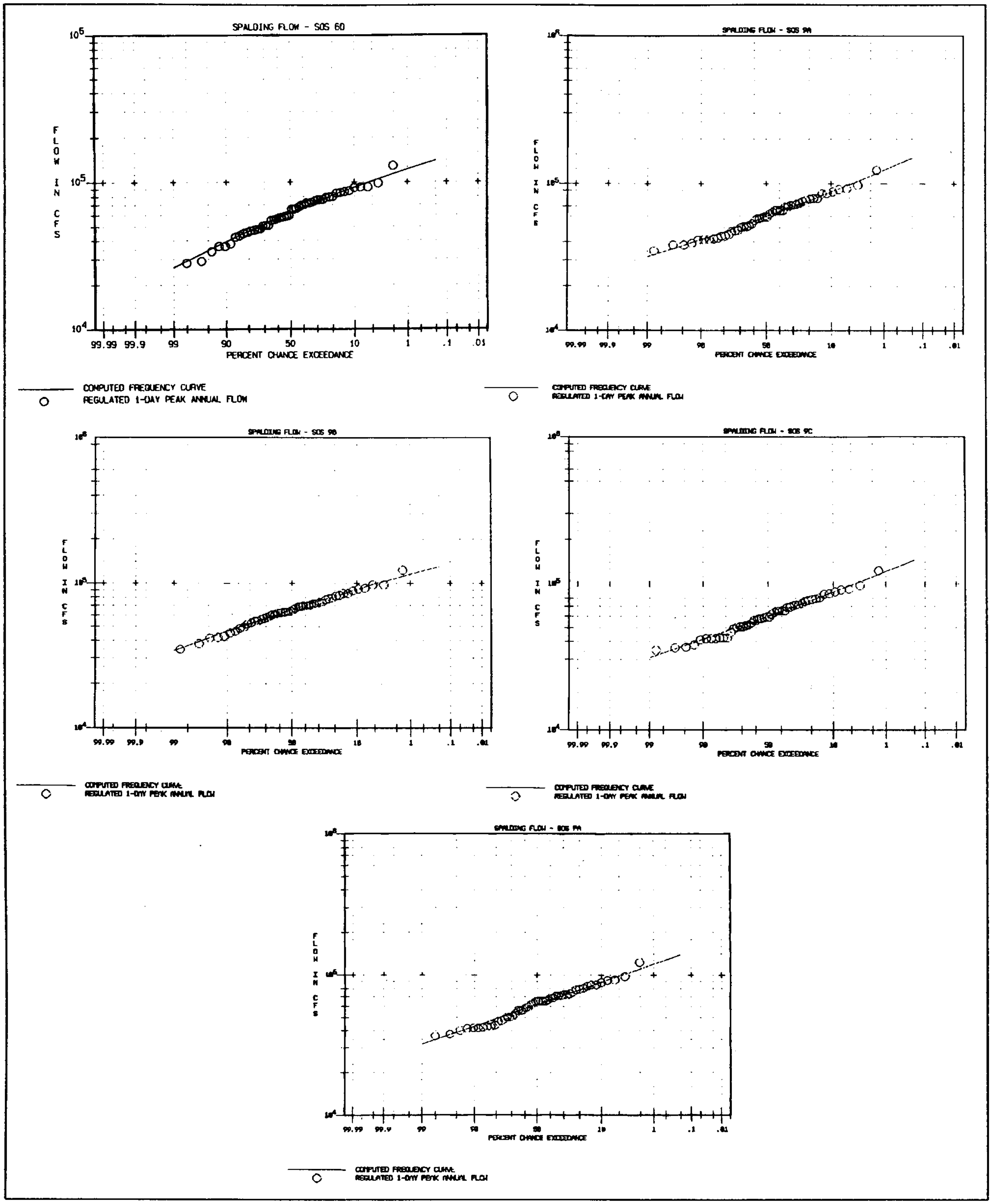

Figure B–8. Frequency Curves for Spalding Flow – CONT

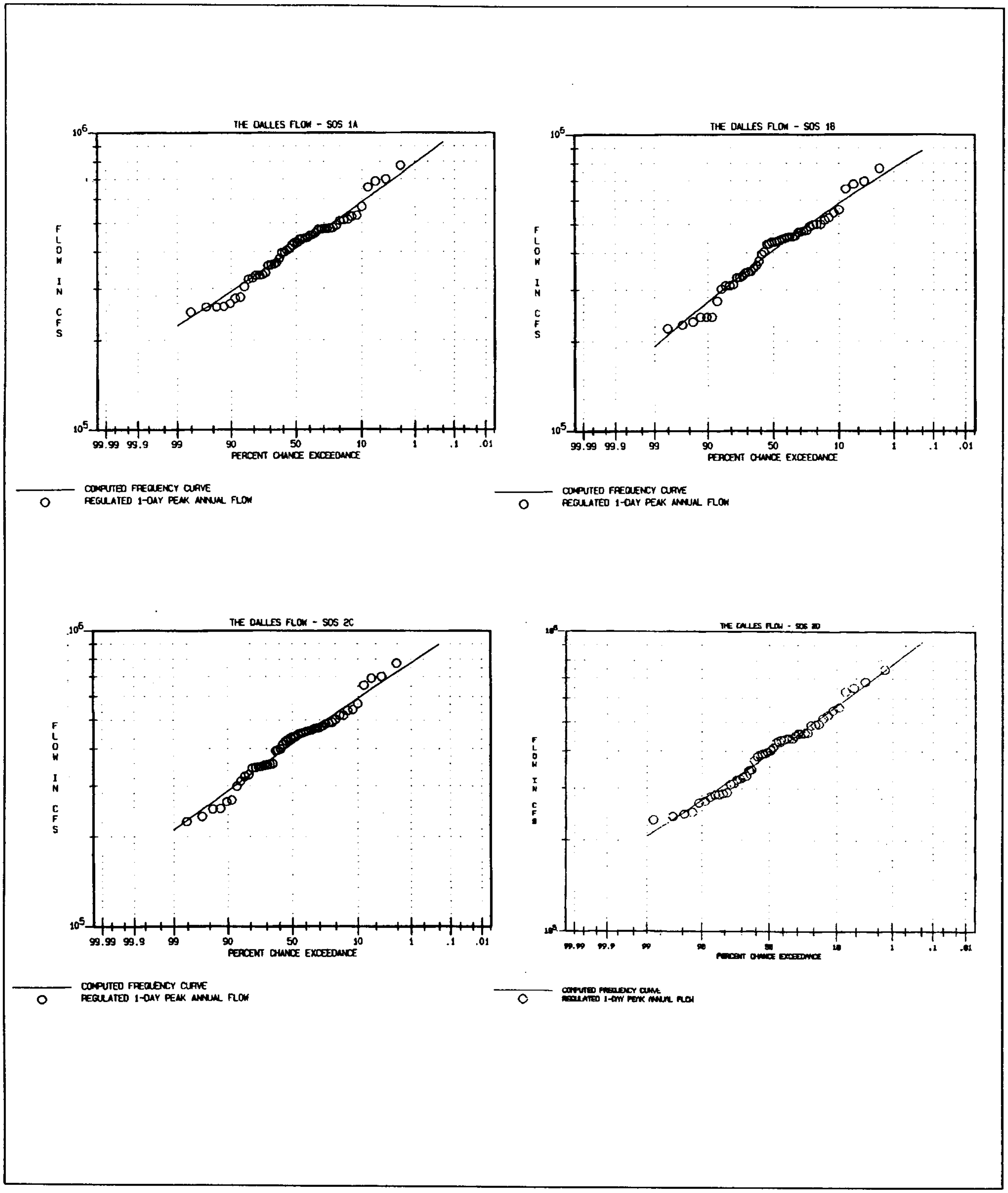

Figure B–9. Frequency Curves for The Dalles Flow

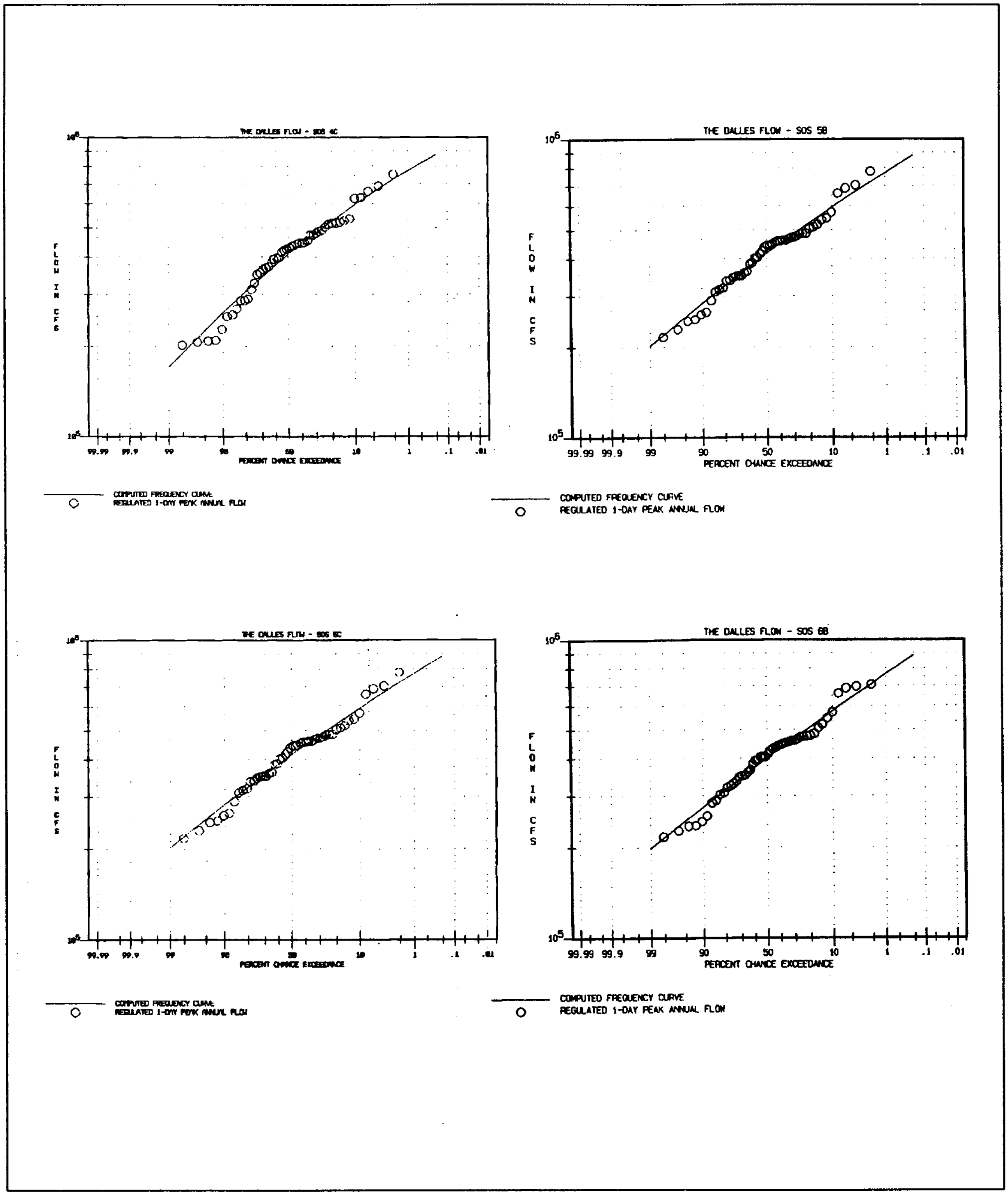

Figure B–9. Frequency Curves for The Dalles Flow – CONT

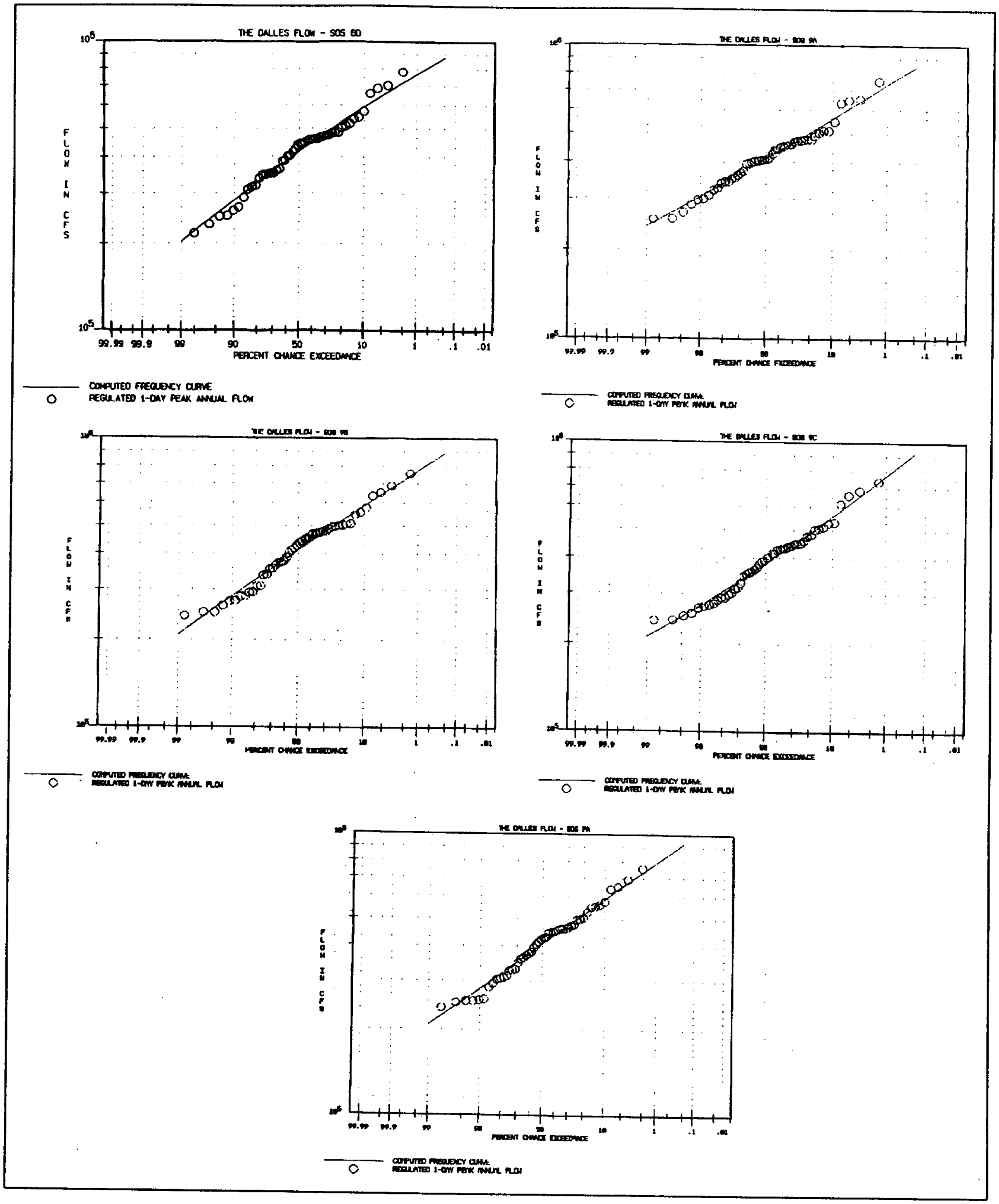

Figure B–9. Frequency Curves for The Dalles Flow – CONT