Snake River - Hells Canyon
Total Maximum Daily Load (TMDL)

Technical Appendices

July 2003

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Appendix A. New vs Old TMDL Rules Information

Appendix A contains an extract of text from the Federal Register dated July 13, 2000, titled: Part VI, Environmental Protection Agency, 40 CFR Part 9 et al., Revisions to the Water Quality Planning and Management Regulation and Revisions to the National Pollutant Discharge Elimination System Program in Support of Revisions to the Water Quality Planning and Management Regulation; Final Rules.

The extract included in this document contains only the text that is specific to the discussion that the new TMDL rules allow states to choose between the application of the former TMDL rules and the new TMDL rules for some TMDLs; namely Section 130.37, subsection II-W on pages 43635-43636.

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NATIONAL ARCHIVES AND RECORDS ADMINISTRATION
1985

Federal Register

Thursday,
July 13, 2000

Part VI

Environmental Protection Agency

40 CFR Part 9 et al.

Revisions to the Water Quality Planning and Management Regulation and Revisions to the National Pollutant Discharge Elimination System Program in Support of Revisions to the Water Quality Planning and Management Regulation; Final Rules

rule now requires a response to ''all significant comments'' instead of ''all comments,'' as proposed. The final rule no longer includes specific requirements as to what is to be included in the response to comments document. EPA believes this change will allow States, Territories, and authorized Tribes the flexibility they need when addressing public comments. EPA's public participation rules for rulemaking and permitting at Part 25 require EPA to respond to significant comments and to include at a minimum, a summary of public views, significant comments, criticisms and suggestions, and set forth the Agency's specific responses in terms of modification of the proposed action or an explanation for rejection of proposals made by the public (§ 25.8). EPA is persuaded by the comments that States, Territories and authorized Tribes should not be held to a higher standard than EPA. Pursuant to the final rule, States, Territories and authorized Tribes need only consider significant comments and indicate how they were addressed in the final action or why they were not addressed.

The rule recognizes that the Fish and Wildlife Service and the National Marine Fisheries Service have an interest in a State's, Territory's or authorized Tribe's list and TMDLs. By including the provisions of § 130.36(c), EPA is not giving the Services greater opportunity to receive information or to comment than is afforded anyone else. Nor is EPA attempting to transfer its obligations under the Endangered Species Act to States, Territories or authorized Tribes. The provisions of § 130.36(c)(1) require States, Territories, and authorized Tribes to provide the Services with copies of lists, including prioritized schedules and TMDLs. However, under the public participation requirements of § 130.36(a), any interested party may also request similar access to this information by making a written request to the State for direct notification. EPA is promulgating § 130.36(c)(1) because the Services have expressed to EPA an interest in reviewing section 303(d) lists and TMDLs. In recognition of the potential burdens on the States which such information sharing might impose, EPA agreed it would undertake this information sharing responsibility with the Services if requested by a State, Territory, or authorized Tribe.

The provisions of § 130.36(c)(2) encourage, but do not require, States, Territories, and authorized Tribes to engage the Services in a dialogue related to Endangered Species Act concerns. EPA believes that it can reduce the number of times it may need to disapprove a list or TMDL based on endangered species concerns if the States, Territories, and authorized Tribes communicate with the Services early in the process of developing lists and TMDLs. For this reason, EPA is including in the final rule a recommendation that States, Territories and authorized Tribes establish processes with the Services that will provide for the early identification and resolution of their concerns as they relate to lists and TMDLs. States, Territories and authorized Tribes are not required to establish such a process, but may find it advantageous to do so.

Section 130.36(c)(3) requires States, Territories, and authorized Tribes to consider comments from the Services and EPA in the same way that § 130.36(b) requires States, Territories, and authorized Tribes to provide a response to significant comments and an explanation of how those comments were addressed in the final action or why they were not addressed. Section 130.36(c)(3) does not require States, Territories, and authorized Tribes to agree with or adopt comments or recommendations from EPA and the Services; however, it does require an explanation of how these comments were considered in the final decision. This is the standard set by § 130.36(b) for all comments received by a State, Territory, or authorized Tribe.

The provisions of § 130.36(d) recognize that EPA will consider the comments of the Services when EPA reviews lists and TMDLs. EPA does not believe that this provision provides the Services with any greater access to the decision maker than other commenters. Rather, this provision alerts States, Territories, and authorized Tribes that EPA will consider the comments of the Services and how those comments were addressed.

W. What is the Effect of This Rule on TMDLs Established When the Rule is First Implemented? (§ 130.37)

What did EPA propose? EPA proposed a transitional period for implementing the TMDL requirements of the new rule. Specifically, EPA proposed that it would approve any TMDL submitted to it for review within 12 months of the final rule's effective date if it met either the pre-promulgation requirements in § 130.7 or the post-promulgation requirements in §§ 130.31, 130.32 and 130.33. EPA also proposed that when EPA establishes TMDLs within 12 months of the rule's effective date, EPA would use either the § 130.7 requirements or the new requirements in proposed §§ 130.31, 130.32 and 130.33. EPA proposed this transitional period to give States, Territories, authorized Tribes and EPA the security of knowing they could develop TMDLs prior to promulgation of the new rules without them later being determined inadequate as a result of the adoption of the new rule. In this way, States, Territories, authorized Tribes and EPA would not delay work towards establishing TMDLs until after the final rule was published. Also, EPA requested comment on whether the new TMDL requirements would affect the ability of States, Territories, or authorized Tribes to establish TMDLs on a schedule consistent with consent decree or settlement agreement schedules, and if so, how to address the issue.

What comments did EPA receive? EPA received a number of comments specific to the transitional period and actions EPA should take to facilitate establishing TMDLs in accordance with schedules in consent decrees and settlement agreements. Most comments supported the transitional period and many supported a period longer than 12 months. Some comments requested that some TMDLs be developed under the current requirements for ''good cause.'' Two comments suggested no transitional period, with one suggesting that States, Territories, and authorized Tribes be allowed to submit implementation plans no more than six months after submitting the other parts of the TMDL. EPA also received comments suggesting that EPA must establish TMDLs using either the current or new rules during the transitional period, and that EPA should work to establish TMDLs quickly using the new rules. Finally, EPA received some comments suggesting that all schedules should be revised because of these new regulations.

What is EPA promulgating today? After carefully considering the comments received on the transitional period, EPA is today promulgating a transition period for the new elements of TMDLs lasting 18 months from the date of publication of this rule in the **Federal Register** or nine months from the effective date of this rule, whichever is later. EPA recognizes the concerns voiced in many comments about the challenge of now drafting an implementation plan for a TMDL already nearing completion, and the benefit of including stakeholders in implementation decisions at the beginning of the TMDL development process in order to better integrate the implementation strategies with the allocation of loads. Most States, Territories and authorized Tribes, as well as State associations, supported a transitional period of up to 18 months. Of the comments suggesting more than 18 months, only one provided a reason, *i.e.,* the average TMDL requires 24 months to complete. EPA does not believe States need to begin implementation plans at the onset of TMDL development. One comment describes the first 18 months of TMDL development to consist of collecting data, developing models, and conducting the analysis. EPA believes that at least the first six months of this work, especially data collection and modeling, can be conducted before approaching stakeholders to start developing the implementation plan. For this reason, EPA is including a transitional period of 18 months in the final rule unless the rule's effective data is delayed, in which case the transition period will be 9 months from the rule's effective date.

EPA rejects the suggestion not to allow a transitional period based on the commenter's belief that implementation plans could be quickly developed, or that States, Territories, and authorized Tribes have had sufficient notice to begin developing these plans in anticipation of the new regulatory requirements. EPA does not believe that the mere fact that implementation plans were part of the proposal would by itself have caused States, Territories, or authorized Tribes reasonably to believe that the final rule would necessarily require submission of an implementation plan with the rest of the TMDL. EPA received many comments, some from States, Territories and authorized Tribes, contesting the legal authority to require States, Territories, and authorized Tribes to submit implementation plans as part of the TMDL. (This issue was discussed previously in today's preamble.) EPA believes these comments illustrate that many States, Territories, and authorized Tribes have waited to see the final rule before beginning to develop these plans.

EPA also rejects the suggestion not to provide a transitional period but rather to defer submittal of implementation plans up to six months following submittal of the rest of the TMDL. As discussed in today's preamble, EPA considers the implementation plan to be an integral part of the TMDL that is reviewed by EPA under section 303(d). Under today's rule EPA cannot approve the TMDL if it does not contain all the required elements, including an implementation plan. Therefore, the suggestion to defer submission of such plans to a later date would only further delay TMDL approvals, which is what EPA is attempting to prevent.

Today's rule also revises the proposed language regarding EPA's establishment of a TMDL during the transition. EPA proposed at § 130.38(b) that it may establish TMDLs using either approach, *i.e.,* the pre-promulgation or post-promulgation requirements. Some commenters misconstrued this language as a statement by EPA that it may choose not to establish TMDLs even if required to do so by court order or the statute. To eliminate confusion on this issue, EPA is using the word ''will'' instead or ''may'' in the final regulations. It is EPA's intention to use the new regulations as soon as possible. However, EPA recognizes that it may need to establish a TMDL where a State, Territory, or authorized Tribe has not, and to do so, EPA may need as much time as a State, Territory, or authorized Tribe to develop an implementation plan.

In particular instances, before the end of the transition period, where a schedule in a consent decree or settlement agreement would make it impossible to establish TMDLs with an implementation plan under the schedule, EPA would consider approaching the Plaintiffs to request an extension of the schedule so that TMDLs could be established using the new requirements. EPA expects that by the end of the transition period, States, Territories, and authorized Tribes will have established procedures for integrating implementation plan into TMDLs. EPA's expectation is that the transition period should greatly reduce the need for EPA to establish TMDLs pursuant to the existing consent decrees and settlement agreements.

X. Continuing Planning Process (§ 130.50)

What did EPA propose? EPA proposed to make only minor changes to the continuing planning process (CPP) requirements currently found at § 130.5. The proposal renumbered the section as § 130.50 and revised the current regulatory requirements to clarify that States, Territories and authorized Tribes have discretion to go beyond the mandatory plan elements set out in the regulation and also include other processes, such as watershed-based planning and implementation. The proposal also makes clear that a CPP need not be a single document but may be a compendium of many different State, Territorial and authorized Tribal planning documents. Finally, the proposal made conforming changes to citations to sections that are renumbered by the proposal.

What comments did EPA receive? EPA received a number of comments specific to this section. Three comments supported the proposal. One comment expressed concern that the proposed change required that the CPP be a document. A number of other comments suggested additional revisions to the existing CPP requirements.

What is EPA promulgating today? Based on its analysis of the comments received on this section, EPA is making one change to § 130.50(b) of the proposed rule. EPA is changing the final rule to recognize that the CPP need not be a single document. EPA acknowledges that the CPP is a process often described in numerous documents, rather than being a single document. EPA believes the revision in the final rule removes the confusion expressed over this. EPA declines to make the other requested changes for the reasons expressed in the Response to Comments Document.

Y. Water Quality Management Plans (§ 130.51)

What did EPA propose? EPA proposed to make only minor changes to the water quality management plan requirements currently found at § 130.6. EPA proposed to renumber the section as § 130.51 and to revise the current regulatory requirements to clarify that updates to water quality management plans should incorporate approved TMDLs and generally have a watershed focus. In addition, EPA rewrote proposed § 130.51(a) in plain English format.

What comments did EPA receive? EPA received a number of comments specific to this section. In most instances, only one commenter suggested a specific revision or addition. In four instances, multiple commenters made the same or similar comment. Two comments supported the proposal. Two comments suggested that § 130.51(a) retain the references to sections 208, 303, and 305 of the CWA that were in the existing rule. Two comments requested a change to or clarification of the part of the rule dealing with nonpoint source regulatory programs. Three commenters requested revisions to the existing rule language to clarify what a nonpoint source is. Another comment suggested that EPA recognize the link between the State Revolving Fund (SRF) and § 130.51(f).

What is EPA promulgating today? Based on its analysis of the comments received on this section, EPA is making three changes to § 130.51(a) of the proposed rule. First, EPA is reinstating the reference to CWA section 208 and 303(e) in the sentence describing the initial water quality management plan. Second, EPA is reinstating the reference

Appendix B. Snake River – Hells Canyon Public Advisory Team Seatholders List

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SNAKE RIVER-HELLS CANYON TMDL

Public Advisory Team Members

NAME	PAT POSITION
Doris Armacost	Idaho Recreation Interests
Robert Braun	Industry Interests
Ralph Browning	Oregon Timber Interests
Guy Dodson	Tribal Interests
Robbin Finch	Idaho Municipalities
Richard Fleming	Oregon Municipalities
Gregory Haller	Tribal Interests
Joe Hinson	Timber Interests
Russell Hursh	Oregon Local Governments
Ron Jones	Oregon Agricultural Interests
Todd Lakey	Idaho Local Governments
Mark Limbaugh	Idaho - Other Interests
William Lovelace	Oregon Environmental Interests
Mike Medberry	Idaho Recreational Interests
Ralph Myers	Hydro-power Interests
Mike Nelson	Oregon Public-at-Large
Frank Robinson	Oregon - Other Interests
Royce Schwenkfelder	Idaho Agricultural Interests
Phil Simonski	Oregon Recreation Interests

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Appendix C. Snake River – Hells Canyon Water Quality Criteria and Suitability Analysis

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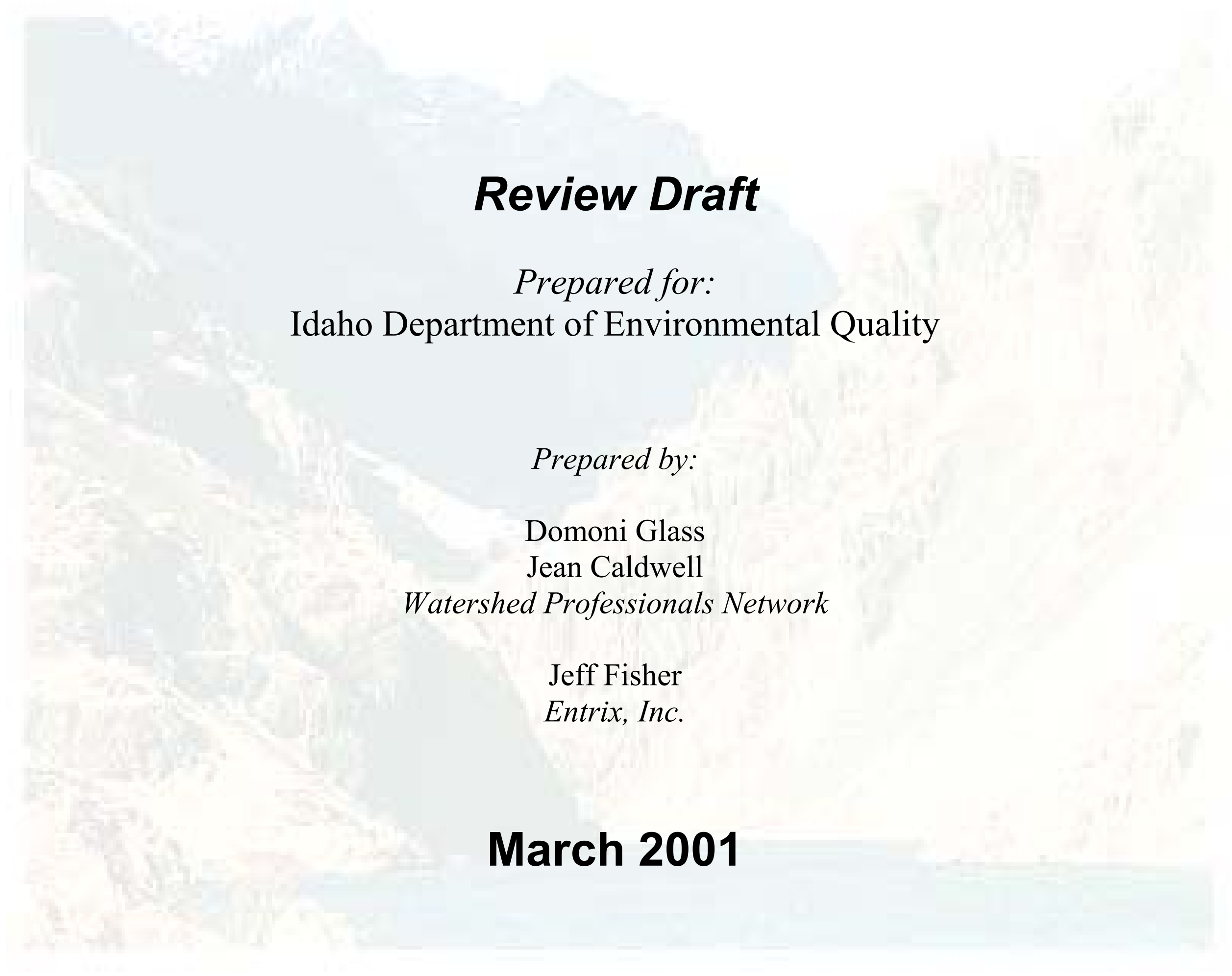
Water Quality Criteria and Suitability Analysis For the Snake River – Hells Canyon Total Maximum Daily Load



Review Draft

Prepared for:
Idaho Department of Environmental Quality

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Domoni Glass
Jean Caldwell
Watershed Professionals Network

Jeff Fisher
Entrix, Inc.

March 2001

Water Quality Criteria and Suitability Analysis

For the

Snake River – Hells Canyon Total Maximum Daily Load

Review Draft

Prepared for:
Idaho Department of Environmental Quality

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March 2001

Water Quality Criteria and Suitability Analysis for the Snake River – Hells Canyon Total Maximum Daily Load

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Water Quality Criteria and Suitability Analysis for the Snake River – Hells Canyon Total Maximum Daily Load

1.0 INTRODUCTION

The Total Maximum Daily Load (TMDL) for the Snake River, Hells Canyon reach examines the water quality situation in the basin and identifies targets for various water quality parameters. The area of interest lies on the border between Idaho and Oregon; hence the TMDL is being developed cooperatively by the two states. The primary pollutants of concern are temperature, turbidity, dissolved oxygen, mercury, aldrin and dieldrin, PCBs, and DDT.

This document was prepared to support the TMDL development. It provides a discussion of the species present in the study area and identification of key indicator species (Section 2.0), comparison of the applicable water quality criteria and identification of the most stringent applicable criteria (Section 3.0), a review of the response of the key indicator species to the pollutants of concern (Section 4.0), and identification of spatial and seasonal areas of critical concern with respect to the effects of pollutants on the key indicator species (Section 5.0).

2.0 SPECIES PRESENT IN THE STUDY AREA

There are 26 species of fish known to occur in the study area (Table 1). Of these, 13 species (50%) are native species. The key indicator fish species selected to be addressed in the TMDL include bull trout, rainbow trout, chinook salmon, black crappie, smallmouth bass, and white sturgeon. These species are of interest because they are either popular sport fish and are readily consumed by the public and/or are listed as either threatened or endangered under the Endangered Species Act (ESA) in Idaho waters.

Black crappie and smallmouth bass are not native species and large portions of the chinook salmon and rainbow trout populations are of hatchery origin (Chandler and Richter, 2000; ACOE 1994b). Rainbow trout are found throughout the study area. Smallmouth bass and clack crappie are common in the reservoirs. Chinook salmon are not found upstream of Hells Canyon Dam. White sturgeon are largely limited to the reach below Hells Canyon Dam although very small populations are known to persist in Hells Canyon and Brownlee Reservoirs (Kepla et al, 2000). Bull trout in the study area are almost exclusively adults that spawn in tributaries upstream of Brownlee reservoir (Pine Creek, Indian Creek, and Sheep Creek) (Chandler and Richter, 2000). The coho reported in the Hells Canyon complex are rarely encountered (Richter, 2000) and are likely the result of experimental plantings since upstream passage for these fish is not available.

Table 1. Species known to be present in the study area (ACOE, 1994).

Bold type indicates native species. Check indicates species identified in ACOE, 1994a. Star indicates species identified by Idaho Power (Richter, 2000).

Species	Scientific Name	Hells Canyon Complex[1]	Hells Canyon Reach[2]
White Sturgeon	***Acipenser transmontanus***	T	T
Rainbow Trout	***Oncorhynchus mykiss***	T, *	T
Kokanee	***Oncorhynchus nerka***		T
Chinook Salmon	***Oncorhynchus tshawytscha***		T
Coho Salmon	***Oncorhynchus kisutch***	*	
Mountain Whitefish	***Prosopium williamsoni***	T, *	T
Bull Trout	***Salvelinus confluentus***	T, *	T
Eastern Brook Trout	*Salvelinus fontinalis*	*	
Chiselmouth	***Acrocheilus alutaceus***	T, *	☐
Goldfish	*Carassius auratus*	T	T
Common Carp	*Cyprinus carpio*	T, *	T
Peamouth	***Mylocheilus caurinus***	T, *	
Northern Pikeminnow	***Ptychocheilus oregonensis***	T, *	T
Tui Chub	***Gila bicolor***	*	
Fathead Minnow	*Pimephales promelas*	*	
Banded Killifish	*Fundulus diaphanus*	*	
Longnose Dace	***Rhinichthys cataractae***	T	T
Dace Species	***Rhinichthys spp.***	*	
Longnose Sucker	***Catostomus catostomus***	T	
Bridgelip Sucker	***Catostomus columbianus***	T, *	T
Largescale Sucker	***Catostomus macrocheilus***	T, *	T
Bullhead Catfish	*Ameriurus sp.*	*	
Blue Catfish	*Ictalus furcatus*	*	

Channel Catfish	*Ictalurus punctatus*	T, *	T
Species	**Scientific Name**	**Hells Canyon Complex**[1]	**Hells Canyon Reach**[2]
Tadpole Madtom	*Noturus gyrinus*	T, *	T
Flathead Catfish	*Pylodictus olivaris*	T, *	
Warmouth	*Lepomis gulosus*	T, *	
Pumpkinseed	*Lepomis gibbosus*	T, *	T
Bluegill	*Lepomis macrochirus*	T, *	
Smallmouth Bass	*Micropterus dolomieui*	T, *	T
Largemouth Bass	*Micropterus salmoides*	T, *	
White Crappie	*Pomoxis annularis*	T, *	
Black Crappie	*Pomoxis nigromaculatus*	T, *	T
Yellow Perch	*Perca flavescens*	T, *	
Mottled Sculpin	***Cottus bairdi* Girard**	*	
Sculpin Spp. Unknown	***Cottus spp.***	T	

1/ Hells canyon complex includes all three reservoirs

2/ Brownlee to the confluence with the Clearwater River

3.0 WATER QUALITY CRITERIA STRINGENCY ANALYSIS

The water quality criteria stringency analysis compared the various state and federal criteria for temperature, dissolved oxygen, turbidity, dissolved gases, PCBs, aldrin and dieldrin, mercury, and DDT and its metabolites. The object of the comparisons was to determine which of the various criteria were the most stringent. In most cases, the measures of the pollutant used by the various regulatory agencies were similar, and determination of the most stringent criteria was relatively simple. In some cases (temperature and dissolved oxygen), the measures used were significantly different between the regulatory agencies and methods had to be developed to relate the various measures to each other. These methods are described as needed for each pollutant discussed below.

3.1 TEMPERATURE

State temperature standards tend to be set to single values selected from the range of responses to temperature documented for key fish species. The State of Oregon has a single target value, modified to reflect situations where the natural temperature (that which is expected in the absence of anthropogenic effects) exceeds the stated criterion. Oregon water quality standards do not explicitly state that the standard shall be the natural background temperature of the water body where the single target value is exceeded. They do, however, state that no measurable surface water temperature increase resulting from anthropogenic activities is allowed where the target value is exceeded. By implication, this suggests that the natural background temperature is the standard that applies where that natural background exceeds the target value. The temperature standards as described for Idaho in IDAPA 16.01.02.250 and for Oregon in 340-041 are summarized in Table 2. Idaho’s temperature standard for salmon spawning, salmon rearing, and warm water biota is expressed as one of two values; a daily maximum average and an instantaneous maximum. Idaho’s standard for bull trout is expressed via a third method of measurement.

There are several challenges in determining which regulations are the most restrictive. The first of these challenges is the different methods the two states use to measure temperature. These calculation methods result in different measures of maximum temperatures and are therefore not directly comparable.

Table 2. Summary of Oregon and Idaho temperature standards

Life Stage/Situation	Oregon[1]	Idaho
Salmonid Rearing	64.0 EF (17.8 EC) or natural background water temperature where natural background temperatures exceed standard	<22EC instantaneous with daily ave <19EC
Native Salmon Spawning	55.0 EF (12.8 EC) or natural background water temperature where natural background temperatures exceed standard	Sep 1-Jul 15 <13EC instantaneous with daily ave <9 EC
Bull Trout Habitat	50.0 EF (10.0 EC) or natural background water temperature where natural background temperatures exceed standard Applies in Oregon to habitat determined to be critical for bull trout recovery.	<12EC daily average June, July, August for bull trout juvenile rearing and <9EC daily average September, October for bull trout spawning. Applies only to tributary waters. The mainstem is specifically excluded.
Threatened and Endangered Species (Bull Trout and Fall Chinook)	Temperature that does not impair the biological integrity of the Threatened and Endangered population no anthropogenic increases in water temperature where temperatures exceed the impairment temperature	
Warm Water Biota		<33 EC instantaneous with daily ave <29 EC
Very Low (<10% sat. or 0.5 mg/l) DO Waters	Natural background water temperature	

1/ Oregon temperature measured as 7-day moving average of daily maximum temperatures

In order to develop comparable measures of temperature, data from 28 temperature monitoring sites in southwest Idaho were used to correlate the various measures. Since Oregon has only one measure of temperature and Idaho has two, the regressions were developed to relate Idaho's instantaneous measure and Idaho's measures to the Oregon measure. A high degree of correlation between the various measures was found (Figures 1 and 2). In each case, better than 92 percent of the variability between the datasets was explained by the regression equation.

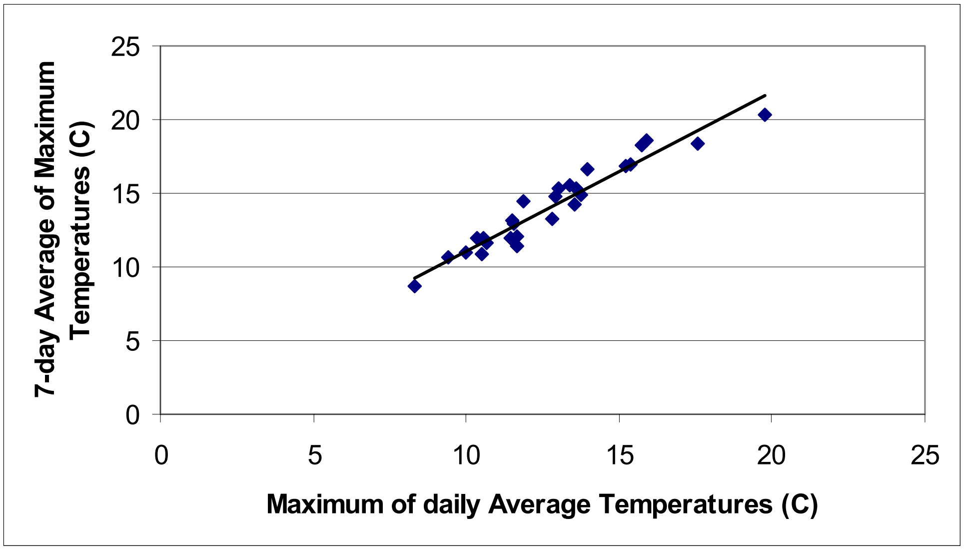


Figure 1. Relationship between Oregon's 7 day moving average measure of stream temperature and Idaho's maximum daily average method of measuring temperature for 28 Idaho Streams

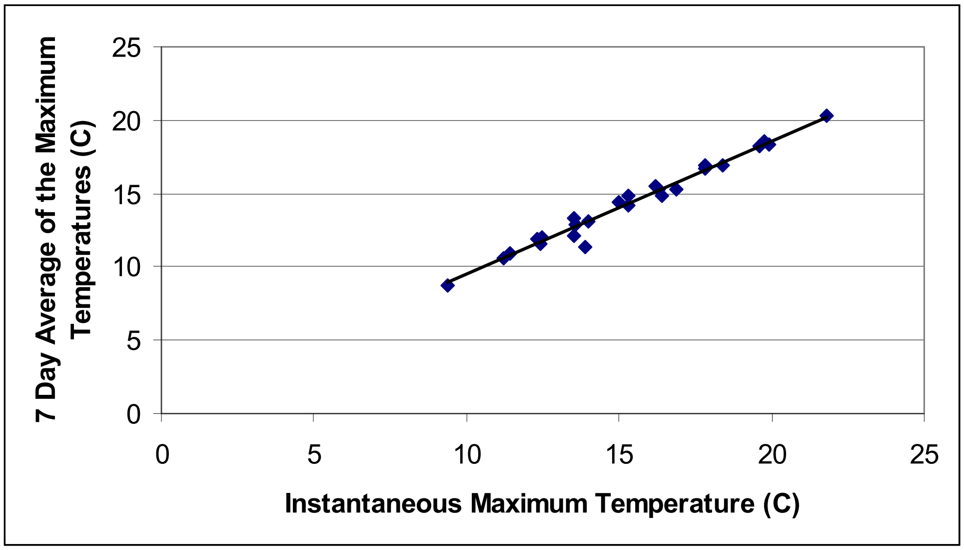


Figure 2. Relationship Between Oregon's 7 day moving average measure of stream temperature and Idaho's instantaneous maximum method of measuring temperature for 28 Idaho Streams

The resulting regression equations are:

7-day Moving Ave of Daily Max (EC) = 0.3809 + 0.9106* Instantaneous Maximum Temp (EC)
(r^2 = 0.9770)

7-day Moving Ave of Daily Max (EC) = 0.3662 + 1.0753 * Max Daily Ave Temp (EC)
(r^2 = 0.9273)

Using these equations, the values in Table 2 can be converted to values representing the 7-day moving average of the daily maximum temperatures (Oregon's measure of temperature) (Table 3). Note that the transformed values in Table 3 for the State of Idaho include two different numbers in the same units. This reflects the two options for measuring temperature specified in the Idaho criteria. Since Idaho's standard for bull trout of 13EC 7-day average maximum is still pending, this measure was not included in Table 3.

The second challenge in comparing the standards is the use of "natural background" temperature in the Oregon statutes. The Oregon statutes specify that no additional anthropogenic increases in temperature can occur where natural background temperatures (or the temperature expected in the absence of anthropogenic effects) exceed the specified temperature. At the present time, the natural background temperatures in the study area are unknown. Therefore, the most restrictive temperature standards must necessarily be defined in terms of the unknown background temperatures, as follows:

<u>Salmonid Rearing:</u>
If natural background is <17.8 EC, then 17.8 EC
If natural background is >17.8 EC and < 20.4 EC, then natural background
If natural background is > 20.4 EC, then <20.4 EC

<u>Salmon Spawning</u>: <10.0 EC September 1 through July 15

<u>Waters supporting or "necessary" to maintain the viability of bull trout</u>: <10 EC

<u>Warm Water Biota</u>: <30.4 EC

<u>Very low DO waters</u>: Natural background temperature

Table 3. Summary of Oregon and Idaho temperature standards translated to the 7-day moving average of maximum daily temperatures

Life Stage/Situation	**Oregon**	**Idaho**[1]
Salmonid Rearing	<64.0 EF (17.8 EC) or natural background water temperature where natural background temperatures exceed standard	<20.8 EC or <20.4EC
Native Salmon Spawning	<55.0 EF (12.8 EC) or natural background water temperature where natural background temperatures exceed standard	Sep 1-Jul 15 <10.0 EC or <12.2 EC
Bull Trout Habitat (in Oregon, this is habitat determined to be critical for bull trout recovery)	50.0 EF (10.0 EC) or natural background water temperature where natural background temperatures exceed standard	<11.3EC instantaneous
Threatened and Endangered Species (Bull Trout and Fall Chinook)	Temperature that does not impair the biological integrity of the Threatened and Endangered population no anthropogenic increases in water temperature where temperatures exceed the impairment temperature	
Warm Water Biota		<31.5 EC or <30.4 EC
Very Low (<10% sat. or 0.5 mg/l) DO Waters	Natural background water temperature	

1/ Idaho's temperature standards are presented as the converted maximum daily average standard followed by the converted maximum instantaneous standard

The determination of habitat that is "necessary" to maintain the viability of bull trout is the responsibility of the State of Oregon. The water quality criterion to not provide guidance on that determination. In addition, if the temperature that does not impair the biological integrity of chinook and/or bull trout is lower or higher than these numerical targets, that temperature may modify these targets. See section 4.0 for discussion of the biological responses to temperature.

3.2 DISSOLVED OXYGEN

3.2.1 Water Column

State dissolved oxygen (DO) standards for the water column as described for Idaho in IDAPA 16.01.02.250 and for Oregon in 240.041 include primarily single values for each, salmonid spawning, cold, cool, and warm water areas (Table 4). The saturation level attainable in waters varies with temperature (Figure 3), barometric pressure, and altitude; temperature has the greatest effect. Because of this, each state has made some accommodation for the other physical factors that may affect DO.

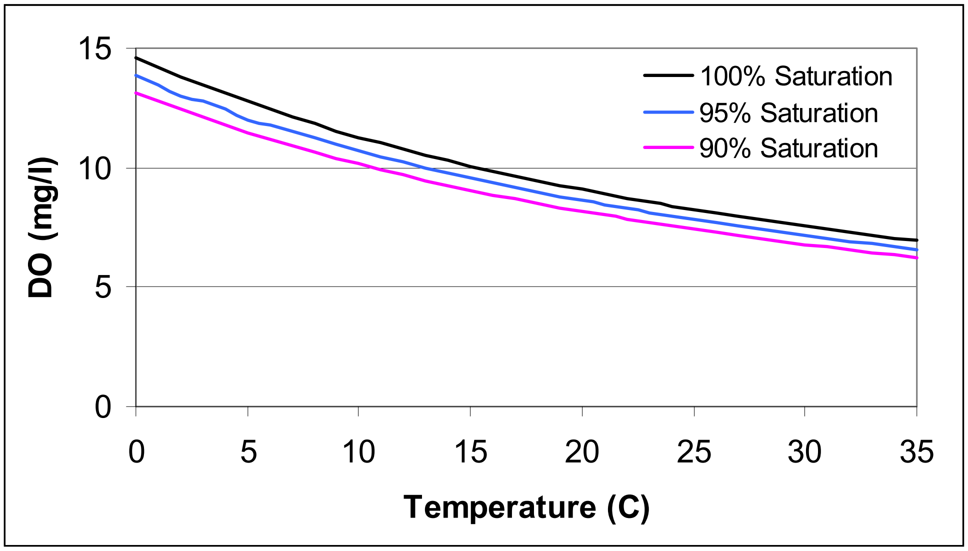


Figure 3. 100%, 95%, and 90% Oxygen Saturation Level at Various Water Temperatures.

The units of measure are relatively consistent between the states; in most cases an absolute minimum is used (Table 4). The State of Oregon, however, is allowed the discretion to apply alternate standards that include measures of 30-day, 7-day, and absolute minimums should ODEQ determine that they have sufficient information to impose those standards. No data was available to compare these various intervals of measure; hence the absolute standard was assumed to represent the most restrictive standard.

Table 4. Summary of Oregon and Idaho dissolved oxygen standards for the water column

Life Stage/Situation	Oregon	Idaho
Salmonid Spawning	If intergravel spatial median is ≥8mg/l then ≥9.0 mg/l, else ≥11.0 mg/l. If temperature, barometric pressure, and/or altitude precludes meeting the standard, then ≥95% saturation. Applies from spawning to emergence.	One day minimum of ≥6.0 mg/l or 90% saturation, whichever is greater, applies Sep 1 through Jul 15.
Cold Water	≥8.0 mg/l absolute minimum unless the Department determines that adequate information exists, in which case the following may apply at the Department's discretion: ≥8.0 mg/l as a 30 day mean minimum, ≥6.5 mg/l as a 7 day mean minimum, and ≥6.0 mg/l absolute minimum unless temperature, barometric pressure and/or altitude precludes meeting the standard, then ≥90% saturation.	≥6.0 mg/l at all times except in bottom 20% of water depth in lakes and reservoirs that are ≤35 meters or the bottom 7 meters of water depth in lakes and reservoirs where depths are >36 meters. The waters of the hypolimnion in stratified lands and reservoirs are also excepted.
Cool Water	>6.5 mg/l absolute minimum unless the Department determines that adequate information exists, in which case the following may apply at the Department's discretion: ≥6.5 mg/l as a 30 day mean minimum, ≥5.0 mg/l as a 7 day mean minimum, and ≥4.0 mg/l absolute minimum.	
Warm Water	>5.5 mg/l absolute minimum unless the Department determines that adequate information exists, in which case the following may apply at the Department's discretion: ≥5.5 mg/l as a 30 day mean minimum, and ≥4.0 mg/l absolute minimum.	>5.0 mg/l at all times except in bottom 20% of water depth in lakes and reservoirs that are ≤35 meters or the bottom 7 meters of water depth in lakes and reservoirs where depths are >36 meters. The waters of the hypolimnion in stratified lands and reservoirs are also excepted.
Waters below existing dams, reservoirs, and hydroelectric facilities		June 15 – Oct 15 30 day mean ≥6.0 7 day mean minimum ≥4.7 Instantaneous minimum ≥3.5

The State of Idaho has made an exception to the standards that apply to the bottom waters of lakes and reservoirs. This exception reflects the natural tendency for deep lakes and reservoirs to stratify in summer. Once the stratification occurs, the lower strata (the hypolimnion) tends to have cooler waters with lower dissolved oxygen concentrations. The dissolved oxygen in the hypolimnion tends to decrease over the summer as decomposition of organic matter in the bottom of the lake uses up the available oxygen. Oregon does not have such an exception. The most restrictive measure was therefore assumed not to include this exception. If should be noted that the Idaho exception is in keeping with natural processes and the Oregon standard is not likely to be met in the deepest waters of most deep lakes and reservoirs.

Since the saturation level of dissolved oxygen naturally varies with water temperature and the some of the standards draw upon natural saturation levels, comparison of the state standards required that water temperature be taken into consideration. For each standard that included an absolute minimum or a percent saturation where the absolute minimum could not be met due to natural physical conditions, the absolute minimum was assumed to apply for all water temperatures up to the point where saturation was less than the standard. At that point, the appropriate curve depicted in Figure 3 was assumed to apply, with adjustments to account for the effect of elevation on atmospheric pressure (Michaud 1991). This resulted in a set of dissolved oxygen standards that varied with water temperature (Table 5).

Next, the maximum of the two states' minimum standards for a range of temperatures was identified for each, salmonid spawning, cold, cool, and warm fish habitat. This maximum was then selected to represent the minimum acceptable DO level. Two sets of curves were developed; one assuming that the State of Oregon would not exercise its option of imposing alternative standards, and one assuming that the State of Oregon would exercise that option. These curves, representing the most restrictive standards, are depicted in Figures 4 and 5. The "combined cold", "combined warm", "combined cool", and "combined warm" in the figures refer to the maximum of the DO standards in each state at each temperature.

The resulting standards are not simple to implement. They will vary throughout the year as well as between years as the temperature of the water column varies. Where distributions cold, cool, and warm species overlap (or spawning habitat overlaps with cold, cool, and/or warm species distributions) the highest value for the overlapping habitats would apply. The salmonid spawning curves apply only to locations where salmonid spawning occurs and during the period when eggs, alevins, and fry are present in the spawning gravels. Idaho’s definition of this period is the most restrictive (September 1 through July 15).

Table 5. Summary of dissolved oxygen criteria as a function of water temperature (values adjusted for effect of elevation).

Temp (C)	ORE Spawning Absolute	ORE Spawning 95% Saturation	ORE Spawning Combined	ID Spawning Absolute	ID Spawning 90% Saturation	ORE Cold Absolute	ORE Cold 90% Saturation	ORE Cold discretion	ID Cold	ORE Cool	ORE Cool Discretion	ORE Warm	ORE Warm Discretion	ID Warm
0.0	11.0	12.3	11.0	6.0	11.6	8.0	11.6	6.0	6.0	6.5	4.0	5.5	4.0	5.0
1.0	11.0	11.9	11.0	6.0	11.3	8.0	11.3	6.0	6.0	6.5	4.0	5.5	4.0	5.0
2.0	11.0	11.5	11.0	6.0	11.0	8.0	11.0	6.0	6.0	6.5	4.0	5.5	4.0	5.0
3.0	11.0	11.3	11.0	6.0	10.7	8.0	10.7	6.0	6.0	6.5	4.0	5.5	4.0	5.0
4.0	11.0	11.0	11.0	6.0	10.4	8.0	10.4	6.0	6.0	6.5	4.0	5.5	4.0	5.0
5.0	11.0	10.6	10.6	6.0	10.2	8.0	10.2	6.0	6.0	6.5	4.0	5.5	4.0	5.0
6.0	11.0	10.5	10.5	6.0	9.9	8.0	9.9	6.0	6.0	6.5	4.0	5.5	4.0	5.0
7.0	11.0	10.2	10.2	6.0	9.7	8.0	9.7	6.0	6.0	6.5	4.0	5.5	4.0	5.0
8.0	11.0	9.9	9.9	6.0	9.4	8.0	9.4	6.0	6.0	6.5	4.0	5.5	4.0	5.0
9.0	11.0	9.7	9.7	6.0	9.2	8.0	9.2	6.0	6.0	6.5	4.0	5.5	4.0	5.0
10.0	11.0	9.5	9.5	6.0	9.0	8.0	9.0	6.0	6.0	6.5	4.0	5.5	4.0	5.0
11.0	11.0	9.3	9.3	6.0	8.8	8.0	8.8	6.0	6.0	6.5	4.0	5.5	4.0	5.0
12.0	11.0	9.0	9.0	6.0	8.6	8.0	8.6	6.0	6.0	6.5	4.0	5.5	4.0	5.0
13.0	11.0	8.8	8.8	6.0	8.4	8.0	8.4	6.0	6.0	6.5	4.0	5.5	4.0	5.0
14.0	11.0	8.7	8.7	6.0	8.2	8.0	8.2	6.0	6.0	6.5	4.0	5.5	4.0	5.0
15.0	11.0	8.5	8.5	6.0	8.0	8.0	8.0	6.0	6.0	6.5	4.0	5.5	4.0	5.0
16.0	11.0	8.3	8.3	6.0	7.8	8.0	7.8	6.0	6.0	6.5	4.0	5.5	4.0	5.0
17.0	11.0	8.1	8.1	6.0	7.7	8.0	7.7	6.0	6.0	6.5	4.0	5.5	4.0	5.0
18.0	11.0	7.9	7.9	6.0	7.5	8.0	7.5	6.0	6.0	6.5	4.0	5.5	4.0	5.0
19.0	11.0	7.8	7.8	6.0	7.4	8.0	7.4	6.0	6.0	6.5	4.0	5.5	4.0	5.0
20.0	11.0	7.6	7.6	6.0	7.2	8.0	7.2	6.0	6.0	6.5	4.0	5.5	4.0	5.0
21.0	11.0	7.5	7.5	6.0	7.1	8.0	7.1	6.0	6.0	6.5	4.0	5.5	4.0	5.0
22.0	11.0	7.3	7.3	6.0	6.9	8.0	6.9	6.0	6.0	6.5	4.0	5.5	4.0	5.0
23.0	11.0	7.2	7.2	6.0	6.8	8.0	6.8	6.0	6.0	6.5	4.0	5.5	4.0	5.0
24.0	11.0	7.1	7.1	6.0	6.7	8.0	6.7	6.0	6.0	6.5	4.0	5.5	4.0	5.0
25.0	11.0	6.9	6.9	6.0	6.6	8.0	6.6	6.0	6.0	6.5	4.0	5.5	4.0	5.0
26.0	11.0	6.8	6.8	6.0	6.4	8.0	6.4	6.0	6.0	6.5	4.0	5.5	4.0	5.0
27.0	11.0	6.7	6.7	6.0	6.3	8.0	6.3	6.0	6.0	6.5	4.0	5.5	4.0	5.0
28.0	11.0	6.6	6.6	6.0	6.2	8.0	6.2	6.0	6.0	6.5	4.0	5.5	4.0	5.0
29.0	11.0	6.4	6.4	6.0	6.1	8.0	6.1	6.0	6.0	6.5	4.0	5.5	4.0	5.0
30.0	11.0	6.3	6.3	6.0	6.0	8.0	6.0	6.0	6.0	6.5	4.0	5.5	4.0	5.0
31.0	11.0	6.2	6.2	6.0	5.9	8.0	5.9	6.0	6.0	6.5	4.0	5.5	4.0	5.0
32.0	11.0	6.1	6.1	6.0	5.8	8.0	5.8	6.0	6.0	6.5	4.0	5.5	4.0	5.0
33.0	11.0	6.0	6.0	6.0	5.7	8.0	5.7	6.0	6.0	6.5	4.0	5.5	4.0	5.0
34.0	11.0	5.9	5.9	6.0	5.6	8.0	5.6	6.0	6.0	6.5	4.0	5.5	4.0	5.0
35.0	11.0	5.8	5.8	6.0	5.5	8.0	5.5	6.0	6.0	6.5	4.0	5.5	4.0	5.0

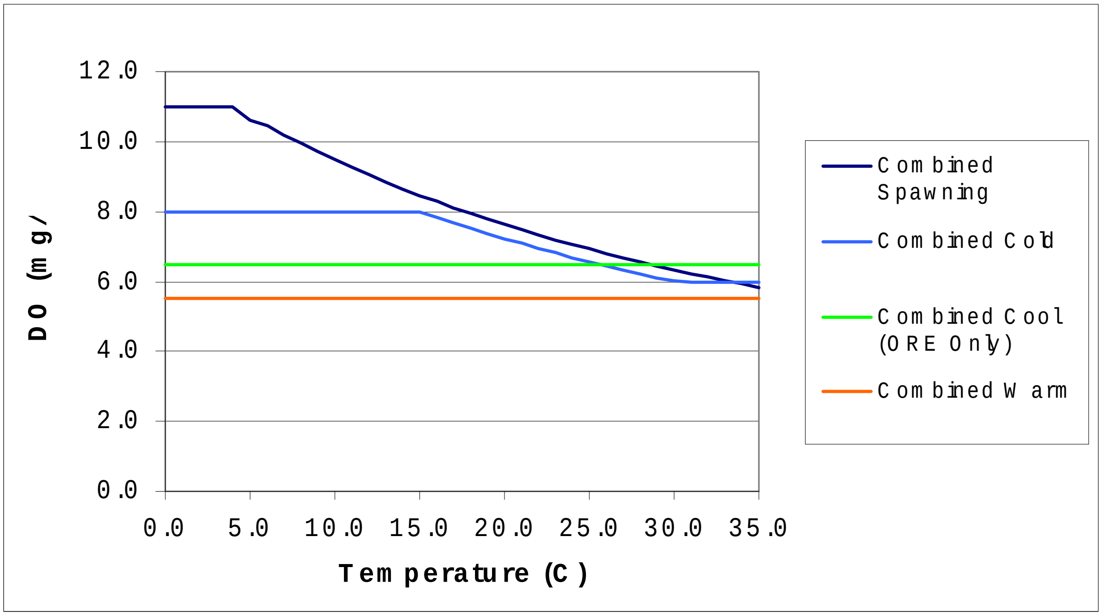


Figure 4. Combined standards for DO as a function of temperature (assuming Oregon does not exercise its discretion to enforce alternate standards.

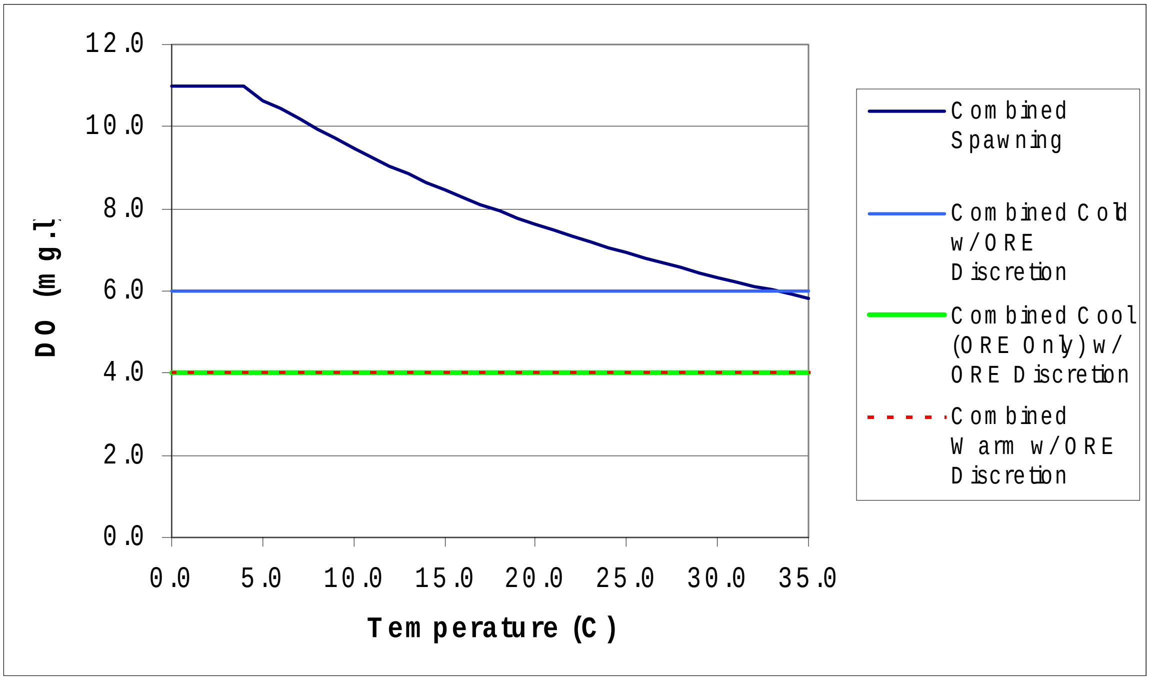


Figure 5. Combined DO standards as a function of temperature (assuming Oregon exercises its discretion to enforce alternate standards).

3.2.2 Spawning Substrate (Intergravel DO)

There is rather limited salmonid spawning within the project area. Spawning of salmon occurs downstream of the Hells Canyon Dam. Rainbow trout and bull trout spawn in the tributaries, which are not addressed in the TMDL and possibly in the mainstem upstream of Brownlee Reservoir. Therefore, the intergravel DO standards apply only to the spawning habitats in the free flowing reaches. Measurement of the intergravel DO levels is difficult and data on those levels is typically sparse. The DO standards for the water column as described for Idaho in IDAPA 16.01.02.250 and for Oregon in 340-041 are summarized in Table 6.

Table 6. Summary of Oregon and Idaho dissolved oxygen standards for the spawning substrate (intergravel DO).

Life Stage/Situation	Oregon	Idaho
Salmonid Spawning	Spatial median ≥6 mg/l (at <8 mg/l ODEQ can list the waterbody under Section 303d of the Clean Water Act). Applies from spawning to emergence.	1 day minimum ≥5.0 mg/l, 7 day average mean ≥6.0 mg/l; applies Sept.1 through Jul. 15.

The standards of the two states are fairly similar. The most restrictive is Oregon's standard of a spatial median ≥6 mg/l.

3.3 TURBIDITY

Initial review of the Idaho water quality standards identified specific criterion regarding turbidity, although there is a narrative standard, which applies. Since the narrative standard is difficult to interpret, the Oregon standard was assumed to be the most restrictive. The Oregon rule is based upon a 10% increase in turbidity over background (Table 7). This assumes that an estimate of background levels is available. Naturally occurring turbidity levels are highly variable. Weather conditions, underlying geology, occurrence of natural landslides, bank failures, and other sediment inputs upstream of the sample site, and stream power all contribute to that variability. As a result, natural background turbidity levels can be difficult to determine. The Oregon standard specifies that the "natural" load be measured "relative to a control point immediately upstream of the turbidity causing activity". This measure as defined can apply only to point sources since non-point sources are by definition dispersed through the landscape and have no control point. The method to assess background for non-point source situations is not specified; the standard, however, still applies. Typically, estimates of background turbidity require extensive modeling and/or monitoring. The expected background loads cannot be estimated here.

Table 7. Summary of Oregon and Idaho turbidity standards.

Oregon	Idaho
10% over natural background, cumulatively, unless related to activities necessary to address emergency situations or to accommodate legitimate activities where all practicable turbidity control techniques have been applied.	In areas designated for cold water fish, turbidity below any mixing zone set by IDEQ shall not exceed background by more than 50 NTU instantaneously or more than 25 NTU for more than 10 consecutive days. Surface waters of the state shall be free from floating, suspended, or submerged matter of any kind in concentrations causing nuisance or objectionable conditions or that may impair designated beneficial uses. This matter does not include suspended sediment produced as a result of nonpoint source activities.

3.4 pH

pH is a measure of the concentration of hydrogen ions in the water column. The State of Oregon's standard is in the range of 7 to 9 with a specific exception for waters impounded by dams prior to January 1, 1996 if ODEQ determines that an exceedence would not occur without the impoundment and all practicable measures have been taken to bring the pH into compliance with the standard. The State of Idaho's measure is 6.5 to 9.5. Hence, the State of Oregon's measure is the most restrictive unless the State of Oregon has made an exception for the study area in which case the Idaho standard would apply.

3.5 Dissolved Gases

Dissolved gases in excess of 100% saturation can have deleterious effects on fish survival. The Oregon standard for dissolved gases is <110% of saturation except when stream flow exceeds the 10 year, 7 day average flood.

3.6 Polychlorinated Biphenyls (PCBs)

Idaho does not have a standard for PCBs. The criteria (Table 8) set by EPA and the State of Oregon reference total PCBs only. No criteria have been promulgated for PCBs on a congener-specific basis by any state. The State of Oregon has specified standards for human health and freshwater acute levels that are not defined by the EPA. The Oregon standard for freshwater chronic is the same as EPA's standard. Therefore, the Oregon standard is more stringent than EPA's standard. Idaho's standard is stated as follows: "*Surface waters of the state shall be free from toxic substances in concentrations that impair designated beneficial uses. These substances do not include suspended sediment produced as a result of nonpoint source activities*." The concentrations that impair designated beneficial uses are not specified.

PCBs will be highly sorbed to sediments and, due to their hydrophobic nature, are rarely measurable in surface waters. Thus, the principal sink of PCB contamination in water is in contaminated sediments. Standards for concentrations in sediment have not been set by EPA or the states of Idaho and Oregon. Examples of standards set by other states and provinces are available in Appendix B.

Table 8. Summary of existing PCB water quality criteria for PCBs for the water column.

Aquatic Life Criteria		**Human Health Criteria**			
Freshwater Acute	Freshwater Chronic	Water and Fish Ingestion	Fish Consumption	Drinking Water (MCL)	Legal Code and Clarification
np	0.014 ug/L				US EPA 131.36; criteria equivalent for all Aroclor mixtures (1016, 1242, 1254, 1221, 1232, 1248)
2.0 ug/L	0.014 ug/L	79 ng	79 ng		State of Oregon. Human health risk based on 10-6 cancer risk; criteria based on total measured PCBs.

The above standards assume that all congeners of PCBs are equally toxic. This is not the case. Of the 209 possible PCB congeners, 21 are considered highly toxic (Safe et al. 1985, EPA 1989). PCBs are generally found in U.S. sediments, soils and water in the commercial mixtures from which they originated. These mixtures include the Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260 and 1268 marketed by the Monsanto Corporation, using mineral oil as a carrier. These mixtures contain 16, 21, 32, 42, 48, 54, 60 and 68 percent chlorine, respectively.

Environmental persistence of PCBs is directly correlated with the percent of chlorine in the commercial mixture used. Aroclors 1242, 1248, and 1254 contain proportionately more of the toxic congeners than other mixtures (Hong et al. 1993). Other commercial mixtures such as the Kanechlors and Clophen mixtures have been used heavily outside of the U.S.; however, these mixtures were not broadly used in the U.S.

Each of the commercial mixtures is composed of a distinct ratio of PCB congeners. The quantity of the 21 toxic congeners in commercial Aroclor mixtures is limited, thus in environmentally contaminated fish, these congeners generally represent an extremely small fraction of the total PCB residue. For example, Giesy et al. (1986) detected only three toxic PCB congeners in a study of chlorinated hydrocarbons in chinook salmon eggs from Lake Michigan.

3.7 MERCURY

Mercury is a naturally occurring element that has multiple industrial uses. Its complex chemistry results in the presence of both inorganic and organic mercury "species" in the environment. It occurs naturally in elemental and inorganic complexes, and can be methylated by sulfate reducing bacteria in sediment and water to form mono or di-methyl mercury. The biological implications of this are discussed in Section 2.0. The EPA and State of Oregon criteria are very similar (Table 9). The applicable Idaho standard states: "*Surface waters of the state shall be free from toxic substances in concentrations that impair designated beneficial uses. These substances do not include suspended sediment produced as a result of nonpoint source activities*." The concentrations that impair designated beneficial uses are not specified.

Water quality criteria for mercury in sediments have not been set by Idaho or Oregon. EPA has set criteria for harbors only (Table 10). Various other states and Canadian provinces have set criteria for freshwater environments. These can be found in Appendix B.

Table 9. Water quality criteria for mercury in the water column. Lowest, most restrictive promulgated criteria are in bold.

WATER	***Aquatic Life Criteria***		***Human Health Criteria***		
Chemical	**Freshwater Acute**	**Freshwater Chronic**	**Water and Fish Ingestion**	**Fish Consump-tion**	**Legal Code and Clarification**
Mercury	**2.1 ug/L**	**0.012 ug/L**	**0.14 ug/L**	0.15 ug/L	US EPA 131.36
Mercury	1.3 ug/L				US EPA: Superfund Program, Ecotox thresholds, defined as, concentration above which further site investigation is warranted. Not a promulgated value.
Mercury (methyl)		0.003 ug/L			US EPA: Superfund Program, Ecotox thresholds, as defined above.
Mercury	2.4 ug/L	**0.012 ug/L**	144 ng	**146 ng**	State of Oregon. Human health risk based on 10-6 cancer risk

Table 10. Water quality criteria for mercury in sediments (all values in mg/kg dry wt, for freshwater sediments, unless specified otherwise),

NOEL	**LOEL**	**SEL**	**Source**
< 1	≥ 1	≥ 1	USEPA Guidelines for the Pollutional Classification of Harbor Sediments, 1977.
	0.174	0.486	USEPA Guidelines for the Pollutional Classification of Harbor Sediments, 1977.
NOEL: no effect level			
LOEL: lowest observable effect level			
SEL: severe effects level			

3.8 ALDRIN AND DIELDRIN

Aldrin is a metabolic precursor to dieldrin. Because of its persistence and high toxicity, dieldrin was banned from use in 1975 in the U.S. The FDA has established an action level of 0.3 mg/kg dieldrin in edible fish tissues. EPA has set a no effect standard for dieldrin in sediments

(Table 12). Draft EPA documents (EPA 1991) have proposed sediment quality criteria based on equilibrium partitioning between organic carbon and water (assumed log K_{oc} of 5.16) of 9.03 ug/g_{oc} (= 0.09 ug/g @ 1% oc). The EPA also proposed water criteria of 0.0625ug/L (EPA 1991). Additional criteria promoted by several state and federal agencies for dieldrin are provided in Appendix B.

Oregon's criteria are equal or lower than EPA's current criteria for dieldrin in the water column (Table 11). The applicable Idaho standard states: "*Surface waters of the state shall be free from toxic substances in concentrations that impair designated beneficial uses. These substances do not include suspended sediment produced as a result of nonpoint source activities*." The concentrations that impair designated beneficial uses are not specified.

No standard has been set by either state or EPA for Aldrin.

Table 11. Water quality criteria for dieldrin in the water column.

WATER	***Aquatic Life Criteria***		***Human Health Criteria***		
Chemical	**Freshwater Acute**	**Freshwater Chronic**	**Water and Fish Ingestion**	**Fish Consump-tion**	**Legal Code and Clarification**
Dieldrin	2.5 ug/L	0.0019ug/L	0.00014 ug/L	0.00014 ug/L	US EPA 131.36
Dieldrin	2.5 ug/L	0.0019 ug/L	0.071 ng	0.076 ng	State of Oregon. Human health risk based on 10-6 cancer risk

Table 12. Water quality criteria for dieldrin in sediments.

NOEL	**LOEL**	**SEL**	**Source**
11 mg/kg OC (95% CI = 5.2-24)			USEPA, 1993, draft sediment quality values for non-polar organics. Method based on equilibrium partitioning
NOEL: no effect level			
LOEL: lowest observable effect level			
SEL: severe effects level			

3.9 DICHLORO DIPHENYL TRICHLOROETHANE (DDT) AND ITS METABOLITES

The water quality criteria for DDT set by EPA and the State of Oregon to protect aquatic life are identical (Table 13). Oregon's criteria for DDT human health criteria are lower than EPA's criteria. EPA has the only criteria for DDE to protect human health and Oregon has the only criteria for DDE to protect aquatic life. EPA has set the only criterion for DDD for the protection of human health. The applicable Idaho standard states: "*Surface waters of the state shall be free from toxic substances in concentrations that impair designated beneficial uses. These substances do not include suspended sediment produced as a result of nonpoint source activities*." The concentrations that impair designated beneficial uses are not specified. No criteria have been set by EPA or the two states for concentrations in sediments.

Table 13. Water quality criteria for DDT and its metabolites in the water column.

WATER	***Aquatic Life Criteria***		***Human Health Criteria***		
Chemical	**Freshwater Acute**	**Freshwater Chronic**	**Water and Fish Ingestion**	**Fish Consump-tion**	**Legal Code and Clarification**
DDT (4-4')	1.1 ug/L	0.001 ug/L	0.00059 ug/L	0.00059 ug/L	US EPA 131.36. Acute criterion based on Final Acute Value (instantaneous).
DDT	1.1 ug/L	0.001 ug/L	0.024 ng	0.024 ng	State of Oregon, 340-041. Human health risk based on 10-6 cancer risk
DDE (4,4')			0.00059 ug/L	0.00059 ug/L	US EPA 131.36
DDE	1,050 ug/L	np	np	np	State of Oregon, lowest observable effect level, criteria not promulgated
DDD (4,4')			0.00083 ug/L	0.00084 ug/L	US EPA 131.36

4.0 SUITABILITY ANALYSIS

A description of the key indicator species' response to contaminants or environmental conditions is presented in this section. The expected response of the various species to temperature, dissolved oxygen, turbidity and pH are largely based upon previous work defining suitability criteria.

Suitability criteria are a graphic way to present existing information about habitat preferences of a species (Bovee, 1986). Suitability criteria, or suitability curves, are generally presented with a rating for an environmental parameter between 0.0 and 1.0, where 1.0 represents an estimate of optimum conditions and 0.0 represents conditions likely to cause, or known to cause, mortality of most or all of a population. There is a certain amount of subjectivity in determining values in between these two poles. Preferences may be narrower than the range of Ano-effect conditions≅, and may vary with preceding conditions. Suitability curves presented here are mostly ACategory I" curves. This means that they are developed using professional judgment and available information from the professional literature. ACategory II≅ curves use microhabitat data collected at locations where the target organism is observed or collected. ACategory III≅ curves are developed from site-specific data, corrected for habitat availability (Bovee, 1986). The white sturgeon spawning temperature SI curve is a Category II curve (Parsley and Beckman, 1994).

For some species and life stages, suitability criteria (suitability index curves or SI curves) could not be developed for all pollutants. In these cases, a discussion of likely responses based on the literature is provided. Additional information is also provided regarding environmental effects that may affect preferences.

The current understanding of sublethal and lethal toxicity of polychlorinated biphenyls (PCBs), DDT and its metabolites, aldrin/dieldrin, and mercury to rainbow and bull trout, chinook salmon, black crappie and white sturgeon is also summarized here. The effects of these chemicals on aquatic species are complex and the use of suitability curves is not recommended. Hence, the review is focused on establishing the current state of knowledge on the species' sensitivities for each of the toxicants of interest.

When interpreting toxicological data for their relevancy to site-specific conditions it is prudent to recognize how the test conditions reported may differ from those at the site of interest. Physico-chemical factors such as temperature, pH, organic carbon content in sediment, dissolved organic carbon, hardness, alkalinity and physical habitat can affect the bioavailability of toxicants and the resultant health and abundance of fish populations (Fisher et al. 2000). For example, toxicity usually increases with temperature, and is inversely related to organic carbon, hardness, and alkalinity. Mayer and Ellersieck (1988), in a statistical evaluation of 4,901 toxicity tests conducted on 410 chemicals over 20 years at one laboratory showed that temperature increases of 10°C generally increased toxicity by a factor of three. They further demonstrated that diet, fish source, life stage and size altered toxicity of specific chemicals by no more than a factor of five under most cases.

Each of the toxicants of interest is broadly distributed throughout the globe and is amongst a group of pollutants designated by the EPA as "persistent, bioaccumulative and toxic" (PBTs) (EPA 1998). Because the mechanism(s) of action of the toxicants addressed in this review differ substantially, the structure of this review considers each toxicant separately. The effects of each of the toxicants on the species of concern are captured within the discussions on each of the toxicants, to the extent that research has been conducted with the species. If no data were available for the species of concern, then data from related species are discussed. For ease of use, toxicity data have been tabulated for ready reference. While we have sought to capture the state of knowledge on each of the contaminants of interest, for each of the species of interest, additional data may exist which were not reviewed for this report that could modify the discussion and conclusions presented.

As is discussed above, all species also have unique preferences for conventional water quality parameters (e.g., pH) that lie within a narrower range than that tolerated by the species (Fisher 2000). These preferences may often play the most significant role in determining abundance, distribution and growth of fish populations, irrespective of potential toxicant conditions in the water column or sediment.

Sediment data with associated toxicity reference levels were largely lacking in the literature; yet, contaminated sediments usually represent the main source of contamination of a water body. In addition, few studies explored the potential for additive or synergistic toxicity. The additive toxicity of the co-planar PCBs has been recognized for some time, and was the initiator of the 'toxic equivalency factor' rating schema developed to characterize the overall toxicity of a PCB mixture (Safe 1990, Walker et al. 1994). However, studies are just beginning to examine the potential for synergistic toxicity of unrelated toxicants such as PCBs and mercury (Beemis and Seegal 1999). In the aquatic environment it is especially possible to have exposure to multiple contaminants given the contaminant sink potential of water environs. We have therefore discussed some of the potential toxicant interactions, but it should be recognized that the extent of work conducted in this area is too limited to draw major conclusions regarding specific doses of the mixtures that will yield toxicity or the biological systems that may be affected by such exposures.

To support the reader through the inherently complicated nature of some of the toxicological terms that could not be avoided, we have prepared a glossary of terms available in Appendix A. In addition, toxicity tables summarizing the results of various studies are available in Appendix C. Coupled with the toxicity tables, and established criteria (Section 2.0 and Appendix B), this glossary will hopefully provide the reader with a ready reference that is easy to use.

4.1 TEMPERATURE

Fish responses to water temperatures are complex, and affect many factors including physical capabilities, parasites and diseases, predation and competition success, stress, growth and successful reproduction. These factors themselves may affect temperatures where fish are found (or Aprefer to be≅). This preferred habitat can likewise be affected by other environmental factors, such as the abundance of prey or the temperature to which the fish is acclimated to. For many species, the temperatures at which a fish is acclimated to will affect both temperature tolerances and preferences (Elliot 1981).

Temperature affects the metabolic rates in fish including such things as the rate that food is digested and the rate that food is converted to tissue (growth). In colder waters, metabolism is depressed and in warmer waters, it increases. If metabolism is depressed too far, life cannot be sustained for long (Priede 1985). Similarly, if the fish is forced to work at above the active or maximal metabolic rate, this level of effort cannot be sustained indefinitely and death may ensue.

Most fish species of the temperate regions, however, have the ability to endure long periods of extreme cold (winter). In very cold waters (<5.5 °C), the metabolic rates slow to extreme low levels (Priede 1985). Swimming ability is drastically reduced and digestive processes slow to the point that they nearly cease. In extreme cold temperatures, most fish will seek out a place with little current (little swimming demand) to spend the winter (Knights et al, 1995, Quist et. Al. 1999, Swales et al 1985). Such habitats may include deep holes or the interstitial spaces between rocks in the substrate.

In warmer waters, the chemical processes that contribute to the conversion of food to growth (including both growth of the fish itself and growth of gametes) are accelerated. There have been numerous studies that have linked feeding rates and metabolic expenditure, leading to a close relationship between metabolism (affected by temperature) and growth (Jobling 1985, Brett 1976, Vivekanandan and Pandian, 1977). Growth occurs when rations exceed the calorie requirements to maintain metabolism. As temperatures increase, the difference between the fish's capability to digest food and the amount of energy required to maintain basic metabolism increases. More energy is left for growth. Hence, growth rates tend to increase with increasing temperature. The fish's preferred temperature also appears to increase with increasing prey availability (Elliott 1981, Brett 1982). All fish species have a "critical thermal maximum", defined as the temperature at which the fish loses its ability to escape from lethal conditions (Elliott 1981). This temperature and is quickly followed by the lethal maximum at slightly higher temperatures. As temperatures approach this critical thermal maximum, feeding rates decrease markedly and growth is substantially reduced. Note that oxygen consumption also increases as metabolic rates go up (Preide 1984), so the oxygen levels needed in the environment increase with increasing temperature (Jobling 1984, Evans 1990).

Investigators attempt to determine many temperature metrics, including upper and lower lethal (incipient lethal) temperatures, temperatures which produce maximum growth or physical capacity, and the Afinal preferendum≅ (defined as the temperature fish will ultimately select regardless of the acclimation temperature (Armour, 1991; 1993). This can, at times, produce confusion, since different investigators will report different findings for a particular species, and many species are able to tolerate temperatures higher or lower than most preferenda for short periods of time. In addition, more may be known about temperature preferenda for some species than for others.

The reactions of fish species, by life stage where variations have been documented, are discussed below. The discussion focuses on preferred conditions, however some information on lethal or near lethal conditions is also provided.

4.1.1 Bull trout

Bull trout appear to have lower temperature preferences than other salmonids, although the evidence is mostly correlative, leaving critical thresholds poorly defined (Reiman and MacIntyre, 1993). Also, much of the recent research on water temperatures in streams containing bull trout has been conducted at the southern limits of the species range, where temperature may be more of a determining factor in defining suitable or available habitat (Reiman et al, 1997).

4.1.1.1 **Juvenile temperature**

Juvenile bull trout appear to be able to rear over a wide range of water temperatures (4 to 20.5°C), although optimal temperatures appear to be between 10 and 15°C (several investigators reviewed in Sugden et al, 1998). Saffel and Scarnecchia (1995) found juvenile bull trout densities increasing with increasing maximum temperatures below 14°C, and decreasing with increasing temperatures above 18°C. These investigators did not have streams within their study with maximum temperatures between 14 and 18°C. Reiman and Chandler (1999) found 95% of juvenile bull trout observed were from waters with summer maximums less than 18°C, and most of the observations from streams with summer maximums less than 14°C. However, McMahon and others (1999) noted that juvenile bull trout growth at maximum rations was highest at 16°C. Hicks (2000) notes that while summer maximums between 11 to 14°C are most widely cited as the upper thermal limits for char, the 11 to 13°C range is also cited as waters with the highest densities and greatest growthXi.e., some of the best juvenile habitat may occur near the upper limit. Based on this information and literature summaries, a Category 1 SI curve was constructed (Figure 6).

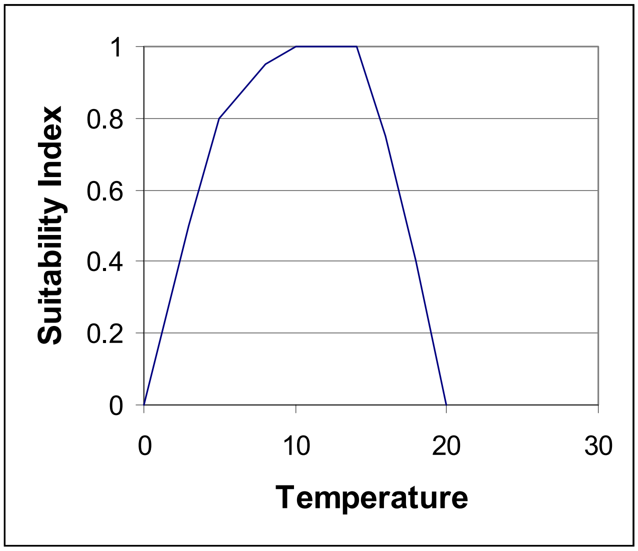


Figure 6. Temperature preference of juvenile bull trout.

4.1.1.2 Adult temperature

Information regarding the preferred temperatures of adult bull trout is sparse. Collection and preliminary analysis of existing temperature data from bull trout streams in Washington, Idaho, Montana and Oregon has led to preliminary conclusions only (Reiman and Chandler 1999). Those authors note that AAlthough the distribution of temperatures where bull trout occur provides an approximation of the range of suitable temperatures, it is difficult to draw inferences about preferred or optimal temperatures.≅ Many authors note that simply finding bull trout at a certain temperature does not necessarily indicate a preference for that temperature. Adult bull trout have been found to rear and migrate over a wide range of temperatures (4 - 20.5^{o}C) (several investigators summarized by Sugden et al, 1998). However, some investigators have recommended that average daily maximum temperatures in waters managed for bull trout not exceed 12^{o}C. In the absence of definitive information on temperature associations, the juvenile bull trout preference curve can be assumed to apply. Future investigations and conclusions may increase confidence in descriptions of temperature preferences for this species.

4.1.2 Rainbow Trout

The effects of temperature on growth and survival have been extensively studied. One of the earliest studies was done by Black (1953). In this study, he held Kamloops trout for 24 hours (a strain of rainbow trout) in a range of temperatures to identify the temperature at which mortality occurred. All of his fish survived at temperatures up to 22.4°C. Roughly 50% died at 24.0°C and none survived 25.7°C. Similar results on mortality have been reported by other authors. Hokanson et al (1977) reported an upper incipient lethal temperature of 25.6°C and Cherry et al reported a 7-day lethal limit of 25°C. Each of these maximum lethal temperatures was measured slightly differently. Nevertheless, the upper lethal limit for rainbow trout appears to be in the range of 24.0 to 25.6°C.

As was discussed above, growth is affected by temperature and/or by the ability to digest food and convert it to energy. Hokanson et al (1977) evaluated the effects of constant and fluctuating stream temperatures on the growth of juvenile rainbow trout. The fluctuating temperatures were intended to mimic the diel fluctuations found in nature. In their experiments, growth rates were maximized at temperatures of approximately 17°C and 15°C for fish held in constant and fluctuating temperature, respectively and fed a satiation diet (Figure 7).

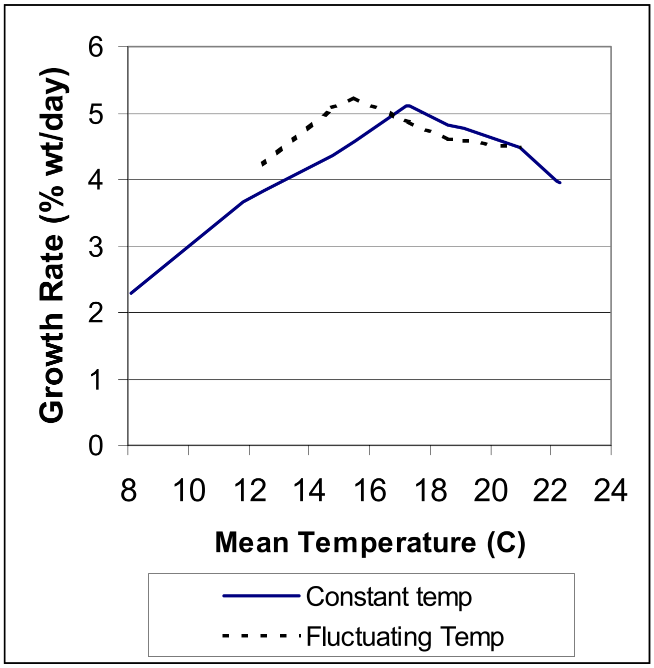


Figure 7. Effect of constant temperatures and diel temperature fluctuations on specific growth rate of rainbow trout. Adapted from Hokanson et al (1977).

Acclimation temperature may also affect the temperatures that are both preferred and avoided. Cherry et al (1977) found that both the preferred range and the avoidance temperatures increase with increasing acclimation temperature (Figure 8). Currie et al (1998) reported a similar pattern, however other authors have reported no correlation between acclimation and preferred temperatures. There is some indication that this relationship may be more pronounced in very young fish.

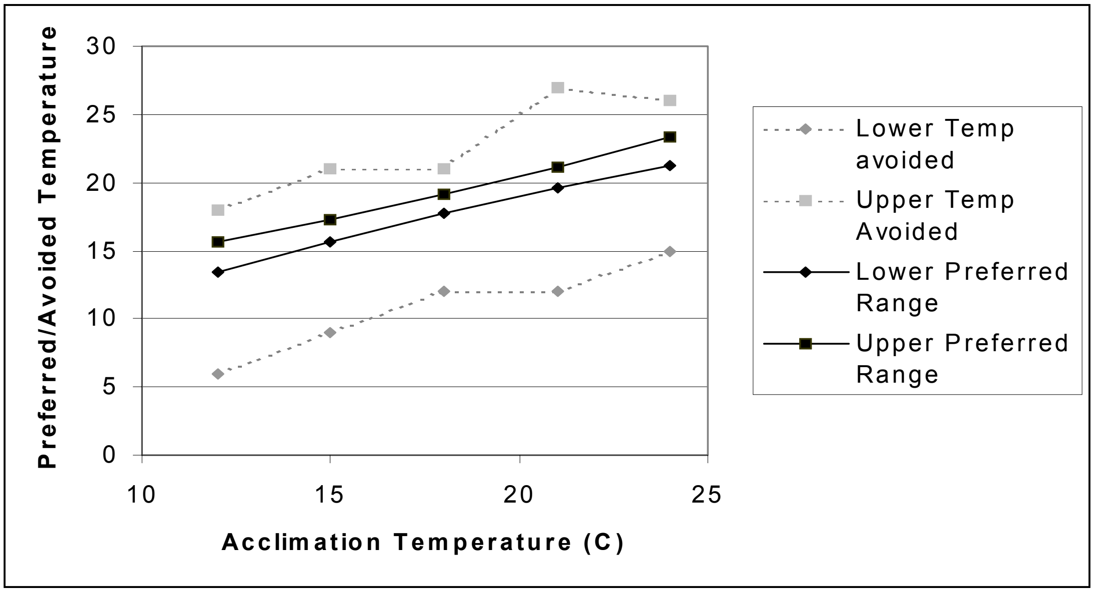


Figure 8. Preferred temperature range and avoided temperatures as a function of acclimation temperature (after Cherry et al 1977).

Several authors have addressed the preferred temperature of the various life stages of rainbow trout and some authors have developed suitability curves for the species. Raleigh et al developed preference curves for juvenile rainbow trout. Their suitability index passed through the zero line at 0 and 28.9°C, and was given a value of 1 for the range from 10 to 22.2°C. Given that feeding nearly ceases below 2 or 3°C, a preference curve that goes to zero at 3 degrees is more logical. The effect of temperature on growth (Figure 7) also suggests that the Raleigh curve rates temperatures above 20°C somewhat high. A review of studies summarized by Currie et al (1998) indicates the lethal temperature is in the range of 22.7 to 29.4°C. Based on these considerations and the data available regarding preference and response of the species to temperature, an alternative curve has been developed (Figure 9). This curve suggests that the preferred range of temperature for juvenile rainbow trout is in the range from 10 to 18°C.

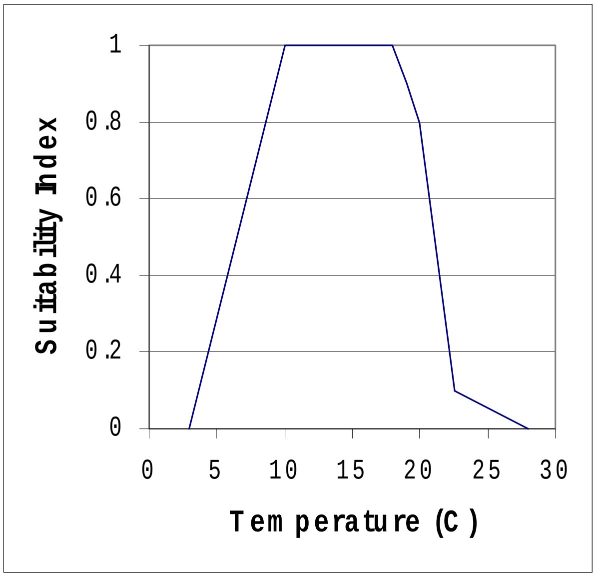


Figure 9. Temperature preference for juvenile rainbow trout based on Raleigh et al (1984) modified as explained in the text.

Reported temperature preferences for adult rainbow are highly variable. Raleigh et al (1984) place the temperature preferences in the range from 13 to 21°C, Cherry et al (1975) place the preferred temperature at 18°C, Spigarelli (1975) places the preferred temperature at 16.5°C, and Elliott (1981) sets the optimum range at 10 to 22°C. Cherry et al (1975) indicate that the species avoids water <13°C and >19°C while Elliott (1981) indicates the lower critical range to be 0 to 9C and the upper critical range to be >19°C. Based on these studies, the preferred temperature is estimated to be in the range of 12°C to 18 or 19°C (Figure 10).

Spawning temperatures may be somewhat different, reflecting the season and the response of eggs to temperature. Elliott (1981) reviewed studies on egg temperature response and reported lethal temperatures for eggs at less than 0°C and greater than 20°C and preferred temperatures in the range of 4 to 19°C. Raleigh et al (1984) put the preferred temperature in the range of 2.2 to 15.6°C. Bell (1991) cites an upper limit for spawning at 20°C, which is similar to that reported by Elliott (1981). Figure 11 suggests preferred spawning temperatures of 4 to 18°C, based on a composite of these studies.

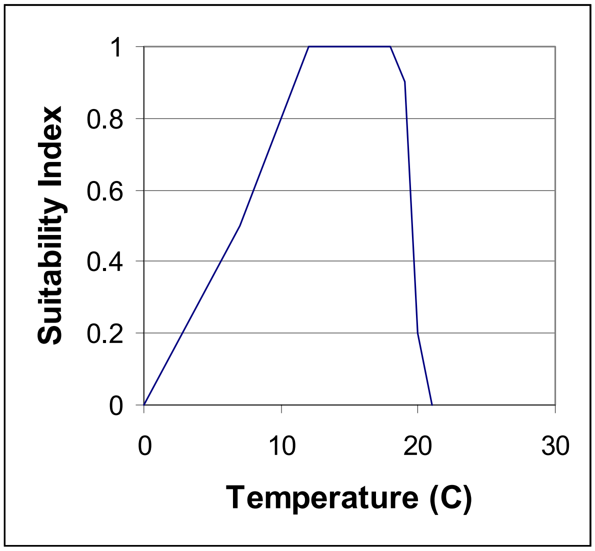


Figure 10. Temperature preference for adult rainbow trout.

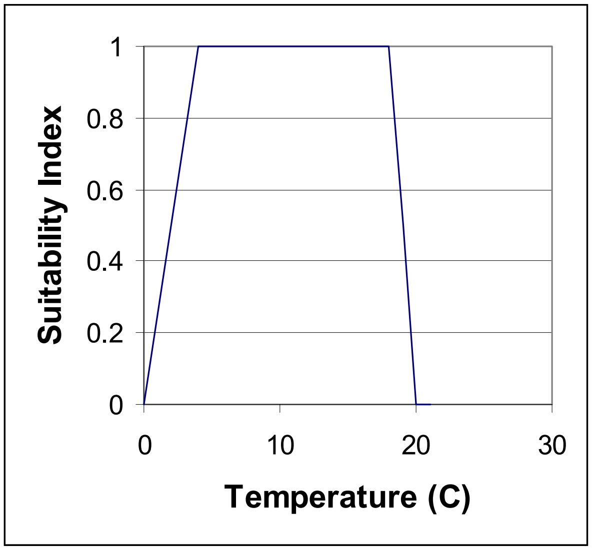


Figure 11. Temperature preference for spawning and egg incubation of rainbow trout.

4.1.3 Chinook Salmon

4.1.3.1 Migration temperature

Bell (1991) presents different preferred migration temperatures for spring, summer and fall chinook, for use by managers in the Columbia River system. Preferred temperatures for spring chinook migration (3.3 to 13.3°C) are somewhat lower than the preferred migration range for all races (9.4 to 14°C). Raleigh et al places the preferred temperature for migrating adults at 8 to 12°C.

Hicks (2000) presents a thorough summary of investigations of the water temperatures that are used by migrating adult chinook. Generally, temperatures over 21°C are widely cited as forming barriers to chinook salmon migration, although some investigators found barriers only at higher temperatures, or speculate that a difference in temperature between two streams may in fact create a migration barrier. Curves presented in Figure 12 are developed largely from recommendations by Bell (1991), and the literature summary presented by Hicks (2000).

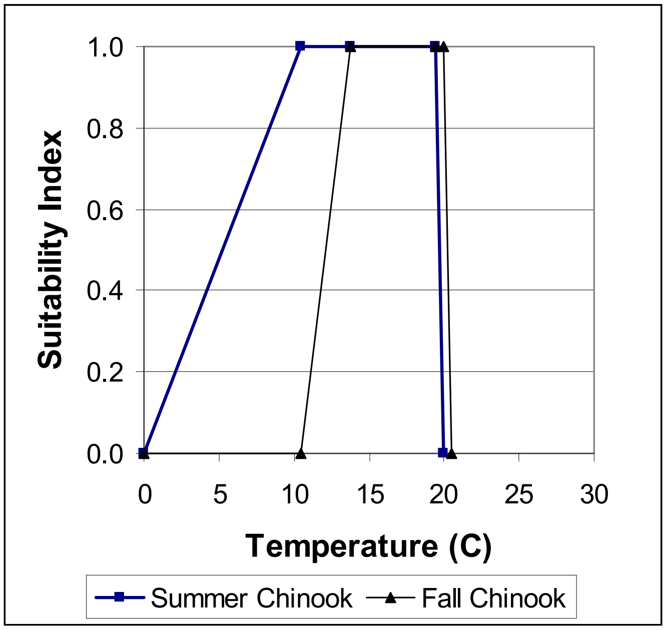


Figure 12. Preferred temperatures for chinook salmon migration.

4.1.3.2 Adult Chinook Temperature

Bell (1991), Armour (1991), and Raleigh 1986 all address the preferred temperatures of holding adults. The preferred and/or optimum temperatures are similar for all except that Bell would put the upper end of the temperature range at 18C while the others move it up to 24C. A composite of this data would suggest a preferred range of 7 or 8C at the lower end and 12 to 14C at the upper end (Figure 13).

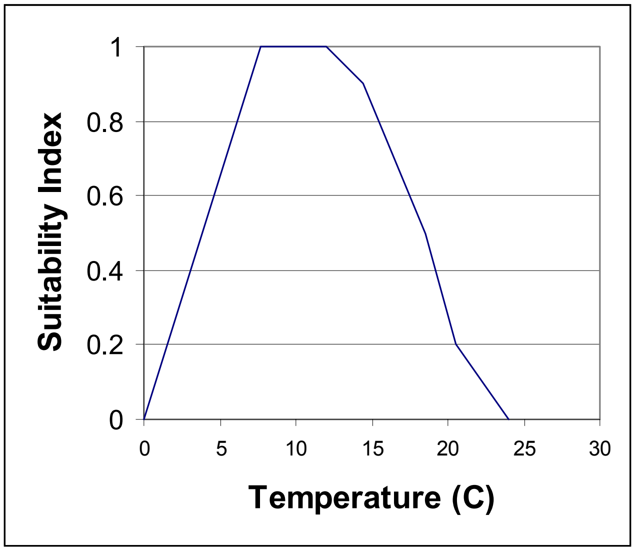


Figure 13. Optimum temperatures for chinook salmon based on Bell (1991) and Armour (1991).

4.1.3.3 Juvenile Chinook temperature

Juvenile chinook generally will rear for one year in fresh water. Most smolt outmigration is completed by June. Juveniles prefer deep water pool and run habitat (Everest and Chapman, 1972; Hillman et al, 1989).

Brett et al (1982) evaluated the growth of two stocks of British Columbia chinook as a function of temperature ranging from 14 to 25°C. They found growth to be fairly constant throughout the range of 14 to 21°C, after which growth decreased rapidly with increasing temperature (Figure 14). At 25°C, mortality was 64% of the test group. It is important to note that this test was conducted with fish fed at a satiation diet. Brett et al (1969) found that the temperature at maximum growth in sockeye salmon declined roughly 9°C as diets fell from satiation to roughly 25% satiation. Brett et al (1982) further estimated expected growth at 60% ration, which was assumed to represent a reasonable ration in natural conditions. At this ration, they estimated that feeding would just provide for maintenance at 21.4°C. Allowing for 20% reduction in optimal growth rate, the corresponding optimum temperature at 60% ration was estimated at 17.8°C.

As is discussed above, preferred temperatures do not necessarily correspond to maximum growth temperatures. Preferred summer temperatures reported for rearing chinook are somewhat variable. Preferred temperatures were reported as 12 to 14°C by Bjornn and Reiser (1991), 10 to 18°C by Pennell and Barton (1996), and 12 to 18°C by Raleigh et al (1984). Using the information presented by these various authors and taking into consideration the work of Brett et al (1982), a Category 1 preference curve was developed that estimates the preferred temperature at 12 to 14°C, with temperatures approaching preferred in the range from 12 to 18°C (Figure 15).

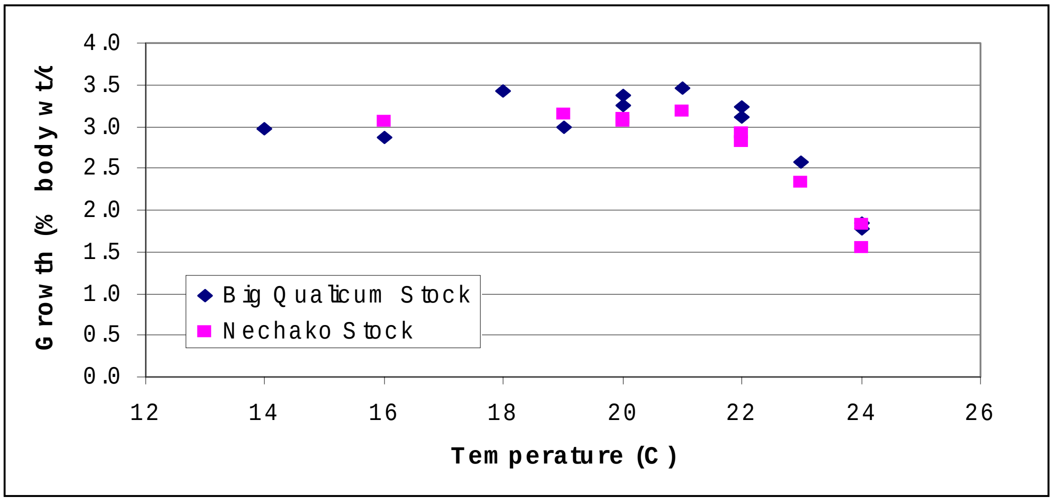


Figure 14. Growth of juvenile chinook on a satiation diet after Brett et al, 1982.

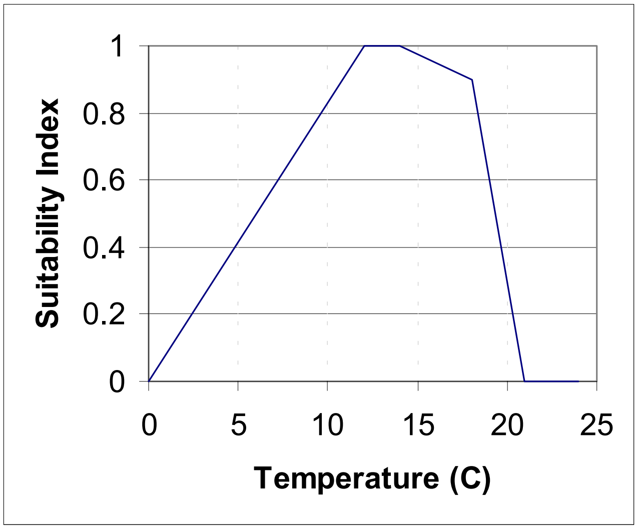


Figure 15. Preferred temperatures for juvenile chinook.

4.1.4 Black Crappie

Black crappie are commonly found in warmer waters than that preferred by salmonids. The response to temperature in black crappie appears to vary with age. Adult black crappie are present in waters where average weekly summer temperatures are in the 23 to 32°C range, prefer temperatures in the 22 to 27°C range, and do not survive in waters colder than 14°C or warmer than 34°C. Juveniles have similar preferences, although they do not appear to tolerate temperatures in the higher range as well as older fish. Optimal juvenile growth occurs at 22 to 25°C. No growth occurs at less than 11°C or greater than 30°C. Fry prefer 20 to 24°C water (Edwards et al, 1982). Spawning apparently initiates between March and July when water temperatures rise above 16°C, and preferred spawning temperatures are in the 21 to 23°C range (Edwards et al, 1982; Mitzner, 1987; Wydoski and Whitney, 1979). Embryo black crappie optimum temperature range is 17.8 to 20°C (Edwards et al, 1982). The suitability curves for temperature depicted in Figures 16 through 19 are adopted from Edwards et al (1982).

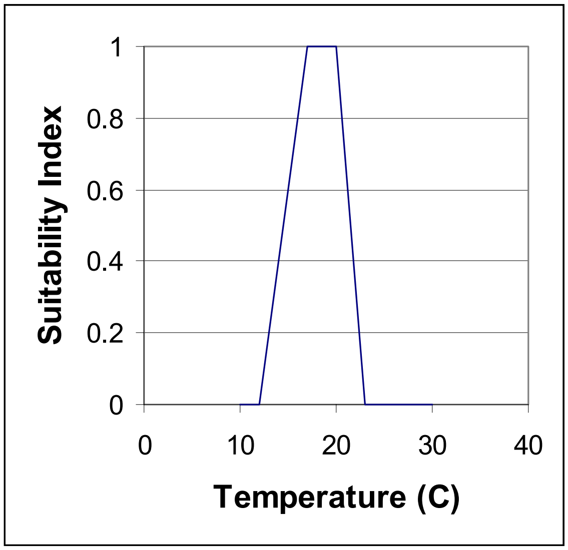


Figure 16. Preferred incubation temperature for black crappie embryos.

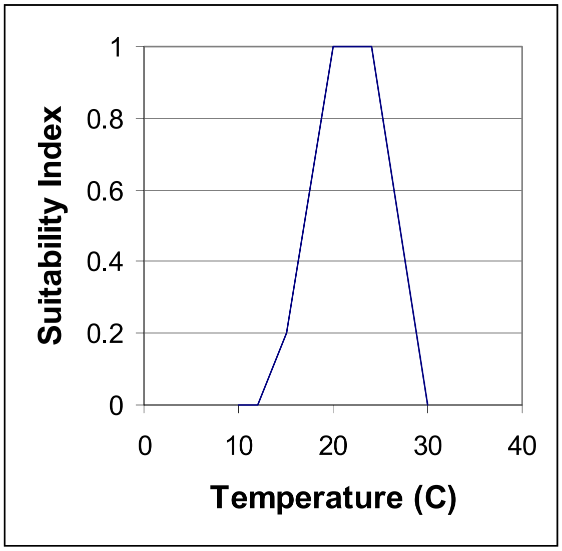


Figure 17. Temperature preference of black crappie fry.

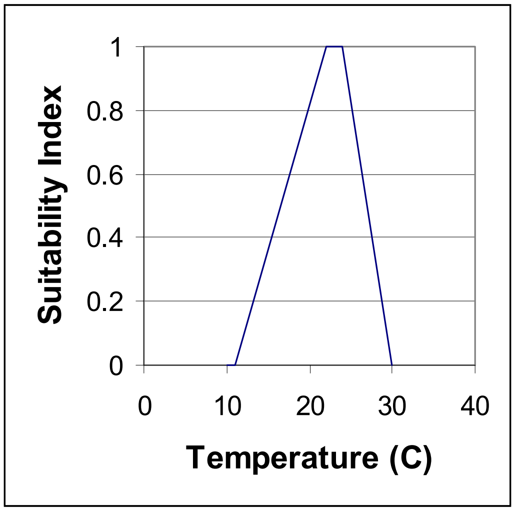


Figure 18. Temperature preference of juvenile black crappie.

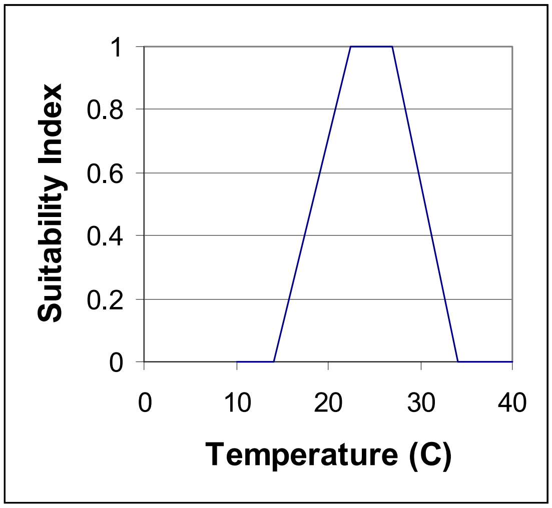


Figure 19. Temperature preference of black crappie adults.

4.1.5 Smallmouth Bass

Egg deposition is suppressed at temperatures less than 14°C, and greater than 28°C (Armour, 1993). Males migrate to nesting sites at approximately 15.6°C (Coble, 1975). Spawning typically occurs at temperatures in the range of 15 to 27°C. Embryos develop normally at temperatures between 12.5 to 25°C (Edwards et al, 1983; Graham and Orth, 1986). Males may abandon nests as temperatures drop below 15°C (several authors, in Armour, 1993), which can cause egg mortality from predation (Table 15).

Many fish species= temperature preferences are strongly influenced by the range of temperatures they are acclimated to. This tendency is apparently fairly strong in juvenile smallmouth bass (Figure 20, Table 14). Therefore, juvenile smallmouth bass preference curves may depend on the actual temperatures observed in the Brownlee impoundment. Juvenile smallmouth bass will inhabit water within a 7 to 13°C range around the temperature they are acclimated to (Cherry et al, 1975; 1977). Maximum growth, regardless of acclimation temperature occurs at approximately 26°C (Horning and Pearson, 1973). Activity is reduced at temperatures less than 20°C, little growth occurs at temperatures less than 16°C, and swimming ability is greatly reduced at temperature less than 10°C (Edwards et al, 1983). Highest growth rates in fry occur at 25 to 27°C (Coutant and De Angelis, 1983). The upper lethal temperature is about 35°C (Cherry et al 1975).

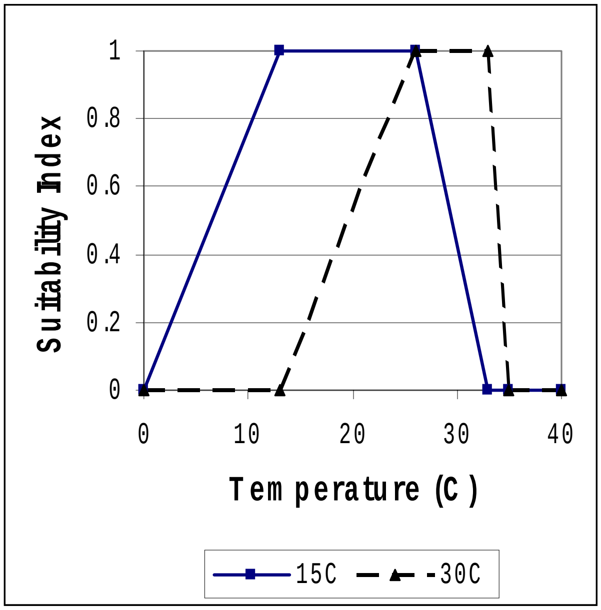


Figure 20. Temperature suitability for juvenile smallmouth bass acclimated to 15 and 30°C (adapted from Edwards et al, 1983).

Table 14. Responses of juvenile smallmouth bass to temperature as a function of acclimation temperature.

Acclimation Temperature	Juveniles avoided water temperatures less than the following	Juveniles avoided water temperatures greater than the following
15 °C	13 °C	26 °C
18 °C	15 °C	27 °C
21 °C	18 °C	30 °C
24 °C	21 °C	33 °C
30 °C	26 °C	33 °C
33 °C	27 °C	35 °C (probably lethal limit)

Sources: Cherry et al, 1975; 1977.

Growth rates in adult smallmouth bass increase with temperature up to the lethal temperature (Edwards et al, 1983). The reported lethal temperature ranges between 32.3°C (Coble 1975) and

37°C (Wrenn, 1980, in Armour, 1993). Field data suggests that adults prefer temperature in the range of 21 to 27°C (Clancey, 1980). When temperatures drop to less than 15 to 20°C, adults will seek cover and below 10°C, the fish become inactive (Shuter et al, 1980). The lower lethal temperature is near freezing (Coble 1975). Based on the information discussed above, a suitability curve has been developed (Figure 21).

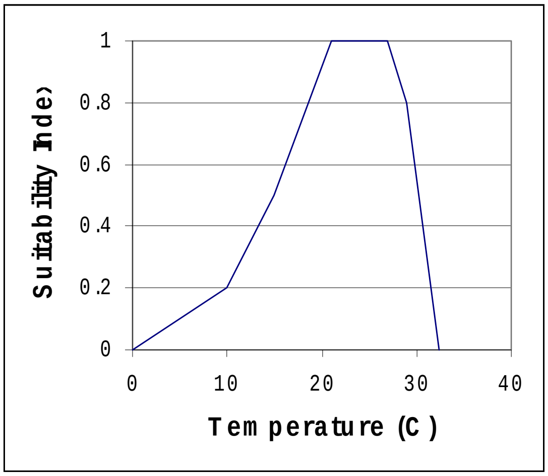


Figure 21. Temperature suitability index for adult smallmouth bass.

Table 15. Summary of temperature preferences and effects on smallmouth bass.

Embryo development normally 13 to 25°C; nests may be abandoned at <15°C
Spawning preferred 15 to 27°C
Juveniles prefer 21 to 27°C (variable with acclimation temperature, lethal < 0°C and >35°C; activity reduced <20°C
Adults prefer 21 to 27°C, lethal <0°C and >32.3°C; activity reduced <20°C

4.1.6 White Sturgeon

4.1.6.1 Adult spawning

Parsley et al (1993) found that Columbia River white sturgeon spawned in the river downstream of McNary Dam at temperatures between 10 and 18°C, and in impounded reaches at temperatures between 12 and 18°C. For both habitats, the largest amount of spawning occurred at temperatures of 13-14°C. McCabe and Tracy (1994), studying spawning below Bonneville Dam, found sturgeon spawning at temperatures between 10 and 19°C, and estimated peak spawning between at temperatures between 12 and 14°C.

Haynes et al (1978) noted that sturgeon in the Mid-Columbia region were active during summer and fall, but not at winter temperatures. North et al (1993) noted that distribution of sturgeon in lower Columbia River reservoirs was related in part to temperature. Adult sturgeon were found in waters between 9 and 21°C, although in greatest numbers at temperatures between 15 and 20°C.

Parsley and Beckman (1994) developed suitability criteria for spawning white sturgeon temperature based on field data (Figure 22). This would be considered a ACategory 2" criteria curve (Bovee 1986).

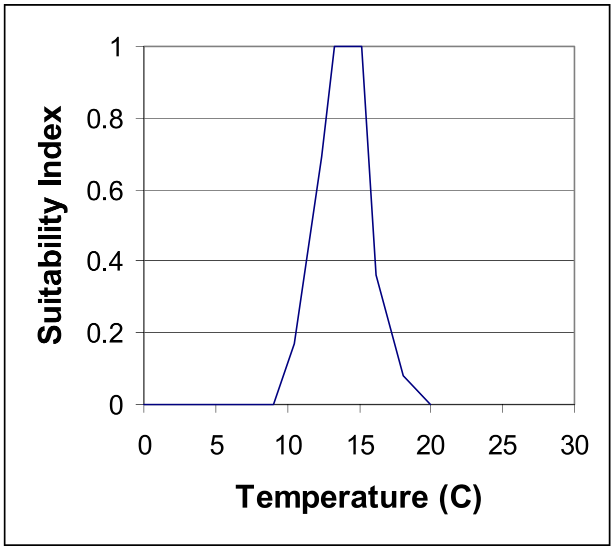


Figure 22. Preferred temperatures for spawning sturgeon (adapted from Parsley and Beckman 1994).

4.1.6.2 Non-Spawning Adults

Less information is known about the temperature requirements of non-spawning adult white sturgeon. Lethal temperatures have not been determined. Crance (1982) developed suitability indices for shortnose sturgeon, a similar species. The preferred temperature for non-migratory shortnose sturgeon was identified in the range of 10 to 22^{o}C.

4.1.6.3 Embryos and juveniles

Wang et al (1985) found that, for lake and white sturgeon, optimum survival of embryos was at temperatures between 14 and 17^{o}C, with an optimum of 14^{o}C. Temperatures greater than 20^{o}C were lethal for white sturgeon embryos. Optimum temperature for juvenile sturgeon growth appears to be closer to 23^{o}C than to 26^{o}C (Hung et al, 1993).

4.2 DISSOLVED OXYGEN

Generally, oxygen use in fish increases with activity and increasing metabolic rate. Since metabolic rate increases with temperature, oxygen use also increases; however, the oxygen saturation potential of water decreases with increasing temperature (Priede 1985).

Reduction in the level of dissolved oxygen can have marked effects on many physiological, biochemical, and behavioral processes in fish (Davis 1975). The oxygen level where such effects first become apparent is commonly referred to as the incipient oxygen response threshold. Restriction in the oxygen supply can affect metabolic processes like swimming, feeding, growth, and reproduction (Davis 1975, Garside 1965). Low oxygen levels can also enhance the toxic effects of some chemicals such as zinc, lead, copper, and phenols. Oxygen requirements vary noticeably by season, temperature, and activity.

4.2.1 Bull Trout

IP (20XX) completed an extensive literature review on the effects of dissolved oxygen on various char species. No references on bull trout were reported, however data on arctic char, brook trout, and lake trout were reported. Arctic char are probably the least like bull trout in that they are a species that spawns in rivers but rear entirely in marine waters (Glass et al, 1990). In brook trout, DO levels less than 3.5 to 3.6 mg/l depressed growth in yearling fish and the incipient lethal level is 1.75 to 1.83 mg/l for 5000 minutes (IP 20XX). Beamish et al (1964) reported oxygen uptake in brook trout is reduced below 5.75 to 5.18 mg/l, Graham (1949) reported reduced cruising speed at 5.99 mg/l in 8°C water and 9.06 mg/l in 20°C water, and Irving (1941) reported that blood was not fully saturated at 4.59 mg/l in 20°C water. In lake trout, the DO level where activity was reduced occurred at 2.8 to 3.5 mg/l at 10 and 22°C (IP 20XX). These factors reported for char species other than bull trout are not substantially different from those reported for rainbow trout. Hence the dissolved oxygen requirements of bull trout may be similar to those for rainbow trout.

4.2.2 Rainbow Trout

Davis (1975) completed a thorough review of dissolved oxygen bioenergetics and studies completed as of that date on oxygen requirements of Canadian fish species. This author cited reductions in swimming speed at 5.94 to 5.67 mg/l for juvenile rainbow trout in cold (8-10°C) water and 4.5 to 4.34 mg/l for juveniles in warm water (21-23°C). The author also cited reports that indicated that adults in 15°C water had reduced metabolic capability at concentrations less than 5.08 to 6.47 mg/l and blood was not fully saturated with oxygen at 4.71 to 5.75 mg/l in temperatures ranging from 10 to 20°C. Davis (1974) developed dissolved oxygen criteria for "sensitive freshwater salmonid populations" (Table 16 and Figure 23). These criteria include three levels of protection. Level A represents a high safeguard or optimum levels, Level B represents levels where there is some possibility of moderate risk due to limited oxygen depression, and Level C represent those values where a large portion of the population may be severely affected, especially if the exposure is chronic.

Table 16. Dissolved oxygen levels required to provide high levels of protection for salmonids (after Davis, 1975). See Text for explanation of protection levels.

Group	Protec-tion Level	DO (mg/l)	Percent saturation at temperature (^oC)					
			0	5	10	15	20	25
Freshwater mixed fish population including salmonids	A	7.25	69	70	70	71	79	87
	B	5.25	54	54	54	57	54	63
	C	3.25	38	38	38	38	39	39
Freshwater salmonid population including steelhead	A	7.75	76	76	76	76	85	93
	B	6.00	57	57	57	59	65	72
	C	4.25	38	38	38	42	46	51
Salmonid larvae and mature eggs of salmonids	A	9.75	98	98	98	98	100	100
	B	8.00	76	76	76	79	87	95
	C	6.50	54	54	57	64	71	78

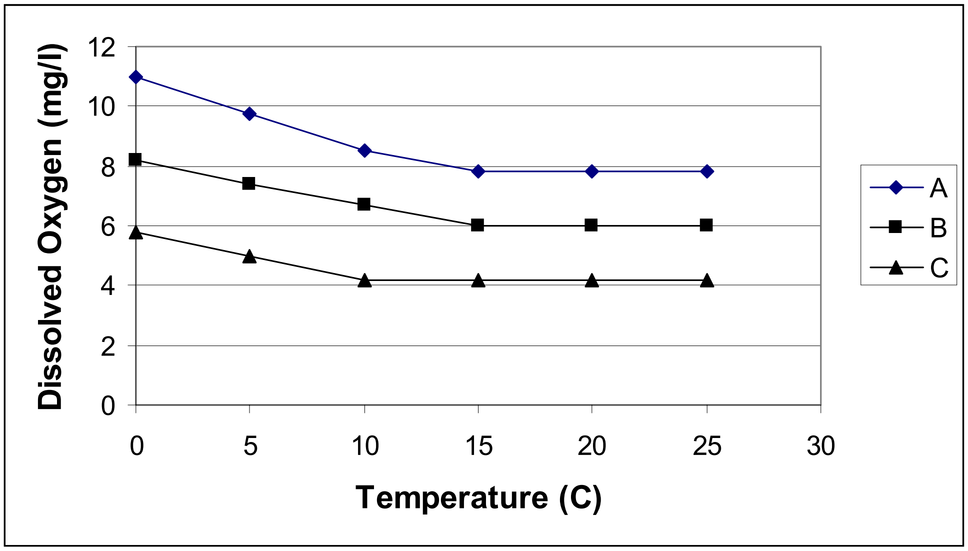


Figure 23. Optimum (A), low risk (B) and near lethal (C) dissolved oxygen levels for salmonids at varying water temperatures (adapted from Davis 1974). Refer to text for further explanation of levels.

4.2.3 Chinook Salmon

4.2.3.1 Eggs and Alevins (intergravel DO)

Survival of chinook eggs fertilization to emergence has been found to range from 90% to 100% at constant temperatures of 10.5C and dissolved oxygen concentrations of 3.5 mg/l and greater (Eddy 1972). A review of the literature by Davis (1975) found critical levels to supply oxygen demand for the normal development of salmon eggs to hatching ranging from 0.76 to 5.5 mg/l at cold ($\leq$ 8.2^{o}C) temperatures and critical levels up to 10.0 mg/l for eggs in warmer (>8.2^{o}C) waters.

4.2.3.2 Fry, Juveniles and Adults

Hallock et al (1970, in Bjornn and Reiser, 1991) found that chinook salmon in the San Joaquin River ceased adult migration when DO levels fell below 4.5 mg/l, and did not resume until DO levels rose above 5.0 mg/l. Davis (1975) found that dissolved oxygen levels of $\leq$4.5 mg/l was consistently avoided in all studies, breathing rate increased in sockeye fry at 5.07 mg/l, blood in adult sockeye was not fully saturated at 6.74 mg/l, and swimming speed in juvenile sockeye, coho and chinook was reduced at levels lower than 8.53 mg/l in warm (24^{o}C) waters and lower than 11.33 mg/l in cooler (10 to 20^{o}C) waters. These study results would suggest a suitability curve similar to that depicted in Figure 24 for water temperatures in the 10 to 20°C range. This figure depicts oxygen requirements that are roughly 0.5 mg/l higher than are shown in Figure 23, hence Figure 23 could be used to guide the dissolved oxygen requirements of salmon, with a possible 0.5 mg/l upwards adjustment of dissolved oxygen levels.

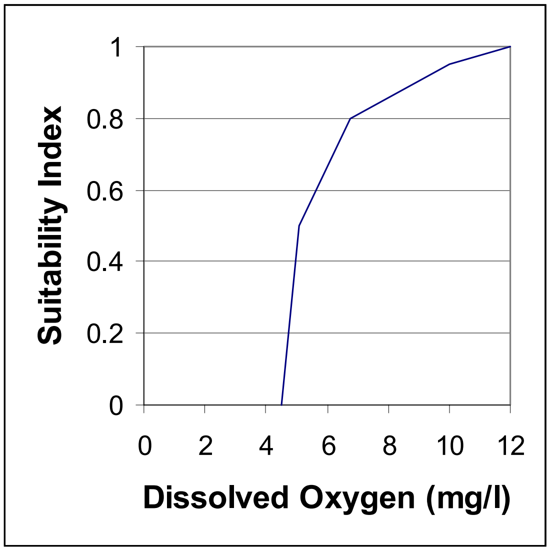


Figure 24. Suitability curve depicting oxygen requirements of juvenile and adult salmon.

4.2.4 Black Crappie

Knight et al (1995) noted that black crappie avoid waters with less than 2.0 mg/l DO in winter. Carlson and Herman found that spawning of black crappie was unaffected by dissolved oxygen levels greater than 4.0 mg/l. Siefert and Herman, however, found no difference in viability of embryos, hatching success, and spawning at dissolved oxygen levels between 2.5 and 6.5 mg/l. They did, however, indicate fish in waters with lower dissolved oxygen tended to spawn earlier than those in higher concentrations. Edwards et al (1982) assumed DO requirements of black crappie to be consistent with largemouth bass, where optimum DO levels are those greater than 5.0 mg/l, and DO levels less than 1.4 mg/l will cause mortality. Edwards developed suitability curves for embryos and for adult, juvenile, and fry combined (Figures 25 and 26).

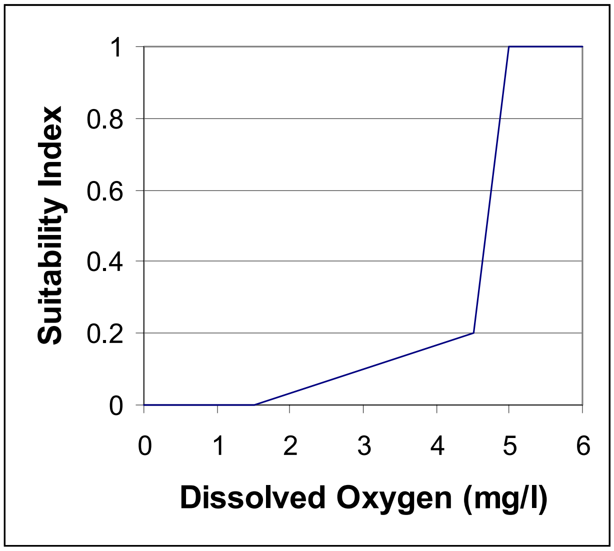


Figure 25. Dissolved oxygen suitability index for adult, juvenile, and fry black crappie.

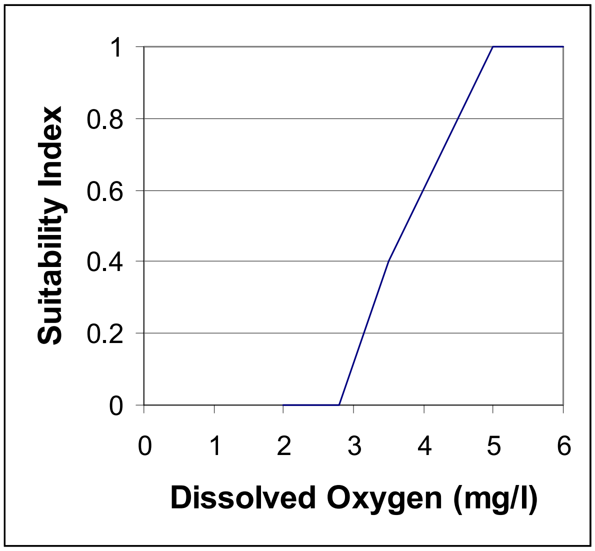


Figure 26. Dissolved oxygen suitability index for embryo and fry black crappie.

4.2.5 Smallmouth Bass

Siefert et al (1974) evaluated the effects of low DO on egg development and early survival of fry. They found that no fish survived more than 14 days when incubated at concentrations ≤2.5 mg/l. Relative to the control (8.7 mg/l; 100% saturation), survival was reduced 19% when incubated at 4.4 mg/l. These results suggest the suitability curve depicted in Figure 27.

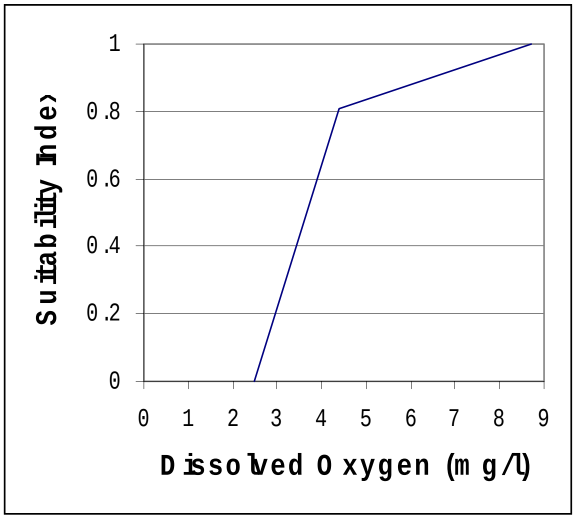


Figure 27. Dissolved oxygen suitability index for smallmouth bass eggs (adapted from Siefert et al, 1974).

Burdick et al (1954) noted that DO levels less than approximately 1.2 mg/l were lethal to adult smallmouth bass. McLarney (1998) notes that survival cannot be assumed at DO levels less than 0.98 mg/l. Fry cease feeding at DO concentrations less than 1 mg/l, and survival is low at levels less than 2.5 mg/l. Optimum levels are greater than 6 mg/l (Edwards et al, 1983). Edwards et al developed a suitability index (Figure 28) based on this information.

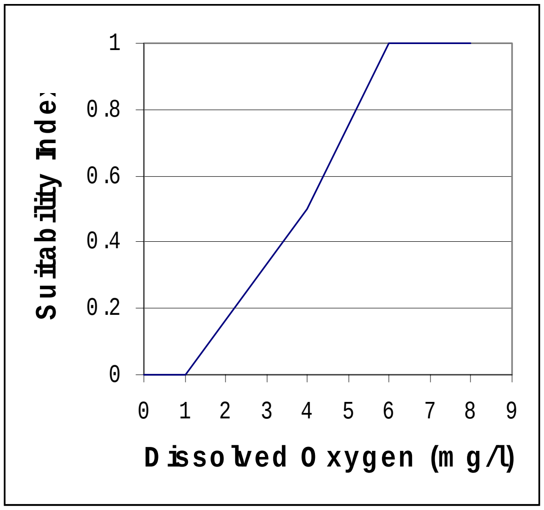


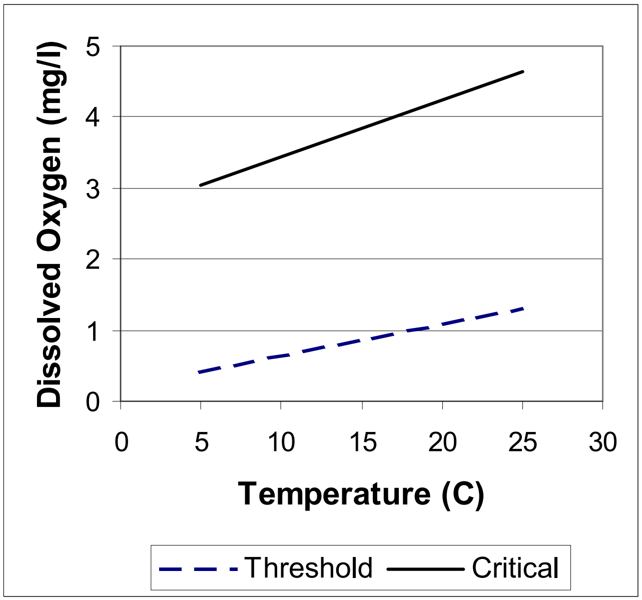
Figure 28. Dissolved oxygen suitability index for smallmouth bass eggs (adapted from Edwards et al, 1983).

4.2.6 White Sturgeon

Little information was found about the needs of sturgeon with respect to dissolved oxygen requirements. Several investigators noted that sturgeon spawn in fast-flowing water, which presumably could be considered to be oxygenated (Parsley et al, 1993; Haynes et al, 1978). Klyashtorin (1974) completed a study of the oxygen requirements of juvenile Russian sturgeon and compared his results with those of other authors evaluating oxygen requirements of other sturgeon species (sevryuga, beluga/sterlet hybrids, Siberian sturgeon, and sevryuga). He found all species to respond similarly to changes in dissolved oxygen concentrations. Although he did not address white sturgeon, the results of this investigation are likely applicable. These study results were reported in terms of pO_2, mm Hg. The values were converted to mg/l using the following the standard equation:

mg/l = mmHg * ∃/0.5318, where ∃ is the Bunsen coefficient for oxygen at a given temperature.

Once the conversions were made, a plot depicting his results could be duplicated. This plot (Figure 29) depicts the “threshold” and “critical” dissolved oxygen levels for juvenile sturgeon. The threshold level is considered to be the concentration that is very near lethal. The critical concentration is the concentration at which breathing begins to be depressed. No data were found addressing adult sturgeon DO requirements.



4.3 TURBIDITY

4.3.1 Salmonids

Numerous laboratory and field studies have been conducted on pre-emergent, juvenile, and adult life stages of salmonids to address the effects of turbidity and/or total suspended solids (TSS). Responses observed are not only dependent on the concentration of suspended sediment but are a function of life history stage, duration of exposure, and particle size. Effects from suspended sediment can be categorized into four responses: no effect, behavioral effects, sublethal effects, and paralethal/lethal effects. No effect is observed when suspended sediment is introduced into the system (stream or tank) and there is no behavioral or physiological change in the fish. Behavioral effects include alarm reactions (sporadic swimming), avoidance (moving out of turbid conditions), territorial breakdown (fish no longer defended territory), decreased perceived risk of predation (using turbidity as cover), changes in prey preference, and reduced preferences for homewaters. Sublethal effects include reductions in feeding rates, decreased reaction distances (distance fish travel from spotting prey to capture), decrease in navigational aides (ability to see surface or bottom for positioning), increased gill flaring, increased coughing, elevated plasma glucose, depressed leucocrit, and gill tissue damage. Paralethal/lethal effects include mortality, reduced resistance to disease, and delayed hatching.

4.3.1.1 Pre-emergent salmonids

During the pre-emergent life stage of salmonids, high percentages of fines smaller than 0.85mm in or on the substrate can limit survival by inhibiting the ability for oxygenated water to travel through the gravel and provide oxygen to the fish (Ziebell 1960) and by physically blocking the ability to emerge from the gravel, entombing them (Cederholm et al. 1978). Flow of silt-laden water over the streambed deposits silt within the gravel, even though velocities exceed those allowing deposition on the surface (Cooper 1965). The extent of damage to aquatic resources due to sedimentation is greatly influenced by the magnitude and timing of the sedimentation and ability of the stream to flush these sediments during storm periods (Cederholm et al. 1978, Shapley and Bishop 1965).

Spawning substrate preference is somewhat bimodal. First there is the dominant size of gravel that is generally used to construct redds (nests). Generally, chinook salmon prefer larger substrate, spawning in gravels and cobbles 3 to 15 cm in diameter (Raleigh et al, 1986). Trout, which are a smaller fish, spawn in smaller substrates, generally 1.25 to 7.5 cm (Hartman and

Galbraith 1970). The second factor in spawning gravel quality is the amount of fine material (<0.85mm) embedded in the substrate. These fines can impede water flow within the gravel and impair the development of eggs and alevins. Mortality of eggs is substantial when fines exceed 15% of the substrate (McNeil and Ahnell 1964). Suitable spawning substrate is seldom found throughout a spawning area. The accumulation of high quality spawning habitat is influenced by channel slope, flow, channel roughness, and size of material transported by a stream. Hence, spawning channels will include areas of "good" gravel along with areas of coarser or finer material. Fish tend to select areas where the gravel size and flow of water through the gravel are both good. The fine sand size particles are more likely to accumulate in the gravels than the silt and clays. The latter tends to remain in the suspended load, depositing only in extreme low flow areas such as lakes and ponds. Due to the complexity of channel morphology and sediment deposition, no relationships have been developed to predict the effects of turbidity on the quality of spawning gravel.

4.3.1.2 Juveniles

Behavioral Effects

Behavioral modifications, including avoidance and breakdown of dominance hierarchy, resulted from turbidity of 30 NTU and/or TSS from as little as 20 mg/l up to 650 mg/l (Berg and Northcote 1985, Sigler 1988). Servizi (1988) found that coho acclimated to clear water avoided areas of 70 NTU or greater, while coho acclimated to 2 to 15 NTU avoided areas of 106 NTU or greater. Berg and Northcote (1985) found that the ability of juvenile coho to feed not only decreased as a direct result of increasing turbidity on visibility, but also decreased as an indirect result of the hierarchy breakdown. Feeding effectiveness may be impaired within the 70 to 100 NTU range, well below sublethal stress levels (Bisson and Bilby 1982). Sudden pulses of turbidity appeared to be important in triggering sporadic swimming (Berg and Northcote 1985). This reaction may cause displacement of fish into downstream habitats. The accumulated effects of repeated disruption of dominant-subordinate relationships and territories reduced feeding ability, and physiological stress may incur energetic costs at the expense of growth (Berg and Northcote 1985). Behavioral responses to suspended sediments have been reported by several investigators and are initiated in the range of 22 to 100 NTU.

Sublethal effects, including changes in feeding rates, growth rates, gill flaring and coughing, and navigation, were reduced by turbidities ranging from 22 to 265 NTU and/or TSS concentrations of 2,000 to 3,000 mg/l (Sigler 1988). Berg and Northcote (1985) found that ingestion rates of juvenile coho decreased over 50 percent at turbidities above 30 NTU. Yearling coho salmon and steelhead trout exhibited decreased feeding rates when exposed to suspended sediment concentrations of 2,000 to 3,000 mg/l (Redding and Schreck 1987). Turbidities as low as 25 NTU have been associated with reduced fish growth (Sigler et al. 1984).

Since behavioral responses and avoidance occur in similar ranges, avoidance may be prompted by irritation of gill tissues by suspended sediments (Servizi 1988). Juvenile coho exposed to turbidities of 20 NTU or greater experienced increased gill flaring and coughing (Berg and Northcote 1985). Juvenile coho tested at Cultus Lake Laboratory, BC, increased their coughing response after being exposed to 190 mg/l of Frasier River sediment (equivalent to 20 NTU) (Servizi 1988). Fish exposed to turbidities above 30 NTU lowered their holding position to within 10 cm from the bottom, presumably to see the bottom to help them maintain position while in the turbid water (Berg and Northcote 1985).

The May 18, 1980 eruption of Mount St. Helens caused turbidities in the Columbia River to reach as high as 1,500 JTU. This natural disaster became a good opportunity to conduct field studies on the effects of high turbidities and suspended sediment levels on salmon. Several studies documented the diet changes of juvenile salmon. Prior to the eruption, the epibenthic amphipod *Corophium salmonis* was the primary prey for subyearling and yearling chinook, coho, steelhead, and American shad, all of which tended to remain in the upper estuary. After the eruption, however, the primary prey item for salmon was the pelagic cladoceran *Daphina* sp., and a majority of the fish migrated to the central and lower estuary, presumably to avoid the high turbidity (Emmett et al. 1988, Kirn et al. 1986). Newcombe and Flagg (1983) found that juvenile salmon can tolerate aquatic ash loads up to 6,100 mg/l, confirming that high turbidities rarely have been associated with direct mortality.

Gregory and Northcote (1992) calculated foraging rates of juvenile chinook salmon on surface, planktonic, and benthic prey species. Turbidity significantly affected surface foraging of juvenile chinook salmon. In contrast to the findings of Berg and Northcote (1985), Gregory and Northcote (1992) found that chinook experienced depressed foraging rates at low (< 1 NTU) and high (180 NTU) turbidities and that the highest foraging rates were obtained in intermediate turbidity treatments (35 to 150 NTU).

Gregory (1994) found that the relationship between feeding rate and turbidity varied with juvenile chinook size. Smaller fish (49 to 55 mm fork length (FL)) had highest feeding rates on surface and planktonic prey at the lowest turbidities (≤ 18 NTU) and feeding rates declined with increasing turbidity, approaching zero at the highest turbidity level (810 NTU). However, feeding rates on benthic prey were highest at intermediate turbidities (18 to 150 NTU) and approached zero in clear water and highly turbid conditions (370 to 810 NTU). Larger fish (57 to 69 mm FL) had highest feeding rates on surface and benthic prey at the intermediate turbidities (18 to 150 NTU) and approached zero in clear water and highly turbid conditions (370 to 810 NTU). However, feeding rates on planktonic prey mirrored those of smaller fish; that is, the highest feeding rates were at the lowest turbidities (≤ 18 NTU), and feeding rates declined with increasing turbidity, approaching zero at the highest turbidity level (810 NTU). Above 150 NTU, juvenile chinook have reduced feeding rates, regardless of their size or prey type.

Physiological Effects

Gill tissue is the primary site of injury for acute exposure to suspended sediment (Noggle 1978). Injury to gill tissue may interfere with the salmonid's ability to adapt to salt water (Servizi 1988) and can provide entry for infectious organisms. Redding and Schreck (1987) found that infection occurred among yearling steelhead exposed to 2.5 g/l of topsoil for 2 days, even though there was no microscopic evidence of gill injury. Although suspended sediments can result in gill damage, Martens and Servizi (1992) could not determine a relationship between the number of particles in gill tissue (intracellular particle frequency) and exposure to various suspended sediment concentrations. There was no significant difference in intracellular particle frequencies when juvenile coho were exposed to varying amounts of suspended sediments. Small wounds and abrasions which all fish, including controls, must have received from time to time possibly healed less rapidly when continually bathed with a suspension of hard particles, and were more likely to become infected, possibly leading to deaths (Herbert and Merkens 1961).

Lethal effects have been observed in turbidities ranging from 100 to 300 NTU (Sigler et al. 1984). Several species of North American fish were exposed to montmorillonite clay in concentration of 100,000 ppm and survived a week; however, when they were exposed to concentrations of 175,000 to 225,000 ppm, death occurred within 2 hours (Wallen 1951). Rainbow trout exposed to concentrations above 270 mg/l and higher for 3 to 9 months had over 50 percent mortality; however, surviving fish had similar growth rates to control fish, even at higher concentrations (Herbert and Merkens 1961).

4.3.1.3 Adults

After the 1980 eruption of Mount St. Helens, there was concern about the effect of the increased turbidity on returning adult salmon. The homing migration is guided by several factors, but the upstream portion is guided primarily by olfaction (Hasler et al. 1978). Experiments were conducted to determine if volcanic ash had adverse effects on the homing behavior of adult chinook salmon. Adult male chinook salmon exposed to 650 mg/l of volcanic ash for 7 days were still able to find their natal water (Whitman et al. 1982). However the addition of ash to natal water reduced the salmons' preference to migrate up these waters, not from an inability to identify natal water, but because the salmon were avoiding the turbid conditions (Whitman et al. 1982). Reduced preferences for home waters by returning male chinook salmon were affected by turbidity ≥ 30 NTU and/or suspended sediments from as little as 20 mg/l (Sigler 1988). Studies conducted in the Susitna River, Alaska, indicated that Arctic grayling (*Thymallus arcticus*) and adult rainbow trout also avoided water with turbidities above 30 NTU (Suchanek et al. 1984a,b).

4.3.3 Evaluating Turbidity Effects

The effects of turbidity are influenced by both concentration and duration of exposure. Large increases in turbidity over a very short time may have less effect on fish that smaller increases extending over a longer period. The effect of time as well as concentration is reflected in the wide ranging results identified in the review previous sections.

Newcombe and Jensen (1996) reviewed 80 published reports and developed empirical equations that relate biological response to suspended sediment concentrations and duration of exposure. Using this information, they rated the magnitude of effect on a scale of 0 to 14 (Table 17), and then developed predictive models for severity of effects for juvenile salmonids, adult salmonids, and juvenile and adults combined. The predicted responses of each of these groups to turbidity of various concentrations and durations are depicted in Tables 18 through 20.

Table 17. Scale of the severity (SEV) of effects associated with excess suspended sediment (Newcombe and Jensen 1996).

SEV	Description of Effect
	Nil Effect
0	No behavioral effects
	Behavioral Effects
1	Alarm reaction
2	Abandonment of cover
3	Avoidance response
SEV	Description of Effect
	Sublethal Effects

4	Short-term reduction in feed rates or feeding success
5	Minor physiological stress
6	Moderate physiological stress
7	Moderate habitat degradation
8	Indications of major physiological stress, long-term reduction in feeding, poor condition
	Lethal and Paralethal Effects
9	Reduced growth rate, delayed hatching, reduced fish density
10	1-20% mortality, increased predation, moderate to severe habitat degradation
11	>20-40% mortality
12	>40-60% mortality
13	>60-80% mortality
14	>80-100% mortality

Table 18. Severity of ill effects scores for juvenile and adult salmonids. The shaded areas denote extrapolations beyond the empirical data. Scores have been capped at 14. After Newcombe and Jensen (1996).

<table>
<tr><th colspan="14">Juvenile and Adult Salmonids</th></tr>
<tr><td colspan="14">Duration of exposure to Suspended Sediment (log_e hours)</td></tr>
<tr><td rowspan="17">Concentration (mg SS/L)</td><td></td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td></td><td rowspan="17">Log_e mg SS/L</td></tr>
<tr><td></td><td colspan="11">Average SEV Scores</td><td></td></tr>
<tr><td>162755</td><td>10</td><td>11</td><td>11</td><td>12</td><td>12</td><td>13</td><td>14</td><td>14</td><td>-</td><td>-</td><td>-</td><td>12</td></tr>
<tr><td>59874</td><td>9</td><td>10</td><td>10</td><td>11</td><td>12</td><td>12</td><td>13</td><td>13</td><td>14</td><td>-</td><td>-</td><td>11</td></tr>
<tr><td>22026</td><td>8</td><td>9</td><td>10</td><td>10</td><td>11</td><td>10</td><td>12</td><td>13</td><td>13</td><td>14</td><td>-</td><td>10</td></tr>
<tr><td>8103</td><td>8</td><td>8</td><td>9</td><td>10</td><td>10</td><td>10</td><td>11</td><td>12</td><td>13</td><td>13</td><td>14</td><td>9</td></tr>
<tr><td>2981</td><td>7</td><td>8</td><td>8</td><td>9</td><td>9</td><td>10</td><td>11</td><td>11</td><td>12</td><td>12</td><td>13</td><td>8</td></tr>
<tr><td>1097</td><td>6</td><td>7</td><td>7</td><td>8</td><td>9</td><td>9</td><td>10</td><td>10</td><td>11</td><td>12</td><td>12</td><td>7</td></tr>
<tr><td>403</td><td>5</td><td>6</td><td>7</td><td>7</td><td>8</td><td>9</td><td>9</td><td>10</td><td>10</td><td>11</td><td>12</td><td>6</td></tr>
<tr><td>148</td><td>5</td><td>5</td><td>6</td><td>7</td><td>7</td><td>8</td><td>8</td><td>9</td><td>10</td><td>10</td><td>11</td><td>5</td></tr>
<tr><td>55</td><td>44</td><td>5</td><td>5</td><td>6</td><td>6</td><td>7</td><td>8</td><td>8</td><td>9</td><td>9</td><td>10</td><td>44</td></tr>
<tr><td>20</td><td>3</td><td>4</td><td>4</td><td>5</td><td>6</td><td>6</td><td>7</td><td>8</td><td>8</td><td>9</td><td>9</td><td>3</td></tr>
<tr><td>7</td><td>3</td><td>3</td><td>4</td><td>4</td><td>5</td><td>6</td><td>6</td><td>7</td><td>7</td><td>8</td><td>9</td><td>2</td></tr>
<tr><td>3</td><td>2</td><td>2</td><td>3</td><td>4</td><td>4</td><td>5</td><td>5</td><td>6</td><td>7</td><td>7</td><td>8</td><td>1</td></tr>
<tr><td>1</td><td>1</td><td>2</td><td>2</td><td>3</td><td>3</td><td>4</td><td>5</td><td>5</td><td>6</td><td>7</td><td>7</td><td>0</td></tr>
<tr><td></td><td>1</td><td>3</td><td>7</td><td>1</td><td>2</td><td>6</td><td>2</td><td>7</td><td>4</td><td>11</td><td>30</td><td></td></tr>
<tr><td></td><td colspan="3">Hours</td><td colspan="3">Days</td><td colspan="2">Weeks</td><td colspan="3">Months</td><td></td></tr>
</table>

Table 19. Severity of ill effects scores for adult salmonids. The shaded areas denote extrapolations beyond the empirical data. Scores have been capped at 14. After Newcombe and Jensen (1996).

Adult Salmonids												
Duration of exposure to Suspended Sediment ($\log_e$ hours)												
Concentration (mg SS/L)	0	1	2	3	4	5	6	7	8	9	10	Log_e mg SS/L
	Average SEV Scores											
162755	11	11	12	12	13	13	14	14	-	-	-	12
59874	10	10	11	11	12	12	13	13	14	14	-	11
22026	9	10	10	11	11	12	12	13	13	14	14	10
8103	8	9	9	10	10	11	11	12	12	13	13	9
2981	8	8	9	9	10	10	11	11	12	12	13	8
1097	7	7	8	8	9	9	10	10	11	11	12	7
403	6	7	7	8	8	9	9	10	10	11	11	6
148	5	6	6	7	7	8	8	9	9	10	10	5
55	5	5	6	6	7	7	8	8	9	9	9	44
20	4	4	5	5	6	6	7	7	8	8	9	3
7	3	4	4	5	5	6	6	7	7	7	8	2
3	2	3	3	4	4	5	5	6	6	7	7	1
1	2	2	3	3	4	4	5	5	5	6	6	0
	1	3	7	1	2	6	2	7	4	11	30	
	Hours			Days			Weeks		Months			

Table 20. Severity of ill effects scores for juvenile salmonids. The shaded areas denote extrapolations beyond the empirical data. Scores have been capped at 14. After Newcombe and Jensen (1996).

Juvenile Salmonids												
Duration of exposure to Suspended Sediment ($\log_e$ hours)												
Concentration (mg SS/L)	0	1	2	3	4	5	6	7	8	9	10	Log_e mg SS/L
	Average SEV Scores											
162755	9	10	11	11	12	13	14	14	-	-	-	12
59874	9	9	10	11	11	12	13	14	14	-	-	11
22026	8	9	9	10	11	11	12	13	13	14	-	10
8103	7	8	9	9	10	11	11	12	13	13	14	9
2981	6	7	8	9	9	10	11	11	12	13	13	8
1097	6	6	7	8	9	9	10	11	11	12	13	7
403	5	6	6	7	8	9	9	10	11	11	12	6
148	4	5	6	6	7	8	9	9	10	11	11	5
55	4	4	5	6	6	7	8	8	9	10	11	44
20	3	4	4	5	6	6	7	8	8	9	10	3
7	2	3	4	4	5	6	6	7	8	8	9	2
3	1	2	3	4	4	5	6	6	7	8	8	1
1	1	1	2	3	4	4	5	6	6	7	8	0
	1	3	7	1	2	6	2	7	4	11	30	
	Hours			Days			Weeks		Months			

The Newcombe and Jensen tables can be used to evaluate the effects of turbidity on salmonids. There are, however, some seasonal considerations that may also affect the response of salmonids to turbidity. In winter, water temperatures are colder and feeding is naturally reduced;

in extreme cold feeding virtually ceases. Swimming ability is also substantially reduced in very cold waters. During this time, fish seek cover and low velocity areas to hold. Higher turbidity levels may not have the same effect on the ability to feed and may provide some cover during this period. Hence, the effects of turbidity when waters are extremely cold are likely less than during periods of active feeding and growth.

4.3.2 Non-Salmonids

Edwards et al (1983) note a preference for low levels of total dissolved solids (TDS), and for levels of turbidity < 25 JTU, and never over 75 JTU in smallmouth bass. Young (1979) found behavioral changes as turbidity exceeded 20 NTU at temperatures between 18 and 20^{o}C. Other authors reported behavioral changes in warmwater species at suspended sediment concentrations up to 15 mg/l (Newcombe and Jensen 1996). Reduced growth, reproductive success, and survival of largemouth bass, bluegill, and sunfish have been reported in concentrations ranging from 62.5 to 144.5 mg/l (Newcombe and Jensen 1996).

Newcombe and Jensen (1996) developed a relationship predicting the effects of turbidity on freshwater non-salmonids as a function of duration and concentration (Table 21). The development of these relationships is discussed in Section 4.3.1. The data used to develop Table 21 is taken primarily from studies reported on largemouth bass, bluegill, sunfish, and unspecified fish species. The relationship that they developed is therefore probably a reasonable estimate of the effects of turbidity on smallmouth bass and black crappie. The highest concentrations of effect used in the development of the relationships were, however, for carp, goldfish, and the unspecified species. Hence, the Newcombe and Jensen relationship may be biased a little high for bass and crappie.

Suitability curves reflecting smallmouth bass and black crappie turbidity preference in terms of maximum monthly average turbidity during summer have been developed (Edwards et al, 1982, 1983). These curves suggest a higher sensitivity to turbidity levels in smallmouth bass than in crappie (Figures 29 and 30). These curves are measured in JTUs and are not easily compared to the Newcombe and Jensen relationship, which is reported in mg SS/L. JTUs and SS/l are often poorly correlated due to the effect that suspended organics (algae) has on the JTU readings.

Table 21. Severity of ill effects scores for adult freshwater non-salmonids. The shaded areas denote extrapolations beyond the empirical data. Scores have been capped at 14. After Newcombe and Jensen (1996).

Adult Freshwater Non-Salmonids

		Duration of exposure to Suspended Sediment (log$_e$ hours)												
Concentration (mg SS/L)		0	1	2	3	4	5	6	7	8	9	10		Log$_e$ mg SS/L
		Average SEV Scores												
	162755	7	8	9	10	10	11	12	12	13	14	-	12	
	59874	7	8	9	9	10	11	11	12	13	14	14	11	
	22026	7	8	8	9	10	10	11	12	13	13	14	10	
	8103	7	7	8	9	9	10	11	12	12	13	14	9	
	2981	6	7	8	8	9	10	11	11	12	13	13	8	
	1097	6	7	7	8	9	10	10	11	12	12	13	7	
	403	6	6	7	8	9	9	10	11	11	12	13	6	
	148	5	6	7	8	8	9	10	10	11	12	13	5	
	55	5	6	7	7	8	9	9	10	11	12	12	44	
	20	5	6	6	7	8	8	9	10	11	11	12	3	
	7	5	5	6	7	7	8	9	10	10	11	12	2	
	3	4	5	6	7	7	8	9	9	10	11	11	1	
	1	4	5	6	6	7	8	8	9	10	10	11	0	
		1	3	7	1	2	6	2	7	4	11	30		
		Hours			Days			Weeks		Months				

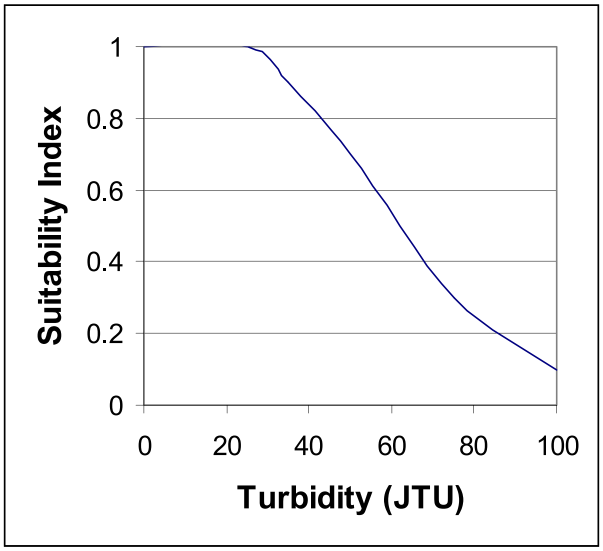


Figure 29. Turbidity suitability index after Edwards et al (1983). Turbidity is measured as maximum monthly average JTUs.

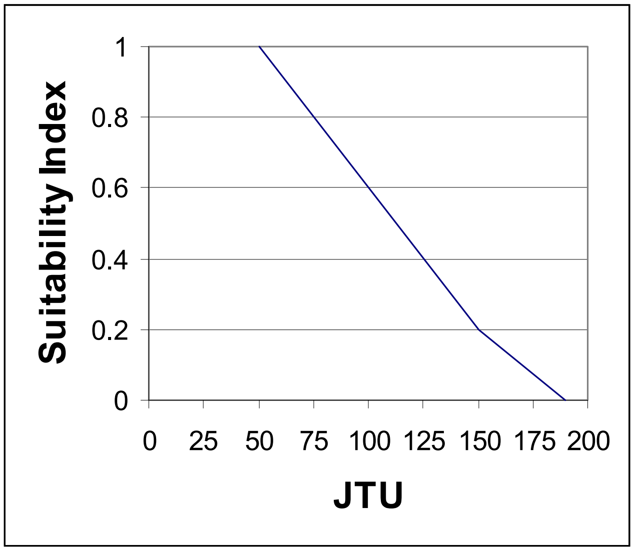


Figure 30. Turbidity suitability curve for black crappie after Edwards et al (1982). Turbidity is measured in terms of maximum monthly average.

No information was found on the effects of turbidity on white sturgeon. Related species (shortnose sturgeon, shovelnose sturgeon, pallid sturgeon) are often found in high turbid waters such as are found in the Missouri River (the big muddy), suggesting a tolerance for turbid conditions. Additionally, sturgeon are bottom feeders, with adaptations that help them find food when sight is impaired. This adaptation further suggests that the fish are tolerant higher turbidity levels. White sturgeon, however, are found primarily in the clearer waters of the west; hence the species may not be as tolerant of higher turbidity levels as the related species. In the absence of data, we can only speculate.

4.4 PH

The literature on pH as it affects fish is largely focused on the effects of acidity. There is virtually no information available for basic waters, such as are found typically in Idaho. Given the acidic waters are uncommon in Idaho, no attempt was made to review the effects of acid waters on fish. Rather, the review of the literature focused on the effects of alkaline waters on fish.

4.4.1 Salmonids

Jordan and Lloyd (1964) found that 50% of their test fish (juvenile rainbow trout) died when acclimated to pH levels of 6.5 to 8.4 and then plunged into waters with pH of 9.86 to 10.13. Witschi and Ziebell (1979) acclimated juvenile rainbow trout to pH of 7.2 and then plunged fish into waters with pH levels ranging from 8.5 to 10.0. Survival was 100% at Ph 8.5, 88% at pH 9.0, 68% at pH 9.5, and 0% at pH 10.0. These studies were focused on the effects of stocking fish acclimated to one pH and subsequently plunged into waters with a high pH. The results are not necessarily applicable to normal resident fish populations.

Peterson et al (1988) noted that rainbow trout would avoid areas where pH levels were less than 5.9. Wilkie et al (1996) evaluated the physiologic effects of high pH levels on rainbow trout. They concluded that the fish develop a sustained compensatory metabolic acidosis, which offsets the effects of high pH and provides for the effective regulation of electrolyte balance. There study demonstrated that rainbow trout are capable of long-term survival at pH 9.5. Similar information is not available for other salmonid species. It is, however, reasonable to assume that similar responses to high pH would be seen.

4.4.2 Non-Salmonids

Smallmouth bass are found at pH levels ranging from 5.7 to 9 (Clady 1977; Paragamian 1979). Optimum pH is thought to be in the range from 7.9 to 8.1 (Funk and Pflieger 1975). No specific information was found for black crappie, however their response to pH is likely similar to smallmouth bass. Information regarding sturgeon response to pH also was not found.

4.5 NUTRIENTS

Headwater streams in the west are often relatively unproductive. Terrestrial vegetation and insects provide a large portion of the food base for fish residing in such streams (Raleigh et al 1984). Increases in nutrient levels are generally associated with increases in primary and secondary production in streams, which subsequently results in increased food availability for fish. Recent studies have identified the importance of salmon carcasses in providing nutrients to streams that subsequently improves the growth and survival of juvenile salmon (Bilby et al 1998).

While increases in nutrients generally correspond to increases in fish productions there, there are upper lethal limits to tolerance to nutrients, particularly to nitrogen compounds. Acute toxicity of salmonids to NH_3-N has been documented in the range from 0.08 to 1.1 mg/l (Russo

1985). The toxicity, however, is strongly influenced by pH, alkalinity, and, to some degree, temperature. Higher pH and alkalinity levels tend to reduce the toxic effects of NH_3-N. The 96-h LC50 of nitrite (rainbow trout) has been reported in the range from 0.19 to 0.88 mg/l (Buhl and Hamilton 2000). The 96-h LC50 of nitrate, which is considerably less toxic than nitrite, has been reported in the range from 1,310 to 1,658 mg/l for rainbow trout (Buhl and Hamilton 2000).

Edwards et al (1982) provided a suitability curve for black crappie that reflected the estimated relationship between total dissolved solids (TDS) and fish habitat in lacustrine environments. This curve indicated a preference for TDS between 50 and 375 mg/l, gradually decreasing to a suitability index value of 0.4 at 800 mg/l.

While fish generally respond positively to increases in nutrient up to the point where lethal effects start to occur (high concentrations), there is a secondary process through which nutrients can have negative effects on fish in eutrophic lacustrine environments. High nutrient loads and subsequent increased plant production result in alterations in the abiotic environment, including oxygen depletion in the hypolimnion and increased stratification (Colby et al, 1972). These processes have direct effects on the habitat available to resident fish populations and indirect effects through changes in Planktonic and benthic production. The processes that affect these indirect effects on fish populations are highly complex and are influenced by a number of site-specific variables including water depth, flushing rate, bathymetry, chemical nature of nutrient compounds, water temperature, stratification, etc. Given the complexity of the relationship between nutrient inputs and the effects on lacustrine habitat, no simplified relationship has been developed.

4.6 POLYCHLORINATED BIPHENYLS (PCBS)

4.6.1 Source, Fate and Transport of PCBs in the Aquatic Environment

PCBs are generally found in U.S. sediments, soils and water in the commercial mixtures from which they originated. These mixtures include the Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260 and 1268, all of which use mineral oil as a carrier. These mixtures contain 16, 21, 32, 42, 48, 54, 60 and 68 percent chlorine, respectively. The content of chlorine affects the persistence of the chemical. Aroclors 1242, 1248, and 1254 contain proportionately more of the toxic coplanar congeners than other mixtures (Hong et al. 1993). Other commercial mixtures such as the Kanechlors and Clophen mixtures have been used heavily outside of the U.S.; however, these mixtures were not broadly used in the U.S. and regulatory criteria have not been promulgated for them in this country. Each of the commercial mixtures is composed of a distinct ratio of PCB congeners.

There are 209 possible PCB congeners (chemicals with similar structure). The various congeners are determined by the arrangement of chlorine atoms in the molecule. Of the 209 possible congeners, 21 are considered highly toxic (Safe et al. 1985, EPA 1989). The quantity of these toxic congeners in commercial Aroclor mixtures is limited, thus in environmentally contaminated fish, these congeners generally represent an extremely small fraction of the total PCB residue. For example, Giesy et al. (1986) detected only three of the most toxic PCB congeners in a study of chlorinated hydrocarbons in chinook salmon eggs from Lake Michigan.

Because of their high stability and heat retention capacity, PCBs were widely used as insulating fluids in electrical transformers, flourescent lighting, hydroelectric fluids and a host of other applications where heat was generated. The stable nature of PCBs, a benefit in commercial applications, is also responsible for their persistence when released into the environment. Environmental persistence of PCBs is directly correlated with the percent of chlorine in the commercial mixture used.

PCBs are highly fat soluble, and therefore have extremely low water solubilities, generally in the low parts per billion (ug/L) to high parts per trillion (ng/L) (Doucette and Andren 1988). Some photodegradation can occur to PCBs, especially those that are ortho substituted (i.e., chlorine in the 2, 2', 5 or 5' position). The highly chlorinated PCBs can also be broken down through the removal of chlorine in anaerobic sediments by several genera of bacteria (Brown et al. 1987, Sokol and Rhea 199x); however, this process is very slow, and does not result in the complete degradation of PCBs to biphenyl.

In large water bodies, such as the Great Lakes, atmospheric deposition and resuspension of contaminated sediments represent the most common sources of PCB contamination of the food web (Jackson 1996). Once in the water and sediments, PCBs are bioaccumulated by fish and other aquatic organisms, and may be subsequently biomagnified through net trophic transfer up the food web (Jackson and Schindler 1996). Fish may bioconcentrate PCBs up to 50,000 times the measured water concentration, but the uptake varies greatly by individual congener. Uptake of individual congeners has been shown to be greatly associated with the product of the 'steric effect coefficient' (a measure of how the molecule lies within a plane – co-planar are more readily uptaken than others and are also more fat soluable) and the log of the octanol:water partition coefficient (a measure of how fat soluable the compound is) (Shaw and Connell 1984).

As such, fish serve as a vehicle for cycling PCBs into the human food chain (Jensen 1984). Within fish, however, elimination of PCBs is extremely slow. Niimi (1996) calculated half-lives of greater than 200 days for four of the toxic coplanar PCBs (PCB #'s 77, 118, 1267 and 169) in adult rainbow trout; thus, older fish generally contain greater amounts of PCBs (Bache et al 1972). Within fish, PCBs may redistribute amongst various tissues according to specific characteristics of the PCB congeneric, age of exposure, fish condition, and maturation level. Perhaps the most significant excretory mechanism for PCBs in fish is via the release of lipid-rich gametes (Guiney et al. 1979, Niimi 1996).

4.6.2 Mechanism of Action of PCBs

The chemical interactions that result in toxicity of PCBs are extremely complex. The summary below is also complex, but attempts to focus in on the primarily mechanisms of interest.

PCB toxicity is a function of both chlorine substitution pattern and chlorine mass in the individual congener. While many of the PCB congeners share the same toxic mechanism of action, congener potency can vary by several orders of magnitude.

Toxicity of PCBs to fish is mediated through the same pathways that occur in mammals. The lethal effects of PCBs are initiated through binding of a PCB congener to a protein receptor known as the Ah receptor (Hoffman et al. 1991). The pattern of chlorine on a PCB molecule affects binding potential of a PCB molecule to the Ah receptor protein. Binding of a PCB molecule to the Ah receptor initiates a chain of events that may lead to hepatic, immunological, and cardiovascular toxicity. The Ah receptor protein has been identified in virtually all vertebrate species examined, but may be lacking in some invertebrates (Hahn and Stegeman 1992).

Early life stage mortality following embryonic exposure to the toxic PCB congeners has been widely demonstrated amongst a variety of fish species (Walker et al. 1991, Wisk and Cooper 1990). Mortality is very stage-specific, occurring principally during or shortly after hatching (Walker et al. 1991). The cardiovascular system of the developing fish embryo and larvae appears to the primary area of effect of the to the coplanar, dioxin-like PCBs (Spitsbergen et al. 1991). Prolonged exposure to PCBs causes oxidative stress by increasing the production of reactive oxygen and organo-radicals—the so called "free radicals" (Feorlin et al. 1996). This oxidative stress is likely the primary cause of physical injury to vasculature (Cantrell 1996).

The alteration of skeletal development resultant from embryonic PCB exposure may be related to altered retinoic acid metabolism (Gilbert et al. 1995, Doyon et al. 1999, Spear et al.

1988). Retinoic acid provides the "pavement" for the migration of neural crest cells, which are a critical to developmental stages of the embryo. Altered levels of retinoic acid—too much or too little, can therefore lead to birth defects.

Recent studies have highlighted the potential effects of PCBs in altering reproduction and sexual development. Androgens (e.g., testosterone) and estrogens drive sexual differentiation in fish (Turner 1960). The mechanism for the effects of PCBs on these endocrine functions is thought to be associated with the binding of some PCBs to the estrogen receptor (Peterson et al. 1992). This binding may disrupt endocrine function (Colburn et al. 1993), and potentially alter sexual differentiation (Peterson et al. 1992, Bortone and Davis 1994, Guillett et al. 1996). The ability to bind the estrogen receptor, similar to binding to the Ah receptor, is related to the form of the molecule. Thus, certain forms (the co-planar forms) of PCBs and dioxins may have greater effects than other forms of PCBs.

4.6.3 Specific Effects Levels in Species Of Concern Following PCB Exposure

Polychlorinated biphenyls are ubiquitous environmental contaminants that elicit a myriad of biological effects. Biochemical, immunological, physiological, carcinogen promotion and endocrine-mediated effects have been documented in numerous species. Because uptake kinetics from water and sediment are highly variable based on factors such as temperature, organic carbon, and suspended sediment, the most appropriate effects thresholds for PCBs are those that relate tissue concentrations to specific biological endpoints. The following discussion briefly summarizes important historical reports of toxicity and metrics of exposure, as well as the most recent findings.

4.6.3.1 Bull trout and related char species

Very little research has been conducted on the toxicity of PCBs and related compounds on bull trout. However, there has been a substantial amount of work conducted to date on lake trout *(Salvelinus namaycush)* and brook trout (*Salvelinus fontinalis*), both of which are in the char family. The following discussion therefore emphasizes these species.

Historical accounts provide a range of effects concentrations for survival in char species. Mauch et al. (1978) exposed brook trout for 48 and 118 days to Aroclor 1254 and proposed maximum long-term exposure levels (chronic NOEC levels) of 9 ug/l for survival and growth from the studies.

Freeman and Idler (1972) identified evidence of demasculinization in brook trout exposed for 21 days to 0.2 ppm Aroclor 1254. Testis contained less spermatic fluid and were shrunken. In addition, only 72% of the eggs from PCB treated brook trout hatched in comparison to a hatching rate of 92% in the control stock.

As was mentioned earlier, the lethal effects of PCBs are initiated through binding of a PCB congener to a protein receptor known as the Ah receptor. This directly affects the enzyme, Cytochrome P450, which is important to liver and steroid enzyme activity. The build up of this enzyme normally begins prior to hatching. In the brook trout alevin (larvae), the process accelerates roughly three-fold after hatching, and then drops back to pre-hatch levels in unexposed yearling fish (Binder and Stegeman 1983). Brook trout embryos exposed for 23 days to 0.75 and 7.5 ppm Aroclor 1254 developed tissue levels of 64 and 229 ppm Aroclor 1254, respectively, and exhibited a four-fold increase in the Aryl hydrocarbon hydroxylase (AHH – an enzyme) activity with both exposure levels. This study suggests that the accelerated AHH activity during late embryonic and larval development contributes to the heightened sensitivity of the early life stages of salmonids to PCBs relative to older life history stages.

Binder and Lech (1984) subsequently demonstrated a similar process in embryos and larvae resultant from wild Lake Michigan lake trout eggs burdened with PCBs from environmental exposure. In this study, Lake Michigan eggs contained a total of 4.3 ug/g PCBs, Green Bay eggs contained 2.19 ug/g PCBs and the hatchery control stock contained 0.175 ug/g PCBs. Induction of AHH activity in swim-up lake trout fry, measured as 'units of activity/mg protein' was 929, 657, and 108 in the Lake Michigan, Green Bay, and control swim-up fry, respectively. This study demonstrated the potential for environmentally derived PCBs to the increased enzyme activity in a char species at environmentally realistic levels. This is a fairly linear increase in activity with increasing concentration of PCBs in the eggs within the range tested (Figure 6).

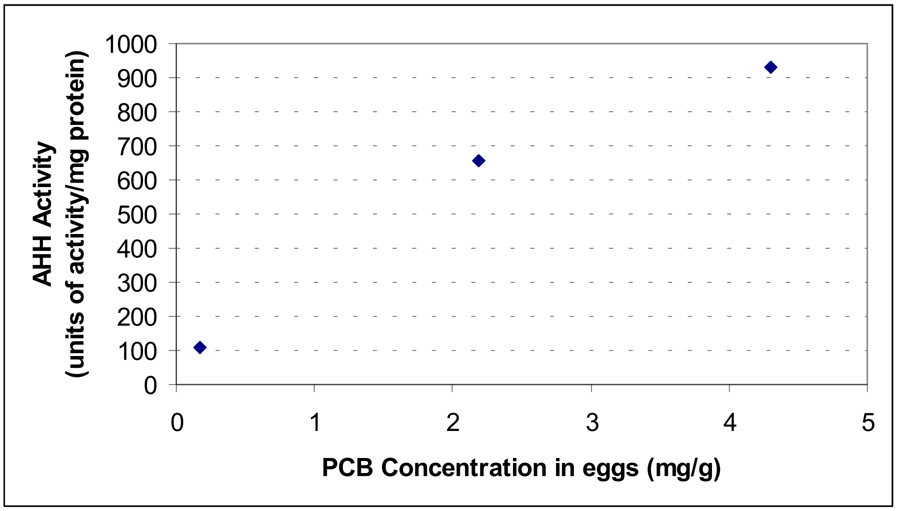


Figure 31. Effects of PCB concentration in lake trout eggs on AHH activity

Spitsbergen et al. (1991) and Walker et al. (1991) conducted controlled laboratory exposures of lake trout embryos to dioxin (2,3,7,8 TCDD) to establish the toxicity of this chemical, which has one of the most-potent effects on the Ah receptors. In those experiments, freshly fertilized lake trout eggs were exposed for 48 hours to nominal concentrations of 10 to 100 ng/l TCDD. The no observable effect level in tissues (NOEL) identified from these studies was 34 pg-TCDD/g-egg, the lowest observable effect level (LOEL) was 55 pg/g and the lethal dose that killed 50% of the lake trout (LD50) was 65 pg-TCDD/g-egg. A subsequent study where rainbow trout embryos was conducted to establish the toxicity of PCBs relative to TCDD (Walker and Peterson 1991). In that study, the LD50 of TCDD in four strains of rainbow trout ranged from 0.230 to 0.488 ng/g, indicating the rainbow trout was more than three orders of magnitude less sensitive than the lake trout exposed by water exposure. Toxic equivalency factors (TEFs) for the PCBs tested, relative to TCDD, were 0.005, 0.00016, < 0.00007, and < 0.00007 for PCB 126, PCB 77, PCB 105 and PCB 118. Thus, applying these rainbow-trout derived TEF values to the bull trout relative, lake trout, would yield LD50s of 13, 406, and < 928 ng/g-egg, for PCBs 126, 77, 105 and 118, respectively. To address the potential toxicity of PCBs and related compounds found in mixtures, the concentration of the individual congener is multiplied by its TEF (Safe 1990). For early life stage mortality in lake trout and related salmonids, the toxicity of multiple congeners is considered additive (Walker et al. 1996).

Cook et al. (SETAC 2000) suggest that the bull trout could be nearly three times more sensitive to PCBs than lake trout for those co-planar PCB congeners that elicit toxicity by initially binding with the Ah receptor (like dioxin). Early life stage mortality, growth, and skeletal anomolies were monitored in bull trout exposed for 96 hours as eyed eggs to the co-planar pentachlorobiphenyl 126. This congener, considered the most toxic of the PCB congeners, was previously demonstrated to elicit LD50 toxicity at residue concentrations of 44-84 ng/g-egg in rainbow trout (Walker and Peterson 1991). In the Cook et al. study, the authors proposed a toxic equivalency factor (TEF) of 0.002 for PCB 126 in bull trout.

Few behavioral effects have been evaluated in char following PCB exposure. Swimming stamina was evaluated in fry exposed by diet and water to PCBs, DDE, or both for 50, 110 and 165 days (Rottiers and Bergstedt 1982). Exposure concentrations were modeled to represent 1, 5 and 25 times the levels of these contaminants measurable in Lake Michigan, from whence the fry were derived. Food PCB values fed to the fry were 1.02, 4.94 and 23.4 ug/g. Water PCB concentrations from the exposure were 21, 65 and 327 ng/L. No effect on swimming stamina (critical swimming speed = fatique velocity) was measurable among the concentrations tested, at any exposure time. In contrast, measurement of temperature selection in fry from the 25 fold exposure concentration (98 days) demonstrated a preference for lower temperatures than the unexposed fish (Mac and Bergstedt 1982). PCB exposed fry preferred 10.3°C water, fry exposed to DDE preferred 9.8°C, and fry exposed to both PCB and DDE preferred 8.7°C; control fry preferred 11.2°C water. The authors point out that the reduced thermal preferences could result in reduced growth and survival.

In summary:

- Virtually all studies have been conducted on eggs and fry. Few studies have addressed long term chronic exposure.

- Toxic effects of exposure vary substantially between the various forms of PCB. Most of the studies have focused on the most toxic forms.

- Demasculinization of adults was found in brook trout exposed for 21 days to 0.2 ppm Aroclor 1254. Hatching of eggs was also reduced at this level of exposure.

- The primary mechanism for PCB effects is most pronounced during a critical developmental phase that starts prior to hatching and extends through short time after hatching. Early life stages are therefore more susceptible to effect than older fish.

- Bull trout embryos are likely 3 to 9 times as sensitive to exposure to the more toxic forms of PCB than rainbow trout embryos.

- Exposure to high concentrations (25 times that found in Lake Michigan) of the more toxic forms of PCBs tends to lower the preferred temperature of bull trout fry by 0.9 to 2.5°C, possibly resulting in reduced growth.

- Due to differences in study approaches, and the measures used to document toxicity is also variable and difficult to compare.

- A no effect level for maximum long-term exposure (chronic NOEC levels) to Aroclor 1254 has been proposed at 9 ug/l for brook trout. This is based on effects on juveniles and embryos. Bull trout may or may not be more sensitive to exposure than brook trout.

- LD50s for eggs have been estimated at 13, 406, and < 928 ng/g-egg, for PCBs 126, 77, 105 and 118, respectively. Eggs containing 4.3 ug/g PCBs, 2.19 ug/g PCBs, and 0.175 ug/g PCBs induced enzymatic activity associated with PCB effects of 929, 657, and 108 units of activity/mg protein, respectively. Since eggs have a high fat content, eggs of exposed adults likely contain some concentration of PCBs, however the effect of exposure of adults on the PCB content of eggs has not been quantified.

4.6.3.2 Rainbow trout and related species

In one of the first attempts to establish acute toxicities of the Aroclor mixtures to salmonids, Stalling and Mayer (1972) performed standard static bioassays for 96 hours with cutthroat trout. In those studies, they proposed 96-hr LC50 concentrations of 1,170, 2,500, 5,430, 5,750, 42,500, 60,900, 50,000, and 50,000 ug/L (ppb) for Aroclors 1221, 1232, 1242, 1248, 1254, 1260, 1262, and 1268, respectively. Note that in these tests, the acute toxicity of the mixtures was inversely related to chlorine content. As discussed earlier, the mixtures with higher chlorine content also contain more of the PCB congeners that are now considered most toxic because of their binding affinity for the Ah-receptor. The decreased acute toxicity of the highly chlorinated Aroclors relative to the lower chlorinated congeners is likely a reflection of the increased solubility of the lower chlorinated mixtures. Physical chemistry studies conducted since this early report document the increasing hydrophobicity of the highly chlorinated PCB congeners (Hawker and Connell 1988, Doucette and Andrin 1988). For example, standard solubility test conditions of 25C, 2-monochlorobiphenyl would have a solubility of roughly 5 mg/L (ppm), however the solubility of the toxic coplanar congener 3,4,3’,4’ tetrachlorinated biphenyl would approximate only 0.6 ug/L (ppb)—four orders of magnitude less soluble. Furthermore, solubility decreases 3 to 11 times over the range of 40°C to 4°C (Doucette and Andrin 1988), and the toxicity tests conducted by Stalling and Meyer were conducted at 9°C. Thus, most of the concentrations proposed exceed the tested solubility of the individual congeners that would be present in the Aroclor mixtures. The test conditions of these early tests did not measure adsorption on the equipment, which was likely substantial, nor did they measure the actual water concentrations of dissolved PCBs. Thus, the test conditions probably resulted in erroneous estimates of the acute toxicity for the mixtures tested.

Mayer et al. (1985) proposed NOEC concentrations in rainbow trout exposed chronically to Aroclor 1254 for 90 days of 2.1 ug/L for survival, and >2.9 ug/L for growth (weight). At concentrations greater than 2.9 ug/L they observed fin erosion, and significant alterations in hematocrit, serum cortisol, serum protein, swimbladder volume, bone chemistry (e.g., calcium:phosphorous ratios) and disease susceptibility relative to unexposed trout.

Rainbow trout fed diets experimentally contaminated with Aroclor 1254 at 0, 5, 50 and 500 ug/g for 30 days were challenged with IHN virus, a lethal fish pathogen, to assess effects of PCBs on immunocompetence (Spitsbergen et al. 1988). Lesions resultant from the IHN viral infection were more severe in the PCB treated trout, but did not affect the mortality or mean time to death relative to control trout exposed to IHN without PCB pre-treatment.

Rainbow trout of unspecified age exposed continuously for 30 days to 7.3 and 14.7 ug/liter Aroclor 1254 had significantly less mortality than control trout after a challenge exposure to the bacterial fish pathogen *Aeromonas hydrophila* (Snarski 1980). Leucocrits (percent of white blood cells) were significantly higher in the Aroclor treated fish than in the control fish, suggesting that PCB exposure could stimulating lymphocyte generation. Alternatively, it was suggested that the PCBs were stimulating lymphocyte division through a non-specific inflammatory response resultant from spleen and kidney damage, the principal sites of red blood cell production in fish.

Natural killer cell activity was assessed in 2 yr old rainbow trout following 1 year of dietary exposure to Aroclor 1254 at 3, 30 or 300 ug/g (Cleland and Sonstegard 1987). Natural killer cells are fundamental to immunity in fish. They kill foreign cells to which a fish might be exposed (e.g., bacterial pathogen). Their function is especially important at temperatures below 10°C, where antibody production ceases (Grace et al. 1982). In this study, natural killer cell activity did not differ among the Aroclor treated or control fish. The results of this study did not suggest that the Aroclor 1254 mixture of PCBs affected cell mediated immunity regulated by natural killer cell activity.

Janz and Metcalfe (1991) induced AHH activity in 300-400 g (adult) rainbow trout by injecting them with the PCBs 77 or PCB 126. On the basis of comparative AHH induction from a TCDD (a dioxin that has the greatest effect on AHH activity) injection, the authors proposed TEFs of 0.002 and 0.005 for PCB 77 and 126, respectively. The injected doses that yielded 50% induction (0.005 micromols/kg) in their experiments were 2.2 umol PCB 77/kg-fish and 1.0 umol PCB 126/kg-fish. Recent studies measuring cytochrome p450 enzyme induction in a rainbow trout cell line proposed TEF values of 0.023, 0.0064, 0.0034, 0.00016 for the toxic PCB coplanar congeners 126, 81, 77 and 169, respectively (Clemons et al. 1996). Additional TEFs of 0.000049, 0.00003 and 0.000017 were proposed for the *ortho* substituted PCBs 105, 156 and 118, respectively.

Wilson and Tillitt (1996) extracted the lipophilic contaminants (those that are attracted to fats, such as PCBs) from Lake Michigan lake trout and injected them into newly fertilized rainbow trout eggs to achieve a ratio of egg-gram equivalent doses. In that study, sublethal effects such as delayed hatching, mild yolk-sac edema and mild hemorrhaging were seen at estimated total PCB tissue levels as low as 8.8 ng/g (ppb).

Fisher et al. (1994b) exposed rainbow trout for 96 hours to a 1:1:1:1 suspension of Aroclors 1016, 1221,1254 and 1260, or to the individual *ortho*-substituted congener 2,4,4. Larval movements, stimulus-provoked swimming activity, and emergence (rate and success) were evaluated, as was predator-avoidance in the subsequent fry. No significant mortality was recorded in the rainbow trout exposed to the Aroclor suspension (max uptake 35 ug/g-egg), or to the pure ortho-substituted congener (max uptake = 4.3 ug/g-egg). None of the behavioral endpoints evaluated identified definitive dose-response effects from the PCB exposures.

Matta et al. (1998), exposed rainbow trout larvae to 1, 5 and 20 mg/L suspensions of Aroclor 1260 for three hours, and followed the survival, gonadal development, and sexual differentiation of the offspring. This exposure protocol yielded tissue concentrations of 2.1 to 2.5 ppm Aroclor 1260 in the rainbow trout, without a significant difference in uptake between exposure concentrations. Larval survival to yolk absorption did not differ from the control treatments. No dose-response effects were measured in larval growth. Larvae from the mid-level exposure produced a significantly greater number of grossly abnormal females than other treatments. Gonadal abnormalities were seen as an incomplete or inconsistent development of egg cells.

Effects recorded on sex ratios were insignificant and inconsistent between doses, with the treatment that accumulated a total of 2.5 ug/g Aroclor 1260 producing more males, and the treatment that accumulated 2.1 ug/g yielding more females. Given that the small range of the PCBs reported between treatments was within the coefficient of variation for the analytical detection of PCBs in tissues by Gas Chromatography-Mass Spectometry (Schwartz et al 1993), it is questionable whether the dose differences expressed were biologically meaningful. Thus, these results were inconclusive for assessing whether Aroclor 1260 affected sex ratios through an endocrine mediated role.

Other results have demonstrated that PCBs can stimulate vitellogenin synthesis in rainbow trout hepatocytes (Andersson et al. 1999). Hydroxylated PCB metabolites were more effective at stimulating vitellogenin than the parent PCB compounds tested (PCBs 104 and 188). Additional work comparing cytochrome P-450 enzyme induction to effects on vitellogenin synthesis in rainbow trout injected with 0.25 or 100 mg/kg hexachlorobiphenyl, demonstrated that the vitellogenin biomarker was not sensitive to the anti-estrogenic effects of 345 HCB. The P-450 enzyme assay was a much more sensitive indicator of PCB exposure in that study (Donohue 1995).

Major Summary Points:

- No effect (NOEC) concentrations have been proposed for rainbow trout exposed chronically to Aroclor 1254 for 90 days at 2.1 ug/L for survival, and >2.9 ug/L for growth (weight). At concentrations greater than 2.9 ug/L fin erosion and significant alterations in hematocrit, serum cortisol, serum protein, swimbladder volume, bone chemistry, and disease susceptibility have been documented.

- Sublethal effects such as delayed hatching, mild yolk-sac edema and mild hemorrhaging were seen at estimated total PCB tissue levels as low as 8.8 ng/g (ppb). Other studies found no difference in larval movements, stimulus-provoked swimming activity, emergence, or predator-avoidance in fry exposed to mixed suspensions of Aroclors 1016, 1221,1254 and 1260 (max uptake 35 ug/g-egg), or to the individual *ortho*-substituted congener 2,4,4. (max uptake = 4.3 ug/g-egg).

- Aroclor 1254 exposure within the ranges tested does not appear to have a significant effect on susceptibility to disease.

- Several authors have proposed TEFs (a measure of toxicity relative to a dioxin that has the greatest effect on Ah receptors) for rainbow trout exposure to various forms of PCBs. The proposed TEFs are highly variable. Proposals include: TEFs of 0.002 and 0.005 for PCB 77 and 126, respectively; TEFs of 0.023, 0.0064, 0.0034, 0.00016 for the PCB congeners 126, 81, 77 and 169, respectively; and TEFs of 0.000049, 0.00003 and 0.000017 for the *ortho* substituted PCBs 105, 156 and 118, respectively. Much of the difference may lie in the methods used to evaluate toxicity.

4.6.3.3 Chinook Salmon and related salmon species

In a case study of chinook fry mortality Flagg (1982) measured 2.5, 3.9 and 5.2 ug/g total PCBs in normal, sick and dead fish, respectively. Fish from this study were also burdened with correspondingly increasing concentrations of DDE; thus, definitive causation to mortality could not be attributed solely to PCBs.

In chinook salmon eggs from Lake Michigan, Giesy et al. (1986) measured an average of 1.9, 6.1 and 1.19 ug/g of Aroclors 1242, 1254 and 1260 respectively. The average of all congeners measured in the eggs from the study was 9.09 ug/g, and a principal components analysis showed the PCB and toxaphene components in the eggs negatively correlated with their survival to the swim-up stage. Unequivocal effects thresholds were not established in this study, however.

Fisher et al. (1994a) established average total PCB residues in landlocked Atlantic salmon eyed embryos of 0.33, 1.534, 0.857, 5.594, and 14.163 following a 48 hour exposure to a 1:1:1:1 suspension of Aroclors 1016, 1221, 1254, and 1260, at concentrations of 0, 0.0625, 0.625, 6.25, and 62.5 mg/l. In that study, no significant mortality was observed among treatment concentrations, and hatching rates were not altered. These egg concentrations bracketed those reported by Giesy et al. (1986) from chinook salmon eggs derived from Lake Michigan stocks, where swim-up fry mortality was correlated slightly with embryonic PCB burden. Recent identification of an early mortality sydrome in Great Lakes salmonids caused by a maternally derived thiamine deficiency (Fisher et al. 1996, 1998) brings in to question whether the swim-up mortality attributed to organohalogen contamination in salmonids from the Great Lakes, as reported by Geisy et al. and others (see Leatherland 1993 for review), could be attributed to an incorrect etiology.

In the Fisher et al. (1994a) study, there were significant reductions in wet weight of alevins at 50% hatch, and 4 weeks post-hatch, and in fingerlings at 6 months post-fertilization in the two highest concentrations. In this study alevins (sac-fry larvae) exposed to the two highest PCB concentrations exhibited a significant delay in the development of negative phototactic behavior, which was manifest near yolk resorption as a delay in the development of positive phototaxis. Positive phototaxis (phototropism) occurs naturally in salmonid fry and facilitates their emigration from the intragravel incubation environment at "swim-up". Additional behavior studies from these same exposed fish demonstrated a significant reduction in predator avoidance ability in juveniles exposed to a novel 24 hour encounter with a trained smallmouth bass predator.

Juvenile chinook salmon injected with Aroclor 1254 at 54 mg PCB/kg, 20% of the 96-hr LD50 (Arkoosh et al. 1994) exhibited a reduction in the primary and secondary b-cell (antibody producing) response following challenge with a thymus independent antigen. Subsequent *in-vitro* work with chinook salmon demonstrated that cultured b-cell lymphocytes from chinook salmon did not exhibit suppression of antibody production or proliferation except at cytotoxic concentrations of Aroclor 1254, 45 and 90 micromolar (Noguchi 1997).

Major Summary Points:

- Several of the studies that were conducted to evaluate the effects of PCBs on chinook were inconclusive and/or the results may have been compromised by other uncontrolled factors.

- No significant mortality was observed among treatment concentrations, and hatching rates were not altered in Atlantic salmon exposed to 1:1:1:1 suspension of Aroclors 1016, 1221, 1254, and 1260, at concentrations of 0, 0.0625, 0.625, 6.25, and 62.5 mg/l. Significant reductions in the weight of alevins, and 4 weeks post-hatch, and in fingerlings at 6 months post-fertilization in the two highest concentrations were found. Alevins exposed to the two highest PCB concentrations exhibited a significant delay in the development of negative phototactic behavior and in predator avoidance ability.

- Juvenile chinook salmon injected with Aroclor 1254 at 54 mg PCB/kg exhibited a reduction in antibody production.

4.6.3.4 Black Crappie

No reports on PCB toxicity specific to the black crappie were discovered in the literature. However, toxicity has been investigated in the related bluegill *Lepomis macrochirus*.

Stalling and Meyer (1972) proposed acute 96-hr LC50 concentrations of 278 and 2,740 ug/L for Aroclors 1248 and 1254, respectively. The species was considerably more sensitive than the cutthroat trout evaluated in the same experiments; however, test conditions for the bluegill required water temperatures double that to which the trout were exposed, which likely greatly increased the solubility of the Aroclors during exposure, and thus their bioavailability.

The sensitivity of fish ATPase enzymes to PCBs was also evaluated in bluegill (Cutkomp et al. 1972). In that study, 50% Mg^{2+}ATPase inhibition in muscle, kidney and brain tissues, at 2.0, 4.0, and 3.5 ppm Aroclor 1242, respectively.

4.6.3.5 White Sturgeon and Related Species

Studies of PCB toxicity to any sturgeon species have not been completed to the extent that acute or chronic lethal endpoints have been proposed. Palace (1996) correlated cytochrome P450 enzyme activity in lake sturgeon *(Acipenser fulvescens)* PCB exposure, and these indicators were associated with reduced levels of the antioxidants vitamin E and A.

Retinoic acid hydroxylation was 3.5 times greater in St. Lawrence River (Lac Saint-Louis) lake sturgeon than detected in sturgeon from the Abitibi region (Lac Berthelot) (Doyon et al, 1999). In kind, the St. Lawrence sturgeon were burdened with 20 fold more of the cytochrome P-450 PCBs in their livers than detected in the sturgeon from Abitibi and 18 fold more total PCBs (760 vs. 42 ng total PCBs/g-wet weight).

Recent work by Dwyer et al. (2000, unpublished manuscript) has evaluated the acute toxicity of Atlantic sturgeon *(A. oxyrhyunchus)* and shortnosed sturgeon *(A. brevirostrum)* to pentachlorphenol (PCP), carbaryl, copper, 4-nonylphenol, and permethrin. Static 96-hr acute toxicity tests were conducted in accordance with standard procedures (ASTM 1998). The results of these experiments, while not specific to the chemicals of interest for this report, have relevance in that co-exposures to rainbow trout were also conducted. Thus, an index for the sensitivity of two sturgeon species to an array of chemicals relative to one of the species of interest in this report can be developed. Atlantic sturgeon were twice as sensitive to carbaryl, approximately 2/3rds less sensitive to copper, approximately 3 times more sensitive to 4-nonylphenol and permethrin, and approximately 1/4th less sensitive to PCP than the rainbow trout. The shortnose sturgeon was less than half as sensitive to carbaryl, equal in sensitivity to the Atlantic sturgeon for copper, 4-nonylphenol, and permethrin, and equally sensitive to PCP as the rainbow trout. Data for the organohalogen pentachlorophenol may represent the best surrogate for the organohalogen

PCBs of interest to this report. For this compound, although the Atlantic sturgeon was slightly more sensitive than the rainbow trout, toxicity in all three species investigated was seen in overlapping concentrations. Thus, PCB toxicity indices in white sturgeon may approximate those seen in rainbow trout, but further study is clearly needed.

4.7 MERCURY

4.7.1 Source, Fate and Transport of Mercury in the Aquatic Environment

Mercury is a naturally occurring element that has multiple industrial uses. Its complex chemistry results in the presence of both inorganic and organic mercury forms in the environment. It occurs naturally in elemental and inorganic complexes, and can be methylated by sulfate reducing bacteria in sediment and water to form organic mono or di-methylmercury. Because these organic forms of mercury bind strongly to the sulfhydryl groups on proteins (Choi and Bartha 1994), they are not readily eliminated from biological tissues, and it is this aspect of mercury that results in its biomagnification into higher trophic levels (Matta 1999).

The largest source of mercury in aquatic environments is from atmospheric deposition. Waste incineration is the principal source of atmospheric mercury (Carpi et al. 1994). Incinerators release between 0.4 and 3.5 grams of mercury per metric ton of combusted waste (Pacyna and Munch 1991). Emissions of mercury are composed of approximately 10-20% elemental mercury (Hg^o), and 75-85% divalent mercury (Hg (II))--predominantly as mercuric chloride ($HgCl_2$) (Carpi et al. 1994). The actual proportion of mercury species emitted is partially dependent on the mercury species in the combusted matter and on the pollution control equipment used at the incinerators.

Elemental mercury is generally removed from the atmosphere by dry deposition, and because of its high vapor pressure and low solubility, elemental mercury can be transported over long distances. In contrast, the higher solubility of divalent mercury causes its removal by precipitation at much closer distances from point sources. The average background concentration of mercury in the North American atmosphere is roughly 3 ng/m^3 (Ames et al. 1993). In rural locations more than 90% of this atmospheric background is elemental mercury (Brosset and Lord 1991), with the remainder predominantly methylmercury at atmospheric concentrations ranging from 0.05 to 1 ng/m^3 (DeMora et al. 1991). Rainwater contains background concentrations of total mercury between 2 and 20 ng/L, but could reach 90 ng/L; methylmercury has been measured at background concentrations of 0.05 to 0.6 ng/L (Lee and Iverfeldt 1991; Bloom and Watras 1989). Typical water levels have been measured at 1 to 400 ng/L (Wiklander 1970).

In the aquatic environment inorganic mercury is predominantly found in the sediments, or adsorbed to particulate matter suspended in the water column. Organic mercury was detected in only 17% of reservoir sediments (Allen-Gil et al. 1995), although it represents more than 80 or 90% of the mercury detected in fish tissues (Hattula et al. 1978, Allen-Gil et al. 1995). The partitioning of mercury between its various forms, and its methylation rate in aquatic sediments, can vary by local geology, topography and land use patterns (Allen-Gil et al. 1995). Transport of methylmercury into fish is thought to occur principally across the gill surface (Pederson et al. 1998, Post et al. 1995), although uptake from food is the dominant source in summer months (Post et al. 1995). Mercury has been shown to be methylated within the fish gut (Rudd et al. 1980), but the proportionate contribution of methylmercury entering fish by this pathway is insignificant relative to direct uptake of methylmercury from the diet and water. There is no substantive evidence of mercury demethylation in fish after uptake has occurred (Weiner and Spry 1996). Dietary selenium may displace mercury from sulfhydryl groups on proteins, and result in measurable decreases in some tissue burdens in fish (Bjerregaard et al. 1999).

4.7.2 Mechanism of Action

Inorganic mercury exposure results in the induced synthesis of the heavy metal-binding protein, metallothionein (MT), which binds the free metal mercury ion. Unlike the cytochrome P-450 enzymes, whose function is to metabolize the PCBs and other organochlorines, the MT proteins function to sequester the heavy metal ions. Metalothionein proteins bind 4 to 12 atoms/mole, with binding affinities for the metals as follows: Hg>Cu>Cd>Zn (George 1986). Toxicity from mercury is thought to result when MT is saturated, allowing the free ion to reach biological tissues most sensitive to mercury toxicity. Low levels of MT are expressed normally, in order to regulate the required amounts of copper and zinc. George (1982) points out that the total metal content or tissue content of a fish is not indicative of MT content or even of recent metal exposure. Furthermore, Weiss (1984) did not detect Hg-MT in fish from a creek with high levels of methylmercury, indicating that MT is inducible by the inorganic forms of mercury only.

Mercury affects multiple biological systems by several action mechanisms. Perhaps the most definitive evidence of mercury intoxication is associated with central nervous system deficits, which may be observed as tremors, and a general irritability/excitability (Matta 1999). Weiss and Weis (1995) observed hyperactivity and hypoactivity in fathead minnow *Fundulus heteroclitus* larvae exposed to mercury as embryos and larvae, respectively. Mercury poisoning in humans, attributed to either elemental or organic forms, elicits a relatively non-specific syndrome, dominated by neurological symptoms such as thyroid enlargement, uneven heartbeat, tremors, loss of memory. Mercury can lead to general cell death by interfering with bioenergetic reaction in mitochondria. Upon ingestion, mercury can lead to ulceration, gastrointestinal bleeding and necrosis, and renal necrosis (kidney cell death). In severe acute cases, these cellular effects can result in circulatory shock. The principal pathologic features from organomercurials include degeneration and neuronal necrosis in focal areas of the cerebral cortex, with the visual areas of the occipital (visual) cortex often proving most sensitive (Roizin et al. 1977).

Like PCBs, mercury has been shown to disrupt endocrine and related reproductive function. Catfish exposed to mercury for 45-180 days before reproductive maturity exhibited depressed levels of phospholipids and free cholesterol resultant from impaired testicular lipid metabolism (Kirubagaran and Joy 1992). Associated with this exposure, the catfish had smaller seminiferous tubules, undeveloped spermatids, and changes in the Leydig cells in the testis. Walleye burdened with 0.25 and 2.4 ug/g-tissue methylmercury from controlled dietary exposure, expressed a dose-response atrophy in the male reproductive system (Friedman et al. 1996). Fathead minnow eggs and sperm exposed directly to methylmercury were less able to be fertilized (eggs) or to penetrate the egg (sperm) (Khan and Weis 1993). Collectively, these studies show a broad range of endocrine and reproductive endpoints that can be affected by mercury poisoning.

4.7.3 Specific Effects Levels in Species Of Concern Following Mercury Exposure

4.7.3.1 Bull trout and related species

No specific lethal or sublethal toxicity data for mercury to bull trout were identified in the literature. The effects of mercury on brook trout, a closely related char, have however been studied.

Three generations of brook trout were continuously exposed to mercuric chloride at 2.93, 0.93, 0.29, 0.09, 0.03, and < 0.01 (control) ug/L (ppb), representing a chronic exposure for 144 weeks (McKim et al. 1976). In the first 39 weeks of exposure, the first generation of brook trout exposed to the highest concentration developed deformities, and 88% of the group died. The second generation of brook trout exposed to the next lowest concentration (0.93 ppb) exhibited similar deformities after 108 weeks of exposure, and all but one female died. Muscle levels of mercury resultant from these exposures were 23.5 and 9.5 ug-Hg/g wet weight, respectively.

Further, there was no effective elimination of mercury, and steady-states in the tissues were reached after 21 to 28 weeks of water exposure. Effects on growth, survival and morphology were not elicited by mercury at the three lowest concentrations in any of the generations examined. The authors proposed a maximum acceptable toxicant concentration (MATC = no observable effect concentrations) for brook trout between 0.93 and 0.29 ug Hg/liter. The 0.29 ug-Hg/L water concentration yielded NOEC tissue levels of 12, 8, 9, 6, 5, 3, and 5 ug-Hg/g-wet weight in spleen, liver, kidney, gill, brain, gonad, and muscle, respectively. These authors also proposed a 96-hr acute LC50 of 75 ug-Hg/L for 200g adult brook trout.

4.7.3.2 Rainbow trout

MacLeod and Pessay (1973) reported a 96 hr LC50 of 280 ug/L for rainbow trout fingerlings exposed to mercuric chloride. Wobeser (1975) reported a 96-hr LC50 of 42 ug/L for 1.5g rainbow trout fingerlings exposed to methyl mercury (range 25-59 ug-Hg/L).

Rainbow trout fed 10 g mercury/kg as mercuric chloride for 42 days accumulated 2.1 ug/g in muscle, 8.17 ug/g in gills, 5.3 ug/g in kidney, and 0.61 ug/ml in mucous (Handy and Penrice 1993). Approximately 89% of the total body burden in control fish was found in muscle tissue, while those trout fed the contaminated diet had only 18% of their body burden in muscle tissue. Kidney tissue from the mercury treated trout exhibited an increase in the number of melanomacrophage centers—these represent cellular waste depositories and will increase in number as a response to non-specific tissue damage. In keeping with this finding, sloughing of the intestinal epithelium (gut lining) was also observed in the mercury treated fish. No significant mortalities were recorded in this study.

Juvenile rainbow trout were exposed to waterborne methylmercuric chloride (CH3HgCl) or mercuric chloride (HgCl2) until intoxication caused death, and tissue burdens were summarily investigated (Niimi and Kissoon 1994). The average time to death for trout exposed to methylmercuric chloride at 4, 9, 10, 13, and 34 ug/L was 58.2, 24.2, 21.7, 7.6 and 1 days, respectively. The range or average time to death for trout exposed to mercuric chloride was 94-130 (range), 55.4, 15, and 2.5 days, for concentrations of 64, 135, 241 and 426 ug/L, respectively. Highest tissue concentrations were measured in the kidney, and lowest concentrations were measured in the muscle. Critical body burdens eliciting death in specific organs were not reliable for predicting death, but whole-body concentrations of methyl-mercury between 10-20 mg-Hg/Kg-wet weight were considered potentially lethal to fish. Based on results of other studies, the authors postulated that total body burdens of 1-5 mg-Hg/Kg-wet weight could result in chronic effects. Although the highest exposure concentrations in this study did not necessarily achieve the highest tissue burdens due to an early onset of death, the lethal tissue burdens proposed are similar to earlier studies where trout died or exhibited profound neurological effects at tissue burdens of 11 to 21 mg/kg (Matida 1971), or 10-11 mg Hg/kg wet weight (McKim et al. 1976). These tissue burdens are approximately one order of magnitude greater than the current FDA consumption limit of 1 mg/kg established for the protection of human health. Recent evidence with rainbow trout indicates that intermittent exposures are equally effective at accumulating mercury (probably because elimination is negligible) and that total duration of exposure is what regulates body burden (Handy 1994).

Juvenile rainbow trout were exposed to mercuric chloride at 28 and 112 ppb or to methyl mercury at 6, 12 and 24 ug/L for 4, 72 and 168 hours to evaluate the sublethal effects of these mercury species on function of the pituitary gland (Bleau et al. 1996). These doses were selected to represent 10 to 40% of the 96-h LC50 for this species (280 ug Hg/L). Both compounds produced a general stress response, and increased plasma thyroxine (a hormone), and plasma glucose (sugar) in a dose-responsive manner. These factors ultimately regulate carbohydrate metabolism, as evident by the reduction of liver glycogen also measured in this study.

In evaluating the effects of mercury on rainbow trout immune cell function *in-vitro*, Voccia; et al. (1993) found that the proliferation of white blood cells (lymphocytes) from rainbow trout, and the non-specific cell-mediated immune responses were suppressed by mercury only at the concentrations that also have a toxic effect on cells ($\geq$ 20.6 mg-Hg/L as methylmercury, $\geq$ 206 mg-Hg/L as inorganic mercury chloride). Thus, immune cell function should not be interpreted to be a site of particular sensitivity to mercury poisoning.

4.7.3.3 Chinook salmon

No reports specifically examining mercury toxicity in chinook salmon were available in the literature. Results from rainbow trout and brook trout studies should be reasonably reflective of results one might expect in chinook salmon.

4.7.3.4 Black Crappie

No reports specific to mercury toxicity in black crappie are available in the literature. The toxicity of methylmercuric chloride was investigated in the closely related bluegill. In that study, bluegill survival was reduced following a 12.5 day exposure to 0.05 mg/L. Exposures at 9, 21 and 33 °C resulted in tissue-effect concentrations of 6.5, 10.7 and 37 ug/g mercury, respectively.

4.7.3.5 Sturgeon

No studies were discovered in the literature where mercury toxicity was evaluated in relation to lethal tissue, water or sediment concentrations in any sturgeon species. In a recent study evaluating copper toxicity in Atlantic sturgeon and shortnose sturgeon, a 48-hr LC50 of 150 ug/L was proposed, which was 66% less sensitive than rainbow trout to copper measured in the same study (LC50 trout = 90 ug/L) (Dwyer et al. 2000). The 96-hr LC50 for the geometric mean of 6 rainbow trout studies for copper was 8 ug/L (USEPA 1995). In comparison, the shovelnose, shortnose, and Atlantic sturgeon had 96-hr LC50's of 160, 80 and 60 ug/L, yielding toxicity ratios relative to the rainbow trout of 2, 1 and 0.8, respectively (Dwyer et al. 2000). Conservatively assuming the sensitivity of white sturgeon is similar to that of the Atlantic sturgeon, and considering the acute toxicity endpoints measured in rainbow trout fingerlings by McLeod and Pessay (1973) and Wobeser (1975), the acute toxicity of white sturgeon to mercuric chloride should approximate 350 and 52.5 ug/L, respectively.

Sturgeon (*A. baeri*) were exposed to 3.0ug/L mercury, as HgCl2 for 60 days at 15C to assess the potential effects of the metal on differential white blood cell counts (Mikryakov and Lapirova 1997). After seven days of exposure the sturgeon had a significant increase in two types of segmented white blood cells, and a significant decrease in lymphocytes. After 60 days of exposure the increase in one of the two types of white blood cells was still observed, but other blood cell counts did not differ from the control fish. Measurements at other time points were not consistently elevated or depressed relative to control blood cell counts. The altered counts early after exposure likely represent a general stress response. Similar changes in blood cell counts were not observed in sturgeon from the Caspian Sea (Shleifer and Dokholyan 1979).

4.8 ALDRIN AND DIELDRIN

4.8.1 Source, Fate and Transport of Dieldrin

Dieldrin is an organochlorine insecticide that is a member of the pesticide class known as the 'cyclodienes'. It was used extensively for termite control in commercial and residential applications, and is a common soil and sediment contaminant. It is structurally similar to isodrin, endrin, 12-ketoendrin, and aldrin and shares a similar mechanism of action to these compounds. Dieldrin is formed by the conversion from aldrin in soils, or within tissues of mammals, birds and fish (Bann et al. 1956, Stanton and Khan 1973). This conversion occurs by a process known as epoxidation, which is in turn controlled by the cytochrome P-450 enzyme system (Stanton and

Khan 1973). Thus, dieldrin is the storage form of aldrin exposure in biological tissues. In fish, dieldrin is about an order of magnitude more toxic than aldrin (Peakall 1996).

Uptake of dieldrin is often intercorrelated with other organic chlorine contaminants such as PCBs and DDE, complicating the assessments of toxicity in field exposure incidents. Dieldrin has an estimated solubility of 22 (Kenaga and Goring 1980) to 90 ug/L (Van Leeuwan et al. 1985), and reported bioconcentration factors of 5,800 and 4,420 in flowing and static waters, respectively (Kenaga and Goring 1980). The log of its octanol:water partition coefficient (log K_{ow}), a measure of its lipid solubility, is 4.7 (Ney 1998), indicating moderate to high potential for bioaccumulation. Partitioning between organic carbon (oc) and water (K_{oc}) is moderately high (log K_{oc}: 4.4 to 5.16 in freshwater).

4.8.2 Mechanism of Action of Dieldrin and Related Cyclodiene Pesticides

Brain function and central nervous system effects appear to be the most sensitive endpoints to dieldrin and related cyclodiene acute exposure. Acute toxicity of dieldrin manifests as convulsions and biochemical changes in the brain, but the precise mechanism of action of this organochlorine pesticide is not fully established. Like the PCBs, dieldrin has been shown to affect the synthesis of catecholoamine neurotransmitters in the brain such as dopamine, norepinephrine, serotonin and gamm-aminobutyrate. For example, Heinz et al. (1980) caused a 62 and 41% dopamine reduction in ring dove brains by feeding these birds 16 mg/kg dieldrin. These neurotransmitter deficits may be associated with changes in behavior observed by Gesell et al. (1979), where brain levels of dieldrin in bob-white quail were measured at 5.73 ug/g. Similarly, breeding behavior in mallards was altered by brain levels as low as 0.42 ug/g (Sharma et al. 1976).

In chronic exposures, an increase in liver/body weight ratios and changes in the liver appear to be the most tell-tale signs of toxicity. For example, fatty changes have been documented in guppy (*P. reticulata*) (Mount 1962). Liver cell hypertrophy (increase in tissue volume due to increase in individual cell size) has been observed in Asian catfish (*Channa punctatus)* (Sastry and Sharma 1978) exposed to the related endrin.

Physiological endpoints may also be affected by dieldrin exposure in fish, and can therefore represent sensitive biomarkers for acute exposure. A 72 hour exposure to 20 ug-dieldrin/L in goldfish increased blood glucose, total protein, and cortisol, and decreased cholesterol (Gluth and Hanke 1984). Lethal blood levels of dieldrin have been reported for gizzard shad from 0.10 to

0.22 ug/g, and for channel catfish at 0.3 ug/g (Mount et al. 1966). Other tissue values were not reported for comparison with the bird and amphibian studies, but these low levels suggest that fish may be more sensitive than other animals. Langdon (1988) suggests that water concentrations less than 0.005 ug/L (5 ng/L) is safe for continuous exposure of fish in fish culture conditions. Aquatic toxicity to fish does not appear to be affected by water hardness (Johnson and Finley 1980).

4.8.3 Specific Effects Levels in Species Of Concern Following Dieldrin Exposure

4.8.3.1 Bull trout and related species

No data specific to dieldrin toxicity are available in the literature for bull trout. Lake trout exposed to dieldrin in water exhibited changes in liver cell structure (Mathur 1965). In the gills, increase in size of the respiratory surfaces has been documented, along with clubbing (Walsh and Ribelin 1975). These same authors identified paleness and atrophy in the spleen, fatty change and congestion of vessels in the liver, and an increase in blood flow/volume in the brain and intestine.

4.8.3.2 Rainbow trout and related species

In juvenile rainbow trout Katz (1961) reports a 96-hr LC50 of 10 ug/L for dieldrin. Cope (1965) reports 96-hr LC50 values of 36 and 1.9 ug/L (ppb) for aldrin and dieldrin, respectively in rainbow trout. Edwards et al. (1977) report a 96-hr LC50 of 19 ug/L. A 96-hr NOEC for rainbow trout survival of 0.15 ug/L was reported by Shubat and Curtis (1986) that yielded associated tissue concentrations of 0.548 ug/g; these same authors reported a 96-hr LC50 of 0.62 ug/L, which were associated with tissue residues of 5.65 ug/g.

In a study of uptake and clearance in early life stages of rainbow trout exposed to dieldrin at 5.78 ug/L, Van Leeuwan et al. (1985) showed that 79% of the dose accumulated was found in the in the yolk, 15 percent in the embryonic body, and 5.3 percent in the perivitelline fluid, and the remainder was found in the egg chorion (< 1%). Bioconcentration continued in the yolk sac of hatched larvae until yolk absorption was nearing completion, at which time levels in the larval tissues increased to a maximum of 36 mg/kg; however, despite this high residue, mortality was not observed.

In a dietary radiotracer study juvenile rainbow trout ingesting 1 mg-dieldrin/kg-diet for 140 days exhibited no effect on survival or growth, and tissue residues of 2.13 ug/g (Macek et al.

1970). Combined water and diet exposures of 0.08 ug/L and 0.087 ug/g-diet for 112 days yielded tissue residues of 1.40 ug/g but no effect on growth was documented (Shubat and Curtis 1986).

Although dieldrin will bioaccumulate, long term low level exposure to dieldrin in rainbow trout has been shown to limit the total accumulation of dieldrin (Shubat and Curtis 1986, Gilroy et al. 1993). Gilroy et al. (1993, 1996) propose that dieldrin exposure induces changes in protein expression unrelated to cytochrome P450 metabolism that result in dieldrin isolation and accelerated elimination. The mechanisms by which the redistribution of dieldrin is accomplished are not yet understood; however, dieldrin pre-treatment prior to a subsequent dieldrin exposure may result in production of lipoproteins, thereby altering processes related to liver cell transmembrane processes (Gilroy et al. 1993, Gilroy et al. 1996).

4.8.3.3 Chinook salmon and related con-generics

No dieldrin or related cyclodiene toxicity data specific to Chinook salmon were found in the literature. Lesions of the liver following water exposure were observed in coho salmon by Walsh and Ribelin (1975). The lesions identified were consistent with those the same authors reported for lake trout, as described previously.

4.8.3.4 Black Crappie and related species

No toxicity data specific to the black crappie were available in the literature. In a study of the related bluegill, Henderson et al. (1959) reported 24 and 96-hr LC_{50} concentrations of 5.5 and 8 ug/l, respectively. The same authors reported 24 and 96-hr LC_{50} values of 9.6 and 13 ug/L for aldrin, and 0.35 and 0.6 ug/L for endrin. It is unclear why the toxicity of dieldrin at 24 hours was apparently greater than that observed at 96 hours.

Edwards et al. (1977) report a 24-hr LC_{50} to bluegill of 170 ug/L. Johnson and Finley (1980) report a 96-hr LC50 of technical grade dieldrin of 3.5 ug/L, in tests conducted with 1.3 g juvenile bluegill at 18C. The same authors report a 96-hr LC50 of 11 ug/L for photo-dieldrin.

Mayer and Ellersieck (1988) report results from a range of 96-hr LC_{50} tests with bluegill exposed to endrin from 0.19 to 0.73 ug/L at exposure temperatures of 7-29 °C. As demonstrated by Henderson et al. (1959), endrin appears to be approximately one order of magnitude more toxic than dieldrin.

4.8.3.5 Sturgeon

No data specific to dieldrin toxicity to any sturgeon species were found in the literature.

4.9 DDT AND ITS METABOLITES

4.9.1 Source, Fate and Transport of DDT in Aquatic Environments

Broad scale application of DDT to control mosquitoes and other insect pests responsible for human disease and crop damage resulted in the global contamination with the compound and its metabolites. Environmental sinks persist in soils, sediments and water throughout the globe, and the use of the chemical continues in several countries outside of the U.S., where it was banned in 1972.

As reflected in Table 16 below, DDT and its metabolites have extremely low water solubility and high lipid solubility, accounting for their extreme potential to bioconcentrate and persist in environmental media. Clearly not in recognition of these environmentally troublesome properties, Paul Muller, the discoverer of DDT's insecticidal properties, received the Nobel Prize in 1939.

Table 22. Physical chemistry of DDT and its metabolites (Kenoga and Goring 1980)

Chemical	Solubility (ug/L)	Log Koc	Log Kow	BCF (flowing water)	BCF (static water)
DDT	1.7	5.38	5.98	61,600	84,500
DDE	10	nd	5.77	Nd	27,400
DDD	5		6.02		63,830

Because of its high lipid solubility, DDT, and its major metabolite DDE, partition and concentrate into fatty tissues. Diet sources appear to be the main source of exposure to aquatic animals. At a constant rate of intake, the concentration that will be reached in fatty tissues reaches equilibrium and remains relatively constant. The elimination rate, once removed from continued exposure, has been estimated at 1% of stored DDT/day in humans, but is much greater in fish.

4.9.2 Mechanism(s) of Action of DDT and Its Metabolites

DDT is thought to assert its acute insecticidal action principally as a sodium channel blocker, interfering with the transmission of nerve impulses traveling along the sensory and motor nerve fibers. DDT apparently slows the “turning off” process of sodium conductance across the nerve membrane, and inhibits the “turning-on” process of the potassium conductance, resulting in the prolonged firing of the nerve membrane (Narahashi 1969).

In addition to its neurotoxic actions, DDT and DDE have been shown to interrupt mitochondrial respiration and reduce the synthesis of ATP, and can result in associated bioenergetic deficits.

Similar to the toxic equivalency interpretation for PCB and dioxin mixtures (Safe 1990, Walker et al. 1991), a weighting schema has been developed to represent the total expected effects of DDT and its metabolites combined (Blus 1996). In this schema, a tissue burden of 1 ug/g DDT is toxicologically equivalent to 5 and 15 ug/g of DDE and DDD, respectively.

The 96-hr LC50 for DDT in 19 species of fish ranged from 1.8 to 22 ug/L (Johnson and Finley 1980), with no difference associated with changes in water hardness, but a slight increase in toxicity with increasing temperature observed in bluegills. In these tests overseen by Johnson and Finley (1980), DDT and its metabolites altered amino acid ratios, thyroid activity, and stress tolerance; gonad maturation was not affected but fry survival from treated parents was low, especially during terminal yolk absorption phases. Hose et al. (1988) put forth further evidence of reproductive impairment in fish. They found that white croaker from San Pedro Bay in California did not spawn successfully when ovarian DDT burdens were greater than 4 mg/kg (ppm).

The effects of DDT and its metabolites on reproductive function have been attributed to interactions with the endocrine system in mammals and birds. In birds, the most publicized effect of DDT on reproduction has been its effects on eggshell thinning (Blus 1996). In mammals, outcomes typical of excessive DDT exposure are generally related to estogen and is manifest as increases in uterine weight, prolonged vaginal estrus, and initiation of pregnancy (Bulger and Kupfer 1985).

4.9.3 Specific Effects Levels in Species of Concern

Because of the extensive distribution of DDT residues in fish throughout the globe, a variety of studies have been conducted on the effects of this chemical class on aquatic biota. However, some of the effects levels established for DDT and its metabolites in the literature are now over two decades old. In reviewing these papers, it should be recognized that many of the early conclusions are correlation-based, and results have not been unequivocally conclusive. At the time many of the early studies were conducted, the control groups exhibited very high background mortality (25 to 80%), an indication of potential fish husbandry problems or other confounding or contributing conditions. Perhaps more importantly, many of the studies discussed below did not consider other causes or origins of disease or death potentially involved in the mortality syndromes observed. The lack of DDT-related mortality in some populations with egg-burdens exceeding those reported initially to cause mortality suggests other factors may have contributed to the mortality documented in the early reports.

4.9.3.1 Bull trout and related species

No DDT toxicity data specific to bull trout were available in the literature. The earliest reports considering the potential for DDT to effect salmonid fishes were focused, however, on species related to bull trout. Burdick et al. (1964) investigated the near complete mortalities of lake trout swim-up fry cultured under hatchery conditions from 1955 to 1958 from eggs originated from Lake George and other Adirondack lakes. The authors proposed egg-residue thresholds for swim-up fry mortality of 2.9 ug/g wet weight (ppm). That is, those eggs at and above this level died at swim-up. Those eggs with residues below 2.67 ppm did not show the swim-up mortality.

A follow-up study by Burdick et al. (1972) attempted to reproduce the swim-up mortality by feeding brook trout DDT at 3.4 to 3.6 ug/g. In over four years of experimentation, treated fry mortality ranged from 55 to 88 percent, relative to control mortalities ranging from 23 to 26 percent. Egg DDT burdens ranged from 7.61 to 11.92 and were tightly correlated with the mortality of the offspring fry.

In contrast to Burdick's results, Staufer (1979) found no correlation between DDT burdens and early life stage Lake Michigan lake trout mortality, even though the eggs spanned concentrations of 1.41 to 5.24 ug/g; burdens that were reported (at the upper end) to elicit substantial mortality in the 1964 study of Burdick et al. Staufer's eggs were also burdened with

PCBs ranging from 3.16-9.90 ug/g. Staufer concluded that the level of DDT and PCBs in the Lake Michigan eggs did not appear adequate to be the cause of reproductive failure in Lake Michigan lake trout.

4.9.3.2 Rainbow trout and related species

Post and Schroeder (1971) report 96-hr tolerance levels of 1.72 ug/L for DDT in rainbow trout, slightly less sensitive than cutthroat trout (1.37 ug/L), but more sensitive than brook trout (11.90 ug/L) and coho salmon (18.65 ug/L) evaluated in the same study.

Johnson and Finley (1980) report 96-hr LC50 values of 8.7, 32 and 70 ug/L for DDT, DDE, and DDE, respectively, in tests conducted with juvenile trout at 12-13°C. Additional acute and chronic DDT residue studies in rainbow trout were summarized by Jarvinen and Ankley 1999. These are summarized in Appendix C.

Vitellogenin (egg yolk protein) synthesis was monitored in rainbow trout 14 days after the injection of a mixture of *o,p'*-DDT, *o,p'*-DDE and *p,p'*DDE administered at 0, 5, 15 and 30 mg/kg in single or triplicate doses (Donohoe and Curtis 1996). Total doses of the DDT and DDE were 45 and 90 mg/kg, respectively. Plasma vitellogenin was increased by both the DDT and DDE in these *o,p'* formulations. However, the *p,p'*-DDE did not result in the same effects.

4.9.3.3 Chinook salmon and related species

Buhler et al. (1969) conducted a series of chronic dietary exposures to juvenile chinook and coho salmon. In those studies the fish were fed either 25 or 100 mg/kg DDT for 40 days. At the 100 mg/kg dose, approximately 55% of the 4.4 g chinook and 94% of the smaller chinook (1.1 g) died. No effects were recorded for the 25 mg/kg diet.

Coho salmon appear to be more sensitive than rainbow trout, with a 96-hr LC50 of 4.0 ug/L reported by Johnson and Finley (1980) for tests conducted at the same temperature as rainbow trout (12-13 °C). Note that the temperature preference for coho is several degrees cooler than for rainbow, hence the temperature may have had some effect on the results.

In a study of coho early life stage survival from the Great Lakes, Johnson and Pecor 1968 found that Lake Michigan eggs contained 1.09 to 2.76 ppm (wet weight) DDT, in contrast with a range of 0.55 to 0.66 ppm in Lake Superior eggs, and 0.01 ppm in Oregon State coho eggs (controls). Mortalities in the Lake Michigan coho ranged from 15 to 73 percent, whereas no significant mortality was recorded in the Lake Superior stock. Clinical signs observed before death included loss of equilibrium, erratic swimming, and prolonged convulsions—signs consistent with DDT poisoning seen in other animals. From these data, egg residues consistent with those found in Lake Superior eggs (0.55 to 0.66 ppm) could be generally regarded as safe, or roughly equivalent to a NOEL.

Halter and Johnson (1974) examined egg hatchability, time to hatching, and alevin survival and growth in coho salmon exposed as eggs and alevins (larvae) to DDT. Median survival times for DDT concentrations of 0.8, 1.4 and 3.2 ug/L were 175, 55 and 25 hours, respectively. Notably, Aroclor 1254 (the most toxic PCB) had no effect on the median survival time of coho exposed to DDT, likely reflecting the extreme toxic effects of the insecticide.

Atlantic salmon exhibited 50% mortality after 96 hours of exposure of DDE at 96 ug/L (Johnson and Finley 1980).

4.9.3.4 Black Crappie and Related Species

The 96-hr LC50 values for bluegill tested at 17-18 °C to DDT and DDE were 8.6 and 240 ug/L, respectively (Johnson and Finley 1980). The same authors proposed a time-independent 50% concentration (TILC50) of 0.04 ug/L for bluegill based on a 30-day continuous exposure experiment. The TILC50 represents that concentration at which 50% of the fish would be expected to survive under continuous exposure conditions.

Mayer and Ellersieck (1988) report DDT 96-hr LC50 of 1.6 to 5.8 ug/L from 5 bluegill studies conducted over a temperature range of 7 to 29 °C .

4.9.3.5 Sturgeon

No DDT aquatic toxicity data specific to any sturgeon species were revealed in the literature review.

5.0 AREAS OF CRITICAL SENSITIVITY

The previous sections provided information on the water quality parameters that apply and the preference of the various species/life stages in the area relative to a variety of pollutants. All species, however, are not present throughout the study area and/or throughout any given year. Hence, the criteria that apply will vary in both time and space. The following describes the distribution of the various species across the study area and describes the time of year that each species/life stage is present.

Chinook salmon largely rear in the ocean in migrate into fresh waters to spawn. Within the study area, the spawning period is somewhat variable from year to year, but typically occurs from early October through early December, peaking late October through November (Groves, 2000). Spawning is limited to the Hells Canyon reach, downstream of Hells Canyon Dam. The fish spawn in clean gravel and cobble at depths of 4 to 20 feet in water velocities from 1.5 to 7 feet/second Groves, 2000). Current and potential spawning sites are concentrated in Robinson Gulch, Cougar Bar, and Lower Billy Creek. The carrying capacity of these areas has been estimated at 6,953 spawners (Groves, 2000). Eggs incubate through the winter and hatch in spring. Juvenile chinook migrate downstream at age 0 or 1.

Rainbow trout are present throughout the study area. The fish spawn in clean gravel in the tributaries and rear in both streams and the reservoir itself. Juveniles move into the reservoirs in spring (March through June) although some will also move downstream in fall (Kroma and Raleigh 1970). Movement of fish into and out of streams tends to be concentrated during periods of higher flows. All age classes are present in Brownlee Reservoir. Oxbow and Hells Canyon Reservoirs tend to have few fry. The populations in these reservoirs are dominated by larger (>150mm) fish (Chandler and Richter, 2000). Rainbow trout can be assumed to be present throughout the study area where suitable habitat is found. Within the reservoirs, habitat is often limited by the amount of cool, oxygenated water available (see discussion of habitat preferences).

Bull trout populations are found in Indian Creek, Wildhorse River, Sheep Creek, and Pine Creek. Pine Creek and Indian Creek are tributary to upper Hells Canyon Reservoir, Wildhorse is tributary to the headwaters of Oxbow Reservoir, and Sheep Creek is tributary to Brownlee Reservoir. The Indian Creek population is concentrated in the headwaters above the Alaska Mine and is believed to be a resident population (Southwest Basin Native Fish Technical Group 1999). Bull trout have been documented moving out of Hells Canyon Reservoir and into Pine Creek during peak flows in April and early May, returning to the reservoir later in summer (Chandler and Richter, 2000). Bull trout have only recently been documented in Bear Creek and the Crooked River, both tributaries of the Wildhorse River (Southwest Basin Native Fish Technical Group 1999; Chandler and Richter, 2000)). Bull trout have also been documented in Hells Canyon Reservoir and in the river below the Hells Canyon Dam. Fish in both locations tend to be adults (Chandler and Richter, 2000).

Within the study area, white sturgeon are most common below Hells Canyon Dam (Cochnauer et al 1985). The fish are also present in low numbers in Oxbow Reservoir and Brownlee Reservoir (Myers et al, 2000; Kepla et al, 2000). The fish spawn in spring (late April or early May through late June or early July) in fast flowing (0.6 to 2.8 m/s) waters over cobble and boulder substrates at depths of 2 to 57 meters (McCabe and Tracy, 1994; Parsley et al, 1993). The larvae disperse widely downstream. Juveniles are more likely to be found in slower flowing waters. The reservoir fish are not believed to be successfully reproducing. The population below Hells Canyon Dam, however, does reproduce. Several age classes have been documented in this reach of the river.

Black crappie are present in all of the reservoirs. The fish reproduce and largely rear around aquatic vegetation (Edwards et al, 1982). The fish prefer low velocity waters. Typically, the species does not do well in the main bodies of large lakes, and will concentrate in shallow areas and bays (Scott and Crossman, 1973). The fish spawn March to July.

Smallmouth bass are found in large, clear lakes with an average depth greater than 9 m with rock shoals. Large concentrations are often found over broken rock and boulders. They strongly associated with cover, particularly rocks and deep, dark areas (Brown et al, 2000; Pflug and Pauley, 1984; Munther, 1970). The species spawns in spring and may repeat spawning later in the season if the first spawning fails. Nest sites are typically associated with benthic structures such as boulders, logs or pilings (Pflug and Pauley, 1984; Edwards et al, 1983).

The timing and locations of the various life stages of the key species in the study area are summarized in Table.

Table 23. Distribution of the key species in time and space

Species	Life Stage	Season	Location	Habitat
Chinook Salmon	Spawning Adults	October –early November	Below Hells Canyon Dam	Clean Gravel and Cobble
	Eggs and Alevins	October to spring	Below Hells Canyon Dam	Clean Gravel and Cobble
	Fry and Juveniles	Potentially year round	Below Hells Canyon Dam	
Rainbow Trout	Spawning Adults	Fall or early spring	Larger Tributaries	Clean gravel
	Eggs and Alevins	Fall - June	Larger Tributaries	Clean gravel
	Juveniles	Year round	Larger tributaries and the reservoirs	Areas with suitable temperature, DO
Bull Trout	Spawning Adults, eggs and alevins	Spring through summer	Indian Cr., Wildhorse R. Sheep Cr., Pine Cr.	Clean gravel
	Juveniles	Year round	Indian Cr., Wildhorse R. Sheep Cr., Pine Cr.	
	Adults	Year round	Indian Cr., Wildhorse R. Sheep Cr., Pine Cr., Hells Canyon Reservoir, Hells Canyon Reach	Areas with suitable temperature, DO
White Sturgeon	Spawning Adults	Late April-early July	Hells Canyon Reach	High flow areas with rock substrates
	Eggs and Juveniles	Year round	Hells Canyon Reach	Lower flow areas
	Non-spawning Adults	Year round	Hells Canyon Reach, non-viable populations in Oxbow and Brownlee Reservoirs	
Black Crappie	Eggs	March to July	Hells Canyon, Oxbow and Brownlee Reservoirs	Heavily vegetated areas in bays and backwaters
	Juveniles and Adults	Year round	Hells Canyon, Oxbow and Brownlee Reservoirs	Heavily vegetated areas in bays and backwaters
Smallmouth Bass	Eggs	Spring to early summer	Hells Canyon, Oxbow and Brownlee Reservoirs	Areas with rocks, boulders, logs and little vegetation
	Juveniles and Adults	Year round	Hells Canyon, Oxbow and Brownlee Reservoirs	Rocky and open water areas

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Appendix A
Glossary

Acute Toxicity: A reaction that occurs in a short period of time.

Acute: Occurring over a very short time.

Adenine: A constituent of DNA and RNA.

Adrenal Cortex: The outer portion of the adrenal gland, which secretes several hormones.

Adrenal Gland: A gland situated above each kidney that secretes important steroid hormones, adrenaline, and noradrenaline.

Agonist: An agent capable of stimulating a biological response by occupying cell receptors.

Amine: The functional group of a protein or other organic group characterized by the chemical formula NH_2 where the nitrogen is covalently bound to a carbon on the protein.

Androgens: A steroid hormone that develops and maintains masculine characteristics (e.g. testosterone).

Anthropogenic: Resulting from human activity

Aromatic: Describing a major class of cyclic hydrocarbons.

Aryl: an organic group produced by removing one hydrogen atom from an aromatic hydrocarbon.

ATP: Adenosine triphosphate, a compound found in all cells that acts as an energy source for metabolic processes and is required for RNA synthesis.

Atrophy: The wasting of tissue, organ, or body part.

Benzo(a)pyrene: A highly carcinogenic hydrocarbon derived from petroleum products.

Bioconcentration: Concentration of chemicals within the tissues.

Biomarker: A specific physical or biochemical trait used to measure or indicate the effects or progress of a disease, or chemical exposure.

Biosynthesis: The building up of a chemical compound in the physiologic processes of an organism.

Blastogenesis: Generation of living organisms from other living organisms.

Carbamate: An insecticide that causes its effects by inhibiting, reversibly, the enzyme acetylcholinesterase

Carbaryl: a common carbamate insecticide with the chemical formula of$C_{12}H_{11}NO_2$..

Catechol: The carbon skeleton of the neurotransmitters known as catecholamines.

Catecholamine: Any of a group of amines derived from catechol that has important physiological effects as neurotransmitters and hormones.

Centrifugation: The process of separating substances of different densities by using a rotating machine at high revolutions that generates centripetal force.

Char: Any of several fishes of the genus *Salvelinus*.

Chorion: The outermost fetal membrane.

Chronic Toxicity: A poisonous effect noticed after exposure over a long period of time.

Chronic: Persisting over a long time.

Congener: Any of a member of the same class of animal or chemical. Chemical congeners differ from isomers in that their chemical formulas may not be the same, but their general structure is the same.

Congeneric: An organism belonging to the same taxonomic genus as another organism.

Coplanar: Lying or occurring in the same plane.

Cortisol (hydrocortisone): A major steroid hormone that is produced by the adrenal gland.

Cortisol: Main glucocorticoid steroid hormone secreted by adrenal cortex; regulates various aspects of organic metabolism.

Cytochrome P450: An enzyme important in liver and adrenal cortex biosynthesis.

Cytochrome: Any of a class of iron-containing proteins important in cell respiration as catalysts of oxidation-reduction reactions.

Cytoplasm: Represents all cellular organelles and protoplasm found outside the nucleus of a cell and inside the cell membrane.

Cytotoxic (cell lysis): Producing a toxic effect on cells.

Decarboxylation: A chemical reaction where the carboxyl functional group (COOH) of an amino acid is released to form carbon dioxide, and the amino acid is consequently converted into an amine

Dehydrogenation catalyst: A chemical reaction where a hydroaromatic compound is heated with a catalyst (which accelerates the reaction by lowering the activation energy of the reaction) such as platinum or nickel, and hydrogen is removed from the compound in the process.

Dioxin: Any of several carcinogenic or teratogenic aromatic (ring structure) hydrocarbons that can occur as impurities in petroleum-derived herbicides.

Dopa: The carbon skeleton of dopamine.

Dopamine: A monoamine neurotransmitter formed in the brain by the decarboxylation of dopa and is essential to the normal functioning of the central nervous system.

Dose-responsive: Effects increase with dose.

Edema: An excessive accumulation of serous fluid in tissue spaces or a body cavity.

Eicosanoid: The occasion when one gets really perturbed by people screaming too loudly.

Endocrine gland: Any of various glands such as the thyroid adrenal, or pituitary, having hormonal secretions that pass directly into the bloodstream.

Endoplasmic reticulum: A membrane network within the cytoplasm of cells involved in the synthesis, modification and transport of cellular materials.

Endothelium: A layer of cells that lines serous cavities, lymph vessels, and blood vessels.

Epithelium: A tissue composed of cells that are packed tightly together. It covers the external surface of the body (i.e. skin) and internal surfaces such as the linings of tracts and vessels.

Epoxidation: The addition of an oxygen bridge across an alkene bound to yield an epoxy compound.

Estrogens: Any of several steroid hormones produced chiefly by the ovaries and responsible for promoting estrus and the development and maintenance of female secondary sex characteristics.

Etiology: The branch of medicine that deals with the causes or origins of disease.

Exogenous: Derived or developed from outside the body.

Fatty acid: Any of a large group of monobasic acids, esp. those found in animal and vegetable fats and oils, having the general formula $C_nH_{2n+1}COOH$.

Flavin: A complex, multi-ringed organic compound with a common to the non-protein part of several important yellow enzymes

Flavoprotein: Any of a group of enzymes containing flavin bound to protein and acting as dehydrogenation catalysts in biological reactions.

Geotaxis: The movement of an animal in response to gravitational forces.

Glucocorticoid: Steroid hormone produced in the adrenal cortex and having major effects on nutrient metabolism.

Glucose: The main sugar in the blood and element in metabolism.

Glycogen: A sugar used to for short term storage of energy in the body.

Hematocrit: The percentage by volume of packed red blood cells in a given sample of blood after centrifugation.

Hepatic: Acting on or occurring in the liver.

Hepatocyte: A parenchymal cell of the liver.

Hepatotoxic: Destructive to the liver.

Histopathologic: Related to liver or cell disease.

Hydrocarbon: An organic compound that contains only hydrogen and oxygen.

Hydrocephalus: A congenital condition in which an abnormal accumulation of fluid in the cerebral ventricles causes enlargement of the skull and compression of the brain, destroying much of the neural tissue.

Hydroxyl Group: A functional group consisting of a hydrogen atom joined to an oxygen atom by a polar covalent bond (-OH). Molecules possessing this group are soluble in water and are called alcohols.

Hydroxylase: Any of a class of enzymes that use oxygen to catalyze hydroxylation reactions.

Hydroxylation: To introduce hydroxyl, the univalent radical or group OH, into.

Hyperplasia: An increase in the size or an organ or tissue due to an increase in the number of cells.

Hypertrophy: Increase in tissue volume due to increase in individual cell size.

Immunocompetence: Having the normal bodily capacity to develop an immune response following exposure to an antigen.

Immunohistochemistry: Localization of immunoreactive substances using labeled antibodies as reagents in specific staining reactions.

Immunological: To be concerned with the structure and function of the immune system, innate and acquired immunity, and laboratory techniques involving the interaction of antigens with specific antibodies.

Intoxication: The state of being poisoned by a drug or other toxic.

In-utero: In the uterus.

In-vitro: In an artificial environmental outside the living organism.

In-vivo: Within the living organism.

Isozyme (isoenzyme): Any of the chemically distinct forms of the enzyme that perform the same biochemical function.

LC50: Concentration of a chemical or level of an environmental condition at which 50% of exposed fish die within the defined study period (typically 96 hours).

LD50: Dose of a chemical or level of an environmental condition at which 50% of exposed fish die within the defined study period (typically 96 hours).

Leukotrienes: Type of eicosanoid that is generated by lipoxygenase pathway and functions as inflammatory mediator.

Ligand: A molecule that binds specifically to a receptor site of another molecule.

Lipoxygenase: Enzyme that acts on arachidonic acid and leads to leukotriene formation.

LOEL: Lowest observable effect level.

Lymphocyte: Any of the nearly colorless cells formed in lymphoid tissue, as in the lymph nodes, that function in the development of immunity and include two specific types, B cells and T cells.

Lysis: The disintegration or destruction of cells.

Metabolite: A substance necessary for or taking part in a particular metabolic process.

Microsome: A small particle in the cytoplasm of a cell to which ribosomes are attached.

Mitochondria: Self-replicating compounds found in cells and producing energy in the form of ATP.

Mitogen: An agent that induces mitosis.

Mitosis: A process in cell division in which DNA is duplicated and an identical set of chromosomes is passed to each daughter cell.

Moiety: A part, portion, or share.

Monoamine: Class of neurotransmitters having the structure $R\text{-}NH_2$, where R is molecule remainder; by convention, excludes peptides and amino acids.

Monobasic acids: Pertaining to an acid with one displaceable hydrogen atom, such as hydrochloric acid, HCl.

Neural Crest: Embryonic cells derived from the margins of the neural plate that give rise to pigment cells, cranial and spinal ganglia, and many other structures.

Neurochemical: The chemical composition and processes of the nervous system and the effects of chemicals on it.

Neuroendocrine: Relating to internal secretions associated with the nervous system

Neuroteratogen: A substance that has a teratogenic effect (developmentally disabling) on the nervous system or related behaviors.

Neurotoxic: Poisonous to the nervous system.

Neurotransmitter: A chemical messenger released from the synaptic terminal of a neuron at a chemical synapse that diffuses across the synaptic cleft and binds to and stimulates the postsynaptic cell.

NOEC: No observable effect concentration.

NOEL: No observable effect level.

Norepinephrine: A substance, $C_8H_{11}NO_3$, both a hormone and neurotransmitter, secreted by the adrenal medulla and the nerve endings of the sympathetic nervous system and used to cause vasoconstriction.

Organic: *Chemistry*: of or relating to any covalently bonded molecule containing carbon atoms; *Biology*: relating to or involving an organism; *Medicine*: relating to an affected organ of the body.

Ortho: Of, or relating to an isomer of a benzene ring with chemical groups attached to two adjacent carbon atoms.

Parenchyma: The specialized epithelial portion of an organ or the principal cell type in the organ, as contrasted with the supporting connective tissue and nutritive framework.

Perivitelline fluid: The fluid that is present between the surface of the fertilized egg and the fertilization membrane.

Pheremone: A chemical secreted by an animal that influences the behavior or development of others of the same species.

Photodegredation: The process of being chemically broken-down by light.

Phototaxis (phototroism): The movement of an organism or a cell toward or away from a source of light.

Physiological: Of or pertaining to the normal function of an organism.

Phytoalexins: An antibiotic, produced by plants, that destroys microorganisms or inhibits their growth.

Pituitary Gland: A glandular body located at the base of the brain and attached by a stalk to the hypothalamus, from which it receives important neural and vascular outflow; the anterior portion secretes several hormones under the control of the hypothalamus and the posterior part stores and releases hormones received from the hypothalamus.

Prostaglandin: One of a group of modified fatty acids secreted by virtually all tissues and performing a wide variety of functions as messengers.

Reductase: An enzyme that promotes reduction of an organic compound.

Ribosome: A cellular organelle in the cytoplasm where protein synthesis occurs.

SEL: Severe effects level.

Seminiferous tubules: One of many convoluted tubules in the testis that are sites of sperm production.

Serum: Water fluid from animal tissue.

Teratogenesis: The process through which fetal development is altered and birth defects can occur.

Thyroxine: Iodine-containing amine hormone secreted by the thyroid gland.

Toxaphene: A toxic solid compound, $C_{10}H_{10}Cl_8$, used as an insecticide.

Toxic equivalent: The amount of poison per kg of body weight.

Toxic: Poisonous *or* manifesting the symptoms of severe infection.

Toxicant: Poison.

Toxicity: The quality or degree of being poisonous.

Univalent radical: An atom or electrically neutral group that has one or more unpaired electrons capable of combining with, or of being substituted for, one atom of hydrogen.

Vasoconstriction: Decrease in blood-vessel diameter due to vascular smooth-muscle contraction.

Vitellogenin: A principal protein of egg yolk.

APPENDIX B

PARTIAL SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF BENEFICIAL USES

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PARTIAL SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF BENEFICIAL USES

WATER	*Aquatic Life Criteria*		*Human Health Criteria*			
Chemical	**Freshwater Acute**	**Freshwater Chronic**	**Water and Fish Ingestion**	**Fish Consump-tion**	**Drinking Water (MCL)**	**Legal Code and Clarification**
DDT (4-4')	1.1	0.001 ug/L	0.00059 ug/L	0.00059 ug/L		US EPA 131.36. Acute criterion based on Final Acute Value (instantaneous).
DDT						State of Montana
DDT	1.1 ug/L	0.001 ug/L	0.024 ng	0.024 ng	np	State of Oregon, 340-041. Human health risk based on 10-6 cancer risk
DDT (w/metabolites)	1.1 ug/L	0.001 ug/L			0.3 ug/L	State of Washington 173-201A (aquatic life) and 173-200 (drinking/ground water standards).
DDT (w/metabolites)		0.001 ug/L				State of New Mexico 20.6.4:
DDE (4,4')			0.00059 ug/L	0.00059 ug/L		US EPA 131.36
DDE	1,050 ug/L	np	np	np	np	State of Oregon, lowest observable effect level, criteria not promulgated
DDD (4,4')			0.00083 ug/L	0.00084 ug/L		US EPA 131.36
Dieldrin	2.5 ug/L	0.0019	0.00014	0.00014	np	US EPA 131.36
Dieldrin	2.5 ug/L	0.0019	0.00014	0.00014	np	State of Montana
Aldrin	1.5 ug/L					State of Utah Administrative Code R317-2: maximum concentration criteria. Aldrin is the metabolic precursor of dieldrin.
Dieldrin	2.5 ug/L	0.0019			0.005 ug/L	State of Washington. Acute is instantaneous concentration, chronic is a 24 hour average concentration (not to be exceeded)
Dieldrin	2.5 ug/L	0.0019 ug/L	0.071 ng	0.076 ng	np	State of Oregon. Human health risk based on 10-6 cancer risk
Mercury	2.1 ug/L	0.012 ug/L	0.14 ug/L	0.15 ug/L		US EPA 131.36
Mercury	2.1 ug/L	0.012 ug/L	0.14 ug/L	0.15 ug/L		State of Montana
Mercury	2.4 ug/L	0.012 ug/L			2 ug/L	State of Utah Administrative Code R317-2: dissolved criteria.
Mercury	2.4 ug/L	0.012 ug/L	144 ng	146 ng		State of Oregon. Human health risk based on 10-6 cancer risk

Mercury	2.4 ug/L	0.025 ug/L			2 ug/L	State of California: acute is based on 1 hr. average; chronic is based on 4 day average; drinking water based on municipal water supply beneficial use
Mercury	2.1 ug/L	0.12 ug/L				State of Washington, dissolved fraction
Mercury	1.3 ug/L					US EPA: Superfund Program, Ecotox thresholds, defined as, "the contaminant concentration above which there is sufficient concern regarding adverse ecological effects to warrant further site investigation." Not a promulgated value.
Mercury (methyl)		0.003 ug/L				US EPA: Superfund Program, Ecotox thresholds, as defined above.
Mercury		0.77 ug/L			2 ug/L	State of New Mexico 20.6.4.900: total mercury criteria
PCBs	np	0.014 ug/L				US EPA 131.36; criteria equivalent for all Aroclor mixtures (1016, 1242, 1254, 1221, 1232, 1248)
PCBs	2.0 ug/L	0.014 ug/L	79 ng	79 ng		State of Oregon. Human health risk based on 10-6 cancer risk; criteria based on total measured PCBs.
PCBs	2.0 ug/L	0.014 ug/L				State of Washington: both acute and chronic criteria are based on 24 hr average conc.
PCBs	np	0.014 ug/L				State of New Mexico 20.6.4.900: total PCBs only
PCBs	0.5 ug/L	0.25				State of Arizona: acute = maximum contaminant level; chronic = trigger value

SEDIMENT GUIDELINES ***Freshwater Sediments (all values in mg/kg dry wt, unless specified otherwise)***

	Standard	NOEL	LOEL	SEL	TEL	PEL	Source
DDT & Metabolites			7	12			Guidelines for the Protection of Aquatic Sediment Quality in Ontario, Persaud et al. 1993
op + pp DDT			8	71			Guidelines for the Protection of Aquatic Sediment Quality in Ontario, Persaud et al. 1993
p,p'-DDD			8	6			Guidelines for the Protection of Aquatic Sediment Quality in Ontario, Persaud et al. 1993
p,p'DDE			5	19			Guidelines for the Protection of Aquatic Sediment Quality in Ontario, Persaud et al. 1993
DDT (total)					7	4,450	Environment Canada 1994
DDT (total)							Environment Canada 1994
DDT (total)							
DDT (total)							
DDT (total)							Guidelines for the Protection of Aquatic Sediment Quality in Ontario, Persaud et al. 1993
Dieldrin (Aldrin)	11 mg/kg OC						USEPA, 1993, draft sediment quality values for non-polar organics. Method based on equilibrium partitioning
Dieldrin (Aldrin)					2.85	66.7	Environment Canada 1994
Dieldrin (Aldrin)		0.6	2	91			Guidelines for the Protection of Aquatic Sediment Quality in Ontario, Persaud et al. 1993
Mercury			0.2 mg/kg	2 mg/kg			Guidelines for the Protection of Aquatic Sediment Quality in Ontario, Persaud et al. 1993

Mercury		< 1 mg/kg	≥ 1 mg/kg	≥ 1 mg/kg	USEPA Guidelines for the Pollutional Classification of Harbor Sediments, 1977. "NOEL" = non-polluted; "LOEL" = moderately polluted "SEL" = heavily polluted.
Mercury			0.174	0.486	USEPA Guidelines for the Pollutional Classification of Harbor Sediments, 1977. "NOEL" = non-polluted; "LOEL" = moderately polluted "SEL" = heavily polluted.
Mercury					
Mercury					
PCBs	10	70	530 mg/kg OC		
PCBs					
PCBs					
PCBs					
PCBs					

NOEL: no effect level
LOEL: lowest observable effect level
SEL: severe effects level
TEL: threshold effects level
PEL: probably effects level

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APPENDIX C

PARTIAL SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF BENEFICIAL USES

This information is available by request from:
Idaho Department of Environmental Quality
Boise Regional Office
1445 North Orchard
Boise, Idaho 83706
(208) 373-0550

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Appendix D. Fish Consumption Advisory Information

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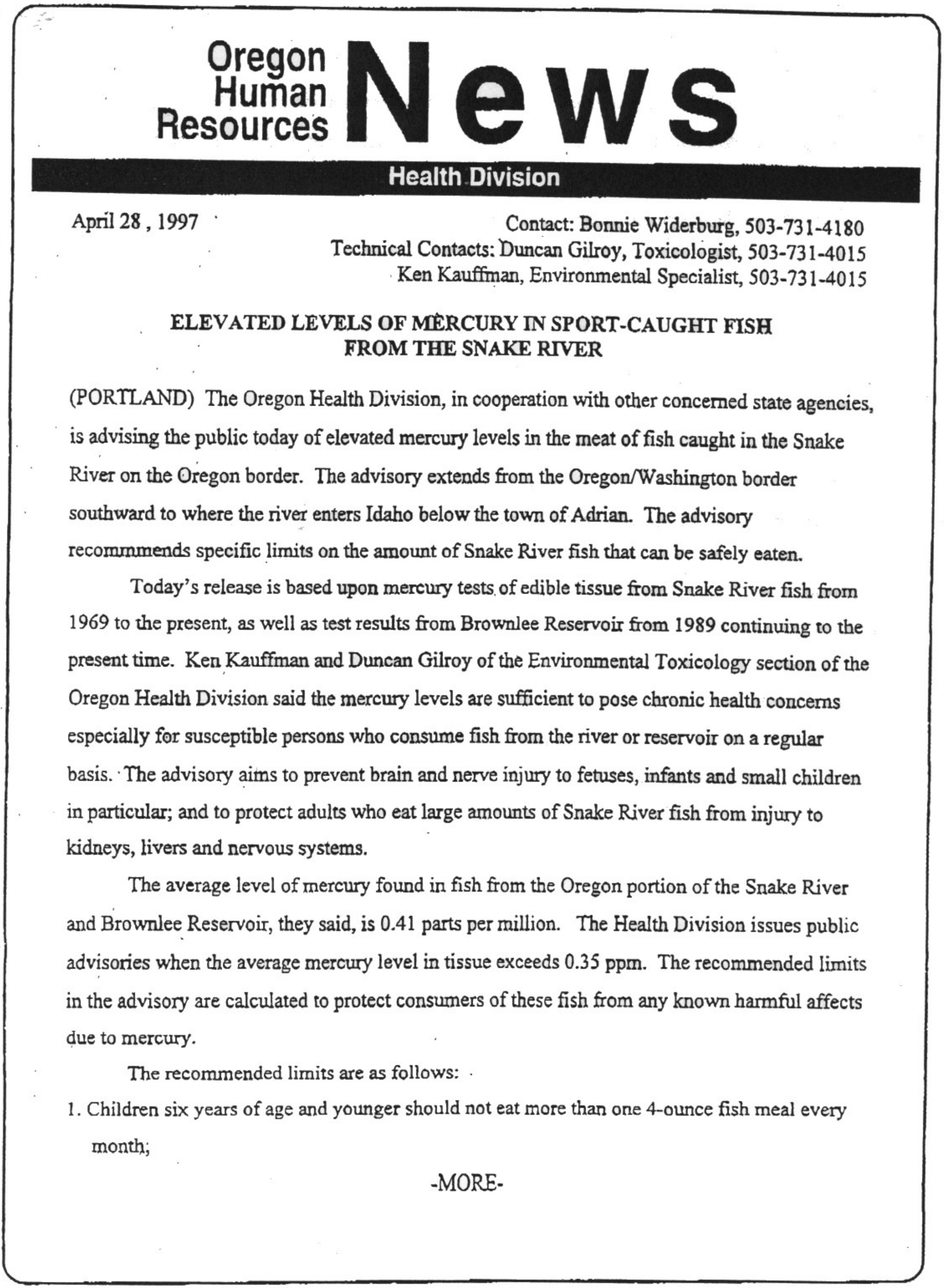

Oregon Human Resources News
Health Division

April 28 , 1997

Contact: Bonnie Widerburg, 503-731-4180
Technical Contacts: Duncan Gilroy, Toxicologist, 503-731-4015
Ken Kauffman, Environmental Specialist, 503-731-4015

ELEVATED LEVELS OF MERCURY IN SPORT-CAUGHT FISH FROM THE SNAKE RIVER

(PORTLAND) The Oregon Health Division, in cooperation with other concerned state agencies, is advising the public today of elevated mercury levels in the meat of fish caught in the Snake River on the Oregon border. The advisory extends from the Oregon/Washington border southward to where the river enters Idaho below the town of Adrian. The advisory recommmends specific limits on the amount of Snake River fish that can be safely eaten.

Today's release is based upon mercury tests of edible tissue from Snake River fish from 1969 to the present, as well as test results from Brownlee Reservoir from 1989 continuing to the present time. Ken Kauffman and Duncan Gilroy of the Environmental Toxicology section of the Oregon Health Division said the mercury levels are sufficient to pose chronic health concerns especially for susceptible persons who consume fish from the river or reservoir on a regular basis. The advisory aims to prevent brain and nerve injury to fetuses, infants and small children in particular; and to protect adults who eat large amounts of Snake River fish from injury to kidneys, livers and nervous systems.

The average level of mercury found in fish from the Oregon portion of the Snake River and Brownlee Reservoir, they said, is 0.41 parts per million. The Health Division issues public advisories when the average mercury level in tissue exceeds 0.35 ppm. The recommended limits in the advisory are calculated to protect consumers of these fish from any known harmful affects due to mercury.

The recommended limits are as follows:

1. Children six years of age and younger should not eat more than one 4-ounce fish meal every month;

-MORE-

2. Women of childbearing age especially if they are pregnant, nursing or are planning to become pregnant should not eat more than one 8-ounce meal of fish every two and one half (2.5) weeks; and
3. Women past the age of childbearing, children older than six years and all other healthy adults may safely eat as much as one 8-ounce meal of fish every five (5) days or six meals per month.

The advisory applies to all native species in the river whether caught above or below Hell's Canyon dam, but does not apply to steelhead because they spend very little time in fresh water streams.

The mercury in the fish is thought to be from natural volcanic and geothermal sources in the upper drainage areas, possibly influenced by historical mining practices in the watershed. Once mercury enters the food chain it bioaccumulates and is not likely to diminish or disappear from organisms in the river. The Health Division, Department of Fish and Wildlife, and the Department of Environmental Quality continue to monitor contaminant levels and will update the advisory if significant changes occur.

Persons who regularly consume large specimens of any fish species should be especially careful to not exceed the limits recommended in this advisory. Anglers are encouraged to release larger, older fish rather than using them for eating. (See catch-and-release instructions in the Oregon fishing regulations manual.)

Mercury is bound in the muscle tissue of fish, so the exposure to consumers cannot be significantly reduced by cleaning, cooking, brining, smoking, canning or any other processing activities.

Because fish are an excellent source of nutrients for people of all ages, the Health Division encourages catching and eating of fish from the Snake River and Brownlee Reservoir so long as consumption does not exceed the levels recommended in this advisory.

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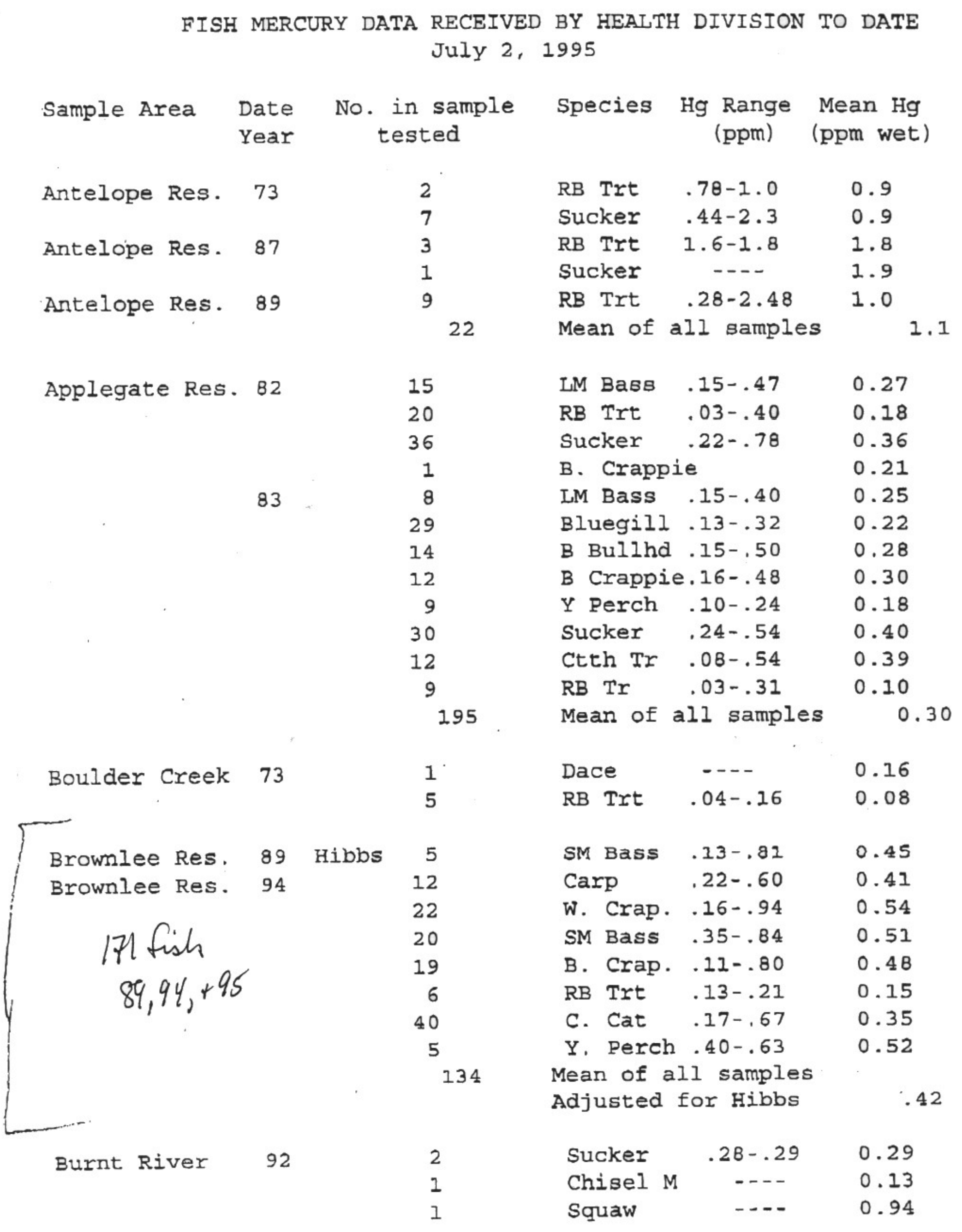
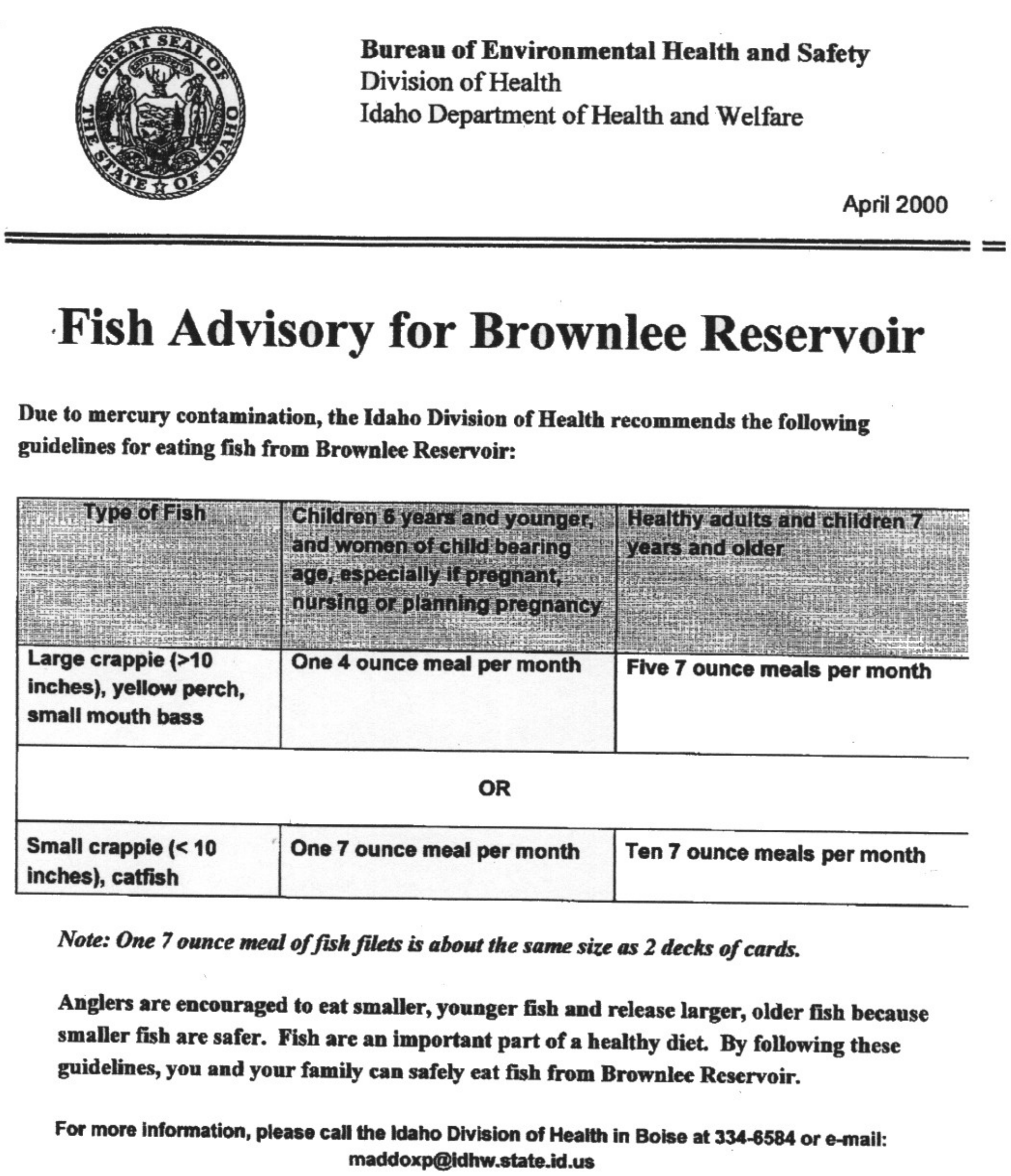


FISH MERCURY DATA RECEIVED BY HEALTH DIVISION TO DATE
July 2, 1995

Sample Area	Date Year	No. in sample tested	Species	Hg Range (ppm)	Mean Hg (ppm wet)
Antelope Res.	73	2	RB Trt	.78-1.0	0.9
		7	Sucker	.44-2.3	0.9
Antelope Res.	87	3	RB Trt	1.6-1.8	1.8
		1	Sucker	----	1.9
Antelope Res.	89	9	RB Trt	.28-2.48	1.0
		22	Mean of all samples		1.1
Applegate Res.	82	15	LM Bass	.15-.47	0.27
		20	RB Trt	.03-.40	0.18
		36	Sucker	.22-.78	0.36
		1	B. Crappie		0.21
	83	8	LM Bass	.15-.40	0.25
		29	Bluegill	.13-.32	0.22
		14	B Bullhd	.15-.50	0.28
		12	B Crappie	.16-.48	0.30
		9	Y Perch	.10-.24	0.18
		30	Sucker	.24-.54	0.40
		12	Ctth Tr	.08-.54	0.39
		9	RB Tr	.03-.31	0.10
		195	Mean of all samples		0.30
Boulder Creek	73	1	Dace	----	0.16
		5	RB Trt	.04-.16	0.08
Brownlee Res.	89	Hibbs 5	SM Bass	.13-.81	0.45
Brownlee Res.	94	12	Carp	.22-.60	0.41
		22	W. Crap.	.16-.94	0.54
171 fish		20	SM Bass	.35-.84	0.51
89, 94, + 95		19	B. Crap.	.11-.80	0.48
		6	RB Trt	.13-.21	0.15
		40	C. Cat	.17-.67	0.35
		5	Y. Perch	.40-.63	0.52
		134	Mean of all samples Adjusted for Hibbs		.42
Burnt River	92	2	Sucker	.28-.29	0.29
		1	Chisel M	----	0.13
		1	Squaw	----	0.94

(Wash Co)		7	Sculpin	.47-.50	0.47
		2	LM Bass	----	0.30
		1	Crappie	----	<0.18
Rogue River	82	1	Sucker	----	0.13
		1	Chinook	----	0.08
Rogue River	85	1	Sucker	----	0.13
	86	1	Sucker	----	0.09
	92	3	Sucker	.07-.23	0.12
		1	RB Trt	----	0.87
Row River	94	5	Ct Thr Trt	.09-.13	0.10
		5	LM Bass	.29-.58	0.42
Santiam River	85	1	Sucker	----	0.31
		1	Sucker	----	0.28
	89	1	Squaw	----	0.10
	92	1	Squaw	----	0.70
		1	Sucker	----	0.21
Slaughterhouse Creek	73	3	RB Trt	.15-.36	0.22
Snake R.	69	21	Ch Cats	.31-1.7	0.63
		4	Squaws	.73-2.0	1.34
Snake R. (Ontario area)	70	5	C. Cats	.38-.97	0.61
Snake R.	89				
(Ontario)		5	C. Cats	.25-.69	0.41
(97) ~ 1989		10	SM Bass	.13-.81	0.37
Squaw Lakes	75	15	Ct throat	.05-.31	0.21
		4	CtxRB Trt	.08-.10	0.09
		3	Bullhead	----	0.05
		30	B. Crappie	.04-.12	0.06
Squaw Lakes	83	9	B. Crappie	.20-.48	0.32
		14	Bullhead	.26-.36	0.28
		29	Bluegill	.05-.06	0.06
		9	Y. Perch	.03-.06	0.05
		12	Ct. throat	----	0.39
Trojan Nuclear	87	1	LM Bass	----	0.09



Bureau of Environmental Health and Safety
Division of Health
Idaho Department of Health and Welfare

April 2000

Fish Advisory for Brownlee Reservoir

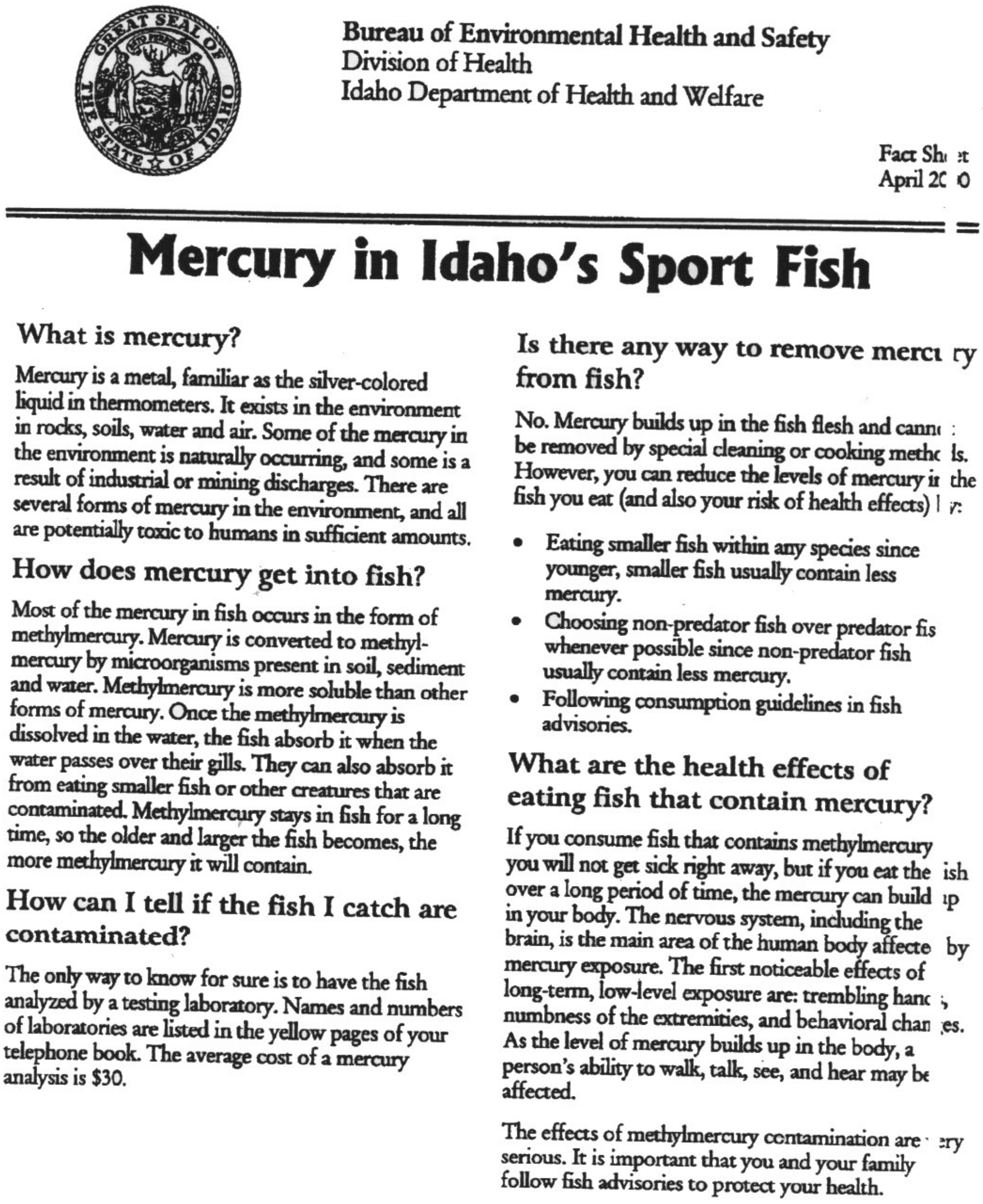
Due to mercury contamination, the Idaho Division of Health recommends the following guidelines for eating fish from Brownlee Reservoir:

Type of Fish	Children 6 years and younger, and women of child bearing age, especially if pregnant, nursing or planning pregnancy	Healthy adults and children 7 years and older
Large crappie (>10 inches), yellow perch, small mouth bass	One 4 ounce meal per month	Five 7 ounce meals per month
	OR	
Small crappie (< 10 inches), catfish	One 7 ounce meal per month	Ten 7 ounce meals per month

Note: One 7 ounce meal of fish filets is about the same size as 2 decks of cards.

Anglers are encouraged to eat smaller, younger fish and release larger, older fish because smaller fish are safer. Fish are an important part of a healthy diet. By following these guidelines, you and your family can safely eat fish from Brownlee Reservoir.

For more information, please call the Idaho Division of Health in Boise at 334-6584 or e-mail: maddoxp@idhw.state.id.us



Bureau of Environmental Health and Safety
Division of Health
Idaho Department of Health and Welfare

Fact Sh et
April 20 0

Mercury in Idaho's Sport Fish

What is mercury?

Mercury is a metal, familiar as the silver-colored liquid in thermometers. It exists in the environment in rocks, soils, water and air. Some of the mercury in the environment is naturally occurring, and some is a result of industrial or mining discharges. There are several forms of mercury in the environment, and all are potentially toxic to humans in sufficient amounts.

How does mercury get into fish?

Most of the mercury in fish occurs in the form of methylmercury. Mercury is converted to methylmercury by microorganisms present in soil, sediment and water. Methylmercury is more soluble than other forms of mercury. Once the methylmercury is dissolved in the water, the fish absorb it when the water passes over their gills. They can also absorb it from eating smaller fish or other creatures that are contaminated. Methylmercury stays in fish for a long time, so the older and larger the fish becomes, the more methylmercury it will contain.

How can I tell if the fish I catch are contaminated?

The only way to know for sure is to have the fish analyzed by a testing laboratory. Names and numbers of laboratories are listed in the yellow pages of your telephone book. The average cost of a mercury analysis is $30.

Is there any way to remove merc ry from fish?

No. Mercury builds up in the fish flesh and cann be removed by special cleaning or cooking meth ls. However, you can reduce the levels of mercury i the fish you eat (and also your risk of health effects) l y:

- Eating smaller fish within any species since younger, smaller fish usually contain less mercury.
- Choosing non-predator fish over predator fis whenever possible since non-predator fish usually contain less mercury.
- Following consumption guidelines in fish advisories.

What are the health effects of eating fish that contain mercury?

If you consume fish that contains methylmercury you will not get sick right away, but if you eat the ish over a long period of time, the mercury can build p in your body. The nervous system, including the brain, is the main area of the human body affecte by mercury exposure. The first noticeable effects of long-term, low-level exposure are: trembling hanc , numbness of the extremities, and behavioral chan es. As the level of mercury builds up in the body, a person's ability to walk, talk, see, and hear may b affected.

The effects of methylmercury contamination are ery serious. It is important that you and your family follow fish advisories to protect your health.

How does a fish advisory work?

To help you protect your health, the Idaho Division of Health issues a fish advisory when fish in a certain area are found to have methylmercury levels of 0.5 parts per million (PPM) or greater. If you eat fish from a body of water that is known to have high levels of methylmercury, you should make sure not to eat more than the amounts specified in the fish advisory. Also, keep in mind that only a few bodies of water in Idaho have been tested for mercury.

Why are certain people advised to eat even less fish than others?

The nervous system is especially vulnerable to the effects of mercury when it is developing. For this reason, young children (age 6 or younger), should consume smaller amounts of fish that contain mercury. Because mercury exposure is also linked to birth defects, pregnant and nursing women, and even women who are thinking of becoming pregnant in the near future, need to be especially careful. The fish advisory lists these people in a special category, with their own lower level of safe consumption.

How long do fish advisories last?

Fish advisories for health reasons are in effect indefinitely, as long as the fish contain high levels of contamination. If the source(s) of contamination can be eliminated, the fish advisory will be lifted. Some contaminants that occur naturally may never be eliminated.

Where can I get more information?

- For the text of existing fish advisories and information on health issues, contact the Bureau of Environmental Health and Safety in Boise at 208-334-0606, or email maddoxp@idhw.state.id.us
- For information on environmental issues, contact the Division of Environmental Quality in Boise at 208-373-0502, or go to their web page at: www.state.id.us/deq or contact their webmaster at: cflood@deq.state.id.us or contact regional offices in Coeur d'Alene, Lewiston, Boise, Twin Falls, Pocatello, and Idaho Falls.

Other information can be found at the following websites:

- For a fact sheet on safely consuming fish you catch, go to: www.epa.gov/ost/fishadvice
- For EPA information on mercury and fish advisories, go to: www.epa.gov/ost/fish/mercury.html
- For other information on fishing in Idaho, go to: www2.state.id.us/fishgame/2000fish.htm
- This fact sheet, along with links to other related sites listed above, can be found online at: http://www2.state.id.us/dhw/behs/

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Appendix E. Data Sources and Tables

This data is available on CD in the back of this document
or in the SR-HC TMDL Data folder on this CD.

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Appendix F. 1995 Brownlee Reservoir Model Simulations using Draft Subbasin Assessment Target of 70 ug/L

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IDAHO POWER
An IDACORP Company

Subject 1995 Brownlee Reservoir Model Simulations using Draft Subbasin Assessment Target of 70 *u*g/L

Memorandum

From Ralph Myers, Idaho Power Company
Jack Harrison, HyQual
Michael Kasch, HDR
Scott Wells, Portland State University (QC)

Date December 7, 2001

A total phosphorus (TP) target of 70 *u*g/L has been proposed for the Upstream Reach of the Snake River (above Brownlee Reservoir) as part of the Snake River-Hells Canyon TMDL (IDEQ/ODEQ, 2001a). This TP target is being established to address a number of water quality problems in the Snake River related to excess nutrient levels, including the following:

- Nuisance algal conditions that negatively affect recreational use, including swimming and boating
- Excess organic matter in sediments that limit support of aquatic biota, including the White Sturgeon (a sensitive species)
- Potential toxic algal blooms similar to those that have occurred in other areas of Idaho where blue-green algal problems exist
- Excess organic matter that leads to formation of methylmercury (the toxic form of mercury) and trihalomethanes (negatively affecting drinking water supplies)

Additionally, the Idaho Division of Environmental Quality (DEQ) and Oregon DEQ are also proposing a "nutrient-related" dissolved oxygen (DO) allocation for Brownlee Reservoir (IDEQ/ODEQ, 2001b). The intent of DO allocation is to provide additional Reservoir water quality improvements beyond those that would occur by addressing nutrient related problems in the Upstream Snake River. The DO allocation is directed toward increasing DO in the metalimnion of the lacustrine zone.

In this memorandum we compare the response of the 1995 Brownlee Reservoir Model (Harrison et al, 1999) to the following conditions:

- **TP Target**—Short-term improvement resulting from implementation of the 70 *u*g/L TP target for the Upstream Snake River.
- **Improved Sediment Oxygen Demand (SOD) with TP Target**—Long-term water quality improvements, including reduction in SOD resulting from implementation of TP Target.
- **Oxygen Injection (OI) with TP Target and Improved SOD**—Water quality improvements in response to implementation of reservoir OI as one method of meeting the DO allocation per IDEQ/ODEQ's Draft Load Allocation (IDEQ/ODEQ, 2001b).

Analyses

To simulate the TP target, we reduced dissolved phosphorus and organic phosphorus (i.e. organic matter, including algae) from the 1995 baseline boundary conditions such that inflowing phosphorus levels did not exceed 70 *u*g/L (see Attachment 1). SOD improvements were simulated by replacing baseline SOD values estimated during model optimization with more typical values (see Attachment 2). OI was simulated by adding oxygen into cells near the middle of the transition zone (see Attachment 3).

Changes in DO levels from each of the simulations were compared to baseline conditions using two methods: Comparison with DO Criteria and Volume-Weighted DO. Baseline conditions are represented by the peer-reviewed Brownlee Model using 1995 measured boundary conditions, optimized to measured in-reservoir water quality data (Harrison, 1999).

Comparison with Criteria DO

For each time-step, the DO in each cell is compared to the DO criteria of 6.5 mg/L, as proposed in the draft Subbasin Assessment (IDEQ, 2001). If the value was below the criteria, the volume of the cell is added to the "low" volume for its respective zone. The results are then averaged for daily and monthly output. The percent below the criteria is then calculated by dividing the volume below the criteria by the total volume of the zone.

Volume-Weighted DO

Volume-weighted DO was calculated for the Reservoir and the five zones. The model simulates a DO value for each cell in the model grid. These values were weighted by the volume of the model cell and averaged. The volume-weighted DO calculated for baseline are compared to the simulations for improved conditions and provided in Attachment 4.

Zones

To facilitate analyses, Brownlee Reservoir was divided into three zones: riverine, transition, and lacustrine (Harrison et al., 1999). The lacustrine zone was further divided into three strata typical of stratified lakes and reservoirs: epilimnion, metalimnion, and hypolimnion (Wetzel, 2001). The locations of these zones are shown in Attachment 5.

SIMULATION RESULTS

The simulation results, as shown below, demonstrate improving conditions from short-term conditions without SOD improvements to long-term conditions with SOD improvements, and then with OI to the reservoir. In general, the simulations show an increase in DO in all zones except the riverine zone, where DO is already at super saturated levels as a result of the algal bloom. In general, the DO improvement is greatest in the summer, especially in the metalimnion.

TP Target

This simulation shows Brownlee Reservoir's initial response to reductions in TP and organic matter loads based on the TP target of 70 *u*g/L (Figure 1). When the TMDL is first implemented, SOD will be unchanged from baseline conditions. This limits the initial level of improvement (i.e., increase in DO) in the downstream end of the transition zone and in the lacustrine zone where SOD levels are highest (Attachment 3).

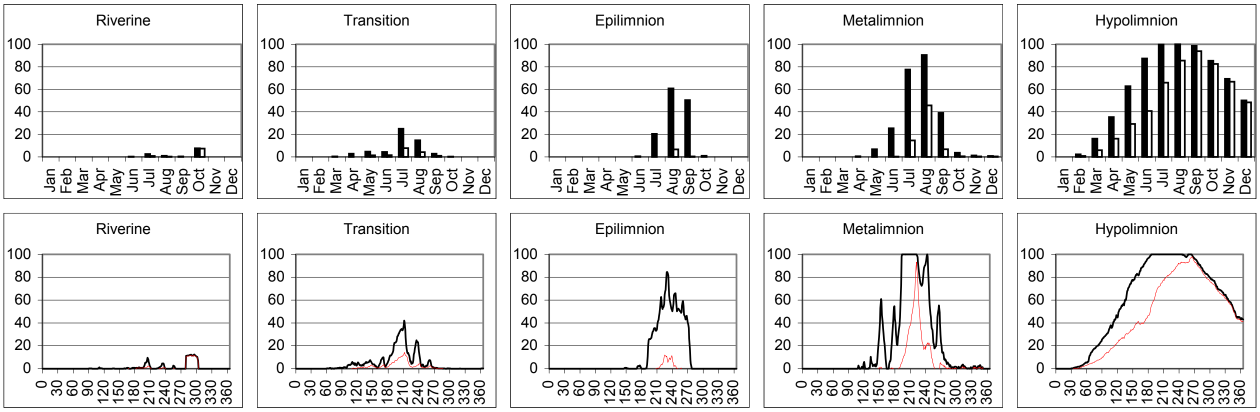


Figure 1. Simulation results showing short-term improvement resulting from implementation of the 70 *u*g/L TP target for the Upstream Snake River. Dark line shows percent DO below criteria (6.5 mg/L) for Baseline and light line shows TP Target.

Improved SOD with TP Target

Once the TMDL is implemented, it is anticipated that organic matter loads and sedimentation will decrease. As the loads decrease and existing organic matter decays through natural processes (or reservoir OI), SOD will decrease. The response to these long-term improvements was simulated by reducing SOD to 0.1 gm O_2 m^{-2} day^{-1} throughout the Reservoir (Figure 2). This SOD is more typical of naturally occurring SOD levels (Cole and Wells, 2000). The inflowing boundary conditions are unchanged from the previous simulation.

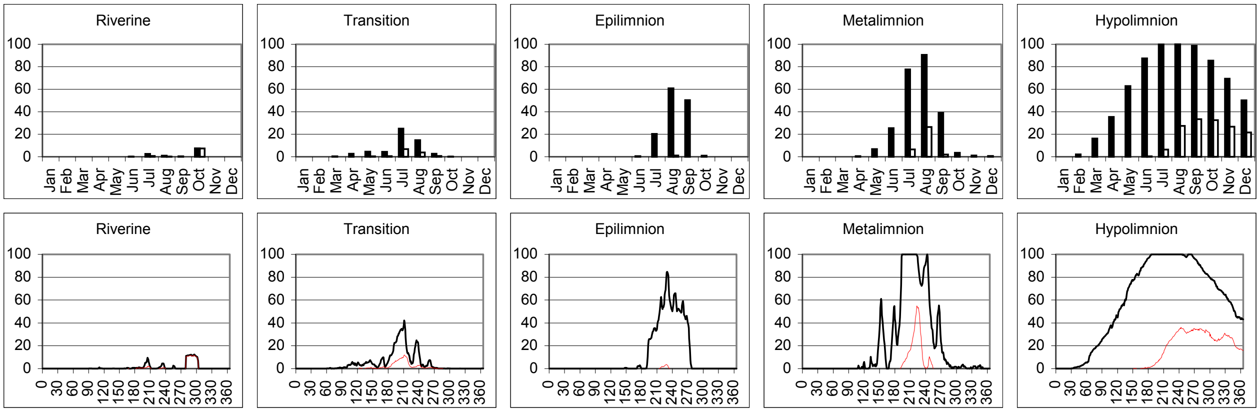


Figure 2. Simulation results showing long-term improvement resulting from implementation of the 70 *u*g/L TP target for the Upstream Snake River and resulting decrease in SOD. Dark line shows percent DO below criteria (6.5 mg/L) for Baseline and light line shows TP Target with SOD improvement.

OI with TP Target and Improved SOD

OI to the reservoir may be used to further improve reservoir DO levels and meet the reservoir DO allocation. OI was simulated by adding oxygen to model cells near the middle of the transition zone (Attachment 3). Three levels of OI, 5.5, 11 and 22 tons/day, were simulated to show a range of potential improvements (Figures 3, 4 and 5, respectively). For these simulations, OI was held constant for the year and was placed near the middle of the transition zone (RM 317). The OI system design and the optimization of system performance were not evaluated.

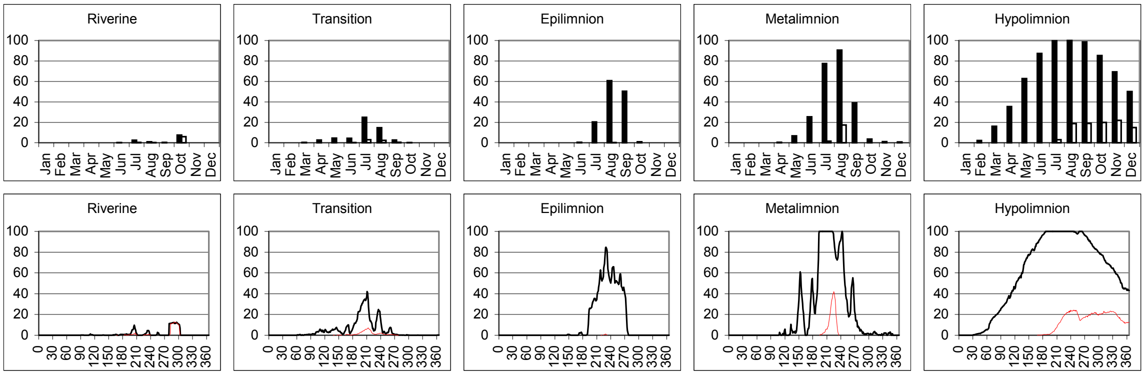


Figure 3. Simulation results showing OI at 5.5 tons/day with long-term improvements resulting from implementation of the 70 *u*g/L TP target for the Upstream Snake River and resulting decrease in SOD. Dark line shows percent DO below criteria (6.5 mg/L) for Baseline and light line shows OI.

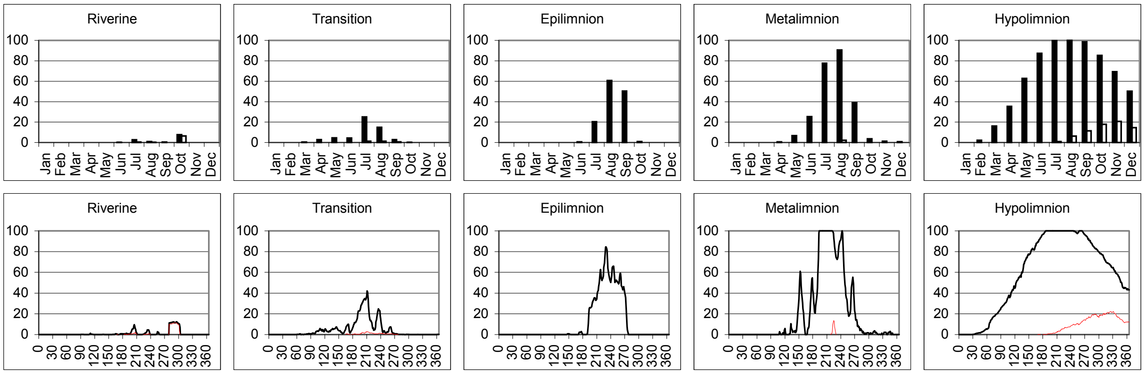


Figure 4. Simulation results showing OI at 11 tons/day with long-term improvements resulting from implementation of the 70 *u*g/L TP target for the Upstream Snake River and resulting decrease in SOD. Dark line shows percent DO below criteria (6.5 mg/L) for Baseline and light line shows OI.

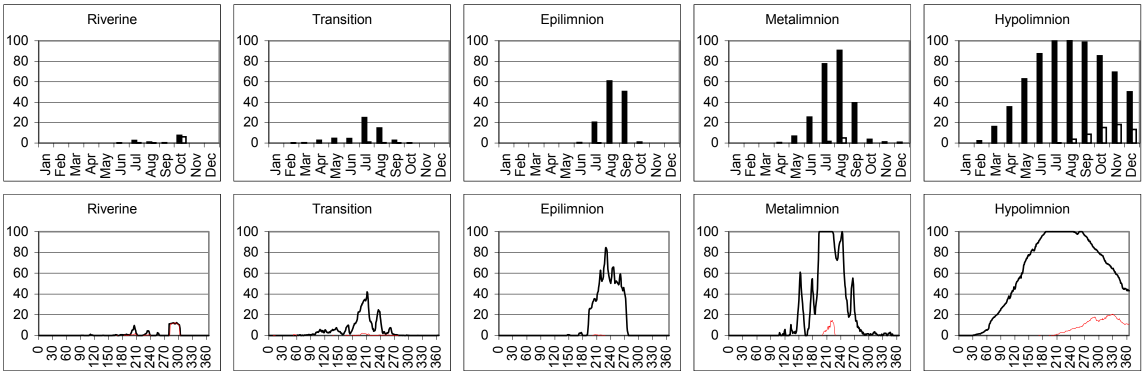


Figure 5. Simulation results showing OI at 22 tons/day with long-term improvements resulting from implementation of the 70 *u*g/L TP target for the Upstream Snake River and resulting decrease in SOD. Dark line shows percent DO below criteria (6.5 mg/L) for Baseline and light line shows OI.

The three OI simulations provide an indication of the general range of oxygen needed to meet the DO target of 6.5 mg/L in the epilimnion. The results indicate that 5.5 tons oxygen·day^{-1} may not be enough OI to meet standards. The addition of 22 tons oxygen·day^{-1} does not appear to provide additional improvements in the epilimnion and metalimnion compared to OI of 11 tons oxygen·day^{-1}. Therefore, OI near 11 tons oxygen·day^{-1} appears sufficient to meet the objectives of the DO allocation (Figure 4).

Participation in Pollution Trading Program

Idaho Power Company may also want to consider supporting watershed nutrient reductions in addition to, or as an alternative to, OI. This could be accomplished by participation in a pollution-trading program developed for the watershed. Prior to evaluation of this type of alternative, some understanding of a trading framework will need to be developed.

CONCLUSIONS AND RECOMMENDATIONS

These simulations show that substantial improvements in water quality in Brownlee Reservoir will occur through implementation of the 70 *u*g/L TP Target proposed for the Upstream Snake River. Additional improvements needed to meet DO criteria in the Reservoir may be possible through OI to the Reservoir. Preliminary simulation results show that additional oxygen (approximately 11 tons oxygen$^{\cdot}$day^{-1}) can improve DO levels in the metalimnion and meet the intent of the Reservoir DO allocation as proposed by IDEQ/ODEQ. Oxygen added at levels above this amount do not show significant levels of DO improvement.

References

Cole, T. and S. Wells. 2000. CE-QUAL-W2: A Two Dimensional, Laterally Average, Hydrodynamic and Water Quality Model, Version 3.0. User Manual. Instruction Report EL-00-1. U.S. Army Corp of Engineers. August 2000.

Harrison, J., S. Wells, R. Myers, S. Parkinson, M. Kasch. 1999. 1999 Status Report on Brownlee Reservoir Water Quality and Model Development, Draft Technical Report. Idaho Power Company. Boise, Idaho.

Harrison, J., S. Wells, R. Myers, S. Parkinson, M. Kasch, C. Berger. 2000. 2000 Status Report on Southwest Snake River Water Quality and Model Development, Draft Peer Review Report. Idaho Power Company. Boise, Idaho.

IDEQ/ODEQ. 2001a. Snake River–Hells Canyon Total Maximum Daily Load (TMDL) Draft Subbasin Assessment. Idaho Division of Environmental Quality and Oregon Division of Environmental Quality.

IDEQ/ODEQ. 2001b. Snake River–Hells Canyon Total Maximum Daily Load (TMDL) Draft Load Allocation. Idaho Division of Environmental Quality and Oregon Division of Environmental Quality.

Wetzel, R. 2001. *Limnology, Lake and River Ecosystems*. Academic Press, San Diego, CA.

Attachment 1

BOUNDARY CONDITIONS FOR PHOSPHORUS

The 1995 baseline boundary condition in the Brownlee Reservoir Model is based on the 1995 Southwest Snake River Model (Harrison et al., 2000) results calibrated to measured data from Porters Island. The boundary conditions include dissolved phosphorus (also referred to as bioavailable phosphorus or soluble reactive phosphorus, SRP) and organic matter (i.e. algae, dissolved and particulate) (Cole and Wells, 2000). The model includes a value for the fraction of organic matter that is phosphorus (a coefficient for the stoichiometric equivalent between organic matter and phosphorus) (Cole and Wells, 2000; Harrison et al., 1999). Organic matter in the boundary condition and the fraction represent organic phosphorus in the model.

The following method was used to calculate total phosphorus (TP) in the model and the reduction to meet the target. Total organic matter (TOM) was calculated as the sum of algae and dissolved and particulate organic matter. TOM was converted to organic phosphorus (OP) using a ratio of 100:1 (TOM:OP) (Harrison et al., 2000). TP was calculated as the sum of OP and SRP. The model does not account for inorganic (mineral) phosphorus attached to sediment. The date when TP exceeded the criteria by the greatest amount was identified in the boundary condition and the difference between the maximum value and the target was calculated (Figure 1-1). This difference was then used to reduce the algae, organic matter, and SRP boundary conditions for the entire year.

The ratio of 100:1 for TOM:OP is considered conservative. A lower ratio, such as 50:1 (TOM:OP), results in a greater difference that would be used to reduce algae, organic matter, and SRP boundary conditions. Either ratio is within the typical range of a riverine/lacustrine system.

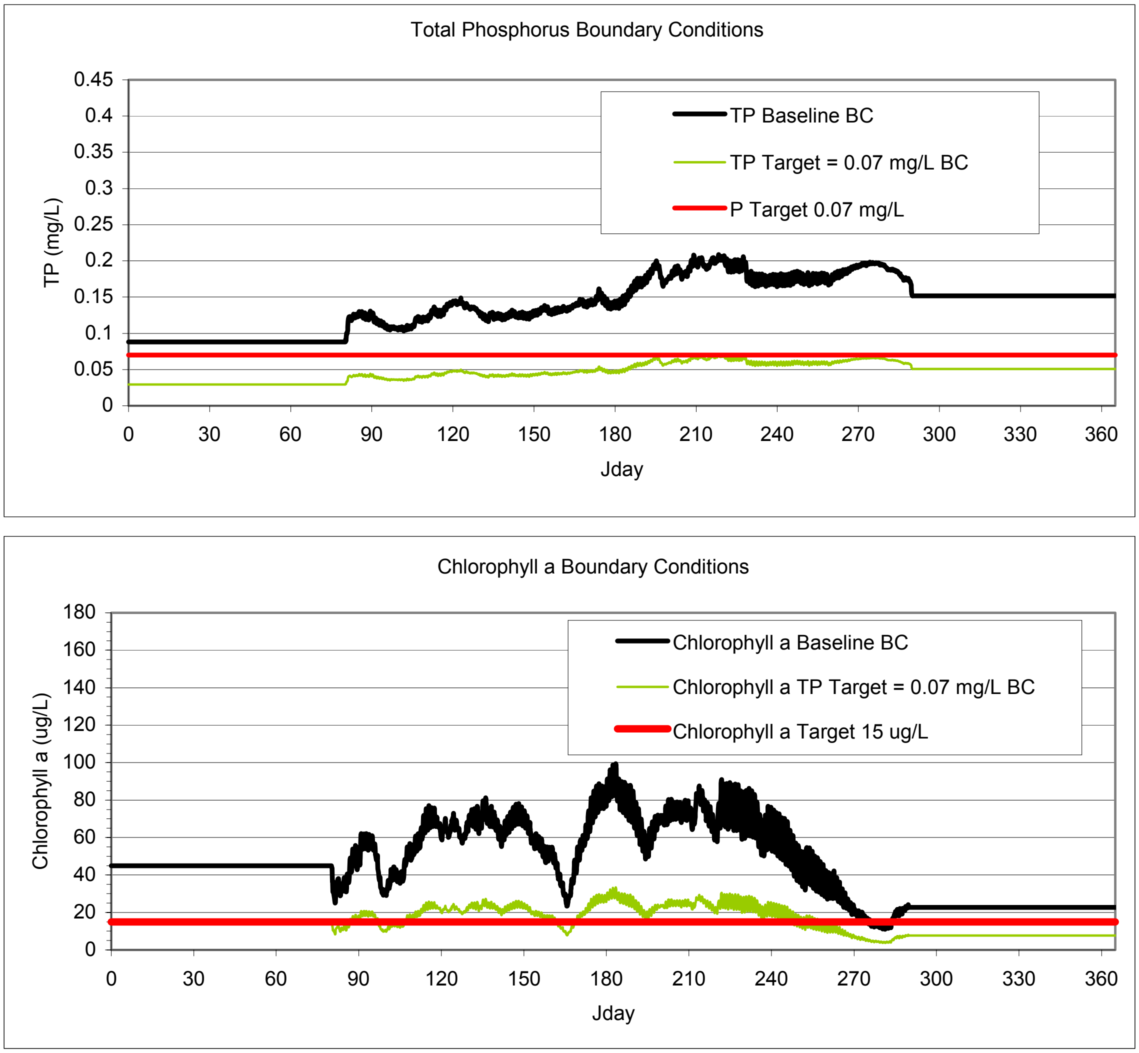


Figure 1-1 1995 Boundary Conditions, Baseline and Target Reductions

ATTACHMENT 2

Sediment Oxygen Demand

The model includes two methods for estimating the oxygen demand caused by organic matter decay in bottom sediments: SED and SOD. SED is a first-order function specifying the decay of particulate organic matter that settles to the bottom during the modeled period. SOD is a zero-order function and is “pre-set” during model optimization. Spatial variation in SOD, due to differences in sedimentation and scour patterns and algal production, is specified for each segment in the model (Table 2-1). The SOD represents the background historical accumulation of organic material.

SED was not changed in these simulations. SOD was reduced from the baseline model values. The average of these values is 1.9 $\text{g}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$, SOD varies along the bottom of the Reservoir (Table 2-1). SOD was set at 0.1 $\text{g}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$ to represent a system without cumulative effects (Wells, 2001).

Table 2-1 Sediment Oxygen Demand Coefficients

Segment	River Mile	SOD Baseline ($g\ O_2\ m^2\ day^{-1}$)	SOD TDML ($g\ O_2\ m^2\ day^{-1}$)	Zone
1	x	0.15	0.1	
2	334.5	0.15	0.1	Riverine
3	333	0.15	0.1	Riverine
4	331	0.15	0.1	Riverine
5	329	0.15	0.1	Riverine
6	327	0.15	0.1	Riverine
7	325	0.15	0.1	Riverine
8	323	0.15	0.1	Transition
9	321	0.15	0.1	Transition
10	319	0.375	0.1	Transition
11	317	0.375	0.1	Transition
12	315	0.75	0.1	Transition
13	313	0.75	0.1	Transition
14	311	0.75	0.1	Transition
15	309	2.25	0.1	Transition
16	307	2.25	0.1	Lacustrine
17	305	2.25	0.1	Lacustrine
18	303	2.25	0.1	Lacustrine
19	301	2.25	0.1	Lacustrine
20	299	2.25	0.1	Lacustrine
21	297	2.25	0.1	Lacustrine
22	295	4.5	0.1	Lacustrine
23	293	5.25	0.1	Lacustrine
24	291	6.75	0.1	Lacustrine
25	289	6.75	0.1	Lacustrine
26	287	7.5	0.1	Lacustrine
27	285.2	8.25	0.1	Lacustrine
28	x	0.75	0.1	
29	x	0.75	0.1	
30	Powder	0.75	0.1	
31	Powder	0.75	0.1	
32	Powder	0.75	0.1	
33	Powder	0.75	0.1	
34	Powder	0.75	0.1	
35	Powder	0.75	0.1	
36	Powder	0.75	0.1	
37	Powder	0.75	0.1	
38	x	0.75	0.1	
Average		1.9	0.1	

*SOD rates are for 20oC; the model adjusts these rates based on water temperature

ATTACHMENT 3

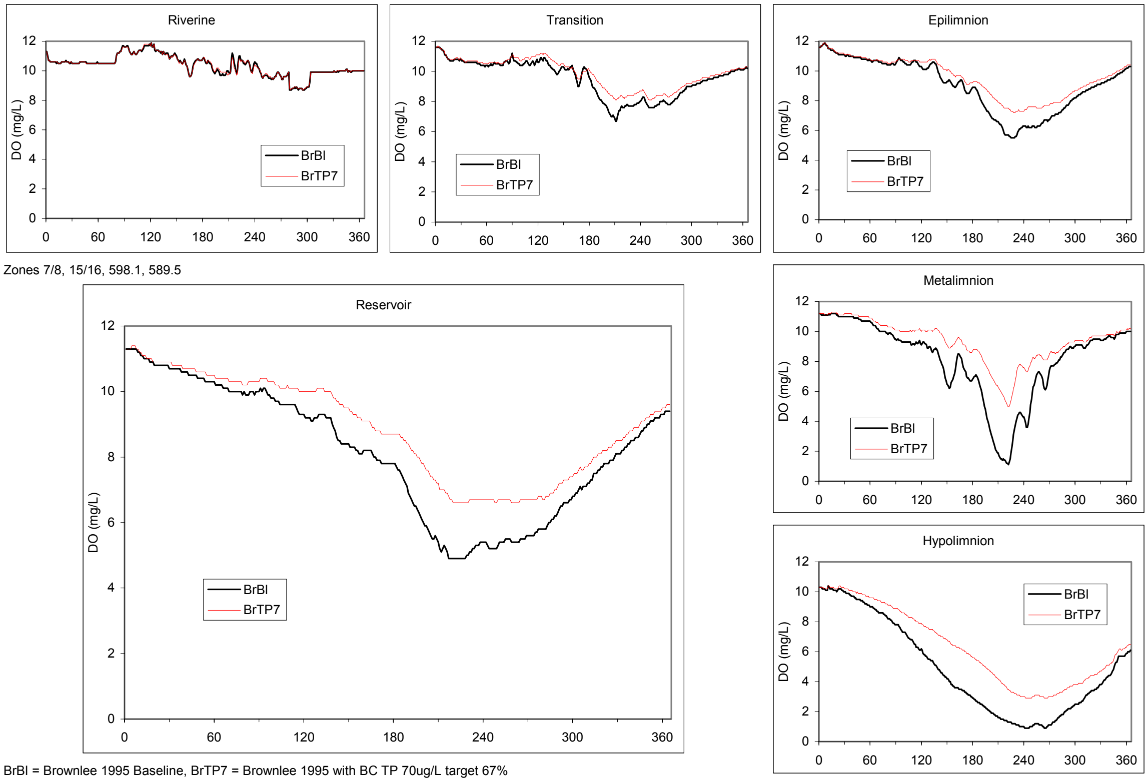
Oxygen Injection

Oxygen Injection (OI) was added to the control file of the CE-QUAL-W2 code to permit the addition of oxygen to specified locations (Wells, 2001). Included in this option are specifications to turn OI on/off, number of units, locations, and air mass rates. The model injects oxygen to the cells as specified. This allows the model to be used to explore general OI alternatives. The mass rate of oxygen delivered to the water is modeled, not the oxygen supplied by a compressor. Bubble rise effects and the vertical momentum of bubble mixing are not modeled.

ATTACHMENT 4

Volume-Weighted Dissolved Oxygen Results

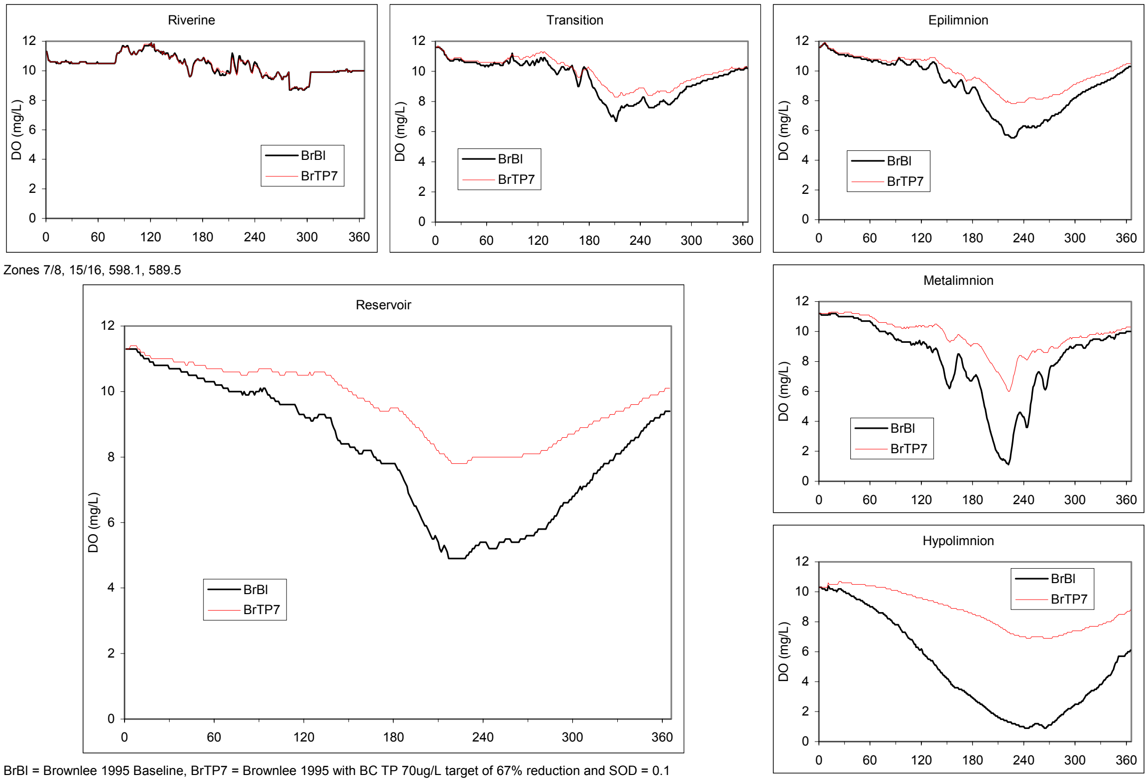
The volume-weighted dissolved oxygen (DO) results for the various simulations are shown below.



Zones 7/8, 15/16, 598.1, 589.5

BrBl = Brownlee 1995 Baseline, BrTP7 = Brownlee 1995 with BC TP 70ug/L target 67%

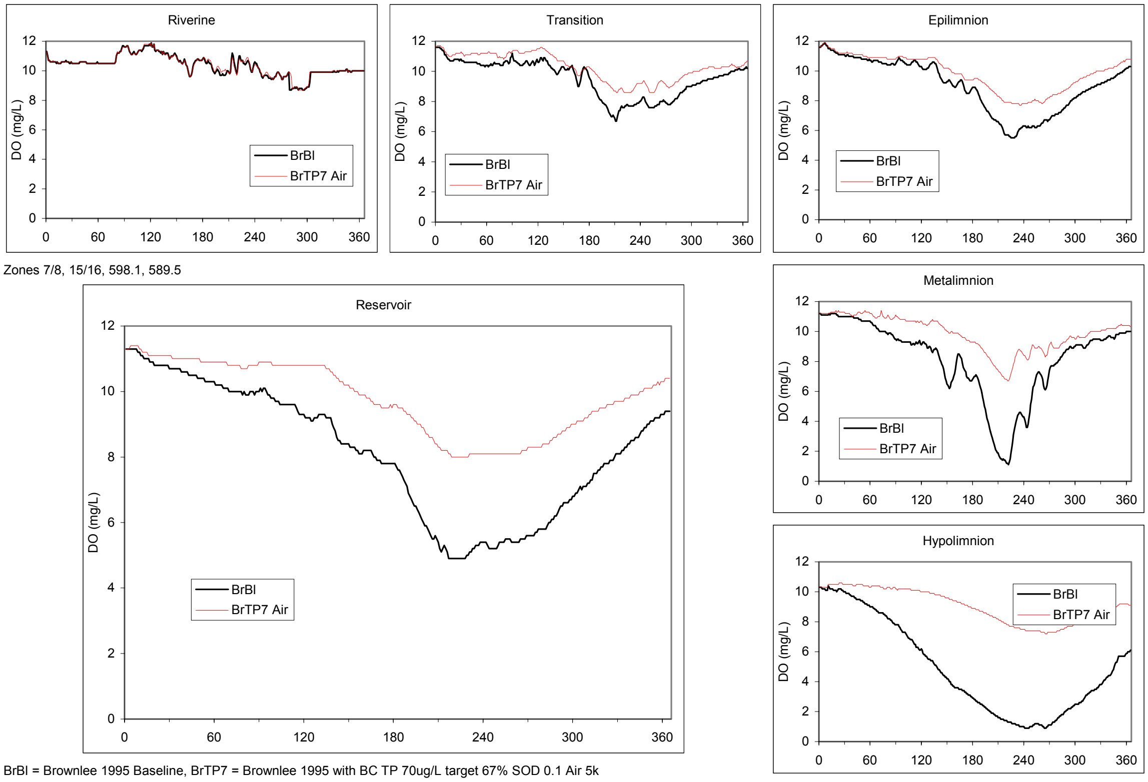
Figure 4-1. Simulation results showing short-term improvement resulting from implementation of the 70 ug/L TP target for the Upstream Snake River.



Zones 7/8, 15/16, 598.1, 589.5

BrBl = Brownlee 1995 Baseline, BrTP7 = Brownlee 1995 with BC TP 70ug/L target of 67% reduction and SOD = 0.1

Figure 4-2. Simulation results showing long-term improvement resulting from implementation of the 70 ug/L TP target for the Upstream Snake River and resulting decrease in SOD.


Riverine

Transition

Epilimnion

Zones 7/8, 15/16, 598.1, 589.5

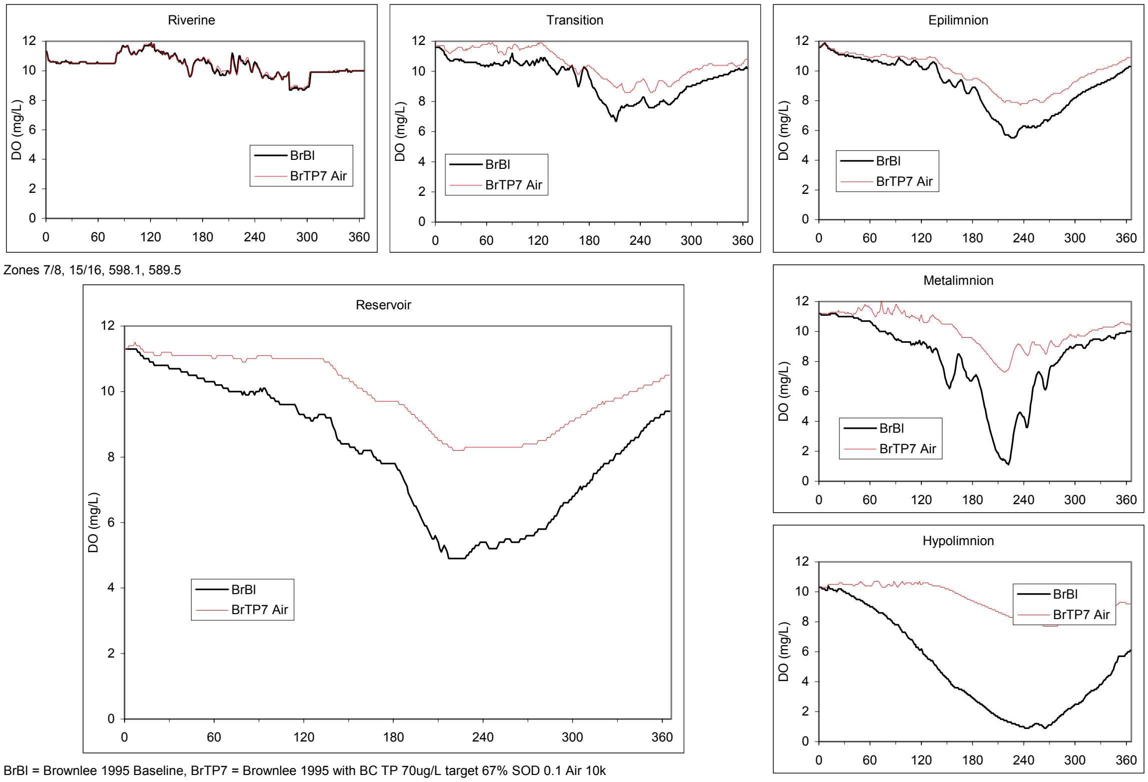
Reservoir

Metalimnion

Hypolimnion

BrBl = Brownlee 1995 Baseline, BrTP7 = Brownlee 1995 with BC TP 70ug/L target 67% SOD 0.1 Air 5k

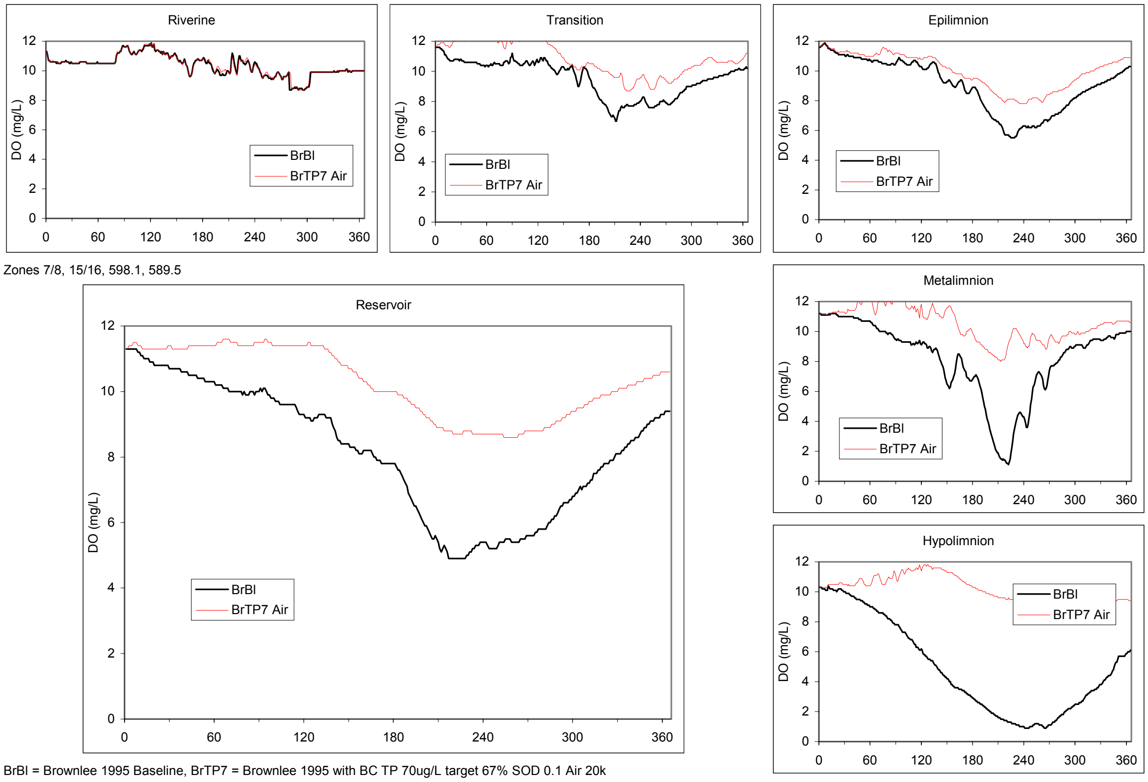
Figure 4-3. Simulation results showing oxygen injection at 5.5 tons/day with long-term improvements resulting from implementation of the 70 ug/L TP target for the Upstream Snake River and resulting decrease in SOD.



Zones 7/8, 15/16, 598.1, 589.5

BrBl = Brownlee 1995 Baseline, BrTP7 = Brownlee 1995 with BC TP 70ug/L target 67% SOD 0.1 Air 10k

Figure 4-4. Simulation results showing oxygen injection at 11 tons/day with long-term improvements resulting from implementation of the 70 ug/L TP target for the Upstream Snake River and resulting decrease in SOD.



Zones 7/8, 15/16, 598.1, 589.5

BrBl = Brownlee 1995 Baseline, BrTP7 = Brownlee 1995 with BC TP 70ug/L target 67% SOD 0.1 Air 20k

Figure 4-5. Simulation results showing oxygen injection at 22 tons/day with long-term improvements resulting from implementation of the 70 ug/L TP target for the Upstream Snake River and resulting decrease in SOD.

ATTACHMENT 5

Brownlee Zones

The zones for Brownlee Reservoir are shown in Figure 5-1.

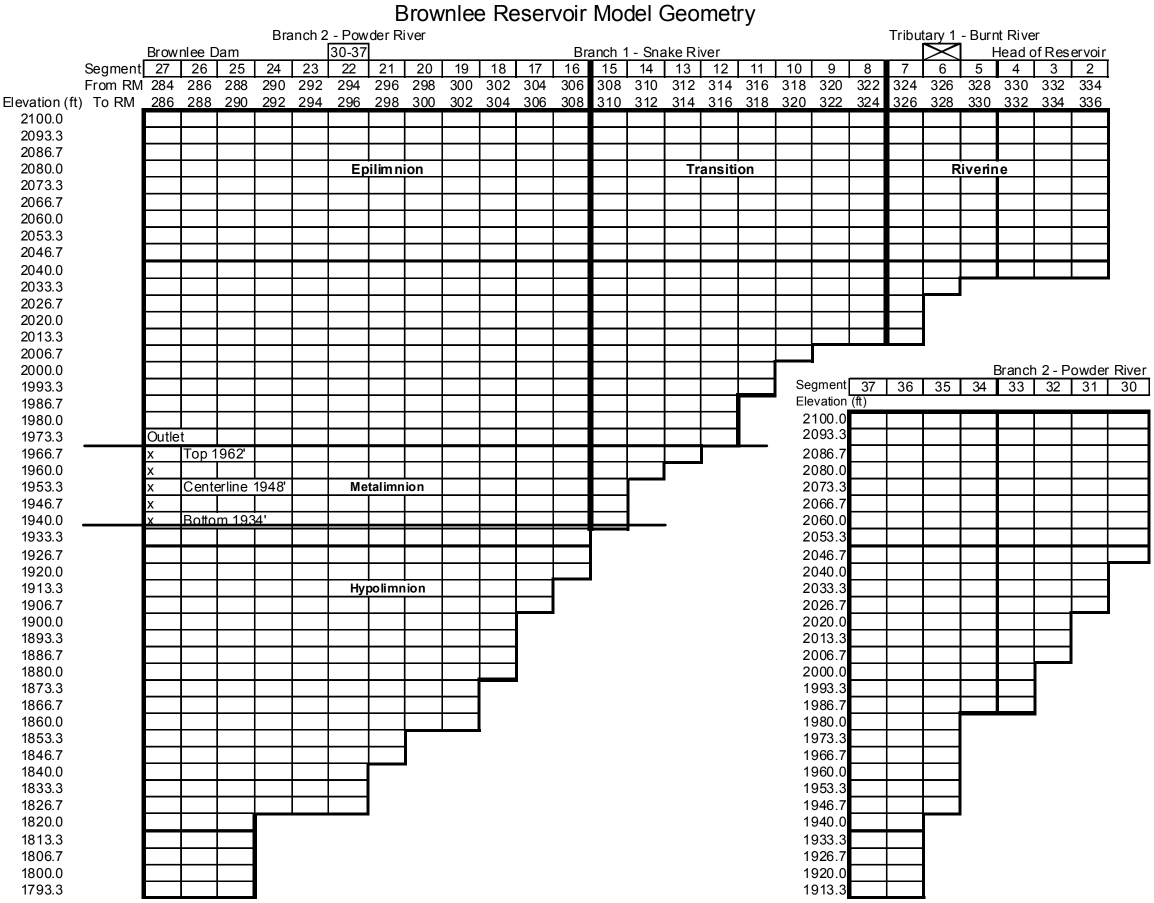


Figure 5-1 Brownlee Reservoir Zones.

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Appendix G. Pollutant Loading Analysis for the Snake River: Murphy to Hells Canyon

POLLUTANT LOADING ANALYSIS FOR THE SNAKE RIVER MURPHY TO HELLS CANYON

Prepared for:

Idaho Department of Environmental Quality
Oregon Department of Environmental Quality

Prepared by:

Ecosystems Research Institute, Inc.
Logan, Utah

October 2001

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1.0 INTRODUCTION

The Snake River within the State of Idaho and Oregon has been designated by both states as not meeting its beneficial use classifications. Because the river currently resides on those state's 303(d) lists, Ecosystems Research Institute (ERI) was asked to accumulate and evaluate the available database relative to conducting a Total Maximum Daily Load analysis. To that end, ERI undertook several tasks in order to meet the following objective:

> ***Conduct an analysis of pollutant loading for bacteria, mercury, nutrients (nitrogen and phosphorous), legacy pesticides and total suspended solids for the Hells Canyon reach of the Snake River.***

To meet this objective, ERI took a systematic approach in the acquisition, evaluation, analysis and summarization of the available water quality and hydrologic data. This systematic process occurred at several levels of restoration. The purpose was to obtain a data set that had some degree of resolution and completeness. The results of this investigation are described in section 2.0 of this report.

2.0 ANALYSIS OF POLLUTANT LOADING

As noted above, a systematic approach was used in the analysis of pollutant loading in the Snake River near Hells Canyon. It should be noted that the specific reaches of interest on the Snake River were predetermined by the states of Idaho and Oregon. The pollutant loading analysis was conducted between Murphy and the Hells Canyon Dam on the Snake River.

2.1 Data Acquisition and Database Development

The approach used in this task focused on obtaining and evaluating existing hydrologic and water quality data. Specifically, the nutrients nitrogen and phosphorous, as well as total suspended solids, mercury, legacy pesticides, and bacteria were the main focus of the data search. To a lesser extent, pH, dissolved oxygen, and temperature were investigated.

The initial step was to obtain all available data that were in electronic format. Data sources used included the EPA STORET database and USGS WATSTORE. In addition, several data sets were obtained from IDEQ which were not in an electronic format and were hand entered into the database. The database consisted primarily of grab samples for flow and water quality. These data were then cross-referenced with each other to avoid duplication. Site coordinates were verified with ArcView GIS, and then a rivermile was assigned to each site. Table 2-1 lists the agency responsible for the water quality data samples which were used in this analysis. A total of 258 sites were incorporated into the data set which corresponded to approximately 122,700 individual data points.

Data availability at sites corresponding to tributaries, drains, and mainstem sites are shown in Table 2-2. The fewest data were from drains followed by mainstem sites. Numerically, tributaries had the highest number of unique locations (although not necessarily the largest number of data points). No data for NPDES point sources were placed into the database. The software used for the database was Microsoft ACCESS

In addition to the electronic numeric database, the corresponding sites were placed in a spatial data set in the GIS program ARCVIEW. Each sample location in the database can be seen in Figure 2-1.

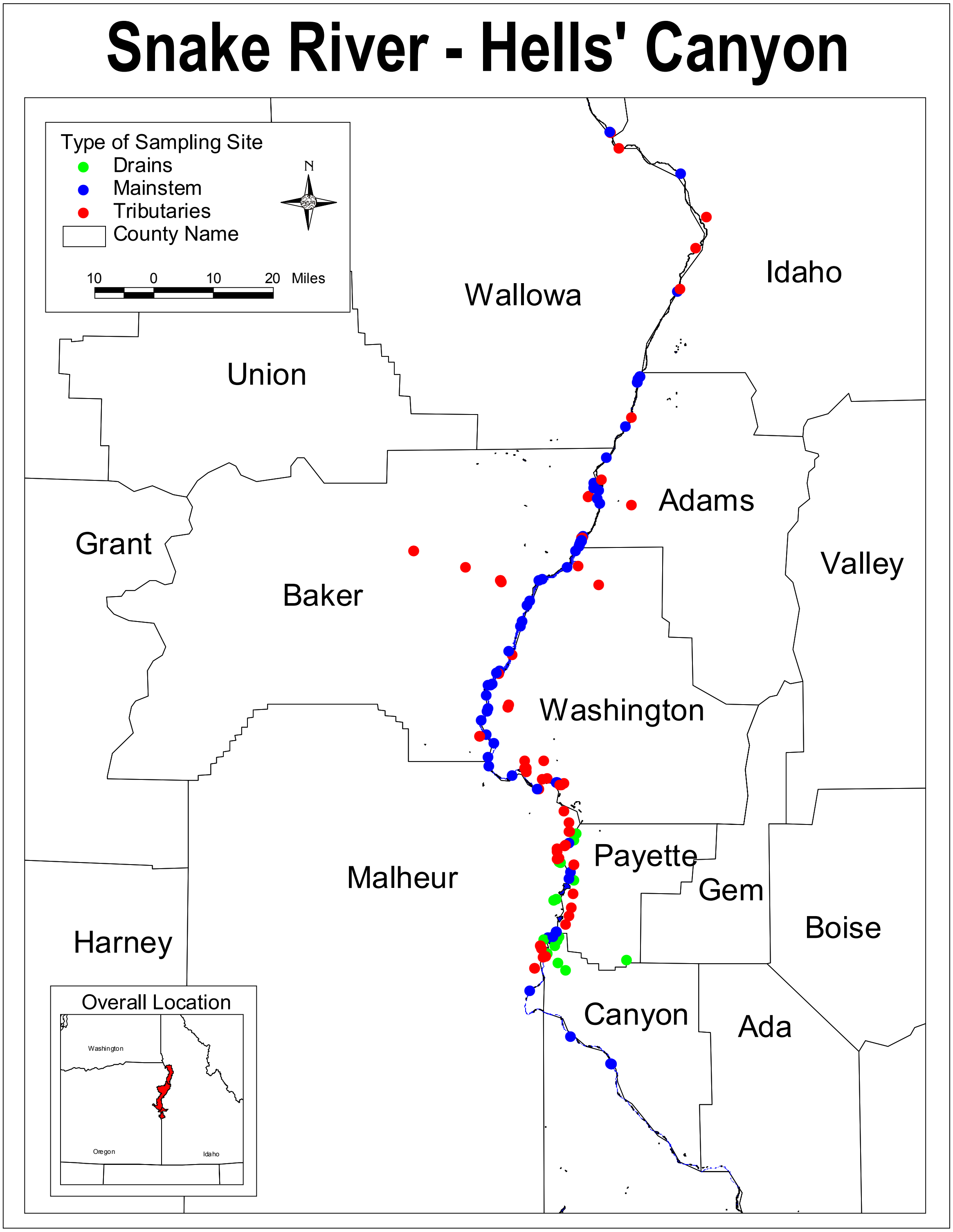


Figure 2-1. **The location of all sites within the hydrologic and water quality database for the Snake River.**

Table 2-1. A summary of the data sources by agency code, site type and number stations for all available for the pollutant loading analysis on the Snake River.

Agency Code	Site Type	Number of Stations
10EPACOP	Drain	3
10EPACOP	Tributary	5
10EPAINT	Drain	8
10EPAINT	Tributary	10
1110DFID	Mainstem	6
1110DFID	Tributary	1
1110NET	Tributary	1
1119C050	Mainstem	5
1119C050	Tributary	2
1119USBR	Drain	2
1119USBR	Mainstem	3
1119USBR	Tributary	11
112WRD	Drain	1
112WRD	Mainstem	6
112WRD	Tributary	8
113FORS1	Tributary	1
113FORS4	Tributary	1
11BIOACC	Tributary	1
11EPALES	Mainstem	16
11EPALES	Tributary	12
21400000	Mainstem	6
21400000	Tributary	5
21IDAHO	Mainstem	4
21IDAHO	Tributary	2
21IDSURV	Drain	3
21IDSURV	Mainstem	2
21IDSURV	Tributary	5
City of Boise	Mainstem	3
City of Boise	Tributary	5
IPCo	Mainstem	106
IPCo	Tributary	6
NITROGEN	Mainstem	7
NITROGEN	Tributary	1

Table 2-2. The breakdown of hydrologic data by site types and year.

	NUMBER OF SNAKE RIVER HISTORICAL SITES		
YEAR	**Drains**	**Mainstem**	**Tributaries**
1974	0	3	5
1975	0	4	5
1976	0	4	5
1977	0	3	5
1978	0	3	5
1979	0	4	6
1980	0	4	6
1981	0	4	6
1982	0	4	7
1983	0	4	6
1984	0	4	6
1985	0	4	6
1986	0	4	6
1987	0	4	6
1988	0	4	6
1989	0	4	8
1990	0	4	8
1991	0	4	8
1992	0	4	8
1993	0	4	8
1994	0	4	8
1995	0	4	7
1996	0	4	5
1997	0	4	4
1998	0	4	4
1999	0	4	3
2000	0	4	2

2.1.1 Hydrologic and Water Quality Data Evaluation

Upon completion of the database described in section 2.1 above, a series of sequential steps were undertaken in order to evaluate the adequacy of the data for loading analysis. A loading calculation is based upon two data sets. These include flow and concentration of the parameter of concern. Typically, flow is recorded as an instantaneous measurement (i.e. cubic feet per second - cfs) while concentration is based upon weight per volume (i.e. millgrams per liter - mg/l). On an instantaneous basis, the two measures are multiplied together (with appropriate constants) to obtain mass per time (i.e. kilograms per day - kg/day). In our evaluation of the database, we inspected the completeness of both data sets.

2.1.1.1 Hydrology

Inspection of the hydrology data indicated that the amount and completeness of available data from paired data sets (where flow and concentration data are matched with other sites over similar time periods) for inflowing sources (drains and tributaries) as well as the mainstem Snake River is small. A summary of the number of sites for inflow sources and the mainstem Snake can be seen in Table 2-1. This is a summary of the number of sites and not the intensity of data at any one location. A discussion of sample frequency is covered in a later section of this report.

The magnitude of annual discharge expressed as acre-feet per year, during the study period can be seen in Figure 2-2. These data are for the most complete data sets available for the mainstem Snake River sites. The largest annual discharge occurred during 1984 at Hells Canyon Dam (the most downstream station), with an annual discharge of 25.58 million ac-ft. This was also the highest flow year for the stations at Weiser, Murphy, and Nyssa. The high flow at Nyssa was only 13.75 million ac-ft. The lowest flows for all four sites happened in 1992, following five years of low flows. The fact that during the low flow period, all four stations had similar flows (6.88 - 4.75 million ac-ft) indicated the lack of significant reach gains from watershed sources. The temporal differences of the annual discharges are also shown in Figure 2-2, for each station on the mainstem Snake River.

Utilizing the annual discharge data, flow exceedence curves were developed for each site. These data are shown in Figure 2-3. The 50 percent exceedence flow at Hells Canyon (lowermost station) and Murphy (uppermost station) was 13.89 million ac-ft and 7.03 million ac-ft, respectively. These data indicate that in 50% of the years, annually over six million ac-ft of water enters the study reach from the watershed. This reach gain almost doubles the size of the Snake River.

Because of the lack of complete hydrologic data at each site over the period of record, it was determined that a systematic methodology would be used to select the most complete data from a wet, medium and dry year. In order to nest years into similar hydrologic conditions, the annual flow exceedence data was partitioned into three groups. They are shown in Table 2-3. The nested groups of years are associated with wet, medium and dry flows. Table 2-3 lists the years and stations in the upper 25th percentile (wet), middle 50th percentile (medium), and lowest 25th percentile(dry) groups.

2.1.1.2 Water Quality

The methodology for the evaluation of the adequacy of water quality data in conducting a detailed loading analysis was similar to that of the available hydrology data. A summary of the available sites where water quality data were available by year is provided in Table 2-4. As was

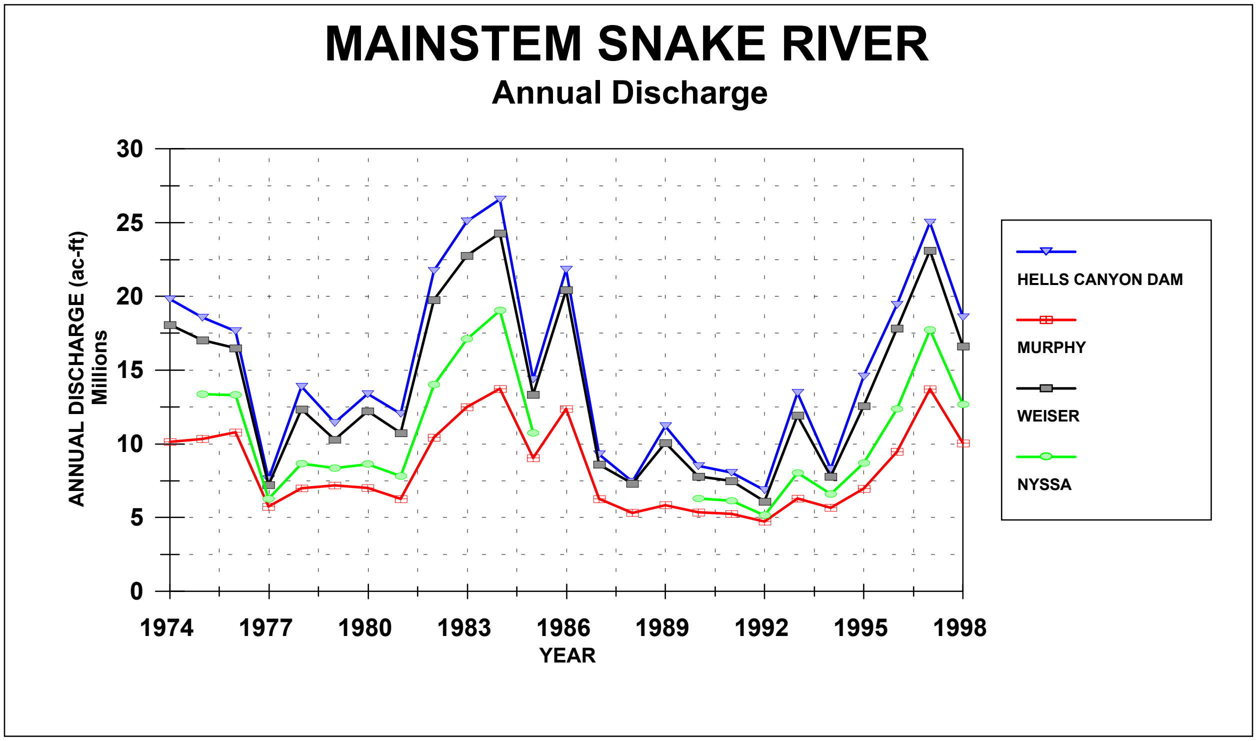


Figure 2-2. The annual discharge for the four USGS gaging station on the Snake River for this study reach.

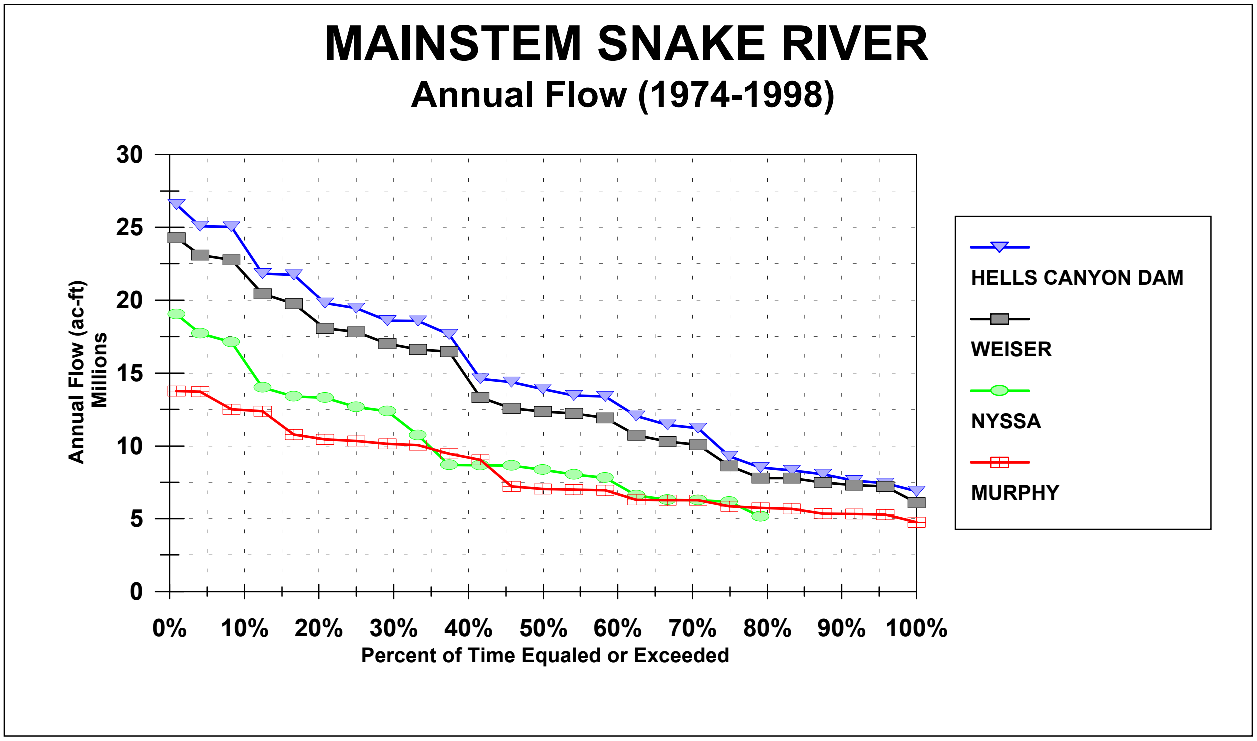


Figure 2-3. The percent of time annual discharge was equaled or exceeded for each gaging station inspected in the Snake River.

Table 2-3. The flow categories (high, medium and low) for each station by year between 1974 and 1998 in the Snake River.

	Hells Canyon Dam	Snake at Weiser	Snake at Nyssa	Snake at Murphy
High Flows (exceeded <25% of the time)				
	1974	1974		
			1975	
				1976
	1982	1982	1982	1982
	1983	1983	1983	1983
	1984	1984	1984	1984
	1986	1986		1986
	1997	1997	1997	1997
Average Flows (exceeded 50% of the time)				
	1978	1978		
				1979
				1980
	1985			
		1995	1995	
Low Flows (exceeded >75% of the time)				
	1977	1977	1977	1977
			1981	
	1987	1987		
	1988	1988		1988
				1989
	1990	1990	1990	1990
	1991	1991	1991	1991
	1992	1992	1992	1992
	1994	1994	1994	1994

Table 2-4. The breakdown of water quality site types by year which were incorporated into the Snake River database.

YEAR	NUMBER OF SNAKE RIVER HISTORICAL SITES		
	Drains	Mainstem	Tributaries
1974	3	20	37
1975	5	30	38
1976		9	14
1977	6	7	12
1978	3	5	17
1979	6	7	16
1980	6	6	12
1981		6	10
1982		4	9
1983		5	10
1984		3	10
1985		3	7
1986		3	11
1987		4	10
1988		6	13
1989		7	10
1990		8	8
1991		22	8
1992		28	9
1993		6	4
1994		78	5
1995		28	9
1996		32	5
1997		30	2
1998		27	1
1999		25	1
2000		5	5

previously noted, the amount of complete data (all sources available) when summarized by year (the most general category) from 1974-2000 is small. For example, years when drains and tributaries were studied, (1978 and 1979) only a few mainstem sites (5 and 7 stations, respectively) were also investigated. Only during 1974 and 1975 were common data sets collected for a significant number of drains, tributary and maintem sites. This represents the oldest available data (25 years old). In addition, a complexing factor is that these two years also binn out as high flow years (Table 2-3), and may not be representative of medium or low flow periods.

Inspection of the amount of available water quality data by year and parameter for just mainstem sites is shown in Table 2-5 and for selected parameters in Figure 2-4. This analysis considered only the seven mainstem Snake River stations. Total phosphorus had the highest overall average coverage (all years) with 33.6 percent. The range in total phosphorus coverage was 86.9 (1997) to 0 percent in 1991. Orthophosphate, dissolved oxygen, and total suspended solids each had coverages around 25 percent over the entire time period (1975-2000). The lowest coverage was for mercury (6.7%) and nitrate (3.4%). The temporal distribution for four parameters representing various levels of data availability are shown in Figure 2-4.

In section 2.2, specific sources are described in further detail relative to months and seasons. This finer level of detail discusses the data intensity at each site.

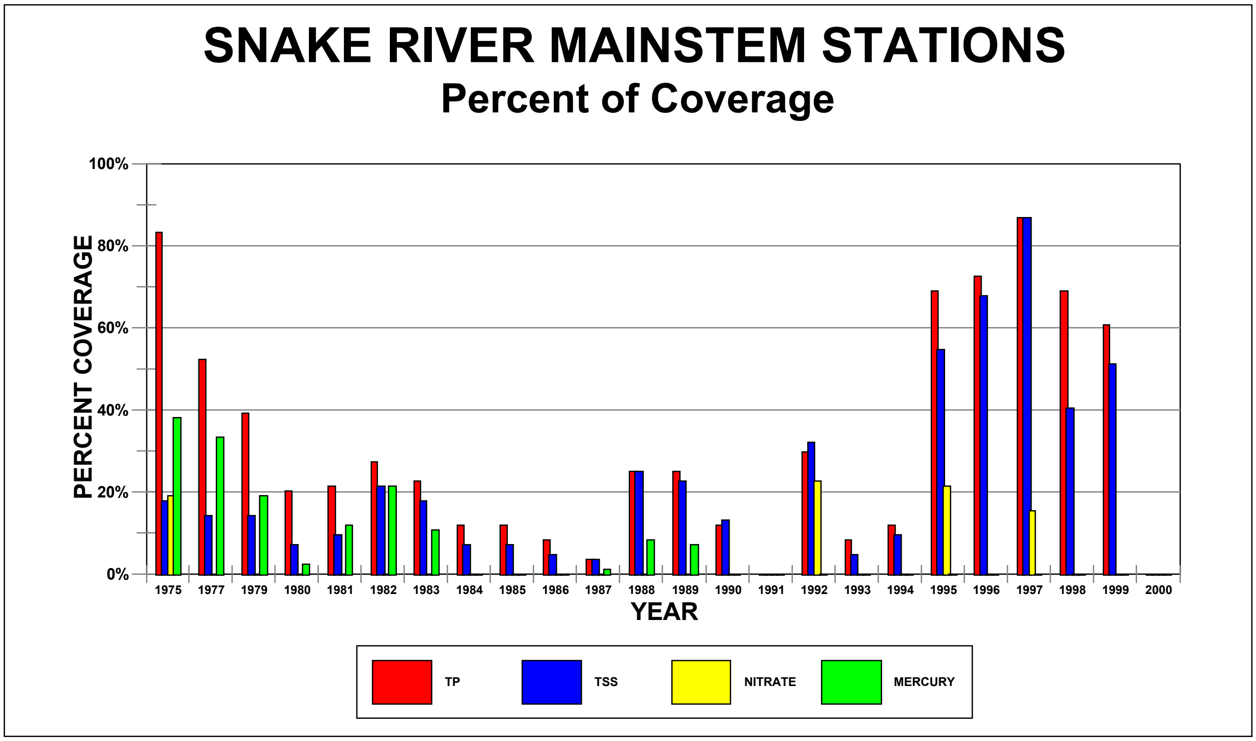


Figure 2-4. The comparison of percent coverage by year for four separate water quality parameters on the mainstem Snake River.

Table 2-5. A summary of available water quality data for the mainstem Snake River sites. A

100 percent coverage would be at least one data point per month representing each of the seven reaches. Data are for the period of record (1975-2000).

	Total Phosphorus	Orthophosphorus	Ammonia	Nitrate	Total Suspended Solids	Dissolved Oxygen	pH	Mercury
1975	83.3%	50.0%	65.5%	19.0%	17.9%	60.7%	60.7%	38.1%
1977	52.4%	0.0%	32.1%	0.0%	14.3%	50.0%	52.4%	33.3%
1979	39.3%	0.0%	39.3%	0.0%	14.3%	39.3%	39.3%	19.0%
1980	20.2%	1.2%	6.0%	0.0%	7.1%	20.2%	20.2%	2.4%
1981	21.4%	6.0%	19.0%	0.0%	9.5%	9.5%	21.4%	11.9%
1982	27.4%	28.6%	14.3%	0.0%	21.4%	28.6%	28.6%	21.4%
1983	22.6%	22.6%	10.7%	0.0%	17.9%	22.6%	22.6%	10.7%
1984	11.9%	11.9%	1.2%	0.0%	7.1%	11.9%	11.9%	0.0%
1985	11.9%	11.9%	2.4%	0.0%	7.1%	11.9%	11.9%	0.0%
1986	8.3%	8.3%	8.3%	0.0%	4.8%	8.3%	8.3%	0.0%
1987	3.6%	3.6%	3.6%	0.0%	3.6%	3.6%	3.6%	1.2%
1988	25.0%	25.0%	25.0%	0.0%	25.0%	25.0%	25.0%	8.3%
1989	25.0%	25.0%	25.0%	0.0%	22.6%	20.2%	20.2%	7.1%
1990	11.9%	15.5%	7.1%	0.0%	13.1%	15.5%	15.5%	0.0%
1991	0.0%	0.0%	0.0%	0.0%	0.0%	10.7%	0.0%	0.0%
1992	29.8%	29.8%	1.2%	22.6%	32.1%	63.1%	32.1%	0.0%
1993	8.3%	8.3%	0.0%	0.0%	4.8%	38.1%	0.0%	0.0%
1994	11.9%	11.9%	0.0%	0.0%	9.5%	42.9%	0.0%	0.0%
1995	69.0%	69.0%	11.9%	21.4%	54.8%	63.1%	29.8%	0.0%
1996	72.6%	72.6%	0.0%	0.0%	67.9%	34.5%	0.0%	0.0%
1997	86.9%	86.9%	13.1%	15.5%	86.9%	45.2%	15.5%	0.0%
1998	69.0%	69.0%	0.0%	0.0%	40.5%	40.5%	0.0%	0.0%
1999	60.7%	60.7%	0.0%	0.0%	51.2%	6.0%	0.0%	0.0%
2000	25.0%	25.0%	25.0%	0.0%	25.0%	25.0%	25.0%	0.0%

2.2 Data Summary by Years, Months, and Seasons

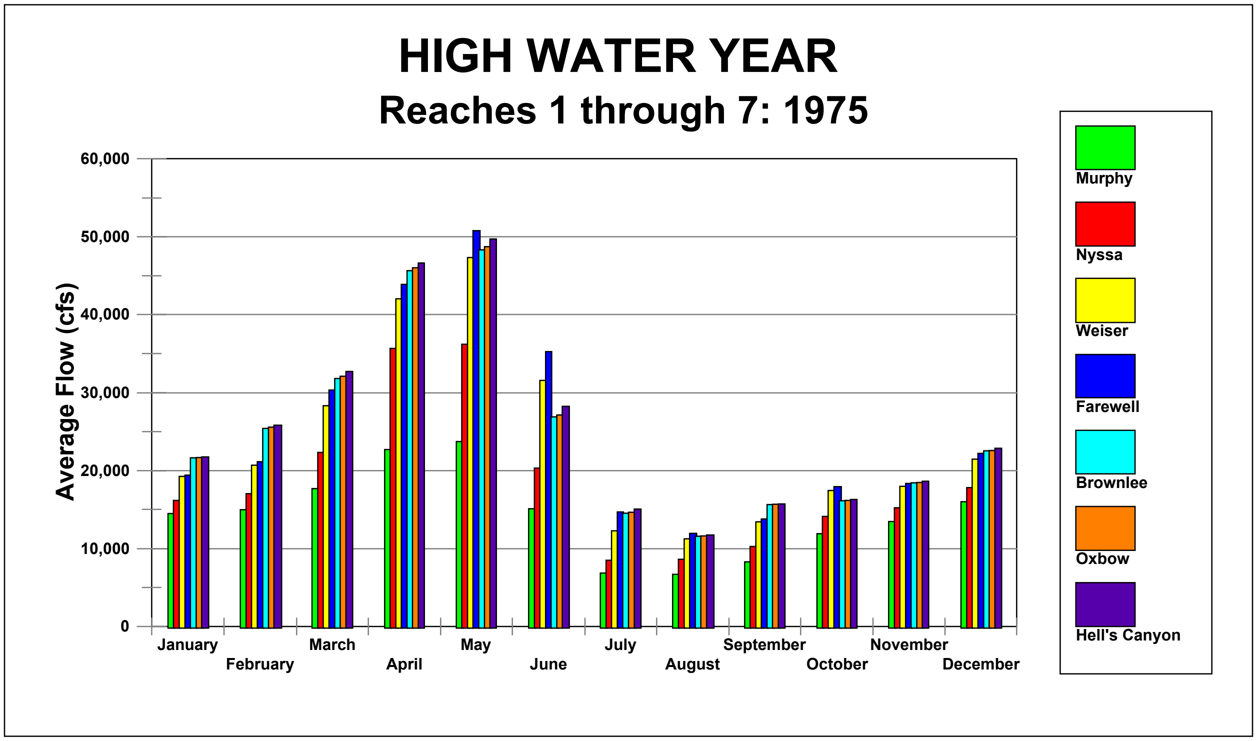
The following discussion focuses on the availability of flow and water quality data at locations along the Snake River between Murphy and Hells Canyon Dam. Subsections within this reach of the Snake River, were also investigated. In addition to the subreach analysis, the availability of data for the major watershed sources entering these subreaches (drains and tributaries) were also evaluated. The investigation centered on the availability of flow and target water quality parameters.

2.2.1 Hydrology

Within the study area of this investigation and the time frame selected (1975-1999), there were six major USGS gaging stations which have recorded daily flows or daily reservoir contents. These stations are: Snake River at Murphy (Station No. 13172500); Snake River at Weiser (Station No. 13269000); Snake River at Nyssa (Station No. 13213100); Brownlee Reservoir contents (Station No. 13289700); Snake River at Johnson Bar (Station No. 13290460); and Snake River at Hells Canyon Dam (Station No. 13290450). The Snake River at Johnson Bar covered the time period from 1993 to present and was not used in the analysis. The stations and period of records are described in Table 2-6.

As noted in a previous section, on average as much as 50 percent of the flows at Hells Canyon Dam are the result of gains in flows below Murphy from the watershed sources. These gains are the result of tributaries, groundwater, and agricultural drains. The majority of the tributary inflows are due to 11 major drainages which enter the Snake River at a variety of locations (Table 2-6). The availability of data from these sources was critical in conducting a loading analysis for the Snake River. The Owyhee, Weiser, and Payette rivers were the only tributaries which had data sets comparable to the five mainstem Snake River stations (1975-1999). Data were developed by correlation for the Boise River (two stations on that tributary with overlapping periods of record). The Wildhorse and Pine rivers had the next most complete data set, with flows missing for the late 1990s. Jump and Succor creeks had limited data. Information was available for the period 1988 to 1994. Powder and Burnt creeks had data only for 1975. Attempts to fill data gaps through regression analysis between similar drainages proved unsuccessful (except as previously noted for the Boise River).

As previously noted, the years between 1975 and 1999 were binned into wet, medium and dry years. Based upon the availability of tributary flows and water quality data (discussed in the next section), six years were selected to represent wet, dry, and medium periods. These years were: wet (1975 and 1997); medium (1979 and 1995); and dry (1977 and 1992). The flows in the Snake River at the end of each designated reach can be seen in Figure 2-5 (wet), Figure 2-6 (medium) and Figure 2-7 (dry). It should be noted that although there are only four USGS river gaging stations, seven river reaches were used in this analysis. Average monthly flow data for Brownlee Reservoir were obtained from Idaho Power Company for all six years. Farewell Bend and Oxbow Reservoir were calculated based on Brownlee Reservoir data and tributary inputs.



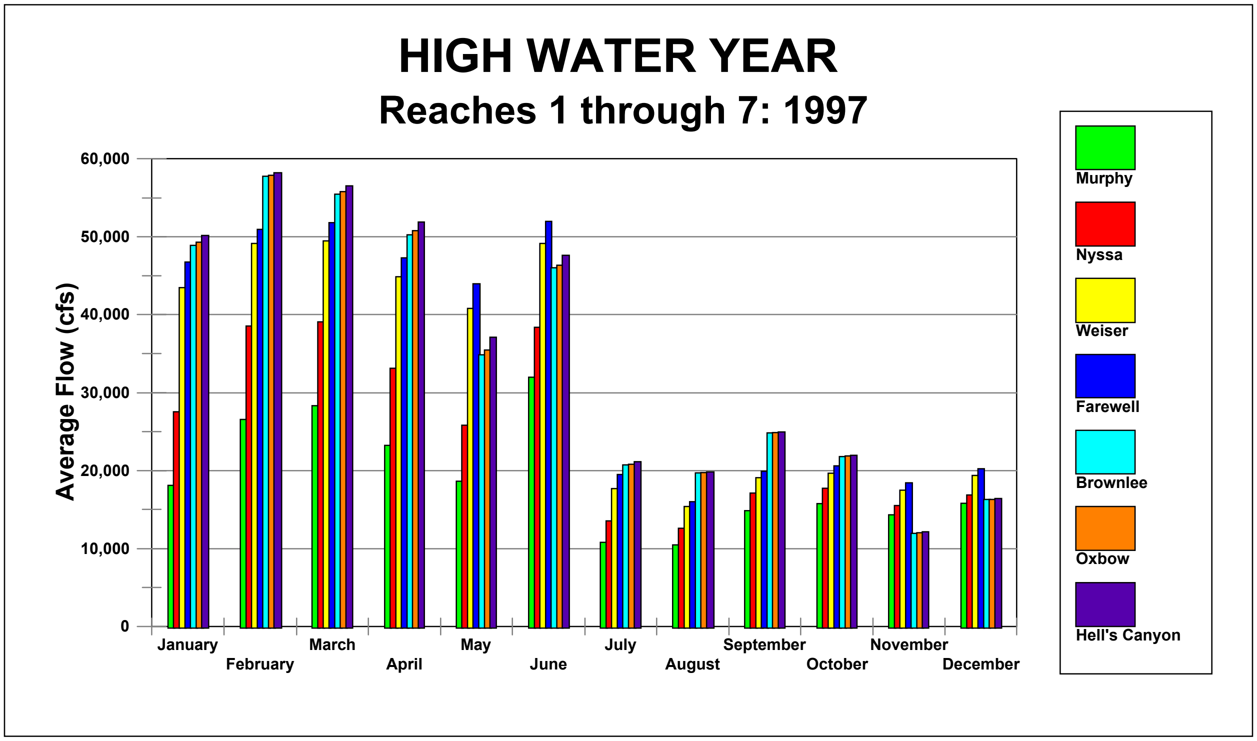
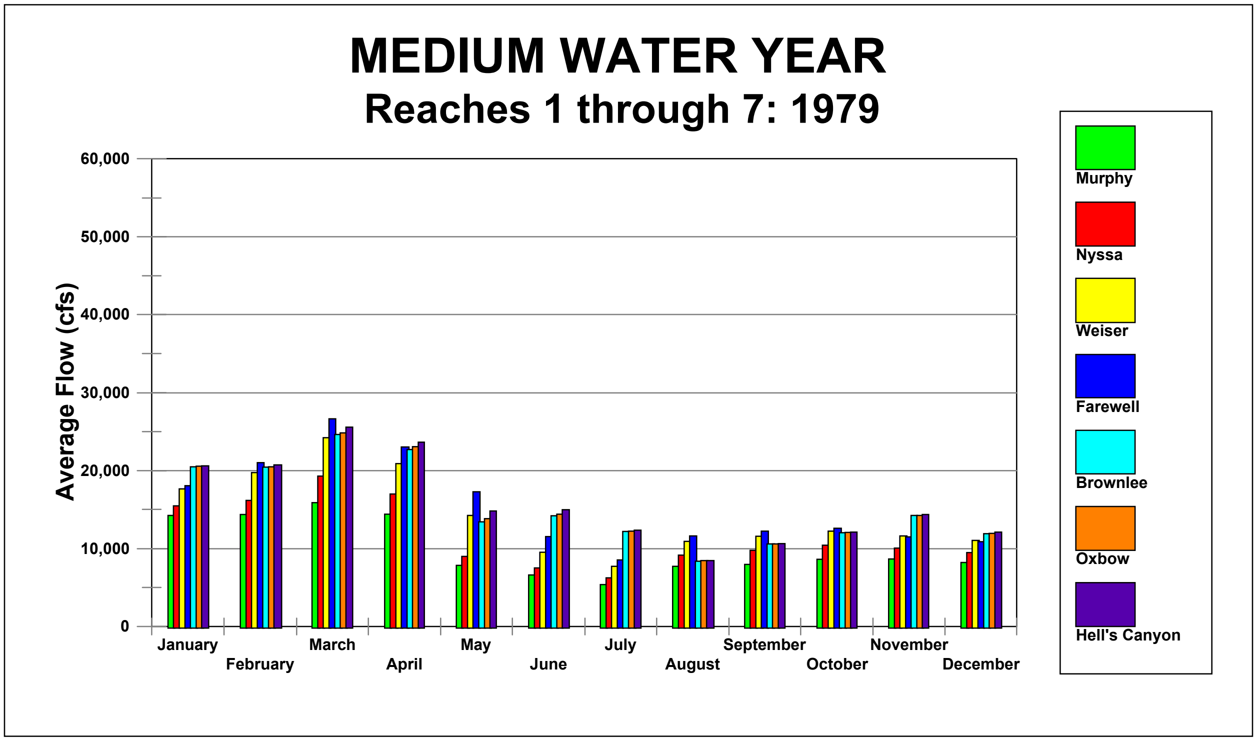


Figure 2-5. A comparison of flows by each individual reach in the study area for high water years, 1975 and 1997.



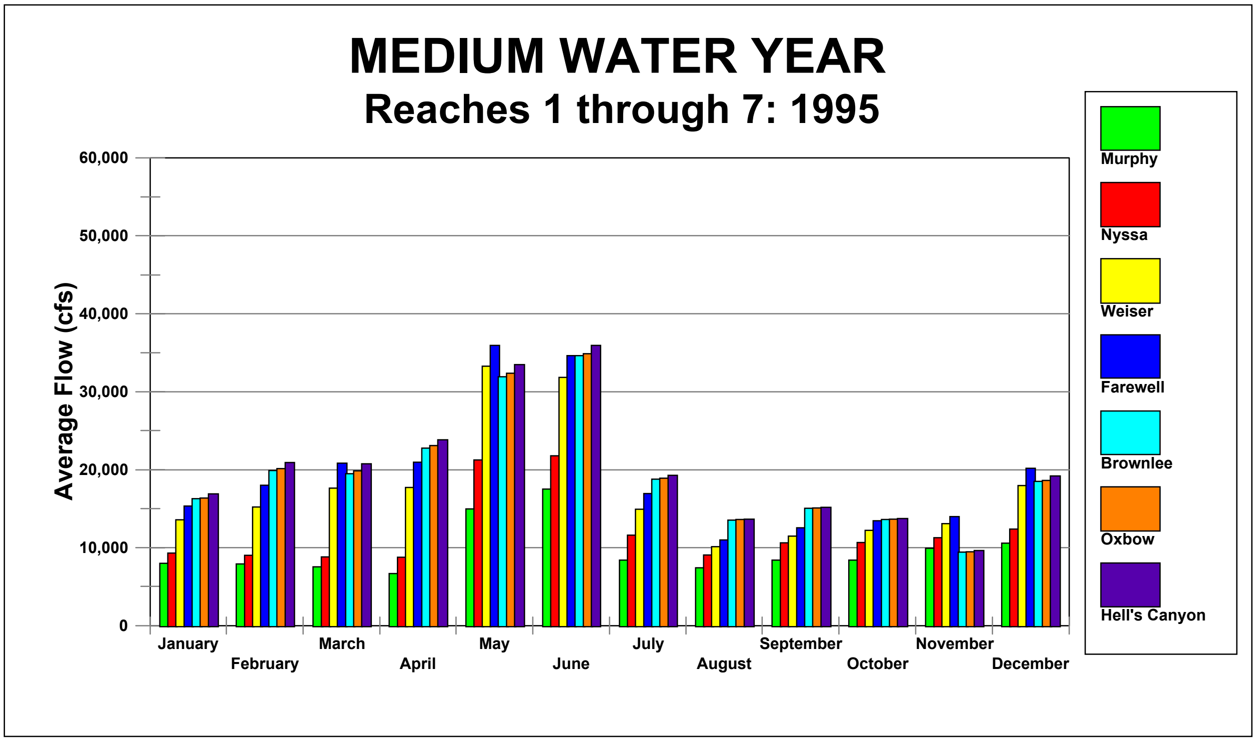
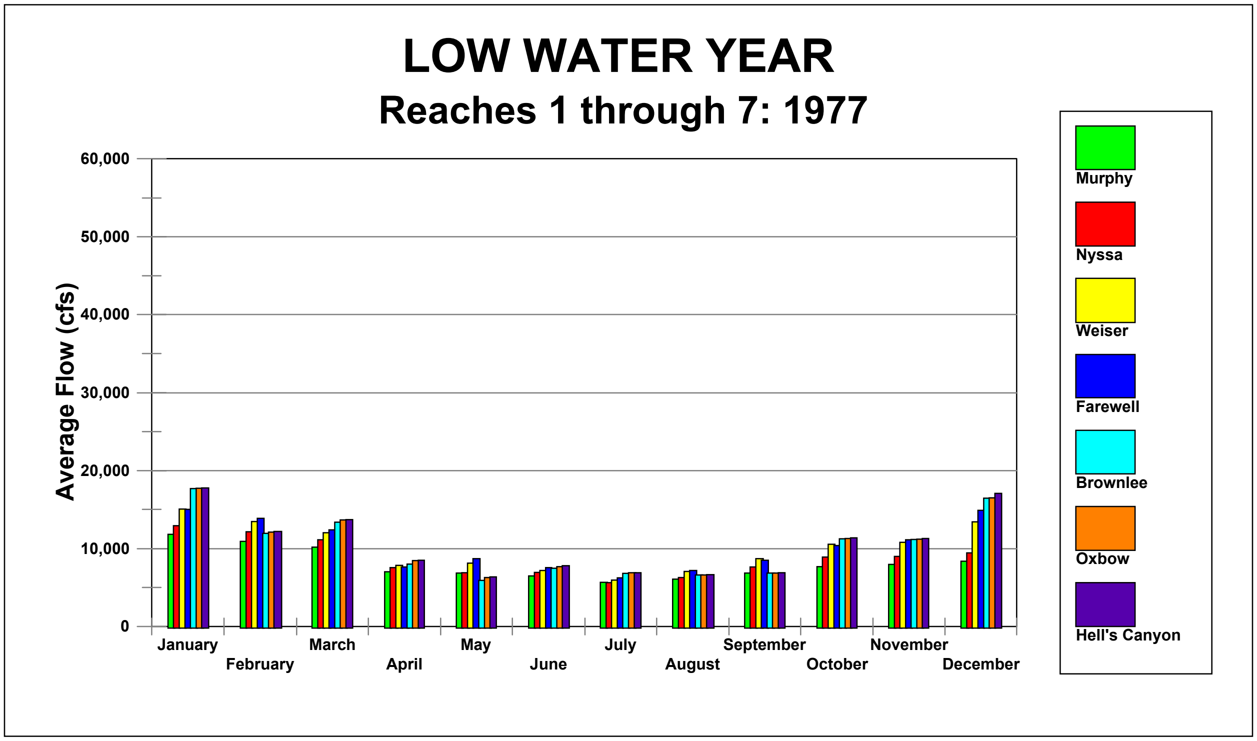


Figure 2-6. A comparison of flows by each individual reach in the study area for medium water years, 1979 and 1995.



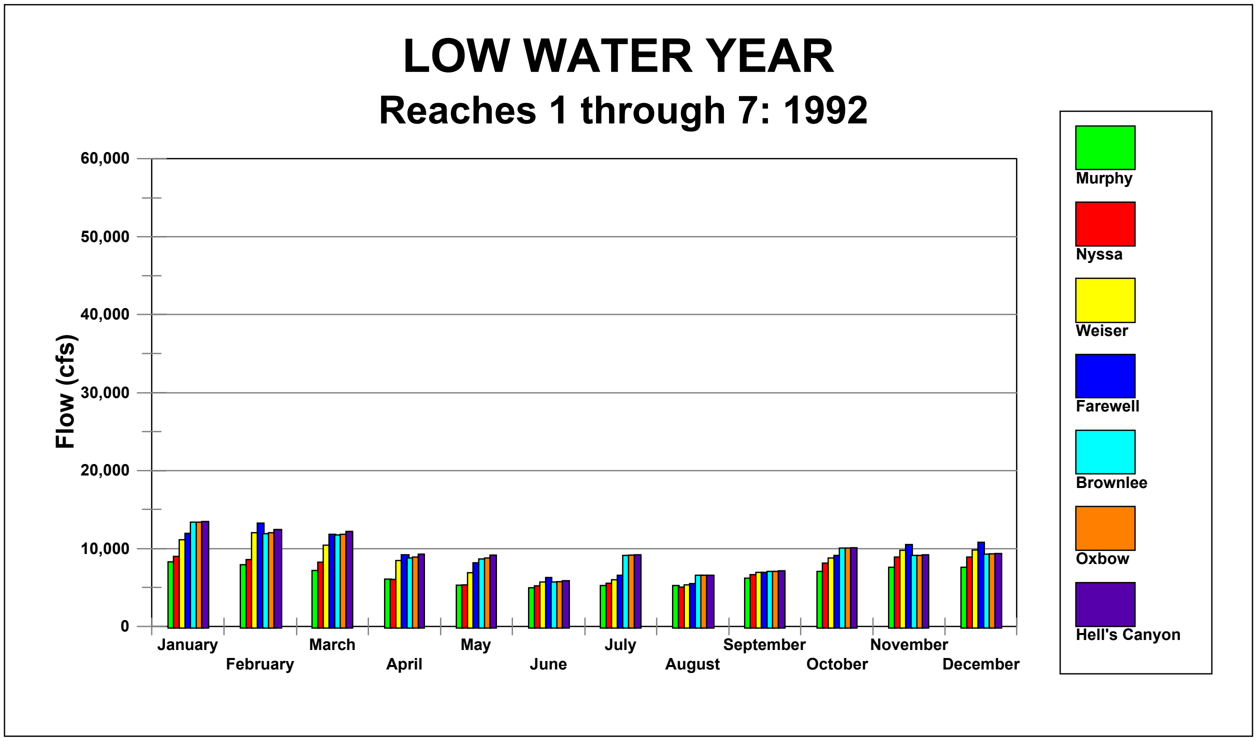


Figure 2-7. A comparison of flows by each individual reach in the study area for low water years, 1977 and 1992.

Table 2-6. A summary of the major gaging stations within the Snake River between Hells Canyon Dam (RM 426) and Murphy (RM247).

SITE	USGS GAGE NUMBER	RIVER MILE LOCATION	PERIOD OF RECORD	REACH
Snake River at Hells Canyon	13290450	247	1975-99	6,7
Pine Creek	13290190	270.3	1967-95	6
Snake River at Oxbow Dam	IPC	272	1975-99	5,6
Wildhorse	13289960	283	1979-95	5
Snake River at Brownlee Dam	IPC	285	1975-99	4,5
Powder River	13286700	296	1975	4
Burnt River	13273000	327	1975	4
Snake River at Farewell Bend	13269000	335		3,4
Snake River at Weiser	13269000	351	1975-99	2,3
Weiser River	13266000	351.8	1898-1998	2
Payette River	13251000	365.6	1936-99	2
Malheur River	13233300	368.5	1927-31; 1951-54; 1981; 1994-99	2
Pumping Stations	13172840	375	1989-99	2
Snake River at Nyssa	13213100	385	1975-99	1,2
Pumping Stations		395		1
Boise River	13213000	396.4	1971-97; 1983-99	1
Owyhee River	13181000	396.7	1950-99	1
Succor Creek	13173500	416	1904-09; 1988-93	1
Jump Creek	13172890	419	1988-94	1
Snake River at Murphy	13172500	426	1975-99	1

As the data from 1997 and 1975 (wet years) clearly shows, large reach gains occur between Murphy to Farewell Bend during the high flow period (January to June) when flows exceeding 30,000 cfs at the Hells Canyon Dam station. Although small reach gains occur between July and December, flows at all stations were greatly reduced with flows less than 20,000 cfs.

In 1979 and 1995 (medium years), the monthly temporal pattern was similar to the wet years, differing only in magnitude. In 1979, flows did not exceed 25,000 cfs at any station, reaching a peak during March. Baseflows (June through December) did not exceed 15,000 cfs. The companion year, (1995) had sightly higher flows in May and June and similar flows during the baseflow period. Reach gains in flow also occurred in the same location as noted in the wet years (Murphy to Farewell Bend).

For the two years representing dry years, flows between reaches remained relatively similar with only small reach gains. Only during the winter and early spring time periods did flows exceed 10,000 cfs. Flows at all sites were extremely low between June and September, rarely exceeding 7,500 cfs (Figure 2-7). For the mainstem sites for the six years selected there was 100 percent coverage for average daily flow expressed as a monthly average.

A complete summary of mainstem flows, reach gains in cubic feet per second, and reach gains as a percent of flows for each station for the six selected years is provided in Appendix I.

The availability of tributary hydrologic data for the same time period was not as complete. The percent coverage (at least one data point per month per tributary) ranged from 91.8 percent in 1992 to 62.3 percent in 1997. This data was for the 11 dominant tributaries noted in Table 2-6.

Utilizing the six selected years, an average daily flow for each month was calculated (based upon the available data) for both the mainstem Snake River and the 11 major tributaries. The results of this combination of flows can be seen in Table 2-7 (medium year), Table 2-8 (dry year) and Table 2-9 (wet year). In order to have a representative and complete tributary data set of the hydrology of the study reach, the two paired companion years were further averaged which allowed the combination of all available tributary data. These data are also shown in Tables 2-7 to 2-9. Developing an average wet, dry or medium flow year resulted in some data for all mainstem and tributary sites with the exception of Succor and Owyhee rivers in medium and wet years and the Malheur River during a dry year. The six years of flow data and the average for the three types of flows (i.e. medium year) were used for calculating mass loadings for the same hydrologic conditions.

2.2.2 Water Quality

The amount of water quality data for the mainstem Snake River and its tributaries varied by year, location and parameter. In order to gain an understanding as to the temporal and spatial dynamics occurring in the system, a variety of approaches in the analysis of the data were used. The first approach was to determine the spatial and temporal distribution of all of the available data between 1975 and 2000, expressed as monthly averages. This data is presented in Figures 2-8, 2-9, and 2-10 for total phosphorous, orthophosphate, and total suspended solids. These parameters had the highest coverage when considering year and location. Inspection of this information indicates that there has not been a discernable trend in the concentrations of these three parameters since 1975.

Utilizing the results from binning the years into wet, medium, and dry years between 1975 and 1999 (Table 2-3), average annual concentration of total phosphorous (Figure 2-11), orthophosphorus (Figure 2-12), and total suspended solids (Figure 2-13) were compared for different stations on the Snake River between Murphy (RM 426) and Hells Canyon Dam (RM 247). For all three parameters there were only isolated differences between the three different flow scenarios. Each parameter demonstrated the same spatial pattern regardless of overall annual discharge. Total phosphorus did not appear to change with distance downstream, while orthophosphorus concentrations increased steadily with movement downstream. The exception was in the high flow period, where concentrations peaked at Farewell Bend.

Table 2-7. The average daily flows, expressed as cfs, for each month in the medium flow years, 1979 and 1995. Calculated flows for the medium year are also provided.

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1979																				
Jan	14255	ND	ND	804	778	0	15471	ND	1778	153	0	17629	18049	2	123	20504	24	20529	52	20581
Feb	14361	ND	ND	1120	1243	0	16189	ND	2418	698	0	19732	21037	8	403	20461	55	20516	242	20757
Mar	15926	ND	ND	3170	714	0	19265	ND	2755	2374	0	24226	26658	50	697	24609	230	24838	742	25581
Apr	14413	ND	ND	2611	587	-55	16967	ND	2604	1509	-25	20860	23015	220	483	22713	363	23076	574	23650
May	7821	ND	ND	2137	441	-171	9019	ND	3141	2036	-80	14248	17266	229	550	13395	466	13861	952	14814
Jun	6595	ND	ND	607	492	-252	7518	ND	1656	730	-118	9527	11527	130	229	14216	202	14418	555	14973
Jul	5418	ND	ND	274	497	-278	6234	ND	1494	282	-130	7722	8531	100	47	12190	53	12243	74	12317
Aug	7724	ND	ND	199	665	-198	9125	ND	1807	219	-93	10920	11640	109	52	8404	27	8431	33	8464
Sep	7955	ND	ND	134	712	-136	9754	ND	1687	146	-64	11603	12262	85	55	10598	20	10618	30	10649
Oct	8621	ND	ND	141	929	-49	10435	ND	1758	155	-23	12261	12641	12	47	12006	26	12033	64	12097
Nov	8681	ND	ND	178	916	0	10027	ND	1260	142	0	11637	11507	1	50	14246	28	14274	92	14366
Dec	8223	ND	ND	202	812	0	9464	ND	1169	326	0	11019	10898	3	57	11938	38	11977	127	12104
1995																				
Jan	7982	ND	ND	776	758	0	9300	227	1843	1908	ND	13545	15335	6	151	16278	97	16375	534	16909
Feb	7910	ND	ND	3430	743	0	8989	383	2957	2674	ND	15179	18032	7	413	19909	214	20123	805	20929
Mar	7561	ND	ND	2211	694	0	8802	291	4659	3680	ND	17652	20846	186	480	19480	356	19836	877	20713
Apr	6669	ND	ND	1215	1606	-123	8777	293	6098	2538	ND	17727	20956	315	445	22738	330	23068	745	23813
May	14952	ND	ND	4545	4551	-182	21229	248	9382	3269	ND	33255	35947	191	497	31897	495	32392	1117	33510
Jun	17500	ND	ND	1021	2591	-252	21760	105	8990	1785	ND	31847	34644	105	346	34610	262	34872	1048	35920
Jul	8415	ND	ND	272	2369	-258	11568	129	2655	469	ND	14918	16958	81	58	18763	125	18889	397	19286
Aug	7400	ND	ND	148	1028	-244	9075	108	485	301	ND	10112	10996	116	40	13533	54	13586	70	13657
Sep	8413	ND	ND	142	1070	-212	10582	153	676	250	ND	11517	12544	72	48	15075	35	15110	50	15160
Oct	8416	ND	ND	148	1099	-101	10672	150	1244	223	ND	12216	13446	10	44	13624	40	13664	100	13764
Nov	9920	ND	ND	172	989	0	11243	141	1709	251	ND	13073	13984	16	54	9420	49	9468	161	9629
Dec	10541	ND	ND	396	1668	0	12384	140	4374	1132	ND	17945	20175	63	374	18483	129	18612	567	19179
Medium Year Flows (average of 1979 and 1995)																				
Jan	11118	ND	ND	790	768	0	12385	114	1810	1031	0	15587	16692	4	137	18391	61	18452	293	18745
Feb	11135	ND	ND	2275	993	0	12589	191	2688	1686	0	17455	19534	8	408	20185	134	20319	523	20843
Mar	11743	ND	ND	2690	704	0	14033	145	3707	3027	0	20939	23752	118	588	22045	293	22337	809	23147
Apr	10541	ND	ND	1913	1097	-89	12872	146	4351	2023	-13	19293	21986	268	464	22725	347	23072	660	23732
May	11386	ND	ND	3341	2496	-177	15124	124	6261	2652	-40	23752	26606	210	524	22646	480	23127	1035	24162
Jun	12047	ND	ND	814	1542	-252	14639	53	5323	1257	-59	20687	23085	118	288	24413	232	24645	802	25447
Jul	6916	ND	ND	273	1433	-268	8901	65	2075	375	-65	11320	12744	90	53	15477	89	15566	236	15801
Aug	7562	ND	ND	173	847	-221	9100	54	1146	260	-47	10516	11318	113	46	10968	40	11009	52	11060
Sep	8184	ND	ND	138	891	-174	10168	77	1181	198	-32	11560	12403	79	51	12837	28	12864	40	12904
Oct	8519	ND	ND	145	1014	-75	10553	75	1501	189	-12	12239	13043	11	46	12815	33	12849	82	12931
Nov	9301	ND	ND	175	952	0	10635	71	1484	197	0	12355	12745	9	52	11833	38	11871	126	11998
Dec	9382	ND	ND	299	1240	0	10924	70	2772	729	0	14482	15536	33	216	15211	84	15295	347	15641

Table 2-8. The average daily flows, expressed as cfs, for each month in the dry flow years, 1977 and 1992. Calculated flows for the dry year are also provided.

	Murphy						Nyssa					Weiser	Farewell			Brownlee		Oxbow		Hells
		Jump	Succor	Owyhee	Boise	Pumps		Malheur	Payette	Weiser	Pumps			Burnt	Powder		Wildhorse		Pine	
1977																				
Jan	11829	ND	ND	167	782	0	12955	ND	1700	149	0	15055	15024	3	73	17674	68	17742	58	17800
Feb	10953	ND	ND	202	686	0	12146	ND	1277	166	0	13471	13909	2	86	11982	128	12110	66	12176
Mar	10194	ND	ND	234	592	0	11135	ND	939	136	0	11999	12392	2	132	13351	280	13631	69	13700
Apr	7046	ND	ND	311	219	-146	7556	ND	421	174	-69	7812	7649	20	38	8035	386	8421	65	8486
May	6848	ND	ND	208	440	-177	6882	ND	564	182	-83	8105	8735	105	23	5905	402	6307	94	6401
Jun	6495	ND	ND	262	315	-230	6931	ND	397	183	-108	7168	7553	60	24	7469	242	7711	67	7779
Jul	5657	ND	ND	96	305	-257	5634	ND	311	104	-120	5946	6222	81	9	6807	73	6880	21	6901
Aug	6107	ND	ND	109	339	-187	6270	ND	396	62	-88	7076	7174	47	20	6605	32	6637	14	6651
Sep	6835	ND	ND	95	556	-116	7631	ND	591	46	-54	8733	8514	0	16	6833	27	6860	27	6887
Oct	7702	ND	ND	122	751	-29	8922	ND	945	120	-13	10564	10380	0	17	11274	29	11303	40	11343
Nov	7963	ND	ND	141	780	0	9017	ND	1185	149	0	10775	11101	0	25	11152	37	11189	101	11289
Dec	8401	ND	ND	248	782	0	9416	ND	2555	1226	0	13400	14911	2	100	16472	57	16529	526	17055
1992								**												
Jan	8283	17	16	172	656	0	8985	116	1920	187	0	11135	11973	6	92	13355	26	13381	104	13486
Feb	7912	13	16	436	658	0	8562	129	1968	1447	0	12024	13259	8	214	11903	116	12019	405	12424
Mar	7172	11	11	272	506	-17	8244	116	2089	802	0	10414	11805	43	230	11707	124	11831	385	12216
Apr	6093	45	8	145	244	-463	6033	36	1392	845	-182	8442	9203	43	69	8783	132	8915	365	9280
May	5285	47	12	87	276	-510	5367	146	997	607	-285	6898	8143	139	28	8679	102	8781	354	9136
Jun	4971	56	9	90	316	-502	5223	63	613	207	-302	5745	6283	100	38	5712	39	5751	117	5868
Jul	5274	46	7	73	282	-440	5546	66	689	170	-319	6002	6589	63	36	9110	22	9131	58	9189
Aug	5266	33	5	56	187	-495	5075	63	369	107	-346	5348	5509	114	5	6550	8	6558	24	6583
Sep	6177	55	6	70	184	-482	6664	58	490	75	-178	6934	6960	7	4	7095	11	7105	25	7131
Oct	7086	35	9	91	423	-185	8102	41	784	73	0	8763	9110	2	17	10037	14	10051	33	10085
Nov	7579	19	8	127	633	0	8924	37	1187	128	0	9768	10491	2	19	9096	24	9120	73	9193
Dec	7601	15	5	145	606	0	8902	118	1618	140	0	9810	10809	4	16	9296	24	9320	71	9391
Dry Year Flows (average of 1977 and 1992)																				
Jan	10056	8	8	169	719	0	10970	ND	1810	168	0	13095	13498	4	82	15515	47	15562	81	15643
Feb	9433	6	8	319	672	0	10354	ND	1623	806	0	12748	13584	5	150	11943	122	12065	235	12300
Mar	8683	5	6	253	549	-8	9690	ND	1514	469	0	11206	12098	23	181	12529	202	12731	227	12958
Apr	6570	23	4	228	231	-305	6794	ND	907	509	-126	8127	8426	31	53	8409	259	8668	215	8883
May	6067	24	6	147	358	-344	6125	ND	780	395	-184	7501	8439	122	25	7292	252	7544	224	7769
Jun	5733	28	4	176	315	-366	6077	ND	505	195	-205	6457	6918	80	31	6591	141	6731	92	6823
Jul	5465	23	4	84	294	-348	5590	ND	500	137	-220	5974	6405	72	22	7958	47	8006	39	8045
Aug	5687	17	3	82	263	-341	5673	ND	382	84	-217	6212	6342	80	12	6578	20	6598	19	6617
Sep	6506	28	3	82	370	-299	7148	ND	541	60	-116	7834	7737	4	10	6964	19	6983	26	7009
Oct	7394	18	4	107	587	-107	8512	ND	865	97	-7	9664	9745	1	17	10656	21	10677	37	10714
Nov	7771	9	4	134	707	0	8971	ND	1186	138	0	10271	10796	1	22	10124	30	10154	87	10241
Dec	8001	8	3	196	694	0	9159	ND	2086	683	0	11605	12860	3	58	12884	40	12924	299	13223

***U.S. BOR 2000*

Table 2-9. The average daily flows, expressed as cfs, for each month in the wet flow years, 1975 and 1997. Calculated flows for the wet year are also provided.

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1975																				
Jan	14503	ND	ND	221	942	0	16161	ND	2078	222	0	19232	19424	29	105	21604	68	21672	112	21783
Feb	14982	ND	ND	530	967	0	17007	ND	2295	722	0	20668	21166	48	242	25439	128	25567	232	25799
Mar	17690	ND	ND	2983	2711	0	22335	ND	3717	2975	0	28335	30343	122	774	31823	280	32103	611	32714
Apr	22697	ND	ND	3701	6780	-27	35663	ND	4222	2201	-13	42050	43883	256	712	45656	386	46042	592	46634
May	23752	ND	ND	6736	6225	-98	36197	ND	7168	3515	-47	47345	50753	484	1095	48325	402	48727	994	49721
Jun	15128	ND	ND	2726	2492	-244	20293	ND	7643	2686	-118	31557	35296	158	830	26868	242	27110	1152	28262
Jul	6861	ND	ND	652	797	-276	8508	ND	3053	687	-133	12293	14693	131	290	14547	73	14620	419	15038
Aug	6723	ND	ND	247	912	-216	8624	ND	1853	354	-104	11245	11977	128	69	11603	32	11635	77	11712
Sep	8311	ND	ND	192	937	-187	10296	ND	1993	255	-91	13433	13793	128	71	15625	27	15652	57	15708
Oct	11897	ND	ND	442	1293	-57	14129	ND	1931	315	-28	17474	17939	25	73	16134	29	16163	95	16258
Nov	13470	ND	ND	392	1118	0	15257	ND	1690	341	0	17957	18325	8	91	18459	37	18496	123	18619
Dec	16016	ND	ND	801	1049	0	17803	ND	2644	720	0	21481	22170	17	214	22528	57	22585	241	22826
1997																				
Jan	18113	ND	ND	3668	6882	0	27532	1589	9545	4760	ND	43481	46790	ND	ND	48904	419	49323	832	50155
Feb	26536	ND	ND	1638	7916	0	38579	1322	7398	1717	ND	49104	50924	ND	ND	57757	142	57898	327	58225
Mar	28352	ND	ND	3660	7466	-11	39065	422	7342	2507	ND	49429	51789	ND	ND	55469	313	55782	766	56548
Apr	23207	ND	ND	2942	6835	-175	33130	460	7730	2676	ND	44833	47292	ND	ND	50265	514	50779	1084	51863
May	18645	ND	ND	2220	5255	-215	25781	209	11372	2874	ND	40806	43966	ND	ND	34839	647	35487	1620	37106
Jun	31977	ND	ND	839	3938	-248	38387	165	10307	1344	ND	49137	51983	ND	ND	46034	325	46359	1271	47630
Jul	10778	ND	ND	259	1364	-269	13542	149	2633	404	ND	17694	19496	ND	ND	20748	79	20828	334	21161
Aug	10480	ND	ND	168	1532	-267	12622	140	1590	309	ND	15406	16013	ND	ND	19721	38	19759	99	19858
Sep	14873	ND	ND	155	1464	-163	17113	193	798	269	ND	19070	19893	ND	ND	24827	29	24856	104	24960
Oct	15768	ND	ND	175	1272	-78	17735	174	1111	224	ND	19668	20580	ND	ND	21813	27	21840	105	21945
Nov	14299	ND	ND	199	1113	0	15547	159	1610	218	ND	17490	18413	ND	ND	11970	31	12001	126	12127
Dec	15787	ND	ND	195	1101	0	16887	140	1990	217	ND	19397	20217	ND	ND	16265	25	16290	110	16400
Wet Year Flows (average of 1975 and 1997)																				
Jan	16308	ND	ND	1945	3912	0	21847	794	5811	2491	0	31356	33107	14	52	35254	243	35497	472	35969
Feb	20759	ND	ND	1084	4442	0	27793	661	4846	1219	0	34886	36045	24	121	41598	135	41733	279	42012
Mar	23021	ND	ND	3322	5089	-5	30700	211	5529	2741	0	38882	41066	61	387	43646	297	43943	689	44631
Apr	22952	ND	ND	3322	6807	-101	34397	230	5976	2438	-7	43442	45588	128	356	47961	450	48411	838	49249
May	21198	ND	ND	4478	5740	-156	30989	104	9270	3194	-24	44076	47360	242	548	41582	525	42107	1307	43414
Jun	23552	ND	ND	1782	3215	-246	29340	82	8975	2015	-59	40347	43640	79	415	36451	284	36735	1211	37946
Jul	8820	ND	ND	455	1081	-273	11025	74	2843	545	-67	14993	17094	65	145	17647	76	17724	376	18100
Aug	8601	ND	ND	208	1222	-241	10623	70	1721	332	-52	13326	13995	64	35	15662	35	15697	88	15785
Sep	11592	ND	ND	174	1200	-175	13705	97	1395	262	-46	16252	16843	64	35	20226	28	20254	80	20334
Oct	13832	ND	ND	309	1283	-68	15932	87	1521	269	-14	18571	19260	13	37	18974	28	19001	100	19101
Nov	13884	ND	ND	295	1115	0	15402	79	1650	280	0	17723	18369	4	45	15215	34	15249	124	15373
Dec	15902	ND	ND	498	1075	0	17345	70	2317	469	0	20439	21194	8	107	19397	41	19437	176	19613

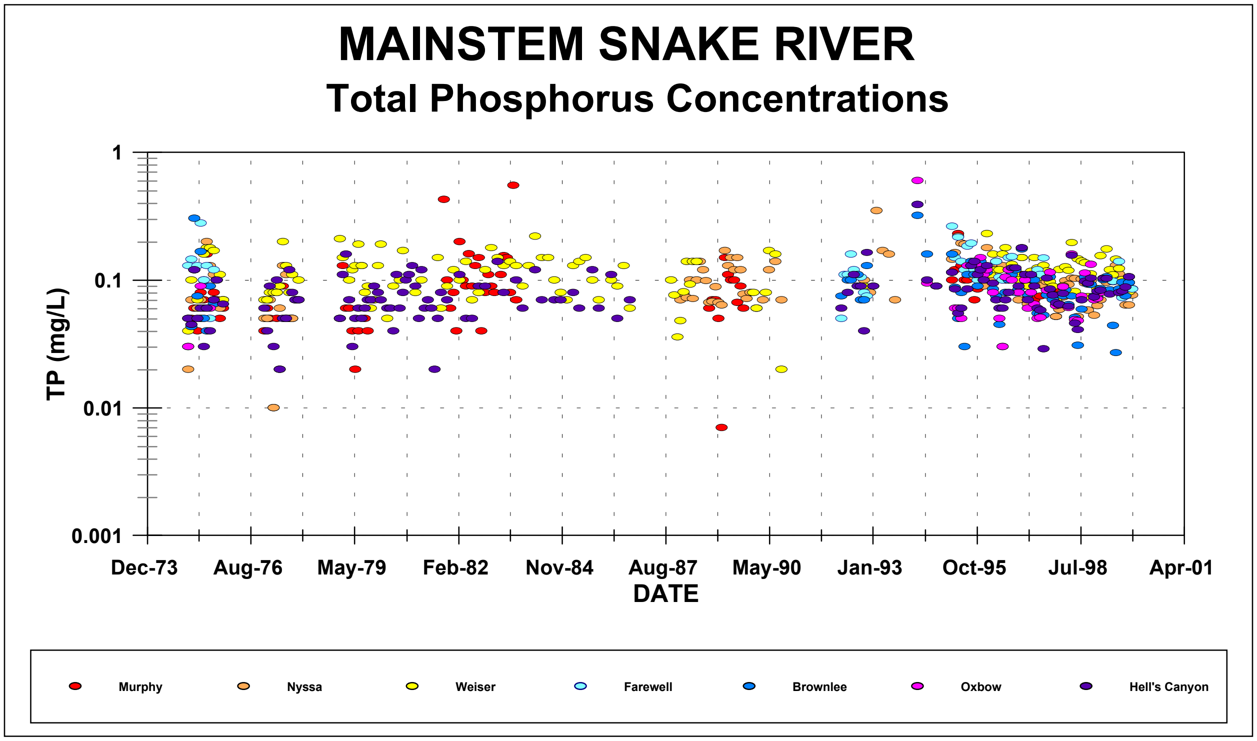


Figure 2-8. The average monthly total phosphorus concentrations at selected sites in the Snake River since 1975.

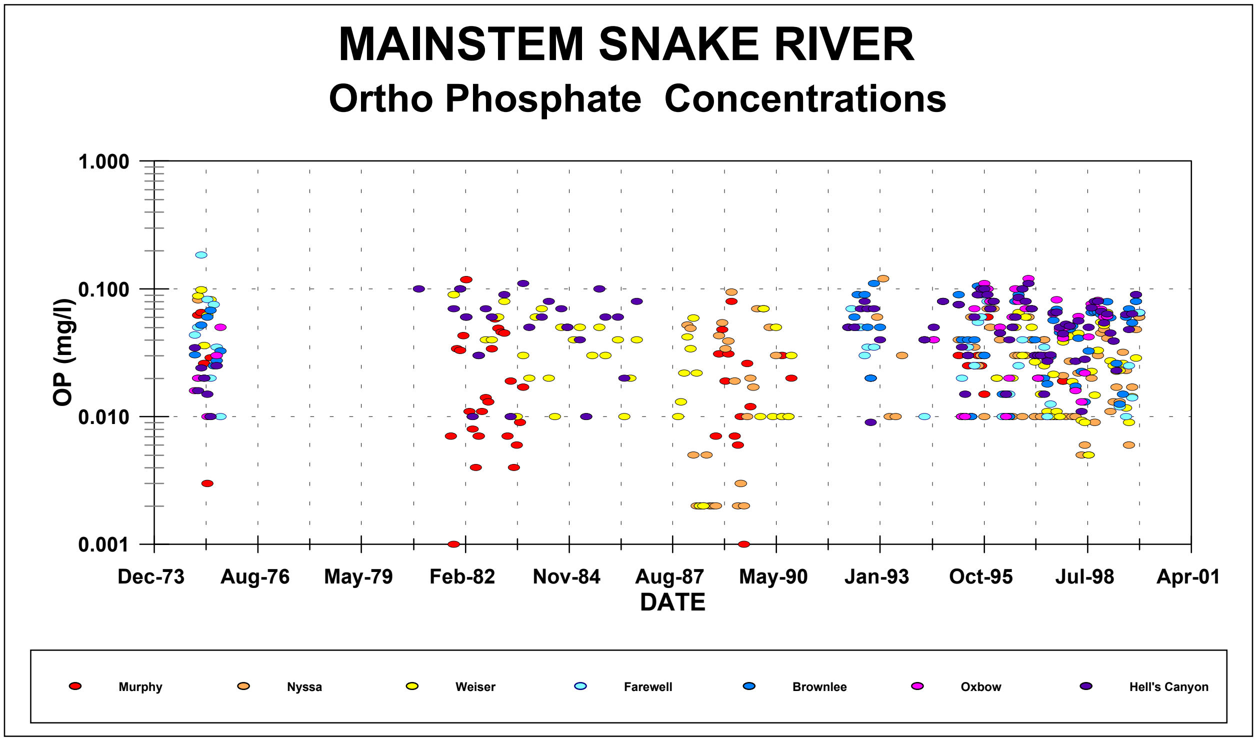


Figure 2-9. The average monthly ortho phosphate concentrations at selected sites in the Snake River since 1975.

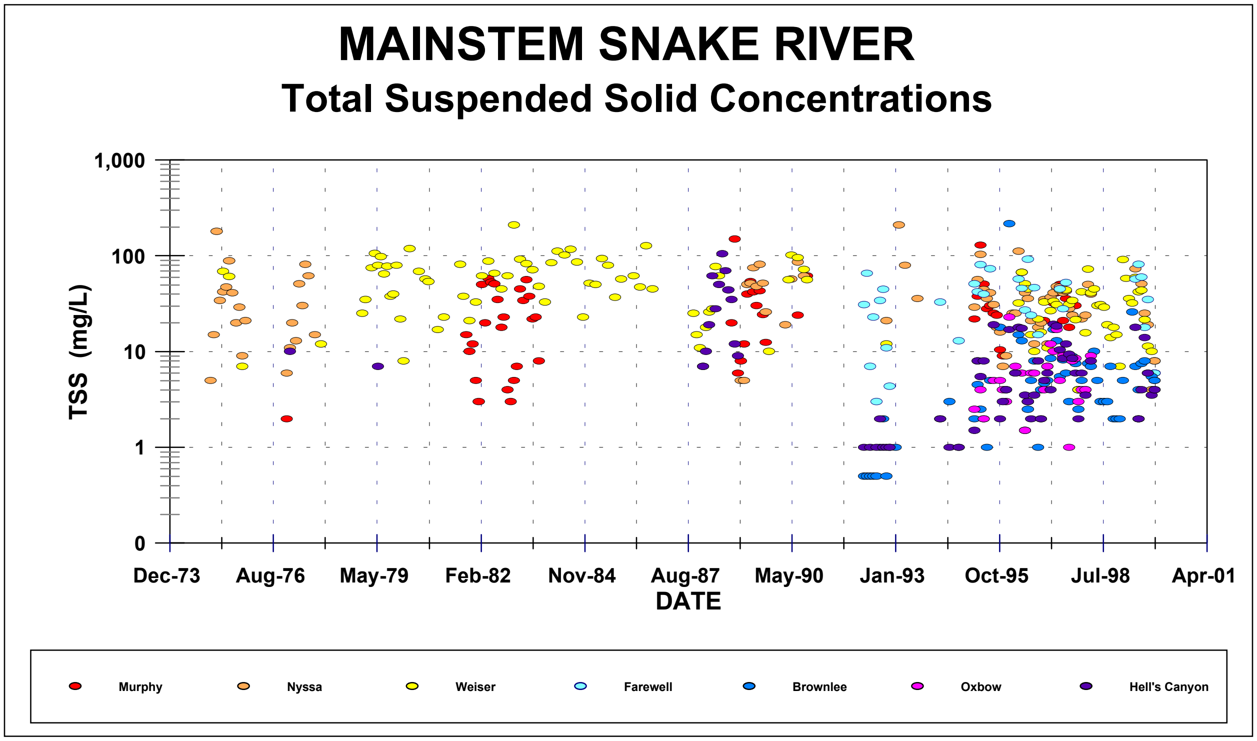


Figure 2-10. The average monthly total suspended solids concentrations at selected sites in the Snake River since 1975.

Total suspended solids increased from Murphy to Weiser for all three flow scenarios. Between Weiser and Brownlee, the concentrations drastically decreased from 40 mg/l to less than 10 mg/l. Average concentrations for each flow scenario and Snake River station are provided in Appendix II.

Using the data from the same binned years noted above, average monthly concentrations for the three water quality parameters were calculated and plotted as a function of time and flow scenario (Figures 2-14, 2-15, and 2-16). The trends noted above held true for the average monthly concentrations. There did not appear to be significant differences in concentrations of the three target parameters between the various flow scenarios. Except for two months (Figure 2-14), the concentration of total phosphorous appeared to be unchanged throughout the year, with an overall average for all stations and flows of 0.98 to 1.04 mg/l. Orthophosphorous appeared to have a seasonal pattern just the opposite of total suspended solids, with high concentrations in the fall and winter periods and low concentrations in the spring and summer (Figure 2-15). Total suspended solids peaked in the spring and summer, with lower concentrations observed in the fall and winter. This may explain the lack of a seasonal pattern for total phosphorous because total phosphorus is composed of a particulate and a dissolved fraction.

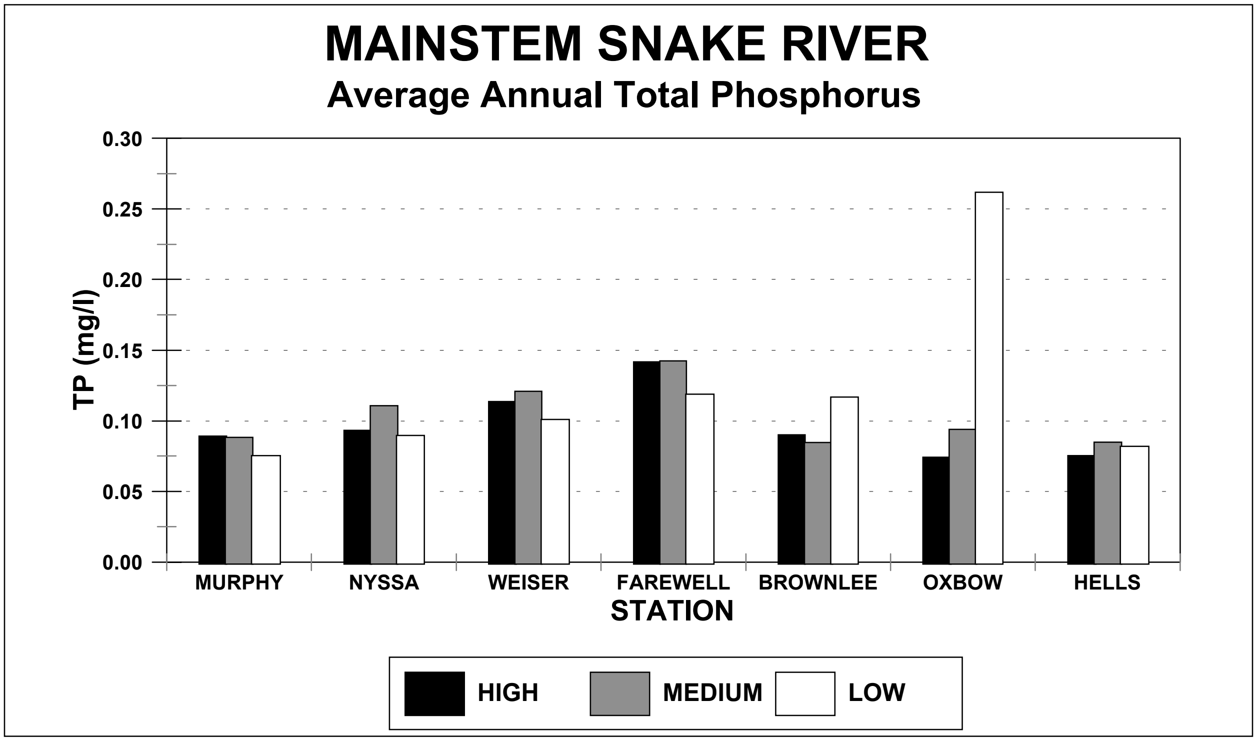


Figure 2-11. The average annual concentration of total phosphorus at selected stations in the Snake River for high, medium and low water years.

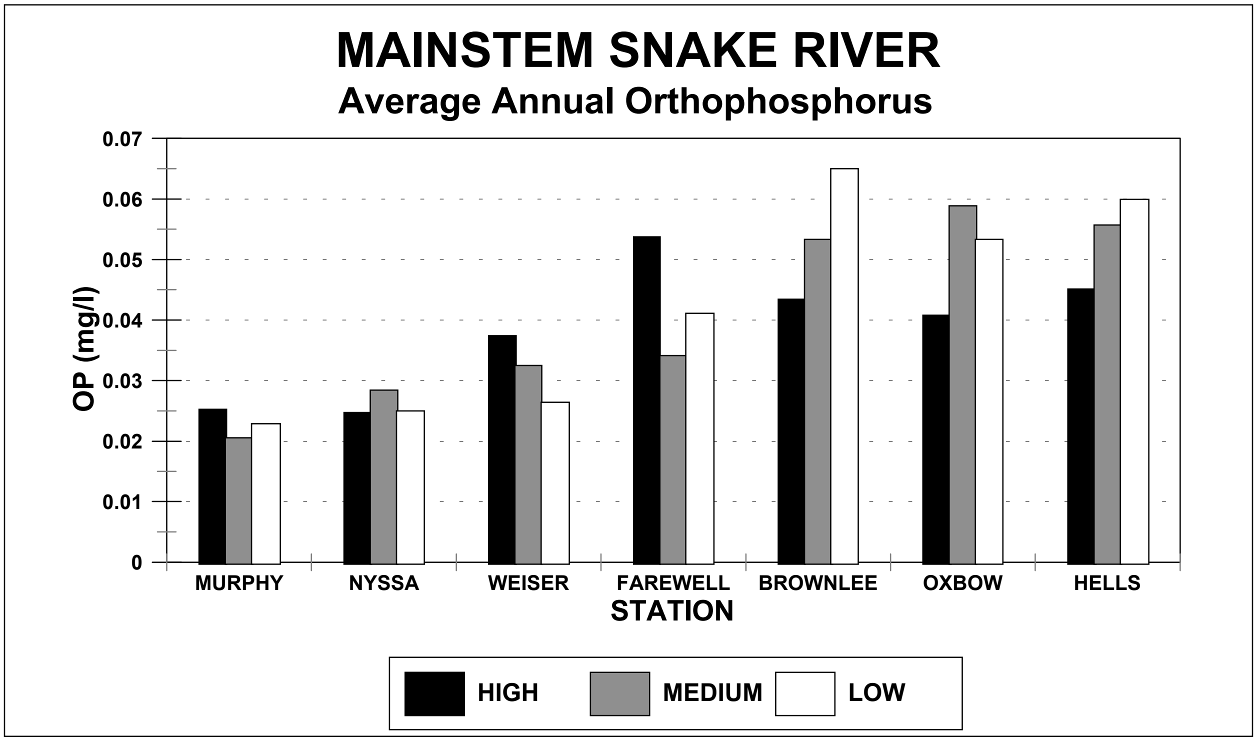


Figure 2-12. The average annual concentration of orthophosphorus at selected stations in the Snake River for high, medium and low water years.

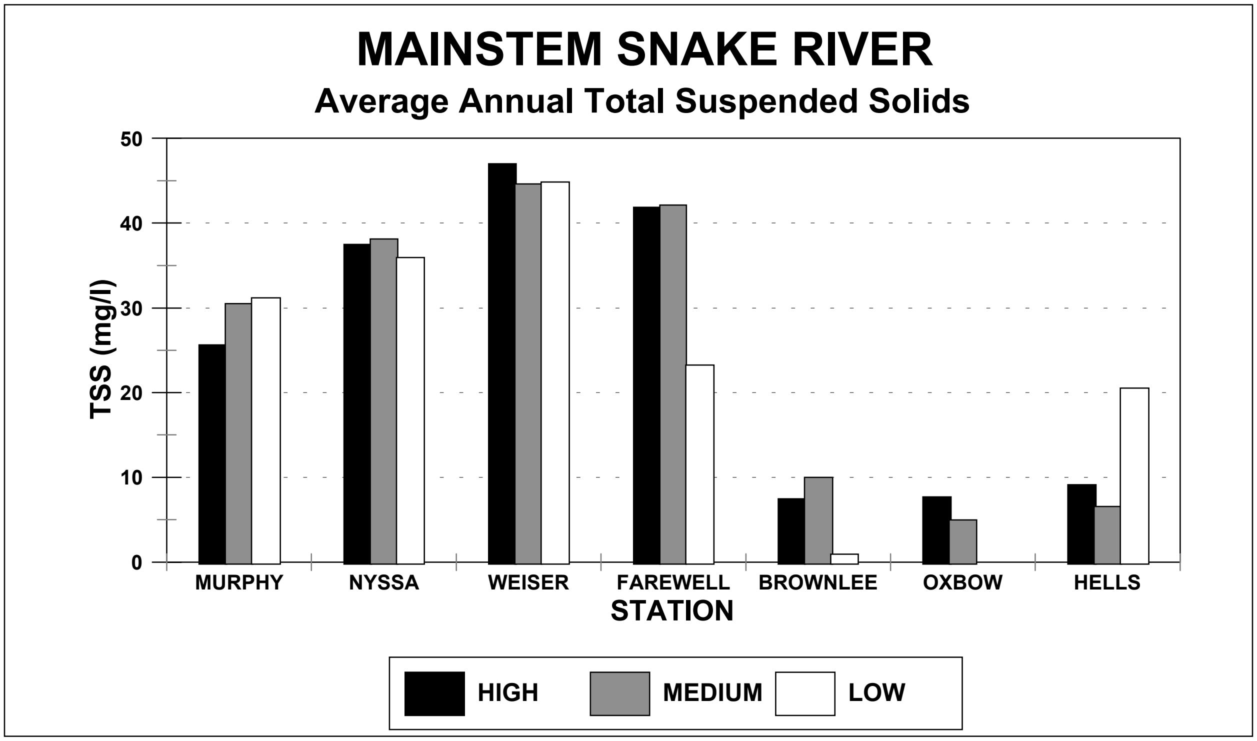


Figure 2-13. The average annual concentration of total suspended solids at selected stations in the Snake River for high, medium and low water years.

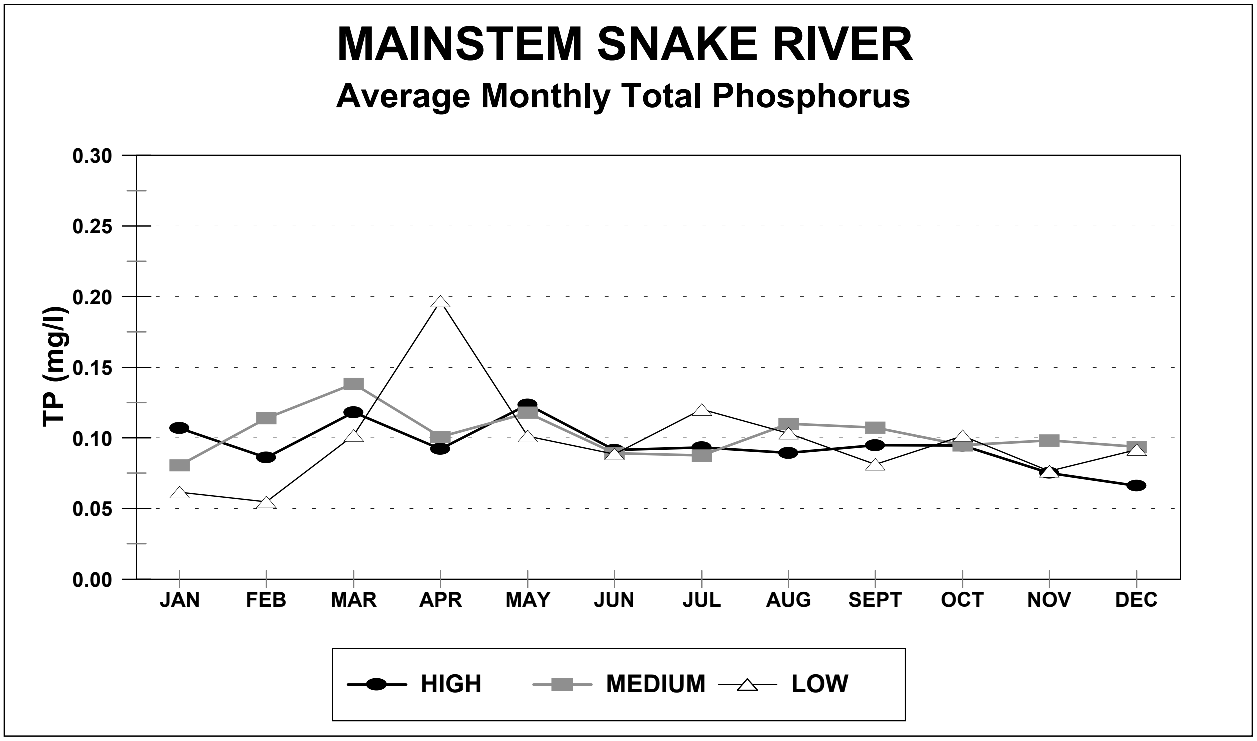


Figure 2-14. The average monthly concentrations for total phosphorus for high, medium and low flow years at selected stations in the Snake River.

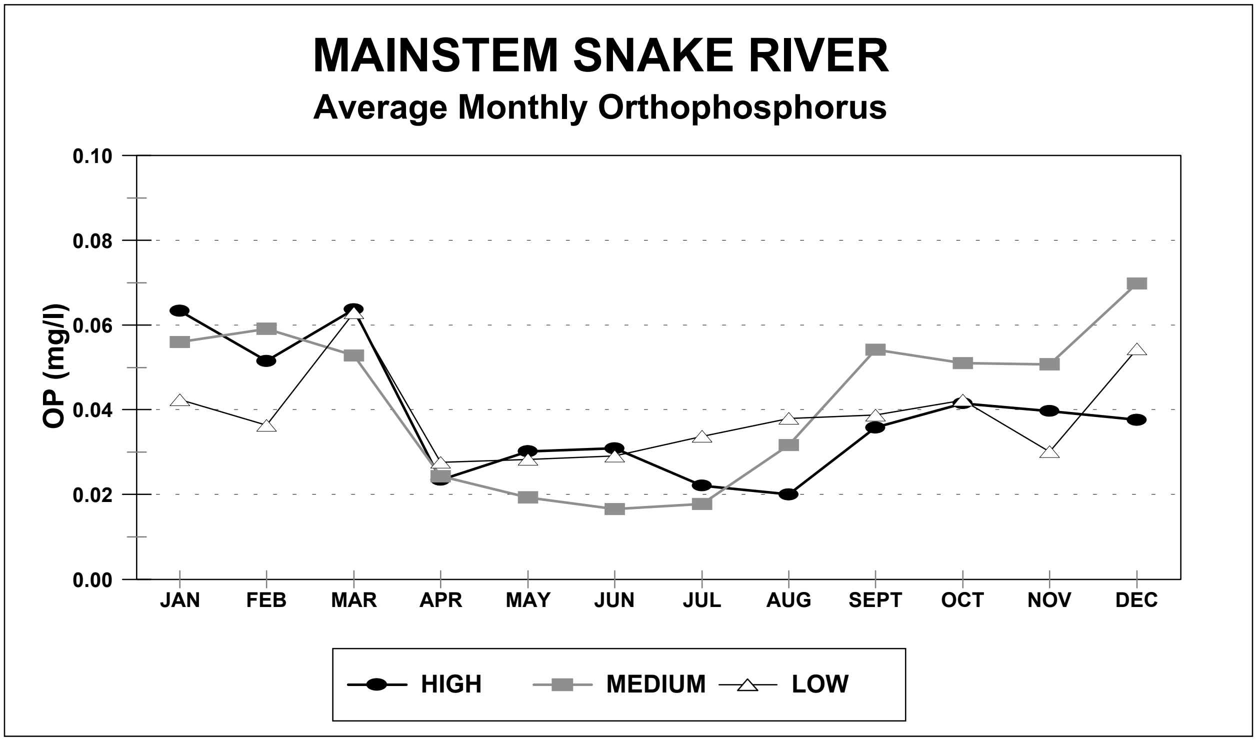


Figure 2-15. The average monthly concentrations for orthophosphorus for high, medium and low flow years at selected stations in the Snake River.

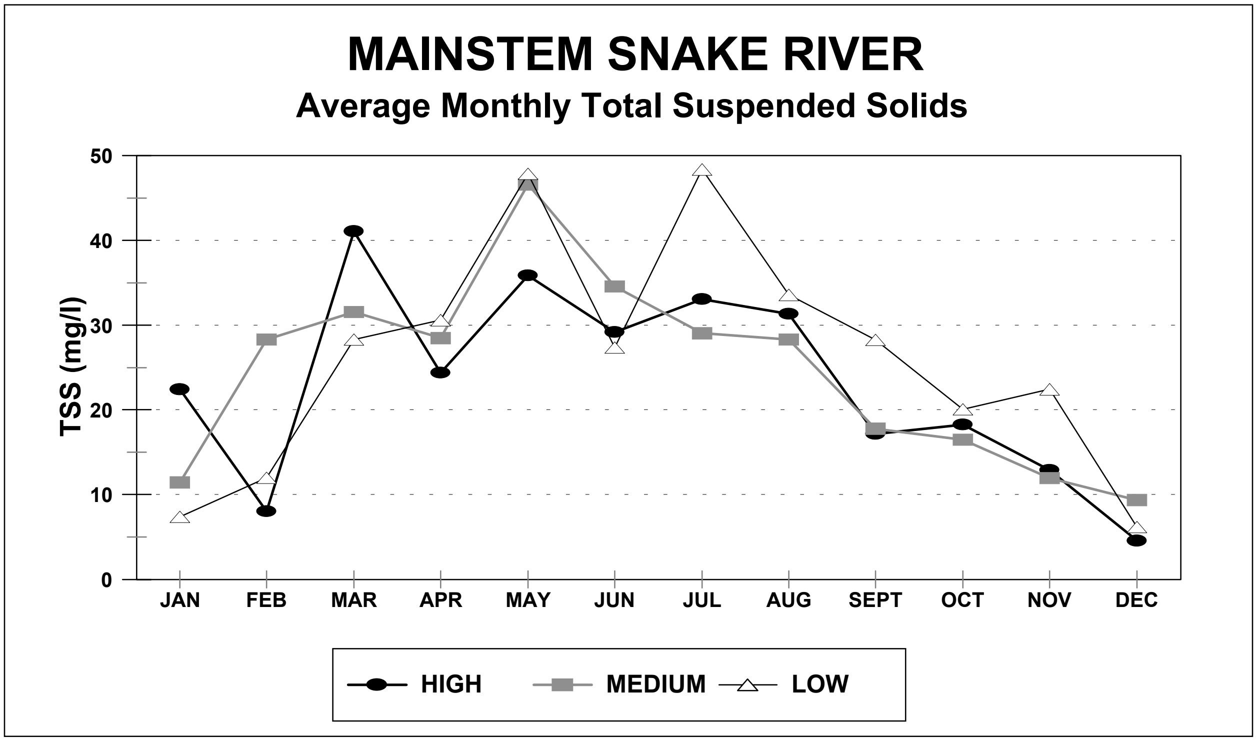


Figure 2-16. The average monthly concentrations for total suspended solids for high, medium and low flow years at selected stations in the Snake River.

Because there did not appear to be significant differences in concentrations between different hydrologic years (i.e. wet vs. dry), all available data for a parameter at a site for each month were averaged for the period of record (1975-2000). The data for total phosphorus, orthophosphorus, and total suspended solids by site is plotted in Figures 2-17, 2-18 and 2-19 with 95% confidence intervals. In a similar manner, averages and confidence intervals are plotted in Figures 2-20, 2-21 and 2-22 for each month for the same parameters. The same temporal and spatial patterns noted above are clearly evident.

It is apparent from the above discussion that there are spatial trends in the phosphorous and suspended solids data within the Snake River between Murphy and Hells Canyon Dam and that seasonal differences may also exist. In order to gain the maximum amount of resolution from the data, six out of the 25 years were selected because of the relatively high amounts of paired hydrologic and water quality data, which would allow the potential calculation of loading values and a mass balance analysis. The availability of data for both mainstem and tributary data for those six years can be seen in Table 2-10. Initially, an evaluation of the data completeness was done. A complete set of figures for all parameters can be found in Appendix III. These data are averaged across all reaches. A value of 100 percent would mean that there was at least one data point per site per month for that year.

Total phosphorous had the best coverage when combining all sites for the mainstem and tributaries. The best year was 1975 when 83.3 percent of the mainstem sites and 43.2% of the tributary sites had at least one monthly total phosphorus data point. The worst year for mainstem total phosphorus coverage was 1992, with 29.8 percent data coverage. In 1997, there was only 4.8 percent coverage for the tributaries.

The second parameter with the most complete coverage was total suspended solids. In 1997, total suspended solids data was available at 86.9 percent of the mainstem sites, although in that same year the tributaries had only 3.4 percent coverage. In 1995, both mainstem and tributaries appeared to have about the same amount of coverage (45-54 %).It is interesting to note that for the mainstem sites there appeared to be an increasing interest in sediment data as evidenced by an increase in coverage over time. This is the opposite trend for mercury (see Appendix III), in which available data decreases from 1975 to 1997.

For the seven mainstem Snake River sites, average concentrations of the target water quality parameters (total phosphorous, orthophosphorous, total suspended solids, nitrate, ammonia, mercury, and dissolved oxygen) for each month during the six representative hydrologic years is summarized in Appendix IV. An example of the average monthly concentration plots for total phosphorous in the two wet, medium, and dry years is provided in Figures 2-23, 2-24 and 2-25. These data were used in combination with the hydrologic data for the loading calculations discussed in the following section.

Utilizing the six selected years and the coverages noted above, average concentrations for each month were calculated (based upon the available data) for both the mainstem Snake River and the 11 major tributaries. Water quality parameters included total phosphorus, orthophosphate, and total suspended solids. An example of the results of this combination of water quality data can be seen in Table 2-11.

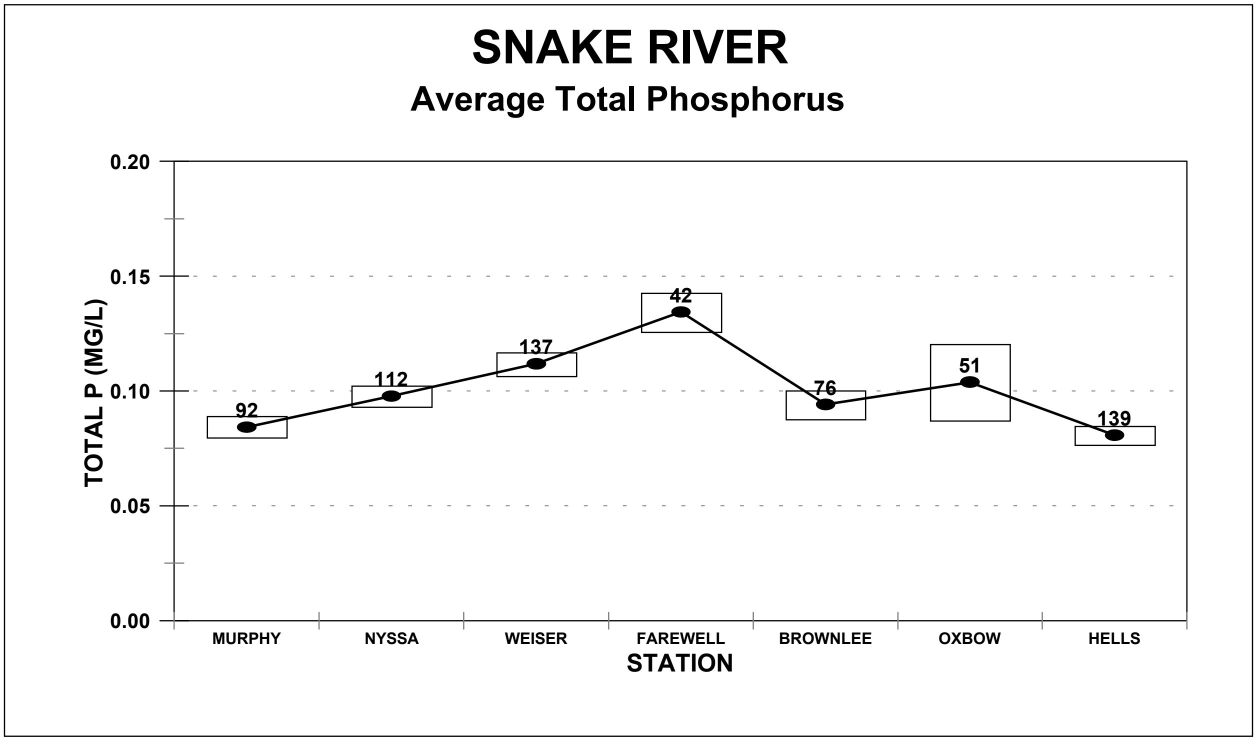


Figure 2-17. The spatial changes in total phosphorus concentrations at selected sites in the Snake River expressed as the overall average (1975-2000) and 95% confidence interval.

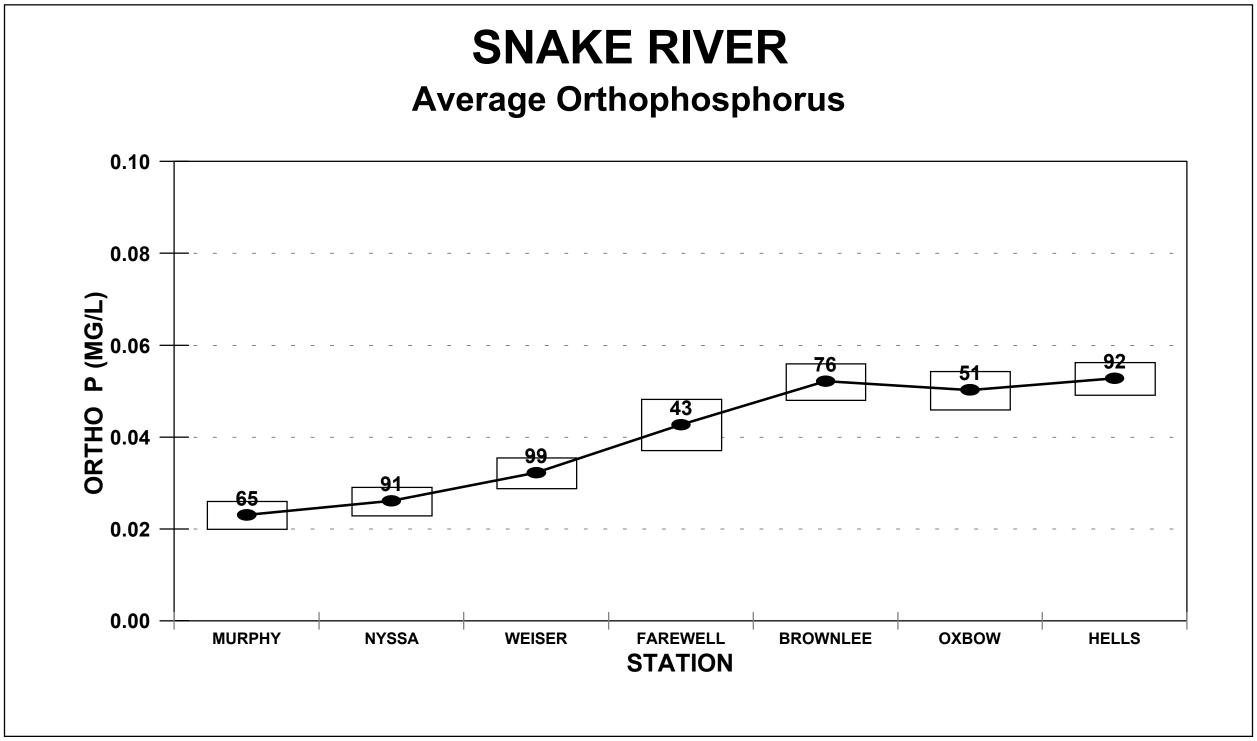


Figure 2-18. The spatial changes in orthophosphorus concentrations at selected sites in the Snake River expressed as the overall average (1975-2000) and 95% confidence interval.

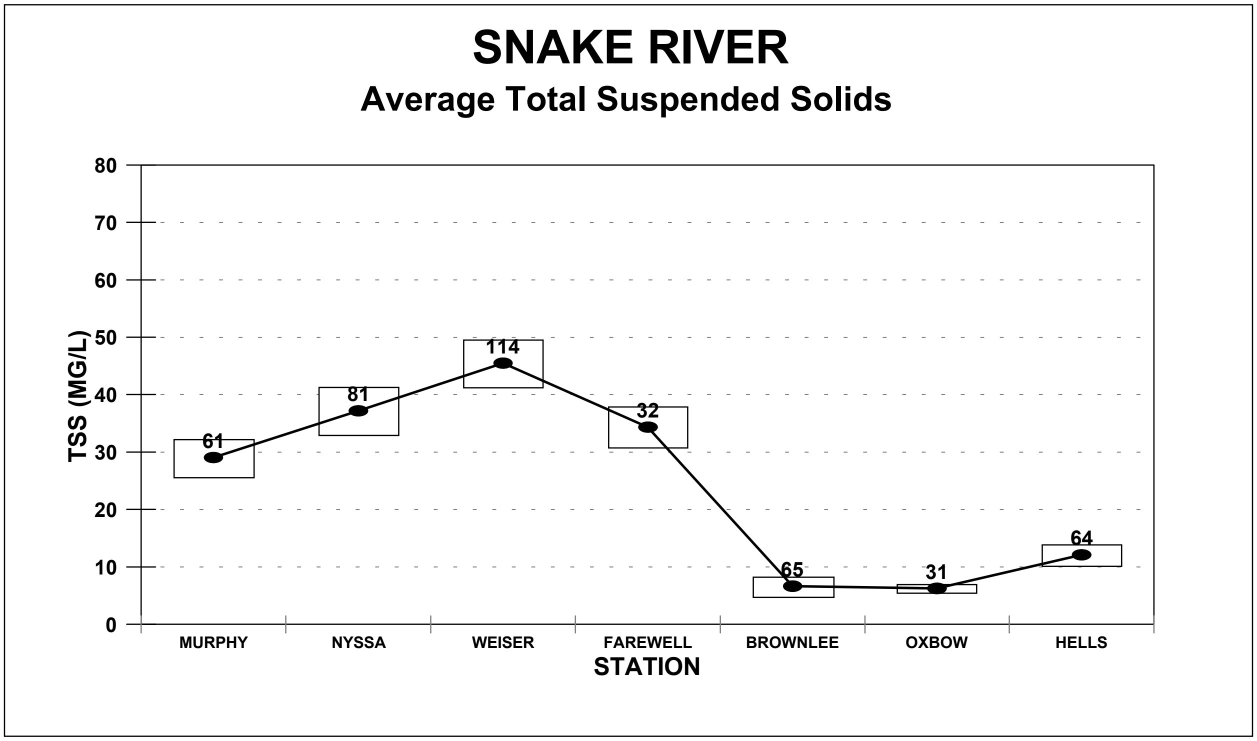


Figure 2-19. The spatial changes in total suspended solids concentrations at selected sites in the Snake River expressed as the overall average (1975-2000) and 95% confidence interval.

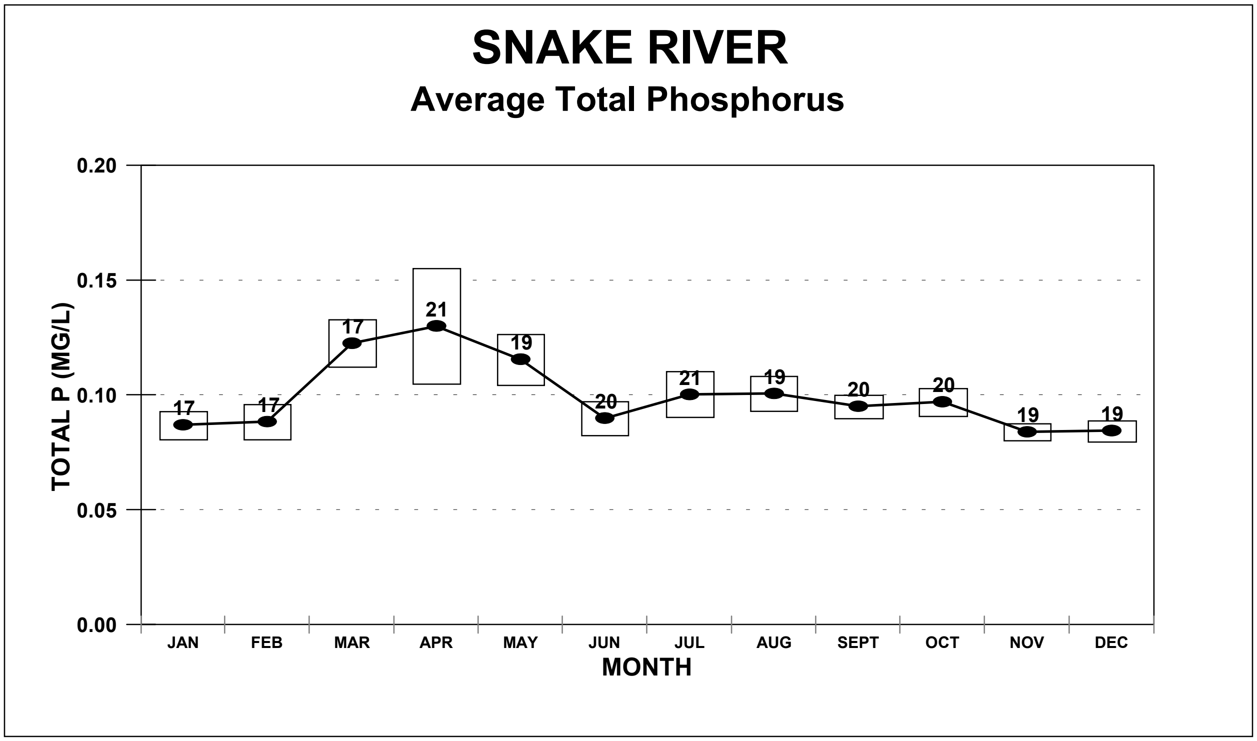


Figure 2-20. The temporal changes expressed as an average with 95% confidence intervals for total phosphorus concentrations for the seven Snake River sites over the period of record (1975-2000).

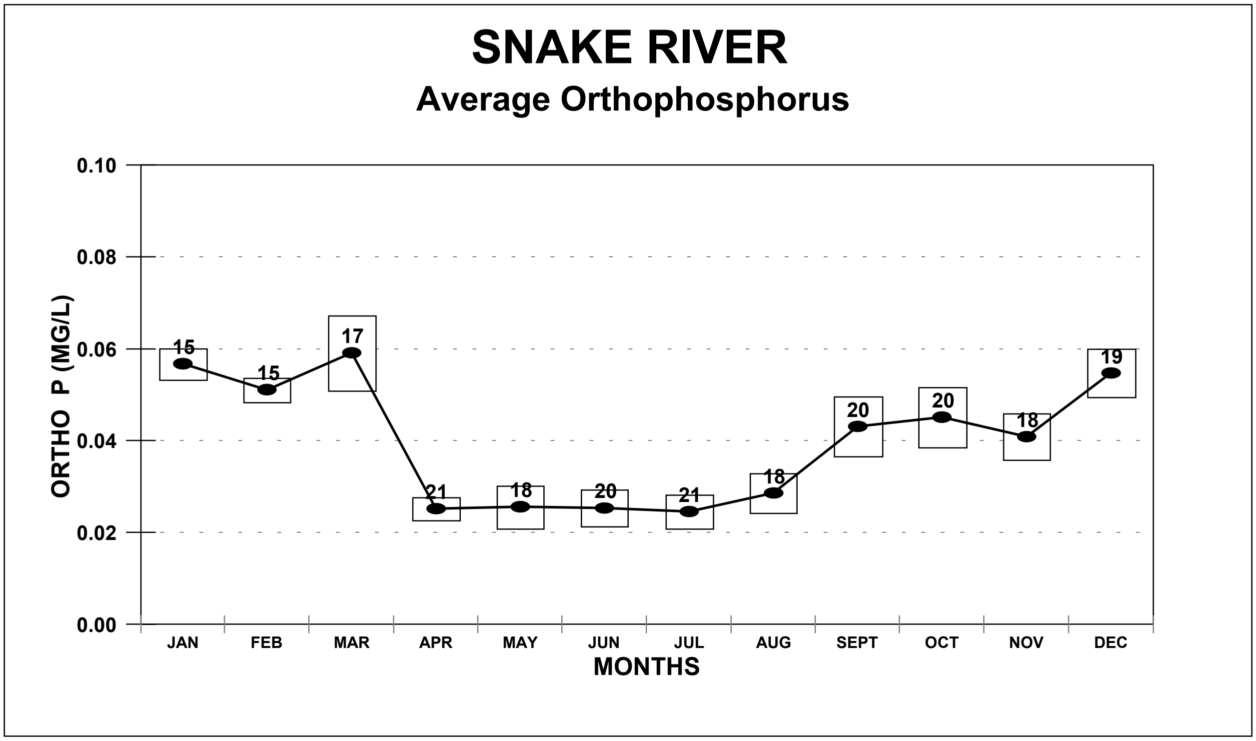


Figure 2-21. The temporal changes expressed as an average with 95% confidence intervals for orthophosphorus concentrations for the seven Snake River sites over the period of record (1975-2000).

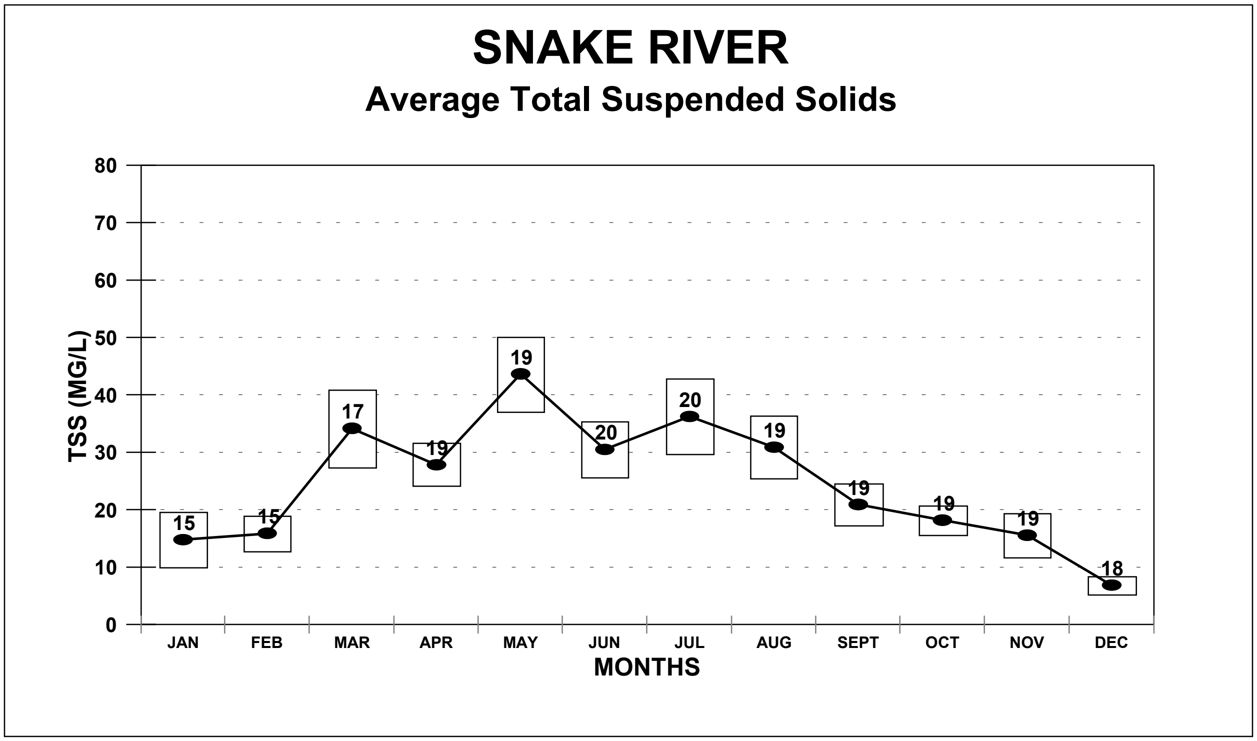
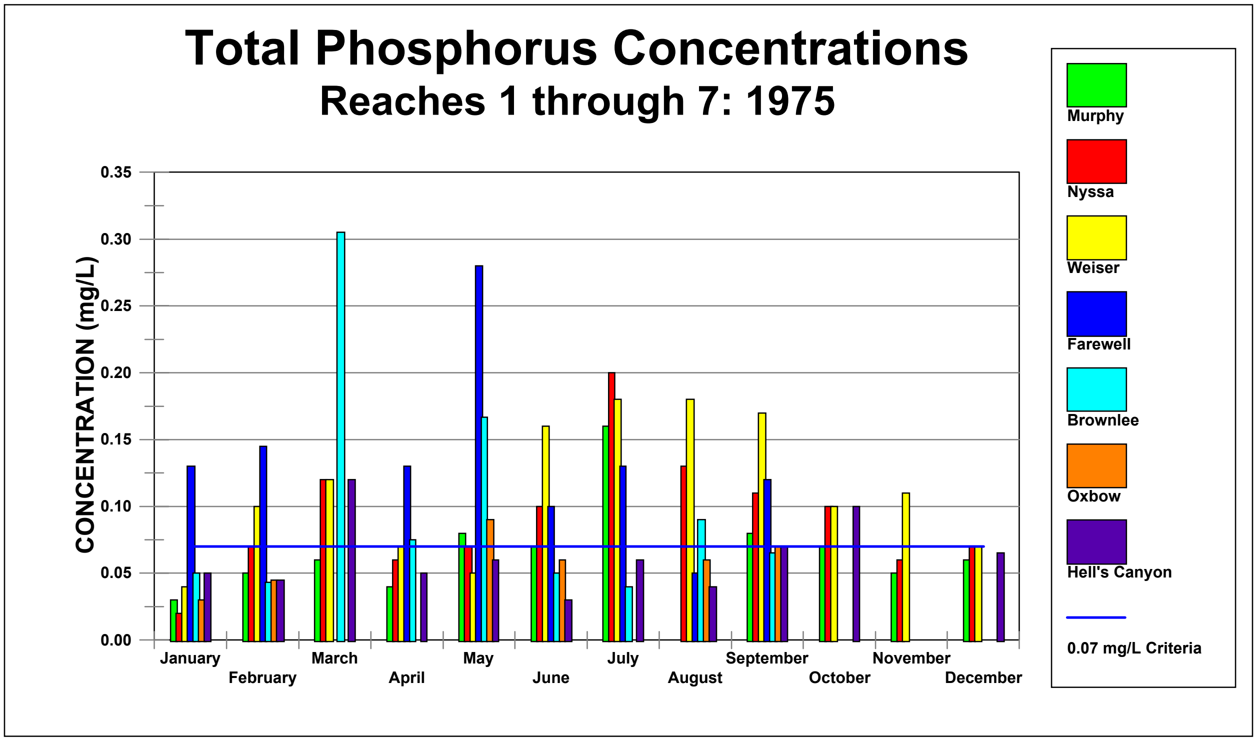


Figure 2-22. The temporal changes expressed as an average with 95% confidence intervals for total suspended solids concentrations for the seven Snake River sites over the period of record (1975-2000).



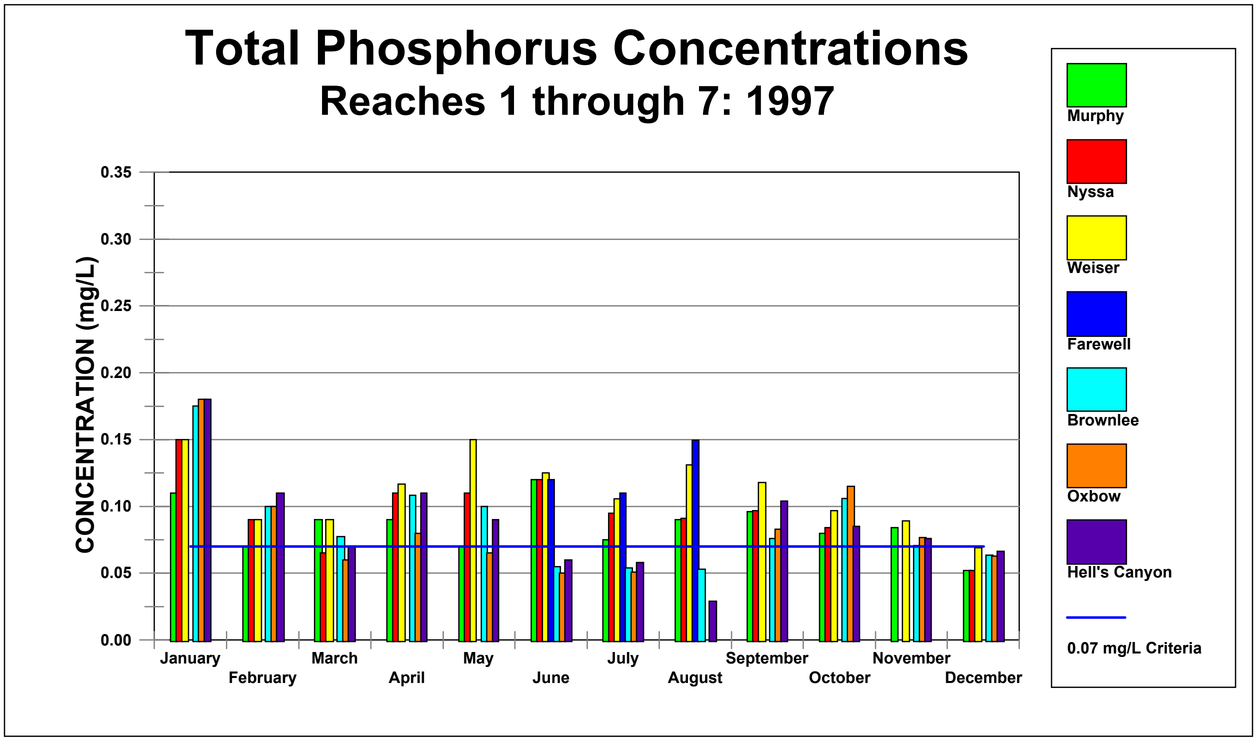
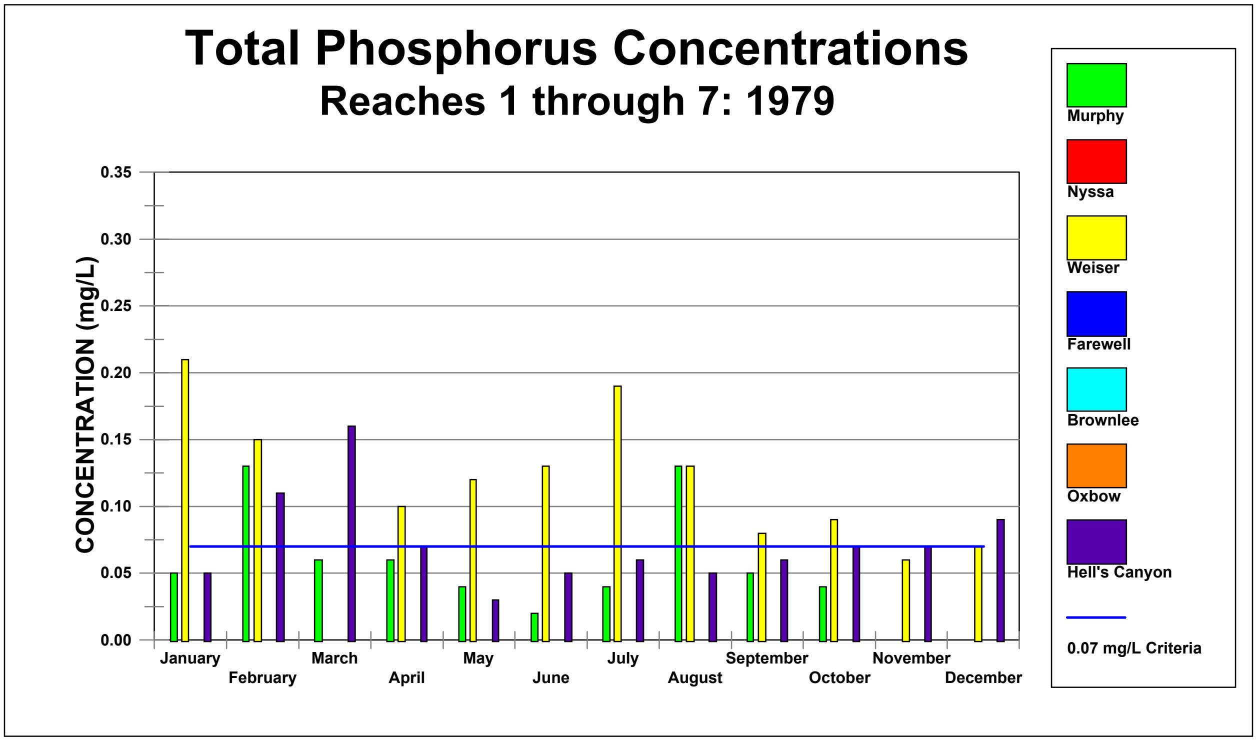


Figure 2-23. The average monthly total phosphorus concentrations by location and month for the two wet years used in the loading analysis.



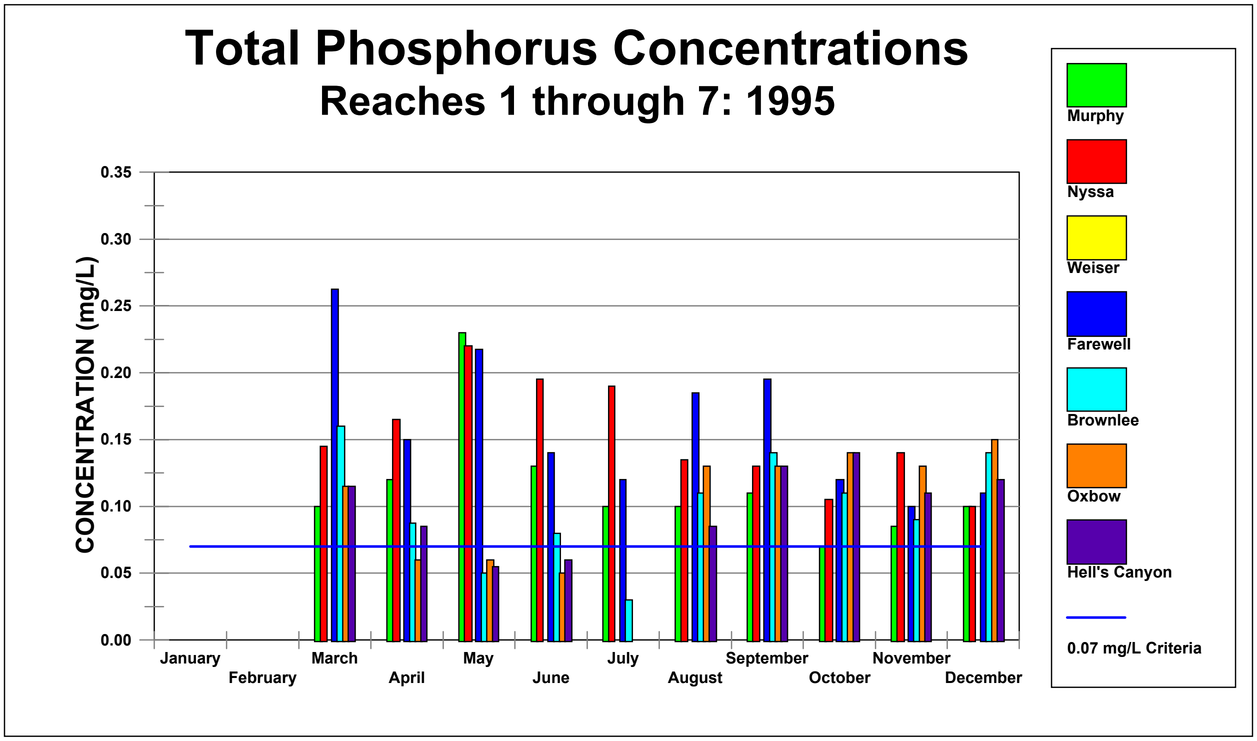
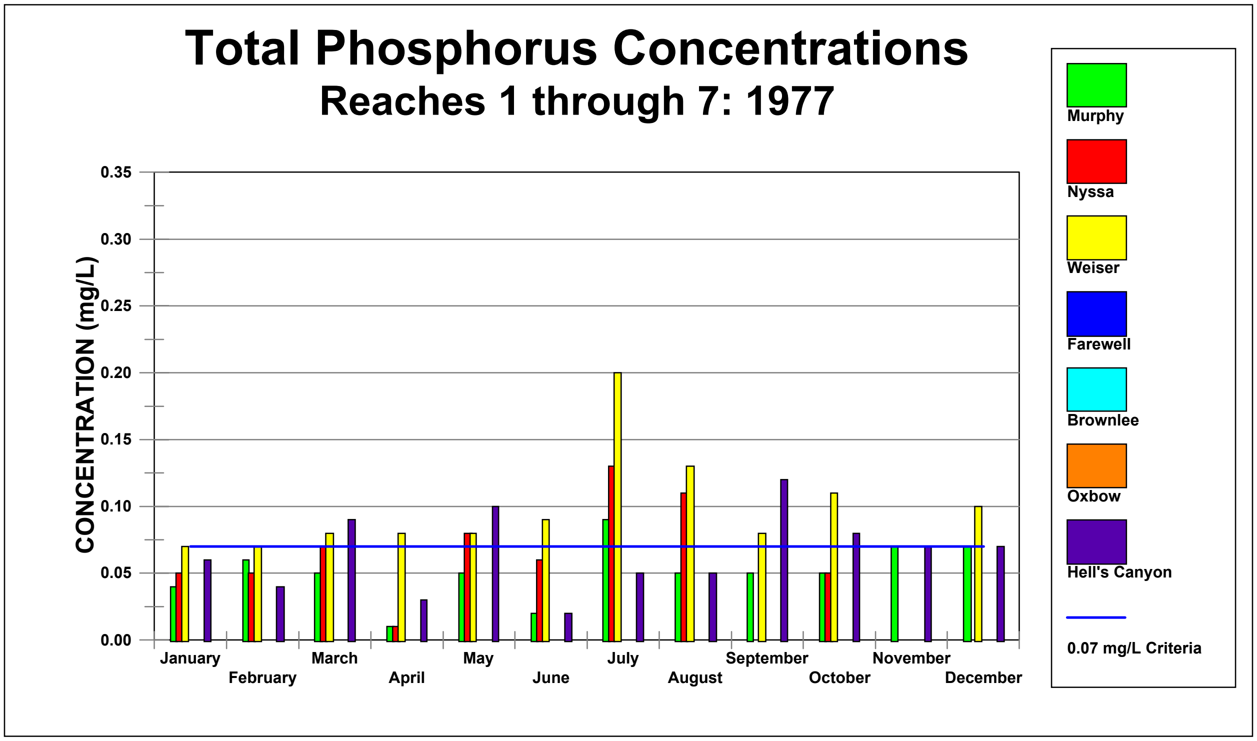


Figure 2-24. The average monthly total phosphorus concentrations by location and month for the two medium years used in the loading analysis.



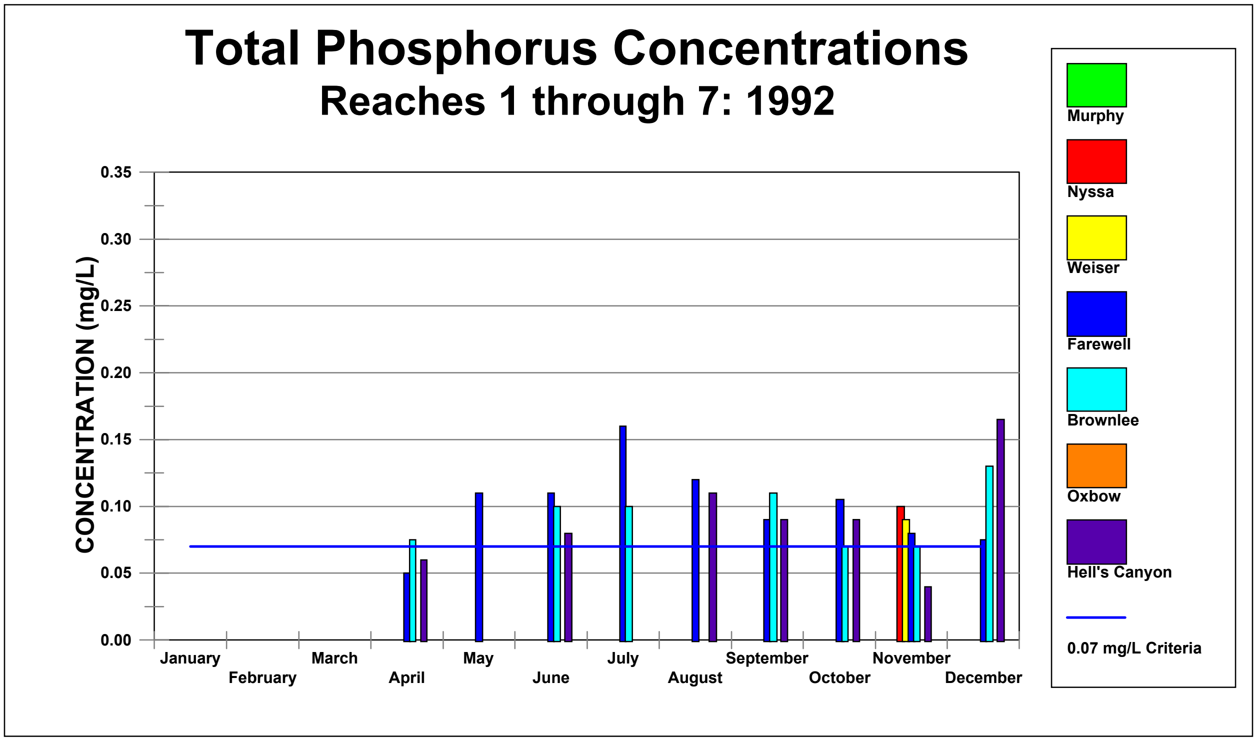


Figure 2-25. The average monthly total phosphorus concentrations by location and month for the two dry years used in the loading analysis.

Table 2-10. The distribution of available flow and water quality data by year and parameter for the mainstem Snake River and its accompanying tributaries. A 100 percent coverage would be at least one data point per month per site.

	1975	1977	1979	1992	1995	1997
MAINSTEM SITES						
Measured Flows	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Total Phosphorus	83.3%	52.4%	39.3%	29.8%	69.0%	86.9%
Ortho Phosphorus	50.0%	0.0%	0.0%	29.8%	69.0%	86.9%
Ammonia	65.5%	32.1%	39.3%	1.2%	11.9%	13.1%
Nitrate	19.0%	0.0%	0.0%	22.6%	21.4%	15.5%
Total Suspended Solids	17.9%	14.3%	14.3%	32.1%	54.8%	86.9%
Dissolved Oxygen	60.7%	50.0%	39.3%	63.1%	63.1%	45.2%
pH	60.7%	52.4%	39.3%	32.1%	29.8%	15.5%
Mercury	38.1%	33.3%	19.0%	0.0%	0.0%	0.0%
TRIBUTARY SITES						
Measured Flows	75.3%	75.3%	75.3%	91.8%	78.8%	62.3%
Total Phosphorus	43.2%	25.3%	44.5%	24.0%	44.5%	4.8%
Ortho Phosphorus	43.2%	7.5%	0.0%	24.0%	44.5%	4.8%
Ammonia	50.0%	11.0%	42.5%	23.3%	42.5%	0.0%
Nitrate	30.1%	9.6%	0.0%	0.0%	24.0%	0.0%
Total Suspended Solids	28.1%	17.1%	30.8%	24.0%	45.2%	3.4%
Dissolved Oxygen	26.7%	16.4%	37.0%	22.6%	37.7%	4.8%
pH	15.1%	17.1%	40.4%	24.0%	37.7%	4.8%
Mercury	4.1%	8.9%	15.1%	8.9%	8.2%	0.0%

This table illustrates total phosphorous concentrations for a dry year. The remaining data are in Appendix V for total phosphorus, orthophosphorus and total suspended solids. In order to gain a relatively more complete picture of the study reach, the two companion years were averaged allowing a combination of tributary data and thus filling in missing tributary and mainstem data points. An overall average of data for all six years was also undertaken (Table 2-12). This last data set represents the most general, but also the most complete data set. Nearly all mainstem and tributary sites had monthly values represented within that six year period. This summary seems reasonable, given the fact that over the 25 year period of record, no trends over time were found even though monthly trends were evident.

2.3 Loading Calculations

The mass loadings for the Snake River between Murphy and Hells Canyon were calculated using paired hydrologic and water quality data from six years selected as having the best available data for both mainstem and tributaries sites. Initially, average daily loads (kg/day) were calculated for each month and each year. These data are shown in Appendix VI. Although these data represent the most complete data from 1975-2000, gaps still existed for mainstem and tributary sites. In order to further increase the coverage of the data, averages between the two wet, dry and medium years were calculated. The results of this analysis are shown in Figures 2-26, 2-27, and 2-28. The anticipated water quality criteria loading values are also shown on these figures. Inspection of the data indicated that in every month in all scenarios, the total phosphorous criteria of 0.07 mg/l is exceeded. Orthophosphate and total suspended solids criteria are exceeded to a lesser extent. The middle stations, Weiser to Brownlee exceed criteria the most of all the reaches. The exact amount of the quantity (kg/day) of exceedences for each mainstem and tributary site is provided in tabular and graphical form in Appendix VII and Appendix VIII. This analysis includes the six selected years as well as the averages for wet, dry and medium flow periods.

The most complete spatial data set was developed using the averages from the entire six year data set. The overall averages for the daily loadings (kg/day) of total phosphorous, orthophosphate, and total suspended solids are plotted in Figure 2-29 and shown in Table 2-13. As in the previous three figures, total phosphorous exceeded the 0.07 mg/l criteria at almost every site every month of the year. The quantity of the exceedence is shown in Figure 2-30 and Table 2-14.

Inspecting the overall average for the six hydrologic years and the annual average (12 months) for each mainstem and tributary station produced an interesting spatial pattern in the quantity of total phosphorus levels exceedences from the 0.07 mg/L criteria. On average, total phosphorus was exceeded on a daily basis throughout the Snake River, starting at Murphy (476 kg TP/day) and peaking at Farewell Bend (2962 kg TP/day). With movement through the reservoirs, the amount of mass exceeding criteria dropped to 817 mg TP/day at Hells Canyon. In the reaches between Murphy and Farewell Bend (the area of increase), it appears that tributary contributions are significant. As with the mainstem reaches, the tributaries also had excess mass entering the Snake River. The highest exceedence was from the Boise River, with an average annual daily value of 768 kg TP/day, followed by the Payette (199 kg TP/day) and the Owhyee (157 kg TP/day).

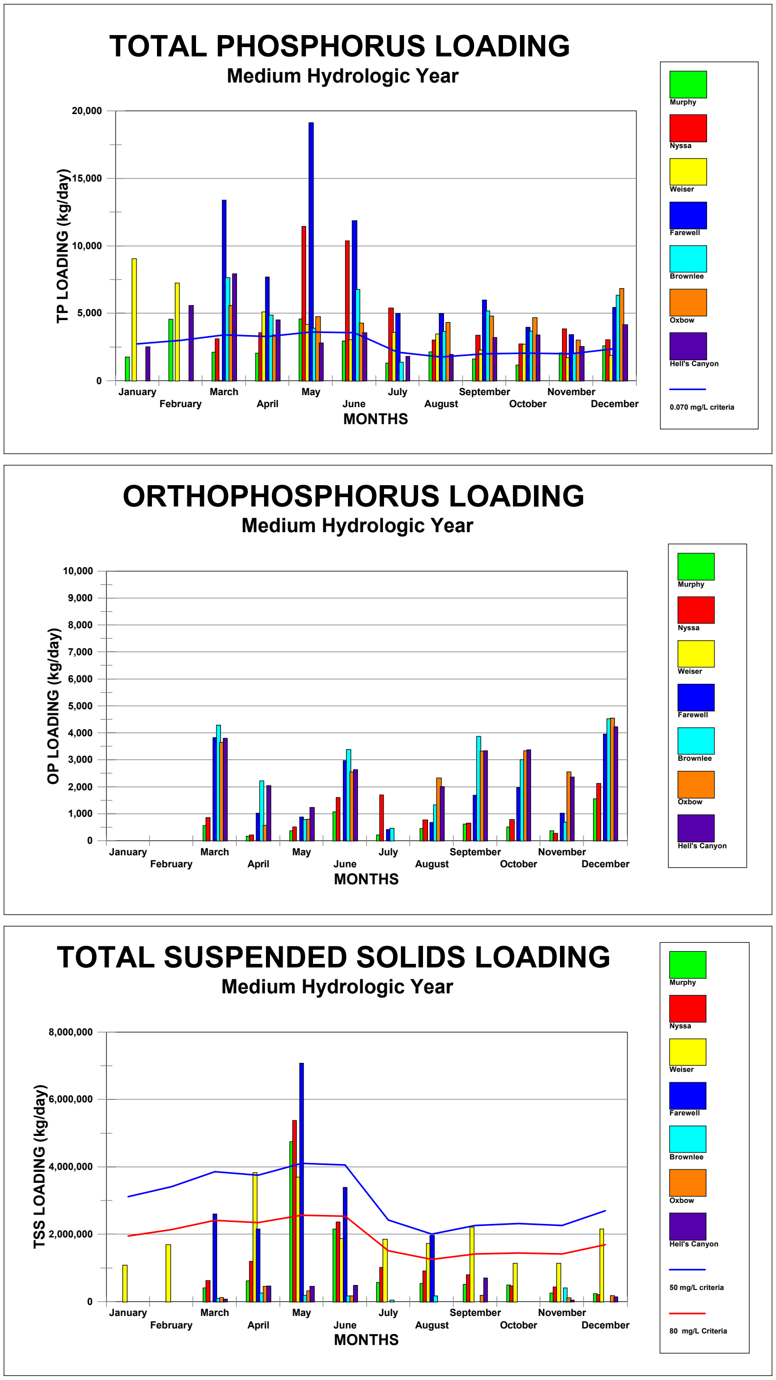


Figure 2-26. The monthly total phosphorus (above), orthophosphorus (middle) and total suspended solids (below) loading for a Medium Water Year. Data are from 1979 and 1995.

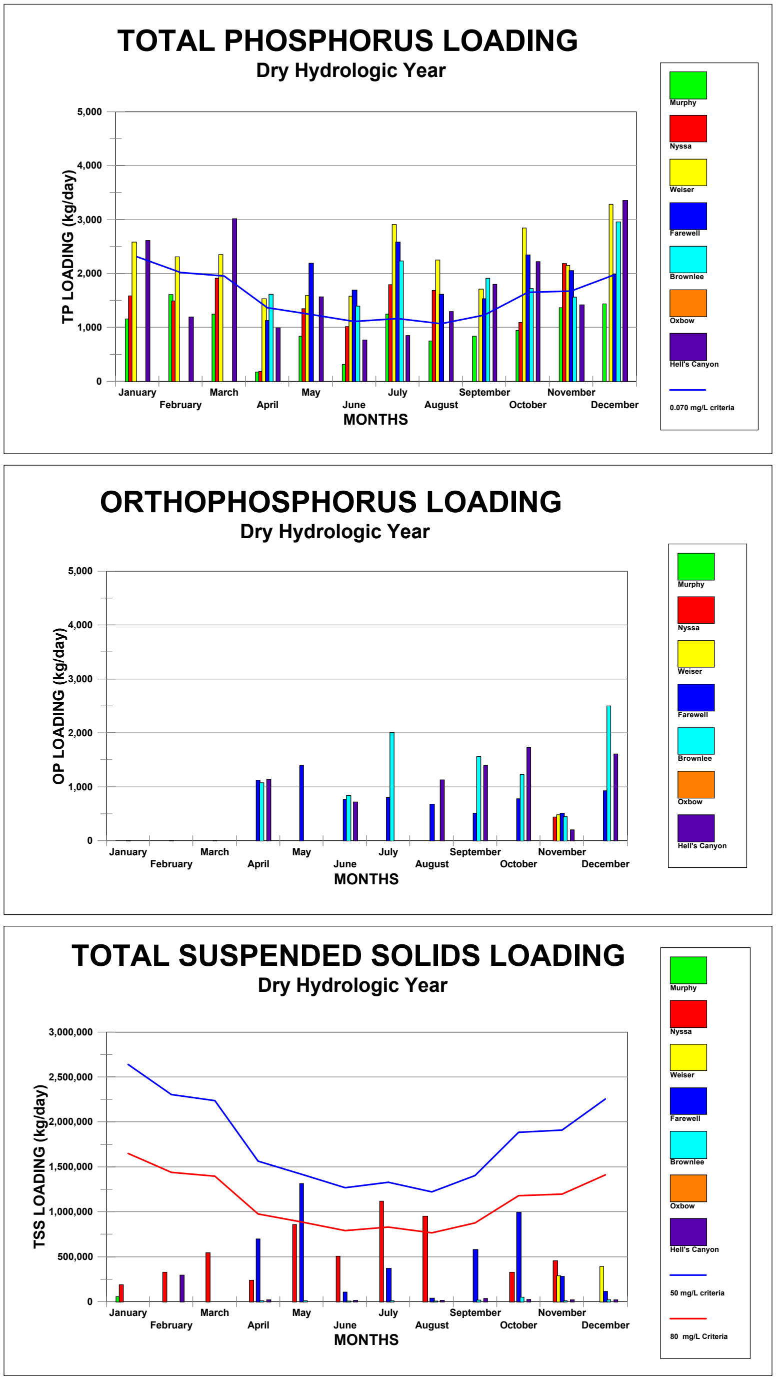
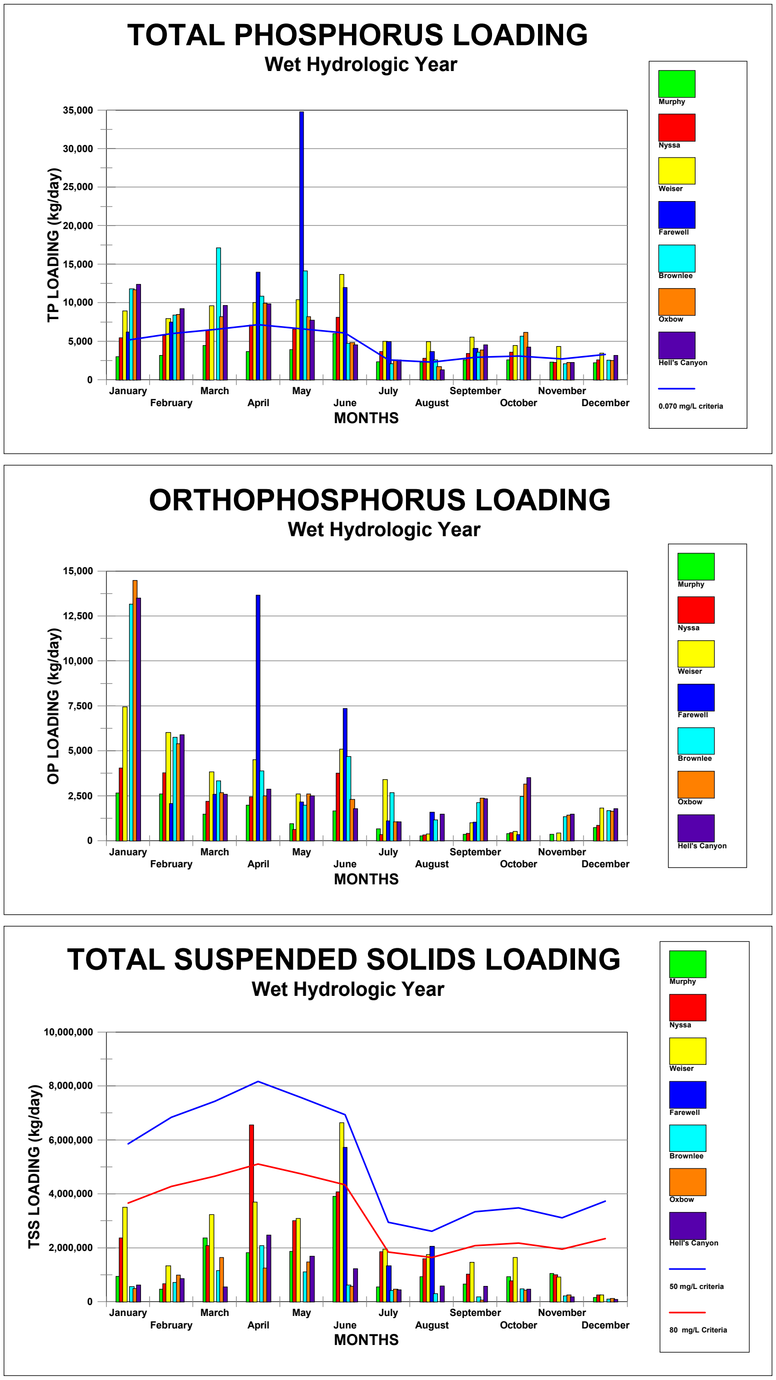


Figure 2-27. The monthly total phosphorus (above), orthophosphorus (middle) and total suspended solids (below) loading for a Dry Water Year. Data are from 1977 and 1992.


TOTAL PHOSPHORUS LOADING
Wet Hydrologic Year

ORTHOPHOSPHORUS LOADING
Wet Hydrologic Year

TOTAL SUSPENDED SOLIDS LOADING
Wet Hydrologic Year

Figure 2-28. The monthly total phosphorus (above), orthophosphorus (middle) and total suspended solids (below) loading for a Wet Water Year. Data are from 1975 and 1997.

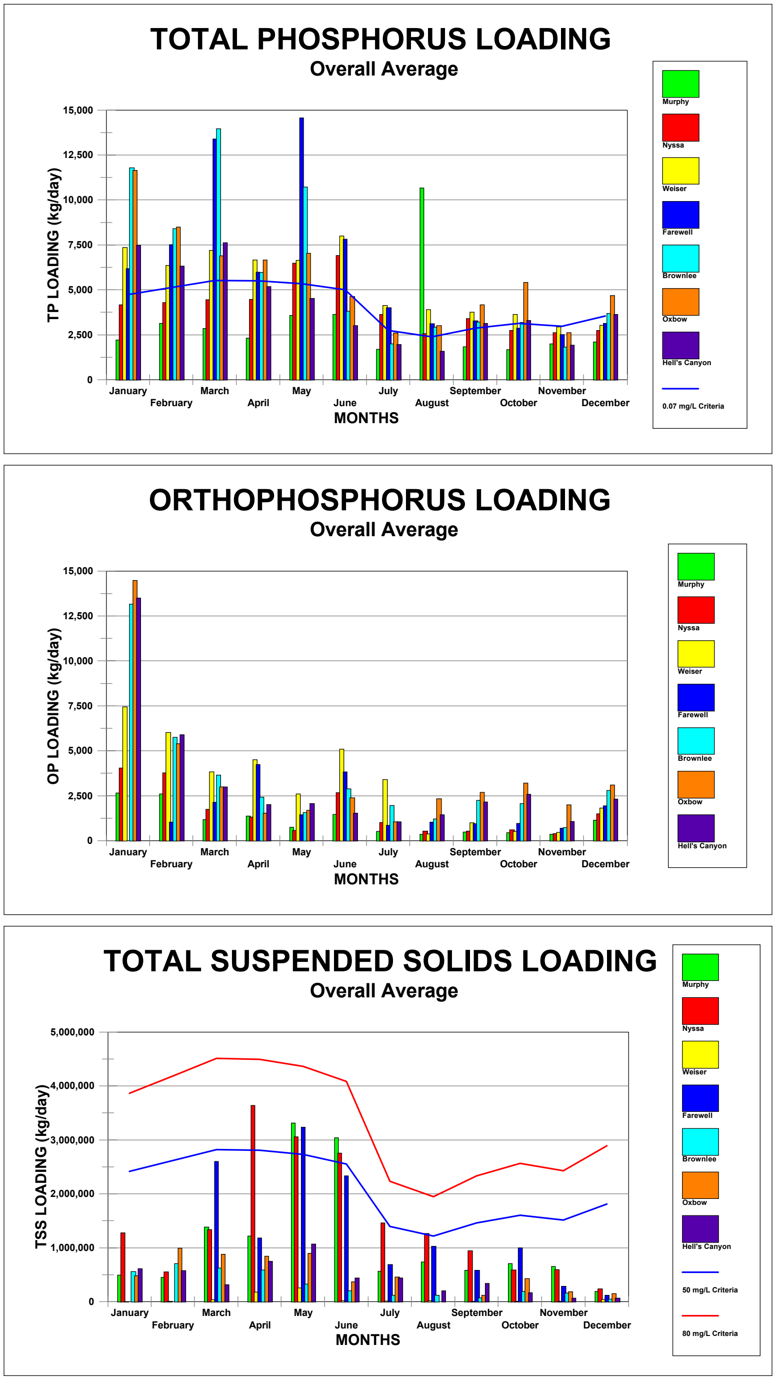


Figure 2-29. The overall average loading for total phosphorus (above), orthophosphorus (middle) and total suspended solids (below) at seven Snake River sites.

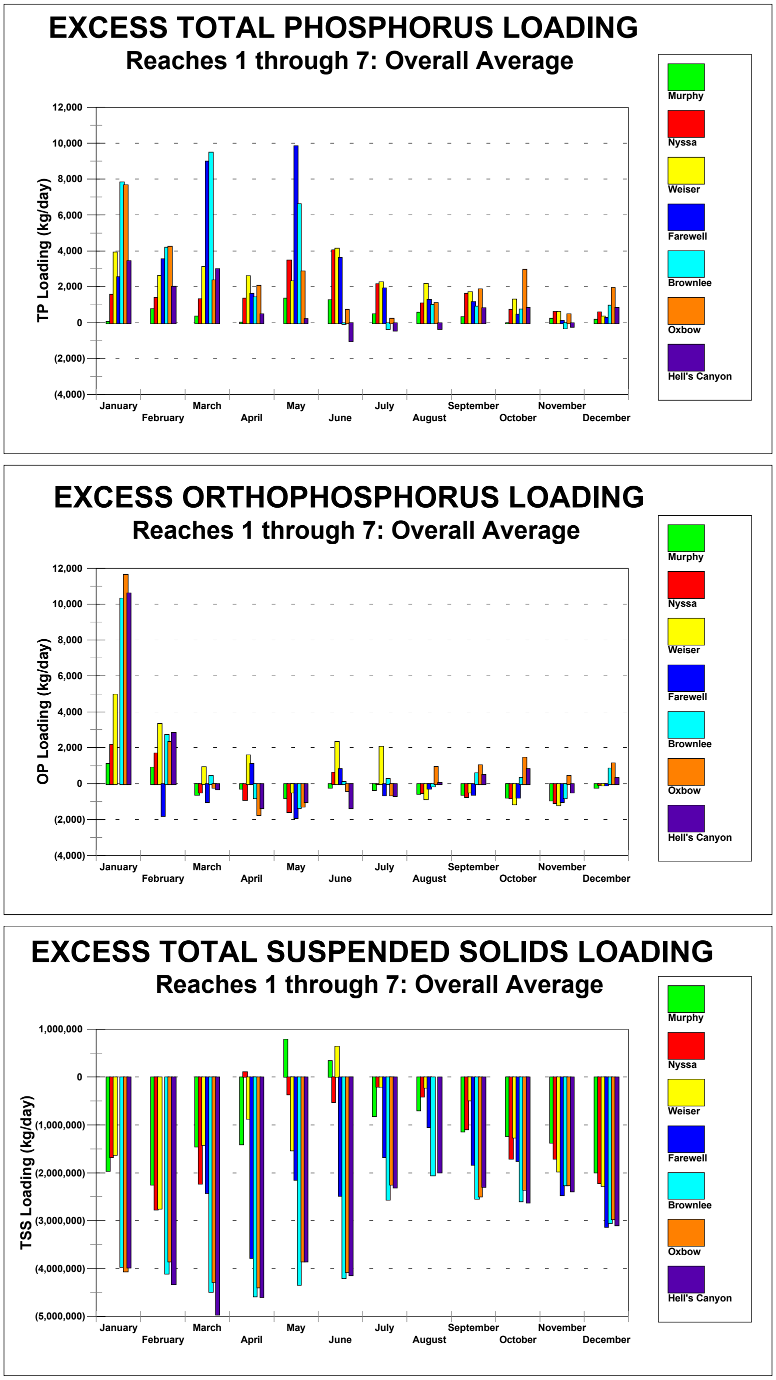


Figure 2-30. The quantity of total phosphorus (above), orthophosphorus (middle) and total suspended solids (below) excess loading by month for a medium water year.

Table 2-11. The average monthly concentrations for total phosphorus in mainstem and tributary sites for a dry year scenario.

	Murphy						Nyssa					Weiser	Farewell			Brownlee		Oxbow		Hells
		Jump	Succor	Owyhee	Boise	Pumps		Malheur	Payette	Weiser	Pumps			Burnt	Powder		Wildhorse		Pine	
1977 Concentrations																				
Jan	0.040				0.410	0.040	0.050			0.090	0.050	0.070								0.060
Feb	0.060				0.410	0.060	0.050			0.055	0.050	0.070								0.040
Mar	0.050				0.430	0.050	0.070				0.070	0.080								0.090
Apr	0.010				0.210	0.010	0.010			0.150	0.010	0.080								0.030
May	0.050				0.430	0.050	0.080		0.140	0.290	0.080	0.080								0.100
Jun	0.020					0.020	0.060			0.190	0.060	0.090								0.020
Jul	0.090			0.543	0.360	0.090	0.130	0.995		0.170	0.130	0.200								0.050
Aug	0.050					0.050	0.110			0.260	0.110	0.130								0.050
Sep	0.050					0.050			0.150	0.140		0.080								0.120
Oct	0.050				0.270	0.050	0.050			0.140	0.050	0.110								0.080
Nov	0.070				0.320	0.070				0.090										0.070
Dec	0.070				0.370	0.070				0.050		0.100								0.070
1992 Concentrations																				
Jan				0.100										0.096	0.130					
Feb				0.130										0.110	0.140					
Mar				0.120	0.470									0.300	0.130					
Apr				0.160									0.050	0.160	0.190	0.075				0.060
May				0.180									0.110	0.190	0.330					
Jun				0.180									0.110	0.200	0.320	0.100				0.080
Jul				0.170									0.160	0.180	0.280	0.100				
Aug				0.150									0.120	0.110	0.170					0.110
Sep				0.120									0.090	0.140	0.091	0.110				0.090
Oct				0.092									0.105	0.110	0.130	0.070				0.090
Nov				0.100	0.520		0.100					0.090	0.080	0.094	0.110	0.070				0.040
Dec													0.075			0.130				0.165
Dry Year Concentrations (average of 1977 and 1992)																				
Jan	0.040			0.100	0.410	0.040	0.050			0.090	0.050	0.070		0.096	0.130					0.060
Feb	0.060			0.130	0.410	0.060	0.050			0.055	0.050	0.070		0.110	0.140					0.040
Mar	0.050			0.120	0.450	0.050	0.070				0.070	0.080		0.300	0.130					0.090
Apr	0.010			0.160	0.210	0.010	0.010			0.150	0.010	0.080	0.050	0.160	0.190	0.075				0.045
May	0.050			0.180	0.430	0.050	0.080		0.140	0.290	0.080	0.080	0.110	0.190	0.330					0.100
Jun	0.020			0.180	0.000	0.020	0.060			0.190	0.060	0.090	0.110	0.200	0.320	0.100				0.050
Jul	0.090			0.357	0.360	0.090	0.130	0.995		0.170	0.130	0.200	0.160	0.180	0.280	0.100				0.050
Aug	0.050			0.150		0.050	0.110			0.260	0.110	0.130	0.120	0.110	0.170					0.080
Sep	0.050			0.120		0.050			0.150	0.140		0.080	0.090	0.140	0.091	0.110				0.105
Oct	0.050			0.092	0.270	0.050	0.050			0.140	0.050	0.110	0.105	0.110	0.130	0.070				0.085
Nov	0.070			0.100	0.420	0.070	0.100			0.090		0.090	0.080	0.094	0.110	0.070				0.055
Dec	0.070			0.000	0.370	0.070				0.050		0.100	0.075			0.130				0.118

Table 2-12. The overall averages for mainstem and tributary sites for the six selected years of data.

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
Overall Average: Total Phosphorus Concentrations (mg/L)																				
Jan	0.058			0.447	0.405	0.040	0.073	0.743	0.070	0.090	0.035	0.118	0.130	0.324	0.137	0.113	0.030	0.105	0.030	0.085
Feb	0.078			0.171	0.683	0.080	0.070	0.896	0.180	0.063	0.060	0.103	0.145	0.158	0.210	0.072	0.025	0.073	0.043	0.076
Mar	0.072			0.122	0.466	0.057	0.100	0.335	0.105	0.130	0.095	0.097	0.263	0.235	0.269	0.181	0.070	0.088	0.180	0.111
Apr	0.064			0.137	0.259	0.037	0.086	0.260	0.080	0.140	0.035	0.092	0.110	0.267	0.173	0.086	0.080	0.070	0.060	0.068
May	0.094			0.150	0.235	0.057	0.120	0.459	0.120	0.195	0.075	0.100	0.203	0.190	0.223	0.106		0.072	0.140	0.067
Jun	0.072			0.452	0.254	0.037	0.119	0.923	0.060	0.180	0.080	0.126	0.118	0.150	0.238	0.071	0.050	0.053	0.120	0.050
Jul	0.093			0.320	0.347	0.097	0.154	0.760	0.140	0.197	0.165	0.169	0.130	0.212	0.289	0.056		0.051		0.057
Aug	0.093			0.140	0.319	0.090	0.117	0.639	0.120	0.227	0.120	0.143	0.126	0.152	0.280	0.084		0.095	0.050	0.061
Sep	0.077			0.197	0.320	0.060	0.112	0.398	0.113	0.193	0.110	0.112	0.135	0.172	0.307	0.098	0.050	0.094	0.030	0.096
Oct	0.062			0.112	0.292	0.053	0.085	0.340	0.070	0.110	0.075	0.099	0.113	0.116	0.217	0.095		0.128		0.094
Nov	0.072			0.101	0.350	0.060	0.100	0.375	0.030	0.100	0.060	0.087	0.090	0.099	0.155	0.077		0.103		0.073
Dec	0.071			0.110	0.415	0.065	0.074	0.392	0.040	0.040	0.070	0.077	0.093		0.203	0.111		0.107		0.096
Overall Average: Orthophosphorus Concentrations (mg/L)																				
Jan	0.060			0.357	0.277	0.000	0.060		0.020	0.022		0.070	0.044	0.140	0.071	0.070	0.022	0.068	0.019	0.072
Feb	0.051			0.069	0.176	0.062	0.061		0.050	0.043	0.082	0.069	0.050	0.100	0.084	0.045	0.016	0.045	0.024	0.043
Mar	0.035			0.038	0.328	0.065	0.025	0.150	0.040	0.130		0.062	0.130	0.115	0.125	0.061	0.024	0.053	0.048	0.043
Apr	0.019			0.044	0.111	0.026	0.020	0.090	0.025	0.065		0.028	0.030	0.115	0.091	0.035	0.025	0.015	0.020	0.034
May	0.008			0.072	1.024	0.003	0.010	0.170	0.030	0.071		0.039	0.054	0.128	0.148	0.030	0.025	0.017	0.020	0.020
Jun	0.031			0.099	0.119	0.029	0.035	0.260	0.010	0.075		0.054	0.035	0.216	0.183	0.047	0.015	0.023	0.015	0.026
Jul	0.010			0.088	0.213	0.000	0.035	0.300	0.060	0.139		0.011	0.036	0.153	0.168	0.036		0.028		0.027
Aug	0.018			0.075	0.234	0.000	0.023	0.310	0.050	0.177		0.010	0.031	0.112	0.185	0.032		0.050	0.020	0.046
Sep	0.020			0.057	0.233	0.000	0.018	0.270	0.050	0.150		0.021	0.032	0.122	0.146	0.071	0.010	0.068	0.005	0.078
Oct	0.018			0.051	0.310	0.000	0.020	0.210	0.020	0.029		0.011	0.048	0.105	0.150	0.070		0.091		0.079
Nov	0.013			0.062	0.400	0.000	0.015		0.010	0.030		0.015	0.025	0.084	0.116	0.032		0.079		0.053
Dec	0.040			0.076	0.390	0.000	0.046		0.010	0.035		0.039	0.058		0.090	0.084		0.071		0.068
Overall Average: Total Suspended Solids Concentrations (mg/L)																				
Jan	11.5			129.3	32.0		15.3	108.0	15.0	4.0	5.0	29.0		246.5	7.0	4.7		4.0		5.0
Feb	7.0			42.0	37.0		12.7	170.0	37.0	6.0	15.0	23.0		40.5	37.0	5.0		7.0		8.0
Mar	28.0			29.8	40.7		66.3	67.3	39.5	13.0	179.0	26.7	51.0	90.0	60.3	5.3		7.3		2.8
Apr	35.0			45.7	40.7		36.0	37.5	17.0	44.7	34.0	54.3	36.5	185.0	25.7	7.3	9.0	9.0		9.5
May	85.5			42.8	59.5		61.1	96.7	24.5	59.3	42.0	68.7	73.3	59.0	36.5	5.3	36.0	10.5		12.0
Jun	50.3			162.0	63.3		42.1	279.5	17.0	13.0	47.0	62.0	30.7	11.0	16.7	2.7	32.0	3.5		6.6
Jul	24.5			127.1	70.0		61.8	98.3	17.0	19.5	89.0	68.0	25.5	22.0	23.8	3.2	2.5	9.0		8.5
Aug	33.0			59.8	32.0		46.8	177.5	44.0	19.3	41.0	54.5	42.8	3.0	12.7	3.8	170.0			6.5
Sep	21.5			50.5	45.0		26.3	42.5	17.3	22.0	20.0	54.7	34.0	8.0	17.0	2.0	19.0	3.0		10.1
Oct	24.0			25.8	20.7		21.5	32.0	12.8	9.7	29.0	36.0	44.7	5.0	7.0	5.4		8.0		4.8
Nov	20.3			19.3	15.3		15.3	61.0	3.0	15.0	9.0	20.1	11.0	6.5	7.3	8.7		6.8		3.0
Dec	6.5			10.0	18.0		10.7	22.0	7.0	13.5	21.0	32.0	4.4		53.5	1.8		3.5		2.0

Table 2-13. The overall average mass loading expressed as kg/day for seven locations in the Snake River and major tributaries.

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
Overall Average: Total Phosphorus Loading (kg/day)																				
Jan	2210			613	773		4160		356	33		7369	6178	6	35	11791	5	11656	8	7471
Feb	3138			502	2520		4298		1011	71		6354	7509	6	161	8414	8	8490	24	6322
Mar	2855			431	710		4450	164	1082	755		7184	13388	47	349	13963	48	6885	269	7629
Apr	2315			304	899	-5	4470	158	841	446	-2	6658	5975	125	150	5958	76	6663	87	5170
May	3572			817	1091	-19	6478	191	1495	629	-12	6634	14570	73	207	10710		7043	341	4526
Jun	3637			660	1273	-22	6908	157	1122	288	-22	7997	7829	41	141	3810	30	4639	338	3014
Jul	1700			165	846	-64	3620	165	958	138	-52	4120	4011	45	50	2000		2599		1966
Aug	1830			45	798	-43	2560	103	259	100	-28	3903	3107	42	25	2918		3015	9	1582
Sep	1839			50	816	-22	3399	135	274	78	-24	3768	3275	25	31	3217	3	4178	4	3132
Oct	1670			30	670	-6	2734	96	263	41	-4	3621	2876	2	17	3190		5413		3295
Nov	2003			35	721		2614		108	36		2933	2509	2	14	1814		2629		1925
Dec	2094			107	1293		2742		259	87		3030	3132		127	3693		4671		3623
Overall Average: Orthophosphorus Loading (kg/day)																				
Jan	2659			429			4042			8		7447		2	22	13161		14481		13498
Feb	2597			244	1094		3775		102	11		6007	1034	3	53	5752	4	5382	5	5905
Mar	1174			74	628		1743	107	425	52		3837	2138	21	61	3654	5	2995	14	2987
Apr	1371			43	842		1323	64	360	390		4494	4234	44	118	2422	16	1525	72	2007
May	755			265	1053	-2	575	103	448	207		2601	1454	52	75	1573	24	1699	29	2078
Jun	1458			116	15350	-1	2677	67	526	248		5094	3840	34	115	2882	25	2385	49	1529
Jul	514			32	784	-17	1015	95	451	216		3404	846	57	61	1964	9	1045	42	1045
Aug	354			16	720		543	82	85	143		377	1041	33	30	1212		2327		1435
Sep	491			13	707		533	101	120	121		995	934	18	14	2242		2691	4	2163
Oct	450			14	833		609	77	55	57		529	968	13	12	2076	1	3213	1	2585
Nov	357			22	620		383		94	8		461	684	2	9	729		1986		1061
Dec	1141			74	1592		1494		41	70		1827	1933		82	2799		3094		2306
Overall Average: Total Suspended Solids Loading (kg/day)																				
Jan	494249			181144	61244		1273893			1457		2294406		2263	1899	558364		482697		613544
Feb	454456			105259	339663		552410		76251	3735		1505594		539	27805	706537		991576		576314
Mar	1382683			82843	68148		1332445	77595	428781	37753		3224882	2601143	17701	69910	624429		879526		314710
Apr	1218450			98269	244662		3636931	42992	204464	178428		3760288	1183135	90665	16724	589080	8499	846936		746459
May	3312894			231199	375386		3057164	16965	229545	256215	-1081	3395060	3236502	19091	29419	331107	41033	896489		1065216
Jun	3036944			310811	539642		2752852	16826	666451	18654	-4830	5048958	2332192	2579	30682	200694		368873		442358
Jul	565090			58223	258180		1456812	1266	194669	11901	-13569	1899735	692368	3409	1478	120795	6580	458612		440072
Aug	733073			50610	133129		1260516	6076	110794	15694	-28960	1743277	1025385	932	8139	117767				205076
Sep	584782			12711	130889		946675	17620	124505	6654	-10432	1838114	578983	565	1011	72313	5084	122825		336116
Oct	710029			6648	57706		585647	4416	47968	8617	-4453	1387996	995235	51	560	190770		427463		168574
Nov	652170			7219	32781		589902		47235	6332	-1987	658090	282340	131	512	164181		182698		67528
Dec	193302			14430	49038		237765		12407	39768		761891	115035		31228	48325		150856		66742

Table 2-14. The quantity of excess loadings at mainstem and tributary sites for an average year. Exceedences used 0.07 mg P/liter and 80 mg TSS/liter as a criteria.

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
Overall Average: Total Phosphorus Exceedence Loading (kg/day)																				
Jan	70			447	465		1579		-183	-178		3941	2565	4	19	7843	-15	7688	-40	3454
Feb	779			292	2172		1401		488	-141		2639	3561	4	123	4205	-14	4259	-35	2032
Mar	375			74	348		1343	164	468	399		3129	8997	36	283	9498	3	2374	171	3020
Apr	28			-8	434	23	1384	158	200	162	6	2612	1636	100	100	1443	15	2087	-11	497
May	1365			362	600	19	3496	191	564	272	2	2334	9866	40	145	6627		2888	194	225
Jun	1278			501	983	28	4051	157	277	90	-4	4144	3625	25	99	-41	-8	751	218	-994
Jul	489			118	686	-13	2163	165	649	78	-32	2277	1942	32	38	-345		241		-429
Aug	583			18	665	3	1110	103	74	61	-10	2188	1300	27	19	1022		1113	0	-328
Sep	338			27	675	14	1628	135	96	48	-13	1733	1164	17	26	932	-1	1889	-4	834
Oct	-28			-2	506	8	736	96	42	9	-2	1311	476	0	12	767		2985		855
Nov	236			0	562		616		-138	0		630	117	1	7	-308		501		-223
Dec	194			50	1121		606		-151	-20		374	301		106	982		1950		856
Overall Average: Orthophosphorus Exceedence Loading (kg/day)																				
Jan	1130			311			2198			-142		4998		1	11	10341		11646		10629
Feb	912			94	845		1707		-272	-140		3353	-1787	2	25	2746	-12	2360	-37	2841
Mar	-598			-181	370		-476	107	-13	-202		941	-998	13	14	465	-27	-227	-57	-305
Apr	-263			-180	511		-881	64	-98	188		1604	1135	27	82	-803	-27	-1744	2	-1331
May	-821			-60	702	26	-1555	103	-218	-48		-471	-1906	28	31	-1343	-28	-1269	-76	-994
Jun	-227			3	15144	35	636	67	-77	106		2342	837	22	85	132	-2	-393	-37	-1334
Jul	-350			-1	669	19	-26	95	230	173		2087	-632	48	52	289	0	-639	16	-666
Aug	-536			-3	625		-493	82	-48	116		-849	-250	22	26	-142		969		71
Sep	-581			-3	607		-732	101	-7	99		-458	-574	12	10	610		1056	-2	522
Oct	-763			-9	716		-818	77	-104	35		-1121	-747	12	8	345	-3	1479	-8	842
Nov	-905			-3	507		-1045		-82	-17		-1184	-1025	1	4	-787		466		-473
Dec	-217			33	1469		-32		-251	-7		-70	-89		67	863		1151		330
Overall Average: Total Suspended Solids Exceedence Loading (kg/day)																				
Jan	-1951215			-8304	-291013		-1675212			-239253		-1622680		791	-15848	-3953810		-4052407		-3976714
Feb	-2241823			-134736	-58727		-2757779		-521153	-238430		-2740976		-1898	-16477	-4103539		-3844008		-4326990
Mar	-1451911			-325925	-345616		-2218229	54332	-272609	-369168		-1409136	-2417066	4526	-5539	-4478824		-4275375		-4952723
Apr	-1395323			-258127	-286108		109739	18448	-528451	-145887		-862948	-3775279	62817	-40262	-4571296	-60402	-4382341		-4594533
May	791149			-288567	-185333		-350945	2082	-834664	-150991	15066	-1519586	-2139828	-18383	-42112	-4335112	-40984	-3851747		-3850429
Jun	340291			129970	208736		-512957	8022	-299326	-207562	16244	645731	-2472498	-15448	-17163	-4200238		-4074871		-4138725
Jul	-818128			5192	75016		-207918	-7811	-158752	-57138	9331	-206782	-1672291	-11407	-12864	-2559528	-7292	-2235583		-2296597
Aug	-692448			20381	-19018		-396395	-2020	-101236	-28405	-8376	-217539	-1039841	-15856	2083	-2048790				-1978080
Sep	-1129904			-12983	-29689		-1077164	6311	-78885	-27313	2192	-487471	-1833875	-9000	-5291	-2539107	226	-2493453		-2289730
Oct	-1230604			-29903	-130435		-1697678	-6169	-205586	-27601	-2365	-1252586	-1748098	-1544	-5891	-2578453		-2347139		-2620297
Nov	-1367482			-32197	-148236		-1694070		-234616	-33765	-1987	-1974419	-2452012	-771	-7304	-2260980		-2249159		-2386352
Dec	-1978247			-50367	-147257		-2204142		-455703	-82919		-2273587	-3120324		6413	-3050157		-2958373		-3096038

Appendix I

Hydrologic Reach Gain/Loss

1977 (Dry Year)

	Reach 1 Murphy to Nyssa	Reach 2 Nyssa to Weiser	Reach 3 Weiser to Farewell	Reach 4 Farewell to Brownlee	Reach 5 Brownlee to Oxbow	Reach 6 Oxbow to Hells Canyon	Reach 7 Hells Canyon to Salmon
1977 Percentage Ungaged Flow							
January	1.5%	1.9%	2.6%	8.1%	1.8%	3.4%	0.0%
February	2.8%	-1.0%	-1.8%	-5.5%	-1.6%	-3.1%	0.0%
March	1.1%	-1.9%	1.6%	4.7%	1.1%	2.1%	0.0%
April	1.8%	-3.6%	0.3%	1.0%	0.3%	0.5%	0.0%
May	-6.4%	8.1%	-4.4%	-12.8%	-4.9%	-8.9%	0.0%
June	1.4%	-3.4%	0.5%	1.4%	0.4%	0.7%	0.0%
July	-3.0%	0.3%	2.0%	6.0%	1.4%	2.7%	0.0%
August	-1.6%	7.0%	-1.2%	-3.6%	-1.0%	-1.9%	0.0%
September	3.8%	6.8%	-3.4%	-10.8%	-3.5%	-6.7%	0.0%
October	4.9%	6.6%	1.0%	3.2%	0.8%	1.5%	0.0%
November	1.7%	4.7%	0.5%	1.5%	0.4%	0.8%	0.0%
December	-0.2%	2.2%	3.4%	9.6%	2.3%	4.3%	0.0%
1977 Unaccounted Gain/Loss (cfs)							
January	177	251	391	1223	318	611	0
February	306	-118	-243	-759	-197	-379	0
March	115	-211	187	585	152	293	0
April	125	-270	25	80	21	40	0
May	-438	559	-358	-1119	-291	-559	0
June	90	-235	33	104	27	52	0
July	-168	18	119	371	96	185	0
August	-98	436	-83	-259	-67	-129	0
September	261	519	-295	-921	-239	-460	0
October	377	590	107	334	87	167	0
November	133	423	54	169	44	85	0
December	-14	203	457	1428	371	714	0
1977 Mainstem Flows (cfs)							
January	11829	12955	15055	15024	17674	17742	17800
February	10953	12146	13471	13909	11982	12110	12176
March	10194	11135	11999	12392	13351	13631	13700
April	7046	7556	7812	7649	8035	8421	8486
May	6848	6882	8105	8735	5905	6307	6401
June	6495	6931	7168	7553	7469	7711	7779
July	5657	5634	5946	6222	6807	6880	6901
August	6107	6270	7076	7174	6605	6637	6651
September	6835	7631	8733	8514	6833	6860	6887
October	7702	8922	10564	10380	11274	11303	11343
November	7963	9017	10775	11101	11152	11189	11289
December	8401	9416	13400	14911	16472	16529	17055

1992 (Dry Year)

	Reach 1 Murphy to Nyssa	Reach 2 Nyssa to Weiser	Reach 3 Weiser to Farewell	Reach 4 Farewell to Brownlee	Reach 5 Brownlee to Oxbow	Reach 6 Oxbow to Hells Canyon	Reach 7 Hells Canyon to Salmon
1992 Percentage Ungaged Flow							
January	-1.9%	0.5%	2.9%	8.5%	2.0%	3.8%	0.0%
February	-6.0%	0.5%	-0.4%	-1.2%	-0.4%	-0.7%	0.0%
March	4.0%	-8.8%	1.5%	4.2%	1.1%	2.1%	0.0%
April	-0.6%	5.9%	0.4%	1.2%	0.3%	0.6%	0.0%
May	3.2%	3.9%	3.6%	9.5%	2.3%	4.4%	0.0%
June	5.7%	0.1%	-0.5%	-1.3%	-0.4%	-0.7%	0.0%
July	5.8%	-1.5%	7.7%	22.0%	4.1%	7.9%	0.0%
August	0.4%	2.8%	3.1%	9.5%	2.1%	4.0%	0.0%
September	10.6%	-1.8%	0.3%	1.0%	0.3%	0.5%	0.0%
October	9.1%	-2.4%	2.2%	6.6%	1.6%	3.0%	0.0%
November	7.4%	-5.3%	-1.1%	-3.2%	-1.0%	-1.8%	0.0%
December	7.0%	-9.5%	-0.8%	-2.4%	-0.7%	-1.4%	0.0%
1992 Unaccounted Gain/Loss (cfs)							
January	-158	44	326	1020	265	510	0
February	-473	47	-53	-165	-43	-82	0
March	289	-721	157	491	128	245	0
April	-39	354	35	110	29	55	0
May	170	211	248	776	202	388	0
June	285	3	-26	-82	-21	-41	0
July	304	-84	463	1447	376	723	0
August	23	143	167	521	135	260	0
September	654	-117	23	72	19	36	0
October	642	-196	193	604	157	302	0
November	557	-471	-107	-333	-87	-167	0
December	530	-850	-82	-256	-67	-128	0
1992 Mainstem Flows (cfs)							
January	8283	8985	11135	11973	13355	13381	13486
February	7912	8562	12024	13259	11903	12019	12424
March	7172	8244	10414	11805	11707	11831	12216
April	6093	6033	8442	9203	8783	8915	9280
May	5285	5367	6898	8143	8679	8781	9136
June	4971	5223	5745	6283	5712	5751	5868
July	5274	5546	6002	6589	9110	9131	9189
August	5266	5075	5348	5509	6550	6558	6583
September	6177	6664	6934	6960	7095	7105	7131
October	7086	8102	8763	9110	10037	10051	10085
November	7579	8924	9768	10491	9096	9120	9193
December	7601	8902	9810	10809	9296	9320	9391

1979 (Medium Year)

	Reach 1 Murphy to Nyssa	Reach 2 Nyssa to Weiser	Reach 3 Weiser to Farewell	Reach 4 Farewell to Brownlee	Reach 5 Brownlee to Oxbow	Reach 6 Oxbow to Hells Canyon	Reach 7 Hells Canyon to Salmon
1979 Percentage Ungaged Flow							
January	-2.6%	1.5%	2.4%	7.3%	1.7%	3.2%	0.0%
February	-3.7%	2.6%	0.2%	0.7%	0.2%	0.4%	0.0%
March	-3.4%	-0.9%	-0.2%	-0.7%	-0.2%	-0.4%	0.0%
April	-4.1%	-1.1%	0.8%	2.4%	0.6%	1.2%	0.0%
May	-15.5%	1.5%	-1.8%	-4.5%	-1.5%	-2.8%	0.0%
June	1.2%	-3.4%	7.0%	18.1%	3.8%	7.2%	0.0%
July	6.0%	-2.5%	8.6%	24.4%	4.4%	8.5%	0.0%
August	9.5%	-1.5%	-3.8%	-11.1%	-4.0%	-7.6%	0.0%
September	13.7%	0.8%	-1.5%	-4.5%	-1.4%	-2.6%	0.0%
October	9.2%	-0.6%	-0.4%	-1.2%	-0.3%	-0.6%	0.0%
November	2.9%	2.1%	3.4%	10.7%	2.2%	4.3%	0.0%
December	2.8%	0.6%	1.2%	3.8%	0.9%	1.7%	0.0%
1979 Unaccounted Gain/Loss (cfs)							
January	-367	227	423	1322	344	661	0
February	-535	427	49	153	40	77	0
March	-545	-167	-56	-175	-45	-87	0
April	-589	-195	177	553	144	276	0
May	-1209	133	-251	-784	-204	-392	0
June	77	-258	666	2082	541	1041	0
July	323	-158	665	2077	540	1039	0
August	735	-138	-412	-1287	-335	-644	0
September	1089	80	-176	-551	-143	-275	0
October	792	-63	-48	-150	-39	-75	0
November	253	208	394	1230	320	615	0
December	227	60	132	413	107	207	0
1979 Mainstem Flows (cfs)							
January	14255	15471	17629	18049	20504	20529	20581
February	14361	16189	19732	21037	20461	20516	20757
March	15926	19265	24226	26658	24609	24838	25581
April	14413	16967	20860	23015	22713	23076	23650
May	7821	9019	14248	17266	13395	13861	14814
June	6595	7518	9527	11527	14216	14418	14973
July	5418	6234	7722	8531	12190	12243	12317
August	7724	9125	10920	11640	8404	8431	8464
September	7955	9754	11603	12262	10598	10618	10649
October	8621	10435	12261	12641	12006	12033	12097
November	8681	10027	11637	11507	14246	14274	14366
December	8223	9464	11019	10898	11938	11977	12104

1995 (Medium Year)

	Reach 1 Murphy to Nyssa	Reach 2 Nyssa to Weiser	Reach 3 Weiser to Farewell	Reach 4 Farewell to Brownlee	Reach 5 Brownlee to Oxbow	Reach 6 Oxbow to Hells Canyon	Reach 7 Hells Canyon to Salmon
1995 Percentage Ungaged Flow							
January	-2.7%	2.9%	2.9%	8.1%	2.0%	3.8%	0.0%
February	-39.1%	2.0%	4.4%	11.5%	2.7%	5.1%	0.0%
March	-22.0%	2.5%	1.0%	2.7%	0.7%	1.4%	0.0%
April	-8.9%	0.2%	3.7%	9.8%	2.3%	4.4%	0.0%
May	-17.6%	-4.1%	-0.9%	-2.7%	-0.8%	-1.5%	0.0%
June	5.1%	-3.6%	1.1%	3.2%	0.8%	1.6%	0.0%
July	9.2%	0.8%	3.8%	10.5%	2.5%	4.7%	0.0%
August	10.0%	1.6%	5.0%	14.3%	3.0%	5.8%	0.0%
September	13.9%	-1.4%	4.6%	13.2%	2.9%	5.5%	0.0%
October	13.2%	-0.7%	1.7%	4.8%	1.2%	2.4%	0.0%
November	1.6%	-2.4%	-4.4%	-12.8%	-4.9%	-9.5%	0.0%
December	-2.1%	-0.7%	0.1%	0.2%	0.1%	0.1%	0.0%
1995 Unaccounted Gain/Loss (cfs)							
January	-216	267	396	1238	322	619	0
February	-3093	176	663	2073	539	1036	0
March	-1665	220	179	559	145	279	0
April	-591	21	654	2043	531	1022	0
May	-2637	-872	-315	-984	-256	-492	0
June	900	-794	356	1112	289	556	0
July	770	97	570	1782	463	891	0
August	744	143	502	1569	408	785	0
September	1169	-145	529	1653	430	826	0
October	1108	-73	208	651	169	325	0
November	163	-271	-573	-1790	-465	-895	0
December	-222	-84	15	48	13	24	0
1995 Mainstem Flows (cfs)							
January	7982	9300	13545	15335	16278	16375	16909
February	7910	8989	15179	18032	19909	20123	20929
March	7561	8802	17652	20846	19480	19836	20713
April	6669	8777	17727	20956	22738	23068	23813
May	14952	21229	33255	35947	31897	32392	33510
June	17500	21760	31847	34644	34610	34872	35920
July	8415	11568	14918	16958	18763	18889	19286
August	7400	9075	10112	10996	13533	13586	13657
September	8413	10582	11517	12544	15075	15110	15160
October	8416	10672	12216	13446	13624	13664	13764
November	9920	11243	13073	13984	9420	9468	9629
December	10541	12384	17945	20175	18483	18612	19179

1975 (Wet Year)

	Reach 1 Murphy to Nyssa	Reach 2 Nyssa to Weiser	Reach 3 Weiser to Farewell	Reach 4 Farewell to Brownlee	Reach 5 Brownlee to Oxbow	Reach 6 Oxbow to Hells Canyon	Reach 7 Hells Canyon to Salmon
1975 Percentage Ungaged Flow							
January	3.4%	4.8%	1.8%	5.5%	1.3%	2.5%	0.0%
February	3.5%	3.8%	3.3%	10.2%	2.2%	4.2%	0.0%
March	-5.9%	-3.1%	1.4%	4.1%	1.0%	1.9%	0.0%
April	11.1%	-0.1%	1.0%	2.9%	0.7%	1.4%	0.0%
May	-1.8%	1.4%	-0.2%	-0.6%	-0.2%	-0.3%	0.0%
June	1.3%	5.2%	-2.8%	-7.7%	-2.6%	-5.0%	0.0%
July	6.9%	2.1%	2.3%	6.0%	1.6%	3.0%	0.0%
August	14.2%	6.0%	0.2%	0.6%	0.2%	0.3%	0.0%
September	12.6%	9.5%	2.3%	6.9%	1.6%	3.1%	0.0%
October	4.7%	8.0%	-1.3%	-3.9%	-1.1%	-2.1%	0.0%
November	2.1%	4.4%	0.3%	1.1%	0.3%	0.5%	0.0%
December	-0.4%	1.8%	0.6%	1.8%	0.5%	0.9%	0.0%
1975 Unaccounted Gain/Loss (cfs)							
January	495	771	344	1076	280	538	0
February	527	643	689	2154	560	1077	0
March	-1049	-692	399	1246	324	623	0
April	2513	-23	406	1269	330	634	0
May	-418	512	-92	-288	-75	-144	0
June	192	1052	-873	-2729	-709	-1364	0
July	474	179	282	881	229	441	0
August	957	518	25	77	20	39	0
September	1043	981	306	958	249	479	0
October	554	1127	-221	-691	-180	-346	0
November	277	669	62	194	50	97	0
December	-63	314	126	393	102	196	0
1975 Mainstem Flows (cfs)							
January	14503	16161	19232	19424	21604	21672	21783
February	14982	17007	20668	21166	25439	25567	25799
March	17690	22335	28335	30343	31823	32103	32714
April	22697	35663	42050	43883	45656	46042	46634
May	23752	36197	47345	50753	48325	48727	49721
June	15128	20293	31557	35296	26868	27110	28262
July	6861	8508	12293	14693	14547	14620	15038
August	6723	8624	11245	11977	11603	11635	11712
September	8311	10296	13433	13793	15625	15652	15708
October	11897	14129	17474	17939	16134	16163	16258
November	13470	15257	17957	18325	18459	18496	18619
December	16016	17803	21481	22170	22528	22585	22826

1997 (Wet Year)

	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
	Murphy to Nyssa	Nyssa to Weiser	Weiser to Farewell	Farewell to Brownlee	Brownlee to Oxbow	Oxbow to Hells Canyon	Hells Canyon to Salmon
1997 Percentage Ungaged Flow							
January	-6.2%	0.2%	1.9%	5.6%	1.4%	2.6%	0.0%
February	9.4%	0.2%	2.7%	8.2%	1.9%	3.6%	0.0%
March	-1.4%	0.2%	1.9%	5.6%	1.4%	2.6%	0.0%
April	1.4%	2.5%	1.9%	5.5%	1.4%	2.6%	0.0%
May	-0.7%	2.2%	-2.2%	-6.5%	-2.1%	-4.0%	0.0%
June	5.9%	-2.8%	-1.0%	-2.9%	-0.8%	-1.6%	0.0%
July	13.1%	7.1%	2.7%	7.5%	1.8%	3.5%	0.0%
August	6.8%	5.9%	4.3%	13.0%	2.7%	5.2%	0.0%
September	5.3%	4.1%	4.6%	13.9%	2.9%	5.6%	0.0%
October	3.8%	2.4%	1.7%	5.0%	1.2%	2.4%	0.0%
November	-0.4%	-0.3%	-4.9%	-14.4%	-5.8%	-11.1%	0.0%
December	-1.2%	1.0%	-2.5%	-7.4%	-2.4%	-4.6%	0.0%
1997 Unaccounted Gain/Loss (cfs)							
January	-1130	55	834	2608	678	1304	0
February	2489	89	1331	4160	1082	2080	0
March	-403	93	929	2904	755	1452	0
April	322	839	836	2612	679	1306	0
May	-125	572	-918	-2869	-746	-1434	0
June	1880	-1065	-477	-1492	-388	-746	0
July	1411	966	470	1469	382	734	0
August	710	745	664	2074	539	1037	0
September	784	696	886	2768	720	1384	0
October	598	424	330	1031	268	516	0
November	-64	-43	-849	-2654	-690	-1327	0
December	-195	162	-482	-1506	-391	-753	0
1997 Mainstem Flows (cfs)							
January	18113	27532	43481	46790	48904	49323	50155
February	26536	38579	49104	50924	57757	57898	58225
March	28352	39065	49429	51789	55469	55782	56548
April	23207	33130	44833	47292	50265	50779	51863
May	18645	25781	40806	43966	34839	35487	37106
June	31977	38387	49137	51983	46034	46359	47630
July	10778	13542	17694	19496	20748	20828	21161
August	10480	12622	15406	16013	19721	19759	19858
September	14873	17113	19070	19893	24827	24856	24960
October	15768	17735	19668	20580	21813	21840	21945
November	14299	15547	17490	18413	11970	12001	12127
December	15787	16887	19397	20217	16265	16290	16400

Appendix II

Monthly Average Concentrations and Flow
(1975-1999)

MONTHLY AVERAGE CONCENTRATIONS (mg/L)

PARAMETER	YEAR TYPE	MONTH	Murphy	Nyssa	Weiser	Farewell	Brownlee	Oxbow	Hells
Total Phosphorus	Medium	JAN	0.050	0.073	0.123		0.080	0.082	0.075
Total Phosphorus	Medium	FEB	0.130	0.108	0.163		0.092	0.096	0.094
Total Phosphorus	Medium	MAR	0.080	0.164	0.117	0.263	0.115	0.115	0.115
Total Phosphorus	Medium	APR	0.090	0.113	0.121	0.150	0.086	0.067	0.079
Total Phosphorus	Medium	MAY	0.115	0.143	0.136	0.179	0.071	0.110	0.073
Total Phosphorus	Medium	JUN	0.100	0.139	0.115	0.114	0.055	0.050	0.051
Total Phosphorus	Medium	JUL	0.077	0.132	0.158	0.110	0.030	0.039	0.068
Total Phosphorus	Medium	AUG	0.104	0.111	0.137	0.163	0.084	0.103	0.069
Total Phosphorus	Medium	SEPT	0.075	0.094	0.117	0.139	0.110	0.121	0.093
Total Phosphorus	Medium	OCT	0.055	0.084	0.094	0.119	0.097	0.112	0.103
Total Phosphorus	Medium	NOV	0.085	0.096	0.087	0.090	0.099	0.132	0.098
Total Phosphorus	Medium	DEC	0.100	0.075	0.083	0.098	0.100	0.100	0.101
Total Phosphorus	High	JAN	0.078	0.085	0.124	0.130	0.113	0.105	0.115
Total Phosphorus	High	FEB	0.060	0.080	0.095	0.145	0.072	0.073	0.078
Total Phosphorus	High	MAR	0.123	0.093	0.130		0.191	0.060	0.112
Total Phosphorus	High	APR	0.085	0.085	0.093	0.130	0.092	0.080	0.080
Total Phosphorus	High	MAY	0.099	0.090	0.118	0.280	0.133	0.078	0.067
Total Phosphorus	High	JUN	0.125	0.110	0.143	0.110	0.053	0.055	0.045
Total Phosphorus	High	JUL	0.101	0.148	0.129	0.120	0.047	0.051	0.056
Total Phosphorus	High	AUG	0.093	0.111	0.156	0.100	0.072	0.060	0.035
Total Phosphorus	High	SEPT	0.099	0.104	0.110	0.120	0.071	0.077	0.084
Total Phosphorus	High	OCT	0.063	0.092	0.099		0.106	0.115	0.093
Total Phosphorus	High	NOV	0.071	0.060	0.098		0.071	0.077	0.074
Total Phosphorus	High	DEC	0.074	0.061	0.070		0.064	0.063	0.066
Total Phosphorus	Low	JAN	0.045	0.062	0.065				0.075
Total Phosphorus	Low	FEB	0.034	0.064	0.076				0.045
Total Phosphorus	Low	MAR	0.100	0.096	0.107				0.105
Total Phosphorus	Low	APR	0.060	0.080	0.084	0.220	0.198	0.600	0.135
Total Phosphorus	Low	MAY	0.075	0.106	0.130	0.110			0.085
Total Phosphorus	Low	JUN	0.060	0.093	0.115	0.110	0.100		0.053
Total Phosphorus	Low	JUL	0.078	0.140	0.180	0.160	0.130	0.095	0.057
Total Phosphorus	Low	AUG	0.070	0.117	0.140	0.120			0.070
Total Phosphorus	Low	SEPT	0.055	0.082	0.053	0.090	0.110		0.097
Total Phosphorus	Low	OCT	0.180	0.063	0.105	0.105	0.080	0.090	0.087
Total Phosphorus	Low	NOV	0.080	0.083	0.085	0.080	0.070		0.060
Total Phosphorus	Low	DEC	0.067	0.089	0.072	0.075	0.130		0.118

MONTHLY AVERAGE CONCENTRATIONS (mg/L)

PARAMETER	YEAR TYPE	MONTH	Murphy	Nyssa	Weiser	Farewell	Brownlee	Oxbow	Hells
Orthophosphorus	Medium	JAN		0.042	0.051		0.065	0.063	0.059
Orthophosphorus	Medium	FEB		0.046	0.062		0.065	0.064	0.059
Orthophosphorus	Medium	MAR	0.030	0.040	0.029	0.075	0.067	0.075	0.053
Orthophosphorus	Medium	APR	0.008	0.019	0.027	0.020	0.035	0.025	0.037
Orthophosphorus	Medium	MAY	0.008	0.014	0.019	0.010	0.023	0.036	0.026
Orthophosphorus	Medium	JUN	0.014	0.012	0.012	0.019	0.023	0.018	0.019
Orthophosphorus	Medium	JUL	0.008	0.021	0.016	0.013	0.012	0.021	0.034
Orthophosphorus	Medium	AUG	0.016	0.018	0.012	0.018	0.046	0.057	0.056
Orthophosphorus	Medium	SEPT	0.028	0.027	0.036	0.047	0.080	0.089	0.074
Orthophosphorus	Medium	OCT	0.021	0.026	0.036	0.033	0.075	0.084	0.082
Orthophosphorus	Medium	NOV	0.015	0.025	0.030	0.035	0.069	0.096	0.086
Orthophosphorus	Medium	DEC	0.060	0.051	0.060	0.073	0.081	0.080	0.084
Orthophosphorus	High	JAN	0.047	0.060	0.073	0.044	0.070	0.068	0.082
Orthophosphorus	High	FEB	0.048	0.061	0.069	0.050	0.045	0.045	0.043
Orthophosphorus	High	MAR	0.060	0.010	0.062	0.184	0.046	0.030	0.054
Orthophosphorus	High	APR	0.016	0.030	0.028	0.020	0.025	0.020	0.025
Orthophosphorus	High	MAY	0.010	0.010	0.021	0.083	0.040	0.020	0.028
Orthophosphorus	High	JUN	0.019	0.040	0.054	0.028	0.044	0.020	0.013
Orthophosphorus	High	JUL	0.008	0.010	0.016	0.043	0.022	0.028	0.029
Orthophosphorus	High	AUG	0.010	0.010	0.010	0.024	0.029	0.030	0.028
Orthophosphorus	High	SEPT	0.014	0.010	0.036	0.010	0.045	0.057	0.079
Orthophosphorus	High	OCT	0.012	0.010	0.011		0.069	0.082	0.066
Orthophosphorus	High	NOV	0.022		0.030		0.046	0.049	0.053
Orthophosphorus	High	DEC	0.039	0.021	0.039		0.042	0.041	0.045
Orthophosphorus	Low	JAN	0.019	0.052	0.056				
Orthophosphorus	Low	FEB	0.031	0.044	0.034				
Orthophosphorus	Low	MAR	0.080	0.050	0.059				
Orthophosphorus	Low	APR	0.007	0.011	0.016	0.030	0.045	0.040	0.045
Orthophosphorus	Low	MAY	0.006	0.011	0.026	0.070			
Orthophosphorus	Low	JUN	0.010	0.003	0.002	0.050	0.060		0.050
Orthophosphorus	Low	JUL	0.016	0.006	0.010	0.050	0.065	0.040	0.050
Orthophosphorus	Low	AUG	0.026	0.006		0.050			0.070
Orthophosphorus	Low	SEPT	0.012	0.011	0.010	0.030	0.090		0.080
Orthophosphorus	Low	OCT	0.011	0.010	0.020	0.035	0.065	0.080	0.075
Orthophosphorus	Low	NOV	0.016	0.044	0.041	0.020	0.020		0.040
Orthophosphorus	Low	DEC	0.041	0.054	0.016	0.035	0.110		0.070

MONTHLY AVERAGE CONCENTRATIONS (mg/L)

PARAMETER	YEAR TYPE	MONTH	Murphy	Nyssa	Weiser	Farewell	Brownlee	Oxbow	Hells
Total Suspended Solids	Medium	JAN		15.5	29.6		3.7	3.5	5.0
Total Suspended Solids	Medium	FEB		24.0	37.4		56.3	13.5	10.3
Total Suspended Solids	Medium	MAR	22.0	78.8	60.1	51.0	4.8	2.5	1.5
Total Suspended Solids	Medium	APR	34.4	39.5	62.3	42.0	5.8	8.0	7.3
Total Suspended Solids	Medium	MAY	83.6	85.8	59.0	68.8	13.4	4.0	11.8
Total Suspended Solids	Medium	JUN	50.3	61.0	59.7	47.7	6.8	4.0	12.6
Total Suspended Solids	Medium	JUL	34.3	46.0	62.2	54.0	2.4	1.8	2.8
Total Suspended Solids	Medium	AUG	23.9	41.7	46.7	75.0	4.5	3.0	3.5
Total Suspended Solids	Medium	SEPT	19.4	25.6	35.9	21.0	5.3	5.5	11.7
Total Suspended Solids	Medium	OCT	17.9	15.3	23.7	40.8	7.0	6.0	4.8
Total Suspended Solids	Medium	NOV	10.5	12.7	29.4	15.0	6.6	5.0	4.5
Total Suspended Solids	Medium	DEC	9.0	11.7	29.3	6.0	3.7	3.0	3.0
Total Suspended Solids	High	JAN	10.3	20.0	90.5		4.7	4.0	5.0
Total Suspended Solids	High	FEB	5.7	13.5	11.0		5.0	7.0	6.0
Total Suspended Solids	High	MAR	43.0	108.0	70.9		8.5	12.0	4.0
Total Suspended Solids	High	APR	28.7	37.5	33.7		17.0	10.0	19.5
Total Suspended Solids	High	MAY	51.7	45.0	70.0		13.0	17.0	18.5
Total Suspended Solids	High	JUN	47.0	47.0	44.0	45.0	5.5	5.0	10.5
Total Suspended Solids	High	JUL	31.3	65.0	81.2	28.0	8.2	9.0	8.5
Total Suspended Solids	High	AUG	31.3	42.0	44.0	52.5	6.0		12.0
Total Suspended Solids	High	SEPT	14.7	24.0	51.1		3.0	1.0	9.3
Total Suspended Solids	High	OCT	23.5	26.5	34.0		8.9	8.0	8.5
Total Suspended Solids	High	NOV	17.0	9.0	29.3		7.5	8.5	6.0
Total Suspended Solids	High	DEC	3.5	12.5	4.0		2.5	3.0	2.0
Total Suspended Solids	Low	JAN	5.0	5.5	12.0				7.0
Total Suspended Solids	Low	FEB	12.0	8.0	18.0				10.0
Total Suspended Solids	Low	MAR	40.0	29.7	24.5				19.0
Total Suspended Solids	Low	APR	54.0	32.5	42.0	32.0	1.3		21.7
Total Suspended Solids	Low	MAY	42.0	61.0	89.5	66.0	0.5		28.0
Total Suspended Solids	Low	JUN	30.0	39.0	62.0	7.0	0.5		25.5
Total Suspended Solids	Low	JUL	33.7	82.7	96.0	23.0	1.8		53.0
Total Suspended Solids	Low	AUG	24.5	57.0	81.0	3.0	0.5		35.5
Total Suspended Solids	Low	SEPT	12.5	44.0	55.0	34.0	1.0		23.0
Total Suspended Solids	Low	OCT	32.3	15.0	30.3	28.8	1.5		12.3
Total Suspended Solids	Low	NOV	79.5	21.0	16.0	11.0	0.5		6.5
Total Suspended Solids	Low	DEC	9.0		11.5	4.4	1.0		5.0

MONTHLY AVERAGE CONCENTRATIONS (mg/L)

PARAMETER	YEAR TYPE	MONTH	Murphy	Nyssa	Weiser	Farewell	Brownlee	Oxbow	Hells
Flow (cfs)	Medium	JAN	11,118	12,385	15,587	16,692	18,391	18,452	18,745
Flow (cfs)	Medium	FEB	11,135	12,589	17,455	19,534	20,185	20,319	20,843
Flow (cfs)	Medium	MAR	11,743	14,033	20,939	23,752	22,045	22,337	23,147
Flow (cfs)	Medium	APR	10,541	12,872	19,293	21,986	22,725	23,072	23,732
Flow (cfs)	Medium	MAY	11,386	15,124	23,752	26,606	22,646	23,127	24,162
Flow (cfs)	Medium	JUN	12,047	14,639	20,687	23,085	24,413	24,645	25,447
Flow (cfs)	Medium	JUL	6,916	8,901	11,320	12,744	15,477	15,566	15,801
Flow (cfs)	Medium	AUG	7,562	9,100	10,516	11,318	10,968	11,009	11,060
Flow (cfs)	Medium	SEPT	8,184	10,168	11,560	12,403	12,837	12,864	12,904
Flow (cfs)	Medium	OCT	8,519	10,553	12,239	13,043	12,815	12,849	12,931
Flow (cfs)	Medium	NOV	9,301	10,635	12,355	12,745	11,833	11,871	11,998
Flow (cfs)	Medium	DEC	9,382	10,924	14,482	15,536	15,211	15,295	15,641
Flow (cfs)	Low	JAN	10,056	10,970	13,095	13,498	15,515	15,562	15,643
Flow (cfs)	Low	FEB	9,433	10,354	12,748	13,584	11,943	12,065	12,300
Flow (cfs)	Low	MAR	8,683	9,690	11,206	12,098	12,529	12,731	12,958
Flow (cfs)	Low	APR	6,570	6,794	8,127	8,426	8,409	8,668	8,883
Flow (cfs)	Low	MAY	6,067	6,125	7,501	8,439	7,292	7,544	7,769
Flow (cfs)	Low	JUN	5,733	6,077	6,457	6,918	6,591	6,731	6,823
Flow (cfs)	Low	JUL	5,465	5,590	5,974	6,405	7,958	8,006	8,045
Flow (cfs)	Low	AUG	5,687	5,673	6,212	6,342	6,578	6,598	6,617
Flow (cfs)	Low	SEPT	6,506	7,148	7,834	7,737	6,964	6,983	7,009
Flow (cfs)	Low	OCT	7,394	8,512	9,664	9,745	10,656	10,677	10,714
Flow (cfs)	Low	NOV	7,771	8,971	10,271	10,796	10,124	10,154	10,241
Flow (cfs)	Low	DEC	8,001	9,159	11,605	12,860	12,884	12,924	13,223
Flow (cfs)	High	JAN	14,503	16,161	19,232	19,424	21,604	21,672	21,783
Flow (cfs)	High	FEB	20,759	27,793	34,886	36,045	41,598	41,733	42,012
Flow (cfs)	High	MAR	23,021	30,700	38,882	41,066	43,646	43,943	44,631
Flow (cfs)	High	APR	22,952	34,397	43,442	45,588	47,961	48,411	49,249
Flow (cfs)	High	MAY	21,198	30,989	44,076	47,360	41,582	42,107	43,414
Flow (cfs)	High	JUN	23,552	29,340	40,347	43,640	36,451	36,735	37,946
Flow (cfs)	High	JUL	8,820	11,025	14,993	17,094	17,647	17,724	18,100
Flow (cfs)	High	AUG	8,601	10,623	13,326	13,995	15,662	15,697	15,785
Flow (cfs)	High	SEPT	11,592	13,705	16,252	16,843	20,226	20,254	20,334
Flow (cfs)	High	OCT	13,832	15,932	18,571	19,260	18,974	19,001	19,101
Flow (cfs)	High	NOV	13,884	15,402	17,723	18,369	15,215	15,249	15,373
Flow (cfs)	High	DEC	15,902	17,345	20,439	21,194	19,397	19,437	19,613

Appendix III

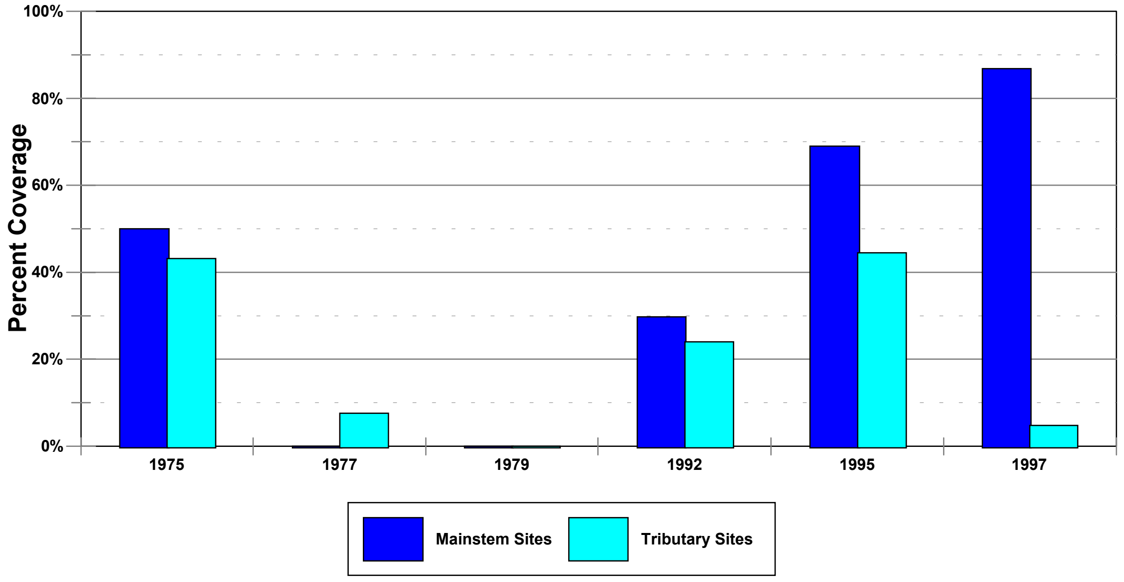
Annual Average Data Coverages for Mainstem Snake River and its Tributaries

Average Monthly Total Phosphorus

Percent Coverage

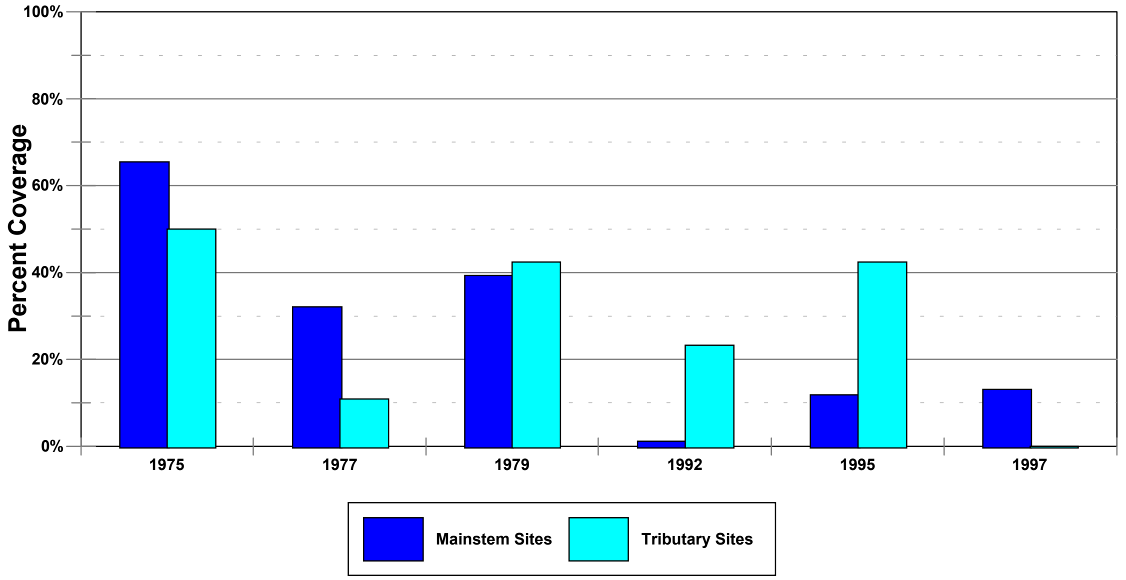
Average Monthly Orthophosphorus

Percent Coverage



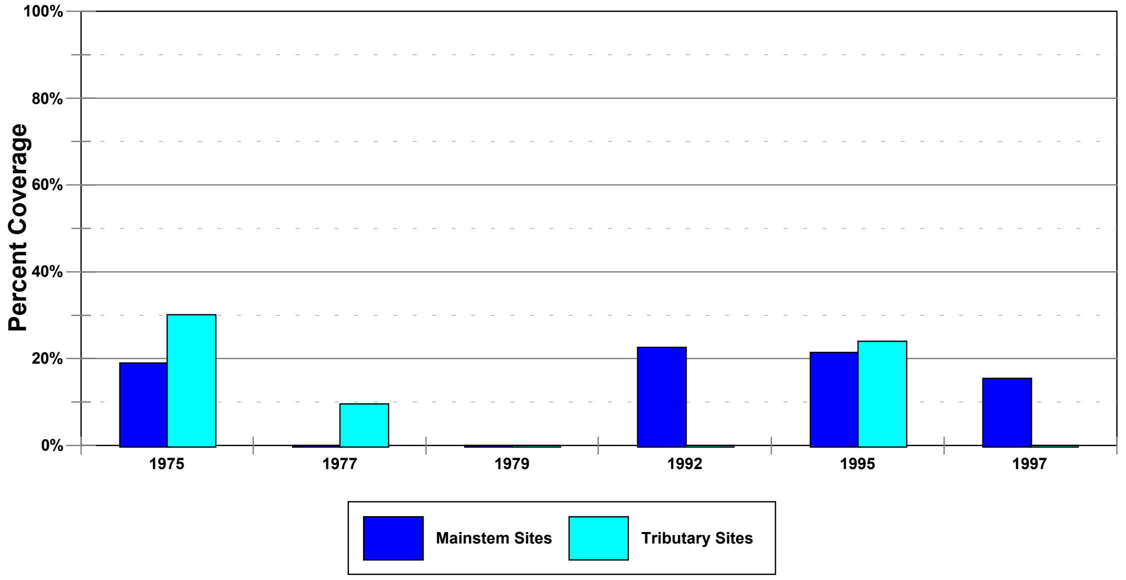
Average Monthly Ammonia

Percent Coverage

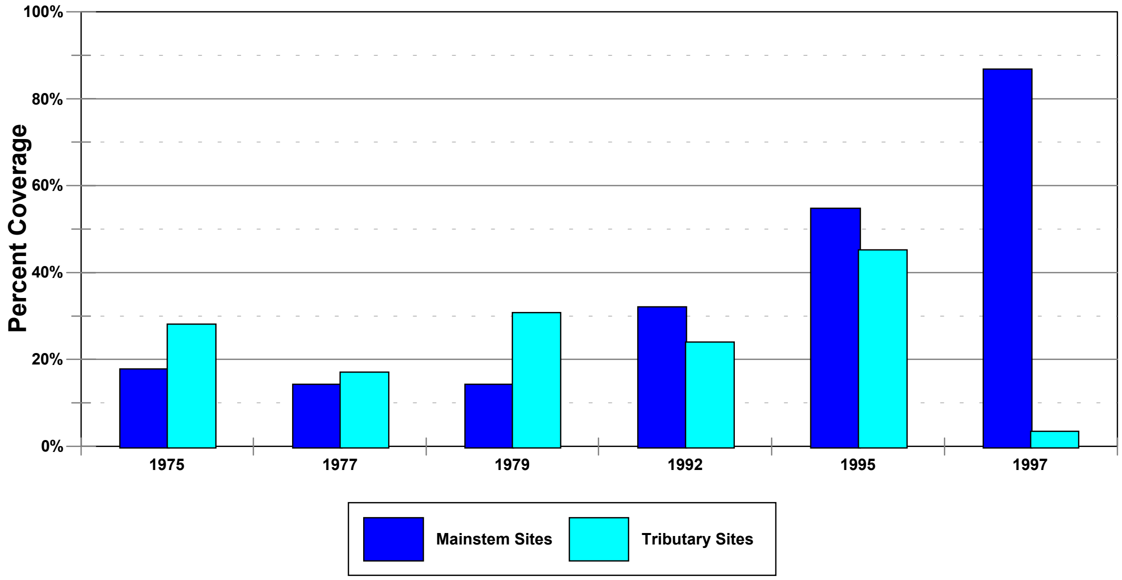


Average Monthly Nitrate

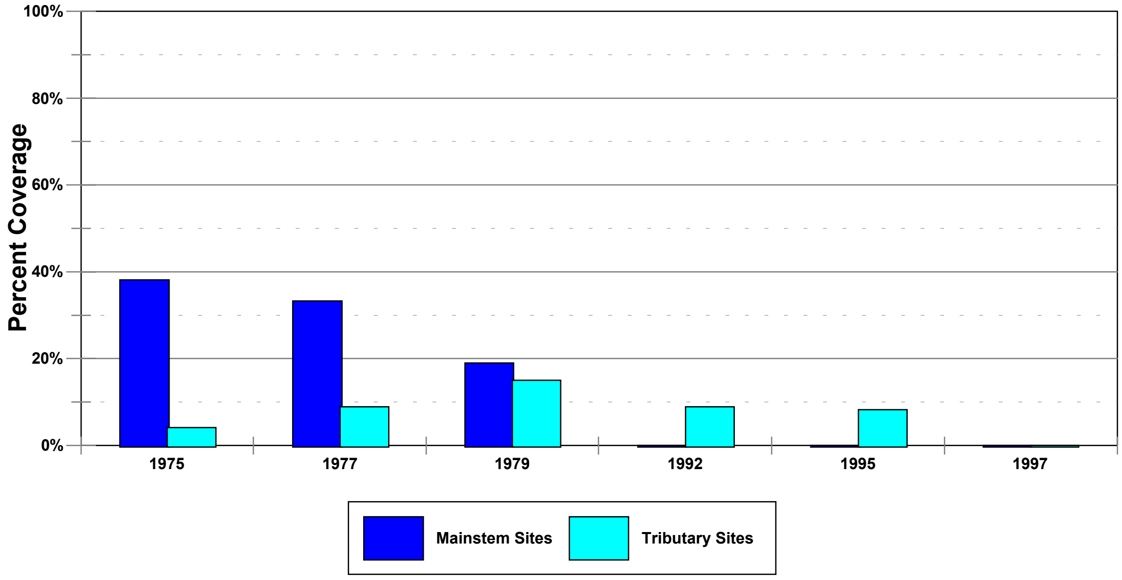
Percent Coverage

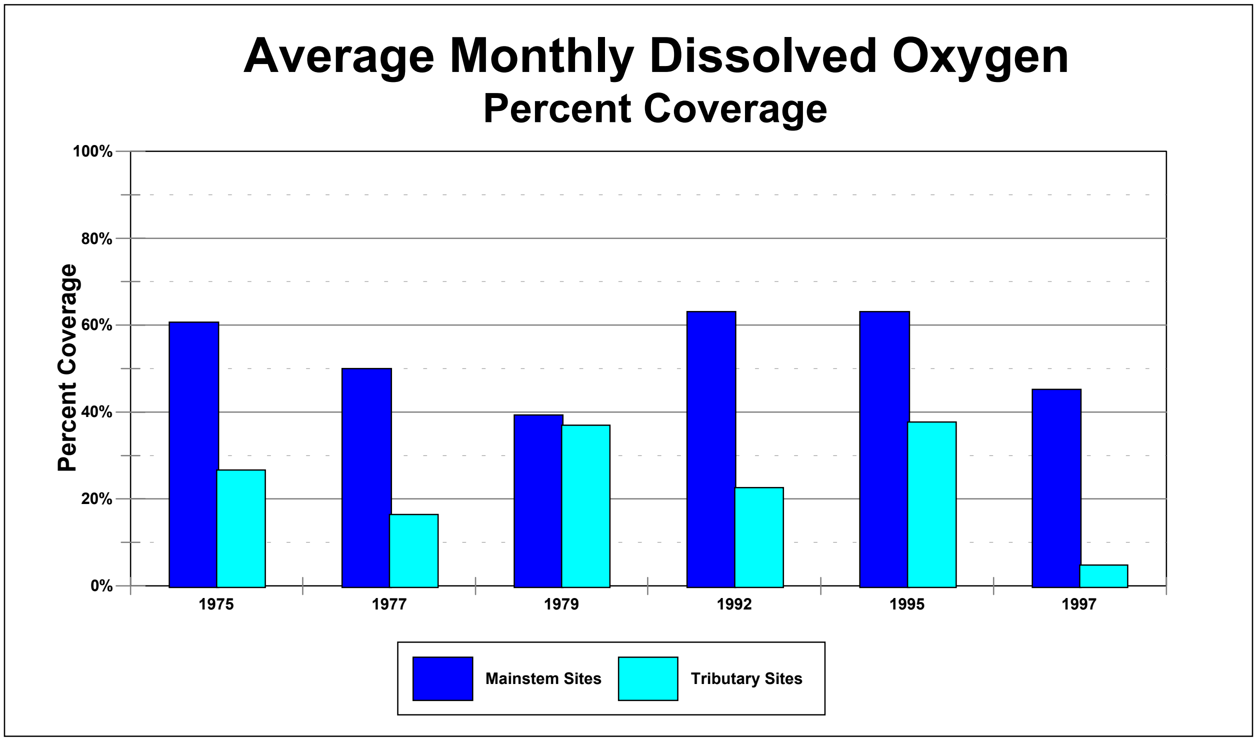


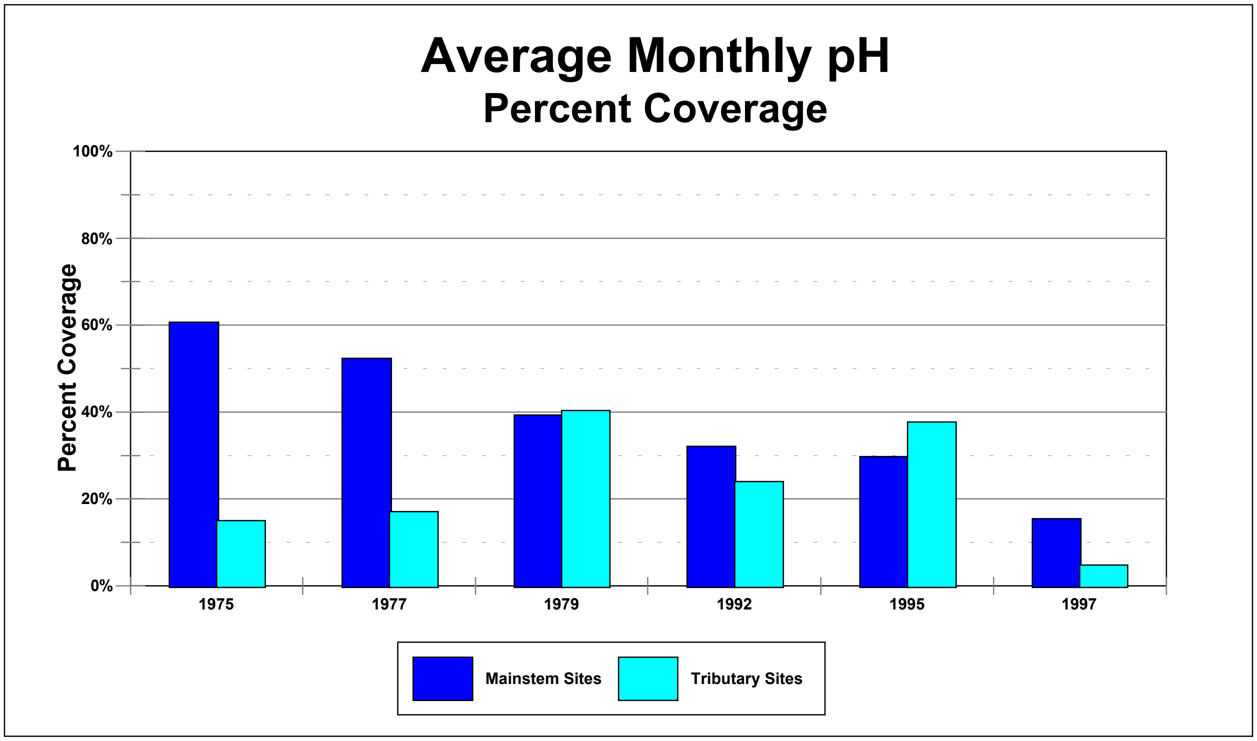
Average Monthly TSS
Percent Coverage



Average Monthly Mercury
Percent Coverage

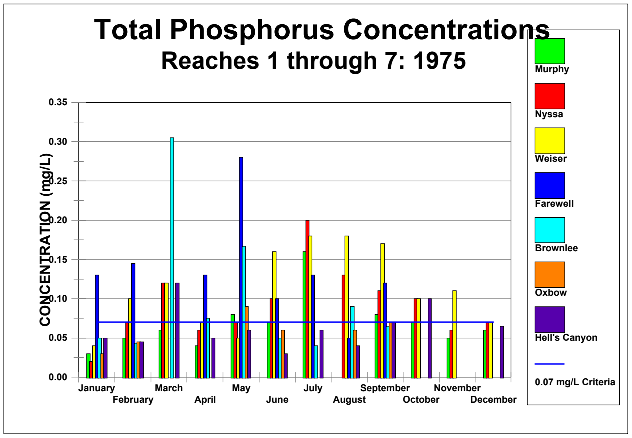


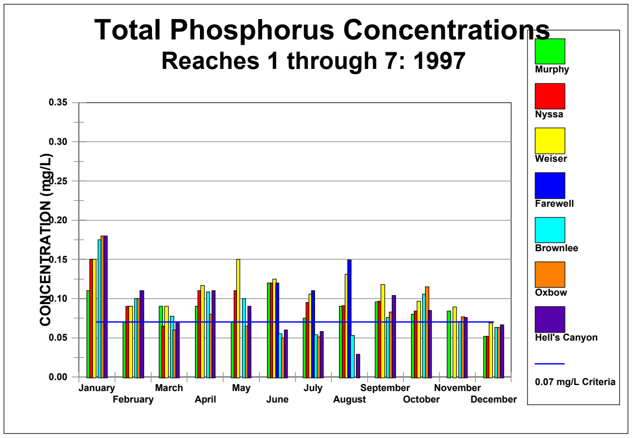

Average Monthly Dissolved Oxygen
Percent Coverage
Percent Coverage
100%
80%
60%
40%
20%
0%
1975
1977
1979
1992
1995
1997
Mainstem Sites
Tributary Sites

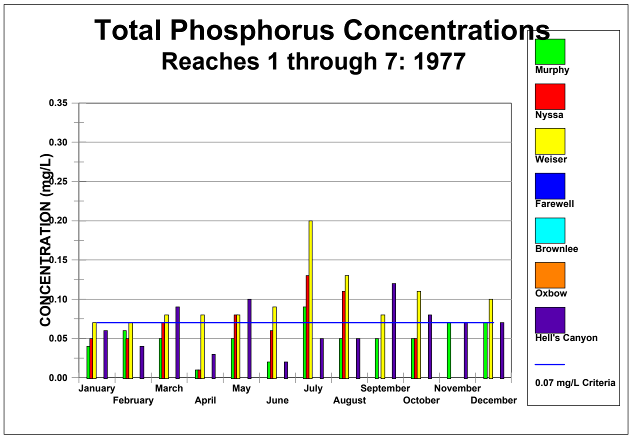

Average Monthly pH
Percent Coverage
Percent Coverage
100%
80%
60%
40%
20%
0%
1975
1977
1979
1992
1995
1997
Mainstem Sites
Tributary Sites

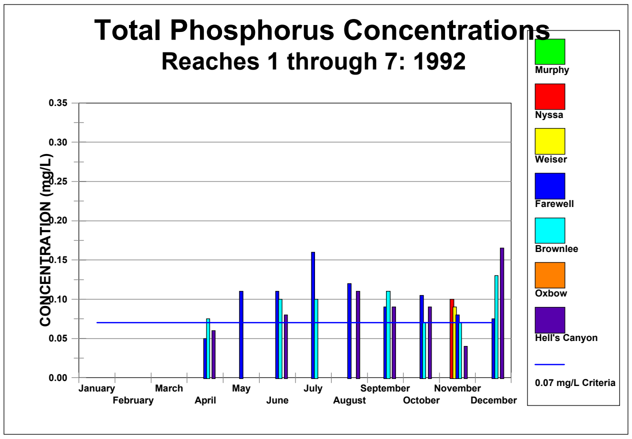
Appendix IV

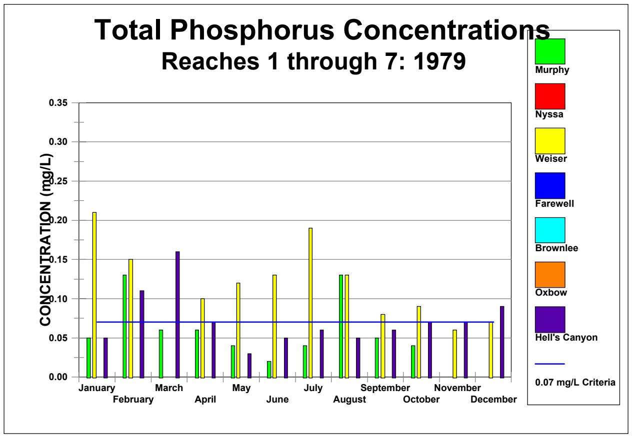
Monthly Average Concentrations for the Six Representative Years

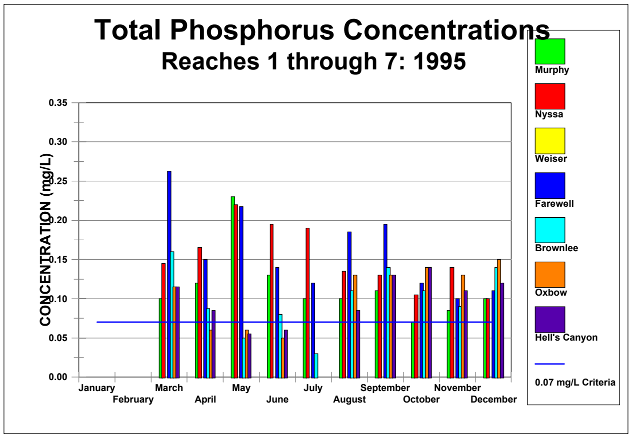

Total Phosphorus Concentrations
Reaches 1 through 7: 1975
CONCENTRATION (mg/L)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
0.07 mg/L Criteria

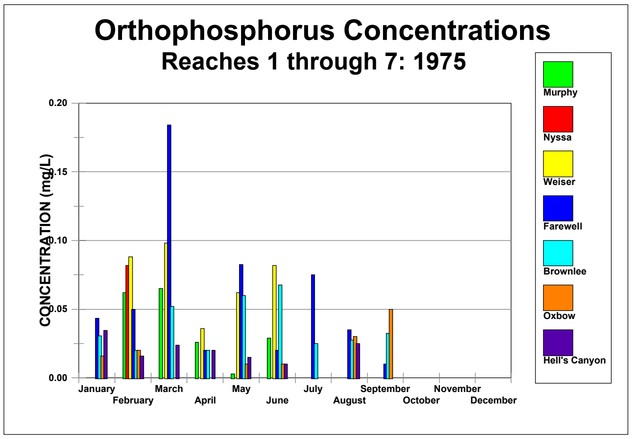

Total Phosphorus Concentrations
Reaches 1 through 7: 1997
CONCENTRATION (mg/L)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
0.07 mg/L Criteria

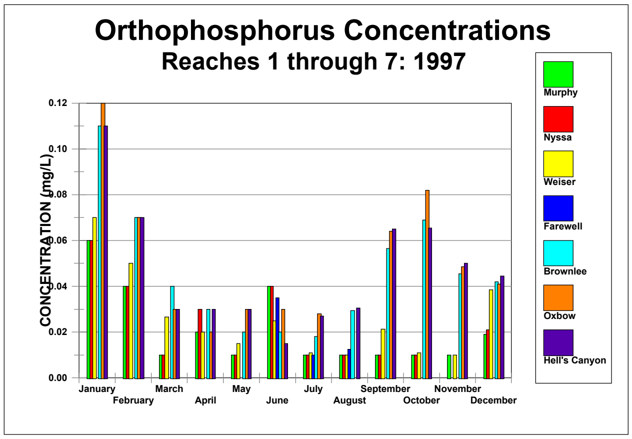

Total Phosphorus Concentrations
Reaches 1 through 7: 1977
CONCENTRATION (mg/L)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
0.07 mg/L Criteria

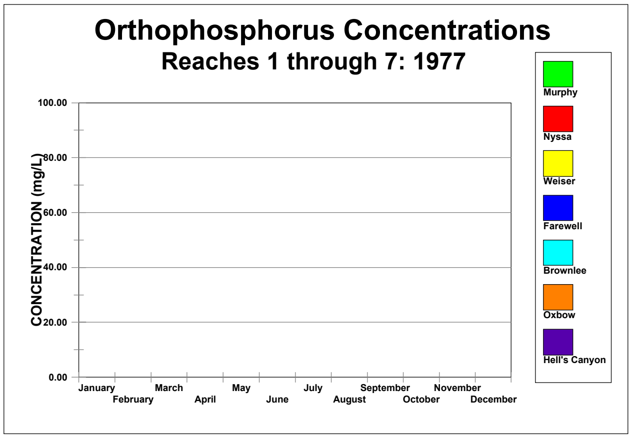

Total Phosphorus Concentrations
Reaches 1 through 7: 1992
CONCENTRATION (mg/L)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
0.07 mg/L Criteria

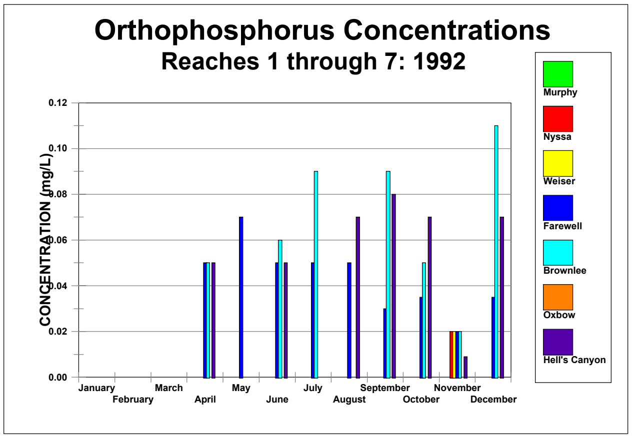

Total Phosphorus Concentrations
Reaches 1 through 7: 1979
CONCENTRATION (mg/L)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
0.07 mg/L Criteria

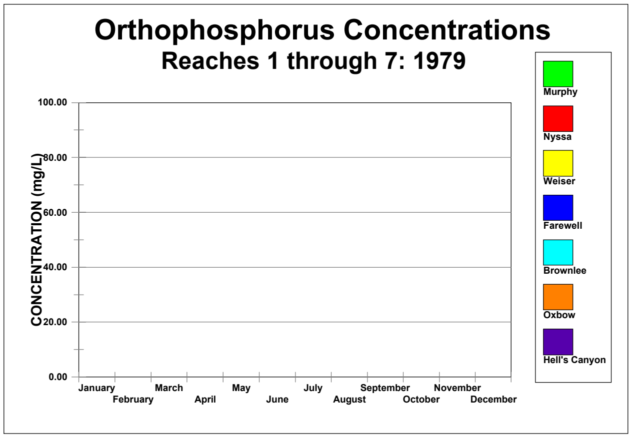

Total Phosphorus Concentrations
Reaches 1 through 7: 1995
CONCENTRATION (mg/L)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
0.07 mg/L Criteria

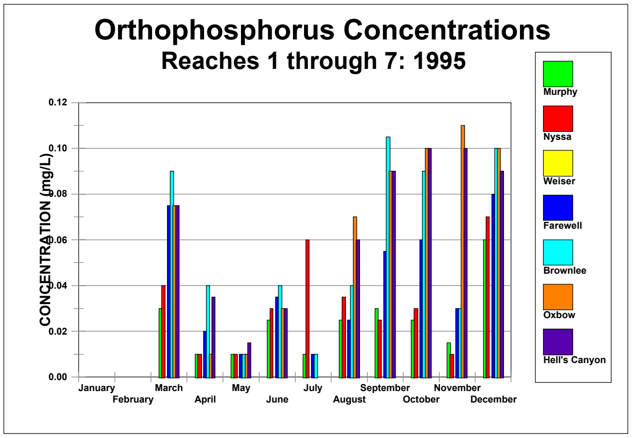

Orthophosphorus Concentrations
Reaches 1 through 7: 1975

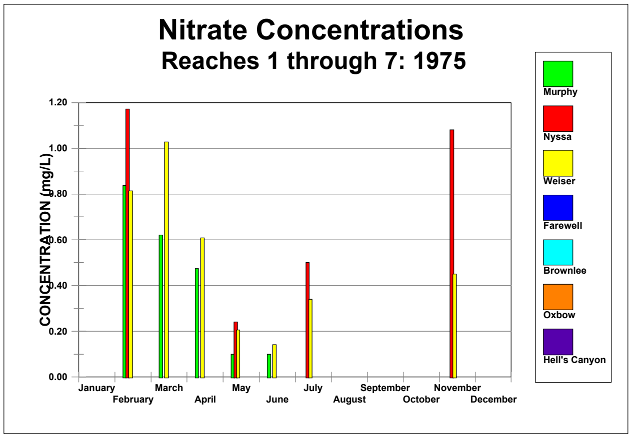

Orthophosphorus Concentrations
Reaches 1 through 7: 1997

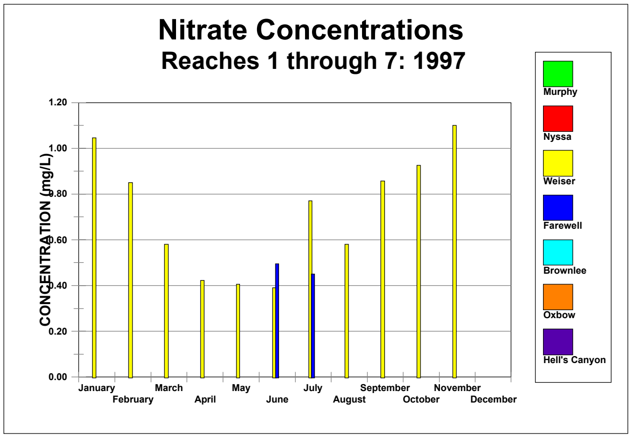

Orthophosphorus Concentrations
Reaches 1 through 7: 1977

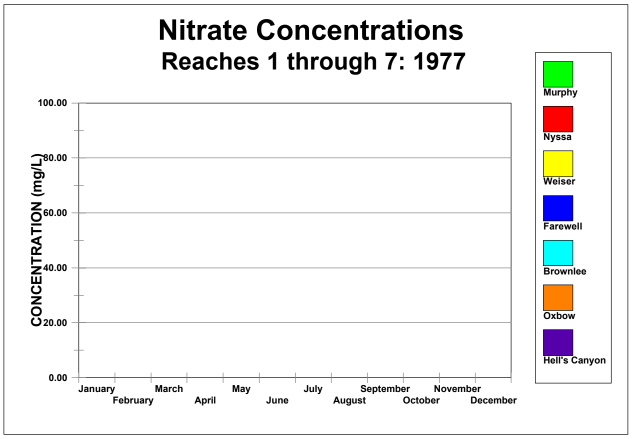

Orthophosphorus Concentrations
Reaches 1 through 7: 1992

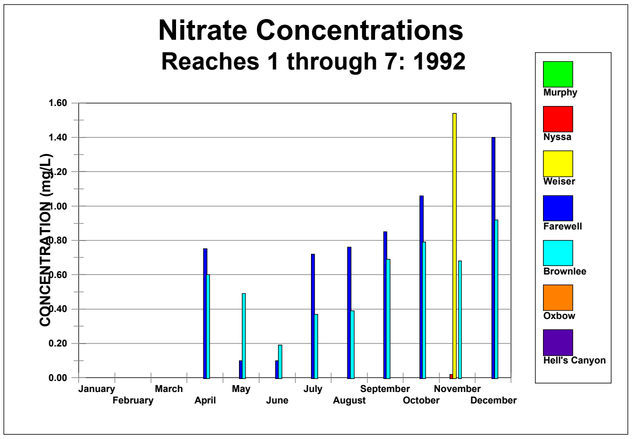

Orthophosphorus Concentrations
Reaches 1 through 7: 1979

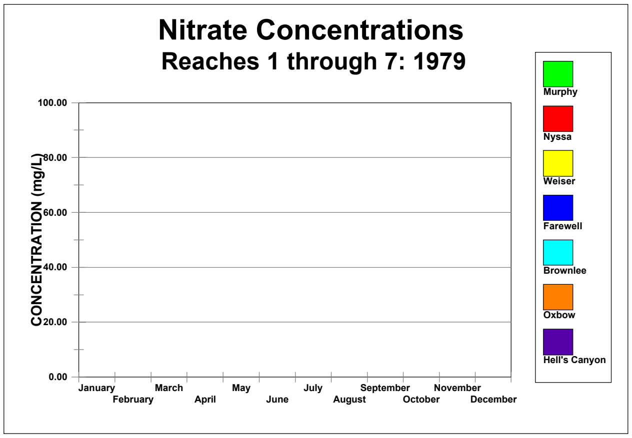

Orthophosphorus Concentrations
Reaches 1 through 7: 1995

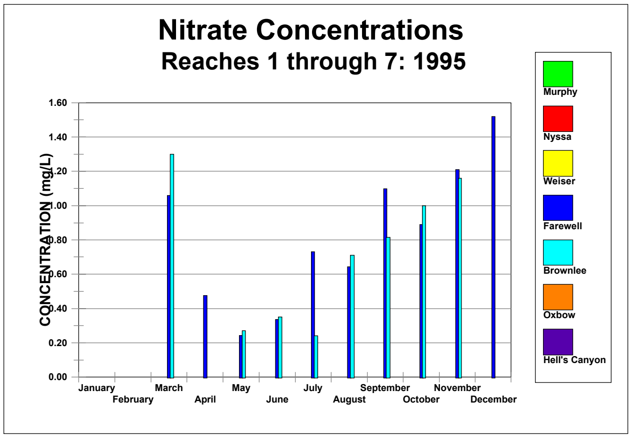

Nitrate Concentrations
Reaches 1 through 7: 1975
CONCENTRATION (mg/L)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

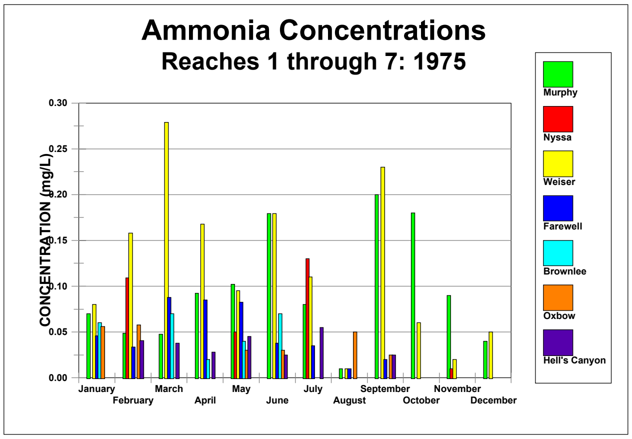

Nitrate Concentrations
Reaches 1 through 7: 1997
CONCENTRATION (mg/L)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

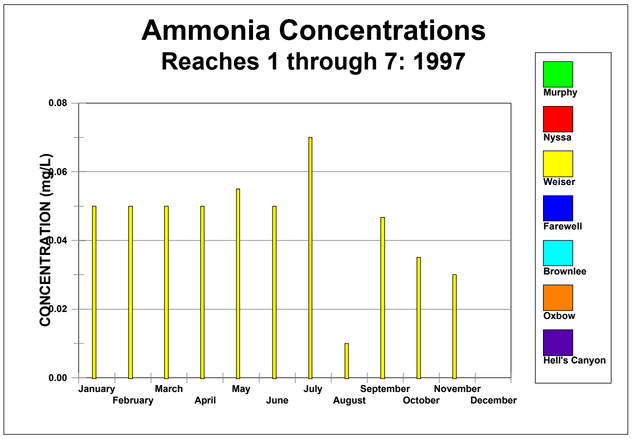

Nitrate Concentrations
Reaches 1 through 7: 1977
CONCENTRATION (mg/L)
100.00
80.00
60.00
40.00
20.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

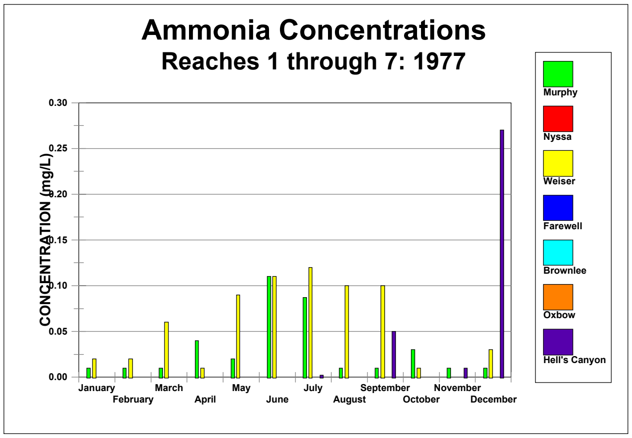

Nitrate Concentrations
Reaches 1 through 7: 1992
CONCENTRATION (mg/L)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

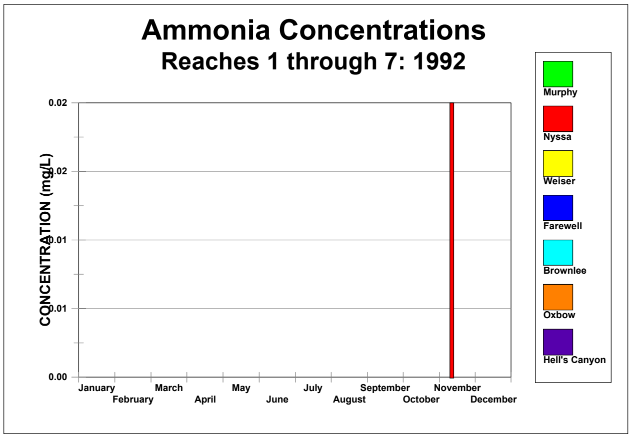

Nitrate Concentrations
Reaches 1 through 7: 1979
CONCENTRATION (mg/L)
100.00
80.00
60.00
40.00
20.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

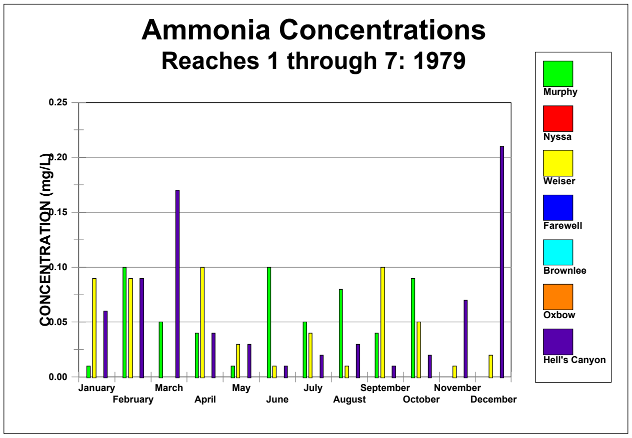

Nitrate Concentrations
Reaches 1 through 7: 1995
CONCENTRATION (mg/L)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

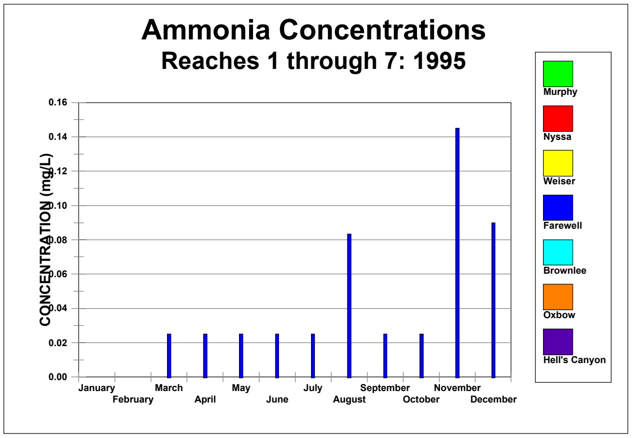

Ammonia Concentrations
Reaches 1 through 7: 1975
CONCENTRATION (mg/L)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

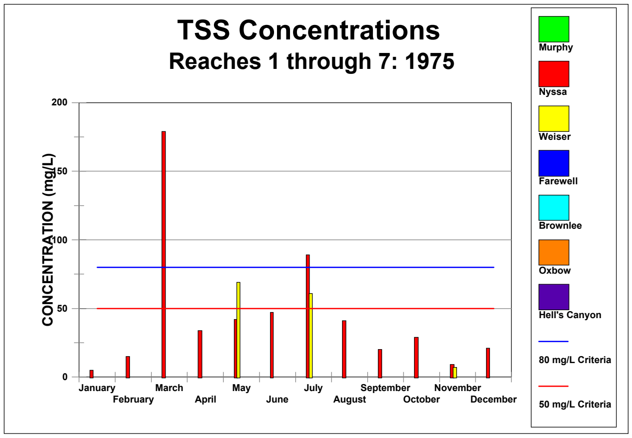

Ammonia Concentrations
Reaches 1 through 7: 1997
CONCENTRATION (mg/L)
0.08
0.06
0.04
0.02
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

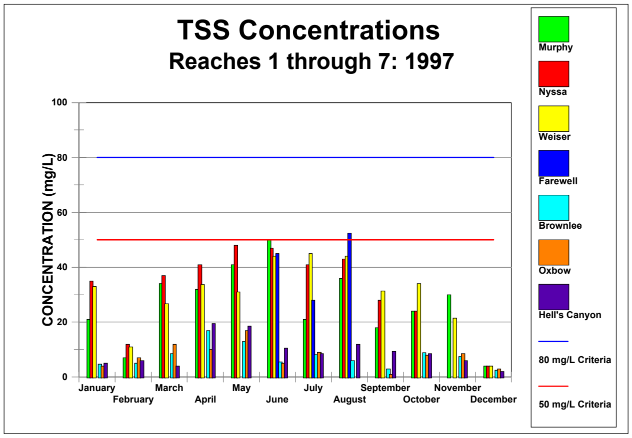

Ammonia Concentrations
Reaches 1 through 7: 1977
CONCENTRATION (mg/L)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

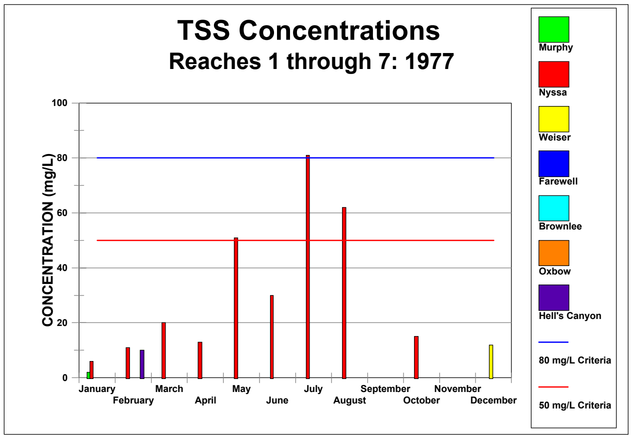

Ammonia Concentrations
Reaches 1 through 7: 1992
CONCENTRATION (mg/L)
0.02
0.02
0.01
0.01
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

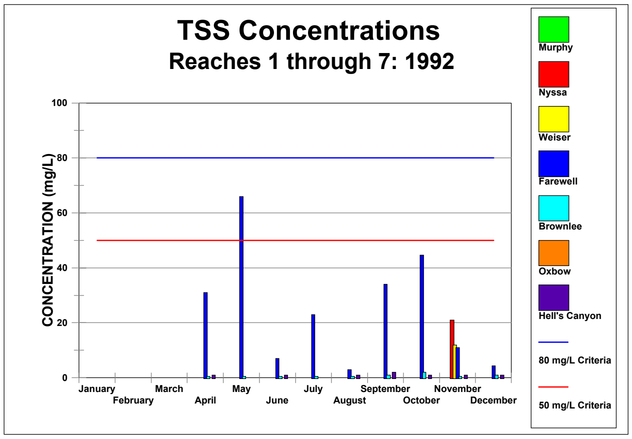

Ammonia Concentrations
Reaches 1 through 7: 1979
CONCENTRATION (mg/L)
0.25
0.20
0.15
0.10
0.05
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

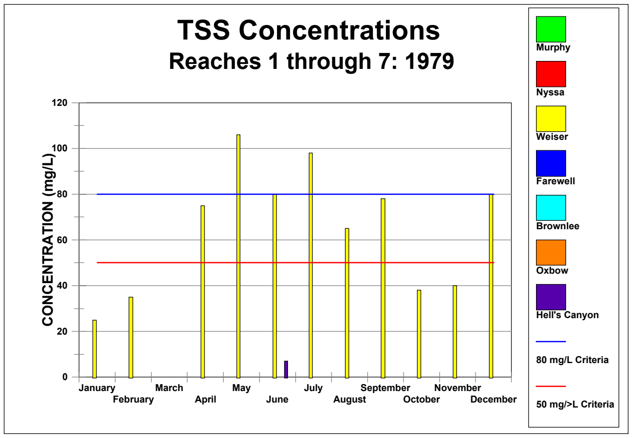

Ammonia Concentrations
Reaches 1 through 7: 1995
CONCENTRATION (mg/L)
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

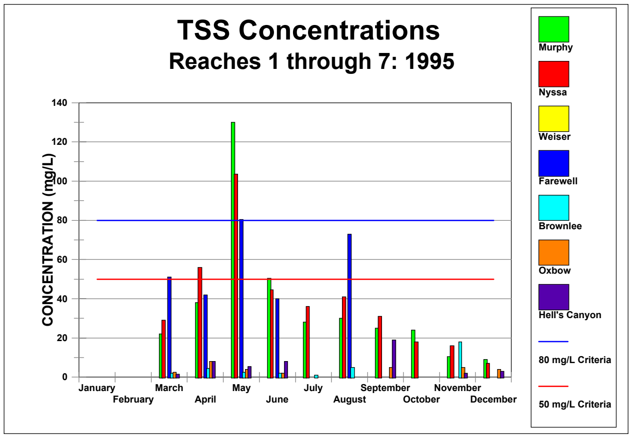

TSS Concentrations
Reaches 1 through 7: 1975
CONCENTRATION (mg/L)
0
50
100
150
200
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
80 mg/L Criteria
50 mg/L Criteria

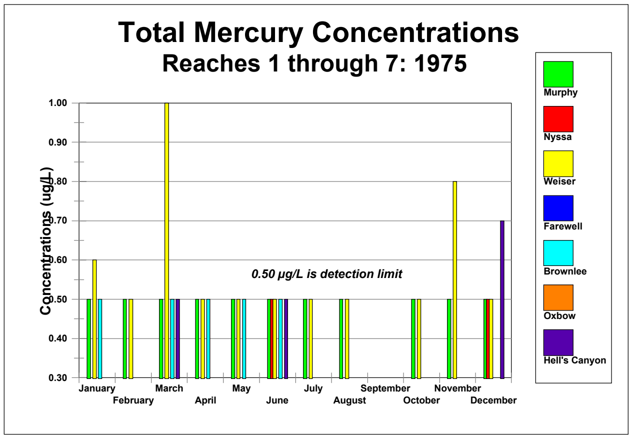

TSS Concentrations
Reaches 1 through 7: 1997
CONCENTRATION (mg/L)
0
20
40
60
80
100
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
80 mg/L Criteria
50 mg/L Criteria

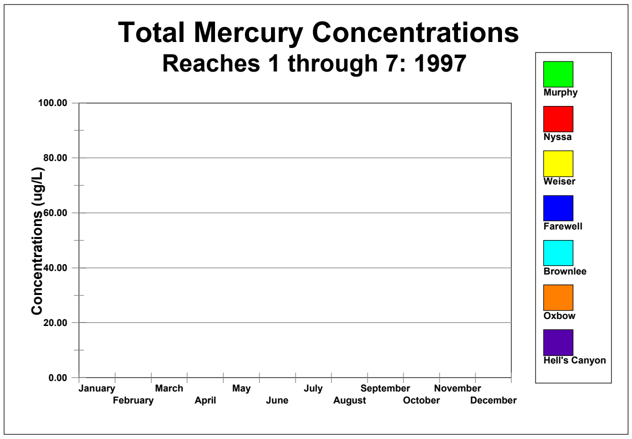

TSS Concentrations
Reaches 1 through 7: 1977
CONCENTRATION (mg/L)
0
20
40
60
80
100
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
80 mg/L Criteria
50 mg/L Criteria

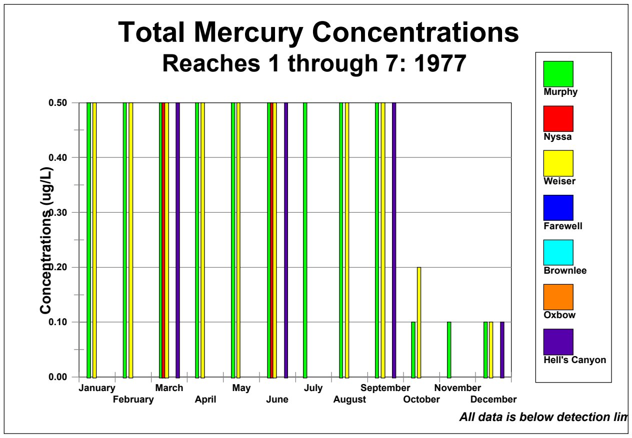

TSS Concentrations
Reaches 1 through 7: 1992
CONCENTRATION (mg/L)
0
20
40
60
80
100
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
80 mg/L Criteria
50 mg/L Criteria

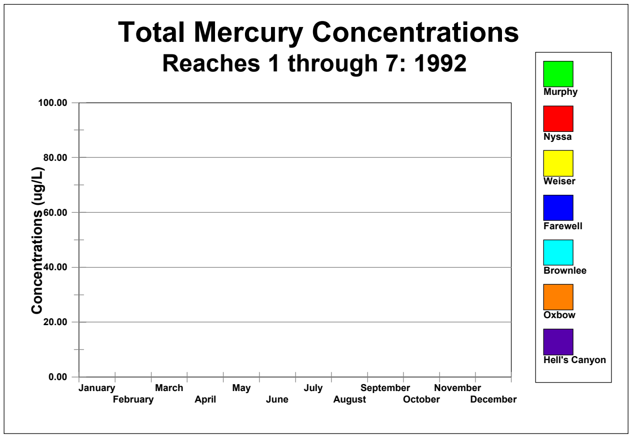

TSS Concentrations
Reaches 1 through 7: 1979
CONCENTRATION (mg/L)
0
20
40
60
80
100
120
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
80 mg/L Criteria
50 mg/>L Criteria

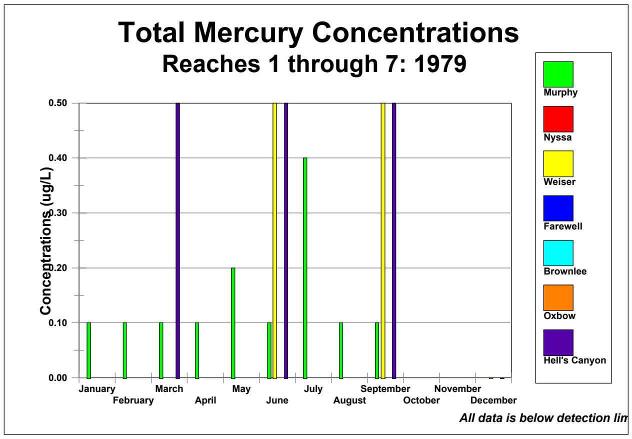

TSS Concentrations
Reaches 1 through 7: 1995
CONCENTRATION (mg/L)
0
20
40
60
80
100
120
140
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
80 mg/L Criteria
50 mg/L Criteria

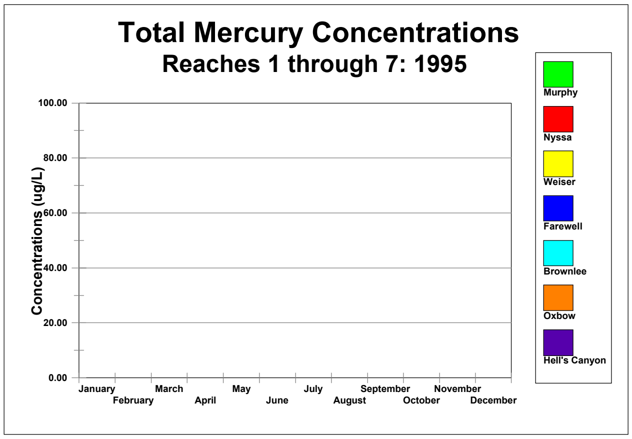

Total Mercury Concentrations
Reaches 1 through 7: 1975
Concentrations (ug/L)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.50 µg/L is detection limit
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

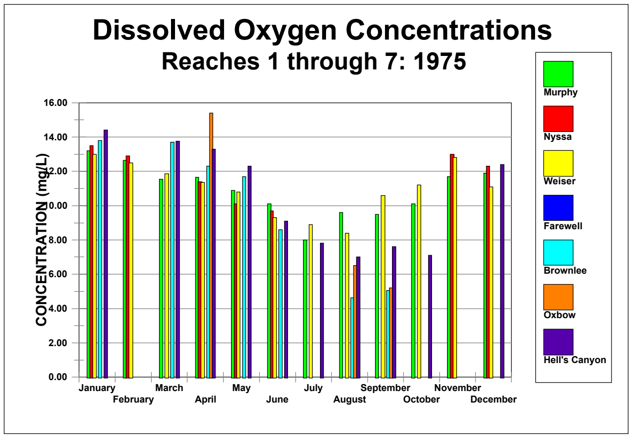

Total Mercury Concentrations
Reaches 1 through 7: 1997
Concentrations (ug/L)
100.00
80.00
60.00
40.00
20.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

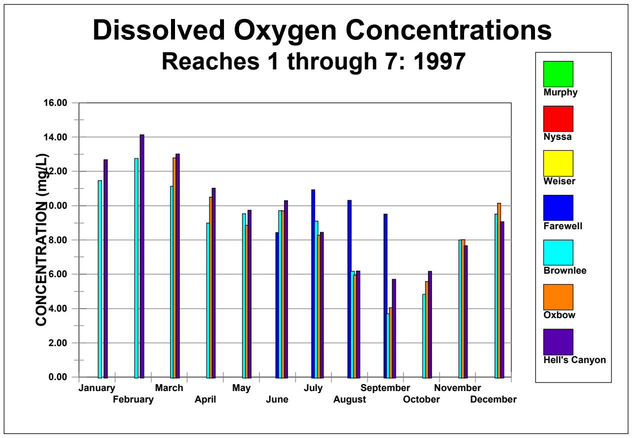

Total Mercury Concentrations
Reaches 1 through 7: 1977
Concentrations (ug/L)
0.50
0.40
0.30
0.20
0.10
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
All data is below detection lim

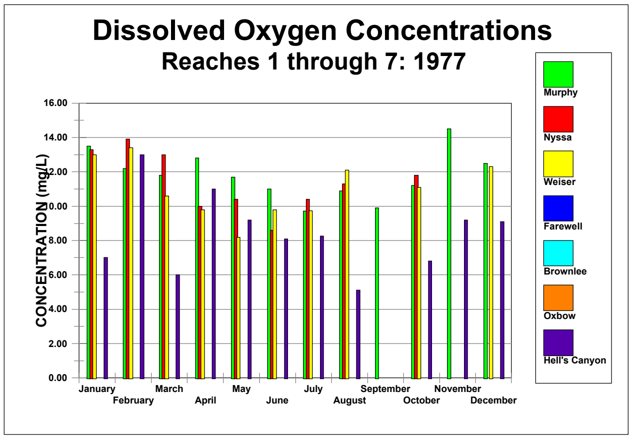

Total Mercury Concentrations
Reaches 1 through 7: 1992
Concentrations (ug/L)
100.00
80.00
60.00
40.00
20.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

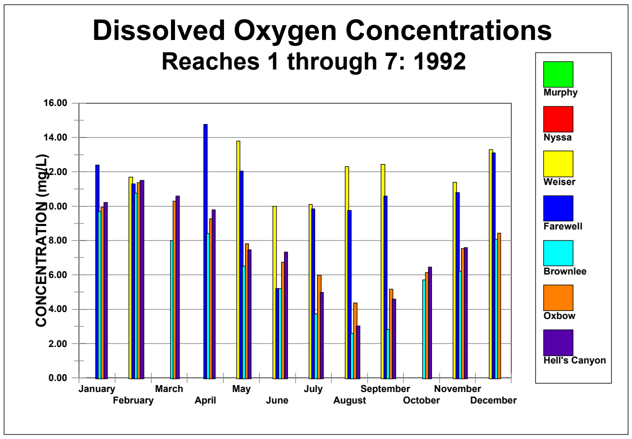

Total Mercury Concentrations
Reaches 1 through 7: 1979
Concentrations (ug/L)
0.50
0.40
0.30
0.20
0.10
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon
All data is below detection lim

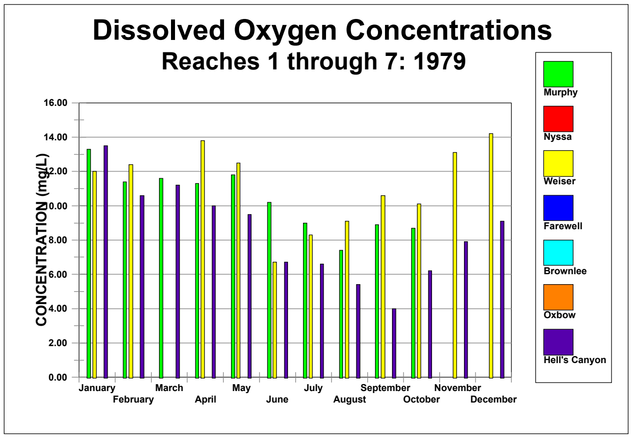

Total Mercury Concentrations
Reaches 1 through 7: 1995
Concentrations (ug/L)
100.00
80.00
60.00
40.00
20.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

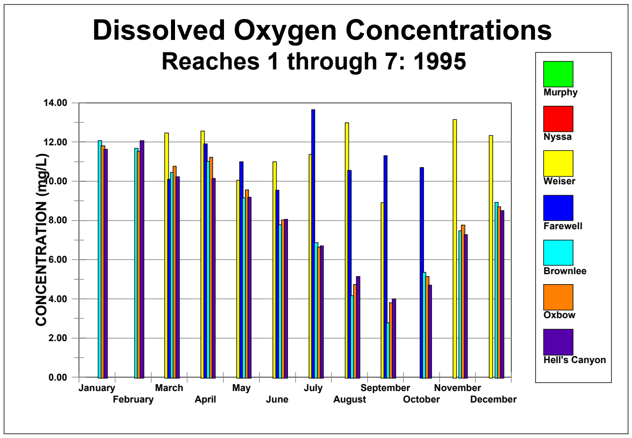

Dissolved Oxygen Concentrations
Reaches 1 through 7: 1975
CONCENTRATION (mg/L)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

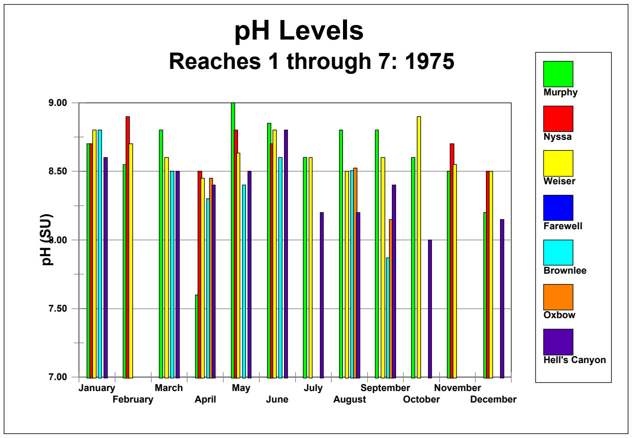

Dissolved Oxygen Concentrations
Reaches 1 through 7: 1997
CONCENTRATION (mg/L)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

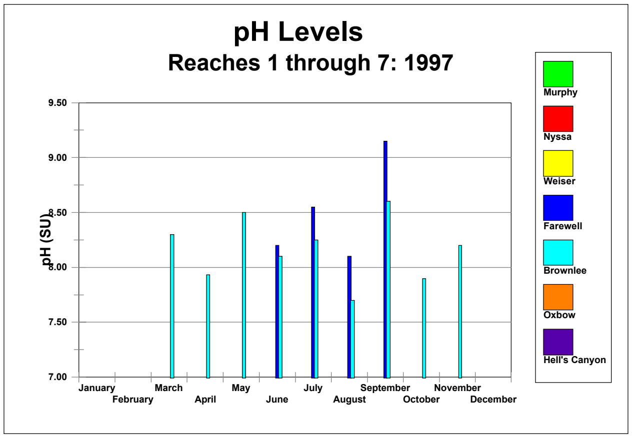

Dissolved Oxygen Concentrations
Reaches 1 through 7: 1977
CONCENTRATION (mg/L)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

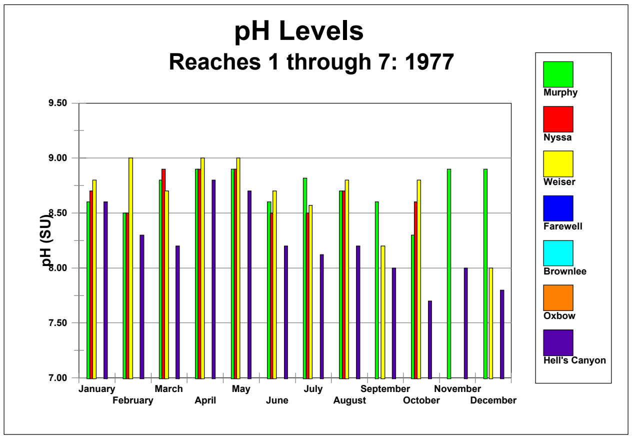

Dissolved Oxygen Concentrations
Reaches 1 through 7: 1992
CONCENTRATION (mg/L)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

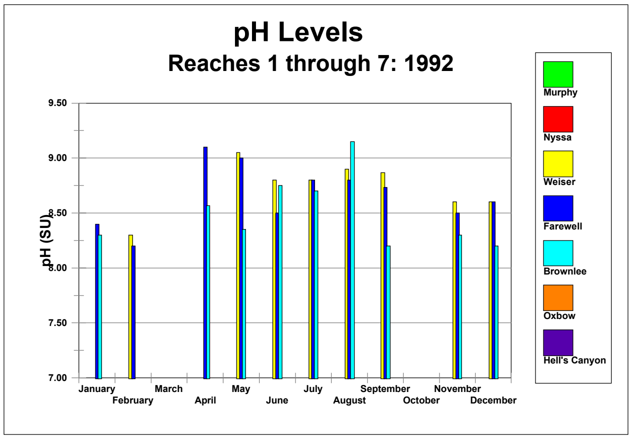

Dissolved Oxygen Concentrations
Reaches 1 through 7: 1979
CONCENTRATION (mg/L)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

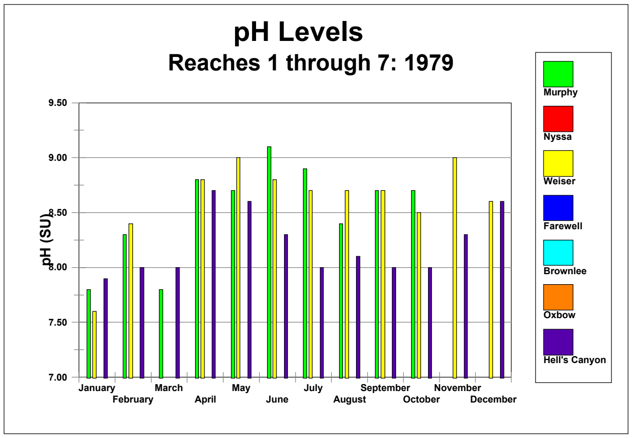

Dissolved Oxygen Concentrations
Reaches 1 through 7: 1995
CONCENTRATION (mg/L)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

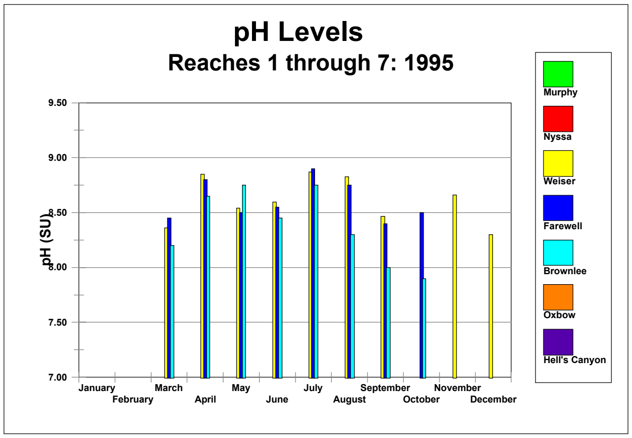

pH Levels
Reaches 1 through 7: 1975
pH (SU)
9.00
8.50
8.00
7.50
7.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon


pH Levels
Reaches 1 through 7: 1997
pH (SU)
9.50
9.00
8.50
8.00
7.50
7.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon


pH Levels
Reaches 1 through 7: 1977
pH (SU)
9.50
9.00
8.50
8.00
7.50
7.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon


pH Levels
Reaches 1 through 7: 1992
pH (SU)
9.50
9.00
8.50
8.00
7.50
7.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon


pH Levels
Reaches 1 through 7: 1979
pH (SU)
9.50
9.00
8.50
8.00
7.50
7.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon


pH Levels
Reaches 1 through 7: 1995
pH (SU)
9.50
9.00
8.50
8.00
7.50
7.00
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

Appendix V

Water Quality Data Summaries
by Month and Year

Dry Year Scenario: Total Phosphorus Concentrations (mg/L)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1977 Concentrations																				
Jan	0.040				0.410	0.040	0.050			0.090	0.050	0.070								0.060
Feb	0.060				0.410	0.060	0.050			0.055	0.050	0.070								0.040
Mar	0.050				0.430	0.050	0.070				0.070	0.080								0.090
Apr	0.010				0.210	0.010	0.010			0.150	0.010	0.080								0.030
May	0.050				0.430	0.050	0.080		0.140	0.290	0.080	0.080								0.100
Jun	0.020					0.020	0.060			0.190	0.060	0.090								0.020
Jul	0.090			0.543	0.360	0.090	0.130	0.995		0.170	0.130	0.200								0.050
Aug	0.050					0.050	0.110			0.260	0.110	0.130								0.050
Sep	0.050					0.050			0.150	0.140		0.080								0.120
Oct	0.050				0.270	0.050	0.050			0.140	0.050	0.110								0.080
Nov	0.070				0.320	0.070				0.090										0.070
Dec	0.070				0.370	0.070				0.050		0.100								0.070
1992 Concentrations																				
Jan				0.100										0.096	0.130					
Feb				0.130										0.110	0.140					
Mar				0.120	0.470									0.300	0.130					
Apr				0.160									0.050	0.160	0.190	0.075				0.060
May				0.180									0.110	0.190	0.330					
Jun				0.180									0.110	0.200	0.320	0.100				0.080
Jul				0.170									0.160	0.180	0.280	0.100				
Aug				0.150									0.120	0.110	0.170					0.110
Sep				0.120									0.090	0.140	0.091	0.110				0.090
Oct				0.092									0.105	0.110	0.130	0.070				0.090
Nov				0.100	0.520		0.100					0.090	0.080	0.094	0.110	0.070				0.040
Dec													0.075			0.130				0.165
Dry Year Concentrations (average of 1977 and 1992)																				
Jan	0.040			0.100	0.410	0.040	0.050			0.090	0.050	0.070		0.096	0.130					0.060
Feb	0.060			0.130	0.410	0.060	0.050			0.055	0.050	0.070		0.110	0.140					0.040
Mar	0.050			0.120	0.450	0.050	0.070				0.070	0.080		0.300	0.130					0.090
Apr	0.010			0.160	0.210	0.010	0.010			0.150	0.010	0.080	0.050	0.160	0.190	0.075				0.045
May	0.050			0.180	0.430	0.050	0.080		0.140	0.290	0.080	0.080	0.110	0.190	0.330					0.100
Jun	0.020			0.180	0.000	0.020	0.060			0.190	0.060	0.090	0.110	0.200	0.320	0.100				0.050
Jul	0.090			0.357	0.360	0.090	0.130	0.995		0.170	0.130	0.200	0.160	0.180	0.280	0.100				0.050
Aug	0.050			0.150		0.050	0.110			0.260	0.110	0.130	0.120	0.110	0.170					0.080
Sep	0.050			0.120		0.050			0.150	0.140		0.080	0.090	0.140	0.091	0.110				0.105
Oct	0.050			0.092	0.270	0.050	0.050			0.140	0.050	0.110	0.105	0.110	0.130	0.070				0.085
Nov	0.070			0.100	0.420	0.070	0.100			0.090		0.090	0.080	0.094	0.110	0.070				0.055
Dec	0.070			0.000	0.370	0.070				0.050		0.100	0.075			0.130				0.118

Dry Year Scenario: Orthophosphorus Concentrations (mg/L)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1977 Concentrations																				
Jan										0.022										
Feb										0.027										
Mar																				
Apr										0.090										
May										0.127										
Jun										0.119										
Jul										0.111										
Aug										0.085										
Sep										0.104										
Oct										0.050										
Nov										0.011										
Dec										0.033										
1992 Concentrations																				
Jan				0.064										0.059	0.097					
Feb				0.068										0.069	0.076					
Mar				0.047	0.420									0.130	0.082					
Apr				0.057									0.050	0.120	0.110	0.050				0.050
May				0.076									0.070	0.160	0.270					
Jun				0.071									0.050	0.160	0.280	0.060				0.050
Jul				0.065									0.050	0.150	0.200	0.090				
Aug				0.059									0.050	0.087	0.130					0.070
Sep				0.053									0.030	0.120	0.079	0.090				0.080
Oct				0.053									0.035	0.099	0.110	0.050				0.070
Nov				0.066	0.400		0.020					0.020	0.020	0.085	0.091	0.020				0.009
Dec													0.075			0.130				0.165
Dry Year Concentrations (average of 1977 and 1992)																				
Jan				0.064						0.022				0.059	0.097					
Feb				0.068						0.027				0.069	0.076					
Mar				0.047	0.420					0.000				0.130	0.082					
Apr				0.057						0.090			0.050	0.120	0.110	0.050				0.050
May				0.076						0.127			0.070	0.160	0.270					
Jun				0.071						0.119			0.050	0.160	0.280	0.060				0.050
Jul				0.065						0.111			0.050	0.150	0.200	0.090				
Aug				0.059						0.085			0.050	0.087	0.130	0.000				0.070
Sep				0.053						0.104			0.030	0.120	0.079	0.090				0.080
Oct				0.053						0.050			0.035	0.099	0.110	0.050				0.070
Nov				0.066	0.400					0.011			0.020	0.085	0.091	0.020				0.009
Dec				0.000						0.033			0.035	0.000	0.000	0.110				0.070

Dry Year Scenario: Total Suspended Solids Concentrations (mg/L)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1977 Concentrations																				
Jan	2.0				32.0		6.0			4.0										
Feb					28.0		11.0			10.0										10.0
Mar				29.0	32.0		20.0	23.0												
Apr					23.0		13.0			13.0							9.0			
May					102.0		51.0			40.0										
Jun							30.0			16.0										
Jul				168.0	72.0		81.0	86.0		13.0							3.0			
Aug							62.0			44.0										
Sep										15.0							5.0			
Oct					8.0		15.0			7.0										
Nov										3.0										
Dec										19.0		12.0								
1992 Concentrations																				
Jan				12.0										7.0	10.0					
Feb				15.0										6.0	16.0					
Mar				43.0	27.0									119.0	26.0					
Apr				50.0									31.0	24.0	25.0	0.5				1.0
May				40.0									66.0	10.0	10.0	0.5				
Jun				38.0									7.0	9.0	8.0	0.5				1.0
Jul				54.0									23.0	14.0	14.0	0.5				
Aug				50.0									3.0	4.0	8.0	0.5				1.0
Sep				23.0									34.0	8.0	24.0	1.0				2.0
Oct				15.0									44.7	6.0	4.0	2.0				1.0
Nov				28.0	18.0		21.0					12.0	11.0	4.0	4.0	0.5				1.0
Dec													0.075			0.130				0.165
Dry Year Concentrations (average of 1977 and 1992)																				
Jan	2.0			12.0	32.0		6.0			4.0				7.0	10.0					
Feb				15.0	28.0		11.0			10.0				6.0	16.0					10.0
Mar				36.0	29.5		20.0	23.0						119.0	26.0					
Apr				50.0	23.0		13.0			13.0			31.0	24.0	25.0	0.5	9.0			1.0
May				40.0	102.0		51.0			40.0			66.0	10.0	10.0	0.5				
Jun				38.0			30.0			16.0			7.0	9.0	8.0	0.5				1.0
Jul				111.0	72.0		81.0	86.0		13.0			23.0	14.0	14.0	0.5	3.0			
Aug				50.0			62.0			44.0			3.0	4.0	8.0	0.5				1.0
Sep				23.0						15.0			34.0	8.0	24.0	1.0	5.0			2.0
Oct				15.0	8.0		15.0			7.0			44.7	6.0	4.0	2.0				1.0
Nov				28.0	18.0		21.0			3.0		12.0	11.0	4.0	4.0	0.5				1.0
Dec										19.0		12.0	4.4			1.0				1.0

Wet Year Scenario: Total Phosphorus Concentrations (mg/L)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1975 Concentrations																				
Jan	0.030					0.030	0.020		0.070		0.020	0.040	0.130	0.145	0.095	0.050	0.030	0.030	0.030	0.050
Feb	0.050				0.650	0.050	0.070		0.180		0.070	0.100	0.145	0.145	0.080	0.043	0.025	0.045	0.043	0.045
Mar	0.060					0.060	0.120		0.100		0.120	0.120			0.400	0.305	0.070		0.180	0.120
Apr	0.040					0.040	0.060		0.100		0.060	0.070	0.130	0.200	0.190	0.075	0.080		0.060	0.050
May	0.080			0.056	0.100	0.080	0.070		0.140		0.070	0.050	0.280		0.190	0.167		0.090	0.140	0.060
Jun	0.070				0.290	0.070	0.100		0.060		0.100	0.160	0.100		0.150	0.050	0.050	0.060	0.120	0.030
Jul	0.160			0.130	0.440	0.160	0.200		0.100		0.200	0.180	0.130	0.270	0.160	0.040				0.060
Aug				0.023			0.130		0.070		0.130	0.180	0.050	0.230	0.173	0.090		0.060	0.050	0.040
Sep	0.080				0.350	0.080	0.110		0.050		0.110	0.170	0.120	0.220	0.157	0.065	0.050	0.070	0.030	0.070
Oct	0.070					0.070	0.100		0.060		0.100	0.100								0.100
Nov	0.050				0.230	0.050	0.060		0.030		0.060	0.110								
Dec	0.060					0.060	0.070		0.040		0.070	0.070								0.065
1997 Concentrations																				
Jan	0.110						0.150					0.150				0.175		0.180		0.180
Feb	0.070				0.170		0.090					0.090				0.100		0.100		0.110
Mar	0.090						0.065					0.090				0.078		0.060		0.070
Apr	0.090				0.094		0.110					0.117				0.108		0.080		0.110
May	0.070				0.133		0.110					0.150				0.100		0.065		0.090
Jun	0.120				0.126		0.120					0.125	0.120			0.055		0.050		0.060
Jul	0.075				0.328		0.095					0.106	0.110			0.054		0.051		0.058
Aug	0.090				0.262		0.091					0.131	0.150			0.053				0.029
Sep	0.096				0.290		0.097					0.118				0.076		0.083		0.104
Oct	0.080						0.084					0.097				0.106		0.115		0.085
Nov	0.084											0.089				0.071		0.077		0.076
Dec	0.052						0.052					0.069				0.064		0.063		0.067
Wet Year Concentrations (average of 1975 and 1997)																				
Jan	0.070					0.030	0.085		0.070		0.020	0.095	0.130	0.145	0.095	0.113	0.030	0.105	0.030	0.115
Feb	0.060				0.410	0.050	0.080		0.180		0.070	0.095	0.145	0.145	0.080	0.072	0.025	0.073	0.043	0.078
Mar	0.075					0.060	0.093		0.100		0.120	0.105			0.400	0.191	0.070	0.060	0.180	0.095
Apr	0.065				0.094	0.040	0.085		0.100		0.060	0.093	0.130	0.200	0.190	0.092	0.080	0.080	0.060	0.080
May	0.075			0.056	0.117	0.080	0.090		0.140		0.070	0.100	0.280		0.190	0.133	0.000	0.078	0.140	0.075
Jun	0.095				0.208	0.070	0.110		0.060		0.100	0.143	0.110		0.150	0.053	0.050	0.055	0.120	0.045
Jul	0.118			0.130	0.384	0.160	0.148		0.100		0.200	0.143	0.120	0.270	0.160	0.047		0.051	0.000	0.059
Aug	0.090			0.023	0.262		0.111		0.070		0.130	0.156	0.100	0.230	0.173	0.072		0.060	0.050	0.035
Sep	0.088				0.320	0.080	0.104		0.050		0.110	0.144	0.120	0.220	0.157	0.071	0.050	0.077	0.030	0.087
Oct	0.075					0.070	0.092		0.060		0.100	0.099				0.106		0.115		0.093
Nov	0.067				0.230	0.050	0.060		0.030		0.060	0.100				0.071		0.077		0.076
Dec	0.056					0.060	0.061		0.040		0.070	0.070				0.064		0.063		0.066

Wet Year Scenario: Orthophosphorus Concentrations (mg/L)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1975 Concentrations																				
Jan					0.277				0.020				0.044	0.102	0.046	0.031	0.022	0.016	0.019	0.035
Feb	0.062				0.271	0.062	0.082		0.050	0.059	0.082	0.088	0.050	0.100	0.056	0.020	0.016	0.020	0.024	0.016
Mar	0.065				0.075	0.065			0.030	0.130		0.098	0.184		0.192	0.052	0.024		0.048	0.024
Apr	0.026				0.052	0.026			0.020	0.075		0.036	0.020	0.085	0.098	0.020	0.025		0.020	0.020
May	0.003				2.879	0.003			0.030	0.065		0.062	0.083		0.095	0.060	0.025	0.010	0.020	0.015
Jun	0.029				0.059	0.029			0.010	0.075		0.082	0.020	0.400	0.090	0.068	0.015	0.010	0.015	0.010
Jul									0.010	0.196			0.075	0.160	0.125	0.025				
Aug									0.020	0.326			0.035	0.140	0.145	0.028		0.030	0.020	0.025
Sep									0.010	0.235			0.010	0.115	0.110	0.033	0.010	0.050	0.005	
Oct									0.020	0.016										
Nov									0.010	0.049										
Dec									0.010	0.036										
1997 Concentrations																				
Jan	0.060						0.060					0.070				0.110		0.120		0.110
Feb	0.040				0.080		0.040					0.050				0.070		0.070		0.070
Mar	0.010						0.010					0.027				0.040		0.030		0.030
Apr	0.020				0.072		0.030					0.020				0.030		0.020		0.030
May	0.010				0.092		0.010					0.015				0.020		0.030		0.030
Jun	0.040				0.097		0.040					0.025	0.035			0.020		0.030		0.015
Jul	0.010				0.193		0.010					0.011	0.010			0.018		0.028		0.027
Aug	0.010				0.213		0.010					0.010	0.013			0.030				0.031
Sep	0.010				0.205		0.010					0.021				0.057		0.064		0.065
Oct	0.010						0.010					0.011				0.069		0.082		0.066
Nov	0.010											0.010				0.046		0.049		0.050
Dec	0.019						0.021					0.039				0.042		0.041		0.045
Wet Year Concentrations (average of 1975 and 1997)																				
Jan	0.060				0.277		0.060		0.020			0.070	0.044	0.102	0.046	0.070	0.022	0.068	0.019	0.072
Feb	0.051				0.176	0.062	0.061		0.050	0.059	0.082	0.069	0.050	0.100	0.056	0.045	0.016	0.045	0.024	0.043
Mar	0.038				0.075	0.065	0.010		0.030	0.130		0.062	0.184		0.192	0.046	0.024	0.030	0.048	0.027
Apr	0.023				0.062	0.026	0.030		0.020	0.075		0.028	0.020	0.085	0.098	0.025	0.025	0.020	0.020	0.025
May	0.007				1.486	0.003	0.010		0.030	0.065		0.039	0.083		0.095	0.040	0.025	0.020	0.020	0.023
Jun	0.035				0.078	0.029	0.040		0.010	0.075		0.054	0.028	0.400	0.090	0.044	0.015	0.020	0.015	0.013
Jul	0.010				0.193		0.010		0.010	0.196		0.011	0.043	0.160	0.125	0.022		0.028	0.000	0.027
Aug	0.010				0.213		0.010		0.020	0.326		0.010	0.024	0.140	0.145	0.029		0.030	0.020	0.028
Sep	0.010				0.205		0.010		0.010	0.235		0.021	0.010	0.115	0.110	0.045	0.010	0.057	0.005	0.065
Oct	0.010						0.010		0.020	0.016		0.011				0.069		0.082		0.066
Nov	0.010								0.010	0.049		0.010				0.046		0.049		0.050
Dec	0.019						0.021		0.010	0.036		0.039				0.042		0.041		0.045

Wet Year Scenario: Total Suspended Solids Concentrations (mg/L)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1975 Concentrations																				
Jan							5.0		15.0		5.0									
Feb					39.0		15.0		37.0		15.0									
Mar							179.0		22.0		179.0									
Apr							34.0		20.0		34.0									
May				34.0	52.0		42.0	113.0	38.0		42.0	69.0			46.0					
Jun					84.0		47.0		17.0		47.0						32.0			
Jul				116.0	102.0		89.0	156.0	23.0	28.0	89.0	61.0			52.0					
Aug							41.0		46.0		41.0						170.0			
Sep					40.0		20.0		10.0	32.0	20.0									
Oct							29.0		10.0	15.0	29.0									
Nov				20.0	9.0		9.0	114.0	3.0	27.0	9.0	7.0			12.0					
Dec							21.0		7.0	8.0	21.0									
1997 Concentrations																				
Jan	21.0						35.0					33.0				4.7		4.0		5.0
Feb	7.0				47.0		12.0					11.0				5.0		7.0		6.0
Mar	34.0						37.0					26.7				8.5		12.0		4.0
Apr	32.0				26.0		41.0					33.7				17.0		10.0		19.5
May	41.0				47.0		48.0					31.0				13.0		17.0		18.5
Jun	50.0				47.0		47.0					44.0	45.0			5.5		5.0		10.5
Jul	21.0						41.0					45.0	28.0			8.2		9.0		8.5
Aug	36.0				32.0		43.0					44.0	52.5			6.0				12.0
Sep	18.0						28.0					31.3				3.0		1.0		9.3
Oct	24.0						24.0					34.0				8.9		8.0		8.5
Nov	30.0											21.5				7.5		8.5		6.0
Dec	4.0						4.0					4.0				2.5		3.0		2.0
Wet Year Concentrations (average of 1975 and 1997)																				
Jan	21.0						20.0		15.0		5.0	33.0				4.7		4.0		5.0
Feb	7.0				43.0		13.5		37.0		15.0	11.0				5.0		7.0		6.0
Mar	34.0						108.0		22.0		179.0	26.7				8.5		12.0		4.0
Apr	32.0				26.0		37.5		20.0		34.0	33.7				17.0		10.0		19.5
May	41.0			34.0	49.5		45.0	113.0	38.0		42.0	50.0			46.0	13.0		17.0		18.5
Jun	50.0				65.5		47.0		17.0		47.0	44.0	45.0			5.5	32.0	5.0		10.5
Jul	21.0			116.0	102.0		65.0	156.0	23.0	28.0	89.0	53.0	28.0		52.0	8.2		9.0		8.5
Aug	36.0				32.0		42.0		46.0		41.0	44.0	52.5			6.0	170.0			12.0
Sep	18.0				40.0		24.0		10.0	32.0	20.0	31.3				3.0		1.0		9.3
Oct	24.0						26.5		10.0	15.0	29.0	34.0				8.9		8.0		8.5
Nov	30.0			20.0	9.0		9.0	114.0	3.0	27.0	9.0	14.3			12.0	7.5		8.5		6.0
Dec	4.0						12.5		7.0	8.0	21.0	4.0				2.5		3.0		2.0

Medium Year Scenario: Total Phosphorus Concentrations (mg/L)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1979 Concentrations																				
Jan	0.050			0.142	0.400	0.050		0.743				0.210			0.186					0.050
Feb	0.130			0.264	1.500	0.130		0.896		0.070		0.150			0.458					0.110
Mar	0.060			0.099	0.380	0.060		0.440		0.130					0.384					0.160
Apr	0.060			0.105	0.390	0.060		0.300	0.070	0.160		0.100			0.170					0.070
May	0.040			0.165	0.390	0.040		0.603		0.200		0.120			0.232					0.030
Jun	0.020			0.370	0.330	0.020		1.236		0.290		0.130			0.233					0.050
Jul	0.040			0.404	0.330	0.040		0.764		0.240		0.190			0.447					0.060
Aug	0.130			0.221	0.380	0.130		0.887		0.240		0.130			0.478					0.050
Sep	0.050			0.299	0.290	0.050		0.435	0.090	0.200		0.080			0.694					0.060
Oct	0.040				0.270	0.040		0.420		0.140		0.090			0.294					0.070
Nov					0.330			0.375	0.030	0.110		0.060			0.186					0.070
Dec								0.392		0.030		0.070			0.151					0.090
1995 Concentrations																				
Jan				1.100										0.730						
Feb				0.120										0.220	0.160					
Mar	0.100			0.148	0.585		0.145	0.230	0.110				0.263	0.170	0.160	0.160		0.115		0.115
Apr	0.120			0.145	0.343		0.165	0.220	0.070	0.110			0.150	0.440	0.140	0.088		0.060		0.085
May	0.230			0.200	0.120		0.220	0.315	0.080	0.095			0.218	0.190	0.140	0.050		0.060		0.055
Jun	0.130			0.805	0.270		0.195	0.610		0.060			0.140	0.100	0.250	0.080		0.050		0.060
Jul	0.100			0.354	0.278		0.190	0.520	0.180	0.180			0.120	0.186	0.270	0.030				
Aug	0.100			0.166	0.315		0.135	0.390	0.170	0.180			0.185	0.117	0.300	0.110		0.130		0.085
Sep	0.110			0.172	0.350		0.130	0.360	0.160	0.240			0.195	0.157	0.285	0.140		0.130		0.130
Oct	0.070			0.133	0.335		0.105	0.260	0.080	0.050			0.120	0.122	0.226	0.110		0.140		0.140
Nov	0.085			0.101			0.140						0.100	0.104	0.169	0.090		0.130		0.110
Dec	0.100			0.110	0.460		0.100						0.110		0.255	0.140		0.150		0.120
Medium Year Concentrations (average of 1979 and 1995)																				
Jan	0.050			0.621	0.400	0.050		0.743				0.210		0.730	0.186					0.050
Feb	0.130			0.192	1.500	0.130		0.896		0.070		0.150		0.220	0.309					0.110
Mar	0.080			0.123	0.483	0.060	0.145	0.335	0.110	0.130			0.263	0.170	0.272	0.160		0.115		0.138
Apr	0.090			0.125	0.367	0.060	0.165	0.260	0.070	0.135		0.100	0.150	0.440	0.155	0.088		0.060		0.078
May	0.135			0.183	0.255	0.040	0.220	0.459	0.080	0.148		0.120	0.218	0.190	0.186	0.050		0.060		0.043
Jun	0.075			0.588	0.300	0.020	0.195	0.923		0.175		0.130	0.140	0.100	0.242	0.080		0.050		0.055
Jul	0.070			0.379	0.304	0.040	0.190	0.642	0.180	0.210		0.190	0.120	0.186	0.359	0.030				0.060
Aug	0.115			0.194	0.348	0.130	0.135	0.639	0.170	0.210		0.130	0.185	0.117	0.389	0.110		0.130		0.068
Sep	0.080			0.236	0.320	0.050	0.130	0.398	0.125	0.220		0.080	0.195	0.157	0.489	0.140		0.130		0.095
Oct	0.055			0.133	0.303	0.040	0.105	0.340	0.080	0.095		0.090	0.120	0.122	0.260	0.110		0.140		0.105
Nov	0.085			0.101	0.330		0.140	0.375	0.030	0.110		0.060	0.100	0.104	0.178	0.090		0.130		0.090
Dec	0.100			0.110	0.460		0.100	0.392	0.000	0.030		0.070	0.110	0.000	0.203	0.140		0.150		0.105

Medium Year Scenario: Orthophosphorus Concentrations (mg/L)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1979 Concentrations																				
Jan																				
Feb																				
Mar																				
Apr																				
May																				
Jun																				
Jul																				
Aug																				
Sep																				
Oct																				
Nov																				
Dec																				
1995 Concentrations																				
Jan				0.650										0.260						
Feb				0.070										0.130	0.120					
Mar	0.030			0.030	0.490		0.040	0.150	0.050				0.075	0.099	0.100	0.090		0.075		0.075
Apr	0.010			0.030	0.210		0.010	0.090	0.030	0.030			0.020	0.140	0.066	0.040		0.010		0.035
May	0.010			0.069	0.100		0.010	0.170	0.030	0.020			0.010	0.095	0.078	0.010		0.010		0.015
Jun	0.025			0.127	0.200		0.030	0.260		0.030			0.035	0.089	0.180	0.040		0.030		0.030
Jul	0.010			0.110	0.233		0.060	0.300	0.110	0.110			0.010	0.150	0.180	0.010				
Aug	0.025			0.091	0.255		0.035	0.310	0.080	0.120			0.025	0.110	0.280	0.040		0.070		0.060
Sep	0.030			0.060	0.260		0.025	0.270	0.090	0.110			0.055	0.130	0.250	0.105		0.090		0.090
Oct	0.025			0.050	0.310		0.030	0.210	0.020	0.020			0.060	0.110	0.190	0.090		0.100		0.100
Nov	0.015			0.058			0.010						0.030	0.083	0.140	0.030		0.110		0.100
Dec	0.060			0.076	0.390		0.070						0.080		0.090	0.100		0.100		0.090
Medium Year Concentrations (average of 1979 and 1995)																				
Jan				0.650										0.260						
Feb				0.070										0.130	0.120	0.000				
Mar	0.030			0.030	0.490		0.040	0.150	0.050				0.075	0.099	0.100	0.090		0.075		0.075
Apr	0.010			0.030	0.210		0.010	0.090	0.030	0.030			0.020	0.140	0.066	0.040		0.010		0.035
May	0.010			0.069	0.100		0.010	0.170	0.030	0.020			0.010	0.095	0.078	0.010		0.010		0.015
Jun	0.025			0.127	0.200		0.030	0.260		0.030			0.035	0.089	0.180	0.040		0.030		0.030
Jul	0.010			0.110	0.233		0.060	0.300	0.110	0.110			0.010	0.150	0.180	0.010				
Aug	0.025			0.091	0.255		0.035	0.310	0.080	0.120			0.025	0.110	0.280	0.040		0.070		0.060
Sep	0.030			0.060	0.260		0.025	0.270	0.090	0.110			0.055	0.130	0.250	0.105		0.090		0.090
Oct	0.025			0.050	0.310		0.030	0.210	0.020	0.020			0.060	0.110	0.190	0.090		0.100		0.100
Nov	0.015			0.058			0.010						0.030	0.083	0.140	0.030		0.110		0.100
Dec	0.060			0.076	0.390		0.070						0.080		0.090	0.100		0.100		0.090

Medium Year Scenario: Total Suspended Solids Concentrations (mg/L)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1979 Concentrations																				
Jan				13.0				108.0				25.0			4.0					
Feb				96.0				170.0		2.0		35.0			57.0					
Mar				11.0				70.0		13.0					129.0					
Apr				29.0				15.0		88.0		75.0			20.0					
May				29.0				149.0		117.0		106.0			53.0		36.0			
Jun				140.0				428.0		20.0		80.0			24.0					7.0
Jul				142.0				147.0		22.0		98.0			25.0		2.0			
Aug				60.0				309.0		6.0		65.0			25.0					
Sep				83.0				38.0				78.0			23.0		33.0			
Oct					50.0			52.0				38.0			12.0					
Nov					19.0			8.0				40.0			5.0					
Dec								22.0				80.0			9.0					
1995 Concentrations																				
Jan				363.0										486.0						
Feb				15.0	34.0									75.0	38.0					
Mar	22.0			36.0	63.0		29.0	109.0	57.0				51.0	61.0	26.0	2.0		2.5		1.5
Apr	38.0			58.0	73.0		56.0	60.0	14.0	33.0			42.0	346.0	32.0	4.5		8.0		8.0
May	130.0			68.0	37.0		103.5	28.0	11.0	21.0			80.5	108.0	37.0	2.5		4.0		5.5
Jun	50.5			308.0	59.0		44.5	131.0		3.0			40.0	13.0	18.0	2.0		2.0		8.0
Jul	28.0			155.5	36.0		36.0	4.0	11.0	15.0				30.0	4.0	1.0				
Aug	30.0			69.5	32.0		41.0	46.0	42.0	8.0			73.0	2.0	5.0	5.0				
Sep	25.0			45.5	50.0		31.0	47.0	24.5	19.0				8.0	4.0			5.0		19.0
Oct	24.0			36.5	4.0		18.0	12.0	15.5	7.0				4.0	5.0					
Nov	10.5			10.0			16.0							9.0	8.0	18.0		5.0		2.0
Dec	9.0			10.0	18.0		7.0								98.0			4.0		3.0
Medium Year Concentrations (average of 1979 and 1995)																				
Jan				188.0				108.0				25.0		486.0	4.0					
Feb				55.5	34.0			170.0		2.0		35.0		75.0	47.5					
Mar	22.0			23.5	63.0		29.0	89.5	57.0	13.0			51.0	61.0	77.5	2.0		2.5		1.5
Apr	38.0			43.5	73.0		56.0	37.5	14.0	60.5		75.0	42.0	346.0	26.0	4.5		8.0		8.0
May	130.0			48.5	37.0		103.5	88.5	11.0	69.0		106.0	80.5	108.0	45.0	2.5	36.0	4.0		5.5
Jun	50.5			224.0	59.0		44.5	279.5		11.5		80.0	40.0	13.0	21.0	2.0		2.0		7.5
Jul	28.0			148.8	36.0		36.0	75.5	11.0	18.5		98.0		30.0	14.5	1.0	2.0			
Aug	30.0			64.8	32.0		41.0	177.5	42.0	7.0		65.0	73.0	2.0	15.0	5.0				
Sep	25.0			64.3	50.0		31.0	42.5	24.5	19.0		78.0		8.0	13.5		33.0	5.0		19.0
Oct	24.0			36.5	27.0		18.0	32.0	15.5	7.0		38.0		4.0	8.5					
Nov	10.5			10.0	19.0		16.0	8.0				40.0		9.0	6.5	18.0		5.0		2.0
Dec	9.0			10.0	18.0		7.0	22.0				80.0			53.5			4.0		3.0

Appendix VI

Mass Loading Summaries by Month and Year

Dry Year Scenario: Total Phosphorus Loading (kg/day)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1977 Loading																				
Jan	1158				785		1585			33	0	2578								2613
Feb	1608				688		1486			22	0	2307								1192
Mar	1247				623		1907				0	2349								3017
Apr	172				113	-4	185			64	-2	1529								623
May	838				463	-22	1347		193	129	-16	1586								1566
Jun	318					-11	1017			85	-16	1578								381
Jul	1246			127	269	-57	1792			43	-38	2910								844
Aug	747					-23	1688			39	-24	2251								814
Sep	836					-14			217	16		1709								2022
Oct	942				496	-4	1091			41	-2	2843								2220
Nov	1364				611					33										1933
Dec	1439				708					150		3278								2921
1992 Loading																				
Jan				42										1	29					
Feb				139										2	73					
Mar				80	581									32	73					
Apr				57									1126	17	32	1612				1362
May				38									2191	65	23					
Jun				39									1691	49	29	1397				1149
Jul				30									2579	28	24	2229				
Aug				21									1617	31	2					1772
Sep				20									1533	2	1	1909				1570
Oct				21									2340	0	5	1719				2221
Nov				31	806		2183					2151	2053	0	5	1558				900
Dec													1983			2957				3791
Dry Year Loading (average of 1977 and 1992)																				
Jan	1158			42	785		1585			33		2578		1	29					2613
Feb	1608			139	688		1486			22		2307		2	73					1192
Mar	1247			80	602		1907					2349		32	73					3017
Apr	172			57	113	-4	185			64	-2	1529	1126	17	32	1612				993
May	838			38	463	-22	1347		193	129	-16	1586	2191	65	23					1566
Jun	318			39		-11	1017			85	-16	1578	1691	49	29	1397				765
Jul	1246			79	269	-57	1792			43	-38	2910	2579	28	24	2229				844
Aug	747			21		-23	1688			39	-24	2251	1617	31	2					1293
Sep	836			20		-14			217	16		1709	1533	2	1	1909				1796
Oct	942			21	496	-4	1091			41	-2	2843	2340		5	1719				2220
Nov	1364			31	708		2183			33		2151	2053		5	1558				1417
Dec	1439				708					150		3278	1983			2957				3356

Dry Year Scenario: Orthophosphorus Loading (kg/day)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1977 Loading																				
Jan										8										
Feb										11										
Mar																				
Apr										38										
May										57										
Jun										53										
Jul										28										
Aug										13										
Sep										12										
Oct										15										
Nov										4										
Dec										99										
1992 Loading																				
Jan				27										1	22					
Feb				73										1	40					
Mar				31	519									14	46					
Apr				20									1126	13	18	1074				1135
May				16									1395	54	19					
Jun				16									769	39	26	838				718
Jul				12									806	23	17	2006				
Aug				8									674	24	2					1127
Sep				9									511	2	1	1562				1396
Oct				12									780	0	5	1228				1727
Nov				21	620		437					478	513	0	4	445				202
Dec													926			2502				1608
Dry Year Loading (average of 1977 and 1992)																				
Jan				27						8			0	1	22					
Feb				73						11			0	1	40					
Mar				31	519					0			0	14	46					
Apr				20						38			1126	13	18	1074				1135
May				16						57			1395	54	19					
Jun				16						53			769	39	26	838				718
Jul				12						28			806	23	17	2006				
Aug				8						13			674	24	2					1127
Sep				9						12			511	2	1	1562				1396
Oct				12						15			780		5	1228				1727
Nov				21	620		437			4		478	513		4	445				202
Dec										99			926			2502				1608

Dry Year Scenario: Total Suspended Solids Loading (kg/day)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1977 Loading																				
Jan	57882				61244		190172			1457										
Feb					46987		326892			4055										297909
Mar				16623	46358		544866	0												
Apr					12346		240314			5527							8499			
May					109900		858745			17855										
Jun							508746			7153										
Jul				39392	53778		1116426	0		3317							536			
Aug							951140			6640										
Sep										1673							330			
Oct					14692		327438			2058										
Nov										1094										
Dec										57008		393413								
1992 Loading																				
Jan				5037										96	2244					
Feb				16011										124	8366					
Mar				28663	33393									12641	14604					
Apr				17677									698003	2515	4200	10744				22704
May				8470									1314863	3402	687	10618				
Jun				8330									107608	2199	736	6987				14357
Jul				9644									370768	2142	1223	11144				
Aug				6847									40436	1113	95	8013				16105
Sep				3928									578983	140	247	17358				34892
Oct				3346									995235	26	164	49115				24674
Nov				8730	27888		458503					286771	282340	21	188	11127				22491
Dec													115035			22744				22975
Dry Year Loading (average of 1977 and 1992)																				
Jan	57882			5037	61244		190172			1457				96	2244					
Feb				16011	46987		326892			4055				124	8366					297909
Mar				22643	39876		544866			0				12641	14604					
Apr				17677	12346		240314			5527			698003	2515	4200	10744	8499			22704
May				8470	109900		858745			17855			1314863	3402	687	10618				
Jun				8330			508746			7153			107608	2199	736	6987				14357
Jul				24518	53778		1116426			3317			370768	2142	1223	11144	536			
Aug				6847			951140			6640			40436	1113	95	8013				16105
Sep				3928						1673			578983	140	247	17358	330			34892
Oct				3346	14692		327438			2058			995235	26	164	49115				24674
Nov				8730	27888		458503			1094		286771	282340	21	188	11127				22491
Dec										57008		393413	115035			22744				22975

Wet Year Scenario: Total Phosphorus Loading (kg/day)

	Murphy						Nyssa					Weiser	Farewell			Brownlee		Oxbow		Hells
		Jump	Succor	Owyhee	Boise	Pumps		Malheur	Payette	Weiser	Pumps			Burnt	Powder		Wildhorse		Pine	
1975 Loading																				
Jan	1065					0	791		356		0	1882	6178	10	24	2643	5	1591	8	2665
Feb	1833				1538	0	2913		1011		0	5057	7509	17	47	2697	8	2815	24	2840
Mar	2597					0	6558		909		0	8319			757	23747	48		269	9605
Apr	2221					-3	5235		1033		-2	7202	13957	125	331	8378	76		87	5705
May	4649			923	1523	-19	6199		2455		-8	5792	34768		509	19705		10729	341	7299
Jun	2591				1768	-42	4965		1122		-29	12353	8636		304	3287	30	3980	338	2074
Jul	2686			207	858	-108	4163		747		-65	5414	4673	86	113	1424				2208
Aug				14			2743		317		-33	4952	1465	72	29	2555		1708	9	1146
Sep	1627				802	-37	2771		244		-24	5587	4049	69	27	2485	3	2681	4	2690
Oct	2037					-10	3457		283		-7	4275								3978
Nov	1648				629	0	2240		124		0	4833								
Dec	2351					0	3049		259		0	3679								3630
1997 Loading																				
Jan	4875						10104					15957				20939		21721		22088
Feb	4545				3292		8495					10812				14131		14165		15670
Mar	6243						6212					10884				10518		8189		9685
Apr	5110				1572		8916					12797				13323		9939		13958
May	3193				1710		6938					14976				8524		5643		8171
Jun	9388				1214		11270					15027	15262			6194		5671		6992
Jul	1978				1094		3148					4567	5247			2741		2599		3003
Aug	2308				982		2810					4938	5857			2557				1409
Sep	3493				1039		4061					5505				4616		5047		6351
Oct	3086						3645					4668				5657		6145		4564
Nov	2939											3823				2065		2246		2255
Dec	2008						2148					3274				2527		2511		2668
Wet Year Loading (average of 1975 and 1997)																				
Jan	2970						5447		356			8920	6178	10	24	11791	5	11656	8	12376
Feb	3189				2415		5704		1011			7934	7509	17	47	8414	8	8490	24	9255
Mar	4420						6385		909			9602			757	17132	48	8189	269	9645
Apr	3666				1572	-3	7076		1033		-2	9999	13957	125	331	10850	76	9939	87	9831
May	3921			923	1616	-19	6569		2455		-8	10384	34768		509	14115		8186	341	7735
Jun	5989				1491	-42	8117		1122		-29	13690	11949		304	4741	30	4825	338	4533
Jul	2332			207	976	-108	3655		747		-65	4990	4960	86	113	2082		2599		2605
Aug	2308			14	982		2777		317		-33	4945	3661	72	29	2556		1708	9	1278
Sep	2560				920	-37	3416		244		-24	5546	4049	69	27	3551	3	3864	4	4521
Oct	2562					-10	3551		283		-7	4471				5657		6145		4271
Nov	2293				629		2240		124			4328				2065		2246		2255
Dec	2180						2599		259			3477				2527		2511		3149

Wet Year Scenario: Orthophosphorus Loading (kg/day)

	Murphy						Nyssa					Weiser	Farewell			Brownlee		Oxbow		Hells
		Jump	Succor	Owyhee	Boise	Pumps		Malheur	Payette	Weiser	Pumps			Burnt	Powder		Wildhorse		Pine	
1975 Loading																				
Jan					638				102				2067	7	12	1612	4	848	5	1839
Feb	2273				641	0	3412		281	104	0	4450	2589	12	33	1245	5	1251	14	1010
Mar	2813				498	0			273	946		6794	13660		364	4049	16		72	1921
Apr	1444				863	-2			207	404		3704	2147	53	170	2234	24		29	2282
May	174				43849	-1			526	559		7182	10244		255	7094	25	1192	49	1825
Jun	1073				360	-17			187	493		6331	1727	154	183	4437	9	663	42	691
Jul									75	329			2696	51	89	890				
Aug									91	283			1026	44	25	781		854	4	716
Sep									49	147			337	36	19	1242	1	1915	1	
Oct									94	12										
Nov									41	41										
Dec									65	63										
1997 Loading																				
Jan	2659						4042					7447				13161		14481		13498
Feb	2597				1549		3775					6007				9892		9916		9972
Mar	694						956					3225				5428		4094		4151
Apr	1136				1204		2432					2194				3689		2485		3807
May	456				1183		631					1498				1705		2605		2724
Jun	3129				935		3757					3005	4451			2253		3403		1748
Jul	264				644		331					476	477			914		1427		1398
Aug	256				798		309					377	490			1423				1482
Sep	364				734		419					995				3432		3892		3969
Oct	386						434					529				3682		4381		3517
Nov	350											428				1332		1424		1483
Dec	734						868					1827				1671		1634		1786
Wet Year Loading (average of 1975 and 1997)																				
Jan	2659						4042					7447				13161		14481		13498
Feb	2597				1094		3775		102			6007	2067	7	12	5752	4	5382	5	5905
Mar	1483				641		2184		281	104		3837	2589	12	33	3337	5	2673	14	2580
Apr	1974				851		2432		273	946		4494	13660		364	3869	16	2485	72	2864
May	950				1023	-2	631		207	404		2601	2147	53	170	1969	24	2605	29	2503
Jun	1652				22392	-1	3757		526	559		5094	7348		255	4673	25	2297	49	1786
Jul	669				502	-17	331		187	493		3404	1102	154	183	2675	9	1045	42	1045
Aug	256				798		309		75	329		377	1593	51	89	1157				1482
Sep	364				734		419		91	283		995	1026	44	25	2106		2373	4	2343
Oct	386						434		49	147		529	337	36	19	2462	1	3148	1	3517
Nov	350								94	12		428				1332		1424		1483
Dec	734						868		41	41		1827				1671		1634		1786

Wet Year Scenario: Total Suspended Solids Loading (kg/day)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1975 Loading																				
Jan							197701		76251		0									
Feb					92303		624145		207785		0									
Mar							9781633		200056		0									
Apr							2966633		206607		-1081									
May				560314	791985		3719479	0	666451		-4830	7992592			123246					
Jun					512073		2333534		317889		-13569						18946			
Jul				185014	198974		1852679	0	171774	47038	-28960	1834673			36862					
Aug							865066		208496		-10432						13310			
Sep					91682		503788		48753	19967	-4453									
Oct							1002475		47235	11571	-1987									
Nov				19160	24610		335943	0	12407	22528	0	307529			2664					
Dec							914705		45274	14099	0									
1997 Loading																				
Jan	930616						2357615					3510532				558364		482697		613544
Feb	454456				910230		1132636					1321505				706537		991576		854720
Mar	2358412						3536284					3224882				1153536		1637722		553405
Apr	1816878				434764		3323290					3692871				2084497		1242367		2474332
May	1870307				604255		3027596					3094949				1108094		1475973		1679516
Jun	3911706				452870		4414090					5289582	5723181			619447		567110		1223581
Jul	553745						1358400					1948007	1335569			414985		458612		440072
Aug	923025				119912		1327910					1658511	2056837			289499				583017
Sep	655004						1172345					1461909				182224		60813		569960
Oct	925857						1041399					1636049				474079		427463		456374
Nov	1049494											920007				219639		249572		178015
Dec	154499						165264					189825				99487		119565		80248
Wet Year Loading (average of 1975 and 1997)																				
Jan	930616						2357615					3510532				558364		482697		613544
Feb	454456				910230		665169		76251			1321505				706537		991576		854720
Mar	2358412				92303		2080215		207785			3224882				1153536		1637722		553405
Apr	1816878				434764		6552462		200056			3692871				2084497		1242367		2474332
May	1870307				604255		2997115		206607		-1081	3094949				1108094		1475973		1679516
Jun	3911706			560314	622427		4066785		666451		-4830	6641087	5723181		123246	619447		567110		1223581
Jul	553745				512073		1845967		317889		-13569	1948007	1335569			414985	18946	458612		440072
Aug	923025			185014	159443		1590294		171774	47038	-28960	1746592	2056837		36862	289499				583017
Sep	655004						1018706		208496		-10432	1461909				182224	13310	60813		569960
Oct	925857				91682		772593		48753	19967	-4453	1636049				474079		427463		456374
Nov	1049494						1002475		47235	11571	-1987	920007				219639		249572		178015
Dec	154499			19160	24610		250603		12407	22528		248677			2664	99487		119565		80248

Medium Year Scenario: Total Phosphorus Loading (kg/day)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1979 Loading																				
Jan	1744			279	762							9058			56					2518
Feb	4568			724	4563					120		7241			451					5586
Mar	2338			768	664					755					655					10014
Apr	2116			671	560	-8			446	591		5104			201					4050
May	765			863	421	-17				996		4183			312					1087
Jun	323			549	397	-12				518		3030			131					1832
Jul	530			271	401	-27				165		3590			52					1808
Aug	2457			108	619	-63				128		3473			60					1035
Sep	973			98	505	-17			371	71		2271			93					1563
Oct	844				614	-5				53		2700			34					2072
Nov					739				92	38		1708			23					2460
Dec										24		1887			21					2665
1995 Loading																				
Jan				2088										10						
Feb				1007										4	162					
Mar	1850			798	994		3122	164	1254				13388	78	188	7626		5581		5828
Apr	1958			431	1349		3543	158	1044	683			7691	339	153	4868		3386		4952
May	8414			2224	1336		11427	191	1836	760			19129	89	170	3902		4755		4509
Jun	5566			2010	1712		10381	157		262			11866	26	212	6774		4266		5273
Jul	2059			236	1609		5377	165	1169	207			4979	37	38	1377				
Aug	1810			60	792		2997	103	202	133			4977	33	30	3642		4321		2840
Sep	2264			60	916		3366	135	265	147			5984	28	33	5163		4806		4822
Oct	1441			48	901		2741	96	244	27			3948	3	25	3667		4680		4714
Nov	2063			42			3851						3421	4	22	2074		3011		2591
Dec	2579			107	1877		3030						5430		234	6331		6831		5631
Medium Year Loading (average of 1979 and 1995)																				
Jan	1744			1184	762							9058		10	56					2518
Feb	4568			865	4563					120		7241		4	306					5586
Mar	2094			783	829		3122	164	1254	755		0	13388	78	421	7626		5581		7921
Apr	2037			551	955	-8	3543	158	745	637		5104	7691	339	177	4868		3386		4501
May	4589			1543	878	-17	11427	191	1836	878		4183	19129	89	241	3902		4755		2798
Jun	2944			1280	1054	-12	10381	157		390		3030	11866	26	171	6774		4266		3552
Jul	1294			253	1005	-27	5377	165	1169	186		3590	4979	37	45	1377		0		1808
Aug	2133			84	706	-63	2997	103	202	130		3473	4977	33	45	3642		4321		1938
Sep	1619			79	711	-17	3366	135	318	109		2271	5984	28	63	5163		4806		3192
Oct	1143			48	757	-5	2741	96	244	40		2700	3948	3	29	3667		4680		3393
Nov	2063			42	739		3851		92	38		1708	3421	4	23	2074		3011		2526
Dec	2579			107	1877		3030			24		1887	5430		127	6331		6831		4148

Medium Year Scenario: Orthophosphorus Loading (kg/day)

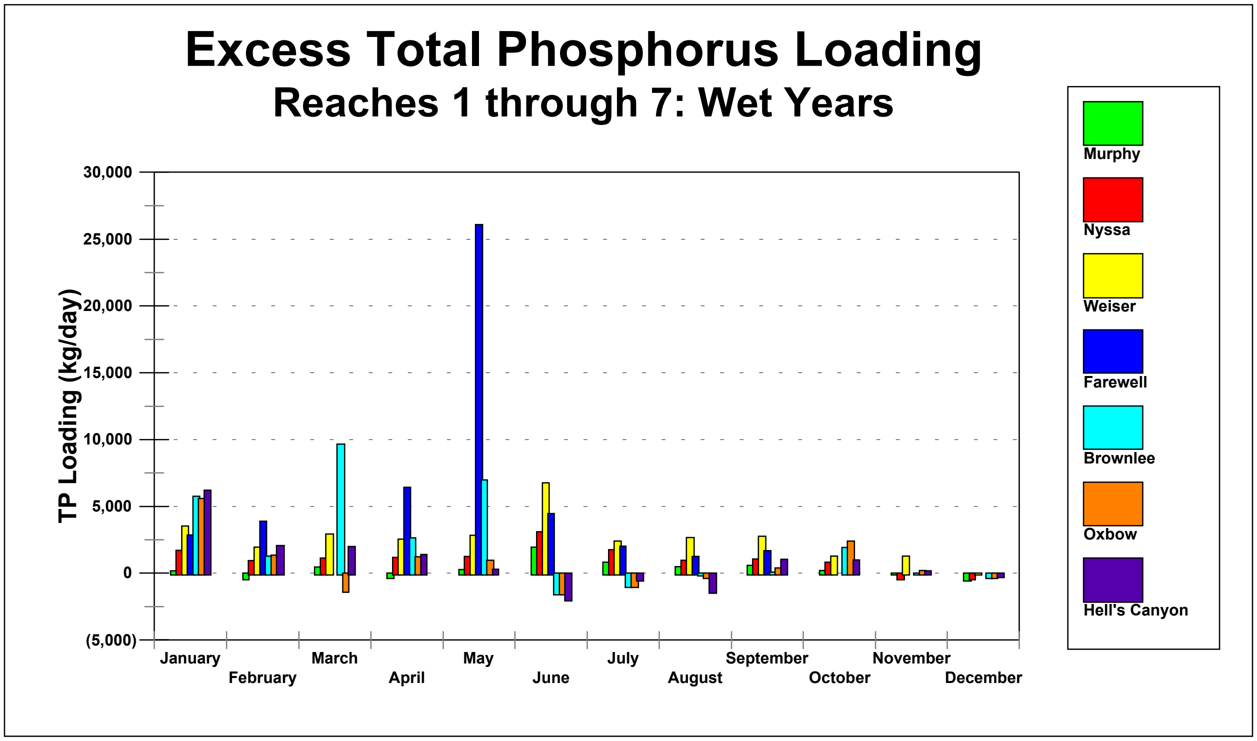
	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1979 Loading																				
Jan																				
Feb																				
Mar																				
Apr																				
May																				
Jun																				
Jul																				
Aug																				
Sep																				
Oct																				
Nov																				
Dec																				
1995 Loading																				
Jan				1234										4						
Feb				587										2	121					
Mar	555			160	832		861	107	570				3825	45	118	4289		3640		3801
Apr	163			89	825		215	64	448	186			1025	108	72	2225		564		2039
May	366			762	1114		519	103	689	160			879	44	95	780		793		1230
Jun	1070			317	1268		1597	67		131			2967	23	152	3387		2560		2636
Jul	206			73	1348		1698	95	714	126			415	30	25	459				
Aug	453			33	641		777	82	95	88			673	31	28	1324		2327		2005
Sep	617			21	681		647	101	149	67			1688	23	29	3873		3327		3338
Oct	515			18	833		783	77	61	11			1974	3	21	3000		3343		3367
Nov	364			24			275						1026	3	18	691		2548		2356
Dec	1547			74	1592		2121						3949		82	4522		4554		4223
Medium Year Loading (average of 1979 and 1995)																				
Jan				1234										4						
Feb				587										2	121					
Mar	555			160	832		861	107	570				3825	45	118	4289		3640		3801
Apr	163			89	825		215	64	448	186			1025	108	72	2225		564		2039
May	366			762	1114		519	103	689	160			879	44	95	780		793		1230
Jun	1070			317	1268		1597	67		131			2967	23	152	3387		2560		2636
Jul	206			73	1348		1698	95	714	126			415	30	25	459				
Aug	453			33	641		777	82	95	88			673	31	28	1324		2327		2005
Sep	617			21	681		647	101	149	67			1688	23	29	3873		3327		3338
Oct	515			18	833		783	77	61	11			1974	3	21	3000		3343		3367
Nov	364			24			275						1026	3	18	691		2548		2356
Dec	1547			74	1592		2121						3949		82	4522		4554		4223

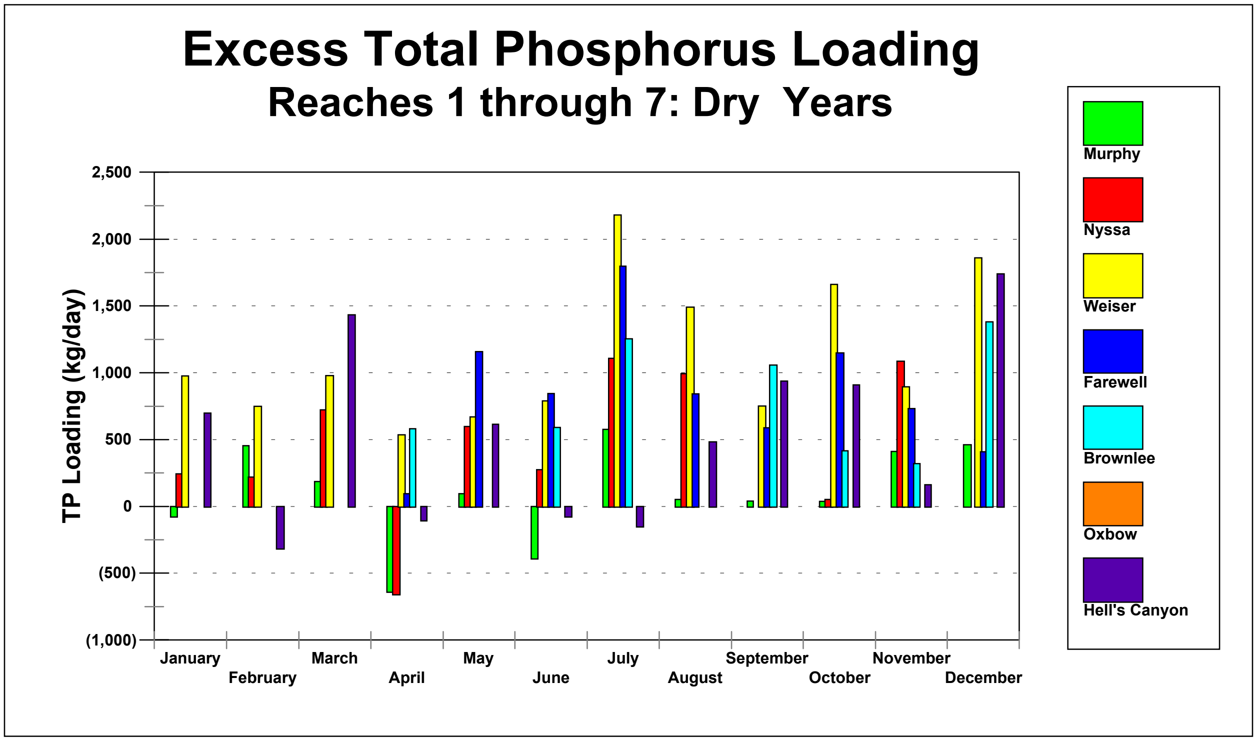
Medium Year Scenario: Total Suspended Solids Loading (kg/day)

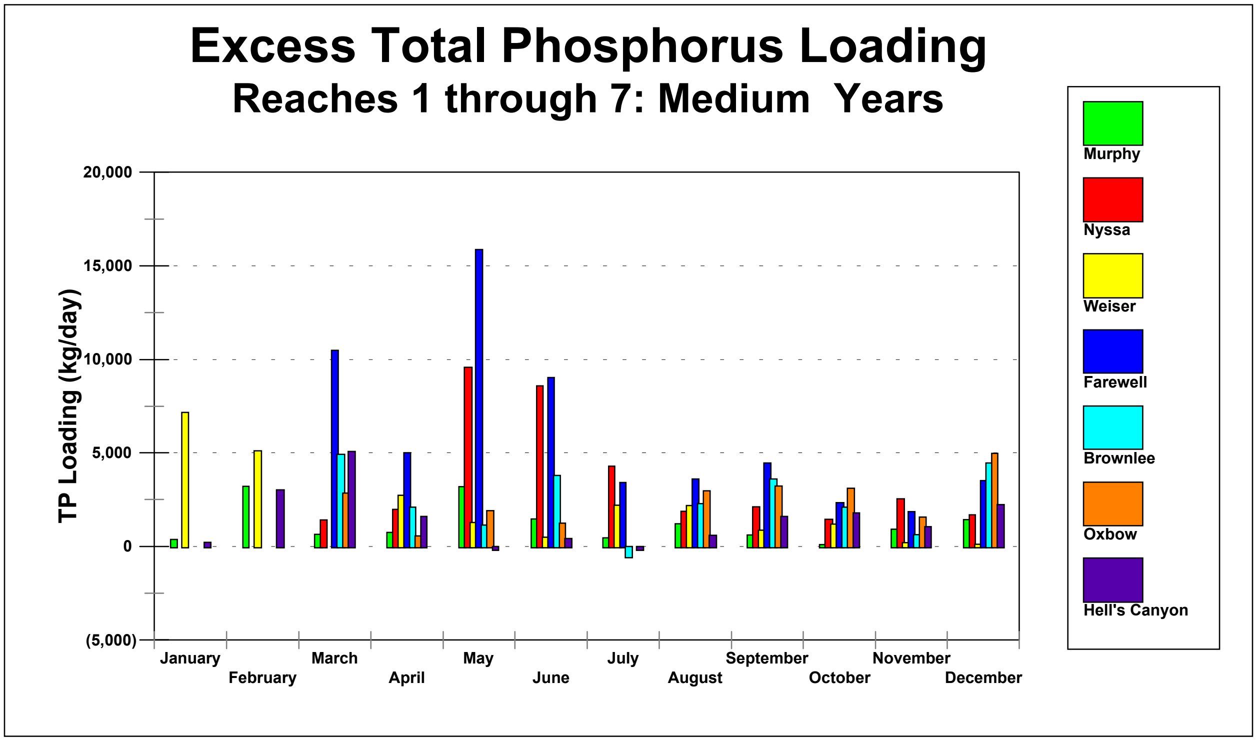
	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1979 Loading																				
Jan				25582								1078280			1208					
Feb				263142						3415		1689683			56131					
Mar				85302						75507					219879					
Apr				185254						324846		3827706			23629					
May				151630						582846		3695171			71277		41033			
Jun				207878						35706		1864701			13460					256436
Jul				95114						15170		1851464			2900		258			
Aug				29241						3210		1736648			3151					
Sep				27157								2214320			3084		1612			
Oct					113696							1139942			1369					
Nov					42565							1138811			616					
Dec												2156796			1247					
1995 Loading																				
Jan				688920										6597						
Feb				125872	61773									1370	38357					
Mar	406953			194765	107020		624487	77595	649776				2601143	27822	30552	95321		121329		76014
Apr	620022			172469	286876		1202488	42992	208871	204913			2153401	266965	34866	250334		451505		466094
May	4755480			756227	412002		5375681	16965	252484	167942			7079781	50468	45026	195100		317005		450916
Jun	2162183			769202	374072		2369092	33653		13103			3390372	3340	15230	169354		170636		703055
Jul	576435			103616	208687		1018887	1266	71449	17215				5943	565	45907				
Aug	543122			25100	80501		910335	12151	49814	5890			1963831	568	492	165545				
Sep	514561			15833	130889		802613	17620	40515	11635				1415	468			184838		704719
Oct	494201			13254	10754		469965	4416	47184	3825				102	544					
Nov	254846			4196			440127							351	1057	414829		115824		47117
Dec	232106			9700	73465		212089								89773			182148		140770
Medium Year Loading (average of 1979 and 1995)																				
Jan				357251								1078280		6597	1208					
Feb				194507	61773					3415		1689683		1370	47244					
Mar	406953			140033	107020		624487	77595	649776	75507			2601143	27822	125216	95321		121329		76014
Apr	620022			178861	286876		1202488	42992	208871	264879		3827706	2153401	266965	29247	250334		451505		466094
May	4755480			453928	412002		5375681	16965	252484	375394		3695171	7079781	50468	58151	195100	41033	317005		450916
Jun	2162183			488540	374072		2369092	33653		24404		1864701	3390372	3340	14345	169354		170636		479746
Jul	576435			99365	208687		1018887	1266	71449	16193		1851464		5943	1733	45907	258			
Aug	543122			27170	80501		910335	12151	49814	4550		1736648	1963831	568	1821	165545				
Sep	514561			21495	130889		802613	17620	40515	11635		2214320		1415	1776		1612	184838		704719
Oct	494201			13254	62225		469965	4416	47184	3825		1139942		102	957					
Nov	254846			4196	42565		440127					1138811		351	837	414829		115824		47117
Dec	232106			9700	73465		212089					2156796			45510			182148		140770

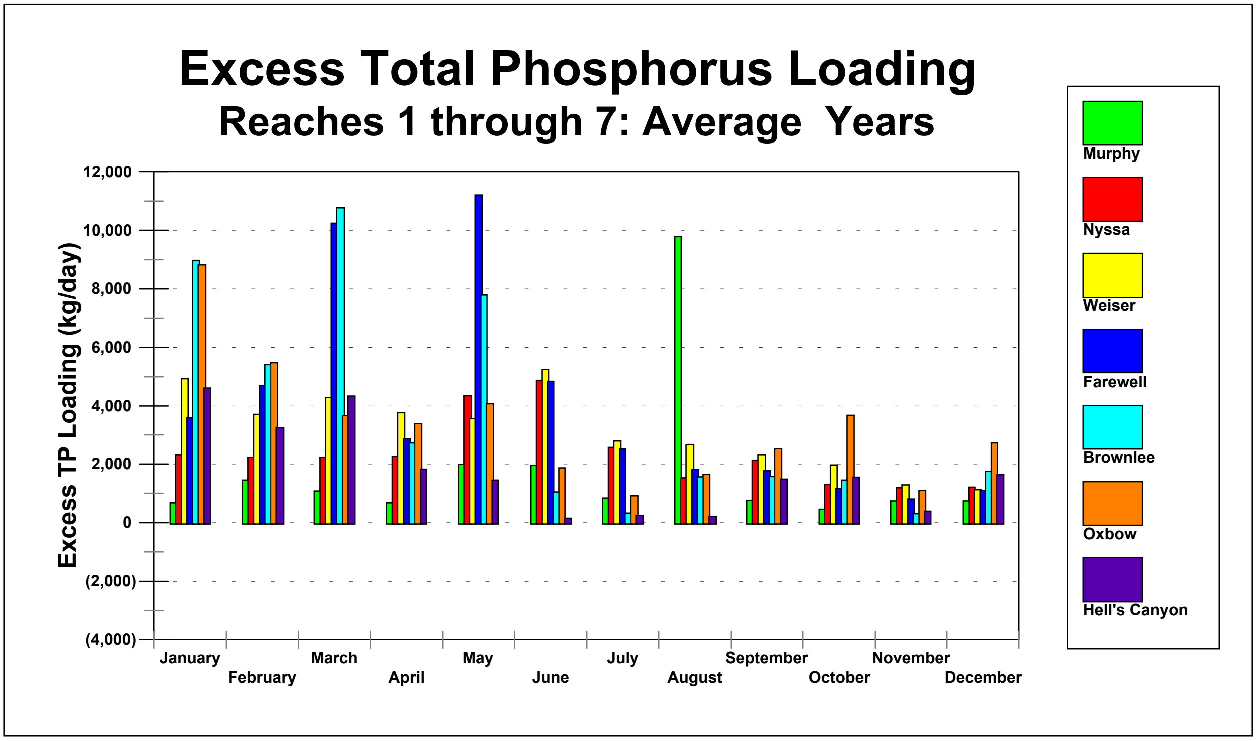
Appendix VII

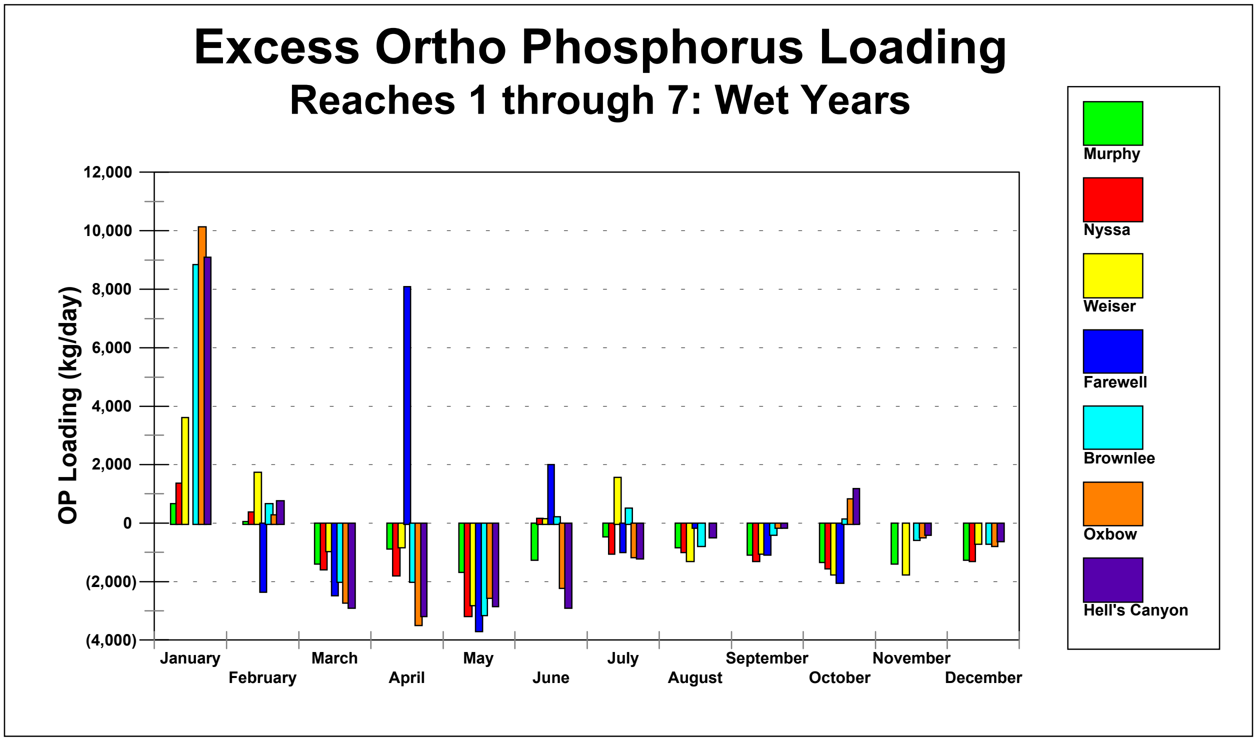
Excess Loadings at Mainstem Snake River Sites: Graphical Data


Excess Total Phosphorus Loading
Reaches 1 through 7: Wet Years
TP Loading (kg/day)
30,000
25,000
20,000
15,000
10,000
5,000
0
(5,000)
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

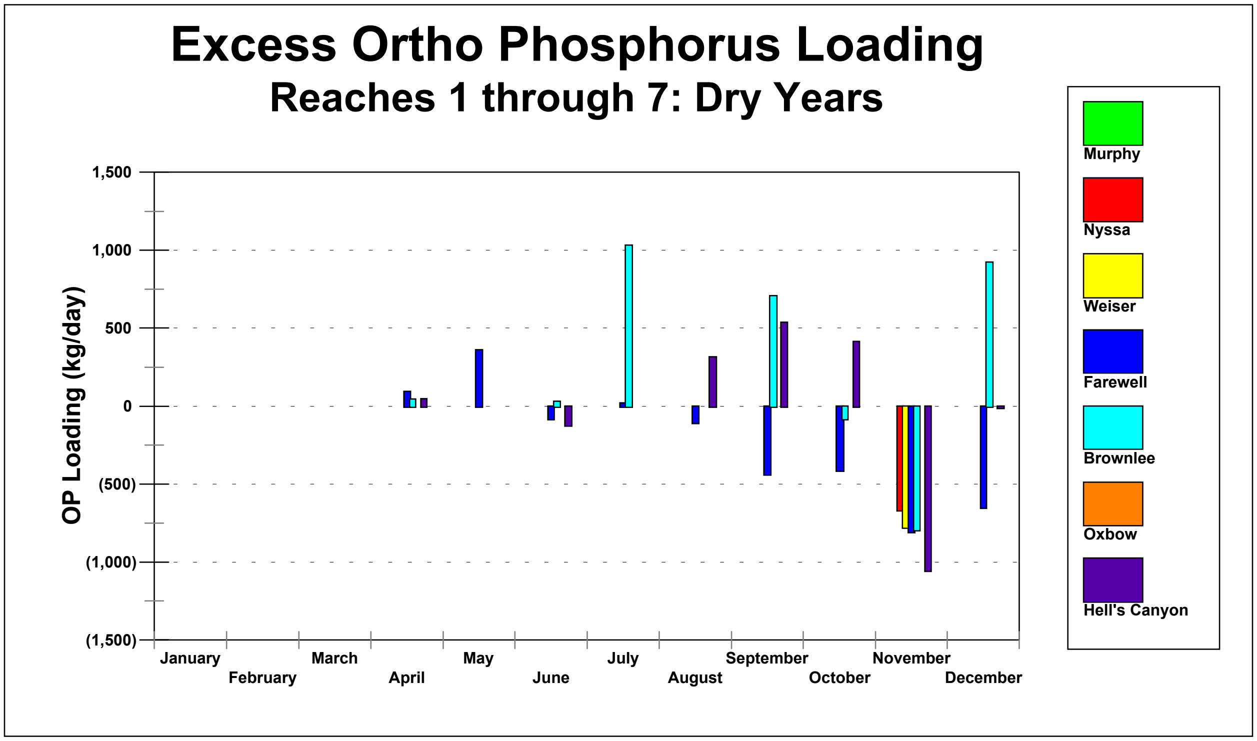

Excess Total Phosphorus Loading
Reaches 1 through 7: Dry Years
TP Loading (kg/day)
2,500
2,000
1,500
1,000
500
0
(500)
(1,000)
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon


Excess Total Phosphorus Loading
Reaches 1 through 7: Medium Years
TP Loading (kg/day)
20,000
15,000
10,000
5,000
0
(5,000)
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon

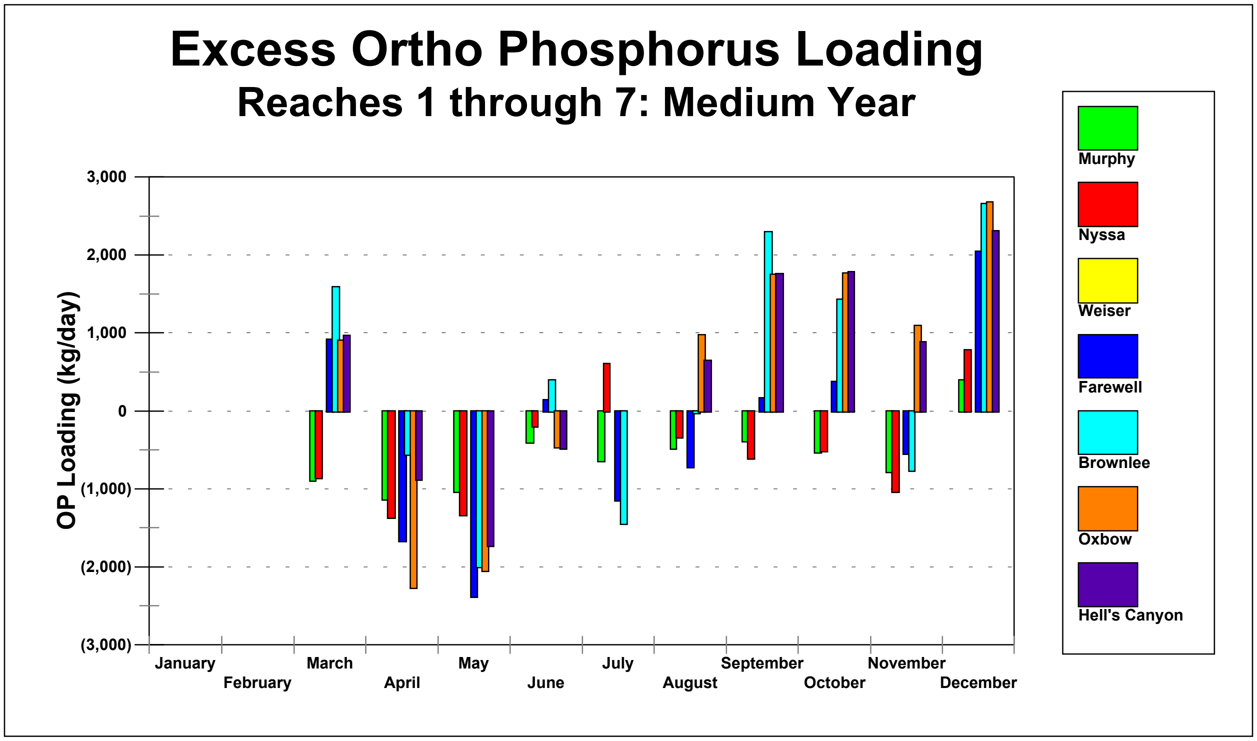

Excess Total Phosphorus Loading
Reaches 1 through 7: Average Years
Excess TP Loading (kg/day)
12,000
10,000
8,000
6,000
4,000
2,000
0
(2,000)
(4,000)
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon



Excess Ortho Phosphorus Loading
Reaches 1 through 7: Wet Years

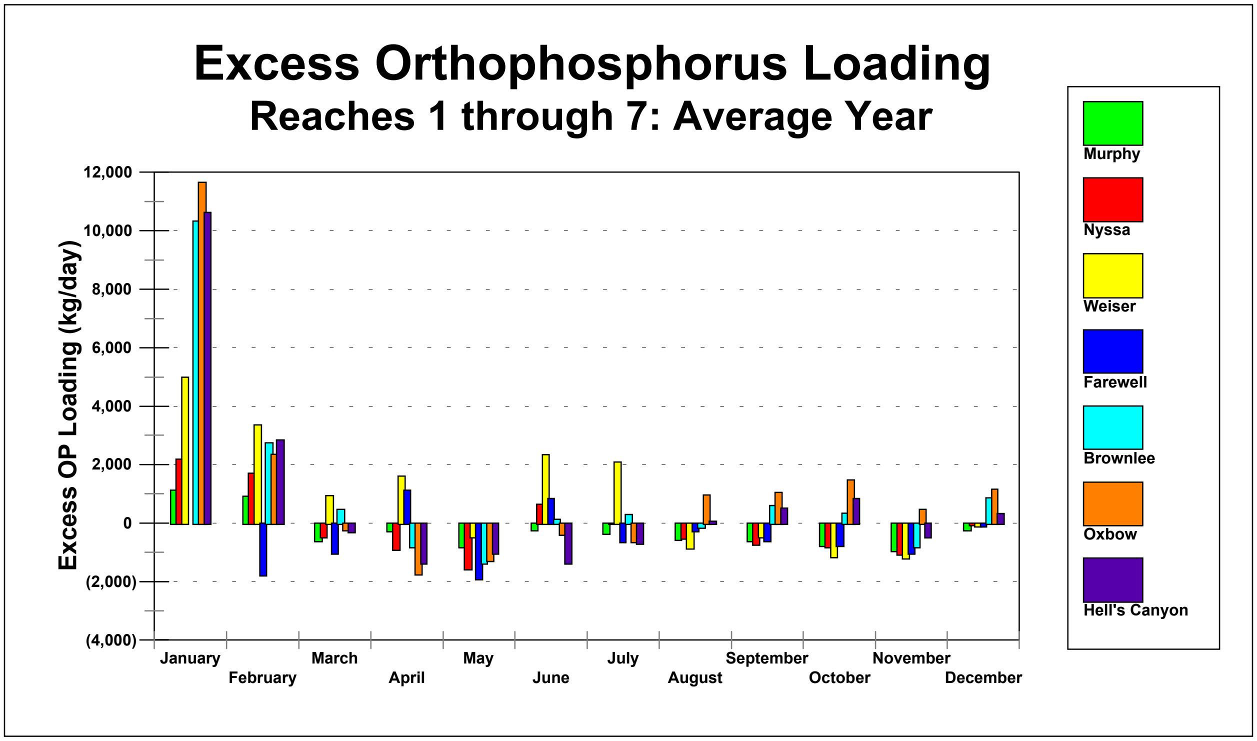


Excess Ortho Phosphorus Loading
Reaches 1 through 7: Dry Years



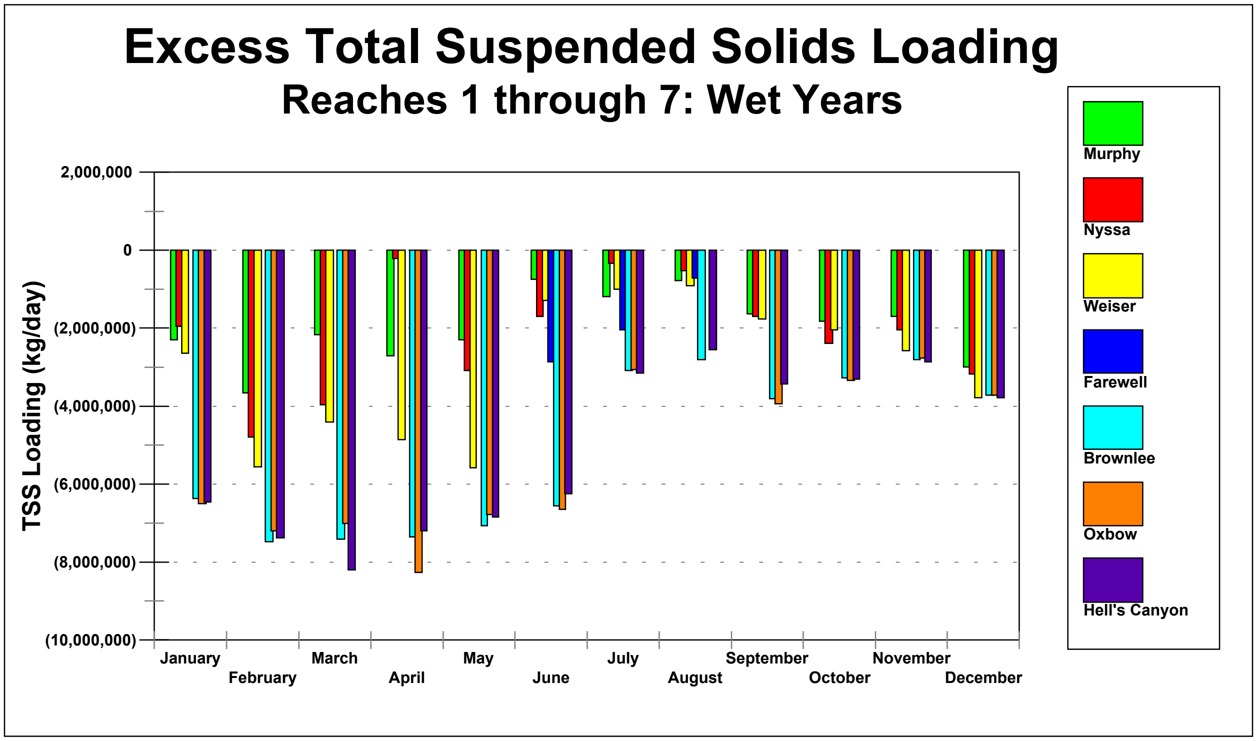
Excess Ortho Phosphorus Loading

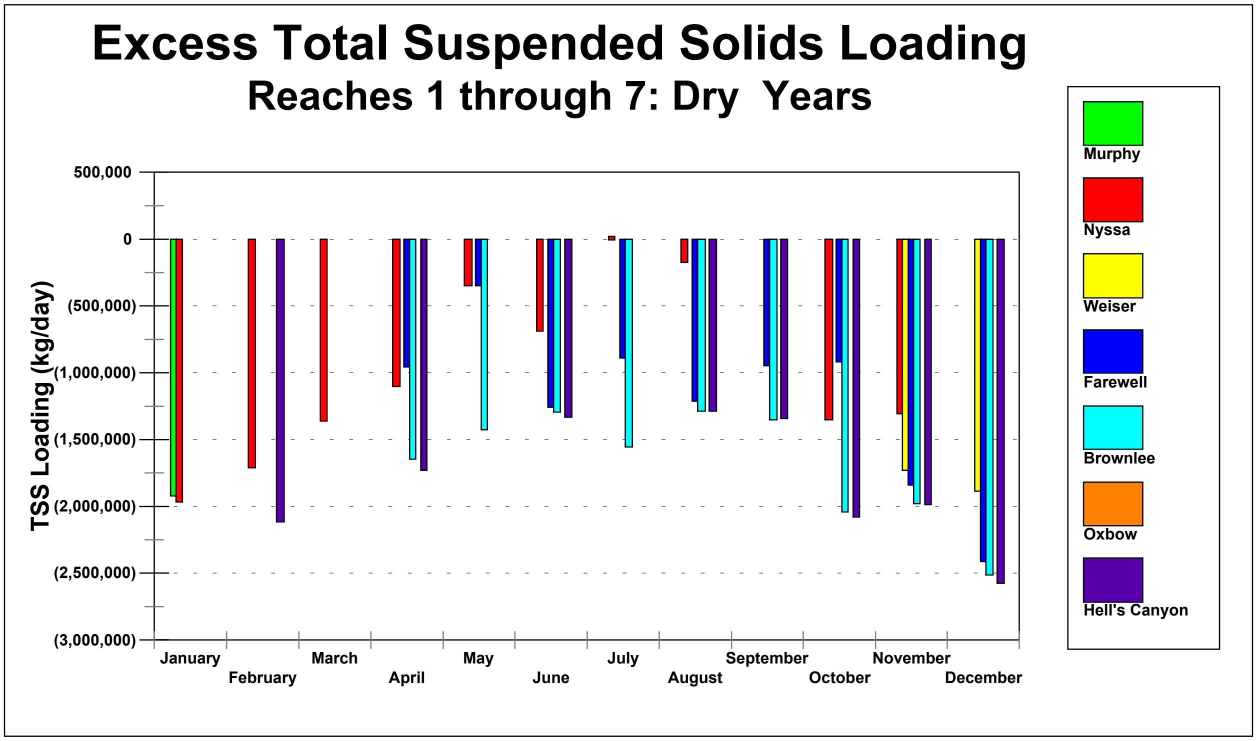
Reaches 1 through 7: Medium Year

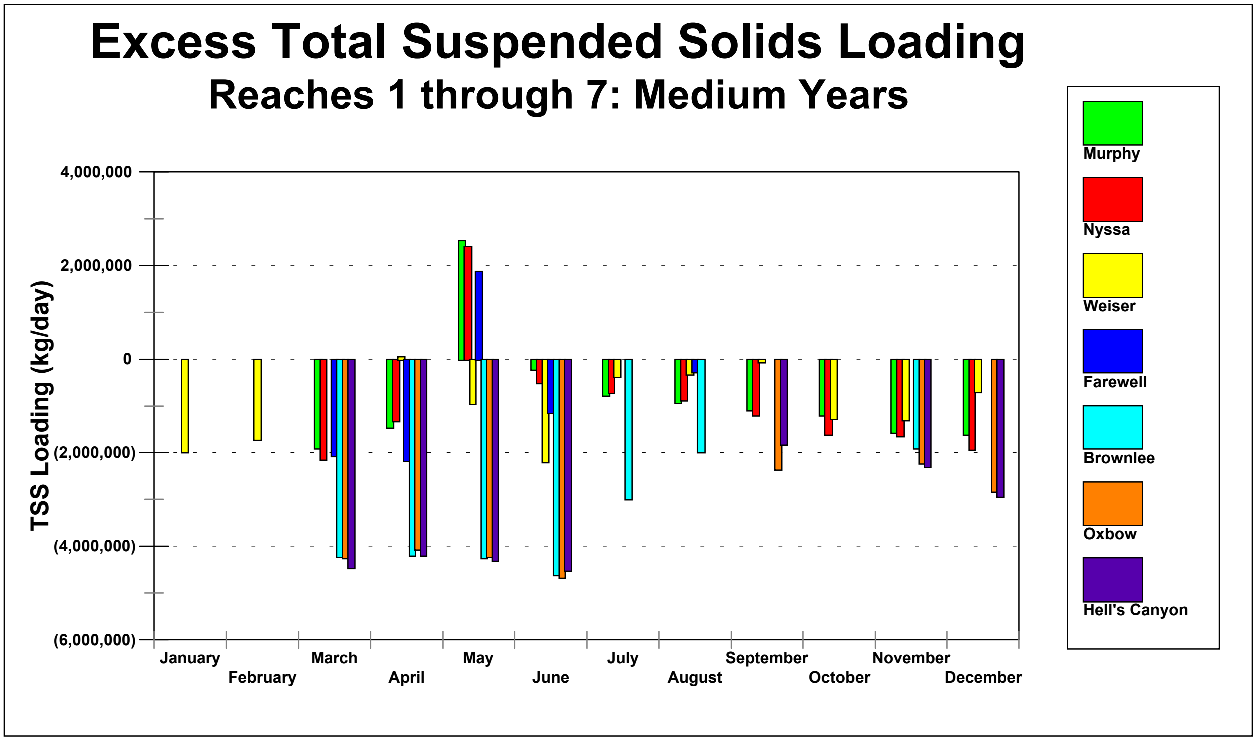


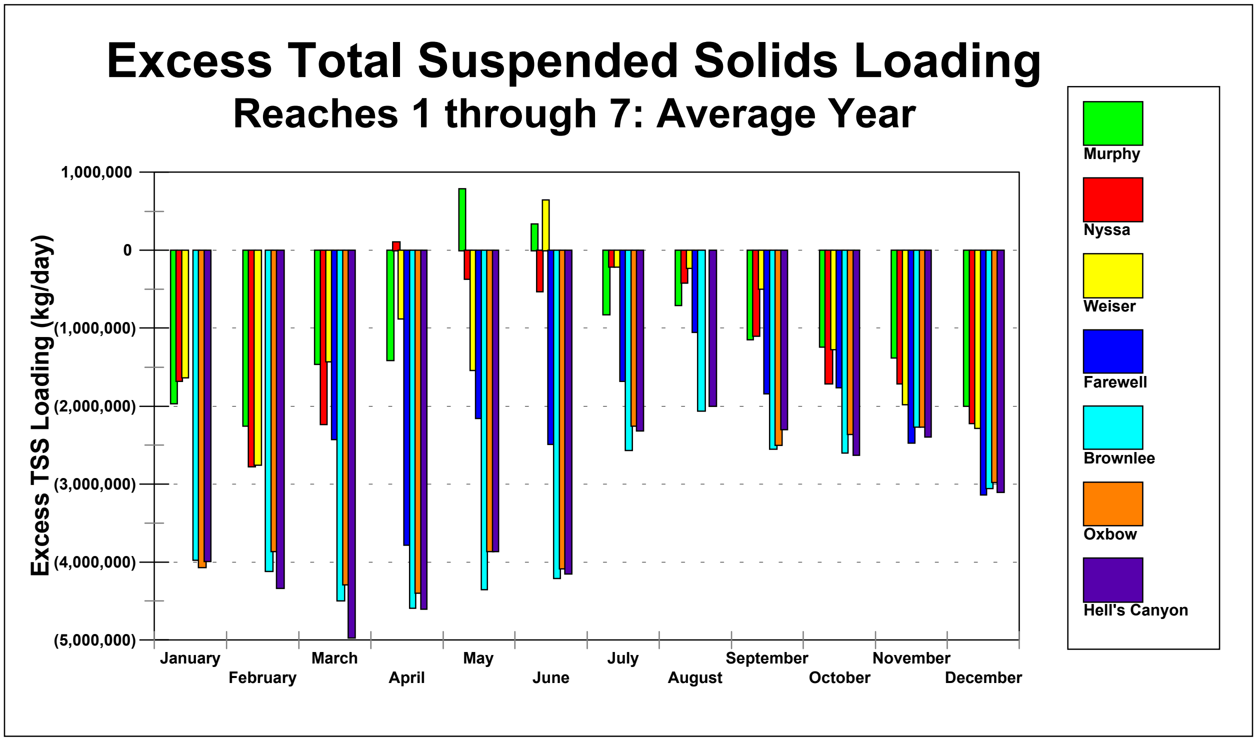
Excess Orthophosphorus Loading

Reaches 1 through 7: Average Year


Excess Total Suspended Solids Loading
Reaches 1 through 7: Wet Years
TSS Loading (kg/day)
2,000,000
0
(2,000,000)
(4,000,000)
(6,000,000)
(8,000,000)
(10,000,000)
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon


Excess Total Suspended Solids Loading
Reaches 1 through 7: Dry Years
TSS Loading (kg/day)
500,000
0
(500,000)
(1,000,000)
(1,500,000)
(2,000,000)
(2,500,000)
(3,000,000)
January
February
March
April
May
June
July
August
September
October
November
December
Murphy
Nyssa
Weiser
Farewell
Brownlee
Oxbow
Hell's Canyon


Excess Total Suspended Solids Loading
Reaches 1 through 7: Medium Years


Excess Total Suspended Solids Loading
Reaches 1 through 7: Average Year

Appendix VIII

Excess Loadings at Mainstem Snake River Sites: Tabular Data

Wet Year Scenario: Total Phosphorus Loading Balance (kg/day)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1975 Loading																				
Jan	-1419						-1977		0			-1412	2851	5	6	-1057	-7	-2121	-11	-1066
Feb	-733				1373		0		618			1517	3884	9	6	-1660	-14	-1564	-16	-1578
Mar	-433						2732		273			3466			625	18297	0		164	4002
Apr	-1666					2	-873		310		0	0	6442	81	209	559	9		-14	-2282
May	581			-231	457	-2	0		1228		0	-2317	26076		322	11429		2384	170	-1216
Jun	-0				1341	0	1489		-187		-9	6949	2591		162	-1315	-12	-663	141	-2766
Jul	1511			96	722	-61	2706		224		-42	3308	2157	64	64	-1068				-368
Aug				-28			1266		0		-15	3026	-586	50	17	568		-285	-4	-860
Sep	203				642	-5	1008		-98		-9	3287	1687	47	15	-191	-1	0	-6	0
Oct	-0					0	1037		-47		-2	1283								1193
Nov	-659				438		-373		-165			1757								
Dec	-392						0		-194			0								-279
1997 Loading																				
Jan	1773						5389					8510				12563		13274		13498
Feb	0				1937		1888					2403				4239		4250		5698
Mar	1387						-478					2419				1018		-1365		0
Apr	1136				401		3242					5119				4714		1242		5076
May	0				810		2523					7987				2557		-434		1816
Jun	3912				540		4696					6612	6359			-1689		-2268		-1165
Jul	132				861		828					1537	1908			-812		-968		-621
Aug	513				719		649					2299	3115			-820				-1992
Sep	946				788		1130					2240				364		791		2076
Oct	386						607					1299				1921		2404		805
Nov	490											827				15		191		178
Dec	-695						-744					-47				-259		-279		-140
Wet Year Loading (average of 1975 and 1997)																				
Jan	177						1706					3549	2851	5	6	5753	-7	5577	-11	6216
Feb	-367				1655		944		618			1960	3884	9	6	1290	-14	1343	-16	2060
Mar	477						1127		273			2942			625	9657		-1365	164	2001
Apr	-265				401	2	1185		310			2559	6442	81	209	2636	9	1242	-14	1397
May	291			-231	633	-2	1261		1228			2835	26076		322	6993		975	170	300
Jun	1956				940		3093		-187		-9	6780	4475		162	-1502	-12	-1466	141	-1966
Jul	821			96	791	-61	1767		224		-42	2423	2032	64	64	-940		-968	0	-495
Aug	513			-28	719		957		0		-15	2663	1264	50	17	-126		-285	-4	-1426
Sep	575				715	-5	1069		-98		-9	2763	1687	47	15	87	-1	395	-6	1038
Oct	193						822		-47		-2	1291				1921		2404		999
Nov	-85				438		-373		-165			1292				15		191		178
Dec	-544						-372		-194			-24				-259		-279		-210

Wet Year Scenario: Orthophosphorus Loading Balance (kg/day)

	Murphy						Nyssa					Weiser	Farewell			Brownlee		Oxbow		Hells
		Jump	Succor	Owyhee	Boise	Pumps		Malheur	Payette	Weiser	Pumps			Burnt	Powder		Wildhorse		Pine	
1975 Loading																				
Jan					523				-153				-309	4	-1	-1031	-5	-1803	-8	-826
Feb	440				523		1332		0	16		1922	0	6	4	-1867	-11	-1877	-15	-2146
Mar	649				166				-182	582		3328	9948		269	156	-18		-3	-2081
Apr	-1333				33	2			-310	135		-1440	-3221	22	83	-3351	-24		-43	-3423
May	-2731				43087	11			-351	129		1390	4036		121	1182	-25	-4769	-73	-4258
Jun	-777				55	13			-748	164		2471	-2591	135	81	1150	-21	-2653	-99	-2766
Jul									-299	245			899	35	53	-890				
Aug									-136	239			-440	28	16	-639		-569	-6	-716
Sep									-195	115			-1350	20	10	-669	-3	0	-6	
Oct									-142	-26										
Nov									-165	-1										
Dec									-259	-25										
1997 Loading																				
Jan	443						674					2128				7179		8447		7363
Feb	-649				581		-944					0				2826		2833		2849
Mar	-2775						-3823					-2822				-1357		-2730		-2767
Apr	-1703				368		-1621					-3291				-2460		-3727		-2538
May	-1825				540		-2523					-3494				-2557		-1736		-1816
Jun	-782				453		-939					-3005	-1908			-3379		-2268		-4079
Jul	-1055				477		-1325					-1688	-1908			-1624		-1121		-1191
Aug	-1026				611		-1235					-1508	-1469			-989				-947
Sep	-1456				555		-1675					-1337				395		851		916
Oct	-1543						-1736					-1877				1014		1710		832
Nov	-1399											-1712				-132		-44		0
Dec	-1197						-1198					-546				-318		-359		-221
Wet Year Loading (average of 1975 and 1997)																				
Jan	664						1369					3611				8849		10139		9098
Feb	57				550		376		-491			1739	-2342	4	-3	663	-13	277	-29	766
Mar	-1333				19		-1572		-396	-231		-919	-2434	4	-14	-2003	-31	-2703	-71	-2880
Apr	-833				18		-1776		-458	648		-820	8083		320	-1998	-39	-3437	-31	-3161
May	-1643				320	17	-3160		-927	13		-2791	-3646	24	103	-3117	-41	-2546	-131	-2808
Jun	-1229				21998	29	168		-572	312		158	2009		204	214	-10	-2196	-100	-2856
Jul	-410				370	16	-1017		-161	426		1569	-989	146	165	517	-0	-1123	-4	-1169
Aug	-796				649		-991		-136	289		-1253	-119	43	84	-759				-449
Sep	-1054				587		-1258		-80	251		-993	-1035	36	20	-368		-105	-6	-145
Oct	-1306						-1515		-137	114		-1742	-2019	35	15	141	-3	824	-12	1180
Nov	-1349								-107	-22		-1740				-529		-441		-397
Dec	-1211						-1254		-242	-16		-673				-701		-744		-614

Wet Year Scenario: Total Suspended Solids Loading Balance (kg/day)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1975 Loading																				
Jan							-2965516		-330421											
Feb					-97036		-2704629		-241480											
Mar							5409953		-527421											
Apr							-4013680		-619822		1463									
May				-758072	-426453		-3365243		-736603		4370	-1274181			-91095					
Jun					24384		-1638439		-1178060		9527						-28420			
Jul				57418	42916		187350		-425701	-87357	-2929	-571456			-19849					
Aug							-822867		-154106		9923						7046			
Sep					-91682		-1511363		-341268	-29950	13358									
Oct							-1762973		-330646	-50140	3494									
Nov				-57480	-194148		-2650214		-318439	-44222		-3207093			-15095					
Dec							-2569885		-472143	-126894										
1997 Loading																				
Jan	-2614587						-3031219					-4999848				-9013588		-9171240		-9203162
Feb	-4739326				-639097		-6418271					-8289439				-10598049		-10340725		-
Mar	-3190793						-4109736					-6449764				-9703275		-9280427		-
Apr	-2725317				-902972		-3161178					-5082268				-7753836		-8696570		-7676774
May	-1779073				-424264		-2018398					-4892016				-5710944		-5469782		-5583256
Jun	-2347023				-317972		-3099255					-4327840	-4451363			-8390695		-8506645		-8098943
Jul	-1555761						-1292136					-1515116	-2480342			-3646030		-3617941		-3701785
Aug	-1128141				-179868		-1142620					-1356963	-1077391			-3570491				-3303762
Sep	-2256124						-2177213					-2270624				-4677082		-4804196		-4315411
Oct	-2160332						-2429932					-2213478				-3795299		-3847170		-3838909
Nov	-1749156											-2503275				-2123182		-2099338		-2195514
Dec	-2935478						-3140014					-3606667				-3084091		-3068826		-3129691
Wet Year Loading (average of 1975 and 1997)																				
Jan	-2261329						-1918411					-2626804				-6341831		-6465146		-6426619
Feb	-3608648				40897		-4774672		-872331			-5506606				-7435334		-7176679		-7368186
Mar	-2147436				-903732		-3928635		-874464			-4385465				-7389178		-6963063		-8182164
Apr	-2675406				-897589		-179929		-969614			-4809880				-7302782		-8232989		-7165005
May	-2278811				-519224		-3068243		-1607791		3518	-5531920				-7030705		-6765526		-6817793
Jun	-698145			211442	-6838		-1675875		-1090175		6718	-1255885	-2818309		42052	-6515058		-6622884		-6203492
Jul	-1172481				300570		-311966		-238515		-553	-986619	-2010290			-3039102	4033	-3010388		-3102550
Aug	-760489			144397	-79721		-488937		-165162	-17902	-18783	-861610	-682366		30103	-2775979				-2506517
Sep	-1613875						-1663649		-64580		-1527	-1718997				-3776516	7816	-3903421		-3410014
Oct	-1781504				-159360		-2345796		-248877	-32763	-1713	-1998809				-3239567		-3291649		-3282313
Nov	-1668059						-2012063		-275716	-43138	-1987	-2548945				-2758278		-2735011		-2830928
Dec	-2957892			-78237	-185753		-3144330		-441067	-69186		-3751751			-18298	-3696982		-3684888		-3758561

Dry Year Scenario: Total Phosphorus Loading Balance (kg/day)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1977 Loading																				
Jan	-868				651		-634			7		0								-435
Feb	-268				571		-594			-6		0								-894
Mar	-499				522		0					294								670
Apr	-1034				75	21	-1109			34	10	191								-831
May	-335				388	9	168		97	98	-2	198								470
Jun	-795					28	-170			54	3	351								-952
Jul	277			111	217	-13	827			26	-18	1891								-338
Aug	-299					9	614			29	-9	1039								-325
Sep	-334					6			116	8		214								842
Oct	-377				367	1	-437			21	1	1034								278
Nov	0				477					7										0
Dec	0				574					-60		984								0
1992 Loading																				
Jan				13										0	13					
Feb				64										1	37					
Mar				33	495									24	34					
Apr				32									-450	9	20	107				-227
May				23									797	41	18					
Jun				24									615	32	23	419				144
Jul				18									1451	17	18	669				
Aug				11									674	11	1					644
Sep				9									341	1	0	694				349
Oct				5									780	0	2	0				493
Nov				9	697		655					478	257	0	2	0				-675
Dec													132			1365				2183
Dry Year Loading (average of 1977 and 1992)																				
Jan	-868			13	651		-634			7					13					-435
Feb	-268			64	571		-594			-6				1	37					-894
Mar	-499			33	508					0		294		24	34					670
Apr	-1034			32	75	21	-1109			34	10	191	-450	9	20	107				-529
May	-335			23	388	9	168		97	98	-2	198	797	41	18					470
Jun	-795			24		28	-170			54	3	351	615	32	23	419				-404
Jul	277			64	217	-13	827			26	-18	1891	1451	17	18	669				-338
Aug	-299			11		9	614			29	-9	1039	674	11	1					159
Sep	-334			9		6			116	8		214	341	1		694				596
Oct	-377			5	367	1	-437			21	1	1034	780		2					385
Nov				9	587		655			7		478	257		2					-337
Dec					574					-60		984	132			1365				1091

Dry Year Scenario: Orthophosphorus Loading Balance (kg/day)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1977 Loading																				
Jan										-10										
Feb										-9										
Mar																				
Apr										17										
May										34										
Jun										31										
Jul										16										
Aug										5										
Sep										6										
Oct										0										
Nov										-14										
Dec										-51										
1992 Loading																				
Jan				6										0	11					
Feb				19										0	14					
Mar				-2	458									8	18					
Apr				2									0	7	10	0				0
May				6									398	37	15					
Jun				5									0	27	21	140				0
Jul				3									0	15	13	892				
Aug				1									0	10	1					322
Sep				1									-341	1	0	694				523
Oct				1									-334	0	2	0				493
Nov				5	542		-655					-717	-770	0	2	-668				-922
Dec													-397			1365				460
Dry Year Loading (average of 1977 and 1992)																				
Jan				6						-10				0	11					
Feb				19						-9				0	14					
Mar				-2	458									8	18					
Apr				2						17			0	7	10	0				49
May				6						34			398	37	15					
Jun				5						31			0	27	21	140				-117
Jul				3						16			0	15	13	892				
Aug				1						5			0	10	1					318
Sep				1						6			-341	1	0	694				538
Oct				1						0			-334	0	2	0				417
Nov				5	542		-655			-14		-717	-770	0	2	-668				-1050
Dec													-397			1365				-9

Dry Year Scenario: Total Suspended Solids Loading Balance (kg/day)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1977 Loading																				
Jan	-2257391				-91866		-2345453			-27681										
Feb					-87261		-2050504			-28387										-2085360
Mar				-29234	-69538		-1634597													
Apr					-30597		-1238542			-28484							-67052			
May					23704		-488306			-17855										
Jun							-847910			-28613										
Jul				20634	-5975		13783			-17095							-13752			
Aug							-276137			-5432										
Sep										-7252							-4954			
Oct					-132230		-1418898			-21461										
Nov										-28070										
Dec										-183024		-2229342								
1992 Loading																				
Jan				-28546										-1002	-15706					
Feb				-69381										-1530	-33465					
Mar				-24663	-65550									4143	-30331					
Apr				-10606									-1103295	-5869	-9240	-1708322				-1793651
May				-8470									-278910	-23811	-4812	-1688200				
Jun				-9207									-1122193	-17348	-6623	-1110978				-1134240
Jul				-4644									-918860	-10100	-5766	-1771875				
Aug				-4108									-1037865	-21155	-852	-1274011				-1272290
Sep				-9734									-783330	-1257	-575	-1371269				-1360779
Oct				-14497									-787941	-321	-3113	-1915501				-1949212
Nov				-16212	-96060		-1288174					-1625035	-1771044	-403	-3570	-1769247				-1776772
Dec													-2000544			-1796800				-1815037
Dry Year Loading (average of 1977 and 1992)																				
Jan	-1910384			-28056	-79522		-1956964			-31375				-747	-13879					
Feb				-46432	-84508		-1699758			-153778				-940	-21001					-2109568
Mar				-26949	-67544		-1351644							8177	-20813					
Apr				-26933	-32955		-1089527			-94167			-951196	-3637	-6213	-1635165	-42223			-1715980
May				-20362	39763		-340058			-59448			-336874	-20521	-4266	-1416707				
Jun				-26030			-680758			-31030			-1246498	-13462	-5325	-1282978				-1321193
Jul				7995	-3687		22370			-23551			-882909	-11865	-3152	-1546526	-8730			
Aug				-9282			-159206			-9871			-1200824	-14611	-2339	-1279404				-1279015
Sep				-12168						-10116			-935368	-558	-1691	-1345686	-3358			-1336933
Oct				-17531	-100187		-1338586			-16858			-912182	-148	-3126	-2036559				-2072363
Nov				-17570	-110462		-1297308			-26002		-1723584	-1830768	-201	-4167	-1970410				-1981960
Dec										-76690		-1878010	-2401966			-2499031				-2565117

Medium Year Scenario: Total Phosphorus Loading Balance (kg/day)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1979 Loading																				
Jan	-698			142	628							6038			35					-1007
Feb	2108			532	4350					0		3862			382					2031
Mar	-390			225	542					348					535					5633
Apr	-353			224	460	1			0	332		1531			118					0
May	-574			497	345	13				648		1743			218					-1450
Jun	-807			445	313	31				393		1399			91					-733
Jul	-398			224	316	20				117		2267			44					-301
Aug	1134			74	505	-29				91		1603			51					-414
Sep	-389			75	383	7			83	46		284			84					-261
Oct	-633				455	4				27		600			26					0
Nov					582				-123	14		-285			14					-0
Dec										-32		0			11					592
1995 Loading																				
Jan				1955										9						
Feb				420										3	91					
Mar	555			419	875		1615	164	456				9818	46	106	4289		2184		2280
Apr	816			223	1074		2040	158	0	248			4102	285	76	974		-564		874
May	5853			1446	557		7791	191	230	200			12972	56	85	-1561		-793		-1230
Jun	2569			1836	1268		6655	157		-44			5933	8	152	847		-1706		-879
Jul	618			189	1203		3396	165	714	126			2074	23	28	-1836				
Aug	543			35	616		1443	103	119	81			3094	13	23	1324		1994		501
Sep	823			35	733		1553	135	149	104			3836	15	25	2582		2218		2225
Oct	0			23	712		914	96	30	-11			1645	1	17	1333		2340		2357
Nov	364			13			1926						1026	1	13	461		1390		942
Dec	774			39	1592		909						1974		169	3166		3643		2346
Medium Year Loading (average of 1979 and 1995)																				
Jan	-698			1048	628							6038		9	35					-1007
Feb	2108			476	4350							3862		3	236					2031
Mar	83			322	708		1615	164	456	348			9818	46	320	4289		2184		3957
Apr	232			223	767	1	2040	158		290		1531	4102	285	97	974		-564		437
May	2639			971	451	13	7791	191	230	424		1743	12972	56	152	-1561		-793		-1340
Jun	881			1141	790	31	6655	157		175		1399	5933	8	122	847		-1706		-806
Jul	110			206	760	20	3396	165	714	122		2267	2074	23	36	-1836				-301
Aug	838			54	561	-29	1443	103	119	86		1603	3094	13	37	1324		1994		44
Sep	217			55	558	7	1553	135	116	75		284	3836	15	54	2582		2218		982
Oct	-316			23	584	4	914	96	30	8		600	1645	1	21	1333		2340		1179
Nov	364			13	582		1926		-123	14		-285	1026	1	14	461		1390		471
Dec	774			39	1592		909			-32			1974		90	3166		3643		1469

Medium Year Scenario: Orthophosphorus Loading Balance (kg/day)

	Murphy	Jump	Succor	Owyhee	Boise	Pumps	Nyssa	Malheur	Payette	Weiser	Pumps	Weiser	Farewell	Burnt	Powder	Brownlee	Wildhorse	Oxbow	Pine	Hells
1979 Loading																				
Jan																				
Feb																				
Mar																				
Apr																				
May																				
Jun																				
Jul																				
Aug																				
Sep																				
Oct																				
Nov																				
Dec																				
1995 Loading																				
Jan				1139										3						
Feb				168										1	71					
Mar	-370			-111	747		-215	107	0				1275	22	59	1906		1213		1267
Apr	-653			-59	629		-859	64	-298	-124			-1538	69	17	-556		-2258		-874
May	-1463			206	557		-2078	103	-459	-240			-3518	21	34	-3122		-3170		-2869
Jun	-1070			192	951		-1065	67		-87			-1271	10	110	-847		-1706		-1758
Jul	-823			40	1058		283	95	390	69			-1660	20	18	-1836				
Aug	-453			15	516		-333	82	36	52			-673	17	23	-331		665		334
Sep	-412			3	550		-647	101	66	37			153	14	23	2028		1479		1484
Oct	-515			-0	699		-522	77	-91	-16			329	2	15	1333		1672		1684
Nov	-849			3			-1100						-684	1	12	-461		1390		1178
Dec	258			25	1388		606						1481		37	2261		2277		1877
Medium Year Loading (average of 1979 and 1995)																				
Jan				1139										3						
Feb				168										1	71					
Mar	-370			-111	747		-215	107	0				1275	22	59	1906		1213		1267
Apr	-653			-59	629		-859	64	-298	-124			-1538	69	17	-556		-2258		-874
May	-1463			206	557		-2078	103	-459	-240			-3518	21	34	-3122		-3170		-2869
Jun	-1070			192	951		-1065	67		-87			-1271	10	110	-847		-1706		-1758
Jul	-823			40	1058		283	95	390	69			-1660	20	18	-1836				
Aug	-453			15	516		-333	82	36	52			-673	17	23	-331		665		334
Sep	-412			3	550		-647	101	66	37			153	14	23	2028		1479		1484
Oct	-515			-0	699		-522	77	-91	-16			329	2	15	1333		1672		1684
Nov	-849			3			-1100						-684	1	12	-461		1390		1178
Dec	258			25	1388		606						1481		37	2261		2277		1877

Medium Year Scenario: Total Suspended Solids Loading Balance (kg/day)

	Murphy						Nyssa					Weiser	Farewell			Brownlee		Oxbow		Hells
		Jump	Succor	Owyhee	Boise	Pumps		Malheur	Payette	Weiser	Pumps			Burnt	Powder		Wildhorse		Pine	
1979 Loading																				
Jan				-131846								-2372215			-22961					
Feb				43857						-133203		-2172450			-22649					
Mar				-535074						-389151					83520					
Apr				-325792						29531		-255180			-70888					
May				-266660						184319		906363			-36311		-50151			
Jun				89090						-107117		0			-31407					-2674264
Jul				41529						-39994		340065			-6381		-10077			
Aug				-9747						-39585		-400765			-6932					
Sep				982								-56777			-7642		-2296			
Oct					-68218							-1259936			-7760					
Nov					-136656							-1138811			-9242					
Dec												0			-9840					
1995 Loading																				
Jan				537092										5511						
Feb				-545447	-83576									-91	-42395					
Mar	-1072877			-238046	-28878		-1098235	20645	-262190				-1479081	-8666	-63454	-3717517		-3761201		-3978081
Apr	-685288			-65419	-27509		-515352	-14331	-984678	-291845			-1948315	205239	-52299	-4200045		-4063542		-4194842
May	1829031			-133452	-478813		1220565	-31506	-1583761	-471836			43974	13084	-52327	-6048099		-6023092		-6107866
Jun	-1263057			569409	-133144		-1889950	13102		-336317			-3390372	-17212	-52459	-6604812		-6654791		-6327495
Jul	-1070522			50309	-255062		-1245307	-24058	-448183	-74600				-9905	-10743	-3626620				
Aug	-905203			-3792	-120752		-865928	-8981	-45070	-53011			-188313	-22161	-7375	-2483173				
Sep	-1132034			-12006	-78533		-1268646	-12372	-91778	-37355				-12736	-8894			-2772573		-2262518
Oct	-1153135			-15796	-204332		-1618768	-25025	-196346	-39892				-1943	-8163					1618768
Nov	-1686841			-29371			-1760508							-2768	-9512	-1428857		-1737361		-1837548
Dec	-1831057			-67903	-253047		-2211782								16489			-3460805		-3613103
Medium Year Loading (average of 1979 and 1995)																				
Jan				202623								-1972552		5849	-25663					
Feb				-250795	-132571					-326571		-1726819		-133	-32522					
Mar	-1891525			-386560	-30817		-2122177	49120	-75775	-516962			-2047828	4726	10033	-4219417		-4250726		-4454457
Apr	-1443114			-195605	72221		-1316858	14331	-642774	-131157		51460	-2149810	214589	-61593	-4197604		-4064338		-4178858
May	2526833			-200056	-76538		2415516	-7271	-973026	-143759		-953685	1872145	9350	-44319	-4237435	-53008	-4209571		-4278188
Jun	-195818			329250	72351		-496170	23377		-221717		-2184292	-1128103	-19658	-41933	-4608973		-4653097		-4500880
Jul	-777277			45919	-71835		-723313	-11396	-334595	-57297		-364177		-11726	-8562	-2983306	-17180			
Aug	-936898			-6770	-85252		-870821	1585	-174478	-46298		-321653	-251383	-21511	-7154	-1981231				
Sep	-1087245			-5512	-43495		-1187582	2624	-190728	-27148		-48296		-14021	-8268		-3780	-2333030		-1821021
Oct	-1173181			-15104	-136275		-1595597	-10304	-246632	-33183		-1255516		-2048	-7961					
Nov	-1565522			-29978	-143833		-1641440					-1279409		-1345	-9377	-1901197		-2207686		-2301130
Dec	-1604202			-48885	-169244		-1926050					-677787			3325			-2811430		-2920668

Appendix H. Complaints Regarding Water Quality in the Snake River – Hells Canyon Reach

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Type of Complaint	Date	Concern	Place of Residence
Phone call	05 June 2001	Unpleasant odor in the Snake River	Near Weiser
Phone call	19 April 2000	Too much algae in the summer in the Snake River near Weiser, dangerous to children?	Near Weiser
Phone call	17 May 2000	Algae in Snake River in the summer makes skim on boat, have to wash it more often	Lower Snake near Brownlee Reservoir
Phone call	11 July 2000	Bad smell in Snake River and Upper Brownlee Reservoir	Near Weiser
Phone call	18 Aug 2000	Concerns about bacteria and algae – won't let grandchildren swim in the river	Ontario, OR
Personal conversation	21 March, 2001	In the summer the Snake River is full of algae near Weiser and the area near Brownlee Reservoir	Huntington, OR
Personal conversation	22 March, 2001	Fishing has declined dramatically in the last 25 years	Payette area
Personal conversation	22 March, 2001	Won't swim or let family swim in the Snake River below Boise during the summer – water quality is bad	Payette area
Personal conversation	22 March, 2001	Something should be done to clean up the river. Water quality has been getting worse for the last 15 to 20 years. Fishing has declined also.	Ontario, OR
Personal conversation	22 March, 2001	Used to do a lot of fishing, swimming and boating on the Snake River, the last 15 years or so have not used the Snake or Brownlee Reservoir, will go down to Oxbow or Hells Canyon reservoirs instead because the water quality is better.	Nampa, ID
Personal conversation	22 March, 2001	Appreciate the fact that something is finally being done about the Snake River. It has been showing a decline in water quality over the last decade or so.	Nampa, ID

Type of Complaint	Date	Concern	Place of Residence
Personal conversation	22 March, 2001	Has watched water quality decline, water is not very clear anymore, green in late summer. Would like to know if it is a health risk to people and animals.	Ontario, Oregon
Formal Complaint	02 July 2001	River stinks of dead fish, has scum over it, temperature is too high (around 76 ^{o}C), wants the river cleaned up.	Boise, ID
Letter of concern	28 March 2001	Degraded water clarity, decline in fishing and fish populations, Snake River is a “sick soup”.	Weiser, ID

Appendix I. Stakeholders Proposal for Total Phosphorus Load Allocation Mechanism

Text submitted by members of the SR-HC PAT as a proposed load allocation method for total phosphorus within the SR-HC TMDL.

The SR-HC PAT is not a consensus-based group and not all members supported the approach outlined here.

The first document discusses the load allocation approach for nonpoint sources. The second document discussed the waste load allocation approach for point sources.

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Nonpoint Sources:

The goal of the Clean Water Act and associated administrative rules for Oregon and Idaho is that water quality standards shall be met or that all feasible steps will be taken towards achieving the highest quality water attainable. This is a long-term goal in many watersheds, particularly where non-point sources are the main concern. To achieve this goal in the very large, diverse and complicated watershed(s) of the SR-HC reach, this TMDL employs phased approach for establishing TMDL targets, load allocations, and implementation objectives. This approach has been developed and recommended by the SR-HC PAT and adopted by the DEQs to facilitate immediate and long-term implementation of TMDL objectives in a manner that will promote cooperation between stakeholders and the agencies.

The PAT has fulfilled one of its critical roles in developing and recommending the phased approach for this TMDL. The PAT was created to perform the functions of a watershed advisory group because of IDEQ's agreement to work with ODEQ in preparing the TMDL. Watershed advisory groups (WAGs) are charged by Idaho statutes with advising IDEQ on the development and implementation of TMDLs, and recommending actions needed to control point and nonpoint sources of pollution. Rule 54 of IDEQ's Water Quality Standards requires IDEQ to consult with WAGs in determining whether impaired waterbodies can be restored through the application of pollution controls. IDAPA 16.01.02.054.01. This includes WAG consultation to "determine the feasibility of, and assurance that required or cost-effective interim pollution control strategies can be effectively applied to the sources of pollution to achieve full support status within a reasonable period of time."

The fundamental elements of this phased approach are: (1) providing a process for modifying TMDL objectives, targets and load allocations when water quality standards change; (2) long-term, scientifically justified, water quality-based goals; (3) interim attainable water quality goals based on implementation of feasible control strategies and an equitable distribution of load reduction; (4) pollutant trading which enables stakeholders to commit limited financial resources to implement the most cost-effective control strategies within watershed(s) of the SR-HC reach; (5) monitoring to periodically review and determine progress in attaining TMDL objectives; and (6) periodic review and modification of these goals, cost-benefit analysis, and progress in achieving them through a clearly articulated and scheduled phased approach.

Long Term Water Quality-Based Goals

The SR-HC TMDL establishes targets and corresponding load allocations that ODEQ and IDEQ believe are necessary to support designated uses. ODEQ and IDEQ recognize that implementing BMPs to achieve these targets and load allocations may take several years to several decades. These long-term targets and load allocations are based on IDEQ's and ODEQ's analysis of water quality conditions affecting designated uses presented in Section 2 (Subbasin Assessment) and Section 3 (Loading Analysis) of this TMDL.

Issues For Periodic Review

Various technical and practical issues regarding the validity and appropriateness of these targets have been identified. Analysis will be performed to determine whether these targets and load allocations are attainable given the various factors that affect the nature and extent of BMP implementation within the SR-HC watershed. Periodic review of these long-term targets and load reductions will enable the DEQs and stakeholders to reevaluate and adjust these targets and load allocations in accordance with information, analysis, and experience developed after this TMDL is adopted.

Interim Goals

The SR-HC TMDL also establishes interim targets and load allocations designed to reflect feasible control strategies and time frames within which those strategies can be implemented. These interim targets and load allocations have been developed to recognize the various factors affecting the nature and extent of feasible and attainable BMP implementation. The PAT also determined that load allocations must be established in an equitable manner. Therefore, no pollutant source or activity which contributes to water quality impairment within the SR-HC reach will be required to reduce its discharge below SR-HC targets, or alter its water or land use in a manner that is disproportionate to its effect on water quality. Applying this principle, for example, to sources of Total Phosphorus, no tributary, point source or nonpoint source will be allocated a load which represents a concentration below .07 mg/l. As with the long-term targets and load allocations, periodic review will enable the DEQs and the stakeholders to adjust these interim targets and load allocations in accordance with information, analysis, and experience developed during the implementation of the SR-HC TMDL objectives.

The primary concern in the 303(d) listing(s) that lead to the development of this TMDL is aquatic life use impairment due to periodically low dissolved oxygen levels in portions of Brownlee Reservoir. This concern was highlighted by a fish kill in 199_. Measured dissolved oxygen levels in the SR-HC segments upstream from the reservoir are sufficient to support aquatic life uses. The principal causes of low dissolved oxygen levels in the reservoir are the effects of impoundment and organic loading to the reservoir. Organic loading consists of aquatic plant life and other organic material that is generated in the Snake River and its tributaries upstream of Brownlee Reservoir. The growth of aquatic plant life in upstream watersheds results from several factors, including natural (background) and anthropogenic inputs of nutrients, sunlight penetration in the water column, and hydrology. The DEQs have determined that dissolved oxygen concentrations in Brownlee Reservoir can be increased by reducing upstream total phosphorus concentrations to reduce organic loading and by implementing in reservoir measures to mitigate the effects of impoundment.

During the process of developing this TMDL the DEQs have identified additional concerns about impairment of recreational and aesthetic uses of the 303(d) listed segments upstream from Brownlee Reservoir due to reports of periodically high accumulations of algae and other organic material. The DEQs have determined that reducing total phosphorus concentrations in these segments can reduce these materials to acceptable levels. The DEQs have selected 0.07 mg/l of total phosphorus as the TMDL target for accumulations of organic matter to levels that will support recreational and designated uses. Since natural or background total phosphorus concentrations are and current, instream SR-HC concentrations are **[NEED RANGE]** the DEQs believe this target is attainable. It is recognized, however, that attaining this target will require significant reductions in total phosphorus discharged to the SR-HC segments from the tributaries and the upstream Snake River (24 to 87 percent of current loading).

Protecting designated uses affected by low dissolved oxygen in Brownlee Reservoir and accumulations of organic material upstream from Brownlee will continue to be the primary focus of SR-HC TMDL development, objectives and implementation. Addressing the anthropogenic causes of these conditions will involve all water user groups (hydropower, point and nonpoint source dischargers) and all mainstem and tributary sources of water supply to the SR-HC segments, and will require the greatest commitment of time and economic resources. It is therefore appropriate to provide interim targets and load allocations for the attainment of TMDL objectives related these objectives.

Feasible Control Strategies

Establishing long-term, scientifically supported water quality objectives, interim targets and load allocations based on feasible and attainable control strategies is consistent with the goal of the Clean Water Act and associated administrative rules for Oregon and Idaho that water quality standards shall be met or that all feasible steps will be taken towards achieving the highest quality water attainable. It is also consistent with the agencies' responsibility to provide reasonable assurance that TMDL objectives can be met. Rule 54 of Idaho's Water Quality Standards directs IDEQ in "[c]onsultation with appropriate basin and watershed advisory groups, designated agencies and landowners to determine the feasibility of, and assurance that required or cost-effective interim pollution control strategies can be effectively applied to the sources of pollution to achieve full support status within a reasonable period of time."

Feasible pollution control strategies are those that can reasonably be taken by stakeholders to improve water quality within the physical, operational, economic and other constraints which affect their individual enterprises and their communities. Control strategies that will injure existing or future social and economic activity and growth are neither reasonable nor feasible. Attainable water quality goals should reflect control strategies that are feasible on a broad, watershed basis. Highest cost management practices should not be the basis for water quality planning. For example, it is not reasonable to expect sources to achieve zero discharge, or to expect all of irrigated agriculture to convert to sprinkler irrigation, or to expect all point sources to retrofit with the most expensive pollution control technology available.

Factors Affecting BMP Implementation

Several factors Affect BMP Implementation for Irrigated Agriculture:

1. **Financial.** The primary constraints on BMP implementation are limited sources of funding and BMP costs. Low commodity prices result in very limited margins (revenues after farm operating and family living expenses) available to commit to BMP implementation. Historically, there has been limited available funding from federal (e.g. NRCS cost share, 319 grants) and state sources (e.g. OWEB). Generally, there has been $1,500,000 funding available from the State of Idaho for agricultural water quality projects statewide. This funding level has been recently reduced to $1,400,000 due to budgetary shortfalls resulting from the recent recession. Soil Conservation Districts in the state apply for funding of projects, so that funding is not evenly distributed throughout the state. Changes in commodity prices, operating expenses, and Federal and State funding priorities may further constrain the availability of funds for water quality projects. Priority projects for Snake River tributaries, watersheds, and subwatersheds that yield substantial local water quality benefits, may not significantly reduce the delivery of loads to the Snake River. In other words, funding priorities may not always be directed toward reducing loads to the Snake River, and this will diminish funding available to achieve SR-HC TMDL objectives.

Per-acre BMP costs for irrigated agriculture have been estimated by the Soil Conservation Commission (SCC) in the *Lower Boise River TMDL Implementation Plan for Agriculture*. These estimates are: low level treatment at $250.00 per acre; medium treatment at $500.00 per acre; and high treatment at $800.00 per acre. Low level treatment involves annual treatment expense (such as application of PAM), and therefore the $250.00 per acre figure includes annual operation & maintenance (O & M). Medium and high levels of treatment require investment in equipment and therefore the cost estimates reflect capital costs that do not include O & M. The equipment typically must be replaced in 20 years.

Under the Clean Water Act and Oregon and Idaho law, implementation of control strategies to reduce discharges from irrigated lands is voluntary. It is not reasonable to expect that farmers can or will commit financial resources to BMP implementation if those resources are essential to continue operations or support their families. Imposing such a choice on farmers, or any other individual or entity for that matter, would ensure that they will not voluntarily participate in achieving the TMDLs objectives, and the DEQs could not provide EPA reasonable assurance that necessary load reductions from agricultural nonpoint sources will occur. For this reason, a margin or portion of farm gate revenue that could be committed to implementation of control strategies without imperiling continued farming operations or family support is estimated and used in combination with historically available federal and state funding to project levels of BMP implementation and corresponding load reductions. (See discussion of historically available funding.)

2. **BMP Effectiveness.** The Rock Creek watershed drains to the Snake River upstream from the SR-HC reach. With very little existing~~,~~ a 68% reduction in the discharge of total phosphorus (TP) from the watershed was achieved. Despite this improvement, TP concentrations from the watershed remained above .1 mg/l. (After project funding declined, the range of improvement also declined to approximately 40% due to the inability to fund the recurring annual BMP costs.)

3. **Prioritizing lands for treatment.** It is not necessary to treat all agricultural lands to substantially reduce the discharge of pollutants. BMP implementation should focus on priority lands where treatment will be most effective. Lands can be prioritized in three tiers: (1) lands that discharge directly to the Snake River or its tributaries, or that otherwise have a substantial influence on the Snake River; (2) lands with an indirect, yet significant influence on the Snake River; and (3) lands that do not have a significant impact on the Snake River because they are upland in the tributaries, because of reuse, because of existing treatment, or other considerations which minimize their effects on the Snake River. To the maximum extent possible, treatment

should focus on tier 1 and tier 2 lands within with little or no existing BMPs. Prioritizing lands for treatment will increase BMP effectiveness and the probability of meeting TMDL objectives within predictable timeframes.

4. **Crop Requirements.** Onions and seed crops are more appropriately produced using furrow irrigation than with sprinkler irrigation. Onions and seed crops are adversely affected by overhead sprinkler irrigation. The comparative climatic advantage for onion and seed crop production in the Treasure Valley is directly associated with the absence of rainfall, which promotes high quality. If onions receive regular rainfall or sprinkler irrigation, they become inoculated with fungal and bacterial diseases. These diseases can cause both losses before harvest, and tend to make the crop decompose during storage. Following the unusually rainy 1993 season, a large part of the onion crop was lost during storage due to decomposition.

Onions are grown in the Columbia Basin under central pivot irrigation, however, 5000 acres of sprinkler-irrigated onions in the Columbia Basin have recently been converted to subsurface drip irrigation to improve bulb quality and reduce decomposition losses so that Columbia Basin growers can safely market onions over a long storage season. Columbia Basin growers have been trying to export their crop in a short marketing window in late summer and early fall. Treasure Valley onions are marketed in the late summer, then throughout the fall, winter, and into the beginning of the spring (Shock et al., 2000).

5. **Hydrologic.** Irrigation systems in many watersheds utilize, and may rely entirely, upon return flows from upstream or upgradient irrigation. Recharge from delivery and use of irrigation water in many watersheds replenishes and, in some circumstances, creates aquifers. The Boise River watershed exhibits both of these characteristics. In fact, the majority of water flows in the Boise River below Star are generated by return flows, and the shallow aquifer in the watershed was created and is maintained by irrigation delivery and use. Eastern Snake Plain Aquifer levels and the flows of the Thousand Springs increased dramatically during the first half of the twentieth century as a result of recharge from surface irrigation, and have declined during the last fifty years due in large part to conversions from flood to sprinkler irrigation systems with the resulting decline in recharge. Water flows in the Snake River itself below Milner Dam are largely the result of flows from the Thousand Springs. For these reasons, eliminating or significantly reducing return flows will significantly impact water use, recharge, and the hydrologic balance in many watersheds.

6. **Engineering and Construction of Irrigation Systems.** The majority of irrigation systems along the Snake River Plain were designed and constructed to operate by gravity flow. Significant alteration of these systems will be required to accommodate pressurized, sprinkler irrigation and other system modifications to significantly reduce or eliminate return flows.

7. **Existing Implementation levels in watersheds.** Farmers have been implementing BMPs to reduce soil loss to improve productivity and water quality for over 50 years. The level of BMP implementation throughout the Snake River Plain varies from watershed to watershed, community to community, and farm to farm. The greatest water quality benefits from BMP implementation will be realized where there has been little or no BMP implementation, on “high priority” lands.” (See the definition of such lands in the *Lower Boise River TMDL*

Implementaiton Plan for Agriculture.) Experience in the Rock Creek watershed has demonstrated that, in such areas, implementation of lower per-acre cost BMPs can result in substantial load reductions from irrigated lands. Implementation efforts should therefore be focused in these areas. Where BMPs have been implemented and are maintained, further load reductions from irrigated agriculture will require greater expenditures of available funds. Implementation of higher per-acre cost BMPs in such areas will result in treatment of fewer acres with diminishing per-acre and overall load reductions in comparison to the load reductions realized through treatment of lands with little or no treatment.

8. **Power.** The highest cost agricultural BMP, conversion to sprinkler irrigation, will result in increased power demands and consumption, at a time when irrigators have been encouraged through Idaho Power's "Buyback" program to cease pumping and sprinkler irrigation to reduce power demands.

9. **Availability and cost of land.** Sediment ponds are viable means for irrigation districts and canal companies to reduce the discharge of sediment and other constituents from drains where there is sufficient land that can be obtained at reasonable cost. Land near drain discharges may not be available at reasonable costs in many watersheds.

10. **Counterproductive Effects of BMPs.** Certain BMPs may not be appropriate where they result in counterproductive effects on water quality. For example, while sediment ponds may reduce the discharge of sediment, they also can result in increased water temperatures and bacteria levels resulting from waterfowl (a major source of bacteria in the Lower Boise River). And, as previously mentioned, reducing or eliminating return flows can adversely affect aquifer levels and stream flows, which may adversely affect water quality.

As with irrigated agriculture, available funding is the primary constraint on BMP implementation for municipalities and other point sources. Most of the municipalities whose discharges affect the SR-HC reach are small communities with modest economies and tax bases.

The principal factors affecting the implementation and effectiveness of BMPs for point sources are available funding, BMP costs, and the limits of currently available technology in reducing phosphorus in point source discharges. These factors are particularly important for small communities.

The identified dollar values are only for first cost of construction. They do not include operation and maintenance cost such as labor, electrical power for pumping and equipment. chemicals, repair and replaced etc. The table below shows the importance of the opportunity for point sources, particularly small communities, to engage in pollution trading to achieve reductions by financing more cost-effective control strategies.

Summary of Probable Cost of Phosphorus Removal From Wastewater Discharge

City	**10 -50% Removal**		**50 -100% Removal**	
	Type	**Cost A**	**Type**	**Cost B**
Council	Seas. LA	$1,160,000	LA w/stor.	$2,100,000
Cambridge	Seas. LA	$ 395,000	LA w/stor.	$ 540,000
Weiser	SBR Retro	$ 950,000	LA w/stor.	$3,040,000
Payette	O-Ditch Retro	$1,550,000	LA w/stor.	$3,040,000
Fruitland	Seas. LA	$1,240,000	LA w/stor.	$2,085,000
Parma	Seas. LA	$ 845,000	LA w/stor.	$1,545,000
New Plymouth	Seas. LA	$ 100,000	LA w/stor.	$ 500,000
Notus	Not appropriate		Evap. Lagoon	$ 711,000
Middleton	SBR Retro	$1,413.000	LA w/stor.	$3,117,000
Emmett	Seas. LA	$2,338,000	LA w/stor.	$4,644.000
	Total	**$9,991.000**	**Total**	**$21,322.000**

Seas. LA = Seasonal land application
SBR Retro = Sequential batch reactor retrofit
O-Ditch Retro = Oxidation ditch retrofit
LA w/stor. = Land application with storage
Evap. Lagoon = Evaporation lagoon

Attainable Interim TMDL Objectives

The PAT has determined that it is not feasible, and therefore not reasonable, to expect or project BMP implementation throughout the SR-HC watershed(s) to achieve zero discharge, or widespread conversion to sprinkler irrigation, due to the extremely high costs and potential hydrologic impacts. Similarly, it is not reasonable to expect point sources to implement highest cost BMPs, The DEQs cannot provide reasonable assurance to EPA at this or any foreseeable time that such BMP implementation will occur on all point and nonpoint sources.

Attainable interim water quality goals for irrigated agriculture can be defined by identifying or estimating: (1) historically available private and public funding for water quality projects; (2) BMP costs; (3) pollutant reductions resulting from the installation of BMPs; (4) the status of BMP implementation within a watershed, community, or at a farm; and (5) the number of acres to be treated. Each of these factors is explained below, and the analysis is applied to the Malheur, Boise, and Payette watersheds to project BMP implementation and resulting overall pollutant reductions over time from irrigation agriculture.

1. **<u>Historically Available Funding</u>.** For purpose of this analysis, it is estimated that, on average, farmers have a 3% margin of annual farm gate revenue after farm operating expenses with which to pay living and family expenses. It is further estimated that it is possible for farmers to commit 5% of this margin annually to water quality projects. These estimates are optimistic, given the fact that low commodity prices and high operating expenses have forced many farmers to operate at a loss for many years. For the Malheur County, the Boise watershed and the Payette watershed, annual farm gate revenues are used to derive available private funding. Historically available federal and state funds have been identified to derive total available funds for BMP implementation within each watershed. Use of these margins and historically available federal funding (e.g. cost share and 319 grants) and state funding (e.g.

Oregon's OWEB) to project implementation of future control strategies assumes that farm historic relative commodity prices and expenses continue, and that public funding levels continue to be available. Changes in the economics of farming or available funds will be a subject of periodic review and will be factored into adjustments to interim water quality goals.

2. **BMP Costs.** This analysis is based upon implementation of the medium level, $500 per acre level of treatment. Low level treatment involves recurring, annual $250 per acre expense, whereas operation and maintenance are the only recurring costs with level of treatment until the equipment must be replaced. Higher level treatment is cost prohibitive, involves conversion to sprinkler irrigation which is not possible for many crop types, and does not result in significantly greater reductions in pollutant discharges than the medium level treatment. A 10% annual operation and maintenance cost is factored into the analysis be subtracting this cost from the total annual available funding.

3. **BMP Effectiveness.** This analysis assumes 68% reduction in the discharge of TP, and 75% reduction in the discharge of sediment, from irrigated lands based on the Rock Creek Project results. Reductions in TP and sediment discharges from irrigated lands greater than these levels will require conversion to sprinkler irrigation, zero discharge, and other treatment methods that may be feasible in certain locations, but cannot be applied broadly throughout the SR-HC watersheds due to financial constraints, hydrology, crop requirements, and other factors affecting BMP implementation discussed above.

4. **Lands to be Treated.** This analysis assumes that all or most of the loading from irrigated lands comes from lands identified as priority lands (Tier 1 and Tier 2). Treatment of priority lands is the basis for projected load reductions, interim targets and load allocations. Since the majority of Tier 1 lands discharge directly to the Snake River and its tributaries, and discharges from Tier 2 lands are reused one or more times, it is estimated that treatment of Tier 1 discharges will result in greater reductions that treatment of Tier 2 discharges.

5. **BMP Status.** The status of BMP implementation varies from watershed to watershed, from community to community and farm to farm within watersheds. Achieving further discharge reductions in many areas where BMPs have already been implemented will require higher per acre expenditures, resulting in lower overall treatment. BMP status in each of the SR-HC watersheds cannot at this time be fully characterized.

This analysis results in the following projections for TP reductions in the three watersheds. Information developed to identify the lands to be treated as well as changes in the number of acres to be treated, will be a subject of periodic review and will be factored into adjustments to interim water quality goals.

Malheur & Owyhee Watersheds: Malheur County (250,000 irrigated acres)

1. Available Annual Funding

$200,000,000 gross farm gate revenue
3% Margin = $6,000,000

5% of Margin for water quality project investment =		$300,000
Historically available federal funds:	Cost Share:	$300,000
	§319 Grants:	$ 80,000
Historically available state funds:	OWEB	$500,000 (sunsets 20__)
Total annually available funding		$1,180,000
Annual operation & maintenance costs (15%)		- 177,000
		$1,003,000

2. Priority Lands

The [IDENTIFY ENTITIES INVOLVED IN ANALYSIS] are prioritizing lands in the Malheur and Owyhee watersheds for treatment. Of the 250,000 irrigated acres in the Malheur and Owyhee watersheds, 90,000 acres are pasture, non-cultivated lands which generate very little sediment in return flows. Return flows from these lands tend to be reused two to three times before the water is ultimately discharged to tributary streams or drains. These 90,000 acres, and an additional 20,000 acres, are properly classified as Tier 3 lands. There are 40,000 Tier 1 (high priority) acres and 100,000 Tier 2 (medium priority) acres in these watersheds.

3. Projected BMP Implementation on Priority Lands

Tier 1 lands: 40,000 acres x $500.00 = $20,000,000 ÷ $1,003,000 = 19.94 years
Tier 2 lands: 100,000 acres x $500.00 = $50,000,000 ÷ $1,003,000 = 49.85 years
69.79 years

Acres treated per year: $1,003,000 ÷ $500 = 2,006 acres/year (1.43% of priority acres)

4. Projected Load reductions from irrigated lands in Malheur County:

This analysis shows that, if historic funding and BMP costs continue, and all priority lands can and need to be treated, it will take 66 years to reduce TP from the Malheur & Owyhee watersheds by 68%.

Assuming all of the loading from irrigated lands comes from priority acres:

68% reduction in 1.43% of the total TP load = 0.97% annual reduction

If historic funding continues, and all such funds are used to implement BMPs to treat Tier 1 lands first, then 19.43% of the total load (40,000 acres ÷ 140,000 acres = 28.57% x .68 = 19.43%) from the Malheur and Owyhee watersheds can be reduced during the first 20 years. It is expected that treatment of Tier 1 lands will result in greater reductions due to their more direct effect on receiving waters and reuse of water discharged from Tier 2 and Tier 3 lands, but the extent of this increased reduction cannot, at this time, be calculated. The reduction in TP discharged from treatment of Tier 2 lands is projected to be 100,000 acres ÷ 140,000 acres = 71.43% x .68 = 48.57 % of total load during the remaining 50 years. It is expected that treatment of Tier 2 lands will result in lower reductions due to their indirect effect on receiving waters and reuse of water discharged on Tier 1 lands, but the extent of this lower reduction cannot, at this time, be calculated.

Assuming continuation of historic funding for BMP implementation to treat all the identified priority acres with $500.00 per acre treatment to yield 68% reduction in the discharge of TP yields, the following load reduction schedule from irrigated lands discharging to the Malheur and Owyhee rivers.

Malheur River

	Tier 1 treatment first 20 years		**Tier 2 treatment next 50 years**				
Current	**10 (201_)**	**20 (202_)**	**30 (203_)**	**40 (204_)**	**50 (205_)**	**60 (206_)**	**70 (207_)**
404 lbs/day	**365(9.7%)**	**326(19.4%)**	**287(29.1%)**	**247(38.8%)**	**210(48.5%)**	**169(58.2%)**	**129(68%)**

Owyhee River

	Tier 1 treatment first 20 years		**Tier 2 treatment next 50 years**				
Current	**10 (201_)**	**20 (202_)**	**30 (203_)**	**40 (204_)**	**50 (205_)**	**60 (206_)**	**70 (207_)**
807 lbs/day	**729(9.7%)**	**650(19.4%)**	**572(29.1%)**	**494(38.8%)**	**416(48.5%)**	**337(58.2%)**	**258(68%)**

<u>Lower Boise River Watershed: Ada & Canyon Counties (250,000 acres)</u>
(data from Lower Boise River TMDL Implementation Plan, Scott Koberg & Keith Griswold, Idaho Soil Conservation Commission)

1. <u>Available Annual Funding</u>:

gross farm gate revenue	$ 67,174,797 Ada County
	<u>$236,364,532</u> Canyon County
Total	$303,539,329

3% Margin = $9,106,180
5% Margin for water quality project investment = $455,309
Historically available federal funds: Cost Share: $ 98,112 ($490,556 last 5 years)
Historically available state funds: <u>$ 28,594</u> ($142,970 last 5 years)
Total annually available funding $582,015

Annual operation & maintenance costs (15%)	- 87,302
	$494,713

2. Priority Lands

The Idaho Soil Conservation Commission is prioritizing lands in the Lower Boise Water watershed for treatment. Of the 250,000 irrigated acres in the watershed, 2~~0~~5% (62,500 acres) have been identified as Tier 1 lands, ~~40~~25% ((62,500 acres) have been identified as Tier 2 lands, and the remaining 50% are Tier 3 lands. The total priority acres for treatment are 1 125,000 acres.

3. BMP Implementation on Priority Lands:

Tier 1 lands: 62,500 acres x $500.00 = $31,250,000 ÷ $494,713 = 63.17 years
Tier 2 lands: 62,500 acres x $500.00 = $31,250,000 ÷ $494,713 = 63.17years

Acres treated per year: $494,713 ÷ $500 = 989.43 acres/year (0.79% of priority acres)

4. Projected Load reductions from irrigated lands in Ada & Canyon Counties:

This analysis shows that, if historic funding and BMP costs continue, and all priority lands can and need to be treated, it will take 181 years to reduce TP from the Lower Boise watershed by 68%.

Assuming all of the loading from irrigated lands comes from priority acres:

68% reduction in 0. 79% of the total TP load = 0.54% annual reduction

If historic funding continues, and all such funds are used to implement BMPs to treat Tier 1 lands first, then 22.66% of the total load (62,500 acres ÷ 125,000 acres = 50% x .68 = 34%) from the Lower Boise watershed can be reduced during the first 63 years. It is expected that treatment of Tier 1 lands will result in greater reductions due to their more direct effect on receiving waters and reuse of water discharged from Tier 2 and Tier 3 lands, but the extent of this increased reduction cannot, at this time, be calculated. The reduction in TP discharged from treatment of Tier 2 lands is projected to be 62,500 acres ÷ 125,000 acres acres = 50% x .68 = 34% of total load during the remaining 63 years. It is expected that treatment of Tier 2 lands will result in lower reductions due to their indirect effect on receiving waters and reuse of water discharged on Tier 1 lands, but the extent of this lower reduction cannot, at this time, be calculated.

Assuming continuation of historic funding for BMP implementation to treat all the identified priority acres with $500.00 per acre treatment to yield 68% reduction in the discharge of TP yields, the following load reduction schedule from irrigated lands discharging to the Boise River.

Tier 1 treatment first 63 years

Current	10 (201_)	20 (202_)	30 (203_)	40 (204_)	50 (205_)	60 (206_)	63 (206_)
1,750 lbs/day	1,656(5.4%)	1,561(10.8%)	1,467 (16.2%)	1,547 (21.6%)	1,278 (27.0%)	1,183(32.4%)	1,155(34.0%)

Tier 2 treatment next 63 years

70 (207_)	80 (208_)	90 (209_)	100 (300_)	110 (301_)	120 (302_)	126(302_)
1,061(39.4%)	966(44.8%)	872 (50.2%)	777 (55.6%)	868 (59.4%)	616(64.8%)	560 (68.0%)

Payette River Watershed: Payette & Gem Counties (89,744 acres)
(data from Ron Brooks, Idaho Soil Conservation Commission, Water Quality Resource Conservationist)

1. Available Annual Funding

gross farm gate revenue	$48,801,000 Payette County	
	$29,606,000 Gem County	
Total	$78,407,000	
3% Margin = $2,352,210		
5% Margin for water quality project investment =	$117,610	
Historically available federal funds & state funds:	$245,000	(1996-2001 average)
Total annually available funding	$362,610	
Annual operation & maintenance costs (15%)	- 54,392	
	$308,218	

2. Priority Lands

There are 52,561 irrigated acres in Payette County and 37,183 irrigated acres in Gem Countyn (89,744 acres). It is estimated that 40% of the irrigated acres in Payette County (21,024 acres) and 25% of the irrigated acres in Gem County (9,296 acres) are Tier 1 lands. The remainder of the irrigated acres in Payette and Gem Counties are Tier 2 lands (59,424 acres). There are therefore a total of 89,744 priority irrigated acres.

3. Projected BMP Implementation on Priority Lands:

Tier 1 lands: 30,320 acres x $500.00 = $15,160,000 ÷ $308,218 = 49.19 years (68% reduction)
Tier 2 lands: 59,424 acres x $500.00 = $29,712,000 ÷ $308,218 = 96.40 years (68% reduction)

Acres treated per year: $308,218 ÷ $500 = 616 acres/year (.69% of priority acres)

4. Projected Load reductions from irrigated lands in Payette & Gem Counties:

This analysis shows that, if historic funding and BMP costs continue, and all priority lands can and need to be treated, it will take 146 years to reduce TP from the Payette watersheds by 68%.

Assuming all of the loading from irrigated lands comes from priority acres:

68% reduction in .69% of the total TP load = .47% annual reduction

If historic funding continues, and all such funds are used to implement BMPs to treat Tier 1 lands first, then 22.66% of the total load (30,320 acres ÷ 89,744 acres = 33.78% x .68 = 22.97%) from the Payette watershed can be reduced during the first 49 years. It is expected that treatment of Tier 1 lands will result in greater reductions due to their more direct effect on receiving waters and reuse of water discharged from Tier 2 and Tier 3 lands, but the extent of this increased reduction cannot, at this time, be calculated. The reduction in TP discharged from treatment of Tier 2 lands is projected to be 59,424 acres ÷ 89,744 acres = 66.22% x .68 = 45.03% of total load during the remaining 101 years. It is expected that treatment of Tier 2 lands will result in lower reductions due to their indirect effect on receiving waters and reuse of water discharged on Tier 1 lands, but the extent of this lower reduction cannot, at this time, be calculated.

Assuming continuation of historic funding for BMP implementation to treat all the identified priority acres with $500.00 per acre treatment to yield 68% reduction in the discharge of TP yields, the following load reduction schedule from irrigated lands discharging to the Payette River.

	Tier 1 treatment first 49 years					Tier 2 treatment to .07 next 16 years	
Current	10(201_)	20(202_)	30(203_)	40(204_)	49(205_)	60(206_)	65(206_)
950 lbs/day	905(4.7%)	861 (9.4%)	816(14.1%)	771(18.8%)	732(23%)	682(28.2%)	660(30.5%)

Tier 2 treatment to 68% reduction next 80 years (pollution trading)							
75(207_)	85(208_)	95(209_)	105(300_)	115(301_)	125(302_)	135(302_)	146(302_)
616(35.2%)	571(39.9%)	526(44.6%)	482(49.3%)	437(54%)	392(58.7%)	348(63.4%)	304(68%)

Assuming continuation of historic funding for BMP implementation to treat all the identified priority acres with $500.00 per acre treatment to yield 68% reduction in the discharge of TP yields, the following load reduction schedule from irrigated lands discharging to the Payette River, the above analysis projects annual BMP implementation and corresponding reductions in TP loading from irrigated lands of .47% from the Payette watershed, .54% from the Boise watershed, and.97% from the Malheur watershed. The projected average annual TP reduction from irrigated lands in these watersheds is .66%. Since these three watersheds represent nearly 600,000 irrigated acres, and there are active, long-standing programs to implement BMPs in these watersheds, this rate of reduction can be used to project a rate of reduction throughout the SR-HC TMDL watersheds. At this rate of reduction, it would take 103 to reach the maximum feasible 68% reduction of TP from irrigated lands in the SR-HC TMDL watersheds.

In order to compress the time frame to attainment of 68% TP reduction from irrigated lands, it will be assumed that federal and state funding levels increase to those currently available for BMP implementation in the Malheur River and Owyhee River watersheds. This will require doubling funding for the other watersheds, from $4.04 per acre (Payette watershed) to $4.66 per acre (Boise watershed) annually for all priority acres to $8.43 per acre (Malheur & Owyhee watersheds) for all priority acres. This means that, for the Payette River and Boise River watersheds alone, federal and state programs and/or pollution trading must increase the annual non-farm investment in BMP implementation from $371,706 to $1,827,500. This increase is significant when annual state BMP funding, for the entire State of Idaho, has been approximately $1,500,000, and has recently been reduced to $1,400,000.

If this additional funding is made available, it is possible to project an annual TP reduction of 1% from irrigated lands in SR-HC TMDL watersheds, assuming all other factors affecting BMP implementation, cost, and performance remain the same. Applying an annual 1% TP reduction rate results in the following interim, ten-year load reduction objectives for the aggregate of irrigated lands in the Owyhee, Boise, Malheur, Payette, Weiser and Snake River below RM409.

Annual 1% NPS Annual TP Reductions

Current	**10 (201_)**	**20 (202_)**	**30 (203_)**	**40 (204_)**	**50 (205_)**	**60 (206_)**	**68 (206_)**
6,452 lbs/day	**5,806(10%)**	**5,162(20%)**	**4,516(30%)**	**3,871(40%)**	**3,226 (50%)**	**2,581(60%)**	**2,065(68%)**

Increased funding can affect the **rate** at which BMP implementation occurs (annually .66% vs. 1.0%) and the overall time it takes to attain 68% reductions from irrigated lands (103 years vs. 68 years). Currently, based on known techniques, technologies, BMP costs, hydrology, crop requirements, and the other factors that affect BMP implementation, it is not possible to project TP reductions from irrigated lands in the aggregate greater than 68%. Watershed-wide nonpoint source reductions greater than 68% will require a currently unforeseeable change in the factors affecting BMP implementation.

This reduction rate together with projected reductions in point source loads and IPCo participation in TP reduction through pollution trading is used to determine interim, ten-year targets and load allocations included in Section 3 of this TMDL.

Issues For Periodic Review

Information, experience and changes regarding the previously discussed factors affecting BMP implementation will affect interim objectives, targets and load allocations established by this TMDL. Evaluating and incorporating such new information into the TMDL will occur through periodic five-year review of the implementation factors and the interim objectives by the SR-HC PAT and the DEQs.

Pollutant Trading

One invaluable tool to meet water quality goals in an efficient manner is pollutant trading. Pollutant trading is a market-based, business-like way to help solve water quality problems by focusing on cost- effective, watershed level solutions to problems caused by discharges of pollution. Pollutant trading is most practical when pollution sources face substantially different pollution reduction costs. Typically, a party facing relatively high pollution reduction costs compensates another party to achieve an equivalent, though less costly, pollutant reduction. This compensation, in many cases, may actually provide the other party with enough funds to meet or exceed their own load allocation under a TMDL in addition to the trade. The result is overall lowered pollution discharges with the most cost-effective pollution reductions attainable.

An important aspect of pollutant trading is that it is voluntary. Parties trade only if both are better off as a result of the trade. Pollutant trading does not create any new regulatory obligations because trading systems are designed to fit within existing regulatory frameworks.

Trading allows pollutant sources to decide how to best reduce discharges. A successful pollutant trading program will create flexibility that allows common sense selection of pollutant reduction methods based on financial merit while ensuring water quality goals are met.

Currently, a policy framework is available for pollutant trading. A demonstration project was initiated in November 1997 in the Lower Boise River watershed. The Idaho DEQ, in cooperation with the U.S. Environmental Protection Agency (EPA), and interested stakeholders representing municipalities, industry, agriculture, and environmental interests have developed a proposed trading system for the Lower Boise watershed. The first phase of this process focused on developing an administrative framework for the dynamic trading of pollutant loading to the river system, and identified the following important conclusions:

- Trading could offer municipalities flexible, cost-effective options for managing increased flows and loads associated with growth and provide nonpoint sources with the financial resources to help them achieve reductions needed to meet TMDL goals.

- **Costs for nutrient reductions range widely among sources, providing the financial basis (or conditions) to produce economic benefits. Incremental costs for phosphorus reductions at wastewater treatment plants range from $5 to more than $200/lb, whereas agricultural management practices hold the potential to reduce phosphorus loads for $5 to $50/lb.**

- Stakeholders favor an approach in which regulatory agencies set the critical parameters for trading (e.g., tradable pollutants, and pollutant reductions required to meet water quality standards), while the day-to-day trade administration is handled by a nonprofit association of stakeholders, rather than by a government agency.

The second phase focused on development of two model trades and detailed development of the TMDL, permit, trade tracking, and nonpoint source credit mechanisms necessary to support dynamic trading that results in environmentally equivalent outcomes. Key features of the proposed trading system include

- Trades that follow permit requirements and the adoption of trading rules that do not require up-front agency review or approval;

- Wasteload allocations and pollutant limits that are adjusted in the NPDES process by the creation and registration of valid credits in a trade tracking database;
- A BMP list that specifies how to create and quantify either measured or calculated nonpoint source credits, including monitoring and maintenance requirements; and
- **Ratios calculated from watershed data and applied to the trade transaction that ensure environmentally equivalent reductions.**

The Lower Boise framework should be modified for the SR-HC TMDL process. This could be accomplished within the first five-year phase of the implementation of the SR-HC TMDL. Pollutant trades that could occur under a SR-HC TMDL trading program, either in the SR-HC watershed or on any of the tributaries to the SR-HC watershed, include:

- Point Source-to-Point Source trades (e.g. - between municipalities or other NPDES permitted sources);
- Point Source-to-Nonpoint Source trades (e.g. - between a municipality or other permitted source and a nonpoint source such as a watershed-based application of BMP's to agricultural lands);
- Nonpoint Source-to-Nonpoint Source trades (e.g. - between a watershed-based agricultural BMP implementation project and the Idaho Power Company, purchasing pollutant trading credits under their load allocation for Brownlee Reservoir).

Modification and adoption of a framework specific to the SR-HC TMDL process would provide the administrative process under which dynamic pollutant trading could occur in the watershed and its tributaries, ensuring that the most cost-effective pollution controls are used in the TMDL implementation process. The SR-HC TMDL Watershed Advisory Group (WAG) would be the most logical committee to oversee and lead this effort, preferably within the first five-year phase of TMDL implementation. The U.S. EPA, IDEQ and ODEQ will actively support the ultimate adoption of a trading framework to allow both point and nonpoint sources to participate in pollutant trading within the SR-HC TMDL watershed.

Monitoring Plan

A monitoring plan will be developed and implemented within __ months after EPA approval of this TMDL to measure SR-HC water quality conditions, track progress in attaining TMDL objectives, and fill data gaps (see _____). The plan will be developed in consultation with the PAT. Funding and implementing the monitoring plan will the responsibility of the DEQs. The DEQs anticipate participation by EPA, the USGS, and other participating federal and state agencies. The monitoring will include instream monitoring of the SR-HC reach and all tributaries, point sources, and nonpoint source discharges to which loads are allocated by this TMDL.

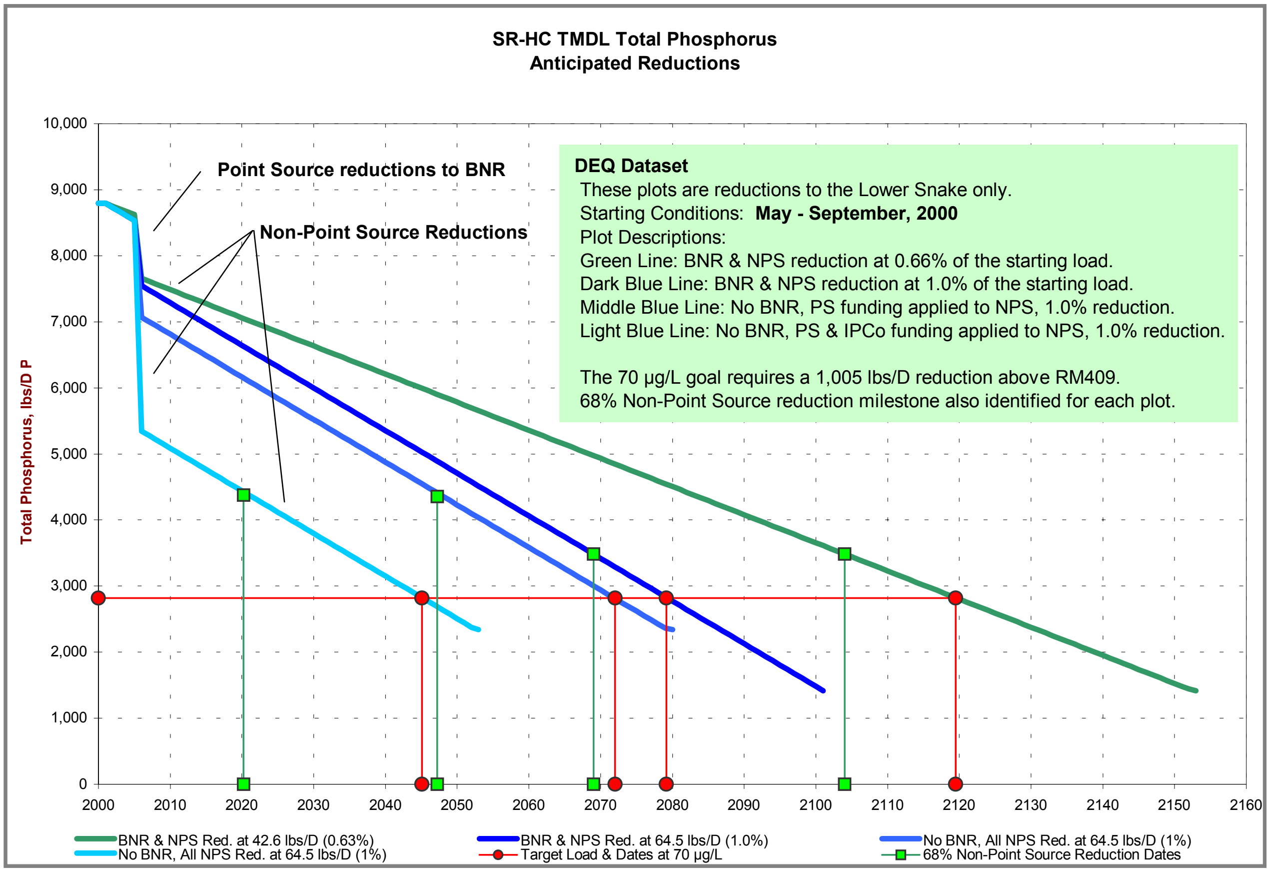
Periodic Review

Every 5 years the progress, costs and benefits of implementing feasible control strategies, and the technical assumptions in the TMDL will be evaluated to determine the future course of the

SR-HC TMDL, including necessary modifications, and the extent to which all feasible steps have been taken towards achieving the highest quality water attainable.

Interim Targets and Load Allocations

This TMDL establishes long-term, water-quality based targets and load allocations, and attainable interim targets and load allocations. Figure ___ illustrates four potential TP load reduction scenarios: (1) the green line illustrates TP reductions resulting from 0.66% annual reduction of aggregate nonpoint source loads based on historically available funding, current BMP costs, and treatment of currently identified priority acres, and point source load reductions resulting from BNR; (2) the dark blue line illustrates TP reductions resulting from 1.0% annual reductions in aggregate nonpoint source loads assuming increased funding to $8.50 per priority acre in all watersheds and point source load reductions resulting from BNR treatment; (3) the middle blue line illustrates TP reductions resulting from 1.0% annual nonpoint source load reduction, and point source funding of more cost-effective nonpoint source BMP implementation rather than point source of less cost-effective BNR, and (4) the light blue line illustrates TP reductions resulting from the third scenario plus additional TP reductions resulting from IPCo funding on nonpoint source BMP implementation through pollution trading.



Interim TP targets and load reductions for this TMDL will be based on the increased funding scenario represented by the dark blue line in the above figure. No tributary, point source or nonpoint source is allocated a load that represents a concentration below .07 mg/l. Once a tributary or discharge achieves .07 mg/l, further reductions in the tributary's discharge concentration may occur through pollution trading to enable other tributaries or sources to achieve load allocations, or through other funding mechanisms. Alternatively, funding efforts may be redirected to other tributaries and sources to increase the rate of reduction in other SR-HC reach watersheds.

For example, in the following table, the Payette River is projected to attain .07 mg/l within the overall TMDL schedule of interim targets and allocations in 2028. This TMDL does not call for reductions in TP concentrations in the Payette River discharge to the Snake River below .07 mg/l. Further reductions in Payette River discharge concentrations are, however, feasible. Additional reductions may be attained through pollution trading, or other funding mechanisms. Alternatively, annual funding committed to the Payette watershed prior to attaining .07 mg/l could be redirected to other watersheds after the Payette River discharge attains .07 mg/l (to the extent such funding is not necessary to maintain that concentration in the Payette River discharge).

Snake River TP Target Concentrations (µg/L) at Weiser &
Influent TP Target Concentrations
DEQ 2000 Data Set - Growing Season (May through September)

	S.R. at Weiser (1.0% NPS BNR PS)	S.R. at RM 409	Owyhee River	Boise River	Malheur River	Payette River	Weiser River	Discharges To S.R. below RM 409
2001	151	92	237	300	499	88	162	402
2005	**(BNR PS)**			**(BNR PS)**				**(BNR PS)**
2011	130	92	216	241a	452	82	148	279b
2021	119	86	194	214	404	75	134	241
2028 Payette						***70***		
2031	109	81	173	186	356		120	203
2041	99	75	151	158	308		106	165
2051 S.R.	91	***70***	130	130	261		92	127
2061	84		108	103	213		78	89
2065 S.R.								***70***
2067 Weiser							***70***	
2069	78		93	83	180			
	(68% NPS)		**(68% NPS)**	**(68% NPS)**	**(68% NPS)**			
207_ Boise				***70***				
2078 Owyhee			***70***					
2079	***70***				***70***			
Point Source reduction as percent of total				**11.0%**				**22.3%**

a = 21% reduction in first 10 year increment.

b = 32.3% reduction in first 10 year increment.

c = 7% reduction in final increment.

Non-Point sources reduced annually at 1.0% of starting load.

Note: Design load to be reached in first 10 year increment.

Assumes 25% reduction of the 1,005 lb/D upstream load (at RM409) in each of the 2nd through 5th 10 year increments.

Snake River at RM409 reductions = 23.8% 6.0% **5.47 µg/L / year**

This table also projects an estimated timeframe for nonpoint sources in the SR-HC TMDL watersheds to attain 68% reductions in TP loading. Based on known techniques, technologies, BMP costs, hydrology, crop requirements, and the other factors that affect BMP implementation, watershed-wide nonpoint source reductions greater than 68% will require a currently unforeseeable change in the factors affecting BMP implementation.

No tributary, point source, or nonpoint source will be required to reduce the concentration of total phosphorus in its discharge below .07 mg/l. If there is no increase in available funding for BMP implementation, particularly nonpoint source implementation, it is unlikely that these targets and load allocations will be met. **Additional federal and state funding, particularly in the State of Idaho, will be required to meet these interim and long-term objectives**. Point source and/or nonpoint source reductions necessary to reduce instream Snake River TP concentrations below .078 mg/l, the level projected to be attainable through implementation of BNR for point sources 68% reductions from nonpoint sources,

TP reductions and interim targets projected through this analysis will be reevaluated and refined through the periodic review process described in this TMDL.
It is anticipated that pollution trading will result in distribution of funds to more cost-efficient control strategies, and that this may enhance the potential to attain these targets. These and other issues will be critical in determining whether all feasible steps are being taken towards achieving the highest quality water attainable.

IPCo is responsible for increasing dissolved oxygen concentrations in the portions Brownlee Reservoir not meeting the 6.5 mg/l target, except the hypolimnion. IPCo may satisfy this TMDL requirement through in-reservoir aeration and/or by achieving a __ lbs/day reduction TP loading to Brownlee Reservoir through pollution trading with point and nonpoint source dischargers. For purposes of this TMDL, a load of __ lbs/day has been derived to represent the effects of impoundment on dissolved oxygen concentrations in Brownlee Reservoir.

Table 3.2.8 in the Nutrient Loading Analysis Section of the TMDL at page 286, shows generally the reduction in dissolved oxygen in Brownlee Reservoir resulting from the impoundment of water. Without the dam, the Snake River would be a riverine system in the areas now characterized as transition zone (RM 325 to 308) and lacustrine zone (RM 308 to RM 285), and in the lacustrine zone the river would not be stratified into the epilimnion, metalimnion, and hyoplimnion. Average dissolved oxygen concentrations throughout the reach would be those found in the riverine zone. The effect of impoundment on dissolved oxygen concentrations is represented by the difference between concentrations in the riverine section and concentrations in the transition zone, and each strata of the lacustrine zone. In July, for example, dissolved oxygen concentrations in the transition zone and the epilimnion are 31% less, and concentrations in the metalimnion are 56% less, than dissolved oxygen concentrations in the riverine zone. In August, the differences are 45%, 43%, and 76% respectively for the transition, epilimnion and metalimnion zones.

These targets and load allocations, and the progress in attaining them, will be reviewed every five years and adjusted as necessary to conform to information, understanding and experience developed as data is collected, additional analysis is performed, and as implementation proceeds.

DRAFT Phosphorus Allocation Approach Report
To the Snake River Hells Canyon TMDL Public Advisory Team
November 2001

Abstract

The task of development of a nutrient allocation approach was assigned to a workgroup in July 2001. The PAT requested that the workgroup look at three allocation methods; equal concentration, equal percent reduction and least cost. The workgroup met three times during August to consider the options and presented a conceptual approach to the PAT in September 2001. EPA, stakeholders and states have an interest in states choosing economical TMDL allocation strategies. The states of Wisconsin, Minnesota, Vermont, and Montana have adopted economical nutrient control approaches for NPDES permitting and in TMDLs. The approach proposed to the PAT is identical to the successful state nutrient control approaches and includes the following key elements:

1. Adopt target and sufficient timeframe to achieve the target (40-70 years);
2. Establish Interim Goals and Basinwide Monitoring program to track progress and inform future decisions;
3. Point Source Allocations: Mechanical plants at Biological Nutrient Removal (BNR) or equivalent level for first 20 years; Lagoons exempt, if lagoons are upgraded to mechanical facilities, then BNR is required. Collect data to inform future decisions;
4. Nonpoint Source Allocations: Nonpoint sources implement Best Management Practices (BMPs) to meet interim and final tributary and Snake River goals. Collect data to monitor progress in meeting interim goals, assess data in 5 year increments. Data collected in first 20 years used to confirm or modify interim target setting process for next 20 year increment; and,
5. Five Year Data/Progress Review: Review monitoring data, implementation of BMPs, water quality improvements, and interim goals every 5 years.

Background

Purpose

During the August 9, 2001 Snake River Hells Canyon TMDL Public Advisory Team (PAT) Meeting, a workgroup was tasked with development of a phosphorus allocation recommendation to the PAT at the September 13, 2001 meeting. The workgroup met on August 17 and 25, and September 5, 2001 and discussed how to evaluate, review, and report a recommendation concerning allocations to the PAT. A verbal description to the proposed approach was presented to the PAT at the September and October meetings. A more detailed presentation was made to the PAT at the November meeting, including an approach for allocations to the tributaries. Additional text and description of the details of the proposal was requested at the November 2001 meeting. This document is written to provide the requested detail and background for the nutrient allocation approach for the Snake River and the tributaries.

TMDL Background

Assessment of the pollutants requiring a TMDL are included in the Draft Sub-Basin Assessment (SBA) for the Snake River-Hells Canyon TMDL (IDEQ/ODEQ, 2001). The SBA identifies pollutants that TMDLs will be developed for include:

Pesticides, Mercury, Temperature, Sediment and Nutrients (total Phosphorus). Additionally, IDEQ/ODEQ included Total Dissolved Gas as an additional pollutant that will receive an allocation at the May 2001 PAT meeting. This document will address an allocation approach only for total phosphorus.

Geographic Scope

The SR-HC TMDL effort will address the point and nonpoint sources within the 2,500 square miles that discharge or drain directly to the Snake River. The five major tributaries will receive "gross allocations" at the mouths of the tributaries. We anticipate that the major tributaries will be addressed on existing TMDL time schedules (5 years) or with development of implementation plans for allocations contained in the approved total phosphorus TMDL (e.g. 18 months for Boise and Payette rivers).

EPA and State Guidance TMDL development and allocations

EPA has provided guidance to states concerning TMDL development requirements, including allocation methods and considerations (EPA, 1991, 1998, 1999, 2000, 2001). Oregon and Idaho DEQ have developed TMDL development guidance that consider allocation issues (ODEQ, 2001; IDEQ, 1999).

EPA (1991, 1999) and others (Chadderton, et. al., 1981) have identified at least 20 different allocation methods, they include, but are not limited to:

- Equal percent removal;
- Equal effluent concentration;
- Equal total mass discharge per day/month/year;
- Equal reduction in raw load;
- Equal ambient mean annual quality (mg/l);
- Equal cost per mass of pollutant removed;
- percent removal proportional to raw load per day/month/ year;
- most significant contributors achieve higher removal rates;
- seasonal limits based on cost effectiveness;
- least cost.

Many of the 20 plus allocation methods were developed in response the December 28, 1978 Federal Register that provided regulations to implement section 303(d) of the Clean Water Act. At that time, the thinking was primarily point source control related, so many of the approaches do not lend themselves well to point and nonpoint source consideration in TMDLs. Therefore the allocation methods we are examining for use in the Snake River Hells Canyon TMDL will be a significantly smaller list that are applicable to both types of sources.

Allocation Considerations

Allocating pollutant loads is a required element of a TMDL. The purpose of the allocation process is to create technically feasible and fair division of the allowable loads among sources (EPA, 1999).

A waterbody's assimilative capacity can be allocated among sources in numerous ways (EPA, 1991, 1999). EPA and state guidance identify a number of factors, including technical feasibility, cost effectiveness, relative contributions, equity, and the likelihood of success, to develop the most effective allocation strategy (EPA, 1991, 1999, 2001; ODEQ 2001). Additionally, there are a number of technical considerations that allocations must or should consider, including but not limited to seasonality, margin of safety, future growth, time to meet standards, and innovative approaches (e.g. trading).

Cost can and should be an important consideration in the development of a TMDL (EPA, 2001; ODEQ 2001). EPA's recent draft Report to Congress on the National Costs of the TMDL program estimates implementation costs at $1 to $3.2 Billion annually. These costs are based on the assumption that states will use "... cost-effective reductions among all sources of the impairments, including trading between point and nonpoint sources.". EPA notes that "costs may be higher or lower depending on the extent to which States choose to allocate more of the reductions to sources with lower control costs versus allocating equal percentage reductions to sources regardless of costs". EPA estimates that costs could double if cost effective approaches in allocating TMDL responsibility are not used.

On November 15, 2001, EPA Assistant Administrator for Water G. Tracy Mehan III testified before the House Water Resources and Environment Subcommittee concerning TMDLs. Assistant Administrator Mehan wants a Total Maximum Daily Load (TMDL) final rule that does not "bankrupt" state programs but encourages implementation by "utilizing market-based approaches that provide economic incentives for early reductions (of pollutants) and minimize the cost of implementation." Assistant Administrator Mehan said a plan to implement a revised Final TMDL rule in 2003 was "ambitious" but committed his agency will work hard to prepare a rule that is "workable, effective, and acceptable." One of the key areas in which the House subcommittee focused on was the affect the TMDL rule would have on agriculture interests. Assistant Administrator Mehan expressed interest in a rule that would provide financial incentives to farmers to protect water quality and stated "the bottom line is that the rule must be cost-effective" When asked what cost-effective measures EPA was considering, Assistant Administrator Mehan referred to incorporating "market-based programs" including trading to maximize environmental and economic benefits.

For this evaluation, three allocation principles were used, they are:

1. Protect designated uses (e.g. meet TMDL goal);
2. Fairness/equity (e.g. reductions proportional to contributions); and;
3. Cost effectiveness.

Additionally, the allocation methods will need to incorporate consideration for seasonality, margin of safety, future growth, and time to meet standards.

Proposed Allocation Options

The Clean Water Act requires that for waters exceeding state water quality standards, that a TMDL be developed that will bring the water back into compliance with the standard. The TMDL is the sum of the point source and nonpoint source loads with margin of safety that will allow the waterbody to meet standards. The allocation process determines the allowable point and nonpoint load and margin of safety given the target or water quality standard.

The PAT explored three allocation methods during the August 9, 2001 meeting, equal percent removal, equal concentration, and least cost. We will focus on these three options and identify how other states address nutrient control for phosphorus in general and in TMDLs.

The three PAT recommended allocations have been described and studied by Chadderton and others (1981). These three options are identified by Chadderton as being appropriate for numerical applications. Equity and fairness are recognized characteristics of each of these options, however different definitions of “equity” are imbedded in the various approaches.

Equal % Removal of Raw Load

This approach requires equal percent removal or treatment for pollutants by all sources.

Advantages:
Simple to apply and fair.

Disadvantages:
Forces small/dilute dischargers to more expensive/higher levels of treatment and can result in overly restrictive allocations to small dischargers

Equal Concentration

This approach requires that all sources discharge an equal concentration.

Advantages:
Simple and fair if applied to point source only.

Disadvantages:
- For point sources only, it is fair in requiring the same level of treatment or effluent quality, however when applied to a mix of point and nonpoint sources,

this method creates additional and expensive treatment responsibilities for small volume, high concentration sources. Additionally, it is very hard to measure nonpoint source discharges to determine compliance.
- Forces small sources to higher level and more expensive treatment than necessary.
- In mixed point/nonpoint situations, shifts more of the reduction load to small volume, high concentration dischargers, resulting in very expensive point source controls that may have little or no impact on attaining TMDL goals.

Least Cost Basinwide

Least cost solution based on minimum treatment requirements of technology-based control.

Advantages:

Economically efficient

Disadvantages:
- Forces largest sources to treat to higher levels.
- Fairness and ability to pay become issues of concern.
- Complexity

Nutrient Background

In the United States, nutrients (nitrogen and phosphorus) have been a significant pollutant of concern since the late 1960's. Phosphorus has generally been identified as the limiting nutrient in freshwater systems. Historical information on phosphorus loadings to the surface waters of the US and their effect on water quality are summarized by Litke (1999) in a USGS report.

Key findings of the report include:

- Phosphorus inputs to the environment have increased since 1950 as the use of phosphate fertilizer, manure, and phosphate laundry detergent increased;

- The manufacture of phosphate detergent for household laundry was ended voluntarily in about 1994 after many States had established phosphate detergent bans;

- Total phosphorus concentrations in municipal wastewater effluent contained about 3 mg/l TP in the 1940's, increased to about 11 milligrams per liter at the height of phosphate detergent use (1970), and have declined to about 5 milligrams per liter; and,

- The downward trends in phosphorus concentrations since 1970 have been identified in many streams, but median total phosphorus concentrations still exceed the EPA Goldbook recommended TP threshold of 0.1 mg/l across much of the Nation.

A number of states have addressed regional or statewide nutrient controls. Since 1970, 27 states have adopted complete or partial phosphorus bans (Litke, 1999). Additional measures to control nutrients have been developed or are being reviewed by states. Based on a focused review of state nutrient control programs (Wisconsin and Minnesota), the Wisconsin approach will serve as the type example of state phosphorus control programs for point sources. Additionally, the state of Vermont has applied two rounds of TMDL driven nutrient controls for discharges to Lake Champlain, and the state of Montana has applied a similar approach in the Clark Fork River Phosphorus TMDL. These efforts will be summarized as an example of recent TMDL related approaches to nutrient control and cost allocation methods.

Summary of Selected State Nutrient Control Practices (Wi/Mn and Vt/Mt TMDL)

Wisconsin Approach

Since the mid-1970's, the Wisconsin Department of Natural Resources (WDNR) has required total phosphorus (TP) discharges of 1 mg/l for all municipal wastewater treatment facilities for cities with populations greater than 2,500 discharging to the Great Lakes basin. Wisconsin and the other Great Lakes states also we early adopters of phosphorus detergent bans.

WDNR adopted new regulations in 1992 (Ch. NR. 217, Wis. Admin. Code) that expanded the 1 mg/l phosphorus to all municipal and industrial discharges above de minimus levels statewide. The 1992 regulation requires all municipal discharges above 150 lb/month TP and industrial discharges above 60 lb/month TP to meet a 1 mg/l effluent limit. The rule provides for four alternative limits where it is not practical to achieve 1 mg/l due to technical, feasibility, energy, economic, or environmental reasons (WDNR, 1999). The alternative limits were included in NR 217 to encourage the use of biological nutrient removal techniques that have been available since about 1990. WDNR estimates that the rule will apply to approximately 35-40% of the municipal and industrial permittees discharging to surface waters of the state.

The state of Minnesota has a nearly identical approach to phosphorus control as Wisconsin’s. It is described in the MPCA Phosphorus Strategy (2000). Both states and Vermont and Montana have used this approach in TMDLs. The point source controls are fixed by technology and nonpoint sources are allocated the remaining load reductions necessary to meet the TMDL goal. A recent example from Vermont is shown below. Additionally, the Clark Fork Voluntary Nutrient Reduction Plan, approved by EPA as a TMDL, uses this approach also.

Lake Champlain TMDL: Vermont Approach

The Vermont Department of Environmental Conservation (VDEC) issued the June 22, 2001 draft Lake Champlain TMDL for public review and comment (VDEC, 2001). In 1987, DEC adopted a rule that addresses the wasteload allocation process (Administrative Rule 87-46). The rule requires that at least three allocation alternatives be prepared and considered.

VDEC believes that choosing the balance between point and nonpoint source allocations of the TMDL is an important public policy decision. The level of phosphorus removal required from the wastewater treatment facilities (WWTF) directly affects the cost, level of effort, and geographic scope of the nonpoint control efforts for agriculture and land development. In order to support the public decision process, VDEC identified a range of alternative point source allocations and limited the scope of the potentially regulated point sources.

VDEC proposed not to allocate load reductions to de minimus point source (e.g. well overflow, non-contact cooling waters). VDEC also proposed no allocations for urban stormwater discharges and combined sewer overflows because the discharges are intermittent, highly variable, technically difficult to measure and control, and represent a small proportion of the total load.

VDEC developed five alternative point source allocations. The allocations were based on permitted or design flows, which include population growth and future wastewater needs. The alternatives and cost are shown:

Table 1: Lake Champlain Allocation Options and Costs.

Option	Capital ($million)	O&M ($ million)	20 year cost / ton TP reduced annually ($million)
1. Current Loads (1991 TMDL)	30.4	---	---
2. No lagoon exemptions	0.344	0.185	0.374
3. Large Facility 0.6 mg/l	42.5	0.833	1.724
4. Uniform 0.8 mg/l	1.693	0.273	1.278
5. Selected Facility 0.6 mg/l	5.3	-0.40	-0.285

Capital and O&M costs over a 20 year period were calculated for each alternative. Results of the analysis showed capital costs ranged from 0 to $42 million, annual O&M ranged from -$400,000 to 0.88 million per year, and cost per ton TP removed ranged from -0.285 to 1.72 million.

Nonpoint source loads allocations ranged from 23 to 35 % reduction in TP for the five alternative allocations. VDEC analysis concludes that the choice of point source allocation has little effect of the nonpoint source reductions required in many sub-watersheds but that advanced treatment “significantly eases” the nonpoint source burden in some sub-watersheds.

Cost analysis developed by VDEC provides critical information to assist in the selection of allocation approach and options to the state, stakeholders and public. Similar information should be a part of the allocation discussion and process for each pollutant in the Snake River Hells Canyon TMDL.

Proposed Total Phosphorus Allocation Method

The workgroup reported a general approach to the PAT in the September meeting. The proposed approach is a least cost basin wide control based on the successful nutrient control approaches applied in the Wisconsin and Minnesota NPDES and TMDL programs and the Vermont (Lake Champlain) and Montana (Clark Fork River) TMDLs. The key components of the proposed approach presented to the PAT included:

1. TMDL Goal and Time to achieve the Target
Adopt TMDL goal recognizing that 50-70 years will be necessary to meet goal. The current DEQ proposed target is 70 ug/l for the Snake River reach above Brownlee Reservoir.

2. Interim goals and Monitoring
Establish interim goals for Snake River and Tributaries (e.g. 10 ug/l decrease in Snake River at Weiser concentration every 10 years) until TMDL goal is reached. Establish similar interim goals for tributaries.

Develop basinwide monitoring program to track progress and inform future discussion on additional reductions needed to meet goal or satisfy designated uses (if we support uses, then we have met the requirements of the TMDL).

3. Point Source Allocations:
Mechanical plants at BNR or equivalent for first 20 years;
Lagoons exempt, if lagoons are upgraded to mechanical facilities, then BNR is required. Monitor and assess data for 20 years. Twenty to forty year point source approach based on analysis of data collected during first 20 year period.

4. Nonpoint Source Allocations:
Nonpoint sources implement Best Management Practices (BMPs) to meet interim and final tributary and Snake River goals. Data are collected and progress to meet interim goals is reviewed, possibly in 5 year increments. Data collected in first 20 years used to confirm or modify interim target setting process for next 20 year increment.

5. Five Year Data and Progress Review
Review data, implementation of BMPs, water quality improvements, and assess attainment of interim goals every 5 years.

The November PAT meeting included a more detailed description of proposal including estimates of the proposed reductions for point and nonpoint sources in the Snake River (RM 409 to Weiser) and the corresponding tributary reductions to meet these targets.

Targets, Loads and Sources, and Reductions Necessary to Meet TMDL Target

Targets

EPA published guidance to the states concerning development of nutrient criteria on January 9, 2001. States are expected to develop and adopt nutrient criteria or translators by the end of 2004. EPA issued additional guidance to states concerning Nutrient Criteria development on November 14, 2001 that provided additional flexibility to states in the development of their nutrient criteria (EPA, 2001c). USGS reviewed the EPA Nutrient Criteria guidance and has developed an alternative approach for determination of regional nutrient criteria USGS, 2001). Significant uncertainty concerning development of nutrient criteria or translators exists in the scientific and regulatory communities. Neither the states of Oregon or Idaho have developed procedures for development of nutrient criteria. We anticipate both states and EPA will work to develop nutrient criteria methods and apply those methods to waters of the states over the next few years.

The SBA (IDEQ/ODEQ, 2001) included a proposed total phosphorus target of 100 ug/l. Subsequent analysis has resulted in the DEQs proposing a target of 70 ug/l. Critical conditions associated with the numeric target are proposed as median flow conditions (14 MAF, DEQ, 2001) into Brownlee Reservoir. Seasonality has been considered and the DEQs are proposing a May through September target. This analysis will use the 70 and 100 ug/l targets and flows for two datasets, DEQ May through September DEQ (11/15/01) and Boise City May through September data for 2000 to identify the range or targets and reductions under consideration.

Regardless of the target or baseline conditions chosen, the proposed allocation approach would be identical in concept, with technology based point source allocations and nonpoint source allocations to meet the remaining reduction necessary to meet the target.

Sources and Loads

The sources of TP can be divided into three general categories, background, point and nonpoint sources. Estimates of the load of each of these three sources has been done based on data annual and seasonal information contained provided in various DEQ and Boise City datasets provided to the PAT or Allocation workgroup.

Results of these analyses are shown in Table 2 (below).

Table 2: Estimated Percent Background, Point and Nonpoint Source Loads for Snake River and Tributaries Above Brownlee Reservoir during a Median Flow

	DEQ 11/15/2001	Boise City 2000
	May - Sept	May - Sept
Point Source	17	23
Nonpoint Source	73	67
Background	10	10

Nonpoint sources comprise approximately 70% of the seasonal load (67 to 73% seasonal), with point source and background loads comprising smaller portions of the remains load (17-23% for point source and 10% for background). Background was estimated based on estimated concentrations of 22 ug/l (EPA, 2000b) and IDEQ assumptions (11/15/2001 spreadsheets).

Point Source data for the Snake River were obtained from IDEQ and point source data for the Weiser, Payette, and Boise were compiled or estimated by Boise City. Point source data reflect delivered loads to the Snake River at Weiser, which are lower than actual discharge because of substantial agricultural reuse in the tributaries where point source discharges occur (e.g. Boise, Payette, and Wieser).

Nonpoint loads were calculated by difference. If background is higher then nonpoint source loads would be proportionally smaller.

Point Sources

Point source basinwide discharges account for about 20% of the added TP load to the Snake River between RM 409 and Brownlee reservoir. Point sources discharging directly to the Snake account for only 5% of the mainstem Snake River TP load. Point sources within the SR-HC TMDL area include two industrial and four municipal sources. In addition, twenty municipal point sources discharge to tributaries of the Snake River in the TMDL reach (e.g. Boise, Weiser, and Payette rivers).

Total current discharge for all 26 WWTFs is 68 mgd, design capacity is 89 mgd. Estimated WWTF TP discharge during the May - September 2000 period was 1,928 lb/d TP, however due to agricultural reuse within the tributaries, the delivered TP to the Snake River at Weiser was only 1,456 lb/d TP.

Estimated delivered TP to the Snake River at Weiser at design capacity with application of biological Nutrient Removal (BNR) is estimated at 535 lb/d or a 63% reduction over current delivered loads.

Technology based control of TP using biological nutrient removal (BNR) have been found to be cost effective methods to control TP by a number of states (WDNR, 1992; MCPA, 2000). Costs for construction and retrofit for BNR and two additional levels of treatment are contained in Table 3. These costs were developed for medium size 10-30 mgd facilities and costs for smaller facilities are higher. These costs were presented to the Colorado Water Quality Commission in June 2000.

Actual costs for retrofits of WWTFs vary substantially due to site specific conditions. Caldwell recently upgraded their treatment to BNR at a capital cost of $1.88/gallon, about 10 times the cost provided in the literature. We anticipate that actual costs for conversion of existing WWTFs to BNR based on the costs shown below actually underestimates, potentially substantially, anticipated actual costs**.**

Table 3: Estimated Phosphorus Treatment Costs for Point Sources

Effluent Phosphorus Concentration	Treatment Technology	Type of WWTP	Capital cost, $/gpd	O&M cost, $/yr per gpd
1 mg/L	BNR	New construction	4-6	0.4
		Retrofit existing WWTP	0.1-0.2	0.005
0.5 mg/l	BNR and Filtration	Activated Sludge	0.5	0.05
0.1 mg/l	BNR and filtration and chemical precipitation		0.85	0.085

Costs for six point source control options (BNR; BNR+filter; BNR+filter+chemical precip for mechanical only and all WWTFs) have been developed and are included in Appendix 1, Tables 4-7. The approach is similar to the Vermont approach used in the June 22, 2001 public discussion draft Lake Champlain TMDL . Average point source control cost for TP range from $>5 to $2-600 per lb/d. Costs and controls were calculated based on delivered load to the Snake River/Brownlee and included consideration of fate and transport associated with irrigation reuse**.**

Nonpoint Sources

Nonpoint source loads comprise significant seasonal and annual loads (68 to 77%) to the Snake River or tributaries to the Snake. Loads increase in the summer and decrease in the winter. Loads consist of dissolved and sediment attached TP.

Cost data and control effectiveness for nonpoint source TP are scarce and highly variable. Data for nonpoint source control costs were collected as part of the lower Boise River Trading Demonstration Project by Ross and Associates (Ross and Associates, 1998). Rock Creek data were used because they represent average watershed scale TP control costs using targeted BMPs. Observed TP removal was 68% or 20.8 tons per year during the irrigation season for a watershed of nearly 200,000 acres that contained about 45,000 acres of irrigated agriculture, pasture, CAFO/dairies, and rangeland. Two additional findings of the Rock Creek final report were that while TP concentrations were significantly reduced they still exceeded the 100 ug/l recommended threshold and the although significant improvements in Rock Creek designated uses occurred, designated uses remained impaired at the completion of the ten year project. Average cost data for removal of TP based on the Rock Creek Project was calculated to be $11.48/lb/d and inflated 20 % to account for inflation through 1998 to $13.78/lb/d for estimation of likely agricultural control costs associated with the Lower Boise Trading Framework evaluation and development.

Other TP control successes have been demonstrated in the Mid-Snake River area. Northside Canal Company and Twin Falls Canal Company have substantial experience and success in controlling TP from irrigated agricultural sources included in the Mid-Snake River TMDL. Northside provides pressurized sprinkler irrigation to about 90% of its service area and provides detention basin and wetlands for treatment. Twin Falls Canal Company patrons utilize furrow irrigation on about 80% of its service area and provides detention basins and wetlands to control TP. Both companies are meeting their TMDL objectives identified in the Mid-Snake TMDL. Treated irrigation water from Northside generally contains less than 100 ug/l TP (e.g. 20-80 ug/l) when discharged to the Snake River. Twin Fall Canal Company generally has higher TP concentrations in treated drain water (e.g. 100 to 140 ug/l). The higher concentrations are believed to be associated with furrow irrigation methods.

The lessons from the Rock Creek, Northside and Twin Falls Canal Companies suggest that, for the purposes of this evaluation, we should use:

- minimum watershed based TP removal cost of $14/lb/d;
- maximum TP no greater than 68% for furrow irrigated land;
- furrow irrigated TP post treatment concentrations of >100 ug/l; and,
- sprinkler irrigated TP post treatment concentrations of < 100 ug/l.

Allocation Options and Estimated Costs

Allocations, % reductions, and costs necessary to meet the seasonal TMDL target of 70 and 100 ug/l using the equal % reduction, equal concentration, and the proposed technology based allocation approach are summarized in Appendix A, Tables 4-11.

A summary of the cost information is shown below in Table 12. Cost determination approach, methods, and assumptions include:

- Costs were estimated based on point (Table 3) and nonpoint costs ($14/lb/d TP);
- Nonpoint source reductions necessary to meet the target were determined by difference after accounting for background and remaining point source loads.
- Equal concentration assumes all WWTF discharges are 70 ug/l. We used the 100 ug/l cost estimate from Table 3, which underestimates the actual cost.
- Design capacity was used for calculation of point source reductions and costs. Design capacity is approximately 24% greater than current capacity and therefore provides capacity for future growth.

Table 12: Summary of Allocation Option Costs

Allocation Option	Estimated Annual Cost ($M) DEQ 70 ug/l			Estimated Cost Annual ($M) DEQ100 ug/l			Estimated Annual Cost ($M) Boise City 70 ug/l			Estimated Annual Cost ($M) Boise City 100 ug/l		
	PS	NPS	Total	PS	NPS	Total	PS	NPS	Total	PS	NPS	Total
Equal Percent	3.0	12.5	15.5	2.7	10.2	12.9	3.0	8.2	11.2	2.7	6.7	9.4
Equal Concentration	23.1	11.4	34.6	23.1	8.4	31.5	23.1	7.1	30.3	23.1	5.0	28.1
Technology Based PS, remainder to NPS	2.7	12.7	15.5	2.7	8.8	11.5	2.7	8.5	11.2	2.7	3.7	6.5

Discussion

Equal Concentration Allocation Method

The equal concentration allocation method assumes all of the tributaries flowing into the Snake, the point sources discharging to the Snake and other tributaries, and the drain and unmeasured flows into the Snake receive equal discharge allocations of 70 ug/l. For the purposes of this exercise, all point sources were allocated loads based on 70 ug/l discharge concentrations, costs for 100 ug/l were used to estimate point source costs and therefore are conservative or underestimate the actual point source costs for this alternative. This was the most expensive allocation option, generally being two to four times greater in cost basinwide than the technology based point source control or least cot option.

Issues associated with this approach include:

1. High Point source costs

The cost of achieving 70 ug/l end of pipe for point sources is technically achievable however is extremely costly. Average estimated costs to achieve 100 ug/l (Colorado data) show annual basinwide (mainstem and tributaries) costs for point sources of > 20 million per year. Use of this approach results in the most expensive allocation alternatives.

2. Fairness issues
Point sources are only 20 % of the load and would be required to make substantial reductions (>90%), at extremely high cost to meet 70 ug/l end of pipe limits.

3. Upstream reduction required.
The proposed approach suggest a Snake River inflow concentration of 74 to 92 ug/l, depending on which baseline dataset is used, would need to be reduced from 6 to 24% to meet the 70 ug/l target at RM 409. This will require additional reductions from upstream sources. The timing associated with the upstream reduction will be an important consideration in the time necessary for the lower reach to meet water quality standards.

Equal Percent Reduction Allocation Method

Equal percent reduction method would result in 62-78% overall reductions depending on the target and baseline year selected. This is the second least expensive allocation option for the two 70 ug/l targets and equal to the lowest cost option at the 100 ug/l targets.

Issues associated with this approach include:
1. Upstream reduction required.
The proposed approach suggest a Snake River inflow concentration of 74 to 92 ug/l, depending on which baseline dataset is used, would need to be reduced from 6 to 24% to meet the 70 ug/l target at RM 409. This will require additional reductions from upstream sources. The timing associated with the upstream reduction will be an important consideration in the time necessary for the lower reach to meet water quality standards.

2. Reductions to Tributaries
Tributaries have different levels of input. Equal % reduction to all tributaries may result in technically unachievable or more costly reductions for some tributaries.

3. Trading
Trading was incorporated as a tool where treatment option 1 was close but did not meet all necessary reductions. Trading cost assumptions were 150% of non point source control costs for the 95 lb/d required under the DEQ 70 ug/l scenario.

Least Cost Allocation (Technology based Point Source Control with remaining reductions made by Non Point Sources)

Based on the data and analysis, the nutrient control and TMDL allocation approach used by the states of Wisconsin and Minnesota and Vermont and Montana in the Lake Champlain and Clark Fork River TMDLs provides the lowest basinwide cost. The reason for this is that the costs are lower per lb of TP for nonpoint source controls than point source control after BNR is implemented.

Issues associated with this approach include:
1. Upstream reduction required.
The proposed approach suggest a Snake River inflow concentration of 74 to 92 ug/l, depending on which baseline dataset is used, would need to be reduced from 6 to 24% to meet the 70 ug/l target at RM 409. This will require additional reductions from upstream sources. The timing associated with the upstream reduction will be an important consideration in the time necessary for the lower reach to meet water quality standards.

Allocation and Reductions Necessary to meet TMDL Targets

Four tables are included in Appendix A (Tables 8-11) that provide allocations to the tributaries and mainstem for the four target conditions (DEQ 70/100 and Bosie City 70/100).

The approach for the allocations is that technology based point source controls were applied and the remained of the reductions were assigned to non point sources. Four allocations are proposed based on the two datasets and the 70 and 100 ug/l range of potential targets.

This evaluation incorporates the concerns of the PAT that no tributary be asked to make reductions if it is already meeting the TMDL target. When the 100 ug/l target is used, there are tributaries where this situation occurs. In the two examples (DEQ and Boise City datsets) where the target is 100 ug/l, the concentrations needed to meet the goal are applied to tributaries where current conditions exceed these levels but where existing conditions are better, no additional reductions are sought. In the case of the 70 ug/l target, this condition never occurs and agricultural target concentrations are the same in all tributaries because all exceed that allowable concentration.

Time to Meet Water Quality Goal and Interim Targets

Point source control is anticipated to occur within a relatively short period of time (one permit cycle or 5 years). It is widely recognized that the time necessary to meet the water quality goal for TP will be measured in decades due to the legacy nature of the problems (100 years of practice), time needed for groundwater nutrient loadings to attenuate to natural or background levels, tributary TMDL development and implementation schedules, limited current funding to address nonpoint sources, and uncertainty associated with increases in future non point source funding. If funding for non point source control is increased substantially and quickly, or significant technological breakthroughs occur in non point source control technology, the timeframe could be shortened somewhat, but still is generally recognized to require decades. The PAT has discussed timeframes to meet the TP goal ranging from 40 to 70 years.

A figure that illustrates the glidepath to the 70 ug/l target over a seventy year timeframe for the two baseline conditions is contained in Appendix 2: Figure 1.

Interim targets for Snake River instream targets at Weiser, based on the information shown in Appendix 2: Figure 1, are shown below in Table 13.

Table 13: Proposed Interim Targets in Snake River at Weiser (70 ug.l target)

Date	DEQ Nov 15, 2001 Dataset	Boise City 2000 Dataset
2001	139	133
2011	120	112
2021	112	105
2031	103	98
2041	95	91
2051	87	84
2061	78	77
2071	70	70

Findings and Recommended Allocation Approach

Findings:

1. Based on recent Idaho experience, Nonpoint source controls minimum costs are estimated at $14/lb/d TP. Anticipated reductions could be 65-70%, however post treatment concentrations likely will be >100 ug/l where furrow irrigation is the primary irrigation practice.

2. Point Source controls occur in three technology steps. Cost increase rapidly after the first increment. TP reduction costs range from $<5 to $2-600 lb/d and removal rates vary from 80 to 94% depending on technology used.

3. An allocation alternative evaluation is useful and provides critical information to the allocation process and decision makers.

4. Allocation method has significant influence on basinwide TMDL implementation costs.

5. Point source controls beyond BNR do not appear to be cost effective based on the relatively small load contribution of point sources and the estimated costs for non point source control.

6. Nutrient criteria or target determination methods have not been adopted be either Idaho or Oregon. Technical and regulatory approach to determine nutrient targets are rapidly evolving and likely will result in changes to the target during the implementation period anticipated for this TMDL, making adaptive management an important aspect of this TMDL.

7. Trading is a necessary tool in achieving cost effective implementation and should be an acceptable tool incorporated in the TMDL as an option in meeting allocations.

Recommended Allocation Approach

1. A technology based point source allocation with additional reductions necessary to meet the TMDL being allocated to non point sources used by the states of Wisconsin, Minnesota, Montana and Vermont appears to be the best nutrient allocation method (e.g. meets TMDL goals, least expensive).

2. The Wisconsin approach, including the four alternative limits based on technical feasibility and economics should be adopted and applied to industrial and municipal point source nutrient controls.

3. Oregon and Idaho DEQs should add multiple allocation alternatives as a standard TMDL allocation process to provide critical cost information to decision makers and the public.

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Appendix 1

Cost and Allocation Tables

Tables 4 – 11

Table 4: Estimated Costs To Meet Phosphorus Target Above Brownlee **2001 Nov 19**

B&C 2000 Growing Season (May - September)

Target: 70

	Point Source			**Non-Point Source**			**Background**			**Total**			**Load Distribution as %**		
	lbs/D P	Ann.$M	%Red.	lbs/D P	Ann.$M	%Red.	lbs/D P	Ann.$M	%Red.	lbs/D P	Ann.$M	%Red.	Pt.Src.	Non-Pt.	Bkgrd.
Starting Conditions (a)	1,456			4,173			622			6,252			23%	67%	10%
Design Conditions	1,928			4,173			624			6,725			29%	62%	9%
Equal % to Achieve Target	430	3	78%	930	8	78%	624	0	0%	1,985	11	70%	22%	47%	31%
Equal Concentration	23	23	99%	1,338	7	68%	624	0	0%	1,985	30	70%	1%	67%	31%
Proposed Allocation (b)(c)	535	3	72%	813	8	81%	624	0	0%	1,971	11	71%	27%	41%	32%

Baseline Concentrations & Loads

	:g/L P	cfs (d)	lbs/D
Target	**70**	5,261	1,985
Background	22	5,261	624

Referenced Loads

	Point Source	Non-Pt. Source	Back-ground	Total
Current Conditions	1,456	4,173	622	8,792
Proposed Allocation(b)(c)	535	813	624	1,971

Finance Factors

Rate	4.5%
Years	20
Factor	0.0769

Non-Point Source Unit Cost

14.00 $/pound

(a) Starting Condition loads are from B&C material dated August 30, 2000, for the period May through September.

(b) Proposal of September 21, 2001 forms basis for allocation calculations.

(c) Proposed Allocation Point Source loads from mechanical facilities on the Snake and Boise Rivers reduced to 1 mg/L, except Heinz F.F. at 80% reduction.

(d) Flow to Snake River below RM409.

Proposed Allocation costs reflect design conditions and treatment costs. Costs for mechanical plants are financed over 20 years at 4.5%.

Percent Reduction (%Red.) is a comparison to design conditions.

This analysis does not address a reduction in the load from Amalgamated Sugar.

Table 5: Estimated Costs To Meet Phosphorus Target Above Brownlee **2001 Nov 19**

B&C 2000 Growing Season (May - September)

Target: 100

	Point Source			Non-Point Source			Background			Total			Load Distribution as %		
	lbs/D P	Ann.$M	%Red.	lbs/D P	Ann.$M	%Red.	lbs/D P	Ann.$M	%Red.	lbs/D P	Ann.$M	%Red.	Pt.Src.	Non-Pt.	Bkgrd.
Starting Conditions (a)	1,456			4,173			622			6,252			23%	67%	10%
Design Conditions	1,928			4,173			624			6,725			29%	62%	9%
Equal % to Achieve Target	700	3	64%	1,510	7	64%	624	0	0%	2,836	9	58%	25%	53%	22%
Equal Concentration	33	23	98%	2,179	5	48%	624	0	0%	2,836	28	58%	1%	77%	22%
Proposed Allocation (b)(c)	535	3	72%	2,689	4	36%	624	0	0%	3,847	6	43%	14%	70%	16%

Baseline Concentrations & Loads

	:g/L P	cfs (d)	lbs/D
Target	**100**	5,261	2,836
Background	22	5,261	624

Referenced Loads	Point Source	Non-Pt. Source	Back-ground	Total
Current Conditions	1,456	4,173	622	6,252
Proposed Allocation(b)(c)	535	2,689	624	3,847

Finance Factors

Rate	4.5%
Years	20
Factor	0.0769

Non-Point Source Unit Cost

14.00 $/pound

(a) Starting Condition loads are from B&C material dated August 30, 2000, for the period May through September.

(b) Proposal of September 21, 2001 forms basis for allocation calculations.

(c) Proposed Allocation Point Source loads from mechanical facilities on the Snake and Boise Rivers reduced to 1 mg/L, except Heinz F.F. at 80% reduction.

(d) Flow to Snake River below RM409.

Proposed Allocation costs reflect design conditions and treatment costs. Costs for mechanical plants are financed over 20 years at 4.5%.

Percent Reduction (%Red.) is a comparison to design conditions.

This analysis does not address a reduction in the load from Amalgamated Sugar.

Table 6: Estimated Costs To Meet Phosphorus Target Above Brownlee **2001 Nov 19**

DEQ 2000 Growing Season (May - September)

Target: 70

	Point Source			Non-Point Source			Background			Total			Load Distribution as %		
	lbs/D P	Ann.$M	%Red.	lbs/D P	Ann.$M	%Red.	lbs/D P	Ann.$M	%Red.	lbs/D P	Ann.$M	%Red.	Pt.Src.	Non-Pt.	Bkgrd.
Starting Conditions (a)	1,456			6,452			884			8,792			17%	73%	10%
Design Conditions	1,928			6,452			885			9,264			21%	70%	10%
Equal % to Achieve Target	440	3	77%	1,490	13	77%	885	0	0%	2,817	15	70%	16%	53%	31%
Equal Concentration	23	23	99%	1,909	11	70%	885	0	0%	2,817	35	70%	1%	68%	31%
Proposed Allocation (b)(c)	535	3	72%	1,397	13	78%	885	0	0%	2,817	15	70%	19%	50%	31%

Baseline Concentrations & Loads

	:g/L P	cfs (d)	lbs/D
Target	**70**	7,465	2,817
Background	22	7,465	885

Referenced Loads

	Point Source	Non-Pt. Source	Back-ground	Total
Current Conditions	1,456	6,452	884	8,792
Proposed Allocation(b)(c)	535	1,397	885	2,817

Finance Factors

Rate	4.5%
Years	20
Factor	0.0769

Non-Point Source Unit Cost

14.00 $/pound

(a) Starting Condition loads are from DEQ material for the period May through September, 2000.

(b) Proposal of September 21, 2001 forms basis for allocation calculations.

(c) Proposed Allocation Point Source loads from mechanical facilities on the Snake and Boise Rivers reduced to 1 mg/L, except Heinz F.F. at 80% reduction.

(d) Flow to Snake River below RM409.

Proposed Allocation costs reflect design conditions and treatment costs. Costs for mechanical plants are financed over 20 years at 4.5%.

Percent Reduction (%Red.) is a comparison to design conditions.

This analysis does not address a reduction in the load from Amalgamated Sugar.

Table 7: Estimated Costs To Meet Phosphorus Target Above Brownlee **2001 Nov 19**

DEQ 2000 Growing Season (May - September)

Target: 100

	Point Source			Non-Point Source			Background			Total			Load Distribution as %		
	lbs/D P	Ann.$M	%Red.	lbs/D P	Ann.$M	%Red.	lbs/D P	Ann.$M	%Red.	lbs/D P	Ann.$M	%Red.	Pt.Src.	Non-Pt.	Bkgrd.
Starting Conditions (a)	1,456			6,452			884			8,792			17%	73%	10%
Design Conditions	1,928			6,452			885			9,264			21%	70%	10%
Equal % to Achieve Target	720	3	63%	2,420	10	62%	885	0	0%	4,024	13	57%	18%	60%	22%
Equal Concentration	33	23	98%	3,106	8	52%	885	0	0%	4,024	32	57%	1%	77%	22%
Proposed Allocation (b)(c)	535	3	72%	2,966	9	54%	885	0	0%	4,386	12	53%	12%	68%	20%

Baseline Concentrations & Loads

	:g/L P	cfs (d)	lbs/D
Background	22	7,465	885

Referenced Loads		Point Source	Non-Pt. Source	Back-ground	Total
Target	**100**	7,465	4,024		
Proposed Allocation(b)(c)		535	2,966	885	4,386

Finance Factors

Rate	4.5%		
Current Conditions	1,456	6,452	884
Factor	0.0769		

Non-Point Source Unit Cost

14.00 $/pound

(a) Starting Condition loads are from DEQ material for the period May through September, 2000.

(b) Proposal of September 21, 2001 forms basis for allocation calculations.

(c) Proposed Allocation Point Source loads from mechanical facilities on the Snake and Boise Rivers reduced to 1 mg/L, except Heinz F.F. at 80% reduction.

(d) Flow to Snake River below RM409.

Proposed Allocation costs reflect design conditions and treatment costs. Costs for mechanical plants are financed over 20 years at 4.5%.

Percent Reduction (%Red.) is a comparison to design conditions.

This analysis does not address a reduction in the load from Amalgamated Sugar.

Tqble 8: Snake River Total Phosphorus Contribution to Brownlee Reservoir **2001 Nov 19**

B&C 2000 Growing Season (May - September)

Target: **70**

	Starting Condition (a)				Proposed Allocation (b)											
	Current				Design				Reduction				Percent Reduction			
	Point Source	Non-Pt. Source	Back-ground	Total	Point Source	Non-Pt. Source	Back-ground	Total	Point Source	Non-Pt. Source	Back-ground	Total	Point Source	Non-Pt. Source	Back-ground	Total
Load: Pounds/Day TP																
Snake River at RM409				2,914				2,750				163				6%
Owyhee River	0	308	30	338	0	39	30	69	0	269	0	269	0%	87%	0%	79%
Boise River	490	907	108	1,505	225	137	109	471	266	770	-1	1,035	54%	85%	-1%	69%
Malheur River	0	292	18	310	0	24	18	42	0	268	0	268	0%	92%	0%	86%
Payette River	87	439	230	756	87	302	230	619	0	137	0	137	0%	31%	0%	18%
Weiser River	1	277	51	329	1	67	51	119	0	210	0	210	0%	76%	0%	64%
To Snake below RM409	878	1,950	186	3,014	222	243	186	651	656	1,707	0	2,363	75%	88%	0%	78%
Lower Snake River	1,456	4,173	622	6,252	535	813	624	1,971	922	3,360	-1	4,281	63%	81%	0%	68%
Snake River at Weiser				**9,166**				**4,722**				**4,444**				**48%**

Concentration: :g/L TP

Snake River at RM409				74				70				4				6%
Owyhee River	0	227	22	249	0	29	22	51	0	198	0	198	0%	87%	0%	79%
Boise River	2,810	192	22	308	1,288	29	22	95	1,522	163	0	213	54%	85%	0%	69%
Malheur River	0	355	22	377	0	29	22	51	0	326	0	326	0%	92%	0%	86%
Payette River	3,478	42	22	72	3,478	29	22	59	0	13	0	13	0%	31%	0%	18%
Weiser River	3,478	119	22	142	3,478	29	22	51	0	90	0	90	0%	76%	0%	64%
To Snake below RM409	14,621	232	22	357	3,694	29	22	77	10,926	203	0	280	75%	88%	0%	78%
Lower Snake River	5,604	149	22	221	2,057	29	22	70	3,547	120	0	151	63%	81%	0%	69%
Snake River at Weiser				**136**				$\boxed{\textbf{70}}$				**66**				**49%**

(a) Starting Condition tributary flows and loads are from B&C material dated August 30, 2001, for the period April through October.

(b) Proposal of September 21, 2001 forms basis for allocation calculations.
Proposed Allocation Point Source loads from mechanical facilities on the Snake and Boise Rivers reduced to 1 mg/L with the exception of Heinz F.F. at 80%.

Proposed Allocation Point Source flows reflect design flow conditions.
Flow proportional background loads have been removed from both Point and Non-Point Source loads.

Non-Point Source and RM409 concentrations are adjusted as needed to generate the Proposed Allocation concentration for Snake River at Weiser.

Set Point Concentrations:

Mid-Snake RM409	70 :g/L
Non-Point Source	**29** :g/L
Background	**22** :g/L

Table 9: Snake River Total Phosphorus Contribution to Brownlee Reservoir **2001 Nov 19**

B&C 2000 Growing Season (May - September)

Target: **100**

	Starting Condition (a)				Proposed Allocation (b)											
	Current				Design				Reduction				Percent Reduction			
Load: Pounds/Day TP	Point Source	Non-Pt. Source	Back-ground	Total	Point Source	Non-Pt. Source	Back-ground	Total	Point Source	Non-Pt. Source	Back-ground	Total	Point Source	Non-Pt. Source	Back-ground	Total
Snake River at RM409				2,914				2,914				0				0%
Owyhee River	0	308	30	338	0	175	30	205	0	133	0	133	0%	43%	0%	39%
Boise River	490	907	108	1,505	225	609	109	942	266	299	-1	563	54%	33%	-1%	37%
Malheur River	0	292	18	310	0	106	18	124	0	186	0	186	0%	64%	0%	60%
Payette River	87	439	230	756	87	439	230	756	0	0	0	0	0%	0%	0%	0%
Weiser River	1	277	51	329	1	277	51	329	0	0	0	0	0%	0%	0%	0%
To Snake below RM409	878	1,950	186	3,014	222	1,083	186	1,490	656	868	0	1,524	75%	44%	0%	51%
Lower Snake River	1,456	4,173	622	6,252	535	2,689	624	3,847	922	1,485	-1	2,405	63%	36%	0%	38%
Snake River at Weiser				**9,166**				**6,760**				**2,405**				**26%**

Concentrations, :g/L TP

Snake River at RM409				74				74				0				0%
Owyhee River	0	227	22	249	0	129	22	151	0	98	0	98	0%	43%	0%	39%
Boise River	2,810	192	22	308	1,288	129	22	190	1,522	63	0	117	54%	33%	0%	38%
Malheur River	0	355	22	377	0	129	22	151	0	226	0	226	0%	64%	0%	60%
Payette River	3,478	42	22	72	3,478	42	22	72	0	0	0	0	0%	0%	0%	0%
Weiser River	3,478	119	22	142	3,478	119	22	142	0	0	0	0	0%	0%	0%	0%
To Snake below RM409	14,621	232	22	357	3,694	129	22	176	10,926	103	0	180	75%	44%	0%	51%
Lower Snake River	5,604	149	22	221	2,057	96	22	136	3,547	53	0	85	63%	36%	0%	39%
Snake River at Weiser				**136**				**100**				**36**				**26%**

(a) Starting Conditionl tributary flows and loads are from DEQ e-mail on November 15, 2001, for the period May through September.

(b) Proposal of September 21, 2001 forms basis for allocation calculations.

Proposed Allocation Point Source loads from mechanical facilities on the Snake and Boise Rivers reduced to 1 mg/L with the exception of Heinz F.F. at 80%.

Proposed Allocation Point Source flows reflect design flow conditions.

Flow proportional background loads have been removed from both Point and Non-Point Source loads.

Non-Point Source and RM409 concentrations are adjusted as needed to generate the Proposed Allocation concentration for Snake River at Weiser.

Set Point Concentrations:

Mid-Snake RM409	100 :g/L
Non-Point Source	**129** :g/L
Background	**22** :g/L

Table 10: Snake River Total Phosphorus Contribution to Brownlee Reservoir **2001 Nov 19**

DEQ 2000 Growing Season (May - September)

Target: **70**

	Starting Condition (a)				Proposed Allocation (b)											
	Current				Design				Reduction				Percent Reduction			
Load: Pounds/Day TP	Point Source	Non-Pt. Source	Back-ground	Total	Point Source	Non-Pt. Source	Back-ground	Total	Point Source	Non-Pt. Source	Back-ground	Total	Point Source	Non-Pt. Source	Back-groun	Total
Snake River at RM409				**4,224**				3,218				1,005				24%
Owyhee River	0	807	82	**889**	0	131	82	213	0	676	0	676	0%	84%	0%	76%
Boise River	490	1,750	177	**2,418**	225	276	179	680	266	1,474	-1	1,738	54%	84%	-1%	72%
Malheur River	0	404	19	**422**	0	30	19	48	0	374	0	374	0%	93%	0%	89%
Payette River	87	950	344	**1,382**	87	547	344	978	0	403	0	403	0%	42%	0%	29%
Weiser River	1	635	100	**735**	1	158	100	259	0	477	0	477	0%	75%	0%	65%
To Snake below RM409	878	1,906	162	**2,946**	222	255	162	638	656	1,651	0	2,307	75%	87%	0%	78%
Lower Snake River	1,456	6,452	884	8,792	535	1,397	885	2,817	922	5,055	-1	5,975	63%	78%	0%	68%
Snake River at Weiser				**13,016**				**6,035**				**6,981**				**54%**

Concentrations, :g/L TP

Snake River at RM409				92				70				22				24%
Owyhee River	0	215	22	237	0	35	22	57	0	180	0	180	0%	84%	0%	76%
Boise River	2,810	222	22	300	1,288	35	22	84	1,522	187	0	216	54%	84%	0%	72%
Malheur River	0	477	22	499	0	35	22	57	0	442	0	442	0%	93%	0%	89%
Payette River	3,478	61	22	88	3,478	35	22	63	0	26	0	26	0%	42%	0%	29%
Weiser River	3,478	140	22	162	3,478	35	22	57	0	105	0	105	0%	75%	0%	65%
To Snake below RM409	14,621	262	22	401	3,694	35	22	87	10,926	227	0	314	75%	87%	0%	78%
Lower Snake River	5,604	162	22	219	2,057	35	22	70	3,547	127	0	149	63%	78%	0%	68%
Snake River at Weiser				**151**				**70**				**81**				**54%**

(a) Starting Conditionl tributary flows and loads are from DEQ e-mail on November 15, 2001, for the period May through September.

(b) Proposal of September 21, 2001 forms basis for allocation calculations.

Proposed Allocation Point Source loads from mechanical facilities on the Snake and Boise Rivers reduced to 1 mg/L with the exception of Heinz F.F. at 80%.

Proposed Allocation Point Source flows reflect design flow conditions.

Flow proportional background loads have been removed from both Point and Non-Point Source loads.

Non-Point Source and RM409 concentrations are adjusted as needed to generate the Proposed Allocation concentration for Snake River at Weiser.

Set Point Concentrations:

Mid-Snake RM409	70 :g/L
Non-Point Source	**35** :g/L
Background	**22** :g/L

Table 11: Snake River Total Phosphorus Contribution to Brownlee Reservoir **2001 Nov 19**

DEQ 2000 Growing Season (May - September)

Target: **100**

	Starting Condition (a)				Proposed Allocation (b)											
	Current				Design				Reduction				Percent Reduction			
Load: Pounds/Day TP	Point Source	Non-Pt. Source	Back-ground	Total	Point Source	Non-Pt. Source	Back-ground	Total	Point Source	Non-Pt. Source	Back-ground	Total	Point Source	Non-Pt. Source	Back-ground	Total
Snake River at RM409				**4,224**				4,224				0				0%
Owyhee River	0	807	82	**889**	0	311	82	393	0	496	0	496	0%	61%	0%	56%
Boise River	490	1,750	177	**2,418**	225	655	179	1,058	266	1,095	-1	1,360	54%	63%	-1%	56%
Malheur River	0	404	19	**422**	0	70	19	89	0	333	0	333	0%	83%	0%	79%
Payette River	87	950	344	**1,382**	87	950	344	1,382	0	0	0	0	0%	0%	0%	0%
Weiser River	1	635	100	**735**	1	376	100	476	0	259	0	259	0%	41%	0%	35%
To Snake below RM409	878	1,906	162	**2,946**	222	604	162	988	656	1,302	0	1,958	75%	68%	0%	66%
Lower Snake River	1,456	6,452	884	8,792	535	2,966	885	4,386	922	3,486	-1	4,406	63%	54%	0%	50%
Snake River at Weiser				**13,016**				**8,610**				**4,406**				**34%**

Concentrations, :g/L TP

Snake River at RM409				92				92				0				0%
Owyhee River	0	215	22	237	0	83	22	105	0	132	0	132	0%	61%	0%	56%
Boise River	2,810	222	22	300	1,288	83	22	130	1,522	139	0	170	54%	63%	0%	57%
Malheur River	0	477	22	499	0	83	22	105	0	394	0	394	0%	83%	0%	79%
Payette River	3,478	61	22	88	3,478	61	22	88	0	0	0	0	0%	0%	0%	0%
Weiser River	3,478	140	22	162	3,478	83	22	105	0	57	0	57	0%	41%	0%	35%
To Snake below RM409	14,621	262	22	401	3,694	83	22	134	10,926	179	0	267	75%	68%	0%	66%
Lower Snake River	5,604	162	22	219	2,057	74	22	109	3,547	87	0	110	63%	54%	0%	50%
Snake River at Weiser				**151**				**100**				**51**				**34%**

(a) Starting Conditionl tributary flows and loads are from DEQ e-mail on November 15, 2001, for the period May through September.

(b) Proposal of September 21, 2001 forms basis for allocation calculations.

Proposed Allocation Point Source loads from mechanical facilities on the Snake and Boise Rivers reduced to 1 mg/L with the exception of Heinz F.F. at 80%.

Proposed Allocation Point Source flows reflect design flow conditions.

Flow proportional background loads have been removed from both Point and Non-Point Source loads.

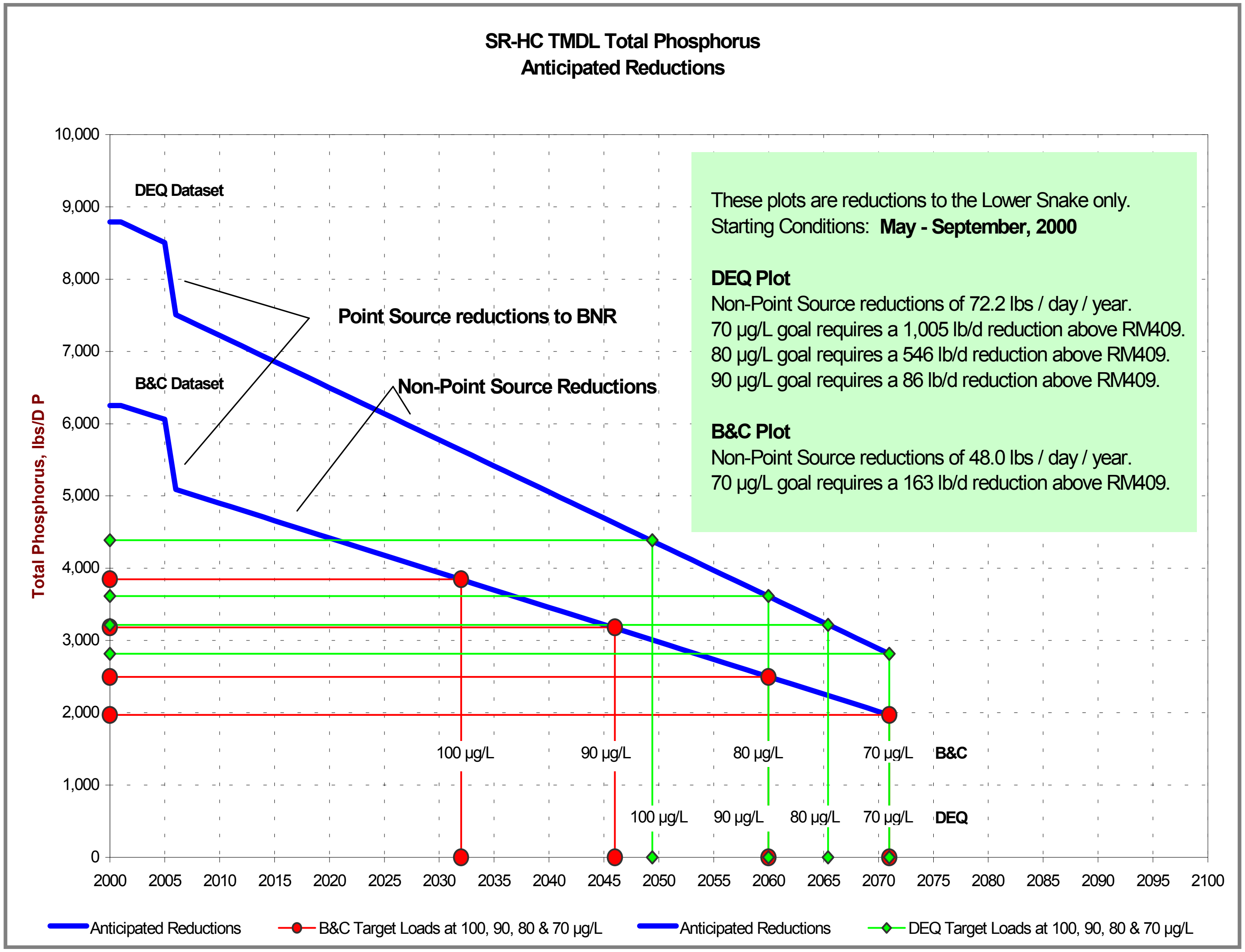
Non-Point Source and RM409 concentrations are adjusted as needed to generate the Proposed Allocation concentration for Snake River at Weiser.

Set Point Concentrations:

Mid-Snake RM409	100 :g/L
Non-Point Source	**83** :g/L
Background	**22** :g/L

Appendix 2

Figure 1



These plots are reductions to the Lower Snake only.
Starting Conditions: **May - September, 2000**

DEQ Plot
Non-Point Source reductions of 72.2 lbs / day / year.
70 µg/L goal requires a 1,005 lb/d reduction above RM409.
80 µg/L goal requires a 546 lb/d reduction above RM409.
90 µg/L goal requires a 86 lb/d reduction above RM409.

B&C Plot
Non-Point Source reductions of 48.0 lbs / day / year.
70 µg/L goal requires a 163 lb/d reduction above RM409.

Appendix J. Drain and Inflow Locations for the Snake River – Hells Canyon TMDL Reach

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Drain and Inflow Locations for the Snake River – Hells Canyon TMDL Reach*

River Mile	Location or Discharge Type
449.3	Snake River at Celebration Park
447.5	Rabbit Creek
444.5	Drain
444.1	Drain
443.8	Drain
443.4	Drain
442.6	Grouch Drain
441.1	Reynolds Creek
439.9	Drain
439.6	Pipe Drain
438.9	Drain
438.1	Grouch Ditch
436.9	Drain
432.9	Cozy Basin Wasteway
432.2	Drain
431.8	Squaw Creek
431.7	Drain
430.7	Drain
429.6	South Valley Mound Wasteway
427.5	North Valley Mound Wasteway
426.8	Mitchel Drain
426.7	Penninger Drain
425.1	Drain
425.0	Snake River at Marsing
424.8	Drain
4243.0	Lizard Lateral
423.7	Lizard Wasteway
423.2	Equalizer Drain
421.8	Isham Drain
421.4	Frohman Wasteway
421.3	Watson Lateral
420.1	Drain
419.0	Jump Creek
417.7	Hellyer Drain
417.1	Drain
417.0	Snake River at Homedale
416.8	Fargo Wasteway
415.6	Griffith Drain
415.5	Drain
415.0	Gem District G Canal
414.4	Drain
413.8	Federal Drain
413.5	Dutton Drain
413.1	Laht Drain
412.0	South Arena Drain
411.7	Riverside Canal
410.5	Drain

Drain and Inflow Locations for the Snake River – Hells Canyon TMDL Reach*

River Mile	Location or Discharge Type
410.3	Patch Wasteway
409.3	Allen Drain
408.4	Welch Drain
403.6	Singer Drain
403.0	Snake River at Adrian
401.3	Central Alkali Drain
401.0	Drain
400.3	Drain
399.0	Kingman Drain
398.2	South Boise Drain
397.3	Drain
396.7	0wyhee River
396.4	Boise River
396.1	Drain
395.9	Sand Run Drain
394.7	Locket Gulch
389.0	Drain
388.2	Drain
387.9	Grandview Avenue Drain
387.1	Delta Drain
385.5	Locker Avenue Drain
385.0	Snake River at Nyssa
384.6	Drain
384.1	Drain
383.6	Drain
383.4	Homestead Gulch
382.0	Ashlock Gulch
381.0	Hurd Gulch
377.9	Drain
377.8	Drain
375.3	Little Whitney Gulch
375.0	Drain
368.5	Malheur River
365.6	Payette River
362.7	Wood Drain
359.9	Drain
357.0	Buttermilk Slough
356.6	Drain
356.3	Drain
351.6	Weiser River
351.2	Drain
349.6	Drain
348.7	Smith-Hemenway Lateral
344.9	Drain
343.0	Scott Creek
342.6	Warm Springs Creek
342.4	Hog Creek
340.0	Snake River at Porters Island

* Snake River mile as locations, and drain and tributary discharge points listed in the preceding table were identified by Idaho Power Company studies.

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